IAMAS (Meteorology)

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IUGG-0833

The southern ocean clouds, radiation, aerosol transport experimental study (socrates): determining role of clouds, aerosols and radiation in climate system

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The Southern Ocean (SO) region is one of the cloudiest on Earth, with clouds largely determining its albedo and playing a major role in climate. The Earth climate sensitivity and Intertropical Convergence Zone location depend upon SO clouds. But, climate models are challenged by uncertainties and biases in the simulation of clouds, aerosols, and air-sea exchanges in this region which trace back to a poor process-level understanding. Due to the SO's remote location, there have been sparse observations of clouds, aerosols, precipitation, air-sea fluxes and radiation apart from those by satellites.

SOCRATES is proposed to improve our understanding of clouds, aerosols, air-sea exchanges and their interactions over the SO. SOCRATES will obtain a comprehensive dataset on the boundary-layer structure and associated vertical distributions of liquid and mixed-phase cloud and aerosol properties across a range of synoptic settings, especially in the cold sector of cyclonic storms to better understand (1) the synoptically-varying vertical structure of SO aerosols and boundary layer clouds, (2) seasonal variability in SO cloud condensation nuclei and ice nuclei, including the role of local biogenic sources, and (3) mechanisms controlling supercooled liquid and mixed-phase clouds. Parameterization development and testing needs are integrated in the design so that systematic confrontation and improvement of leading climate models with data will be possible. The observational strategy consists of observations from Macquarie Island over a complete annual cycle, from the NSF G-V, cruises by the Australian Research Vessel Investigator and a U.S. ship, boundary layer observations from the

NOAA P-3 aircraft, and the use of unmanned aerial systems for aerosol profiling.

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IUGG-2287

Large sensitivity of cloud radiative effect to enhancement in cloud drop concentrations over low SST in the Southern Oceans

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Satellite measurements showed that cloud drop concentrations (Nd) of water boundary layer clouds in the Southern Oceans increase sharply with decreasing sea surface temperature (SST) below 7C. This finding prompted testing the relationships between Nd and the components of the solar cloud radiative effect. The relationships between Nd and CRE were quantified using MODIS cloud products over the storm track of the Southern Oceans during the summer months there. Surprisingly high dependence of CRE on Nd was found, with a tight relationship that has the functional shape of CRE = 56 - 80 log(Nd), for the range of Nd between 10 and 200 cm^{-3}. Most (75%) of the added CRE is contributed by the fractional cloud cover (CF) effect, which increases from 0.44 to 0.76 when Nd increases from 14 to 170 cm^{-3}. The functional relationship is CF = 0.07 +0.314 log(Nd). Similar partition between the Twomy effect (25%) and the cloud cover and liquid path effects (75%) were previously observed for the transitions between closed and open cells in marine stratocumulus. The present results for the low clouds in the storm track generalize these relationships and no longer restrict them to the mechanism of pockets of open cells (POCS). While the strong relationship was known for POCS, it was considered until now unimportant climatologically, due to their limited global coverage. Now this relationship is shown to be applicable to all marine boundary layer clouds in the Southern Oceans. The functional dependence of CRE and CF on Nd given here can be readily implemented in GCMs. This may have a big impact, because present GCMs show little sensitivity of CF to Nd. Implementation of this to GCM is likely to take them out of energy balance, thus revealing other issues that have been hiding until now.

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IUGG-2655

In-situ observations of "warm ice" over the Southern Ocean

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The prevalence of supercooled liquid water (SLW) recorded by satellite observations down to -40°C has been found to be a remarkable feature over the remote Southern Ocean (SO). The underrepresentation of SLW in climate models is considered to be a major contributor to the large simulated radiative bias in this region.

An effort has been made by a collaborative field project in Australia to better understand the cloud nature over this measurement-sparse area. Here we present a wintertime research flight during which shallow (~2500) convective clouds were observed within in a post-frontal environment. The cloud-top temperature was ~ -6° C. The thermodynamics phase of these clouds varied from primarily glaciated to mixed phase to supercooled liquid water. Ice particles were observed at relatively warm temperatures (~-5°C) within and below cloud. The formation of “warm ice” is exceptional given the pristine environment where ice nuclei are considered to be lacking.

The general synoptic conditions of this case were not considered to be exceptional, although relatively strong southwesterly winds (15-20 m/s) were present at the sampling levels. Analyses of back trajectories indicate no obvious history of continental influence on aerosol transport, suggesting a potential oceanic source of ice nuclei. In-situ measurements are combined with the coincident A-Train satellite observations and numerical simulations to further examine the cloud properties and help understand the formation of warm ice.

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IUGG-3240

High droplet number concentrations in Southern Ocean boundary layer clouds observed during the 4th HIAPER Pole-to-Pole Observations (HIPPO 4) campaign

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Data from the standard cloud physics payload during the NSF/NCAR High-performance Instrumented Airborne Platform for Environmental Research (HIAPER) Pole-to-Pole Observations (HIPPO) campaigns provide a unique snapshot of the microphysical conditions in the boundary layer over the Southern Ocean. On 29 June 2011, the HIAPER sampled the boundary layer in a region of pre-frontal warm air advection between 58 and 48S to the south of Tasmania. Cloud droplet number concentrations were unusually high for the SO at 150--250/cc in the southernmost profiles, with mean particle diameters of about 10um. Sub-micron (0.06<d
< D < 1um) aerosol concentrations were up to 400/cc.

For these profiles, aerosol concentrations in the free troposphere (about 20/cc) were more typical of a clean remote ocean airmass. Analyses of back trajectories and atmospheric chemistry observations indicate that the aerosol loading of the boundary layer was not due to long range transport from the Australian continent. Instead, the gale force surface winds in this case (160m wind speed was 20--25m/s) were most likely responsible for production of sea spray aerosol which has influenced the microphysical properties of the boundary layer clouds. The smaller size and higher number concentration of cloud droplets is inferred to increase the albedo of these clouds, and these conditions may occur regularly over the Southern Ocean.</d

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IUGG-3537

What is the role of Sea Surface Temperature in modulating cloud and precipitation properties over the Southern Ocean?

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The persistent deficit of reflected shortwave radiation over the Southern Ocean (SO) simulated by many climate models compared to satellite observations suggests a pressing need for a better understanding of cloud and aerosol processes in this remote region.

Here we analyze a range of cloud and precipitation properties in relation to sea surface temperature (SST), latitude, polar front location, mid-latitude cyclone locations, and surface wind over the SO. Using multi-satellite measurements from A-Train constellation, over 2 billion MODIS (level-2) cloud pixels and spatiotemporally matched AMSR-E, CloudSat, and CALIPSO observations are processed to produce a 4-yr summertime climatology.

While ice clouds are poorly correlated with the underlying ocean, the ubiquitous liquid clouds are. In particular, cloud-top temperature, effective radius (r_e), droplet number concentration (n_d), and optical depth of liquid clouds are strongly correlated with the SST. Despite the sector differences, r_e (n_d) reveals a decreasing (increasing) trend over colder SSTs, consistent with some earlier studies of aerosol source over the Artic (Zábori et al. 2013).

The most illuminating finding is the mixed-phase clouds and precipitation over SST<4°C. This area is associated with the highest cloud cover, but largest simulated cloud bias. While MODIS and CALIPSO commonly record liquid phase (>50%) non-precipitating (~ 90%) clouds, mixed-phase precipitation or snow is more commonly retrieved by CloudSat. Through case studies, we consider two possible explanations for this discrepancy.

The presentation herein provides an argument for a more careful consideration of SST and microphysics processes in parameterizations for climate models. It also may serve as a reference for SOCRATES strategic planning.

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IUGG-3728

Ship-based ceilometer measurements of Clouds over the Southern Ocean

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The weather in the Southern Ocean (SO) is well known for its severity; however the amount of weather and climate observations in the region is exceptionally limited. The meteorology over the SO is therefore poorly understood and, accordingly, poorly represented in both weather forecast and climate simulations. Current models display a consistent deficit of reflected shortwave radiation over the SO which is due to the poor representation of clouds. Recent work has also shown that reanalysis also perform poorly relative to satellite observations. In particular, satellite observations have shown that low-level clouds (with tops below 3 km) are ubiquitous over the SO. But, most satellite instruments, even the current generation of active satellite instruments, have difficulties in sampling low-level clouds.

This study discusses the deployment of a Väisälä CL51 laser ceilometer on a research voyage in the Southern Ocean and initial results. The route of the voyage covers a return trip from Wellington (New Zealand) to Terra Nova Bay (Antarctica) and occurred in the 2015 austral summer. The sampling provided by the ships route allows the ceilometer measurements of the height of the cloud base and the occurrence of super-cooled liquid cloud amongst other properties to be made in a region where limited data apart from, potentially biased, satellite measurements of low-level cloud exist. The climatological structure derived from the ceilometer measurements is first detailed and efforts to correct for pointing direction errors due to ship motion are discussed. The observations from the ceilometer are then contrasted with observations from CALIPSO and CloudSat satellite data. Analysis of the boundary layer height derived from the ceilometer is also presented.

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IUGG-1719

Simulations of Arctic Mixed-Phase Clouds: Impact of surface heterogeneities

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The Arctic is a highly sensitive region to changes in climate. Shallow and persistent mixed-phase layer clouds play an important role in determining the surface energy budget in this region. They can absorb longwave radiation from the surface and also reflect solar radiation back to space, which can lead to either cooling or warming of the atmosphere. Different surfaces may change cloud evolution and properties due to influences from the surface sensible and latent heat fluxes. Therefore, a closer look will be given to arctic clouds and how their microphysical properties are influenced by different surface properties. These mixed phase clouds, which contain supercooled liquid water and ice at same time, will be analyzed with COSMO (Consortium for Small-scale Modelling) which includes a double-moment cloud microphysics scheme. In order to improve and adjust the model, comparisons with measurements of cloud properties from the VERDI (Vertical Distribution of Ice in arctic Clouds) campaign in Canada 2012 will be carried out. In particular, the hydrometeor concentrations and size distributions are compared to in-situ observations. Different heat and moisture fluxes above ocean and sea ice surfaces influence the boundary layer structure. In sensitivity experiments varying the areas of the ice and ocean surfaces at the lower model boundary, it will be investigated in how far these surface heterogeneities (representing e.g. open leads) impact the clouds above them and are discernible in the cloud optical and microphysical properties.

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IUGG-2160

The microphysics of clouds over the Antarctic Peninsula – part one observations.

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During the Antarctic summer of 2010 and 2011 in-situ measurements of clouds were made over the Antarctic Peninsula using the British Antarctic Surveys instrumented Twin Otter aircraft. The Antarctic Peninsula is a narrow high barrier (reaching over 3000 in places), between the oceanic air masses originating in the South Pacific and the more polar air masses found over the Weddell Sea. The aircraft measurements looked at differences in the cloud microphysics on either side of the peninsula. It was expected that local sources of cloud condensation nuclei and ice nuclei would be important over the Weddell Sea while to the West the clouds would be oceanic in nature. However the observations show no substantial differences between the two sides. Runs with the Weather Research and Forecasting (WRF) model also show no difference between the clouds on the two sides of the peninsula, but do not reproduce the detailed microphysics of the observations.

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IUGG-2254

The Microphysics of Clouds over the Antarctic Peninsula – Part Two Modelling

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Antarctic clouds are known to be poorly represented in atmospheric models. They are responsible for shortwave and longwave biases directly affecting surface temperatures. It has been suggested that the main issue would not be the prediction of the cloud cover itself, rather the phase (liquid or ice/snow) of the clouds. Failure of properly accounting for supercooled liquid droplets for instance may be one of the biggest challenges, leading to strong positive shortwave biases at the surface. Using the Weather Research & Forecasting model we investigate cloud formation in Antarctica by using various microphysical schemes implemented in WRF (v3.5.1). We aim at understanding how they differ from the default scheme (used e.g in the Antarctic Mesoscale Prediction System), and assessing their ability to form the liquid/ice phase, and represent their mutual interaction. We compare Polar-WRF nested simulations ouputs to flight data and radiation measurements in the Antarctic Peninsula. The Single Column Model is also used to better explain the behaviour of the various schemes in the 3D simulations. Simulations over the Halley station region with comparison to radiation measurements will also be discussed.
The Antarctic environment is characterized by its remoteness and low aerosol concentrations. Cloud condensation Nuclei (CCN) parameterizations used in microphysical schemes are almost exclusively based on mid-latitudes measurements. A mandatory step is a new parameterization of CCN for the Antarctic.
We will present our ongoing work heading towards a new parameterization, and improvement of Antarctic clouds microphysics modelling.

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IUGG-3134

Observational efforts to understand aerosol-cloud interactions at high latitudes

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Of the uncertainties surrounding our understanding of global climate, one of the largest involves the effects of aerosol particles on cloud radiative transfer and precipitation intensity. Due to limited profiling of aerosol properties, traditionally aerosol-cloud interactions are statistically evaluated using surface aerosol measurements as a proxy for aerosol at cloud height. At low- and mid-latitudes, clouds often form atop a well-mixed atmospheric boundary layer, meaning that the use of surface-based aerosol measurements may not be unreasonable. At high latitudes, however, the atmosphere is often very stable. This stability limits vertical mixing of aerosols, meaning aerosol properties (e.g. number, hygroscopicity, scattering, size) observed at the Earth's surface may be very different from those at cloud height. This limitation makes it challenging to interpret previous efforts to understand the impacts of aerosols on liquid-containing Arctic clouds (e.g. Lubin and Vogelmann, 2006; Garrett and Zhao, 2006).

In this presentation, I will present recent and ongoing efforts to better understand relationships between aerosol particles and clouds. This will include evaluation of in-situ and ground-based remote sensing datasets to evaluate the impact of different atmospheric stability regimes on the vertical distribution of aerosol. Additionally, I will provide updated estimates of aerosol-cloud interactions in thin, liquid-containing Arctic clouds, taking into account the possible disconnect between surface-based aerosol and those at cloud height. Finally, I will provide insight into upcoming field campaigns using unmanned aircraft that should provide additional detail on the vertical distribution of aerosol at high latitudes.

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IUGG-3432

A comparison of observed cloud microphysical properties and evolution at high latitudes

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Clouds at high latitudes are often poorly represented in global models. In these regions the effects of climate change can be extreme, so it is important that the radiative cloud properties and their feedbacks are correctly represented. However, clouds are often poorly reproduced in their extent, lifetime and particularly phase, all of which significantly affect their radiative properties.

There is a paucity of insitu measurements of clouds in high latitudes. Detailed knowledge of cloud properties, processes, and interactions with aerosol and radiation is thus lacking. Parameterisations based on insitu-measurements in significantly different regions of the globe are often used for high latitudes too, potentially accounting for poor model performance in predicting cloud properties in these regions.

Here, data recently collected from campaigns in both the Arctic and Antarctic will be presented. From the Arctic, measurements made during the ACCACIA experiments of spring and summer 2013, by the UK Facility for Airborne Atmospheric Measurement (FAAM) BAe146 and the British Antarctic Survey (BAS) Twin Otter aircraft, respectively, will be examined. Measurements made by the BAS aircraft over the Peninsular region of the Antarctic in summers 2010 and 2011will also be shown. A comparison of cloud properties and dominant cloud processes operating between seasons in the Arctic, and between northern and southern high latitudes in summer, will be discussed. Attempts to simulate observed clouds with various models (including WRF and Met Office LEM) will be reported, alongside results of sensitivity tests undertaken to pin down

improvements required in cloud descriptions and of their interaction with aerosols and the environment.

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IUGG-4686

Southern and northern hemisphere cloud processing

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Airborne CCN and cloud microphysics measurements are presented from projects near Tasmania, Australia; one wintertime and two summertime. For strictly maritime trajectories CCN concentrations, N_{CCN}, were higher during summer; i.e., by a factor of 7 at 1% critical supersaturation, S_c, and progressively greater for lower S_c; i.e., a factor of 33 at 0.02% S_c. Cloud droplet concentrations, N_c, were only a factor of 3 higher in summer because of the lower cloud S due to droplet competition; i.e., 0.15% S summer, 0.95% S winter. Droplet mean diameter and drizzle were greater in winter, but the latter contrast probably led to lower wintertime cloud water content. Recently appreciated high-resolution CCN spectra often reveal bimodality. However, the considerable observed variability of CCN spectral modality that includes extreme monomodality can be used to ascertain relative influences of the cloud droplet processes that make bimodal CCN spectra; i.e., gas-to-particle chemical reactions, Brownian scavenging and coalescence. These alterations of CCN spectra can feed back onto cloud microphysics. For instance coalescence, which predominates at lower N_{CCN} and N_c obviously further reduces N_c and subsequently further reduces N_{CCN} while it makes bimodal CCN spectra. This results in observed negative relationships between spectral modality and N_c; i.e., more bimodal CCN spectra associated with lower N_c. However, with higher $N_{CCN}$where chemistry, which changes S_c but not N_{CCN}, and Brownian scavenging (because of lower cloud S) dominate over coalescence, CCN modality shows higher N_c with more bimodal spectra. Therefore, better understanding of cloud processing is just as necessary as differentiation between natural and anthropogenic CCN in order to quantify the indirect aerosol effect.

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IUGG-1099

Modeling of sea salt production from blowing snow on sea ice and comparison with data collected in the Weddell Sea

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The hypothesis of blowing snow lifted snow particles, via a subsequent sublimation process, as a significant sea salt aerosol (SSA) source over sea ice has recently been strongly supported by a winter cruise through the Weddell Sea during June-August 2013. The newly collected data, including both physical and chemical components, provide a unique way to test and validate the parameterisation used to date. A medium snow salinity of 0.27 PSU, representing an average of the top 10 cm of snow plus blowing snow samples, was measured, which is more than an order in magnitude smaller than column mean value. This new snow salinity has been used in a global Chemistry-Transport Model (CTM) pTOMCAT to investigate its effect on SSA reaching central Antarctic, such as Concordia and Kohnen stations. Our model experiments indicated that open ocean-sourced SSA could neither explain the observed winter SSA peaks at these two sites nor the elevated SSA plume observed in the Weddell Sea during the winter cruise.

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IUGG-1277

Aerosol optical depth over Northern high latitudes from multi-year active and passive satellite observations

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Aerosol is an important component of the Earth system that affects radiative fluxes and plays an important role in high latitude environment. Due to very limited ground observations, satellite remote sensing retrievals become an important source of information. The long-term time series of Aerosol Optical Depth (AOD) retrievals became available in a recent decade from passive and active satellite observations, such as those from the Moderate Resolution Imaging Spectroradiometer (MODIS) onboard Terra and Aqua platforms, and the Cloud-Aerosol Lidar with Orthogonal Polarization (CALIOP) onboard CALIPSO satellite. While aerosol retrievals from passive observations are limited to daytime observations over snow-free surfaces, the lidar retrievals are available for cloud free pixels day and night regardless of surface conditions. In this study, the multi-year monthly statistics from both sources are compared over the Northern high-latitude region above 45N. Lidar retrievals demonstrate consistently lower total AOD than retrievals from MODIS (by 0.1-0.2). MODIS retrievals are missing over significant part of the region due to bright snow/ice background and/or low sun elevation angle. The average aerosol optical depth over the Arctic from CALIPSO is below 0.04. The AOD is higher in winter by 0.01-0.02 relative to summer period. Further details of AOD analysis and their impact on retrieval of surface properties and radiative fluxes will be also discussed.

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IUGG-2763

Validation of GCOM-C1 satellite aerosol optical properties retrievals from sky radiometer measurements at High Latitudes

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Aerosols and clouds play an important role in the Earth climate change at high latitudes. We provide the information, in this presentation, on the aerosol optical properties with respect to their temporal and spatial variability in the world. The global distributions of aerosols have been derived from earth observation satellite (ex. The GCOM-C1 satellite scheduled to be launched in JFY 2016), and have been simulated in numerical model, which assume optical parameters. However, these distributions are difficult to derive because of variability in time and space. Therefore, Aerosol optical properties were investigated using the measurements from ground-based and ship-borne sky radiometer (POM-01, & -02: Prede Co. Ltd., Tokyo, Japan). We started the long-term monitoring of aerosols optical properties since 1990's, by using a sky radiometer (http://skyrad.sci.u-toyama.ac.jp/). Sky radiometer has become a useful tool for aerosol observations and establishment of SKYNET network. The sky radiometer is an automatic instrument that takes observations only in daytime under the clear sky conditions. Observation of diffuse solar intensity interval was made every ten minutes by once. The aerosol optical characteristics were computed using the SKYRAD.pack version 4.2 developed by Nakajima et al. (1996). The obtained Aerosol optical properties (Aerosol optical thickness, Ångström exponent, Single scattering albedo, and etc.) and size distribution volume clearly showed spatial and temporal variability. In this study, we present the temporal and spatial variability of Aerosol optical properties at North part of Japan (Hokkaido site: Sapporo, Takikawa, Abashiri) and over the Arctic Ocean (R/V Mirai) and applied to validation of satellite programs.

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IUGG-4485

A marine biogenic source of atmospherically relevant ice nucleating particles

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Ice particle formation in clouds is facilitated by the presence of ice nucleating particles (INPs). There is limited data on marine sources of INPs despite sea spray aerosol being one of the dominant sources of atmospheric particles. While there is an indication that some marine aerosol particles act as INPs, the source and identities of these particles has not been resolved. The sea surface microlayer is enriched in surface active organic material representative of that found in sub-micron sea spray aerosol. We show that the sea surface microlayer is enriched in INPs that nucleate ice under conditions pertinent to both high-altitude ice clouds and low to mid-altitude mixed-phase clouds. The INPs pass through 0.2 μm pore filters and are heat sensitive. Spectroscopic analysis of Arctic microlayer samples indicates the presence of material consistent with phytoplankton exudates. We propose that phytoplankton exudates are a candidate for the source of the observed activity of the microlayer samples. We also show that laboratory produced exudates from a marine diatom culture contains INPs despite its separation from diatom cells. Finally we use a parameterisation of our field data to estimate the atmospheric INP contribution from primary marine organic emissions using a global model and validate the model against existing INP measurements in the

remote oceans. The model shows that biogenic marine INPs are dominant in remote marine environments, such as the Southern Ocean.

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IUGG-4773

Recent measurements of ice nucleating particles over oceans and from sea spray

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The nature and abundance of oceanic ice nucleating particle (INP) sources remain unclear. While it has previously been inferred that oceans are weak sources of INPs in comparison to terrestrial sources, this has not been clearly demonstrated, and it is inevitable that ocean emissions could provide the primary source of INP to cold clouds in some regions. Thus, the extent to which INP emissions may influence cloud and radiative properties, especially over the Southern Ocean, is unclear.

We apply online and offline methods to measure the number concentrations of INP in air at a coastal site, on ocean ship cruises, and in studies of sea spray aerosols during simulated laboratory phytoplankton blooms at the Center for Aerosol Impacts on Climate and the Environment at the University of California, San Diego. An intensive aerosol and INP measurement site has operated for two winter seasons at the Bodega Bay Marine Laboratory in California. Cruises have included regions between Hawaii and California, from South Korea north to Alaska and south to New Zealand, and from New Zealand to Antarctica.

Online processing uses a continuous flow diffusion chamber (CFDC), which also permits isolation of activated INP for various physical and chemical analyses. Time-integrated collections onto filters and into liquid are used for offline

measurements of the immersion freezing temperature spectra of aerosols dispersed into small liquid volumes, and studies to isolate the sizes, chemistry, and potential biological origins of INPs. The INP temperature spectrum characteristic of ocean regions is distinct from that found over land regions, with lower typical abundance at modestly supercooled conditions. Sources of INP appear to be both from biological organisms and their byproducts.

IAMAS (Meteorology)

M01d - M01 Clouds, Precipitation and Aerosols and their Influence on Climate at High Latitudes, including the Role of the Southern Ocean and Sea Ice

IUGG-1418

The seasonal dependence of climate on high latitude cirrus clouds

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While previous aerosol-cloud-climate research at high latitudes has focused mostly on low-level clouds, recent CAM5 simulations indicate that cirrus clouds may have a strong influence on climate at high latitudes with their radiative forcing depending on mineral dust concentrations. To determine the nature of this forcing, the frequency of occurrence of homo- and heterogeneous ice nucleation at high latitudes during different seasons must be assessed.

A new understanding of thermal absorption in two split-window channels renders a reinterpretation of a standard CALIPSO satellite retrieval; the effective absorption optical depth ratio or β_{eff}, where β_{eff} is tightly related to the ice particle number concentration/ice water content ratio, or N/IWC. When applied to cold semi-transparent cirrus clouds, we find that (1) polar cold cirrus (T < -38 C) occur much more often during winter than summer and (2) N/IWC is relatively high at high latitudes during winter, suggesting that homogeneous nucleation occurs frequently there. Homogeneous nucleation is further supported by the fact that high N/IWC values tend to coincide with regions of low mineral dust concentrations, as simulated by CAM5 (Storelvmo and Herger, 2014, JGR). This high N/IWC during winter is likely to have a strong greenhouse effect that may increase high latitude temperatures by 2-5°K relative to cirrus conditions where heterogeneous nucleation dominates (Storelvmo et al. 2014, Philos. Trans. A, Royal Soc.). Thus, the lack of mineral dust in the high latitudes and Polar Regions during winter may result in a strong warming influence over these regions.

IAMAS (Meteorology)

M01d - M01 Clouds, Precipitation and Aerosols and their Influence on Climate at High Latitudes, including the Role of the Southern Ocean and Sea Ice

IUGG-2135

Investigating the impact of spaceborne radar blind zone on surface snowfall statistics in polar regions

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Currently, global statistics of snowfall are only available from the CloudSat satellite launched in 2006. However, measurements from CloudSat can be only obtained at an altitude of at least 1200 m above ground, because measurements below are contaminated by ground clutter. As a consequence, global estimates of snowfall at the surface have to be estimated from observations at 1200 m above ground. In the presented study, it is investigated how this blind zone impacts snowfall statistics obtained from CloudSat observations in polar regions. For this, 12-months datasets containing observations of a vertically pointing 24 GHz Micro Rain Radar (MRR) are analyzed for three sites: the Princess Elisabeth station in East-Antarctica, and for Ny-Ålesund as well as Longyearbyen in Svalbard, Norway. Statistical comparison of CloudSat and MRR observations shows that MRRs are suited to study snowfall when reflectivity exceeds -5 dBz. To study the vertical variability of snowfall, MRR radar reflectivity profiles are analyzed with respect to changes in frequency distribution, the number of observed snow events and total precipitation. Results show that the blind zone leads to reflectivity being underestimated by up to 1 dB, the number of events being altered by ±5% and the precipitation amount being underestimated by 9 to 11 percentage points. In order to account for future satellite missions which feature a smaller blind-zone, also the impact of a reduced blind zone of 600 m is analyzed. Even though reducing the blind zone to 600 m leads to better representation of mean reflectivity, it does not improve the bias in event numbers and total precipitation amount.

IAMAS (Meteorology)

M01d - M01 Clouds, Precipitation and Aerosols and their Influence on Climate at High Latitudes, including the Role of the Southern Ocean and Sea Ice

IUGG-4278

Observational evidence of strong hemispheric differences in the freezing efficiencies in stratiform mid-level clouds

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Lidar observations of stratiform mid-level clouds were used to investigate the efficiency of heterogeneous ice nucleation as a function of cloud-top temperature. The long-term lidar-based cloud datasets were collected between 2000 and 2010 in Germany (51° N, 12° E), in southeastern China (22°N,112°E), Cape Verde (15° N,24° W), the Amazon Basin (1° N, 60° W), South Africa (34° S,19° E), and southern Chile (53° S, 71° W). They thus cover a variety of northern- and southern latitudinal belts from the midlatitudes to the tropics. Observations of the depolarization ratio were used to categorize the observed cloud layers into either ice-free (no depolarized signals observed) or ice-containing clouds (signals depolarized by scattering at ice crystals).

Strong hemispheric and regional differences were observed in the heterogeneous ice formation efficiency at the different sites, especially in the high-temperature range between -20 and 0 °C. The fraction of ice containing clouds in this temperature range is highest at the northern-latitudinal sites of Germany and southeastern China. Over Leipzig, 50% of all clouds contain ice at -10 °C. In contrast, over southern Chile virtually no ice-containing clouds were observed between -20 and 0 °C. Seasonal differences in the ice-cloud fraction were found over Germany and the Amazon Basin. The observed regional, hemispheric and seasonal contrasts can be explained by differences in the aerosol concentration at cloud level above the different sites. Cloud vertical motion (observed with Doppler lidar), which also determine the microphysical cloud evolution, were found to be similar for all cloud layers.

IAMAS (Meteorology)

M01d - M01 Clouds, Precipitation and Aerosols and their Influence on Climate at High Latitudes, including the Role of the Southern Ocean and Sea Ice

IUGG-4793

Cloud and precipitation properties in East Antarctica: from ground-based remote sensing and in regional climate models

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Clouds control radiative fluxes and precipitation formation thus influencing the surface energy and mass balance of the Antarctic ice sheet. We use measurements from Princess Elisabeth (PE) base in Dronning Maud Land (DML), East Antarctica, to understand local cloud and precipitation patterns and evaluate two regional climate models. The observatory consists of a set of ground-based remote-sensing instruments (ceilometer, infrared pyrometer and vertically profiling precipitation radar) combined with automatic weather station measurements of near-surface meteorology, radiative fluxes, and snow height. Two regional climate models - RACMO2 and MAR - are used to simulate DML climate at 5-km horizontal resolution during 2012. Analysis of the summer months (January-February) shows that both models simulate the occurrence of midlevel ice-only clouds well, while underestimating their occurrence near the surface. Both models agree with PE observations on the height of the most frequent liquid cloud occurrence (1-3 km). MAR simulated much higher cloud liquid water contents compared to RACMO2 leading to a better agreement with observations of the downwelling longwave flux (DLW) during liquid cloud occurrence. Both models underestimated surface DLW during clear-sky and most cloudy periods (mean bias

during February is -18 W m^{-2} for RACMO2 and -20 W m^{-2} for MAR). The models captured the timing of significant precipitation events well, while showing different precipitation intensities. Year-long radar measurements at PE during 2012 showed annual total snowfall amount of 110±20 mm w.e, only 53±10 mm w.e. of which accumulated on the ground. Snowfall rate for each event as well as yearly snowfall and accumulation simulated by models will be compared to observations during entire 2012.

IAMAS (Meteorology)

M01d - M01 Clouds, Precipitation and Aerosols and their Influence on Climate at High Latitudes, including the Role of the Southern Ocean and Sea Ice

IUGG-5397

Three-dimensional radiative effects in satellite remote sensing of clouds at high latitudes

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This presentation examines the way the three-dimensional (3D) nature of solar radiative processes influences satellite-based cloud remote sensing at high latitudes. Several studies have shown that 3D radiative processes are especially important in polar regions due to the typically low solar elevation. This study explores 3D effects by comparing statistics from 1D and 3D radiation simulations performed for dozens of cloudy scenes specified through Large-Eddy Simulations. Specifically, it examines the way 3D effects and the impacts of unresolved small-scale variability depend on wavelength, sun-view geometry, resolution, and scene variability parameters. The results help identify the optimal observation conditions in which 3D effects cause the smallest remote sensing uncertainties. As the simulations reveal, ultraviolet and blue wavelengths have weaker 3D influences than the longer wavelengths used in cloud remote sensing; the presentation explores the use of ultraviolet and blue measurements for reducing the uncertainties 3D radiative processes cause in satellite-based cloud remote sensing at high latitudes.

IAMAS (Meteorology)

M01d - M01 Clouds, Precipitation and Aerosols and their Influence on Climate at High Latitudes, including the Role of the Southern Ocean and Sea Ice

IUGG-5458

The radiative response of cloud regimes to the Arctic Oscillation.

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As the leading mode of natural variability in the Northern Hemisphere (NH), the Arctic Oscillation (AO) strongly influences weather and climate over mid- and high-latitudes. The variability in heat and moisture transport, mainly caused by changing atmospheric circulation, leads to variability in cloud distribution during the positive and negative phases of the AO. Via their radiative effects, clouds in turn influence atmospheric dynamics. Although our understanding of these processes in increasing, the insufficient description of clouds still remains a major stumbling block in achieving the desired accuracy and confidence in forecasting and climate models over NH regions. The vertical distribution of clouds typically shows a dipole structure that is centred around Greenland during the positive and negative phases of the AO, with different signs of dipole anomalies in the low and medium/high level clouds. The net radiative impact of such dipole structure and its implications for local dynamics however remains to be evaluated.

In that context, using the combined lidar and radar (CloudSat+CALIPSO) data from the A-Train constellation of satellites from 2006 through 2011, we investigate the following aspects.

1. How does the vertical distribution of various cloud regimes changes during the enhanced AO positive and negative phases and under which meteorological conditions?
2. What is the TOA, in-atmosphere and surface radiative impact of these cloud regimes during AO?
3. How sensitive is the cloud radiative impact to cloud microphysical properties during enhanced positive and negative phases of the AO?

We furthermore evaluate the response of clouds to the water vapour transport into the Arctic when it exceeds 10, 50 and 90 percentile levels during the winter and summer half years.

IAMAS (Meteorology)

M01p - M01 Clouds, Precipitation and Aerosols and their Influence on Climate at High Latitudes, including the Role of the Southern Ocean and Sea Ice

M01p-101

The spectral transparency of the surface layer marine atmosphere

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We present the results of numerical modeling of the spectral transparency of the surface layer marine and coastal atmospheric aerosols, which are based on the microphysical model Marine Aerosol Extinction Profiles (MaexPro). The model is created on long-term observations of size distributions for 0,01–100 μm particles.

The fundamental feature of the model is a parameterization of amplitudes and widths for aerosol modes of the aerosol size distribution function (ASDF) as functions of fetch and wind speed. The shape of the ASDF and its dependence on meteorological parameters, altitudes above the sea level (H), fetch (X), wind speed (U), and relative humidity is investigated.

The model is primarily to characterize aerosols for the near-surface layer (within 25 m). The model is also applicable to higher altitudes within the atmospheric boundary layer, where the change in the vertical profile of aerosol is not very large. In this case, it is only valid for “clean” marine environments, in the absence of air pollution or any other major sources of continental aerosols, such desert dust or smoke from biomass burning.

The spectral profiles of the aerosol extinction coefficients calculated by MaexPro are in good agreement with observational data and the numerical results obtained by the well-known Navy Aerosol Model and Advanced Navy Aerosol Model codes. Moreover, MaexPro was found to be an accurate and reliable instrument for investigation of the atmospheric aerosols transparence.

IAMAS (Meteorology)

M01p - M01 Clouds, Precipitation and Aerosols and their Influence on Climate at High Latitudes, including the Role of the Southern Ocean and Sea Ice

M01p-103

Scanning electron microscopy of aerosol particles on the White Sea coast

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Atmospheric transport of particulate matter is a fast way of delivery of many substances to the remote areas. This mechanism of matter transport is important for the Arctic environment. Continuous research of atmospheric aerosol is carried out from 2010 near the White Sea Biological Station of Moscow State University (WSBS). This area is considered to be under the background conditions. There is only electric winter heating system on WSBS. Collecting of aerosols is carried out by air sampling device UAS-310 pumping air through filters. Sample device is equipped by impactor dividing air into two streams with particle size less than 2.5 μm and 2.5–10 μm which are caught by separate filters. Duration of one sample collection is about a week. Aerosol sampling is intermitted in winter. 30 samples (60 filters Whatmann 41) collected in summer and autumn 2012 and spring 2013 were studied by scanning electron microscopy. The back trajectory analysis using HYSPLIT model [Draxler, R.R. and G.D. Ralph, 2003] was carried on to identify sources of aerosols. Particulate matter in the atmosphere of White Sea coast is generally composed of spores and pollen and mineral particles. The main compound of aerosol in the summer is biogenic particles. Content and diversity of biogenic particles increase with air masses coming from South. Particles of soot and salt often occur too.

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M01p - M01 Clouds, Precipitation and Aerosols and their Influence on Climate at High Latitudes, including the Role of the Southern Ocean and Sea Ice

M01p-104

The Antarctic Clouds and Radiation Experiment at Macquarie Island (54S) and Davis (69S)

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Clouds over the Southern Ocean are poorly represented in present day reanalysis products and global climate model simulations. The large errors in top-of-atmosphere broadband radiative fluxes in this region have large implications for forecasting and climate modelling. These errors are due to an incorrect representation of clouds and aerosols in the models. Knowledge of southern high latitude clouds is mainly from satellites, yet there are uncertainties in their retrievals and surface radiative flux estimates based on the satellite data.

An observational project called Antarctic Clouds and Radiation Experiment (ACRE) is in the planning stage to help address these issues. Key objectives include:

(a) Quantify key cloud and radiation properties between sub-diurnal and seasonal time-scales using a suite of ground-based instruments deployed for campaigns at Macquarie Island (54S) and Davis (69S) for 1 – 2 year duration. Macquarie Island is planned for winter 2016 while the Davis deployment will overlap with the YOPP (Year of Polar Prediction) period (to include either winter 2018 or winter 2019).

(b) Validate satellite cloud observations and products over the Southern Ocean and East Antarctica.

(c) Evaluate climate and numerical forecasting models (such as ACCESS-Cities Polar and AMPS-Polar WRF) to provide a pathway for forecasting model development. Provide collaborative opportunities for other modelling groups to evaluate their models in the southern high latitudes.

The US Atmospheric Radiation Measurement program will deploy a variety of surface radiometers to Macquarie Island for two years which will supplement observations made with Australian cloud radar, lidars and CCN counter. We will present an overview of the experimental design, objectives and expected outcomes.

IAMAS (Meteorology)

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M01p-105

High Latitude CCN Measurements in the Arctic and Antarctic Region

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Cloud Condensation Nuclei (CCN) measurements were conducted in two different campaigns. The Radiation-Aerosol-Cloud Experiment in the Arctic Circle (RACEPAC) took place in North Canada (Inuvik and Tuktoyaktuk) during spring 2014. Measurements were also done at the Princess Elisabeth Antarctica Research Station during the Antarctic summer 2013/2014. In both cases the total particle number concentration and the CCN number concentration was measured and used to estimate the hygroscopicity parameter κ [1] and the activation behaviour of sub-micron arctic aerosol particles.

In the northern sub-arctic region the total particle background concentration varied between 100 and 500 particles per cm^3. The κ-values for the sub-arctic aerosol in North Canada were estimated to be between 0.1 and 0.5. This large variability can be explained due to the varying origin of the air masses. The total particle concentration in the Antarctic is comparable with the background that was measured in Canada. Furthermore single events up to 4000 particles per cm^3 were detected. Since the CCN number concentration for the highest measured supersaturation of 0.7% is not affected during these events, a large particle number of diameter below 35 nm must be present. The κ-values of the Antarctic were found to have a mean of 0.76 and show lower variation. The κ of both data sets were found to agree well with global field simulation [2].

[1] Petters and Kreidenweis (2007), Atmos. Chem. Phys., 7, 1961–1971.

[2] Pringle et al. (2010), Atmos. Chem. Phys., 10, 5241–5255.

IAMAS (Meteorology)

M01p - M01 Clouds, Precipitation and Aerosols and their Influence on Climate at High Latitudes, including the Role of the Southern Ocean and Sea Ice

M01p-106

An Evaluation of Boundary Layer Cloud Forecasts over the Southern Ocean in a Limited-area Numerical Weather Prediction System

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Near synchronized in-situ, space-borne (A-Train) and ground-based lidar observations are employed to evaluate the boundary layer clouds (BLCs) over Tasmania and the adjacent Southern Ocean (SO) simulated by the limited-area version of Australian Community Climate and Earth System Simulator. Two winter cases featured by BLCs associated with a post-frontal environment and the leading side of a high pressure ridge are studied. Previous studies showed that these synoptic conditions contribute to the largest reflected shortwave radiation biases simulated over the SO.

Results suggest that the model demonstrates an appreciable level of skill in simulating the macrophysical properties, generally consistent with the in-situ and remote-sensing observations. However, some notable challenges remain: the area cloud fraction is consistently under-predicted; the fine-scale structure of the marine cumuli is poorly represented in the 4-km grid length simulations; the capping inversion over the marine boundary layer is generally too high, associated with the marine BLCs being predicted at the wrong altitude and temperature ranges; the liquid water content (LWC) of the BLCs is underestimated; the model representation of drizzle production can be too efficient.

Sensitivity studies are also conducted to test a newly developed autoconversion microphysics scheme and shear-dominated PBL scheme. These parameterizations show notable improvement in cloud prediction for CASE B. However, none of these tests is able to improve the simulated marine PBL structure. Overall, the simulated cloud biases are jointly influenced by physical parameterizations, poor representations of large-scale advection, surface fluxes and subsidence.

IAMAS (Meteorology)

M01p - M01 Clouds, Precipitation and Aerosols and their Influence on Climate at High Latitudes, including the Role of the Southern Ocean and Sea Ice

M01p-108

Comparing microphysical conditions of high-latitude low-level maritime clouds in the northern and southern hemispheres

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Satellite retrievals of cloud occurrence and radiative properties at similar latitudes in the remote Southern Ocean and North Atlantic have been shown to be similar (Mace, 2010), but more recent work suggests that there are differences in the retrievals of cloud structure and microphysical properties (Huang et al, 2014). In-situ observations made during the HIAPER Pole-to-Pole Observations global transects in the remote North Pacific (NP) and the Southern Ocean (SO) provide a unique opportunity to compare the microphysical properties of clouds in similar meteorological conditions.

Other cloud physics studies have already used the HIPPO dataset. Diao et al. (2014, 2013) examined the evolution of ice crystal regions in cirrus clouds on the local scale, and performed hemispheric comparisons of these processes. Chubb et al. (2013) showed that supercooled liquid water throughout the boundary layer cloud in nearly all of the profiles over the SO in HIPPO-2 and -3, and identified large liquid drops at temperatures as low as -20°C. The SO flight in HIPPO-4 revealed that wind-induced sea spray aerosol may be important in controlling cloud droplet number concentration (N_C) in a pristine environment (Chubb et al, in preparation).

We propose to use observations from a number of the HIPPO flights to perform a comparison of maritime stratocumulus cloud conditions in the remote NP and SO, over the different seasons in which the observations were made. In particular, we seek to examine the links between N_C and sub-cloud boundary layer conditions such as aerosol concentration, wind speed and sea surface temperature, as well as considering the air-mass history. Where supercooled liquid water is present, we intend to document the occurrence of ice crystals within these clouds.

IAMAS (Meteorology)

M01p - M01 Clouds, Precipitation and Aerosols and their Influence on Climate at High Latitudes, including the Role of the Southern Ocean and Sea Ice

M01p-110

A-train observations of maritime mid-latitude storm-track cloud systems: Comparing the Southern ocean against the north Atlantic

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Cloud and precipitation properties of the mid-latitude storm-track regions over the Southern Ocean (SO) and North Atlantic (NA) are explored using reanalysis and multi-sensor observations from A-Train for 2007-2011. In addition to high-level retrievals, lower-level observed variables, i.e. CloudSat radar reflectivity and Cloud-Aerosol Lidar and Infrared Pathfinder Satellite Observations satellite (CALIPSO) lidar attenuated backscatter, are directly examined using contoured frequency by altitude diagrams and contoured frequency by temperature diagrams to provide direct insight into thermodynamic phase properties.

While the wintertime temperature profiles are similar over the two regions, the summertime environment is warmer over the NA. The NA atmosphere is generally moister than the SO, while the SO boundary layer is moister during winter. Our results suggest that although the two regions exhibit many similarities in the prevalence of boundary layer clouds (BLCs) and frontal systems, notable differences exist. The NA environment exhibits stronger seasonality in thermodynamic structure, cloud and precipitation properties.

The regional differences of cloud properties are dominated by microphysics in winter and thermodynamics in summer. Glaciated clouds with higher reflectivities are found at warmer temperatures over the NA. BLCs (< 1.5 km) are a predominant component over the SO. The wintertime boundary layer is shallower over the SO. Mid-level clouds consisting of smaller hydrometeors in higher concentration (potentially supercooled liquid water) are more frequently observed over the SO. Cirrus clouds are more prevalent over the NA. Notable differences exist in both the

frequencies of thermodynamic phases of precipitation and intensity of warm rain over the two regions.

IAMAS (Meteorology)

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M01p-111

Windsat observations of Southern ocean cyclone structure

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In this study, we use the WindSat satellite dataset to form an integrated view of the characteristics of cyclones over the Southern Ocean (SO). WindSat polarimetric microwave measurements of brightness temperature can be used to derive sea-surface temperature, near-surface horizontal wind velocities, total column water vapour (TCWV), cloud liquid water content (CLW) and rain rate (RR) over the ocean surface and are not presently assimilated into reanalyses. Thus, this dataset provides a powerful tool to examine the strengths of reanalyses' representations of cyclones.

To examine cyclones over the SO statistically, we transform the data into a cyclone centred coordinate system by forming composites of data based on cyclone positions ascertained from the ERA-Interim reanalysis surface pressure field; composites are derived using all cyclone centres between 40 and 60°S for the period 2007 to 2012. The composites are shown to match well with composites formed from other satellite datasets, namely AMSR-E and NVAP-M, and confirm the quality of the WindSat dataset. We then compare the WindSat composites with those from the ERA-Interim output to examine their similarities. Our results suggest that the mean cyclone composite horizontal wind field observed by WindSat and ERA-Interim matches rather well, providing an independent validation of the ERA-Interim output. However, inspection shows that the two datasets' velocity distributions are quite different in some quadrants, suggesting analysis of mean patterns around the cyclone can hide relevant detail. Comparisons for the TCWV show larger differences near the cold frontal region. The correspondence becomes still poorer when the CLW and RR fields are compared, with relative differences being as large as 30%.

IAMAS (Meteorology)

M01p - M01 Clouds, Precipitation and Aerosols and their Influence on Climate at High Latitudes, including the Role of the Southern Ocean and Sea Ice

M01p-112

Non-stationary Relationship between Cloud Radiative Forcing and Sea Ice Concentration in the Arctic Ocean during Summer

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In this study, we have examined changes in the relationship between surface cloud radiative forcing (CRF) and sea ice concentration (SIC) / surface temperature (TS) in the Arctic Ocean during summer (June-July-August-September). The monthly observation data of shortwave (SW) and longwave (LW) CRFs, SIC and TS were obtained over the Arctic Ocean (North of 70°N) from the Extended AVHRR Polar Pathfinder (APP-x) product for the period of 1982–2012. We found that the relationship between CRF and SIC/TS changed over time. The negative (positive) correlation between SW CRF (LW CRF) and SIC has become stronger over the Pacific sector of the central Arctic since the late 20th century. This indicates that the cloud radiative effect by LW radiation has been reduced, whereas that by SW radiation has increased over the Pacific sector of the Arctic Ocean. In addition, the impact of LW CRF to SIC has increased over the marginal sea areas. Similar relationship is also found in the TS data. This recent change in the relationship based on the satellite observation is not reproduced in current climate models. Rather, most models tend to overemphasize the cloud radiative effect by LW radiation on SIC/TS during summer.

IAMAS (Meteorology)

M01p - M01 Clouds, Precipitation and Aerosols and their Influence on Climate at High Latitudes, including the Role of the Southern Ocean and Sea Ice

M01p-113

Aerosol physical properties studied in Spitsbergen

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On the global scale a major unknown of the spatial aerosol distribution is the vertical distribution. Transport in the planetary boundary layer and the free troposphere can be decoupled, resulting in different chemical composition and thus aerosol properties in different layers.

The Arctic region represents a sensitive ecosystem, which is susceptible to even small changes in the local climate.

The Arctic atmospheric boundary layer (ABL) poses a challenge for all models due to its persistent stable stratification and the important role of ice phase microphysical processes in the formation of boundary layer clouds. Moreover, forcing factors as radiation, conduction, turbulence, subsidence and advection processes increase the complexity of the system.

The aerosol studies presented were carried out onboard the r/v Oceania between 2000-2014, partly within the NASA/MAN program. During each campaign the vessel cruised for six weeks in the European Arctic between 0 and 14 E and 69 and 79 N. There was also a number of land based experiments, within the framework of the POLAR-AOD program or MACRON on Andoya in northern Norway (16 E, 69 N) in 2006, and in Ny-Alesund in 2014.

Using the obtained data, primary trajectory analyses, source regions of different aerosols were identified. We also examined the spatial and temporal variation of aerosol optical depth in different parts of Spitsbergen.

IAMAS (Meteorology)

M01p - M01 Clouds, Precipitation and Aerosols and their Influence on Climate at High Latitudes, including the Role of the Southern Ocean and Sea Ice

M01p-114

Poleward moisture transport in Antarctica: an objective look

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Changes and variability in the surface mass balance (SMB) signify one of the most puzzling questions of the present and future changes in Antarctica. Antarctic SMB is dependent upon the amount of atmospheric moisture transported poleward over the coastline and its subsequent precipitation. Observing these phenomena in Antarctica is extremely difficult due to sparse nature of ground measurements and known problems with reanalysis data.

In this research we make use of the unique infrared satellite composite dataset developed at the University of Wisconsin. Combining Antarctic imagery at 1-hour, 5-km resolution we perform manual evaluation of poleward pathways of clouds into the Antarctic interior. We identify several regions of preferred poleward pathways based on 20+ years of available data. In general, West Antarctic region reveals much more vigorous transport, consistent with documented maximum in synoptic and mesoscale storm activity in the Ross and Amundsen Seas. Poleward cloud and moisture transport in the East Antarctica is organized trough narrow “favoring” sectors. Our unique data-driven approach provides an objective look at poleward moisture transport, which is useful for validating reanalysis data and regional climate model simulations.

IAMAS (Meteorology)

M02a - M02 Advances in Atmospheric Dynamics Including Topographic Forcing

IUGG-1080

Dynamics of the large-scale flow during the extreme 2013/14 Boreal Winter.

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During the Boreal Winter of 2013-14 a zonal swath of the extra-tropical Northern Hemisphere that extended from California to the Middle East experienced extreme and often destructive weather. Here the focus is upon salient upper-tropospheric features of the principal weather systems during this season.
An exploration is undertaken of the linkage of these weather features to:- the differing weather extremes; the season's decidedly unusual time-mean anomaly patterns; and the prevailing 'external' forcing factors. It is demonstrated that the amplitude, recurrence, and location of these features relates closely to the weather extremes and accounts directly for the establishment of the anomaly patterns. Also it is shown that the features themselves occur sequentially and are inter-related. Furthermore evidence is provided of the unexpected and nuanced nature of their dynamical link to two plausible forcing factors - the region of anomalous sea surface temperature spread across the tropical and subtropical western Pacific with its attendant precipitation pattern, and the significantly asymmetric configuration of the stratospheric polar vortex.

IAMAS (Meteorology)

M02a - M02 Advances in Atmospheric Dynamics Including Topographic Forcing

IUGG-2313

Relating objectively detected jet axes, blocking and wave-breaking events

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When detecting jets by a wind-speed threshold, information like the existence of several wind maxima is lost. We propose to identify jets based on their axes and present a new detection scheme for upper tropospheric jets which is based on a zero-wind-shear condition. We show that the new detection scheme reliably detects jet axes in instantaneous data from reanalysis data sets, as well as in weekly, or monthly averaged wind fields.

We demonstrate the dynamical implications of the detected jet axes using the synoptic evolution during the boreal winter 2013/14 as an example. This winter featured a stable high over the East Pacific, which led to anomalously cold conditions over eastern North America. Using published objective detection methods for Rossby wave breaking and dynamical blocks, we relate the detected jet axes to conceptual models describing the interplay between jet axis, wave breaking, and blocking. We show that the synoptic situation during the cold spell closely resembles the winter climatology, suggesting that only the persistence of this situation made it exceptional.

With the same tools, we furthermore discuss different dynamical interpretations of the NAO and the PNA, which are often thought to reflect variability of wave breaking and blocking. Our results support the Woollings et al high-latitude blocking interpretation of the NAO, whereas the relation between the PNA and blocking is less clear.

IAMAS (Meteorology)

M02a - M02 Advances in Atmospheric Dynamics Including Topographic Forcing

IUGG-2612

Rossby wave breaking in the Australian region and its connection to summertime weather

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As Rossby waves propagate away from their source, they sometimes organize weather systems far from their origin. On occasion these waves break, producing isolated potential vorticity streamers and anomalies. In the Australian region during summer, Rossby waves preferentially break anticyclonically around the longitudes of eastern Australia, and in the process, cyclonic potential vorticity is transported equatorward and anticyclonic potential vorticity is transported poleward. Much of the significant summertime weather in the region can be attributed to this kind of stirring of the potential vorticity field and the potential vorticity anomalies so produced. Three interconnected aspects of the summertime weather pattern in the region are discussed here, each of which is related to Rossby wave propagation and breaking. First, active and break phases of the monsoon are controlled by the equatorward propagation of Rossby waves. Second, the summer monsoon convection often forms on the potential vorticity anomalies formed from Rossby wave breaking, and in northwestern Australia 40-50% of the monsoon rainfall is directly associated with potential vorticity anomalies formed this way. Third, deep, organized convection in the tropics (especially tropical cyclones) affect how Rossby waves break in the midlatitudes through the advection of anomalously anticyclonic potential vorticity from regions of deep convection into the upper level anticyclones. In this way, deep tropical convection affects the strength of blocking anticyclones and heatwaves in the midlatitudes.

IAMAS (Meteorology)

M02a - M02 Advances in Atmospheric Dynamics Including Topographic Forcing

IUGG-2780

Can recent observed changes indicate whether we should expect more intense extratropical cyclones in the future?

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Current climate model projections do not exhibit a large change in the intensity of extratropical cyclones. However, there are concerns that current models represent moist processes poorly, and this provides motivation for investigating observational evidence for how cyclones behave in warmer climates.

In the North Atlantic in particular, recent decades provide a clear contrast between warm and cold climates due to Atlantic Multidecadal Variability. We compare these past changes in reanalyses to the projected future changes to see if they may provide a guide to future cyclone behaviour. While temperature and moisture rise in recent warm periods as in the projections, differences in energetics and temperature gradients imply that these periods are only partial analogues for future warming. Despite this, the past changes do provide support for the model projections of little change in storm intensities in the future.

IAMAS (Meteorology)

M02a - M02 Advances in Atmospheric Dynamics Including Topographic Forcing

IUGG-5162

Scale interactions and deep tropical potential vorticity intrusions during sudden stratospheric warmings

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Using reanalysis data we examine extratropical-to-tropical potential vorticity (PV) intrusions in the upper troposphere-lower stratosphere (UTLS) in the time period surrounding major sudden stratospheric warmings (SSWs). Our analysis reveals that PV intrusion events that are associated with SSWs are notably different in both geographic location and magnitude when compared to their climatological counterparts.
In particular, while PV intrusions during non-SSW time periods are concentrated in the eastern Pacific and Atlantic Ocean basins where the presence of climatological 'westerly ducts' supports the propagation of wave energy deep into the tropics, PV intrusion events that are associated with SSWs have unique geographic centers of action that are dependent on the type of SSW involved (i.e. split versus displacement). Our results indicate that these geographic patterns are associated with two mechanisms. First, during the highly amplified prewarming period, the stratospheric surf zone extends downward and equatorward into the subtropical and tropical upper troposphere; this represents the dominant mechanism for supplying high PV air to the subtropical UTLS. However, the SSW-related amplified planetary waves and associated material PV deformations also induce zonally asymmetric shifts in jet structure that deform the UTLS synoptic-scale wave guide; this secondary mechanism ducts additional wave energy equatorward. Together these two mechanisms produce PV intrusions that are significantly stronger than their climatological counterparts. In light of these results, we consider the implications for how the PV intrusions and associated wave breaking events may modulate tropical convection and the mixing of trace constituents between the extratropical and tropical UTLS.

IAMAS (Meteorology)

M02b - M02 Advances in Atmospheric Dynamics Including Topographic Forcing

IUGG-3628

Roles of barotropic and baroclinic eddy feedbacks in the atmospheric response to the lower tropospheric thermal forcing

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Both observations and climate model simulations have shown that the eddy-driven jet exhibits significant meridional shift in response to the lower boundary thermal forcing, such as the recent Arctic amplified warming induced by the sea ice loss, El Nino-like oceanic warming and extratropical sea surface temperature anomalies. Understanding the dynamical mechanisms of the atmospheric response to such lower boundary thermal forcing is central for the prediction of mid-latitude climate and the evaluation of climate sensitivity.

In this study, using a nonlinear beta plane quasi-geostrophic channel model, the mechanism through which lower level thermal forcing affecting the jet shift is investigated. In addition to the direct thermal wind adjustment, the eddy feedbacks, including the changes in the baroclinic processes such as the lower-level eddy generation and the barotropic processes such as the upper-level wave propagation and breaking, all play a role in the atmospheric response to the thermal forcing. By diagnosing the finite amplitude wave activity budget and setting up overriding experiments, the relative roles of baroclinic and barotropic processes in the eddy feedbacks to the lower-level thermal forcing are further estimated and explicitly compared. With the two methodologies, it is shown that the lower-level thermal forcing affects the eddy-driven jet rapidly by modifying the upper-level zonal thermal wind distribution, as well as the associated meridional wave propagation and breaking. Unlike the traditional baroclinic viewpoint, our results suggest that the barotropic eddy feedback dominates the total atmospheric response to the lower boundary thermal forcing.

IAMAS (Meteorology)

M02b - M02 Advances in Atmospheric Dynamics Including Topographic Forcing

IUGG-4497

Recent developments in the theory of Rossby waves and their interaction with the mean flow

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Rossby waves and balanced eddies play major roles in arranging angular momentum and temperature of the mid-latitude atmosphere. Whilst theory is most complete for linear Rossby waves and geostrophic turbulence, meshing of the two in an inhomogeneous environment remains a challenging task. In 2010 we introduced a potential vorticity (PV)-based finite amplitude wave activity (FAWA) diagnostic applicable to both Rossby waves and balanced eddies, which quantifies advective and diffusive contributions to eddy-mean flow interaction. In this talk we (i) utilize conservation of FAWA and a related finite-amplitude pseudoenergy density to derive a generalized dispersion relation for finite-amplitude, near-plane Rossby waves in a slowly varying mean flow and (ii) generalize FAWA as a function of longitude ['local wave activity (LWA)']. We will test the theories with both idealized numerical simulations on a sphere and reanalysis data.

IAMAS (Meteorology)

M02b - M02 Advances in Atmospheric Dynamics Including Topographic Forcing

IUGG-4531

Formation and maintenance mechanism of the tropospheric jet stream

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To examine the climatological conditions that govern the formation and maintenance of the tropospheric jet stream, we used a new analysis technique that isolates the responses of specific forcings from observational data. Our analysis showed that although the tropical flank of the subtropical jet is thermally forced by heating associated with tropical convection and subtropical cooling, the core of the jet and its polar flank are forced mainly by eddies throughout the year. In particular, stationary waves are the main drivers of the core of the jet throughout the year in the Northern Hemisphere, and they are its strongest drivers during boreal winter. In comparison, both stationary and low-frequency transient waves are the main drivers of the jet during austral winter, and synoptic waves play a major role during austral summer.

IAMAS (Meteorology)

M02b - M02 Advances in Atmospheric Dynamics Including Topographic Forcing

IUGG-4804

Global circulation regimes in the presence of stationary planetary wave forcing

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The three way interaction of the Hadley circulation, zonal jet streams and baroclinically unstable eddies gives rise to different circulation regimes, characterized by the type of jet stream. Idealized models which resolve the interactions between these three components show three main kinds of equilibrated jet streams- a thermally driven subtropical jet, an eddy driven jet, and a merged thermally-eddy driven jet. These regimes differ in the location and variability of the jet stream, as well as in the structure and zonal wavenumber and phase speed of the dominant modes. A main component missing from these models is the presence of stationary planetary waves. These waves influence the zonal jet stream and the Hadley circulation through their momentum fluxes, while the wave response to stationary forcing depends on the structure and position of the jet relative to the mountain. We will examine how the global circulation regime morphology varies in the presence of idealized stationary forcing at subtropical, mid- and high latitudes.

IAMAS (Meteorology)

M02b - M02 Advances in Atmospheric Dynamics Including Topographic Forcing

IUGG-4890

The role of planetary waves in determining the location of the tropospheric jet

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An idealized general circulation model is used to assess the importance of planetary-scale waves in determining the position of the tropospheric jet, in particular its tendency to shift poleward as winter stratospheric radiative cooling is increased. Full model integrations are compared against integrations in which planetary waves are eliminated by truncating in the zonal direction to include wavenumber six only. To enable the comparison, two series of truncated integrations are considered, using (i) a modified radiative equilibrium temperature, or (ii) a nudged-bias correction procedure. Both produce tropospheric time-mean states that are similar to that of the full model when the stratospheric cooling is weak, and allow an assessment of the changes that result when the stratospheric cooling is increased. The results indicate that planetary waves play an important role in determining the structure of the tropospheric mean flow and rule out the possibility that the jet shift occurs purely as a response to changes in the synoptic-scale wave field alone.

IAMAS (Meteorology)

M02c - M02 Advances in Atmospheric Dynamics Including Topographic Forcing

IUGG-1740

Declining Trend in Simulated Snow Water Equivalent over the Highlands of Turkey

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In this study, the snow water equivalent (SWE) over the highlands of Turkey has been analyzed by using regional climate model outputs from ICTP-RegCM4. The high resolution climate simulations (horizontal grid: 10-km) driven by ERA-Interim Reanalysis (period: 1979-2012) and NCEP/NCAR Reanalyis (period: 1982-2012) have been applied to solve the complex and steep topography of Turkey where the elevation average is 1132 m. The mountains in eastern Turkey are highly prominent in terms of transboundary rivers system since the main headwaters of the Euphrates and Tigris rivers are fed by snow-melting process over these highlands. SWE is produced by land surface model, called BATS, coupled with RegCM4. The simulated SWE validated with the snow height observations gathered form meteorological station located in higher altitudes (>1500 m). The trend analysis of SWE is calculated for the each month from November to May during the simulation period. The decadal trend for SWE decreases in the range of 10-50 mm which correspond 5-10% of the monthly mean of SWE over the eastern highlands. The maximum SWE change determined in February and the negative trend disappeared in April. This decline in the regional climate simulation has been defined over four different basins (Upper Euphrates, Tigris, Coruh and Aras) which are located in the eastern Turkey. In addition, these snowmelt-driven rivers are flowing over the territory of seven different countries including Georgia, Armenia, Azerbaijan Iran, Iraq, Syria and Turkey. The water scarcity caused by the SWE decline may have inevitable outcomes considering the water demand conflicts and political tension in this region.
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IAMAS (Meteorology)

M02c - M02 Advances in Atmospheric Dynamics Including Topographic Forcing

IUGG-2415

"Synoptic-scale flow structures associated with extreme precipitation events in northern Switzerland"

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A climatological analysis of upper-level flow structures associated with extreme precipitation events in north-western and north-eastern Switzerland is presented. A potential vorticity (PV) perspective on the tropopause-level flow is used. PV structures at tropopause-levels that are common to many extreme precipitation events are identified by a K-means clustering approach. The way in which the location and structure of the upper level flows affects the local distribution of the precipitation is analyzed. Moreover for each class the main forcing mechanism behind the ascent of moist air, the magnitude of the total precipitable water and the seasonal distribution are presented. The way in which the location and structure of the defined upper level classes affect the local distribution of precipitation is analysed. In addition we analyse the directions of the moisture flux that interacts with the topography and results in extreme precipitation events. The flow conditions range from advective situations in which large amounts of moisture are transported toward the Alps, to flow situations in which heavy precipitation occurs on the lee side of the Alps and ascent is mostly driven by large-scale forcing.

IAMAS (Meteorology)

M02c - M02 Advances in Atmospheric Dynamics Including Topographic Forcing

IUGG-2889

Structural and environmental characteristics of extratropical cyclones that cause a tornado outbreak

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We examine differences in the structural and environmental characteristics of extratropical cyclones (ECs) that cause tornado outbreaks and that do not through composite analyses of reanalysis data and idealized numerical simulations.

In the composite analyses, we have categorized ECs in the USA in April and May between 1995 and 2011 into two groups: ECs accompanied by 15 or more tornadoes (hereafter, referred to OCs (outbreak cyclones)) and ECs accompanied by 5 or less tornadoes (NOC (non-outbreak cyclones)).

The composite analyses display significant differences in convective environmental parameters between OCs and NOCs. For OCs, convective available potential energy (CAPE) and storm relative environmental helicity (SREH) are larger and the areas in which these parameters have significant values are wider in the warm sector. The larger CAPE in OCs is due to larger amount of low-level water vapor, while the larger SREH in OCs due to stronger wind at low levels.

In the idealized numerical experiments, ECs are developed in basic states which are obtained from 5-day average of composite environment for OCs and NOCs, and their structures are examined. WRF model is used for the numerical experiments. The results of the numerical experiments for the composite environments for OCs and NOCs (hereafter, referred to as EX-OC and EX-NOC, respectively) show that SREH in the east-southeast region of the EC center in EX-OC is larger than that in EX-NOC. Larger anticyclonic shear of the environmental jetstream for OCs causes meridionally elongated structure of EC in the southeast region of the EC center in EX-OC, resulting stronger low-level winds and larger SREH than in EX-NOC.

IAMAS (Meteorology)

M02c - M02 Advances in Atmospheric Dynamics Including Topographic Forcing

IUGG-2890

Stratosphere-troposphere-exchange in the vicinity of Southern Hemispheric cyclones – measurement, model analysis, and climatology

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During the international aircraft measurement campaign DEEPWAVE (Deep Propagating Gravity Wave Experiment) in July 2014, one flight has been performed to investigate stratosphere-troposphere-exchange (STE) in the vicinity of a tropopause folding event over New Zealand. Since STE-events along tropopause folds are known to influence tropospheric chemistry e.g. by transporting stratospheric, ozone-rich air masses into the troposphere, it is crucial to analyze these events in detail. In the presented study we focus on small scale mixing processes, which are not well captured by global model simulations.

From high precise N2O in-situ measurements stratospheric air masses can clearly be identified on various flight levels between 200 and 700 hPa in the troposphere in the vicinity of the tropopause fold. We compare the in-situ data with high resolution model data. For this purpose the global and regional atmospheric chemistry model system MECO(n) ("MESSy-fied ECHAM and COSMO models nested n-times") is used, which allows for very consistent, simultaneous simulations in different spatial resolutions. Additionally, MECO(n) enables the release of artificial, passive tracers under defined conditions which are helpful to determine the origin of different air masses, time scales, and regions of exchange.

Furthermore, we compare the results of the case study with a newly derived climatology of STE events in the vicinity of Southern Hemispheric cyclones. A Lagrangian approach is used to identify STE events from the stratosphere to the troposphere and vice versa. Together with a sophisticated cyclone identification and tracking tool, we are able to investigate the spatial and temporal distribution of STE events in the vicinity of SH cyclones as well as the corresponding mass flux.

IAMAS (Meteorology)

M02c - M02 Advances in Atmospheric Dynamics Including Topographic Forcing

IUGG-2951

Diabatic PV anomalies related to clouds and precipitation in an idealized extratropical cyclone

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Extratropical cyclones have a large impact on the weather in the mid-latitudes through the accompanying strong winds and precipitation. The formation of clouds and precipitation and subsequent phase changes like freezing, melting, sublimation and evaporation lead to distinct diabatic potential vorticity (DPV) anomalies. Positive low-level DPV anomalies - which typically are formed along the fronts and close to the cyclone center - have been shown to interact with the upper-level PV anomalies thereby potentially enhancing storm intensification. We performed idealized moist baroclinic wave simulations with an accurate representation of the different cloud microphysical processes. Through calculating backward trajectories we are able to construct a PV budget for each individual anomaly. Thereby we quantify the contributions of, e.g., cloud condensation, depositional growth of snow and melting of snow to the individual anomalies and in turn to the near-surface circulation. Both the in-cloud microphysical processes as well as the below-cloud phase changes of hydrometeors are shown to contribute significantly to the formation of DPV-related near-surface winds, which underlines the importance of the microphysical scheme for an accurate prediction of (intense) wind structures in a mid-latitude cyclone.

IAMAS (Meteorology)

M02c - M02 Advances in Atmospheric Dynamics Including Topographic Forcing

IUGG-3872

Dynamics of the January 2013 Gong Storm: A sting jet offshore Portugal

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The Gong storm crossed the Portuguese coast on 19 January 2013, leading to significant devastation by extreme wind, with more than 1000 km of disabled power lines. Numerical simulations with the WRF model at resolutions down to 3 km indicate that the storm presented characteristics of a Shapiro-Keyser cyclone, with a T-bone structure and a sting jet on its southern sector, with details very similar to those described by Browning (2004). Such storms are unusual in Europe, although they have been identified in a few remarkable extreme events in recent decades, notably in the great 1987 wind storm in the UK (Schutts 1990), with the Gong storm being the second case of sting jet storm affecting Portugal in less than 5 years.

While WRF simulations forced by the ECMWF forecast are able to reproduce an extreme wind event, as observed, results are found to be sensitive to parametrization choices and, remarkably, to the chosen boundary conditions, with poor results obtained when ERA-Interim reanalysis data is used instead of the operational forecast. On the other hand, results are found to be not too dependent on horizontal resolution. An analysis of fine structure of the storm when the sting jet is produced, supports results recently published by Schultz and Sienkiewicz (2013).

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IAMAS (Meteorology)

M02d - M02 Advances in Atmospheric Dynamics Including Topographic Forcing

IUGG-2087

The impact of tropical convection and interference on the extratropical circulation

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An idealized multi-level primitive equation model along with diagnostic analyses with ERA-Interim Reanalysis data are used to examine the impact of (1) tropical convection and (2) interference between the climatological stationary eddies and transient eddies on the extratropical circulation and surface air temperature. For the model calculations, realistic heating profiles are specified. These heating profiles are decomposed into separate contributions from various parts of the tropical Indian and Pacific Oceans. For the diagnostic analysis, an index is generated that measures the strength and sign of the interference. This index is obtained by projecting the daily 250-hPa streamfunction eddy field onto the corresponding stationary eddy field. Key atmospheric variables are regressed against this interference index.

The idealized model calculations show that the extratropical response to tropical convection is most sensitive to the convection in two particular regions, the tropical Indian and central Pacific Oceans. The impact from the warm pool region is relatively small because of cancellation between the tropical and extratropical Rossby wave sources. It is found that both tropical convection and a reduction in Arctic sea ice precede constructive interference between the stationary and transient eddies, and constructive interference is followed by a warming of the Arctic and the excitation of the negative phase of the Northern Annular Mode (NAM). The relationships are reversed when there is destructive interference. These teleconnective interference relationships involve Rossby wave propagation and changes in the strength of the stratospheric polar vortex.

IAMAS (Meteorology)

M02d - M02 Advances in Atmospheric Dynamics Including Topographic Forcing

IUGG-2646

Idealized numerical experiments of cyclone development in the tropical, subtropical and extratropical environments

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Cyclone development is active in the tropics and extratropics, whereas it is inactive in the subtropics, particularly in the Southern Hemisphere summer. To assess the influence of environmental fields on the cyclone development in the tropics, subtropics and extratropics, idealized numerical experiments are conducted using a regional non-hydrostatic model. The experiment examines the development of a weak initial vortex within a zonally uniform environmental field which consists of five factors: the Coriolis parameter, zonal wind, potential temperature, relative humidity, and surface temperature difference between the ocean and atmosphere. The experiments successfully reproduced the cyclone development in the tropical and extratropical environment as well as no cyclone development in the subtropical environment. This result confirms the dominant role of environmental field in controlling the cyclone development.
To clarify which environmental factor is responsible for the suppression of cyclone development in the subtropics, a series of sensitivity experiments are performed. A tropical cyclone cannot develop in the subtropics because of low temperature, strong stratification and strong vertical shear compared to the tropics. On the other hand, an extratropical cyclone cannot develop in the subtropics, because of the relatively small Coriolis parameter and weak vertical shear. The relative humidity and surface temperature difference play only minor roles. These results provide useful insights into the climatological distribution of various types of synoptic-scale cyclones.

IAMAS (Meteorology)

M02d - M02 Advances in Atmospheric Dynamics Including Topographic Forcing

IUGG-2923

Sensitivity of the downstream impact to the eddy kinetic energy budget of transitioning tropical cyclones

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The extratropical transition (ET) of a tropical cyclone (TC) may strongly impact the midlatitude wave pattern by amplifying or triggering a Rossby wave train and my thus facilitate high impact weather events even in regions lying far downstream of the transitioning TC. The processes involved in the transition and interaction are often not well represented in numerical weather prediction (NWP) systems. As a result, predictability for downstream regions is frequently reduced during ET. A better understanding of the important processes and their representation in NWP systems will help to overcome those issues in predictability. Our study aims to identify the impact of a transitioning TC as an additional source of kinetic energy on the modification of the midlatitude flow and the associated forecast uncertainty. We employ ECMWF ensemble forecasts to gain multiple solutions for the interaction of two transitioning TCs with the midlatitude flow. By determining the sensitivity of the amplifying downstream wave train to the eddy kinetic energy (Ke) budget within the ensemble, we are able to identify the role of the ET in modifying the midlatitude flow configuration. Specific features of the Ke budget associated with the transitioning cyclone are found to have a significant impact on the amplification of the downstream wave train, while the Ke budget of the upstream midlatitude flow seems to be of secondary importance. We further seek to link the identified dependencies to predictability in downstream regions.

IAMAS (Meteorology)

M02d - M02 Advances in Atmospheric Dynamics Including Topographic Forcing

IUGG-3321

Phenomenology of summer blocking and links with surface heatwaves over the Eurasian sector

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Atmospheric blocking is known to largely impact the weather from daily to seasonal time scales. In particular, its imprint on the surface temperature is often in the form of extremely cold spells in winter and strong surface heatwaves in summer. Dynamically, the former requires a meridional dipole in pressure to occur, where easterlies are generated geostrophically at its centre and consequently drive the cold air advection from poleward regions. The latter strongly relies on static and persistent anticyclonic structures, which in principle do not require the low pressure counterpart. A simple diagnostic tool is applied to the summer seasons, for the period 1979-2013, to analyse both the dipole blocking structures (DBSs) and the large scale ridges (LSRs) and their impact at the surface. It is found that their combination accounts for more than 90% of the frequency of surface heatwaves over the Eurasian region. LSRs lead to hot weather episodes over southern and central Europe as they develop within the weak summer jet, which allows for mid-latitude ridges to amplify and persist over several days. On the other hand, DBSs tend to affect the surface temperature over the northern part of the continent, whereby wave-breaking processes drive isolate low-PV air masses further north. Examples of these dynamical features are provided, looking in particular at summer 2003 and 2010.

IAMAS (Meteorology)

M02d - M02 Advances in Atmospheric Dynamics Including Topographic Forcing

IUGG-3393

Nadine the unseen: How a north Atlantic hurricane dropped the predictability over the mediterranean

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Operational forecasts for the western Mediterranean exhibited a persistent uncertainty around 20 September 2012, while Hurricane Nadine was slowly moving over the eastern North Atlantic. The forecasts showed a bifurcation in the track of Nadine – a significant fraction predicting its landfall over the Iberian Peninsula – and a high spread in the synoptic conditions downstream. The persistent forecast uncertainty occurred during the first special observation period of the HyMeX. Clustering the ensemble forecast of the ECMWF reveals the crucial interaction between Nadine and an Atlantic cutoff. The interaction controls both the track of Nadine and the synoptic conditions downstream. In cases of weak interaction, the cutoff moves over western Europe and triggers intense precipitation over the Cévennes, which was observed during HyMeX SOP1. In cases of strong interaction, the cutoff remains over the Atlantic and merges with Nadine. In some intermediate cases, Nadine is steered eastward by the cutoff and makes landfall over the Iberian Peninsula. A critical distance of about 1000 km between Nadine and the cutoff distinguishes between cases of weak and strong interaction in the ensemble forecast. The critical distance is supported by shifting the initial position of Nadine in Meso-NH numerical experiments. The interaction between Nadine and the cutoff mimics the vortex-vortex interaction previously observed for tropical storms. It differs from the usual interaction between a hurricane and a larger trough during extratropical transition over the western North Atlantic. The unusual vortex-vortex interaction of Nadine over the eastern North Atlantic dropped the predictability over the Mediterranean. This study was sponsored by the DRIHM project.

IAMAS (Meteorology)

M02e - M02 Advances in Atmospheric Dynamics Including Topographic Forcing

IUGG-1067

The interaction between coastal topography and midlatitude cyclones in a regional climate model

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Extratropical cyclones are a major cause of severe weather in the midlatitudes, particularly during the winter months. They can develop very rapidly, and cause widespread flooding, strong winds, and high seas in coastal areas. One area of above average cyclone activity is in the Tasman Sea to the east of Australia, with cyclones responsible for a large proportion of severe weather events along the Australian east coast.

The Great Dividing Range is Australia's largest mountain range, and runs parallel to the east coast. This is a major contributor to spatial patterns of both mean rainfall and rainfall variability. However, there is as yet little understanding of how it may contribute to the development, intensity, location, or impacts of midlatitude cyclones in Australia.

To assess this, a number of major cyclones have been modelled using the Weather Research and Forecasting (WRF) regional climate model, at both 50 km and 10 km resolution. Using a large ensemble of initial conditions for both the control case and a case with flattened topography, we identify significant changes to the mean characteristics of cyclones, as well as large changes to their associated rainfall impacts. This has important implications for the representation of cyclones in areas of complex topography, particularly in coarse-resolution models.

IAMAS (Meteorology)

M02e - M02 Advances in Atmospheric Dynamics Including Topographic Forcing

IUGG-1248

Topographic control of stratified flows: Blocking, upstream jets, isolating layers and downslope flows

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We consider stratified flows over isolated obstacles in the limit of strong stratification and tall obstacles for which the total kinetic energy of the flow is insufficient to draw all of the fluid up and over the obstacle crest and so the fluid below some height is arrested or blocked. Optimal solutions to the nonlinear, hydrostatic, Boussinesq equations are developed for steady, density-stratified, topographically controlled flows characterized by blocking and upstream influence. These flows are jet-like upstream and are asymmetric and thinning as they accelerate over the crest. A stagnant, uniform-density isolating layer, surrounded by a bifurcated uppermost streamline, separates the accelerated flow from an uncoupled flow above. The flows are optimal in the sense that, for a given stratification, the solutions maximize the topographic rise above the blocking level required for hydraulic control while minimizing the total energy of the flow. Hydraulic control is defined mathematically by the asymmetry of the accelerated flow as it passes the crest. A subsequent analysis of the Taylor-Goldstein equation shows that these sheared, non-uniformly stratified flows are indeed subcritical upstream, critical at the crest, and supercritical in the downslope flow with respect to gravest-mode, long internal waves. The solutions are not just relevant to atmospheric flows over mountains but also arrested wedge flows, selective withdrawal, stratified towing experiments and oceanic flows over topography.

IAMAS (Meteorology)

M02e - M02 Advances in Atmospheric Dynamics Including Topographic Forcing

IUGG-1279

Climatology and dynamics of cold air outbreaks in the South Pacific

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Cold air outbreaks (CAO) are severe weather events in polar latitudes, which greatly affect turbulent heat fluxes from the ocean, but also have strong dynamical impacts, as they provide a favorable environment for the genesis of mesoscale vortices. We present a novel, Lagrangian climatology of CAOs in the South Pacific based on ERA-Interim and investigate the life-cycle of a severe CAO in a high-resolution simulation using the limited area weather prediction model COSMO.

Firstly, we investigate origin and evolution of the characteristics of CAO air masses in the South Pacific from a climatological viewpoint. We show that about 50% of the CAO air masses has descended from the Antarctic continent, with the Ross Ice Shelf corridor being the major pathway. Sensible and latent heat fluxes are tremendously enhanced in CAOs once the air masses have crossed the sea ice edge, such that especially during winter the interannual variability of the air-sea heat flux is largely determined by the frequency of CAOs. Furthermore, CAO air masses initially have strongly negative potential vorticity (PV), but sensible heat fluxes immediately erode the PV over open ocean. This has implications for the origin of cyclonic PV values during mesocyclone development commonly observed with CAOs.

Secondly, detailed quantitative insights into the physical processes governing the life-cycle of CAOs are obtained from a COSMO case-study of a severe CAO in the Amundsen Sea from June 2010, which was associated with the development of a train of mesocyclones along its baroclinic outer edge. We show that besides turbulent mixing due to intense surface sensible heating, latent heat release associated with the mesocyclones essentially contributed to the erosion of the CAO air mass.

IAMAS (Meteorology)

M02e - M02 Advances in Atmospheric Dynamics Including Topographic Forcing

IUGG-2267

Easterly Gap winds over the Antarctic Peninsula – Observations, Modelling, and the impact on Aircraft operations

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During January and February 2011 observations of the flow across the Antarctic Peninsula were made. These observations included ground-based measurements with automatic weather stations and a manned surface field camp as well as in-situ measurements made with an instrumented aircraft. The westerly flow and the impact of the flow on the Larsen Ice Shelf have been reported elsewhere. Here we look at cases of easterly flow, particularly the enhanced gap wind, that are observed close to the British Rothera Station. Observations of winds made with the aircraft and at the station are reported and compared with high resolution model simulations made with the WRF model. These easterly flows can have a large impact on the aircraft operations at Rothera station and we consider how easy it is to model these winds.

IAMAS (Meteorology)

M02e - M02 Advances in Atmospheric Dynamics Including Topographic Forcing

IUGG-3887

The dynamics of polar lows in reverse shear

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Polar lows are intense, mesoscale cyclones developing over ice-free oceans at high latitudes. A significant fraction of polar lows develops in so-called reverse shear conditions, which are characterised by a mean flow that is opposite to the thermal wind. This is in contrast to the standard model for baroclinic instability, where the mean wind is usually aligned with the thermal wind. So far, the standard model of baroclinic instability has mainly been employed for research on polar low dynamics. Thus, our knowledge about the dynamical nature of reverse-shear polar lows is rather limited.

To shed light on the dynamics of reverse-shear cyclogenesis, we utilize an idealized baroclinic channel setup with WRF. This setup allows us to explore the sensitivity of the development to several parameters in reverse-shear conditions, including the strength of the vertical shear and the height of the wind reversal. In addition, we explore the role of moisture and surface fluxes in reverse-shear conditions. We present the evolution of these reverse-shear polar lows as well as their energy cycle pinpointing the relative contributions of shear, moisture, and wind reversal to the rapidity of the development.

IAMAS (Meteorology)

M02e - M02 Advances in Atmospheric Dynamics Including Topographic Forcing

IUGG-4399

Isentropic analysis of polar cold air mass streams in the northern hemispheric winter

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Isentropic analysis of polar cold air mass streams in the northern hemispheric winter
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1. Mass-weighted isentropic zonal mean (MIM) cold air streams

A diagnostic method is presented of polar cold air mass streams defined below a threshold potential temperature (pt). In winter hemispheres, MIM's mass stream functions show a strong extratropical direct (ETD) meridional circulation in addition to the Hadley circulation. The mass stream functions have local maxima at around (pt=280K, 45N) for NH winter, indicating that pt=280K may be an appropriate threshold of the polar cold air mass. The high-latitude downward motion indicates the diabatic generation of cold air mass, whereas the mid-latitude equatorward flow does polar cold air outbreaks toward mid-latitudes. The strength of equatorward flow is under significant control of wave-mean flow interactions.

2. Geographical distribution of the cold air mass stream in the NH winter

In the NH winter, the polar cold air mass flux has two distinct mainstreams, hereafter called as the East Asian (EA) stream and the North American (NA) stream. The former grows over the northern part of the Eurasian continent, turns down southeastward toward East Asia over Siberia and disappears over the western North Pacific Ocean. The latter grows over the Arctic Ocean, flows toward the East Coast of North America and disappears over the western North Atlantic Ocean. Both streams coincide well with main routes of sever cold surges frequently occuring over East Asia and central/eastern North America.

Iwasaki et al., 2014: Isentropic analysis of polar cold air mass streams in the northern hemispheric winter. J. Atmos. Sci., 71, 2230-2243.

IAMAS (Meteorology)

M02f - M02 Advances in Atmospheric Dynamics Including Topographic Forcing

IUGG-2270

"DEEPWAVE 2014; Observing Gravity Waves from the Troposphere to the Mesosphere"

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The recent DEEP-WAVE field project in New Zealand ran from May 25 to July 28, 2014. Its objectives were to observe, understand and predict the deep propagation of gravity waves from the Troposphere into the Stratosphere and Mesosphere . In addition to surface, balloon and satellite-borne sensors, the project used two research aircraft with airborne sensors; the NSF/NCAR Gulfstream V (GV) and the German DLR Falcon. The GV was uniquely instrumented to observe wave launching (dropsondes), waves properties in the low stratosphere (flight level winds, pressure and temperature), waves in the middle stratosphere (MTP and Rayleigh Lidar) and waves near the mesopause (Sodium Lidar and OH IR mapper). In this report, we describe the first results and discoveries from the DEEPWAVE project.

An emerging hypothesis from the DEEP-WAVE projects is that the deep propagation of gravity waves over NZ is controlled by a “valve layer” from 16 to 20km. During about ¾ of the strong wave generation events, the wind speed is too small there and the waves become non-linear, steepen and break. The remaining ¼ time, the waves remain linear and pass through maintaining their vertical energy flux. This hypothesis is tested using flight data and numerical model. A newly designed spatial filter is used to identify the gravity waves in the complex numerical model output.

IAMAS (Meteorology)

M02f - M02 Advances in Atmospheric Dynamics Including Topographic Forcing

IUGG-2412

"Simulations of 3D tomographic measurements of gravity waves with the infrared limb sounder GLORIA"

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The forcing of gravity waves (GWs) is an important coupling mechanism in the atmosphere. GWs are a major driver of the middle atmosphere circulation and may play a role, for instance, in sudden stratospheric warmings and the rebuilding of the stratopause afterwards. To get a better understanding of GWs, airborne 3D tomographic measurements of mountain waves with the German research aircraft HALO are planned. A central question concerns the achievable accuracy of the 3D wave vector, GW temperature amplitude, and the associated momentum flux derived from the measurements.

To answer this, we study, based on GW resolving model data, which GW parameters can be retrieved from 3D temperature distributions measured by the airborne infrared limb sounder GLORIA.

GLORIA is a joint development of the Helmholtz Research Facilities Karlsruher Institut für Technologie (KIT) and Forschungszentrum Jülich (FZJ) and combines a classical Fourier Transform Spectrometer with a 2D detector array. The capability to image the atmosphere and thereby take up to 16384 spectra simultaneously improves the spatial sampling of conventional limb sounders by an order of magnitude. For circular flight patterns tomographic methods can be applied and temperature and tracer fields with spatial resolutions of better than 30km x 30km x 300m can be achieved.

We will present simulated measurements and retrievals for both circular and linear flight patterns and deduce GW parameters from these data. The determined GW momentum flux will be compared to the one estimated from the original model data. Based on these data, an optimal flight strategy for the upcoming POLSTRACC/GW-LCycle campaign is developed.

IAMAS (Meteorology)

M02f - M02 Advances in Atmospheric Dynamics Including Topographic Forcing

IUGG-2779

Can inertia-gravity waves persistently alter the tropopause inversion layer?

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Previous simulations of baroclinic life cycles have shown, amongst many other features, the evolution of a tropopause inversion layer (TIL) as well as the spontaneous emission of inertia-gravity waves (IGWs). This study suggests that the latter two are related to each other, i.e. that IGWs may affect the TIL in a persistent manner. The IGWs are emitted along the jet and grow to large amplitudes, leading to the appearance of low Gradient Richardson numbers that indicate Kelvin-Helmholtz instability. Ensuing energy dissipation, local heating, and turbulence may persistently alter the thermodynamical structure of the tropopause region and, therefore, contribute to TIL formation or alter an existing TIL. Moreover the flow in the region of the IGW favors the occurrence of wave capture, which may enhance the effect of wave breaking.

IAMAS (Meteorology)

M02f - M02 Advances in Atmospheric Dynamics Including Topographic Forcing

IUGG-3012

Equatorial mountain torques, equatorial angular momentum and cold surges in a general circulation model

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The dynamical relations between equatorial atmospheric angular momentum, equatorial mountain torques and cold surges are analyzed in a General Circulation Model. First we show that the global equatorial atmospheric momentum budget is very well closed in the model, which is a clear benefit when we compare with results from the NCEP reanalysis. We then confirm that the equatorial torques due to the Tibetan plateau, the Rockies and the Andes are well related to the cold surges developing over East-Asia, North America, and South-America respectively. For all these mountains, a peak in the equatorial mountain torque component that points locally toward the pole precedes by few days the development of a cold surge, yielding a potential predictive interest to our results. We also analyze the contributions to the torques of the subgrid scale orography effects that are parameterized and find that they contribute substantially. In experiments without subgrid scale orography drags, we find that the explicit pressure torques change substantially to compensate the reductions in the parameterized torques, and that the cold surges are not much affected. This shows that the cold surges can be well captured in General Circulation Models, provided that the synoptic conditions prior to their onset are well represented. The compensation between torques is nevertheless not complete and some weakening of the cold surges is found when the mountain forcings are reduced. This illustrates how the exact torques are needed at a given time to produce the correct synoptic scale dynamics at a later stage.

S. Mailler and F. Lott, 2014: Equatorial Mountain Torques, Equatorial Angular Momentum and Cold Surges in a GCM, Submitted to Monthly Weather Review.

IAMAS (Meteorology)

M02f - M02 Advances in Atmospheric Dynamics Including Topographic Forcing

IUGG-3950

Deep vertical propagation of mountain waves above Scandinavia

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The project 'Investigation of the life cycle of gravity waves' (GW-LCYCLE) is part of the German research initiative ROMIC (Role of the Middle atmosphere In Climate) funded by the ministry of research. In close cooperation with Scandinavian partners a first field phase was conducted in Nov./Dec. 2013. The field program combined ground-based observations of tropospheric and lower stratospheric flow and stratospheric and mesospheric temperature by lidars and radars at Alomar (Norway) and at Esrange (Sweden) with airborne and balloonborne observations. Northern Scandinavia was chosen since the westerly flow across the mountains is often aligned with the polar night jet permitting gravity waves (GWs) to propagate into the middle atmosphere.

From 2 until 14 December 2013, 24 hours of the DLR Falcon flown in four intensive observing periods provided in-situ and remote-sensing observations of atmospheric wind, temperature, water vapour and other trace gases in the vicinity of the tropopause. The airborne observations were supported by 3 hourly simultaneous radiosonde launches from Andøya (Norway), Esrange (Sweden) and Sodankylä (Finnland). Additionally, 1.5 hourly high-frequency radiosonde launches were conducted from the Arena Arctica at Kiruna airport.

During GW-LCYCLE, the atmospheric flow above the Scandinavian mountains was observed under conditions enabling or attenuating the deep vertical propagation of mountain waves. The presentation juxtaposes two different cases and analyses the associated meteorological conditions. The unique combination of airborne tropospheric wind lidar measurements, flight level data, high-frequency radiosonde profiles and the ground-based lidar observations allow a comprehensive study of deeply propagating gravity waves up to the mesosphere.

IAMAS (Meteorology)

M02g - M02 Advances in Atmospheric Dynamics Including Topographic Forcing

IUGG-2437

A convection-based model for the generation of atmospheric internal waves by explosive volcanic eruptions.

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Observations of microbarograph recordings on the island of Montserrat in the Caribbean have shown signals with periods of several minutes and amplitude of approximately 1 mb following explosive eruptions of the Soufrière Hills Volcano. These properties suggest that the explosions are causing the generation of atmospheric internal waves. The pattern and distribution of these depend on the nature of the explosion, which has a timescale of the order of 1 min. Here a theoretical model of wave generation is developed, based on the dynamical model of Woods (Bull. Vol. 1988, Ann. Rev. Fluid Mech. 2010) of the convective flow associated with a variety of explosive eruptions with varying height and intensity. The theoretical results resemble the effect of 'throwing a stone' into the atmosphere, producing transient waves that radiate radially away from the source. Near the source, these waves have frequency around 0.7–0.8N (where N is the buoyancy frequency) initially, and approach N with decreasing amplitude. These results are compared with observations of surface pressure. The results imply that forcing confined to the troposphere is more effective in generating waves observed at surface level, whereas large eruptions that penetrate into the stratosphere have weaker signals at the ground.

IAMAS (Meteorology)

M02g - M02 Advances in Atmospheric Dynamics Including Topographic Forcing

IUGG-2979

Origin and history of air parcels in orographic banner clouds

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Banner clouds are clouds in the lee of steep mountains or sharp ridges. Previous work suggests that the main formation mechanism is vertical uplift in the lee of the mountain. On the other hand, little is known about the Lagrangian behavior of air parcels as they pass the mountain, which motivates the current investigation. Three different diagnostics are applied in the framework of Large Eddy Simulations of air flow past an isolated pyramid-shaped obstacle: Eulerian tracers indicating the initial positions of the parcels, streamlines along the time-averaged wind field, and online trajectories computed from the instantaneous wind field.

All three methods diagnose a plume of large vertical uplift in the immediate lee of the mountain. According to the Eulerian tracers the cloudy parcels originated within a fairly small coherent area at the inflow boundary. In contrast, the time-mean streamlines indicate a bifurcation into two distinct classes of air parcels with very different characteristics. The parcels in the first class originate at intermediate altitudes, pass the obstacle close to its summit, and proceed directly into the cloud. By contrast, the parcels in the second class start at low altitude and take a fairly long time before they reach the cloud on a spiralling path. A humidity tracer quantifies mixing, revealing partial moistening for the first class of parcels and drying for the second class of parcels. For the online trajectories, the originating location of parcels is more scattered. Although this partly blurs the separation into two distinct classes, the results are still consistent with the basic features revealed by the other two diagnostics.

IAMAS (Meteorology)

M02g - M02 Advances in Atmospheric Dynamics Including Topographic Forcing

IUGG-4082

Sensitivity of orographic precipitation in Switerland to atmospheric processes – simulations with the high-resolution numerical model COSMO

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Dimensioning of flood protections is based on the estimation of the probable maximum flood. A reliable estimate of this quantity can only be made using a realistic estimate of the probable maximum precipitation (PMP) in the considered catchment. However, traditionally used procedures to estimate the PMP are not well suited for mountainous regions. Indeed complex terrain does strongly affect the precipitation distribution and impose strong non-linearities in results of small variations in the atmospheric flow conditions. Therefore an in-depth knowledge of the precipitation characteristics of a catchment is needed to obtain realistic estimates of the PMP.

We use the high-resolution numerical weather prediction model COSMO to study small-scale processes induced by topography-flow interactions. A sensitivity analysis is performed to determine the influence of subtle variations in atmospheric parameters such as specific humidity and temperature on the precipitation distribution. For this purpose, various approaches are used to modify the initial and boundary conditions of humidity and temperature. Simulations are performed for flood events in Switzerland, including different type of synoptic forcing, such as blocked and unblocked cases or characterized by atmospheric rivers.

The results show that, for instance an increase of the specific humidity of the incident flow does not necessarily produce an increase of precipitation in the target catchment. Indeed, with increased ambient moisture, smaller mountains upstream of the catchment can be more efficient in triggering precipitation and therefore reduce the moisture available downstream. This novel approach with a set of sensitivity experiments allows estimating, for a particular catchment, the physical limits of the PMP value.

IAMAS (Meteorology)

M02g - M02 Advances in Atmospheric Dynamics Including Topographic Forcing

IUGG-4338

Dynamics of rotor formation in single-layer mountain flows

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Boundary layer separation (BLS) may occur when a strong adverse pressure gradient force is imposed on boundary layer flow, leading to strong deceleration and detachment of streamlines from the surface. This process commonly occurs at the salient edge of very sharp obstacles. In stably stratified flows, pressure perturbations strong enough to cause BLS can also be induced by internal gravity waves such as mountain waves.
A well-known phenomenon related to wave-induced BLS is that of leeside atmospheric rotors, i.e., boundary-layer zones characterized by strong turbulence, surface wind direction reversals, large values of spanwise vorticity and near-neutral stability.
Using linear theory and numerical simulations performed with the CM1 model, we explore systematically the impact of different mountain shapes and different stratifications on the size and strength of rotors. Varying mountain width and stratification lead in fact to a variety of flow regimes ranging from weakly to strongly non-linear and from hydrostatic to non-hydrostatic flows. Strongly non-linear and moderately non-hydrostatic flows appear to give rise to the most intense rotors.
In hydrostatic flows, wave breaking in the first wave crest favors the formation of persistent rotors trains extending far downstream of the mountain (rotor streaming). Different processes like self-induced wave ducts or undular bores have been suggested in the literature to be responsible for this phenomenon, however the underlying dynamics have not been clarified yet. We will show that rotor streaming can generate vertically propagating non-hydrostatic wave modes in the atmosphere aloft and can be explained using linear interfacial wave theory.

IAMAS (Meteorology)

M02g - M02 Advances in Atmospheric Dynamics Including Topographic Forcing

IUGG-4494

Accounting for topographic and frictional forcings in a unified theory of the nocturnal low-level jet

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The nocturnal low-level jet (LLJ) is an atmospheric phenomenon common to the U. S. Great Plains and other places worldwide, typically in regions east of mountain ranges. Low-level jets develop around sunset in weather conditions conducive to strong radiative cooling, reach peak intensity in the pre-dawn hours, and then dissipate with the onset of daytime convective mixing. In this study we consider the LLJ as an inertia-gravity oscillation of a stably stratified atmosphere overlying a planar slope on the rotating Earth. The oscillation arises from diurnal changes in both the heating of the sloping terrain and the turbulent mixing. The governing equations are the equations of motion, mass conservation, and thermal energy in the Boussinesq approximation, with turbulent heat and momentum exchange parameterized through spatially constant but diurnally varying turbulent diffusivities. Analytical solutions are obtained with diffusivities that undergo step changes at sunrise and sunset, and with a slope buoyancy that varies as a saw-tooth function having a maximum before sunset and a minimum at dawn. The jets are governed by eleven parameters: slope angle, Coriolis parameter, ambient Brunt-Väisälä frequency, geostrophic wind magnitude, daytime and nighttime diffusivities, maximum (day) and minimum (night) slope buoyancies, duration of daylight, lag time between peak slope buoyancy and sunset, and a Newtonian cooling time scale. An exploration of the parameter space yields solutions that are broadly consistent with findings particular to the previously proposed theories. The results also agree with climatological observations, attributing stronger jets to regions with slopes of 0.15-0.25 degrees characteristic, for example, of the slope of the U. S. Great Plains.

IAMAS (Meteorology)

M02g - M02 Advances in Atmospheric Dynamics Including Topographic Forcing

IUGG-5256

A numerical study of atmospheric Karman vortex shedding from Jeju Island

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Karman vortex shedding occurs when a uniform flow encounters a bluff body as well known in fluid mechanics. A similar vortex shedding occurs when an atmospheric flow strikes an isolated mountain or island, and can be observed by satellite when the vortices are accompanied by clouds.

A mesoscale non-hydrostatic numerical model, which is used for daily numerical weather prediction, successfully reproduces the observed atmospheric Karman vortex shedding in the lee of Jeju Island, South Korea, on 16 and 20 February 2013. Based on the numerical results, we discuss the environment and dynamics of atmospheric Karman vortex shedding.
When the winter monsoon flows out from the Eurasian continent, a convective mixed layer develops through the supply of heat and moisture from the relatively warm Yellow Sea and encounters Jeju Island; dynamical conditions favorable for the formation of lee vortices are thus realized.

Vortices that form behind the island induce updraft to trigger cloud formation at the top of the convective boundary layer. A sensitivity experiment in which surface drag on the island is eliminated demonstrates that the formation mechanism of the atmospheric Karman vortex shedding is different from that behind a bluff body in classical fluid mechanics.

IAMAS (Meteorology)

M02p - M02 Advances in Atmospheric Dynamics Including Topographic Forcing

M02p-346

The utility of enstrophy based diagnostic tools in examining atmospheric blocking

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In the last few years, research has demonstrated that enstrophy and enstrophy based relationships are reliable indicators of the stability of large-scale flows. Thus, these quantities can be used to identify the change in flow regimes, including the onset and decay periods for blocking events. These studies have tested the derived quantities using the coarser NCAR-NCEP reanalysis dataset, or more fine-scale re-analyses such as the ERA-Interim reanalysis data set. In particular the geopotential height and winds are used. Given that entrophy can be readily calculated from observed datasets and model output, such quantities may be of use in an operational forecasting environment. In this presentation, entrophy based diagnostics will be applied in the Global Ensemble Forecast System (GEFS) and shown that using the ensemble system can be more effective than the single dynamical control forecast. This will especially be true for indentifiying block decay, which currently is difficult to forecast, even once block onset occurs. This work will also demonstrate that enstrophy can be related to other quantities such as the time rate of change in deformation and ageostrophicvorticity.

IAMAS (Meteorology)

M02p - M02 Advances in Atmospheric Dynamics Including Topographic Forcing

M02p-347

The continuous vibration of Eurasia with the northern cyclone

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During the autumn and winter, the strong cyclone from North Atlantic and the Arctic Ocean pass into the northern Europe. It may cause the continent to generate continuous vibration. The seismic signals caused by strong low pressure cyclones from the Norwegian Sea into continent can be observed by almost the whole of Eurasia seismographs. Their changes can reflect the evolution process of cyclone movement . This paper focuses on analyzing the seismic signal in detail caused in the process of landing Scandinavia Peninsula and the discussion of its mechanism. The results show that: the characteristics of seismic signals caused by cyclone in this region are different from other region, and the frequency spectrum of the signal change with landform of cyclone tracks. Seismological observation can be use for monitor the change of cyclone movement in time and space, which will help explore the interaction mechanism of cyclone motion and the earth surface .

IAMAS (Meteorology)

M02p - M02 Advances in Atmospheric Dynamics Including Topographic Forcing

M02p-348

The variation of different blocking highs and its influence on temperature in North Hemisphere

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The variation characteristics of different blocking intensity and duration and its influence on surface temperature are analysed during 1968-2010 in three regions of Northern Hemisphere (NH) where blocking highs occur frequently (Atlantic, Pacific and eastern Europe-Asia regions). The results show that the blocking frequency of Atlantic is the highest in the three regions of NH, while that of the eastern Europe-Asia is the lowest. From aspect of blocking intensity, it revealed that the strong blockings all exhibit decreasing trend over the three regions, especially in the Atlantic, and there were a slightly upward trendency for weak blocking. The increasing trend for long duration (≥13 days) blockings are insignificant from 1968-2000 for the three regions, espacially since 2000. A decrease of short duration blocking frequency is only found in Atlantic region. In addition, long duration blocking cotributes 25% for the strong blocking in Atlantic region, while 14% for Pacific blocking region. It is found that the increasing probability is accompanied by the enhanced intensity of blocking. Negative anomaly of the temperature difference between the longer duration blocking years and the shorter duration blocking years (medium blocking duration for eastern Europe-Asia) are mainly in the mid-low latitude regions, while that on the high latitude indicate positive temperature anomaly. However, for strong blocking, the temperature difference are not significant for most regions in NH. Comparied with strong blocking, the influence of long duration blocking on temperature are more remarkable over the Atlantic and Pacific regions. Blocking with different intensity and duration yieldes significantly different influence on temperature by analysing the blocking in eastern Europe-Asia.

IAMAS (Meteorology)

M02p - M02 Advances in Atmospheric Dynamics Including Topographic Forcing

M02p-349

Climatological analysis of the tendencies of the slope of isentropic surfaces over the North Atlantic

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The existence of confined storm tracks requires efficient restoring mechanisms for baroclinicity to maintain an environment conducive for consecutive cyclone development. Hoskins and Valdes (1990) [1] argue for a self-maintaining mechanism via latent heat release associated with the storms. However, baroclinicity is spatially strongly concentrated in the midlatitudes, indicating that local processes other than latent heat release in storms play an important role in building up baroclinicity too.

We propose a diagnostic based on the slope of isentropic surfaces, which incorporates the horizontal temperature gradient and an inverse dependence on static stability, as a proxy for baroclinicity. A tendency equation for the slope of isentropic surfaces is derived, which allows to disentange the contributions of dynamical and diabatic processes to the baroclinicity tendency. Using the YOTC dataset (Year of Tropical Convection) we quantiatively analyse the atmospheric processes by which baroclinicity is maintained over the North Atlantic. The results indicate that both latent heat release and sensible heat fluxes along the Gulf Stream are essential.

Furthermore, we analyse the evolution of the isentropic slope along the tracks of extratropical cyclones. One of the most important findings is, that along the tracks of extratropical cylcones the slope remains relatively constant before the lowest SLP along the track is reached. Thereby, latent heat release associated with the cyclones is the dominant process maintaining the slope against its reduction by baroclinic conversion.

[1] Hoskins B. J. and P. J. Valdes, 1990: On the existence of storm-tracks, J. Atmos. Sci., 47, 1854-1864

IAMAS (Meteorology)

M02p - M02 Advances in Atmospheric Dynamics Including Topographic Forcing

M02p-350

On the Co-Occurrence of Warm Conveyor Belt Outflows and PV Streamers

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Warm conveyor belts (WCBs) are moist ascending airstreams in extratropical cyclones. Climatologically, they are key for the meridional and vertical transport of water vapor and heat. They ascent in about 1-2 days from the boundary layer to the upper troposphere leading to cloud formation, (intense) precipitation and the release of latent heat, which modifies their potential vorticity (PV) in a significant way. Typically WCBs reach the tropopause level with low PV values (~0.5 pvu). The cross-isentropic transport of low-PV air in WCBs can amplify upper-level Rossby waves and contribute to the formation of PV streamers downstream, which are here regarded as clear signs of breaking Rossby waves. PV streamers in turn can act as precursors of extreme weather events and/or trigger the genesis of another cyclone, potentially generating a new WCB.

The aim of this study is to quantify the interaction of WCBs and PV-streamers from a climatological point of view for the ERA-Interim data set for the period 1989-2010. WCBs are identified from comprehensive trajectory calculations that select air parcels in the vicinity of cyclones with a minimum ascent of 600 hPa in 48 hours. From these WCB trajectories, coherent features of WCB outflows are derived and checked for overlapping with PV streamers, which are identified using a contour searching algorithm. Both, WCBs and PV-streamers are then tracked using a novel feature tracking technique, which is based upon a modified region growing approach. With this technique, the interaction of WCBs and PV-streamers is analyzed for a 22-years period leading to novel insight about the role of WCBs for triggering the breaking of Rossby waves, as well as, vice versa, about the importance of PV-streamers for the formation of new WCBs.

IAMAS (Meteorology)

M02p - M02 Advances in Atmospheric Dynamics Including Topographic Forcing

M02p-351

Disentangling the co-variability of jet location and intensity

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Local weather in the mid-latitudes is strongly influenced by the variability of the jet and the storm track. The variability is generally characterized through EOF analyses of the geopotential or the zonal wind. These EOFs, however, only capture the co-variability of the jet location and the jet intensity. This co-variability complicates the dynamical interpretation of the variability patterns, because it obfuscates the the relation to the dynamical drivers of the jet.

A new method to objectively detect jet axes provides a basis to disentangle the co-variability. By analysing the wind speed along the detected jet axes, we demonstrate that weak jets tend to meander more, while strong jets tend to straightly follow the climatological mean jet location. Hence, the jet intensity strongly influences the variability of the jet location.

To further explore this relation, we construct variability patterns of the jet location, disregarding the jet intensity. In both the Atlantic and the Pacific, the two leading variability patterns of the jet axis location represent (a) a meridional shifting of the jet and (b) a transition between a straight and an undulating jet. We show that the straightening corresponds to the pulsing-type variability identified in previous studies of storm track and jet variability, thereby supporting our previous finding that stronger jets undulate less than weaker jets.

IAMAS (Meteorology)

M02p - M02 Advances in Atmospheric Dynamics Including Topographic Forcing

M02p-352

"Temporal Clustering of Regional-scale Extreme Precipitation Events in Southern Switzerland"

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Temporal clustering of extreme precipitation events on sub-seasonal time scales is of crucial importance for the formation of large-scale flood events. Here, the temporal clustering of regional-scale extreme precipitation events in southern Switzerland is studied. These precipitation events are relevant for the flooding of lakes in southern Switzerland and northern Italy. This research determines whether temporal clustering is present and then identifies the dynamics that are responsible for the clustering. An observation-based gridded precipitation data set of daily rainfall sums and ECMWF reanalysis data sets are used. We use a modified version of Ripleys K-function to characterize temporal clustering on sub-seasonal time-scales and to determine the statistical significance of the clustering. Significant clustering of regional-scale precipitation extremes is found on sub-seasonal time scales during the fall season.
Four high-impact clustering episodes are then selected and the dynamics responsible for the clustering are examined. During the four clustering episodes, all heavy precipitation events were associated with an upper-level breaking Rossby wave over Western Europe and in most cases strong diabatic processes upstream over the Atlantic played a role in the amplification of these breaking waves. Atmospheric blocking downstream over Eastern Europe supported this wave breaking during two of the clustering episodes. During one of the clustering periods, several events of extratropical transitions of tropical cyclones contributed to the formation of high-amplitude ridges over the Atlantic basin and downstream wave breaking. During another event, blocking over Alaska assisted the phase locking of the Rossby waves downstream over the Atlantic.

IAMAS (Meteorology)

M02p - M02 Advances in Atmospheric Dynamics Including Topographic Forcing

M02p-353

Simultaneous multiple radiosonde launches across a mountain range captured two types of strong local winds

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We carried out an innovative set of radiosonde observations of an extremely strong westerly wind on the lee side of a mountain range oriented from north to south. To depict the detailed horizontal and vertical structure of the winds from the windward side to the leeward side, we simultaneously launched six GPS radiosondes at four sites that were separated by ~13 km along a 35-km-long transect in the direction of the prevailing wind, including one site on the mountain top, at seven times on 21 March 2010 in Japan. The observations revealed two kinds of strong winds on the lee side of the mountain. One type was a typical downslope strong wind. We successfully delineated the isentropes associated with this wind in the horizontal-vertical plane. The isentropes curved downward in the form of a wave passing over the mountain range. The region of highest winds was located along the lee side. A wave-like pattern of the isentropes, apparent throughout the horizontal-vertical plane, signified the presence of updrafts and downdrafts of a gravity wave and was closely associated with anomalies in the rates of ascent of balloons. The other type of strong wind was not associated with a wave-like pattern of isentropes in the lower troposphere. The area of high winds in the lee of the mountains was a well-mixed mass of cold air. In addition, a large northerly wind component, which was approximately parallel to the axis of the mountain range, was observed only on the lee side. The calculated Froude number was consistent with conditions for the occurrence of a hydraulic jump for the first type of strong wind, whereas the Froude number associated with the second type did not reach the critical value for a hydraulic jump.

IAMAS (Meteorology)

M02p - M02 Advances in Atmospheric Dynamics Including Topographic Forcing

M02p-354

The theoretical study of the time tendency equation of the frontogenesis function

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In this paper, the importance of front and frontogenesis is introduced, and the frontogensis function is simply reviewed. Based on the frontogenesis function, the time tendency equation of the frontogenesis function is theoretically derived. This time tendency equation can be used for diagnosing front evolution. The equation is a fundamental basis for forecasting frontegenesis and frontolysis.

IAMAS (Meteorology)

M02p - M02 Advances in Atmospheric Dynamics Including Topographic Forcing

M02p-355

Sensitivity of circulation biases to orographic drag

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Climate models exhibit circulation bias, and single-model studies have shown sensitivity of many of these biases to orographic drag. A notable such bias is the too-late breakdown of the Southern Hemisphere stratospheric polar vortex, which could have implications for Southern Hemisphere summertime climate. The impact of drag on bias is difficult to elucidate in free-running climate models because of dynamical feedbacks. Here we use a nudging technique where the free atmosphere is constrained, to look at the sensitivity in a more controlled situation, with a focus on Southern Hemisphere high latitudes. In particular, we look at the sensitivity of the surface torques to orographic drag parameters, and their impact on momentum tendencies in the free atmosphere.

IAMAS (Meteorology)

M02p - M02 Advances in Atmospheric Dynamics Including Topographic Forcing

M02p-356

Mountain gravity waves: A new family of solutions

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A theory of mountain gravity waves present when the incident wind a is (1) null at the ground and aloft the ridge and (2) slowly increasing with altitude is presented. It circumvents the fundamental problem of linear mountain wave theories, where the surface winds need to be non-zero at the surface for mountain waves to develop substantially. These “classical” theories somehow contradict the fact that in reality the winds go to zero at the surface. A fundamental problem is in fact that a zero wind at the surface corresponds to a critical level for mountain waves, a situations that pause conceptual difficulties. We hope that the solutions presented here could help to benchmark Numerical Weather Prediction models that aim at representing mountains and including the smallest scales gravity waves. The wave responses proposed can also be used to analysz at a cheap numerical cost the refraction by the gravity waves and mountains of the infrasounds trapped in the low tropospheric waveguide.

Some details about the mathematical functions used can be found in: F. Lott, C. Millet, and J. Vanneste, 2014: Inertia-gravity waves in inertially stable and unstable sheared flows, Submitted to J. Fluid Mech.

IAMAS (Meteorology)

M02p - M02 Advances in Atmospheric Dynamics Including Topographic Forcing

M02p-357

Forecast errors of Rossby waveguides: An object-basedspatial forecast verification tool and a short climatology of forecasterrors.

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The significance of upper level Rossby wave trains (RWTs) for weather forecasting has long been recognized. Moreover the existence of the upstream Rossby wave precursors to extreme weather events indicates a potential for enhanced predictability on the medium-range time-scale. Spatially localized areas of high PV gradients at the tropopause are co-located with the jet streams and can serve as waveguides for the precursor RWTs. Location or amplitude errors in the forecast of Rossby waveguides can result in inaccurate locations of RWTs and therefore a misforecast of high-impact weather events (Piaget et al., 2015). Our study is focused on the characterization of forecast errors of Rossby waveguides at the tropopause-level. We present an object based spatial forecast verification tool which compares form, amplitude and location characteristics of waveguide objects in the analysis and in the forecast. The tool can be used with any forecast and verification source. In this study the application was demonstrated using ERA-interim reanalysis and IFS forecast of ECMWF, for the time period 2008-2010 and for five different forecast lead times. Results suggest that, the IFS model underestimated the PV gradient field and the area errors increased with the forecast lead time. Location error vectors pointed to a systematic northerly bias of the waveguides in the forecast compared to ERA-interim. Easterly or westerly phase errors of the waveguides were occurred with the same likelihood.

Piaget N, Froidevaux P, Giannakaki P, Gierth F, Martius O, Riemer M, Wolf G, Grams CM. 2015. Dynamics of a local Alpine flooding event in October 2011: moisture source and large-scale circulation. Accepted in Quarterly Journal of the Royal Meteorological Society.

IAMAS (Meteorology)

M02p - M02 Advances in Atmospheric Dynamics Including Topographic Forcing

M02p-358

Leading modes of variability in AP simulations

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We present a study of the low-frequency variability of the zonal-mean circulation in full-physics, steady-state Aqua-Planet simulations. The leading mode appears to conform to a delayed-oscillator paradigm. We analyze the involvement of fluxes of moisture and angular momentum, both in the inner domain and at the boundaries, in shaping and sustaining this mode, and we discuss its sensitivity to peculiarities of simulations with current General Circulation Models, such as non-conservation.

IAMAS (Meteorology)

M02p - M02 Advances in Atmospheric Dynamics Including Topographic Forcing

M02p-359

High-resolution measurements of vertical velocity and their power spectra observed with the MAARSY radar at Andøya, Norway (69.30N, 16.04E)

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Vertical velocity of air motion contains key information on various dynamical processes in the lower and middle atmosphere. MST (=mesosphere – stratosphere – troposphere) radars have proven to be a valuable tool to measure vertical velocity along a vertically directed beam. MAARSY, the new MST radar at the island of Andøya uses a phased array antenna and provides continuous wind measurements including vertical wind in the troposphere and lower stratosphere and the mesosphere and lower thermosphere. In this study, we present the vertical velocity measurements with high temporal resolution (minutes) in the troposphere and stratosphere observed with MAARSY during the period of 2010-2013. The distribution of the vertical velocity and profiles of mean vertical velocity are shown and compared under conditions with strong wind (active condition, background winds larger than 10 m/s) or with weak wind (quiet condition). We also present vertical velocity variances on different time scales. Frequency spectra of vertical velocity derived from these data sets are derived using Lomb-Scargle periodograms. Statistical results show spectral slopes approaching the $f^{--5/3}$-power law for active condition, whereas much shallower spectral slopes are observed for quiet condition. Profiles of the spectral slopes show that the spectra become steeper with increasing altitude for both conditions. Therefore, we further calculate turbulent energy dissipation rates ε from the measurements of spectral width with MAARSY. The derived ε-values are significantly larger under active conditions than under quiet conditions. Furthermore, the spectral slopes of vertical velocity are directly compared with corresponding energy dissipation rates, showing that there is a robust positive correlation between them.

IAMAS (Meteorology)

M02p - M02 Advances in Atmospheric Dynamics Including Topographic Forcing

M02p-360

Influence of summer blocking on atmospheric circulation in East Asia

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The influence of boreal summer blocking on atmospheric circulation in East Asia was examined using the reanalysis data over the three decades of 1981–2010. The summer blocking over Sea of Okhotsk (OK) was the major mode in the region according to principal component analysis using 500 hPa geopotential heights. OK blocking frequencies (OK BFs) showed negative and positive correlations with summer temperature and precipitation of Northeast Asia centered around the East Sea/Sea of Japan, respectively. In particular, the OK BF had a statistically significant correlation coefficient of -0.54 with summer temperatures in the Korean Peninsula. This indicates that the summer temperature and precipitation in this region were closely related to the OK blocking. According to the composite analysis for the years of higher-than-average BF (positive BF years), the OK High became stronger and expanded, while the North Pacific High was weakened over the Korean Peninsula and Japan and an anomalously deep trough was developed in the upper layer (200 hPa). As the cool OK High expanded, the temperature decreased over Northeast Asia centered around the East Sea/Sea of Japan and the lower level (850 hPa) air converged cyclonically, resulting in the increased precipitation, which induced the divergence in the upper layer and thereby strengthened the jet stream. Thus, the boreal summer OK blocking systematically influencing the area as the most dominant mode.

Acknowledgements

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IAMAS (Meteorology)

M02p - M02 Advances in Atmospheric Dynamics Including Topographic Forcing

M02p-361

Phase-speed analysis of annular mode anomalies

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This work will present some recent results from an observational study of Annular Mode anomalies and their associated phase-speed structure. Following previous studies in the literature that provide evidence for feedbacks between Annular Mode anomalies and eddies of various time and length-scales, phase-speed spectra of wave drag in ERA Interim data have been computed for waves of various length-scales. The inter-annual variations in the regions of this wave drag have then been analysed in the context of inter-annual variations of the Annular Mode. Together these results develop further the theory of eddy-zonal flow feedback and provide some insight into the mechanisms governing inter-annual Annular Mode variability.

IAMAS (Meteorology)

M02p - M02 Advances in Atmospheric Dynamics Including Topographic Forcing

M02p-362

Stratified water tank experiments of lee wave and rotor development in flow over double ridges

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We present an overview of water tank experiments designed to investigate lee waves and rotors in flows over single and double 2D topographic obstacles. The water tank size and typical obstacle towing speeds used allow us to simulate flows with high Reynolds number, in a reasonably close dynamical similarity to atmospheric flows.

The experimental setup consists of a two-layer flow with a lower neutral and an upper stable layer separated by a sharp density discontinuity. This type of layered flow over terrain is known to generate a variety of possible responses in the atmosphere, from hydraulic jumps to lee waves and highly turbulent rotors. The latter have been linked to the separation of the boundary layer on the lee side of the obstacle due to perturbation pressure gradients induced by the wave field aloft.

Observations of boundary-layer separation, rotors and mountain waves in the lower troposphere have been recently reported in the literature. However, the existing observational studies are limited to a small number of cases that provide limited insight into the phenomenon. Using high-resolution reconstructions of the velocity

and density fields in two spatial dimensions and time, our set of experiments extends the exploration of rotor formation to a broader range of flow regimes.

The experiments were focused on boundary layer separation and rotor formation in stratified flow over double ridges. Constructive or destructive interference of lee waves is expected in such flows and depends on the ratio of the ridge separation distance to the horizontal lee wavelength. Here we present preliminary results on the comparison between laboratory experiments and the theory of trapped lee wave interference, and seek the optimal conditions for rotor formation.

IAMAS (Meteorology)

M02p - M02 Advances in Atmospheric Dynamics Including Topographic Forcing

M02p-363

The splitting of synoptic systems at the Rocky mountain barrier

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One of the best-known conceptual models describing the passage of synoptic systems over a ridge is that of stretching potential vorticity (PV) columns between two isentropic surfaces. This model, however, assumes that the low-level isentropes follow the orography and hence cannot describe a situation in which parts of the approaching flow are orographically blocked.

We use a lagged composite analysis for strong surface pressure perturbations off the west coast of North America to study the crossing of the Rocky Mountains by synoptic systems for the fall (SON) and winter (DJF) seasons. The analysis shows that both negative (cyclonic) and positive (anticyclonic) anomalies are typically blocked below crest level, such that one part of the system remains west of the barrier. For the cyclonic case, a new cyclone forms in the lee, while pressure rises across the mountain range in the anticyclonic situation.

In the upper troposphere, the trough above the surface cyclone and its potential vorticity maximum approach the coast, but do not fully cross the mountain range before decaying. They contribute, however, to lee cyclogenesis. For the anticyclonic case, the ridge is part of a wave train, which moves slowly eastward.

We apply these results to discuss the relevance of further theories of wave-mountain interaction.

IAMAS (Meteorology)

M02p - M02 Advances in Atmospheric Dynamics Including Topographic Forcing

M02p-364

Dynamics of a local Alpine flooding event in October 2011: Moisture source and large-scale circulation

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Alpine heavy precipitation events often affect small catchments, although the circulation pattern leading to the event extends over the entire North Atlantic. Here a comprehensive study of an event in the northern Alps in October 2011 is presented with particular focus on the role of the large-scale circulation in the North Atlantic/European region. During the event exceptionally high amounts of total precipitable water occurred in and north of the Alps. This moisture was initially transported along the flanks of a blocking ridge over the North Atlantic. Subsequently, strong and persistent northerly flow established at the upstream flank of a trough over Europe and steered the moisture towards the Alps. Lagrangian diagnostics reveal that a large fraction of the moisture emerged from the West African coast where a subtropical upper-level cut-off low served as an important moisture collector. Wave activity flux diagnostics show that the ridge was initiated as part of a low-frequency, large-scale Rossby wave train while convergence of fast transients helped to amplify it locally in the North Atlantic. A novel diagnostic for advective potential vorticity tendencies sheds more light on this amplification and further emphasizes the role of the ridge in amplifying the trough over Europe. Operational forecasts misrepresented the amplitude and orientation of this trough.

For the first time, this study documents an important pathway for northern Alpine flooding, in which the interaction of synoptic-scale to large-scale weather systems and of long-range moisture transport from the Tropics are dominant. Moreover, the trapping of moisture in a subtropical cut-off near the West African coast is found to be a crucial precursor to the observed European event.

IAMAS (Meteorology)

M02p - M02 Advances in Atmospheric Dynamics Including Topographic Forcing

M02p-365

A high quality reprocessed ground-based GPS dataset for atmospheric process studies, radiosonde and model evaluation, and reanalysis of HYMEX SOP

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Data from more than 1000 ground-based GPS receivers in the north-western Mediterranean area have been reprocessed in a consistent way using GIPSY-OASIS II software for the period from 1st September 2012 to 31 March 2013 which encompasses the Special Observation Periods (SOPs) 1 and 2 of the HYMEX project. The reprocessed GPS ZTD data were screened and converted to IWV. The ZTD data were used to assess the accuracy of the near real time ZTD data assimilated for operational weather forecasting. The mean of delay differences between the operational and reprocessed solutions is about 0 +/- 3 mm (mean +/- standard deviation of bias over all stations) and the standard deviation of delay differences ranges between 4 and 8 mm. Significant bias reduction is thus expected from a reanalysis ingesting the reprocessed delay data. Various methods and auxiliary data (surface pressure and weighted mean temperature) are investigated for the conversion of ZTD data into IWV. The final IWV dataset is used to evaluate radiosonde humidity observations and operational analyses produced with the AROME model. The spatial and temporal distribution of IWV is also studied with a focus on heavy precipitation events in the north-western Mediterranean area during the HYMEX SOP1.

IAMAS (Meteorology)

M02p - M02 Advances in Atmospheric Dynamics Including Topographic Forcing

M02p-366

Diurnal cycle of convective activity in the Tropics observed by Rain Radar mounted on the Tropical Rainfall Measuring Mission satellite

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In this study, the influence of land mass on the diurnal cycle of convective activity is analyzed. 17-year observation of Tropical Rainfall Measuring Mission (TRMM) 2A25 V7 (1998-2014) Estimated Surface Rain (ESR) is used as a precipitation data. We rasterized the ESR data into 0.1x0.1 degree mesh for each local solar time (LST) of observation. U. S. Geological Survey Global Land Cover Characterization (USGS GLCC) Version 2 data is used for determining the shoreline. As the many studies indicated, the precipitation peak time is about 3 LST over the Tropical ocean near the coastline, and about 15 LST over the Tropical land. Although the total precipitation amount strongly depends on the distance from the shoreline, The phase of the diurnal cycle over the ocean is not dependent on the distance from the nearest shoreline. We also performed a series of ideal experiments with a quasi-three dimensional domain using non-hydrostatic atmospheric model to elucidate the detailed feature of the relationship between land-sea contrast and local convection systems.

IAMAS (Meteorology)

M02p - M02 Advances in Atmospheric Dynamics Including Topographic Forcing

M02p-367

Impact of mesoscale meteorological processes on anomalous radar propagation conditions

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The impact of mesoscale processes on the occurrence of anomalous propagation (AP) conditions for radio waves, including ducts, super refractive and subrefractive conditions were studied. The chosen meteorological situations are the bora wind and the sporadic sea/land breeze (SB/LB) during three selected cases over a large portion of the northern Adriatic. For this purpose, we used available radiosoundings and numerical WRF-ARW model simulations (of real cases and their sensitivity tests) at a horizontal resolution of 1.5 km. The model simulated the occurrences of AP conditions satisfactorily, although their intensities and frequency were underestimated at times. Certain difficulties appeared in reproducing the vertical profile of the modified refractive index, which is mainly dependent on the accuracy of the modeled relative humidity. The spatial distributions of summer AP conditions reveal that the surface layer above the sea (roughly between 30 and 100 m asl) is often covered by super refractive conditions and ducts. The SB is highly associated with the formations of AP conditions: (i) in the first 100 m asl, where super refractive conditions and ducts form because of the advection of colder and moister air, and (ii) inside the transition layer between the SB body and the anti-SB current in the form of subrefractive conditions. When deep convection occurs, all three types of AP conditions are caused by the downdraft beneath the cumulonimbus cloud base in its mature phase that creates smaller but significant pools of cold and dry air. The bora wind usually creates an AP conditions pattern associated with the hydraulic jump and influences AP conditions distribution over the sea surface.

IAMAS (Meteorology)

M02p - M02 Advances in Atmospheric Dynamics Including Topographic Forcing

M02p-368

Impacts of convection initiation on the diurnal rainfall cycle over tropical lands

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Diurnal cycle of rainfall is especially important as it manifests interactions between atmosphere,land, and ocean. However, biases of diurnal rainfall cycle such as too early-onset of land convection, lack of nocturnal rainfall, and lack of propagating diurnal convective organization near the topographical regions, are often found in climate models. These biases have been attributed to deficiencies of cumulus parameterization and/or insufficiency of model resolution to represent important processes on the diurnal scale in previous studies.

This study focuses on the impacts of resolution and deep cumulus schemes on diurnal rainfall cycle simulated by Community Atmosphere Model version 5.0. Processes on the diurnal scales imulated by CAM is validated with TRMM observations and ERA-Interim reanalysis. Early onset of convection and lack of nocturnal rainfall are both noticed in model simulations over tropical lands. These biases are found to be mostly attributed to the triggering function of deep cumulus scheme, not to the model resolutions, whereas finer model resolution contributes to improvements over topographical regions. When the triggering function is added to the deep cumulus scheme, great improvements of diurnal rainfall are found over the tropical topographical regions, such as maritime continents, central Africa, and central America.

IAMAS (Meteorology)

M02p - M02 Advances in Atmospheric Dynamics Including Topographic Forcing

M02p-369

Numerical investigation for effects of vertical wind shear on cloud droplet spectra broadening at lateral boundary of cumulus clouds

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The liquid water content and the average radius of the cloud droplets of the cumulus clouds from the aircraft detection data are less than the values calculated by the air parcel theory. The dry air entrainment and the homogeneous mixing at the lateral boundary of the cumulus clouds are used to explain this phenomenon. However, the recent studies show the existence of the new cloud droplet activation at the top of the cumulus clouds at the early developing stage due to the upward expansion cooling induced by the gradient force of the dynamic perturbation pressure. In order to investigate the impacts of the vertical wind shear on the cloud droplet spectra broadening at the lateral sides, we used WRF Model coupled with an aerosol-cloud interaction bin model with a high spectrum resolution (90 bins for aerosols, 160 bins for water drops) and a high spatial resolution (25m in vertical, 50m in horizontal). We run the Large Eddy Simulation (LES) case in the Tianhe supercomputer. In our simulations, a new aerosol parameterization scheme has been proposed in order to investigate the secondary activation of cloud condensation nuclei (CCN). Unlike most of the current studies, the activated CCN will not be cleaned in this approach. Therefore, CCN coming from the evaporated cloud droplets can be explicitly examined. This approach can also calculate the coalescence and the sedimentation of CCN.Our results show that the entrained air at the early developing stage of cumulus clouds can lead to new cloud droplet activation at their lateral sides due to the upward expansion cooling induced by the gradient force of the dynamic perturbation pressure. Our results also show that the vertical wind shear can enhance the cloud droplet nucleation at the leeward lateral side.

IAMAS (Meteorology)

M02p - M02 Advances in Atmospheric Dynamics Including Topographic Forcing

M02p-370

Analysis of the barotropic sudden warming in a global model

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A number of recent papers have highlighted the importance of the external, or barotropic mode, in the evolution of those stratospheric sudden warming events that exhibit a predominantly wavenumber-two development and a split of the polar vortex throughout the depth of the stratosphere. To focus more clearly on the barotropic dynamics, we here analyze the vortex splitting sudden warming in a simple global model, comprising the rotating shallow water equations on the sphere, with and without the effects of thermal forcing; the restriction to shallow water effectively removes the secondary complications arising from upward propagating planetary waves. A quasi-stationary approach is suggested as an effective means of exploring the two-dimensional parameter space of forcing amplitude and a suitable measure of vortex strength. We find that the main dynamical regimes obtained previously in a quasigeostrophic f-plane model persist in the global model, with the exception of certain rotating vortex states that depend on the method of initialization. Short-lived regimes in which the vortex splits and reforms repeatedly are observed under certain parameters, although gradual dissipation of the vortex means that these cannot be classified as persistent vacillating states. Persistent vacillating states may be obtained under appropriate conditions that adequately constrain angular momentum tendencies in the tropics.

IAMAS (Meteorology)

M02p - M02 Advances in Atmospheric Dynamics Including Topographic Forcing

M02p-371

Equilibration of the wave energy spectrum in different jet regimes

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The tropospheric flow regime can be categorized according to the type of jet stream: subtropical, eddy driven or merged. The maintenance of each type of jet depends on the wave fluxes and hence on the wave spectrum. We examine what determines the wave spectrum in the equilibrated state, by analyzing the equilibration of the waves in a two-layer model, based on the quasi-geostrophic (QG) assumptions on a sphere, modified to include a crude Hadley circulation. The model qualitatively reproduces the subtropical, eddy driven and merged jet regimes observed in the atmosphere and their properties. For each of the three regimes we examine the energy balance for each zonal wavenumber in the equilibrated state. The fully nonlinear model runs are compared with a quasi-linear version of the model, to assess the relative role of wave-mean flow interactions and wave-wave interactions. Most of the wave-mean flow interaction involves only medium scale waves (wavenumbers 4-6). In the eddy driven jet regime the spectrum is wide and medium scale waves transfer energy to long waves by nonlinear interactions. In the merged jet regime the spectrum is dominated by a single wavenumber (5 or 6) and in the subtropical jet regime there are both long and medium scale waves, but with a relatively weak amplitude. In all the regimes the dominant mode does not coincide with the linearly most unstable mode, rather it is determined by the criterion that its fluxes will maintain the mean flow in a marginally stable configuration.

IAMAS (Meteorology)

M03a - M03/M15 Weather and the Global Atmospheric Electric Circuit / Electrical Charging and Discharging in Thunderclouds

IUGG-2058

The Global Atmospheric Circuit from Antarctic Plateau Electric Field Measurements at Vostok and Concordia

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Atmospheric electric field measurements from Concordia station on the Antarctic Plateau are compared with those from Vostok (560 km away) for the period of overlap (2009-2011) and to earlier Vostok (2006-2009) and Carnegie (1915-1929) measurements. The Antarctic data are sorted according to several sets of criteria for rejecting local variability to examine a local summer-noon influence on the measurements and to improve estimates of the global signal. The relatively small contribution to ionospheric potential and surface electric field of the solar wind influence is evaluated and removed, giving monthly-average diurnal variations which reflect the seasonally changing output of the thunderstorms and electrified cloud generators at low latitudes.

IAMAS (Meteorology)

M03a - M03/M15 Weather and the Global Atmospheric Electric Circuit / Electrical Charging and Discharging in Thunderclouds

IUGG-3716

The Casey Station thunderstorm, East Antarctica

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Antarctic thunderstorms are extremely rare. Over a century of albeit sparse occupation of the icy continent, only 3 verifiable sightings on the Antarctic Peninsula had been made before the 2011 Casey station thunderstorm in East Antarctica. Three isolated strikes directly over Casey were coincidentally detected by the World Wide Lightning Location Network. The dynamics of the thunderstorm are reviewed using numerical weather prediction modelling from the Antarctic Mesoscale Prediction System, supplemented with local surface and radiosonde observations and satellite imagery. Given the World Wide Lightning Location Network recorded no other strikes within the convective complex before or after it passed over Casey, it is speculated that the sufficient vertical motion to produce electrical discharge resulted from a local orographic disturbance, whereby a weakly convective moist maritime airmass was abruptly lifted by a vertically propagating internal gravity wave and/or a hydraulic jump.

IAMAS (Meteorology)

M03a - M03/M15 Weather and the Global Atmospheric Electric Circuit / Electrical Charging and Discharging in Thunderclouds

IUGG-4645

Modulation of UK lightning and the atmospheric electric circuit by heliospheric magnetic field polarity

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Observational studies have reported solar magnetic modulation of terrestrial lightning on a range of time scales, from days to decades. The proposed mechanism is two-step: lightning rates vary with galactic cosmic ray (GCR) flux incident on Earth, either via changes in atmospheric conductivity and/or direct triggering of lightning. GCR flux is, in turn, primarily controlled by the heliospheric magnetic field (HMF) intensity. Consequently, global changes in lightning rates are expected. This study instead considers HMF polarity, which doesn't greatly affect total GCR flux. Opposing HMF polarities are, however, associated with a 40 to 60% difference in observed UK lightning and thunder rates. As HMF polarity skews the terrestrial magnetosphere from its nominal position, this perturbs local ionospheric potential at high latitudes and local exposure to energetic charged particles from the magnetosphere. We speculate as to the mechanism(s) by which this may, in turn, redistribute the global location and/or intensity of thunderstorm activity

IAMAS (Meteorology)

M03a - M03/M15 Weather and the Global Atmospheric Electric Circuit / Electrical Charging and Discharging in Thunderclouds

IUGG-5192

Seasonal variations of lightning activity in southern Brazil

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The recent installation of the Brazilian Lightning Location System (BrasilDAT) sensors in southern Brazil should enable a better understanding of the lightning activity in one of the regions with highest lightning incidence in the world. The total lightning technology of BrasilDAT provides intra-cloud (IC) and cloud-to-ground (CG) lightning information. Regarding the seasonal distribution of lightning over southern Brazil, it is observed a predominance of negative CGs near the coast in the warm period, which is probably related to topographic effects and sea breeze. Lightning during the winter is less frequent; however, the number of positive CG associated with the passage of frontal systems increases. Maximum CG lightning densities are observed during the Mesoscale Convective Systems (MCS) activity in the south austral spring. In this work, BrasilDAT lightning data for the period June/2012-July/2014 were analyzed. The characterization of the electrical activity over southern Brazil will consider the analysis of total lightning occurrence per season and per hour.

IAMAS (Meteorology)

M03a - M03/M15 Weather and the Global Atmospheric Electric Circuit / Electrical Charging and Discharging in Thunderclouds

IUGG-5492

Japan winter upward lightning and their parent storm charge structure

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We have for the first time applied LMA into Japan winter lightning observation. In this paper, we have reported the triggering source, initial leader progression and parent storm charge structure of 7 upward lightning that occurred during three storm cells with a total duration of about 4 hours. At least 3 of the 7 upward lightning were triggered by the following discharge processes of nearby positive return strokes. The three parent storm cells have a positive dipole charge structure with its lower negative charge at about 2 km and its upper positive charge at about 3 or 4 km. We have also for the first time reported the luminous backward propagation of an upward positive leader. In the final presentation, we will report more detailed results.

IAMAS (Meteorology)

M03b - M03/M15 Weather and the Global Atmospheric Electric Circuit / Electrical Charging and Discharging in Thunderclouds

IUGG-0620

Calculations of electric field in numerical weather prediction models

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There are several approaches to predicting thunderstorm activity using indirect non-electrical parameters. However, for lightning forecasting improvement electric processes should be taken into account. A new method of electric parameters calculations based on the use of Weather Research and Forecasting model for prediction of thunderstorms is proposed.
We suggest that the charge densities of ice and graupel are proportional to their mass in elementary air volume. According to the models by Saunders and Takahashi, in the lower part of thunderclouds graupel pellets are charged positively and in the upper part negatively. Two normalization conditions for charges were used. The first is electric neutrality in the vertical air column in the course of vertical charge separation due to collisions between falling graupel pellets and carried upward by updraft wind ice crystals. The second condition contains the maximum observable values of charge on large particle and graupel concentration. A numerical 3D Poisson solver allows us to find electric potential and electric field throughout the system.
Suggested method was applied for prediction of cloud-to-ground lightning flashes occurrence by analysis of the electric potential difference between ground and cloud layer for the actual thunderstorms in July - August 2014 in Nizhny Novgorod. Comparison of calculation results with radar and World Wide Lightning Location Network data shows a good correlation and superiority of direct calculated electric parameters over meteorological indices. Therefore proposed method may be used as a good and quite accurate algorithm for prediction of lightning activity.

IAMAS (Meteorology)

M03b - M03/M15 Weather and the Global Atmospheric Electric Circuit / Electrical Charging and Discharging in Thunderclouds

IUGG-3238

How does atmospheric ionization influence aerosols and clouds?

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Throughout the atmosphere cosmic rays continually create ions, which attach to aerosol particles. Away from clouds the concentrations of positively charged, negatively charged, and neutral aerosol particles are comparable, but inside cloud borders the ratios are determined by the downward flowing current density (Jz) of the global electric circuit. As clouds form, ions also attach to droplets. Collisions between particles and droplets remove (scavenge) the particles. On a timescale of hours the collision rates, size distributions, and overall concentrations of the particles are affected by the electric charges on particles and droplets, and for cloud condensation nuclei these changes persist for their lifetimes of several days, during successive cycles of cloud formation and dissipation. As layer clouds form with low updraft speeds the size distribution of the droplets reflects the size distribution of the condensation nuclei, in turn affecting coagulation processes and precipitation and cloud cover. For winter storms the changes in droplet size distribution can lead to small but significant effects on storm invigoration, enhancements in lightning, storm vorticity, and high altitude moisture. Charge-induced changes in collision rates with ice-forming nuclei also affect contact ice nucleation and storm dynamics. Additional effects may be due to nucleation on ions of ultrafine condensation nuclei. Such effects explain small observed meteorological responses to changes in atmospheric ionization production and transport, induced by external (solar wind) and internal (global circuit generator) inputs. Modelling of the processes to date, and requirements for future modeling will be discussed.

IAMAS (Meteorology)

M03b - M03/M15 Weather and the Global Atmospheric Electric Circuit / Electrical Charging and Discharging in Thunderclouds

IUGG-3297

Charge balance and ionospheric potential dynamics in time dependent global electric circuit model

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We have developed a time-dependent model of global electric circuit (GEC) in spherical coordinates. The model solves time-dependent charge continuity equation coupled with Poisson's equation. An implicit time stepping is used to avoid strict dielectric relaxation time step condition, and boundary conditions for Poisson's equation are implemented to allow accurate description of time evolution of the ionospheric potential. The concept of impulse response of GEC is introduced that allows effective representation of complex time dynamics of various physical quantities in the circuit using model results obtained for instantaneous deposition of a point charge. The more complex problems, like continuous charging of thunderstorms and different types of lightning discharges are then reconstructed using convolution and linearity principles. It is shown that for a thundercloud charging phase, typically represented by a current dipole, the ionospheric potential can be determined from the difference of time integrals of two ionospheric potential impulse responses corresponding to charge locations at the opposite ends of the current dipole. During a cloud to ground lightning discharge, the ionospheric potential changes instantaneously by a value proportional to the charge moment change produced by lightning and then relaxes to zero.

IAMAS (Meteorology)

M03b - M03/M15 Weather and the Global Atmospheric Electric Circuit / Electrical Charging and Discharging in Thunderclouds

IUGG-3466

A modeling study of the effects of aerosol on development of thunderstorm electrification

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The effects of aerosol on electrification of a supercell storm are investigated using the Weather Research and Forecasting model coupled with parameterizations of electrification and an explicit treatment of aerosol activation. It is found that the microphysical and electrification processes of the thunderstorm are distinctly different under different aerosol background. Enhancing aerosol loading increases growth rate of snow and graupel particles, and leads to higher concentration of ice particles. Increasing aerosol concentration also results in enhancement in electrification process, due to more ice particles participating in the electrification processes in the more polluted case. In the clean case, the charge structure maintained dipolar distribution throughout the simulation, while in the polluted case the charge structure transformed from dipolarity at the initial stage of charging separation to the structure of a negative charge region above the main positive and the main negative charge centers in the later stage of the storm. A detailed analysis of the microphysical processes shows that increasing aerosol loading led to more liquid water content and higher rime accretion rate (RAR) above the freezing level, which was in favor of graupel charge positively and ice crystal and snow charge negatively in this region. In a word, increasing aerosol loading leads to increased cloud liquid water content, resulting in a new negative charge region developed above the main positive charge center.

IAMAS (Meteorology)

M03b - M03/M15 Weather and the Global Atmospheric Electric Circuit / Electrical Charging and Discharging in Thunderclouds

IUGG-3826

Effects on winter circulation and sea surface temperature of solar wind changes

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Indices of the North Atlantic Oscillation and the Arctic Oscillation show correlations on the day-to-day timescale with the solar wind speed (SWS). Minima in the indices were found on days of SWS minima during years of high stratospheric aerosol loading. The spatial distribution of surface pressure changes during 1963-2011with day-to-day changes in SWS shows a pattern resembling the NAO. Such a pattern was noted for year-to-year variations by Boberg and Lundstedt (2002), who compared NAO variations with the geo-effective solar wind electric field (the monthly average SWS multiplied by the average southward component, i.e., negative Bz component, of the interplanetary magnetic field). The spatial distribution of the correlations of geopotential height changes in the troposphere and stratosphere with the SWS; the geoeffective electric field (SWS*Bz); and the solar 10.7 cm flux suggests that solar wind inputs connected to the troposphere via the global electric circuit, together with solar ultraviolet irradiance acting on the stratosphere, affect regional atmospheric dynamics. The possible relationship between solar wind speed and the sea surface temperature (SST) was also visited. Results revealed a significant correlation between the solar wind speed (SWS) and SST at the North Atlantic Ocean in Northern Hemisphere winter from 1963 to 2010, and the correlation is varied with Bz (Bz is the interplanetary magnetic field component parallel to the Earth's magnetic dipole) phases and SWS phases, but independent with the quasi-biennial oscillation (QBO) phases.

IAMAS (Meteorology)

M03p - M03/M15 Weather and the Global Atmospheric Electric Circuit / Electrical Charging and Discharging in Thunderclouds

M03p-463

Diurnal variation of the vertical E-field during fair weather days in Israel on annual and seasonal scales

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Atmospheric electricity refers to the electrical activity taking place in the volume between the ionosphere and the Earth. Both serve as the plates of a "spherical capacitor" which, together with the atmospheric medium between them and the thunderstorms that act as generators, define the global electric circuit (GEC).

The potential gradient, also referred as the vertical electric field (Ez), is one of the key sampled parameters used to investigate the GEC. Past fair weather measurements over land show two types of Ez diurnal variations. The two land curves show either a single peak or a double peak. The difference between the two curves were assumed to arise from local seasonal variations [Israël 1970]. The same curve over the oceans (The Carnegie curve) shows a single peak and correlates positively with the diurnal distribution of global thunderstorm area [Harrison 2013].

Ground measurements of the Ez during fair weather days were performed from June 2013 in the Negev desert, southern Israel (30°35'N, 34°45'E). The measurements aim to investigate the diurnal behavior of the Ez during fair weather days on an annual and seasonal time-scale. The diurnal distribution of the global thunderstorm activity for the same days of the Ez measurement was obtained by the identification of lightning clusters around the globe using data from the World Wide Lightning Location Network (WWLLN) as described by Mezuman et al [2014].

We present results showing diurnal variations of the Ez in Israel compared with the Carnegie curve over the annual and seasonal time scales. Our results show a good agreement between the diurnal variations of the Ez and WWLLN-based lightning clusters analysis, supporting the existence of the global circuit. Local meteorological effects will also be discussed.

IAMAS (Meteorology)

M03p - M03/M15 Weather and the Global Atmospheric Electric Circuit / Electrical Charging and Discharging in Thunderclouds

M03p-464

Spatial and time distribution of the flash rate over the central Andes

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The lowlands to the east of the central Andes exhibit a tropical continental climate, with a peak in rainfall at the height of the austral summer (December–January–February) when the South American Low Level Jet (SALLJ) transports warm, moist air from the Amazon Basin toward the subtropical part of the continent. Situated in the southwest of Bolivia there is a high-level plateau known as the Altiplano (15° and 22° S), about 250 km wide and at an average elevation of 4000 m. The Altiplano exhibits a distinctive climate, about 90% of the annual precipitation concentrates between October and March in the form of intense thunderstorms.

The lightning flash rate over the central Andes in South America was analyzed using lightning data from two independent lightning detection systems, the Lightning Imaging Sensor (LIS) and the World Wide Lightning Location Network (WWLLN). Spatial and time distributions of lightning activity were studied using different spatial and temporal scales.

We show that the lightning activity over this region presents a pattern with a localized center of high lightning activity located on the eastern foot of the Altiplano; this center is located between [16°; 17°]S of latitude and [65°; 66°]W of longitude and presents a steady flash rate throughout all seasons of the year. The maximum seasonal flash rate occurs in the September–November period with a lightning activity around 100 flashes km-2 yr-1.

The lightning activities observed seem to be strongly influenced by the topography, the SALLJ and upper-level anticyclone established in the southeast of the central Andes, the so-called Bolivian high.

IAMAS (Meteorology)

M03p - M03/M15 Weather and the Global Atmospheric Electric Circuit / Electrical Charging and Discharging in Thunderclouds

M03p-465

Numerical simulation of influence of tilting effect on intra-cloud lightening using an explicit 1-D time-dependent cloud model

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In the present work, an explicit 1-D time-dependent cloud Model (ETM) and its tilted version (ETTM) based on formulation described in Chen and Sun (2002, 2004) have been used to examine the influence of tilting effect on the intra-cloud mean charge transfer and the resulted electric field. For this purpose a measured cumulus cloud case has been focused. In ETM and ETTM cloud models non-hydrostatic pressure, entrainment, cloud microphysics, lateral and vertical eddy mixing processes have been included.

The intra-cloud charge transfer per collision between graupel and ice crystals is parameterized using relations suggested by Saunders et al. (1991), depending on temperature and Liquid Water Content. In this study, lightening initiates when the intra-cloud electric field exceeds the threshold suggested by Marshall et al. (1995).

Results of this research indicates that for the considered cumulus cloud case, tilting effect increased values of graupel mixing ratio and decreased values of ice mixing ratio in downdraft column. In updraft column, ice mixing ratio values did not show significant change compare with the vertical cloud model results. In the simulated tilting cloud, intensity of resulting intra-cloud electric field and the number of lightening occurrences increased for both up- and down-draft columns.

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M03p-466

Prediction of lightning potential index using WRF model: a case study over Iran

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Lightning is one of the natural disasters and the characteristic of severe weather; therefore there is an obvious need for its prediction. Generally many indices are used to predict the thunderstorms such as KI, CAPE and CPTP that are based on thermodynamic instability parameters. However the Lightning Potential Index (LPI), an advanced index for evaluating the potential for lightning activity is introduces by Yair et al. (2010) recently, which is based on the dynamics and microphysics of clouds.

In the current study, the high-resolution Weather Research and Forecasting (WRF) model running at 36 km, 12 km, 4 km and 1.333 km grid spacing of cloud-scale processes has been used to predict LPI over the northern part of Iran for a case study of thundercloud event on 9 Dec 2013. The simulated values of mixing ratios of hydrometers and vertical velocity have been used to calculate the LPI.

Results were evaluated using Cloud-to-ground (CG) lightning flash data from NASA Lightening Imaging Sensor (LIS). Results show that there is a good consistency of both the location and the intensity of lightning occurrence between the model outputs and observations. LPI is highly correlated with observed lightning and it may be a useful predictor for lightning over the studying area.

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M03p - M03/M15 Weather and the Global Atmospheric Electric Circuit / Electrical Charging and Discharging in Thunderclouds

M03p-467

Correlations between electric field fluctuations characteristics and other troposphere parameters

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Experimental and theoretical investigations of atmospheric electric field fluctuations in the wide range of time periods are being of interest for atmospheric turbulence diagnostics and global source signal recognition. This paper is devoted to the investigations of the background level of atmospheric electric field fluctuations at very large periods (T>>1 day) and detection of the cycled relations of solar activity and GEC. The diagnostic of the cloud transformation from normal convective state into lightning activity thunderstorm state was one of the goals of investigations. Simultaneous measurements of atmospheric electric field and brightness temperature were performed. Continuous data records of electric field values and day average temperatures at the ground surface were analyzed. Correlative and spectral analysis methods and also spectral adaptive analysis method were used for the data processing. Studies of correlations between electric field fluctuations characteristics (spectra and structure functions) and other local and non-local parameters of the troposphere using simultaneous microwave and electrical measurements were presented. Using the data of two electrostatic fluxmeters and the microwave radiometer we obtained that the spectral characteristics of electric field fluctuations in the lower atmosphere are related to atmospheric air turbulence on all the temporal scales from 1 s to 100 days and are quantitatively described by the Kolmogorov-type spectra and structure functions with different spectral index depending on the weather conditions. Cloudless and normal cloudy atmosphere were considered as well as thunderstorm conditions.

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M03p-468

On the relationship between the separation of ground contacts within a cloud-to-ground flash and their cloud charge sources

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The processes and mechanisms that lead to the formation of new ground contacts (NGCs) in negative multiple ground contact flashes (MGCFs) are investigated through case studies. This was achieved through the analysis of a dataset collected by a network of eight slow electric field antennas, high- and standard-speed video cameras and ten Lightning Mapping Array (LMA) stations installed in Kansas, USA from May to August 2013. Nine natural MGCFs were analyzed in detail and the in-cloud processes that led to their NGC strokes seemed to be intrinsically related to the horizontal distance between the different ground contact points. Widely-spaced NGCs (separated by over one kilometer) were formed from in-cloud branches that were initiated away from the preceding channels to ground, although the LMA plots clearly showed a common root. This is consistent with the existence of multiple closely-spaced regions of high (and lower) negative charge density within a cloud, or with horizontal variations in the lower positive charge region that can facilitate or inhibit preliminary breakdown in specific areas. Closely-spaced NGCs (separated by hundreds of meters), on the other hand, were formed when a subsequent dart leader diverged from the original path of a preceding stroke as it was already moving towards ground, a process that can be also be seen in the video records. In both types of NGC formation, a fast field recovery was observed in close (up to 5 km) electric field measurements following the stroke that preceded the NGC, suggesting that charge with the same polarity as the return stroke was accumulating in the channel and not flowing to ground. For contrast, ten case studies of multi-stroke, single ground contact flashes were analyzed and none of them presented this signature.

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M03p-469

Space weather influence on the climate system: atmospheric electricity and water cycle

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The influence of solar activity on the climate is subject of our investigation. In the study we use numerical model to investigate an influence of the space weather on the global atmospheric electrical circuit and the water cycle.

We have calculated the dependence of the density of amospheric electric current and ionospheric potential on the solar modulation potential. The calculations are based on the assumption that solar activity affects on the electrical conductivity of the atmosphere by changing the ionization rate by cosmic rays. Comparision of simulation results with experimental data shows a good agreement. Therefore, our theory of solar-terrestrial relationships is based on the solar influence on the atmospheric electricity.

The main object of the study is to determine the physical mechanism of the influence of the atmospheric electricity on the water cycle. We carried out laboratory experiments and observed an influence of electric currents on the water evaporation rate. This phenomenon can help to explain the influence of atmospheric electricity on the parameters of the water cycle: evaporation rate, precipitable water vapor, liquid water path, and precipitation rate.

The results of numerical simulation and satellite data analysis show the similarity and indicate the presence of strong dependence of global precipitable water vapor on the solar modulation potential. The importance of this study can be evaluated by its significance in the fields of solar-terrestrial relationships, global electric current circuit, water cycle, as well as climate science.

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M03p-470

The effect of isolated strong geomagnetic storms on the geopotential height distribution in the northern winter lower atmosphere

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The contribution examines the effect of isolated strong geomagnetic storms ($Ap \geq 60$) on the geopotential height (GPH) distribution in the northern lower atmosphere (20 hPa/850 hPa) of the winter periods (December-March) of 1952-2002. The GPH data were adopted from NCEP/NCAR reanalysis. The 10-day mean values of GPH before and after the onset of geomagnetic storm were compared. The comparison pointed to distinct changes in the distribution of GPH over Atlantic following the onset of the storms. Whereas in the period 1952-1969 the changes were significant for storms with $Ap \geq 60$, in the period 1970-2002 they were significant only for $Ap \geq 80$. The relevance of results was estimated using the Monte Carlo method, based on nonparametric test. The storms, during which stratospheric warming took place, were excluded from the analysis.

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M03p-471

"An optical lightning simulator in an electrified Cloud Resolving Model as a support of future lightning observation missions"

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The next generation of meteorological satellites will embark optical detectors for monitoring and studying the lightning activity of the Earth. For example, the coming GOES-R mission will carry the Geostationary Lightning Imager (GLM) while the third generation of Meteosat satellites MTG will be equipped with the Lightning Imager (LI). In the same vein, the CNES polar orbiting mission TARANIS (Tool for the Analysis of Radiation from lightNIng and Sprites) will observe the atmospheric discharges at high spatial resolution with a similar technique.

These missions represent a huge volume of new and original data for the scientific community and for weather prediction centres. However fundamental questions remain on the interpretation of the optical signal property and lightning discharge processes. The pertinent approach suggested here is to exploit an electrical module and its lightning scheme which is fully coupled to a cloud resolving model (CRM).

The French mesoscale model MesoNH is one of the only CRMs simulating the full lifecycle of the electrical charges in realistic clouds. The optical lightning simulator uses the 3D location of the lightning branches of each simulated flash. The optical emission at 777.4 nm is parameterized as a function of the pressure and amount of neutralized charges. The scattering by the hydrometeors is taken into account. Simulations are performed at high resolution (1 km) and downgraded to the sensor resolution: 1 km for the Micro Cameras and Photometers onboard TARANIS and 8-10 km for MTG-LI/GOES-R GLM. Several simulations of different storms will be presented and compared to observations from the Lightning Imaging Sensor and the Lightning Mapping Array deployed in the Southeast of France for the HyMeX experiment during Fall 2012.

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M03p-472

Development and observation of the phase array radar at X band for thunderstorm research

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A Phased Array Radar (PAR) system for thunderstorm observation has been developed by Toshiba Corporation and Osaka University under a grant of NICT. Severe thunderstorms and the related phenomena such tornado are threats to our lives and is closely related to the production of lightning discharges. Over the past decade, mechanically rotating radar systems have been used for the thunderstorm research. However, severe thunderstorm sometimes develops rapidly on the temporal and spatial scales comparable to the resolution limit (-10 min. and -500m) of typical S-band or C-band radar systems, and cannot be fully resolved with these radar systems. In order to understand the fundamental process and dynamics of lightning producing thunderstorm, volumetric observations with both high temporal and spatial resolution are required. The phased array radar system developed has the unique capability of scanning the whole sky with 100m and 10 to 30 second resolution up to 60 km. In this paper, this unique phased array weather using digital beam forming technique is presented particularly focused on radar system structure, observation results, and comparison with lightning mapping system. The initial comparison with C band radar system shows that the developed PAR system can observe the behavior of the thunderstorm structure in much more detail than any other radar system. The observed high temporal resolution images of the severe thunderstorm and lightning are introduced, showing the potential capabilities of the PAR and lightning location system.

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M03p-473

Observations of solar-wind-driven atmospheric electricity connections to weather and climate

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There are a large number of responses, on the day-to-day timescale, of the dynamics of the troposphere to regional changes in the downward current, J_z, of the global atmospheric electric circuit (GEC). They provide compelling evidence that, via the GEC, the solar-wind plays a role in influencing surface weather and climate. We review these apparently diverse observations and place them in a conceptual framework. We concentrate on recent investigations into the Mansurov effect - the clearest and most direct example of a meteorological response to changes in J_z. This effect was first observed as a correlation between the duskward component B_y of the interplanetary magnetic field (IMF) and surface atmospheric pressure anomalies at high latitudes. Here we shed light on the origins of this polar surface effect by examining the correlation between IMF B_y and geopotential height anomalies throughout the Antarctic troposphere and lower stratosphere. We find that the correlation is highly statistically significant within the troposphere, and not so in the stratosphere. The peak in the correlation occurs at larger time lags with increasing altitude, which is consistent with an upward propagation by conventional atmospheric processes of a solar-wind-induced variability in the lower troposphere. It has been suggested that this variability is a result of the action of J_z on cloud microphysics. We should not expect GEC effects on the troposphere to be confined to polar regions: the atmospheric sensitivity to the internal thunderstorm-driven driver is comparable to its sensitivity to IMF B_y, and even the polar Mansurov effect can influence the mid-latitude atmospheric planetary waves and therefore weather systems impacting more highly-populated regions of the world.

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M03p-476

Thunderstorm activity in central area of typhoons

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On base of the World Wide Lightning Location Network, the best-track archives and the ASCAT scatterometer data lightning fields in the typhoons (TY) and it's concatenation with a meteorological characteristics of TY and kinematic characteristics of ocean surface wind are studied. It's shown that the central region of maximum winds of intense TY in the distribution of lightning can distinguish typical structures, which are part of the circular mesoscale formations. In the days of the typhoon deepening thunderstorm activity increases. On the day of the maximum intensity value and density of lightning is more than twice greater than for the preceding days. The number of lightning strikes in the core of the TY correlated with their meteorological characteristics. Also analyses of the geometric characteristics of the lightning's points were made. They are compared to the characteristics of the TY maximum wind areas. For clusters of lightning points picked out in the core of TY the estimations of the statistical characteristics of pair distances and time intervals between discharges was provided. These characteristics can be interpreted in terms of approach to the convective clouds in TY as to the relaxation oscillators (what can be represented by the individual convective cells), which provides a mechanism of chain transfer reactions perturbations in space.
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M03p-478

Characteristics of lightning 3D distributions and polarimetric parameters in a thunderstorm

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Lightning occurrence is closely related the distribution of hydrometers in thunderstorms, especially graupel and hail. But it is very difficult to know the accurate hydrometer's distributions and kinematic characteristics in thunderstorms. In this study, we analyze microphysics in the thunderstorm from polarimetric radar data and compare the lightning location data with three-dimensional observation. We try to clarify the microphysical and kinematic characteristics of the lightning initiation in a thunderstorm. We focus on summertime isolated thunderstorm with heavy hail fall and lightning on 24 June 2014 in Japan. Large volume of hail region was observed by polarimetric radar using Kdp parameters and lightning initiation points from the VHF observation were located around the hail region in the thunderstorm. And also, lightning initiated at moderate Ze area where is neighbor maximum Ze, between graupel and ice area, and slightly small rho-hv area. It is noted that maximum Ze location is not so important but the location of moderate Ze with neighboring maximum Ze is important for lightning initiation point.

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M03p-479

Signatures in schumann resonance signals in Europe from giant squall lines in the Amazon basin

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Giant squall lines in the South American tropics has long been recognized (Kousky, 1980; Garstang et al., 1994; Cohen et al., 1995). These systems tend to initiate on the sea breeze front at the edge of the Atlantic Ocean along the northeastern edge of the continent. The squall lines can propagate southwestward at speeds of 50-60 km/hr, sometimes as far as the Andes Mountains in less than two days, producing lightning continuously along the line for 1000 km or more. The location and geometry of these squall lines have fortuitous connections with Schumann resonances (SR) observations from Europe. First of all, the distance between the SR receiver (Nagycenk Observatory (NCK) in Hungary) and the squall line is often close to 10 Megameters, which places the observer near the nodal boundary in case of the 1st and 3rd E_Z modes for this range-confined source in South America. Secondly, these lines tend to be oriented perpendicular to the great circle path linking source and observer. The SR frequencies exhibit exceptionally large variations at the observer if the source is compact and in nodal position. This means considerable increase/decrease of frequencies with opposite sign for the 1st and 3rd E_Z modes if the squall line translates with respect to the NCK observer. Exceptional SR frequency variations observed at NCK for squall line days in Brazil are presented. Comparisons will also be made of the South American source activity on days with and without exceptional squall lines.

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M03p-480

Development of thunderstorm nowcasting system in Vietnam: initial results

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Vietnam is located in Asia's thunderstorm center resulting lightning activity hotspots near the Mekong delta and along Vietnam's extensive coastline have a significant impact on the country's social economic development. Thunderstorm season in Vietnam is relatively long, starting in early March and through late November. The average number of annual thunder days and hours is on the order of about 100 days and 250 hours per year, respectively. Although, a wide variation in thunderstorm prevalence in any one area ranges from 50 to 500 thunder hours per year. A possible explanations for geographic differences in lightning prevalence include the division of the country by high mountain ranges in different directions.

In 2011, a monitoring network of atmospheric electricity including electric field mills and lightning detection devices has been established in Quang Nam province of central Vietnam. The network consists of four stations with spatial base lines of about 15-20 km. Analysis of the data showed that in this region lightning occurs from late March to October every year. Lightning activity increases sharply in April, peaks in May, has a decreasing trend in June, July and August. A secondary mode exists in September and ends in October. Storm electrical activity is the most active in period of 14-20 h local time.

Based on the combined data, we have developed the algorithm for lightning nowcasting in the area with lead times up to 60 minutes ahead of an initiating cloud to ground lightning. The results showed good agreement with the visual observations. Further investigations are underway to provide validation and refinement of the algorithm. Future developments include the use of radar and satellite data.

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M03p-481

3D Cloud electrification model: convection and dynamics description

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Cloud electrification models are a powerful tool to study the physical mechanisms that are responsible for the existence of electric field inside thunderstorms. These models are very complex and include a wide variety of cloud properties, atmospheric motions and physical interactions. In this work, we present the equations to simulate the dynamics and convection of a cloud in 3D. By solving the three equations of conservation of momentum, the thermodynamic and the continuity equations we can simulate various physical processes necessary to create a thunderstorm cloud. The equations for conservation of momentum include the contribution from the pressure, wind advection and friction and the thermodynamic equation will consider turbulent effects as well as latent heat absorbed or released from the hydrometeors phase transitions. Coriolis effects will be neglected. The next stage of the study will be the inclusion of the microphysical equations, considering seven classes of hydrometeors, charge transfer equations to be associated with the microphysical interactions and a parametrization of the initiation of a lightning discharge. The electrification model will be fully coupled with the dynamical and microphysical equations. Sensitivity tests will be performed to verify which electrification mechanism leads to the most realistic results by comparing the output of the model with data acquired from a real thunderstorm.

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M03p-482

Differences between visible characteristics of lightning flashes for a case study occurred in southeast Brazil during the summer of 2012/2013.

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The objective of the work is to analyze one thunderstorm day that produced lightning with peculiar characteristics, different from those commonly found in other works on the literature. The data was obtained by the RAMMER network, composed by four high-speed cameras, during the summer of 2012/2013 in the city of São José dos Campos, Brazil. The relatively large number of high-speed cameras has enabled us to record a statistically significant amount of negative cloud-to-ground lightning flashes per thunderstorm day. We chose as control-cases the five days that had the highest amount of lightning recorded by the cameras, making a total of 361 flashes. The analysis was performed in two ways, the first one considering the control-cases and the second one considering only the case study. After analyzing all lightning data we found that the geometric mean of the flash duration was 270 ms, the average multiplicity was 4.3 and the percentage of single strokes was 20.8% (75 events). These values are similar to those found in previous single-station studies for the same region. The case study of this work is February 22nd, 2013, which had a sample size of 55 negative cloud-to-ground lightning. The visible lightning characteristics found for this day were: geometric mean of flash duration of 193 ms; average of multiplicity of 2.8; and percentage of single stroke flashes, around 36.4% (20). After evaluation of the statistical tests of the sample obtained on that day, the lightning location system BrasilDAT, satellite and radar images were used as complementarily tools for the analysis. We point the hypothesis that the formation of clouds with smaller vertical development, has led to lightning temporally shorter and single-stroke flashes.

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M03p-483

Simulation in a mesoscale model of several electrified storms observed by a LMA during HyMeX in the South-West of France

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The Lightning Mapping Array (LMA) is a powerful 3D lightning flash detector that was operated during SOP1 of HyMeX in Fall 2012. In addition to the high resolution of the flash patterns by detection of thousands of VHF sources per flash, LMA data are well suited for testing an electrication scheme like CELLS in the cloud resolving model MesoNH at kilometer scale resolution. The information carried by LMA data includes not only the count of the intra-cloud and cloud-to-ground flashes but also, the spatial extension and triggering altitude of the flashes and the polarity of the cloud volume where flashes propagate. The mesosocale model MesoNH was run for at least 5 HyMeX cases for which the cloud electrical activity was recorded by the LMA. MesoNH was configured in gridnesting mode (4 km and 1 km) with 50 levels and domain sizes of 192x192 and 384x384 grid points, respectively. Electrified storms lasting several hours are simulated by the CELLS module in real conditions thanks to the Arome analyses available each 3 hour. The study presents simulations made with three different charge separation diagrams (Takahashi, Saunders et al. and Sanders and Peck) which basically represent a major uncertainity of the cloud charging processes. Detailed results concerning two case studies and a compilation of all simulated flash rates and characteristics will be given and compared to the HyMeX-LMA dataset.

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M03p-484

Extreme events of lightning in southeastern Brazil

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The study of lightning is a topic that has gained significant attention in the scientific community. By monitoring the periods of higher flash incidence, it is possible to issue alerts with information about the intensity, duration and severity of the storm, so that preventive measures can be taken in order to minimize the impacts of severe weather phenomena. In this context, the objective of this study was to identify extreme events of lightning that occurred in the state of São Paulo, in Southeastern Brazil, during 2011-2013 and analyze the correlation between intra-cloud and cloud-to-ground lightning in these events. Lightning data used in this study are from the Brazilian lightning detection Network - BrasilDAT. Extreme events were selected using the Method of Percentiles, applied to the data of intra-cloud and cloud-to-ground lightning in 13 (thirteen) cities spatially distributed within the state of São Paulo. We considered the extreme events as those days when the number of both types of discharges were higher than Percentile 98. As a result, we obtain 31 cases, with total lightning occurrence exceeding 10.000. For these events, we found a characteristic intra-cloud to cloud-to-ground ratio that can be used to identify these extreme events.

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M03p-485

Lightning characteristics related to radar morphology in linear convective systems over north China plain

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Abstract: Based on SAFIR3000 Lightning Location Network and radar information, 89 linear mesoscale convective systems are analyzed occurred in Beijing area from the year of 2007 to 2011. All the linear convective system are classified to six categories by radar morphologies, including leading convective lines with trailing stratiform region (TS), leading stratiform region trailing convective region (LS), leading convective lines with parallel stratiform region (PS), leading convective lines with no stratiform region (NS), bow echo of leading line (BE), break line in the convective region and trailing stratiform region (BL). The results showed that linear convective systems occurred frequently in summer time over Beijing area, particularly the TS and LS mode, accounted for 61% of the whole linear MCSs. According to 89 cases, the linear convective system influenced mainly by cold vortex, shear, moving trough and western pacific subtropical high. On average, lightning mainly located in the linear convective region, and less or no lightning located in the trailing stratiform region. At the dissipating stage, lightning activities in different categories present apparently different. In the stratiform region, the lightning gradually increased in TS MCSs, and +CGs account for large percentage of lightning in PS MCSs, whereas there are no lightning occurred in the stratiform region of LS MCSs.

IAMAS (Meteorology)

M04a - M04 Numerical Models for Climate Studies and Forecasting at High Latitudes

IUGG-0498

Simulation of Arctic climate with the Regional Arctic System Model (RASM): Sensitivity to atmospheric processes

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A new regional Earth system model of the Arctic, the Regional Arctic System Model (RASM), has recently been developed. The initial version of this model includes atmosphere (WRF), ocean (POP), sea ice (CICE), and land (VIC) component models coupled with the NCAR CESM CPL7 coupler. The model is configured to run on a large pan-Arctic domain that includes all sea ice covered waters in the Northern Hemisphere and all Arctic Ocean draining land areas.

Results from multi-decadal (1979 to present) simulations with RASM will be presented and will focus on the model climate's sensitivity to atmospheric processes and a comparison of the fully coupled model and atmosphere-only simulations. The modeled radiation budget, and sea ice cover, was found to be sensitive to the details of the cloud and radiation parameterizations in the atmospheric component (WRF) of RASM, including details of cloud droplet size. Another model sensitivity was found in relation to atmosphere-land processes. Care is needed to ensure that decoupling between the atmosphere and land do not occur under strongly stable conditions over land areas in winter.

Comparison of RASM near surface climate with that simulated with stand-alone WRF show areas of both improved and degraded results. Improvement in the coupled model climate are related to more physically realistic representation of coupled processes such as energy transfer from the ocean to the atmosphere through leads in the sea ice during winter. Degraded results come from feedbacks in model component biases, such as atmospheric circulation biases resulting in incorrect local sea ice cover that then result in large local atmospheric temperature biases.

IAMAS (Meteorology)

M04a - M04 Numerical Models for Climate Studies and Forecasting at High Latitudes

IUGG-3373

Polar lows over the Nordic Seas: Improved representation in ERA-interim compared to ERA-40 and the impact on downscaled simulations

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Polar lows are intense high-latitude mesocyclones that form during the cold season over open sea. Their relatively small-scale and short life span lead to a rather poor representation in model outputs and meteorological reanalyses. In this paper, the ability of the Interim European Centre for Medium-Range Weather Forecasts (ECMWF) Re-Analysis (ERA-Interim) to represent polar lows over the Norwegian and Barents Sea is assessed, and a comparison with the 40-yr ECMWF Re-Analysis (ERA-40) is provided for three cold seasons (1999–2000 until 2001–02). A better representation in ERA-Interim is found, with 13 systems captured out of the 29 observed, against 6 in the case of ERA-40. Reasons for the lack of representation are identified. Unexpectedly, the representation of different polar low sizes does not appear to be linked to the resolution. Rather, it is the representation of synoptic conditions that appears to be essential. In a second part, a downscaling is conducted using the mesoscale model Méso-NH. For each observed polar low, a pair of simulations is performed: one initialized by ERA-Interim and the other one by ERA-40. An improvement is noted with 22 polar lows represented when ERA-Interim is used. Through a model-to-satellite approach, it is shown that even if polar lows are simulated, convective processes remain insufficiently represented. Wind speeds, which were underestimated in reanalyses, are nevertheless more realistic in the Méso-NH simulations. These results are supported by a spectral analysis of reanalyses and Méso-NH fields.

IAMAS (Meteorology)

M04a - M04 Numerical Models for Climate Studies and Forecasting at High Latitudes

IUGG-3893

Influence of surface fluxes on polar low development: Idealised simulations

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Polar lows are intense, maritime cyclones developing during marine cold air outbreaks over areas with relative large sea surface temperature (SST) gradients. The conditions result in large temperature differences between the atmosphere and the ocean and are thus favorable for large surface sensible and latent heat fluxes. Furthermore, the differential heating resulting from the SST gradient can provide a source for baroclinicity.

We utilise WRF in an idealised channel configuration to gain insight into the role of surface turbulence fluxes on the dynamical evolution of polar lows. The initial setup consists of a baroclinic jet in thermal wind balance with a meridional temperature gradient. To mimic cold air outbreaks we introduce a SST which is warmer than the low level surface air temperature, where the SST has a meridional gradient similar to the SST gradient in the Nordic Seas during winter.

This setup allows for a systematic investigation of the relative contributions from surface sensible and latent heat fluxes on polar low development by varying the intensity of the initial baroclinicity and moisture as well as temperature difference between the SST and low level air temperature. In addition we performed all simulations with either sensible or latent heat fluxes switched off to test the sensitivity of the development to these individual fluxes.

The simulations are evaluated in terms of structural evolution and the relative importance of the generation of eddy available potential energy by diabatic versus baroclinic processes, where the diabatic contributions are separated for the different parameterized sub-gridscale processes.

IAMAS (Meteorology)

M04a - M04 Numerical Models for Climate Studies and Forecasting at High Latitudes

IUGG-4092

Nonlinear Perspectives on CMIP5 GCM Skill and Greenland's Melt-Season Variability

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GCM skill in the climate change-sensitive polar regions is key to using them to predict future changes in the ice sheet environment, as is knowing why a GCM is wrong (or right) versus observed climate. We evaluate GCM skill and variability for modern (1981-2000) melt-season surface climates in Greenland with a nonlinear data analysis tool, self-organizing maps (SOMs). Intermodel variability is evaluated via 19 CMIP5 models with sub-daily data needed for regional-scale modeling and internal variability with the 30-member CESM1.0-CAM5-BGC Large Ensemble.

Three scenarios test GCM skill: placing models in the context of the variability of our reference dataset (the ERA-Interim reanalysis, ERAI); locating GCMs in a “universal” data space covering all models plus ERAI; and comparing GCM patterns to those associated with extremes such as the July 2012 ice sheet melt event. In each case, SOMs abstract complex datasets (e.g., daily near-surface air temperature) into a relatively small set of generalized patterns representing dataset variability.

The ERAI SOM provides a summary of variability in the reanalysis and a test of how well each GCM reproduces ERAI variability. Mismatches in pattern frequencies indicate shortcomings in GCM skill with pattern over/underoccurence potentially providing insights to mechanisms.

The “universal” SOM analyzes ERAI and CMIP5 models together and thus both summarizes the variability of multiple realizations of climate and helps place each GCM in a common context.

Analysis of 35 years (1979-2013) of ERAI temperatures indicates that SOM patterns associated with the July 2012 ice sheet-wide melt event are present only since 2006. GCM skill in reproducing such statistics will inform our analyses of GCM-based predictions of future melting.

IAMAS (Meteorology)

M04a - M04 Numerical Models for Climate Studies and Forecasting at High Latitudes

IUGG-4563

Impact of radiosonde observations on forecasting summertime Arctic cyclone formation

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The impact of Arctic radiosonde observations on the forecasting of the 2012 early August Arctic cyclone AC12—the 'strongest' since records began—have been investigated using an observing system experiment (OSE). An atmospheric ensemble reanalysis (ALERA2) was used as the control experiment (CTL) to reproduce the development of the Arctic cyclone and surrounding large-scale fields. The OSE applies the same reanalysis as the CTL except for the exclusion of radiosonde observations from the German icebreaker Polarstern, which cruised near Svalbard during mid-July to early August 2012. Comparison of the two reanalyses revealed a difference in the upper tropospheric circulation over northern mid-Eurasia, just before the Arctic cyclone developed, in the form of a stronger tropopause polar vortex in the CTL. This indicated that the upper tropospheric field in the CTL had greater potential for baroclinic instability over mid-Eurasia. Ensemble predictions were then conducted using the two reanalyses as initial values at which the polar vortex approached to northern mid-Eurasia. The CTL prediction reproduced the development of the Arctic cyclone, but the OSE did not. These results indicate that the improved reproduction of upper tropospheric circulation in the Arctic region due to additional radiosonde observations, is indispensable for the prediction of Arctic cyclones. In particular, observations being acquired far from the Arctic cyclone affect the prediction of the cyclone via the upper tropospheric circulation in the west wind drifts.

IAMAS (Meteorology)

M04b - M04 Numerical Models for Climate Studies and Forecasting at High Latitudes

IUGG-0855

Breaking the ice: storm-induced sea-ice breakup and the implications for ice extent in climate models

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The propagation of large, storm-generated waves through sea ice was only recently measured for the first time, in either polar region, as reported in Nature by Kohout et al, 2014. This experiment demonstrated that storm-generated ocean waves propagating through Antarctic sea ice are able to transport enough energy to break sea ice hundreds of kilometres from the ice edge, much further than would be predicted by the accepted theory of exponential decay. This result implied a more prominent role for large ocean waves in sea-ice breakup and retreat than previously thought. The paper also demonstrated that the observed trends in the retreat and expansion of the Antarctic sea-ice edge is highly correlated with trends in significant wave height in the Southern Ocean. This includes capturing the spatial variability in sea-ice trends found in the Ross and Amundsen–Bellingshausen seas. In this presentation the atmospheric drivers responsible for these trends in wave height are further explored using ERA-Interim reanalyses. However, the relative importance of this new mechanism for sea ice change remains tantalizingly out of reach, as climate models do not include wave-ice interaction. The failure to capture the observed changes in Antarctic sea ice as well as the underestimate of the rate of sea ice loss in the Arctic suggests that the incorporation of explicit or parameterized interactions between ocean waves and sea ice may be an important piece of "missing physics" needed to improve even our best climate models. The steps required to address this problem are briefly outlined, and progress made to date by a number of groups is considered.

IAMAS (Meteorology)

M04b - M04 Numerical Models for Climate Studies and Forecasting at High Latitudes

IUGG-1987

Sensitivity of Arctic climate to spectral nudging in the Regional Arctic System Model

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Large-domain regional climate models often suffer climate biases due, in part, to poor representation of planetary scale waves and stratospheric processes. Spectral nudging – where the largest scales of a finite-area model are nudged toward a reference dataset – is one method of reducing these biases. Thus to eliminate atmospheric biases in the Regional Arctic System Model and explore the sensitivity of the coupled system to the degree of data, we perform a series of sensitivity experiments applying spectral nudging to RASM's atmosphere, WRF. Using spectral nudging constrains RASM-WRF by its atmospheric reanalysis boundary conditions (ERA Interim), which already include direct data assimilation of a very large quantity of observations (i.e., satellite radiances, radiosondes, etc). With well-configured nudging in RASM-WRF and standalone WRF, we can virtually eliminate atmospheric biases in highly constrained and well-observed variables (e.g. SLP). However, both coupled and uncoupled simulations still have some large biases compared to atmospheric reanalysis in variables that aren't directly nudged in WRF or as well-observed (e.g., radiation and cloud cover). Using a series of multi-decade reanalysis-driven simulations, we examine the sensitivity of large-scale atmospheric climate representation (i.e., SLP biases) and the surface interface (e.g., heat fluxes), as well as sea ice diagnostics (e.g., extent and concentration), to nudging in our large-domain, coupled system. With no nudging RASM's climate moves to a very unrealistic state; with over-constrained nudging RASM develops unrealistic interchanges of fluxes at the surface interface, highlighting the importance of nudging configuration in regional climate model simulations.

IAMAS (Meteorology)

M04b - M04 Numerical Models for Climate Studies and Forecasting at High Latitudes

IUGG-2542

Arctic budget study of inter-member variability using HIRHAM5 ensemble simulations

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One of the challenges in evaluating and applying atmospheric regional climate models (RCM) is the non-linear behavior of atmospheric processes, which is still not well understood. These non-linearities determine the internal variability in the model. Therefore, an ensemble of RCM simulations with different initial atmospheric conditions has been run and a diabatic budget study for potential temperature (Nikiema et al. 2010) has been applied to investigate the origin of internally generated variability. Hence, the physical processes associated with diabatic and dynamical terms inducing the inter-member variability have been analyzed. The study is carried out for the Arctic applying an ensemble of 20 members, differing in their initial conditions only, simulated with the RCM HIRHAM5 during summer (July- September) 2012. This time period is of particular importance because of the melting sea ice and its influence on atmospheric circulation and the resulting effect on the inter-member variability. The model is driven by the Era-Interim data set and runs with a spatial resolution of 25 km. The amplitude of the inter-member variability of the HIRHAM5 ensemble simulations fluctuates both temporally and spatially. The spatial distribution reveals two centers of high inter-member variability, over the Laptev Sea and over the Beaufort Sea/North America. The inter-member variability is generated/reduced by horizontal/vertical baroclinicity terms, which fluctuates in time like the inter-member variability. The maximum inter-member variability is associated with the great Arctic cyclone event during the beginning of August 2012.

IAMAS (Meteorology)

M04b - M04 Numerical Models for Climate Studies and Forecasting at High Latitudes

IUGG-4237

Impact of the high-resolution on seasonal prediction skill and reliability at mid- to high-latitudes

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The resolution in climate models is thought to be an important factor for advancing our understanding of near-term climate change. We present here a batch of 10--member retrospective seasonal predictions (1993-2009) carried out with the European community model ECEarth in three different configurations: coarse resolution (~1° and ~60 km in the ocean and atmosphere models, respectively), mixed resolution (~0.25° and ~60 km) and high resolution (~0.25° and ~30 km). The hindcasts are initialized the 1st of May and November from oceanic and atmospheric reanalyses. We find positive impacts of increased resolution in the prediction of near-surface air temperatures anomalies in Scandinavia over winter, and in the NorthEastern U.S. in summer. At the same time, we note slight improvements in the simulation of interannual variations of the summer Arctic sea ice cover and the NAO. We examine poleward oceanic and atmospheric heat transports as possible factors for explaining these differences, as well as the impact of resolution on the statistics (dispersion) of our ensembles. The results of this novel and unique experiment confirm that higher resolution is a key aspect for improving today's global prediction systems.

IAMAS (Meteorology)

M04b - M04 Numerical Models for Climate Studies and Forecasting at High Latitudes

IUGG-5035

Examining Arctic ocean-atmosphere-sea ice processes using a hierarchy of high resolution coupled and uncoupled models (HIRHAM5 – HYCOM – CICE)

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Rapid changes in key climatic indicators such as sea ice, seasonal snow cover and glacier and ice sheet surface mass balance show that the Arctic is a region in rapid transition. Understanding the feedbacks and processes requires a wide range of data, observations and model studies. Here we introduce a high resolution coupled regional model system that describes ocean, atmosphere, ice sheet and sea ice processes in the Arctic Ocean and North Atlantic. The system has been developed using three existing models, the high resolution regional climate model HIRHAM5, the ocean model HYCOM and the CICE model that describes sea ice. These models are run individually and fully coupled to examine the relative importance of ocean and atmospheric forcing and internal dynamics to explain the recent rapid decline of Arctic sea ice and low surface mass balance of the Greenland ice sheet. Analysis of the model results indicates the model can successfully reproduce the interannual and seasonal variability in sea ice extent within the bounds of internal variability in the system while Greenland climate and ice sheet surface mass processes are also well represented. Future projections downscaling the EC-Earth GCM to high resolution give us further insights into the potential further evolution of Arctic climate where internal variability remains similar to that currently observed at present but substantial increases in annual mean temperature among other fields are projected.

IAMAS (Meteorology)

M04b - M04 Numerical Models for Climate Studies and Forecasting at High Latitudes

IUGG-5533

Modeling the arctic climate change and variability at process scale using the regional arctic system model

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The Arctic has experienced some of the most coordinated changes currently occurring anywhere on Earth, including the decline of sea ice cover and related surface temperature amplification. While historical reconstructions of Arctic climate by global climate and Earth System models are in broad agreement with the observed changes the rate of change in their forecasts remains outpaced by observations. There are a number of reasons why models may not be able to simulate rapid environmental change in the Arctic, which stem from a combination of coarse model resolution, inadequate parameterizations, unrepresented processes, and a limited knowledge of physical, real world interactions.

To address some of these limitations we have developed a high resolution Regional Arctic System Model (RASM). It includes the Los Alamos Sea Ice Model and Parallel Ocean Program, Weather Research and Forecasting Model and Variable Infiltration Capacity land hydrology model coupled using a state-of-the-art flux coupler. This approach allows both investigation of the importance of mesoscale processes and their interactions in a fully coupled climate system framework and direct comparison with observations. In addition, RASM allows the sensitivity studies of modeled sea ice states to varying parameter space as well as addition of new model components, such as marine biogeochemistry and ice-shelf/ocean interactions. In this talk we demonstrate the capability of RASM in simulating observed seasonal to decadal variability and trends in the sea ice cover and its sensitivity to varying parameter space. RASM results, corroborated with

observational data, appear to support the importance of mesoscale processes and their feedbacks in the Arctic.

IAMAS (Meteorology)

M04c - M04 Numerical Models for Climate Studies and Forecasting at High Latitudes

IUGG-0998

Climate variability over West Antarctica: What has happened and what's to come

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Over the last 50 years West Antarctica has experienced one of the largest increases in regional temperature on Earth. Spatial patterns in observed temperature and sea-ice-extent trends indicate that these are likely linked to changes in the Amundsen Sea Low (ASL): a highly dynamic and mobile climatological low pressure system located in the Pacific sector of the Southern Ocean.

To date, it has been difficult to assess the impact that external influences, such as anthropogenic emissions and tropical variability, have had on the ASL due to the large regional climate variability and the relatively short satellite-based observational record.

In order to diagnose the comparative importance of external forcing on observed change, we will use simulations from the Fifth Coupled-Model Intercomparison Project (CMIP5), which includes more than 40 state-of-the-art climate models with many simulations spanning historical and projected future emissions pathways from the year 1850 to 2100. By using a new set of indices which characterise the ASL, we show how wind patterns are likely to change over the coming century and the subsequent impact of these changes on West Antarctic climate.

IAMAS (Meteorology)

M04c - M04 Numerical Models for Climate Studies and Forecasting at High Latitudes

IUGG-1628

The response of the ACCESS climate model to recent ozone change over Antarctica and the Southern Ocean

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Two sets of historical 3-ensemble simulations have been obtained with versions 1.0 and 1.3 of the Australian Community Climate and Earth System Simulator (ACCESS) to examine the effects of ozone change since 1960. The first simulation follows the standard CMIP5 'historical' setup using forcing by ozone, greenhouse gas, aerosol, volcanic and solar terms. In the second simulation, the ozone distribution follows a perpetual 1960 realisation, while the remaining forcing terms use the historical prescription.

The two ACCESS versions show some differences in response to ozone forcing, both at the surface and in the upper levels. However, we find that the model well captures observed patterns of long-term surface pressure and temperature changes in summer over Antarctica, and that forcing by ozone appears to play a key role in these changes.

In our presentation, we interpret the modelled influence of ozone change at southern high latitudes, and discuss the implications of these changes on the Southern Annual Mode (SAM) pattern, the Antarctic projection of the El Niño-Southern Oscillation (ENSO) and coupling between the troposphere and stratosphere.

IAMAS (Meteorology)

M04c - M04 Numerical Models for Climate Studies and Forecasting at High Latitudes

IUGG-1788

Surface energy balance over Larsen C Ice Shelf as represented in three high-resolution atmospheric regional models

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We compare modelled surface energy balance (SEB) components from three high-resolution atmospheric models with observations from an automatic weather station (AWS) on Larsen C Ice Shelf, Antarctica, for a one-month period in the austral summer of 2010-11. The models studied are the polar version of the Weather Research and Forecasting model (Polar WRF, run as part of the Antarctic Mesoscale Prediction System, AMPS), the UK Met Office Unified Model (UM) and the Regional Atmosphere and Climate MOdel version 2 (RACMO2). All three models were run with a horizontal grid spacing of 5 km or less. Measurements from the AWS show that the mean SEB is dominated by the radiative fluxes, with turbulent fluxes of heat playing a secondary role. The modelled SEB broadly reflects this partition but the radiative fluxes from all three models exhibit significant biases. A poor representation of cloud water content and its partition into liquid and ice phases contributes to biases in longwave and shortwave radiative fluxes in all three models, while the use of a unrealistically low surface albedo in the UM and AMPS adds to the bias in net shortwave radiation in these models. Although there is some cancellation between longwave and shortwave biases, there is a clear need to improve the representation of the SEB in these models before they can be used to make reliable predictions of surface melt.

IAMAS (Meteorology)

M04c - M04 Numerical Models for Climate Studies and Forecasting at High Latitudes

IUGG-2000

Föhn over the Larsen Ice Shelf - a comparison of measurements and model simulations.

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Strengthened circumpolar westerly winds due to a more positive index of the Southern Annular Mode are likely increasing the occurrence of Föhn wind across the Antarctic Peninsula. Such warm, dry winds are thought to have contributed to the break-up of parts of the Larsen Ice Shelf in 1995 and 2002.

This presentation will compare the representation of Föhn events over the Larsen Ice Shelf, Antarctica, in measurements by an Automatic Weather Station and model simulations by the Weather Research and Forecasting Model WRF, run at 5km resolution.
The comparison of six-hourly data covers most of 2011. It shows generally good agreement between the measurements and model simulations for basic meteorological near surface parameters with the model being slightly too warm and dry.
Two independent methods have been developed to identify Föhn events in both data sets. Taking only into account data points where both algorithms agree, composites were formed for Föhn (n=224) and no Föhn (n=774). Analysis of these composites reveals that during Föhn events the bias between simulated and observed temperature and humidity is not only bigger than that for no Föhn conditions, but it also changes sign, leading to the model being too cold and too wet during Föhn, quite in contrast to conditions usually attributed to Föhn. We will put these findings into a broader context as well as investigating possible causes for the discrepancy.

IAMAS (Meteorology)

M04c - M04 Numerical Models for Climate Studies and Forecasting at High Latitudes

IUGG-4258

Meteorological change in the Ross sea region and its link to Antarctic sea ice trends

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We describe a project which aims to quantify the links between synoptic meteorological variations and sea ice in the Ross Sea region. The project also examines the influence of the Amundsen Sea Low (ASL) on meteorological variability in the same region. We hope to determine whether changes in weather patterns can potentially explain the positive trends observed in sea ice extent. Using the ERA-Interim reanalyses, this study first examines the importance of the ASL on forcing meteorology over the Ross Sea. We then examine the response of sea ice to changes in the atmosphere, employing reanalysis and satellite data products. We supplement this analysis by examining corresponding output of the NIWA UKCA climate model. This work allow us to identify whether certain weather patterns have changed in frequency or intensity, potentially due to variations in the position or depth of the ASL, and determine whether corresponding sea ice changes can be observed.

Finally, we discuss the latest field deployment of SNOW WEB, a unique wireless sensor network developed for use in Antarctica. In the 2014/15 field season, SNOW WEB is used to increase the density of surface observations available to the south and east of Ross Island. These measurements, along with data from nearby Wisconsin AWS, are intercompared with Polar WRF simulations and remotely sensed sea ice observations. Our aim is to examine the role of strong southerly storms on sea ice at synoptic time scales. SNOW WEB observations aid in defining the edge of these storms and how they interact with the complex topography of

Ross Island. By completing this analysis, we hope to determine whether sea ice is strongly impacted by different weather patterns and understand the processes that produce this relationship.

IAMAS (Meteorology)

M04c - M04 Numerical Models for Climate Studies and Forecasting at High Latitudes

IUGG-5133

Sensitivity study of the blowing snow horizontal flux with a regional climate model

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The parameterization of blowing snow in the regional climate model MAR has been tested. Model parameters such as surface roughness length and air density profile in the boundary layer may be influenced by snow erosion by the wind. Surface roughness increases due to the building of sastrugis and air density near the surface increases because of the weight of blowing snow particles and the cooling due to their sublimation. In turn turbulence intensity and downslope pressure gradient force are respectively weakened and strengthened by an increase of air density near the surface, while an increase of roughness length due to snow erosion by the wind is responsible for an increased turbulence and a slowing down of the wind speed near the surface. Finally the relative humidity increases due to the sublimation of blowing snow. The model is setup over Adélie Land, Antarctica, with a fine horizontal resolution (5 km) and an improved vertical resolution near the surface (lowest level is now situated 0.7 m above the surface). The domain of the model covers the steepest slopes of Adélie Land, on an area of 500 times 500 km 2 . Simulations last 2 summer months (December 2010 and January 2011). The influence of model parameterizations on the simulated wind speed, relative humidity and horizontal blowing snow flux near the surface is assessed. It is found that model parameters influencing turbulence and in particular the parameterization of the roughness length are the main contributors to the sensitivity of the above-mentioned model variables. Therefore model sensitivity tests to various parameterizations of the roughness length are performed, allowing to define a new parameterization of the roughness length depending on snow erosion by the wind.

IAMAS (Meteorology)

M04p - M04 Numerical Models for Climate Studies and Forecasting at High Latitudes

M04p-196

Study on the future ship accessibility at the Arctic Sea based on the ?IPCC fifth assessment report

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Change of arctic sea ice extent by climate change offers new opportunity as social, environmental and economic aspects. Especially, it became an important issue to use the Arctic ship route via Northern Sea Route (NSR) & Northwest Passage (NWP). A high resolution climate model, GME model, has been used to provide an essential information on the sea ice extent as well as thickness in the Arctic in detail. The simulated sea ice extent has been evaluated by comparison to observation (HadlSST-SIC) for all months in 1979-2009.

Projections of marine access are based on daily sea ice thickness data for 2010-2039, 2040-2069, and 2070-2099. Under RCP 4.5 scenarios, ice cover was maintained until 2100 except for Barents Sea. Under RCP 8.5 scenario, the sea ice extent decreased dramatically after 2060. Finally, it would be continue the almost ice-free seasons over the Arctic in 2090s. Ship-accessible days which is estimated by three vessel (PC3, PC6 and OW) classes from 2010 to 2099. Under RCP4.5 & RCP8.5 scenarios, Changes in days over study area for vessel classes, PC3 has the largest number and OW shows the smallest number. After 2070, PC3 & PC6 are projected to be possible to access year-round over the Arctic Ocean by RCP 8.5 scenario.

From the estimation of ship accessibility for Northern Sea Route (NSR) and Northwest Passage (NP) results it has been shown the decreasing trend in sea ice extent and increasing trend in ship-accessible days estimated by three vessel classes. The year to year variation of ship-accessible days is an important information to make a decision to operate The Arctic shipping routes.

Also, the “Automatic navigation” algorithm has been introduced to project the best navigation routes in the Arctic Ocean.

IAMAS (Meteorology)

M04p - M04 Numerical Models for Climate Studies and Forecasting at High Latitudes

M04p-197

An analysis of simulated global sea ice extent, thickness, and causes of error with the BCC_CSM Model

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In this study, we evaluate the global sea ice modeling capability of the Beijing Climate Center Climate System Model (BCC_CSM). Comparative analysis results indicate that the model simulates the spatial and temporal distribution characteristics of global sea ice extent and thickness well and that its simulation performance in the Southern Hemisphere is better than that in the Northern Hemisphere. The maximum simulation bias of the annual mean sea ice extent (SIE) occurs in the Sea of Okhotsk, the Bering Sea, and the Barents Sea. The spatial distribution results for simulated sea ice thickness are similar to those from observation data, with thinner sea ice in the Northern Hemisphere winter. The mean annual cycle of sea ice extent has a negative bias in summer and a positive bias in winter, as compared with observation data. The annual mean SIE in the past 60 years in both the Northern and Southern Hemispheres is excessive, while the positive bias in the Southern Hemisphere is smaller. However, the simulated interannual variation trend in the Northern Hemisphere is more accurate. In addition, lower net radiation results lead to anomalous cold sea surface temperatures, which may be the main reason for the sea ice simulation error.

IAMAS (Meteorology)

M04p - M04 Numerical Models for Climate Studies and Forecasting at High Latitudes

M04p-198

Applications of a Polar Automatic Weather Station Network to benefit polar numerical modeling

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Automated weather observations of the Antarctic began as a means to both learn about the weather the continent experiences and to support weather forecasting. For the past 35 years, science research, weather forecasting and operational logistics utilize all available observations, especially the surface automatic weather station (AWS) network. In recent years, regional numerical modeling has come into its own showing invaluable skill at forecasting along with advancing research on meteorological phenomena and aiding in logistical planning. Today, in seeking improvements, numerical modeling performance has seen the community turn to observations and the assimilation of those observations. The key set of observations in such a data sparse region as Antarctica does play a critical role in impacting numerical modeling success via data assimilation. Observations such as those from surface based networks like the Antarctic AWS network capture processes that may be poorly represented in numerical models. Better parameterization methods to represent these processes are one of the critical frontiers in numerical modeling. Further, numerical modeling systems confirm their capabilities via comparisons to observations. This presentation outlines the multi-prong benefits that observational networks, specifically the Antarctic AWS network, provide to numerical modeling efforts in the Antarctic.

IAMAS (Meteorology)

M04p - M04 Numerical Models for Climate Studies and Forecasting at High Latitudes

M04p-201

Surface radiation balance, surface layer climate and turbulent exchange in the ablation zone of the Pine Island Glacier

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The observed thinning and acceleration of glaciers along the Amundsen Coast of Antarctica produces the majority of Antarctica's contribution to sea-level rise. Pine Island Glacier, one of the largest ice streams in Antarctica flows into the Amundsen Sea embayment. Winds over the Amundsen Sea shelf break are thought to modulate transport of relatively warm ocean water onto the continental shelf. Results from modelling experiment have also shown that stronger westerly winds over the Amundsen Sea can increase the ow of relatively warm ocean water to the base of ice shelves that drain into the Amundsen Sea. However, the lack of long-term in situ observational records limits our understanding of the climatology over the Amundsen Sea area. Until now, reanalysis datasets have been used to compensate for the lack of in situ observational long-term data. An automatic weather station has been in operation on PIG since 2009. The main goal of this meteorological observatory was to collect a comprehensive database of meteorology, radiative fluxes, snow height changes, cloud cover and precipitation properties. Here, data for five years of operation (2009 and 2010 to 2014) are used to provide the general description of meteorological conditions and snow accumulation at PIG. We also present a description of meteorological regimes and accumulation variability, using a k-means clustering technique based on five parameters derived from the AWS measurements (wind speed, specific humidity, near-surface temperature inversion, surface pressure, and incoming long-wave).

IAMAS (Meteorology)

M04p - M04 Numerical Models for Climate Studies and Forecasting at High Latitudes

M04p-202

Amplification of Arctic warming by air pollution reductions in Europe

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The Arctic cryosphere is an important component of the climate system of the Earth that has experienced rapid climatic changes in the past decades. In the Arctic region the mean surface temperatures in winter and fall have increased substantially and the September sea ice area has declined at a rate of 13.3% per decade since 1979 (NASA, 2015). An acceleration of the Arctic warming and sea ice loss during the late 1990s and early 2000s coincides with strong global particulate matter reductions dominated by Europe and North America.

Using 3-member ensemble simulations with the Earth System Model NorESM (Bentsen et al., 2013; Iversen et al., 2013; Kirkevåg et al., 2013), we have investigated the impact on the global and Arctic climate of two future emission scenarios developed by IIASA within the ECLIPSE and PEGASOS projects (Klimont et al., in preparation): Current legislation emissions (CLE) and Maximum Feasible Reductions (MFR). Under the CLE scenario, global average fossil fuel SO_2, black carbon and organic carbon emissions decrease by approximately 5%, 15% and 20%, respectively, between 2010 and 2050. Contrastingly, the MFR scenario assumes a reduction of 73%, 75% and 86%.

The 2046-2070 mean surface temperature of the Arctic (60N-90N) is about 1.0 K higher if the MFR, instead of the CLE emission scenario is followed. Globally, the surface temperature difference is about 0.3 K higher with MFR than CLE. Between 2046-2070, in the Arctic region, precipitation is higher by 14.6 mm/year and specific humidity (900hPa – 1000hPa) is higher by 5%, if MFR is followed instead of CLE. About two thirds of the increase in water vapour is due to meridional transport from southern latitudes, the remaining third is caused by larger surface evaporation.

IAMAS (Meteorology)

M04p - M04 Numerical Models for Climate Studies and Forecasting at High Latitudes

M04p-203

Modeling the atmospheric river in East Antarctica

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Recent studies illustrated that atmospheric rivers can reach the continent of Antarctica and thus potentially influence the Antarctic accumulation patterns and the ice sheet mass balance. Are these events more likely to form in the future? To answer this question one must look at the synoptics and dynamics of the formation of an atmospheric river to analyze which factors play a big role in its development.

In this study we perform a detailed analysis of the May 2009 atmospheric river event recorded in East Antarctica utilizing data from ERA -Interim and Weather Research and Forecasting (WRF) model simulations. We assess the role of the large-scale atmospheric circulation, particularly the role of the Zonal Wave 3 anomaly. We also investigate the synoptic-scale development of a storm that led to anomalous precipitation event in East Antarctica. We investigate the role of upper level vs lower level forcing. We also perform sensitivity studies to figure out the role of sea ice on the development of this synoptic system.

We believe that such in-depth analysis of the dynamics of an atmospheric river event is crucial for better understanding present and future accumulation in the East Antarctica.

IAMAS (Meteorology)

M05a - M05 Observations and Modelling of Cloud Condensate and Water Vapour Variability

IUGG-1412

Cloud horizontal heterogeneity from a regime perspective

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Previous attempts to characterize global cloud horizontal heterogeneity from passive observations employed only rudimentary cloud type classifications, such as a simple distinction based on water thermodynamic phase. But for areas of the order (100km)2, multiple cloud types can coexist at any given time, so separate phase-based calculations of inhomogeneity parameter may not be appropriate. An alternate approach is to examine cloud inhomogeneity as a function of "cloud regime" where the regimes represent the most commonly encountered mixtures of cloud types. In our presentation we show results from such an approach. We use 10 years of MODIS Level-3 Terra and Aqua data to build a new regime-based climatology of the inhomogeneity parameter "chi" introduced by Cahalan et al. (1994). Specifically, we use as basis the MODIS cloud regimes of Oreopoulos et al. (2014) derived from clustering analysis applied on joint histograms of cloud top pressure and cloud optical thickness. The MODIS Level-3 data provide the statistical information necessary to calculate chi daily for each cloudy 1 degree gridcell. The inhomogeneity parameter can then be composited by cloud regime, and its intra-regime variability further analyzed by location (land/ocean), season etc. Our goal is to find patterns in this regime-based breakdown of chi that can inform a parameterization of horizontal cloud inhomogeneity suitable for climate models.

IAMAS (Meteorology)

M05a - M05 Observations and Modelling of Cloud Condensate and Water Vapour Variability

IUGG-2826

Condensate variability - mining observations from the Atmospheric Radiation Measurement archive

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The ARM archive contains long-term records of cloud condensate retrievals from sites around the world. Shorter, more limited data sets from the ARM and other ground-based sites have already been used to inform parameterizations of condensate variability, but the full depth of the available information has yet to be explored.
This exploration is hampered by the diversity of the instrumentation and retrieval algorithms used at various sites and over time. We propose an objective approach to determine how comparable variability observed at one site with a particular retrieval method is to variability at another site, derived with a different algorithm. To ensure that different retrieval algorithms observe substantially the same cloud scene, the ARM Best Estimate product is used to classify scenes based on cloud boundaries, presence of precipitation and water path. As might be expected, retrievals are more often successful in the absence of surface precipitation, and tenuous clouds with low water path are more likely to be missed. Condensate variability is characterised in the form of the Fractional Standard Deviation (FSD) from several products and compared where products overlap.
With consistency checks in place, robust variations in FSD become apparent. For example, the Mace, Microbase and Cloudnet retrievals all suggest that condensate variability in boundary layer clouds at Darwin is greater than that of similar clouds observed in Oklahoma. Early results indicate that parametric descriptions of FSD from literature may not fully capture regional differences in condensate variability.

IAMAS (Meteorology)

M05a - M05 Observations and Modelling of Cloud Condensate and Water Vapour Variability

IUGG-4148

Study of integrated water vapour trends and variability using ground-based GPS data and climate models

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A high-quality, consistent, global, long-term dataset of zenith tropospheric delay (ZTD) and integrated water vapour (IWV) was produced from Global Positioning System (GPS) measurements at more than 400 sites over the globe among which 120 sites have more than 15 years of data. The GPS ZTD data were screened and homogenized using ERA-Interim reanalysis as a reference, and converted to IWV using surface pressure and weighted mean temperature from SYNOP observations and ERA-Interim. The resulting GPS IWV time series were used to assess the spatial and temporal distribution of IWV, as well as trends and variability in IWV over the period 1995-2010, from global (IPCC AR5) and regional (Med-CORDEX) climate model simulations. Observed and modelled trends are globally in the range -2 to +2 kg/m2/decade with large coherent spatial patterns of moistening and drying. While both the global and regional climate models are fairly consistent with GPS IWV and with ERA-Interim for the spatial distribution and seasonal cycle, some dispersion is observed in the monthly anomalies and trends with the global models. Tests are made to investigate the origin of the observed dispersion using the IPSL model with different physics and nudging options.

IAMAS (Meteorology)

M05a - M05 Observations and Modelling of Cloud Condensate and Water Vapour Variability

IUGG-4269

Integrated water vapor variability – exploiting unique field campaign data and high-resolution reanalysis

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Since water vapor is part of various atmospheric processes, it is very variable in both space and time. Quantifying this variability in terms of the integrated water vapor (IWV) is difficult as the different measurement techniques available can exhibit significant differences due to sampling. To overcome this issue a combination of high-resolution field campaign and model data is exploited.

During the High Definition Clouds and Precipitation for advancing Climate Prediction (HD(CP)^2) Observational Prototype Experiment (HOPE) in Jülich, Germany (April/May 2013) IWV is available from a GPS antenna, 5 microwave radiometers, a sunphotometer, >200 radiosoundings, several lidar systems, and 3 Moderate Resolution Imaging Spectroradiometer (MODIS) retrievals. With this data a multi-instrument comparison of IWV focusing on its small-scale variability is performed. We investigate the temporal variability within time intervals of a few minutes up to 1 day. To expand the quantification of variability into the spatial domain a high resolved (156 m) simulation with the novel ICOsahedral Non-hydrostatic modeling framework (ICON) is used.

While the analysis of HOPE data focuses on small scales, IWV variations for central Europe are assessed using 2 regional reanalyses with resolutions of 2 and 6 km which are produced in the Hans Ertel Centre for several years with the COSMO model of Deutscher Wetterdienst (DWD). To evaluate the IWV, measurements at 157 GPS stations are provided by Geoforschungszentrum Potsdam. These are independent measurements with a good spatial coverage of the model domain and the same temporal resolution (15 minutes) as the model output. The comparison focuses on the dependence of errors on the diurnal and annual cycle, weather conditions, and geographic location.

IAMAS (Meteorology)

M05a - M05 Observations and Modelling of Cloud Condensate and Water Vapour Variability

IUGG-4657

Water vapour and cloud condensate variability simulated by statistical cloud parametrizations in the global ICON model

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Parameterizations of cloud processes are generally unresolved by the numerical resolution of present day and future general circulation models used for climate prediction. A promising approach is to base cloud parameterizations on assumed subgrid-scale variability of total (cloud condensate and water vapour) water, expressed by a subgrid-scale probability density function (PDF).
Traditional cloud parameterizations diagnose cloud fraction from grid-box mean quantities (e.g. RH), while new schemes implicitly try to capture the underlying cloud processes.Following the latter approach clouds can respond to a warming climate in a physically consistent manner. Additionally the total water PDF can be shared by other cloud related parameterizations which increases model consistency.
Well established and recently developed cloud parameterizations (e.g. EDMF-DualM) are reviewed and their skill to simulate variance and skewness of the total water PDF is analyzed. Being a subproject of the HD(CP)2-initiative we use the icosahedral general circulation model (ICON) with 50 to 100 km horizontal resolution, satellite observations and large eddy simulation to exploit and evaluate the behavior of cloud parameterizations under different dynamical regimes.

IAMAS (Meteorology)

M05b - M05 Observations and Modelling of Cloud Condensate and Water Vapour Variability

IUGG-0702

Characteristics of cloud vertical structure over the Tibetan Plateau and its neighboring areas

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By using CloudSat/CALIPSO and TRMM data, the characteristics of cloud vertical structure over the Tibetan Plateau (TP), its southern adjacent land (southern region) and the tropical region are comparatively analyzed. The cloud vertical structure over the TP and its southern region shows significant seasonal variation. In the TP, the cloud amount presents a single peak in January-April, while two peaks after mid-June, and resumes one peak after mid-August. In the southern region, the cloud occurs rarely from October to April, and the cloud amount is mostly below 4% ; while from May to September, the cloud is located at 10-17.5 km and the amount are more than 44%, which is the largest among the three regions. In the tropical region, the cloud is located stably through whole year. Due to the TP restrictions on moisture supply in lower level, there is a significant compression of cloud thickness, cloud layers, as well as cloud top height, so the possible precipitation intensity is smaller over the TP than the other two regions. The variation range of cloud thickness, cloud layers number and cloud top height corresponding to different precipitation intensity is significantly smaller over the TP than the other two regions. In summer, deep convection cloud, which can reach 12-16 km altitude, is significantly smaller over the TP than the other two regions, while the relatively shallow cloud, located in 5-8 km and corresponding to mixed phase cloud water content, appears much more than the other two regions. These significant differences of cloud microphysical characteristics over the TP and other regions may have impacts on the radiation and precipitation. Our results can be applied on the improvements of model simulation on the cloud characteristics and precipitation.

IAMAS (Meteorology)

M05b - M05 Observations and Modelling of Cloud Condensate and Water Vapour Variability

IUGG-3328

"On the frequency of warm rain over West Africa using CloudSat and European geostationary satellite observations"

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Shallow warm clouds prevail across southern West Africa during the monsoon. However, climate models have significantly underestimated warm cloud cover over this region, leading to large errors in the surface radiation budget. Additionally, we have little knowledge on how frequent these warm clouds precipitate because it remains challenging to distinguish the warm rain signal from the land surface using passive satellite observations. This detection issue can be partially alleviated by active space-borne radar that probes the vertical structure of precipitation and detects warm rain. In this paper, with added assistance from CloudSat radar measurements, we introduce a new method for detecting warm rain using shortwave observations from the Spinning Enhanced Visible and Infrared Imager onboard the Meteosat Second Generation geostationary satellite. Using this new technique, we will demonstrate the variability in the frequency of warm rain over the region during 2004–2011. Our results provide unique information not only for expanding the rainfall monitoring capability of geostationary measurements, but may also enhance the study of aerosol-precipitation interactions in warm clouds.

IAMAS (Meteorology)

M05b - M05 Observations and Modelling of Cloud Condensate and Water Vapour Variability

IUGG-3511

Tropical and subtropical humidity and cloud organization by thermodynamic and dynamic states using AIRS, MODIS, and MERRA reanalysis data

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In this talk, we will discuss the variability of cloud properties, temperature, water vapor, horizontal winds, and vertical velocity using the Atmospheric Infrared Sounder (AIRS) and Moderate Resolution Imaging Spectroradiometer (MODIS) retrievals and MERRA reanalysis data. All observational and reanalysis data are matched in time and space at the native instrument pixel resolution and MERRA grid resolution so that the statistical variance and co-variance available in geophysical data is retained in composite analyses built from instantaneous data. We define cloud organization by the mean, variance, and skewness of visible reflectance and infrared radiance from the AIRS and MODIS instruments, as well as by the thermodynamic phase retrievals from AIRS. We focus this analysis on shallow marine boundary layer (MBL) clouds, and on tropical cirrus and deep convection. We will show that the major stratus regimes do not necessarily have similar relationships between cloud, humidity, MBL depth, and cloud organization. Furthermore, we will show relationships of moist static energy (MSE) in the convective tropics and how it relates to cloud, thermodynamic, and dynamic variables from the satellite and reanalysis data.

IAMAS (Meteorology)

M05b - M05 Observations and Modelling of Cloud Condensate and Water Vapour Variability

IUGG-4765

Global Cloud height variability since 2000 observed using Stereophotogrammetry from MISR on the Terra Satellite

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The Multiangle Imaging SpectroRadiometer (MISR) on the Terra satellite has been measuring cloud-top altitudes since early 2000. The lower limit of optical thickness observed using the standard product is about 0.3, and heights are retrieved with an instantaneous rms accuracy of about 500 m. The sampling is (almost) from pole to pole, sun-synchronous at about 10:30 am. All equatorial regions are sampled about 4 times per month, and higher latitudes more frequently. This results in an rms sampling error of the global, annual average effective [i.e., the frequency weighted] cloud-top height of about 8 m. After correcting for minor sampling issues due to satellite maneuvers, the time series yields decadal trends in cloud-top height that are statistically significant, and of interest to climate science.

Some regions of the Tropics show opposite trends. The central Pacific shows a large overall decrease in effective height at rates up to 300 m/decade, whereas the effective cloud height over the maritime continent has risen at up to 350 m/decade. Overall, the Tropical effective height has fallen at the rate of 10m/decade. Outside the tropics there is a notable hemispheric asymmetry, with the NH extratropics falling at 60 m/decade and the SH extratropics rising at 14 m/decade. The global value has decreased at about 16 m/decade. This is less than reported earlier, but still about twice the equilibrium effect of carbon dioxide over the same period (in the opposite direction.)

IAMAS (Meteorology)

M05b - M05 Observations and Modelling of Cloud Condensate and Water Vapour Variability

IUGG-5026

Global analysis of ice microphysics and ice super-saturation from CloudSat, CALIPSO and AIRS

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Relationship between ice microphysics and ice super-saturation was examined. Ice microphysical properties were retrieved using cloud profiling radar on CloudSat and lidar on the Cloud-Aerosol Lidar and Infrared Pathfinder Satellite Observation (CALIPSO). Relative humidity was retrieved from Atmospheric Infrared Sounder (AIRS) on AQUA. Ice microphysics was derived using radar reflectivity factor from CloudSat and backscattering coefficient and depolarization ratio from CALIPSO lidar [Okamoto et al., 2010]. Unique feature of the algorithm is that it can treat the variability of ice crystal shape and orientation. We applied Ishimoto's algorithm [Ishimoto 2009] to AIRS data to retrieve water vapor density and temperature with much finer resolutions (13.5km in horizontal and 1km in vertical) compared with the AIRS standard product with 45km in horizontal and 2km in vertical. Therefore combined use of these two algorithms allowed us to study relationship between ice microphysics and relative humidity in the vicinity of the ice clouds. Excess of water vapor amount respect to ice saturation from AIRS was converted to equivalent ice water content to compare retrieved ice water content from CloudSat and CALIPSO.

Global analysis of ice water content and collocated equivalent ice water content showed that both maxima of frequency distribution of these two values were located at about 10 [mg/m^3]. The equivalent ice water content tended to be larger than the ice water content when the equivalent ice water content exceeded 10 [mg/m^3]. The relation was similar in low, mid and high latitude regions.

IAMAS (Meteorology)

M05c - M05 Observations and Modelling of Cloud Condensate and Water Vapour Variability

IUGG-0273

A modified scheme that parameterizes depositional growth of ice crystal: A modeling study

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The schemes that parameterize depositional growth of cloud ice are compared and evaluated in terms of cloud hydrometeors, surface rainfall and heat budget, and fractional coverage of clouds and rainfall through the analysis of sensitivity experiments of pre-summer heavy rainfall over southern China. The schemes that parameterize depositional growth of ice crystal using the growth timescale from 40 μm to 50 μm (Hsie et al., 1980) and from 40 μm to 100 μm (Krueger et al., 1995) assume that ice crystal spectral density is not a function of crystal size. Zeng et al. (2008) proposed a scheme with the assumption that the number of ice crystal is proportional to the mass of ice crystal. The results show that the Zeng's scheme with low ice crystal concentration and the Hsie's and Krueger's schemes produce similar cloud hydrometeors, surface rainfall and heat budget, and fractional coverage. Zeng's scheme with a moderately high ice crystal concentration generates anomalous growth of cloud ice, which leads to model domain mean radiative heating, downward surface sensible flux, and anomalous area expansion for stratiform rainfall. The original Zeng's scheme calculates depositional growth of cloud ice from 0 to 50 μm. The Zeng's scheme is modified by calculating depositional growth of cloud ice from 40 μm to 50 μm. The modified scheme significantly reduces growth of cloud ice, which in turn decreases the mean radiative heating, downward surface sensible heat flux, and fractional coverage of stratiform rainfall.

IAMAS (Meteorology)

M05c - M05 Observations and Modelling of Cloud Condensate and Water Vapour Variability

IUGG-2470

A new estimation of the atmospheric moisture residence time

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The atmospheric branch of the hydrological cycle substantially modulates the global water and energy budget but also affects ecosystems on the regional scale. By applying a refined Lagrangian diagnostic based on along-trajectory specific humidity budgets we obtain a new estimate of the atmospheric moisture residence time. The results show that the concept of a previous estimate suggests a non-physical e-folding time constant potentially being interpreted as the physical residence time of atmospheric moisture. The new approach dynamically estimates the global climatological mean residence time as the time from evaporation to precipitation to be around 4 days compared to the e-folding time constant being just over 8 days. The differences between the estimates are mainly explained by the fact that the previous estimate neglects atmospheric moisture transport and by the simple assumptions being made. The new technique crucially changes the picture of atmospheric moisture residence and shows large potential to exhibit unique features of the atmospheric moisture transport and its dynamics.

IAMAS (Meteorology)

M05c - M05 Observations and Modelling of Cloud Condensate and Water Vapour Variability

IUGG-3337

Giga-LES of Hector the Convector keeping the tallest updrafts undiluted

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The trend of stratospheric water vapour during the past decades is not correctly reproduced by current GCMs. This may be due to lack of representation of rapid water transfers from troposphere to stratosphere. Our modeling study focused on a particular case of tropical very deep convection, a Hector thunderstorm observed on 30 November 2005 over Tiwi Islands, Australia, for which plumes of ice particles reaching 19 km altitude were measured by lidar. We performed a Giga Large-Eddy Simulation (100 m horizontal resolution, more than 1 billion grid points) using cutting-edge computing resources, as well as a series of simulations with coarser resolutions, from 200 m to 1600 m. Deep convection quickly reached 14 km altitude. The most intense upward transport started 1 hour later and lasted around 2 hours. As a result, a couple of updrafts overshot the tropopause carrying ice crystals in the stratosphere. Part of the ice particles precipitated then whereas the remainder sublimated in the lower stratosphere. The consequent vapour pockets were transported and diluted within the stratosphere by easterlies. While moistening appeared to be robust with respect to the grid spacing used, grid spacing on the order of 100 m may be necessary for a reliable estimate of hydration (Dauhut et al. ASL 2014, doi: 10.1002/asl2.534). A comprehensive analysis of individual updrafts and of their properties shows that the overshooting updrafts presents a higher buoyancy, stronger vertical velocities and larger hydrometeor contents compared to the ordinary deep convective updrafts. The preconditioning through cold pools generation and troposphere moistening is found to be determinant for the transition from the deep to the very deep convection. This study was supported by the StratoClim project.

IAMAS (Meteorology)

M05c - M05 Observations and Modelling of Cloud Condensate and Water Vapour Variability

IUGG-3684

Probing clouds in 3D using scanning radars and shortwave spectral radiances

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Cloud heterogeneity plays an important role in representing microphysical and radiative processes in both weather forecast and climate models. Characterising cloud heterogeneity requires 3D cloud fields, but ground-based instruments have mainly observed clouds in a 1D view. The lack of the probing ability for 3D cloud fields also makes it difficult to investigate how cloud heterogeneity changes through cloud life cycle. The new scanning cloud radars from the Atmospheric Radiation Measurement (ARM) Climate Research Facility provide an excellent opportunity to make robust 3D cloud observations. This paper introduces a novel retrieval method, providing 2D fields of cloud drop number concentration, and 3D fields of liquid water content and cloud effective radius for non-precipitating warm clouds. The new method, dubbed ENCORE, exploits not only synergetic measurements of scanning cloud radar and shortwave spectral radiances, but also takes an ensemble Kalman Filter approach to incorporate 3D radiative transfer, which remains challenging for other retrieval techniques. Using the ARM data collected from the Azores over the Atlantic Ocean and the Oklahoma site in the US, we will show examples that range from patchy cumulus to overcast stratocumulus, and compare and contrast properties and variability of continental and maritime clouds.

IAMAS (Meteorology)

M05c - M05 Observations and Modelling of Cloud Condensate and Water Vapour Variability

M05p-213

A budget analysis of variance of total water in shallow cumulus convection

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A good understanding of the spatial variability of moisture is essential for cloud modelling on all scales. Especially parameterizations of cloud processes include assumptions about the sub-grid variability of moisture.

The focus of this study are the budgets of moisture and temperature variance in precipitating shallow convection. Large eddy simulations are used to calculate and analyze the individual terms of the budget equations of variance and vertical flux of total water, as well as of temperature. Several tendencies contributing to the time evolution of these four quantities are evaluated based on the LES data. Besides the effect of turbulent transport and production, a special focus is on the correlation terms of microphysical processes (evaporation of rain, autoconversion and accretion) with turbulent fluctuations. These tendencies are investigated with respect to magnitude, sign and structure. For example, accretion is an important sink of total water variance in the cloud layer. The obtained information will be helpful for understanding the effects of the microphysical processes on the boundary layer and cloud dynamics and their influence on the production and dissipation of variance of moisture and temperature.
Based on the information a first simple parameterization is suggested, which could be used to include the impact of accretion on variance of moisture in parameterizations.

IAMAS (Meteorology)

M05p - M05 Observations and Modelling of Cloud Condensate and Water Vapour Variability

M05p-204

Determining the most suitable Artificial Neural Network for short term fog forecasting at Urmia Airport

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Fog is one of the important environmental factors affecting the safety of transportation. The aim of study is to know whether Artificial Neural Networks (ANN) are applicable for fog forecasting of Urmia airport in North west of Iran. Here fog only taken into consideration and defined when the humidity amount is greater than 75% and maximum visibility is less than 1000 meters. Nine different Artificial Neural Network including Multiple Layer Perceptions, Generalized Feed Forward, Modular Feed Forward, Jordan and Elman Networks, Principal Component Analysis, Radial Basis Function, Self Organizing Feature Maps, Time Lagged Recurrent networks and Recurrent Networks models are used for fog forecasting. First of all, the correlation coefficients of nine meteorological variables including three hourly: wind directions, wind speed, dry and wet bulb temperature differences, dew point, relative humidity, mean sea level pressure, cloudiness, maximum horizontal visibility, and water vapor pressure with relative humidity as well as visibility are calculated. These meteorological variables are then used as inputs of different ANN methods in order to forecast relative humidity and visibility. In the first step, just one variable which had the biggest correlation coefficient is used as the input. This procedure is continued until all nine meteorological variables are used as inputs of ANN models. After training and evaluating the different ANN models, it is concluded that the Multiple Layer Perceptions model was the most suitable model for fog forecasting of Urmia airport.

IAMAS (Meteorology)

M05p - M05 Observations and Modelling of Cloud Condensate and Water Vapour Variability

M05p-205

Homogenization of the GNSS-derived atmospheric water vapour time series

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Homogenous data obtained from Global Navigation Satellite Systems (GNSS) are of great importance to monitor the long-term variability of the atmospheric water vapour on a global scale. However, many changes, e.g., replacements of instruments and the change of the electromagnetic environment, that take place during the period of the GNSS data record, can cause systematic errors in the estimated water vapour from the reprocessed GNSS data. In this work, the potential temporal inconsistencies in the GNSS-derived Integrated Water Vapour (IWV) time series were comprehensively investigated. We applied a statistical test, the penalized maximal t (PMTred) test, to identify the possible mean shifts (changepoints) in the time series of the difference between the GPS IWV and the one obtained from the European Centre for Medium-Range Weather Forecasts (ECMWF) reanalysis data (ERA Interim). The IWV difference time series formed for 101 globally distributed GPS sites were tested, where 47 of them were found to contain changepoints. The result indicates that 69 % of the detected changepoints were due to inconsistencies in the GPS IWV time series and 26 % of them were ECMWF related. After the bias correction for the GPS data, an improved consistency in the IWV trends is evident for the GPS sites from the same region. In addition, the IWV trends estimated for 48 GPS sites were compared to the corresponding IWV trends obtained from a globally homogenized radiosonde data set. The correlation coefficient of the two trends increases significantly by 26 % after the bias correction.

IAMAS (Meteorology)

M05p - M05 Observations and Modelling of Cloud Condensate and Water Vapour Variability

M05p-206

Aerosol effects on Cloud Condensation Nuclei over Europe

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Aerosols indirectly effect the climate through the modification of clouds, therefore an accurate representation of the spatial and temporal variability of aerosols is needed. The Consortium for Small-scale Modeling (COSMO) Multi-Scale Chemistry Aerosol Transport (MUSCAT) modeling system was used to simulate the emission and transport of anthropogenic and natural aerosols in Europe. The aerosols fields indicate there is a large amount of temporal and spatial variability in aerosol concentrations. A parameterisation is applied to various aerosol types to estimate the cloud condensation nuclei (CCN) concentrations, which show similarly large spatial and temporal variability. A method is presented to introduce a updraft dependent climatological description of CCN concentrations into limited-area numerical models or large eddy simulations for process studies over Europe.

IAMAS (Meteorology)

M05p - M05 Observations and Modelling of Cloud Condensate and Water Vapour Variability

M05p-207

Study and mitigation of calibration error sources in a water vapor Raman lidar

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The Raman lidar ability to retrieve atmospheric water vapor with high accuracy makes it a premium instrument in different research fields such as climatology, meteorology or calibration of GNSS altimetry data. In order to achieve long term stability of the measurements, the system has to be carefully calibrated. The calibration allows the reduction of uncertainties due to Raman cross sections, atmospheric transmittance and instrumental efficiency. In this work we focus on reducing instrumental uncertainties, in particular the optical design of the detection system, of the IGN Raman lidar (Institut National de l'information Géographique et forestière), which has shown to have produced substantial drifts during the DEMEVAP campaign conducted at OHP (Observatoire de Haute Provence, France) in 2011. Above all, the optical fiber and the photomultipliers -which are widely used components in lidar systems- both, together, appeared to induce unwanted fluctuations. We conducted numerical simulations as well as experimental tests to identify and quantify the different instability sources and come up with practical solutions. Finally, long term calibration stability of the overall system will be assessed with regular water vapor profile recordings and calibration measurements spread over several months.

IAMAS (Meteorology)

M05p - M05 Observations and Modelling of Cloud Condensate and Water Vapour Variability

M05p-208

Modelling of entrainment rate for cumulus parameterization based on cloud-resolving model

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Variability of water and condensate in convective clouds greatly depends on entrainment occurring in cloud interface. Therefore, modelling of entrainment rate is the key component for cumulus parameterization, and its better representation still has been required. However, measurement and the modelling of the entrainment rate are difficult, because detailed cloud structure as well as transport of saturated (or unsaturated) airs in the cloud interface must be accurately captured. In addition, there difficulty in the modelling of entrainment rate exists in estimating relationship between in-cloud properties and environmental air that could be implemented into numerical models. In order to derive the entrainment rate model for cumulus parameterization, we performed relatively long-range cloud-resolving model simulation, and extracted statistical in-cloud properties using recently proposed direct measurement method. The obtained in-cloud properties show that in-cloud properties estimated from existing entrainment rate models partly match with those of simulated clouds, but the models are found to lack effect of detrainment on the buoyancy. A novel entrainment rate model is proposed based on the analysis for the in-cloud property. In the model, the entrainment rate is modelled using buoyancy and detrainment rate. The proposed model is found to be valid for both deep convective and shallow convective clouds, as the parameters of entrainment rate model are identical for both clouds. Finally, the proposed entrainment model is implemented into cumulus parameterization, and impact of the model on climate simulation is investigated.

IAMAS (Meteorology)

M05p - M05 Observations and Modelling of Cloud Condensate and Water Vapour Variability

M05p-209

Evolution of cloud population and convection associated with the Madden-Julian Oscillation over the tropical Indian Ocean and Maritime Continent

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The evolution of tropical cloud populations associated with the Madden-Julian Oscillation (MJO) is investigated using multiple satellite data sets and the cloud-resolving model (CRM). First, an objective index is established to describe the modulation of cloud regimes (CR) over the tropical Indian Ocean, Maritime Continent, and the Western Pacific warm pool. The index is based on the leading pair of the multivariate empirical orthogonal functions (EOF) of the daily areal fraction of deep, high, and low clouds, derived from the 6-year CloudSat cloud classification data. The pattern of the EOFs signifies the spatial distribution of the relative abundance of each cloud type, while the principle components time series is well correlated with the real-time multivariate MJO index based on observed outgoing longwave radiation and wind fields at the intraseasonal time scale. This CR index captures the coherent evolution of cloud composition with the variation of convective activity and large-scale environment associated with the propagation of the MJO. Detailed MJO case study is carried out using the co-located A-Train satellite and ECMWF high-resolution analyses data set. For each MJO cloud phases, the hydrometeors vertical structures, precipitation efficiency, and cloud radiative forcing from CloudSat are examined; the relationships between cloud composition and the ambient thermodynamics and dynamics are identified. Finally, idealized CRM experiments corresponding to different cloud regime ambient conditions are carried out to investigate how cloud and convection interact with the environment. The results can lead to the development of process-oriented diagnostics and constraints for evaluating the representation of MJO and moist-convection processes in the global models.

IAMAS (Meteorology)

M05p - M05 Observations and Modelling of Cloud Condensate and Water Vapour Variability

M05p-210

Simultaneous cloud and drizzle properties in the stratocumulus-to-cumulus transition zone over the Pacific

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Cloud feedback remains one of the primary sources of the large spread in climate projections over the coming decades. In particular, climate models disagree substantially in the magnitude of cloud feedback for the regimes of subtropical marine low-altitude clouds, and suffer from the so-called “too few, too bright” problem. This problem calls for further observational constraints to advance understanding of cloud and precipitation life cycle for marine low clouds. However, simultaneous, collocated cloud and drizzle observations remain limited because they rely heavily on aircraft in-situ measurements. In this paper, we will report simultaneous cloud and drizzle properties using ground-based measurements from the Atmospheric Radiation Measurement (ARM) Mobile Facility deployment in the stratocumulus-to-cumulus transition zone over the eastern north Pacific. These properties are retrieved through an ensemble approach and a synergy between vertically-pointing cloud radar and shortwave radiation measurements. From these new retrievals, we will show how drizzle variability depends on cloud properties, helping shed lights in representing sub-grid drizzle variability in models.

IAMAS (Meteorology)

M05p - M05 Observations and Modelling of Cloud Condensate and Water Vapour Variability

M05p-214

Satellite remote sensing of vertically resolved cloud microphysics and water vapour

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Vertical variability of cloud water have been derived based on a Backward Monte Carlo-based inversion algorithm developed for space-borne lidars as the Cloud-Aerosol Lidar with Orthogonal Polarization (CALIOP lidar). The retrieved liquid phase microphysics information were combined with the Atmospheric Infrared Sounder (AIRS), CloudSat radar and the reanalysis data to extend our earlier analysis, where a high-resolution water vapour inversion algorithm developed for AIRS [Ishimoto et al., 2009, 2014] and the ice microphysics retrieval algorithms for CALIOP lidar and Cloudsat radar synergy [Okamoto et al., 2010, Sato et al., 2011] had been used to investigate the relation between water vapour amount and ice cloud microphysics on cloud scales, globally. Synergy with CloudSat has also been attempted to determine the cloud processes present, i.e., drizzle and light precipitation formation.

IAMAS (Meteorology)

M05p - M05 Observations and Modelling of Cloud Condensate and Water Vapour Variability

M05p-215

Implementation of a new empirical relationship between aerosol and cloud drop number concentrations to HadGEM2-AO

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In the Hadley Centre Global Environmental Model version 2 - Atmosphere-Ocean (HadGEM2-AO), cloud drop number concentration is estimated according to the empirically determined relationship between aerosol and cloud drop number concentrations. However, the observational dataset used for establishing the relationship was obtained from limited regions of the earth; as such, it may not be representative of the entire Earth. In this study, we have re-established the relationship between aerosol and cloud drop number concentrations, based on a composite of the observational dataset obtained from many different regions around the world, including the original dataset. The new relationship tends to provide a lower cloud drop number concentration when the aerosol number concentration is < 600 cm^{-3} and the opposite when it is > 600 cm^{-3}, compared to those from the original relationship. Experiments are performed under the same conditions as the Coupled Model Intercomparison Project phase 5 (CMIP5). The results from the complete historical run with the new relationship are expected to show a number of significant differences from the original historical run. With the new relationship, the cloud droplet effective radius became closer to the results retrieved from the observed data, and the total cloud amount changed significantly over the ITCZ region. Changes in the total precipitation rate tend to follow the changes in the total cloud amount. More detail will be discussed at the conference.

IAMAS (Meteorology)

M06a - M06 Observations of Anthropogenic Aerosol-Cloud Interactions

IUGG-2286

Has the cloud-mediated anthropogenic aerosol forcing really saturated?

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Sensitivity of aerosol cloud interactions on cloud radiative effect (ACI) is very large in ultra-clean environments, where there are simply not enough aerosols for sustaining extensive low cloud coverage while meteorological considerations allow it otherwise. However, anthropogenic aerosols overwhelm the aerosol concentrations and shut off this effect. The Twomey effect also saturates at modest aerosol concentrations, in part due to buffering effects of enhanced cloud mixing and drying. This situation led recently to portray a picture by which the anthropogenic ACI has nearly or fully saturated, and its magnitude is determined by the poorly known pre-industrial aerosol background. This would be true if we examined the ACI of a cloud system in isolation from other processes which have not been considered yet, which are not saturated.

Polluted air mass that flows from the continent into the ocean is cleansed mainly by cloud processing of the aerosols, which is a slow process until cloud top effective radius exceeds 14 micrometer and significant precipitation occurs and accelerates greatly the cleansing. This leads to breaking the cloud cover and a large decrease in the cloud radiative effect. This maritimization process of clouds is shown to take 2 to 4 days. To the extent that the time required for cleansing does not saturate with enhanced amount of aerosols, the area over ocean in which clouds are affected by anthropogenic aerosols is not saturated as well. Since the cloud cover effect dominates the ACI (X4 of the Twomwy effect), the sensitivity of the globally integrated ACI would be quite large to this area effect, rendering the climate system not saturated to anthropogenic aerosols.

IAMAS (Meteorology)

M06a - M06 Observations of Anthropogenic Aerosol-Cloud Interactions

IUGG-2432

A ‘natural observatory’ for aerosol cloud interaction studies

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Anthropogenic aerosols are suspected to contribute to regional scale climate change via aerosol cloud interactions. The first step (first indirect effect) changes the cloud microphysics towards smaller droplet sizes resulting in changes in the cloud albedo, the second indirect effect modifies the time scale of raindrop formation and subsequently the spatial, temporal and intensity rainfall distribution. While a regional scale change in cloud albedo and a possible change of cloud type or lifetime is difficult to observe on a long term (climate relevant) time scale due to the high variability of clouds and missing long term observations rainfall data are available from meteorological observations over long enough time periods to derive statistically significant trends. For Western Australia (WA) the rainfall data show a significant decline within a few years in the early 1970ies, for Eastern Australia (Queensland, Qld) a constant decline of rainfall is reported since 1970, while in both areas no positive or negative trend was observed over 80 years from 1890 to 1970. Fortunately experimental observations on aerosol concentrations and aerosol sources are available already from a 1974/1976 survey allowing a reconstruction of the historic development of anthropogenic aerosol emissions and a comparison to present day measurements of aerosol abundance. Aerosol emissions are anti-correlated to the rainfall trends. Including these anthropogenic aerosol emissions into regional scale rainfall calculations for Western Australia using a high resolution WRF CHEM model with an aerosol-aware microphysics scheme matches both, rainfall rate and timeline of the rainfall decline

IAMAS (Meteorology)

M06a - M06 Observations of Anthropogenic Aerosol-Cloud Interactions

IUGG-4504

An imager-based retrieval of above-cloud absorbing aerosol optical depth and the optical and microphysical properties of underlying marine stratocumulus clouds

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Clouds, aerosols, and their interactions are widely considered to be key uncertainty components in our current understanding of the Earth's atmosphere and radiation budget. The work presented here is focused on the quasi-permanent marine boundary layer (MBL) clouds over the southeastern Atlantic Ocean, which underlie a near-persistent smoke layer produced from extensive biomass burning in the southern African savanna during austral winter. The absorption of the above-cloud smoke layer, which increases with decreasing wavelength, can introduce biases into imager-based cloud optical and microphysical property retrievals of the underlying MBL clouds. This effect is more pronounced for cloud optical thickness retrievals that are typically derived from the visible or near-IR wavelength channels (effective particle size retrievals, derived from short and mid-wave IR channels, are less affected by aerosol absorption).

Here, a new method is introduced to simultaneously retrieve the above-cloud absorbing aerosol optical depth (AOD) and the cloud optical thickness (COT) and effective radius (CER) free of aerosol absorption-induced biases using multiple spectral channels in the visible and near- and shortwave-IR. The technique has been applied to the entire Aqua and Terra MODIS record during the peak burning season, i.e. the months of June through October. Retrieval results for selected case studies are presented, as is an evaluation of the above-cloud aerosol retrievals using CALIOP. Finally, a MODIS-derived above-cloud aerosol and MBL cloud climatology for the selected region and season is shown, from which preliminary estimates of the instantaneous shortwave above-cloud aerosol direct radiative effect are produced.

IAMAS (Meteorology)

M06a - M06 Observations of Anthropogenic Aerosol-Cloud Interactions

IUGG-4523

Assessing aerosol-warm cloud radiative sensitivities with satellite observations

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Important aerosol-warm cloud radiative interaction problems relevant to climate prediction include indirect effects related to changes in cloud microphysics and enhancements to the direct aerosol radiative effect for absorbing aerosol overlying lower level clouds. A number of challenges are obvious in attempting to understand these effects from satellite observations, including: (a) the need to isolate radiative changes due to aerosol perturbations from dynamic/thermodynamic changes, and (b) the existence of an observing system that has the necessary microphysical and radiative retrieval capabilities for understanding coupled aerosol-cloud processes. While statistical studies over large temporal and/or spatial scales can be filtered to lessen the impact of some of these issues, satellite observations alone do not provide sufficient tools for quantifying aerosol-cloud radiative interactions. For indirect effects in particular, it may be extremely challenging to obtain the necessary information even from in situ observations (e.g., maximum cloud parcel supersaturation, turbulence/entrainment, etc.).

It is well-recognized that a synergistic observation and modeling approach is needed to advance our understanding of aerosol-cloud interactions and radiative impacts. Thus an overarching issue is to what extent current and future observations (satellite and sub-orbital) assist with microphysical and radiative model development.

We provide an overview of the challenges in quantifying the two above-mentioned aerosol-cloud effects from satellite observations, including experience from our own work on cloud susceptibility. We also discuss future observations and modeling capabilities that would help facilitate progress on the aerosol-warm cloud problem.

IAMAS (Meteorology)

M06a - M06 Observations of Anthropogenic Aerosol-Cloud Interactions

IUGG-5213

From aerosols to cloud droplets: A joint satellite-reanalysis approach

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Aerosols are known to have a significant impact on cloud microphysics, acting as cloud condensation nuclei (CCN) and thereby altering cloud properties, such as cloud droplet number concentration (CDNC) and cloud albedo. Global estimates of indirect aerosol effects purely from satellites are very uncertain and often give insignificant results.
To improve observationally based estimates we use a joint multi-component approach combining cloud retrievals from the A-Train satellite instruments and aerosol information from the MACC-II reanalysis. An aerosol activation parameterization is applied to this synthesized, collocated satellite-reanalysis dataset by which CCN as well as CDNC can be computed. This approach promises a significant improvement over previous work since aerosol properties are linked to cloud properties in an observationally constrained follow-up approach rather than using metrics (e.g. aerosol optical depth for CCN) from different satellite retrievals. Here, we present the ability of this approach to compute CCN and validate the results with insitu measurements. Furthermore, we analyse CDNC sensitivities to anthropogenic aerosol perturbations. Our aim is to disentangle uncertainties in the related parts to get a better estimate of the first indirect aerosol effect.

IAMAS (Meteorology)

M06a - M06 Observations of Anthropogenic Aerosol-Cloud Interactions

IUGG-5423

Understanding the aerosol interactions with warm clouds

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Physical representations of aerosol microphysical and radiative effects on warm clouds are included in global climate models. Parameterizations are evaluated with observations at process and cloud scales. Global observations of satellite, however, show little inter-hemispheric differences in cloud optical thickness and weaker aerosol indirect effects than global model estimates. This presentation will discuss aspects of rapid adjustment of land surface and clouds to aerosol radiative effect (the semi-direct effect) as well as “clean air” aerosol properties, microphysical processes, and turbulent dynamics that may contribute to the buffering of expected anthropogenic aerosol effects on clouds.

IAMAS (Meteorology)

M06b - M06 Observations of Anthropogenic Aerosol-Cloud Interactions

IUGG-1789

Impact of activation process on fog life cycle

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Fogs are complex meteorological system dealing with fine scale processes. Subtle interaction between radiative, dynamic, turbulent and microphysic processes can lead to different life cycle, which make forecasting difficult. Water droplets are formed trough activation of aerosols particles but understanding the impact of the aerosols properties on the fog life cycle still remains a challenge. This is especially an issue for airport traffic which are generally under the influence of anthropogenic aerosols. In the frame of the PreViBOSS project, in-situ measurements of fog properties were performed during winters 2010 to 2013 at SIRTA which is an area impacted by pollution. Microphysics data supply a detailed characterization of number size spectrum from dry to wet aerosols particles and droplets and inform us on the abilities of the aerosols to act as a CCN. A set of 48 fog events have been studied. Supersaturation values and concentrations of CCN have been determined and linked to aerosols properties. This study of fog life cycle and droplets spectra evolution reveals the major physical processes and suggests that even if thermodynamic dominates the fog life cycle, aerosol trough activation process seems to have a significant effect. Large eddy simulation of fog cases are performed with the Meso-NH model to explore very precisely the interaction between aerosols and physical processes. Supersaturation modelling is a key point, a two moments scheme is used for microphysic with a new pseudo-prognostic scheme. Emphasis is put on the activation process. Aerosols sensibility tests are performed by modifying their chemistries and distributions in model input to investigate their impact on the fog life cycle. These results are compared to the detailed experimental study.

IAMAS (Meteorology)

M06b - M06 Observations of Anthropogenic Aerosol-Cloud Interactions

IUGG-2510

Aerosol-cloud interactions in ship tracks using MODIS/MISR

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Simultaneous ship track observations from Terra Moderate Resolution Imaging Spectroradiometer (MODIS) and Multi-angle Imaging SpectroRadiometer (MISR) have been compiled to investigate how ship-injected aerosols affect marine warm boundary layer clouds for different cloud types and environmental conditions. By taking advantage of the high spatial resolution multiangle observations available from MISR, we utilized the retrieved cloud albedo, cloud top height, and cloud motion vectors to examine cloud property responses in ship-polluted and nearby unpolluted clouds. The strength of the cloud albedo response to increased aerosol level is primarily dependent on cloud cell structure, dryness of the free troposphere, and boundary layer depth. Under open cell cloud structure the cloud properties are more susceptible to aerosol perturbations as compared to closed cells. Aerosol plumes caused an increase in liquid water amount (+38%), cloud top height (+13%), and cloud albedo (+49%) for open cell clouds, whereas for closed cell clouds, little change in cloud properties was observed. Further capitalizing on MISR's unique capabilities, the MISR cross-track cloud speed was used to derive cloud top divergence. Statistically averaging the results from the identified plume segments to reduce random noise, we found evidence of cloud-top divergence in the ship-polluted clouds, whereas the nearby unpolluted clouds showed cloud-top convergence, providing observational evidence of a change in local mesoscale circulation associated with enhanced aerosols. These results suggest that detailed cloud responses, classified by cloud type and environmental conditions, must be accounted for in global climate modeling studies to reduce uncertainties in calculations of aerosol indirect forcing.

IAMAS (Meteorology)

M06b - M06 Observations of Anthropogenic Aerosol-Cloud Interactions

IUGG-3641

Extensive closed-cell marine stratocumulus downwind of Europe – a large cloud radiative effect or forcing?

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Marine stratocumulus clouds cover large areas over the oceans and possess super sensitivity of their cloud radiative effect to changes in aerosol concentrations. Aerosols can cause transitions between regimes of fully cloudy closed cells and open cell. The possible role of aerosols in cloud cover has a big impact on the amount of reflected solar radiation from the clouds, thus potentially constitutes very large aerosol indirect radiative effect, which can exceed 100 Wm^{-2}.
It is hypothesized that continentally polluted clouds remain in closed cells regime for longer time from leaving continents and hence for longer distance away from land, thus occupying larger ocean areas with full cloud cover. Attributed this to anthropogenic aerosols would imply a very large negative radiative forcing with a significant climate impact. This hypothesis is confirmed by analyzing geostationary and polar-orbiting satellite observations of the microphysical and dynamical evolution of marine stratocumulus over the Atlantic Ocean together with results from a chemical transport model and in-situ observations. We will present a case study in which large area of closed cells was formed over the northeast Atlantic Ocean downwind of Europe in a continentally polluted air mass. The closed cells undergo cleansing process that was tracked along 3.5 days that resulted with a rapid transition from closed to open cells once the clouds started drizzling heavily. The mechanism leading to the eventual breakup of the clouds due to both meteorological and aerosol considerations will be explained. Our observations suggest that continents can act as huge aerosol sources and form 'continent tracks', similar to ship tracks, but at a much larger scale.

IAMAS (Meteorology)

M06b - M06 Observations of Anthropogenic Aerosol-Cloud Interactions

IUGG-3978

Development of an aerosol-cloud resolving model for studying aerosol-clould-precipitation interactions

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Accurate representation of aerosol physics and chemistry is important for robust understanding of aerosol-cloud interactions for assessing the aerosol indirect effect and also for understanding the role of aerosol-cloud droplet interaction in precipitation formation. In this study, we develop an aerosol-cloud resolving coupled model in which an explicit physics and chemistry of aerosols and the processes are represented. In particular, aerosol activation is represented as an explicit mass transfer between the ambient atmosphere and the aerosols. The aerosol mixing state, complex composition and multiple aerosol distributions are used to comprehensively incorporate the initial state of the aerosols. The activation of hydrophobic particles like black carbon and dust due to adsorption of gases is also represented. The condensation of water vapor and gases is represented as a diffusion-limited kinetic process. The model computes the different thermodynamic properties of the solution of the dissolved salts. The cloud resolving model is three dimensional and non-hydrostatic, computes the microphysics of hydrometeors using bulk mass mixing ratios and number concentrations. In this presentation, the aerosol and cloud resolving models and their physics will be described and possible test simulations will be shown. Further, the possible studies for which it can be used will also be discussed.

IAMAS (Meteorology)

M06b - M06 Observations of Anthropogenic Aerosol-Cloud Interactions

IUGG-4194

Aerosol-cloud-climate interactions from regional to global scale

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Atmospheric aerosols play an important role in regulating the radiative balance and hydrological cycle in the Earth-Atmosphere system, directly by reflecting or absorbing the incoming solar radiation and indirectly by influencing cloud formation. Recently increasing levels of anthropogenic aerosols in Asia have raised considerable concern about its potential impacts on the global atmosphere, but the magnitude of the associated climate forcing remains to be quantified. We use the cloud-resolving and global climate model simulations and satellite observation analysis to investigate the anthropogenic aerosol radiative and microphysical effects on the extreme weathers in East Asia and the regional climate with the North Pacific storm track. Moreover, the influence of the geographical shift of global anthropogenic emission sources from developed countries to Asia are investigated to illustrate the impacts of emission changes on global cloud systems, precipitation, and large-scale circulation through combining modeling and observational efforts.

IAMAS (Meteorology)

M06b - M06 Observations of Anthropogenic Aerosol-Cloud Interactions

IUGG-5091

Convective invigoration of precipitating clouds by anthropogenic aerosol

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The 'convective invigoration' hypothesis posits that aerosol affects precipitating clouds by delaying the onset of precipitation until the cloud has grown above the freezing level, making more efficient ice-phase precipitation processes available and leading to more intense precipitation than would have been produced by the same cloud in a less polluted atmosphere. In this paper, we use a combined dataset of spaceborne radar and lidar retrievals of precipitation and cloud thermodynamic phase to derive a climatology of rain occurrence from liquid-phase cloud ('warm rain') and ice-phase cloud ('cold rain'). Warm rain is found to be strongly suppressed over land compared to ocean. By calculating the change of warm-rain fraction at each grid point with a unit change in dry AOD, we show that this difference is partially explained by the higher aerosol loading of the continental atmosphere compared to the maritime atmosphere, providing observational evidence in support of the convective invigoration hypothesis. We derive the top-of-atmosphere anthropogenic radiative forcing due to this effect based on the satellite dataset and model estimates of anthropogenic AOD.

IAMAS (Meteorology)

M06p - M06 Observations of Anthropogenic Aerosol-Cloud Interactions

M06p-264

Quantifying the absorption efficiency of organic aerosol by observations

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Atmospheric aerosols change the earth's radiation balance by absorbing and scattering solar radiation. Organic aerosols (OA) absorb and scatter sunlight but the absorption has been assumed to be very little-to-none based on theoretical studies. Recently, it was found that some OAs absorb sunlight, and those were named brown carbon (BrC). BrC particles have various absorption efficiencies. The past theoretical studies used to determine the absorption efficiency of OA did not consider recent findings on various absorption efficiencies of BrC. In this study, we integrate data from a ground based aerosol network and satellite based aerosol sensors, and extract the amount of sulfate+nitrate aerosols. This observation-based estimate within the uncertainty of employed parameters is at the lower end of the simulations that vary in global average by a factor of 4. Moreover, OA single scattering albedo (SSA), an employed parameter, has to be < 0.85 to have realistic sulfate+nitrate amounts over the tropical biomass burning regions. This low OA SSA compels strongly absorbing BrC to represent a sizable fraction of OAs over the globe

IAMAS (Meteorology)

M06p - M06 Observations of Anthropogenic Aerosol-Cloud Interactions

M06p-265

Numerical modeling of thundercloud passing through an aerosol island

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It is well known that megapolises strongly influence the physical processes occurring in the thunderclouds passing over them. However, the causes of the urban effect are still insufficiently understood. There are two possible reasons that lead to this effect: the influence of heat island and the influence of urban aerosol. The possible concept of modeling a thundercloud passing through an aerosol island is proposed. The Weather Research and Forecasting model with two–moment microphysics scheme including influence of cloud concentration nuclei was used. We appied a non-standard mode for this parameterization scheme, artificially limiting the area occupied by aerosol.
Test example simulation with the Weather Research and Forecasting model have demonstrated substantial influence of aerosol on a test cell development including updraft invigoration and delay of precipitation, thereby affecting the electric field rate and lightning activity.

IAMAS (Meteorology)

M06p - M06 Observations of Anthropogenic Aerosol-Cloud Interactions

M06p-266

Impact of absorbing aerosols from forest fires on clouds and rain over Southeast Asia

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Overground fire is one of the major sources of aerosols in Southeast Asia. A set of recent data analysis (Cohen, 2014) and inverse modeling studies (Cohen and Wang, 2014) over this region, using measurements from both satellite and ground stations, have concluded that the estimated emissions of Black Carbon (BC) is strongly underestimated in this region, in large part due these fires. Additionally, the inter- and intra-annual variability of the fire sources correlate well with the extreme dry and wet phases of the TRMM precipitation fields, in both space and time, with the relationships holding both regionally and sometimes even a thousand kilometers downwind.

In this work, we explore various measurements of precipitation and clouds over this region from the remote sensing records, incorporating clouds from MODIS, MISR, and various LIDAR measurements, and precipitation from TRMM as well as ground observations where they are available. We have noticed that while the large-scale variability is dependent on the large-scale Monsoon convection and hence what is occurring with the global energy balance, that there are additional signals which are changing and are not readily explained as such.

Intercomparisons will be discussed between multiple remotely sensed and ground measurements of clouds and precipitation will be made with remotely sensed and in-situ measurements of absorbing aerosols. A particular emphasis will be made with the cloudiness and precipitation rates during both the most intense wet and dry phases of the local Monsoon. The impacts of absorbing aerosols on both the direct and semi-direct effect will be quantified, and the unknowns, including the use of exclusively non-overlapping measurements, will be made.

IAMAS (Meteorology)

M06p - M06 Observations of Anthropogenic Aerosol-Cloud Interactions

M06p-269

Observations of the first aerosol indirect effect using ground based remote sensing at JOYCE

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The first aerosol indirect effect (1st AIE), according which increasing aerosol loading leads to increased cloud droplet number concentration and decreased effective radius, is investigated based on the ground-based remote sensing observations at Jülich ObservatorY for Cloud Evolution (JOYCE) in Germany. An aerosol cloud interaction (ACI) index based on measurements from cloud radar and ceilometer is proposed to measure the magnitude of ACI. The ACI index is the linear regression slope of cloud radar observation (reflectivity factor) at 35.5 GHz and ceilometer observation (backscatter coefficient) at 1064 nm, and it is separately calculated for 10 gm^{-2} liquid water path (LWP) bins. The radar observation is logarithm of the height averaged integration of reflectivity factors (Z) from cloud base to 90 m above cloud base, and the ceilometer observation is logarithm of height averaged integration of backscatter coefficients (β) from 200 to 290 m below cloud base. Based on the relationships $Z \approx n_{cloud} * D^6_{cloud}$, and $\beta \approx n_{aerosol} * D^2_{aerosol}$, a negative ACI index is expected when increasing aerosol number concentrations ($n_{aerosol}$) lead to an increase in cloud droplet number (n_{cloud}), but a decline in droplet size (D_{cloud}). Using the ACI index to detect 1st AIE is at first implemented for one stratus cloud case, and further applied to long-term observations of shallow stratus clouds in the atmospheric boundary layer over JOYCE. The proposed ACI index could serve as a simple tool to exploit long-term observations for improving understanding of aerosol-cloud coupling.

IAMAS (Meteorology)

M06p - M06 Observations of Anthropogenic Aerosol-Cloud Interactions

M06p-270

Bimodal CCN spectra

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Desert Research Institute (DRI) airborne high-resolution CCN spectrometers show bimodality previously seen by differential mobility analyzers, DMA. Sizes at minima concentrations between modes implied cloud supersaturation, S, but this required particle hygroscopicity, which is not needed for CCN measurement. CCN bimodality is due to gas-to-particle chemical reactions, Brownian scavenging, and coalescence, which act only on activated cloud droplets. Resulting soluble material increases within the activated droplets separate size/critical S, S_c, distributions from CCN distributions within unactivated droplets. Resulting size/S_c gaps in CCN distributions after droplet evaporation (outside of clouds) have shown lower cloud S than S inferred by matching CCN spectra with cloud droplet concentrations, N_c. This S disagreement is because Hoppel minima include cloud processing effects, which are greater for larger droplets grown on lower S_c CCN. Agreement between DRI CCN spectra and DMA spectra provides continuous particle hygroscopicity. High-resolution CCN/DMA observations display greater spectral shape variability than previous DMA measurements. This indicates aerosol non-equilibria. Since chemistry makes better CCN but does not reduce CCN concentrations, lower concentrations consistently observed in bimodal than monomodal spectra indicate physical processing. Greater N_c for more bimodal than monomodal CCN spectra near cumulus clouds implies coalescence, but in polluted stratus lower N_c for more bimodal CCN indicates chemical or Brownian processing. Thus, cloud processing reduces or enhances the indirect aerosol effect. Thus, cloud processing needs as much study as CCN sources. CCN modality correlations with various cloud microphysics have revealed important cloud properties.

IAMAS (Meteorology)

M06p - M06 Observations of Anthropogenic Aerosol-Cloud Interactions

M06p-271

Adverse particulate pollution in Vietnam: quantification in regions of intensive biomass burning

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In Southeast Asia biomass burning (BB) comprises the residential burning, domestic heating and cooking, while agriculture practices is a particularly important emission source during seasons of most intensive BB in agricultural provinces. Emitted particulates interact directly and indirectly with Earth’s radiation, and subsequently affect cloudiness, regional and global climate. The biggest Vietnamese cities face severe levels of urban air pollution, with critical particulate matter (PM) concentrations significantly exceeding the air quality standards. Lack of knowledge concerning the source-dependent BB aerosols hinder environmental and health risk assessments, and prevent the development of rational abatement strategies for air quality regulation.

Development of Particulate Pollution Program in Vietnam is suggested in order to address the major combustion emissions which constitute the dangerous air pollution, especially in regions of highest population. It is aimed on advanced aerosol instrumentation and methodology for near-source field measurement campaigns and PM monitoring with the purpose of characterizing the particulate pollutants in the regions of most intensive biomass burning. A number of measurement campaigns are performed with PM measurements, including sampling and chemical speciation of adverse particulate constitutes emitted by typical Vietnamese agricultural and waste disposal activities, as well as by urban emissions such as domestic heating and cooking. Seven South East Asian Studies (7-SEAS) are performed during dry season in province Sonla. Identification of source-specific BB markers provides an advanced approach for quantitative assessment of source contributions to dangerous PM pollution.

IAMAS (Meteorology)

M07a - M07 The Relationship of Cloud Ice Properties and Processes in Observations and Models

IUGG-1602

New Continuous Flow Diffusion Chamber for Ice Nucleation and Growth Experiments

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To obtain quantitative information on the ice nucleation activity of various atmospheric aerosol species, we have built a new continuous flow diffusion chamber (CFDC) called INKA (Ice Nucleation Instrument of the KArlsruhe Institute of Technology). The CFDC design was originally developed and theoretically described by Rogers et al. (1988). The main part of the new INKA instrument consists of two vertically-oriented, concentric tubes with a total length of 150 cm. Together with particle-free, dry sheath air, the sampled aerosol particles flow through the annular space between these two cylinders. The walls of the annular space are coated with ice and can be set to a preset temperature difference in order to expose the aerosol particles in the sample flow to a well-defined temperature and relative humidity. The bottom part (about 50 cm) of the outer cylinder of INKA is separately cooled, which allows operation in two different modes: In the ice nucleation mode, the CFDC is operated with an ice nucleation and growth section, covering the upper 100 cm of its length. The bottom part is the so called droplet evaporation section, which allows the ice particles to grow on the expense of the evaporating droplets. In the ice growth mode, the full length of the cylinders is operated as a longer nucleation and growth section. Since the wall temperatures can be reduced to values as low as -80 °C, ice nucleation and growth of relevance for both mixed-phase and cirrus clouds can be investigated under well controlled temperature and humidity conditions. In this contribution, we will present the setup of INKA and show first measurements.

IAMAS (Meteorology)

M07a - M07 The Relationship of Cloud Ice Properties and Processes in Observations and Models

IUGG-1972

Preactivation of solid ice nuclei by pore condensation and freezing of supercooled water

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Almost fifty years ago, it was shown that various dust and volcanic ash particles could be preactivated to become nuclei for ice crystal growth even at a temperature as high as 270 K. Preactivation was achieved under ice subsaturated conditions without any preceding macroscopic ice growth by just temporarily cooling the particles to temperatures below 235 K. A two-step mechanism involving capillary condensation of supercooled water and subsequent homogeneous freezing was proposed to account for the particles' observed enhanced ice nucleation ability at high temperatures. Only recently, this potential mechanism has gained new attention, as it could explain the sudden increase of the ice nucleation ability of a variety of clay minerals and mineral dusts just below the homogeneous freezing temperature of supercooled water at 235 K. In this work, we reinvestigate the efficiency of the proposed preactivation mechanism by performing temperature cycling experiments with airborne particles in the AIDA aerosol and cloud chamber of the Karlsruhe Institute of Technology. As a reference, we first probe compounds with a high degree of porosity, like pure zeolithe and diatomite particles, where the efficiency of the mechanism should be highest. Our second set of experiments then includes common classes of solid ice nuclei in the atmospheric aerosol, like clay minerals, natural dust, and soot. We analyse our results in terms of the fraction of aerosol particles that are preactivated by temperature cycling below 235 K, and show up to which upper temperature their enhanced ice nucleation ability is preserved, i.e., the threshold where ice in the pores of the particles starts to melt.

IAMAS (Meteorology)

M07a - M07 The Relationship of Cloud Ice Properties and Processes in Observations and Models

IUGG-2867

Temperature matters more than time: The consecutive activation of ice nucleation sites

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This study examines the effect of time in the immersion freezing process, based on laboratory data of different substances. We focus on the immersion freezing process as it is thought to be the most important heterogeneous ice nucleation process in mixed phase clouds, which in turn are important for the formation of precipitation and in which ice influences their radiative effects.

Measurements have been performed with two different laboratory devices, LACIS (Leipzig Aerosol Cloud Interaction Simulator [1]) and BINARY (Bielefeld Ice Nucleation ARraY [2]), examining the ice nucleation behavior of ice active biological particles (Snomax) and a mineral dust (illite). Additionally, literature data are included in the study as well (illite [3] and kaolinite [4]).

It is shown that the assumption of a (Gaussian) contact angle distribution is well suited for describing the dependence of the ice nucleation process on both temperature and time, and that the time dependence of the freezing process is stronger for substances being characterized through larger mean contact angles. However, it is also shown that temperature matters more than time for the immersion freezing process, and an estimation of the deviation caused by using of a time-independent parameterization for the description of this process is presented.

[1] Hartmann et al., Atmos. Chem. Phys., 11, 2011.

[2] Budke & Koop, Atmos. Meas. Tech., in press, 2015.

[3] Broadley et al., Atmos. Chem. Phys., 12, 2012.

[4] Welti et al., Atmos. Chem. Phys., 12, 2012.

IAMAS (Meteorology)

M07a - M07 The Relationship of Cloud Ice Properties and Processes in Observations and Models

IUGG-4157

Ice nucleation studied in the laboratory, field and models: Overview of results from the INUIT project

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The formation of ice in mixed-phase clouds is studied within the German coordinated research project INUIT. The studies include a) laboratory investigations on the nature of the ice nucleation process and on the chemical, microphysical, mineralogical and biological characterization of atmospherically relevant ice nucleating particles as a function of temperature and water saturation, b) intensive field experiments, conducted to study the number concentration, variability, size, chemical composition, and sources of atmospheric ice nucleating particles, and c) modelling activities that focus on the numerical assessment of heterogeneous ice nucleation and its importance for cloud parameters. An overview of key results obtained so far is given, including comprehensive characterizations of the ice nucleating properties of the clay mineral illite NX as well as pseudomonas syringae bacteria from various laboratory studies. Results from physical and chemical characterizations of ice nucleating particles and ice crystal residuals sampled at the Jungfraujoch high alpine measurement site, as well as the implementation of laboratory and field observations in a cloud model and larger-scale models are presented.

IAMAS (Meteorology)

M07a - M07 The Relationship of Cloud Ice Properties and Processes in Observations and Models

IUGG-4830

Competition between contact and immersion freezing in the experiments with single suspended water droplets

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Freezing of supercooled cloud droplets on collision with ice nucleating particle (INP) has been considered to be the most effective heterogeneous freezing mechanism. Potentially, it could play an important role in rapid glaciation of a mixed phase cloud especially if coupled to some ice multiplication mechanism active at moderate supercooling temperatures. The necessary condition for such coupling would be, among others, the presence of efficient INPs capable of inducing ice nucleation in the supercooled drizzle droplets in the temperature range of -5°C to -20°C. However, the question, under what conditions and to what extent the contact freezing could be responsible for the onset of cloud glaciation is the subject of intensive debate.

In this contribution we present the quantitative results of contact nucleation experiments conducted with the individual supercooled water droplets suspended in an electrodynamic balance (EDB). Recently we have extended our studies to very effective INPs – particles of potassium-reach feldspar, biological particles (bacteria and residual dry particles of birch pollen washing water), and the mixtures of mineral dusts and biological material. For these INPs, however, we have found that the contact nucleation has to compete with other heterogeneous freezing mechanisms (immersion and condensation freezing) on the time scales of single droplet experiment. In this paper we explore the competition between different freezing modes under various experimental conditions. The link to ice multiplication via splintering of freezing drizzle droplets and possible atmospheric implications will be discussed as well.

IAMAS (Meteorology)

M07a - M07 The Relationship of Cloud Ice Properties and Processes in Observations and Models

IUGG-5233

Sensitivity of liquid clouds to the representation of homogeneous freezing

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Liquid water droplets in some clouds can supercool to temperatures where homogeneous ice nucleation becomes the dominant freezing mechanism. In many cloud resolving and mesoscale models it is assumed that homogeneous ice nucleation in water droplets only occurs below some threshold temperature typically set at either -38 °C or -40 °C. However, laboratory measurements of homogenous ice nucleation show that there is a finite rate of nucleation at warmer temperatures, which the thresholds do not capture. We use an idealised adiabatic parcel model with detailed microphysics and a range of updraught speeds to show that cloud properties may be sensitive to homogeneous ice nucleation at temperatures as warm as -30 °C. Thus homogeneous ice nucleation may be more important for cloud development, precipitation rates, and key cloud radiative parameters than is often assumed. Furthermore, we show that the cloud development is particularly sensitive to the temperature-dependence of the nucleation rate. In order to better constrain the parameterisation of homogeneous ice nucleation laboratory measurements are needed at both high (> -35 °C) and low (< -38 °C) temperatures

IAMAS (Meteorology)

M07b - M07 The Relationship of Cloud Ice Properties and Processes in Observations and Models

IUGG-1706

Seasonal variability of Ice Nucleating Particles over Europe

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Dust aerosols are thought to be the main contributor to atmospheric ice nucleation. While there are case studies supporting this, a climatological sense of the importance of dust to atmospheric ice nucleating particle (INP) concentrations, and it's seasonal variability over Europe is lacking. Here we use mesoscale model to estimate Saharan dust concentrations over Europe in winter and summer of 2007–2008. There are large differences in median dust concentrations between seasons, with the highest concentrations and highest variability in the lowest 4 km. Laboratory based ice nucleation parameterisations are applied to these dust number concentrations to calculate the potential INP resulting from immersion freezing and deposition nucleation on these dust particles. The potential INP concentrations generally increase with height due to decreasing temperatures in the lower and mid-troposphere and exhibit a maximum in the upper troposphere where INP concentrations decrease again with altitude due to decreasing dust concentrations. The potential INP profiles exhibit similarly large differences between seasons, with the highest concentrations in winter (median potential immersion INP concentrations up to 10^3 m^−3, median potential deposition INP concentrations at 120% relative humidity with respect to ice up to 10^5 m^−3) occurring closer to the ground for both nucleation modes. Using these results, a best-fit function is provided to estimate the potential INPs for use in limited-area models, which is representative of the normal background INP concentrations over Europe. A statistical evaluation of the results against field and laboratory measurements indicates that the INP concentrations are in close agreement with available observations from various measurement platforms.

IAMAS (Meteorology)

M07b - M07 The Relationship of Cloud Ice Properties and Processes in Observations and Models

IUGG-3122

Probabilistic framework for representation of ice crystal size distributions observed during High Ice Water Content (HIWC) campaign as gamma functions

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Cloud particle size distributions (SDs) are measured in cloud by in-situ measuring probes, and need to be parameterized for use in models. In addition to the conventional exponential Marshall-Palmer distributions, gamma distributions are also frequently used to represent SDs. Gamma distributions are characterized by intercept (N_0), slope (l) and shape (m) parameters determined from fits to SDs measured in-situ within clouds. The development of the Incomplete Gamma Fit (IGF) technique at the University of Illinois has shown that a three-dimensional volume in N_0-l-m phase space is required to represent these gamma fit parameters because all parameters that occur within the allowed tolerance of the fitting algorithm, based on the statistical uncertainty of the measured SDs, are equally realizable solutions. In this presentation, SDs measured during flight 23 of the High Altitude Ice Crystals (HAIC)/HIWC campaign are analyzed to determine how these volumes of equally realizable solutions vary with temperature, ice water content (IWC), median mass diameter and vertical velocity. Comparisons against observations and fits made in other tropical and mid-latitude clouds during past field campaigns are conducted to determine the uniqueness of the gamma functions characterizing the conditions of high IWCs and prevalent small crystals sampled during HIWC. Implications for the development of cloud parameterization schemes for remote sensing retrievals, models and associated calculations of microphysical process rates are discussed.

IAMAS (Meteorology)

M07b - M07 The Relationship of Cloud Ice Properties and Processes in Observations and Models

IUGG-3712

How important are glassy SOA ice nuclei for the formation of cirrus clouds?

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Extremely low ice numbers (i.e. 5 – 100 / L) have been observed in the tropical troposphere layer (TTL) in a variety of field campaigns. Various mechanisms have been proposed to explain these low numbers, including the effect of glassy secondary organic aerosol acting as heterogeneous ice nuclei (IN). In this study, we explored these effects using the CAM5.3 model. SOA fields were provided by an offline version of the University of Michigan-IMPACT model, which has a detailed process-based mechanism that describes aerosol microphysics and SOA formation through both gas phase and multiphase reactions. The transition criterion of SOA to glassy heterogeneous IN follows the parameterization developed by Wang et al. 2012. With this parameterization, glassy SOA IN form mainly when the temperature (T) is lower than 210K.

In the default CAM5.3 set-up in which only the fraction of Aitken mode sulfate aerosols with diameter larger than 100nm participate in ice nucleation (Liu and Penner 2005 parameterization), glassy SOA IN are barely able to alter the relationship between Ni and T. At low temperatures, ice number concentrations remain higher than the observations summarized by Kramer et al. 2009. This remains true even when pre-existing ice are included in the removal of water vapor during ice formation (Shi et al., 2014), in contrast to studies using the ECHAM model (Kuebbeler et al., 2014).

To explore differences in predicted aerosol number concentrations, we also report results when the IMPACT aerosol model is used. This model has a much higher Aitken mode sulfate particle number concentration, so that the ice number concentration is significantly reduced in the presence of a sufficient number of IN. Results will be reported at the meeting.

IAMAS (Meteorology)

M07b - M07 The Relationship of Cloud Ice Properties and Processes in Observations and Models

IUGG-3722

Progress in representing microphysical processes in a mixed-phase snow growth model

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A steady-state snow growth model (SGM) has been developed based on the microphysical growth processes of vapor deposition, aggregation and riming. Climate models use mass-dimension (m-D) and area-dimension (A-D) power laws (e.g. $m = \alpha D^{\beta}$) to formulate ice particle growth rates, however it is well known that the m-D and A-D power laws for the smallest ice particles differ considerably from the power laws for the largest particles. To overcome this problem, β and α are predicted as a function of D where the m-D expression is a 2nd-order polynomial in log-log space. By tailoring these m-D and A-D relationships to the SGM, ice particle growth rates and fall speeds are represented more accurately and realistically. The size spectra predicted by the SGM are in good agreement with observed spectra from the Colorado Airborne Mixed-Phase Cloud Study (CAMPS).

Although ice particle riming often has a minor impact on ice particle size, its impact on ice particle mass and projected area can be considerable. A new method is introduced that calculates the rimed mass fraction of an ice particle, based on both field observations (of rimed and unrimed snowfall) and theory. The treatment for riming is explicit, accounting for the dependence of collision efficiency on droplet and ice particle size using both hydrodynamic theory and experimental measurements. Snowfall rates are found to be sensitive to the median mass dimension of the cloud droplet size distribution. This analytical SGM, due to its accuracy and short execution time, may find application in climate models.

IAMAS (Meteorology)

M07b - M07 The Relationship of Cloud Ice Properties and Processes in Observations and Models

IUGG-4952

Impact of ice microphysics on the dynamics of deep convective clouds

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Deep convective clouds are usually categorized as mixed phase clouds because most of the time they consist of both liquid and solid phases of water substance. Earlier studies on the role of ice processes in deep convective process mostly focused on the impact of latent heat release or consumption on the local cloud thermodynamics that influences the updraft in the cloud. In this paper, we will show that the ice microphysics also has significant impact on the dynamics of the deep convective clouds. We have performed sensitivity studies utilizing a cloud-resolving model which show that the elimination of ice processes in such clouds will significantly reduce the life span of the convection process and the physical cause of this is ice microphysics, not thermodynamics. We will further perform sensitivity studies of individual ice processes (cloud ice, snow, and graupel/hail) again utilizing the cloud model and determine their impact on the deep convective process.

IAMAS (Meteorology)

M07c - M07 The Relationship of Cloud Ice Properties and Processes in Observations and Models

IUGG-3152

On the origin of high altitude high ice water content regions in oceanic deep convection

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This work presents a case study of a tropical convective storm sampled during 18 February 2014 conducted in the frame of HAIC/HIWC project. The outcomes of this study may shed light on the formation of high ice water content regions at high altitudes. The data were collected at three altitudes 7100(m) (-11C), 8100m (-17C) and 9100m (-24C) from the SAFIRE Falcon-20. The multi-altitude sampling allows few conclusions about the formation of microphysics in this specific MCS. First, high ice water content regions are associated with convective updraft 5-15m/s. The IWC contrast between convective cells and stratiform regions usually ranged from 1 to 3g/m^3. The horizontal extent of the convective cells and therefore HIWC regions ranged from approximately one to twenty kilometers. The ice crystals in the convective cells are mainly composed of small columns and capped columns. Low concentration of circular images in vertical updrafts at -11C along with the absence of noticeable airframe icing is indicative that glaciation of the cloud occurred at higher temperatures (0C>T>-10C). Along with the fact that ice particle habits in convective updrafts were dominated by small ice columns, it suggests that the ice particles formed at -4C to -8C due to the Hallett-Mossop ice multiplication process The analysis of the ice crystals shapes in stratiform regions showed high

occurrence of aggregates dominated by chain type aggregates. The observation of chain aggregates was reported in convective storms and it is most likely related to aggregation of ice crystal polarized in an electric field. The conceptual model of main mechanisms involved in the formation of HIWC regions at high altitude is presented.

IAMAS (Meteorology)

M07c - M07 The Relationship of Cloud Ice Properties and Processes in Observations and Models

IUGG-3507

In situ observations and simulations of rapid glaciation in tropical cumulus updrafts: Results from Ice in Clouds Experiment - Tropical

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The rapid glaciation of tropical cumulus clouds has been an enigma and debated in the literature for over 60 years. Possible mechanisms responsible for the rapid freezing have been postulated, but until now, direct evidence has been lacking. Recent high-speed photography of electro-statically suspended supercooled drops in the laboratory by Thomas Leisner (Karlsruhe Institute of Technology) has shown that freezing events produce small secondary ice particles, via fracturing and from spicules that eject bubbles.

Aircraft observations from the Ice in Clouds Experiment – Tropical, strongly suggest that the drop-freezing secondary ice production mechanism is operating in strong, tropical cumulus updrafts. The result is production of small ice particles colliding with and freezing large supercooled drops. The large drops freeze and produce more small ice, generating a cascading process that results in rapid glaciation of water drops in the updraft.

Results are presented from data collected using state-of-the-art cloud particle probes during 54 Learjet penetrations of strong cumulus updrafts in a temperature range from +5 to –20 °C. Repeated Learjet penetrations of updrafts containing 3 to 5 g m^{-3} supercooled liquid show an order of magnitude decrease in liquid mass concentration 3 to 5 min later at an elevation 1 to 1.5 km higher in the cloud.

The observations were simulated using a one-dimensional cloud model with explicit bin microphysics. The model was initialized with drop and ice particle size distributions observed prior to rapid glaciation. Simulations show that the model can explain the observed rapid glaciation by the drop-freezing secondary ice production process and subsequent 'riming': Large supercooled drops settle and collide with small ice particles.

IAMAS (Meteorology)

M07c - M07 The Relationship of Cloud Ice Properties and Processes in Observations and Models

IUGG-3842

Investigation of Ice Cloud Microphysical Properties of DCSs using Aircraft in situ Measurements during MC3E over the ARM SGP Site

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Six deep convective systems (DCSs) with a total of 5,589 5-s samples and a range of temperatures from -41 °C to 0 °C during the Midlatitude Continental Convective Clouds Experiment (MC3E) were selected to investigate the ice cloud microphysical properties of DCSs over the ARM SGP site. The ice cloud measurements of the DCS cases were made by the University of North Dakota Citation II research aircraft and the ice cloud properties were derived through the following processes. First, the instances of super-cooled liquid water in the ice dominated cloud layers of DCSs have been eliminated using multi-sensor detection, including the Rosemount icing detector, King and CDP probes, as well as 2DC and CIP images. Then the Nevzorov-measured IWCs at maximum diameter D_{max} < 4,000 µm are used as the best estimation to determine a new mass-dimensional relationship. Finally the newly derived mass-dimensional relationship (a = 0.00365, b = 2.1) has been applied to the full spectrum of particle size distributions (PSDs, 120-30,000 µm) constructed from both 2DC and HVPS measurements to calculate the best-estimated IWCs of DCSs during MC3E. The averages of the total number concentrations (N_t), median mass diameter (D_m), maximum diameter (D_{max}), and IWC from six selected cases are 0.035 cm^{-3}, 1,666 µm, 8,841 µm, and 0.45 g m^{-3}, respectively. The gamma-type-size-distributions are then generated matching the observed PSDs, and the fitted gamma parameters are compared with the observed PSDs through multi-moment assessments including first moment (D_m), third moment (IWC), and sixth moment (equivalent radar reflectivity Z_e). For application of the observed PSDs to the remote sensing community, a series of empirical relationships between fitted parameters and Z_e values has been derived.

IAMAS (Meteorology)

M07c - M07 The Relationship of Cloud Ice Properties and Processes in Observations and Models

IUGG-4995

Surface roughness of small cirrus ice particles

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The microphysical properties of ice crystals play an important role in the radiative impact of cirrus clouds. In order to compile representative parameterizations of single scattering properties of natural ice particles, detailed in situ microphysical and optical measurements are required. Up to now such detailed in situ investigations are mostly restricted to larger particles (>50 μm), mainly because of optical resolution limitations.

In recent years, satellite observations have provided indirect evidence for i) small ice particles and ii) highly distorted ice crystal structures with hollowness and surface roughness. There are a few reports on crystal distortion and hollowness observed for small ice particles in ice replicas from cirrus clouds. In case of crystal surface roughness, recent measurements of spatial light scattering patterns of individual ice particles by the Small Ice Detector 3 (SID3) indicate prevailing surface roughness or highly distorted ice crystals in mid-latitude cirrus clouds.

In this contribution cloud chamber studies on the microphysical and light scattering properties of small cirrus ice particles are discussed. The SID3 method was applied in these experiments to investigate the dependence of ice particle surface roughness or crystal distortion on the prevailing thermodynamic conditions. Clear correlations between surface roughness and ice supersaturation by temperature were observed which could be explained by different ice crystal growth rates. Changes in the angular light scattering function with crystal roughness were recorded by two polar nephelometer instruments. SID3 measurements during the MACPEX, ML-CIRRUS, and ACRIDICON-CHUVA aircraft studies are presented and discussed in the context of the results from cloud chamber measurements.

IAMAS (Meteorology)

M07c - M07 The Relationship of Cloud Ice Properties and Processes in Observations and Models

IUGG-5112

Nearly spherical ice in anvil cirrus clouds and its influence to climate

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Deep convective cloud systems are an important source of ice particles in the upper troposphere. Field measurements have shown that single frozen droplets are the dominant particle type in the upper parts of these cloud systems (e.g. Stith et al., 2013). Although frozen droplets are frequently measured, our understanding of the microphysical and optical properties of these ice particles is weak.

There is evidence (Rosenfeld and Woodley, 2000) that homogeneous freezing of droplets is an important source of ice crystals in the upper regions of deep convective systems. We simulated the homogeneous freezing process in cloud chamber studies, where we formed supercooled liquid water droplets with maximum sizes of 20 μm and in a homogeneous freezing process these liquid droplets were turned into frozen droplets with sizes ranging from 6-50 μm. The microphysical and optical properties were measured to determine the microstructure and the light scattering properties of the frozen droplets.

All of the frozen droplets developed rough surface features almost immediately upon freezing and during initial growth. When the ice particles were exposed to ice sub-saturated conditions, we detected that the rough surface features were smoothened out in the sublimation process, leaving a nearly perfectly spherical core of the frozen droplet. The sublimated frozen droplets were proved to behave as optically near spherical and the scattering properties of the quasi-spherical ice particles did not significantly differ from that of liquid water.

Additionally, we measured quasi-spherical ice particles during MACPEX and ACRIDICON aircraft studies. The results from the aircraft campaign will be presented and discussed in the context of what was learned from the chamber studies.

IAMAS (Meteorology)

M07c - M07 The Relationship of Cloud Ice Properties and Processes in Observations and Models

IUGG-5136

Use of observations and simulations to investigate primary microphysical pathways between deep convection updrafts and the stratiform melting level

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Motivated to improve aircraft safety and climate projections, respectively, the High Ice Water Content/High Altitude Ice Crystals (HIWC/HAIC) and Mid-Latitude Continental Convective Cloud Experiment (MC3E) field campaigns gathered unique measurements to study the microphysical pathways that drive the evolution of ice mass size distributions from updraft outflow to heavy stratiform rain. Here we examine data obtained on 18 February 2014 near Darwin during the HIWC/HAIC campaign, and on 20 May 2011 over Oklahoma during the MC3E campaign. In both cases, outflow mass size distributions aloft are commonly dominated by particles that are several hundred micrometers in maximum dimension. We use a combination of observational analysis and model simulations with size-resolved microphysics to investigate the modal properties of ice mass size distributions as a function of height, proximity to updraft cores, and near-surface precipitation rate.

IAMAS (Meteorology)

M07d - M07 The Relationship of Cloud Ice Properties and Processes in Observations and Models

IUGG-1729

The importance of Secondary Ice Processes in Layer and Convective clouds

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Secondary ice plays a major role in precipitation production in supercooled clouds but the processes responsible for it are generally poorly treated in large scale models. It is established that the Hallett-Mossop (HM) process plays an important role in the glaciation of supercooled convective clouds in the temperature range -3C to -8C. Recent work has shown that the process can also be important in deep frontal layer clouds and some stratocumulus clouds. It has been proposed that secondary ice produced (SIP) by the fragmentation of snow crystals and the freezing of supercooled water drops can be significant sources of secondary ice. Here we present recent field data from a range of cloud types examining the role of SIP in these clouds. Cloud types investigated include: Shallow layer clouds in the Arctic in spring and summer; Deep frontal clouds; Deep convective clouds; Shallow layer clouds in cold Arctic air outbreaks. It is shown that a number of factors control the effectiveness of the secondary ice processes in these clouds. The observations are compared to a detailed cloud process model. Splinter concentrations of around $100L^{-1}$ were observed in frontal clouds, where riming sites were likely provided by snow. This is in contrast to much higher concentrations of secondary ice associated with graupel production in deep convective clouds. It is found that when the splinter production rate is large, super cooled water drops greater than 50 um in diameter are often observed. In some circumstances a lack of primary ice nuclei markedly inhibits the process. It is found that drop fragmentation or shattering of ice particles may slightly enhance the ice crystal concentration outside the Hallett-Mossop zone and in the absence HM maybe important in developing the ice phase

IAMAS (Meteorology)

M07d - M07 The Relationship of Cloud Ice Properties and Processes in Observations and Models

IUGG-1735

The Origin of Ice at High-Alpine site Jungfraujoch

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Cloud microphysics measurements conducted as part of the Ice Nucleation Process Investigation and Quantification (INUPIAQ) project together with the Cloud Aerosol Characterisation Experiments (CLACE) were made during winter months of 2013 and 2014 at Jungfraujoch, Switzerland. Utilising high-resolution data from a Cloud Droplet Probe (CDP) and a 3-View Cloud Particle Imager (3V-CPI) we observed several hundred cloud events during this time in which liquid, mixed phase and glaciated conditions were present with evidence of transitions between each phase on temporal scales spanning seconds to hours. Ice number concentrations during some of these events were in excess of 1000 L^{-1}. Using measurements of the aerosol size distribution during the 2014 campaign we are unable to explain these through primary ice nucleation using existing parameterisations. As the clouds lie outside of a known temperature zone, between -3°C and -8°C, where secondary ice production can enhance concentrations through rime splintering, we conclude that the snow covered surfaces around the measurement site are the source of production of high concentrations of small ice crystals that have been measured in clouds close to the surface at this site. We consider several mechanisms including: blowing snow; seeding of clouds with pre-activated aerosol; surface based rime splintering and fracture of fragile vapour grown ice deposits on the surface that may explain our observations. The data strongly suggest that blowing snow is only a minor contributor with another surface based secondary ice particle mechanism dominating. We also consider the implications of this source of ice particles for precipitation production in mountain clouds.

IAMAS (Meteorology)

M07d - M07 The Relationship of Cloud Ice Properties and Processes in Observations and Models

IUGG-2559

Sensitivity study of microphysical properties of cirrus in combination to natural aerosol on synthetic SEVIRI observation

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The by Meteosat SEVIRI-observed infrared radiances are used to identify cirrus as well as natural aerosol for studying the evaluation of the spatiotemporal distributions. Quantification of the cirrus and aerosol properties from satellite measurements is particular important for understanding the interaction of the two phenomena/parameter cirrus and aerosol. This study examines the information content inferred from synthetic infrared radiances by SEVIRI for the microphysical properties of ice cloud versus natural aerosol. Our foci are to i) Identify the ambiguity of the SERVIRI observation with respect to ice clouds and natural aerosol, and to ii) Determine the information content dedicated to the microphysical properties of ice cloud and natural aerosol. This is addressed by using the forward model RTTOV and the regional-scale model COSMO-MUSCAT. First, we simulated synthetic satellite observation to elaborate the information content with respect to the microphysical properties. As test bed we used the COSMO-MUSCAT simulations for the CHARMEX ('Chemistry Aerosol Mediterranean Experiment') field experiment in June and July 2013, which include a dust event with spatially close ice cloud formations. Defined by the motivation of examining both microphysical and aerosol properties, we combined the input parameter for the forward operator RTTOV as following: only natural aerosol, only ice cloud and both as well as for different ice and dust parametrisation. Eventually, these permutations built the basis for the information content study reflecting common atmospheric conditions. In this way, uncertainties are quantified for different parametrisation with respect to macrophysical properties like ice water content as well as the atmospheric profiles.

IAMAS (Meteorology)

M07d - M07 The Relationship of Cloud Ice Properties and Processes in Observations and Models

IUGG-3323

"Supercooled water droplets observed in an upper part of a precipitation cell over the western tropical Pacific Ocean"

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To clarify the microphysical structure in mecoscale convective systems (MCSs) over the tropical ocean, we conducted an intensive field observation in Republic of Palau in June 2013 using an X-band polarimetric radar and hydrometeor videosondes (HYVISs). This study shows an observation result of supercooled water droplets (SCDs) in the upper part of a precipitation cell passed over the observation region on June 26, 2013.
A HYVIS can capture images of cloud and precipitation particles whose resolution is 1.875 micrometer and size is greater than 13 micrometer. We identify their shape, size, and number concentration, thus their particle size distributions with high vertical resolution.
A HYVIS was launched at 1013 LST on June 26 into a MCS. The HYVIS is expected to intrude into a precipitation cell above a height of 9 km by its tracking of the GPS sounding and the time series of radar data. Echo-top heights defined by 10 (30) dBZe reach 10 (8) km and the existence of graupel is confirmed in the convective core below a height of 8 km by a hydrometeor classification.
In the upper part of the precipitation cell, total 82 SCDs are detected between heights of 9 km and 11 km (-38 degree Celsius). The median diameter of SCDs is 40 micrometer and their number concentration is an order of 10^4 /m^3. The diameter (number concentration) of SCDs observed in this study is greater (quite lesser of order of 3-4) than that observed over the continental region (Rosenfeld and Woodley 2000). Almost same size of frozen drops are simultaneously observed in the area. This result should be useful for understanding on the ice nucleation process in a precipitation cell.

IAMAS (Meteorology)

M07d - M07 The Relationship of Cloud Ice Properties and Processes in Observations and Models

IUGG-5656

Investigating oriented ice and correlations with precipitation in mid latitude marine clouds using collocated CALIOP, CloudSat, and MODIS

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This presentation explores a recent finding by our team that a significant fraction (up to 20%) of mid/high-latitude ocean low to middle level clouds (cloud tops less than 5 km) are composed of oriented ice crystals as determined by the CALIOP V3 phase retrieval. The discovery of ice in these relatively warm (250- 270K) clouds is surprising and may have significant implications for our understanding of the processes that control clouds and precipitation in the high-latitude ocean regions. **Preliminary results suggest that clouds with the oriented ice signature have a much higher probably of precipitation compared water clouds with a distinct seasonal dependence in the northern hemisphere.** This finding likely has important implications for understating the processes that control cloud lifecycle and precipitation in these regions. It suggests that for many mid-latitude marine cloud systems the mechanisms controlling cloud formation and precipitation maybe more closely associated with high latitude processes where ice nucleation dominates cloud lifecycle and precipitation.

IAMAS (Meteorology)

M07e - M07 The Relationship of Cloud Ice Properties and Processes in Observations and Models

IUGG-0351

A study of the importance of the parameterization of heterogeneous ice nucleation for the modelling of a convective cloud

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The 1.5D bin-resolved microphysics model DESCAM was used to assess the role of the parameterizarion of different ice initiation processes in clouds. Homogeneous nucleation, deposition freezing, contact freezing, immersion freezing and condensation freezing were treated explicitly and their impact alone and in competition with each other on cloud microphysics and precipitation were studied. Several sensitivity studies were performe.
For the conditions studied, it was found that the way deposition and contact freezing are generally parameterized in models, they only played a negligible role with respect to the other ice nucleating mechanisms. Homogeneous freezing and immersion freezing were found to have similar impact, as the used parameterizations are based on similar physical concepts. Both freezing rates increase with increasing drop size (volume or surface) and with respect to drop impurities. This suggests a possibility for regrouping the processes in future parameterized cloud models. Condensation freezing, however, acts at much warmer temperatures in clouds and for much smaller drops. The associated release of latent heat caused significantly different cloud dynamics with respect to homogeneous/immersion freezing. The addition of large quantities of very IN active bacteria could, thus, be able to significantly modify precipitation.
This suggests that even though the thermodynamics principles of germ formation and evolution are the same in each heterogeneous ice nucleation process, the respective mechanical conditions and latent heat releases are sufficiently different, that the way they are parameterized for cloud models is of essential importance.

IAMAS (Meteorology)

M07e - M07 The Relationship of Cloud Ice Properties and Processes in Observations and Models

IUGG-0384

Laboratory measurements of falling velocity of individual ice columns

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Model studies of Earth´s climate typically represent ice particle fall velocities with theoretically derived power-law formulations. However, there is a significant lack of experimental data covering fall velocities of ice particles with maximum dimension less than 100 um. Therefore, the model studies may suffer from non-negligible error due to reliance on extrapolation of the representative equations for the smallest ice crystals.

In the current work we directly determined the ice particle geometry, fall orientation and velocity of laboratory grown ice columns that form at temperatures ranging from -5 °C to - 10°C. The experimental apparatus consisted of an ice growth chamber for preparation of the ice crystals and a vertically oriented settling tube through which the ice crystals attain terminal velocity while being illuminated and recorded with a high-speed video camera.

The fall velocities of pristine columns were determined as a function of the length (L) and width (W) of the columns. The measurements were performed for ice columns with L<150 um and W<40 um. A fitting function which depends on the capacity of the ice column is proposed to parameterize the fall velocities obtained in the present work.

The fall orientation was characterized by the angle formed between the direction of fall and the direction of the major axes of the column. The observations do not show any preferential fall orientation of the columns. Besides, no drifts were observed from the vertical during fall.

IAMAS (Meteorology)

M07e - M07 The Relationship of Cloud Ice Properties and Processes in Observations and Models

IUGG-0489

A laboratory study of warm cloud droplet coalescence in an acoustic wave field

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The coalescence of cloud droplets is one of the significant mechanisms for the formation of raindrops in clouds. Given the importance of weather modification, one way to do so could be by use of acoustic waves for the coalescence of cloud droplets that would make small droplet merge and, thus, form rain drops.

The purpose of this research is to investigate, experimentally, the effects of standing acoustic waves on the coalescence of warm cloud droplets in a vertical cloud chamber, acting as sound tube with inner diameter of 6 cm and length of 160 cm. In this study, the effects of frequency, sound pressure level, and duration of the applied acoustic waves on the coalescence of warm cloud droplets were investigated.

Experimental results show that the acoustic waves have high efficiency in the warm cloud droplet coalescence and precipitation enhancement. When the acoustic waves are applied with appropriate frequency and intensity, the cloud droplets' diameter becomes more than ten times larger than that of their initial values and acoustic precipitation starts quickly. Typical time scale of this process could be less than one second. Acoustic precipitation is sensitive to sound level pressure, acoustic wave frequency, and its duration as well as concentration and size distribution of droplets. For the droplet coalescence of 15 micron diameter, the optimal frequency of 622 Hz was obtained in experimental conditions. The acoustic precipitation efficiency can reach 90 percent under the best conditions (optimal frequency and time duration and maximum of sound pressure level).

IAMAS (Meteorology)

M07e - M07 The Relationship of Cloud Ice Properties and Processes in Observations and Models

IUGG-3532

The characteristics of atmospheric ice nuclei in different regions in China

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The concentrations of ice nuclei (IN) in different regions in China, including a relatively polluted urban site, a relative clean remote mountainous site, and a desert meteorological station in northwest China, were measured and analyzed by using a newly builtstatic vacuum water vapor diffusion chamber.This presentation will show how the concentrations of IN vary with temperature, supersaturation, and the relationship with the concentration and size distribution of aerosol particles under different background conditions. Parametrization schemes will be proposed to calculate IN concentration based on temperature, supersaturation, and the concentration of aerosol particles, and will be compared with those obtained in other regions in the world.

IAMAS (Meteorology)

M07p - M07 The Relationship of Cloud Ice Properties and Processes in Observations and Models

M07p-167

Relation between natural deposition ice nuclei concentration and precipitation at an urban site

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Ice nucleation in the atmosphere is of practical and fundamental importance since ice crystals influence the release of snow, rain and hail. Some aerosols serve to nucleate ice in clouds. They are called ice nuclei (IN) and they are generally solid particles, insoluble in water. Temperature (T) and the supersaturation ratio with respect to ice (SS) are the two main parameters which determine ice nucleation.

In this work we use an experimental device designed to measure the concentration of natural deposition ice nuclei under controlled T and SS [1]. Ice nuclei concentrations were measured in a cloud chamber placed in a cold room.

The measurements were performed in an urban site at Cordoba City during a time period between July and December 2014, at a temperature around -25 C and SS around 15%. It was observed that IN concentrations were enhanced during rain events, with concentrations increasing by a factor of 10 or even more during rain in good agreement with results previously reported by other authors [2].

The results show that variations in the number of deposition ice nuclei are correlated with changes in the relative humidity (RH) of the air injected into the cloud chamber used in the experiments. A fitting function which depends on RH is proposed to parameterize the results obtained in the present work.

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IAMAS (Meteorology)

M07p - M07 The Relationship of Cloud Ice Properties and Processes in Observations and Models

M07p-168

An experimental study of the role of surfactant materials on warm cloud formation in laboratory

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The physical and chemical characteristics of the aerosols that act as cloud condensation nuclei are important in the way droplets form and grow in clouds, hence they can affect the climate indirectly. Surfactant materials usually help cloud formation by lowering water surface tension force.

In this study different surfactants solute in water were used to produce cloud condensation nuclei in a chamber to create warm cloud in the laboratory. In this experimental research, Cloud lifetime and its opacity was measured by a laser device. Some 12 surfactants were tested (twice each) with three different concentrations. Among them, acetaldehyde and acetic acid showed significant variations with different trends. The same experiments were performed for these two materials with five different concentrations (0.25, 0.50, 0.75, 1.00, 1.25 ppm) and the base state (with distilled water only) with 4 repetitions.

The results showed that with increasing surfactant materials concentration in water, the rate of droplet formation augments until a certain level depending on material. The maximum cloud opacity was acquired in for 0.5 ppm of acetaldehyde and 1.25 ppm of acetic acid. Acetic acid had the strongest effect on droplet formation. As a result, its cloud lifetime also reduced due to faster growth of droplets. For acetaldehyde, minimum cloud lifetime occurred for the first concentration, lower than the base state while acetic acid had increasing trend until the fourth concentration and after that it was reduced.

IAMAS (Meteorology)

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M07p-169

Comparative study of ice nucleating efficiency of K-feldspar in immersion, deposition and contact freezing modes

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Understanding the impact of ice nucleating aerosols on the life cycle of atmospheric clouds and their radiative properties is of crucial importance for the comprehension of Earth's climate evolution. K-feldspar was recently identified as one of the most active atmospheric ice nucleating particles (INP) of mineral origin. Seeking the explanation of this phenomena we have conducted extensive experimental investigation of the ice nucleating efficiency of K-feldspar in three heterogeneous freezing modes. This study is focused on the experimental characterization of ice forming activity of K-feldspar particles in immersion and deposition mode conducted with humidity-controlled cold stage. This newly build setup allows for simultaneous observation of up to 2000 individual nanoliter droplets containing suspension of mineral dust particles, as they follow a complex trajectory on the phase diagram: from liquid droplets via supercooling and immersion freezing, followed by melting or sublimation of ice to the dry residual and subsequent condensation of deposition nucleation of ice. Our results are combined with in-situ observations of deposition nucleation of ice on the crystalline surfaces of macroscopic feldspar particles in Environmental Scanning Electron Microscope (ESEM). We also show the very recent results on freezing efficiency of various feldspars in contact mode, obtained with electrodynamically levitated droplets of supercooled water. Based on the experimental results, we discuss the influence of the surface chemistry and morphology of feldspar onto its ability to nucleate ice at moderate supercooling.

IAMAS (Meteorology)

M07p - M07 The Relationship of Cloud Ice Properties and Processes in Observations and Models

M07p-170

Immersion freezing experiments using PM10 filter samples from Cape Verde

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Selected PM_{10} filter samples collected at the Cape Verde atmospheric observatory (CVAO; 16,848°N, 24.871°W) are re-used to investigate the seasonal trends in ice nuclei number concentration at CVAO. The samples are collected on a tower 30m above the sea surface, representing the subtropical marine boundary layer. Besides marine sources, aerosol transported from the Saharan desert, the Sahel zone and SW Europe contribute to the PM_{10} particle composition at CVAO (Fomba et al., 2014). Using the drop freezing technique described in Conen et al., 2012 the concentration of ice active nuclei above 258K, typical for rare, biological particles, is determined. Multiple, small samples are cut out of each PM_{10} filter, immersed in a droplet and subject to temperatures down to 258K, allowing ice formation by immersion freezing. The measured number concentration of active ice nuclei per volume of atmospheric sample air can be calculated and attributed to the different source regions by back trajectories. Using this information, the geographic sources of ice nucleating aerosol active in slightly supercooled clouds can be evaluated.

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IAMAS (Meteorology)

M07p - M07 The Relationship of Cloud Ice Properties and Processes in Observations and Models

M07p-171

"Real case study" simulations of aerosol-cloud interactions for the INUIT campaign at Jungfraujoch research station using different ice nucleation parameterizations

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Ice crystal formation affects cloud radiative properties and may initiate or enhance precipitation. Mixed-phase clouds are composed of both super-cooled liquid droplets and ice crystals. Ice crystal formation within mixed-phase clouds requires the presence of an ice nucleating particle (INP) as a seed. A large variety of different aerosol particles can act as an INP and initiate the ice-phase in atmospheric clouds, but there are still open questions regarding the concentration, variability and micro-physical properties of atmospheric INPs.

In recent years parameterizations of ice nucleation have been developed and improved in order to calculate the abundance and variability of INP number concentration not only as a function of temperature and humidity, but also as a function of aerosol properties. A number of different state-of-the-art ice nucleation parameterizations have been included in the comprehensive model-system COSMO-ART. It is set up and run as a full 3D model with realistic orography and initial boundary conditions from operational analysis for a selected episode during a field campaign at the High Alpine Research Station Jungfraujoch, Switzerland, during which mixed-phase clouds were observed. Extensive measurements of aerosol and ice particle properties were conducted during the field campaign. The measured total aerosol number size distribution and composition serve as an input to the physics scheme in COSMO-ART.

This contribution will present the results of simulations with different ice nucleation parameterizations and the comparison to measurements during the Ice Nuclei research UnIT (INUIT) joint field campaign in January/February 2013.

IAMAS (Meteorology)

M07p - M07 The Relationship of Cloud Ice Properties and Processes in Observations and Models

M07p-172

Millimeter cloud radar observations of mixed-phase clouds – The Doppler spectra story of a riming case study observed in Finland

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Cloud radar Doppler spectra offer a wealth of information about cloud processes. By looking at the evolution of the radar Doppler spectra from cloud-top to cloud-base in a liquid-topped mixed-phase cloud through which ice and snow from an upper level cloud are falling, we try to tell the microphysical evolution story of the hydrometeor populations that are present by disentangling the contributions of the solid and liquid particles to the total radar returns. Instead of considering vertical profiles, dynamical effects are taken into account by following the particle population evolution along slanted tracks which are caused by horizontal advection of the cloud. In the super-cooled liquid layer at the top of the mixed-phase cloud, the identified liquid droplets are used as air motion tracer to correct the Doppler spectrum for vertical air motion. The methodology is demonstrated using vertically pointing cloud Doppler radar measurements from the deployment of the Department of Energy (DOE) Atmospheric Radiation Measurement Program's (ARM) mobile site AMF2 during the BAECC (Biogenic Aerosols – Effects on Clouds and Climate Snowfall Experiment) in Finland 2014. For the Feb 21, 2014 case study, the liquid water path conditions were favorable for riming to occur on the ice particles from the upper level cloud falling through the supercooled liquid layer. Besides an overview of the profiles of radar moments of the different hydrometeor populations, we will show first results of model simulations including riming using a 1D microphysical bin model. The final goal of this study is to constrain microphysical parameterizations about riming rates.

IAMAS (Meteorology)

M07p - M07 The Relationship of Cloud Ice Properties and Processes in Observations and Models

M07p-174

Ice nucleation by cellulose and its potential contribution to ice formation in clouds

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Only a minor fraction of the atmospheric aerosol acts as ice nucleating particles (INPs) to induce the freezing of supercooled droplets in tropospheric clouds, a process which often initiates the formation of precipitation after a cascade of secondary processes. By that, INPs can have a strong impact on clouds, precipitation and climate. Biological particles contribute to the diverse spectrum of ice-nucleating particles, but only little is known about their atmospheric abundance and ice nucleation efficiency. Consequently, their representation in atmospheric models is still limited and their role in clouds and the climate system is poorly constrained. Cellulose, the major plant structural polymer, has to date been overlooked as a potential biological ice-nucleating particle, even though studies show that airborne cellulose is prevalent throughout the year even at remote and elevated locations. We used a cloud simulation chamber to demonstrate that microcrystalline and fibrous cellulose particles can act as efficient ice-nucleating particles in simulated supercooled clouds. Applying the surface-based ice nucleation parameterization to observed atmospheric cellulose and plant debris concentrations and comparing the results to concentrations of mineral dust ice-nucleating particles from a global aerosol model, we observed that ice nucleation by cellulose became significant (>0.1 L-1) below about -21 ˚C. In this contribution we will summarize the ice nucleation and modelling results and discuss atmospheric implications.

IAMAS (Meteorology)

M08a - M08/M09 Comparative Planetary Atmospheres within and beyond the Solar System / Solar System Exploration of Atmospheres with Ground-Based and Space-Based Platforms

IUGG-1435

Comparative origin of the Gas Giant Planets and their volatiles

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Models of the origin of the largest planets, Jupiter and Saturn, are key to understanding the formation of the solar system, and by extension, the extrasolar systems. The core accretion model is widely accepted as the preferred scenario for the formation of the giant planets and their atmospheres, with evidence coming from the abundances of the heavy elements (mass $>^{4}He$) in Jupiter determined by the Galileo probe, Cassini spacecraft at Saturn, and ground-based telescopes. In the past two decades, the extrasolar giant planets have also been providing evidence that favors core accretion. The atmospheres of the gas giants evolved from the release of volatiles in the core during accretional heating and the capture of the most volatile gases from the protoplanetary nebula in the last stages of planetary formation. In this talk I will discuss the models, key observational constraints, missing pieces of the puzzle such as the oxygen abundance in Jupiter and the noble gases in Saturn, and provide ideas on how to close the gap between what is already known and what must be known in order to fully constrain the models of the origin and evolution of the gas giant planets and their atmospheres.

IAMAS (Meteorology)

M08a - M08/M09 Comparative Planetary Atmospheres within and beyond the Solar System / Solar System Exploration of Atmospheres with Ground-Based and Space-Based Platforms

IUGG-2232

Simulation of Jupiter's stratosphere: new radiation code and impacts on the dynamics

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We have developed a new radiation code of radiative heating and cooling for Jupiter's upper troposphere and stratosphere (10^3 to 10^{-3} hPa) suitable for general circulation models (GCMs). It is based on the correlated k-distribution approach, and accounts for all the major radiative mechanisms in the Jovian atmosphere. The code can be applied for Saturn and extrasolar gas giants. Vertical 1-D calculations using this code demonstrated that temperature of Jupiter's stratosphere is close to radiative-convective equilibrium, and that the radiative relaxation time decreases exponentially with height (from 10^8 s near the tropopause to 10^5 s in the upper stratosphere). The latter differs from the study of Conrath et al. (1990), which showed the very long (~10^8 s) relaxation time approximately constant throughout the stratosphere. Our calculations with the GCM show that the radiative relaxation time suggested by Conrath et al. (1990) is too long, and cannot sustain convergence of model solutions. With the newly derived vertical profile of relaxation time, simulations converge and produce realistic temperature and wind in Jovian stratosphere.

IAMAS (Meteorology)

M08a - M08/M09 Comparative Planetary Atmospheres within and beyond the Solar System / Solar System Exploration of Atmospheres with Ground-Based and Space-Based Platforms

IUGG-2338

Superrotation in Held & Suarez-like flows with weak surface temperature gradient

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Using a global general circulation model which solves the dry primitive equations, we investigate the generation of equatorial superrotation in Earth-like planetary atmospheres under zonally-symmetric thermal forcing. In the classic Held and Suarez (1994) setup, which normally does not exhibit equatorial superrotation, a robust transition to superrotation occurs when the equator-to-pole surface equilibrium temperature gradient is weakened. Such a reduced temperature gradient setup can be relevant to Earth-like exoplanets or past and future climates of the Earth. Two factors contribute to the transition in this situation: 1) reduction of equator-ward propagating mid-latitiude Rossby waves that break in the tropics and decelerate the equatorial flow and 2) presence of barotropic instability in the equatorial region that provides stirring to accelerate the equatorial flow. The instability also excites Kelvin waves important for generation and maintenance of superrotation. In addition, we find that superrotation can be artificially enhanced in under-resolved and/or over-dissipated simulations. By achieving numerical convergence, we quantify the roles of the Kelvin waves and the diffusion on superrotation.

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M08a - M08/M09 Comparative Planetary Atmospheres within and beyond the Solar System / Solar System Exploration of Atmospheres with Ground-Based and Space-Based Platforms

IUGG-2942

Saturn’s seasonal atmosphere from solstice to solstice

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Cassini's decade-long exploration of the Saturnian system has provided an unprecedented opportunity to characterise and understand the influence of seasons on giant planet atmospheric phenomena. Saturn's 26.7-degree axial tilt and multi-decade orbit subject the atmosphere to slow seasonal shifts in sunlight, with the poles spending up to fifteen years in the darkness of polar winter. Hemispheric asymmetries in atmospheric temperature, gaseous composition and aerosol properties were identified early in the mission, shortly after the southern summer solstice (2002) and Saturn's orbital perihelion. These asymmetries have evolved with time through the northern spring equinox (2009) as we approach northern summer solstice (2017) and orbital aphelion (e.g., the warming northern hemisphere, variable polar vortices, thickening of spring hemisphere aerosol opacity, shifts in stratospheric hydrocarbon distributions), yielding a greater understanding of the processes shaping and perturbing the mean atmospheric state. On more regional scales, processes such as equatorial overturning (Hadley circulations), vertical and horizontal wave activity, storm eruptions and the variable polar circulations modify the smooth distributions of these atmospheric properties. This presentation will utilise Cassini infrared remote sensing to assess the timescales for temperature, cloud and compositional change on Saturn, relating these to the predictions of radiative climate and photochemical models. We focus on unusual circulation systems revealed at the equator and poles from a decade of Cassini Composite Infrared Spectrometer (CIRS) observations.

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M08a - M08/M09 Comparative Planetary Atmospheres within and beyond the Solar System / Solar System Exploration of Atmospheres with Ground-Based and Space-Based Platforms

IUGG-3731

Inferring the depth of the atmospheric circulation on Jupiter and Saturn through gravity measurements by Juno and Cassini

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In approximately one year Juno and Cassini will both perform close flybys of Jupiter and Saturn respectively,obtaining a high precision gravity spectrum for these planets. This data can be used to estimate the depth of the observed flows on these planets. Here we use a hierarchy of dynamical models in order to relate the three-dimensional flow to perturbations of the density field, and therefore to the gravity field. The models are set up to allow either zonal flow only, or a full horizontal flow in both zonal and meridional directions based on the observed cloud-level winds. In addition, dynamical perturbations resulting from the the non-spherical shape of the planets are accounted for.In order to invert the gravity field to be measured by Juno and Cassini into the 3D circulation, an adjoint model is constructed for the dynamical model, thus allowing backward integration of the dynamical model. This tool can be used for examination of various scenarios, including cases in which the depth of the winds depend on latitudinal position.

We show that given the expected sensitivities of Juno and Cassini, it is possible to use the gravity measurements to derive the depth of the winds, both on Jupiter and Saturn. This hold for a large range of zonal wind possible penetration depths, from 100km to 10000km, and for winds depth that vary with latitude. This method proves to be useful also when Incorporating the full horizontal flow, and thus taking into account gravity perturbations that vary with longitude. We show that our adjoint based inversion method allows not only to estimate the depth of the circulation, but allows via iterations with the spacecraft trajectory estimation model to improve the inferred gravity field.

IAMAS (Meteorology)

M08a - M08/M09 Comparative Planetary Atmospheres within and beyond the Solar System / Solar System Exploration of Atmospheres with Ground-Based and Space-Based Platforms

IUGG-5336

Possible solar effects on cloud cover at low and high altitudes: Sun versus solar wind

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The effect of solar variability on terrestrial climate is largely unknown, despite increasing research efforts. There is no clear assessment of the existence of solar effects on cloud cover. Studies showing correlations at long-term scale are contradicted by opposing opinions stating that correlations might be random or they are affected by artefacts. Cloud cover is not accurately shown in General Circulation Models due to the fact that continuous, long-term observations of cloud cover are missing. We present a review of results showing solar fingerprints identified in high and low cloud cover data, both retrieved by satellite instruments. Comparison with long term reanalysis data is also shown, which might indicate whether observation and reanalysis data show similar fingerprints. This might also help in identifying possible mechanism of energy transfer from Sun to clouds. High clouds seem to be affected by solar variability via sea surface temperature, while low clouds might be affected by solar UV, cosmic rays or, as we lately have shown, interplanetary electric field variations. We show results identifying area where the correlation is coherent and supported by valid mechanisms. Possible mechanisms connecting various solar proxies as solar radiation, cosmic rays, solar wind fields with clouds are briefly presented.

IAMAS (Meteorology)

M08b - M08/M09 Comparative Planetary Atmospheres within and beyond the Solar System / Solar System Exploration of Atmospheres with Ground-Based and Space-Based Platforms

IUGG-0329

Utilization of satellite data as a tool for assistance in decision making of cloud seeding operations

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Investigation of the physical and microphysical properties of clouds helps the implementation of cloud seeding at the appropriate time and location. A MODIS high resolution sensor with 36 spectral channels and sensors installed for cloud studies will enable researchers to indentify different types of cloud and cloud properties.

The purpose of the present research; is to utilize the products of the level two of MODIS sensor (MODIS6) for determination of physical and microphysical properties of cloud. The study was conducted for rainfall events of February 2009 in the Fars province of Iran. In this month, the highest monthly seeding flights in 2009, 13 cloud seeding flights in 8 days, were applied. It should be mentioned that this area did not have weather radar data and satellite data was not used prior to cloud seeding.

This study reveals that if MODIS6 products of satellite were used before the implementation of former mentioned cloud seeding operation, the number of days of cloud seeding operations could be reduced from 8 to 3. This means that the weather conditions for cloud seeding were not suitable for 5 of the 8 mentioned days, so that seeding flight were not necessary for those days. The study showed that if satellite data was to be combined with other data, the accuracy of cloud seeding operations will increase. Meanwhile the operations costs will decrease promising well progress for cloud seeding operations in the country.

IAMAS (Meteorology)

M08b - M08/M09 Comparative Planetary Atmospheres within and beyond the Solar System / Solar System Exploration of Atmospheres with Ground-Based and Space-Based Platforms

IUGG-0633

Exploring the atmospheric composition over Pakistan during last decade and the changing climate

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According to reports from Pakistan Meteorological Department (PMD, 2010) and Global Climate Risk Index (GW, 2012), Pakistan is among the top ten countries most affected by extreme weather events from 1991 to 2010. Additionally Pakistan is a resource constraints country with extra stress on its economy due to geopolitical activities in the region (e.g. war against terror, extremism, internally displaced people and Afghan refugee etc.). Hence, it is strongly needed to implement efficient but cost effective strategies in order to cope with impacts of climate change. A newly established research group (C-CARGO) aimed to analyze the evolution of different greenhouse gases and chemically active trace gases during the time period of 2002 - 2012. This will help to identify the distributions of sources within and/or outside Pakistan. Efforts are made to track the spatial and temporal changes in atmospheric gas concentrations over Pakistan. Analyses exhibit a temporal increase of about 60 and 70 percent in NO_2 and SO_2 columns while HCHO did not exhibit any temporal increase. Analyses of surface temperature, CO_2 and CH_4 exhibited increasing trends over Pakistan during the selected time period. Seasonal cycles of these trace gas are identified over all regions. Further focus is made on the comparison of satellite-born and ground-based measurements. Although the validation of tropospheric trace gas products from satellite observations is a challenging task for several reasons e.g. vertical sensitivity of satellite instruments, spatial extent of the satellite ground pixel, cloud coverage etc. The efforts are made to validate satellite data from SCIAMACHY, OMI and GOME-2 by using mini MAX-DOAS observations at fixed locations and at a moving platform.

IAMAS (Meteorology)

M08b - M08/M09 Comparative Planetary Atmospheres within and beyond the Solar System / Solar System Exploration of Atmospheres with Ground-Based and Space-Based Platforms

IUGG-0986

Titan's chemical composition evolution with time from the Cassini mission

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Up until mid 2012, Titan's Northern atmosphere exhibited the enriched chemical compounds found at the time of Northern Spring Equinox (NSE) since the Voyager days (November 1980), with a peak around the NSE in 2009 [1,2]. Since then, a reversal in the abundances of some species from north to south has been observed with the appearance for the first time at Titan's south pole of some species such as HC3N at 663 cm-1 and C6H6 in large quantities. These species had previously been clearly observed only at high northern latitudes. Though not present in the south until February 2012, the 663 cm-1 emission appeared in CIRS spectra recorded on 24 July 2012 next to the CO2 band at 667 cm-1 and has been increasing since then. This is strong indication of the buildup of the gaseous inventory in the southern stratosphere, as the pole movesinto winter. Downwelling nitrile gases that accumulate in the absence of ultraviolet sunlight, evidently increased quickly during 2012 and may be responsible also for the haze decrease in the north and its appearance in the south from its 220 cm-1 feature [3,4]. We present analysis for temperature and composition of the trace gases in Titan's stratosphere until late 2014. HC3N has increased by 2 orders of magnitude in the south over the past 2 years, while decreasing rapidly in the north. We find other interesting, although weaker transitions, from north to south for other molecules and we will discuss HCN, C3H4 and C4H2, which need to be monitored more in the future.

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IAMAS (Meteorology)

M08b - M08/M09 Comparative Planetary Atmospheres within and beyond the Solar System / Solar System Exploration of Atmospheres with Ground-Based and Space-Based Platforms

IUGG-1196

Internal gravity wave processes on Earth and Mars

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Internal gravity waves generated in the lower atmosphere shape the dynamical and thermal structure of atmosphere-ionosphere system of terrestrial-like planets. Global modeling studies increasingly indicate that gravity waves can play a crucial role for the general circulation of Earth's upper atmosphere. Owing to the advent of satellite technology, gravity waves are continuously detected in the thermosphere, supporting recent modeling results. Our research indicates that gravity waves possess similar, or even greater dynamical importance in the middle and upper atmosphere of Mars. Based on two state-of-the-art general circulation models for Earth and Mars, we present recent results on the vertical coupling induced by small-scale gravity waves in the atmospheres of these planets. Both on Mars and Earth, lower atmospheric gravity waves propagate into the upper atmosphere and produce there appreciable dynamical and thermal effects during quiet times and dust storm periods. These are crucial findings that can help interpret Martian obserservations, such as, MAVEN data.

IAMAS (Meteorology)

M08b - M08/M09 Comparative Planetary Atmospheres within and beyond the Solar System / Solar System Exploration of Atmospheres with Ground-Based and Space-Based Platforms

IUGG-1434

Origin and evolution of Titan's atmosphere, as revealed by the Cassini-Huygens Mission

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Ten years ago, the Huygens entry probe played a key role in demystifying the unique nature of Titan in the solar system. Coupled with the observations of the Cassini orbiter, we can now construct feasible scenarios for the origin and evolution of Titan's earth-like atmosphere of nitrogen and the role of methane cycle in it. In the giant planets, nitrogen is bound to hydrogen in the form of ammonia. Thus ammonia (NH_3), not N_2, is the dominant reservoir of nitrogen in these objects. The satellites that form in the relatively warm and dense subnebula of the gas giant planets, Jupiter and Saturn, may acquire nitrogen as NH_3 during their accretion, although some models had proposed N_2, not NH_3, as the stable form of nitrogen in the subnebulae. Before Cassini-Huygens, it was debated whether Titan, the largest moon of Saturn, acquired its nitrogen directly as N_2, which would place Titan in the same category as Neptune's moon Triton half the size of Titan, or the nitrogen on Titan was a secondary atmosphere produced from nitrogen bearing molecules, placing Titan in the same class as the terrestrial planets, Earth, Mars and Venus. The evidence from Cassini-Huygens is unequivocal in that Titan's nitrogen atmosphere is secondary. The sustenance and evolution of this atmosphere depends critically on methane, however. In this talk I will discuss our current understanding of the various pathways for the generation of nitrogen on Titan and the role of methane cycle in Titan's atmospheric evolution.

IAMAS (Meteorology)

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IUGG-5122

Constraints on past climate on Mars from the North Polar layered deposits

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The polar layered deposits (PLD) on Mars are km thick ice-rich deposits with a stratigraphy that preserves a record of past climate variations on Mars. The stratigraphy of the PLDs is thought to result from climate variations forced by changes in the orbital parameters of Mars, particularly the obliquity, similar to Milankovitch cycles on Earth. The age of the deposits are not well constrained by geological data, but it has been proposed that the buildup of the NPLD is related to a shift in obliquity at 5 Ma. We investigate which constraints can be inferred from the NPLD stratigraphy on the water and dust cycles and their variations on longer timescales. We use a model of PLD formation driven by insolation. The model simulates the evolution of the PLD based on simplified parameterizations of physical processes controlling ice and dust deposition rates. It captures characteristic features of the complex layer sequences observed in the north polar layered deposits (NPLD). The results suggest that local stability of water ice exerts a strong control on the polar ice deposition rate. The processes controlling dust deposition rates are complex, and may depend on global-scale processes. We discuss the dust deposition component of the model, and consider different parameterizations of the dust deposition rate. The model parameterizations are tested against the NPLD stratigraphy including both visual and radar data. We discuss the implications of the results for the evolution of the NPLD and the processes controlling ice and dust deposition at the poles.

IAMAS (Meteorology)

M08p - M08/M09 Comparative Planetary Atmospheres within and beyond the Solar System / Solar System Exploration of Atmospheres with Ground-Based and Space-Based Platforms

M08p-372

VIMS and RADAR investigation of Titan's equatorial regions

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Data of Titan's surface obtained by Cassini-Huygens remote sensing instruments have shown the presence of diverse terrains, suggesting exogenic and endogenic processes. In this research we focus on some equatorial regions that have been identified as possibly subject to changes, having particular spectral properties. These are Sotra Patera, Hotei Regio and Tui Regio [1,2,3]. We use VIMS data, to which we apply PCA and radiative transfer methods [2;3;4] with updated parameterization for the spectroscopic data and infer the surface albedos of all of these regions, that we interpret in terms of possible surface composition and morphology combining with information from RADAR data. Indeed, by including despeckled SAR images we identify geomorphological units and investigate spatial and temporal geological relationships [5]. This combination provides us with implications on the surface composition of different units. By looking at evolution with time, we find that two of these regions show albedo changes with time, for Tui Regio from 2005-2009 (darkening) and Sotra Patera from 2005-2006 (brightening) at all wavelengths, indicating that dynamical processes control the regions, compatible with their complex morphology. We also correlatedradiometry and topographic data of these regions with the compositional information from VIMS to derive constraints on the chemical composition and the geology of the surface and finally the nature of these regions.

[1] Lopes, R.M.C., et al.: JGR, 118, 416-435, 2013; [2] Solomonidou, A., et al.: JGR, 119, 1729-1747, 2014; [3] Solomonidou, A., et al.: submitted; [4] Hirtzig, M., et al.: Icarus, 226, 470-486, 2013; [5] Bratsolis, E., et al.: PSS, 61, 108-113, 2013.

IAMAS (Meteorology)

M08p - M08/M09 Comparative Planetary Atmospheres within and beyond the Solar System / Solar System Exploration of Atmospheres with Ground-Based and Space-Based Platforms

M08p-374

High-altitude clouds on Earth, Mars and Venus

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Terrestrial polar mesospheric clouds (PMCs or noctilucent clouds) are the highest clouds in the Earth’s atmosphere (83 km on average) and are composed of small water ice crystals. On Mars, mesospheric clouds have also been observed between altitudes of 50 and 100 km. Most observations suggest a CO2 ice composition but water ice composition has also been reported. The mesospheric clouds on both planets form under the influence of gravity waves in an extremely tenuous part of the atmosphere probably on exogenous condensation nuclei (CN) provided by meteoroid ablation.

Clouds composed of sulphuric acid solution droplets are observed in the atmosphere of Venus and in the Earth's stratosphere. The concentration of the Earth’s stratospheric sulphate aerosols varies strongly as a function of volcanic eruptions; these aerosols can serve as CN for the formation of polar stratospheric clouds that are catalysers of ozone destruction. The 20-km thick layer of Venus’ clouds, which is found at 50-70 km altitude and covers the whole planet, lets only a few per cent of solar radiation reach the surface and is an important sink of atmospheric sulphur. Both Venus’ clouds and Earth’s sulphate aerosol layer have a cooling effect on the climate and play an important role in atmospheric chemistry. We are currently developing a Venus cloud model based on an aerosol/cloud model for the Earth’s stratosphere.We will present an overview of these clouds and aerosols on the three planets through review of observations and modelling.

We will discuss the properties of the clouds and recent results on their formation mechanisms, largely based on work carried out within our group.

IAMAS (Meteorology)

M08p - M08/M09 Comparative Planetary Atmospheres within and beyond the Solar System / Solar System Exploration of Atmospheres with Ground-Based and Space-Based Platforms

M08p-375

Atmospheric structure in the venusian polar region; first report on reproduction by general circulation model

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Venus has a vortical structure called polar votex in both northern and southern polar regions. Polar vortices also exist on the Earth, Mars and Titan, and jet streams surrounding them isolate the cold air at high latitudes from the warm air at low latitudes. On the other hand, Venusian polar vortex has a unique structure. There is a hot polar region in it, surrounded by a local cold latitude band called cold collar around 65 km altitude and 60° latitude. A bright hot dipole feature like an inverse S-shape is observed in the polar vortex, and recent optical measurements clarified that the morphology of the Venusian polar vortex varies temporally. These structures have been observed in past and recent Venus Exploration missions, thus they are thought to exist semi-permanently. Here we reproduced the structure of the Venusian atmosphere by using Atmospheric GCM For Earth Simulator (hereafter AFES) with diurnal heating, especially we focused on the atmospheric structure in the polar region. As a result, the structure reproduced in AFES seem to be consistent with those observed by previous and recent measurements. In addition, the residual mean meridional circulation enhanced by thermal tides might be able to explain some observational results which are clarified by recent optical measurements in Venus Express mission such as polar warming and latitudinal trends of the cloud top altitude and the cloud thickness. These results imply that thermal tides would be crucial to reproducing the unique structure of the Venusian polar region.

IAMAS (Meteorology)

M08p - M08/M09 Comparative Planetary Atmospheres within and beyond the Solar System / Solar System Exploration of Atmospheres with Ground-Based and Space-Based Platforms

M08p-376

Climate states of the giant planets and Sun

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All seven deep atmospheres in the solar system exhibit strong differential rotation, but the physical processes that drive these motions and the associated spatial variations in temperature and density are not well understood. Three-dimensional modeling has not shed much light on this problem, even in the case of the Sun where the interior structure can be inferred from helioseismology. It is hoped that the Juno and Cassini missions will provide some constraints on the interiors of Jupiter and Saturn through the measurement of high order gravitational moments, but without a validated forward model the interpretation of those observations will be difficult. A new approach to the climate modeling of fluid bodies leads to a straightforward explanation of the observed phenomena and a feasible framework for assimilating spacecraft observations. The equation of motion is divided between reversible (advective) and irreversible (work and dissipative) terms. In a steady state, both sets of terms balance independently and the thermodynamic requirement of maximum entropy is met. This yields rules applicable to any deep atmosphere: The mean meridional circulation balances Eliassen-Palm flux divergences; the mean zonal wind (differential rotation) is generated by a balance between gravitational torques and viscous dissipation (as predicted for Venus by Gold & Soter, 1971); horizontal temperature gradients are generated by the work of torques against friction; and the thermal wind relation applies at all latitudes. A simple linear model based on a sum of atmospheric torques thus generates interior wind and temperature fields from which the density and gravitational fields (and their sensitivities) can be derived. Results for the Sun, Jupiter, and Saturn will be presented.

IAMAS (Meteorology)

M08p - M08/M09 Comparative Planetary Atmospheres within and beyond the Solar System / Solar System Exploration of Atmospheres with Ground-Based and Space-Based Platforms

M08p-377

Investigation of planetary lightning with ground-based and space-based platforms

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The study of planetary lightning can reveal many insights into the dynamics of the respective atmosphere. Except Earth, Saturn is the only planet of our Solar System where atmospheric lightning was unequivocally detected by spacecraft (Voyagers 1 and 2, Cassini) and ground-based platforms. The latter detection with the giant Ukrainian radio telescope UTR-2 happened within the last years in combination with space-based observations by Cassini. In this contribution we will shortly review the main observations of optical and radio emissions from planetary lightning and discuss which ground-based observations could improve our knowledge about them. For the special cases of Venus and Uranus we will estimate the strength of lightning radio signals and evaluate the potential of ground-based radio telescopes for their detection.

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M08p-378

First detection of 63µm oxygen line in the thermosphere of Mars from GREAT/SOFIA

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Atomic oxygen is the key element in several processes governing the energy and mass flow in the mesosphere-thermosphere-ionosphere of Mars , and its uncertainty strongly impacts both, the outcomes of global circulation modeling as well as interpretation of remotely sensed satellite data. Despite the recognized need for accurate knowledge of atomic O abundances in the upper atmosphere, only few dedicated measurements are available. In this presentation we describe the new opportunities for planetary spectroscopic observations in the far infrared wavelengths provided by the GREAT instrument on board the Stratospheric Observatory for Infrared Astronomy (SOFIA). SOFIA features a 2.5 dish, and the heterodyne spectrometry available with GREAT provides 44 kHz resolution of 9.5 GHz bandwidth with high S/N ratio. Such high spectral resolution is capable resolving Doppler broadened lines, Doppler induced line shifts. Here we report on detection of O(3 P) 63 µm in the thermosphere of Mars with measurements taken place on May 14, 2014. From these measurements we estimate Mars thermospheric column density of atomic O, and averaged wind speed in the region 100-150 km. This detection is a promising introduction in to the future possibility of a systematic monitoring of atomic O in the atmosphere of Mars from the ground.

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M08p-379

Photochemistry in saturn’s ring-shadowed atmosphere: Modulation of key molecules and observations of dust content

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Cassini has been orbiting Saturn for over ten years now. During this epoch, the ring shadow has moved from covering the northern hemisphere to covering a large swath south of the equator and continues to move southward. At Saturn Orbit Insertion in 2004, the ring plane was inclined by 24 degrees. The projection of the B-ring onto Saturn reached as far as 40N along the central meridian (52N at the terminator). At its maximum extent, the ring shadow can reach as far as 48N/S (58N/S at the terminator). The net effect is that the intensity of both ultraviolet and visible sunlight penetrating into any particular latitude will vary depending on both Saturn’s relative tilt and the optical thickness of each ring system. In essence, the rings act like venetian blinds and modulates the solar flux as a function of solar inclination, Here, we report on the impact of the oscillating ring shadow on the photolysis and production rates of hydrocarbons in Saturn’s stratosphere and upper troposphere, including acetylene, ethane, propane, and benzene. Beginning with methane, we investigate the impact on production and loss rates of the long-lived photochemical products leading to haze formation are examined at several latitudes over a Saturn year. Similarly, we assess its impact on phosphine abundance, a disequilibrium species whose presence in the upper troposphere is a tracer of convective processes in the deep atmosphere. We will also present our ongoing analysis of Cassini’s CIRS, UVIS, and VIMS datasets that provide an estimate of the evolving haze content and assess the implications for dynamical mixing. We will examine how the now famous hexagonal jet stream acts like a barrier to

transport, isolating Saturn's north polar region from outside transport of hydrocarbons and haze.

IAMAS (Meteorology)

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M08p-380

Is nitrogen dioxide content in the lower troposphere affected by solar variability?

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It is well known the fact that NO_2 plays an important role in the radiation budget by absorbing solar radiation at ultraviolet (UV) and visible wavelengths and by its effects on other atmospheric components. Space based observations greatly contributed to understanding the variability of atmospheric composition at global level and on a continuous basis. There is increasing interest in estimating whether solar variability might have contributed to recent climate changes. Possible effects on the inter-annual variability and trends in nitrogen dioxide are investigated for a period of 10 years (2004-2013) of measurements recorded by the Ozone Monitoring Instrument (OMI), version 2.0. Possible signatures of solar variability on nitrogen dioxide time series of NO_2 over several cities were analyzed using various statistical methods. Various solar proxies were selected, in order to separate between possible links to solar irradiance and to solar wind. Several locations, with different levels of pollution, located in different places of the world were selected and NO_2 tropospheric Vertical Column Density (VCD) or total Slant Column Density (SCD) were analysed. Results are not conclusive, showing that NO_2 content decreases with increasing activity above polluted areas while for unpolluted areas there is no evident correlation. Possible effects of solar wind on NO_2 content are observed as well, but the relationship is less clear, since polluted areas seem to respond differently to solar wind variations. The mechanism by which NO_2 content can be affected by solar variations relate mainly to ozone production but other paths by which solar energy may be transferred to the lower atmosphere are investigated.

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M08p-381

Temporal variations in the cloud cover of Venus - detection of a seasonal signature

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The Venus Monitoring Camera on European Space Agency's Venus Express orbiter monitored the southern hemisphere of Venus from June 2006 through November 2014. Images were obtained through four narrow band filters (50 nm full width) centered at 365 , 550, 95 and 1050 nm. There are more images obtained at 365 nm on most orbits compared to other filters. While the imaging coverage is not continuous, the temporal sampling is large enough to detect short and long term changes in the cloud cover. We report on the periodic signature found at all four wavelengths with that strongly suggest seasonal variations despite the nearly circular orbit of Venus and its low inclination.

Changes in the normalized brightness and slat unit optical depth at a period very close to the orbital period of Venus (224.7 days) are indicated by the data. In view of the very small eccentricity and the low inclination of the planet's spin axis to its orbital plane, the finding that insolation induced variations are readily detected in the cloud cover suggests that the other influences on the cloud cover as have been suggested for Earth clouds, may be more easily detectable on Venus.

IAMAS (Meteorology)

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M08p-382

Sulfur Dioxide variability in the Venus atmosphere

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SO_2 is strongly related to the formation of the clouds and haze on Venus, which are composed of sulfuric acid combined to water complexes. Presence and variations of SO_2 could be the proof of a possible volcanism on Venus. The most intriguing are discrepancies among different observations, and the suspected long-term variations of the SO_2 abundance observed on the scales of several years, in particular during Pioneer Venus Orbiter and Venus Express missions. Similar trends are also observed in the super-rotation period and circulation patterns, which suggest that these aspects may be more strongly coupled than expected.

An ISSI international team has been built in view of considering different aspects of sulfur chemistry on Venus. This includes comparison and validation of observations, from past missions, from Venus Express, from the Earth, and from Hubble Space Telescope, modeling of photochemistry and of other processes in which the sulfur family is involved. We will consider not only SO_2, but also SO and other constituents involved in its cycle. Reference density and vmr fields will be constructed from the detailed analysis and comparison of data. These will be included into the next generation of the VIRA references atmosphere.

IAMAS (Meteorology)

M08p - M08/M09 Comparative Planetary Atmospheres within and beyond the Solar System / Solar System Exploration of Atmospheres with Ground-Based and Space-Based Platforms

M08p-383

Venus atmospheric structure: Intercomparison of recent observations of thermal structure

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The widely used atmospheric structure tables published as part of the Venus International Reference Atmosphere (VIRA) included data obtained by the Venera entry probes and Pioneer Venus Orbiter and Multi-probe missions only. Venus Express orbiter has obtained vast amounts of new data since April 2006 about the Venus atmosphere which extends knowledge of the atmospheric vertical structure to about 150 km from a variety of in-situ and remote sensing experiments. Concurrency and congruency of observations from the different experiments on Venus Express is not generally possible as the observational geometries are different due to the method of investigation, and hence some understanding of basic physical processes (e.g. thermal tides, gravity waves) that can be modeled is needed. We present here an inter comparison of these results and also with VIRA model and also results from many representative ground based observations.

IAMAS (Meteorology)

M08p - M08/M09 Comparative Planetary Atmospheres within and beyond the Solar System / Solar System Exploration of Atmospheres with Ground-Based and Space-Based Platforms

M08p-499

Water Contents of Habitable Zone Rocky Planets Around M dwarfs

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The searches for habitable planets currently focus on M dwarfs because of observation feasibility considerations. However, the early evolution of M dwarfs are quite different from that of Sun-like stars: the total luminosities of M dwarfs decrease by a factor of 10 during their PMS phase. As a result of this luminosity evolution, rocky planets in the habitable zones of main sequence M dwarfs were too close to the host stars during the first 100 Myrs and were in the runaway and moist greenhouse states.

This scenario has been studied by three groups of researchers recently (Ramirez and Kaltenegger 2014, Tian and Ida, Luger and Barnes 2015), and their consensus is that assive amount of water could have been lost during this time -- early evolution of M dwarfs could have changed the water contents of rocky planets around them. IN this work we will present a summary of current understanding on how early stellar evolution could have impacted the habitability of rocky planets around low mass stars and discuss open issues as well as potential methods to observationally verify these theories.

IAMAS (Meteorology)

M08p - M08/M09 Comparative Planetary Atmospheres within and beyond the Solar System / Solar System Exploration of Atmospheres with Ground-Based and Space-Based Platforms

M08p-500

Evolving Role of Photochemical Escape from Early Mars

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Photochemical escape is a crucial process for neutral oxygen atoms escape from present Mars. Energetic oxygen atoms are produced from O_2^+ dissociative recombination reactions (DR) in the thermosphere/ionosphere of Mars and some of them have sufficient energy to escape Mars. In addition, DR reactions of CO_2^+ could produce energetic C atoms which can escape Mars as well. How carbon and oxygen have escaped photochemically from early Mars remain an important unresolved question challenging our understanding of Mars evolution.

A 1-D Monte-Carlo model simulating the photochemical escape of oxygen was built recently and applied to 1, 3, 10, and 20 times present solar XUV fluxes (Zhao and Tian, Icarus 2015). The results show that photochemical escape is a less important escape mechanism than previously thought for the loss of water and/or CO_2 from early Mars. In this work, a 3-D Monte-Carlo Model is built to check the validity of previous conclusions, to calculate photochemical escape rates of carbon and oxygen simultaneously, and to estimate the possible photochemical loss of CO_2 and H_2O from early Mars.

IAMAS (Meteorology)

M08p - M08/M09 Comparative Planetary Atmospheres within and beyond the Solar System / Solar System Exploration of Atmospheres with Ground-Based and Space-Based Platforms

M08p-501

Biosignature Detection in the Atmospheres of Rocky Planets Around M dwarfs

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Although atmospheric oxygen built-up occurs as a result of photochemistry on a frozen planet such as Mars and rapid hydrogen escape following water vapor photolysis on a planet such as Venus, traditionally O2 and its derivative O3 are considered reliable biosignatures in the atmospheres of Earth-mass exoplanets in the liquid water habitable zones. However, multiple works recently show that atmospheric oxygen could accumulate in the atmospheres of habitable zone exoplanets around M dwarfs as the results of unique stellar UV spectrum (Tian et al. 2014, Hu et al. 2014) or massive water loss during pre-main-sequence stellar luminosity evolution (Luger and Barnes 2015).

In this work we focus on the detectability of atmospheric oxygen and show that the level of atmospheric O2 concentration produced in the Tian et al. (2014) scenario is readily observed by future telescopes and thus constitutes false positive biosignature. We further analyze the detectability of other phtochemical products which necessarily accompanying the presence of detectable level of abiotic O2 in the same scenario in order to identify potential methods to recognize this type of false positive biosignature.

IAMAS (Meteorology)

M10a - M10 Global Monsoons and Climate Change

IUGG-0381

Influences of ENSO on the vertical coupling of atmospheric circulation during the onset of South Asian summer monsoon

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Based on multiple sources of atmospheric and oceanic data, this study performs a series of composite analysis of the South Asian summer monsoon (SASM) onset against ENSO events, and indicates that warm/cold ENSO events induce later/earlier onset of the South Asian summer monsoon (SASM) by modulating the vertical coupling of the upper- and lower-level circulation over the South Asia. Specifically, during the monsoon onset of Bay of Bengal (BOB), the ENSO-induced convection anomalies over the southern Philippines can modulate the position of South Asian High (SAH) in late April in the upper troposphere, which evolves to affect the monsoon onset convection by changing the upper divergence-pumping effect. In the lower troposphere, ENSO induces an anomalous zonal gradient of sea surface temperature (SST) over the Indian–western Pacific Ocean to alter the barotropic instability which further affects the formation of BOB monsoon onset convection. During the Indian summer monsoon onset, the anomalous convection over northeastern BOB and Indochina Peninsula in late May act to change the SAH position and its relevant upper divergence-pumping over the Arabian Sea (AS). Meanwhile, the Indian monsoon onset convection is also modulated by the ENSO-induced changes in intensity of the inertial instability and the forced convection over the AS, which are related to an ENSO-induced anomalous cross-equatorial SST gradient and zonally asymmetric meridional gradient of sea level pressure, and an anomalous westerly over the central AS in the lower troposphere. Results demonstrate that during the BOB and India monsoon onset, the influences of ENSO on the upper circulation are similar, but are distinctly different on the lower-level circulation.

IAMAS (Meteorology)

M10a - M10 Global Monsoons and Climate Change

IUGG-1551

"Asian Monsoon Onset Barrier" and Characteristics of the Indian Summer Monsoon Onset

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Multi- source data were employed to study the dynamical processes associated with the Asian summer monsoon onset. It is demonstrated that the huge latent heat released by the monsoon convection over the Bay of Bengal (BOB) associated with the first Asian summer monsoon onset leads to a remarkable feedback on the atmospheric circulation and the air- sea interaction in the Asian monsoon area. Consequently the Asian summer monsoon onset which happened over the BOB region can propagate freely eastward in a sequence to the Indochina Peninsula, South China Sea (SCS) and Western Pacific. On the contrary, the westward propagation of the monsoon onset is stopped over the western coast of the BOB. This is because the aforementioned feedback intensifies the winter type vertical shear of horizontal wind and generates a change of downward surface sensible heating from atmosphere to ocean, local perturbation and convection are prohibited and the monsoon onset barrier (MOB) is formed over the western coast of the BOB.

Due to the development of the cross- equatorial gradient of surface sea temperature (SST) and the specific land- sea distribution in the region from the eastern Arabian Sea to the southwestern Indian subcontinent, inertial instability and forced convection develop in the region, causing the intensified lower tropospheric convergence. During the course, the South Asian High (SAH) develops westward as a consequence of the convective heating released by the BOB and SCS monsoon, forming an upper tropospheric pumping over the eastern Arabian Sea. The strong upper and lower tropospheric coupling eventually leads to the Indian monsoon onset in the region over the eastern Arabian Sea and Southwestern coast of India.

IAMAS (Meteorology)

M10a - M10 Global Monsoons and Climate Change

IUGG-2460

The role of air-sea interactions in monsoon sub-seasonal variability

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In regions of South and East Asia the summer monsoon, characterised by sub-seasonal active-break cycles, provides over 80% of the total annual rainfall. The fast-developing industry, growing population and continued reliance on rain-fed agriculture in these regions mean more than a billion people's livelihoods rely on the monsoon. Therefore, understanding what drives sub-seasonal variability in the monsoon is of huge societal importance.

Since the ocean is a crucial moisture source for the monsoon, air-sea interactions may modulate sub-seasonal monsoon variability. However, state-of-the-art coupled climate models exhibit considerable biases in their representation of sub-seasonal variability over Asia. In this study the role of air-sea coupling on sub-seasonal variability in the monsoon is investigated in the ocean mixed-layer coupled configuration of the Met Office Unified Model (MetUM-GOML1). This framework allows well-resolved (high near-surface resolution and sub-daily exchanges) air-sea coupling while maintaining a near-observed mean state. MetUM-GOML1 simulations are compared with atmosphere-only versions forced by (a) the mean seasonal cycle and (b) 31-day smoothed SSTs from MetUM-GOML1. This allows the impact of introducing inter-annual variability in SST to be separated from the presence of coupled feedbacks.

Coupling is required to reproduce the observed near-quadrature phase relationship between sub-seasonal precipitation and SST anomalies. Capturing this relationship improves the representation of northward-propagating sub-seasonal precipitation anomalies in some, but not all, monsoon regions. The framework is also used to assess the role of air-sea coupling on the representation of temperature and precipitation extremes in monsoon regions.

IAMAS (Meteorology)

M10a - M10 Global Monsoons and Climate Change

IUGG-3771

The diurnal cycle of precipitation in West Africa: An analysis using ground-based, satellite-based and reanalysis data

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Precipitation is a major ingredient at the Earths global energy- and water cycle, impacting various spatial and temporal scales. Due to its high temporal and spatial variability precipitation is difficult to observe consistently. In recent years efforts have been made to develop satellite-based precipitation datasets which are an alternative to in-situ data, especially in areas sparsely covered by ground stations. Additionally model-based reanalysis datasets are further improving. West Africa is affected by monsoonal rainfall, which is of convective type and characterized by distinct diurnal cycles. Especially when it comes to sub-daily variability, it is often unclear whether satellite-based and reanalysis datasets can reasonably capture the ground truth. Here, results of an intercomparison of the diurnal cycles of precipitation as measured by rain gauges (from the AMMA database), as estimated by satellites (using various datasets) and as derived by model-based reanalysis will be shown.

IAMAS (Meteorology)

M10a - M10 Global Monsoons and Climate Change

IUGG-4759

Changes in the summer monsoon intraseasonal oscillations and extremely dry and wet conditions in India in a warmer planet

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The India summer monsoon (ISM) experiences long periods of wet conditions frequently associated with floods and long dry spells that increase food insecurity. These events are largely governed by northward propagating boreal summer monsoon intraseasonal oscillations (MISO). Here we investigate intraseasonal variability of the ISM in the climate of the 20th century using the Climate Forecast System Reanalysis (1979-2013) and examine future scenarios of climate change using models of the Coupled Model Intercomparison Project Phase 5 project. ISM is characterized with a large-scale index obtained by performing combined EOF analysis of precipitation, low level circulation, specific humidity and temperature. The first mode captures the large-scale features of the South and East Asia Monsoon whereas the second mode relates to ISM and is used as large-scale index for the India Monsoon. This index realistically defines the monsoon's onset and withdrawal, is well correlated with seasonal precipitation in India and exhibits variance on intraseasonal timescales that are related to MISO and extreme wet and dry conditions in India. With similar approach we investigate the skill of the CMIP5 models in realistically simulating MISO in the 'historic' run (1951-2005) and examine projected changes in the amplitude and persistence these events in the high-emission representative concentration pathway 8.5 (RCP8.5) (2006-2100). MISO is well characterized in CMIP5 models that indicate significant increase in the intensity and frequency of extremely dry and wet conditions affecting India by 2050. We explore mechanisms underlying these changes. This research is supported by the National Science Foundation (1116105).

IAMAS (Meteorology)

M10b - M10 Global Monsoons and Climate Change

IUGG-0222

Potential influence of the november-december Southern Hemisphere annular mode on the East Asian winter precipitation: a new mechanism

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As the leading mode of the global atmospheric mass inter-annual variability, the Southern Hemisphere (SH) annular mode (SAM) may exert potential influences to the Northern Hemisphere (NH) climate, but the related physical mechanism is not yet clear. In this study, it is found that the November-December (ND) SAM exhibits a significant inverse relationship with the winter precipitation over East Asia, particularly southern China. Observational and numerical evidences show that anomalous ND SAM is usually associated with a South Atlantic-Pacific dipole sea surface temperature anomaly (SSTA) which persists into ensuring winter. The dipole SSTA can modulate the variability of the Inter-tropical Convergence Zone (ITCZ) in Pacific. Subsequently, a distinguished atmospheric tele-connection pattern is induced and prevails over the NH mid-latitude region as a response to the anomalous ITCZ. Large areas of high pressure anomalies are triggered at upper troposphere over East Asia and centered over southern China, which favors less precipitation over East Asia, particularly southern China, and vice versa. Through such a physical mechanism, the notable influence of the ND SAM can sustain through the following season and impact on the NH winter climate.

IAMAS (Meteorology)

M10b - M10 Global Monsoons and Climate Change

IUGG-1133

Towards achieving potential predictability of Indian summer monsoon in climate forecast system model by addressing the physics errors

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The goal of this study is to extend the realized predictability limit of a dynamical coupled model over Indian monsoon region. In this study we present an optimal way to design a multi-model ensemble prediction system from a suite of different variants of Climate Forecast System (CFSv2) model to increase the spread without compromising the limit of potential predictability of each individual models. The ensembles are generated not only by perturbing the initial condition, but also using different resolutions, parameters, physics formulation and coupling configurations of the same model. Each of these configurations was created to address the role of different physical mechanisms known to have control on the error growth in the 10-20 day time-scale. We also present the bias errors arising from incorrect humidity-convection relationship. The prominent biases of the model simulations are a wet bias of rainfall over Western equatorial Indian Ocean and a dry bias over Indian landmass and Bay of Bengal. We hypothesize that most of these biases arise from relative humidity based entrainment formulation in the model and are addressed by performing a few targeted experiments using a possible range of humidity-entrainment relationships. We carry out a model tendency budget analysis to diagnose and evaluate the modifications to the entrainment formulation. The specific changes in the model formulation of convection is being attempted in such a way as to ensure the mean climate of the model does not change much. Finally, we develop a multi-model consensus forecast, including ensemble-based uncertainty estimates.

IAMAS (Meteorology)

M10b - M10 Global Monsoons and Climate Change

IUGG-1649

Interannual variation of mid-summer heavy rainfall in the eastern edge of the Tibetan Plateau

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Heavy rainfall (HR) often hits the eastern edge of the Tibetan Plateau (EETP) and causes severe flood and landslide in summer, especially in July. In this study, the authors investigate the interannual variation of July HR events and its possible causes. The maximum number of days with HR in July is located at the EETP in China. It is significantly and negatively correlated with the rainfall in southeastern China. More HR events are accompanied by an anomalous lower-tropospheric anticyclone over southeastern China, a westward movement of the western North Pacific subtropical high, and enhanced rainfall in the Maritime Continent (MC). The MC convection exerts a significant impact on the variation of HR events over EETP. Results from analyses of observations and numerical simulations indicate that the convective heating over the MC induces an anomalous anticyclone over southeastern China and the Ekman pumping effect and circulation-convection feedback play vital roles in the process. The high correlation between the HR events over EETP and the equatorial central Pacific SST depends on the relationship between the MC convection and the equatorial central Pacific SST. The relationship is asymmetric, and only the warm SST anomaly in the equatorial central Pacific is accompanied by fewer HR events over the EETP.

IAMAS (Meteorology)

M10b - M10 Global Monsoons and Climate Change

IUGG-2645

Extended-range forecast of tropical Asian summer monsoon: Focus on regional features

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The variations of the South Asia High are characterized by an apparent quasi-biweekly oscillation (QBWO), which is closely related to the convection over East/Southeast Asia. However, the NCEP Climate Forecast System (CFS) shows that the QBWO in Asia is less predictable than that over the North and South Pacific, although overall QBWO is more predictable in El Nino years than in La Nina years.

Skills of subseasonal prediction of monsoon rainfall are overall higher over oceans than over land. The rainfall over the Arabian Sea is most predictable, while that over the Indo-China Peninsula is nearly unpredictable on subseasonal time scale. The sea-air coupling over the Arabian Sea is characterized by strong and fast surface temperature forcing but a weak and slow temperature response, while the interactions over the Bay of Bengal, the South China Sea, and India show weak and slow surface temperature forcing but a strong and rapid temperature response. Air-land interactions are often less noticeable over the Indo-China Peninsula and southern China than over India. The CFS reasonably reproduces these observed features, but the local rainfall-temperature relationships over various regions surfer from different degrees of unrealistic estimation. The observed local rainfall is often related to atmospheric circulation over a limited region, which is more extensive for oceans than for land. In forecasts, as lead time increases, strengthening connections between regional rainfall and large-scale circulation and temperature are found over extensive regions and the regional independence of rainfall variability is progressively obscured by uniform large-scale features except over the Arabian Sea and southern China.

IAMAS (Meteorology)

M10b - M10 Global Monsoons and Climate Change

IUGG-4362

Asian summer monsoon seasonal prediction skill in the Met Office GloSea5 model and its dependence on mean state biases

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Predicting the circulation and precipitation features of the Asian monsoon on time scales of weeks to the season ahead remains a challenge for prediction centres. Current state-of-the-art models retain large biases, particularly dryness over India, which evolve rapidly from initialization and persist into centennial length climate integrations, illustrating the seamless nature of the monsoon problem.

We present initial results from our Ministry of Earth Sciences Indian Monsoon Mission collaboration project to assess and improve weekly-to-seasonal forecasts in the Met Office Unified Model (MetUM) coupled initialized Global Seasonal Prediction System (GloSea5). Using a 14-year hindcast ensemble of integrations in which atmosphere, ocean and sea-ice components are initialized from May start dates, we assess the monsoon seasonal prediction skill and global mean state biases of GloSea5. Initial May and June biases include a lack of precipitation over the Indian peninsula, and a weakened monsoon flow, and these give way to a more robust pattern of excess precipitation in the western north Pacific, lack of precipitation over the Maritime Continent, excess westerlies across the Indian peninsula and Indochina, and cool SSTs in the eastern equatorial Indian Ocean and western north Pacific in July and August. Despite these mean state biases, the interannual correlation of predicted JJA all India rainfall from 1998 - 2009 with TRMM is fairly high at 0.68. Future work will focus on the prospects for further improving this skill with bias correction techniques.

IAMAS (Meteorology)

M10b - M10 Global Monsoons and Climate Change

IUGG-5554

Improving seasonal prediction of East Asian summer monsoon by predictability sources from mid-high latitude forcings

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The East Asian summer monsoon (EASM) affects more than 1 billion people, therefore how to predict the EASM is of great societal significance but a very difficult problem. The EASM may be better predicted by analyzing the mid-high latitude driving forcings. This paper proposed a theory of the 'coupled oceanic-atmospheric bridge (COAB)' which play important roles in understanding the underlying mechanisms of the cross-seasonal effects of the annular modes on climate over East Asia. Some physically-based empirical prediction models for EASM which combine the tropic forcings and the extra-tropic forcings as well are then presented. Operational predictions show that these models display excellent performance for predicting EASM.

IAMAS (Meteorology)

M10c - M10 Global Monsoons and Climate Change

IUGG-0424

Changes in latent heating over South China Sea and surrounding regions and influences on Asian summer climate under global warming

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Global warming is one of the most significant climate change signals at the earth's surface. However, the responses of monsoon precipitation to global warming show very distinct regional features, especially over the South China Sea (SCS) and surrounding regions during boreal summer. To understand the possible dynamics in these specific regions under the global warming background, the changes in atmospheric latent heating and their possible influences on global climate are investigated by both observational diagnosis and numerical sensitivity simulations. Results indicate that summertime latent heating has intensified in the SCS and western Pacific, accompanied by increased precipitation, cloud cover, lower-tropospheric convergence, and decreased sea level pressure. Sensitivity experiments show that middle and upper tropospheric heating causes an east–west feedback pattern between SCS–western Pacific and South Asia, which strengthens the South Asian High in the upper troposphere and moist convergence in the lower troposphere, consequently forcing a descending motion and adiabatic warming over continental South Asia and leading to a warm and dry climate. When air–sea interaction is considered, the simulation results are overall more similar to observations, and in particular the bias of precipitation over the Indian Ocean simulated by AGCMs has been reduced. The results highlight the important role of latent heating in adjusting the changes in sea surface temperature through atmospheric dynamics.

IAMAS (Meteorology)

M10c - M10 Global Monsoons and Climate Change

IUGG-0586

Long-term variation of the principal mode of boreal spring Hadley circulation linked to SST over the Indo-Pacific warm pool

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The variability of the boreal spring (March to May, MAM) Hadley circulation (HC) is investigated, focusing on the long term variation of the first principal mode for 1951–2008, which is an equatorially asymmetric mode (AM) with the rising branch located around 10°S. This mode explains ~70% variance of the MAM HC and shows an obvious upward trend, and thus contributes to the strengthening of the MAM HC. The robust warming trends of sea surface temperature (SST) over the Indo–Pacific warm pool (IPWP) play an essential role in the variations of the MAM HC. When SST over the IPWP is warm, anomalous meridional circulation is induced with descending branches located in regions 30°–20°S and 5°–15°N in each hemisphere and rising located near 10°S. The anomalous rising south of the equator is due to the inhomogeneous warming of SST over the IPWP. SST within the IPWP in the Southern Hemisphere shows a larger warming trend than that in the Northern Hemisphere. The position of the anomalous convergence associated with SST variations over the IPWP is aligned with the maximum meridional gradient of zonal mean SST, resulting in an equatorially asymmetric meridional circulation. This point is further established in theoretical analyses. However, the meridional SST gradient within IPWP shows a decreasing trend, suggesting the associated anomalous meridional circulation intensifies, which in turn explains the strengthening of the MAM HC. Under this scenario, the accompanied descent in the regions of 30°–20°S and 5°–15°N is enhanced, implying a frequent drought in these regions during MAM.

IAMAS (Meteorology)

M10c - M10 Global Monsoons and Climate Change

IUGG-0683

Linkages between the South and East Asian Summer Monsoons

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Connections between the South Asia Monsoon (SAM) and the East Asia Monsoon (EAM) that are controlled by external forcings and internal dynamics have been a long-standing and controversial issue in climate science. This study reviews the linkages between the two monsoon systems as revealed in modern records and model simulations of the past, present, and future, and provides a comprehensive explanation of the key mechanisms controlling the diversity of the SAM-EAM relationship. Particular attention is paid to several external forcings that modulate the relationship, including El Niño and Southern Oscillation (ENSO), Indian Ocean Dipole mode (IODM), boreal summer teleconnection, and Eurasian snow on intraseasonal to interdecadal timescales. The present study focuses on two integral views of the inter-connection between the two monsoon systems: one is the positive inter-correlation, which is associated with decaying El Niño and developing Indian Ocean SST warming anomalies, hereby referred to as the western North Pacific–North America (WPNA) teleconnection pattern; the other is the negative inter-correlation, resulting from developing El Niño and western Pacific SST cooling, and the circumglobal teleconnection pattern (CGT). The IODM mode also has a delayed impact on the negative connection by modulating Eurasian snow cover. The observed evidence reveals that the recent intensification of the negative relationship is attributable to the strengthening of the zonal SST gradient between the Indian Ocean, the western Pacific, and the eastern Pacific. Analysis of experiments in the CMIP5 further indicates a possibility for the negative linkage to be further enhanced under anthropogenic global warming with considerable interdecadal modulation in mid and late 21st century.

IAMAS (Meteorology)

M10c - M10 Global Monsoons and Climate Change

IUGG-3125

Probabilistic changes in precipitation due to anthropogenic climate change

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Typically, climate change modelling studies assess changes and uncertainty using multi-decadal averages of seasonal mean quantities (Tebaldi et al. 2005; Lopez et al. 2006, Collins et al. 2013, Kitoh et al. 2013, Wang et al. 2014, Sperber et al. 2014). Using 5-day averaged precipitation from a comprehensive suite of climate models (Taylor et al. 2012), the added-value of this work is the assessment of probabilistic changes in summer precipitation in terms of amount, onset and, withdrawal date, and duration through the analysis of probability distributions of interannual anomalies. The sensitivity of the climate change projections to the quality of the annual cycle of precipitation is explored. We find that compared to the Historical simulations, in the RCP8.5 simulations the precipitation increases ~6-40% over India, East Asia, Sahel, Australia, and in the Northern Hemisphere extratropics the signal becomes stronger toward the poles. Precipitation decreases of ~4-12% dominate the North and South American monsoon, with decreases >12% over the Mediterranean and portions of the subtropical anticyclones. Using Historical simulation thresholds for three equally probable categories, these RCP8.5 changes in precipitation amount have probabilities of ~0.5-0.8, indicating substantial changes to the frequency of years with below-normal and above-normal precipitation, respectively. These changes, and those associated with the perturbations to the timing and duration of precipitation enhance stressors that are expected to have adverse impacts on agriculture (Challinor et al. 2014, Porter et al. 2014), hydro-meteorological services (Reisinger et al. 2014), and the prevalence of vector-borne disease (Craig et al. 1999, Thompson et al. 2006, Siraj et al. 2014).

IAMAS (Meteorology)

M10c - M10 Global Monsoons and Climate Change

IUGG-4913

Anaylsys of heating mechanisms of sea surface temperatures over tropical oceans after the mature phase of El Nino

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It is well established that after the mature phase of El Nino in winter season, sea surface temperatures over wide areas of tropical oceans rise almost simultaneously. This sea surface temperature variation coincides with the global rise of tropical tropospheric temperatures. The teleconnection between the sea surface temperatures over the eastern tropical Pacific and global oceans are called the 'atmospheric bridge'. In the present study, we reinvestigated the heating mechanisms of global oceans using ERA-Interim. We focused on the Indian Ocean, the Atlantic Ocean, and the eastern tropical Pacific Ocean. We analyzed the surface heat flux over these oceans for four major El Nino events for 1980-2010. In some cases, the reduction of upward latent heat flux and increase of insolation triggered the heating of sea surface temperatures over the Indian and Atlantic Oceans. However, sometimes, the trigger was missing. In almost all cases, the heating by the downward thermal radiation was prominent. The net thermal radiation played roles in the sea surface temperature heating. In 1982-83 El Nino event, the sea surface temperature was low especially over the Atlantic Ocean. This might be the effect of aerosols due to the volcanic eruption of El Chichon.

IAMAS (Meteorology)

M10c - M10 Global Monsoons and Climate Change

IUGG-5083

Relative roles of ENSO and IOD in determining the seasonal mean monsoon rainfall over India

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Among the prominent modes of variability exhibited by the South Asian monsoon, one of them is related to El Niño-Southern Oscillation (ENSO) and the other with the Indian Ocean Dipole (IOD). These two modes are manifested in the atmospheric variables such as precipitation, circulation and outgoing longwave radiation. They persist without much variability during any season but vary from year to year and exhibit interannual variability. The relative strengths of ENSO and IOD modes seem to determine a large part of the seasonal mean rainfall over India. The IOD mode can constructively interfere with the ENSO mode during certain years to enhance the impact of ENSO on monsoon while it can destructively interfere with the ENSO mode, such as in 1997, to produce a normal monsoon. The performance of the models to predict the seasonal mean rainfall over India depends on their ability to correctly simulate the relative strengths of the atmospheric response to ENSO and IOD. This hypothesis is tested in the retrospective forecasts of a group of coupled models that includes NCEP CFSv2 and ECMWF coupled model. The ENSO and IDO modes in the atmospheric variables are extracted from daily forecasts, and their contributions to the seasonal mean rainfall are determined. The performance of the models in predicting the seasonal mean monsoon rainfall over India is assessed by comparing with observation.

IAMAS (Meteorology)

M10d - M10 Global Monsoons and Climate Change

IUGG-0666

The decadal variability of the tropical Indian Ocean SST-the South Asian High relation: CMIP5 model study

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Based on Coupled Model Intercomparison Project phase 5 (CMIP5) models, present study investigates the decadal variability of the tropical Indian Ocean (TIO) sea surface temperature (SST)–the South Asian High (SAH) relation (hereafter TSR) as well as its responses to the global warming. Out of the 17 CMIP5 models, only one (GFDL-CM3) reproduces reasonably the influence of the TIO SST on the SAH. In the historical simulations of GFDL-CM3, the TSR features fluctuations modulated by the western Pacific SST and the Indian subcontinent precipitation. When the TIO warming is accompanied by warm western Pacific, the western Pacific SST-induced tropospheric warming propagates westwards, warms the troposphere surrounding the Indian Ocean, enhances SAH and leads to higher TSR; when accompanied by not so warmed western Pacific, the TSR is lower. While, if the TIO warming is accompanied by negative rainfall anomalies over the Indian subcontinent, the rainfall-induced upper-troposphere cyclone over the subtropical Asia weakens the response of the SAH and leads to lower TSR; if not accompanied by negative rainfall anomalies, the TSR is higher. The decadal variability of the TSR is not subject to the global warming. In RCP45 and RCP85 scenarios, the TSR is also not directly affected by global warming. The rainfall over the Indian subcontinent is still a factor modulating the TSR. While, the western Pacific SST is invalid in the influences of the TIO SST on the SAH.

IAMAS (Meteorology)

M10d - M10 Global Monsoons and Climate Change

IUGG-1008

Changes in precipitation over East Asia projected by Global Atmospheric Models with 20-km and 60-km grid sizes

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A set of global warming projections was conducted using global atmospheric models with high-horizontal resolution of 20-km (MRI-AGCM3.2S, the 20-km model) and 60-km (MRI-AGCM3.2H, the 60-km mode) grid sizes. For the present-day climate (1979-2003, 25 years), models were forced with observed historical sea surface temperatures (SST). For the future climate (2075-2099, 25 years, RCP8.5), models were forced with future SST distributions projected by the models of the Fifth phase of Couple Model Intercomparison Project (CMIP5). The uncertainty of projection was evaluated by ensemble simulations for four different SST distributions and three different cumulus convection schemes.
The increase of precipitation over China is consistently found for all the simulation by the 20-km and 60-km models from May to August. Precipitation change by the 20-km model over Japan tends to decrease from June to August especially in June. The projections by the 20-km model indicate the delay in the onset of rainy season over Japan. The increase of precipitation intensity is consistently found over Japan and China for all the simulations regardless of differences in SST distribution and cumulus convection scheme. In some cases changes projected by 60-km models are not consistent with 20-km models. Precipitation changes in May and June can be attributed to the change in water vapor transport associated with the southward shift of the subtropical high. In July and August, precipitation changes can be attributed to the change in water vapor transport associated with the intensification of the subtropical high.

IAMAS (Meteorology)

M10d - M10 Global Monsoons and Climate Change

IUGG-4573

Convection and its upscale effects in the Indian Monsoon: Insights from convection-permitting multi-day simulations over Indian Subcontinent

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Met Office Unified Model (UM) climate simulations, like many global models, show large errors in rainfall for the Indian Summer Monsoon, with a wet bias over the equatorial Indian Ocean, and a dry bias over India. Here we use the first multi-day continental-scale UM simulations, with grid-spacings that allow explicit convection, to examine how convective parametrisation contributes to the growth of these biases. We focus on the diurnal cycle of convective cloud and precipitation and how this interacts with the larger scale circulation and transport of moisture.

UM simulations for a 21 day period (21 Aug to 9 Sep 2011), with an overlap in grid-spacing between convection-permitting (12, 8, 4 and 2.2 km) and parametrised (120, 24, 12 and 8 km) runs, are analysed. The explicit simulations have a greatly improved diurnal cycle of rainfall over India, but peak 1-2 hours earlier than observed. The parametrised runs peak 4-5 hours early, a problem common to many global models. The delay in convective rainfall and cloud in the explicit runs allows greater surface insolation and generates a greater land-sea temperature contrast, enhancing onshore flow of moist air. Greater rainfall in explicit runs corresponds to greater latent heating of the atmosphere (with a magnitude that dominates the differences in radiative heating). This generates a deeper monsoon trough in explicit runs, again favouring transport of water vapour into the continent. These differences are found to be a function of convection, not model timestep.

Model differences are shown to evolve significantly through the 21-day period, in particular with the arrival of a low pressure system over India from the Bay of Bengal on 29 Aug. The contribution of this to the differences in mean state are discussed.

IAMAS (Meteorology)

M10d - M10 Global Monsoons and Climate Change

IUGG-4924

Exacerbation of South Asian monsoon biases in GCMs using when using coupled ocean models

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Cold biases during spring in the northern Arabian Sea of coupled ocean-atmosphere GCMs have previously been shown to limit monsoon rainfall over South Asia during the subsequent summer, by limiting the availability of moisture being advected. The cold biases develop following advection of cold dry air on anomalous northerly low level flow, suggestive of a too-strong winter monsoon in the coupled GCMs. As the same time, these cold biases and the anomalous advection have been related to larger scales by interaction with progression of the midlatitude westerly upper level flow.

In this study we compare monsoon characteristics in 20th century historical and AMIP integrations of the CMIP5 multi-model database. We use a period of 1979-2005, common to both the AMIP and historical integrations. While all available observed boundary conditions, including sea-surface temperature (SST), are prescribed in the AMIP integrations, the historical integrations feature ocean-atmosphere models that generate SSTs via air-sea coupled processes.

In AMIP experiments, the seasonal mean monsoon rainfall is shown to be systematically larger than in the coupled versions, with an earlier onset date also shown using a variety of circulation and precipitation metrics. In addition, examination of the springtime jet structure suggests that it sits too far south in the coupled models, leading to a delayed formation of the South Asia High over the Tibetan Plateau in summer. Further, we show that anomalous low entropy air is being advected near the surface from the north over the Arabian Sea in spring in the coupled models.

IAMAS (Meteorology)

M10d - M10 Global Monsoons and Climate Change

IUGG-5504

Overview of global monsoons modeling inter-comparison project : GMMIP

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Monsoons occur in various regions around the world. Prediction of the monsoon rainfall change in the coming decades is of deep societal concern and vital for infrastructural planning, water resource management, and sustainable economic development. Climate models are useful tools in climate variability and climate change studies. However, the performance of the current state-of-the-art climate models is very poor and needs to be greatly improved over the monsoon domains. The Global Monsoons Modelling Inter-comparison Project (hereafter **GMMIP**) aims to improve our understanding of physical processes in global monsoon systems and to better simulate the mean state, interannual variability and long-term change of global monsoons by performing multi-model inter-comparisons. The contributions of internal variability (IPO-Interdecadal Pacific Oscillation, AMO-Atlantic Multidecadal Oscillation) and external anthropogenic forcing to the historical evolution of global monsoons in the 20th and 21st century will be addressed. This talk will present an overview of GMMIP project and show some preliminary results of GMMIP Tier-1 and Tier-2 Experiments. The contributions of internal variability and external forcing to global monsoon precipitation changes during the 20th century will be discussed.

IAMAS (Meteorology)

M10e - M10 Global Monsoons and Climate Change

IUGG-0020

Trends in pre-summer frontal and diurnal rainfall activities during 1982-2012 over Taiwan and Southeast China

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Frontal convection (FC) and diurnal convection (DC) are the two most frequently observed weather systems affecting the pre-summer (May and June, MJ) rainfall formation over Taiwan and Southeast China. Focusing on the time period of 1982-2012 MJ months, this study found that the occurrence frequency of FC has declined, but the occurrence frequency of DC has significantly increased over Taiwan and Southeast China. Diagnoses of the atmospheric thermodynamic conditions over the East Asia-Western North Pacific (EAWNP) region indicate that the area favorable for the FC formation (i.e., the area with an increase in meridional temperature gradient) has shifted northward from 20°-30°N to north of 30°N during the recent three decades; this shift has led to a decline in FC numbers over Taiwan and Southeast China. Analyses also indicate that the recent increase in DC activities over Taiwan and Southeast China after 1982 occurred in association with an observed strengthening of the daytime land-sea thermal contrast coupled with an intensification of the afternoon sea-breeze over the EAWNP region and an enhancement of moisture availability along the east coast of China. Possible causes for the observed changes in the atmospheric thermodynamic conditions over the EAWNP region are also discussed.

Reference: Huang, W.-R. and Chen, K.-C. (2014), Trends in pre-summer frontal and diurnal rainfall activities during 1982–2012 over Taiwan and Southeast China: characteristics and possible causes. Int. J. Climatol.. doi: 10.1002/joc.4159

IAMAS (Meteorology)

M10e - M10 Global Monsoons and Climate Change

IUGG-0276

Variations of Broad-scale Asian summer monsoon circulation and possible causes

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The widely applied Webster–Yang index (WYI), which measures the broad-scale dynamical features of the Asian summer monsoon (ASM), has experienced robust interannual and interdecadal variations and a decreasing tendency, with apparent shifts in 1972. The WYI exhibits moderate variability and frequent positive phases before 1972, intensive interannual variability during 1972–98, and an obvious decreasing tendency and mainly negative phase afterward. The vertical shear easterly anomalies over the tropics/subtropics and the anomalous vertical shear anticyclonic circulation over Eurasia (Eu) are the background for the decreasing WYI. On interdecadal time scales, the negative (positive) Atlantic multidecadal oscillation (AMO) is characterized by cooling (warming) in Eurasian tropospheric temperature (TT) via the North Atlantic Oscillation. Global warming manipulates the increasing tendency and the interannual variability of TT over the Indian Ocean (IO). The mutual effects of AMO on Eurasian TT and global warming on Indian Ocean TT correspond to the similar decreasing tendency and interdecadal shift of the difference in TT between Eurasia and the Indian Ocean (EuTT - IOTT) with those of the ASM. Although the interannual relationship between Niño-3 SST and ASM weakens recently as a result of the weakening tendency of ASM, the Niño-3 SST still plays an important role in ASM variability via EuTT - IOTT anomalies. In addition, the WYI in the National Centers for Environmental Prediction–National Center for Atmospheric Research (NCEP–NCAR) reanalysis shows a larger decreasing tendency for 1999–2010 compared to other reanalysis products, a plausible reason for the inconsistent variations between land–sea thermal contrast and the NCEP–NCAR WYI during that period.

IAMAS (Meteorology)

M10e - M10 Global Monsoons and Climate Change

IUGG-2762

Variability and Predictability of the Northern Hemisphere Summer Tropical-Extratropical Teleconnection: The mid-1970s shift

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Two dominant global-scale teleconnections, namely the western North Pacific-North America (WPNA) and circumglobal teleconnection (CGT) patterns, in the Northern Hemisphere (NH) extratropics during boreal summer season (June-July-August) have been identified as important sources for the NH summer seasonal climate variability and predictability. This study investigates interdecadal change in interannual variability and predictability of the WPNA and CGT occurred around late 1970s using reanalysis data and six coupled models' retrospective forecast with May 1st initial condition for the 46 years of 1960-2005. In observation, the interannual variance of the WPNA has been decreased by 5% mainly due to the weakened relationship between its Hemispheric uniform pattern and the decaying phase of El Nino and Southern Oscillation (ENSO), but that of the CGT has been considerably increased by 17% attributable to the enhanced linkage between its zonally symmetric seesaw pattern and the developing phase of ENSO after the late 1970s. It is further noted that the WPNA wave pattern has been highly enhanced due to its strengthened relationship with the WNP summer monsoon rainfall (correlation coefficient (r) change from 0.1 to 0.5) whereas the CGT wave pattern has been considerably weakned owing to its weakened connection with Indian summer monsoon rainfall (r change from 0.47 to 0.24). The multi-model ensemble (MME) prediction using six coupled model has the decreased (increased) forecast skill from 0.78 (0.23) to 0.67 (0.67) for the WNPA (CGT) variation. Predictable mode analysis indicates that potential predictability and actual dynamical models' forecast skill have been slightly increased over the entire extratropics in the NH after the late 1970s.

IAMAS (Meteorology)

M10e - M10 Global Monsoons and Climate Change

IUGG-3620

Oceanic influence of Asian monsoon observed from space

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Large-scale rainfall over the Asian continent is largely affected by monsoons, the seasonal change of winds caused by the reversal of land-ocean temperature gradient. Over land, the consequences of monsoon vagary are well observed, but the breeding ground over ocean has not been sufficiently monitored. The influence of multiscale processes, from synoptic to interannual can only be sufficiently observed from the vantage point of space. We have developed and validated a method to derive the integrated moisture transport from wind measured by QuikSCAT representing surface stress, and cloud-drift winds at 850 mb representing free stream velocity, and vertically integrated water vapor measured by satellite sensors, based on support vector regression. until recently by spacebased sensors. Ocean's role in rainfall over the Asian continent, through El Nino and tropical cyclones is revealed using recent high-resolution spacebased data. The feedback of soil moisture changes to the onset and development of Asian monsoon is also examined.

IAMAS (Meteorology)

M10e - M10 Global Monsoons and Climate Change

IUGG-3935

Role of multidecadal Pacific variability for the 1950-1999 Indian summer monsoon drying

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The observed summertime drying over Northern Central India (NCI) during the latter half of the 20th century is not reproduced by the Coupled Model Intercomparison Project Phase 5 (CMIP5) model ensemble average. At the same time, the spread between precipitation trends from individual model realizations is large, indicating that internal variability potentially plays an important role in explaining the observed trend. Here it is shown that the drying is indeed related to the observed 1950-1999 positive trend of the Pacific Decadal Oscillation (PDO) index and that the relationship is even stronger for a simpler index (S1). Adjusting the CMIP5 simulated precipitation trends to account for the difference between the observed and simulated PDO index and S1 trends increases the original multi-model average NCI drying significantly. On average, the drying that is associated with Pacific decadal variability is found to be of similar magnitude as the drying due to anthropogenic aerosol.The drying (moistening) associated with a increasing (decreasing) S1 can be attributed to an eastward (westward) shift of the boundary between ascent and descent affecting NCI. This shift of the ascent region strongly affects NCI, but not Southeast Asia and south China. The average spread between individual model realizations is only slightly reduced when adjusting for S1 since smaller scale variability also plays an important role. S1 is insensitive to anthropogenic forcing and thus the 1950-1999 S1 trend reflects internal variability.

IAMAS (Meteorology)

M10f - M10 Global Monsoons and Climate Change

IUGG-0742

Two distinct intraseasonal oscillations in summer rainfall over the eastern Tibetan Plateau

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During summer, the weather disturbances over the eastern Tibetan Plateau (ETP) can initiate development of severe weather system downstream, causing flooding in East Asia. In this study, we detected two dominant peak using daily rainfall data over the ETP during the period of 1992–2007. Composite analysis revealed that the two modes with different periodicity were predominantly produced by the non-stationary wave trains in the upper tropospher. For the 15-day mode, the wave train featured a southeastward migration, originating in the Barents Sea and traveling via the East European Plain, the Ural Mountains, Lake Balkhash and Lake Baikal, the Mongolian Plateau, and then continued southward to the ETP and South Asia. In contrast, the 9-day wave train propagated eastward along the westerly jet, extending from the eastern North Atlantic via the Mediterranean, Black and Caspian seas towards the ETP, East Asia and Southeast China. These two transient wave trains took place on different large-scale background circulations: a meridional pattern with a “Giant Ural Mountain Ridge” for the 15-day mode and a zonal pattern with “Western Siberian Trough” for the 9-day mode. In terms of simultaneous downstream linkage, the ETP rainfall anomaly was out-of-phase with the rainfall anomaly over the Yangtze River Basin for the 15-day mode but in-phase with the 9-day mode. The major processes generating the local wet spells for the two modes were found to be commonly linked to topographic lift and mid-tropospheric latent heat release, but the moisture sources are somewhat different. The evolution of the intraseasonal variability over the ETP described here may provide a useful guidance for 2–3 week (extended range) forecasts over the ETP and its downstream regions.

IAMAS (Meteorology)

M10f - M10 Global Monsoons and Climate Change

IUGG-1417

A partial mechanistic understanding of the North American monsoon

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An understanding of the governing processes of the North American monsoon (NAM) system is necessary for climate modeling and predicting the NAM's impacts on the summer circulation, precipitation, and drought over North America. A mechanistic understanding of the NAM is suggested by incorporating local- and synoptic-scale processes. Using ship-launched soundings over the Gulf of California (GC) during the North American Monsoon Experiment (NAME), the local-scale mechanism describes how the low-level inversion over the GC inhibits the moisture transport from the moist marine boundary layer (MBL) to the overlying air. This inversion weakens with increasing GC sea surface temperatures (SSTs) and generally disappears once SSTs exceed 29.5°C, allowing the MBL moist air to mix with free tropospheric air. This leads to a deep, moist layer that can be transported by across-gulf (along-gulf) flow toward the NAM core region (southwestern U.S.) to form thunderstorms. On the synoptic scale, climatologies from 1983 to 2010 exhibit a spatial-temporal correspondence between coastal warm tropical surface water, NAM deep convection, the NAM anticyclone center, and NAM-induced strong descent. Based on soundings at the GC entrance, surface current measurements, these climatologies and the relevant literature, we propose that the warmest SSTs moving up the coast may initiate NAM convection and atmospheric heating, advancing the NAM anticyclone and the region of descent northward. This steers mid-level moisture into the NAM region, enhancing NAM rainfall. These processes appear related to the California Current, the Mexican Coastal Current and the North Pacific High.

IAMAS (Meteorology)

M10f - M10 Global Monsoons and Climate Change

IUGG-4287

Present and future projected changes of asian summer monsoon evolution and intensity in CMIP models

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The evolutions of Asian summer monsoon (ASM) are detected and evaluated based on the models in Couple Model Intercomparison Projects Phase-3 and Phase-5 (CMIP3 and CMIP5) for the 20th Century climate simulation (20c3m and Historical runs, respectively). Considering that the individual models have various biases in rainfall amount simulation, instead of applying a fixed rainfall criterion as used in observation, we use model-dependent rainfall criteria to identify the simulated ASM onset, retreat, and duration. This model-dependent criterion is defined as the height in cumulative distribution function (CDF) of simulated precipitation that the observed criterion occurs. Based on this method, the multi-model ensembles (MMEs) of CMIP3 and CMIP5 both show a delayed monsoon onset but an earlier retreat relative to the observations, indicating that models tend to underestimate the monsoon period. The MME results show a skill in capturing the ASM domain which features monsoon rainfall characteristics, whereas a large spread is found among individual models. Overall, the state-of-the-art CMIP5 models show slightly improvements from the CMIP3 models in the simulations of ASM domain and evolutions. Models with a hybrid method based on bulk mass flux and CAPE closure schemes perform better than models with other types of convection parameterization. For the future projections of ASM evolutions under RCP4.5 and RCP8.5 scenarios, the CMIP5 model tends to show earlier onset and delayed withdraw. Therefore, one would expect a increase of the length of ASM season. CMIP5 model also project a larger ASM domain and mean rainfall intensity near the end of 21 century.

IAMAS (Meteorology)

M10f - M10 Global Monsoons and Climate Change

IUGG-4916

Interannual variability of the East Asian winter monsoon and related modulations of the planetary waves

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Interannual variability of the East Asian winter monsoon has been investigated on the basis of observational data over the recent 50 years. Although the winter monsoon activities themselves are confined within the lower troposphere, their variability in mid-winter tends to be associated with upper-tropospheric geopotential height anomalies similar to the Eurasian (EU) pattern and the Western Pacific (WP) pattern. In the "EU-like" pattern, a wavy signature similar to the EU pattern can be found over the Eurasian continent. In the "WP-like" pattern, a meridional dipole pattern similar to the WP pattern can be found over the Far East region.

The variability of the atmospheric circulations may relate to modulations of the planetary wave formations associated with a seasonal march from late autumn to midwinter. In the climatological seasonal march, geopotential height in the upper troposphere generally lowers since temperature in the lower troposphere also decreases toward midwinter. Decreasing tendencies are especially strong in the mid-latitudes. They are, however, very weak in high latitudes, especially over the eastern Siberia and Alaska, and even a positive tendency can be found over the Bering Straight. Such an asymmetry in the height tendencies corresponds to evolutions or formations of the planetary waves: weak (strong) decreasing signals mean anticyclonic (cyclonic) tendencies, which tend to form ridges (troughs) of the planetary waves. In the seasonal marches in the WP-like patterns, anticyclonic tendencies over the eastern Siberia and Alaska region are strengthened (weakened) in cold (warm) Januaries over the Far East. Even for the EU-like patterns, we can verify similar patterns of the seasonal march.

IAMAS (Meteorology)

M10f - M10 Global Monsoons and Climate Change

IUGG-5057

Diurnally developed coastal rainfall and lightning over Jakarta, Indonesia - Preliminary results of Jakarta Lightning Study (JALS) 2015 campaign

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Lightning frequency over Indonesian Maritime Continent (IMC) is quite high. In particular, Bogor (south of Jakarta) has more than 300 days of lightning every year and up to 322 days in 1988 as recorded in the Guinness Book. Lightning causes serious damages on nature and society over the IMC; forest fire, power outage, inrush/surge currents on many kinds of electronics. We have started to examine lightning climatology and mesoscale characteristics of thunderstorm over the IMC, in particular around Jakarta where social damage is quite serious.

Statistical analysis of lightning and thunderstorm based on TRMM LIS and GSMaP together with long-term surface operational observation data. 13-years SYNOP data shows unique lightning characteristics in terms of diurnal, intraseasonal, and seasonal variations, as well as their dependence to geographical locations, i.e., elevation and proxy to nearest coastline. In addition, we carried out a two weeks campaign observation in February 2015 as a part of MAHASRI to obtain mesoscale structure and dynamics of thunderstorm over Jakarta to focus on graupel and other ice phase particles inside by using a dual-polarimetric radar, intensive soundings with Hydormeter Video Sondes (HYVISs), and VLF receiver network to monitor lightning activity. Climatology of lightning over Jakarta, over view of the campaign, and it preliminary results focused on diurnally developed coastal thunderstorm are briefly resented.

IAMAS (Meteorology)

M10f - M10 Global Monsoons and Climate Change

IUGG-5459

Convective activity over the south american monsoon system and stratospheric water vapor

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Water vapor in the lower stratosphere has an important role in the Earth's energy balance and can directly impact the stratospheric circulation and chemistry. Deep tropical convective activity can inject significant water vapor amounts in the lower stratosphere. The South American Monsoon System (SAMS) is the most important climatic feature in South America and is characterized by intense convective activity and heavy precipitation. This study uses the National Centers for Environmental Prediction Climate Forecast System reanalysis and the Weather Research and Forecasting WRF model to produce downscaled fields with 15 km horizontal grid spacing over South America. Downscaling is produced for extended summer seasons (1 November – 31 March, 1998-2013). Precipitation from WRF is compared against Tropical Rainfall Measurement Mission TRMM data. The presentation will discuss periods of enhanced convective activity over the western Amazon and the ability of WRF to realistically represent water vapor in the lower stratosphere.

IAMAS (Meteorology)

M10p - M10 Global Monsoons and Climate Change

M10p-216

A case study of the impact of boreal summer intraseasonal oscillations on Yangtze rainfall

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The impact on Yangtze rainfall of the boreal summer intraseasonal oscillations over the entire Asian summer monsoon region during summer 1996 was investigated using the APHRODITE gridded rainfall and the NCEP–DOE reanalysis II products. Wavelet analyses suggest that the intraseasonal oscillations of Yangtze rainfall were regulated mainly by both 30–60- and 10–25-day oscillations, respectively linked to the first and second boreal summer intraseasonal oscillation modes. Phase locking of the wet phases of these two intraseasonal oscillations resulted in a prolonged wet episode from late June to mid-July. The circulation evolution of the first boreal summer intraseasonal oscillation mode showed that active convection accompanied by strong convergence of anomalous zonal winds first developed over the equatorial Indian Ocean, with suppressed convection over the South China Sea–Philippine Sea and with active convection over the Yangtze Basin. The triple convection anomaly that aligned meridionally in the East Asian sector arose from a local meridional–vertical cell associated with a Rossby wave-like coupled circulation–convection system. The opposite flow patterns occurred during the dry phase of Yangtze rainfall. The composite cases of the second boreal summer intraseasonal oscillation mode demonstrated a weak convective anomaly initially appeared around the Maritime Continent, with a huge anomalous anticyclone accompanied by suppressed convection over the South China Sea–Philippine Sea. The low-level convergence of the anomalous southwesterlies on the northwestern side of the anticyclone and the consequent ascent led to positive rainfall anomalies over the Yangtze Basin.

IAMAS (Meteorology)

M10p - M10 Global Monsoons and Climate Change

M10p-218

Covariability of western tropical Pacific-North Pacific atmospheric circulation during summer

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North Pacific subtropical high (NPSH) is permanent high-pressure system over the Northern Pacific Ocean and it extends to the western North Pacific during the boreal summer (June-July-August), which is so called the western North Pacific subtropical high (WNPSH). The in-phase relationship of NPSH-WNPSH plays an important role in modulating tropical storm and extreme weather over the Eurasia–North Pacific–North America sector. Here, we examine the covariability of the NPSH-WNPSH during summer using both observation and Coupled Model Intercomparison Project phases 5 (CMIP5) model data. The NPSH-WNPSH covariability shows significant decadal variability and the in-phase relationship of NPSH-WNPSH is enhanced during recent decade. Our analysis indicates that warming of the sea surface temperature in the tropical Indian Ocean and western Pacific plays a key role to enhance the covariability of the NPSH-WNPSH. However, the strengthening of covariability of NPSH-WNPSH is unclear in the future climate, reflecting that a substantial part of strengthening NPSH-WNPSH covariability arises from the natural decadal-to-interdecadal variability.

IAMAS (Meteorology)

M10p - M10 Global Monsoons and Climate Change

M10p-219

Effects of Tibetan Plateau and Tropical Ocean on autumn rainfall variation in Southwest China

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Possible influences of thermal forcing in Tibetan Plateau and Tropical Ocean on the Southwestern China (SWC) autumn rainfall inter-annual variation are studied based on data analysis for the autumns of 1980–2010. Inter-annual variation of autumn rainfall in SWC is correlated with the anomaly of southeastern TP sensible heating (TPesSH), Indian Ocean Dipole mode (IOD) and sea surface temperature of the Eastern Pacific Ocean (Nino3). Their individual effect can be identified and compared by partial regression/correlation method. Positive anomaly of TPesSH arouses an anomalous cyclone in situ which brings water vapor from the south slope of Tibetan Plateau to SWC, causing positive rainfall anomaly, especially in western SWC. Cold source at the eastern Indian Ocean associated with positive IOD event inspires anticyclone at the Bay of Bengal region which transports water vapor from the Indian Ocean to SWC, resulting in positive rainfall anomaly. Adjustment of Walker circulation for positive sea surface temperature anomaly in the Nino3 region is in favor of negative precipitation anomaly in SWC. The contribution of TPesSH to SWC area averaged rainfall is maximum, followed by IOD, and heating in the Nino3 region makes a negative contribution after excluding other two factors' effects. Regressed precipitation based on these three factors is correlated with original rainfall more significantly than that based on any individual factor, indicating that it's essential to take all the three factors into consideration. In summer, Nino3 index, Indian Ocean Dipole mode and sensible heating flux in Hetao area are significantly correlated with autumn SWC rainfall, which can be used as seasonal predictors for autumn SWC precipitation.

IAMAS (Meteorology)

M10p - M10 Global Monsoons and Climate Change

M10p-220

Australian monsoon bursts

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The wet phase of the Australian monsoon is well characterized by sub-seasonal periods of excessively wet or dry conditions, commonly know as monsoon bursts and breaks. This study is concerned with the synoptic evolution prior to monsoon bursts, which are defined here by abrupt transitions of the area-averaged rainfall over the tropical parts of the Australian continent.

There is large variability in the number of monsoon bursts from year-to-year and the time interval between consecutive monsoon bursts. Reanalysis data are used to construct a lag composite of the sequence of events prior to a monsoon burst. It is determined that a burst in the Australian monsoon is preceded by the development of a well-defined group of extratropical disturbances in the Indian Ocean, which propagates toward the Australian continent in the few days leading up to the onset of heavy rainfall in the tropics. Consistent with previous studies on the monsoon onset, the extratropical disturbances propagate equatorward in the presence of the subtropical jet over Australia. The extratropical systems are accompanied by lower tropospheric fronts which also propagate into low latitudes. Ahead of these fronts, relatively warm moist air is advected from the surrounding oceans, locally increasing the convective available potential energy and the likelihood of convection.

Commonly employed climate indices shows that monsoon bursts are more likely to occur when the active phase of the Madden-Julian Oscillation is in the vicinity of Australia. Neither the El-Nino Southern Oscillation nor Southern Annular Mode have a significant impact on the occurrence of monsoon bursts.

IAMAS (Meteorology)

M10p - M10 Global Monsoons and Climate Change

M10p-221

The interdecadal variation of South China Sea summer monsoon onset and its thermodynamic mechanism

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The South China Sea summer monsoon onset dates are in a significant tendency of advance in recent 20 years. The relationship between the South China Sea summer monsoon onset and the reversal of meridional temperature gradient in the middle and upper troposphere around the South China Sea is explored. The thermodynamic mechanism in the interdecadal variation of the South China Sea summer monsoon onset is also studied. It is found that the reversal dates of meridional temperature gradient in the middle and upper troposphere around the South China Sea have a significant positive correlation with the SCSSM onset dates. Both of them show a significant advance around 19993/1994. Furthermore, a interdecadal warming around 1993/1994 is also detected in the middle and upper troposphere of the northern SCS in May, whereas there is no evident interdecadal variability in the southern SCS. Specific to pentad timescale, it is the significant warming during the period from the 26th pentad to the 28th pentad (May 6-20) in the northern SCS that plays a key role in the early overturning of the meridional temperature gradient, which is also a direct cause of the interdecadal advance in temperature transition in the middle and upper troposphere. As for the southern SCS, the temperature variability in the 28th pentad to the 30th pentad (May 16-30) has a great influence on the late overturning of the meridional temperature gradient. The temperature variability of the middle and upper troposphere in both the northern and southern SCS is mainly caused by diabatic heating and adiabatic ascending motion, which is mainly attributed to the anomaly of the vertical velocity.

IAMAS (Meteorology)

M10p - M10 Global Monsoons and Climate Change

M10p-222

Future changes in precipitation and atmospheric fields during the baiu season under RCP scenarios

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Recently, the relationship between global warming and rainfall during the rainy season, which called the baiu in Japan, has been attracting attention. In previous studies, it was examined for future changes in the this season based on the IPCC SRES A1B scenario. Many studies show a delay in the northward march of the baiu front (e.g., Kusunoki et al. 2011). We have intended that these results to verify whether occurring in what mean atmospheric fields.
In this study, we discuss the future changes in precipitation using calculated 60km- and 20km-mesh models (MRI-AGCM3.2H and S) under Representative Concentration Pathways (RCP) scenarios. Support of this dataset is provided by the Meteorological Research Institute (MRI).
These models show that the weak trough exist in upper troposphere around Japan. Therefore, the cold advection stays in the northern part of Japan during June. In July, the front due to the strengthening of the Bonin high moves northward, and then it stays until August. The mean field of future August also show the inflow of rich water vapor content to Japan islands. The results shown in previous studies are apparent from the point of view of atmospheric fields.
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IAMAS (Meteorology)

M10p - M10 Global Monsoons and Climate Change

M10p-223

Climate responses to aerosol-cloud interaction on east asian monsoon

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In order to investigate influence of anthropogenic aerosols emissions on the East Asian summer climate, single forcing experiments of aerosols and GHGs are compared with historical simulations using UK Met Office HadGEM2-AO. Since the mide-20th century, anthropogenic aerosol emission and total AOD increase over East Asia, which is distinct in sulphate aerosol. The aerosols induce negative radiative forcing at the top of atmosphere through directly scattering the solar radiation and indirectly interacting with clouds. In this study we are interested in indirect aerosol effect. Model tends to simulate ISCCP cloud type over East Asia. In the simulation, the spatial distribution of net radiative flux change at the top of the atmosphere in clear-sky condition is consistent with that of total AOD change, whereas the cloud radiative forcing in cloudy-sky condition was dominant over ocean to the north of 30°N. Increasing aerosols affects reducing cloud droplet effective radius, thereby increasing low-level cloud fraction and extending cloud thickness. The large response in cloud radiative effect over ocean is mainly caused by the increase of Stratocumulus fraction that is typical cloud type during summer monsoon season. Strong negative radiative forcing was exhibited over large area from southeast China to north of the Korean peninsula. This cooling at the surface over the land decrease the surface pressure gradient between land and ocean, leading to less moisture and precipitation in southeast China, therefore the East Asian summer monsoon is weakened. More detailed analysis will be shown at the conference.

IAMAS (Meteorology)

M10p - M10 Global Monsoons and Climate Change

M10p-224

The intraseasonal variation of the east asian winter monsoon and its relations with weather and climate

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A new index measuring the East Asian winter monsoon (EAWM) was defined by Li and Yang (2010), which is highly correlated with both the Arctic Oscillation (AO) and Nino-3.4. At the interannual time scale, the index has a close relationship with the EAWM system.

Based on this index, the relationship between it and EAWM system is deeply studied at the intraseasonal time scale. Using observational and reanalysis data, the variation of the East Asian winter monsoon and its relationship with the temperature in Southwest China are investigated by the correlation analysis and composite analysis. The main conclusions are: There existed obviously negative correlation between the East Asian winter monsoon and the temperature in Southwest China. In strong East Asian winter monsoon phase, the Nino-3.4 sea surface temperature is lower, the AO index is weaker, the upper-level subtropical westerly jet is stronger, the East Asia trough is deeper, the Siberian high is stronger, and the Aleutian low is deeper, thus favorable for the dominance of more powerful north wind and lower temperature in Southwest China. On the contrary, in weak East Asian winter monsoon phase, the Nino-3.4 sea surface temperature is higher, the AO index is stronger, the upper-level subtropical westerly jet is weaker, the East Asia trough is shallower, the Siberian high is weaker, and the Aleutian low is shallower, thus unfavorable for the north wind and lower temperature in Southwest China.

IAMAS (Meteorology)

M10p - M10 Global Monsoons and Climate Change

M10p-225

Monsoon precipitation distribution over tibetan plateau with high resolution TRMM satellite data during 2002-2012

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Monsoon plays key roles in precipitation distribution and its variation. Also Tibetan Plateau, its surface situation and precipitation variation plays important roles in China, eastern Asia, as well as worldwide climate and precipitation distribution, as part of global change in this area. Tibetan Plateau, as its geographic distribution, large scale topography distribution and high complexity of its mountain range, in particular in its southern part, Himalaya mountain ranges, result in very complicated water vapor transport, cloud formation and movements, and precipitation distribution.

To understand the precipitation distribution and its variability as well as long-term trend, we use the TRMM PR products with 0.1*0.1 resolution combined with same resolution topography map, analyze the monthly average distribution during 2002-2012, the time period covers pre-Monsoon and Monsoon seasons in this region. With these long term high spatial resolution data, the precipitation pattern and their parameters revealed with intensity, vertical structure, stratiform and convective, and expanding and transition from southern part of Himalaya to main Tibet Plateau and to eastern of Tibet, Sichuan basin. In this paper, the precipitation pattern and their long term change will be shown and discussed.

IAMAS (Meteorology)

M10p - M10 Global Monsoons and Climate Change

M10p-227

Variability of Extreme rainfall at Cherrapunji, northeast India from diurnal to inter-annual timescale

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Cherrapunji is one of the extreme rainfall place with more than 10,000 mm annual rainfall, and its variability has good relation with floods in Bangladesh. The rainfall was characterized by nocturnal rainfall, and correlation with northward shift of the Indian monsoon trough. Based on the observation network, intensive upper-air observation, and rainfall data collection conducted under MAHASRI program, we discuss about the mechanism of the rainfall variation over this area.

IAMAS (Meteorology)

M10p - M10 Global Monsoons and Climate Change

M10p-228

Interaction of convective organization and monsoon precipitation, atmosphere, surface and sea (INCOMPASS)

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The monsoon supplies the majority of water in South Asia, making understanding and predicting its rainfall vital. However, forecasting the monsoon from days to the season ahead is limited by large model errors that develop quickly, with significant inter-model differences pointing to errors in parametrizations such as convection, the boundary layer and land surface. These errors persist into climate projections and many errors persist even with increased resolution. At the same time, lack of detailed observations prevents more thorough understanding of monsoon circulation and its interaction with the land surface: a process governed by the boundary layer and convective cloud dynamics. The INCOMPASS project will support and develop modelling capability, including test development of a new Met Office Unified Model 100m-resolution domain over India. The first UK visit of the FAAM research aircraft to India, in combination with an intensive ground-based observation campaign, will gather new observations of the surface, boundary layer structure and atmospheric profiles to go with detailed information on the timing of monsoon rainfall.

Observations will be focused on transects in the northern plains of India and across the Western Ghats and rain shadow in southern India. A pilot observational campaign is planned for summer 2015, with the main field campaign to take place

during spring/summer 2016.

The observational analysis will allow unique and unprecedented characterization of monsoon processes that will feed directly into model development at the UK Met Office and Indian NCMRWF. The project will also institute a new long-term series of measurements of land surface fluxes through eddy covariance flux towers to support detailed land surface modelling using the JULES model.

IAMAS (Meteorology)

M10p - M10 Global Monsoons and Climate Change

M10p-229

Charge and discharge of polar cold air mass amount below a designated potential temperature north of 45N

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This study shows the variability of polar cold air mass amount below 280K plane north of 45N, where cold air mass is generated, is explained with a concept of charge and discharge of cold air mass. The use of isentropic threshold allows us to analyze the cold air mass amount following the conservation rule with charge due to diabadic generation and discharge due to outbreaks toward the lower latitude.

The equatorward cold air mass flux across latitude of 45N is regarded as an index for cold air outbreaks (CAOI). The autocorrelation of CAOI indicates that the time scale of CAO events is approximately 5 days. Lagged correlation and regression with CAOI clearly express the cold air mass amount north of 45N dramatically decreases as a result of CAO and then gradually recovers for 20 days. South of 45N, on the other hand, the cold air mass increases, but rapidly disappears reflecting the short life time of about 2 days in the loss regions. CAOs mainly occur in the East Asia and eastern North America, so that positive/negative anomalies of the cold air mass appear mid-/high latitudes of these areas, respectively, just after CAO events.

Annual variability of polar cold air mass is also explained with a concept of charge and discharge of cold air mass. Extended discussions will be given on synoptic patterns preferred by its charge and discharge.

IAMAS (Meteorology)

M10p - M10 Global Monsoons and Climate Change

M10p-230

Evaluation of different rainfall products over India for the summer monsoon

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Accurate prediction of Indian summer monsoon rainfall and its variability at various scales is crucial for agriculture, water resources and hydroelectric-power sectors. Reliable rainfall observations are very important for verification of model outputs and model development. However, high spatiotemporal variability of rainfall makes it difficult to measure adequately with ground-based instruments over a large region of various surface types. A number of multi-satellite products are available to users at different scales, each with advantages as well as limitations. Hence it is essential to find a suitable region-specific rainfall products for a particular user application, such as water resources, agricultural modelling etc.

In this study, we examine seasonal-mean and daily rainfall datasets for monsoon model validation. First, six multi-satellite and gauge-only rainfall products were evaluated over India at seasonal scale for 27 (JJAS 1979-2005) summer monsoon seasons against gridded 0.5-degree IMD gauge-based rainfall. Various skill metrics are computed to assess the potential of these data sets in representation of large-scale monsoon rainfall at all-India and sub-regional scales. Among the gauge-only data sets, APHRODITE and GPCC appear to outperform the others whereas GPCP is better than CMAP in the merged multi-satellite category. However, there are significant differences among these data sets indicating uncertainty in the observed rainfall over this region, with important implications for the evaluation of model simulations.

We also show a clear improvement in V7 over V6 of TRMM TMPA-3B42 in the South Asian monsoon region using various skill metrics. Over typical monsoon rainfall zones, biases are improved by 5-10% in V7 over higher rainfall regions.

IAMAS (Meteorology)

M10p - M10 Global Monsoons and Climate Change

M10p-231

On the paradigm of the Indian monsoon depression

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Reanalysis data from the last 34 years and satellite-derived precipitation data from the last 14 have been used with a newly developed feature tracking algorithm to generate composite three-dimensional structures of monsoon depressions occurring within these respective periods; centralising and rotating each one such that the centre falls on the origin and the system travels towards the relative north. Overall, 104 depressions comprise the composite, considerably more than any previous detailed research on monsoon depressions and their structure. Maxima of many fields are found to exist southwest of the depression centre with respect to the direction of propagation, including rainfall, convergence, and vertical wind velocity. The importance of the Himalayas is also discussed, with evidence of anomalous anti-cyclonic vorticity production in the foothills, extending from the surface to the tropopause. Detailed analysis of the temperature fields indicate that most depressions are cold-core cyclones with a central anomaly of around -1.5K, but some have more disorganised, neutral cores and, rarely, tropical cyclone-like warm cores. Analysis is performed on El Niño-minus-La Niña and active-minus-normal composites, showing that La Niña depressions tend to be wetter and warmer. The temporal distribution of depressions and their durations are also considered, as well as the state of the monsoon trough region during these events.

IAMAS (Meteorology)

M11a - M11 Tropical Cyclones

IUGG-0732

Numerical simulation of genesis and intensification of tropical cyclone over Arabian Sea using Global Forecast System model

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The cyclogenesis over Arabian Sea (AS) and monsoon onset, both are very important from societal aspect. The recent case of cyclonic storm Nanauk (11-14 Jun 2014) is considered for the simulation experiment of cyclogenesis over AS. It developed in association with the southwest monsoon surge over Arabian Sea during the onset phase, and caused temporary hiatus in progress of monsoon over south India. TC Nanauk was originated as a low pressure area on 9th June 2014 over Arabian Sea and intensified maximum up-to the cyclonic storm stage (Vmax=45 knots) on 12th June.

In the present study, we have used Global Forecasting System (GFS) at T574 (≈ 25 km) resolution. The model integration started from 6th June which is 96 hrs (4days) prior to the formation of depression. To see the impact of cumulus parameterization schemes we have studied two schemes namely (i) Operational Simplified Arakawa Schubert and (ii) New Simplified Arakawa Schubert (NEW_SAS). Our results show that NEW_SAS simulates the track and intensity variation reasonably and comparable with observation. Also it could well simulate the formation of warm core along with strong updrafts in the eyewall. The formation of the vortex in the monsoon onset serge and its north-west ward track is very well captured. The evolution of lower level convergence and upper level divergence is clearly seen which leads to formation of cyclonic vorticity within 800-600 hPa. Upper level divergence exist almost 24 hrs prior to the formation of cyclonic vorticity at lower levels. Also the maximum upper level divergence leads to maximum cyclonic vorticity at lower levels by 24 hrs. After genesis of low level cyclonic vorticity, with the support of upper level divergence the simulated system intensified and dissipated over the Arabian Sea.

IAMAS (Meteorology)

M11a - M11 Tropical Cyclones

IUGG-1408

Interactions between Super Typhoon Megi (2010) and the Monsoon Gyre

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Accurate prediction of tropical cyclone track is critical for high-impact weather preparedness, especially as the storm is near the coastal region. The track prediction for super typhoon Megi (2010) in the western Pacific was notoriously bad as most operational models predicated a mainly westward movement while Megi actually took a northward turn after it passed over the Philippines islands. In this study, we try to understand this rather irregular motion for Megi. Examination of NCEP reanalysis fields indicates that during this period a low-frequency (10-60 day) monsoon gyre in the vicinity of Megi may have interactions with the latter. To understand the effect of the low-frequency mode on the movement of Megi, numerical experiments were conducted. The total flow from the analyzed field is separated into 1) a slowly varying background state, 2) a 10-60 day low frequency mode representing the monsoon gyre, and 3) a 10-day high-pass filtered component representing Megi. In the control experiment, the total field containing all three components is used as the initial and lateral boundary conditions, and the WRF model is able to simulate Megi's rather sharp northward turning successfully. In the second experiment, the 10-60 day mode is removed from the initial and the lateral boundary condition fields. In the absence of the low-frequency mode, Megi moves westward and slightly northwestward without turning north. In the third experiment where Megi is removed, the movement of the monsoon gyre is also affected. These experiments indicates strong interactions between Megi and the monsoon gyre. The interactions and the way the monsoon gyre affected the track of Megi will be discussed.

IAMAS (Meteorology)

M11a - M11 Tropical Cyclones

IUGG-1930

Adaptive mesh refinement for tropical cyclone prediction: idealized simulations using a spectral element shallow water model

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Next generation numerical weather prediction models require a unified approach for simulating across different time and spatial scales. As part of the spatial unification, the global mesh must be capable of simulating both an embedded regional area of interest at finer resolution and other areas of less interest and impact at coarser resolution. The tropical cyclone (TC) is a classic example of a mesoscale weather system that requires high horizontal resolution in its inner-core to resolve the processes responsible for intensity and structural variability, and lower resolution in the environment to resolve the synoptic-scale features responsible for its track. Thus, adaptive mesh refinement (AMR) is potentially very useful for TC applications.

TC simulations are conducted in a nonlinear shallow water model based upon a flexible dynamical core using either continuous or discontinuous Galerkin numerical methods (NUMA: Nonhydrostatic Unified Model of the Atmosphere). The following experiments are examined, representing idealizations of TC processes in the real atmosphere: (a) a hurricane-like vortex advecting in a background environmental flow, (b) dynamic instability of the hurricane eyewall, and mesovortex and polygonal eyewall formation, and (c) genesis of TC-like vortices from barotropic instability of the Intertropical Convergence Zone (ITCZ). For each case, a fine resolution truth simulation is compared to multiple AMR simulations of varying areal extent as well as a statically refined region simulation, for computational efficiency and accuracy. While these results are idealized, they demonstrate the promise of AMR for TC prediction in next generation numerical weather prediction system

IAMAS (Meteorology)

M11a - M11 Tropical Cyclones

IUGG-3318

Extended-range forecast of tropical cyclogenesis in the western north Pacific using a global nonhydrostatic atmospheric model

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Since tropical cyclones (TCs) frequently cause tremendous damage to human lives and property, accurate extended-range forecast of TC genesis is valuable for inhabitants in low latitudes. Nakano et al. (2015, GRL) performed 31 one-month simulations using a global nonhydrostatic atmospheric model, NICAM, initialized at each day of August 2004 and demonstrated that the model can predict TC geneses 2 weeks in advance. August 2004 is the active phase of boreal summer intraseasonal oscillation (BSISO) in the western north Pacific and TC genesis is affected by the BSISO. Therefore predictability of TC genesis in various phases of BSISO has not been clarified. In this study, a total of 186 one-month simulations using 14-km-mesh NICAM initialized at each day of August 2007-2012 which covers various phases of BSISO and predictability of 13 TC geneses which occurred in the latter half of August are examined. The results show that 7 out of 13 TC geneses are predictable about 2 weeks in advance. Generation of 3 TCs which are weak (minimum sea level pressure is higher than 990 hPa) and/or duration is shorter than 3 days are not predicted. The reasons for missed TC geneses of the remains (3) in the model are not clear so far. The results suggest that NICAM is a promising tool for TC genesis forecasts. In the presentation, the results will be compared with forecast of operational models (ECMWF, JMA, NCEP, MetOffice) which are taken from TIGGE database.

IAMAS (Meteorology)

M11a - M11 Tropical Cyclones

IUGG-3392

Intensity-dependence of tropical cyclone intensification in a simplified dynamical system

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Several recent studies based on best track data for tropical cyclones (TCs) over the North Atlantic revealed a strong dependence of the TC intensification rate (IR) on TC intensity. The TC IR shows a maximum (i.e., most rapid intensification) when the TC intensity reaches about 35 - 40 m s^{-1}. Physically, this intensity-dependence has been explained in terms of the inner-core inertial stability and the decreased potential for a TC to intensify as it approaches its maximum potential intensity (MPI). Here, we propose a new simplified dynamical system based on TC energetics. For this purpose, the TC system is considered as a Carnot heat engine as in earlier theoretical studies, and formulated on the grounds of major energy production and dissipation processes. This offers a way to explain the IR behavior of TCs in terms of its sensitivity to the physical processes involved, and to derive a physically-based relationship between TC intensification and intensity. This relationship is consistent with observations, and in quantitative agreement with that gained from empirical relations in an alternative dynamical system proposed by DeMaria(2009), which has been formulated analogously to the logistic growth equation (LGE).

IAMAS (Meteorology)

M11a - M11 Tropical Cyclones

IUGG-4310

A new local moist available potential energy framework to quantify mechanisms of tropical cyclone intensification

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Despite decades of research and progress in numerical modelling, we still have a limited understanding of the detailed physical processes controlling tropical cyclones intensification. From an energetic viewpoint, it is well known that tropical cyclones intensify by converting available potential energy into kinetic energy. In practice, however, this has proven difficult to exploit, because of the longstanding conceptual difficulties associated with rigorously defining and quantifying available potential energy, as well as its sources and sinks, for a moist atmosphere. In this talk, we will present a new rigorous available potential energy framework for a moist atmosphere that circumvents many of these conceptual difficulties, and which has the following properties: 1) it is defined in terms of a locally defined and positive definite available potential energy density and can hence be used to study local energy budgets; 2) it can use a variety of background reference states, which do not necessarily need to be obtained by means of an adiabatic re-arrangement of the fluid parcels; 3) it cleanly separates thermal and humidity effects; 4) it cleanly separates interior sources and sinks from those occurring at the boundaries. The framework allows one to regard tropical cyclones as a moist heat engine with different (although closely related) thermodynamic efficiencies for thermal and humidity effects. The usefulness of the framework will be illustrated by means of idealised and realistic numerical simulations of tropical cyclone intensification.

IAMAS (Meteorology)

M11b - M11 Tropical Cyclones

IUGG-0342

Lightning activity variation during the evolution of severe tropical cyclones in the South Pacific region

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The South Pacific Island countries are vulnerable to natural hazards which cause devastating effects on infrastructure, crops and at times loss of lives and many others. Tropical cyclones (TCs) are one type of natural hazard experienced by Pacific Island countries (PICs). The South Pacific region has two seasons, namely: the cyclone season, running from November to April, and the non-cyclone season, running from May to October. Tropical cyclones are associated with strong winds, rainfall, and thunderstorms generating strong lightning discharges. The analysis of lightning data obtained from the World Wide Lightning Locations Network for the South Pacific Region, defined as the region bounded between geographic coordinates, lat. 0 - 40°S, long. 135°E - 120°W, during 2013 clearly shows the lightning activity to be higher during the cyclone season due to increased convective activity. The change in the lightning activity with the intensity of severe TCs of categories 4 and 5 occurring in the South Pacific region has been analysed for the years 2005 to 2013. The intensity measurements, as determined by maximum sustained winds and the lightning activity, as determined by flash counts were studied during the stages of evolution of 23 severe TCs. Taking into account the lag between peak lightning activity and peak maximum sustained wind, the two quantities; lightning activity and intensity for individual TCs were correlated. The case studies of lightning variation within 500 km from the TC centre for different sections of the cyclone (eyewall, inner and outer rainbands) will also be presented.

IAMAS (Meteorology)

M11b - M11 Tropical Cyclones

IUGG-1047

Secondary Eyewall Formation in tropical cyclones: Unbalanced dynamics within and just above the Boundary Layer

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A dynamical pathway to secondary eyewall formation (SEF) in tropical cyclones was advanced in Wu et al. (2012) and Huang et al. (2012), suggesting that the unbalanced dynamics within and just above the boundary layer on account of the storm's expanding swirling flow serves as an important mechanism for initiating and sustaining a ring-like deep convection in a narrow supergradient-wind zone outside the primary eyewall.

This follow-up study conducts high-resolution simulations and provides further dynamical analyses to examine such a pathway to SEF. The momentum budget analyses are deployed to investigate 1) how the tangential winds broaden prior to SEF; 2) how the secondary tangential wind maximum forms; and 3) how unbalanced processes impact the radial distribution of the boundary layer inflow. Results from the tangential momentum budget demonstrate the dominant role of the axisymmetric dynamics in SEF and the critical impact of the representation of the boundary layer inflow and its interplay with the atmosphere aloft on SEF. The calculation on the momentum budget of the radial wind further confirms the primary role of the supergradient force in decelerating the boundary layer inflow passing through the SEF region, and thus in helping SEF.

In addition, the balance response to forcings of diabatic heating/cooling and momentum source/sink is also investigated using the Sawyer-Eliassen equations. In the SEF region, the diagnosed boundary layer inflow is generally 25 % weaker than the WRF-simulated inflow, resulting in a negative diagnosed tendency of tangential winds within the boundary layer. This indicates that the balanced dynamics alone without considering the role of the boundary-layer processes is not enough to capture the essence of SEF.

IAMAS (Meteorology)

M11b - M11 Tropical Cyclones

IUGG-2074

Effects of Vertical Wind Shear on Inner-Core Thermodynamics of an Idealized Simulated Tropical Cyclone

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A suite of idealized simulations of tropical cyclones (TCs) with a weak to strong vertical wind shear (VWS) imposed during the mature stage was employed to examine the effects of VWS on the inner-core thermodynamics and intensity change of TCs using a three-dimensional full-physics numerical model as well as a budget analysis of moist entropy.

For sheared TCs with shear-induced convective asymmetries, VWS tends to reduce moist entropy within the mid-level eyewall and the boundary layer (BL), but supply moist entropy outside the eyewall above the BL. Such changes in moist entropy reduce the radial gradient of moist entropy across the eyewall, resulting in weakening of the TC.

Budget analysis showed that the intense eddy fluxes are mainly responsible for the reduction and/or increase in entropy in the sheared TCs. The entropy reduction within the mid-level eyewall is a result of both the radial eddy flux and the vertical eddy flux. These eddy fluxes are effective at introducing low entropy air into the mid-level eyewall. Accompanying the flushing of midlevel low entropy air into the BL, there is an increase in moist entropy outside the eyewall above the BL due to the upward transport of moisture from the BL by shear-induced convection. This represents a possible new pathway to further restrain the radial gradient of moist entropy across the eyewall, and hence TC intensity in the sheared environmental flow.

IAMAS (Meteorology)

M11b - M11 Tropical Cyclones

IUGG-3080

The inner-core asymmetric precipitation structure of landfalling tropical cyclones in South China

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In this study, the temporal and spatial variation of the inner-core precipitation asymmetry in landfalling tropical cyclones (TCs) have been investigated using 10 cases collected by coastal Doppler radars from 2008 to 2013 in South China. The relative contribution of three external factors (vertical shear, storm translation, and differential forcing between land and sea) to the precipitation asymmetry are examined. Based on the radar data, all of cases show a distinctly asymmetry structure in precipitation from the asymmetric components determined by the first-order and second-order Fourier decomposition centered at TCs. The heavy rainfall occurs generally in the downshear-left quadrant (DL) throughout the whole period. Convective cells tend to be triggered in downshear-right (DR) quadrant and mature in the DL, then weaken in the upshear side. When the storm translation speed exceeds the magnitude of the shear vector, the precipitation maximum rotates to the front-right (front) quadrant in the eyewall (rainband). As TCs approaching to the coast, the new convective cells are triggered on the on-shore side due to the enhanced low-level convergence along the coast, so the precipitation is enhanced downwind of the convective generation zone. This is different from previous studies that shows enhanced convection to the west of the TCs (offshore) in South China The analyses, moreover, suggest the vertical shear is the dominate factor in determining asymmetric precipitation structure in inner-core region of landfalling TCs in South China, yet the storm translation and the differential forcing between land and sea can modify the precipitation distribution and intensity.

IAMAS (Meteorology)

M11b - M11 Tropical Cyclones

IUGG-3619

Intensified impact of east Indian ocean sea surface temperature anomaly on tropical cyclone genesis frequency over the western north Pacific

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A recent finding is the significant impact of the sea surface temperature anomaly (SSTA) over the East Indian Ocean (EIO) on the genesis frequency of tropical cyclones (TCs) over the western North Pacific (WNP). In this study it is shown that such an impact is significant only after the late 1970s. The results based on both data analysis and numerical model experiments demonstrate that prior to the late 1970s the EIO SSTA is positively correlated with the equatorial central Pacific SSTA and the latter produces an opposite atmospheric circulation response over the WNP to the former. As a result, the impact of the EIO SSTA on the TC genesis over the WNP is largely suppressed by the latter. After the late 1970s, the area coverage of the EIO SSTA is expanding. This considerably enhances the large-scale circulation response over the WNP to the EIO SSTA and significantly intensifies the impact of the EIO SSTA on TC genesis frequency over the WNP. The results from this study have great implications to seasonal prediction of TC activity over the WNP.

IAMAS (Meteorology)

M11b - M11 Tropical Cyclones

IUGG-5644

The impacts of recurving tropical cyclones on extended-range predictability of midlatitude weather patterns

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Based on several case studies, tropical cyclones that recurve from the tropics into the midlatitudes have been related to high-impact weather over downstream midlatitude regions. Furthermore, recurving tropical cyclones have also been identified as sources of errors and uncertainty in midlatitude forecasts. Although the midlatitude jet stream shifts poleward and is weaker in summer, a recurving tropical cyclone increases the linkage between the tropics and midlatitudes. The purpose of the present study is to extend case studies of tropical cyclone impacts on predictability over the midlatitudes and establish the overall significance of such impacts. In this context, predictability is examined based on spread among ensemble members.

Ensemble and deterministic extended-range predictions of synoptic-scale fields from the National Centers for Environmental Prediction Global Ensemble Forecast System (NCEP/GEFS) Reforecast-2 are used to examine predictability in forecasts over the Northern Hemisphere midlatitudes. This data set is produced with a fixed model and uses re-analysis data for initial conditions. Representative amplitudes and spatial patterns in predictability are established in association with recurving tropical cyclones. Using the long period of forecasts provided in the reforecast data set, climatological values of predictability and uncertainty are computed. The forecast attributes associated with recurving tropical cyclones are statistically compared to climatological values to establish that recurving tropical cyclones are associated with periods of reduced predictability in downstream midlatitude weather patterns. Furthermore, the tendency for predictability to be reduced relative to specific regions or flow patterns is examined.

IAMAS (Meteorology)

M11c - M11 Tropical Cyclones

IUGG-1033

Do West African thunderstorms predict the intensity of Atlantic hurricanes?

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Since 85% of all major Atlantic hurricanes originate as thunderstorm clusters in equatorial Africa, we have investigated the connection between these African thunderstorms and the consequent development of these disturbances into tropical storms. We have analyzed METEOSAT infrared cloud-top temperature data to determine the areal coverage of cold cloud tops over a six year period from 2005-2010. In addition, hurricane statistics from the same period (intensity, date of generation, location, maximum winds) were obtained from the National Hurricane Center (NHC) data base. We first show that the areal coverage of cold clouds (with brightness temperatures T_b<-50^{o}C) in tropical Africa is a good indicator of the monthly number of African Easterly Waves (AEWs) leaving the west coast of tropical Africa. Furthermore, the AEWs that develop into tropical storms have a significantly larger area covered by cold cloud tops compared with non-developing waves. Finally, we show that on a storm-by-storm basis, the cold cloud coverage in West Africa is positively correlated (r=0.57) with the accumulated cyclone energy (ACE) of the future tropical cyclones that develop out of these waves.

IAMAS (Meteorology)

M11c - M11 Tropical Cyclones

IUGG-1316

Influence of equatorial wave disturbances on the genesis of super typhoon Haiyan (2013)

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The influence of equatorial wave disturbances on the genesis of super Typhoon Haiyan (2013) is investigated through spectral, composite and ensemble sensitivity analysis of various observational datasets in combination with forecasts from the operational ensemble prediction system of the European Center for Medium-Range Forecasting (ECMWF). Diagnostic analyses show that, under the favorable large-scale environmental conditions of the Asian monsoon combined with the Madden-Julian Oscillation (MJO), the incipient Haiyan develops from a cyclonic disturbance which originates from a train of westward-propagating mixed Rossby-gravity (MRG) waves. The tropical cyclone eventually develops in the monsoon trough region at the leading edge of the moist MJO phase that has strong low-level convergence, high moisture content, and weak vertical wind shear (below 5 m s^{-1}), along with extremely high sea-surface temperature (>30°C). These favorable environmental conditions promote the intensification and aggregation of deep moist convection that facilitates the development of the cyclonic disturbance from a MRG wave into a tropical depression, which later intensifies rapidly into super Typhoon Haiyan, one of the world's strongest and most destructive tropical storms ever recorded in history. Results from ensemble sensitivity analyses are consistent with this finding and further show that the uncertainties in the tropical waves can impact the large-scale environment surrounding the precursor and therefore limit the predictability of tropical cyclone formation and intensity.

IAMAS (Meteorology)

M11c - M11 Tropical Cyclones

IUGG-3305

A dipole in pre-monsoon Bay of Bengal tropical cyclone intensification induced by ENSO

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Despite the infrequent occurrence of tropical cyclones in the Bay of Bengal compared to other basins, a combination of factors such as a flat coastal terrain and high population density of surrounding countries leads to devastating consequences when landfall occurs. We find that a significant change in the intensification of May tropical cyclones in the Bay of Bengal occurred during the 34-year post-satellite period (1980-2013). The pattern of changes reflects a meridional dipole: In the southern Bay cyclone intensification rates have decreased, while in the northern Bay the intensification rates have increased. It is found that changes in large-scale ocean-atmosphere conditions forced by an ENSO-like decadal change in sea surface temperature (SST) are responsible for these changes in cyclone activity. In the transition to more La Nina-like conditions in the equatorial Pacific in recent decades, the monsoon onset has become earlier, in turn leading to an enhancement of vertical wind shear in the southern Bay and a decrease in intensification rates. Also associated with the changes in Pacific SST has been an enhancement of zonal wind stress over the eastern equatorial Indian Ocean, which has excited downwelling Kelvin waves along the coastal wave guide and increased ocean heat content and cyclone intensification rates in the northern Bay. The result of these oceanic and atmospheric changes is a meridional dipole of intensification rate changes. Our study therefore suggests a dynamic link between ENSO and tropical cyclone activity in the pre-monsoon Bay of Bengal, in part through ENSO-induced changes in the summer monsoon onset.

IAMAS (Meteorology)

M11c - M11 Tropical Cyclones

IUGG-3367

cluster analysis of synoptic environments associated with tropical cloud cluster formation in the western north Pacific

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This study analyzes the synoptic environments associated with the formation of tropical cloud clusters (TCCs) in the western North Pacific (WNP) and their development into tropical cyclones (TCs). A TCC, which is a precursor of TC, must have at least one embedded mesoscale convective system and persist for more than 24 hours. During July–October 1981–2009, a total of 2,248 TCCs were identified using infrared satellite images. To classify the environmental circulation patterns of TCC formations into different clusters, a non-hierarchical cluster analysis scheme was used to analyze the 850-hPa wind fields around the locations where TCCs formed. Based on computed root mean square errors and analyses of variance, eight cluster types were used in the classification procedure. Results show that the numbers, distributions, structures, and sizes of TCCs are significantly different for these eight types. Results also show that the percentage of all TCCs that developed into TCs is quite different for the easterlies type and monsoon confluence type, although most TCC formations belong to these two types. In addition, the yearly numbers of TCCs formed in two major synoptic environments, namely monsoon–related (trough and confluence) and easterlies-related, have opposite correlations with El Niño–Southern Oscillation (ENSO) signal. On the other hand, although ENSO affects the monsoon pattern in the WNP, the yearly numbers of TCs that formed in the monsoon trough, which accounts for 22% (the largest percentage) of all TCs, are not correlated with ENSO signal, especially for those TCs developed from the monsoon confluence TCCs.

IAMAS (Meteorology)

M11c - M11 Tropical Cyclones

IUGG-5448

Developing and non-developing tropical cyclones and their large-scale environment in the West Pacific

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TC genesis occurs only when there is persistent, organized convection. The question of why some cloud clusters develop into a tropical cyclone (TC) and others do not remains unresolved. This study presents a systematic approach in classifying developing and non-developing cloud clusters based on their large-scale environments. Eight years of hourly satellite IR data and global model analysis over the western North Pacific are used. A cloud cluster is defined as an area of ≤ 208 K cloud top temperature, generally mesoscale in size. Based on the overlapping area between successive hourly images, they are then tracked in time as time clusters. The initial formations of nearly all TCs during July-October 2003-2010 were associated with time clusters lasting at least 8 hours (8-h clusters). The occurrence of an 8-h cluster is considered to indicate the minimum degree of convective organization needed for TC genesis. A non-developing system is defined as an 8-h cluster that is considered to be a viable candidate for TC genesis, but was not associated with the TC genesis. The large-scale environmental conditions of cyclonic low-level vorticity, low vertical wind shear, low-level convergence, and elevated tropospheric water vapor are statistically more favorable for developing systems. Synoptic-scale variability in monsoon circulation is one of the dominant features associated with developing cases. Aircraft observations from the Impact of Typhoons on the Ocean in the Pacific (ITOP) field campaign in 2010 are used to further investigate three cases occurred during ITOP.

IAMAS (Meteorology)

M11c - M11 Tropical Cyclones

IUGG-5596

Land convection impact on near-coastal formation of tropical cyclone

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Mesoscale hypotheses have been put forward for the mechanism of tropical cyclone formation, but the major view is on oceanic convections contribution on tropical cyclone over the open ocean. In this study, we have analyzed convection-allowing simulations at a 4 km horizontal resolution using Weather Research and Forecast for Tropical Strom Mekkhala (2008) that developed over the South China Sea off the west coast of Philippines. In this numerical study, we have utilized five experiments that represented storm’s sea level pressure deepening. In addition, the sensitivity tests for the impact of land on developing TC have been performed.

The results show that convection associated with land-sea different heating is found to play a critical role in leading a stronger mid-tropospheric mesoscale vortex and continuous low-level vorticity enhancement through the extended monsoon vortex core from the Asian continent. Then, the pre-Mekkhala mesoscale circulations were vertically aligned, which is regarded as an essential condition for tropical cyclone formation as protecting moisture core from shear flows. Without the impact of the land-origin mesoscale convection, the precursor circulation remained misaligned and non-developed. Finally, this study concludes that the land-origin convective process can be a necessary condition for the near-coastal formation of tropical cyclone in addition to the well-known favorable atmospheric and oceanic conditions.

IAMAS (Meteorology)

M11p - M11 Tropical Cyclones

M11p-314

Impacts of the tropical storms originated from the bay of bengal upon precipitation and soil moisture over the tibetan plateau

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This study investigates the impacts of tropical storms originated from the Bay of Bengal (BOBTSs) on the precipitation and soil moisture over the Tibetan Plateau (TP) in April-June (AMJ) and September-December (SOND) during 1981–2011 based on the best track dataset provided by Joint Typhoon Warning Centre (JTWC). Results indicate that there are about 1.35 BOBTSs influence the TP in each year and most of them occurred in May and October, and the BOBTSs in AMJ influence the TP with larger extension and higher latitudes than those in SOND. The maximum regional precipitation induced by the BOBTSs accounts for more than 50% for the total precipitation in the corresponding month and about 20% for the season. Further analysis reveals that the surface soil moisture anomalies induced by the BOBTSs can persist only 20-25 days in AMJ, and the case is also true for the snow depth in SOND. Numerical simulations by using the regional climate model of Weather Research and Forecasting (WRF) suggest that the soil moisture anomalies in the sub-surface can last 2 months whereas for the surface it can persist only about 20 days, which agrees well with the observation analysis. Overall, the effect of the preceding BOBTSs on the snow depth and soil moisture anomalies over the TP cannot maintain to summer, and there is no robust connection between the BOBTSs and summer precipitation anomalies in East China. Moreover, since the mid-1990s, the spring rainfall over the TP seems to be enhanced to a certain degree because of the intensified BOBTSs.

IAMAS (Meteorology)

M11p - M11 Tropical Cyclones

M11p-315

Synoptic analysis of Haiyan tropical cyclone

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Tropical cyclones as one of the most intense weather hazards, that create a lot of devastation, have been included in many researches and many attempts have been done to investigate this meteorological phenomenon through analysis of case studies or numerical simulations over various ocean areas.

In the current study, Haiyan tropical cyclone originated over Pacific Ocean has been focused. Haiyan tropical cyclone that affected South-east Asia was generated on 2th November of 2013, reached Philippine region on 7th November and continued its activity until 12th November. To proceed our purpose GFS-ANL data with 0.5 degree spatial resolution and at four times a day (00:00, 06:00, 12:00 and 18:00 UTC), for 3-11th November of 2013 have been used. To study Haiyan tropical cyclone, synoptic parameters such as potential vorticity, geopotential height, wind shear, tropopause height, sea surface temperature, local pressure and humidity have been analyzed at source location.

IAMAS (Meteorology)

M11p - M11 Tropical Cyclones

M11p-316

Tropical cyclone secondary eyewall formation in an idealized high-resolution numerical experiment

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Concentric eyewalls are salient feature often observed in radar and satellite images of strong tropical cyclones. As the secondary outer eyewall contracts and intensifies, the original inner eyewall weakens and could be finally replaced by the outer eyewall. During this replacement process, rapid intensity change occurs along with significant broadening of destructive wind radii, presenting a big challenge for numerical prediction of tropical cyclones. Although the evolution pattern following secondary eyewall formation is well documented, the formation mechanism(s) of secondary eyewalls are still not fully understood. In this study, a high-resolution, full-physics model initiated with an idealized tropical cyclone–like vortex is used to simulate and investigate the secondary eyewall formation. The simulation realistically captured the intensity and structure change associated with the formation of the secondary eyewall and the following eyewall replacement cycle. The evolution of inner-core convection during the secondary eyewall formation process is examined, and its effects on secondary eyewall formation are discussed. Details will be shown at the conference.

IAMAS (Meteorology)

M11p - M11 Tropical Cyclones

M11p-317

Study on the cyclonic storms during onset phase of Monsoon over Arabian Sea

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Indian summer monsoon season is considered to be inactive for intense cyclones in Arabian Sea (AS) mainly due to high vertical wind shear. However, last decade has witnessed intense cyclones like 01A (21-29 May 2001, V_{max} 115 knots), Gonu (2-6 June 2007, V_{max} 127 knots), Phet (31-May-6 June 2010, V_{max} 85 knots) and the recent case of Nanauk (10-13 June 2014, V_{max} 45 knots). All cyclonic storms formed and intensified during the onset phase of monsoon. The cyclogenesis over AS and monsoon onset, both are very important from societal aspect. Keeping this in view, we have attempted to address two questions related to tropical cyclones in Arabian Sea during monsoon onset. (1) Does the AS during onset of monsoon have become active in terms of cyclogenesis in recent years? (2) What is the impact of cyclone activity during May-June on onset and progress of monsoon?

In this study, based on 35 years (1980-2014) cyclone data archived from IMD web based e Atlas, it is seen that, there is increasing trend (significant at 90 % confidence level) in the number of cyclonic storms over Arabian Sea during May-June. The parameters like Moist Static Energy (MSE), Ocean Heat Content which favors the cyclogenesis show increasing trend (significant at 99 % confidence level). Also the frequency of cyclonic storm is positively correlated with the MSE and vertical gradient of equivalent potential temperature.

To see the impact of cyclones on monsoon onset, composites of active and inactive years are made and monsoon indices are calculated for both composites using MERRA reanalysis data. The cyclone activity in May-June modulates the indices based on large scale wind and moisture for few days. Whereas monsoon index based on large scale temperature does not show any change due to cyclone activity.

IAMAS (Meteorology)

M11p - M11 Tropical Cyclones

M11p-318

Typhoon kinematic and thermodynamic boundary layer structure from dropsonde composites

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The data from 438 Global Positioning System dropsondes in 6 typhoons are analyzed to investigate the mean atmospheric boundary layer structure in a composite framework. Following a recent study on boundary layer height in Atlantic hurricanes, we aim to quantify characteristics of boundary layer height scales in Western Pacific typhoons including the inflow layer depth, height of the maximum tangential wind speed, and thermodynamic mixed layer depth. In addition, the kinematic and thermodynamic boundary-layer structures are compared between the dropsonde composites using data in typhoons and hurricanes. Our results show that, similar to the hurricane composite, there is a separation between the kinematic and thermodynamic boundary layer heights in typhoons, with the thermodynamic boundary layer depth being much smaller than inflow layer depth and height of the maximum tangential wind speed in the typhoon boundary layer. All three boundary layer height scales tend to decrease toward the storm center. Our results confirm that the conceptual model of Zhang et al. [2011a] for boundary layer height variation is applicable to typhoon conditions. The kinematic boundary layer structure is generally similar between the typhoon and hurricane composites, but the typhoon composite shows a deeper inflow layer outside the eyewall than the hurricane composite. The thermodynamic structure of the typhoon boundary layer composite is warmer and moister outside the radius of maximum wind speed than the hurricane composite. This difference is attributed to different environmental conditions associated with typhoons compared to the hurricanes studied here.

IAMAS (Meteorology)

M11p - M11 Tropical Cyclones

M11p-319

Asymmetric structure and the Band-shaped Convective Rainbands in typhoon Morakot (2009)

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Typhoon Morakot (2009), which was the deadliest typhoon to impact Taiwan in recorded history, produced record-breaking rainfall over 3000mm well to the south of the center. According to the radar imagery from Taiwan CWB radars, the intense convection in Morakot was asymmetric and became increasingly confined to the southern semi-circle of the cyclone during the landfall period. More specially, from 16 UTC 7 August to 03 UTC 9 August 2009, a kind of well-organized band-shaped convective rainband (hereafter BCR) embedded in the large area convective clouds of Morakot. In this study, the asymmetric structure of TC Morakot and kinematic structures of BCR will be analyzed using outputs from the cloud-resolving WRF model with high spatial resolution (1-km horizontal grid spacing).

Results show that, typhoon Morakot has shown asymmetric structure when it passes over the ocean. The asymmetry can be revealed by the comparisons of southern- and northern semi-circle azimuthally averaged fields. But at the time of landfall, the north-south differences decrease because of the significant influence of the Central Mountain Range of Taiwan, the terrain-induced structural changes surpasses the asymmetric TC circulation prior to landfall. Characteristics of BCR are explored with respect to the following details: (i) horizontal shape, (ii) structure, and (iii) development and evolution process. The kinematic structures of convective-scale elements in BCR are also analyzed and compared with that of Hurricane Katrina shown in Hence and Houze (2008).

IAMAS (Meteorology)

M11p - M11 Tropical Cyclones

M11p-320

The characteristics and formation of annular Typhoons in the Western North Pacific

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This study investigates the general features of annular typhoons in the WNP based on 20-year analysis (1990-2009) of global storm centered infrared brightness temperature and passive microwave satellite datasets. Similar to annular hurricanes documented by Knaff et al., annular typhoons also only form under a specific combination of environmental conditions, resulting in a quite low occurrence rate (~4%). There are two seedbeds, locating in east of Taiwan and central WNP respectively, for annular typhoons formation within a narrow zonal belt (20 – 30^0 N). The former is conducive to the landfall of annular typhoons, in particular six of nine annular typhoons formed in this region eventually made landfall. Since the averaged time interval between the annular typhoons landfalling time and ending of annular phase is relative shorter, about 30 hours, they can maintain near peak intensities and hit the landfalling areas with record intensities. Results also show that there are only three ATYs in 1990s, whereas there are nine ATYs during the following decade. Interestingly, the environmental conditions for ATYs during these two decades are quite similar, except that deep total vertical wind shear for category 2 or greater typhoons is significantly larger than that of 2000s.
The annular typhoons formation mechanisms are not clear so far. Our study indicates the concentric eyewall replacement is one of effective pathway to the annular typhoons formation, but not the primary pathway. A real annular typhoon case simulation is performed to further investigate the formation mechanism of annular typhoon.

IAMAS (Meteorology)

M11p - M11 Tropical Cyclones

M11p-321

Variability in tropical cyclone heat potential over the SW Indian Ocean and implications for the East African monsoon

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Tropical cyclone heat potential (TCHP) has been proposed as being important for hurricane and typhoon intensity. Here, a climatology of TCHP is developed for the Southwest Indian Ocean, a basin that experiences on average 11–12 tropical cyclones per year, many of which impact on Mauritius, Reunion and Madagascar, and Mozambique. SODA data and a regional ocean model forced with the GFDL-CORE v.2b reanalysis winds and heat fluxes are used to derive TCHP values during the 1948–2007 period. The results indicate that TCHP increases through the austral summer, peaking in March. Values of TCHP above 40 kJ cm^{-2},suggested as the minimum needed for tropical cyclone intensification, are still present in the northern Mozambique Channel in May. A time series of TCHP spatially averaged over the Seychelles-Chagos thermocline ridge (SCTR), an important area for tropical cyclones, is presented. The model time series, which agrees well with XBT-based observations ($r = 0.82$, $p = 0.01$), shows considerable interannual variability overlaying an upward tendency that matches with an observed increase in severe tropical cyclone days in the Southwest Indian Ocean. Although an increase in severe storms is seen during 1997–2007, the increasing TCHP tendency time series after 1997 coincides with a decrease in total cyclone numbers, a mismatch that is ascribed to increased atmospheric anticyclonicity over the basin. Seasons of increased (decreased) TCHP over the SCTR appear to be associated with dry (wet) conditions over large parts of southern and East Africa and to anomalies in the East African monsoon. The rainfall anomalies may be linked to changes in zonal wind and vertical motion in the mid- troposphere over the region.

IAMAS (Meteorology)

M11p - M11 Tropical Cyclones

M11p-322

Characteristics of tropical cyclone genesis in the western North Pacific during two types of El Niño and recent decades

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During the developing phase of eastern Pacific El Nino (EPEN), a southeastward shift of TC genesis in the western North Pacific (WNP) is favored by the environmental vorticity and accompanying relative humidity. During the central Pacific El Nino (CPEN), however, more frequent TC genesis over the northwest quadrant of WNP is attributed to the horizontal shift of vorticity field. Such a northwestward shift resembles the La Niña composite, even though factors that cause the shift differ (in the La Niña case the relative humidity effect is crucial). Greater reduction of TC frequency over WNP happened during the decaying phase of EPEN than CPEN, due to the difference of the anomalous Philippine Sea anticyclone strength. The TC genesis exhibits an upward (downward) trend over the northern (southern) part of the WNP, which is linked to the SST and circulation changes through local and remote effects. The TC tracks also present a noticeable northward trend in WNP, especially in late TC activity season.

IAMAS (Meteorology)

M11p - M11 Tropical Cyclones

M11p-323

Long-term variation in the spatial pattern of a typhoon's translation velocity field estimated from the typhoon best track data

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The long-term changes in typhoon's path is potentially important to assess the risks of typhoon-related hazards. In the present study, the variation of typhoon's translation velocity on a longer time scale was analyzed using the Gaussian process regression technique, which is a statistical method for spatio-temporal interpolation. The results suggests north-south shifts of the typhoon trajectory pattern on a 5 year or longer time scale, which is distinguishable from the annual variation. Since the motion of a tropical cyclone is mainly controlled by the background large-scale wind velocity field, these changes in the typhoon's translation velocity pattern would suggest the changes in the background wind velocity field. In order to characterize the velocity field changes, we have extracted the typical latitude of typhoon recurvature from the estimated velocity field. It is suggested that the latitude of typhoon recurvature synchronizes with the El Nino Southern Oscillation after 1990, but the correspondence seemed to be poor before 1990. This result could be interpreted to mean that two different types of the El Ninos made different effects on the translation velocity pattern of typhoons.

IAMAS (Meteorology)

M11p - M11 Tropical Cyclones

M11p-324

The more rain, the higher the scores: The key to understand model quantitative precipitation forecast ability for extreme typhoon rainfall

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The Cloud-resolving Storm Simulator has been used by the author since 2010 to produce real-time forecasts for Taiwan at a cloud-resolving grid spacing of 2.5 km. These forecasts are carried out four times a day (initial time at 0000, 0600, 1200, and 1800 UTC) for 72 h (now 78 h), and the domain was 1080 km by 900 km in 2010-2011 and has been enlarged to 1500 km by 1200 km since 2012. In this study, the quantitative precipitation forecasts by this 2.5-km model for all typhoons for which warnings were issued in Taiwan during 2010-2012 are evaluated. Examples are provided to demonstrate the high quality of rainfall forecasts produced by such cloud-resolving models, and their usefulness in hazard reduction with appreciable lead time. The threat scores (defined as the intersection area of the observed and predicted rain areas at a given threshold amount over a given period divided by their union area) of 24-h rainfall forecasts for the most-rainy 24-h (0000-2400 or 1200-1200 UTC), averaged among the five most-rainy typhoons (about top 5%), at the thresholds of 50, 130, 200, and 350 mm are as high as 0.67, 0.58, 0.51, and 0.32 for day 1 (0-24 h) forecasts (that is, from forecasts starting at 0000 UTC on the most-rainy period), 0.73, 0.57, 0.42, and 0.17 for day 2 (24-48 h forecasts starting one day before), and 0.57, 0.37, 0.33, and 0.22 for day 3 (48-72 h forecasts starting two days before), respectively. These strikingly high scores show that the model has superior performance, even at 2-3 days prior to the hazardous events. The characteristics of higher scores when there is more rain are also fundamental in the understanding of model's ability in quantitative precipitation forecasts for extreme typhoon rainfall around the World.

IAMAS (Meteorology)

M11p - M11 Tropical Cyclones

M11p-325

Characterization of tropical cyclones over different ocean basins

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Tropical cyclones (TCs) present different characteristics according to the ocean basins where they form and develop. The analysis of the internal structure of TCs is very difficult. In-situ measurements are not possible due to the strength of the storm and most satellite measurements do not provide suitable temporal and spatial resolution.

The Global Positioning System (GPS) Radio Occultation (RO) technique allows the estimation of atmospheric refractivity, temperature, pressure, and humidity in remote areas and during extreme weather events with high vertical resolution, high accuracy and global coverage. The objective of this study is analyzing the thermal structure of TCs for different storm intensities over different ocean basins by using RO measurements.

The GPS RO profiles were co-located with the TCs best track center coordinates collecting in total more than 20000 cases. For each case the storm intensity was classified based on the Saffir-Simpson Hurricane wind scale. For each ocean basin and for each storm category we sampled RO temperature profiles around the storm center.

In general, the temperature during a TC shows a tropospheric warming and a sharp inversion below the cloud top with a cooling corresponding to the cloud top altitude. However, basins in the northern and southern hemisphere show a different thermal structure. In the southern hemisphere the storms reach higher cloud top altitudes than over ocean basins in the northern hemisphere. An interesting feature was found for storms over the North Indian basin. There, low intensity storms show similar characteristics as storms over southern hemispheric oceans while high intensity storms show northern hemispheric storm characteristics. Studies are ongoing for understanding the reasons of these differences.

IAMAS (Meteorology)

M11p - M11 Tropical Cyclones

M11p-326

Predictability of Typhoon Haiyan with the new weather forecasting model ICON

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Typhoon Haiyan made landfall on 8. November 2013 in the Phillipines with devastating effects. Storm warnings played a crucial role. The purpose of our work is to investigate how a new weather forecasting model (the German ICON model) is representing this typhoon in terms of initial condition and model physics. To investigate predictability the ICON model is initialized with 26 members of the ECMWF ensemble data assimilation (EDA) system at 32km resolution and 40 members of the ICON EDA system at 40km resolution. To investigate the dependence of model error on the physics we apply different physics packages (a TKE closure versus the DUALM-EDMF boundary layer cloud approach). Physical tendencies are analyzed to understand the interaction of transport at the extreme physics of a typhoon. Additionally, we run the ICON model at 40km, 20km and 10km globally and nested to 5km and 2.5km to investigate how simulations at low resolutions with convection parameterization can compete with convection resolving simulations. Generally, the ICON model is able to represent the track as well as the minimum pressure with reasonable accuracy.

IAMAS (Meteorology)

M11p - M11 Tropical Cyclones

M11p-327

The evolution of convection and intensification of tropical storm under the impact of vertical wind shear

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A series of experiments are carried out with the different profiles of vertical wind shear (VWS) imposed on the tropical cyclone (TC) genesis period, in order to investigate the effect of VWS on the TC's structure and intensity. The results indicate that the relative strong initial-imposed VWS tends to delay the rapid intensification of TC. The vertical tilting of vortex forced by the VWS change the thermal and water vapor filed which is beneficial to the burst of convection ahead the tilting direction while detrimental to the burst of convection behind the tiling. Under the effect of relatively strong VWS, the intense convections are mainly spread widely in the outer-region of TC, which is less effective in strengthening the warm core and the rapid intensification of TC.

Once the asymmetric convections initialed, there is downdraft with dry and low equivalent potential temperature air on the downstream of the asymmetric convections. Thus the intense convections is limited in a narrow area in the inner-region while the convection is inhibited in the rest area. Accompanying with the flushing of low entropy air into the boundary layer and swept into the eyewall by the inflows, the eyewall entropy reduces and the heat engine of TC is disrupted. As a result the rapid intensification of TC is suspended.

The lower-level concentrated VWS could lead a relative larger vertical titling of vortex, and then a more significant effect on the modulation of TC low- and mid-level structure. Consequently, the downward flush of low entropy air, the reduction of eyewall entropy in the mid-level and even the reduction of radial gradient is more pronounced when TC is embedded in a lower-level VWS, resulting in a longer period of adjustment and delay of rapid intensification.

IAMAS (Meteorology)

M11p - M11 Tropical Cyclones

M11p-328

Simulation and prediction of hurricane Lili during landfall over the USA Gulf Coast using Mesoscale Model (MM5) for renewable energy

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Devices such as solar cookers and solar sterling engines can be effectively operated under adequate sunlight in converting solar energy to cook food. The study involves in understanding the structure and dynamics of lanfalling tropical cyclones over the USA Gulf coast. Therefore weather conditions must be predicted well in advance so that appropriate measures may be taken for renewal energy. A case study of Hurricane Lili September 21-October 4, 2002, has been modeled to show changes in weather conditions that could affect solar-energy utilization. The PSU/NCAR Mesoscale Model (MM5) is used to simulate the storm's formation and development, and predict its track and intensity change. The simulation was for a period of two days during October 3 and 4 when hurricane Lili made landfall over the coastal areas of Louisiana and Mississippi. Model configuration includes two nested domains of 85x85 and 91x91 dimensions respectively. Inner domain is two-way. The outer domain of grid size 27 km is positioned over the Gulf of Mexico region, and the nested domain of grid size 9 km closer to the coast of LA-MS. Objective analysis are done using NCEP ADP Global Surface Observations**.** Model predicted parameters include sea level pressure, rainfall, temperature, and radiation. The model accurately predicted the intensity of hurricane Lili at landfall with a central pressure of 975mb associated with heavy precipitation of 27cm negative radiation tendency over the Louisiana coastal region. The results are then compared with aircraft observations taken by the National Hurricane Center and noted reasonably good agreement.

IAMAS (Meteorology)

M11p - M11 Tropical Cyclones

M11p-329

On the investigation of global warming and West North Pacific typhoon number oscillation from global dynamic climate index

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In this study, we use the first four principal components of 1948 ~ 2006 summer sea surface temperature 11year run mean data after Empirical Orthogonal Function analysis, as the **global dynamic climate index** to explore the global warming and the oscillation of the West North Pacific typhoons number. We found, the first principal component can well describe the global warming by high correlation score (0.885) with all atmosphere pressure levels fields (surface, 1000mb~10mb). And with el Niño index 4 high correlated. The second can well describe the global 50-year oscillation by high correlation score (0.821) with all troposphere pressure levels fields. And with climate 50-year oscillation index Pacific/North American index, Atlantic Multidecadal Oscillation index, Pacific Decadal Oscillation index, North Atlantic Oscillation Index high correlated. The third can well describe the global 30-year oscillation by high correlation score (0.853) with all troposphere pressure levels fields. And with 30-year climate oscillation index Dipole Mode Index high correlated. The fourth can well describe the global 27-year around oscillation by high correlation score (0.900) with all troposphere pressure levels fields. And with 27-year around climate oscillation index El Niño Modoki Index high correlated. The fourth is also high correlated with the number of typhoons in the Western Pacific with the 27-year period oscillation. This confirms the West North Pacific typhoon multi-decadal variation theory (Matsuura et al. 2003) and the typhoon_number_planetary_scale_related theory (Chan 2008).

IAMAS (Meteorology)

M11p - M11 Tropical Cyclones

M11p-330

Variation of active tropical cyclone season in the western north pacific

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The variation of active tropical cyclone season in the western North Pacific is analyzed using an observational data for 1951-2014. The active tropical cyclone season in the western North Pacific is defined using quantile analysis of annual tropical cyclone formation dates. The length of the active tropical cyclone season is highly dependent on its start date that has large interannual variation. The interannual variation of start dates of tropical cyclone season is closely associated with the sea surface temperature over the Indian Ocean and the eastern Pacific. When the Indian Ocean (eastern Pacific) sea surface temperatures are warm (cold) in the winter and early-spring, anomalous downdraft (updraft) and anticyclonic (cyclonic) circulation are induced around the western, resulting in the delay (advance) of start of the active tropical cyclone season. The interannual variation of the end date is also related to the sea surface temperature over the Indian Ocean during fall. Meanwhile, the length of the active tropical cyclone season become slightly shorter with delayed the season start for the past 64 years. It might be because of the signficant increases in sea surface temperatures over the Indian Ocean.

IAMAS (Meteorology)

M12a - M12 Tropical Dynamics

IUGG-0470

Mechanisms of tropical/extra-tropical circulation change due to anthropogenic forcing

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The impact of long-term sea surface temperature (SST) change on the atmospheric circulation is studied by comparing atmospheric general circulation model (AGCM) simulations forced with a spatially uniform SST increase and a structured SST increase. The structured SST increase is calculated from the response of an ensemble of coupled ocean-atmosphere models to increased CO_2. The impact of SST pattern change is largely confined to equatorial Indo-Pacific. However, the circulation change under the two types of SST forcing is similar over the rest of the tropics and almost identical in the extratropics, indicating that the pattern of future SST change has overall little impact on the response of the atmospheric circulation and, in turn, on the resulting changes in precipitation. The tropical similarity is argued to result from energetic constraints that weaken the atmospheric circulation, whereas the extratropical similarity likely results from the insensitivity of Rossby Wave generation to the changes in near-equatorial upper-level divergence. A comparison of the AGCM simulations with those from externally-forced coupled ocean-atmosphere models suggest that ocean coupling or the direct effect of radiative forcing has a larger impact on the projected changes in circulation and precipitation than the pattern of SST change over most regions.

IAMAS (Meteorology)

M12a - M12 Tropical Dynamics

IUGG-1078

The structure of the ITCZ with and without cumulus parameterization in a tropical channel model in an "aquapatch" configuration

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Numerous studies have found daunting sensitivities of the structure and variability of the intertropical convergence zone (ITCZ) to the representations of unresolved processes, particularly the parameterization of deep convection. Evaluation of such simulations by comparison to cloud-resolving simulations without cumulus parameterization has been rather limited, due to the large computational burden of using horizontal grid spacings of less than 10 km over meaningfully large domains representative of the Earth's tropics (e.g., 10000 km or greater in length). This study introduces a methodology which allows the use of cloud-resolving resolutions over the tropics and larger resolutions over remainder of the planet. Specifically, the Weather Research and Forecasting (WRF) model is used in an "aquachannel" beta-plane configuration, zonally periodic with length equal to that of the real equator. This model is shown to reproduce the same general circulation and similar eddy statistics as similarly configured aquaplanet models. In addition, a channel shortened to one third the length of the equator (the "aquapatch") also reproduces the zonal-mean circulations and eddies. Finally, nested grids embedded in the aquapatch are used to simulate tropical dynamics with 5.15 km resolution, revealing strong biases in the structure of the ITCZ due to cumulus parameterizations. A interesting result is also found, that the use of cloud-resolving grid spacing without cumulus parameterization drastically reduces the sensitivity to other parameterizations, such as surface fluxes and radiation.

IAMAS (Meteorology)

M12a - M12 Tropical Dynamics

IUGG-1413

Mechanisms of interannual variability in the Sahel and eastern Africa

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The recent derivation of century-plus time series for the Sahel and eastern Africa permits examination of decadal-scale changes in the primary forcing factors in these regions. The time series for the Sahel commences in the 1850s. That for eastern Africa commences in 1874. The most detailed analysis was carried out for the 'short rains' season (Oct-Nov) in eastern Africa. The relationships to the zonal winds at the surface and 200 mb over the central equatorial Indian Ocean, Niño 3.4, and the Indian Ocean Zonal Mode were examined. These are shown to be time-dependent, as are the relationships among the indices. The relative strength of the Walker cells over the Pacific and Indian Oceans appears to be a factor in producing these changes. The links to ENSO and the Indian Ocean Zonal Mode are shown to be weaker than suggested by previous studies. However, the relationships are very different for wet and dry years. Several factors appear to act in tandem to produce extremely wet years, but appear to act largely independently in producing drought. In the Sahel, the factors also change over time, but the most consistent is the Atlantic SST contrast between the high latitudes of both hemispheres. For both the Sahel and eastern Africa, the seasons contributing the most to interannual variability change significantly over time. In the Sahelian case, the change in seasonality is indicative of two modes, one in which the location of the ITCZ is the dominant factor in variability and one of which its latitudinal span and/or rate of northward progression is the dominant factor.

IAMAS (Meteorology)

M12a - M12 Tropical Dynamics

IUGG-3833

The role of low cloud feedback in the recent warming hiatus

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The role of feedbacks involving low-level clouds in climate variability and change remains a primary cause of uncertainty in global climate model simulations. Many state of the art climate models fail to accurately simulate the relationships between low level clouds and local meteorology and thus, do not adequately capture the observed climatology and variability of cloud amount in regions dominated by large-scale subsidence. In this paper, we examine how low cloud feedbacks in the eastern subtropical Pacific region are tied to persistence in anomalous sea surface temperatures and the large-scale atmospheric circulation. Using a novel coupled modeling strategy, we incorporate observed patterns of cloud radiative forcing into fully coupled global climate model simulations. Results indicate that positive feedback between low cloud, sea surface temperatures and the large scale atmospheric circulation provide a mechanism for the observed persistence of the recent global warming hiatus.

IAMAS (Meteorology)

M12a - M12 Tropical Dynamics

IUGG-4187

Tropical temperature trends in AGCMs - the role of convection distribution and uncertainties in observed SSTs

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The comparison of trends in various climate indices in observations and models is of fundamental importance for judging the credibility of climate projections. Here, we show that two ensembles of GFDL HiRAM model runs (similar results are shown for NCAR's CESM-v1 model) with different commonly used prescribed sea surface temperatures (SSTs), namely the HadISST1 and `Hurrell' data sets, have a difference in upper tropical tropospheric temperature trends (~ 0.1K/decade at 300hPa for the period 1984-2008) that is about a factor 3 larger than expected from moist adiabatic scaling of the tropical average SST trend difference. We show that this surprisingly large discrepancy in temperature trends is a consequence of SST trend differences being largest in regions of deep convection. Similarly, we show that much of the large (order 30%) differences in tropical atmospheric temperature trends in CMIP5 AGCM runs forced with identical sea surface temperatures can be explained by differences between model runs' tropical precipitation distributions.Further, trends, and the degree of agreement with observations, not only depend on SST data set and the particular atmospheric temperature data set, but also on the period chosen for comparison. Due to the large impact on atmospheric temperatures, the systematic differences between HadISST1 andHURRELL SSTs need to be resolved before the fidelity of climate models' tropical temperature trend profiles can be assessed.

IAMAS (Meteorology)

M12a - M12 Tropical Dynamics

IUGG-5462

Process-oriented diagnostics for the Madden-Julian oscillation in climate models

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The Madden-Julian Oscillation (MJO) exerts pronounced influences on global climate and weather systems. Our current general circulation models (GCMs), however, exhibit rather limited capability in representing this prominent tropical variability mode. Meanwhile, the fundamental physics of the MJO are still elusive. In this presentation, by analyzing 27 climate models participated in the WCRP-WWRP/THORPEX YOTC MJO Task Force and GEWEX GASS global MJO model inter-comparison project, plausible key processes for the realistic MJO simulations are explored. Particularly, roles of several feedback processes including the convection-circulation and cloud-radiative feedbacks for the MJO amplification and propagation as indicated by these multi-model simulations will be discussed based on budget analyses of the moist static energy. Several process-oriented metrics to discriminate good and poor GCMs in simulating the MJO will also be illustrated.

IAMAS (Meteorology)

M12b - M12 Tropical Dynamics

IUGG-1077

Convectively coupled Kelvin waves: structure and variability analysis with different aquachannel configurations

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The Intertropical Convergence Zone is characterized by a hierarchy of transients within a large range of spatial and temporal scales that propagate both eastward and westward with varying speeds in synoptic-scale-like waves. Among these tropical structures, the Convectively Coupled Kelvin Waves constitute one of the most significant in terms of contribution to the total ITCZ variability. This work analyzes simulated CCKWs and their sensitivity to different parameterization schemes as well as horizontal resolution using the ARW-WRF model. The simulations are performed using two types of idealized (tropical channel) domains: the "aquachannel" (an oceanic surface with the Earth dimensions, but extending to the latitude of 60 degrees in both hemispheres on the beta-plane), and the "aquapatch" (same configuration as the aquachannel except for its longitudinal extent, which is 1/3 of the former or approximately 13000 km), with both cases having periodic boundary conditions. Also, different grid spacings are used as part of the sensitivity tests, including a nested version of the aquapatch, in which convection is solved explicitly in the finer grid. Throughout the use of several techniques (power spectra, filtering, wave tracking, compositing, and basic statistics), this work attempts to explain how different model configurations produce different CCKW dynamics (structure and propagation speeds), and in turn, how these are connected to different ITCZ featrues. Results from this approach are also compared with those from the "Aquaplanet Experiment". This research will lead to a better understanding of wave physics as well as numerical modeling in the tropics.

IAMAS (Meteorology)

M12b - M12 Tropical Dynamics

IUGG-1295

Evaluation of vertical momentum transports associated with moist convection and gravity waves in a minimal model of QBO-like oscillation

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Yoden et al. (2014) re-examined the QBO-like oscillations in a radiative-moist convective quasi-equilibrium states in an idealized two-dimensional non-hydrostatic cloud-permitting regional model under a periodic boundary condition, in a similar setting as Held et al. (1993). Unlike the observed equatorial QBO, the oscillation has signals in temperature, clouds, and precipitation in the troposphere, where moist convection dominates and gravity waves are generated. In this study, the momentum budget of the QBO-like oscillation is examined by taking account of these organized motions.

Two types of precipitation patterns appear in accordance with the oscillation of zonal mean zonal wind in the troposphere, i.e., squall-line (SL) type and back-building (BB) type. SL type appears during a limited period when the near-surface wind is strong, and BB type appears during the rest of the period. These precipitation patterns have good coincidence with space-time variation of the vertical flux of horizontal momentum (Fz); Fz becomes large in the stratosphere for the BB type whereas it becomes large in the troposphere for the SL type.

The vertical flux Fz and its convergence are objectively separated into the upward-propagating, stationary, and downward-propagating contributions using a linear group velocity criterion as an extension of Shaw and Lane (2013). In the stratosphere, oscillation of the zonal mean zonal wind is almost maintained by the Fz convergence near the critical level of gravity waves propagating from the troposphere. In the troposphere, strong signals of stationary and downward-propagating contributions coexist, because slantwise moist convection and gravity waves coexist at the same time. Downward-propagating contribution has a dominant role in the acceleration.

IAMAS (Meteorology)

M12b - M12 Tropical Dynamics

IUGG-1426

Dynamics of convectively coupled Kelvin waves in tropics

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What determines the in-phase relationship between convection and low-level zonal wind and what causes slow propagation of the convectively coupled Kelvin wave (CCKW) are investigated by analyzing satellite-based brightness temperature data and reanalysis data and by formulating a simple theoretical model. It is found from observational date that the low-level convergence and moisture have an eastward shift relative to the CCKW convective center. The composited vertical structures show that the low-level convergence lies in the planetary boundary layer (PBL) (below 700 hPa), and is induced by the pressure trough above the PBL through Ekman-pumping process.

A traditional view of slower eastward propagation speed of CCKW compared to dry Kelvin waves is attributed to the reduction of atmospheric static stability in mid-troposphere due to the convective heating effect. Our diagnosis shows that this effect alone cannot explain the observed CCKW phase speed. We hypothesize that additional slowing process arises from the asymmetric PBL moisture effect. Results from a simple theoretical model show that the observed phase speed can be derived when considering both the heating induced effective static stability effect and the PBL moisture effect. Thus the current work suggests the important role of the PBL-free atmosphere coupling in leading to the observed properties of CCKW.

IAMAS (Meteorology)

M12b - M12 Tropical Dynamics

IUGG-2351

Convective activity associated with the planetary 5-day wave in re-analysis and Coupled Model Inter-comparison Project phase 5 data

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The 5-day wave is the gravest symmetric zonal wavenumber 1 Rossby-Haurwitz (or external Rossby) wave, and as a Rossby-Haurwitz wave is characterised by a barotropic and minimally divergent structure. Despite these characteristics suggesting a weak and disorganised relationship between the wave and tropical convection, observational studies of space-time spectral coherences between zonal winds and convection as well as studies examining forcing mechanisms for the wave suggest there is a connection between tropical convection and the 5-day wave. Few studies have investigated how this connection manifests itself, and how this connection is represented in CMIP5 models is similarly not well investigated.

Lag-regression analyses of ERA Interim reanalysis horizontal winds, NOAA satellite-derived outgoing longwave radiation, and TRMM 3B42 precipitation are investigated to determine the geographical and temporal nature of the wave connection with convection, and daily model data from CMIP5 historical runs are examined to gauge the model representation of the connection. Strong convective signals associated with the wave activity are seen in the observational and reanalysis data over the Gulf of Guinea, over the Andes and the eastern Pacific, and near the Marshall Islands. Convective activity over the Andes is in phase with peak zonal wind anomalies from the 5-day wave, but elsewhere the convective activity is in quadrature with the zonal wind anomalies. CMIP5 models as a group show connections in the same areas with similar phase relationships, but individual models have poorer representations, generally identifying only one area of connection. The models also tend to overstate the level of the wave-convection connection in the Maritime Continent.

IAMAS (Meteorology)

M12b - M12 Tropical Dynamics

IUGG-2359

The mechanism of the eastward-propagation of unstable disturbances with convection in the tropics: Eigenvalue problem

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In a linearized numerical model with positive-only heating, a slow eastward-propagating disturbance (SED) appeared in the tropics. The SED arises only when (1) net heating is weakly positive throughout diabatic heating levels, and (2) strong cyclonic vorticity is generated by the stretching at lower levels. In terms of an eigenvalue problem, the SED and its eastward propagation are examined. The vertical structure equation indicates that the SED corresponds to an unstable propagating mode in which the real part of its equivalent depth is generally negative. It appears only with the low-level stretching caused by no or small heating in the boundary layer. The SED is a completely different mode from the first baroclinic mode, which is inherently stationary and appears even when heating is provided in the boundary layer. Scale analysis based on the horizontal structure equations shows the necessity of the horizontal structure of the SED with cyclonic vorticity at the western side and convergence at the eastern side. This positional relation necessarily leads to the eastward propagation due to the dominance of the stretching over the beta effect. The results above indicate that the SED generally and necessarily appears without any assumption on the basic state and so on, as long as the two conditions are satisfied. The mechanism of the slow eastward propagation of the SED with the phase speed of about 4-10 m/s may explain that of the MJO.

IAMAS (Meteorology)

M12b - M12 Tropical Dynamics

IUGG-4677

Updating the paradigm of convectively coupled equatorial waves and the madden julian oscillation

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Most discrepancies between observations and the linear Matsuno-Gill theory of tropical waves are currently attributed to the neglect of coupling between the waves and topical convection. Although these quantities are undoubtedly related, the extent to which this reflects true coupling versus forcing of one by the other has not adequately been established. Our own new theoretical and observational analysis indicates that the neglect of spatial base state variations is the primary limitation of the Matsuno-Gill theory, whereas the neglect of convective coupling is of secondary importance. This suggests an updated paradigm in which models that include both effects, but are still linear, would continue to provide a useful framework for interpreting tropical variations. Such models would retain non-dispersive Generalized Kelvin waves, and also zonally symmetric oscillations, as important eigenmodes of even meridionally and vertically varying base states.

The observational analysis is based on Linear Inverse Modeling (LIM), which deduces the linear evolution operator for tropical anomalies using the time-lag covariances and cross-covariances of the circulation and humidity fields in the ERA-Interim dataset. The eigenmodes of this operator are highly seasonally dependent, consistent with the strong modification of the wave dynamics by the seasonally varying base state. The eigenmodes are also not mutually orthogonal, as they are in the Matsuno-Gill or CCEW paradigm, and this is important for the predictable growth and decay of anomalies. We also show that although the circulation-humidity coupling is overall of secondary importance, it does significantly affect the evolution of some modes and the MJO.

IAMAS (Meteorology)

M12c - M12 Tropical Dynamics

IUGG-1185

Moistening processes for Madden-Julian Oscillations

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A scale-separated moisture budget is calculated using the EC Interim reanalysis for the years 1982-2011. Each budget term is projected onto the intraseasonal moisture anomaly and its time tendency change at equatorial Indian Ocean. The projections and composite life cycle of the budget terms indicate that broad-scale advection by low-frequency and MJO flow and moisture fields are dominant moisture sources, while residual of moisture budget ($-Q_2$) as dominant sink contributing to tendency term (propagation) and intaseasonal moisture anomaly (growth and decay). The pre-moistening in the low-troposphere by boundary-layer moisture convergence leading the deep convection is observed but only in the cloud developing to convective phase of MJOs. A budget analysis for the two MJOs over the Indian Ocean in Oct. and Nov. 2011 by using the special DYNAMO observations. The two MJOs exhibit different budget balances in pre-moistening stage from the suppressed phase to cloud developing phase when low-frequency vertical motion is downward (drying) in MJO1 but upward (moistening) in MJO2 that are balanced by negative Q_2 (re-evaporation in non-raining cloud) in MJO1 and positive Q_2 in MJO2. Nonlinear moisture advection by synoptic disturbances causes moistening in the suppress phase of the two MJOs. The above result reveals two moistening processes for the initiation of MJO over Indian Ocean: moistening by synoptic-scale or low-frequency easterly winds, or by shallow convection in large-scale suppressed condition; The two are being examined by numerical simulations using the Model for Prediction Across Scales (MPAS) that is collaboratively developed, primarily by NCAR and LANL/DOE based on global nonhydrostatic framework using Voronoi Meshes, and a cloud resolving model, respectively.

IAMAS (Meteorology)

M12c - M12 Tropical Dynamics

IUGG-1572

Vertical structure and physical processes of the Madden-Julian oscillation: Medium-range hindcasts and project synthesis

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Many theories for the Madden-Julian oscillation (MJO) focus on diabatic processes, particularly the evolution of vertical heating and moistening. Poor MJO performance in general circulation models (GCMs) is often blamed on biases in these processes and their interactions with the large-scale circulation. We introduce one of three components of an international model-evaluation project that aims to connect MJO fidelity in GCMs to their representations of diabatic heating and moistening. This component consists of 20-day hindcasts, initialised daily during two MJO events in winter 2009-10.

The 13 GCMs exhibit a range of MJO fidelity: from accurate forecasts at 20 days' lead to fidelity indistinguishable from statistical models. We find no relationship between fidelity and the evolution of GCM diabatic-heating profiles with rain rate. A more robust association emerges between MJO fidelity and the total moistening by the GCM sub-grid parameterizations and dynamics: high-fidelity models show a clear transition from low-level moistening for light rainfall to mid-level moistening and moderate rainfall and upper-level moistening for heavy rainfall. The mid-level moistening arises from both GCM dynamics and physics; we hypothesize that this is the most important aspect of this process to accurately represent of the MJO.

We also present 'cross-over' analysis between the three project components, in which the most discriminating diagnostics from each component are applied to data from the other two. We find that both the net moistening diagnostic above, and a diagnostic that captures the relationship between precipitation and relative humidity, are able to distinguish between high- and low-fidelity GCMs in initialized hindcasts and multi-decadal climate simulations.

IAMAS (Meteorology)

M12c - M12 Tropical Dynamics

IUGG-2261

Eastward-propagating vs. eastward-decaying intraseasonal convective events

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Simulating eastward propagation of the Madden-Julian Oscillation (MJO) from the Indian Ocean to the West Pacific Ocean is an unmet challenge for most modern general circulation models (GCMs). With few exceptions, GCMs simulate either westward propagation, or eastward propagation that terminates in the eastern Indian Ocean.

EOF-based MJO indices, such as the real-time multivariate or OLR MJO indices (RMM and OMI, respectively) are often used to composite events that propagate across the Indo-Pacific warm pool. However, these indices can also identify intraseasonal Indian Ocean events that decay as they propagate across the Maritime Continent. Hirata et al. (2013) applied this method to 1979-2011 OLR data and found that ~30% of observed Indian Ocean events decay before they propagate across the Maritime Continent. The natural occurrence of both canonical MJO and eastward-decaying (ED) events can offer insight into processes that promote eastward propagation and which of these processes are deficient in GCMs.

In this study, the moist static energy budget is applied to understand processes associated with the life cycle of canonical MJO and ED events. Evidence for the role of boundary layer moisture asymmetry, ocean coupling, mid-level moisture advection, cloud-radiation interaction, and other processes on eastward propagation is assessed. Preliminary composites indicate that the spatial extent of intraseasonal Indian Ocean convection, and the degree to which it is concentrated on the equator play a role in promoting eastward propagation. MJO and ED composites for select GCMs are also computed for comparison purposes.

IAMAS (Meteorology)

M12c - M12 Tropical Dynamics

IUGG-4901

Relationship between cumulus activity and environmental moisture during the CINDY2011/DYNAMO field experiment as revealed from convection-resolving simulations

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The activity of cumulus convection in the tropical oceanic regions is strongly regulated by the larger-scale environmental atmosphere. At the same time cumulus convection influences the larger-scale atmosphere. It is thus recognized that the spatial and temporal variability of moisture content play an important role in determining such multi-scale interaction processes: the down-scale regulation and up-scale influence. This study investigates the relationship between tropical cumulus convection and its environment in the tropical Indian Ocean during the CINDY2011/DYNAMO field experiment by conducting convection-resolving simulations. Numerical simulations are conducted with the use of the Weather Research and Forecasting (WRF) model with the nesting capability to resolve the area of interest at high resolutions. The four nested computational domains with the resolutions of 12.5-km, 2.5-km, 500-m, and 100-m are set. The vertical development of cumulus clouds are closely related to the relative humidity of the environment at levels lower than the cloud-top height. It is shown that the development and organization of cumulus clouds are significantly affected by moisture variability and the deep convective activity influences moisture fields at the larger-scales. The existence of undiluted updraft cores plays a key role in the interaction processes through undiluted updrafts’ penetrating into the upper troposphere and moistening of the clouds’ environment. The analysis with the use of thermodynamically conserved variables suggests that the mixing between clouds and their environments actively occurs. The results from the 100-m-grid simulations clearly indicate that the environment is moistened by well-resolved cumulus clouds.

IAMAS (Meteorology)

M12c - M12 Tropical Dynamics

IUGG-5042

Breaking down the CINDY2011/DYNAMO Madden-Julian oscillation event reproduced by NICAM

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The Madden-Julian Oscillation (MJO) materialize as a complex of tropical waves. It is controversial whether the waves are principally passive responses to the latent heat released by the massive convective envelope, or the wave-dynamics are the essential pillars of the mechanics of the MJO. Either way, it is of interest to identify the respective contributions from various waves in a MJO convective envelope. The combined-Fourier-wavelet-transform technique introduced by Kikuchi (2014) enables us to dissolve the MJO convective envelope into different tropical-wave components and quantify their contributions, at any given time and location. We applied this technique to the outward longwave radiation data observed during the CINDY2011 campaign, as well as to those simulated (Miyakawa et al. 2014) by the global cloud-system resolving model NICAM on the K computer.

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IAMAS (Meteorology)

M12c - M12 Tropical Dynamics

IUGG-5345

Intraseasonal variability of the moist static energy budget over the eastern Maritime Continent during CINDY2011/DYNAMO field campaign

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This study analyzes radiosonde observations and other datasets to examine variability in the moist static energy (MSE) over eastern part of the Maritime Continent during CINDY2011/DYNAMO field campaign from October 2011 through March 2012. During this period, five events bearing key characteristics of the Madden-Julian Oscillation (MJO) are identified. The MSE budget analysis reveals that both the net source term (a sum of surface turbulent fluxes and radiative heating) and net advection term fluctuate as the MJO events come and go. The surface fluxes and radiative heating contribute to the maintenance of the amplitude of column-integrated MSE anomaly and thus to the intensity of the MJO. The horizontal and vertical advection terms contribute to phase progression and eastward propagation of MJO. The contribution of the vertical advection term is mainly due to lower-tropospheric descent after the precipitation and MSE maxima, presumably associated with rain re-evaporation. On the other hand, the source term tends to hinder eastward propagation.
This study also examines how the MSE budget would be different if key components of the budget were parameterized by two assumptions that have been used in recent idealized models of the MJO: (1) the column-integrated radiative heating anomaly is taken proportional to the column water vapor anomaly, and (2) normalized gross moist stability is taken constant. We find that the first approximation tends to speed up the phase progression of MJO, while the latter one tends to slow it down. On the other hand, both seem to have only small impact on the aspects of the budget associated with maintenance of the MJO' intensity.

IAMAS (Meteorology)

M12d - M12 Tropical Dynamics

IUGG-0476

A characterization of cold pools in the West African Sahel

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Cold pools are integral components of squall-line mesoscale convective systems, but are poorly represented in operational global models. They are an important part of the West African Monsoon, where they also generate substantial dust-uplift. Here, observations of thirty-eight cold pools made at Niamey during the 2006 African Monsoon Multidisciplinary Analysis campaign (1 June to 30 September 2006), are used to generate a seasonal characterization of cold-pool properties by quantifying associated changes in surface meteorological variables. Cold pools were associated with temperature decreases of 2 to 14 ? C, pressure increases of 0 to 8 hPa and wind gusts of 3 to 22 m s-1. Comparison with published values of similar variables from the Great Plains of the USA showed comparable changes. The leading part of cold pools tended to have decreased water vapor mixing ratios, with moister air, likely related to precipitation, approximately 30 minutes behind the gust front. A novel diagnostic used to quantify how consistent observed cold pool temperatures are with saturated or unsaturated descent from mid-levels (Fractional Evaporational Energy Deficit) shows that early-season cold pools are consistent with less saturated descents. Early season cold pools were relatively colder, windier and wetter, consistent with drier mid-levels. Late season cold pools tended to decrease equivalent potential temperature, whereas earlier changes were smaller, with more increases. The role of cold pools may therefore change through the season, with early season cold-pools more able to feed subsequent convection, while later lifting by cold pools may be much more dominant.

IAMAS (Meteorology)

M12d - M12 Tropical Dynamics

IUGG-2620

Precipitation associated with convergence lines

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There is a strong connection between low-level convergence and precipitation, although whether it is a cause or an effect has been much debated. Moreover, precipitation is commonly organized as a linear feature along convergence lines. In climate research, precipitation is often analysed in terms of its statistical properties, with little consideration given to patterns of convergence with which it is connected. The aim of the present study is to determine the relationship between precipitation and convergence lines in observations and reanalysis products, and to use these relationships as part of a climate model evaluation. A new objective method for identifying convergence lines in instantaneous wind fields is introduced. A 35-year (1979-2013) global climatology of convergence lines in ERA-Interim will be presented, along with the proportion of CMORPH precipitation associated with the convergence lines for the 15-year period, 1998-2012. The use of instantaneous wind fields also allows the diurnal variability of convergence lines to be investigated. Some results from a regional study for Australia will be shown.

IAMAS (Meteorology)

M12d - M12 Tropical Dynamics

IUGG-4386

Diagnosing resolution sensitivity over the Maritime Continent in the MetUM

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The Maritime Continent, with over 25,000 islands ranging from hundreds to 780,000 square kilometers, is a key challenge for cumulus-convection and coastal parameterizations in climate resolution GCMs. We studied the resolution sensitivity of precipitation over the Maritime Continent in the MetUM AGCM at horizontal resolutions ranging from approximately 200 to 40 km. We found robust increases in summer precipitation over the Maritime Continent Islands and decreases in summer precipitation over the northern Maritime Continent seas, similar to the resolution sensitivity seen in other studies. These precipitation changes near the Maritime Continent can be large, exceeding 5 mm/day, and are the largest changes in tropical precipitation as resolution is increased.

To explore the source of these changes, we present novel experiments to diagnose the role of increased resolution of different components of the AGCM, such as the orography, coastlines and atmospheric dynamics, in the Maritime Continent domain. Our results suggest that total orographic precipitation in the Maritime Continent domain is resolution dependent at these scales. While increased precipitation associated with the higher resolution of the mean orography is compensated for by decreasing precipitation associated with changes in the subgrid orography and its effect on parameterized drag, the total orographic precipitation is not equal across resolutions. Experiments are in progress to determine the impact of better resolving other boundary conditions, such as coastlines.

IAMAS (Meteorology)

M12d - M12 Tropical Dynamics

IUGG-5350

Robust responses of the Madden-Julian Oscillation to extreme climate changes

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Here we ask how the Madden-Julian Oscillation (MJO) responds to climate changes, and if any of the MJO theories can explain this response. To address these questions, we simulate the MJO in a wide range of climates by using the superparameterized (SP) community atmosphere model (CAM). In each simulation, we force the SPCAM with uniformly distributed SSTs—no zonal and meridional SST gradients, and different simulations are forced by different SSTs, ranging from 1^{o}C to 35^{o}C.

According to our simulation results, we find that 1) the MJO can exist over SSTs as cold as 1^{o}C; 2) the strength of the MJO increases with global warming; 3) the wavenumber of the MJO decreases from 7 in the coldest climate to 1 in the warmest climate. These findings challenge the traditional view of the MJO—that it is a wavenumber 1-2 phenomenon and can only exist over warm SSTs. The latter two findings confirm the theoretical prediction of Yang and Ingersoll (2014, GRL, A theory of the MJO horizontal scale). This suggests that the Yang and Ingersoll model might have already captured the essential MJO physics.

IAMAS (Meteorology)

M12d - M12 Tropical Dynamics

IUGG-5536

Coupled impacts of the diurnal cycle of sea surface temperature on the Madden-Julian oscillation

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This study quantifies, from a series of SCOAR (WRF-ROMS) regional coupled model simulations employing various coupling intervals, the effect of sub-daily SST variability on the intensity and onset of Madden-Julian Oscillation (MJO) convection in the Indian Ocean during DYNAMO. The primary effect of diurnal SST variation (dSST) is to raise time-mean SST and latent heat flux (LH) prior to deep convection. Diurnal SST variation also strengthens the diurnal moistening of the troposphere by collocating the diurnal peak in LH with those of SST. Both effects during the suppressed phase of the MJO enhance the convection during the active phase, such that total precipitation amount scales quasi-linearly with pre-convection dSST. A column integrated moist static energy (MSE) budget analysis confirms the critical role of diurnal SST variability in the buildup of column MSE and the strength of MJO convection. Two complementary WRF-only simulations further elucidate the role of SST conditions in the intensity and onset of the simulated MJO. The WRF forced with the persistent initial SST, lacking enhanced pre-convection warming and moistening, produces a weaker and delayed convection than the diurnally coupled run. The WRF with daily-mean SST prescribed from the diurnally coupled run, while eliminating the delayed peak, continues to exhibit a weaker convection without strong moistening on a diurnal basis. The fact that time-evolving SST with a diurnal cycle strongly influences the intensity and onset of MJO convection is consistent with previous studies that identified an improved representation of diurnal SST as a potential source of MJO predictability.

IAMAS (Meteorology)

M12d - M12 Tropical Dynamics

IUGG-5608

What determines tropical convection in a cloud resolving model?

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The amount of convection in a global climate model (GCM) is determined by the closure in the convective parameterization scheme used in the model. Different types of closures exist in current convective parameterization schemes, from convective quasi-equilibrium, CAPE removal to moisture convergence and boundary layer control. In this study, we use cloud-resolving model simulations of tropical convection in TWP-ICE to determine factors controlling convection. We evaluate the relationship between coarse-grained variables and convection for a range of averaging domain sizes representing GCM horizontal resolutions. Preliminary results show that moisture convergence and CAPE (convective available potential energy) generation by the tropospheric ascending motion are highly correlated with the activity of convection on all scales down to sub-10 km. On the other hand, CAPE and PBL turbulent kinetic energy (TKE)-based closures do not capture the variation of convection with the coarse-grained fields. It is found that moisture convergence and CAPE generation are highly correlated with convective precipitation when they lead convection. This correlation weakens as the averaging domain size decreases to 8 km or smaller. This scale-dependence will be discussed in the context of convective parameterization as GCM resolution increases.

IAMAS (Meteorology)

M12p - M12 Tropical Dynamics

M12p-218

Physical processes of Northern Hemisphere wintertime surface air temperature response to the Madden-Julian oscillation

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Previous studies have shown that the tropical heating associated with the MJO induces the atmospheric circulation anomalies in both the tropics and midlatitudes through equatorially trapped Kelvin and Rossby waves and extratropical Rossby wave train. It is anticipated that the MJO affects the air temperature over the major NH continents. In this study, the physical processes responsible for the variation in the surface air temperature associated with the MJO are examined through an intraseasonal thermodynamic equation. By evaluating each term in the equation representing different processes including horizontal temperature advection, adiabatic warming/cooling, and diabatic process, we present the dominant physical processes for the MJO-induced surface air temperature variation over East Asia, North America and Europe. Over these major continents, dynamic control due to temperature advection and adiabatic subsidence is analyzed to be a major factor. In addition, we demonstrate the occurrence rate of the strong warm/cold events over these continents. The information gained from this study can be of great contribution for improving the prediction skill of the surface air temperature.

IAMAS (Meteorology)

M12p - M12 Tropical Dynamics

M12p-219

"assessment of the amazon climatology in climate models from higem family"

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The global climate models have shown difficulties in simulating the precipitation in Amazon region over South America, which is often attributed to the low resolution of these models, which prevents such models simulate systems of lower spatial scale. The increased horizontal resolution of climate models aims to improve the simulations accuracy and to understand the non-linear processes during interactions between different spatial scales within the climate system. Up to this moment, these interactions did not have a good representation on low horizontal resolution GCMs. The purpose of this study was to understand the impact of the horizontal resolution in high resolution coupled and atmospheric global models of HiGEM project in simulating atmospheric patterns and processes of interaction between spatial scales over Amazon region. The simulations were validated using different reanalysis data and compared with observations in order to understand the impact of horizontal resolution on the precipitation systems over Amazon. Three different horizontal resolutions for HiGEM family models were compared ≈ 60, 90 and 135 km. Both coupled and uncoupled simulations consistently represent the spatial patterns related to seasonal march of the Inter-tropical Convergence Zone (ITCZ), this system affects directly the precipitation in Amazon. An important result is that these models eliminate a common problem of coarse resolution CGCMs, which is the simulation of a semiannual cycle of precipitation due to the semiannual solar forcing over Amazon region. These results show, although still with some problems, that the increased resolution improves the representation of the annual precipitation cycle in Amazon.

IAMAS (Meteorology)

M12p - M12 Tropical Dynamics

M12p-220

Mesoscale convective systems over the Amazon Region during the First Campaign of Green Ocean Amazon (GOAmazon)

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The GOAmazon (Green Ocean AMAZON) project was developed to investigate the interaction among rainfall, aerosols and surface fluxes in the Tropics, more specifically in the Amazon Region. In the present study the MCSs (Mesoscale Convective Systems) that occurred during the First Intensive Campaign of GOAmazon (16 February-27 March/2014) was investigated. They were detected using the ForTraCC (Forecasting and Tracking the evolution of Cloud Clusters) and composites of images from satellites GOES 8/10, Meteosat 7/5 and GMS, with 4 km of spatial and 30 minutes of temporal resolution between 14ºS to 6ºN and 75ºW to 45ºW. The majority of the systems found presented a life cycle less than 3 hours. Here we will focus on those greater than 6 hours. These systems had less than 10% of the total frequency of occurrence and were well distributed in the defined area. They exhibited Northeast-Southwestward displacement but their paths were about 2º of latitude, moving slowly along their life cycle. The formation of these systems is in the morning, emphasizing the importance of radiation cycle on the genesis of the tropical MCSs. Besides, some influence of the pollutants could be inferred because during the night these are trapped in the boundary layer. But the instability caused by the radiation loss will accelerate the updrafts, driving those particles into the clouds, possibly stimulating the MCSs formation. It must be said that these processes are complex and they are currently been investigate.

IAMAS (Meteorology)

M12p - M12 Tropical Dynamics

M12p-221

Vertical structure and diabatic processes of the Madden-Julian Oscillation: Biases and uncertainties at short range

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We present initial results from a project titled 'Vertical Structure and diabatic processes of the Madden-Julian Oscillation'. Results are based on the modelling framework that focuses on general characteristics of diabatic heating and moistening processes and uncertainties in their representation within the first 48 hours of forecasts using 12 Global Circulation Models. 12-36 hour lead time is used here to balance the intitial constraint due to the analysis and initial spin-up issues from using a non-native analysis. The model behaviour during 3 phases (suppressed, transition and convectively active) of Madden-Julian Oscillation are presented. Phases of convection are well represented in the models even though the rainfall in suppressed phase is overestimated. Large scale dynamics is well constrained at 12-36 hours, but there is little separation between forecasts initialised from the different phases at longer lead times. Models generally represent the diabatic processes well with large inter-model spread during the convective phase. Weaker convective tendencies are seen in the models compared to those from the year of Tropical Convection analysis at mid-levels during transition and convective phases, indicating the uncertainties in modelling mid-level convection. Radiative heating and cloud parameters have the largest relative spread across models at upper levels. Some models show strong time step intermittency in rainfall and a preliminary time step analysis highlights the differences in the precipitation and dynamics relationship. The wealth of model outputs archived is expected to benefit understanding of other tropical phenomena as well as defining process model experiments and informing needs for field experiments and observing systems.

IAMAS (Meteorology)

M12p - M12 Tropical Dynamics

M12p-222

Temporal and spatial intermittency of sub-daily tropical precipitation in general circulation models

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General circulation models (GCMs) often fail to reproduce observed spatial and temporal distributions of tropical rainfall. The need for improved understanding of how a warming climate may alter rainfall variability has focused attention on the consequences of poor sub-daily, gridpoint rainfall variability for variability at longer and larger scales.

We present the behaviour of tropical convection in the MetUM GCM at ~10km to ~100km resolution, and in ten GCMs from a recent intercomparison project. We establish analysis methods for timestep rainfall that compare resolutions and physical parameterizations. We investigate relationships between timestep variability of GCM gridscale convection and convective variability on longer and larger scales, and compare GCM and observed variability. We show that parameterization changes that alter timestep variability also affect longer-scale variability. For example, MetUM at ~100 km resolution exhibits timestep intermittency at large spatial scales, which reduce at finer resolutions and with parameterisation changes that suppress convection. Despite a variety of timestep behaviour, the ten GCMs become much more consistent, and agree with observations, when timestep, gridpoint rainfall is aggregated to 3-hr means and ~500km, which may represent the scales of radiative-convective equilibrium in these GCMs.

Next, we analyse spatial distributions of rainfall intensity on timescales from ~30 minutes to daily, in GCMs and observations. We show that some GCMs' convection schemes in some regions produce intense rainfall on a timestep, interspersed with timesteps of little or no rain, to produce low daily accumulations that contribute to the 'dreary' state of GCM tropical rainfall.

IAMAS (Meteorology)

M12p - M12 Tropical Dynamics

M12p-223

Rainfall studies using radars in Darwin, Australia

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Wind profiling radars (WPR), particularly those operating near 50 MHz, are capable of retrieving rainfall information, and provide a unique opportunity to examine precipitation climatologies. The rainfall drop size distribution (DSD) can be retrieved through a de-convolution process, and the rainfall integral parameters such as rain rate and liquid water content can then be calculated. The vertical evolution of rainfall in the descent from cloud to ground can then be studied, and examination of all data in collaboration gives insight into the micro physical processes dictating rainfall events. This information is useful both for developing numerical weather prediction models, and for examining potential changes in climate.

A 55 MHz WPR has operated in Darwin, Northern Australia, intermittently since 2006, and sampled multiple wet seasons. Storms which passed over the profiler during several seasons have been collected and analysed. Storm data has been classified according to occurring during active monsoon or break conditions (determined by direction of the low level winds), and further sub-classified as convective, stratiform or transitional rainfall. Dominant micro physical processes, where they exist, have then been identified. All events are placed in morphological context with the use of a C-band polarimetric scanning radar. Data from selected events will be presented, and variation between storm types and seasons analysed. Progress towards real time rainfall retrieval will also be presented and discussed.

IAMAS (Meteorology)

M12p - M12 Tropical Dynamics

M12p-225

Sensitivity of tropical circulation to air-sea roughness in aquaplanet simulations

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Previous studies with idealized dry general circulation models (GCMs) have shown the location and strength of the midlatitude jet to be sensitive to the surface drag. Here we use a realistic GCM in the aquaplanet configuration to show that the large-scale tropical circulation (surface winds and the Hadley circulation) is also sensitive to changes in surface drag parameters, for changes lying within the range of observational uncertainties. The changes are effected by modifying the air-sea roughness at low wind speeds. In addition to changing the turbulent fluxes of momentum, changes in roughness affect the parameterized sensible and latent heat fluxes, and these turn out to dominate the circulation response. The mechanisms behind the circulation sensitivity, and the coupling between the tropical and extratropical changes, are explored using a variety of mechanism-denial experiments.

IAMAS (Meteorology)

M12p - M12 Tropical Dynamics

M12p-226

Predicting the MJO at various resolutions with the new global model ICON

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The capability of the new ICOsaheadral Non-hydrostatic global model ICON in representing the MJO is investigated. ICON is a joint development of German National Meteorological Service (DWD) and Max-Planck Institute for Meteorology (MPI-M). Its modelling framework allows for numerical weather prediction and climate simulations across a broad range of scales, down to convective permitting resolution. Regional grid refinement and two way nesting enables us to consider particular regions, e.g. areas of active tropical convection with an increased resolution.
To assess the ability of ICON in developing tropical circulations and especially the MJO, 5-year climate simulations with monthly updated SST and sea ice are conducted at 80, 40 and 20km horizontal resolution. An evaluation of the resulting climatological distributions of precipitation and OLR as well as an investigation of the tropical circulations in wavenumber-frequency spectra reveal the capability of ICON in developing MJO and other tropical waves to various degrees. The impact of resolution and other aspects of the model setup will be addressed in this presentation. We will also compare our results with simulations from other global models.
The performance of ICON in predicting a particular MJO event through its life cycle is demonstrated by conducting 10-day NWP forecasts with 20km resolution that are initialized prior and during the major MJO event in Feb/Mar 2012. While the model encounters some difficulties when the active convection crosses the Maritime Continent, the large scale circulation features, like horizontal wind at various levels are captured well, especially once the MJO was already active at initialization time. An outlook will be given on the potential benefit of local grid refinement.

IAMAS (Meteorology)

M12p - M12 Tropical Dynamics

M12p-227

Impact of high-resolution on seasonal forecast in the tropics

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The resolution in climate models is thought to be an important factor for advancing our seasonal prediction capability, crucial in a changing climate. We present here a unique subset of 10-member retrospective initialized seasonal predictions (1993-2009) carried out with the European community model EC-Earth in three different configurations: coarse resolution (~1° and ~60 km in the ocean and atmosphere models, respectively), mixed resolution (~0.25° and ~60 km) and high resolution (~0.25° and ~30 km). The increased resolution leads to a substantial reduction of Sea Surface Temperature and precipitation biases, as well as an increase of skill in some tropical regions. These improvements will be illustrated together with some hypotheses of mechanisms driving them.

IAMAS (Meteorology)

M12p - M12 Tropical Dynamics

M12p-228

Influence of Atlantic basin tropical easterly waves activity by the intraseasonal variability in 2004

C. Prestrelo[1], *T. Ambrizzi*[1]
[1]*SAO PAULO UNIVERSITY,*
Institute os Astronomy- Geophysics and Atmospheric Sciences, SAO PAULO, Brazil

Previous studies indicate that MJO modulates the activity of Tropical Cyclone and African Easterly Waves (AEW) on West African and Tropical north Atlantic Ocean. For this study, the authors used the MJO index created by Wheeler and Hendon to examine that phase of MJO. Subsequently were cases AEW identified occurred in 2004 which have propagation on the Tropical North Atlantic using daily rainfall data from Tropical Rainfall Measuring Mission (TRMM) and 6-hourly atmospheric fields from the ECMWF Interim reanalysis (ERA Interim). During occurrence cases of AEW was observed an increase in rainfall over the Atlantic Ocean Tropical North and decrease on the northern coast of South America.

Increased intraseasonal convective activity intensified convective activity of AEW. This increased convection decreases the magnitude of the wind which consequently reduces the moisture transport from the Atlantic Ocean to the north coast of South America.

A climatology of easterly waves events related to the different phases of the MJO is being prepared as well as the analysis of their influence on the humidity flux entering through the Northern South America which is very important to modulate the precipitation in the region. These results will be presented elsewhere.

IAMAS (Meteorology)

M12p - M12 Tropical Dynamics

M12p-229

Characteristics of the maritime continent convection during the preconditioning stage of the Madden-Julian Oscillation

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Department of Coupled Ocean-Atmosphere-Land Processes Research, Yokosuka, Japan
[2]*Japan Agency for Marine-Earth Science and Technology,*
Department of Seamless Environmental Prediction Research, Yokohama, Japan
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During the international field experiment "Cooperative Indian Ocean experiment on intraseasonal variability in the Year 2011 (CINDY2011)", the preconditioning process of the Madden-Julian Oscillation (MJO) was observed. Diurnal cycle of convection was activated over Sumatra and Borneo Islands in maritime continent during the preconditioning stage of the MJO. Two-day period of westward propagating disturbances was formed from the diurnal cycle of convection and acted a favorable environment for the preconditioning of the MJO over the central Indian Ocean (Kubota et al. 2014). Maritime continent convections are simulated by Nonhydrostatic ICosahedral Atmospheric Model (NICAM) and investigated the characteristics of the diurnal to two-day period and the moistening process during the preconditioning stage of the MJO.

IAMAS (Meteorology)

M12p - M12 Tropical Dynamics

M12p-230

The Madden-Julian Oscillation and extratropical interactions

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[2]*University of California, Earth Research Institute, Santa Barbara, USA*

The Madden–Julian Oscillation (MJO) has a significant role in weather and climate variability. The MJO significantly influences the occurrence of heavy precipitation around the globe. Since the MJO involves intense tropical convective heating anomalies, tropical–extratropical interactions are significant during its life cycle. Consequently, the MJO interacts with the large-scale circulation in the extratropics of both hemispheres.

This presentation examines the life cycle of the MJO, interactions with the North Pacific storm track and extratropical cyclogenesis during boreal winter. The study uses National Centers for Environmental Prediction Climate System Forecast NCEP CFSR reanalysis from 1979-2013 and a tracking algorithm to detect the formation of extratropical cyclones. MJO events are identified with filtered outgoing longwave radiation (OLR) and zonal winds at 850-hPa and 200-hPa anomalies. The presentation will discuss the statistics of extratropical cyclones during the life cycle of the MJO. An isentropic potential vorticity analysis is performed to elucidate the dynamical mechanisms associate with the MJO and its influence on extratropical cyclogenesis. In addition, numerical experiments performed with the National Center for Atmospheric Research Community Earth System Model NCAR CESM model are used to analyze the interaction between extratropical wave train patterns associated with the MJO and the storm track in the Northern Pacific.

IAMAS (Meteorology)

M12p - M12 Tropical Dynamics

M12p-231

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[1]*SAO PAULO UNIVERSITY,*
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IAMAS (Meteorology)

M13a - M13 Regional Climate Variability and Change

IUGG-3535

The potential to improve climate change detection through optimal seasonal averaging: The case of the North Atlantic jet

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[1]*University of Reading, Meteorology, Reading, United Kingdom*

This study shows that the detection of anthropogenic climate change can be improved by recognising the seasonality in the climate change response. This is demonstrated for the detection of the climate change response in the zonal wind at 850 hPa (U850) in the North Atlantic and European region as projected by the models participating in the fifth phase of the Coupled Model Intercomparison Project (CMIP5), under the RCP8.5 scenario. It is found that the U850 future response is characterised by a marked seasonality composed of two different dynamical responses: an eastward extension of the North Atlantic jet into Europe in November-April, and a poleward shift in May-October. The time of emergence of the multi--model mean climate change response in U850 in these two extended seasonal means is found to be 5-15 years earlier than that evaluated for the traditional meteorological seasons (December-February and June-August). This is due to an increase in the signal to noise ratio associated with the spatial coherence of the response within the extended seasons. Furthermore, the U850 response in North Africa in the extended winter and in the South--East North Atlantic (including Iberia) in the extended summer are estimated to emerge by 2025 relative to the 1960-1990 climate, according to the models with a strong future response. This implies that observations might soon be useful to test aspects of the atmospheric circulation response predicted by some of the CMIP5 models. The role of the seasonality in the North Atlantic jet response on the time of emergence of precipitation changes in Central Europe and the Mediterranean area will be finally discussed.

IAMAS (Meteorology)

M13a - M13 Regional Climate Variability and Change

IUGG-3840

Factors causing recent changes in temperature extremes

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[2]University of Colorado, CIRES, Boulder- CO, USA

Multiple factors contribute to changes in the likelihood of temperature extremes in a given region and season. Understanding their relative importance is critical for determining the extent to which such extremes may be predictable, as well as for estimating future changes. Here, we consider regional and seasonal patterns of recent changes in temperature extremes, focusing especially on hot summer and cold winter occurrences over the continental United States since 1980. In addition to the effects of human-induced climate change, ocean fluctuations that are not clearly related to anthropogenic causes can substantially alter the likelihoods of extreme temperature events. We thus consider how the particular observed time trajectory of sea surface temperatures and sea ice concentrations over this period has altered extreme event probabilities. Contributions from the various factors to event likelihood are assessed through ensemble model experiments subjected to various streams of boundary forcings that operated since 1980.

IAMAS (Meteorology)

M13a - M13 Regional Climate Variability and Change

IUGG-4456

A data centred method to estimate and map changes in the full distribution of daily precipitation and its exceedances

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[1]*University of Warwick, Physics, Coventry, United Kingdom*
[2]*London School of Economics,*
Grantham Research Institute on Climate Change and the Environment, London, United Kingdom
[3]*London School of Economics, Centre for the Analysis of Time Series, London, United Kingdom*

Estimates of how our climate is changing are needed locally in order to inform adaptation planning decisions. This requires quantifying the geographical patterns in changes at specific quantiles or thresholds in distributions of variables such as daily temperature or precipitation. Here we focus on these local changes and on a method to transform daily observations of precipitation into patterns of local climate change. We analyse local climatic timeseries to assess which quantiles of the local climatic distribution show the greatest and most robust changes, to specifically address the challenges presented by 'heavy tailed' distributed variables such as daily precipitation. We extract from the data quantities that characterize the changes in time of the likelihood of daily precipitation above a threshold and of the relative amount of precipitation in those extreme precipitation days. Our method[1] is a simple mathematical deconstruction of how the difference between two observations from two different time periods can be assigned to the combination of natural statistical variability and/or the consequences of secular climate change. This deconstruction facilitates an assessment of how fast different quantiles of precipitation distributions are changing. This involves both determining which quantiles and geographical locations show the greatest change but also, those at which any change is highly uncertain. We demonstrate this approach using E-OBS gridded data timeseries of local daily precipitation from specific locations across Europe over the last 60 years.

[1] S C Chapman, D A Stainforth, N W Watkins, 2013, Phil. Trans. R. Soc. A, 371 20120287; D. A. Stainforth, 2013, S. C. Chapman, N. W. Watkins, Environ. Res. Lett. 8, 034031

IAMAS (Meteorology)

M13a - M13 Regional Climate Variability and Change

IUGG-5296

Free and forced changes of the surface atmospheric circulation andstorminess over the last 140 years

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[1]*University of Colorado and NOAA, CIRES/CU and PSD/ESRL/NOAA, Boulder, USA*
[2]*NOAA, PSD/ESRL/NOAA, Boulder, USA*

To gain a clearer understanding of natural versus forced changes of the surface atmospheric circulation and storminess, we have investigated large ensembles of three distinct types of observational datasets and model simulations of the 1874 to 2010 period. The first type is a 56-member ensemble of 6-hourly observational global atmospheric reanalyses, the 20CRv2 dataset. The second type, referred to as the AMIP20C dataset, is a 56-member ensemble of atmospheric GCM simulations of the same period using the same NCEP AGCM used to produce the 20CRv2 dataset, and with identical specifications of time-varying SST, sea ice, and radiative forcings. The third type is a multi-model ensemble of 62 CMIP5 climate model simulations of the same period with observed radiative forcings. These three types of datasets enable cleaner separations of the radiatively forced versus internal natural climate variations than previously possible.

The most important result from this study is that the large observed trends in many circulation variables evident over the second half (1943-2010) of the period are much weaker or non-existent when considered over the full period (1874-2010), and are associated with even weaker long-term storminess trends (defining the storminess at each gridpoint as the r.m.s. of 24-hr SLP differences). This has important implications for the atmospheric circulation response to global warming, and casts doubt on inferences about this response drawn in many studies from considering only the second half (or even shorter subsets) of the record. Consistent with the weak observed long-term circulation trends, the ensemble-mean long-term trends in the AMIP20C and CMIP5 simulations are also weak in most regions of the globe, except in the extratropical southern hemisphere.

IAMAS (Meteorology)

M13b - M13 Regional Climate Variability and Change

IUGG-0568

Ratios of record high to record low temperatures in Europe show an accelerating trend despite slowdown in mean temperature trends

M. Beniston[1]
[1]*The University of Geneva, Institute for Environmental Sciences, CAROUGE / GENEVA, Switzerland*

A study has been undertaken to analyze the behavior of record high and low values of temperature since the early 1950s for 30 locations spread across Europe. When establishing the ratios of the number of record Tmax to record Tmin values in each year, it is seen that there is a quasi-exponential increase in these ratios in the most recent decade. This seems to be an apparent paradox in view of the so-called climate warming hiatus that has been observed since the early 2000s, but closer analysis suggests that the relationship between the record high:low ratios and mean annual temperatures is not linear but rather quadratic. High values of record high to record low ratios in both the Mediterranean region and beyond 60° latitude north are likely related to an amplification of low-level atmospheric temperatures resulting from shorter snow seasons in the north and enhanced summer dryness in the south.

IAMAS (Meteorology)

M13b - M13 Regional Climate Variability and Change

IUGG-1386

Past and future European temperature trends: uncertainty due to internal variability

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[1]*CERFACS, Climate Modelling, Toulouse, France*
[2]*National Center for Atmospheric Research,*
Climate and Global Dynamics division, Boulder, USA

This talk will highlight the relative importance of internally generated versus externally forced climate trends over the past and next fifty years at local and regional scales over Europe. The assessment is based on a large ensemble of climate simulations performed with the CESM1 NCAR model that cover the 1920-2100 period. The ensemble contains a large number of integrations (30), each of which is subject to identical natural and anthropogenic radiative forcing but initialized from a slightly different atmospheric state. The large ensemble shows that natural climate variability superimposed upon forced climate change results in a large range of possible trends for surface air temperature over the past and next fifty years. A variant of the flow-analogue approach is used to partition the temperature changes due to internal variability into dynamical and thermodynamical components. Internal thermodynamical changes are shown to be more important in summer while dynamical ones are the dominant contributors in winter. Removing the unpredictable dynamical contribution results in a significant increase of the signal to noise ratio, particularly in winter. The thermodynamical changes are shown to be linked with the ocean, sea-ice and land surface conditions. In winter, snow cover is shown to be mainly responsible for the spread in thermodynamical changes over continental Europe while soil moisture is important in summer. Ocean and sea-ice conditions are also important, especially along coastal regions. While large ensembles are needed to fully characterize the forced response, they also provide a robust estimation of the uncertainties due to internal variability that is needed to better characterize model structural differences.

IAMAS (Meteorology)

M13b - M13 Regional Climate Variability and Change

IUGG-1580

Persistent cold air outbreaks over North America in a warming climate

L.R. Leung[1]*, Y. Gao*[1]*, J. Lu*[1]*, G. Masato*[2]
[1]*Pacific Northwest National Laboratory,*
Atmospheric Sciences and Global Change Division, Richland, USA
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This study examines future changes of cold air outbreaks (CAO) using a multi-model ensemble of global climate simulations from the Coupled Model Intercomparison Project Phase 5 and high resolution regional climate simulations. Overall, climate models agree on a dip in CAO duration across North America, but the percentage change is consistently smaller from western Canada to the upper mid-western U.S. with historically more frequent CAO. By decomposing the changes of the probability density function of daily surface temperature into changes due to mean warming and changes in standard deviation and skewness/higher order moments, the contributions of each factor to CAO changes are quantified. Results show that CAO changes can be explained largely by the mean warming, but the decrease in temperature standard deviation contributes to about 20% reduction of CAO from Alaska to northeastern U.S. and eastern Canada possibly due to the Arctic amplification and weakening of storm track. A thermodynamical modulation of the skewness called the '0 ^{o}C mode' effect is found to operate prominently along the 0 ^{o}C isotherm hemispherically and reduce CAO in western and northeastern U.S. with winter snow cover by up to 10%. This effect also produces a manifold increase in CAO events over the Arctic sea ice. An increased frequency in atmospheric blocking also contributes to increases in CAO duration over Alaska and the Arctic region. Overall, the multi-model projections emphasize that cold extremes do not completely disappear in a warming climate. Concomitant with the relatively smaller reduction in CAO events in northwestern U.S., the top 5 most extreme CAO events may still occur, and wind chill will continue to have societal impacts in that region.

IAMAS (Meteorology)

M13b - M13 Regional Climate Variability and Change

IUGG-4965

How unusual was the cold winter of 2013-14 in the Upper Midwest?

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. Randall Dole- Martin Hoerling[2], *G.J. van Oldenborgh*[3], *J. Walsh*[4]
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[3]*KNMI, Climate Research, De Bilt, Netherlands*
[4]*University of Alaska, IARC, Fairbanks, USA*

While much of the Northern Hemisphere experienced record-warmth during 2014, a persistent cold anomaly covered the Upper Midwest and adjacent Canada for much of the same year. In particular, the winter of 2013-14 ended up as the coldest since at least 1978-79 for most of the region, as manifested in the biggest Great Lakes ice extent since that winter. This came on the heels of a pronounced regional warming trend since the 1970s that may have exacerbated its impacts (the U.S. economy unexpectedly contracted in the 1st quarter of 2014).

This presentation will examine how the probability of a cold winter over this region has changed since the late 19th century. We will explore how both the mean and the variability of winter temperatures have changed in 2000 yr equilibrium coupled climate simulations each for pre-industrial and current radiative forcings, as well as for the observational and reanalysis records. While the latter will be queried on changes in the vertical structure of cold winter conditions since the 1970s, both model and observational data will be analyzed with respect to the role of snow cover anomalies in maintaining persistent temperature anomalies for a whole season.

IAMAS (Meteorology)

M13c - M13 Regional Climate Variability and Change

IUGG-0873

The response of the equatorial Pacific Ocean to the 11-yr solar cycle: warming or cooling?

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[1]*Aristotle University of Thessaloniki, Thessaloniki, Greece*
[2]*University of Oxford, Atmospheric- Oceanic and Planetary Physics, Oxford, Greece*
[3]*Aristotle University of Thessaloniki, a, Thessaloniki, Greece*
[4]*GEOMAR Helmholtz Centre for Ocean Research Kiel, Christian-Albrechts Universitat zu Kiel, Kiel, Germany*
[5]*Scripps Institution of Oceanography, s, San Diego, USA*

A physical understanding of the response of the tropical Pacific to the external solar cycle forcing may improve efforts in decadal prediction. We here exploit the largest ensemble of coordinated historical simulations undertaken within the 5th phase of the Coupled Model Inter-Comparison Project (CMIP5) in order to detect influences of the 11-yr solar cycle on the equatorial Pacific atmosphere-ocean system. The majority of the CMIP5 models show a lagged surface warming, by one to two years, which is more pronounced in the western equatorial Pacific Ocean. The ascending branch of the Walker circulation shifts to the east resulting in easterly anomalies throughout the equatorial troposphere. The strong atmosphere ocean coupling perturbs the thermocline and causes a dynamical cooling in the ocean subsurface. We discuss a dynamical/thermodynamical mechanism which may result in an EL Nino-like warming on quasi-decadal time scales and additionally we provide evidence that similar solar signals can be detected in the observed record.

IAMAS (Meteorology)

M13c - M13 Regional Climate Variability and Change

IUGG-2377

High resolution wind hindcast over the Bohai and Yellow Sea in East Asia: evaluation and wind climatology analysis

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[3]*University of Hamburg, Center of Excellence CliSAP, Hamburg, Germany*

A 34-year (1979-2012) high-resolution atmospheric hindcast over the Bohai and Yellow Sea (BYS) has been performed using COSMO-CLM 4.14 (CCLM) forced by the ERA-Interim reanalysis data (ERA-I). The skill of CCLM in surface wind reproduction and the added value from dynamical downscaling have been investigated by comparing with the co-located QuikSCAT grid data and the site observation. The results reveal that CCLM has reliable ability to reproduce the regional wind characteristics over the BYS. Added value has been detected in the coastal areas with complex orography; however, no obvious added value in the offshore areas. CCLM wind is revealed with strong seasonal variability, with more improvement in summer relative to ERA-I even in the offshore areas, which may benefit from the well-resolved tropical cyclones or mesoscale convective system by CCLM in summer. CCLM shows better skill in representing light and moderate winds, but has more added values at strong winds relative to ERA-I, though not all the cases when compared with site observation. The spatial digital filter method was used to investigate the source of added value, and results show that CCLM adds value to ERA-I mainly in medium scale, which may due to the better resolved mesoscale processes by CCLM. Furthermore, the wind climatology has been investigated and increasing trend in the south Yellow Sea especially in winter and spring have been found at the 0.05 significant level.

IAMAS (Meteorology)

M13c - M13 Regional Climate Variability and Change

IUGG-2851

The effect of global dynamical factors on the interannual variability of land-based rainfall.

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Rainfall is notoriously variable, even when seasonal means are taken. In part, this may be attributed to the fact that it is influenced by a variety of different dynamical factors. Some of these (such as El Niño/La Niña) are reasonably well known, but others with smaller but significant contributions have received relatively little attention, and these are explored here. We describe a study of the interannual variability of observed global land-based rainfall, and the dynamical factors that may influence it from 1900, utilising a data set of observations compiled from various global sources. Since rainfall is affected by different factors in different seasons, the analysis is seasonal, and a multiple regression analysis based on time series is performed to determine the effects on seasonal rainfall of eleven factors that include the following: ENSO, global warming, Indian Ocean dipole, the quasi-biennial oscillation (QBO), the Atlantic Meridional (or Multi-decadal) Oscillation, the Pacific Gyre Oscillation, the Southern Annular Mode (SAM), the solar cycle and global volcanism. Patterns of influence of these various factors on rainfall are obtained, which are indicative of (mostly, so far poorly understood) dynamical processes associated with these variations. However, a large fraction of the rainfall variance remains random and unpredictable.

IAMAS (Meteorology)

M13c - M13 Regional Climate Variability and Change

IUGG-5034

Connections between tropical pacific convection states and north pacific synoptic activity in hindcast simulations

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Forecasts at lead times of 10 days or less have improved significantly in recent decades, but beyond that, useful forecast skill is encumbered not only by the inherent increased uncertainty and reduced predictability, but also by the poor representation of the remote intraseasonal to seasonal climate shifts in large scale forcing and interactions that dictate the evolution of the atmosphere. For North America, these climate forcing shifts and interactions frequently emanate from the Pacific and depend on its interaction with the North Pacific flow. For this research we utilize the NCAR-DOE Community Earth System Model (CESM). CESM is a fully integrated modeling framework with multiple capabilities. We use the Cloud-Associated Parameterization Testbed (CAPT) framework which allows us to make use of high-quality re-analyses products (e.g. ERA-Interim; NASA-MERRA) to efficiently initialize and cheaply run multiple short term hindcasts.

This presentation will demonstrate the ability of CESM to simulate, in hindcasts, three important aspects of North Pacific intraseasonal variability; 1) West Pacific tropical modes of variability, including the phase, amplitude and teleconnections of the Madden Julian Oscillation (MJO); 2) The spectrum of mid-latitude, eastward propagating disturbances in the North Pacific that impact the Western United States; and 3) The phase relationships between tropical modes of variability and mid-latitude propagating systems, whether they are simulated well, whether they are predictable and whether this prediction skill increases for certain characteristics of tropical variability. All three aspects of the North Pacific variability will be discussed in this talk, particularly as it relates to model skill, atmospheric processes and model resolution.

IAMAS (Meteorology)

M13d - M13 Regional Climate Variability and Change

IUGG-0892

Two regional climate change projections for the Eastern European/Black Sea Region

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Two regional climate models were used to project the regional climate of the **Black Sea** region and **Eastern Europe** in the late XXI century (2071 - 2100). It was a first study to drive the regional models by **INMCM5**, a CMIP5-member GCM from the Institute of Numerical Mathematics of the Russian Academy of Sciences. The regional models used were the **HadRM3P** and the **RegCM4** and the RCP8.5 scenario was chosen. While **HadRM3P** was used by the authors to study the regional climate of the Black Sea area before, the RegCM4 had to be validated first.
To perform the validation step, the **RegCM4** model was applied to downscale the ERA-Interim reanalysis for the period of 1979 – 2014. The analysis confirmed the model is able to correctly simulate the regional climate, keeping the initial domain-averaged climate characteristics and capturing the regional climatic patterns. The model had produced realistic interannual variability of temperature and precipitation, slightly underestimating it in winter. The model had successfully simulated the regional precipitation regime, with mean annual error doesn't exceeding 15%. The main disadvantage was the overestimation (up to 30%) of precipitation during November – March in the northern part of the modeldomain.
The models project significant warming in Southeastern Europe and Turkey, especially pronounced in summer (up to 5°C) and relatively weaker in winter (2 - 3°C). Precipitation is reduced by 30 - 40% in spring and summer in the areas of maximum warming and in the Carpathians. Precipitation reduction occurs mainly due to rarer convective events in future climate, while average intesity stays the same. The regional projections are in good agreement with the large-scale ones and with the results of previous studies.

IAMAS (Meteorology)

M13d - M13 Regional Climate Variability and Change

IUGG-1823

The current Mega Drought in Central Chile: Is the future now?

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[3]*University of Chile, N/A, Santiago, Chile*

Annual precipitation deficits ranging from 30-70% have afflicted most of central Chile (west coast of South America, 30-40°S) for the last decade, most intensely from 2011 onwards, leading to an unprecedented drought in terms of intensity, spatial and temporal extent. The current 'Mega Drought' stands out not only in the historical record but also in precipitation and stream flow reconstructions for the last 1000 years. ENSO is a major driver of central Chile interannual precipitation variability (with La Niña years usually drier than average) but this extended dry period has included both La Niña and El Niño years. Furthermore, the cold phase of the Pacific Decadal Oscillation (PDO) is also associated with less precipitation in central Chile. Indeed, the last decade has exhibited a cold PDO, but the actual precipitation deficit falls well below than expected considering both the instrumental and tree-ring reconstructed periods. Thus, while the ENSO, PDO and internal variability have contributed to the maintenance of the rainfall deficit, there is an strong suggestion that anthropogenic climate change is partially responsible for the present Mega Drought. Such effect is mostly dynamic, due to the decrease in the westerly winds impinging central Chile. We also note that model-based climate projections for the 21st century consistently indicate a marked drying trend over this region.

In this work we also show some of the effects of the Mega Drought in selected physical systems, including natural vegetation, snow pack over the Andes mountains, surface and subsurface hydrology and forest fires. Given the long temporal extent of this events, its effects are distinct from those associated with the intense but shorter droughts that characterize the past century.

IAMAS (Meteorology)

M13d - M13 Regional Climate Variability and Change

IUGG-5197

Understanding model uncertainty in 21st century regional Antarctic climate change

T. Bracegirdle[1], *J. Turner*[1], *T. Phillips*[1]
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West Antarctica is one of the most rapidly warming regions on Earth and climatic changes there are of global relevance due to impacts on sea level and ocean circulation. A key question is whether the rapid rate of change observed over the last few decades will continue into the future. However, the Coupled Model Intercomparison Project Phase 5 (CMIP5) climate models exhibit large inter-model differences in 21st century climate projections for the polar regions. We will present an assessment of the sources of this model uncertainty over West Antarctic, East Antarctica and the whole continent and how these can be related to present-day observable variables. A key finding is that CMIP5 models with more extensive sea ice in their present-day simulations exhibit larger projected increases in temperature and precipitation, both driven by larger decreases in sea ice itself. Of particular relevance to the contribution from Antarctica to sea-level change is that 61% (59%) of the inter-model variance in projected change in net precipitation over terrestrial Antarctica can be explained by inter-model differences in simulated historical mean sea ice area (extent). Most CMIP5 models have too little sea ice in their historical simulations and may therefore be underestimating the magnitude of future warming and precipitation increase. The implications of these results for observationally constraining Antarctic climate projections will be discussed.

IAMAS (Meteorology)

M13d - M13 Regional Climate Variability and Change

IUGG-5220

On the comparison of EuroCORDEX ensemble and ENSEMBLES ensemble of regional simulations

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The assessment of the ensemble of available EuroCORDEX simulations is provided in terms of monthly mean analysis of surface temperature and precipitation monthly amount. Both ERA-Interim perfect boundary conditions simulations and historical runs driven by different GCMs from CMIP5 are validated against E-OBS data and compared for both available resolutions (0.11 and 0.44 deg.). The results are presented using the maps of model biases as well as in terms of the areal statistics for PRUDENCE regions, where former ENSEMBLES ensemble of regional simulations is used for comparison. No significantly better results can be seen when comparing the results of 0.11 deg. resolution with respect to the 0.44 deg. Moreover, while both ensembles (basically all the members) are in very good agreement in annual cycle for temperature and very close to the reality, for precipitation quite significant disagreements appear for many of the simulations over some regions, in both ensembles, especially in terms of annual course.

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Trends in the frequency of high relative humidity over China: 1979-2012

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High relative humidity (HRH) in the troposphere is often associated with the occurrence of cloud layers. Thus the frequency of HRH and its changes in the troposphere may be related to the occurrence frequency of cloud layers and their changes. In this study, trends in the frequency of HRH (defined as days with relative humidity ≥80%) over China were analyzed from surface to mid troposphere during 1979-2012 using a homogenized humidity dataset for spring (March-May), summer (June-August), autumn (September-November), and winter (December-February). Results show that at the ground level, decreasing trends are seen at most stations in Southeast China during spring and in the north part of China during summer. In the lower troposphere (850 hPa and 700 hPa), most stations over China show positive trends in summer, autumn, and winter. For the mid troposphere (500 hPa and 400 hPa), increasing trends predominate over China in spring, summer, and autumn. These results were more significant when rainy days were excluded. These results are consistent with the increasing low-mid cloud amount during recent decades. Finally, six reanalysis datasets, including the NCEP/NCAR I, NCEP/DOE II, CFSR, ERA-Interim, MERRA, and JRA-55, were compared to the observed increasing trends in the HRH frequency in the low-mid troposphere. Similar vertical profiles of HRH trends in the reanalysis datasets and the homogenized humidity dataset are found in certain seasons and for certain regions, with positive or small negative trends at high levels and large negative trends at 850 hPa level. In particular, the positive HRH trends in the MERRA for spring, summer and autumn are consistent with the increasing HRH frequency revealed by the homogenized humidity dataset.

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Precipitation anomalous and its effects in Port Harcourt Metropolis of Rivers State Nigeria

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Weather and climate have been changing globally and regionally as well. Climate change in sub Saharan Africa is manifesting essentially as rainfall variability.The extremes of the weather must be viewed in contest of where, at what times of the year and in what climatic period they occurred, how long they lasted and what area they covered. For instance, mean annual rainfall of 200mm will not be unusual in the Southern part of Nigeria (example, in Rivers State), to compare with the northern part during the rainy season. Changing climate variability causes increase in air temperature, rates of evaporation, stronger atmospheric circulation as well as the intensification of the global hydro-logic cycle. The availability of water is determined by the rainfall pattern. Excessive rainfall therefore, causes flooding, erosion, leaching, loss of soil fertility, land degradation and related diseases etc., while rainfall deficiency cause drought, dehydration, diseases and epidemics. This paper analysis rainfall variability in Port Harcourt, Nigeria using 20 years (1991-2010) precipitation data, and the anomalous is observed in annual excessive rainfall of which the effects is manifesting through flooding and related problems. In 1991 and 1998 mean annual rainfall were 190.4mm and 214mm respectively. In 2009, mean rainfall of 213.7mm was recorded and its associated flooding caused a serious havoc in the metropolis and beyond. The study, however, makes some recommendations on how to reduce the effects of the anomalous.

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The continuum of wintertime Southern Hemisphere atmospheric teleconnection patterns

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This study uses the method of self-organizing maps (SOMs) to categorize the June-August atmospheric teleconnections in the 500 hPa geopotential height field of the Southern Hemisphere (SH) extratropics. This approach yields 12 SOM patterns that provide a discretized representation of the continuum of SH teleconnection patterns from 1979-2012. These 12 patterns are large in spatial scale, exhibiting a mix of annular mode characteristics and wave trains of zonal wavenumber varying from two to four. All patterns vary with intrinsic timescales of about 5-10 days, but some patterns exhibit quasi-oscillatory behavior over a period of 20-30 days, whereas still others exhibit statistically significant enhanced and suppressed frequencies up to about four weeks in association with the Madden-Julian Oscillation. Two patterns are significantly influenced by the El Niño-Southern Oscillation (ENSO) on interannual timescales. All 12 patterns have strong influences on surface air temperature and sea ice concentrations, with the sea ice response occurring over a timescale of about 2-4 weeks. The austral winter has featured a positive frequency trend in patterns that project onto the negative phase of the Southern Annular Mode (SAM) and a negative frequency trend in positive SAM-like patterns. Such atmospheric circulation trends over 34 years may arise through atmospheric internal variability alone and, unlike other seasons in the SH, need not to invoke external forcing as a dominant source of circulation trends.

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M13p-178

Black sea upwellings and its interaction with regional climate

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The paper analyses results of the observation of upwelling events in the north-western part of the Black Sea, mostly near the South Crimea. The main purpose of the paper is the estimation the impact of atmospheric processes on the generation and repeatability of upwelling in the coastal zone of the Black Sea and the study of its interannual variability due to changes in regional climate of the Black Sea region. The statistic of upwelling events in this region over the past decade, its genesis and dynamics, and the impact of these processes on the atmospheric circulation and climate variability are investigated. Used The satellite data, reanalysis data and high-resolution regional models are used. Estimated Accuracy of the atmospheric characteristics determination according to modern reanalysis on the basis of its comparison with the results of experiments in coastal zone of the Black Sea are estimated. One of the goals of the experiments were to compare the results of synchronous direct and remote measurements of ocean-atmosphere coupling parameters. Our measurements demonstrated that the atmosphere boundary layer condition essentially depends on the sea surface structure, which, in turn, transfers the information from processes in a deep sea. A detailed study of oceanic and atmospheric processes occurring in upwelling zones are carried out. Reanalysis data, mesoscale modeling and satellite data use to evaluate the impact of upwelling on the heat transfer characteristics throughout the Black Sea region.

IAMAS (Meteorology)

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Teleconnection between the concurrent variations of the East Asian jet stream and the heavy rainfall patterns in China

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In early 2008, the concurrent variations between the East Asian subtropical jet (EASJ) and the East Asian polar jet (EAPJ) played a pivotal role in modulating the evolution of heavy precipitation over central-southern China. The concurrent intensity variation between two jets influenced the intensity of precipitation over central-southern China, but the concurrent position variation effected the location of rainfall centers. When the EASJ (EAPJ) was stronger (weaker), the rainfall increased markedly over central-southern China. When the two jets both migrated southward during the first two rainfall periods, the precipitation centers located over central China. Thereafter, two jets shifted northward during the last two periods, causing the rainfall centers migrated southward from central to southern China. Lag-regression analysis indicated that the impacts of concurrent variations between two jets on the heavy precipitation in early 2008 mainly reflected in synoptic-scale activities, and these signals can be found nearly one week earlier.

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Link between climate change and halo formation

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Halos are magnificent optical phenomenon that are observed as circular belts around the sun or the moon. Nowadays physics behind the halo formation is thoroughly explained by laws of optics such as refraction, reflection and dispersion of light. They form in the existence of ice crystals, a source of light and an observer. Ice crystals that cause such an optical event found in middle and upper troposphere inside the cirriform clouds. Therefore it is clear that a slight change in the tropospheric temperatures will effect the type of the ice crystals, hence the type of the halo. In this study the types of halo are analyzed by using HALOSIM3.6 halo simulation program. HALOSIM3.6 simulates the halo as light that interacted with the ice crystals, reaches the observer's eyes. In the program the type of a halo strictly depends on shape of ice crystals and altitude of the light source. Since it is well-known that the shape of the ice crystals depend on the temperature, the increase in the temperature due to climate change will effect the halo types. The long-term temperature variability in the tropics, mid-latitudes and the poles, at 500mb, 400mb and 300mb pressure levels is analyzed using ERA-INTERIM data from 1979 to 2013. It is found that temperature at the observed levels has increased and the type of halo viewed at the different latitudinal regions has altered since 1979.

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Regionality of low temperature record-breaking events in China and its associated circulation

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Extreme cold events frequently occur in recent several years and arouse widespread concern. In this study, 17 record-breaking event processes (RBEPs) of low temperature during 1981-2012 are identified by using daily minimum temperature at 1897 meteorological stations in China. These RBEPs are classified into two types according to the occurring area at northern or southern China to compositely examine the associated circulations. It is revealed that the RBEPs under Arctic oscillation (AO) negative phase tend to occur at northern China while the RBEPs at southern China likely happen under AO positive phase. In the RBEPs occurring at southern China, the continent high pressure over Mongolia area was extremely intensified and the East Asian polar front jet stream was enhanced accompanied with strong synoptic-scale eddy kinetic energy transports. Correspondingly, the cold air masses broke out and unobstructed intruded southward to low latitudes, causing severe cooling effect in southern China. In the RBEPs occurring at northern China, however, the extremely intensified high pressure located over northern Siberian area, combining with northward enhanced subtropical jet stream, then cold air masses were accumulated and blocked at mid-latitudes, resulting in RBEPs of low temperature in this area. Further study imply that decadal change of AO phase and synoptic-scale eddy activities might synthetically attribute to the different regional preference of the RBEPs of low temperature which are mostly located at southern China in 1990s but concentrated in northern China in 2000s.

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Trends in frequency and intensity of extreme temperatures of the Irtysh Basin

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The Irtysh River is the largest tributary of the Ob River and is an international river partially joining the territories of China, Kazakhstan and Russia. The trends in the frequency and intensity of extreme temperatures of the Irtysh Basin were analyzed based on the long-term (1936~2005) observed daily temperature data collected from four meteorological stations. The Mann-Kendall method was applied to detect the trend and the linear regression method was applied to estimate the change magnitude of an existing trend. The frequency and intensity of the extreme low temperature are changed significantly, but those of the extreme high temperature are changed slightly. Both the total days and mean intensity of the extreme low temperature are decreased significantly, and the trend in frequency is more significant than the trend in intensity. A new indicator named the weighted extreme temperature index was proposed, which combines the frequency and intensity and reveals the severity of extreme temperature. For all meteorological stations, the weighted extreme low temperature indices are decreased significantly and the weighted extreme high temperature indices are changed slightly, indicating the reduced severity of the extreme low temperature.

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M13p-183

Harmonic analysis of Precipitation over Middle East

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One of the most important features in analyzing the climatology of any region is to study the precipitation as the most variable climatic element. In addition, the abnormal variability and uneven spatial-temporal distribution of precipitation are often the direct reasons for the extreme flood and draught events. The detection of oscillations in precipitation time series yields important information for the understanding of climate. These oscillations can be seen as a response of the climate system either to external forcing or feedback processes.In this study, harmonic analysis has been employed to study the seasonal variation of precipitation over the Middle East using precipitation values obtained from the 20C3M (run1) experiment of the GFLD general circulation model and CPC Merged Analysis of Precipitation (CMAP) from NCEP. Results indicate that the method of harmonic analysis allows a more analytical comparison between model predictions and data than the conventional approach of representing the annual march in the form of a curve of mean monthly rainfall amounts. Comparison between model outputs and observational data based on maps of the first, second and third harmonic amplitudes and phases show that precipitation is highly variable, both spatially and temporally at different scales (interannual and intra-annual). The search for cyclicity in the climatic record can resolve some of the complexities of the atmospheric system. The method delineates regional boundaries of the various precipitation regimes in the Middle East,but the GCM dose not capture a significant amount of the regional detail in precipitation climatology when its results are decomposed by harmonic analysis.

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Effects of aerosols on regional climate in a chemistry-climate model (GRIMs-Chem)

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We analyze the effect of aerosols on regional climate in East Asia using a new chemistry-climate coupled model system (GRIMs-Chem), which is developed by coupling the Global/Regional Integrated Model system (GRIMs) with an offline aerosol module from the GEOS-Chem. This coupled model includes inorganic SO_4^{2-}-NH_4^+-NO_3^-, elemental carbon, organic carbon, sea salt, and soil dust aerosols whose concentrations are calculated at each model time step. The instantaneous aerosol concentrations are then used in the radiative transfer calculation in the model to account for the direct radiative forcing of aerosols. We conducted two 29-year model simulations from 1980 to 2008 with and without aerosols in the model to investigate the interactions of aerosols and regional climate in East Asia. We first evaluate the simulated aerosols by comparing with observations from the Acid Deposition Monitoring Network in East Asia. The comparison shows that the model successfully reproduces the observed seasonal variations of aerosol concentrations, which gives us some confidence in the model capability. We analyze the effect of aerosols on regional climate by comparing the two simulation results and find that aerosols in East Asia cause a warming in the atmosphere but a significant cooling at the surface, resulting in increases of atmospheric stability and decreases of precipitation.

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Characteristics of Tropospheric NO2 over Northeast Asia Using OMI Satellite Data during the Year 2005~2010

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The purpose of this study is to examine the main characteristics and causes of changes in tropospheric NO_2 in the Northeast Asian regions, using the regions' Ozone Monitoring Instrument (OMI) data for the last six years, from 2005 to 2010. In the Northeast Asian areas, China, South Korea, and Japan, with populated cities showed higher yearly mean NO_2 concentration compared to other regions. Especially, the east sectors (sectors 2 and 4) in China, where megacities are located, such as Beijing and Shanghai, showed the highest level of NO_2 concentration. The yearly meanNO_2in Northeast Asia consistently went up from 2005 to 2010 except in 2008 because of increasing NO_2 in China while the NOx reduction policies of South Korea and Japan led to stagnant or decreased NO_2 concentration.
The continued increase in NO_2 in China is caused by economic development of small- and middle-sized cities (groups 2 and 3) rather than big cities (group 1) in the country. Notably, in winter NO_2 concentration elevated in all cities except for the group 1 cities and in summer no pronounced difference was recorded. This indicates that an increase in heating fuel in winter largely affected the yearly mean rise of NO_2 concentration in groups 2~4. In contrast, the summer NO_2 concentration for group 1 had decreased since 2007 and in winter it had been stagnant, indicating the decreased emissions from vehicles in summer and the stagnant emissions from heating fuel in winter. Meanwhile, China experienced a temporary decrease in NO_2 concentration because of the emission regulations during the Beijing Olympic Games in 2008.

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Changes in summer precipitation of South Korea and relation with the large scale atmospheric phenomena

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Recently the understanding of regional climate change became one of the most important issues among the impact and adaptation communities due to different regional impacts of global warming. Regional changes in extreme events, such as heavy rainfall and drought will significantly change the socio-economic system and ecosystems. We investigated the trends and variations in summer precipitation over South Korea, focusing on long-term changes during the periods 1913-2012 (using data from six stations) and 1973-2012 (using data from 56 stations). Over the 1912-2012 periods, the increase in summer precipitation was significant at a 99% confidence level according to the Mann-Kendall test. According to an analysis of decadal changes, the Changma peak has intensified and shifted, and the 20-year return period of daily maximum precipitation has decreased at nearly all stations. Over the 1912-2012 periods, all 56 stations exhibited positive trends in summer total precipitation, and 60.7% of all stations exhibited a significant trend at a 90% confidence level. Extreme summer precipitation totals also increased throughout South Korea at a 90% confidence level at 39.3% of all stations. . We have also investigated the large scale atmospheric phenomena associated with changes in summer extreme precipitation over Korea and indicated that heavy rainfall during summer monsoon was found to be closely associated with a low-level jet.

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M13p-187

Effects of the soil freeze-thaw process on the regional climate of the Qinghai-Tibet Plateau

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Single-point and regional simulation experiments on the Qinghai-Tibet Plateau, both with and without consideration of the soil freeze-thaw process, were set up with CLM3.5 and RegCM4 models. Comparison of the simulated soil temperature and moisture, surface energy flux,and upper−lower atmospheric circulation showed that the regional climate can be influenced by the freeze−thaw process of soil. The results indicate that the freeze−thaw process is a buffer to the seasonal changes in soil and near-surface temperatures and strengthens the energy exchange between the soil and the atmosphere. During the freeze (thaw) process, releasing (absorbing) of phase change energy retards the cooling (heating) effect of air temperature on soil. The soil freeze−thaw process increases (decreases) the surface heat source of the plateau in winter (summer),which increases (decreases) the near-surface temperature in winter (summer). Promoted by atmospheric circulation, the soil freeze−thaw process influences climate at the high and low altitudes of the plateau; this may also contribute to the maintenance of the South Asia High. In the early stages of permafrost degradation, the regional climate effects of freezing and thawing may accelerate the degradation of permafrost.

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M13p-188

Multi-scale variability and trends of precipitation in China

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In this study, a long-term (1960-2013) dataset of rainfall amounts and rainfall frequencies are analyzed. We examined the trend of rainfall amounts and rainfall frequencies in China in terms of light, moderate, heavy, and torrential. An increasing trend of rainfall amounts is found over western China because of more light and moderate rainfall days in all four seasons. Similar increasing pattern is obtained in the southeastern part of China but is mostly contributed from the enhancement of torrential rainfall during summertime. It is also found that substantial decreasing trends are obvious in southwestern and north China with the reduction of light and moderate rainfall. And there are more rainfall days in western China and less rainfall days in eastern part, and the variations in these two regions are mainly due to the change of light rainfall frequencies. Precipitation variability in different latitudes and longitudes is also analyzed on different timescales (from intra-seasonal to decadal time scale). Further, the distribution of rainfall amounts and frequencies under different climate factors in China can be better estimated, which will clearly improve the understanding of regional climate change.

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M13p-189

The amosphere-sand dunes feedback

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Sand dunes cover substantial part of desert area. Fully active dunes are bare while fixed dunes are stabilized by vegetation and biogenic crust. Dune activity is mainly affected by the wind power. Here we suggest the following atmosphere-sand dune feedback: spatial differences in dune vegetation and biogenic crust cover lead to differences in albedo as albedo of bare sand is larger than that of vegetation and biogenic crust. This lead to higher temperature over the vegetated dunes area which lead to air flow from the bare dunes area to the vegetated dunes area, thus increasing the wind activity over the vegetated dune area, leading to enhanced dune activity and thus to decrease in vegetation. Under appropriate conditions this process will continue until the vegetated dune region will become active. We examine this feedback using atmospheric general circulation model, WRF, in selected regions of northwestern Negev Desert and the Sahel region and show that indeed changes in surface albedo lead to significantly enhanced wind activity over the lower albedo region; changes in precipitation due to the albedo contrast are small. We further incorporate this feedback into a simple dune cover model and show that the dune activity becomes rich and complex. We speculate that the atmosphere-sand dune feedback underlies climatic changes in climate transition regions like the Sahel.

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Study of urbanization effect on precipitation in Tianjin

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Based on the daily precipitation data collected from 13 stations in Tianjin between 1961 and 2010, this paper aims to study the influence of urbanization development in Tianjin on precipitation through the comparative analysis of precipitation change between different urbanization development stage in the metropolitan area and suburbs. The study shows that the urbanization development has changed the distribution of precipitation in a limited range. The metropolitan area has altered from the low precipitation center in the 1960s to high precipitation center with adjacent areas since 2000. The influences of urbanization development on diverse rang precipitation is different. Most of the local rainfall on the metropolitan area of Tianjin is the light precipitation that less than 5mm, and the precipitation days are significantly reduced with the urbanization development, i.e. urbanization development inhibits the generation of local light rainfall. With regard to the wide rainfall, the influences of urbanization development vary with season and different size precipitation. Light and moderate rain increase in Spring and Autumn and decreases during Summer, the change is obvious especially when the precipitation is less than 5mm;Both the heavy rain and the higher level of precipitation are increasingly affected by the urbanization development in different seasons and increased by a large margin. The impact of urbanization development on the amount of annual precipitation is weak. There is no evidence that the urbanization development leads to the increase in the number of days of extreme precipitation.

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Long-term trends of atmospheric circulation over Europe: Comparison of three secular datasets and six recent reanalyses

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We compare atmospheric circulation in six European regions from three long datasets: the reconstructed "EMULATE" (EMSLP) dataset spanning back to 1850, the NOAA "20th Century Reanalysis" (20CR) available since 1871, and the ECMWF ERA-20C Reanalysis since 1900. These long datasets are further compared with circulation from 6 reanalyses in the latter half of the 20th century. Circulation is described by indices of flow strength, flow direction, and vorticity, calculated using mean daily sea-level pressure. We used these indices to classify daily circulation into pre-defined circulation types. We studied seasonal changes in the frequency of circulation types, as well as the overall and within-type changes of circulation indices. Circulation types and indices from different databases correspond with each other very well over the British Isles and Baltic region, especially in winter. The least accord is generally in summer, namely in the Mediterranean. The most prominent trend since the mid-19th century is the one connected with a shift towards a positive phase of winter North Atlantic Oscillation (NAO) since the 1960s: increasing occurrence of the SW type over the British Isles and of the W type in Central Europe at the expense of S and cyclonic types. Increasing NAO further resulted in an increase of flow strength especially from the westerly sectors, and a shift towards more westerly flow in types classified as NW, SW, and S. Within-type trends of circulation indices also play a significant role in the overall picture of atmospheric circulation. The three long datasets of gridded sea-level pressure proved useful for representing atmospheric circulation over large parts of Europe. However, some long-term trends found in one database are not always present in the others.

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Land cover change impact on present and future climate simulations over East Asia

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Land surface properties are important in climate simulation for the influences on the Asian summer monsoon region. The dynamic vegetation model simulates the terrestrial biosphere. The effect of the simulated land cover distribution needs to be individually evaluated in present and future climate simulations. Since it is reported that the simulated land surface properties could give influence on the systematic biases in monsoon rainfall and add an impact in the future projection via feedback with the dust loading of the atmosphere [Martin and Levine, 2012]. Motivated by the previous study, we investigate the impact of land cover change generated by the interactive terrestrial carbon cycle in the HadGEM2-ES configuration over East Asia under present-day and future climate condition. Data in this study is HadGEM2-A runs using HadGEM2-ES land cover distribution in Martin and Levine [2012]. In present-day run, over the northern China region, bare soil area increase in HadGEM2-ES rather than HadGEM2-AO. ES land cover by interactive vegetation model gives influences on JJA rainfall and temperature. There is interaction with model systematic biases in the present-day climate. JJA dry bias is larger when HadGEM2-ES land cover distribution was used for Korea. Dust aerosol effect contributes to the dry bias. As bare soil fraction increases, more emitted dust aerosol has direct effect of negative net downward SW, cooling the land surface, weakening monsoon inflow, inducing dry bias over Korea. In global warming, warmer and wetter climate in JJA is expected in East Asia. Relative to global warming, ES land cover and dust direct effects are small and the details are presented.
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Impacts of anthropogenic aerosols and irrigation on the dry season climate over north India

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During the past decade, a significant declining trend in precipitation has been observed over North India in dry season (Oct-Dec). During the same period, this area also exhibits increasing anthropogenic aerosol loadings and more active irrigation activity. The present study aims to investigate the potential influences of anthropogenic aerosols and irrigation on North India dry season climate, using a set of idealized equilibrium global climate simulations with the NCAR CESM v1.0.3. All simulations are forced with sea surface temperature and greenhouse gas levels representing year 1850 and integrated for 30 years. The control run uses the year-1850 aerosol and precursor emission inventories and no irrigation effect is considered in land processes. In the high aerosol run the emission inventories are switched to year-2000 only over North India in the dry season. On a regional, seasonal mean basis relative to the control run, the increased aerosol emissions lead to an 8.31 W m^{-2} decrease in downward solar radiation, a 0.28 ^{o}C surface cooling, and a 3 mm mon^{-1} decrease in precipitation. The interior area around the Indus Valley shows the most severe precipitation decline, associated with regional circulation change and reduced moisture advection. In the irrigation run, in which irrigation effects are imposed during dry season over North India, the increased surface to atmosphere latent heat flux (6 W m^{-2}) caused a significant cooling (-0.42^{o}C) and precipitation decline (-4.16 mm mon^{-1}). The combined aerosol-irrigation simulation reveals their nonlinear effects on regional climate. The current results suggest that anthropogenic aerosols and irrigation can decrease dry season precipitation over North India by perturbing the surface energy budget and regional circulation.

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Influences of the Pacific-Japan teleconnection pattern on synoptic-scale variability in the western North Pacific

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This study investigates the influences of the Pacific–Japan (PJ) teleconnection pattern on synoptic-scale variability (SSV) in the western North Pacific (WNP). The PJ pattern exhibits salient intraseasonal variations, with a dominant peak at 10–50 days. During positive PJ phases, strengthened SSV is found in the WNP, with a much stronger and better organized synoptic wave train structure. Such a synoptic-scale wave train, however, is greatly weakened during negative PJ phases. Examination of the vertical profiles of the observational data suggests that environmental parameters are generally more (less) favorable for the growth of synoptic disturbances under positive (negative) PJ conditions.

Observational results are further verified with an anomaly atmospheric general circulation model, which reveals faster (slower) growth of the synoptic-scale wave train when the environmental anomalies associated with positive (negative) PJ phases are incorporated into the summer mean state of the model. In addition, sensitivity experiments indicate that thermodynamic parameters of the planetary boundary layer (PBL) play a determining role in controlling the development of synoptic disturbances in the WNP. The increase (decrease) in background PBL moisture during positive (negative) PJ phases enhances (suppresses) perturbation moisture convergence and thus the convective heating associated with SSV, leading to strengthened (weakened) synoptic-scale activity in the WNP. Serving as potential seed disturbances for cyclogenesis, the strengthened (weakened) synoptic-scale activity may also contribute to the enhancement (suppression) in intraseasonal TC frequency during positive (negative) PJ phases.

IAMAS (Meteorology)

M13p - M13 Regional Climate Variability and Change

M13p-195

Changes of early summer precipitation in the Korean Peninsula and nearby regions based on RCP simulations

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The projected regional precipitation changes over Northeast Asia (NEA) during early summer (May-July, MJJ) for the late 21st century (2071-2100) were investigated using WRF3.4 based on the Representative Concentration Pathways (RCPs) induced by HadGEM2-AO. The regional model with a 12.5 km horizontal resolution enabled it to reproduce the terrain-following features reasonably well. The Historical (1981-2010) experiment (D_Historical) demonstrated the model's ability to capture the spatial and temporal variations of rain band migrating meridionally during MJJ. According to the regional model projection, intensive precipitation will increase and the rain band will affect the Korean Peninsula approximately 10 days earlier than the D_Historical cases in both RCP4.5 and 8.5. The precipitation will also increase in most of the domain, particularly in the southern Korean Peninsula and Kyushu, Japan. These increases in precipitation are attributed to increases in the northward moist transport coming from the lower latitudes and moist static instability in the lower atmosphere. The convective precipitation contributes mainly to the increase in total precipitation. On the other hand, the large-scale non-convective precipitation related to the stationary front will not change significantly but even tend to decrease approximately from the middle of July. The extreme precipitation intensity is also projected to increase by at least 22% (38%) in RCP4.5 (RCP8.5).

Acknowledgements

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IAMAS (Meteorology)

M13p - M13 Regional Climate Variability and Change

M13p-196

Variation trends of RCP-based climatic scenarios for the Yellow River basin, China

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Based on historical climatic simulations over 1901—2010 of 7 GCMs and the recorded climatic data at 108 basic national meteorological stations within the Yellow River basin of China, the suitability of the 7 CMIP5 GCMs to the Yellow River basin was assessed with three indices of multiple-year average, standard deviation, and linear trend rate. Variation trends of precipitation and temperature over the next decades for the Yellow River basin were then investigated using the climatic projections of the most suitable GCM under the RCPs scenarios. Results show that (1) MPI-ESM performs better for historical climatic simulation of the Yellow River basin as comparing to other GCMs. (2) Temperature over the Yellow River basin was projected a steady rising trend with linear rising rates of 0.28?/10a—0.45?/10a, while precipitation will probably undergo a slight decline trend with high variability. (3) Under the three scenarios of RCP2.6, RCP4.5 and RCP8.5, seasonal patterns as well as spatial patterns of temperature and precipitation over 2021—2050 were altered by climate change. Seasonally, higher temperature rise will probably occur in February, August, and September, and lowest rise occur in May. Precipitations in February, May, and December will likely get a higher increase while that in June to August are all less than baseline. Spatially, higher temperature rise will occur in source area of the Yellow River, and reaches of the Ningxia, Inner Mongolia autonomous regions. Precipitation change is from positive in the source area to negative in the lower reaches of the Yellow River for scenarios of RCP 2.6 and RCP8.5. Precipitation over the 2021—2050 under the scenario RCP4.5 will be probably more than the baseline for most area of the Yellow River basin.

IAMAS (Meteorology)

M13p - M13 Regional Climate Variability and Change

M13p-197

Estimation of regional climate change for the Carpathian Region using dynamical downscaling

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Our research group is participating in the Med-CORDEX international initiative with the specific aim of contributing to the complex regional climate modelling database with RegCM4.3 experiments at 50 km horizontal resolution. RegCM is a 3-dimensional, sigma-coordinate, primitive equation model, originally developed by Giorgi et al. Currently, it is available from the ICTP (Abdus Salam International Centre for Theoretical Physics). Our adapted model version uses the mosaic-type subgridding option in order to take into account subgrid processes. On the basis of 50 km RegCM runs we aim to provide detailed regional scale climate projection results for the Carpathian Region and its vicinity. For this purpose further downscaling is necessary using 10 km as horizontal resolution for a smaller domain covering Central Europe with special focus on the Carpathian Region. Projection runs were preceded by detailed sensitivity analysis to determine the most appropriate configuration of available model parameterizations. In the framework of the model validation process we tested three different cumulus convection schemes (i.e., Kuo, Emanuel, and Grell schemes with different closure methods). Our conclusions suggest that combined use of the Emanuel scheme over ocean and Grell scheme over land with Fritsch and Chappell (1980) closure results the best performance of RegCM simulations for the Carpathian Region. After completing the historical experiments (1950–2005), future scenario experiments are evaluated for 2006–2099 taking into account RCP4.5 and RCP8.5 scenarios.

IAMAS (Meteorology)

M13p - M13 Regional Climate Variability and Change

M13p-198

Hydrological anomalies and trends in the Amur River basin associated with regional and global climate changes

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Causes of extreme rainfall and record flood in the Amur River basin in 2013 are analyzed with a risk assessment of such anomalies in the relation to climate changes. The analysis is based on observations, reanalysis data and model simulations. Flood on the Amur River in the monsoon season of 2013 was due to extremely high precipitation associated with the long-lasting blocking situation in the atmosphere over the Pacific Ocean. Increased risk of extreme flood was related also with the anomalously high sea surface temperature in western part of the Pacific Ocean and with the enhanced soil moisture due to the increase of the snow storage in the Far East regions in winter. Model simulations show an increase in the probability of extreme precipitation and runoff for the Amur River basin in the monsoon season under global warming in the 21st century with a general increase in the atmospheric moisture content. The intensification of monsoon activity and the increase of the total blocking duration in summer over the Pacific Ocean contribute to the flood risk increase.

IAMAS (Meteorology)

M13p - M13 Regional Climate Variability and Change

M13p-199

Regional climate simulations with WRF model

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Regional climate models are commonly used to provide more detailed information on climatic conditions at local or regional scale. Model WRF (Weather Research and Forecasting) is frequently used as a regional climate model (e.g. in CORDEX activities). This work presents evaluation of the simulations with different setting of the WRF model for whole Europe for years 1991–2000. Different options are tested for radiation and convective parameterization and validated against E-OBS reference data. Radiation parameterization RRTM and Goddard for long wave and short wave, respectively, together with Tiedtke and Grell-Devenyi convective schemes provide the best results for full domain of Europe. Next, this work presents validation of WRF simulation results within the same domain, with this settings, but for years 1961–1990, against other simulations performed within ENSEMBLE project and EuroCORDEX activity in terms of basic comparison of monthly series in PRUDENCE regions.

IAMAS (Meteorology)

M13p - M13 Regional Climate Variability and Change

M13p-200

On the integrated climate change assessment with climate classification

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The analysis of climate patterns can be performed for each climate variable separately or the data can be aggregated using e.g. some kind of climate classification. These classifications usually correspond to vegetation distribution in the sense that each climate type is dominated by one vegetation zone or eco-region. This way climate classifications also represent a convenient tool for the assessment and validation of climate models and for the analysis of simulated future climate changes.

The Köppen-Trewartha classification is used on CMIP5 family of GCM simulations and CRU dataset for comparison. This evaluation provides insight on the GCM performance and errors for simulations of the 20th century climate. Common regions are identified, such as Australia or Amazonia, where many state-of-the-art models perform inadequately. Furthermore, the analysis of the CMIP5 ensemble for RCP 4.5 and 8.5 is performed to assess the climate change for future. There are significant changes for some types in most models e.g. increase of savanna and decrease of tundra for the future climate. For some types significant shifts in latitude can be seen when studying their geographical location in selected continental areas, e.g. toward higher latitudes for boreal climate. More detailed analysis is shown in term of this analysis applied on regional EuroCORDEX simulations.

IAMAS (Meteorology)

M13p - M13 Regional Climate Variability and Change

M13p-201

An analysis of the ability of selected CMIP5 GCMs to simulate winter atmospheric circulation over Europe

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The number of studies analysing the ability of climate models to simulate the real atmospheric circulation has been growing over the last decade. Such an ability is essential for subsequent research, including simulations of future climate change or statistical and dynamical downscaling. The most popular approach to analysing the circulation consists in a classification of atmospheric circulation patterns. Recent research on the classification methods has shown that because of the missing inner structure of the circulation data there is no clear statistical reason to prefer any of the plethora of established methods. Therefore, finding the optimal method for a certain purpose requires a broad comparison of methods. The COST 733 classification dataset and software, which includes twenty-seven automatic and six manual methods, and tools for their comparison, is a suitable instrument for the method selection.

In this study, selected methods from the COST 733 software are examined; advantages and drawbacks of the methods are identified in terms of the applicability of the methods to the validation of GCMs. Subsequently, control runs of an ensemble of GCMs from the CMIP5 project are evaluated against several reanalysis datasets, and the ability of the models to simulate winter circulation over Europe is analysed.

IAMAS (Meteorology)

M13p - M13 Regional Climate Variability and Change

M13p-202

Changes to extreme precipitation over North America

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Increased frequency of heavy precipitation has been a consistent signal of climate change over most of the United States. We have studied this trend using the RegCM4 regional climate model to dynamically downscale results of two CMIP5 global models (HadGEM2-ES and GFDL-ESM2M) over the period 1950-2100. RegCM4 simulations were done using different convective parameterizations so as to assess sensitivity of results to the regional model configuration. The results from RegCM4 for 1951-2005 show increased frequency of heavy daily precipitation amounts similar to the trend that has been observed. By the late 21st century the frequency of heavy precipitation increased by a factor or 2 to 3. This increase was produced regardless of the global model used as input to RegCM4 and regardless of the convective parameterization, implying that the trend of more frequent heavy precipitation is a robust result.

IAMAS (Meteorology)

M13p - M13 Regional Climate Variability and Change

M13p-203

Variability of the southern hemisphere sub-tropical jet from the CMIP5 model output

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In this paper we produce projections of the changes in the wind speed and meridional location of the Southern Hemisphere Sub-tropical Jet (STJ) using output of the Coupled Model Intercomparison Project Phase 5 (CMIP5) models. We use the ERA-Interim reanalysis dataset to evaluate the historical simulations of the STJ by 18 CMIP5 models for the period 1979-2012. Based on the climatology of the STJ from ERA-Interim, we selected the area of study as 70° - 290° E and 40 °S - 20°S, which is over the Indian and Southern Pacific Oceans, and 100 hPa to 300 hPa in the vertical. Analysis of historical trends of the STJ in ERA-Interim shows a latitudinal shift of -0.09^{0} $decade^{-1}$ with a decrease of -0.18 ms^{-1} $decade^{-1}$ in the jet strength during winter. The historical simulations the CMIP5 models show a wide range of trends in meridional shift as well as the jet strength with a multimodal average of 0.03^{0} $decade^{-1}$ and 0.5 $ms^{-1}decade^{-1}$ respectively. In contrast to ERA-Interim analysis, 94% of CMIP5 models show a strengthening of jet in the historical runs. Variability of the jet strength is significantly ($p<0.05$) linked to the sea surface temperature changes in the eastern tropical Pacific.

Representative Concentration Pathways (RCPs) 4.5 and 8.5 were chosen for analysis of projections of the STJ for the period 2011-2099. Based on the RCP 4.5 (RCP 8.5) scenario the multi-model mean trend of the 18 CMIP5 models project an increase in jet strength by the end of the century of 0.26 $ms^{-1}decade^{-1}$ (0.55 $ms^{-1}decade^{-1}$). Also, the mean jet meridional location is projected to shift 0.005^{0}/decade (0.039^{0} /decade) poleward by 2100 during winter.

IAMAS (Meteorology)

M14a - M14 Middle Atmosphere Science

IUGG-0866

Variability and trends in UTLS temperatures and water vapor

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A body of work has shown that there are trends and variability in stratospheric water vapor closely related to variability in tropical tropopause temperatures, upwelling variations, the quasi-biennial oscillation, and possibly volcanic aerosol loading and sea surface temperatures. Prior studies have also shown that stratospheric water vapor has a small but non-negligible effect on global radiative forcing; therefore it is key to understand both trends and long-term variations. In this presentation, we will examine both the relationship between tropical tropopause temperatures and stratospheric water for the time period where we have global lower stratosphere water vapor measurements (primarily since the early 1990s), as well as the relationship between tropical tropopause temperatures and assorted atmospheric indices for the longer time period where we only have temperature measurements. We will also present inferences on water vapor stratospheric trends and variability from mid latitude ground based balloon measurements, and results from climate model runs testing the impact of volcanic aerosol loading on UTLS temperatures and stratospheric water vapor.

IAMAS (Meteorology)

M14a - M14 Middle Atmosphere Science

IUGG-1409

UTLS transport by Asian Summer Monsoon and North American Monsoon

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Asian Summer Monsoon (ASM) and North American Monsoon (NAM) systems are shown by satellite observations to be significant drivers in transport between the boundary layer and the upper troposphere/lower stratosphere (UT/LS). Satellite observations (mostly AURA/MLS, AQUA/AIRS and ACE-FTS), although capturing the global impact on seasonal scales, are unable to resolve the details of the transport process. To investigate the interplay of convection and the large-scale monsoonal circulation in UT/LS transport, we analyzed the sub-seasonal scale variability of the Asian monsoon anticyclone using NCAR Whole Atmosphere Community Climate Model run in specified dynamics mode (WACCM-SD). Dynamical variability of the carbon monoxide, a tracer of tropospheric pollutants, at the tropopause level is examined in association with the intra-seasonal variability of the anticyclone. This analysis indicates that the large-scale circulation plays an essential role in transporting convectively pumped boundary layer pollutants into the stratosphere. We will also discuss the role of large-scale circulation in NAM using in situ observations from the NASA ER-2 research aircraft made during the SEAC4RS campaign (August-September 2013). In particular, the result shows that the coupling of convection and large-scale monsoonal circulation is essential in convective injection of water vapor into the lower stratosphere.

IAMAS (Meteorology)

M14a - M14 Middle Atmosphere Science

IUGG-2848

The flushing of the northern lower stratosphere and the influence of the monsoon: Results from TACTS/ESMVal 2012

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We present results from the German research aircraft HALO during the TACTS/ESMVal project (Transport and Composition in the UT/LMS and Earth System Model Validation). Global measurements of various trace gas species were performed from the Arctic to the early Antarctic vortex in August to September 2012. Here, we focus on the northern hemispheric in-situ measurements of CO, N_2O and O_3 in the extratropical stratosphere.

Based on the CO-O_3-correlation we could for the first time identify mixing lines in this region, which indicate irreversible mixing between stratospheric air masses from different source regions. The use of the N_2O-O_3-correlation provides additional knowledge on the origin and therefore the reservoirs involved in the mixing processes within the stratosphere. Backward trajectories indicate that the “younger” stratospheric air masses originate in the Asian monsoon region and contribute to the chemical composition of air above the 380 K isentrope in the extratropics.

The trace gas distributions of the extratropical stratosphere on isentropes at least 30 K above the local dynamical tropopause indicate an increase in the contribution of „younger” stratospheric air masses over the measurement period (28/08/2012 - 27/09/2012). The correlation of N_2O with O_3shows that this results from the transport and mixing of stratospheric air masses originating from the tropical lower

stratosphere. Therefore we conclude that the transport of tropospheric air masses into the tropical stratosphere within the Asian monsoon significantly contributes to the flushing of the extratropical UTLS during summer and autumn.

IAMAS (Meteorology)

M14a - M14 Middle Atmosphere Science

IUGG-3655

What causes intermodel difference in the upwelling in the tropical tropopause layer among CMIP5 models?

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Annual mean climatology of the upwelling in the tropical tropopause layer (TTL) is examined by using the models that participated in the Coupled Model Intercomparison Project Phase 5 (CMIP5) and the atmospheric general circulation model MRI-AGCM3.2. We focus on what causes intermodel upwelling difference in historical climate simulations (1979-2003) and in future climate projections (2075-2099) according to the Representative Concentration Pathway (RCP) 8.5.

Compared with the ERA-Interim, most of historical climate simulations has weaker tropical upwelling at around 100 hPa. Comparison between SST prescribed simulations and ocean-coupled simulations shows that contribution of intermodel SST difference to the upwelling is smaller than that of the intermodel structural difference. Upwelling diagnosis based on zonal momentum budget demonstrates that the meridional eddy momentum flux at around 100 hPa controls large part of the upwelling difference. Additionally, composite analysis indicates tendencies that difference between weak upwelling models and medium upwelling models is induced by equatorward extratropical waves and that difference between medium upwelling models and strong upwelling models is generated by equatorial waves.

Interestingly, in the TTL the models with stronger upwelling tend to drive larger future upwelling changes and vice versa. Intermodel difference in future upwelling change is formed by closely similar causes to historical climate simulation. It is considered that future change in the upwelling in the TTL is controlled by the intrinsic model ability to excite waves.

IAMAS (Meteorology)

M14a - M14 Middle Atmosphere Science

IUGG-3665

The climate impact of past changes in halocarbons and CO2 in the tropical UTLS region

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A chemistry-climate model coupled to an ocean model is used to compare the climate impact of past (1960-2010) changes in concentrations of halocarbons with those of CO2 in the tropical upper troposphere and lower stratosphere (UTLS). This is believed to be the first study of its type. The halocarbon contribution to both upper troposphere warming and the associated increase in lower stratospheric upwelling is about 40% as large as that due to CO2. Trends in cold-point temperature and lower stratosphere water vapour are positive for both halocarbons and CO2, and are of about the same magnitude. Trends in lower stratosphere ozone are negative, due to the increased upwelling. These increases in water vapour and decreases in lower stratosphere ozone feed back onto lower stratosphere temperature through radiative cooling. The radiative cooling from ozone is about a factor of two larger than that from water vapour in the vicinity of the cold-point tropopause, while water vapour dominates at heights above 50 hPa. For halocarbons this indirect radiative cooling more than offsets the direct radiative warming, and together with the adiabatic cooling accounts for the lack of a halocarbon-induced warming of the lower stratosphere. For CO2 the indirect cooling from increased water vapour and decreased ozone is of comparable magnitude to the direct warming from CO2 in the vicinity of the cold-point tropopause, and (together with the increased upwelling) lowers the height at which CO2 increases induce stratospheric cooling, thus explaining the relatively weak increase in cold-point temperature due to the CO2 increases.

IAMAS (Meteorology)

M14a - M14 Middle Atmosphere Science

IUGG-4212

Dynamical and radiative forcing of tropical lower stratospheric temperatures 1980-2012

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We present a synthesis of recent efforts to understand trends in lower stratospheric temperatures over the period 1980-2012 in terms of contributions from dynamical forcing by the stratospheric Brewer-Dobson circulation, and contributions from changes in radiatively active tracers, specifically ozone. We focus on the tropics, where, in addition to an annual mean cooling, temperature trends show a pronounced seasonality, with a maximum cooling in Jan-Feb, and minimum cooling in March-April. We compare estimates of dynamical contribution to trends, and interannual variability, from three reanalyses (ERA-Interim, MERRA and JRA-55), based on several different methods to calculate variations in tropical upwelling. Overall, the deseasonalised time series show a very high correlation between the estimate of dynamically forced and actual temperature (correlations ~0.85) over volcanically quiescent periods. The calculations all agree on a large increase in tropical upwelling (cooling) following the Pinatuboeruption that partially cancels the warming due to the presence of enhanced aerosol. Further, the drop in stratospheric water in October 2000 can be attributed to a strong increase in upwelling from anomalous Southern hemisphere dynamics, though the calculations diverge quantitatively concerning the dynamical contribution to the prolonged dryness in the 2000's relative to the1990's. Similarly, trends in the dynamical forcing differ substantially betweenthe different calculations. Largest differences are seen with respect to the dynamical contribution to the seasonality in trends, with some calculations explaining the seasonality almost entirely as a consequenceof dynamical forcing, while others fail to capture the seasonality.

IAMAS (Meteorology)

M14b - M14 Middle Atmosphere Science

IUGG-1546

Simultaneous spatial and temporal analysis of long-term ozone data sets

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Ozone is an important trace gas species in the Earth’s atmosphere, which has been measured via satellite instruments for nearly 40 years. These measurements have been vital in determining the long-term trend in ozone, though any record spanning the full 40 years requires the use of multiple datasets.Traditionally, the determination of trends in ozone using these data has been done via time series analysis of monthly mean data within specific latitude bands. However, given the sparse sampling of some of the data sets, this can potentially introduce temporal and/or spatial biases.Herein we use a recently developed method for performing time series analysis of long-term data sets, which has already been demonstrated using SAGE II ozone data. This new methodology utilizes daily mean data and performs a simultaneous temporal and spatial analysis, making use of Legendre polynomials to constrain latitudinal variation. This methodology is applied to other ozone data sets and the results are compared.

IAMAS (Meteorology)

M14b - M14 Middle Atmosphere Science

IUGG-1775

Contrasting the impacts of ozone-depleting substances and well-mixed greenhouse gases on Antarctic and Arctic ozone and temperature trends

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The annual occurrence of the ozone hole over Antarctica in austral spring and recently observed large ozone losses in the Arctic (in 2010/11, e.g., Manney et al., 2011), which rivaled those observed in Antarctica, highlight the importance of a detailed understanding of the connection between ozone depleting substances (ODS), cold polar stratospheric temperatures, polar stratospheric clouds and ozone. In recent work, we distinguished the key differences between Arctic and Antarctic ozone depletion (Solomon et al., 2014), and investigated the roles of well-mixed greenhouse gases (WMGG) and ODS on Arctic stratospheric ozone and temperature trends (Rieder et al., 2014). Here we focus on contrasting observed stratospheric changes between the northern and southern polar caps. To this aim we analyze trends and variability in ozone and temperatures using observations from radiosondes, reanalysis data sets (MERRA, ERA-Interim) and simulations ranging from simple idealized chemistry and radiation codes to complex chemistry climate-models. Beyond the observational record, ensemble simulations of chemistry-climate models driven with time-varying ODS and WMGG, specified in isolation and combination, allow us to investigate the roles of changes in ODS and WMGG from the 1960s to the end of the 21st century. Our results highlight the key differences in chemical ozone depletion between the Antarctic and Arctic and illustrate the respective roles of changes in WMGG and ODS for observed and projected stratospheric ozone and temperature trends.

IAMAS (Meteorology)

M14b - M14 Middle Atmosphere Science

IUGG-1954

Future evolution of tropical ozone under different emission scenarios

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The regulation of ozone depleting substances (ODSs) in the Montreal Protocol and its amendments will lead to an increase of stratospheric ozone in the 21st century. The future evolution of ozone, however, is also strongly affected by the increase of well-mixed greenhouse gases (GHGs) since both ozone chemistry and transport are modified. While in the extra-tropics total column ozone (TCO) is predicted to return to pre-1980 levels during the 21st century, this is not the case for the tropics. Here, a GHG-induced increase of the upwelling causes an ozone decrease in the lower stratosphere which counteracts the temperature and ODSs related ozone increase in the upper stratosphere and the positive ozone trend in the troposphere. However, the relative importance of these processes in determining the column ozone change at the surface depends on the emission scenario and thus, the future evolution of tropical ozone is still unclear.
Therefore, in our study we aim to quantify the TCO change in the tropics at the end of the 21st century for two different emission scenarios and identify the role of the different processes. For this analysis we use two transient simulations with the chemistry-climate model EMAC which are integrated from 1960 to 2100 following the RCP6.0 and the RCP8.5 emission scenario, respectively. We find that both scenarios lead to reduced TCO compared to the 1960s, with a larger decrease of the stratospheric partial column in the RCP8.5 than in the RCP6.0 simulation. At the surface, however, the decrease is smaller for the high emission scenario.

IAMAS (Meteorology)

M14b - M14 Middle Atmosphere Science

IUGG-2124

Recent changes in the composition of the stratosphere due to and despite the Montreal Protocol

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The 1987 Montreal Protocol, to protect the stratospheric ozone layer, appears to have been a great success. Networks have shown that total tropospheric organic chlorine peaked in 1993, followed by a decrease of 0.5-1 %/yr. Remote-sensing data revealed a peak in stratospheric chlorine in 1996-1997 followed by a decrease at rates close to -1%/yr. Given this, we expect stratospheric chlorine and bromine to continue to decrease and the ozone layer to 'recover' towards the middle/end of the century.

Despite this, there are a number of factors which could mean that the decrease in stratospheric halogens is not a smooth downward trajectory. Recent observations of stratospheric column HCl (the reservoir of stratospheric chlorine) showed an increase in the northern hemisphere (Mahieu et al., Nature, 2014) from around 2007 to 2011. However, through studies with an atmospheric 3-D chemical transport model, we could show that this increase in HCl was due to multi-year variability in the stratospheric circulation causing air in the NH lower stratosphere to become more aged (i.e. contain more HCl and less organic source gas) – i.e. the protocol is still on track.

In contrast, the protocol only controls the emissions of long-lived ODSs. So-called very short-lived substances (VSLS), with lifetimes less than about 6 months, are not considered. While many VSLS are natural, in Hossaini et al. (Nature Geosciences, 2015) we presented ground-based observations showing a rapid increase in the anthropogenic VSLS CH2Cl2. We will show model results which quantify the potential that these VSLS have to deplete stratospheric ozone, thereby delaying recovery. Through depleting ozone in the very low stratosphere, VSLS also exert a relatively large leverage on climate.

IAMAS (Meteorology)

M14b - M14 Middle Atmosphere Science

IUGG-3974

On the recovery of stratospheric ozone

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The ozone layer has been under surveillance since the discovery of the ozone hole over Antarctica in the early eighties. Since then, the abundance of ozone-depleting substances (ODS) regulated by the Montreal Protocol have peaked by the mid or end of the nineties depending on latitudes and have now started a slow decrease considering the atmospheric lifetimes of these compounds. As a consequence, the ozone layer has stabilized and shows early signs of recovery. While the decrease of ODS content is expected to be the dominant cause of the future long-term evolution of stratospheric ozone, climate change effect and natural variability of the atmosphere still hinder the unambiguous detection of recovery expected from ODS decrease. Indeed, the very low ozone content observed during the Arctic winter 2010/2011 was caused by a very peculiar dynamical situation in the Northern Hemisphere, together with the still high levels of ODS in the stratosphere (WMO, 2014). The detection of the small signal of recovery is also a challenge for the current ozone global observing system, in particular regarding ozone vertical distribution. In that case, quantification of long-term ozone trends requires the combination of satellite records characterized by different frequency sampling and vertical resolution, after careful verification of their long-term stability and mutual consistency using reference ground-based monitoring networks. This presentation will review the current understanding of ozone recovery in various stratospheric regions, both regarding its total content and vertical distribution.

References: WMO, Global Ozone Research and Monitoring Project, Scientific Assessment of Ozone Depletion, Report 55, 2014

IAMAS (Meteorology)

M14b - M14 Middle Atmosphere Science

IUGG-5001

Partitioning of ozone changes between chemistry and transport in the quasi-biennial oscillation simulated by a chemistry-climate model

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Ozone tendencies due to chemistry and transport are evaluated in the quasi-biennial oscillation (QBO) simulated by the chemistry-climate model of Meteorological Research Institute. The model well reproduces the phase transition of ozone anomaly from dynamical to photochemical control at around 20 hPa in observations with one maximum amplitude at around 30 hPa of about 8 % (~0.5 ppmv) below the phase transition and the other one at around 10 hPa of about 3% (~0.3 ppmv) above the phase transition. At 10 hPa chemistry precedes ozone nearly by a quarter cycle, while at 30 hPa transport is advanced from ozone by almost a quarter cycle, while at 20 hPa transport is nearly in-phase to ozone, and chemistry is nearly out-of-phase. To see more clearly the phase relation between transport and chemistry, lagged correlation coefficient is calculated, wherein minus (plus) lags mean that chemistry (transport) leads transport (chemistry). The minimum coefficient is very close to -1 and its lag is -1~0 months at 10 hPa, 0~+1 months at 20hPa, and +1~+2 months at 30 hPa. Thus, it is evident for the ozone QBO that the 10 hPa ozone anomaly driven by chemistry is almost cancelled by transport within 1 month and that below that level the ozone anomaly made by transport is nearly dissipated by chemistry within a few months depending on altitudes.

IAMAS (Meteorology)

M14c - M14 Middle Atmosphere Science

IUGG-1701

Stratospheric NOy: Global budget and variability in 2002-2012 from MIPAS observations

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Reactive nitrogen (NOy) plays a key role in controlling stratospheric ozone chemistry, either by catalytically destroying ozone or by damping the effect of chlorine-induced ozone destruction via the formation of $ClONO_2$. Although the involved chemistry has been well understood for some time, the sparseness of global NOy observations in the middle atmosphere introduced important uncertainties regarding its spatial distribution, its global balance, and its temporal evolution on different time scales. We have derived vertically resolved distributions of 6 principal reactive nitrogen compounds (HNO_3, NO_2, NO, N_2O_5, $ClONO_2$, and HNO_4) with global coverage and independent of illumination (i.e., including the polar night) from mid-IR limb emission spectra measured by MIPAS/Envisat during 2002-2012. The obtained data set provides a unique climatological record of NOy in the middle atmosphere for a for a period close to 10 years. Here, we discuss the MIPAS-derived spatial distributions of NOy and their seasonal/inter-annual variability. Temporal variations are analyzed by means of multi-linear regression and are compared to results of the Whole Atmosphere Community Climate Model (WACCM). Responsible chemical and dynamical mechanisms are identified and an estimation of the global middle atmosphere NOy budget is presented, including a quantitative analysis of individual sources and sinks.

IAMAS (Meteorology)

M14c - M14 Middle Atmosphere Science

IUGG-2178

Vertically resolved long-term changes in stratospheric water vapour

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Water vapour is the most important natural greenhouse gas in the atmosphere and provides a positive feedback to the climate forcing from carbon dioxide. Water vapour is also the source of hydroxyl (OH) which controls the lifetime of shorter-lived pollutants and long-lived greenhouse gases. Despite the importance of water vapour to chemistry and the radiative balance of the atmosphere, its observed long-term changes are not well understood.

The longest available record from balloon observations over Boulder (Colorado, USA) shows increases in stratospheric water vapour concentrations that cannot be fully explained by observed changes in the main drivers, tropical tropopause temperatures and methane. Satellite observations may help resolve the issue, but constructing a reliable long-term data record from individual short satellite data sets is challenging. I here introduce a new approach to merge satellite data sets obtained from the SPARC Data Initiative using a chemistry–climate model nudged to observed meteorology as transfer function between the different instruments. Analysis of long-term changes in the newly merged stratospheric water vapour data record reveals a different behaviour to that derived from the Boulder observations, implying that the Boulder trend is not representative for the zonal mean stratosphere and providing new observational evidence for stratospheric circulation changes.

IAMAS (Meteorology)

M14c - M14 Middle Atmosphere Science

IUGG-2643

Impact of Stratospheric Major Warmings and the Quasi-Biennial Oscillation on Variability of Statospheric Water Vapor

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The decadal change of water vapor entering the stratosphere through the tropical tropopause varies on a broad range of timescales, from daily to decadal. While the seasonal cycle defines the well-known tape recorder, the inter-annual variability is dominated by the Quasi Biennial Oscillation (QBO). Furthermore, transient dehydration events are associated with extratropical planetary waves which, in particular, can be triggered by the Stratospheric Major Warmings (MWs) regularly disturbing the northern polar vortex during the boreal winter. Based on simulations with the Chemical Lagrangian Model of the Stratosphere (CLaMS) for the 1988-2013 period, driven by the ECMWF ERA-Interim reanalysis, we analyse the impact of QBO phase and of Major Stratospheric Warmings (MWs) on the amount of water vapor entering the stratosphere during the boreal winter. The amplitude of H_2O variation related to QBO amounts to 0.5 ppmv. The additional effect of MWs reaches its maximum about 2-4 weeks after the central date of the MW, and strongly depends on the QBO-phase. Whereas during the easterly QBO phase there is a clear drying of about 0.3 ppmv about 3 weeks after the MW, the impact of the MW during the westerly QBO phase is smaller (about 0.2 ppmv) and more diffusely spread over time. The MW-associated enhanced dehydration combined with a higher frequency of MWs after the year 2000 may have contributed to the lower stratospheric water vapor after 2000.

IAMAS (Meteorology)

M14c - M14 Middle Atmosphere Science

IUGG-2717

Global HCFC-22 measurements with MIPAS: Retrieval, validation, climatologies and trends

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HCFC-22 global distributions derived from MIPAS observations in reduced spectral resolution nominal mode from January 2005 to April 2012 from the upper troposphere to about 50 km are presented. The profile retrieval was performed by constrained nonlinear least squares fitting of modeled spectra to measured limb spectral radiances. In the lower stratosphere, we find abundances of about 185 ppt in January 2005, with a linear growth rate in the lower latitudes lower stratosphere of about 6 to 8 ppt/yr for the period 2005 - 2012.

The obtained profiles were compared with ACE-FTS satellite data, MkIV solar occultation balloon profiles, and in-situ cryosampler balloon measurements, providing agreement with ACE-FTS profiles within -5 to +10 ppt, and with MkIV within 10 – 20 ppt. In-situ cryosampler balloon measurements are systematically lower over their full altitude range (up to appr. 30 km). Obtained MIPAS HCFC-22 time series below 10 km altitude are shown to agree mostly well with corresponding time series of near-surface abundances from NOAA/ESRL and AGAGE networks, although a far more pronounced seasonal cycle with latitude-dependent amplitudes is present in the satellite data.

A multivariate linear regression analysis of stratospheric HCFC-22 time series for 10° latitude / 1-2 km altitude bins has been performed, including constant, linear, QBO, and several sine and cosine terms. The linear “trend” was found to be always positive. In the middle stratosphere between 20 and 30 km, the observed positive trend is larger than the age-of-air corrected surface trend for the Southern

hemisphere, and smaller than the surface trend for the Northern hemisphere; this hemispheric asymmetry hints towards changes in the stratospheric residual circulation over the observation period.

IAMAS (Meteorology)

M14c - M14 Middle Atmosphere Science

IUGG-4621

HCl observations in the middle atmosphere as revealed by the Superconducting Submillimeter-Wave Limb-Emission Sounder (SMILES)

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The SMILES made observations of minor species in the stratosphere and mesosphere for about six months from October 2009 to April 2010. The unprecedented high sensitivity measurements using the 4-K mechanical cryocooler provided new insights into the middle atmosphere sciences. In this presentation, we will show results from HCl observations in the following three aspects: vertical transport in the equatorial stratosphere, diurnal variations due to tides, and mesospheric amounts as a constraint of total chlorine.

Because of its long chemical life time, it can be used as a tracer for transport studies. In the equatorial stratosphere during the SMILES observation period, HCl distributions showed double-minima with a maximum over the equator around 10 hPa. The HCl maximum with a positive HCl vertical gradient can be understood as an effect of descending motion related to the quasi-biennial oscillation and the semiannual oscillation.

As shown by Sakazaki et al. (2013) ozone distributions in the equatorial stratosphere show a clear diurnal cycle due to atmospheric tides. For HCl distributions the variation should be controlled by the transport process. In a similar way to Sakazaki et al. (2013) we found a clear HCl diurnal cycle with an amplitude of estimated vertical motion being 2-4 mm/s around 25 km.

Amounts of HCl in the mesosphere should be constant because of no significant loss there. As briefly shown in Kikuchi et al. (2010) SMILES provided the vertical profiles as being almost constant in the mesosphere. The values are around 3.2 ppbv, and we could nail the SMILES HCl observations onto the long-term record.

References:

Kikuchi et al., 2010, doi10.1029/2010JD014379
Sakazaki et al., 2013, doi:10.1002/jgrd.50220

IAMAS (Meteorology)

M14c - M14 Middle Atmosphere Science

IUGG-5429

The role of tropical SST in modulating lower-stratospheric water vapor

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The amount of water vapor in the tropical lower stratosphere (TLS) is highly modulated by temperature in the tropical tropopause layer (TTL), and has an important effect in determining the radiation balance of the global climate system. In the year 2000, the amount of water vapor in the TLS exhibited a stepwise transition to a dry phase, which was often attributed to the strengthening of the Brewer-Dobson circulation. However, the impact of the tropical processes on this stepwise change has received less attention. Here we present observational and modeling evidences that the sea surface temperature (SST) in the tropical central Pacific plays a vital role in modulating the TTL temperature and the associated water vapor entering the lower-stratosphere in the last 30 years. We show that the water vapor “drop” event during the year 2000 can be partly explained by concurrent SST warming in the tropical central Pacific. The quasi-biennial oscillation (QBO) was also identified as critical drivers for TLS water vapor change but the QBO primarily affects TLS water vapor change on the inter-annual time scale. A ‘classical’ El Nino Southern Oscillation (ENSO) event leads to maximum SST variability in the Eastern Pacific, but weakly affects the tropical mean change of water vapor. Our study suggests that on inter-decadal time scales, the central Pacific SST is the leading factor in the tropics for modulating the TLS water vapor.

IAMAS (Meteorology)

M14d - M14 Middle Atmosphere Science

IUGG-0796

The importance of mesopause region airglow "bright nights"

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'Bright nights', when airglow brightness is much greater than usual, are keys to understanding atmospheric dynamics at the emission altitudes. In the mesopause region, the most important airglow emissions of OH and O_2 correspond to nominal altitudes of 87 and 95 km, respectively. Since overlap between the emission layers is not great, differences or similarities in the behaviour of the two emissions are of additional diagnostic value.

The data base of brightness and rotational temperatures corresponding to these airglow emissions acquired with the Argentine Airglow Spectrometer at El Leoncito (31.80°S, 69.29°W) has grown in size and yearly coverage to be now more suitable for a statistical analysis of this relatively rare phenomenon. We limit scope to the years 2006 to 2014, with about 2940 nights of data and 94 nearly completely documented months, so that cases that we have previously reported are not included, and earlier results can be tested independently.

We present new results on the seasonal and year-to-year distribution of bright nights, and case studies of the most prominent cases, with the aim to shed light on the different mechanisms that may be involved.

IAMAS (Meteorology)

M14d - M14 Middle Atmosphere Science

IUGG-2541

Ten years of SCIAMACHY atomic oxygen measurements in the mesopause region

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We present atomic oxygen abundance in the upper mesosphere and lower thermosphere for 2002-2012. The data are derived from the nighttime atomic oxygen green line limb emission measurements of the SCIAMACHY (Scanning Imaging Absorption Spectrometer for Atmospheric Chartography) instrument on the European Environmental Satellite. This data set is compared to other satellite data sets, in particular to recently published data of SABER (Sounding of the Atmosphere using Broadband Emission Radiometry) and the Mass Spectrometer and Incoherent Scatter model. SCIAMACHY atomic oxygen peak abundances are typically $3–6\times10^{11}$ mol/cm^3 at the atomic oxygen maximum region, depending on latitude and season. These values are similar to previous values based on chemiluminescence measurements of the atomic oxygen three-body recombination reaction but at least 30% lower than atomic oxygen abundances obtained from SABER. Atomic oxygen concentrations vary by a factor of 2 to 4 within the 11 year solar cycle which is larger than predicted by atmospheric models.

IAMAS (Meteorology)

M14d - M14 Middle Atmosphere Science

IUGG-2581

Longitudinal features of temperature in the mesopause region from middle-latitude measurements of OH emission

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We present the results of studying the temperature in the mesopause region, obtained from ground-based spectrographic measurements of OH emission (834.0 nm, band (6-2)) at the ISTP Geophysical observatory (52N, 103E, Tory) and Zvenigorod station (56N, 37E). Measurements and data processing at both observatories were carried out by the same method. The period under analysis is 2008-2014. The statistically significant seasonal variations in the mesopause temperature and its day-to-day and night variabilities were revealed. To analyze activity of wave processes in the mesopause region, we used standard deviations of temperature as parameters of its variability. This parameter, depending on duration of an analyzing time interval, can be an indicator of activity of various atmospheric waves, propagating through the mesopause region. The analysis of the temperature standard deviations has revealed higher values of temperature parameters describing its annual, day-to-day, and night variability for Eastern-Siberian region compared the same parameters for the European part of Russia. Seasonal behavior of the temperature standard deviations is characterized by increase in their magnitudes in winter period for both regions probably caused by influence of sudden stratospheric warming on the upper atmosphere. Moreover, for Tory station, a significant rise of wave activity was revealed in March and September, near the equinox transitions. The revealed differences may indicate a possible effect on the temperature regime of the mesopause longitude and orographic effects.

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IAMAS (Meteorology)

M14d - M14 Middle Atmosphere Science

IUGG-2738

WACCM-D: Modelling mesospheric ion chemistry for particle precipitation studies

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Energetic particle precipitation (EPP) affects the neutral chemistry of the middle atmosphere in the polar regions. For example, recent studies have shown that ozone variability caused by EPP can be tens of percent over solar cycle time scales. Ion chemistry plays a vital part in connecting EPP to the resulting changes in neutral odd hydrogen (HOx), odd nitrogen (NOx), and odd oxygen (Ox) species. Also, NOy partitioning can be modulated by ion chemistry, leading to increase of, e.g., HNO3 during EPP events. A good representation of ion chemistry is required to capture the observed changes in models. However, to date the complexity of the ion chemistry at mesospheric altitudes, and below, has restricted modellers to simplified approaches. Now we present WACCM-D, a variant of the Whole Atmosphere Community Climate Model, which includes a selected set of middle atmosphere ion chemistry: 217 reactions of 24 positive ions and 17 negative ions. As an introduction to WACCM-D capabilities, we show WACCM-D results for the January 2005 solar proton event, validate them against those from the Sodankylä Ion and Neutral Chemistry model (SIC), and compare them to satellite observations. The results indicate a good agreement with SIC and significant improvement in the EPP-response of important neutral species, such as HNO3.

IAMAS (Meteorology)

M14d - M14 Middle Atmosphere Science

IUGG-3145

Morphology of the iron layer in the upper polar atmosphere

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Layers of metal atoms such as Fe are created by meteoric ablation in the region of the upper mesosphere and lower thermosphere. These metal layers can be probed with high accuracy by resonance lidars on time scales of less than a minute. Such lidar measurements provide unique opportunities to investigate this otherwise fairly inaccessible but highly dynamic region and its role in the whole atmosphere. Polar latitudes are hereby of particular interest. Many factors such as the seasonal variation of the solar irradiation, the geomagnetic conditions and their effects on the atmosphere are unique. However, measurements with high temporal and spatial resolution are still rather scarce at these remote locations. In this talk, we present recent analyses of more than 2900 hours of Fe lidar measurements obtained at Davis, Antarctica (69°S) in the years 2010 – 2012. We discuss the general Fe layer shape and behaviour as well as some specific aspects such as a regular occurrence of features known as sporadic neutral metal layers and other short term Fe density variations. Additionally, we report the observation of surprisingly regular tides between 80 and 100 km altitude throughout all months of the year. To gain a better understanding of the processes involved, we compare the measurements with WACCM-Fe model results.

IAMAS (Meteorology)

M14d - M14 Middle Atmosphere Science

IUGG-4316

The relation of sporadic meteors and the chemistry of the mesosphere

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The total amount of meteoric input in the upper atmosphere is a hotly debated quantity, which estimates vary by 2 orders of magnitude. The majority of the input is in the form of microgram size particles, which, in most cases, completely ablate injecting metals in the mesosphere. These metals are the primordial material for most of the layered phenomena (LP) occurring in the mesospause region (MR). Accurate knowledge of this quantity is crucial for the study of LPMR and in many cases it can contribute to the improvement of whole atmosphere models by constraining parameters such as vertical transport in the middle atmosphere. In an effort that ultimately aims to estimate this quantity, we investigate the effect that different dust populations of the zodiacal dust cloud have in the global distribution of metals in the mesosphere. In particular we utilized two models of the sporadic meteor complex, coupled with a chemical ablation model and the whole atmosphere climate community model, to constrain the dynamical properties of the incoming flux (i.e. incoming mass and velocity distribution).

IAMAS (Meteorology)

M14e - M14 Middle Atmosphere Science

IUGG-0464

Noctilucent clouds as tracers for dynamics at the mesopause: What and how do they tell us about the background atmosphere?

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Noctilucent clouds (NLC) are visible manifestations of ice particles persistently present in the polar summer mesopause region at an altitude of about 83 km. These particles are on the size of tens of nanometers only and follow the atmospheric motion closely on short time scales. NLC are an attractive tracer as they give information for processes on timescales from seconds to decades in an altitude range that is difficult to investigate.

Since the formation and growth of ice particles is a rather complicated process depending on atmospheric background parameters, such as temperature and water vapor, a detailed understanding of the tracer is needed. Combining different observation methods like lidar and satellite or ground based cameras with microphysical modeling allows understanding and using NLC as tracer for atmospheric conditions in the mesopause region.

The ALOMAR RMR-lidar, located in Northern Norway at 69°N, is used to observe NLC since 20 years. Basic cloud parameters like brightness, altitude and occurrence frequency, but also size and number density of the particles forming NLC are measured. Only recently small scale structures in NLC and particle properties can be detected even below the buoyancy period. Such structures on scales of minutes might be generated by Doppler shifted gravity waves, acoustic waves, or secondary structures generated in gravity wave instabilities. Secondary structures generated by Kelvin-Helmholtz instabilities that are below the lidar resolution but can be studied with high resolution imaging (10 meter, 0.5 second) of noctilucent clouds. We present results from lidar, cameras and microphysical modeling to study atmospheric processes from gravity wave dissipation to solar cylce effects.

IAMAS (Meteorology)

M14e - M14 Middle Atmosphere Science

IUGG-0780

Impact of polar stratospheric ozone loss on vertical coupling of the middle atmosphere in the Southern Hemisphere

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The impact of the Antarctic ozone hole on stratospheric temperatures, atmospheric circulation and surface climate has received a lot of interest in recent studies. It has been shown for example that polar stratospheric ozone loss leads to a positive phase of the Southern Annular Mode, with a zonally symmetric reduction in pressure from the lower stratosphere to the surface, leading to poleward shifts of tropospheric storm tracks, as well as characteristic changes of precipitation and near surface winds. However, the impacts of stratospheric ozone loss at higher altitudes still remain unclear. Here, for the first time, the impact of polar stratospheric ozone loss on vertical coupling of the middle atmosphere up to the lower thermosphere in the Southern Hemisphere is investigated using NCAR's Community Earth System Model (CESM-WACCM), a state-of-the-art high-top coupled chemistry-climate model.

Two simulations were conducted over a 145-year period: one with time-varying anthropogenic halogenated ozone depleting substances (ODSs) and greenhouse gases (GHGs) following the RCP8.5 scenario; the other with fixed ODS and GHG concentrations at 1960 values. To isolate the impact of stratospheric ozone loss from the rising of GHG levels, four 40-yr timeslice experiments were performed, before, during and after the ozone hole period with different combinations of ODS and GHGs.The combination of transient and timeslice simulations will help to understand the relative roles of GHG and ozone levels. Vertical coupling processes from the stratosphere to the lower thermosphere will be analyzed using transformed Eulerian-mean analysis and diagnostics to study the role of parameterized versus resolved wave forcing.

IAMAS (Meteorology)

M14e - M14 Middle Atmosphere Science

IUGG-1334

Impact of stratospheric sudden warming on the general circulation in the MLT region simulated by a whole atmosphere model

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Recent studies has revealed that stratospheric sudden warming event (SSW) affects not only the mesospheric temperature but also electron density in the F-layer. In this study, impact of SSW on the general circulation in the mesosphere and lower thermosphere (MLT) has been investigated using an atmosphere-ionosphere coupled model (GAIA). The GAIA has been developed by coupling three independent models; a whole atmosphere GCM, an ionosphere model and an electrodynamics model. For the neutral atmosphere part, the GAIA has a horizontal resolution of T106 and a vertical resolution with 150 levels. The GAIA has a full set of physical processes appropriate for the troposphere, stratosphere, mesosphere and thermosphere/ionosphere. Our attention is drawn to behaviors of upward propagating tides and gravity waves during SSW, and their influences on the meridional circulation in the MLT region. Our simulation result indicates that behaviors of tides and gravity waves in the MLT region are strongly influenced by SSW. For example, enhancement of the migrating semidiurnal tide in low and middle latitudes and attenuation of gravity wave activity in high latitudes occur during SSW. Furthermore, these changes of upward propagating waves affects the mean meridional circulation and the atmospheric composition in the MLT region.

IAMAS (Meteorology)

M14e - M14 Middle Atmosphere Science

IUGG-2365

Short-term tidal variability in the mesosphere/lower thermosphere from SABER

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The understanding of migrating and nonmigrating tidal propagation from the troposphere and stratosphere into the mesosphere/lower thermosphere and upper thermosphere has much improved over the past few years. Yet, space-borne diagnostics of tides from single satellites like TIMED are limited to > monthly mean averages because of the slow orbit precession and the resulting local solar time coverage. Ground-based observations and whole atmosphere models on the other hand strongly suggest a short-term tidal variability on the order of a factor of two within a few days. This paper attempts to address this challenge by presenting a different approach than the conventional wavenumber/frequency Fourier fits to the satellite data: tides are diagnosed from the vertical/longitudinal structure of ascending-descending orbit node differences. This so-called "tidal deconvolution" method is applied to SABER temperature observations over one solar cycle. The resulting diurnal amplitudes and phases have an effective time resolution of approximately one week and are compared to short-term tidal diagnostics based on Fourier fits to multiple satellites and results from the eCMAM30 and WACCM models for various tidal components. Our results suggest that the SABER "tidal deconvolution" is a useful tool to bridge the time gap until tidal diagnostics from satellite constellations will be routine.

IAMAS (Meteorology)

M14e - M14 Middle Atmosphere Science

IUGG-3630

Interannual variability in the Northern Hemisphere springtime middle atmosphere

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In recent years, we have seen increased variability in dynamical conditions in the Northern Hemisphere winter time middle atmosphere. For example, the occurrence of extended sudden stratospheric warmings with prolonged descent of mesospheric air into the stratosphere has become more frequent in the past decade. Less attention has been paid to the springtime period; however, here too, there has been much variability. One objective of our research is to understand to what extent wintertime conditions can affect the distribution of trace constituents in the spring and summer. For example, using data from the Solar Occultation for Ice Experiment (SOFIE) on the AIM satellite, we show that after the 2009 sudden stratospheric warming, low methane associated with mesospheric air, persisted for many months in the upper stratosphere. Conversely in other years, large planetary wave events, associated with the frozen in anticyclone (FrIAC) phenomenon, have caused significant mixing of low latitude air into high latitudes and also left signatures in methane and other trace constituents that have persisted for many months. In this study, we illustrate the connection between such dynamical variability on middle atmospheric trace constituents and polar mesospheric clouds.

IAMAS (Meteorology)

M14e - M14 Middle Atmosphere Science

IUGG-4850

Global mesospheric and lower thermospheric response to major sudden stratospheric warming events

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Along with the rapid warming and zonal-mean zonal wind reversal in the winter polar stratosphere, major sudden stratospheric warming (SSW) events can impact the mesosphere and lower thermosphere (MLT). Using output from the NCAR Whole Atmosphere Community Climate Model with Specified Dynamics, this study highlights key recent SSW events and develops a composite view of major SSW with respect to the MLT.

In the winter polar hemisphere, SSW can result in mesospheric cooling along with an elevated stratopause as a consequence of the interplay between gravity wave (GW) and planetary wave (PW) forcing. The MLT GW zonal momentum forcing switches from westward to eastward with SSW onset and back to westward with the formation of the elevated stratopause. Enhancement of PWs in the MLT occurs shorty after SSW onset and is associated with strong upward propagating PW, generated in situ by flow instability induced by the altered stratospheric circulation. Anomalous residual vertical motion can promote strong descent of trace species (like NOx) from their MLT reservoirs into the stratosphere, while mesospheric ascent and cooling lead to the enhancement of nighttime ozone between 80-100 km. We also explore the impact of the major SSW events on the recurring quasi two-day wave (QTDW) in the summer hemisphere. As a predominant wave signature in the summer hemisphere, momentum forcing by QTDW may counteract the GW forcing that drives the climatological upwelling near the mesopause.

IAMAS (Meteorology)

M14f - M14 Middle Atmosphere Science

IUGG-0932

Long-term trends in the mesosphere-lower thermosphere region and related variables

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Increasing atmospheric concentration of greenhouse gases affects also the mesosphere-lower thermosphere (MLT) region. The signal-to-noise ratio of MLT trends is much larger than that of tropospheric trends. However, long-term changes and trends in the MLT region are affected also by other drivers, first of all by the stratospheric ozone depletion, then by changes of atmospheric wave activity and water vapour concentration, and its ionized component also by long-term changes of solar and geomagnetic activity. Progress in this area over the last 2-4 years will be reviewed. Long-term changes and trends in some stratospheric parameters, which affect the MLT region, like stratospheric ozone and stratospheric dynamics, will also be briefly mentioned, as well as project ROSMIC devoted to investigations of such trends.

IAMAS (Meteorology)

M14f - M14 Middle Atmosphere Science

IUGG-0971

ROSMIC: A project within SCOSTEP's new VarSITI program

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ROSMIC (Role Of the Sun and the Middle atmosphere/thermosphere/ionosphere In Climate) is one of the four scientific projects launched under SCOSTEP's new science program VarSITI (Variability of the Sun and Its Terrestrial Impact). The science program will run from 2014 until 2018 and is aimed at providing a platform for international collaboration and discussion. ROSMIC is formed of four working groups, namely 1) Solar Influence on Climate, 2) Coupling by Dynamics, 3) Trends in the MLT, and 4) Trends and Solar Influence in the Thermosphere. ROSMIC supports scientific investigations which contribute to our understanding of the impact of the Sun on the terrestrial middle atmosphere/lower thermosphere/ionosphere (MALTI) and Earth's climate and its importance relative to anthropogenic forcing over timescales from minutes to centuries. Close collaborations between the observation and modeling communities is encouraged. Observational activities range from the analysis of existing data records, measurements from ground based, insitu and satellite instruments, the organization of coordinated observing campaigns, and the development and implementation of new instrumentation and observation techniques. Dedicated models directed toward particular phenomena as well as sophisticated whole atmosphere/ionosphere models are expected to play a vital role in this project. Collaborations between the working groups and with the other tree VarSITI projects will be facilitated during this program. This presentation will give an overview of the ROSMIC project, its scientific aims and programmatic organization.

IAMAS (Meteorology)

M14f - M14 Middle Atmosphere Science

IUGG-1401

Long-term observations of gravity wave activity in the lower stratosphere with GPS radio occultation data

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Global gravity wave parameters (potential energy and vertical flux of absolute horizontal momentum) are retrieved from GPS radio occultation data. The radio occultation technique uses GPS signals received aboard low Earth orbiting satellites for atmospheric limb sounding. Atmospheric temperature profiles are derived with high vertical resolution and the GPS radio occultation technique is sensitive to gravity waves with small ratios of vertical to horizontal wavelengths. Since 2006 the six-satellite U.S./Taiwan FORMOSAT-3/COSMIC mission delivers about 2000 global distributed radio occultations daily. This gives the possibility for the determination of absolute momentum flux as the most important parameter for the quantification of gravity wave activity. In this presentation we discuss momentum flux distributions in the lower stratosphere derived from closely spatio-temporal radio occultation temperature fluctuation profiles. The results for different seasons are compared with other momentum flux climatologies (e.g. SABER) and limitations of the method will be addressed. In addition to momentum flux the variability of potential energy derived from several radio occultation missions since 2001 will be discussed.

IAMAS (Meteorology)

M14f - M14 Middle Atmosphere Science

IUGG-2430

50 Years of Standard Phase Height measurements and Long-Term Variability over Europe

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Indirect phase height measurements of low frequency radio waves are used to study the long-term variability of the mesosphere (D layer, about 80 km altitude) over Europe. The concept of standard phase heights (SPH) guaranties the continuity of the series in the case of slight frequency changes. Since February 1959, over 50 years, field strength measurements of the broadcasting station, Allouis (Central France), have been maintained at Kühlungsborn (54° N, 12° E, Mecklenburg, Northern Germany). A homogenized daily series was generated with a coverage of 98 % of time for a 50 year period.

The mean annual cycle of SPH-series shows a negative winter anomaly as known due to enhanced downward transport of NO and subsequent photo-ionization. The SPH-series are partially anti-correlated to the solar cycle because stronger photo-ionization is linked with higher number of electrons, which reduces the SPH. Further the statistical analysis of the SPH-series shows a significant overall trend with a decrease of 114 m per decade induced by a shrinking stratosphere due to global warming and mesospheric processes, but with strong intra-decadal variability in winter.

Stratospheric influences of ENSO-like and QBO-like oscillations on mesospheric SPHs have been shown for solar minimum phases. Especially in winter the SPH changes are linked with change of the residual circulation indicated by the Eliassen-Palm flux divergence. This induces changes of vertical NO transportfrom the lower thermosphere, and the subsequent NO photo-ionization. Furthermore we show that during phases of solar maximum nonlinearity and solar feedback processes seem to be an important factor for changes of SPH-oscillation phase

IAMAS (Meteorology)

M14f - M14 Middle Atmosphere Science

IUGG-3417

Simulation of secular temperature trends in the middle atmosphere

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Anthropogenic emissions of greenhouse gases (GHG) warm the troposphere and cool the atmosphere above about 100 hPa. The pattern of temperature change with altitude depends, not only on the rate of increase of GHG, but also on changes in ozone brought about by changes in the halogen burden of the atmosphere. We use the Whole Atmosphere Community Climate Model (WACCM) to investigate secular trends in temperature over the last 30-35 years and to project these changes into the rest of the 21st century. We compare model results against observations and show that WACCM reproduces many details of the observed trends, including a region of small or statistically insignificant temperature trend near the mesopause. These changes may be understood in terms of the interplay among GHG, ozone, and temperature. The vertical profile of the temperature trend changes substantially in the course of the 21st century compared to the 20th century, as ozone responds to the curtailment of halogen emissions. In particular, the large temperature trend observed near the stratopause in the 20th century becomes considerably smaller in the 21st century, as ozone recovers from catalytic losses due to halogens. At the same time, the temperature trend near the menopause becomes large and statistically significant.

IAMAS (Meteorology)

M14f - M14 Middle Atmosphere Science

IUGG-4722

Solar cycle and trends of CO and CO2 in the mesosphere and lower thermosphere

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In this presentation we compare the distributions of CO and CO2 in the mesosphere and lower thermosphere (MLT) measured by the ACE-FTS and MIPAS satellite-borne instruments with calculations obtained by the Whole Atmosphere Community Climate Model (WACCM). The comparison spans almost one solar cycle, covering solar minimun and solar maximum conditions. We also show the sensitivity of the CO and CO2 distributions simulated by WACCM to the parameterization of the gravity waves and an analysis of the solar cycle and trends in the CO and CO2 distributions.

IAMAS (Meteorology)

M14g - M14 Middle Atmosphere Science

IUGG-0440

Stratosphere/mesosphere coupling during the winter/summer transition at Davis, Antarctica

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The mobile scanning iron lidar of the Leibniz Institute of Atmospheric Physics in Kühlungsborn (IAP) was in operation at Davis, Antarctica, from December 15, 2010, until December 31, 2012. It measured temperatures in the iron layer (~80-100 km). The lidar can operate under daylight conditions. At Davis, the lidar has achieved at total of 2900 hours of temperature measurements which is presumably the largest nearly continuous data set in Antarctica. In this presentation we concentrate on the winter/summer transition and compare with circulation changes in the stratosphere derived from MERRA. We also compare with the northern hemisphere (NH). The thermal structure around the mesopause at Davis is closely coupled to the general circulation in the stratosphere, more precisely to the transition from winter to summer conditions. In contrast to theoretical expectations we occasionally find the mesopause significantly higher and colder(!) compared to the NH. The mesopause altitude changes by several kilometers throughout the summer season, which is significantly different from the summer in the northern hemispheric. Depending on altitude, temperatures can be warmer or colder compared to the NH summer. We studied the seasonal variation of polar mesosphere summer echoes (PMSE). PMSE are strong radar echoes related to ice particles and therefore require very low atmospheric temperatures. The VHF radar frequently detected PMSE. We compare the seasonal variation of PMSE with stratospheric circulation, both at Davis and at ALOMAR (69°N). We present model calculations applying the Kühlungsborn Mechanistic Circulation Model (KMCM) explaining the stratosphere/mesosphere coupling during the winter/summer transition.

IAMAS (Meteorology)

M14g - M14 Middle Atmosphere Science

IUGG-1589

Combined influences of westerly phase of the QBO and 11-year solar maximum on theNorthern Hemisphere extratropical winter circulation

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The combined influences of westerly phase of the quasi-biennial oscillation (QBO-W) and 11-year solar maximum (Smax) on the Northern Hemisphere (NH) extratropical winter circulation are investigated using reanalysis data and Chemistry Climate Model (CCM) simulations. The polar vortex was strong in December during QBO-W and Smax conditions. In December, the dynamical processes of planetary wave propagation and meridional circulation induced by QBO-W conditions around the polar vortex are similar in character to those induced by Smax conditions, and both processes may work in concert to strengthen the polar vortex during QBO-W and Smax conditions. The strengthened polar vortex in December during QBO-W and Smax was occurred simultaneously with the development of a north-south dipole tropospheric circulation anomaly in the Atlantic sector similar to the North Atlantic Oscillation (NAO), which lasted from December to January. The structure of the north-south dipole anomaly has a zonal wavenumber 1 (WN1) component, where the longitude of the anomalous ridge overlaps with that of the climatological ridge in the North Atlantic in January. This implies the amplification of the WN1 wave and results in the enhancement of upward WN1 propagation from the troposphere into the stratosphere in January, leading to the weakened polar vortex in February–March. These results may provide a possible explanation for the mechanisms underlying the complex seasonal evolution of NH wintertime polar vortex anomalies during QBO-W and Smax conditions and the role of the troposphere in this evolution.

IAMAS (Meteorology)

M14g - M14 Middle Atmosphere Science

IUGG-2277

Variability of high-latitude odd-nitrogen in the middle atmosphere: The relative roles of dynamics and energetic particle precipitation

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The concentration of odd-nitrogen species (NOx) in the winter polar middle atmosphere depends on several factors, including the state of stratospheric winds, the strength of diffusive transport near the mesopause, and the deposition of energetic particles in the mesosphere and the lower thermosphere. This paper presents a series of model experiments using the NCAR Whole Atmosphere Community Climate Model that explores the sensitivity of NOx to these factors and how they vary in importance between the hemispheres. We find dramatic differences in the Southern Hemisphere from the choice of Prandtl number used to calculate the diffusivity due to dissipation of gravity waves and whether or not medium energy electron precipitation is included. In the Northern Hemisphere, as previously reported, the concentration of NOx additionally depends on if and when a stratospheric sudden warming occurs. The representation of these processes significantly affects the amount of NOx entering the stratosphere and subsequent EPP-induced ozone loss. In comparison to satellite observations by MIPAS and Odin-SMR, better agreement is achieved with higher values of eddy diffusivity and the inclusion of medium energy electron precipitation.

IAMAS (Meteorology)

M14g - M14 Middle Atmosphere Science

IUGG-2592

Self-sustained oscillations of temperatures and winds in the atmosphere (0-100 km)

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Low frequency oscillations with periods 2.2-2.4 yr; 3.4 yr; and 5.5 yr have been observed in atmospheric temperature measurements (0-100 km). Periods are about constant with altitude. Phases show an intriguing steplike vertical structure. Very similar results were obtained from GCM simulations HAMMONIA ans WACCM). The same type of structures is found in simulations with climatological boundaries. This hints to a new type of vertical coupling in the atmosphere by synchronization of self-sustained oscillators.

A homogeneous vertical set of wind measurements is presently not available in this altitude regime. Our temperature analyses show the HAMMONIA simulations to be good proxies for temperature. Hence we tentatively used HAMMONIA data for a low frequency oscillation analysis of zonal winds, too. Corresponding results are presented. They are compared to radiosonde wind measurements in the lower atmosphere and to the temperature simulations.

IAMAS (Meteorology)

M14g - M14 Middle Atmosphere Science

IUGG-2631

Middle atmosphere chemical and dynamical variability arising from Energetic Particle Precipitation

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In this presentation we will give an overview of the energetic particle precipitation (EPP) impact on the polar middle atmosphere and discuss the latest advances in our understanding of the potential effects of EPP on stratospheric dynamics.

In addition to solar storms the nearly continuous precipitation of energetic particles from the magnetosphere affects ionisation levels in the polar atmosphere. This ionisation peaks in the middle atmosphere, where it leads to enhanced production of NOx and HOx gases, which participate in catalytic ozone destruction. Chemical-dynamical coupling mechanisms in the atmosphere can further provide links between EPP and lower altitudes and thus have indirect implications the to dynamical conditions of the polar stratosphere: studies using meteorological reanalysis data and atmospheric chemistry-climate model results have shown that during the winter season temperatures and winds from about 80km altitude downwards show variability depending on the level of EPP. However, the details of the coupling mechanism have thus far remained unknown.

Recently published studies using satellite observations have shown a significant reduction in mesospheric ozone levels during periods of enhanced energetic electron precipitation, with up to 90% ozone loss for the largest events and around 30% reduction on average. This observed electron precipitation driven ozone loss is comparable in magnitude to that arising from solar proton events, but occurs much more frequently. The frequency in the nature of the electron precipitation events and the discovered impact on middle atmosphere ozone levels may help us to better understand some of the previously proposed linkages between EPP and stratospheric dynamics.

IAMAS (Meteorology)

M14g - M14 Middle Atmosphere Science

IUGG-5032

Coupling by Dynamics in VarSITI/ROSMIC

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‘Coupling by dynamics’ working group is one of the four working groups under the ROSMIC (Role Of the Sun and the Middle atmosphere/thermosphere/ionosphere In Climate) project of SCOSTEP/VarSITI program. In this talk, the scope of ‘Coupling by Dynamics’ and on-going/planned activities will be overviewed.

The primary mechanism for momentum and mechanical energy transfer in the neutral atmosphere from the ground to the mid-thermosphere is through waves. These include gravity waves, tides and planetary waves (and possibly infra-sound). There are a variety of sources for these waves, their propagation is affected by the background temperature and wind fields and in turn they interact with and significantly modify the background fields from the lower atmosphere to the upper thermosphere. There is also some evidence of downward propagation of breaking regions (similar to the QBO mechanism). The working group promotes investigations to provide information on the characteristics and climatology of these wave fields and their role in various regions of the atmosphere. These results will support the robust identification of the effects of solar variability and anthropogenic influences and provide physical insights into the dynamical mechanisms affecting large scale structures and transport. Collaborations between sophisticated modelling, ground-based and satellite observations, and theoretical works are desired to pursue the working group goal.

IAMAS (Meteorology)

M14h - M14 Middle Atmosphere Science

IUGG-0935

Reconciling contradictory results on the Central Pacific El Niño signal in the polar stratosphere: role of Stratospheric Sudden Warmings

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The Central Pacific El Niño (CP) signal in the Northern Hemisphere polar stratosphere remains uncertain. Opposite responses have been reported depending on the CP definition and events considered. Some studies found a weaker and warmer polar stratosphere, while others displayed a stronger and colder polar vortex. Then, there is no consensus about the CP resemblance with the canonical East Pacific El Niño (EP).

Results based on reanalysis data show that, different from EP events, the CP response in the Northern Hemisphere is dominated by the occurrence of Stratospheric Sudden Warmings (SSWs). CP winters with and without SSWs are characterized by significant and opposite anomalies in the Northern Hemisphere polar stratosphere. CP winters with SSWs show significant warm anomalies, related to the overwhelming impact of the SSWs. In contrast, during CP winters without SSWs significant cold anomalies are observed in early winter. This is due to a negative Pacific-North American pattern that leads to a weakened climatological wave number 1 and suppressed upward wave propagation into the stratosphere in this case. Thus, in the absence of SSWs CP and EP polar stratospheric responses are distinguishable in early winter.

Results are robust to the different CP indices and the composite sizes. CMIP5 historical simulations also corroborate our conclusions, found in reanalysis data. Therefore, this study demonstrates that the influence of the SSWs needs to be taken into account to obtain a robust polar stratospheric response for CP. In addition, it explains why different results were previously reported regarding the response to CP.

IAMAS (Meteorology)

M14h - M14 Middle Atmosphere Science

IUGG-0945

Does the definition of Sudden Stratospheric Warmings matter?

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Sudden Stratospheric Warmings (SSWs) are characterized by a dramatic weakening of the polar vortex circulation and warming of the polar stratosphere. They are a potential tool for seasonal forecasting since the SSW signal can reach the troposphere affecting surface weather. Multiple methods have been used in the literature to detect SSWs, yielding discrepancies on the identified events. This work aims to compare the SSWs climatologies of eight representative definitions for the 1958-2009 period in three different reanalysis data (ERA, NCEP/NCAR and JRA-55). Our main results do not depend on the reanalysis considered.
The mean frequency of SSWs across definitions is 7.1 events per decade, with large variability depending on whether or not the methods include minor warmings in their definitions. The monthly distribution of events is similar across definitions, with maximum occurrence in January. However, the multi-decadal variability depends on the selected method, and only three definitions display the well-known minimum in the frequencies in the 1990s. By comparing several dynamical benchmarks, we have found negligible differences among methods in the stratosphere due to the large case-to-case SSW variability within a given definition.
All methods show stratospheric-tropospheric coupling following SSWs, but to a different extent. Robust surface signals before and after SSWs are observed for major events, which are detected by most methods. However, the tropospheric impacts of minor SSWs are weaker and represent the main source of discrepancy across definitions. Therefore, to obtain robust results, future studies on SSWs should minimize the detection of minor events.

IAMAS (Meteorology)

M14h - M14 Middle Atmosphere Science

IUGG-2129

The influence of the Quasibiennal Oscillation on the three-dimensional Brewer-Dobson circulation

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The influence of the quasibiennal oscillation of zonal winds in the equatorial stratosphere (QBO) on the three-dimensional (3D) Brewer-Dobson circulation is investigated based on the approach of the 3D residual circulation. For this purpose we use different data: daily-mean wind fields derived from Aura/MLS satellite data, ERA-Interim reanalysis and simulations with the high-altitude general circulation and chemistry model HAMMONIA. The derivation of the wind fields from Aura/MLS includes two steps: (1) quasi-geostrophically balanced winds are derived from temperature, and (2) unbalanced winds are derived by inversion of tracer transport, where the balanced winds and the observed day-to-day variations of H2O are used as input. The result provides an important tool for validating the assimilations and model simulations at altitudes where direct wind measurements are very sparse. The analysis of the data shows that the QBO modulates the northern winter 3D residual circulation in both the stratosphere and mesosphere (planetary wave one during QBO-East and planetary wave two during QBO-West), with a significant imprint on the transport of O3 and H2O. The associated 3D wave flux divergence elucidates that the QBO induces a change in transient wave activity over North America and in the planetary Rossby wave excited by the Rocky Mountains, which additionally leads to a change of gravity wave propagation into the mesosphere. It is also demonstrated that the induced change of the downwelling in the area of the stratospheric polar low anomaly significantly contributes (by about 30%) to the Northern European / Siberian geopotential high anomaly.

IAMAS (Meteorology)

M14h - M14 Middle Atmosphere Science

IUGG-2237

The precursor role of Blocking in Sudden Stratospheric Warmings

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Major Sudden Stratospheric Warmings (SSWs) are large disruptions of the polar vortex and a potential source for more skillful seasonal forecasts of tropospheric winter weather in the northern extratropics. In the 1980's atmospheric blocking was first proposed as a potential precursor of SSWs but the connection between blocking and SSWs remained elusive for a long time. Recent studies have revisited this topic, reporting controversial results. Some studies have not found clear links between blocking and SSWs, while others report precursor signals in blocking activity when SSWs are stratified into displacement and splitting types. Another conflicting result refers to the geographical location of the blocking precursors and the resulting wave-number amplification associated with each type of SSW. The blocking role in SSWs also depends on slowly-varying forcings of the polar vortex, such as the El Niño-Southern Oscillation. This talk provides an overview on the observational links between blocking and SSWs and the main challenges. In addition, it is assessed whether some of the reported results are robust with respect to the reanalysis product and the blocking detection algorithm.

IAMAS (Meteorology)

M14h - M14 Middle Atmosphere Science

IUGG-2330

Hemispheric asymmetries and seasonality of mean age of air in the stratosphere: Deep versus shallow branch of the Brewer-Dobson circulation.

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Based on multi-annual simulations with the Chemical Lagrangian Model of the Stratosphere (CLaMS), driven by ECMWF ERA-Interim reanalysis, we discuss hemispheric asymmetries and the seasonality of the mean age of air (AoA) in the lower stratosphere. In particular, two questions are raised: (1) why high latitudes show older air in the SH than in the NH during the same season and (2) how to explain the annual cycle of AoA in the tropical lower stratosphere.First, the planetary wave forcing of the Brewer-Dobson (BD) circulation is quantified in terms of Eliassen Palm (EP) flux divergence calculated by using the isentropic coordinate. While the forcing of the deep branch at 1000 K pot. temp. (around 10 hPa) has a clear maximum in each hemisphere during the respective winter, the shallow branch of the BD circulation, i.e. between 100 and 70 hPa (i.e. between 380 and 420 K pot. temp.), shows almost opposite seasonality in both hemispheres with a pronounced minimum between June and September in the SH.Second, we decompose the time-tendency of AoA into the contributions of the residual circulation and of eddy mixing by analyzing the zonally averaged tracer continuity equation. In the tropical lower stratosphere between 30S and 30N, the air becomes younger during boreal winter and older during boreal summer. During boreal winter, the decrease of AoA due to tropical upwelling outweighs aging by isentropic mixing. In contrast, weaker isentropic mixing outweighs an even weaker upwelling in boreal summer and fall making the air older during these seasons. Poleward of 60 deg., the deep branch locally increases AoA and eddy mixing locally decreases AoA with the strongest net decrease during spring. Eddy mixing in the NH outweighs that in the SH throughout the year.

IAMAS (Meteorology)

M14h - M14 Middle Atmosphere Science

IUGG-5164

Sudden stratospheric warmings and anomalous upward wave activity flux

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Abrupt transitions in the polar winter stratospheric circulation such as sudden stratospheric warmings (SSWs) have profound impacts on stratospheric transport and surface weather. SSW-like events are a manifestation of strong two-way interactions between upward propagating planetary waves and the mean flow. The importance of sufficient upward wave activity fluxes from the troposphere as well as the preceding state of the stratospheric circulation in forcing SSW-like events have long been recognized. Past research based on idealized numerical simulations has suggested that the state of the stratosphere may be more important in generating extreme stratospheric events than anomalous upward wave fluxes from the troposphere. Other studies have emphasized the role of tropospheric precursor events. Here we use reanalysis data to define events of extreme stratospheric mean flow deceleration (with SSWs being a subset) as well as events of extreme lower tropospheric upward planetary wave activity flux. We show that while the wave fluxes leading to SSW-like events ultimately originate near the surface, the anomalous upward wave activity fluxes associated with these events primarily originate within the lowermost stratosphere. Furthermore, the enhanced wave fluxes and mean flow decelerations appear essentially synchronously – that is, the mean flow decelerations leading to SSW-like events are as much causing enhanced upward wave activity fluxes as they are caused by these enhanced upward wave activity fluxes. SSW-like events therefore appear to be primarily forced by wave fluxes that are constructively redistributed or generated at or above the tropopause. Anomalous upward wave fluxes from the lower troposphere appear to be less important.

IAMAS (Meteorology)

M14i - M14 Middle Atmosphere Science

IUGG-0754

Latent heat contribution to dynamcs of the middle atmosphere particularly to the forcing of stationary planetary waves.

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During the year the tropics receive more precipitation than higher latitudes. This region is dominated by the deep convection activity and hence large amount of latent heat is released, which is one of the main sources for non-migrating tides. While the latent heat not only substantially influence the non-migrating tides excitation but it impacts the forcing of stationary planetary waves as well. Amplitudes of these waves in the stratosphere of Northern Hemisphere become greater and statonary planetary wave with zonal wave number 2 is capable of penetrating into the higher altitudes. These changes lead to the heating of lower stratosphere and weakening of the polar vortex.

IAMAS (Meteorology)

M14i - M14 Middle Atmosphere Science

IUGG-1807

Long-term Evolution of 3D Residual Circulation in ERA-Interim

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The mean meridional mass circulation (the so-called Brewer Dobson circulation) is characterized by upwelling in the tropics and downwelling in the middle and high latitudes, and can be described by the approach of the residual circulation. For the Northern Hemisphere, the evolution of the residual circulation is studied in a 3D point of view using ERA-INTERIM data from 1979 to 2013 (provided by ECMWF). The work was carried out within a Project (No.113Y545) supported by TUBITAK (The Scientific and Technological Research Council of Turkey). The residual circulation is induced by vertically propagating planetary waves and gravity waves. Thus the longest and most powerful planetary waves, such as waves with zonal wave number 1, are capable of changing the structure of the 3D residual circulation in the middle atmosphere, which is characterized by downwelling in the area of the polar low anomaly and upwelling in the area of the Aleutian high anomaly. This study focuses on the long term variability in the longitudinally dependent middle atmospheric wave structures and the Northern Hemispheric eddy heat flux in winter time, and its contribution to the long-term evolution of the residual circulation. In particular the results suggested an increase in the planetary wave one structure of the residual circulation forced by upward propagating waves in January is associated with an increase in middle atmospheric temperatures in the area of the polar low over Europe and Russia and a decrease in the area of the Aleutian high.

IAMAS (Meteorology)

M14i - M14 Middle Atmosphere Science

IUGG-2134

Is the Brewer-Dobson circulation increasing, or moving upward?

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The stratospheric Brewer-Dobson circulation (BDC), which characterizes the transport of mass through the stratosphere, is projected to accelerate in response to increasing greenhouse gas (GHG) concentrations. In the lower stratosphere, often represented by the constant pressure level of 70 hPa, simulations with general circulation models (GCMs) and chemistry-climate models (CCMs) indicate an increase in the tropical upward mass flux by around 2% per decade through the end of the 21th century. Although there is uncertainty concerning the mechanism driving this circulation change, there is a broad agreement on the sign of the change across nearly all simulations. Simultaneously, the studies show a substantial rise of the tropopause height in response to rising tropospheric temperatures.

Here we use simulations from the CCM EMAC as well as from the Chemistry-Climate Model Initiative (CCMI) to access the changes in the BDC in a different way. Instead of a fixed model pressure level, a reference level relative to the tropopause is chosen to determine the tropical upward mass flux. The benefit of this method is that the level reacts to the height change of the tropopause. By deriving the mass flux relative to the tropopause, it is possible to quantify potential future changes of the mass exchange between the troposphere and the stratosphere. Our analysis shows that most of the positive trend in mass flux is due to the rise of the tropopause height. In terms of the mechanism, this suggest that the increase in mass flux is largely associated with an upward shift of the BDC in response to GHG forcing. More practically, the acceleration of the tropical upward mass flux at a fixed 70 hPa pressure level does not inevitably imply an increase in mass transport through the tropopause.

IAMAS (Meteorology)

M14i - M14 Middle Atmosphere Science

IUGG-2607

Evolution of stratospheric temperatures during 1979-2014 from combined SSU and SABER data

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Long-term variations in stratospheric temperatures are evaluated based on combining measurements from SSU (Stratospheric Sounding Unit, covering 1979-2005) with observations from SABER (Sounding of the Atmosphere using Broadband Emission Radiometry, covering 2002-2014). We create a merged dataset utilizing the 4-year temporal overlap between SSU and SABER. These data show long-term cooling which increases in magnitude from the lower to upper stratosphere, in addition to variations linked to the 11-year solar cycle, QBO, ENSO and volcanic effects. The time series provide evidence that upper stratosphere temperatures have responded to observed changes in ozone, in addition to cooling from increases in CO_2. Comparisons with the WACCM chemistry-climate model show good agreement in the simulation of changes over the past 4 decades.

IAMAS (Meteorology)

M14i - M14 Middle Atmosphere Science

IUGG-2817

Comparison of the Quasi-biennial Oscillation amplitudes among several reanalysis data

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Reanalysis data are important global datasets which have been used for many meteorological studies including middle atmosphere sciences. Several reanalysis data including recently updated are now available. It is necessary to identify similarities and differences among reanalysis and to evaluate them for understanding their availability of research objects. In this work, we focus on the time variations of the QBO amplitudes in seven reanalysis data (i.e., ERA-40, ERA-Interim, JRA-25, JRA-55, MERRA, NCEP-1 and NCEP-2). Radiosonde observation data provided by Free University Berlin (FUB) and Integrated Global Radiosonde Archive (IGRA) are used for evaluation. Kawatani and Hamilton (2013) analyzed radiosonde data and found the negative long-term trend of the QBO amplitudes at 70 hPa, which provides strong support for the existence of a long-term trend of enhanced upwelling neat the tropical tropopause. The QBO amplitudes are calculated for all periods available in each reanalysis. Very similar negative trends are found at the nearest grids to observational points in five reanalysis data except NCEP-1 and NCEP-2, which show unrealistically positive trends. In general, five reanalysis data underestimate the QBO amplitudes at 70 hPa before ~1990 and overestimate around 1995-2005, resulting in smaller negative trends compared with those in radiosondes. Around areas with sparse observational points, differences among reanalysis data are generally large, resulting in much larger differences in zonal mean QBO amplitude variations. Interestingly, these differences also depend on heights, which are small at 20-30 hPa and large at 70hPa and 10 hPa.

IAMAS (Meteorology)

M14i - M14 Middle Atmosphere Science

IUGG-3114

Quantifying the effects of mixing and residual circulation on trends of stratospheric mean age of air

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Trends in stratospheric mean age of air are driven both by changes in the (slow, large scale) residual mean mass circulation and by changes in (fast, locally acting) eddy mixing. However, to what degree both effects affect mean age trends is an open question. Here, we present a method that allows the effects of mixing and residual circulation on trends of mean age of air to be quantified. This method is based on simulations with the Chemical Lagrangian Model of the Stratosphere CLaMS driven by ERA-Interim reanalysis, and on the tracer continuity equation integrated along the residual circulation. CLaMS simulated climatological mean age in the lower stratosphere shows reliable agreement with balloon borne in-situ observations and with satellite observations by the Michelson Interferometer for Passive Atmospheric Sounding MIPAS. During 1990-2013, simulated mean age decreases throughout most of the stratosphere, qualitatively consistent with recent results based on climate model simulations. Remarkably, in the Northern hemisphere subtropics and mid-latitudes above about 24km CLaMS mean age trends are insignificant, consistent with published age trends from in-situ observations. Furthermore, during 2002-2012 CLaMS mean age changes show a clear hemispheric asymmetry in agreement with MIPAS. We find that changes in the transit time along the residual circulation alone cannot explain the mean age trends, and including the effect of mixing integrated along the air parcel history is essential. Therefore, differences in age trends between models or between models and observations are likely related to differences in the integrated effect of mixing. Above about 550K, trends in the integrated mixing effect appear to be likely coupled to residual circulation changes.

IAMAS (Meteorology)

M14j - M14 Middle Atmosphere Science

IUGG-0579

Dissection of the effect on the northern winter stratosphere from the ENSO-related SST anomalies over different tropical ocean basins

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This study applies WACCM, a stratosphere-resolved GCM model to dissect the stratospheric responses in the northern winter extratropics to the imposed ENSO-related SST anomalies in the tropics. It is found that the anomalously warmer and weaker stratospheric polar vortex during warm ENSO is basically a balance of the opposite effects between the SST anomalies in the tropical Pacific (TPO) and that over the tropical Indian Ocean basin (TIO). Specifically, the ENSO-related SST anomalies over the TIO are to induce an anomalously colder and stronger stratospheric polar vortex during warm ENSO, which acts to partially cancel out the much stronger warmer and weaker polar vortex response to the SST anomalies in the TPO. Further analysis indicates that, while the SST forcing from the TPO contributes to the anomalously positive Pacific North America (PNA) pattern in the troposphere, and the enhancement of the stationary wavenumber (WN) -1 in the stratosphere during warm ENSO, the TIO SST forcing is to induce an anomalously negative PNA and a reduction of both WN-1 and WN-2 in the stratosphere. Diagnosis on E-P flux confirms that, the anomalously upward propagation of stationary wave in the extratropics mainly lies over the western coast of North America during warm ENSO, which is mainly associated with the TPO-induced positive PNA response and is partially suppressed by the effect of the accompanying TIO SST forcing.

IAMAS (Meteorology)

M14j - M14 Middle Atmosphere Science

IUGG-0743

The importance of the Stratosphere for North Atlantic climate variability

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The North Atlantic Oscillation is the leading mode of Northern Hemisphere winter atmospheric conditions. It does not only modulate European weather but also influences the surface heat transfer between the ocean and atmosphere in the North Atlantic region. This influence is particularly interesting in the Labrador Sea as deep water formation in this region is known to play an important role in modulating the strength of the Atlantic Meridional Overturning Circulation.
Via modulating the North Atlantic Oscillation, stratospheric polar vortex events might play a substantial role for North Atlantic climate variability, including the strength of the Atlantic Meridional Overturning Circulation.

We investigate the effects of different stratospheric polar vortex states on North Atlantic climate variability from 1955 to 2100 in simulations with NCAR's high-top chemistry-climate model, the CESM-WACCM. We focus on the stratospheric influence on the North Atlantic Oscillation, which in turn influences the state of the North Atlantic ocean. A comparison with NCAR's low-top climate model (CCSM4) provides information about the relative importance of the stratospheric representation in a climate model and its influence on North Atlantic climate variability. Additionally, a comparison to other CMIP5 models will be included.

IAMAS (Meteorology)

M14j - M14 Middle Atmosphere Science

IUGG-2383

High-resolution turbulence observations in the stratosphere with LITOS and comparison to radiosonde analysis

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Although the stratosphere is mostly stably stratified, breaking gravity waves and instabilities produce turbulence and energy dissipation. This modifies the energy distribution from the troposphere to the mesosphere and is an important parameter for the vertical mixing of trace species. In order to precisely infer energy dissipation rates, the viscous subrange has to be covered, which in the stratosphere lies at scales of centimeters and below. Our balloon-borne system LITOS (Leibniz-Institute Turbulence Observations in the Stratosphere) observes small-scale wind fluctuations with a vertical resolution of less than 1mm. The dissipation rate is obtained by fitting a turbulence model to the measured spectrum of fluctuations. Three flights with large payloads were performed from Kiruna (68°N, 21°E) during BEXUS campaigns. Recently, a new small version of LITOS was flown from Kühlungsborn (54°N, 12°E). Various turbulent layers with a vertical thickness in the order of several 10m have been observed. Measured energy dissipation rates greatly vary within only a few 10m, roughly between 1e-7 and 10W/kg, with a mean value of about 1e-3W/kg. The results will be discussed in the geophysical context.
In the literature, turbulence investigations are also performed with regular radiosonde data (vertical resolution 5m) by using a Thorpe analysis. In order to infer dissipation rates, a proportionality between Thorpe length and Ozmidov scale has to be assumed. With our unique dataset, this assumption can be checked. We will present first results that this proportionality may be void in the stratosphere. Furthermore, dissipation rates obtained from radiosondes deviate up to a factor of 100 from those obtained by spectral analysis. Differences between both methods will be discussed.

IAMAS (Meteorology)

M14j - M14 Middle Atmosphere Science

IUGG-3936

Investigation of weak and strong downward wave coupling in the northern hemisphere

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Downward wave coupling occurs when an upward propagating planetary wave from the troposphere decelerates the flow in the upper stratosphere through dissipation. Under certain conditions a reflecting surface is formed which redirects all subsequent planetary waves back down to the troposphere. This process has been observed during dynamically active periods in the stratosphere on a weekly timescale and provides a mechanism for stratosphere-troposphere coupling.

To test this mechanism and potential factors influencing the downward wave coupling, three 145-year sensitivity simulations with NCAR's Community Earth System Model (CESM-WACCM) are analyzed. The results show that the QBO and atmosphere-ocean coupling significantly impact the downward wave coupling. Without the QBO, the occurrence of downward wave coupling is significantly suppressed. In contrast, stronger and more persistent downward wave coupling occurs in the absence of atmosphere ocean coupling with climatologically varying sea surface temperatures.

The downward wave coupling from the stratosphere is associated with a positive phase of the North Atlantic Oscillation in the troposphere. During stronger downward wave coupling periods, in particular the tropospheric surface response is weaker, and during periods with weaker downward wave coupling, the surface response is stronger. This surprising result can be explained by the combined effect of downward wave coupling and synoptic scale eddies.

IAMAS (Meteorology)

M14j - M14 Middle Atmosphere Science

IUGG-4001

First results from comparisons of the ERA-Interim and MERRA reanalysis with long duration balloon observations from Google X Project Loon

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Google [x] Project Loon aims to provide worldwide internet access to remote locations using long-duration balloons that fly in the stratosphere. These balloons fly about 20 km above the Earth's surface and have typical lifetimes of about 55 days. This study compares horizontal wind speeds derived from the Google X Loon trajectory information calculated from GPS measurements with corresponding winds from the ERA-Interim and MERRA reanalysis products. Initial analysis displays excellent agreement between the reanalysis products and the values derived from the long duration balloons with biases between the datasets below 0.5 m/s in both the zonal and meridional directions for most flights. The large number of balloons launched by the Google X team (greater than 100) provides an order of magnitude increase in the number of measurements available compared to previous balloon programmes and thus a significant opportunity for validation of reanalysis products. This increased data density allows us to examine differences between the Project Loon observations and the reanalysis products as a function of latitude in detail. Results show similar patterns of biases in the reanalysis at high latitudes and near the equator to previous long duration balloon missions using limited numbers of balloon launches. Additionally, the Google Loon observations which are densest at Southern hemisphere mid-latitudes, likely as a consequence of the launch site in New Zealand, allow us to examine the quality of the reanalysis in this region for the first time. In addition to deriving the differences between the reanalysis products and the Project Loon observations, we also examine the consequences of the model biases on trajectories derived from the reanalysis relative to the balloon trajectory.

IAMAS (Meteorology)

M14j - M14 Middle Atmosphere Science

IUGG-4870

Mechanisms of Northern Hemispheric response to future climate change

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In this work we proposed a new mechanisms of the Northern hemispheric response of the coupled stratosphere/troposphere system to future climate change.

We first show, using dedicated atmosphere general circulation model experiments, that the ocean, and in particular tropical Sea Surface Temperature (SST) largely controls future anthropogenic circulation changes of the Northern Hemisphere troposphere/stratosphere-system and resulting precipitation. The SST drives wave-induced high-latitude stratospheric warming and easterly wind-anomalies in fall, which propagate into the troposphere and persist through mid-to-late winter. Tropical SST also controls the tropospheric response through wave-induced strengthening of mid-latitude eddy-driven jet and weakening of high latitude westerly wind. The strengthening of the mid-latitude eddy-driven jet largely explains the precipitation-response in the most of socioeconomically relevant latitudes. In northern high latitudes the precipitation is driven mainly by sea-ice.

Afterward we will show how the tropical SST drives the wave induced Northern Hemispheric future climate change in both stratosphere and troposphere. Thereby we show that the resolved wave response to climate change results mainly from the subtropical wind response to tropical SST. The subtropical wind strength controls the poleward wave propagation of long wave (wave number 1 and 2) into the polar stratosphere and the interplay between subtropical zonal wind and its shear and curvature control the synoptic waves propagation in the troposphere.

IAMAS (Meteorology)

M14k - M14 Middle Atmosphere Science

IUGG-1228

Stratosphere-troposphere dynamical coupling in the tropics associated with the equatorial QBO

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The quasi-biennial oscillation (QBO) of the zonal mean zonal wind in the equatorial stratosphere is considered as an internal oscillation due to wave-mean flow interactions under a zonally periodic boundary condition. QBO theory and its laboratory analogue assumed the separation of the troposphere where waves are generated, by prescribing time-constant wave forcing at the bottom boundary. In the real atmosphere, however, there is no such a clear boundary separating the stratosphere and the troposphere.

Recently we proposed a “minimal model of QBO-like oscillation in a stratosphere-troposphere coupled system' for better understanding the QBO dynamics (Yoden et al. 2014), in which long time-integrations of a two-dimensional regional model with explicit moist convections were made under a periodic lateral boundary condition without Coriolis effect. QBO-like oscillations were obtained robustly as a radiative-moist convective quasi-equilibrium state. The obtained QBO-like oscillations show clear signal in the zonal mean zonal wind and temperature even in the troposphere, unlike the observed equatorial QBO. The zonal mean precipitation and organized moist convective systems also vary in accordance with the oscillation in the troposphere.

Even in this highly-idealized minimal model, our understanding of the dynamics of QBO-like oscillation is still limited. For example, in low top experiments without the stratosphere, we still obtain QBO-like oscillations but their period becomes shorter, amplitude becomes smaller, and time variation becomes more irregular. Results on the detailed momentum budget analyses will be reported to show the relative importance of gravity waves and slantwise convections for the momentum transport in the troposphere in these experiments.

IAMAS (Meteorology)

M14k - M14 Middle Atmosphere Science

IUGG-1896

Role of the stratosphere for the time scale of the annular modes new: Re-thinking stratoshperic sudden warnings and their tropospheric impact

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The simulation of the observed annular mode (AM) time scale may be regarded as an important benchmark for climate models. Previous research demonstrated that climate models systematically overestimate this time scale. According to the fluctuation-dissipation theorem this may imply that the climate sensitivity of models is too high. Previous research further suggested that the time scale in the troposphere is influenced by the stratosphere. Here, we ask whether the unrealistic time scale in models is related to flaws in the dynamical coupling between the stratosphere and the troposphere, or whether other reasons such as internal variability, short observational data, and a slow convergence of the AM time scale calculation are responsible. We study our questions from a 4000-year-long control simulation with the GFDL climate model CM2.1. Over the Northern Hemisphere we find relatively weak indication for influences from stratosphere-troposphere coupling on the AM time scale. The situation is different over the Southern Hemisphere, where we find robust connections between the AM time scale in the stratosphere and that in the troposphere, confirming and extending earlier results of influences of stratospheric variability on the troposphere. We further find that internal variability attaches large uncertainty to the AM time scale when diagnosed from decadal records. Even under fixed forcing conditions, at least 100 years of data are required in order to keep the uncertainty in the AM time scale of the Northern Hemisphere to 10%; over the Southern Hemisphere the required length increases to 200 years. If nature's AM time scale is similarly variable, there is no guarantee that the historical reanalysis record is a fully representative target for model evaluation.

IAMAS (Meteorology)

M14k - M14 Middle Atmosphere Science

IUGG-2314

Impact of interactive ozone on climate reconstruction in an Earth system model: the case of Antarctica in mid-Holocene

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Stratospheric ozone change can influence on tropospheric climate. For example, Sigmond and Fyfe (2010) pointed out the Antarctic sea ice could increase due to the Antarctic ozone hole. However, the impact of ozone change in paleoclimate has not been investigated in detail. In most of paleoclimate experiments of CMIP5/PMIP3, the distribution of ozone is fixed to the estimated value of 1850 AD despite the ozone distribution depends on the solar radiation distribution as a function of latitude and time (season). This treatment may cause some bias to the simulation results. In this study, therefore, we examine the impacts of forecasted ozone distribution in paleoclimate experiments with an Earth system model. In this study, we focus on the Antarctic region in the mid-Holocene (6k year before present, hereafter MH) experiment.

We utilize Meteorological Research Institute Earth system model (MRI-ESM), which is a coupled model of the atmosphere-ocean-aerosol general circulation model of MRI-CGCM3 (Yukimoto et al., 2012) which was used in PMIP3 and the chemistry model of MRI-CCM2 (Deushi and Shibata, 2011). We examine the MH experiment and the preindustrial control experiment.

We obtain annual mean zonal mean temperature anomaly up to +1.7 K near the surface in the Antarctic region through the reduction of sea ice. Opposite trend is found to the relationship of sea ice and the Antarctic ozone hole in these decades as described above. Positive anomaly of the ozone is observed in the Antarctic stratosphere in autumn, in which the solar radiation anomaly is negative. This result suggests that the ozone distribution consistent with the solar insolation in the

targeted era should be used in paleoclimate simulations in order to improve the climate reconstruction in the polar regions.

IAMAS (Meteorology)

M14k - M14 Middle Atmosphere Science

IUGG-2499

A stratospheric role on negative phase shift of the winter annular mode by the Arctic sea ice loss

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A possible linkage between the recent reduction in Arctic sea-ice extent and the wintertime Arctic Oscillation (AO)/North Atlantic Oscillation (NAO) through the stratospheric processes was examined by observational analyses and atmospheric general circulation model (AGCM) experiments. The ERA interim reanalysis and merged Hadley/OI-SST data were used for observational analysis. The AFES4.1 (T79L56 with its top at 0.08 hPa) model was used for detecting atmospheric response to recent sea ice reduction. The results reveal that the recent Arctic sea-ice reduction results in cold winters in mid-latitude continental regions, which are linked to an anomalous circulation pattern similar to the negative phase of AO/NAO. It is also found that a reduced sea-ice leads to weakening of the stratospheric polar vortex in mid-winter and thus leads to a negative phase of the tropospheric AO/NAO in late winter. Results from model experiments without wave-mean interaction in the upper stratosphere further suggest a critical role of the stratosphere in deepening the tropospheric annular mode in mid to late winter through stratosphere–troposphere coupling.

IAMAS (Meteorology)

M14k - M14 Middle Atmosphere Science

IUGG-3946

The Quasi-Biennial Oscillation effect on the troposphere and its modulation by the El Niño-Southern Oscillation

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The Quasi-Biennial Oscillation (QBO) is the dominant mode of variability in the equatorial lower to upper stratosphere. Although being primarily a stratospheric phenomenon, there are at least two ways in which it can affect the troposphere: 1) directly in the tropics and extra-tropics, or 2) indirectly through its effect on the stratospheric polar vortex, where anomalies can propagate down and affect extra-tropical surface weather and climate. In this study, we investigate how the tropospheric QBO signal is modulated by the El Niño-Southern Oscillation (ENSO), which is the dominant mode of global sea surface temperature variability.

Here we analyze three 145-year model simulations performed with NCAR's Community Earth System Model where anthropogenic greenhouse gases and ozone depleting substances were set constant to 1960 conditions. We show that the QBO alone does not have a significant influence on the troposphere over the Atlantic. In the North Pacific, however, the subtropical jet is stronger during the westerly phase of the QBO (QBOW) compared to the easterly phase (QBOE). This tropospheric QBO signal is amplified and spatially extended by La Niña events, while it is eliminated by El Niño events. Over the North Atlantic, the combinations of QBOW and La Niña or QBOE and El Niño conditions intensify the ENSO signal in this region, while the other two combinations weaken it and limit it spatially. We present some ideas for the underlying physical mechanisms for this QBO-ENSO modulation.

Our results are useful for tropospheric weather prediction as they have direct implications, e.g., on the strength and tracks of extra-tropical cyclones.

IAMAS (Meteorology)

M14k - M14 Middle Atmosphere Science

IUGG-5267

Ensemble data assimilation to quantify the effect of the 2009 madden julian oscillation on the 2010 polar stratosphere

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It is now well established that sudden stratospheric warming (SSW) events are caused by planetary waves that are generated in the tropopshere and break in the polar stratosphere. Nevertheless, the tropospheric conditions that lead to either enhanced planetary wave generation or poleward wave propagation are still not entirely understood. Statistical connections have been found between SSWs and various natural forcings, including a recent discovery by Garfinkel et al. (2010) that certain phases of the Madden Julian Oscillation (MJO) seem to favor SSW events. Numerous other studies have also found that the MJO modulates the poleward propagation of planetary waves, yet the influence of the MJO on SSW occurrence is still unclear. One difficulty in establishing such a connection is that the observational record of SSWs is relatively short (ca. 60 years) and individual SSW events vary strongly --- this results in high sampling error and low statistical significance. Free-running climate models, on the other hand, allow for a high sample size but have difficulty simulating a realistc MJO. Here we propose using ensemble data assimilation to constrain the MJO in a high-top atmosphere model over a given winter. This system allows us to evaluate the probability distribution of the stratospheric polar vortex state, conditioned upon the observed MJO in the months preceding the warming. We focus on the winter of 2009/10, which had a strong MJO in the preceding autumn, followed by an SSW in Jan 2010 and an extreme negative North Atlantic Oscillation for the rest of the 2010 winter.

IAMAS (Meteorology)

M14l - M14 Middle Atmosphere Science

IUGG-2217

The lifecycle of instability features measured from the Andes Lidar Observatory over Cerro Pachon on March 24, 2012

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The Aerospace Nightglow Imager (ANI) observes nighttime OH emission (near 1.6 microns) every 2 seconds over an approximate 73 degree field of view. ANI had previously been used to study instability features seen over Maui. Here we discuss instabilities seen from 5 to 8 UT on 24 March 2012 over Cerro Pachon Chile. The wind shears, measured by a meteor radar, at altitudes between 85 to 90 km were small but the atmosphere had reduced stability because of the large negative temperature gradients measured by a Na lidar. Thus, regions of dynamical and convective instabilities might be expected to form depending on the exact magnitude of the Richardson number. The brightest primary instabilities that formed with a horizontal wavelength near 9 km showed the subsequent formation of secondary instabilities, rarely seen over Maui, suggesting an initial formation as a dynamical instability. After dissipation of the primary and secondary features smaller-scale features were present with sizes in the buoyancy subrange between 1.5 and 6 km. The spectra of these features was somewhat consistent with the Weinstock model if the turbulence is considered to be increasing. Direct Numerical Simulations (DNS) produce secondary instabilities with scale sizes comparable to what is observed although their spectra are somewhat steeper than is observed.. However, the high spatial resolution DNS model shows that after decay of the primary features even smaller scales are produced than can be seen in the images.

IAMAS (Meteorology)

M14l - M14 Middle Atmosphere Science

IUGG-2268

Satellite observations of gravity-wave mean-flow interactions

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Gravity waves (GWs) are important drivers of the atmospheric circulation. However, due to their small horizontal scales, they are not well represented in global models (GCMs/CCMs). Usually, their effect on the background flow has to be parameterized, which is one of the major shortcomings of GCMs/CCMs. For improvement, global observations of GWs are required. In particular, in recent years, satellite observations of GW momentum flux absolute values and of potential GW drag became available.
We have derived GW momentum flux and potential GW drag from observations of the satellite instruments HIRDLS and SABER. Several examples of gravity-wave mean-flow interactions have been investigated. One example is the quasi-biennial oscillation (QBO) of the tropical zonal wind. The QBO influences the atmosphere over a large range of altitudes and latitudes, and even surface weather and climate. Still, climate models have large difficulties in reproducing a realistic QBO. We compare HIRDLS and SABER GW drag observations with the tropical momentum budget of the ECMWF ERA-Interim reanalysis. Qualitatively, there is good agreement between observed GW drag and an estimate of GW drag from ERA-Interim representing the contribution of GWs including those GWs not resolved by the model. Remaining inconsistencies, however, could be an indication for uncertainties in the ERA-Interim momentum budget.
Other observations of GW mean-flow interactions are the driving of the SAO, the reversal of the summertime mesospheric wind jets, or the GW drag variations during sudden stratospheric warmings (SSWs). Overall, these satellite observations give a very consistent picture of the dynamics of the middle atmosphere, and they can help to further improve the representation of GWs in GCMs/CCMs.

IAMAS (Meteorology)

M14l - M14 Middle Atmosphere Science

IUGG-2495

A ship-borne imager: observing mesospheric gravity waves from the oceans

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Atmospheric gravity waves play an important role in driving global atmospheric circulation patterns: they transport momentum and energy from their source regions in the lower atmosphere and deposit it into the mean flow when they break in the middle atmosphere. Gravity waves in this region can be observed using infrared airglow emissions. Traditionally these observations are performed using a ground-based all-sky camera, which has resulted in many "point source" datasets. This project has developed a novel way to make the first airglow observations from onboard a moving ship. The technique is explained and first results are presented.

IAMAS (Meteorology)

M14l - M14 Middle Atmosphere Science

IUGG-3930

Lidar observations of gravity waves in the middle atmosphere over Lauder, New Zealand

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The DEEP propagating gravity WAVE experiment was carried out over New Zealand in June/July 2014. As part of the DEEPWAVE campaign, we conducted extensive observations with a ground-based Rayleigh lidar at Lauder (45°S, 170°E). The Lauder site is in the proximity of the polar vortex, with sufficiently high horizontal wind speeds in austral winter that allow for deep propagating gravity waves. Moreover, Lauder is located just east of the Southern Alps. Prevailing westerlies facilitate excitation of large orographic gravity waves which can be observed by lidar. We report on gravity waves detected in high-resolution temperature measurements in the altitude range 20-90 km. Spectral filtering of the temperature data reveals large-scale waves with periods of several hours as well as small-scale waves with periods down to 10-20 minutes. Observed vertical wave lengths and periods are retrieved from the 2D Fourier transform of measured temperature. Using this information to calculate phase speeds, waves are then classified into categories which may be associated with different wave types, i.e. waves originating from different wave sources. We present first results from ~500 observation hours acquired between 19 June and 6 November 2014. We identify orographic wave events, deep propagating non-orographic waves, and small-scale waves which possibly result from breaking large-scale waves. Results are compared with ECMWF data. We find that large-scale waves are surprisingly well represented in ECMWF up to the stratosphere.

IAMAS (Meteorology)

M14l - M14 Middle Atmosphere Science

IUGG-5011

Gravity wave momentum transport measurements in the mesosphere lower thermosphere / ionosphere region using partial reflection and meteor radar

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The vertical transport of horizontal momentum by gravity waves accounts for many of the phenomena observed in the mesosphere and lower thermosphere / ionosphere (MLTI) that cannot be explained by radiative effects alone - such as the closure of the mesospheric jets, the residual pole-pole circulation, and the cold summer mesopause. To have a global network of instruments capable of measuring it accurately would greatly improve its parametrization in weather and climate models of this region.

At present, observations of these gravity wave effects are principally provided by ground-based radar, lidar, and airglow imaging techniques. Of the available radar techniques, only the one associated with deriving line-of-sight radial wind velocities from ablating meteor trails (using an all-sky interferometric meteor radar) has a sufficiently low set-up cost to be implemented on a reasonably global scale. On the basis of model measurements, it has been determined that this technique will only provide adequate momentum transport measurements when large averaging periods are used, and that its accuracy will be compromised in the cases of low meteor detection rates, high atmospheric tidal activity, and generally complex motion fields.

We present new momentum flux measurements using standard Doppler analysis of radial velocities from the MF radar at Buckland Park, South Australia, and also compare the statistics of the gravity wave fluxes measured by the MF radar and a co-located meteor radar. We focus on the observing conditions in which the two instruments obtain the best agreement, to assist with experimentally clarifying when meteor radars can be expected to make the most accurate measurements of momentum transport.

IAMAS (Meteorology)

M14l - M14 Middle Atmosphere Science

IUGG-5231

A regional study of atmospheric gravity waves using the USArray Transportable Array

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The USArray Transportable Array (TA) is a network of approximately 400 seismo-acoustic stations deployed on a 70 km Cartesian grid covering an area of 2,000,000 km^2 in the continental United States. The network moves eastward through station redeployments and is now located on the Atlantic coast. This dense network has provided unprecedented opportunities for research in seismology, infrasound and atmospheric science.

We have developed a novel technique to investigate gravity wave occurrence and propagation across the network and have applied it to atmospheric pressure data recorded from Jan 1, 2010 through 2014. We divided the stations in this time range into 3,600 non-overlapping triads. Each triad is most sensitive to propagating gravity waves in the 1-6 hour period range. We report several lines of research with this new dataset. First, we study individual large events in which atmospheric gravity waves are observed to cross the TA. We also study the long-term occurrence statistics of gravity waves and compare them to satellite observations. Thirdly, we analyze recordings of infrasound signals that have propagated through the heterogeneous background that the network has allowed us to characterize. We discuss plans for future work when the network is redeployed in Alaska.

IAMAS (Meteorology)

M14m - M14 Middle Atmosphere Science

IUGG-3021

Expanded role for gravity wave parameterization in WACCM

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The parameterization of gravity waves in the NCAR Whole Atmosphere Community Climate Model (WACCM) includes orographic, convective, and frontal sources. Even with these, the model simulates temperatures in the Antarctic lower stratosphere during winter and spring that are much lower than observed. Recent simulations have shown that polar stratospheric temperatures are much improved by including another set of gravity waves that have horizontal wavelengths in the inertia-gravity range (several hundred km). The impact of orographic waves has also been reassessed after comparisons with wave observations. Improvements include a more realistic seasonal development of the ozone hole and somewhat better timing for the winter to summer transition in the zonal winds and Brewer-Dobson Circulation. We will demonstrate the role of these additional waves in shaping the middle atmosphere climatology and will show comparisons with observations of wave characteristics that constrain the parameterization.

IAMAS (Meteorology)

M14m - M14 Middle Atmosphere Science

IUGG-3937

Observational constraints on gravity wave driving of the global circulation

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Common circulation biases in climate models are related to missing momentum forcing due to small-scale, unresolved gravity waves. A key example is the quasibiennial oscillation (QBO) in lower stratospheric winds, a major component of interannual variability that affects tropical-extratropical teleconnections and regional climate change. A second example is the Southern Hemisphere circulation, where large wind biases in the middle atmosphere are common and affect the timing and depth of seasonal ozone depletion and Southern Hemisphere summertime climate change. In contrast, Northern Hemisphere winds are simulated with smaller biases, due in large part to strong orographic gravity wave drag that is parameterized in most models.

What sources generate missing Southern Hemisphere gravity waves that drive the observed circulation? Are these sources also present in the North, and if so are parameterized orographic waves too strong? Are parameterized tropical gravity waves that generate a QBO in climate models realistic? How will these waves change in the future, and will they lead to changes in the QBO strength or period? Researchers in the field are addressing these questions through combinations of observational analyses and model studies of gravity wave generation and drag on the circulation. Gravity wave drag remains an illusive property to observe on a global scale, and current satellite observation analyses have huge uncertainties due to sampling limitations. On the other hand, gravity wave momentum fluxes in the lower stratosphere can be observed, and these data give useful constraints for middle atmosphere circulation studies. This talk will summarize recent work and present new quantitative constraints derived by combining multiple global datasets.

IAMAS (Meteorology)

M14m - M14 Middle Atmosphere Science

IUGG-4268

Influence of the observation geometry of TIMED-SABER on the estimation of gravity wave amplitudes

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Atmospheric gravity waves are not resolved but parametrized in most climate models such as ECHAM 6 whereas it is distinguished between orographic and non-orographic sources. Deficiencies become obvious when measurement- and model-based gravity wave quantities are compared.

It is known that due to their relatively large field of view satellite-based instruments like TIMED-SABER catch fluctuations, which are caused by gravity waves, only in parts. Additionally, the viewing direction of SABER varies only between two angles for each yaw cycle at a specific geographical position. Amplitudes of gravity waves, which are characterized by a horizontal orientation perpendicular to the line-of-sight, are therefore systematically underestimated compared to those of waves with a parallel wave front orientation. This effect is of special importance for geographically fixed sources.

Gravity wave analyses of radiosonde and SABER data during two campaigns – at ALOMAR, Norway and Oberpfaffenhofen, Southern Germany in late winter / early spring 2012 – are presented. During this time period the majority of gravity waves shows a preferred orientation parallel to the respective mountain ridge. That implies a nearly perpendicular (Scandes) / parallel (Alps) orientation of the waves' fronts to the satellite's line-of-sight. For both locations the underestimation of the waves' amplitudes by SABER is quantified and a statistical correction factor is derived.

Furthermore, SABER data from 2002 to present are used for the calculation of gravity wave dissipation with a special focus on Northern Norway and Southern Germany. The results are compared to model parameterizations (ECHAM 6, setup

of project MiKlip). The location-specific underestimation of the waves’ amplitudes is taken into account.

IAMAS (Meteorology)

M14m - M14 Middle Atmosphere Science

IUGG-4402

Isentropic expression of Eliassen-Palm flux and meridional circulation

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Isentropic expression of Eliassen-Palm flux and meridional circulation

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1. Fundamentals
Isentropic coordinates allow us to exactly formulate the lower boundary condition of Eliassen-Palm (E-P) flux. The vertical E-P flux makes the smooth transition from the form drag over the ground surface to that over the isentropic surface with increasing the potential temperature.

In mid-latitudes, the low-level E-P flux divergence almost balances with the Coriolis force of equatorward flow. The E-P flux propagating upward exchanges the angular momentum of low-level equatorward flows with poleward flows of extratropical direct circulation (ETD) and Brewer-Dobson (BD) circulation.

2. Transient responses of E-P flux and mean-poleward flow to cold air outbreaks
Polar cold air outbreaks of zonally integrated equatorward flows frequently occur in the lower troposphere. Thus, cold outbreaks can be indexed by the equatorward cold airmass flux below a potential temperature (pt) of 280K at 45N. Lagged correlations/regressions with the outbreak index well capture the temporal variations of upwardly propagating E-P flux, E-P flux convergence and mean-poleward flows of ETD and B-D circulations.

3. 3-D structures of E-P flux and poleward flows in isentropic coordinates
3-D version of E-P flux and meridional mass circulation in isentropic coordinates is being formulated. Preliminary analyses will be presented on E-P flux due to zonal waves and meridional mass flux. The equatorward flows of cold airmass below pt=280K in mid-latitudes are confined near the East Asia and the North America. We will show the locality of the E-P flux convergence and poleward flows near UT-LS region.

IAMAS (Meteorology)

M14m - M14 Middle Atmosphere Science

IUGG-4427

Contribution of different wave scales to the convective gravity wave spectrum based on satellite observations

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Gravity waves (GWs) have a strong impact on atmospheric dynamics and play a major role in the driving of large scale circulations, such as the Quasi-Biennial-Oscillation (QBO). One of the most prominent sources of GWs is deep convection, which can excite a broad spectrum of GWs in terms of phase speed and horizontal wavelength. To simulate this kind of source, the convective GW source scheme of Song and Chun (2005) considers a diabatic forcing region. The vertical structure of this forcing directly impacts wave-filtering and resonance processes in the forcing region. These processes are captured analytically by the model and result in a characteristic spectral peak in momentum flux (MF) phase speed spectra. The spatial and temporal scales of the diabatic forcing, which affect the horizontal wavelength and phase speed, are free tunable parameters. For the real atmosphere, the prevailing horizontal wavelengths are unknown. The scheme was validated against global fluctuation distributions from MLS (Microwave Limb Sounder) and from AIRS (Atmospheric Infrared Sounder), proving the general concept. More stringent constraints on the horizontal wavelength distribution can be provided by GW momentum flux spectra from infrared limb sounders. In this work, global simulations were performed by coupling the scheme for convective GW excitation with the GW regional or global ray tracer (GROGRAT). Comparison of simulated spectra and spectra observed by limb sounders is performed using a comprehensive observational filter. Tropical GW drag profiles are calculated and compared to the momentum budget of the QBO. By this synergistic use of model and observations we assess the occurrence of different scales of convectively excited GWs in the tropical and subtropical regions.

IAMAS (Meteorology)

M14m - M14 Middle Atmosphere Science

IUGG-5146

Impact of gravity waves on OH*

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Airglow measurements are often used to infer temperature variations related to gravity waves (GWs). Based on an advanced model of the relaxation of excited hydroxyl (OH*), we simulate the effects of GWs on the OH*-layer and derive expressions for its peak altitude and number density. The numerical model of OH*-relaxation takes into account all major processes such as 1) the production of OH* by the reaction of atomic hydrogen with ozone, 2) deactivation by atomic oxygen, molecular oxygen, and molecular nitrogen, 3) spontaneous emission, and 4) loss due to chemical reaction with atomic oxygen. The OH*-relaxation model is part of a chemistry-transport model (CTM) which is driven by the dynamics simulated with the Kühlungsborn Mechanistic general Circulation Model (KMCM). The KMCM explicitly describes mid-frequency GWs and their effects on the mean flow. We find that the number density and height of the OH*-layer peak are mainly determined by atomic oxygen (O) and temperature (T). There are two ways of GW-influence: On short time scales due to the direct GW-modulation of O and T, and on longer time scales due to GW-mixing of O. The direct GW-related variation of the OH*-layer height amounts to 5-10 km. As a result, the temperature that corresponds to the OH*-layer peak significantly deviates from the temperature at constant pressure. This effect introduces biases in the GW amplitude and wavelength derived from airglow when assuming a constant pressure height of the OH*-layer. Performing a sensitivity experiment with GWs filtered in the dynamical fields, we find that, on average, GW mixing of O moves the OH*-layer down by ~2-4 km and increases its number density by ~50-100 percent. This effect is strongest at middle and high latitudes during the winter season.

IAMAS (Meteorology)

M14n - M14 Middle Atmosphere Science

IUGG-1256

Excitation of long waves by compact anelastic internal wavepackets

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Previous theory and simulations of horizontally periodic, vertically localized internal wavepackets have shown that internal waves can overturn tens of kilometres higher in the atmosphere than predicted by linear theory as a consequence of weakly nonlinear interactions of the waves with the mean flow they induce (Dosser & Sutherland, J. Atmos. Sci., 2011). This work extends the results to horizontally as well as vertically localized wavepackets.

The divergence of the horizontal flux of horizontal momentum associated with surface gravity wavepackets results in a horizontal flow that turns out to be identical to the Stokes drift. This 'divergent-flux induced flow' is itself divergent and so induces a deep response flow whose momentum is equal and opposite to the momentum associated with the Stokes drift. Thus the total momentum is zero. By contrast there is momentum associated with internal wavepackets. Like surface gravity wavepackets, the divergent-flux induced flow of horizontally localized internal waves is itself divergent. However, because the ambient is stratified, and so inhibits vertical motion, there can be no deep return flow. Different from the approach of Bretherton (1969), we follow a physically intuitive but mathematically rigorous quasi-monochromatic wavepacket analysis complemented by fully nonlinear numerical simulations to show that the dominant response is an induced horizontally long internal wave that extends laterally well to either side of the wavepacket. This suggests a new mechanism for efficient energy and momentum transfer from local to long and slow time-scale disturbances that does not involve irreversible deposition through wave breaking. Weakly nonlinear effects and implications for wave drag parameterizations are discussed.

IAMAS (Meteorology)

M14n - M14 Middle Atmosphere Science

IUGG-2290

Frequency resolved momentum fluxes over the Antarctic Peninsula derived from super pressure balloon data

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The Antarctic Peninsula is the scene of strong gravity wave generation by flow over steep terrain. We have extended the analysis of super pressure balloon data over this region from the VORCORE campaign to include data from the Concordiasi campaign. Both campaigns were conducted by the Centre National de la Recherche Scientifique in collaboration with the National Science Foundation. The campaigns comprised a large (~20) set of balloons drifting on constant density surfaces in the lower stratosphere during the spring months. Our analyses employ expressions for momentum fluxes based on a coordinate system where density is the vertical coordinate. This approach provides expressions that are easily applied to the calculation of the vertical fluxes of momentum in specified intrinsic frequency bands. The VORCORE data limited the evaluation to periods of one hour and greater. With Concordiasi data the analysis was extended to periods of 5 minutes. We find that the fluxes for periods below 1 hours are comparable to fluxes in longer period bands, despite larger variances at longer periods. The geographical distribution of fluxes about the Peninsula is found to depend on period with a tendency for the longer periods to peak farther leeward of the main terrain features. We find a large degree of intermittency in the fluxes that can vary with wave frequency. We have examined mountain waves over the Antarctic Peninsula with a dynamical model. A significant addition of the Concordiasi campaign was dropsonde data that enabled an improved definition of the basic state. We report on comparisons between predictions and observations of wave localization with respect to topography as a function of intrinsic wave period.

IAMAS (Meteorology)

M14n - M14 Middle Atmosphere Science

IUGG-2606

The relative influence of wind and stability on gravity wave distributions in the middle atmosphere

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Gravity waves (GWs) and their momentum flux exhibit a pronounced annual cycle in the stratosphere and mesosphere. This behaviour is caused by a complex interplay of GW sources and the modulation of the propagation condition for GWs by the background atmosphere. Modulation of the GW spectrum and critical level filtering by the background winds as well as modulation by the background stability (buoyancy frequency) all contribute. We perform GW ray-tracing experiments based on a climatological background atmosphere and a launch distribution tuned to match satellite observations. The launch distribution is kept constant in order to isolate the effects of the background atmosphere. We find that for the total momentum flux the global shape is almost entirely generated by the background winds which filter different phase speeds and different directions as GWs encounter critical levels. In particular, at mid and high latitudes the potential of GWs to enter the stratosphere in winter and strong filtering due to the wind reversal in summer generates a strong contrast between summer and winter. The situation is different, if only short vertical wavelength waves are considered. This mimics measurements where the background atmosphere is removed by vertical filtering. The short vertical wavelength part of the spectrum is, to a large degree, saturated and the buoyancy frequency directly influences the maximum GW momentum flux. We find strong sensitivity in particular in the mesosphere, where temperature gradients are already negative and temperature variations may cause also larger variations of the buoyancy frequency.

IAMAS (Meteorology)

M14n - M14 Middle Atmosphere Science

IUGG-2637

Gravity-wave induced anomalous potential vorticity gradient generating planetary waves in the winter mesosphere

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We show that gravity wave forcing (GWF) plays a crucial role in the barotropic/baroclinic instability that is frequently observed in the mesosphere and considered an origin of planetary waves (PWs) such as quasi-two-day waves and four-day waves. Simulation data from a GW-resolving general circulation model were analyzed, focusing on the winter northern hemisphere where PWs are active. The unstable field is characterized by a significant potential vorticity (PV) maximum with an anomalous latitudinal gradient at higher latitudes that suddenly appears in mid-latitudes of the upper mesosphere. This PV maximum is attributed to an enhanced static stability (N^2) that develops through the following two processes: (1) strong PWs from the troposphere break in the middle stratosphere, causing a poleward and downward shift of the westerly jet to higher latitudes; and (2) strong GWF located above the jet simultaneously shifts and forms an upwelling in the mid-latitudes causing a significant increase in N^2 . An interesting feature is that the PV maximum is not zonally uniform, but is observed only at longitudes with strong GWF. This longitudinally dependent GWF can be explained by selective filtering in the stratospheric mean flow modified by strong PWs. In the upper mesosphere, the Eliassen–Palm flux divergence by PWs has a characteristic structure, which is positive poleward and negative equatorward of the enhanced PV maximum. This is attributable to eastward and westward propagating PWs, respectively. This fact suggests that the barotropic/baroclinic instability is eliminated by simultaneous generation of eastward and westward PWs causing PV flux divergence.

IAMAS (Meteorology)

M14n - M14 Middle Atmosphere Science

IUGG-3200

Interaction between gravity waves and nightglow as observed by the Suomi-NPP Day/Night Band

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Recent progress in the imaging technology of digital cameras has enabled marked advances in the capturing of various night sky phenomena; atmospheric nightglow, which is discernible on dark moonless nights, being among these. Occasionally, various wave structures can be seen in still photography and video as disturbances to the otherwise homogeneous nightglow background. These structures are the manifestation of interactions between gravity waves and the temperature/density structure of a geometrically thin atmospheric layer between ~ 85-95 km, near the mesopause. The waves are generated by several meteorological or geophysical mechanisms.

The Suomi-NPP satellite and its low-light Day/Night Band (DNB) has enabled the first satellite imaging of nightglow structures at sub-km spatial resolution. On moonless nights, the DNB is able to discern the very faint nightglow emission structures present in the scene, revealing a complex environment replete with waves.

In exceptional cases, it has been possible to match the satellite-observed nightglow patterns with ground-based photography. Here, we detail one such example: concentric gravity waves in nightglow seen high above Tibetan Plateau, generated by nearby violent storms. We show how it is possible to determine the source of these waves, using the satellite imagery, and distinguish unambiguously the mesospheric nightglow signals from the underlying tropospheric clouds.

We then show several DNB examples of similar nightglow waves, stimulated by myriad processes including strong Mediterranean storms, over Europe and its surroundings. The geostationary satellite information complements the instantaneous snap-shots from Suomi-NPP, helping to reveal the specific generator of the gravity waves, observed in nightglow.

IAMAS (Meteorology)

M14n - M14 Middle Atmosphere Science

IUGG-5490

Impact of storm top gravity wave process on the upper troposphere/lower stratosphere physics and chemistry

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Deep convective clouds excite strong internal gravity waves which are especially prominent at the upper troposphere and lower stratosphere (UTLS) level. These gravity waves have significant impact on the physics and chemistry of the UTLS region. In this study, we will report results derived from both cloud resolving model simulations and observations (satellite, aircraft and ground-based) of deep convective storms to demonstrate how gravity wave process impact the UTLS.

We shall show that the gravity wave breaking is responsible for the observed above anvil cirrus plumes that are an important irreversible cross-tropopause mass transport process that sends water substance as well as other chemical species from the troposphere into the stratosphere. Evidence from conventional satellites (GOES, MODIS) as well as CloudSat and Callipso data, aircraft and graound based observations will be shown to substantiate the model results.

The gravity wave process also impacts the storm top thermodynamic processes. We shall show that many satellite observed infrared features such as cold-V, cold ring, warm-cold couplet, and radial cirrus phenomena are all caused by the gravity wave process. Again, we will use cloud model results and satellite observations to demonstrate how this occurs.

Both tropical and extratropical processes will be discussed in this report.

IAMAS (Meteorology)

M14p - M14 Middle Atmosphere Science

M14p-407

Characterization of the lower atmosphere over the Ganges-Brahmaputra-Meghna basin based on GNSS-COSMIC remote sensing products

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Many studies have highlighted the poor reliability of radiosonde observational networks across the South Asian sub-continent, thus, imposing serious challenges in assessing regional changes in the troposphere-stratosphere. The COSMIC mission has overcome many observational limitations recording over 4 million radio occultation (RO) profiles globally in the last 9 years. This study investigated the spatio-temporal variability of the lower atmosphere over the Ganges-Brahmaputra-Meghna (GBM) basin using 35,776 GNSS-COSMIC RO measurements between April 2006 and December 2013. Detailed statistical comparisons were also made with four radiosonde types and reanalysis products. The results indicated very poor performances by IMD's (Indian Meteorological Department) radiosondes, while Chinese-made radiosondes showed near-perfect agreement with COSMIC RO data. The inter-annual variability of the upper tropospheric (UT) and lower stratospheric (LS) temperatures based on principal component analysis (PCA) revealed a strong mean zonal structure in the first two leading orthogonal modes, accounting for a total variance of 98% (UT) and 93% (LS), respectively. The respective temporal components are associated with major regional and global atmospheric circulations. The mean tropopause temperature varied between -70^{o}C to -80^{o}C, with an average height of about 15.5 km to 16.3 km during the winter and summer seasons, respectively, indicating a pronounced annual cycle over GMB. The spatial variations were found to be high (±9.6^{o}C and ±2.2 km) especially during spring season corresponding to the development of convection over the region. The tropopause heights were found to be more sensitive to major stratospheric warming events and major El Niño Southern Oscillation (ENSO) events.

IAMAS (Meteorology)

M14p - M14 Middle Atmosphere Science

M14p-408

An emerging precursor signal in the stratosphere in recent decades for the Indian summer monsoon onset

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This paper reports a significant temporal relationship that has emerged in recent decades

between the Indian summer monsoon (ISM) onset and the seasonal timing of the stratospheric final

warming (SFW). Specifically, early SFWs in spring tend to be followed by late ISM onset and vice versa. During

the ISM onset season after 1979, there exist significant SFW-related zonal wind anomalies over South Asia,

and they are highly consistent with that of the ISM-related in both the upper and lower troposphere. These

SFW-related zonal wind anomalies are not observed before 1979, corresponding to the absence of the SFW-ISM

relationship. Further analysis indicates that the tropospheric Arctic Oscillation anomalies that follow

the stratospheric SFWs to appear during April to early May after 1979 are crucial for the emerging SFW-ISM

linkage. This implies that the seasonal timing of SFWs may act as an emerging precursor for the ISM onset

since 1970s.

IAMAS (Meteorology)

M14p - M14 Middle Atmosphere Science

M14p-409

Influence of dynamical processes in the tropics on the stratosphere

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The Madden - Julian oscillation is the large scale equatorial circulation and it has been shown to impact tropical cyclone activity. In our research we have made an attempt to evaluate this oscillation and we have also reviewed relationships between: Madden -Julian oscillation and wind, and Madden- Julian oscillation and geopotential in polar latitudes. To analyze the oscillation we have used zonal winds components on 850 and 150 mb heights, data has been taken from Modern-Era Retrospective Analysis, National Centers for Environmental Prediction and the National Center for Atmospheric Research reanalyses.

IAMAS (Meteorology)

M14p - M14 Middle Atmosphere Science

M14p-410

Perturbations of the ozone content during the active dynamical processes in the boreal stratosphere

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Influence of dynamical factors on the ozone content in the boreal stratosphere is investigated. We analyzed satellite ozone data observed by the OMI. The results obtained are compared with the reanalysis ozone data (MERRA). The variability of the temperature and planetary wave activity in the stratosphere at the middle and high latitudes is considered. The interdependence between the total ozone column and these thermal and dynamical characteristics has been established. The possible mechanisms responsible for the interaction of chemical and dynamical processes are shortly discussed.

IAMAS (Meteorology)

M14p - M14 Middle Atmosphere Science

M14p-411

Influence of the QBO phase on the propagation conditions of stationary planetary waves

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The influence of the quasi-biennial oscillations (QBO) on propagation conditions of stationary planetary waves (SPW) from the troposphere into the stratosphere is investigated and the difference in the accelerations of the zonal mean flow by the SPW under different phase of the QBO is estimated. The linearized model of the SPW structure is used to calculate the propagation of the SPW with zonal wave numbers m=1 and m=2 (SPW1 and SPW2). The climatic (averaged over 2002 – 2012 years) SPW1 and SPW2 amplitudes and phases in January are used as the lower boundary conditions. To simulate the SPW structure the background zonal mean wind for easterly QBO and westerly QBO phases is specified using the UK Met Office and HWM07 empirical models. The results obtained show that there is a substantial influence of the QBO on propagation conditions of the SPWs from the troposphere into the stratosphere. It is shown that accelerations of the mean flow at the higher-middle latitudes are stronger under easterly QBO phase.

IAMAS (Meteorology)

M14p - M14 Middle Atmosphere Science

M14p-412

Localized IGW breaking region and its implications for middle atmospheric circulation

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Using the GPS RO density profiles, we have found an internal gravity wave activity and breaking hotspot localized in the lower stratosphere of Eastern Asia/North-western Pacific region. With a mechanistic model for the middle atmosphere, we study possible formation and propagation directions of planetary waves caused by such a localized forcing.

We analyze the consequences for the stratosphere-troposphere exchange of the equatorial propagating Rossby wave branch with regard to the analysis of tropopause characteristics and folds in the area of southeastern Asia.

We also focus on the created poleward propagating Rossby wave branch, its interactions with polar vortex and possible influence on the sudden stratospheric warming occurrence.

Finally, applying 3D EP flux and residual circulation diagnostics, we investigate possible role of this area in longitudinal variability of the Brewer-Dobson circulation and a hypothesis of its enhanced branch in this region.

IAMAS (Meteorology)

M14p - M14 Middle Atmosphere Science

M14p-413

Influence of tropospheric disturbances on retrieval of middle-atmosphere characteristics from radiometry data

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Remote sensing techniques are the only affordable way of the regular monitoring of the middle atmosphere. Satellite based sounding techniques are currently the most popular as they provide whole globe coverage; though the cost of this coverage is comparatively low time resolution .Ground-based microwave sounding is the other suitable technique. It has certain advantages namely high time resolution which could be crucial for some applications.

The troposphere obviously is an obstruction for ground based methods. Not only it absorbs the emission of the middle atmosphere lowering signal-to noise ratio but also disturbs the radiance spectrum. Depending on the situation different approaches to treat the issue are used.

In this report we investigate the influence of the tropospheric disturbances on the results of the ground based remote sounding complex developed and used in IAP RAS. . The complex incorporates several radiometers on different frequency regions: 22-31.4, 52.4-53.5 and 110.4-111.3 GHz, as well as various algorithms for the retrieval of temperature and ozone profiles from the measured radiance spectrum data. We describe briefly the algorithms which realize Bayesian approach to treatment of ill-posed problem using various parameterizations and prior constrains. The algorithms use different approaches in treatment of the troposphere caused disturbance: some try to retrieve tropospheric profiles, and the other use the simplified emission and absorption model of the troposphere. Our investigation is based mainly on simulated data but it uses the real data as well. The distortions of the retrieval result caused by troposphere are described for every algorithm and their cause explained.

IAMAS (Meteorology)

M14p - M14 Middle Atmosphere Science

M14p-414

Effects of stratospheric climate change on downward wave coupling in the Northern and Southern Hemispheres

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It is well established that the dynamical coupling between the stratosphere and the troposphere is dominated by planetary waves that are generated in the troposphere by orography and continent-ocean heating asymmetries. These waves propagate upward into the stratosphere, where they either get absorbed or reflected back into the troposphere. The two-way vertical (upward and downward) of planetary-scale waves, is called downward wave coupling (DWC). DWC occurs when an upward propagating wave decelerates the flow in the upper stratosphere, forming negative meridional PV gradients and bounded waveguides. Changes of stratospheric mean states or tropospheric wave sources induced by natural or anthropogenic forcing factors will therefore significantly affect DWC activity and its subsequent impact on the troposphere. This study will focus on how stratospheric changes due to changing polar stratospheric ozone and GHG levels can influence the DWC in the Northern and Southern Hemisphere.

We compared two 145-yr transient simulations of NCAR's Community Earth System Model (CESM-WACCM). The control simulation (CTL) covered the period from 1955 to 2099 and was run by excluding external anthropogenic influences. The second simulation was the same as the CTL except that the GHGs and ODSs follow the RCP8.5 scenario. Differences between the two simulations are used to examine the extent to which natural and anthropogenic forcing factors influence the ozone concentration, and subsequently how the resulting ozone changes impact on wave coupling. Furthermore, in order to separate the effects of ozone changes and global warming, four 40-yr timeslice experiments were performed, before, during, and after the ozone hole period with different combinations of ODS and GHGs.

IAMAS (Meteorology)

M14p - M14 Middle Atmosphere Science

M14p-415

Interannual variations of planetary wave activity and stratospheric regime during sudden stratospheric warming events in the Northern Hemisphere

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In the Northern Hemisphere winter, the stratospheric and tropospheric circulations are dynamically linked through the interaction of the mean flow with upward propagating planetary-scale waves. The sudden stratospheric warming (SSW) are the most striking and revealing example of the stratosphere-troposphere interaction. It is established that the zonal-mean temperature in the winter polar region of the stratosphere is determined by balance of two factors: radiative cooling and dynamical heating. The latter is caused by downwelling in the stratospheric polar region of a global-scale wave-driven meridional circulation, and thus the magnitude of this heating depends on planetary wave activity generated in the troposphere. It was found that on interannual time-scales stratospheric ozone and temperature in the Arctic polar region in winter is regulated by the upward Eliasen-Palm (EP) flux across the tropopause, and that the two have a strong correlation. From the other side there has been some evidence indicating that the stratosphere has been steadily cooling during the past few decades. The main purpose of this work is to investigate the link between the long-term stratospheric variability and planetary wave activity in the stratosphere and troposphere. Evolution of E-P flux before, during, and after SSW events are studied.

IAMAS (Meteorology)

M14p - M14 Middle Atmosphere Science

M14p-416

Interaction between the troposphere and stratosphere at sudden stratospheric warming events

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Most clearly stratosphere-tropospheric coupling occurs during and/or after the development of SSW. However, to date there is no precise theoretical explanation of the mechanism of the dynamical coupling of the stratosphere and troposphere.

On the basis of UK Met Office analysis, we consider the dynamical processes in the stratosphere from the point of view of longterm variability over the last decade and stratosphere-tropospheric coupling. Three-dimensional wave activity flux and its divergence were calculated using an average of SSW events to analyze the dynamical interaction between the stratosphere and the troposphere before, after and during the SSW. The relative role of the various mechanisms of the SSW events changes in recent decades was estimated: the internal processes associated to the nonlinear interaction of stationary planetary waves (SPW) with a mean flow have a predominant role. Nonlinear interaction of SPW and mean flow is more effective under the easterly phase of QBO when modulation of SPW propagation conditions from the troposphere into the stratosphere is stronger. Relationship of convective tropospheric activity, planetary wave propagation and circulation processes in the troposphere and stratosphere were considered using the results of radio occultation observations of the COSMIC-FORMOSAT experiment. We try to identify possible tropospheric precursors of the SSW considering fields of convective indices. Changing the dynamic regime of the stratosphere can affect the circulation of the troposphere, for example, through the reflection of planetary waves and their subsequent transformation in the troposphere into the regional-scale disturbances.

IAMAS (Meteorology)

M14p - M14 Middle Atmosphere Science

M14p-417

Modelling of the general stratospheric circulation: quasi-biennial oscillations, the semiannual oscillations, problem of synchronization

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The paper focuses on the problem of creating atmospheric general circulation models (AGCM) which adequately reproduce the main feature of equatorial stratospheric circulation: quasi-biennial oscillations (QBO). A key problem is to reproduce the mechanism of the QBO formation: the nonlinear interaction of the zonal mean flow and the broad spectrum of vertically propagating waves. We divide two kinds of this mechanism: one through the interaction of planetary waves with the mean flow at critical levels and another through gravity waves obliteration. For the AGCM models the generation of large-scale waves is internal, but gravity waves are subgrid scale, and for their accounting parameterizations are used. On the basis of detailed study of the QBO formation physical processes (using low-parameter models), we show that the high vertical resolution (<500 m) is required to adequately reproduce the interaction of long planetary waves with the mean flow. A new version of AGCM model with high spatial resolution (2°x2.5° and 80 vertical levels) has been developed. It reproduces the QBO very close to observations. Therefore the problem of synchronization of the QBO and the semiannual oscillations (SAO) as possible impact on the QBO characteristics formation was considered through the study of variability of the QBO period according to the observations reanalysis data and to the results of numerical simulation. Our studies show that some synchronization of QBO and the SAO (and possibly the annual cycle) takes place. This process for multiple SAO periods is identified in the transition altitude region between the QBO and SAO. For all altitudes of QBO the synchronization with SAO is identified in the period calculated by the differences of the westerly zonal wind peaks.

IAMAS (Meteorology)

M14p - M14 Middle Atmosphere Science

M14p-418

Polar stratospheric cloud observations by the Spaceborne Cloud-Aerosol Lidar with orthogonal polarization: 2006-2015

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Polar stratospheric clouds (PSCs) form at very low temperatures (below about 195 K) during winter and early spring at high latitudes and play important roles in the chemical depletion of ozone. PSC particles, primarily supercooled ternary solution (STS) droplets, provide sites for heterogeneous chemical reactions that transform stable chlorine reservoir species into highly reactive ozone-destructive forms. Furthermore, odd nitrogen is redistributed irreversibly through sedimentation of large nitric acid trihydrate (NAT) PSC particles, which prolongs ozone depletion by slowing the reformation of the stable chlorine reservoirs. Observations from the CALIOP (Cloud-Aerosol LIdar with Orthogonal Polarization) instrument on the CALIPSO (Cloud-Aerosol Lidar and Infrared Pathfinder Satellite Observations) satellite from mid-June 2006 until 2015 have provided a rich new database for studying PSCs. CALIOP acquires on average over 300,000 backscatter profiles daily at latitudes between 55^{o} and 82^{o} in both hemispheres. Strongly scattering PSCs (e.g., ice) can be detected in the CALIOP data at 5-km spatial resolution, while more tenuous PSCs (e.g., low number density NAT) are found by successively averaging the data over larger spatial scales (up to 135 km). CALIOP PSCs are furthermore separated into composition classes (STS; liquid/NAT mixtures; and ice) based on the 532-nm scattering ratio (the ratio of total-to-molecular backscatter) and particulate depolarization ratio (which indicates the presence of non-spherical, i.e. NAT and ice particles). In this paper, we examine the temporal, vertical, and spatial distribution of PSCs in the Arctic and Antarctic over the nine-year CALIOP data record.

IAMAS (Meteorology)

M14p - M14 Middle Atmosphere Science

M14p-419

On the recovery of the Northern Hemisphere extratropical ozone

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The SBUV/SBUV-2 merged ozone data ver.8.6 are analyzed to search to what extent the trends in the atmospheric ozone since 1979 have been forced by the atmosphere contamination by the ozone depleting substances (ODS) which were regulated by the Montreal Protocol (MP) 1987 and its subsequent amendments. Nowadays there are suggestions that several other gases (e.g. NH4 and N20), which are not controlled by MP, could be responsible for a slower ozone recovery rate in next decades. A residual trend model is proposed to calculate the difference between the observed long-term ozone variability having dynamical effects removed and the trend forced only by ODS changes. The residual trend pattern in total ozone, ozone content in the upper and in the lower stratosphere are calculated for each 5 degree zonal belt for the 30-80N region. The upper stratospheric ozone follows changes in ODS suggesting a limited impact of non-MP controlled gases on the ozone layer in the analyzed period 1979-2012. A superposition of short-term fluctuations in the atmospheric dynamics, which appears since 2005, provides a decline of the lower stratospheric ozone up to 2-3% in some regions (e.g. central Europe). Present chemistry-climate models predict an increase of the ozone recovery rate over the NH extratropics in next decades. Thus it means that the residual trend pattern should show a positive tendency. Our results suggest that such faster recovery has not yet been seen.

IAMAS (Meteorology)

M14p - M14 Middle Atmosphere Science

M14p-420

Sources of UTLS orographic and non-orographic gravity waves observed by VHF radar at Davis, Antarctica

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Both orographic and non-orographic gravity wave sources are present at high southern latitudes. The lower intermittency of non-orographic gravity waves, compared with orographic gravity waves, means that they also contribute an important part of the total momentum flux in the lower stratosphere. The sources of these non-orographic waves probably include emission from fronts and from jet re-adjustment processes but are not well constrained by seasonal observations in the Antarctic.

Here we will present results using VHF radar observations of UTLS winds at Davis (69S, 78E), which we have collected since early 2014. Regular observations of large vertical wind velocity perturbations visible up to the tropopause are attributed through case studies to the downstream orographic effects of a small ice ridgeline located some 60km northeast of Davis. These times co-incide with the presence of an offshore low-pressure system, which directs strong northeasterlies along the Antarctic coastline and normal to the ridgeline. Other, longer-period, waves visible in the UTLS are likely non-orographic in origin, with downward phase progression clearly evident and associated meteorological patterns are emerging. For both orographic and non-orographic cases, we use a combination of observations, reanalyses and case studies to examine the synoptic and regional scale meteorological conditions that are present when these waves are observed in the radar data. We will discuss the seasonal distribution of gravity wave activity from orographic and non-orographic sources.

IAMAS (Meteorology)

M14p - M14 Middle Atmosphere Science

M14p-421

A scale invariance criterion for subgrid-scale parametrizations of general circulation models (and others)

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Turbulent kinetic energy cascades in fluid dynamical systems are usually characterized by scale invariance. However, subgrid-scale (SGS) parametrizations of in large eddy simulations do not necessarily fulfill this constraint. Up to now, scale invariance has been considered only in the context of isotropic, incompressible, and three-dimensional turbulence. Here we extend the theory to anisotropic turbulence in compressible flows that obey the hydrostatic approximation. We present a criterion to check if the symmetries of the governing equations are correctly translated into the equations used in a numerical model including the corresponding SGS parametrizations (model equations).

We validate the criterion by recovering the breakdown of scale invariance in the classical Smagorinsky model and by confirming scale invariance for the Dynamic Smagorinsky Model. We further apply the criterion to the primitive equations completed by horizontal and vertical diffusion as used in a GCM. Our assumption is that the numerical resolution extends into the macroturbulent inertial range of the mesoscales, which is governed by a forward energy cascade. The aforementioned criterion then allows us to formulate both the horizontal and vertical mixing lengths for the free atmosphere in accordance with scale invariance. High-resolution runs with the Kühlungsborn Mechanistic General Circulation Model (KMCM) using triangular spectral truncation at wavenumber 330 are presented, being the first simulations of a -5/3 slope of the kinetic energy spectrum in the upper troposphere and lower stratosphere without numerical dissipation or hyperdiffusion. In particular, a dynamic vertical mixing length leads to a steepening of the spectrum in the synoptic scales and a shallowing in the mesoscales.

IAMAS (Meteorology)

M14p - M14 Middle Atmosphere Science

M14p-422

Stratosphere-troposphere exchange in the vicinity of North Atlantic cyclones

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It is well known that the storm tracks are a preferred region of stratosphere-troposphere exchange (STE), but a systematic and climatological investigation of the connection between cyclones and STE has not yet been performed. We use two established ERA-Interim climatologies of STE and cyclones for the years 1979-2011 to quantify the amount of STE that occurs during the life cycle of North Atlantic cyclones.
A Lagrangian method serves to identify individual STE events, and a sophisticated cyclone identification tool detects cyclones, including their shape and size from the sea-level pressure field. Combining the two data sets reveals that roughly half of the total STE in the North Atlantic occurs in the vicinity of cyclones and that both downward and upward fluxes of mass across the tropopause (STT and TST, respectively) are more intense in deeper cyclones (lower minimum pressure) compared to less intense cyclones.
Systematic patterns of exchange locations relative to the cyclone centre are identified via composite analysis reveal the different characteristics of STT and TST. During cyclone intensification and in the mature stage, TST is mainly confined to the cyclone centre, whereas STT occurs predominantly in a region further southwest. During the decay of the cyclones, both STT and TST are most frequent close to the cyclone centre.

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The relevance of the location of blocking highs for stratospheric variability in a changing climate

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Previous research has shown that blocking highs (BHs) influence wintertime polar stratospheric variability through the modulation of the climatological planetary waves (PWs) depending on the BH location. Whereas BHs over the Euro-Atlantic sector tend to enhance the upward PW propagation, those over the northwestern Pacific reduce it.
In this study, we examine future changes in the response of the wave activity flux to the BH location and the relationship of these changes with wintertime stratospheric variability in transient simulations of the ECHAM/MESSy Atmospheric Chemistry (EMAC) chemistry-climate model. After having verified that EMAC can reproduce qualitatively well the geographical dependence of the BH influence on PW activity injection, we show that this dependence does not change in the future. However, an eastward shift of the pattern of the BH influence on PW propagation over the Pacific, a further eastward extension of the pattern over the Atlantic and an intensification of the wavenumber-1 component of the interaction between climatological and anomalous waves are detected. Changes in the upper-tropospheric jet and an intensification of the wavenumber-1 climatological wave due to a strengthening of the Aleutian low are consistent with these variations. The spatial distribution of future BHs preceding extreme polar vortex events is also affected by the slight modifications in the wave activity pattern. Hence, future BHs preceding strong vortex events tend to be more concentrated over the Pacific than in the past, where BHs interfere negatively with wavenumber-1 climatological waves. Future BHs prior to major stratospheric warmings are located in a broader area than in the past, predominantly over an extended Euro-Atlantic sector.

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Dynamical effects of EEP induced polar ozone loss in WACCM

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Recent studies using satellite observations have shown that energetic electron precipitation (EEP) strongly affects ozone at altitudes below 80 km, leading to ozone loss comparable to those caused by solar proton events.

In this presentation we describe the results of model simulations using the Whole Atmosphere Community Climate Model (WACCM), the atmospheric component of the Community Earth System Model (CESM). In our simulations we apply a polar ozone reduction in the upper mesosphere altitude region so that the reduced ozone amounts correspond to reported observations. Simulations are used to study chemistry-dynamics connections and wave-mean flow interactions potentially resulting from the observed EEP induced ozone losses.

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Comparison of rotational temperatures from various simultaneously measured OH and O2 bands

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Mesopause temperatures are mainly estimated based on rotational level populations of different individual airglow bands. OH bands, such as (3-1) and (6-2), with emissions at about 87 km and O2b(0-1) with an emission peak at about 94 km are preferentially used. For measuring realistic temperatures, a rotational-translational equilibrium with a Boltzmann distribution of the level populations is required. However, this is questionable for OH since the radiative lifetime of the excited vibrational states is relatively short compared to the frequency of suitable collisions. In order to estimate the amount of possible non-LTE contributions, we have investigated simultaneous spectroscopic observations of 25 OH and three O2 bands taken with the near-UV-to-near-IR medium-resolution echelle spectrograph X-shooter at the Very Large Telescope at Cerro Paranal in Chile. Our analysis of several hundred spectra revealed differences in the OH rotational temperatures depending on the selected line set and the upper vibrational level v'. The resulting temperature pattern shows a maximum at v' = 8 and also peaks at v' = 6. This structure can only be explained by significant non-LTE effects, which appear to increase in the course of the night, as indicated by an analysis of the temporal variations. Our conclusions for OH are supported by a comparison with the lower temperatures from the bands O2b(0-1) and O2a(0-0), which can be expected to be more realistic due to the long radiative lifetimes. O2a(0-0) corrected for self absorption is especially interesting since its emission seems to peak at similar altitudes as the high-v' OH bands in the second half of the night.

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Fast stratospheric chemistry for climate models

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It is well known that the representation of atmospheric ozone chemistry in weather and climate models is essential for a realistic simulation of the atmospheric state. Interactively coupled chemistry climate models (CCMs) provide a means to realistically simulate the interaction between atmospheric chemistry and dynamics. The calculation of chemistry in CCMs, however, is computationally expensive which renders the use of complex chemistry models not suitable for ensemble simulations or simulations with mutiple climate change scenarios. Ozone can also be included in model simulations by precribing it as an external variable where the ozone field may not be consistent with the atmospheric dynamics the model simulates. Existing fast ozone chemistry schemes are usually based on Taylor expansions around a mean state and are often too simplistic and may not be applicable outside the climatology they were tuned for.
We introduce a new approach to represent atmospheric chemistry in climate models which can cope with non-linearities in ozone chemistry and is applicable to a wide range of climatic states. This Semi-empirical Weighted Iterative Fit Technique (SWIFT) is driven by reanalysis data and has been validated against observational satellite data and runs of a full Chemistry and Transport Model. SWIFT has now been implemented into the climate model EMAC in which model components can be switched on and off, i.e. the model can be used as a general circulation model or as a CCM. We show first results of EMAC simulations with SWIFT chemistry and validate the performance of the new EMAC-SWIFT model by comparing with simulations using the EMAC model with full chemistry.

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M14p-427

Transport anomalies of heat and minor constituents over Europe during extreme polar temperature events in the stratopause region

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Based on 12-years (2002-2013) Lidar measurements of temperatures over Kühlungsborn (54° N, 12° E; Mecklenburg; Northern Germany) and ALOMAR (60° N, 16° E; Norway) extreme temperature events of the stratopause region over Europe are determined in winter. Further with the help of MERRA reanalysis temperature data the statistical analysis is repeated and extended for different quantities of the 1979-2014 period including the transport of minor constituents.

We found that the Lidar measurements of extreme temperatures events are representative for phases of polar warming and subsequent cooling of the stratopause region. Furthermore based on MERRA reanalysis data, many warm events show a strong heat transport from southwest to northeast causing sudden stratospheric warming events which are accomplished by enhanced water vapor and ozone transport from the subtropics to polar latitudes over Europe at the stratopause region and below.

Furthermore, a PJO series was constructed by the use of EOF 1 and EOF 2 decomposition of the polar cap temperature profile series as proxy for strong temperature anomalies in winter. The strong link between PJO anomalies and different transport of heat and of minor constituents over Europe is examined with the help of a regression analysis.

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M14p-428

Diabatic processes and the tropopause inversion layer in baroclinic life cycles

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Stratosphere-troposphere exchange (STE) and the tropopause inversion layer (TIL) are two distinct features of baroclinic life cycles.The latter has only been reported recently to occur after wave breaking in adiabatic life cycles. Additionally, diabatic processes are known to contribute to the formation of the TIL. Diabatic processes are further necessary for an air parcel to transit irreversibly from the troposphere to the stratosphere or vice versa. One goal of this study is to assess the additional contribution of diabatic processes to the formation and strength of the TIL during a life cycle. Another focus is on the question whether there is a relationship between STE and TIL.
We use the COSMO model in an idealized channel configuration to simulate baroclinic life cycles. In a first step contributions of individual processes from turbulence, radiation, and cloud microphysics to the formation of the TIL are analyzed. In a second step the combined effects of several diabatic processes are studied to further include interactions between these processes as well as to advance towards a more realistic model setup.
The results suggest a much more vigorous development of the TIL due to microphysics and the release of latent heat. Moreover, radiative effects can foster an increase in static stability above the thermal tropopause when large gradients of either water vapor or cloud ice are present. By additionally adding turbulence, a co-location of high static stability and increased turbulent kinetic energy is found in the vicinity of cirrus clouds. The potential relation between STE and high static stability is further discussed based on results from trajectory calculations and the distribution of passive tracers of tropospheric and stratospheric origin.

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M14p-429

Reasearching the airglow continuum in the optical wavelength range

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To gain a better understanding of the mesopause region (~ 80-100 km), one needs to probe it through airglow. Emission lines of OH, O_2, O or Na are commonly used. However, trying to investigate the pseudo continuum contribution of molecules like FeO to the night-sky spectrum is more difficult. FeO emission is found in the range from 0.5-0.7 µm. This emission probes the atmosphere at an altitude of about 89 km, thus lying between OH (87 km) and Na (92 km). FeO and Na are furthermore linked by their common origin, meteors, and share, like OH, a common reactant, O_3.

So far, lidar and limb sounding as well as small samples of ground-based low-to-medium resolution spectra, probed the Fe density and the FeO emission in the upper atmosphere. Obtaining more information on the shape and variability of the FeO spectral features would preferably need high spectral resolution and larger samples. For this purpose, we take spectra from the European Southern Observatory, located at Cerro Paranal in the Chilean Atacama desert at an altitude of 2.635 m. Using data available from two echelle spctrographs (UVES, 0.3-1 µm, Resolution=20.000 to 110.000; X-Shooter, 0.4-2.5 µm, Resolution=3.000 to 18.0000), we can cover a timespan from 2006 to spring 2013.

We studied the nocturnal behavior and intra-annual intensity changes as well as nocturnal variations for different seasons and clearly see a semi-annual oscillation. The data show a variation in the intensity ratios of the FeO peak and its side peaks. Other shape changes (e.g. shift of the main peak) are observed as well. To better understand the structure of the FeO spectrum, we will compare our spectra to simulated spectra.

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Frozen-In Anticyclones simulated by CESM-WACCM

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Recent observational studies of Arctic stratospheric final warmings have shown that tropical/subtropical air masses can be advected to high latitudes and remain confined within a long-lived “frozen-in” anticyclone (FrIAC), embedded in the summer easterlies for several months. A climatology of FrIACs based on ERA reanalyses suggested that these sporadic events develop preferentially (i) under the easterly phase of the Quasi-Biennial Oscillation (QBO), and (ii) in absence of Major Stratospheric Warming (MSW) during the preceding winter. Furthermore, it was noticed that their frequency of occurrence considerably increased over the last decade.

In this study, a chemistry climate model is used for the first time to investigate FrIACs characteristics and variability. Simulations are performed with the National Center of Atmospheric Research’s Community Earth System Model (CESM). To detect FrIACs signature in polar region during springtime, we designed a two-step procedure which, first identifies low-latitude air masses northward of 60°N, and then requires the latter to be collocated with an anticyclonic eddy. While CESM overestimates the amount of low-latitude intrusions by a factor of 2 compared to ERA-Interim, the frequency of occurrence and characteristics of FrIACs are realistically simulated. Dynamical analysis reveals that FrIACs are associated with an abrupt and early winter-to-summer stratospheric circulation transition, characterized by an amplification of planetary wave activity. Furthermore, our model results confirm that FrIACs occur preferentially under the easterly phase of the QBO and in absence of MSW during the preceding winter. Finally, we notice that extreme climate change conditions (RCP8.5 scenario) do not influence FrIACs frequency.

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Variations of the continuum characteristics of the upper atmosphere

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The results of the data analysis of ground-based and satellite measurements of the continuum emission of the upper atmosphere in the visible and near infrared region of the spectrum are presented. The regularities of the spectral distribution of the emission intensity of the continuum and its variations for various helio-geophysical conditions are revealed. Using rate of the photochemical reactions between molecules of nitric oxide and unexcited and excited molecules of ozone, the absolute integrated intensity of the infrared component of the continuum emission has been calculated. It is shown that the altitude distribution of radiation intensity of the continuous spectrum of the upper atmosphere in the infrared region of spectrum covers a range of the middle atmosphere from 10 to 15 km. Comparison of the calculated values of the continuum intensity with the results of spectrophotometric ground-based measurements in the near infrared region of the spectrum allowed us to specify the rate coefficient of the reaction of molecules of nitric oxide with ozone, responsible for the occurrence of the continuum emission in the infrared region of the spectrum. The features and variations of altitude distribution of its volume emission rate for different helio-geophysical conditions have been revealed. It is shown that the main interval of the heights of the continuum emission layer due to process of NO + O is at 80-110 km. Continuum emission layer, the occurrence of which is associated with the processes of molecular interaction of nitric oxide with ozone molecules in the excited and unexcited states, covers the whole middle atmosphere above the troposphere.

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M14p-432

Large scale kelvin and rossby gravity waves in general circulation models

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The realism of the large scale Kelvin and Rossby gravity waves that dominate the day-to-day variability in the low equatorial stratosphere is analysed in a series of Earth System Models with stratosphere that participated to CMIP5, and in different configurations of the stratospheric version of the LMDz General Circulation Model. Although the models seem to simulate better the stratospheric equatorial waves than the tropospheric ones, we found a lot of variability between the different models and simulations. Nevertheless, this variability seems less related to the representation of the equatorial convection than expected. The amplitude of the waves seems more controlled by the filtering by the zonal mean zonal wind and by the vertical resolution. The rather weak effect of the large differences in the representation of the convection variability by the different models, or within the same model but with the different subgrid-scale convection parameterization schemes is also attributed to the fact that a substantial fraction of the large scale waves in part originate from the midlatitudes and subtropics.

Lott, F. and 12 co-authors, 2014: Kelvin and Rossby gravity wave packets in the lower stratosphere of some high-top CMIP5 models, J. Geophys. Res., 119, 5, 2156-2173, DOI: 10.1002/2013JD020797.

Maury, P. and F. Lott, 2014: On the presence of equatorial waves in the lower stratosphere of a general circulation model, Atmospheric Chemistry Physics, 14, 1869-1880, doi:10.5194/acp-14-1869-2014

Maury, P. , F. Lott, L. Guez, and J.-P. Duvel, 2013: Tropical variability and stratospheric equatorial waves in the IPSLCM5 model, Climate Dynamics, 40: 2332-2344.

IAMAS (Meteorology)

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M14p-433

Stable water isotopes in stratosphere retrieved from Odin/SMR

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Being useful tracers of the hydrological cycle in atmosphere, the stable water isotopes (SWIs) and their characterization in stratosphere need to be revealed and understood by available space observation. Using measurements from 2002-2009 by Odin/SMR, global features of the SWIs are presented here for the first time. The vertical profiles of SWIs increase with altitude, well follow the profile of air temperature in stratosphere. Zonal patterns show that the three SWIs are quasi-symmetrical about the equator, larger in high latitudes. The high concentrations of SWIs in upper stratosphere at high latitude tend to transport from summer hemisphere to winter hemisphere, indicating an observational evidence of existence of the Brewer-Dobson circulation. A biannual cycle can be identified from global mean H_2O and O^{18} in upper stratosphere, following the seasonal variation of air temperature the tropical convection in troposphere. While the δD and $\delta^{18}O$ in upper stratosphere closely follow the annual cycle of solar radiation due to production of new water through methane oxidation which is shown by a linear correlation between summer hemisphere SWIs and solar radiation. We also can see the seasonal variation signal of O^{18} (and other SWIs) in upper stratosphere downward to bottom of stratosphere clearly in high latitude, but for composition of heavy isotopes, it seems there is a gap on the level about 35km which separated the stratosphere into upper and lower part.

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M14p-434

Effect of the lower atmosphere gravity wave regional distribution on the middle atmospheric circulation in a global numerical model

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Gravity waves (GW) are important for the dynamics of the middle atmosphere although being generated mainly in the troposphere. In circulation models of the middle and upper atmosphere, GW sources or, alternatively, GW distribution at the lower boundary frequently has to be prescribed. Different distributions, however, will have large effects on the mean circulation in the stratosphere, mesosphere, and lower thermosphere. To analyze the effect of the global horizontal GW distribution at the lower model boundary on the atmospheric circulation, we use a nonlinear primitive equation circulation model of the middle and upper atmosphere with parameterized GW. GW distributions at the lower boundary are chosen either based on realistic global momentum flux fields calculated from GNSS radio occultation observations, or assumed as analytical fields of different complexity. The results of different GW amplitude distributions especially on the mesospheric wind jets are analyzed.

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M14p-435

Inter-comparison of stratospheric mean meridional circulation and eddy mixing among six reanalyses

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Stratospheric mean meridional circulation and eddy mixing are compared among six meteorological reanalysis datasets: NCEP/NCAR, NCEP/CFSR, ERA-40, ERA-Interim, JRA-25, and JRA-55. Reanalysis datasets created using conventional techniques such as 3D-VAR (i.e., NCEP/NCAR, ERA-40, and JRA-25) generally reveal stronger mean meridional circulations in the stratosphere compared with those created using more advanced techniques such as 4D-VAR (i.e., NCEP/CFSR, ERA-Interim, and JRA-55). Significant long-term trends in stratospheric mean meridional circulation during 1978–2012 are not evident for the majority of these datasets. However, ERA-Interim reveals a negative trend in the middle stratospheric circulation in the northern extratropics, which is consistent with the increasing trend in the age of air, as revealed by satellite observations of long-lived species (Stiller et al., 2012). The six datasets all reveal increasing trends in eddy mixing for the surf zone in the Northern Hemisphere. The mean strength of eddy mixing in the lower stratosphere is higher in the newer datasets (NCEP/CFSR, ERA-Interim, and JRA-55), both around the subtropical transport barrier and in the surf zone in the Northern Hemisphere. The stronger eddy mixing in the newer datasets is attributed to stronger planetary wave activities in northern mid-latitudes, whereas small-scale waves (horizontal wave length < several thousand km) are weaker in the newer datasets. In the reanalyses that use conventional assimilation techniques, analysis increments are introduced without maintaining physical balance, which causes spurious change in the mean meridional circulation and creates spurious eddies, especially at small scales.

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M14p-436

In-situ detection of stratosphere-troposphere-exchange of cirrus particles in themid-latitudes

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Airborne trace gas, microphysical, and radiation measurements were performed during the AIRcraft TOwed Sensor Shuttle - Inhomogeneous Cirrus Experiment (AIRTOSS-ICE) over northern Germany in 2013. Based on high precision nitrous oxide (N_2O) and carbon monoxide (CO) in-situ data, stratospheric air could be identified, which contained cirrus cloud particles. Consistent with the stratospheric N_2O data, backward trajectories indicate, that the sampled air masses crossed the dynamical tropopause in the last three hours before the measurement. These air masses contained cirrus particles, which were formed during slow ascent in the troposphere and subsequently mixed with stratospheric air. From the CO-N_2O-correlation the irreversibility of this transport is deduced. To our knowledge, this is the first in-situ detection of cirrus particles mixed with stratospheric air in the mid-latitudes.

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M14p-437

Transport of nitrogen oxides through the mesopause region

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Energetic particles enter the Earth's atmosphere in the polar region; they ionize the atmosphere and increase the amount of nitrogen oxides (NOx). The NOx can be transported downwards from the thermosphere to the stratosphere. However, it is still uncertain which process causes the descent of NOx into the stratosphere. Here, we analyze the transport of nitrogen oxides through the mesopause with the Hamburg Model of Neutral and Ionized Atmosphere (HAMMONIA) with passive tracers and transport processes switched off for two situations: November 2008 and January 2009.

We found that nitrogen oxides in the thermosphere are transported down due to molecular diffusion and advection. Especially at high altitudes, the molecular diffusion is the major force, while with decreasing height the advection takes over. Eddy diffusion has limited impact on the transport in the upper mesosphere and negligible impact on the transport in the thermosphere.

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M14p-438

Recent progress of a synthetic system for atmospheric profiling from troposphere to lower thermosphere

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To understand the whole neutral atmospheric and the coupling from lower to upper atmosphere, a synthetic system called "Atmospheric Profiling Synthetic Observation System (APSOS)" has been funded by the National natural Science Foundation of China (NSFC) since 2012. It is a system mainly consisted of five lidars devoting to observe the vertical structure of atmospheric temperature, wind, air density, water vapor, ozone, CO_2, SO_2, NO_2, aerosol, cirrus cloud, and sodium layer with high vertical and temporal resolution, a W-band Doppler dual polarized radar, a THz radiometer, and a composite optical receiving telescope with equivalent diameter of 2-meter. Seven research institutes and universities have been engaged in this project. By the end of 2016, APSOS system will be fully operated at Yabajing International Cosmic Ray Observatory near Lhasa. During the past three years, the development for each sub-system have achieved initial success and revealed interesting observational results. A lidar has been continuously taking measurements over Tibetan Plateau for more than six months, and obtained some results on aerosol vertical distributions, as well as the temperature profiles from stratosphere to mesopause.

We will present the scientific goals, system design, overall data retrieval strategy and recent progress of APSOS system, and show some preliminary observational results. After the system fully operated in 2017, it will be open to the related scientific communities worldwide.

IAMAS (Meteorology)

M14p - M14 Middle Atmosphere Science

M14p-439

Thermosphere general circulation modelling with calculation of the radiative processes

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The paper presents a new version of the global three-dimensional general circulation model of the Earth's thermosphere (for altitudes from 90 to 500 km) with high spatial resolution (with high spatial horizontal resolution 2°x2.5°, 80 vertical levels), including self-consistent calculation of radiative processes. The model uses simple parameterization for calculation of ion-neutral interaction, turbulent and molecular diffusion. Based on a detailed analysis of reproduction of the radiation transfer various components in the new model a good agreement of the radiation balance with empirical data is shown. According to the modelling and analytical estimations it is shown that the thermosphere global state formation is mainly determined by the ratio between the radiation heating and heat sink due to molecular parameters, as well as the lower boundary conditions. On the basis of the preliminary model identification with empirical data a satisfactory reproduction of the thermal balance and the thermospheric general circulation features is shown.

IAMAS (Meteorology)

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M14p-440

On the coupling between gravity waves and background field including tides observed with MF radar at Poker Flat, and Tromsø

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The neutral wind velocity data from mesosphere to lower thermosphere observed by MF radars at Poker Flat in Alaska and at Tromso in Norway has been observed since the late 1990s. This study examines the daily and seasonal variations of short-period mesospheric gravity wave activities associated with the background field including tides using these MF radars' data for 10 years.

Observed wind velocities having the 1~4 hour period components are analyzed as short-period gravity waves and those having harmonic components with periods of 48, 24, 12, and 8 hours are calculated every 30 minutes. The previous study in AGU2014 showed that the semidiurnal phases of zonal wind and kinetic energy of gravity waves (GW-KE) are locked for more than 10 days. Such phase lock events are found in several years at both observation sites. It is confirmed a phase lock phenomena at both Tromso and Poker Flat continued for about 20 days from November to December in 2000. However, between Tromso and Poker Flat, the phases of 12 hour component of GW-KE differed by 180 degrees. Next, we made climatological 1-day composite plots of 12 hour components of zonal wind and GW-KE. The result showed that the maximum of GW-KE occurs at Poker Flat when zonal wind is easterly from November to December and zonal wind transitions from easterly to westerly from January to February and from May to August. The results of Tromso showed that the maximum of GW-KE occurs at local time when zonal wind is westerly from November to February and easterly from May to September. Thus, it is suggested that the observed phase lock event is possibly to be occurred fluently. We plan to investigate the relations between other harmonic components of zonal wind and GW-KE, and discuss the physical mechanism of the relations.

IAMAS (Meteorology)

M14p - M14 Middle Atmosphere Science

M14p-441

Modulation of the boreal summer water vapour and ozone in the UTLS as simulated by Chemistry Climate models

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The Asian summer monsoon (ASM) in the upper troposphere/ lower stratosphere (UTLS) consists of a large anticyclonic circulation. Confined within the Asian monsoon anticyclone (AMA) are elevated H_2O concentrations and a decreased O_3 concentrations, both a result of uplift within intense convective systems. The AMA has been recognized influencing the transport pathways of trace gases, entering the stratosphere in the tropical UTLS, and tracer concentrations in the extra-tropical lowermost stratosphere.

Here we analyse model runs of the chemistry climate model (CCM) validation activity (CCMVal-2) covering the recent past (REF-B1), and model projections up to 2100 (REF-B2), assessing the H_2O and O_3 concentrations in the UTLS of the ASM region and their possible future changes in a changing climate. The CCM results for the REF-B1 simulations are compared to the ERA-Interim re-analyses and the MIPAS satellite H_2O and O_3 data. The impact of the ASM, as quantified with an index derived from the upper tropospheric velocity potential (MIDX), and ENSO are analysed by multiple linear regression analysis.

The climatological features of the AMA, with enhanced H_2O and a pronounced O_3 minimum, are well represented by the multi model means of the CCMs, although large differences exist among the individual CCMs. The regression analyses of the REF-B1 period H_2O fields show for ERA-Interim and most of the CCMs a significant impact of the MIDX and ENSO on the H_2O in the UTLS from July to September, with enhanced H_2O concentration during intense monsoons and a reduction during ENSO warm events. The preliminary results for the REF-B2 period show a weakening of the monsoon circulation in the UTLS with increasing H_2O transport.

IAMAS (Meteorology)

M14p - M14 Middle Atmosphere Science

M14p-442

Persistent cooling of the polar stratosphere in 2011 winter and spring

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A recent study pointed out that Arctic sea ice reduction in the Arctic in early winter leads to warming of the polar stratosphere in subsequent mid-winter (Kim et al. 2014). Less sea ice in 21 century than before may explain frequent occurrence of major stratospheric sudden warming in this century. In spite of less-than-usual sea ice in preceding autumn in 2010, persistent cooling of the polar stratosphere from January to March was observed, which led significant ozone depletion in spring of 2011 (Manney et al. 2011). A study attributed this cooling to positive sea surface temperature (SST) anomalies in the North Pacific, inducing tropospheric circulation anomalies similar to the Pacific North American pattern or Western Pacific (WP) pattern (Hurwitz et al. 2011). The latter has been shown to suppress upward planetary waves into the stratosphere, thereby lowering polar stratospheric temperatures. Our analysis reveals that cooling of the polar stratosphere followed the WP pattern events in January 2011. However, the cooling of the stratosphere was not accompanied by WP pattern events in February and March. The stratospheric cooling in February was associated with downward planetary wave propagation in the stratosphere, which might be caused by instability in the upper stratospheric jet after a short pulse of upward planetary wave propagation. The reason for the persistent cooling through March has, however, not been uncovered yet.

IAMAS (Meteorology)

M14p - M14 Middle Atmosphere Science

M14p-443

Basic state and gravity wave simulated by high-top global non-hydrostatic atmospheric model NICAM

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We are constructing the high-top version of non-hydrostatic icosahedral atmospheric model, NICAM. This study investigated dependency of the simulated basic state and gravity wave on horizontal and vertical resolution of the model. The horizontal and vertical resolutions were swept from 56 km to 14 km and from 2 km to 300 m, and no gravity wave scheme was employed.The high-top NICAM reproduces the realistic structure of the zonal mean basic state in the troposphere and the middle atmosphere. As the vertical resolution is enhanced, strength of easterly jet, tilt of polar night jet, and lower-stratospheric zonal wind are improved, and the strength of polar night jet becomes stronger. Momentum flux analysis shows that increase in vertical resolution generally causes less gravity wave momentum flux and leads to the enhancement of polar night jet, consistent with the previous study. As the horizontal resolution is enhanced, gravity wave momentum flux is reduced and both the polar night jet and easterly jet are suppressed.

IAMAS (Meteorology)

M14p - M14 Middle Atmosphere Science

M14p-444

Stratospheric gravity waves in the southern-hemisphere high latitudes and their correlation with jet/frontal system in the troposphere

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Stratospheric gravity waves (GWs) in the Southern-Hemisphere high latitudes and their correlation with jet/frontal system in the troposphere are investigated using the ECMWF high-resolution global analysis, which can explicitly resolve most of GW spectrum, and GW momentum flux (GWMF) estimated from the HIRDLS satellite observations. In addition, global reanalysis data sets of MERRA and ERA-Interim are used to calculate two diagnostics of GWs associated with jet/frontal system, frontogenesis function (FF) at 600 hPa and the residual of the nonlinear balance equation (?NBE) at 350 hPa. The zonal GWMF in the lower stratosphere (70 hPa) estimated from the high-resolution ECMWF analysis is negative in July concentrated in major mountain regions, except in Antarctic Plateau, with widely distributed secondary maximum along Southern Ocean near 60^{o}S where troposphere jet exists, and it sustains in the upper stratosphere (5 hPa) without significant filtering by the background wind. In January, weak positive GWMF is distributed in wide regions at 70 hPa with relatively large values near Antarctic coastline, but strong negative GWMF appears near southern tip of Andes, although the negative GWMF is filtered out at 5 hPa due to easterly background wind there. The absolute GWMF estimated from the high-resolution ECMWF analysis is well matched spatially with HIRDLS observation, although the magnitude is 2-3 times smaller. FF and ?NBE are well correlated with the GWMF in the stratosphere estimated from the HIRDLS observation and high-resolution ECMWF analysis data, especially in the eastern sphere. This result implicates for jet/frontal system to be an important source of stratospheric GWs in the Southern-Hemisphere high latitudes in both January and July.

IAMAS (Meteorology)

M14p - M14 Middle Atmosphere Science

M14p-445

Ground-based simultaneous microwave measurements of the lower and middle atmosphere characteristics during sudden stratospheric warming

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We carried out the continuous experimental campaign aimed to study the response of the lower and middle atmosphere on current sudden stratospheric warming above Nizhny Novgorod, Russia (56N, 44E). The equipment consisted of the radiometer HATPRO-G3 by Radiometer Physics GmbH for measurements of temperature and water vapor profiles in the 0-10 km altitude range and two mobile microwave radiometers with digital spectrum analyzers which specially have been designed to retrieve ozone concentration and temperature in the altitude ranges of 15-70 km and 10-55 km accordingly. Here we introduce the first results of the campaign.

IAMAS (Meteorology)

M14p - M14 Middle Atmosphere Science

M14p-447

Vertical winter atmospheric temperature variations over Yakutsk by optical measurements

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The results of simultaneous measurements of winter atmospheric temperature variations in Yakutsk are presented. Temperature measurements for the surface layer from 0 to 20-25 km were obtained from radiosounding data in Yakutsk. Measuring the temperature of the middle atmosphere from 25 to 55-60 km made using Rayleigh Lidar near Yakutsk, with the following parameters: a transmitter Nd-YAG laser at a wavelength of 532 nm and a pulse energy of 200 mJ; receiver - a telescope with a mirror diameter of 60 cm and a focal length of 200 cm, with a photon counting system and a spectroanalyzer. The temperatures of the upper atmosphere were measured at three altitude levels: by hydroxyl emission layer at the mesopause (6,2 band), molecular oxygen radiation using an infrared spectrograph with a CCD camera and atomic oxygen emission line 557.7 nm with Fabry-Perot spectrometer (FPS) at the Maimaga optic range. FPS aperture was 15 cm, gap 1.5 cm, plate's reflectance 0.85 and finess12. Thus, in this work, we covered by the temperature measuring most of the atmosphere except for a layer of the mesosphere from 60 to 87 km. For comparison, also are used CIRA model and the AURA MLS instrument (MicroLimb Sounder) temperature profiles data. Data analysis showed that there is a wave-like change in the vertical temperature profile, which is the result of vertical transmission features planetary waves during a stratospheric warming.
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IAMAS (Meteorology)

M14p - M14 Middle Atmosphere Science

M14p-449

The direct radiative effect of ozone on planetary temperature waves.

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Recent studies have shown that the radiative effects of zonal asymmetries in ozone can significantly affect the stratosphere, mostly during Boreal winter and Austral spring. Since including such effects in climate models is extremely expensive, it is important to quantify and asses the possibility of including them as simple parameterizations. This study aims to asses the direct radiative effect of ozone on the stratospheric planetary wave temperature fields, using reanalysis data. This bridges a gap between model-based studies and a few existing observational analyses using short period satellite data. We evaluate the direct radiative effect of short wave ozone heating on the amplitude of temperature planetary waves, compared to long wave cooling and advective processes, by examining the explicit time tendency products given by the MERRA reanalysis. Examining the climatological daily seasonal cycle, we find that during October in the Southern Hemisphere the direct short-wave effect in stratospheric high latitudes reaches ~30% of the long wave effect, with a much smaller effect in the Northern Hemisphere (less than 10%). This is due to the timing of large ozone waves relative to the timing of radiation- in the Northern Hemisphere ozone waves peak in winter when there is less incoming solar radiation. A similar examination of the MERRA ozone tendency terms is performed to explain the hemispheric differences. It is found that much of the chemical reactions enter the data product as analysis errors. A comparison of the MERRA seasonal climatologies of temperature and ozone waves with a Natural run of the Whole Atmosphere Community Climate Model (WACCM) indicates some some fundamental differences in the vertical structure of ozone and temperature waves.

IAMAS (Meteorology)

M14p - M14 Middle Atmosphere Science

M14p-450

A nudged-CCM simulation of chemical constituent distribution at Northern Hemisphere high latitudes observed by SMILES during the 2010 SSW

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Stratospheric sudden warming (SSW) is a drastic phenomenon in the winter stratosphere. During SSW, distribution of chemical constituents, associated chemical forcing, and transport of chemical constituents change significantly inside and outside the polar vortex. In this study, chemical constituent distributions before and during a major SSW in January 2010 were simulated by the Model for Interdisciplinary Research on Climate 3.2-Chemistry-Climate Model (CCM) nudged toward the ERA-Interim reanalysis data, and the simulation results were compared with Superconducting Submillimeter-wave Limb-Emission Sounder (SMILES) observations. In addition, the dynamical and chemical budgets of ozone in the high-latitude lower stratosphere were analyzed. We discuss the ozone budget inside and outside the Arctic polar vortex. The analyses indicate that inside the polar vortex during the SSW, ozone concentration increased moderately as a result of partial cancelation between large negative ozone forcing due to chemical ozone destruction and large positive ozone forcing due to horizontal ozone influx from outside the vortex as well as downward advection. In a high ozone region outside the vortex, the large ozone increase is primarily due to a downward advection of ozone. These ozone budgets during SSW are compared with those in the transformed Eulerian mean framework. In the zonal-mean framework, ozone at high latitudes increases because of an enhanced downward advection, which corresponds to the large downward ozone advection outside the polar vortex. SMILES observations, nudged-CCM simulations, and the budget analyses reveal a highly longitudinal-dependent ozone budget at high latitudes during the SSW.

IAMAS (Meteorology)

M14p - M14 Middle Atmosphere Science

M14p-451

Boulder ozone sonde data analyses for multiple tropopause origins

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Boulder ozone profile measurements tend to feature structures with multiple layers in the troposphere, so-called laminae. These have been shown to be related to several phenomena, including stratospheric air intrusions that are transported to the location of measurements and local gravity wave perturbations (Boulder is located near the Rocky Mountain range where gravity waves are prevalent). In addition, observations indicate that air from the tropical tropopause layer can be transported into regions with multiple tropopauses over the middle latitudes in the vicinity of the subtropical jets. We use assimilation system products, including Modern-Era Retrospective analysis for Research and Applications (MERRA), interpolated to Boulder, Colorado, USA to assess incidence of upper tropospheric jets that influence UTLS ozone distribution. The proximity of the subtropical jet to Boulder results in frequent observations of multiple tropopauses. We analyze ozonesonde data launched in June-July 2014 to determine the origins of laminae observed in the upper troposphere/lower stratosphere (UTLS). Our tools include back trajectory analysis coupled with 4D satellite ozone profile data, including those from NASA's Aura Microwave Limb Sounder instrument. Filaments causing laminae in ozone profiles observed at Boulder will be tracked to origins in either stratospheric or tropospheric intrusions using reverse domain-filling trajectory methods. Detailed studies of ozone profiles collected over Boulder starting in 1978 will be presented with emphasis on May/June/July season. Ozone variability in the UTLS over Boulder is of importance for studies of local climatological ozone conditions, trends and their causes/attribution to the changes in the long-range transport.

IAMAS (Meteorology)

M14p - M14 Middle Atmosphere Science

M14p-452

Balloon Measurements of the Asian Tropopause Aerosol Layer: BATAL-2014

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Satellite observations have shown that the Asian Summer Monsoon influences the Upper Troposphere and Lower Stratosphere aerosol morphology through its role in the formation of the Asian Tropopause Aerosol Layer (ATAL). To improve our understanding on the nature and origin of ATAL, the Balloon Measurements of the Asian Tropopause Aerosol Layer (BATAL) field campaign, hosted by the National Research Laboratory and sponsored by the National Aeronautic and Space Administration, was organized from Gadanki (Southeast India)between 17-24 August 2014. Over the course of a 10-day deployment, we launched 7 small weather balloons with a two-wavelength aerosol backscatter sonde (COBALD), ozonesonde and regular meteorological sensor and one medium size balloon with a 6-channel Optical Particle Counter (OPC). The balloon campaign was supported by extensive ground-based measurements using Rayleigh and Mie ground-based lidars and, the Mesosphere, Stratosphere and Troposphere (MST) Radars as well as space borne observations from the KALPANA geostationary and CALIPSO space-borne satellites. Preliminary analysis suggests that the ATAL was sampled just above the thermal tropopause. We also observed an elevated backscatter signal above 20km associated with the Kelud eruption which took place 6 months prior to the campaign. The OPC sampled an upper tropospheric layer of particles with radius below 0.5 micron between 8-11km. Using a trajectory analysis sand satellite observations, we will discuss the origin and the nature of elevated aerosol layers revealed by in situ measurements. The BATAL campaign showed that aerosol properties in the Asian Monsoon region can be successfully obtained with light-weight balloon payloads to improve our understanding in how aerosols can influence our climate.

IAMAS (Meteorology)

M14p - M14 Middle Atmosphere Science

M14p-453

Stratospheric ozone trends derived from a combined OSIRIS - SAGE II time series

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Stratospheric ozone profile measurements from the Optical Spectrograph and InfraRed Imager System (OSIRIS) instrument on the Odin satellite (2001–Present) are merged with those from the Stratospheric Aerosol and Gas Experiment (SAGE) II satellite instrument (1984–2005) to calculate decadal trends in stratospheric ozone between 60°S and 60°N. A multi-instrument, multi-decade, deseasonalized and merged stratospheric ozone record (1984–present) is produced by analyzing the measurements during the operational overlap of both satellites (2001–2005). The deseasonalized monthly time series is fit using linear regression with six non-linear predictor basis functions: three quasi-biennial oscillation proxies, the El Niño-Southern Oscillation index, a solar activity proxy, and the NCEP pressure at the tropical tropopause; and two linear trends: before and after 1997, which give the decadal trends in ozone. From 1984–1997, statistically significant negative trends of 5–10% per decade exist throughout the stratosphere (30–50 km). From 1997–present, statistically significant recovery rates of 3–8% per decade exist throughout most of the stratosphere. Below 22 km and between 40°S–40°N a negative trend is measured before and after 1997. The recovery is not significant in the tropical stratosphere between 25–35 km.

IAMAS (Meteorology)

M14p - M14 Middle Atmosphere Science

M14p-454

A combined Odin-OSIRIS and SAGE II stratospheric aerosol data record

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SAGE II has provided 20 years of high quality aerosol extinction measurements that have been used in numerous studies. This work seeks to combine the SAGE II aerosol record with that of OSIRIS, a limb scatter instrument with a now 13 year data set of its own to produce a combined, altitude resolved aerosol extinction record of the past 30 years. In the tropics to mid latitudes coincident OSIRIS and SAGE II measurements agree well over the bulk of the layer with mean di?erences typically less than 10%. At higher latitudes and outside the main aerosol layer larger di?erences are seen compared to SAGE II with a general under-estimation of aerosol at high altitudes and over-estimation at low altitudes. For most locations these di?erence are well corrected by scaling the OSIRIS data to match that of SAGE II based on latitude and altitude, providing good agreement between the two instruments for the three years of mission overlap. This produces a consistent merged product over the majority of the stratosphere, although also highlights regions where additional satellite data would be useful to improve the merged product.

IAMAS (Meteorology)

M14p - M14 Middle Atmosphere Science

M14p-455

Satellite aliasing issues and their impact on tidal and planetary wave determinations

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Aliasing associated with satellite sampling patterns is an issue which has been known for over 20 years. Well known is the folding of spatial or temporal frequency components of higher frequency than the sampling frequency onto lower frequency components associated with the finite sampling capabilities of a satellite. Aliasing also occurs as a result of data gaps in the data record. The temporal variability of wave components during the period required to fully sample the phase space of the component of interest also results in difficulties in cleanly identifying the amplitudes and phases of the waves present in the data set. This has been recognized as an issue for migrating tidal components in particular. However, non-migrating tides and various planetary waves can also alias into each other.

In this paper, the results of a study of aliasing effects on various temperature wave components in SABER and COSMIC data are presented. The phase space sampling for various wave components is determined and discussed. It is found that a least-mean squares analysis of the derived amplitudes depends on the analysis method. Sampling effects are examined using the extended CMAM30 data set and sampling the model data in the same manner as the satellites. Since the various wave amplitudes can be cleanly diagnosed from the original model data set, this provides a means to determine the extent to which aliasing is an issue. The derived amplitudes of the Sun synchronous tides depend on sampling and those of non Sun-synchronous tides and SPWs depend on the method of analysis. The aliasing also depends on latitude since yaw maneuvers or calibrations take place at phase space locations which vary with latitude. Care must be taken in interpreting results from any particular satellite.

IAMAS (Meteorology)

M16a - M16 Radiation in the Climate System

IUGG-1411

Community radiative transfer intercomparisons: Continual Intercomparison of Radiation Codes (CIRC) and beyond

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IRC working group CIRC - science progress report

One of the somewhat overlooked facts about the first Phase of the Continual Intercomparison of Radiation Codes (CIRC) is that besides assessing approximate radiation codes against line-by-line calculations, it also underscored the challenges of building diverse observationally-based test cases. CIRC demonstrated that candidate cases must pass multiple consistency checks, including spectral agreement, and that care needs to be exercised when determining the scales at which to average the measurements for given atmospheric/surface states and instrument characteristics. While there is plenty of motivation to continue to explore which types of observations would be suitable for future phases of CIRC that would test aspects of approximate code performance that eluded the first Phase, the climate modeling community also needs radiation code assessments for conditions far different than those currently observed. For example, in the Coupled Model Intercomparisons (CMIPs), experiments under 4xCO2 conditions have been considered standard. In this report, we will explain the links between CIRC and potential CIRC-like future efforts with more traditional idealized radiation intercomparison protocols. One broad effort currently underway, the Radiative Forcing Model Intercomparison Project (RFMIP), has a component that includes such intercomparisons, namely assessments of accuracy in flux and forcing calculations for greenhouse gases under past and future (including extreme) climates. While details are still being worked out, a preliminary feasibility study by Pincus et al. used CIRC cases as basis around which to build 4xCO2 experiments, and their findings will be presented in this report.

IAMAS (Meteorology)

M16a - M16 Radiation in the Climate System

IUGG-1877

Challenges in the Global Energy Balance

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The global energy balance is the main regulator of Earth’s climate. Despite its central importance for the climate system and climate change, substantial uncertainties still exist in the quantification of its different components, and their representation in climate models. While the net energy flow in and out of the climate system at the top of atmosphere (TOA) is now well known from satellite programs such CERES and SORCE, a major challenge states the energy distribution within the climate system. Still not well established is the partitioning of solar absorption between atmosphere and surface, and between the cloudy and cloud-free atmosphere, as well as the thermal and nonradiative energy exchanges at the surface. Uncertainties in the components of the surface energy budget are therefore larger and less well quantified than at the TOA. Apparent discrepancies between the magnitudes of the global energy and water budgets further pose a challenge.

Since the 1990s, accurate direct measurements become increasingly available from the networks of surface radiation stations, which may provide additional constraints. For IPCC AR5 we established best estimates of the magnitudes of the components of the global energy balance, making full use of the information contained in direct observations from surface and space in combination with modeling approaches (Wild et al. 2013, Clim. Dyn.). Further, an attempt has been made to estimate the global land and ocean mean energy balance separately (Wild et al .2015, Clim. Dyn.).

There is also increasing evidence that the surface radiative components undergo substantial changes on decadal timescales, not only in the longwave as expected from the increasing greenhouse effect, but also in the shortwave, which requires better quantification.

IAMAS (Meteorology)

M16a - M16 Radiation in the Climate System

IUGG-3239

Changing aerosol properties near cloud; 3D or not 3D?

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Many aerosol studies based on remote sensing observations reported changes in aerosol properties as a function of distance to cloud and/or cloud cover. For example, most satellite observations show a positive correlation between aerosol optical depth (AOT) and cloud cover. Part of this correlation is due to remote sensing artifacts resulting from (1) our inability to distinguish between aerosols and weak cloud elements, and (2) cloud-related 3D radiative effects. On the other hand, part of the near-cloud enhancement in AOT is due to aerosol hygroscopic growth in the humid environment surrounding clouds and to cloud processing of aerosols.

In this presentation we give an overview of the current understanding of possible remote sensing artifacts and their possible global impact. We discuss how these artifacts can be mitigated and corrected by combining observations from several A-train instruments, thus helping to quantify the changes of aerosol properties in the vicinity of clouds.

IAMAS (Meteorology)

M16a - M16 Radiation in the Climate System

IUGG-3342

GEWEX's integrated global water and energy product - quality assessment

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IRC working group GEWEX Data and Assessment Panel - science progress report

This presentation will provide an overview of recent progress on the generation of GEWEX's Integrated Water and Energy Products as well as results from ongoing climate data record quality assessments, in particular on atmospheric water vapor.

Satellite and in-situ observations archived as part of GEWEX's GDAP are approaching 30 years with which climate variability and trends can be examined. While the GEWEX products (e.g. International Satellite Cloud Climatology Project (ISCCP), Global Precipitation Climatology Project (GPCP), Surface Radiation Budget (SRB), SeaFlux, and LandFlux) form the basis for estimating the Earth's water and energy fluxes, recent studies mostly focused on long-term global scales at which water and energy closure arguments could be invoked. The actual products have not been examined much at regional and temporal scales at which connections among these variables and physical processes that connect them tend to manifest themselves.

To accelerate research related to the processes that govern water and energy exchanges, the GEWEX GDAP panel is creating an Integrated Water and Energy product that brings together the Clouds, Aerosol, Radiation, turbulent fluxes and precipitation in a consistent manner. By imposing uniform assumptions across the suite of products, the Integrated Product aims to eliminate discontinuities introduced by inconsistencies and allows users to focus on fine scale structures available at 1 degree, 3 hourly time scales from this product. A first analysis of the integrated product reveals that the very interdependence of the individual components makes it difficult to produce, but is also a very strict Quality Control procedure on individual components.

IAMAS (Meteorology)

M16a - M16 Radiation in the Climate System

IUGG-4388

The activities of the International Radiation Commission

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IRC science progress reports

The International Radiation Commission (IRC) is a commission of IAMAS with its roots dating back to the 19th century. The role of the IRC is to promote research into atmospheric radiation as well as application of that research to practical problems. This role is part of IAMAS concerning the earth-atmosphere system and the atmospheres of other planets and is performed in co-operation with all the IAMAS Commissions and with other appropriate bodies. Topics of concern to IRC include optical phenomena in the atmosphere, radiative properties of atmospheric constituents and of the earth's surface, radiative properties of planetary atmospheres, radiant energy transfer, radiant energy interaction with other features of the atmosphere (dynamics, climate etc.) and remote sensing of atmosphere and surface.

Presently, the IRC has eight working groups that coordinate the scientific activities of their topic. (see http://www.irc-iamas.org/groups). These working groups are proposed bottom up, i.e. every group of scientists can propose an activity within the IRC. In this presentation an overview of the IRC is given and outlined how a new working group could be started.

IAMAS (Meteorology)

M16b - M16 Radiation in the Climate System

IUGG-1223

Quality assurance of solar UV irradiance measured with array spectroradiometer

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IRC working group Solar Ultraviolet Radiation (UV) - science progress report:

The main activity of the working group is the reliable quantification of ultra violet (UV) radiation at the Earth's surface. This objective requires accurate measurements of spectral global solar UV irradiance in order to investigate effects of UV exposure on human health and to understand long-term trends in this parameter. Within the European EMRP-ENV03 project "Solar UV", new devices, guidelines, and characterization methods have been developed to improve solar UV measurements and to provide support to the end-user community. This presentation focuses on the quality assurance of array spectroradiometers, which are cost effective instruments and which are increasingly used for spectral irradiance measurements. One major dissemination activity at the end of the EMRP project was the UV intercomparison held at the World Radiation Center (PMOD/WRC) in Davos, Switzerland, from 7 to 16 July 2014, attended by participants from the end user community. The results of the intercomparison revealed that array spectroradiometers, currently used for solar UV measurements, show a large variation in the quality of their solar UV measurements. The participants who were involved within the project showed significantly improved results compared to end-users who did not yet apply the new methods and techniques. The future aim of the working group and of the World Calibration Center for UV radiation (WCC-UV) at PMOD/WRC, operated on the behalf of the World Meteorological Organization (WMO), is to homogenize worldwide the quality of spectral solar UV measurements derived from array spectroradiometers.

IAMAS (Meteorology)

M16b - M16 Radiation in the Climate System

IUGG-3443

Clouds and radiation

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Clouds are the main modulator of the energy flows of the atmosphere. Thus, a proper representation of clouds in (global) modeling is a critical aspect. Unfortunately, the grid resolution in global modeling is too coarse to resolve cloud processes and adopted parameterization are often too simple. Thus, simulated cloud radiative effects show large diversity among different models and comparisons to observations from ground and space reveal biases for many regions and/or seasons. Better understanding of sub-scale processes over the cloud's lifetime cycle is pursued to address model deficiencies via better sub-scale parameterizations. Ongoing efforts are summarized in this presentation.

The WCRP program chose to focus on four questions: (1) How will storm tracks change in the future? (2) What controls tropical rain belt positions? (3) Is convective aggregation important to climate? (4) How does convection impact cloud feedbacks?

The CAUSES program focuses on explanations for the positive temperature bias over NH mid-latitude continents in global modeling. (1) What is the contribution of radiation errors, specifically through errors in cloud properties? (2) What is the contribution of precipitation errors? (3) It the lower surface energy budget in modeling caused by a lack of soil moisture?

The ACPC initiative investigates interactions between aerosols, clouds and precipitation in the climate system: (1) How do atmospheric aerosol properties affect cloud microstructure and precipitation-forming processes? (2) In what way do aerosol particles influence the efficiency of precipitation? (3) How does aerosol solar heating affect the distribution of clouds and precipitation?

IAMAS (Meteorology)

M16b - M16 Radiation in the Climate System

IUGG-3760

A new satellite-based surface solar radiation climate data record

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Long-term observations of radiation and clouds are crucial for climate monitoring. Ground-based measurements provide accurate information for specific sites, but only satellite observations and reanalysis data can provide consistent spatial information on the surface radiation budget for climate monitoring, in particular in regions with limited coverage of well maintained ground based measurements (e.g. oceans, Africa). Here, we present the new Solar Radiation Dataset - Heliosat (SARAH) including surface solar radiation and cloud albedo generated using METEOSAT satellites within the EUMETSAT Satellite Application Facility on Climate Monitoring (CM SAF). This dataset covers more than 30 years (1983 to 2013) and has a high temporal (hourly) and spatial resolution (0.05x0.05 degree) across Europe, Africa and the surrounding oceans. The data is freely available via www.cmsaf.eu. The quality of the data has been evaluated with surface measurements and compared with other satellite-based data sets. Evaluation results will be briefly presented. It will be shown that the SARAH dataset is well suited for climate monitoring, including the monitoring of anomalies and trends. Within this scope, regional dimming and brightening will be also discussed.

IAMAS (Meteorology)

M16b - M16 Radiation in the Climate System

IUGG-4333

The CERES geostationary enhanced diurnally complete flux product

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The Clouds and the Earth's Radiant Energy System (CERES) project has provided the climate community an unprecedented 15-year observed TOA and consistent computed surface flux dataset. The natural variability of the CERES TOA fluxes correlates very well to the multivariate ENSO index, SeaWiFS PAR flux, MODIS cloud fraction, AIRS LW flux, and MISR cloud top height. The CERES instruments are onboard both the Terra and Aqua sun-synchronous spacecraft, which have a local equator crossing time of 10:30AM and 1:30PM, respectively. This leaves 20 hours of the 24 hours during the day unsampled. The unsampled hours include the peak of the land afternoon convection and the maritime stratus maximum. CERES incorporates 3-hourly contiguous geostationary (GEO) imagery from 5 satellites to estimate the regional TOA flux diurnal cycle in between CERES observations. The GEO radiances are calibrated against Aqua-MODIS to ensure consistent and stable calibration between the 15 GEO satellites during the 15-year record. The GEO TOA fluxes are normalized regionally with CERES observations. The CERES-only, using constant meteorology to infer the diurnal cycle, and CERES/GEO monthly regional SW flux difference can be as great as 25 Wm-2 over maritime stratus. Globally, the flux difference is nearly zero. The presentation will focus on the validation of the CERES GEO TOA enhanced fluxes with GERB regional hourly fluxes for accuracy and to quantify the improvement over using the constant meteorology assumption in the CERES-only flux product. The computed surface fluxes are also compared with ground site fluxes.

IAMAS (Meteorology)

M16b - M16 Radiation in the Climate System

IUGG-4762

The NASA/GEWEX Surface Radiation Budget: Integrated data product with reprocessed radiance, cloud, and meteorology inputs

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The NASA/GEWEX Surface Radiation Budget (SRB) project produces shortwave and longwave surface and top of atmosphere radiative fluxes for the 1983-near present time period. Spatial resolution is 1 degree. The current release 3.0 (available at gewex-srb.larc.nasa.gov) uses the International Satellite Cloud Climatology Project (ISCCP) DX product for pixel level radiance and cloud information. This product is subsampled to 30 km. ISCCP is currently recalibrating and recomputing their entire data series, to be released as the H product, at 10km resolution. The ninefold increase in pixel number will allow SRB a higher resolution gridded product (e.g. 0.5 degree), as well as the production of pixel-level fluxes.

Other key input improvements include a detailed aerosol history using the Max Planck Institut Aerosol Climatology (MAC), temperature and moisture profiles from HIRS, and new topography, surface type, and snow/ice.

At the time of abstract submission, results from the year 2007 have been produced. More years will be added as ISCCP reprocessing occurs. Here we present results for the improved GEWEX Shortwave and Longwave algorithm (GSW and GLW) with new ISCCP data, the various other improved input data sets and the incorporation of many additional internal SRB model improvements. Improvements in GSW include an expansion of the number of wavelength bands from five to eighteen, and the inclusion of ice cloud vs. water cloud radiative transfer. The SRB data produced will be released as part of the Release 4.0 Integrated Product, recognizing the interdependence of the radiative fluxes with other GEWEX products providing estimates of the Earth's global water and energy cycle (I.e., ISCCP, SeaFlux, LandFlux, NVAP, etc.).

IAMAS (Meteorology)

M16c - M16 Radiation in the Climate System

IUGG-0274

A multi-pixel approach for correcting biases in cloud radiative effects due to spatial inhomogeneity and aerosols

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Despite advancements in deriving cloud-aerosol radiative effects from space-borne observations, inhomogeneous cloud fields or mixed aerosol-cloud scenes still represent a significant challenge. For different types of inhomogeneous cloud fields, we will illustrate that systematic biases “survive” spatial (or temporal) averaging and other mitigation strategies. We will explain that this is due to the non-local nature of three-dimensional radiative transfer in complex scenes. For top-of-atmosphere irradiance products, inhomogeneity effects are folded into the empirics-based approach as applied to broadband radiometer (e.g., CERES) and accompanying imager (e.g., MODIS) observations. The derivation of surface irradiance products, on the other hand, involves radiative transfer calculations that account for the intervening atmosphere through data from multi-spectral imagery, re-analysis, and climatologies. These calculations do not explicitly take into account non-local effects (pixel-to-pixel exchange of radiation, or net horizontal photon transport). We will show that resulting biases for surface irradiance products from the current observing system can exceed 20%. We will also propose a new method for correcting these biases, based on the recent discovery that they are associated with spectral perturbations which can be detected by multi-spectral imagers. We show that there are robust correlations between 3D irradiance biases and their spectral signature in radiances, which are independent of the specific cloud realization. These form the basis for the parameterization of first-order 3D and aerosol correction terms for irradiance products from populations of pixels within a domain, without the need for costly 3D radiative transfer calculations in future algorithms.

IAMAS (Meteorology)

M16c - M16 Radiation in the Climate System

IUGG-1655

Absorption of solar radiation in the clear and cloudy skies

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We estimate atmospheric solar absorption at 433 locations worldwide through combining ground-based measurements of surface solar radiation (SSR) with collocated satellite-derived surface albedo and top-of-atmosphere net irradiance under both, all-sky and clear-sky conditions. Using two ground-based SSR datasets (BSRN and GEBA) and the CERES EBAF data product, we estimate atmospheric absorption at around 23 +-2% of the TOA incoming radiation under all-sky conditions widely representative of the global scale. The cloud radiative forcing on atmospheric absorption is overall positive at around 5-10 W/m^-2 (2-4%) using ground-based data and the satellite product. Within the frame of the latter, the clear-sky atmospheric absorption is generally lower over the oceans as compared to the land, while the atmospheric cloud effect is more pronounced. Low clouds thereby significantly enhance atmospheric absorption, while high clouds lead to a near-zero cloud radiative forcing on atmospheric absorption. The latitudinal distribution of atmospheric absorption is more uniform under all-sky than under clear-sky conditions, as the cloud radiative forcing acts stronger in the extra-tropics than in equatorial regions, where the fraction of high clouds and the initial clear-sky absorption are the largest.

IAMAS (Meteorology)

M16c - M16 Radiation in the Climate System

IUGG-1890

The ENSO Effects on Tropical Clouds and Top-of-Atmosphere Cloud Radiative Effects in CMIP5 Models

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The El Niño-Southern Oscillation (ENSO) effects on tropical clouds and top-of-atmosphere (TOA) cloud radiative effects (CREs) in Coupled Model Intercomparison Project Phase5 (CMIP5) models are evaluated using satellite-based observations and ISCCP satellite simulator output. The relative effects of changes in cloud properties, temperature and humidity on TOA CRE anomalies during ENSO in the CMIP5 models are assessed using Fu-Liou radiative transfer calculations, including deviations of cloud radiative kernels.

Climatologically, most CMIP5 models produce considerably less total cloud amount with higher cloud top and notably larger optical reflectivity than observations in tropical Indo-Pacific. During ENSO, most CMIP5 models notably underestimate TOA CRE and cloud changes over western tropical Pacific. Over central tropical Pacific, the multi-model mean resembles observations in TOA CRE and cloud amount anomalies, but notably overestimates cloud top increases, with substantial inter-model variations. The CMIP5 models agree with observations on the dominance of proportional cloud fraction change for shortwave TOA CRE anomalies, the comparable contributions from cloud fraction and cloud top pressure (CTP) changes for longwave TOA CRE anomalies, and the negligible effects of temperature and humidity changes. The notable model underestimation of TOA CRE anomalies over western tropical Pacific are mainly due to the model biases in CTP and cloud optical thickness changes for shortwave, and CTP changes for longwave, whereas the model biases in proportional cloud fraction changes make little contribution, due to strong compensations between model underestimation of TOA CRE changes from thin clouds and overestimation from medium and thick clouds.

IAMAS (Meteorology)

M16c - M16 Radiation in the Climate System

IUGG-2075

Comparison of Radiative Fluxes: Differences in global distributions between output from global modeling and satellite data-sets.

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Satellite sensor data based global maps of atmospheric shortwave and longwave radiation flux maps are examined and compared to flux maps from global modeling. Differences in central values and in local spread are analyzed also by looking at contributions associated with clouds (cloud radiative effects) and applied ancillary data (e.g. properties of atmospheric aerosol and of the surface). We focus on two results:

Trusted and consistent satellite data at the top of the atmosphere indicate that models display large deficiencies in the representation and distribution of clouds.

The surface net radiation of satellite data-sets is significantly larger than in global modeling, especially over low latitude oceanic regions. This might suggest that precipitation is underestimated in global modeling, but only if (modeled) satellite data can be trusted. Needed ground-based radiation data for verification are still too few and missing in critical regions to clarify these large differences.

IAMAS (Meteorology)

M16c - M16 Radiation in the Climate System

IUGG-3529

Utility of surface radiation budget from EarthCARE and geostationary satellites

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The third generation geostationary satellite, Himawari-8, was launched in October 2014 with Advanced Himawari Imager (AHI) with 16 bands, 0.5 to 2 km FOV, and 10 minute global scanning functions. We plan to analyze the data by our SW surface radiation budget retrieval system for renewable energy and climate study applications with function of semi-real time data distribution to enterprises. The system includes fast geometrical correction and cloud retrieval modules for accurate SW surface radiation budget of 1km spatial resolution. Aerosol, along with cloud, is an important factor to determine the SW surface radiation budget, so that we like to extend our talk to an evaluation of the global aerosol radiative forcing from CALIPSO (version 2 and 3) and MODIS sensors, in simulation of future use of EarthCARE ATLID and MSI sensors, for understanding how aerosol information can be incorporated to the surface radiation budget retrieval from geostationary satellite.

IAMAS (Meteorology)

M16c - M16 Radiation in the Climate System

IUGG-3841

Evaluation of CMIP5 and NASA GISS post-CMIP5 Simulated Clouds and TOA Radiation Budgets Using NASA Satellite Observations

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Although many improvements have been made to the GCMs involved in the CMIP5 project, clouds and their radiative feedbacks are still a problem. In this study, the simulated total cloud fraction (CF), cloud water path (CWP), TOA radiation budgets and cloud radiative effects (CREs) from 28 CMIP5 models are evaluated and compared with multiple satellite observations from CERES, MODIS, ISCCP, CloudSat, and CALIPSO. The multimodel ensemble mean CF (57.6%) is, on average, underestimated by nearly 8% when compared to CERES-MODIS (CM) and ISCCP results while an even larger negative bias (17.1%) exists compared to the CloudSat/CALIPSO results. CWP bias is similar in comparison to the CF results, with a negative bias of 16.1 gm^{-2} compared to CM CWP. The model simulated and CERES EBAF observed TOA reflected SW and OLR fluxes on average differ by 1.8 Wm^{-2} and -0.9 Wm^{-2}, respectively. The averaged SW, LW, and net CRFs from CERES EBAF are -50.1, 27.6, and -22.5 Wm^{-2}, respectively, indicating a net cooling effect of clouds on the TOA radiation budget. The differences in SW and LW CRFs between observations and the multimodel ensemble means are only -1.3 Wm^{-2} and -1.6 Wm^{-2}, respectively, resulting in a larger net cooling effect of 2.9 Wm^{-2} in the model simulations. NASA GISS CMIP5 (C5) and Post-CMIP5 (P5) simulations were also assessed utilizing multiple satellite observations and CERES EBAF-TOA results. Comparisons revealed that the P5 and C5-simulated global means of clear-sky and all-sky outgoing longwave radiation (OLR) match well with CERES observations, while biases are observed regionally. The comparisons and statistical results from this study may provide helpful insight for improving GCM simulations of clouds and TOA radiation budgets in future versions of CMIP, such as AR6.

IAMAS (Meteorology)

M16d - M16 Radiation in the Climate System

IUGG-1830

Observational Determination of Surface Radiative Forcing by the Major Anthropogenic Greenhouse Gases

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Earth's background atmospheric CO2, CH4, and N2O concentrations have been steadily rising due to anthropogenic emissions, and these increases since 1750 have implications for the radiative balance of the Earth's atmosphere. The physics governing how these well-mixed greenhouse gases (WMGHGs) influence atmospheric infrared energy balance, and thus climate, are well established, but the impact of recent atmospheric WMGHG trends on the surface energy balance has not been experimentally confirmed in the field. Using infrared WMGHG absorption bands and controlling for atmospheric temperature and water vapor, spectra from the DOE ARM Program's Atmospheric Emitted Radiance Interferometers (AERI) yield the first direct observational evidence of the time-series of WMGHG surface radiative forcing directly attributable to recent increases in WMGHGs, in this case between 2000-2010. The time-series shows a secular trend of in the radiative forcing from CO2, CH4, and N2O, both separately and combined. This data record provides the first comprehensive observational evidence of surface radiative forcing by WMGHGs, confirming theoretical predictions of the atmospheric greenhouse effect.

IAMAS (Meteorology)

M16d - M16 Radiation in the Climate System

IUGG-2128

Greenhouse Gas and Ozone Radiative Forcing for the RCP8.5 Scenario with the EMAC Chemistry-Climate Model

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One metric to show the impact of changes in the human and natural emissions of climate active agents on the earth's climate system is the concept of radiative forcing (RF). It quantifies the energy imbalance that occurs when an imposed perturbation, for instance by a change in the mixing ratio of a greenhouse gas (GHG), takes place. There are several ways to calculate the radiative forcing, which differ in the included feedback processes. The instantaneous RF is calculated with fixed atmospheric background conditions to get the net change in the radiative flux ”instantaneously”, while the adjusted RF allows the temperature profile to adjust to a new equilibrium in the stratosphere, with the tropospheric temperature profile remaining unchanged. The goal of this study is to derive the RF of the troposphere due to projected future changes of ozone and GHGs by applying the new sub-model RAD in the ECHAM/MESSy Atmospheric Chemistry (EMAC) model. The instantaneous and adjusted RFs for the GHGs as well as for ozone (tropospheric and stratospheric changes separated) have been calculated. The analyses are based on the reference period 1865 (10 years from a time slice simulation) and the RF is derived for every decade from 1965 (1960–1969) until 2095 (2090–2099). The ozone and GHG concentrations, needed as input for the RF calculations, are taken from a transient simulations of the EMAC chemistry-climate model. The simulations extend from 1960 to 2100, and include forcings by GHGs following the specifications of the RCP8.5 scenario, and by ozone depleting substances following the specification of the adjusted A1 scenario. Sea- surface temperatures and sea-ice concentrations were prescribed from the Max Planck Institute ocean model (MPIOM).

IAMAS (Meteorology)

M16d - M16 Radiation in the Climate System

IUGG-4891

The Total Solar Irradiance measurements with PREMOS/PICARD - absolute accuracy, relative stability and comparison with other instruments

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The Total Solar Irradiance measurements with PREMOS on the satellite PICARD were operational about four years from 2010 to 2014. We discuss in this presentation the absolute value of the TSI measurements of all space instruments and their relative stability over the instrument's measurement periods. In particular we estimate the performance of PREMOS/PICARD from its internal means to assess sensitivity changes as well as using parallel measurements of other instruments to verify the accuracy of the internal PREMOS corrections. On a broader view we assess our knowledge of the long term trend of TSI and discuss different reconstructing of TSI in the past. Finally, we estimate the range of possible future TSI changes with potential impact on the terrestrial energy balance.

IAMAS (Meteorology)

M16d - M16 Radiation in the Climate System

IUGG-5368

TSIS on the international space station: Continuity of the solar irradiance data record

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The Total and Spectral Solar Irradiance Sensor (TSIS), first selected in 1998 for the National Polar-orbiting Operational Environmental Satellite System (NPOESS), re-manifested in 2010 on the NOAA-NASA Joint Polar Satellite System (JPSS), then the NOAA Polar Free Flyer, is now scheduled for deployment in 2017 on the International Space Station. The TSIS will acquire measurements of total and spectral solar irradiance (TSI and SSI, respectively).

TSIS provides continuation of the Total Irradiance Monitor (TIM) and the Spectral Irradiance Monitor (SIM), currently flying on the NASA Solar Radiation and Climate Experiment (SORCE). Launched in 2003, SORCE is now more than seven years beyond its prime-mission lifetime. The launch failure of the NASA's Glory mission in 2011 coupled with diminished battery capacity on SORCE and delays in the launch of TSIS have put the continuous 36-year TSI record at risk. In 2012, a plan to maintain continuity of the TSI calibration scale between SORCE and TSIS was rapidly implemented through the USAF Space Test Program STPSat-3 that launched in late 2013. The shorter SSI record faces a likely gap between SORCE and TSIS.

This paper summarizes the importance of highly accurate and stable observations of solar irradiance in understanding the present climate epoch and for predicting future climate; why continuity in the solar irradiance data record is required; improvements in the TSIS TIM and SIM, including their traceability to ground-based cryogenic standards; and the maturity and implications of transitioning solar irradiance data records from research-to-operations.

IAMAS (Meteorology)

M16d - M16 Radiation in the Climate System

IUGG-5803

Comparison of changes in surface solar radiation in cmip5 global climate models and in cordex regional climate models for europe

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Potential future changes in the spatial and temporal distribution of surface solar radiation (SSR) can be considered not only as a driving factor of environmental changes, but could also directly affect the economy and society. Many impact models across different sectors such as energy, hydrology, and agriculture use SSR as input in order to create comprehensive projections of the consequence of climate change. For this reason, the assessment of consistency regarding SSR projections in different climate models employing different parametrizations or different spatial resolutions is essential. The objective of this study is to compare the projections of changes in SSR outputs from five regional climate models (RCMs) from the EURO-CORDEX multi-model ensemble with a resolution of 12 km (HIRHAM5, CCLM, WRF3.3.1, RACMO22E, SMHI-RCA4) with the respective fields of their driving CMIP5 global climate models (GCMs). First, the consistency of mean seasonal SSR changes for the RCP4.5 and RCP8.5 emission scenarios among the regional models and also among the global climate models is examined. Second, the difference between the changes given by the RCM and by the respective driving GCM are compared, highlighting the role of downscaling for radiation-related processes. In addition, the SSR changes of one specific RCM using different forcing GCMs are analyzed in order to estimate the influence of the boundary conditions provided by the various GCMs on the projected SSR changes. The analysis has also been elaborated vice versa, namely to compare the outputs of different RCMs using the same boundary forcing (i.e., the same GCM). In this case, the effect introduced by the RCM-specific radiation parameterization schemes can be explored. Quantifying the differences of the SSR fields coming from different climate models indicates the degree of robustness of the projected SSR changes on different scales and gives a reference for the uncertainty transferred to impact studies.

IAMAS (Meteorology)

M16e - M16 Radiation in the Climate System

IUGG-0471

An assessment of direct radiative forcing, radiative adjustments, and radiative feedbacks in climate models

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Radiative kernels are used to separate direct radiative forcing from radiative adjustments to that forcing in order to quantify the magnitude and intermodel spread of tropospheric and stratospheric adjustments. The direct radiative forcing due to quadrupling CO_2 is found to have an intermodel spread of ~3 W m^{-2}, which is comparable to spread in the radiative adjustments to that forcing. However, intermodel differences in these quantities are negatively correlated, resulting in an intermodel spread in total forcing of only ~4 W m^{-2}. In contrast to previous studies, relatively small estimates of cloud adjustments are obtained which are both positive and negative. It is shown that the regional patterns in all tropospheric adjustments tend to oppose the radiative feedback. This compensation between feedback and adjustment is closely tied to spatial inhomogeneities in the initial rate of surface warming and can be explained assuming a linear feedback with no adjustment, suggesting that much of the spatial variation in the adjustment may be an artifact of assuming the methodology. Even when assuming that the global-mean estimates of the tropospheric adjustments are valid, neglecting them introduces little uncertainty in estimates of the total forcing, feedback or effective climate sensitivity relative to the intermodel spread in these values.

IAMAS (Meteorology)

M16e - M16 Radiation in the Climate System

IUGG-1272

Analysis of radiative feedbacks in model simulations including interactive chemistry

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Including interactive atmospheric chemistry in climate change simulations may have a significant impact on the climate sensitivity. In CO2-driven simulations the climate sensitivity has been found to be reduced. The reason is a negative feedback from stratospheric ozone (absent from models without chemistry), which is amplified by reducing the positive feedback of stratospheric water vapor. A complete feedback analysis reveals that other physical feedbacks, in particular the cloud radiative feedback, are also modified by the presence of chemical interactions. This feature may be more pronounced in climate change simulations driven by non-CO2 radiative forcings. In such cases the change of conventional (physical) radiative feedbacks could even overcompensate the direct feedback effect from changes of interactive chemical tracers. It will also be emphasized that further methodological developments to radiative feedback analysis is called for, in order to interpret the feedbacks arising in chemistry-climate models in a proper cause and effect sense.

IAMAS (Meteorology)

M16e - M16 Radiation in the Climate System

IUGG-1597

Climate feedbacks and relationships between top-of-atmosphere radiation and temperatures on Earth

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The large monthly global and regional variability in Earth's radiation balance is examined using correlations and regressions between atmospheric temperatures and water vapor with top-of-atmosphere outgoing longwave (OLR), absorbed shortwave (ASR) and net radiation (R_T=ASR-OLR). Temperatures are reasonably coherent throughout the troposphere from the surface to 150 hPa in the tropics to mid-latitudes. Anomalous monthly variability in the radiation fields arises mainly from clouds and transient weather systems. Relationships between OLR and temperatures are strongest and positive, especially over land, except in the deep tropics where high sea surface temperatures are associated with deep convection, high cold cloud-tops and thus less OLR but also less ASR. Tropospheric vertically-averaged temperatures (surface-150 hPa) are thus negatively correlated globally with net radiation (-0.57), implying 2.18±0.10 W m^{-2} extra radiation to space for 1°C increase in temperature. Water vapor is positively correlated with tropospheric temperatures and thus also negatively correlated with net radiation, however when the temperature dependency of water vapor is removed, a significant positive feedback between water vapor and net radiation is revealed with 0.87 W m^{-2} less OLR to space per mm of total-column water vapor. The regression coefficient between R_T and tropospheric temperature becomes -2.98 W m^{-2} K^{-1} if water vapor effects are removed, slightly less than expected from black-body radiation (-3.2 W m^{-2} K^{-1}), suggesting a positive feedback from clouds and other processes. Robust regional structures provide additional physical insights.

IAMAS (Meteorology)

M16e - M16 Radiation in the Climate System

IUGG-3744

Have anthropogenic aerosols impacted the continental hydrological cycle over France since the early 20th century?

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The decline in surface solar radiation related to anthropogenic aerosols from the 1950s to the 1980s followed by its increase afterwards has very likely resulted in modulation of the warming caused by greenhouse gases. The potential impact of the variations in surface solar radiation on the hydrological cycle is less well known, especially in the early 20th century. In this study, the potential role of solar radiation variations caused by anthropogenic aerosols on evapotranspiration (ET) over France during the entire 20th century is analyzed. First, historical and attribution simulations from CMIP5 models are investigated. Some models show virtually no impact of anthropogenic aerosols on ET over France, while others are characterized by a strong response. The impact of aerosols on ET in these models often seems to occur as early as the early twentieth century. These strong inconsistencies among models highlight the need for an estimation of ET over France over the entire 20th century to evaluate their respective realism. Two approaches are developed: long river flows and precipitation observations over France are used to derive through water balance consideration an estimate of ET on the entire 20th century. Additionally, a modified statistical downscaling method that incorporates information from local precipitation observation is used to downscale the 20CR reanalysis on the entire 20th century and force a hydrometorological model to compute ET. The two almost independent estimates of the evolution of ET are used to evaluate the plausibility of the response in ET of CMIP5models over France through the 20th century and the realism of their sensitivity in ET to anthropogenic aerosols.

IAMAS (Meteorology)

M16e - M16 Radiation in the Climate System

IUGG-4451

Reconstruction of energy fluxes at TOA and Earth's surface

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Combining satellite data, atmospheric reanalyses, and climate model simulations, variability in the net downward radiative flux imbalance at the top of Earth’s atmosphere is reconstructed and linked to recent climate change. Over the 1985–1999 period mean ($0.34 \pm 0.67 Wm^{-2}$) is lower than for the 2000–2012 period ($0.62 \pm 0.43 Wm^{-2}$, uncertainties at 90% confidence level) despite the slower rate of surface temperature rise since 2000. While the precise magnitude remains uncertain, the reconstruction captures interannual variability which is dominated by the eruption of Mount Pinatubo in 1991 and the El Nino Southern Oscillation.

Net surface energy fluxes are also reconstructed based upon the reconstructions of radiative fluxes at TOA and the atmospheric energy tendencies and transports from the ERA-Interim reanalysis. The energy divergence from ERA-Interim are mass adjusted and the moist energy transport are corrected through corrections made to changes in total column water vapour content. To optimise the surface flux and its variability over ocean, both divergences over land are constrained to match the monthly area mean surface net energy flux variability derived from a simple relationship between the surface net energy flux and the surface temperature change. The energy divergences over the oceans are then adjusted to remove an unphysical residual global mean atmospheric energy divergence. The estimated net surface energy fluxes are compared with other data sets from reanalysis and atmospheric model simulations.

IAMAS (Meteorology)

M16p - M16 Radiation in the Climate System

M16p-486

Projected changes in solar UV radiation over the high latitudes of the southern and the northern hemisphere

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The UV radiation that reaches the earth's surface is of vital importance for many of the species inhabiting the planet. Exposure to UV radiation may be beneficial or harmful and even small changes in its future levels may induce significant responses in both the human populations and the ecosystems. The Arctic and Antarctic environments are expected to undergo great changes within the next decades, mainly because of the significant impact of the climate change over these regions. Future changes in stratospheric ozone, surface reflectivity, and cloudiness, will in turn lead to changes in the future levels of the surface UV irradiance. The improvement of the tropospheric air quality is also expected to play an important role over the northern Europe and Asia. In the present study, changes in stratospheric ozone, surface reflectivity, cloudiness, and aerosol load are taken into account in order to estimate the corresponding changes in surface noon UVA and UVB irradiance over the high latitudes (greater than 55°) of the southern and the northern hemisphere. The simulations of the monthly mean noon irradiance are performed with the libRadtran radiative transfer package and the input parameters are ensemble means from the Earth System Models participated in Coupled Model Intercomparison Project - Phase 5. The simulations are performed for two time slices, one in the past (1955 – 1965) and one in the future (2085 – 2095), and the differences between the mean UV levels of the two periods are presented for the two regions. The major goal of the study is to estimate and discuss the magnitude and the spatial distribution of these changes.

IAMAS (Meteorology)

M16p - M16 Radiation in the Climate System

M16p-487

Observation of a radon progenies fallout in tropical rainfalls.

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The laboratory of environmental radiation of ITA (São José dos Campos, 23°11′11″S, 45°52′43″W, 650 MAMSL) performs simultaneous monitoring of a natural radiation background and meteorological parameters. A time resolution of up to 1 minute allows a detailed comparison of changes in meteorological parameters with those of a concentration of ambient radon progenies. The paper presents results of a study of variation of a fallout of radon progenies ^{214}Pb and ^{214}Bi concomitanting rainfalls. The radionuclide fallout is reconstructed from the observed gamma rate through a simulation of the first kind Volterra integral equation with difference kernel, determined by ratio of precipitating rates of ^{214}Pb and ^{214}Bi and their decay half times. A straightforward step-by-step procedure was used for the numerical solution of the equation. The radionuclide concentration is calculated as a ratio of the reconstructed fallout to the measured rainfall one. It was observed that the radionuclide fallout rate increases as the rainfall one in approximately power 0.6, i.e. the same as the mean raindrop volume. The concentration thereafter decreases as the rainfall rate in power 0.4. This may probably be explained by the decay of the absorbed radionuclides during a raindrop formation in the cloud and the following precipitation.

IAMAS (Meteorology)

M16p - M16 Radiation in the Climate System

M16p-488

Variations of the natural neutron flux (0.02 eV–10 MeV) in the Brazilian tropics

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The laboratory of environmental radiation of ITA (São José dos Campos, 2 3°11′11″S, 45°52′43″W, 650 MAMSL) monitors neutron fluxes of 0.02 eV to10 MeV energy together with other components of the natural radioactivity. Two devices are used for the observations: an **outdoor** detector with two ^{3}He tubes of 250 cm² area each in paraffin shielding and of 80% efficiency for thermal neutrons and an **indoor** ^{3}He detector of 70 cm² area located on the second floor of a concrete building. The character and amplitudes of the observed flux variation are quite different from those inherent to the neutrons of the cosmic ray origin and are likely related with neutrons from (α,n) reactions of decay products of radon progenies. Four types of variations are observed: 1) seasonal with maxima at wet seasons; 2) diurnal with maximum at about 6 h local time and amplitude of the variation up to 10 for the outdoor detector and 16 h and 0.1 respectively for the indoor detector; 3) short time (several days) quasi-periodic enhancements with amplitudes up to several times higher than the mean daily amplitude; 4) abrupt transient (~1 min) increases with magnitudes up to two orders higher than the mean daily one. The dynamics of first two type events are controlled by corresponding variations of the meteorological parameters in the locality. The fourth type events correlate with lightning strokes in the vicinity (<200 m) of the detector. The more rare third type events were only registered by the outdoor detector. They are not correlated with geomagnetic disturbances and meteorological phenomena and are probably a result of natural radon release from the Earth’s crust triggered by minor seismological activity.

IAMAS (Meteorology)

M16p - M16 Radiation in the Climate System

M16p-489

Impact of ozone changes on the erythemal and vitamin D weighted UV daily doses in South America and Antartica

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Recent studies show that the ozone layer will be recovered until 2050. This is a significant result of the Montreal Protocol which points out the success of this environment protection agreement. However, climate change projections show that the total ozone content will have a relevant increase until the end of this century, mainly at higher latitudes. On one hand, this increase can reduce the adverse effects of UV radiation overexposure. On the other hand, the decrease of UV availability at the surface can reduce the synthesis of vitamin D among the inhabitants of these regions. In this study, we provide erythemal (DoseE) and vitamin D (DoseD) weighted UV daily doses estimates for ten different sites of South America and Antartica. Our calculations are based on the ozone forecasts provided by four climate models reported on the last IPCC report. Unlike previous works, our study evaluates the impact on the daily dose of radiation received. Thus, these results can be used as an important tool for the health studies on the excess or lack of sun exposure. The first results show significant UV attenuation at Southern sites. At 30°S, DoseE and DoseD can be reduced between 5 and 7%, respectively, until the end of this century if the anthropogenic emissions continue to rise throughout the time. At 50°S, these reductions increase to 12 and 21%, respectively; and, in Antartica they will possibly exceed 15 and 30%, respectively. We did not observe significant variations at the equatorial sites. The next step of this study is to evaluate the impact of these UV availability reductions on the population’s health.

IAMAS (Meteorology)

M16p - M16 Radiation in the Climate System

M16p-490

Evaluating 4 WRF shortwave radiation schemes for global horizontal irradiance predictions in Greece.

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The main aim of this study is toassess the differences induced in the middle scale atmospheric Weather Researchand Forecast (WRF) Global Horizontal Irradiance (GHI) estimations due todifferent short-wavelength scheme used in the model's set up. The evaluationtook place in 12 stations of the Hellenic Network of Solar Energy (HNSE) for themonths January, April, July and October of 2013. The short wavelength schemesthat were validated are the Dudhia scheme, the updated Rapid Radiative TransferModel (RRTMG) scheme, the updated Goddard scheme and the Goddard Fluid DynamicsLaboratory (GFDL) scheme. For the long-wavelength radiation the RRTMG schemewas applied for all cases. Both hourly and daily integrated data are evaluated.
All schemes are found to perform better under clear sky conditions due tolimited ability of the WRF model to simulate cloudy conditions. While for thedaily integrated values, the model assimilation result in better agreement whencomparing to the hourly values with the observations; due to the smoothing ofdifferences when integrating in time.
Dudhia, New Goddard and RRTMG SW schemes can perform adequately for solarenergy applications, while GFDL scheme presents a slightly higheroverestimation. Clouds play the most significant role imposing large deviationsin model-estimated GHI. While in cloud-free cases, the coherence between modelestimations and observations are quite good, with aerosols, ozone profiles andmicrophysical interactions to result in slight differences from one SW schemeto another.

IAMAS (Meteorology)

M16p - M16 Radiation in the Climate System

M16p-491

Application and evaluation of a new radiation code under McICA scheme in BCC_AGCM2.0

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This research incorporates the correlated k-distribution BCC-RAD radiation model into the climate model BCC_AGCM2.0.1 and examines the change in climate simulation by implementation of the new radiation algorithm. It is shown that both clear-sky radiation fluxes and cloud radiative forcing (CRF) are improved. The modeled atmospheric temperature and specific humidity are also improved due to changes in radiative heating rates, which most likely stem from the revised treatment of gaseous absorption.

Subgrid cloud variability, including vertical overlap of fractional clouds and horizontal inhomogeneity in cloud condensate, are addressed by using the Monte Carlo Independent Column Approximation (McICA) method. In McICA, a cloud type dependent function for cloud fraction decorrelation length, which gives zonal mean result very close to the observations of CloudSat/CALIPSO, is developed. Compared to utilizing a globally constant decorrelation length, the maximum changes in seasonal CRF by the new scheme can be as large as 10 and 20 Wm^{-2} for longwave and shortwave CRF, respectively, mostly located in the Tropics. The inclusion of an observation-based horizontal inhomogeneity of cloud condensate has also a significant impact on CRF, with global means of ~1.5 Wm^{-2} and ~3.7 Wm^{-2} for LW and SW CRF, respectively. Generally, incorporating McICA and horizontal inhomogeneity of cloud condensate in the BCC-RAD model reduces global mean TOA and surface SW and LW flux biases in BCC_AGCM2.0.1.

These results demonstrate the feasibility of the new model configuration to be used in BCC_AGCM2.0.1 for climate simulations, and also indicate that more detailed real-world information on cloud structures should be obtained to constrain cloud setups in McICA in the future.

IAMAS (Meteorology)

M16p - M16 Radiation in the Climate System

M16p-492

Effects of extreme total column ozone events on UV solar radiation in an urban environment

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We investigate the effects of extreme events in the total ozone column (TOC) time series of Thessaloniki (40.634° N, 22.956° E) on the long-term variability of TOC, as well as on the solar ultraviolet radiation at the Earth's surface. The measurements of TOC used in this study have been derived by a Brewer spectrophotometer and cover the period 1982 – 2011. The extreme events were identified using primarily the Extreme Value Theory (EVT). For comparison, TOC events that are higher (lower) from the climatological monthly mean by two standard deviations were also identified, assuming that the TOC data series exhibits normal distribution. The number of events from the second method is considerably smaller than those derived by the EVT. Effects on the TOC variability were investigated by analyzing the data series with and without including the extreme-event data. The influence of the extreme-low events on the annual mean TOC is up to ~18 DU, while the extreme-high events have a smaller impact (up to 12 DU). Removing the extreme events from the time series results in smoother year-to-year variability and the small long-term linear trend (-0.08 %/year) is reduced by a factor of 2. Furthermore, we compared the effects of the TOC extreme events on the variability of noon erythemal irradiance under clear skies with those produced by the variations in the aerosol optical depth. We provide evidence that, even under extreme-low TOC conditions, the UV radiation levels are determined largely by the latter. Although the influence of aerosols is evident for all seasons, for spring and summer the sensitivity of UV radiation is larger, probably due to the different nature of the aerosols over Thessaloniki during these seasons.

IAMAS (Meteorology)

M16p - M16 Radiation in the Climate System

M16p-493

About the baseline surface radiation network

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'IRC working group <BSRN> - science progress report' M16

The Earth's radiation budget is essential for driving the general circulation of the atmosphere and ocean and for building the main conditions for the Earth's climate system. To detect changes in the Earth's surface radiation field the Baseline Surface Radiation Network (BSRN) and its central archive - the World Radiation Monitoring Center (WRMC) - was created in 1992.

BSRN is a project of the Data and Assessments Panel of the Global Energy and Water Cycle Experiment (GEWEX) under the umbrella of the World Climate Research Programme (WCRP). It is the global baseline network for surface radiation for the Global Climate Observing System (GCOS), contributing to the Global Atmospheric Watch (GAW), and forming a cooperative network with the Network for the Detection of Atmospheric Composition Change (NDACC).

The data are of primary importance in supporting the validation and confirmation of satellite and computer model estimates. At a relatively small number of stations (currently 58) in contrasting climatic zones, solar and infrared radiation is measured with instruments of the highest available accuracy with high temporal resolution (mainly 1 minute). A total of over 7500 station-month datasets were available in the WRMC.

The poster will present the current state of the archive, the quality control mechanisms for the data and how scientists can access and use the data.

IAMAS (Meteorology)

M16p - M16 Radiation in the Climate System

M16p-494

EarthCARE Satellite: Space-borne lidar and radar profiler for linking cloud, precipitation and aerosol to radiation

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The European Space Agency (ESA) has selected the EarthCARE satellite mission for implementation as its sixth Earth Explorer Mission, in cooperation with the Japan Aerospace Exploration Agency (JAXA). The satellite payload consists of two active and two passive instruments. The Atmospheric Lidar (ATLID) operates at 355nm and is equipped with a high-spectral resolution receiver and depolarisation channel that separates molecular from particulate back-scatter and distinguishes cloud and aerosol types. The Japanese Cloud Profiling Radar (CPR) is a highly sensitive W-band Doppler radar (94GHz) that measures cloud profiles, precipitation and vertical motion within clouds. Due to its significantly higher sensitivity when compared to CloudSat, it will detect substantially thinner ice clouds and stratocumulus. The Doppler observation will provide novel information on convection, precipitating ice particles and raindrop fall speed.

A Multi-Spectral Imager (MSI) with a 150km wide swath and seven channels in the visible, near-IR, short-wave IR, and thermal IR, will provide scene context information and allow the reconstruction of three-dimensional atmospheric scenes when combined with lidar and radar retrievals. A Broad-Band Radiometer (BBR) observing broad-band solar and thermal radiation reflected and emitted from the Earth, with three fixed field of view looking forward, nadir and backward, will make collocated measurements of the outgoing reflected solar and emitted thermal radiation.

The synergistic exploitation of the four instruments will provide 3D cloud-aerosol-precipitation scenes, with collocated broad-band radiation data, over a mission lifetime of three years. The satellite acceptance review is scheduled for October 2017.

IAMAS (Meteorology)

M16p - M16 Radiation in the Climate System

M16p-495

Spatial representativeness of ground-based solar radiation measurements: Extension to the full Meteosat disk

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The spatial representativeness of a point measurement of surface solar radiation (SSR) of its larger-scale surrounding, e.g. collocated grid cell, is a potential source of uncertainty in the validation of climate models and satellite products. Here, we expand our previous study over Europe to the entire Meteosat disk, covering additional climate zones in Africa, the Middle east, and South America between -70 to 70 degrees East and -70 to 70 degrees North. Using a high-resolution (0.03 degree) satellite-based SSR dataset (2001–2005), we quantify the spatial subgrid variability in grids of 1 and 3 degree resolution and the spatial representativeness of 887 surface sites with respect to site-centered surroundings of variable size. In the multi-annual mean the subgrid variability is the largest in some mountainous and coastal regions, but varies seasonally due to changes in the ITCZ location. The absolute mean representation errors at the surface sites with respect to surroundings of 1 and 3 degree are on average 1-2% (3 Wm^-2) and 2-3% (4Wm^-2), respectively. The majority of sites are found to be representative within the in-situ measurement accuracy. We show that their site-specific representativeness can be reliably approximated by the subgrid variability in a fixed grid (1 degree). The subgrid variability in turn is only moderately reduced when computed from coarser grid data, typically the only data available in areas not covered by the 0.03 degree resolved Meteosat disk. Together, this paves the way to a fully global assessment of site-specific spatial representativeness

IAMAS (Meteorology)

M16p - M16 Radiation in the Climate System

M16p-496

Projections of long-term changes in solar radiation based on CMIP5 models and their influence on energy yields of photovoltaic systems

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Traditionally, for the planning and assessment of solar energy systems, the amount of solar radiation incident on the Earth's surface is assumed to be constant. However, with changing climate and air pollution levels, solar resources may no longer be stable over time. Here we examine the latest climate model projections of future changes in surface solar radiation, and how this may affect, in combination with global warming, power output from photovoltaic (PV) systems. For this purpose, projections up to the mid 21th century from 39 climate models from CMIP5 are analysed globally and for selected key regions. The large model ensemble allows to assess the degree of consistency of their projections. Models are largely consistent in the sign of the projected changes in solar radiation under cloud-free conditions as well as in surface temperatures over most of the globe, while still reasonably consistent over a considerable part of the globe in the sign of changes in cloudiness and associated changes in solar radiation. A first order estimate of the impact of solar radiation and temperature changes on energy yields of PV systems under the RPC8.5 scenario indicates statistically significant decreases in PV outputs in large parts of the world, but notable exceptions with positive trends in parts of Europe and the South-East of China. Projected changes between 2006 and 2049 under the RCP8.5 scenario overall are on the order of 1 % per decade for horizontal planes, but may be larger for tilted or tracked planes as well as on shorter (decadal) timescales.

Reference

Wild, M, Folini, D., Henschel, F., Fischer, N., Müller, B. 2015: Projections of long-term changes in solar radiation based on CMIP5 climate models and their influence on energy yields of photovoltaic systems, submitted.

IAMAS (Meteorology)

M16p - M16 Radiation in the Climate System

M16p-497

The energy balance over land and oceans: An assessment based on direct observations and CMIP5 climate models

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The energy budgets over land and oceans are key determinants of terrestrial and maritime climates. However, these budgets are still afflicted with considerable uncertainties, particularly at the surface. We combine a comprehensive set of radiation observations from GEBA and BSRN with 43 state-of-the-art climate models from CMIP5 to infer best estimates for present day annual mean downward solar and thermal radiation averaged over land and ocean surfaces, together with their uncertainty ranges. Over land, where most direct observations are available to constrain the surface fluxes, we obtain 184 and 306 Wm-2 for solar and thermal downward radiation, respectively. Over oceans, with weaker observational constraints, corresponding estimates are around 185 and 356 Wm-2. Considering additionally surface albedo and emissivity, we infer a surface absorbed solar and net thermal radiation of 136 and -66 Wm-2 over land, and 170 and -53 Wm-2 over oceans, respectively. The surface net radiation is thus estimated at 70 Wm-2 over land and 117 Wm-2 over oceans, which may impose additional constraints on the poorly known sensible/latent heat flux magnitudes, estimated here near 32/38 Wm-2 over land, and 16/100 Wm-2 over oceans. Estimated uncertainties are on the order of 10 and 5 Wm-2 for most surface and TOA fluxes, respectively. By combining these surface budgets with satellite-determined TOA budgets from CERES/EBAF we quantify the atmospheric energy budgets as residuals (including ocean to land transports), and revisit the global mean energy balance.

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IAMAS (Meteorology)

M16p - M16 Radiation in the Climate System

M16p-498

Anthropogenic aerosol dimming over sea surfaces: mixed layer ocean experiments from 1870 to 2000

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Sea surface temperature (SSTs) changes are known to affect precipitation patterns. However, it is still debated, whether anthropogenic aerosols can affect SSTs.
To influence SSTs, anthropogenic aerosols need to reduce incoming surface solar radiation (SSR) through direct or indirect effects for a sufficiently long time span over a sufficiently large area. To quantify the maximum potential SST response to anthropogenic aerosol dimming over the past decades, we perform equilibrium experiments with the general circulation model, ECHAM and explicit aerosol representation (ECHAM6-HAM2.2) and a mixed-layer ocean (MLO). Each experiment is conducted over 50 years (first 10 years are discarded). We let the system equilibrate to the conditions (aerosol and greenhouse gas burdens, GHG) of one specific year. This way, be generate three sets of equilibria from 1870 to 2000: One set with GHG and anthropogenic aerosols set to the respective decade, one set with GHG levels held constant at 1850s levels, and one set with anthropogenic aerosol emissions held constant at 1850s levels. Deep ocean heat fluxes are prescribed based on the surface energy flux climatology derived from an atmosphere-only integrations with pre-industrial (year 1850) conditions for aerosols and GHG and climatological SSTs (average of Hadley Center SSTs, observation based, covering the years 1871-1900).
Findings will be discussed and put in context with transient experiments with prescribed SSTs. They are part of a project aiming at quantifying the effect of anthropogenic aerosols on SSTs and provide a basis for future experiments using a dynamic ocean model to quantify the transient response of the ocean to anthropogenic aerosol dimming.

IAMAS (Meteorology)

M16p - M16 Radiation in the Climate System

M16p-499

Dimming over the oceans: Transient anthropogenic aerosol plumes in the 20th century

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Anthropogenic aerosols reduce incoming surface solar radiation (SSR), but the magnitude of this effect for reducing sea surface temperature (SST) is still debated. Using simulations from the global climate model ECHAM5 with the Hamburg Aerosol Module (HAM) and prescribed SSTs, we quantify anthropogenic aerosol dimming over sea surfaces by comparing ensembles, which only differ in anthropogenic aerosol emissions. We isolate the anthropogenic aerosol effect on SSR with sufficiently large ensemble sizes to provide statistically significant results. The following simulation results are obtained: Dimming plumes extend from their source regions with clear seasonality. The latter is predominantly shaped by atmospheric circulation, while interdecadal changes follow the gradual increase in anthropogenic aerosol emissions. Comparing the 1990s with the 1870s, on average, 9.4% (clearsky SSR) or 15.4% (allsky SSR) of the entire ocean surface was affected by anthropogenic aerosol dimming larger than −4 W m^{-2} (annual mean). Comparing the same time periods, global average anthropogenic dimming over oceans is −2.3 W m^{-2} and −3.4 W m^{-2} for clearsky and allsky SSR, respectively. Surface dimming is hemispherically asymmetrical with stronger Northern Hemispheric dimming by 2.3 W m^{-2} and 4.5 W m^{-2} for clearsky and allsky SSR, respectively. Zonal average clearsky dimming reaches its maximum (5.5 W m^{-2}) near the Equator. Allsky dimming peaks at 40°N (−8 W m^{-2}) and is regionally larger than clearsky dimming. Regionally, surface dimming can go beyond −20 W m^{-2} (clearsky) and −40 W m^{-2} (allsky). Results are a contribution towards better quantifying spatially heterogeneous and time-dependent anthropogenic dimming effects on SSTs.

IAMAS (Meteorology)

M16p - M16 Radiation in the Climate System

M16p-500

Study on the effect of volcanic aerosol at Mt. Baekdu on East Asian climate in simulation of GloSea5

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Aerosols emitted by volcanic activities reduces the solar radiation that reaches the earth's surface by scattering the light of the sun in the stratosphere, which results in the cooling effect of the atmosphere. Mt. Baekdu, located at the border of China and North Korea, is a dormant volcano which recently has high possibility of eruption. The eruption is expected as strong as Pinatubo, and therefore, it's attracting many academic interests.
In this study, we examined the effect of the volcanic aerosols on the climate of East Asia through the experiment assuming the artificial Mt. Baekdu's eruption. Model used in this experiment was GloSea5 that is developed by UK Met office and used in Korea Meteorological Administration (KMA) for seasonal prediction. The atmospheric model has the spatial resolutions of 432×325 (0.83°×0.56°) horizontally and the 85 vertical levels (model top is about 85km, which includes the most part of the mesosphere). In order to investigate the influence of the volcanic activity, it was assumed that the sulfur dioxide corresponding to the eruption of Pinatubo was emitted. During the model integration, all the forcings such as greenhouse gases, sea surface temperature, sea-ice, etc. were fixed to the climatological values. Initial conditions were generated using the random perturbation method for 10 ensemble member runs. Also, all eruptions were assumed to occur at the location of Mt. Baekdu on the 11th day after the integration started. The results in this study were from the ensemble mean among the 10 members, and also the differences between the experiments and the control run, in which no eruption, occurred were used to show the impacts of sulphate aerosols on the climate of the East Asia.

IAMAS (Meteorology)

M16p - M16 Radiation in the Climate System

M16p-501

Evaluations of anvil radiative forcing in tropics

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The presences of anvil clouds significantly affect the tropical mean radiation budget and this can increase the uncertainty of climate model simulations. In this study, the distributions of thick anvil in the Tropics (20°S −20°N) are investigated by merging data sets of the Tropical Rainfall Measuring Mission's (TRMM) Precipitation Radar (PR) and Visible and Infrared Scanner (VIRS) from 1998 to 2007. Then, the thick anvil radiative forcings at shortwave and longwave length, i.e. SRF and LRF, and their net effects at different altitude are simulated with Santa Barbara DISORT Atmospheric Radiative Transfer Model (SBDART) based on parameters, e.g., anvil top and bottom detected by PR, cloud effective radius and cloud optical depth retrieved with the method of bispectral reflectance of VIRS. The results show that upward SRF are positive warming while upward LRF are negative cooling at TOA. Meanwhile, downward SRF and LRF are negative cooling and positive warming at surface, respectively. Generally, the net effects of anvil radiative forcings cause a cooling of the Earth surface at daytime. In addition, land-ocean differences of net effects at SRF and LRF for anvils exist significantly and these differences vary with different geographical locations in Tropics.

IAMAS (Meteorology)

M16p - M16 Radiation in the Climate System

M16p-502

Development of an aerosol retrieval algorithm for satellite remote sensing, and its application to GOSAT/CAI imager data

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Aerosol is an important atmospheric constituent for determining the earth's radiation budget, especially perturbation by the human activity, so accurate aerosol retrievals from satellite is useful. We have developed a new satellite remote sensing algorithm to retrieve the aerosol optical characteristics using multi-wavelength and multi-pixel information of satellite imagers (MWP method), and directly combining with the radiation transfer calculation, Rstar (Nakajima and Tanaka, 1986, 1988), numerically solved by each iteration step of the non-linear inverse problem, without using Look Up Table with several constraints. Retrieved parameters are aerosol optical thickness (AOT) of fine and coarse mode, a volume soot fraction in fine mode particles, and surface albedo of each observed wavelength. We simultaneously retrieve all the parameters that characterize pixels in each of horizontal sub-domains consisting the target area. Then, we applied this algorithm to GOSAT/CAI. The sensor has a characteristic band at wavelength 380nm, whose land surface reflectance is low and that is useful to distinguish aerosol from cloud by aerosol absorbing property. It is necessary over ocean to correct the observed radiance because of water leaving radiance. We added a process of radiative transfer in water including chlorophyll fluorescence (Ota et al., 2009) into Rstar (done by Morimoto). We compared retrieved and surface-observed AOTs at the closest pixel to AERONET or SKYNET sites, and retrieved AOTs were in agreement with surface-observed ones within ±0.07 in urban area. Retrieved AOTs over ocean were positively correlated with those derived from GOSAT/CAI by 2-channel method. Our future work is to extend the algorithm for other satellites such as GOSAT-2/CAI2 and GCOM/C-SGLI.

IAMAS (Meteorology)

M16p - M16 Radiation in the Climate System

M16p-503

Aerosol and radiation

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Aerosol modulates the Earth's energy flow by modifying properties of clouds (indirect effect) and by aerosol radiative properties (direct effect). Even though this aerosol direct radiative impact is generally small, compared to that of clouds, a significant fraction (ca 30%) of today's aerosol optical depth (a measure for aerosol column amount) is considered anthropogenic. Thus, changes in aerosol are an important factor in climate change studies. However, due to (1) highly variable aerosol properties, (2) many aerosol inter-connections to other atmospheric properties and (3) difficult to capture aerosol changes over time, aerosol has remained a joker in climate research.

Based on a monthly gridded climatology of aerosol optical properties, which is strongly tied to today's observations, global distributions of today's aerosol radiative effects are presented. This includes estimates of the aerosol radiative forcing (the aerosol radiative effects at the top of the atmosphere under all-sky conditions). for today and via scaling with data from global modeling also for past and future times.

IAMAS (Meteorology)

M16p - M16 Radiation in the Climate System

M16p-504

Assessment of clear-sky solar radiation in WRDC surface observations and in IPCC-AR5/CMIP5 GCMs

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Variations in clear-sky radiation indicate the changes of the radiatively active components in the atmosphere apart from clouds. This aspect is considered more and more relevant in order to enhance climate modelling and to understand the changes in the climate system. This study aims to assess the clear-sky radiation based on surface observations at 26 stations in Europe for the period 1965-2012. This data is then compared to the outputs of more than 40 GCMs from IPCC-AR5/CMIP5, in order to evaluate how well GCMs reproduce clear-sky radiation over Europe. In the first part of the study clear-sky data are derived from daily surface solar radiation data obtained from the Word Radiation Data Center (WRDC). The cloudy and cloud-free situations are separated using an empirical threshold-optimizing method. The thresholds between cloudy and cloud-free days are defined in three ways: 1) as the ratio of the surface solar radiation to the extraterrestrial solar irradiation, 2) the percentage between the measured data and the climatology of clear-sky radiation calculated by the MAGIC radiation code, and 3) the amount of clouds in oktas corresponding to the measured surface solar radiation. To decide which of these three definitions gives optimum results, we apply them as well as the high time resolution clear sky detection by Long and Ackermann (2000) to high quality data from the Baseline Surface Radiation Network (BSRN) and compare results. In the second part of the study, clear-sky radiation data collocated with the observation stations are extracted from the gridded GCM outputs using spatial interpolation. Then consistency between modeled and empirically derived clear-sky data (biases, trends, spatial variability) is quantified and evaluated.

IAMAS (Meteorology)

M16p - M16 Radiation in the Climate System

M16p-505

Importance of the direct radiative effect of aerosols in numerical weather prediction for the European region

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Aerosol feedbacks are becoming more accepted as physical mechanisms that should be included in numerical weather prediction models in order to improve the accuracy of the weather forecasts. Many numerical weather prediction models use climatological distributions of aerosols to account for the average impact of aerosols. However, this is insufficient for cases where aerosol concentrations are high. This study focuses on the direct radiative effect of aerosols in Europe.

The default set-up of the HARMONIE (Hirlam Aladin Research for Mesoscale Operational Numerical Weather Prediction in Euromed) model uses a monthly aerosol climatology. The direct radiative effect of this aerosol climatology, and the more realistic MACC IFS reanalysis, is investigated using the HARMONIE model in order to determine whether an up-to-date climatology or real-time aerosols will improve forecasts by HARMONIE.

The direct radiative effect of near real-time aerosols is shown to improve the accuracy of simulated radiative fluxes. In addition, forecasts of near surface air temperatures show better agreement with observations for cases where aerosol concentrations are high, when the direct radiative effect of aerosols is included. However, the effect on large scale atmospheric dynamics in Europe is weak, even when aerosol concentrations are high.

IAMAS (Meteorology)

M16p - M16 Radiation in the Climate System

M16p-506

Correction and homogenization of BSRN radiation records using updated calibrations from the World Standard Group of short- and longwave radiometers

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The objective of our study is to correct and homogenize the ground-based radiation records of the Baseline Surface Radiation Network (BSRN). The unique BSRN archive holds the world's most accurate radiation data which are used by research communities around the globe to validate satellite products and climate model outputs. Recent measurements with newly developed high precision ground-based radiometers have demonstrated, however, that corrections by up to 5 Wm-2 of the World Standard Groups of short- and long-wave radiation hosted by the World Radiation Center in Davos are required. Since most of the BSRN data are traceable to these reference groups, the BSRN data will also need to be corrected and re-calculated. Such a correction is undoubtedly a sensitive and difficult issue, and requires a thorough re-analysis of raw data from BSRN and the World Standard Groups using ancillary information on the current state of the atmosphere.

The foreseen modifications to the short- and long-wave WSGs have profound implications on all networks including the BSRN archive and therefore on satellite-based surface fluxes, climate models and global surface radiation budget studies. The commission for instruments and methods of observations (CIMO) proposed that Task Teams should be established: 1) to assess the consequences of a change in solar/terrestrial reference scales with regard to BSRN, 2) to make recommendations for a modification of the current references, and 3) to propose methods on how to deal with old BSRN data.

In this study we will give an overview of the above-mentioned tasks to be performed in the next several years and current progress.

IAMAS (Meteorology)

M16p - M16 Radiation in the Climate System

M16p-507

"A climatology of cloud optical depth in the central Mediterranean (Lampedusa) based on surface solar radiation"

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Clouds are a major modulator of surface solar radiation playing a significant role for weather and climate. Their radiative effects are strongly dependent on their optical properties. The knowledge of the cloud optical thickness (COT), in particular, is necessary for the assessment of cloud influence on the radiative budget and climate. In the present study, an effort is made to derive a climatology of COT for the island of Lampedusa, in the central Mediterranean (35.5°N, 12.6°E) from long-term surface solar radiation measurements. First, a cloud-screening algorithm has been applied to the surface solar irradiance measurements to exclude cloud-fee periods. Cloud-free intervals have been identified based on co-located measurements of the global and diffuse irradiances and their time variability obtained with a Multi Filter Rotating Shadowband Radiometer (MFRSR). The irradiances measured in cloud-free periods were used to obtain a reference curve for pristine conditions for each season of the year. The theoretical cloud-free surface solar radiation curve has been used in an empirical algorithm in combination with the surface solar irradiance measurements to estimate the cloud optical thickness and its daily average .The derived climatology of COT has been compared with corresponding satellite retrievals from the MODIS instruments onboard the Terra and Aqua satellite, and with Total Sky Images on the ground. A good agreement with MODIS retrieval is obtained at the overpass time. The seasonal and daily evolution of COT at Lampedusa is discussed.

IAMAS (Meteorology)

M16p - M16 Radiation in the Climate System

M16p-509

Impact of central European cities emissions on the regional climate

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The radiative impact of chemical changes triggered by the emissions from central European cities is examined. The emissions of short lived gases and aerosols (non-CO2) is considered only. A coupled modeling system with two way interactions consisting of the regional climate model RegCM (version 4.2) and the chemistry transport model CAMx (version 5.4) was implemented on a 10 km x 10 km resolution domain. For the period of 2001-2010 several experiments were performed: one with urban emissions removed, one with urban emissions included and one having these emissions scaled by a certain factor. The radiative (climate) impact is evaluated as the difference between the scaled experiment and the experiment without city emissions, divided by this factor. This choice was important to obtain statistically significant results. The linearity of the chemical response is examined to justify this approach. In the radiation calculations, the effects of tropospheric ozone, primary (black and organic carbon) and secondary inorganic aerosols (sulfates and nitrates) are taken into account including the 1st and 2nd indirect aerosol effect. Evaluating the radiative impacts, we found that the total effect on 2 m temperature over central Europe is characterized by small but statistically significant summer cooling up to -0.015 K as the 2001-2010 average. Further the impact on radiative fluxes, precipitation, PBL height and wind speed is presented as well.

IAMAS (Meteorology)

M16p - M16 Radiation in the Climate System

M16p-510

Quasi real-time analysis of Solar radiation using Geostationary Satellite HIMAWARI-8/AHI.

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Clouds has strongly influence on the Earth's radiation budget and the climate. Clouds can cool the Earth by reflecting solar radiation but also maintain warmth by absorbing and emitting terrestrial radiation. Cloud activity is complex because its connect to water cycle, aerosols, and other climatic components with feedback. Thus it is important to estimate the radiation budget and influence of cloud based on observations for better understanding of climate. Geostationary satellite is useful for estimate the radiation budget at the TOA and surface. It is suitable for observations of clouds and aerosols with high temporal resolution. Japanese geostationary satellite HIMAWARI-8 is launched on 2014 October 07. Advanced Himawari Imager (AHI) has sixteen channels that five visible channels, two near-infrared channels and ten thermal infrared channels. AHI will provides the detailed information of clouds and aerosols as the geostationary satellite observation of a new generation (10min wide area observation and 2.5min regional rapid scan).
We develop high-speed algorithm for estimate the Solar radiation using HIMAWARI-8/AHI data. EXAM SYSTEM [Takenaka et. al.,2011] has been extended for HIMARARI-8/AHI. It will apply the detailed cloud optical properties by CAPCOM [Nakajima and Nakajima,1995; Kawamoto et.al.,2001]. High-speed algorithm allows a Quasi-real-time analysis of Solar radiation.
Solar radiation is the only energy source on the earth’s climate. As one of the basic parameters, it is widely used in many fields. Especially, the field of Renewable energy has a possibility of progress. We try to semi-real-time monitoring of Photovoltaic power generation by Solar radiation analysis. It is new-innovative collaboration of Renewable energy and Climate study.

IAMAS (Meteorology)

M16p - M16 Radiation in the Climate System

M16p-511

MAX-DOAS technique in the analysis of the vertical distribution of aerosols in São Paulo/Brazil, incorporating data from a LIDAR system

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MAX-DOAS measurements performed at different geometries under cloud-free conditions at São Paulo-SP/BR (-23.55o,-46.73o) were analyzed. The measurements comprised spectral radiances in the 339.54 to 1046.43 nm interval at 0.345 nm resolution. A spectral fitting was applied to the data, based on Beer's Law and taking into account all absorbing gases in a given spectral region. As a result, the differential slant column density (DSCD) was estimated, i.e. integrated concentrations along the effective radiation path of a given atmospheric trace gas. In the present work, O 4 dimmer was analyzed to retrieve aerosol information, since its vertical profile is almost constant throughout the day and its absorption bands are very well defined in the visible spectral region. For each geometry of observation, Differential Air Mass Factor simulations (DAMF) using SCIATRAN code were performed incorporating the aerosol vertical profiles obtained by a Raman and elastic LIDAR system operating at 355nm near the measurement site. At first, we prescribed the urban aerosol optical model proposed by WMO, available in the SCIATRAN library and compared with a manual parameterization, using as input the asymmetry factor, single scattering albedo and Ångström exponent, from climatological data for the city of São Paulo based on AERONET. With the simulated DAMF and the measured DSCD, the values of vertical column density (VCD) were calculated. The results showed agreement with values of O4 VCD of about 1200x1043 molecule2/cm5 and similar at different observation geometries.

IAMAS (Meteorology)

M16p - M16 Radiation in the Climate System

M16p-512

Return glider radiosonde to measure temperature, humidity and radiation profiles through the atmosphere

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Very promising radiation profile measurements through the atmosphere were made in 2011 with a balloon borne short- and longwave net radiometer. New and improved radiation sensors from Kipp&Zonen are now used in a glider aircraft together with a standard Swiss radiosonde from Meteolabor AG. This new return glider radiosonde (RG-R), is lifted up with double balloon technique to prevent pendulum motion and to keep the radiation instruments as horizontal as possible during the ascent measuring phase. The RG-R is equipped with a release mechanism and an autopilot that allows to return the radiosonde to the launch site, or to land it on predefined open space, which makes the landing saver and the recovery much easier. The return glider radiosonde technique as well as new measurement possibilities will be shown. First measurements show temperature, humidity and radiation profiles through the atmosphere up to 30 hPa (24 km) during different atmospheric conditions. Radiation profiles during different daytimes show possibilities with respect to temporal resolution of vertical radiation profiles trough the atmosphere.

IAMAS (Meteorology)

M16p - M16 Radiation in the Climate System

M16p-513

Impact of four-stream radiative transfer algorithm on aerosol direct radiative effect and forcing

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Large uncertainties remain in the estimation of aerosol direct radiative effect (DRE) and forcing (DRF). In this work, using an aerosol-climate model with two- and four-stream radiation schemes, we show that the radiative transfer algorithms contribute to the uncertainties. Aerosol shortwave DREs and heating rate are underestimated significantly by the two-stream algorithm. For present-day conditions, the four-stream algorithms are found to enhance global annual mean aerosol shortwave DREs by more than 8% (14%) at the top of the atmosphere (TOA), 15% (18%) in the atmosphere, and 12% (15%) at the surface for all-sky (clear-sky) case. The regional-averaged relative differences in aerosol shortwave DREs between the two- and four-stream algorithms increase as latitude increases, exceeding 25% at the TOA and 30% at the surface in the high latitudes of the Southern Hemisphere. The DRE differences due to the four-stream algorithms are negative, except for the Arctic, Tibetan Plateau, Arabia, and Sahara, at the TOA, are positive in the atmosphere, and are negative at the surface, with the maximum exceeding 4.0 W m^{-2}. Increases in aerosol shortwave heating rates due to the four-stream algorithms are generally more than 10% and may even exceed 100%. Our results also show that the two-stream algorithm underestimates the DRFs due to anthropogenic aerosols. Significant underestimation appears in the middle latitudes of the Northern Hemisphere, with the maximum being close to the quantity of 0.6 W m^{-2} for clear-sky case. This study indicates that a multi-stream radiative transfer algorithm is necessary to reduce the uncertainties of aerosol DREs and DRFs estimated by global climate models.

IAMAS (Meteorology)

M18a - M18/M17 Past Climate Changes: a Key for the Future / Science of Adaptation to Climate Change

IUGG-1561

Strong chemistry-climate feedbacks in the Pliocene

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The Pliocene epoch was the last sustained interval when global climate was significantly warmer than today, but has been difficult to explain fully based on the external forcings from atmospheric carbon dioxide and surface albedo. Here, we use an Earth system model to simulate terrestrial ecosystem emissions and atmospheric chemical composition in the mid-Pliocene (about 3 million years ago) and the preindustrial (~1750s). Tropospheric ozone and aerosol precursors from vegetation and wildfire are ~50% and ~100% higher in the mid-Pliocene due to the spread of the tropical savanna and deciduous biomes. The chemistry-climate feedbacks contribute a net global warming that is +30-250% of the carbon dioxide effect, and a net aerosol global cooling that masks 15-100% of the carbon dioxide effect. These large vegetation-mediated ozone and aerosol feedbacks operate on centennial to millennial time scales in the climate system and have not previously been included in paleoclimate sensitivity assessments.

IAMAS (Meteorology)

M18a - M18/M17 Past Climate Changes: a Key for the Future / Science of Adaptation to Climate Change

IUGG-2726

Assessing Late Pliocene warming and climate variability with multi-proxy data and climate model simulations

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The Late Pliocene, 3.6–2.6 million years ago, is an accessible geological interval to understand climate processes of a warmer world. We synthesised a global data set of confidence-assessed, proxy-based surface temperature estimates and vegetation reconstructions to assess the ability of eight global climate models to simulate warm climates of the Pliocene Epoch. We show that model-predicted terrestrial and sea surface temperatures reveal a substantial cold bias in the Northern Hemisphere high latitudes. Particularly strong data–model mismatches of mean annual temperatures exist in northern Russia (up to 18°C) and the North Atlantic. Our model sensitivity tests identify insufficient temporal constraints and age resolution hampering the accurate configuration of model boundary conditions as an important factor impacting on data-model discrepancies. Our data-model comparison highlights the need for high resolution studies to further understand the mechanism and variability of climate in a warmer world. To increase the number of high-resolution records, we started a new multi-proxy research project at Ocean Drilling Program (ODP) Site 642, located on the Vøring Plateau in the Norwegian Sea. Our approach combines terrestrial and marine palynology, geochemistry and isotope studies to produce a high resolution reconstruction of Pliocene marine and terrestrial environmental change for selected time slices.

IAMAS (Meteorology)

M18a - M18/M17 Past Climate Changes: a Key for the Future / Science of Adaptation to Climate Change

IUGG-3352

Impact of seaways on AMOC strength during mid-Pliocene

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The mid-Pliocene warm period (mPWP, 3.264 to 3.025 Ma) is a recent warm geological period that shares similarities with predictions of future climate. It is generally thought that the mid-Pliocene Atlantic Meridional Overturning Circulation (AMOC) must have been stronger to explain the weak Atlantic meridional $\delta^{13}C$ gradient and pronounce northern high-latitude warming. In the Pliocene Model Intercomparison Project phase I (PlioMIP I), the mPWP was simulated by eight state-of-the-art coupled climate models. None of them simulates a strong mid-Pliocene AMOC as suggested by proxy studies. Rather, there is no consistent increase in the maximum AMOC strength among the PlioMIP simulations. The only consistent change in AMOC is a shoaling of the overturning cell, and less North Atlantic Deep Water (NADW) at depth in the basin. Furthermore, the simulated mid-Pliocene northward heat transport in the Atlantic is similar to that in the pre-industrial. These climate simulations suggest that the high-latitude mid-Pliocene warming does not require increased northward ocean heat transport associated with the stronger AMOC, and the weak $\delta^{13}C$ gradient can be explained by increased ventilation and reduced stratification in the Southern Ocean. One consideration is that the PlioMIP I experiments use present conditions for seaways. In reality, the Central American Seaway was open, the Indonesian Seaway was wider, the Bering Strait was closed, and the Greenland-Scotland ridge was deeper during the Pliocene. These changes in seaways likely influence AMOC intensity. In this study, we use the NorESM-L, the model that took part in PlioMIP I, to investigate if these changes in seaways could intensify the AMOC strength and the warming in the high-latitude North Atlantic during the mid-Pliocene.

IAMAS (Meteorology)

M18a - M18/M17 Past Climate Changes: a Key for the Future / Science of Adaptation to Climate Change

IUGG-3687

Towards Greenland Glaciation: Cumulative or abrupt transition ?

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During the mid-Pliocene warming period (3-3.3 Ma BP), global annual mean temperature is warmer by 2-3 degree than pre-industrial. Greenland ice sheet volume has a 50% reduction compared to nowadays [Haywood et al. 2010]. Yet around 2.7-2.6 Ma BP, just ~0.5 Ma after the warming peak of mid-Pliocene, there is already a major culprit of the full Greenland Glaciation [Lunt et al. 2008]. How does Greenland ice sheet evolve from a half size to a glaciation level during 3 Ma – 2.6 Ma?

Data show that there is a decreasing trend of atmospheric CO2 concentration from 3 Ma to 2.6 Ma [Seki et al.2010; Bartoli et al. 2011]. However, a recent study [Contoux et al. 2014] suggests that a lowering of CO_2 is not sufficient to initiate a perennial glaciation on Greenland and must be combined to low summer insolation, to preserve the ice sheet during insolation maximum, suggesting a cumulative process.

In order to diagnose whether the ice sheet build-up is an abrupt event or an accumulative process, we carry on, for the first time, a transient simulation of climate and ice sheet evolution from 3 Ma to 2.6 Ma. This strategy enables to investigate waxing and waning of the ice sheet during several orbital cycles. To reach this goal, we use a tri-dimensional interpolation method designed by Ladant et al. (2014) which combines the evolution of CO2 concentration, orbital parameters and sizes of Greenland ice sheet in an off-line way by interpolating snapshots simulations results. Thanks to this new method, we build a transient like simulation through asynchronous coupling between GCM and ice sheet model. With such method, we may consistently answer the question of the build-up of Greenland: abrupt or accumulative process.

IAMAS (Meteorology)

M18a - M18/M17 Past Climate Changes: a Key for the Future / Science of Adaptation to Climate Change

IUGG-3914

The non-analogue nature of Pliocene temperature gradients

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The strong warming of the North Atlantic and high latitudes in the Pliocene (5.3 – 2.6 million years ago) continually fails to be simulated in climate model simulations. Being the last period of Earth history with higher global temperatures and carbon dioxide levels similar to today, the Pliocene is probably the best palaeoclimate analogue of a world with CO_2 at 400 ppm in the atmosphere. Hence it is an important target period for palaeoclimate models. One of the key features of the Pliocene climate is the reduced meridional gradients, particularly in the high latitudes of the Northern Hemisphere. Here we show that previously unconsidered palaeogeographic changes in the North Atlantic region can produce significant sea surface temperature (SST) responses at high latitudes, and significantly decrease equator to pole temperature gradients in the Atlantic Ocean. These palaeogeographic forcings show that the large Arctic warming and significantly reduced temperature gradients in the Pliocene may not be analogous to future warming and that careful consideration of all the possible climatic forcings are required to accurately simulate Pliocene climate.

IAMAS (Meteorology)

M18b - M18/M17 Past Climate Changes: a Key for the Future / Science of Adaptation to Climate Change

IUGG-2920

Simulation of Quaternary glacial cycles

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In spite of significant progress achieved in recent decades in understanding of Quaternary climate dynamics, there are still a number of important questions remained to be answered. Among them is the question of whether glacial cycles are deterministic and solely externally forced. Another important question about the role of CO2 in Quaternary climate variability. To address these questions we used the Earth system model of intermediate complexity CLIMBER-2 which incorporates all major components of the Earth system – atmosphere, ocean, land surface, northern hemisphere ice sheets, terrestrial biota and soil carbon, aeolian dust and marine biogeochemistry. Using the same model version, we performed a large set (30) of simulations covering the entire Quaternary (3 million years). By starting the model at different times (with the time step of 100,000 years) and using identical initial conditions we run the model for 500,000 years using the Earth's orbital variations as the only prescribed radiative forcing. We show that within less than 100,000 years after the beginning of each experiment the modeling results converge to the same solution which depends only on the orbital forcing and lower boundary conditions. The latter include distribution of land, surface elevation and distribution/thickness of terrestrial sediments. By using only three sets of the Northern Hemisphere orography and sediment thickness, we are able to reproduce all major regimes of Quaternary long-term climate variability. Our results thus strongly suggest that Quaternary glacial cycles are externally forced and deterministic.

IAMAS (Meteorology)

M18b - M18/M17 Past Climate Changes: a Key for the Future / Science of Adaptation to Climate Change

IUGG-4251

Lessons for the future from a past warm period, ocean oxygen content and carbon biogeochemistry in deep time

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Future physical climate prediction has benefitted hugely from climate models' validation with recent observed meteorological data. For carbon cycling, this is complicated by the timescales involved because it occurs on periods which are orders of magnitude slower. This study evaluates simulations using the HadCM3L model as well as proxy data from the Latest Cretaceous. The model is run with both physical and biogeochemical components enabling the study of coupled oxygen and carbon cycles and a dynamic ecosystem model gives distributions of both phytoplankton and zooplankton throughout the global ocean.

Compared to the present day, the Latest Cretaceous represents a very different world, both in terms of its atmospheric composition and in its continental configuration. Levels of atmospheric CO2 for example were higher than today's resulting in a perturbed climatology. Ocean temperatures were considerably higher with altered ocean circulation patterns. The combination of these fundamental ocean properties means that in turn the biogeochemical activity was very different. Because of the fully dynamic and coupled nature of the biology and physics of this model, both surface and benthic processes can be studied in tandem without the need for qualitative inference concerning the connection between the two. Benthic oxygen concentrations for example give valuable insight into carbon burial and preservation.

This presentation aims to stimulate future collaborations between modellers and experimentalists and will also be of use for future targeted drilling cruises.

IAMAS (Meteorology)

M18b - M18/M17 Past Climate Changes: a Key for the Future / Science of Adaptation to Climate Change

IUGG-4405

Are models' simulation of modern Arctic sea ice a reliable guide to their performance simulating past or future sea ice?

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Eight general circulation models have simulated the mid-Pliocene Warm Period (mPWP, 3.264 to 3.025 Ma) as part of the Pliocene Modelling Intercomparison Project (PlioMIP). Here, we analyse and compare their simulation of Arctic sea ice, for both the pre-industrial and the mid-Pliocene. As well as being thinner and less extensive when compared to the pre-industrial simulations, the sea ice simulated by the models for the mid-Pliocene displays greater variability across the ensemble, particularly in the summer, when the model spread is more than three times larger than the rest of the year. Correlations between Pliocene Arctic temperatures and sea ice extents are almost twice as strong as the equivalent correlations for the pre-industrial simulations. It is suggested that the weaker relationship between pre-industrial Arctic sea ice and temperatures is likely due to the tuning of climate models to achieve a desired pre-industrial sea ice cover, which may also affect future predictions of Arctic sea ice. This highlights the importance of evaluating climate models via simulation of past climates, and the urgent need for more proxy evidence of sea ice in the Pliocene.

IAMAS (Meteorology)

M18b - M18/M17 Past Climate Changes: a Key for the Future / Science of Adaptation to Climate Change

IUGG-4447

Long term past and future climate sensitivity to orbital forcing

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The climate sensitivity to orbital forcing factors during Quaternary has been intensively studied. Indeed, orbitally induced glacial/interglacial cycles produced large climate shifts involving cryosphere and leading to huge sea level variations. In future long term climate predictions, the ice sheets melting will drastically change the response to orbital forcing. To explore this issue, we may first investigate the response to orbital forcing at geological time. For instance, it has been shown that in warm periods, as Cretaceous or Devonian, orbital forcing produced huge monsoon variations.

Here, we show that in a very different context (Late Miocene/Pliocene), the response to orbital forcing had also a drastic impact on climate changes, environments and hominins spread over Africa. During Tortonian [11-7 Ma], the ultimate shrinkage of a huge epicontinental sea, that extended from Eastern Europe to Western Asia, has been shown to produce major changes on Asian monsoon and triggered the onset of Sahara desert (Zhang et al, Nature 2014). But, more importantly, this shrinkage has for consequences to seriously enhance the climate response to orbital changes. Furthermore, the variation of precipitation pattern explains the occurrences of the Mega Chad Lake and vegetation development (Contoux et al, CP 2013). The discovery of Toumai (7 Ma) and Abel (3.6 Ma) around Mega Chad Lake pinpoints that hominids dispersal was driven by oscillations between wet and dry phases due to precessional forcing.

The climate response to orbital forcing is very dependent on geological context. Quaternary experienced large response to orbital forcing. Long term future

evolution of CO_2 may lead us…back to Eocene like climate; no ice sheets and completely different response to orbital forcing.

IAMAS (Meteorology)

M18b - M18/M17 Past Climate Changes: a Key for the Future / Science of Adaptation to Climate Change

IUGG-5062

Phasing of climate, sea-level, CO2, and insolation changes during the last two glacial terminations

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Although there is consensus on the role of insolation and atmospheric CO_2 concentrations in the glacial-interglacial cycles of the Pleistocene, the mechanisms driving the rapid transitions between glacial and interglacial climate states – so-called glacial terminations – remain debated. For example, the systematic occurrence of prominent millennial-scale climate reorganizations during terminations raises the possibility that these were processes central to the transition between glacial and interglacial climate states. Identifying the role of millennial-scale climate events in glacial terminations hinges on a detailed assessment of their absolute timing and of their relative phasing with respect to changes in ice volume, atmospheric CO_2 concentrations, and insolation.

I will present a new approach that we recently developed to place records of variability in climate, sea level, and CO_2 on the same, radiometrically constrained chronology across the penultimate glacial termination. This allows comparing these records with insolation changes and with the evolution of the same climate parameters during the last glacial termination. Finally, I will discuss differences and similarities between the last two glacial terminations and the implications for the debate on the mechanisms driving glacial-interglacial transitions.

IAMAS (Meteorology)

M18c - M18/M17 Past Climate Changes: a Key for the Future / Science of Adaptation to Climate Change

IUGG-0597

Geospatial technology and information and communication technology for adaptation to climate change, at Lakshadweep Islands, India

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Small Islands have specific ecosystem with spatial and temporal changes evolved due to long term change of climatic variability. There are unequivocally confirmed traction reports for the last a few decades on change in climate due to anthropogenic accelerated emissions of green house gases. Small Island ecosystem will have maximum stress due to climatic changes since such changes are beyond the ability of the existing ecosystem and human community of the Island to adapt. Existing administrative, technical and resources of these islands are to be supported with better technologies, education, and training to increase the capacity of stakeholders to stewards from extreme events and disasters due to climate change. Present study is an attempt to utilize Information and Communication Technology (ICT) as a tool in Lakshadweep islands (India) for adaptation in the scenario of global warming and accelerated sea level rise. Lakshadweep archipelago consists 36 Islands and islets (total area 32 sq.km.), scattered over Arabian sea (Latitude -8° and 13°N & Longitude- 71°and 74°E).ICT will be highly beneficial to Islanders of Lakshadweep due to high literacy and social standards. Lakshadweep islands are very small islands and ICT along with Geospatial Technology (GST) is developed for entrepreneurship and heritage industry. The height of the islands from mean sea level were measured and GeoEye image along with toposheets are applied to develop thematic maps. The high tele-density, e-literacy, ICT were utilised to develop climate change adaptation program for these tiny Islands.

IAMAS (Meteorology)

M18c - M18/M17 Past Climate Changes: a Key for the Future / Science of Adaptation to Climate Change

IUGG-1336

West African Monsoon strength modulated by Saharan dust: a look into the future from a palaeo-perspective

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The West African Monsoon plays a fundamental role in the socio-economic stability of a large part of Africa, and changes in the monsoon’s location and intensity can have a severe impact on the local populations. Climate models can successfully simulate the present-day monsoon but struggle to reproduce historical changes, such as the monsoon’s intensification during the mid-Holocene (6000 yrs BP). Understanding the reasons behind this shortcoming is an essential step in order to improve the projections of future monsoons.

This study tests whether the discrepancies between model simulations and palaeo-data for the mid-Holocene can be attributed to prescribed initial conditions. The focus is on the role of dust loading in the atmosphere. It is found that dust has a profound impact on the hydrological cycle of North Africa, and also triggers complex feedback loops with SSTs. These, in turn, are closely coupled with Sahelian precipitation. The monsoon’s duration, intensity and geographical extent are all highly sensitive to the dust loading over the Sahara: a reduction in dust typically enhances monsoonal precipitations and extends the monsoon's northernmost reach, while slightly reducing the duration of the rainy season.

Dust loadings in the Saharan region are expected to decrease strongly in the future, suggesting that an assessment of the dust’s impacts on precipitation is extremely valuable for our understanding of both the past and future climate in North Africa.

IAMAS (Meteorology)

M18c - M18/M17 Past Climate Changes: a Key for the Future / Science of Adaptation to Climate Change

IUGG-1604

The lifecycles of drought: Science, preparedness and adaptation across timescales

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Drought is a slow-onset hazard. Drought onset and demise are difficult to determine. Impacts are mostly nonstructural, spread over large geographical areas, and can persist long after precipitation deficits end. These factors hinder development of accurate, timely estimates of severity and responses. Drivers range from SST anomalies and global scale atmospheric response, through regional forcing and local land-surface feedbacks. Key climatological questions related to drought risk assessment, perception and management include how might precipitation patterns and strategies on which management systems rely, change in the future.

Effective early warning systems inform strategic responses that anticipate crises and crisis evolution across climate timescales. While such “early information” is critical for defining event onset, it is even more critical for identifying the potential for increases in severity. Form an adaptation standpoint many social and economic systems have buffers in place to respond to onset (storage, transfers and purchase of grain) but lack response capabilities as drought intensifies, as buffers are depleted. Throughout the drought lifecycle (and between events), monitoring, research and risk assessments are required to:

- Map decision-making processes and resource capabilities
- Place multiple climate and land surface indicators within a consistent triggering framework
- Identify policies and practices that impede or enable the flow of information

The presentation will outline the capabilities and framework needed to ensure improved scientific inputs to preparedness and adaptation. Lessons will be drawn from recent and ongoing events in the United States and globally to guide adaptation practices.

IAMAS (Meteorology)

M18c - M18/M17 Past Climate Changes: a Key for the Future / Science of Adaptation to Climate Change

IUGG-5293

Holocene relative sea level history and models of glacial isostatic adjustment: constraints from the regions of forebulge collapse

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Models of the glacial isostatic adjustment (GIA) process enable us to study the regular cycles of glaciation that have characterized the Earth's climate over the past 800,000 years or so. These models can be tested by comparing their predictions to many geophysical observables. Among these, past relative sea level inferences based upon appropriate geological indicators and Global Positioning System (GPS) observations of the movement of the solid Earth's surface are particularly important. In fact, these geophysical observables, depending on the region from which they originate, provide constraints on different features of the GIA process. Also, regions of forebulge collapse, which are located at the periphery of the former ice sheets, are undergoing a more complex relaxation than regions that were once under a thick ice cover.

In this paper, we examine how recently available high-quality geological data sets of relative sea level history for regions of forebulge collapse, such as that of Engelhart et al. (2011, Geology) for the U.S. East coast or Engelhart et al. (2015, Quaternary Science Reviews) for the U.S. West coast, enable us to gain critical information concerning the response of the forebulge associated with former ice sheets, and provide new constraints on both fundamental inputs pertaining to GIA models (models of mantle viscosity and of ice sheet loading history). We will first focus on how misfits between these sea-level evolution inferences and current GIA model predictions can be eliminated, and then on the deglaciation history over North America. In particular, the impact of ice sheet loading history variations will be discussed, and will prove to be especially important to maintain an appropriate fit to present-day vertical uplift over North America.

IAMAS (Meteorology)

M18p - M18/M17 Past Climate Changes: a Key for the Future / Science of Adaptation to Climate Change

M18p-514

Linear/nonlinear responses of temperature change over East China to the climate forcings in the past millennium

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We used the UVic Earth System Climate Model (UVic Model), an Earth system model of intermediate complexity, to investigate the linear and nonlinear contributions of climate forcings (e.g. solar insolation variability, anomalous volcanic aerosols, greenhouse gas, solar orbital change, land cover changes, and anthropogenic sulfate aerosols) to surface air temperature over East China in the past millennium. The simulation of the UVic Model could reproduce the three main characteristic periods (e.g. the Medieval Warm Period (MWP), the Little Ice Age (LIA), and the 20th Century Warming Period (20CWP)) of the northern hemisphere and East China, which were consistent with the corresponding reconstructed air temperatures at century scales. We examined the nonlinear responses among the natural and anthropogenic forcings in terms of surface air temperature over East China. The nonlinear responses between the solar orbit change and anomalous volcano aerosols and those between the greenhouse gases and land cover change (or anthropogenic sulfate aerosols) all contributed approximately 0.2°C by the end of 20th century. However, the output of the energy-moisture balance atmospheric model from UVic showed no obvious nonlinear responses between anthropogenic and natural forcings. The nonlinear responses among all the climate forcings (both anthropogenic and natural forcings) contributed to a temperature increase of approximately 0.27°C at the end of the 20th century, accounting for approximately half of the warming during this period; the remainder was due to the linear response of climate forcings.

IAMAS (Meteorology)

M18p - M18/M17 Past Climate Changes: a Key for the Future / Science of Adaptation to Climate Change

M18p-515

Digital island, e-governance for adaptation due to impact of climate change for small islands - Lakshadweep islands

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Climate Change and Sea level rise (SLR) is detrimental to small low lying Islands. Better governance with application of improved technological developments is inevitable for capacity development of the Island population to resolve the impact of climate change on small Islands. Recent developments in Information Technologies (IT) have major implications in the regional governance and adaptation in small Islands for livelihood security. Lakshadweep Islands, scattered in Arabian sea consist 36 Islands, Islets and Submerged banks would be worst affected, since the maximum height of these inhabited islands are less than five meter. Present study consist the application of e-Governance to develop adaptation and, if essential mitigation as a part of security measures of the Islanders. E-Governance has been initiated to improve the facilities and services for Island and Islanders namely, Lakshadweep SWAN (State Wide Area Network), e- permits system, VSAT based video conferencing services, PLANMIS Ver. 2.0, Computerisation of Public Distribution System etc. Other than the service sector, Information Technology and e- Governance is to be applied for economic development and sustainable resource utilization viz. entrepreneurships, risk management, disaster preparedness for development and distribution of non-conventional energy sources, identification distribution and conservation of fresh water aquifers and other environmental parameters. Present study is an attempt to improve the economic security and preparedness for disaster management in the eventuality of extreme events due to climate change

IAMAS (Meteorology)

M18p - M18/M17 Past Climate Changes: a Key for the Future / Science of Adaptation to Climate Change

M18p-516

Understanding Pliocene climate variability

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Here we use Hadley Centre Coupled Climate Model version 3 (HadCM3) to explore the nature of Pliocene surface temperature variability and to explore the premise that individual benthic oxygen isotope events in the Pliocene will have unique characteristics of surface temperature change caused just by variations in insolation. Firstly, we focus our attention on intervals within the mid Pliocene Warm Period (3.3 to 3 million years ago) that are characterised by negative benthic isotope excursions, and therefore are presumed to represent relatively warm "interglacial-like" events (specifically Marine Isotope Stages K1, KM5c, G17 and KM3). Secondly, we also present results from the first fully transient simulation using a full complexity climate model (FAMOUS) for the interval between the "glacial" event M2 and "interglacial" event KM3. We demonstrate how comparing model simulations that capture the effects of orbital variability with newly generated high resolution proxy records of surface temperature change can alter our current understanding of where (geographically) models perform well or poorly compared to data.

We conclude that even when considering orbital forcing alone, discrete climate events in the Pliocene were indeed characterised by unique regional signals of surface temperature change, and that broad generalisations concerning Pliocene surface temperature patterns are at best incomplete.

M18p - M18/M17 Past Climate Changes: a Key for the Future / Science of Adaptation to Climate Change

M18p-517

Impact on a future air quality for North-East Asia of Chinese future emissions changes with respect to RCP scenarios

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Future O_3 and $PM_{2.5}$ concentrations changes for North-East Asia with respect to future Chinese emissions changes have estimated using RCP (Representative Concentration Pathways) emissions scenarios for 2020s (2016~2025) and 2050s (2046~2055) in this study. The Integrated Climate and Air quality Modeling System (ICAMS) has been applied to estimate future air quality change which is consisted with HadGEM2-AO (global climate model), GEOS-Chem (global chemical transport model), MM5 (regional climate model), and CMAQ (regional climate model). The modeling system has adopted unique global-regional linking tools developed by National Institute of Environmental Research (NIER) and Seoul National University (SNU). A modeling domain coverseastern and central China, the Korean peninsula, Japan, and a part of Mongolia, and only Chinese future emissions changes have been considered with respect to RCP scenarios to estimate the impact. For other countries, past dedicate (1996~2005) emissions under RCP8.5 have been applied.

In preliminary results, O_3 and $PM_{2.5}$ concentrations were predicted to be increased resulted from increased Chinese emissions. Increase range of integrated O_3 concentration is 1.5ppb by daily maximum 8 hoursaverage under Case 4-reflect Chineseemissions under RCP2.6- to 3.4ppb under Case 1-reflect Chinese emissions under RCP8.5- and $PM_{2.5}$ is 1.1 ?/? under Case 2-reflect Chinese emissions under RCP6.0- to 2.3 ?/? under Case 4, for 2020s. For 2050s, O_3 and $PM_{2.5}$ concentrations were estimated to be decreased except for Case 2, O_3 and $PM_{2.5}$ will be increased 4.1 ppb and 3.1 ?/?.

IAMAS (Meteorology)

M18p - M18/M17 Past Climate Changes: a Key for the Future / Science of Adaptation to Climate Change

M18p-518

Impact of stratospheric ozone on surface climate in an Earth system model: the Antarctic sea ice change in mid-Holocene

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Stratospheric ozone change can influence on tropospheric climate. For example, Sigmond and Fyfe (2010) pointed out the Antarctic sea ice could increase due to the Antarctic ozone hole. However, the impact of ozone change in paleoclimate has not been investigated in detail. In most of paleoclimate experiments of CMIP5/PMIP3, the distribution of ozone is fixed to the estimated value of 1850 AD despite the ozone distribution depends on the solar radiation distribution as a function of latitude and time (season). This treatment may cause some bias to the simulation results. In this study, therefore, we examine the impacts of forecasted ozone distribution in paleoclimate experiments with an Earth system model. In this study, we focus on the Antarctic region in the mid-Holocene (6k year before present, hereafter MH) experiment.

We utilize Meteorological Research Institute Earth system model (MRI-ESM), which is a coupled model of the atmosphere-ocean-aerosol general circulation model of MRI-CGCM3 (Yukimoto et al., 2012) which was used in PMIP3 and the chemistry model of MRI-CCM2 (Deushi and Shibata, 2011). We examine the MH experiment and the preindustrial control (hereafter PI) experiment.

As results of 100-year time integrations, we obtain annual mean zonal mean temperature anomaly up to +1.7 K near the surface in the Antarctic region through the reduction of sea ice. The sea surface temperature in MH is about 0.5 K higher than that of PI. Cold bias of PMIP3 models in the South Hemisphere (Harrison et al., 2013) is corrected by using interactive ozone. This result suggests that the

ozone distribution consistent with the solar insolation in the targeted era should be used in paleoclimate simulations in order to improve the climate reconstruction in the polar regions.

IAMAS (Meteorology)

M18p - M18/M17 Past Climate Changes: a Key for the Future / Science of Adaptation to Climate Change

M18p-519

Drivers and mechanisms for enhanced summer monsoon precipitation over East Asia during the mid-Pliocene in the IPSL-CM5A

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A comparative analysis of East Asian summer monsoon (EASM) precipitation is performed to reveal the drivers and mechanisms controlling the similarities of the mid-Pliocene EASM precipitation changes compared to the corresponding pre-industrial (PI) experiments derived from atmosphere-only (i.e. AGCM) and fully coupled (i.e. CGCM) simulations, as well as the large simulated differences in the mid-Pliocene EASM precipitation between the two simulations.

The area-averaged precipitation over the EASM domain is enhanced in the mid-Pliocene compared to the corresponding PI experiments performed by both the AGCM (LMDZ5A) and the CGCM (IPSL-CM5A). The surface warming has been identified as the drivers of the mid-Pliocene EASM precipitation increase in both simulations by examining the moisture budget equation. Moist static energy (MSE) diagnosis identifies the combined effect of enhanced zonal thermal contrast and column-integrated meridional stationary eddy velocity and its convergence as the physical mechanisms that sustain the enhancement of mid-Pliocene EASM precipitation in both simulations compared to the PI experiments. This takes place through a strengthening of the EASM circulation and moisture transport into the

EASM domain associated with an increase in local moisture convergence in the mid-Pliocene in both simulations.

Moisture budget analysis and MSE are also an effective way to identify the cause and mechanism for the larger mid-Pliocene EASM precipitation increase in the CGCM compared to its AGCM component. This discrepancy of mid-Pliocene EASM precipitation between both simulations is mainly caused by warmer SST bias between CGCM and PRISM3 SST imposed in AGCM.

IAMAS (Meteorology)

M18p - M18/M17 Past Climate Changes: a Key for the Future / Science of Adaptation to Climate Change

M18p-520

Modeling MIS M2 glacial period during the early late warm Pliocene: Sensitivity experiment with shallow open Panama isthmus.

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The early late warm Pliocene (3.0-3.6 Ma) is known to have a high CO2 concentration (~400 ppmv) similar to present level, and its global climate is warmer by 2-3 degree than nowadays. However, during this warm period, a glacial MIS M2 (peak in 3.3 Ma) occurred. The reason for M2 inception is still unclear. Deep ocean sediment records show that the sea level drop between MG1 (3.32 Ma) and M2 (3.3 Ma) is estimated to ~55-77m (Miller et al. 2005, 2012). Stijn et al (2013) found that, during MG1 to M2 maximum, a shallow open Panama seaway existed, which allowed the invasion of less salty and cooler water from Pacific to Atlantic. Such invasion of water could weaken AMOC as well as the northward heat transport, finally cooled high latitude areas. In our model test (AOGCM model, IPSL_CM5A) by setting a shallow Panama seaway (width of 440 km, depth of 50 m), we observe water flow from east Pacific to Caribbean region through Panama seaway. Total water mass through this CAS (Central American Seaway) oscillates between ~4 sv and ~1-2 sv, which is positively correlated with the AMOC strength (~28 sv-~11 sv). There is no decrease of AMOC when open Panama by 50m sill depth in our model. In order to preclude the model-dependent effect, we tend to use other models to test the impact of shallow CAS on AMOC. On the other hand, we also investigate the shallow CAS sensitivity to CO2 concentration and to insolation changes to account for the results observed by Lunt et al. [2008].

IAMAS (Meteorology)

M18p - M18/M17 Past Climate Changes: a Key for the Future / Science of Adaptation to Climate Change

M18p-521

Mantle Plumes and aridity

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Development and secular behavior of the landscapes triggered by climate changes are mostly linked to the atmospheric/ hydrospheric activities -- which are relatively short time processes. However recent cross-disciplinary studies of East Africa emphasizes that much long term Afar plume induced tectonic forces have played a critical role in the climate changes in East Africa. In view of this and geophysical and geological evidences present study suggests that the origin of aridity of the Thar desert may be linked to the Reunion mantle plume through recent uplift of the old Aravalli mountain which being parallel to SW Indian monsoon does not allow precipitation of moisture over the western Rajasthan or the Thar region. These associations are strongly corroborated by the global correlation between the mantle plumes their traces (past and present) and arid zones as elucidated here Since Afar plume has been linked to the evolution from the multidisciplinary investigations in East Africa; and fine scale analyses of deep sea sediments have indicated that occurrence of mantle plumes might be periodic. In view of this the possibility of a causal connection between the long period plume activity and short period evolution/ extinction may have some interesting implications.

IAMAS (Meteorology)

M18p - M18/M17 Past Climate Changes: a Key for the Future / Science of Adaptation to Climate Change

M18p-522

Can uncertainties in sea ice albedo reconcile patterns of data-model discord for the Pliocene and 20th/21st centuries?

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General Circulation Model simulations of the mid-Pliocene warm period (mPWP, 3.264 to 3.025 Myr ago) currently underestimate the level of warming that proxy data suggest existed at high latitudes, with discrepancies of up to 11?C for sea surface temperature estimates and 17?C for surface air temperature estimates. Sea ice has a strong influence on high-latitude climates, partly due to the albedo feedback. We present results demonstrating the effects of reductions in minimum sea ice albedo limits in general circulation model simulations of the mPWP. While mean annual surface air temperature increases of up to 6?C are observed in the Arctic, the maximum decrease in model-data discrepancies is just 0.81?C. Mean annual sea surface temperatures increase by up to 2?C, with a maximum model-data discrepancy improvement of 1.31?C. It is also suggested that the simulation of observed 21st century sea ice decline could be influenced by the adjustment of the sea ice albedo parameterization.

IAMAS (Meteorology)

M18p - M18/M17 Past Climate Changes: a Key for the Future / Science of Adaptation to Climate Change

M18p-523

Heat-stress vulnerability assessment with monitoring, modeling, social survey, and E-science for health adaptation

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Increased mortality was observed on hot days worldwide in recent years. A proactive heat-stress vulnerability assessment was conducted in support of reducing health risks and formulating health adaptation strategies. This presentation showcases scientific findings from a trans-disciplinary research framework using Taiwan, a sub-tropical island, as an example. A novel two-tier heat-stress vulnerability assessment was conducted with multiple innovative facets. First, physical (heat), chemical (air pollution), and social (behavior and response capacity) aspects of vulnerability were assessed with crowdsourcing technology as well as mature methodologies in atmospheric chemistry monitoring/modeling and survey research. Secondly, both direct (heat) and indirect (air pollution) exposures due to temperature were assessed. Thirdly, taking advantages of the bottom-up and top-down approaches, a two-tier framework is adopted to examine important factors and associated physical, chemical, and social mechanisms at the community level as well as to identify the spatial distribution of vulnerable groups and areas at the national level. Fourthly, the controllable factors of exposure to heat-stress and air pollutants and those of individual and community response capacities were targeted so that the health risks can be minimized by either interrupting the exposure pathway or enhancing the response capacity of the stressed population. Lastly, the vulnerability factors studied correspond directly to the respective policy options in social and health promotion programs and heat-warning system establishment so as to facilitate the science-policy dialogue. Recommendations for health adaptation strategy were made accordingly to reduce heat-stress vulnerability.

IAMAS (Meteorology)

M18p - M18/M17 Past Climate Changes: a Key for the Future / Science of Adaptation to Climate Change

M18p-524

Empirical validation of conceptual climate models for the Mid-Pleistocene Transition

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Conceptual models are often used to model the Earth's climate since they are sufficiently simple as to allow an analysis of their fundamental structures; thereby investigating the core processes underlying the observed behavior. However, because of their high degree of simplification, they usually can only qualitatively match empirical records. Frequently, disparate models have comparable correlations with any given observation even when based on substantially different physics. Simple comparisons of model results to observations have proven insufficient to distinguish between such models; more robust model validation procedures are needed.

The study of the Mid-Pleistocene Transition (MPT) is an ideal test case for the development of such procedures. The Pleistocene era is characterized by a slow cooling trend overlain by glacial cycles - oscillations in global land-based ice volume, primarily in the northern hemisphere. These cycles transition from dominant oscillations on a 41 kyr time scale to dominant oscillations on a 100 kyr time scale. Both the character and cause of the transition between these two regimes are poorly understood. A number of conceptual models have been proposed to explain the MPT, all of which qualitatively capture the behavior of the empirical records. But they are based on different combinations of the components of the underlying physics including astronomical forcing, atmospheric carbon dioxide, deep ocean circulation, Antarctic sea ice and isostatic rebound of the bedrock under large ice sheets. We will show how modern time series analysis, such as Empirical Mode Decomposition, techniques can be used to extract and compare subtler features of the observational records and of the model outputs and thereby improve the validation of each model.

IAMAS (Meteorology)

M18p - M18/M17 Past Climate Changes: a Key for the Future / Science of Adaptation to Climate Change

M18p-525

Holocene sea level and climate change at the southern Cape coast, South Africa, as inferred from coastal lake sediment records

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Within the RAIN project (Regional Archives for Integrated iNvestigations) interdisciplinary investigations on climate evolution and environmental change in southern Africa during the Late Quaternary are being conducted. For this purpose, spatial and temporal variations of the three major rainfall zones covering South Africa (winter-, summer- and year-round rainfall zone) are being studied using both marine and terrestrial archives. Here we present results inferred from sediment records from lakes Groenvlei and Eilandvlei located on the southern Cape coast within the year-round rainfall zone.

From Eilandvlei, a brackish lake that is connected to the Indian Ocean via an estuary, a 30.5 m sediment core was recovered. Radiocarbon ages reveal a maximum basal age of about 10,000 cal BP. This ultra-high-resolution record of environmental change during the Holocene represents a unique discovery for southern Africa. Using geochemical data from this record, different phases of marine and terrestrial sediment deposition can be reconstructed. Hence, this record reflects changes in sea level, but also variations in terrestrial sediment transport and thus changing climatic conditions.

The sediment core from Groenvlei, which is not connected to the Indian Ocean, covers the past 4,200 cal BP. Sediments from this lake are predominantly composed of autochthonous carbonates. Mineralogical investigations reveal alternating deposition of calcite and aragonite/dolomite, pointing to variable Mg/Ca ratios and thus variations in lake water salinity. These changes can be linked to variations in the precipitation/evaporation ratio, and hence climate. Consequently,

the Groenvlei record indicates a trend from generally drier to wetter conditions between 4,200 cal BP and the present.

IAMAS (Meteorology)

M18p - M18/M17 Past Climate Changes: a Key for the Future / Science of Adaptation to Climate Change

M18p-526

Tropical state, ITCZ shifts, and South Pacific Split Jet during abrupt climate changes of the last glacial period

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A number of key paleoclimate records in the Southern Hemisphere midlatitudes exhibit climate changes synchronous with abrupt climate changes in the North Atlantic. We advance a hypothesis that attributes climate changes in the Southern Hemisphere to a modulation in the strength of the South Pacific Split Jet, a pronounced zonally asymmetric feature of the wintertime Southern Hemisphere westerlies. North Atlantic cooling is associated with a weaker Split Jet - characterized by weaker South Pacific subtropical and subpolar jets and a strengthened midlatitude jet. Thus, it leads to climate impacts over the South Pacific sector coincides with observed changes timed to the North Atlantic in other regions. These circulations changes are envisioned to operate in addition to the climate impacts resulting from the oceanic bipolar seesaw.

A proposed global atmospheric teleconnection links North Atlantic cooling to the weakening of the Split Jet. North Atlantic cooling induces a southward shift of the marine ITCZ. The resulting Hadley circulation change weakens the wintertime South Pacific subtropical jet, and which in turn leads to a weaker South Pacific Split Jet. A weaker Split Jet leads to a southward shift of the zero wind-stress curl line, implying a shift in the same sense for the South Pacific subtropical front. Over land, it leads to winter warming over New Zealand, winter cooling over subtropical South America, drying over Western Patagonia, and winter warming and wetting of southernmost Patagonia. Our hypothesis also predicts reduced storminess over West Antarctica. Similar changes but of opposite sign occur in the Northern Hemisphere, where a stronger wintertime North Pacific subtropical jet increases precipitation over the Western United States.

IAMAS (Meteorology)

M18p - M18/M17 Past Climate Changes: a Key for the Future / Science of Adaptation to Climate Change

M18p-527

Regional climate model assessment of the urban land-surface impact on climate over Central Europe

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When aiming higher resolution in dynamical downscaling the effects of land use and land use changes are playing increasing role. For the purpose of qualifying and quantifying the impact of cities and in general the urban surfaces on climate, the surface parameterization in regional climate model RegCM4 has been extended with the Single Layer Urban Canopy Model (SLUCM), which can be used both in dynamic scale within BATS scheme and in a more detailed SUBBATS scale to treat the surface on a higher resolution subgrid. A set of experiments was performed over the period of 2005-2009 over central Europe, either without considering urban surfaces and with the SLUCM treatment. Results show a statistically significant impact of urbanized surfaces on temperature (up to 1.5 K increase in summer), on the boundary layer height (ZPBL, increases up to 50 m).

The comparison with observational data showed significant improvement in modeling the monthly surface temperatures in summer and the models better describe the diurnal temperature variation reducing the afternoon and evening bias due to the UHI development, which was not captured by the model if the urban parameterization not used.

A further important conclusion is that statistically significant impacts are modeled not only over large urbanized areas (cities), but the influence of cities is evident over rural areas as well with rather minor but more frequent urban surfaces. We show that this is the result of the combined effect of the distant influence of surrounding cities and the influence of the minor local urban surface coverage.

Analysis of Prague options and attempts to mitigate UHI is shown as achieved in UHI project.

IAMAS (Meteorology)

M18p - M18/M17 Past Climate Changes: a Key for the Future / Science of Adaptation to Climate Change

M18p-528

Response of interglacial climate to insolation and CO2 during the past 800,000 years

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The climate of nine interglacials of the past 800,000 years has been simulated with both snapshot and transient experiments using the model LOVECLIM in response to changes in insolation and CO2 concentration. These simulations allow to investigate the relative contributions of insolation and CO2 to the intensity and duration of each interglacial as well as the differences between the interglacials at global and regional scales. The transient simulations which cover a full range of precession, obliquity and eccentricity allow to investigate the response of different climate variables at different latitudes to these three astronomical parameters. The results show that the relative contribution of insolation and CO2 on the warmth intensity varies from one interglacial to another. They also show that CO2 plays a dominant role on the variations of the global annual mean temperature and the southern high latitude temperature and sea ice, whereas, insolation plays a dominant role on the variations of monsoon precipitation, vegetation and of the northern high latitude temperature and sea ice. The past interglacials are compared to the Holocene and the near future natural climate, which allows looking for interglacial analogue for the whole Holocene and its natural future.

IAMAS (Meteorology)

M19a - M19 El NiNo / Southern Oscillation and Decadal Variability under Climate Change

IUGG-1570

Causes of Evolution Asymmetry between El Niño and La Niña

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The composite analysis of the eastern equatorial Pacific SST anomaly reveals an asymmetric evolution characteristic between El Niño and La Niña. While the composite El Niño is characterized by a rapid decay after its peak and a phase transition from a positive to a negative SST anomaly (SSTA), the composite La Niña is characterized by a weaker decay after its peak and a re-intensification of the cold SSTA in the later of the second year.

The physical mechanisms responsible for the distinctive asymmetric evolutions are investigated through a mixed layer heat budget analysis. The result shows that the faster decay of El Niño is attributed to stronger dynamic and thermodynamic damping. The former is attributed to an asymmetric low-level wind response in the western Pacific, whereas the latter is due to asymmetric cloud and latent heat flux responses. A positive SSTA in the eastern equatorial Pacific during the mature phase of El Niño induces, through local air-sea interaction processes, an anomalous anticyclone in the WNP. Easterly anomalies south of the anticyclone trigger upwelling Kelvin waves, promoting a fast transition from a warm to a cold SSTA by summer of the El Niño decaying year. Strengthened air-sea coupled instability in northern fall further amplified the cooling. In contrast, La Niña induces an anomalous cyclone west of Philippines. Because of this asymmetric wind response, the equatorial thermocline anomaly is much weaker during the La Niña decaying phase. This weak dynamic forcing effect, along with a weaker negative cloud-SST and evaporation-SST feedback, leads to a slow damping of La Niña. The negative SSTA re-develops in northern fall of the second year and leads to re-occurrence of La Niña episode.

IAMAS (Meteorology)

M19a - M19 El NiNo / Southern Oscillation and Decadal Variability under Climate Change

IUGG-2453

Importance of background seasonality in the coupled atmosphere-ocean response to westerly wind events

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A coupled atmosphere-ocean response to westerly wind events (WWEs), sometimes triggering El Nino, was investigated using a coupled general circulation model with particular attention to the dependence on location and timing of WWEs. Twelve sets of 20-member ensembles were made with an idealized pattern of WWEs imposed in different months from January to July and also in different longitude from 160E to 160W. Initial ocean states are set to be near-neutral so that the lagged response to WWEs can be isolated. The results show that the Nino3 sea surface temperature (SST) increases persistently when the WWE is imposed in May at any longitude, favorable to El Nino growth. In contrast, the WWE imposed in March acted to induce SST increase only at the easternmost equatorial Pacific. In both cases, warm subsurface water produced by the WWE propagates eastward and reaches the surface in the eastern equatorial Pacific. When forced by WWE in May, the positive SST anomaly appears in boreal summer when it can strongly interact with the atmospheric circulation and convective activity, which amplify the SST anomaly spreading toward the central equatorial Pacific. The above mechanism works conditioned by the seasonal march of the background atmosphere-ocean states, and therefore the coupled response is sensitive to timing rather than longitude of WWEs. A preferable set of their combination that maximizes the role in triggering El Nino in the subsequent winter is suggested.

IAMAS (Meteorology)

M19a - M19 El NiNo / Southern Oscillation and Decadal Variability under Climate Change

IUGG-4588

Does recent variation in Tropical Pacific seasonal forecast skill represent base state-related change in ENSO predictability, or just dumb luck?

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Recently, it has been suggested that the predictability of ENSO has changed in the last few decades in correspondence with the observed increase of central Pacific relative to east Pacific ENSO events. We investigate this issue within the context of a statistically stationary stochastically forced multivariate linear dynamical system. Using a Linear Inverse Model (LIM) constructed from observed tropical Pacific oceanic and atmospheric anomalies, it is suggested that decadal changes in realized ENSO forecast skill (for both the LIM and the forecast models of the North American Multi Model Ensemble) may also reflect variations of different precursors to ENSO events and not necessarily a change in the underlying predictability of tropical Pacific coupled dynamics. These precursors can be excited by random weather forcing and subsequently result in sea surface temperature anomaly amplification primarily through surface or thermocline feedbacks, respectively. That is, some ENSO events are inherently less predictable than others due to the relative importance of different physical processes, and periods when such events are more often randomly excited will be periods of reduced forecast skill. A contrast is also drawn with a marked change in (perfect model) tropical Pacific predictability found between two extended simulations of the NCAR CESM1 coupled model, run under fixed 1850 and 2000 radiative forcing conditions, respectively.

IAMAS (Meteorology)

M19a - M19 El NiNo / Southern Oscillation and Decadal Variability under Climate Change

IUGG-5530

Who killed the big 2014-15 El Niño (and is climate change a suspect?)

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The year 2014 started out with a bang when a series of westerly wind bursts occurred west of the date line between January and April. These wind bursts generated a series of powerful downwelling Kelvin waves that led to anomalous warming in the equatorial cold tongue of the eastern Pacific, apparently signaling the onset of an El Niño. The Kelvin waves observed in February through April 2014 were as large as those seen at the onset of the 1997-98 El Niño, the strongest on record, leading to speculation that a major event was underway. Moreover, there was broad consensus among forecast models for development of an El Niño during the second half of 2014. Thus, the scientific community and the popular press were abuzz with the prospect of climate fireworks reminiscent of 1997-98. However, the atmosphere did not immediately respond to the initial oceanic warming and the positive ocean-atmosphere feedbacks that characterize El Niño evolution did not materialize. This presentation will describe what happened in the tropical Pacific this past year, how forecasts for the event evolved with time, and whether climate change was a factor in the unexpected turn of events.

IAMAS (Meteorology)

M19b - M19 El NiNo / Southern Oscillation and Decadal Variability under Climate Change

IUGG-1681

Relative roles of the Central Pacific and Western North Pacific precipitation anomalies in El Nino teleconnection

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El Nino, the strongest interannual variability, has great global impacts via atmospheric teleconnection, but its impact is quite various among inter-El Nino events and season due to the distinct teleconnection patterns. Precipitation responses to El Nino SST are characterized by positive precipitation anomalies over the equatorial central Pacific (CP) and negative precipitation anomalies over the Western North Pacific (WNP) to a large extent. It is demonstrated here that the CP and WNP precipitation anomalies play opposite roles in leading El Nino teleconnection pattern over North Pacific. We show that different teleconnection patterns among inter-model El Nino events can be explained by considering two precipitation effects to some extent. Moreover, we found that the seasonality in El Nino teleconnection is closely related to changes in the relative magnitude of two precipitation anomalies. During early winter, the WNP precipitation effect is relatively strong so that the anticyclonic flow is observed over North Pacific, while the explosive cyclonic flow overwhelms during late winter due to relatively strong CP precipitation effects. The Linear Baroclinic Model and CMIP5 model analyses strongly support the arguments from the observational analyses.

IAMAS (Meteorology)

M19b - M19 El NiNo / Southern Oscillation and Decadal Variability under Climate Change

IUGG-2729

Water vapor transport and moisture budget over East China: Remote forcing from the two types of El Niño

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The water vapor transport and moisture budget over East China remotely forced by the cold-tongue (CT) and warm-pool (WP) El Niño show striking differences throughout the life period. The responded water vapor transport is weak in the developing summer but strong in the remaining phases of CT El Niño; while the opposite appears during WP El Niño. WP El Niño causes moisture deficit over the Yangtze River valley (YZ) in the developing summer and over Southeast China (SE) in the developing fall; while CT El Niño induces moisture surplus first over SE during the developing fall with the influent area expanded in the decaying spring and shifted northward in the decaying summer. It is the divergence of meridional water vapor transport dominates the total water vapor divergence anomaly, with that of zonal transport showing an opposite pattern but a smaller magnitude.

Investigation of the vertical profile of moisture budget shows a great barocline, with the strongest abnormal moisture budget occurring in different levels. The moisture transport via the southern boundary plays crucial roles in the regional moisture budget anomalies and it is located near the surface over SE, in the lower troposphere over the YZ, and at the lower-middle troposphere over the eastern North China. The enhanced moisture surplus near the surface forced by WP El Niño over SE in the mature winter and decaying spring is offset by a moisture deficit within the lower-middle troposphere due to diverse responded circulation in different vertical levels.

IAMAS (Meteorology)

M19b - M19 El NiNo / Southern Oscillation and Decadal Variability under Climate Change

IUGG-3201

Interdecadal change of ENSO examined by a process-based stability analysis

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Here, we performed Bjerkness Stability index (BJ index; growth rate of ENSO) analysis for two decadal periods: one before the late 1970s (nPDO period) and the other after the late 1970s (pPDO period). BJ index for the pPDO is significantly larger than that for the nPDO, and the larger BJ index is mainly due to the enhanced zonal advection feedback (ZA) and thermocline feedback (TH), and the reduced damping by mean meridional current (MD). The increase of ZA and TH is attributed to the shoaling of mean thermocline depth during pPDO, which increases the sensitivity of ocean dynamic fields to the wind forcing. The enhanced positive feedbacks are partly compensated by the enhanced thermodynamical damping (TD) including the shortwave, sensible heat flux and latent heat flux. Interestingly, change in the response of the surface winds to sea surface temperature forcing from nPDO to pPDO was small.

IAMAS (Meteorology)

M19b - M19 El NiNo / Southern Oscillation and Decadal Variability under Climate Change

IUGG-4101

Oceanic Rossby waves induced by meridional shift of Inter-Tropical Convergence Zone in association with El Niño-Southern Oscillation

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This study investigated the eastern Pacific Intertropical Convergence Zone (ITCZ) as an atmospheric forcing to the ocean by using various observed and reanalysis data sets over 29 years. Climatologically, a zonal band of positive wind stress curl (WSC) with a 10° meridional width was exhibited along the ITCZ. A southward shift of the positive WSC band during the El Niño phase induced a negative (positive) WSC anomaly along the northern (southern) portion of the ITCZ, and vice versa during the La Niña phase. This meridional dipole accounted for more than 25% of interannual variances of the WSC anomalies (WSCAs), based on analysis of the period 1993–2008. The negative (positive) WSCA in the northern portion of the ITCZ during the El Niño (La Niña) phase was collocated with a positive (negative) sea surface height anomaly (SSHA) that propagated westward as a Rossby wave all the way to the western North Pacific. This finding indicates that this off-equatorial Rossby wave is induced by the WSCA around the ITCZ. Our analysis of a 1.5-layer reduced gravity model revealed that the Rossby waves are mostly explained by wind stress forcing rather than reflection of an equatorial Kelvin wave on the eastern coastal boundary. The off-equatorial Rossby wave had the same SSHA polarity as the equatorial Kelvin wave, and generation of a phase-preserving Rossby wave without the Kelvin wave reflection was explained by meridional movement of the ITCZ. Thus, the ITCZ acts as an atmospheric bridge that connects the equatorial and off-equatorial oceanic waves.

IAMAS (Meteorology)

M19b - M19 El NiNo / Southern Oscillation and Decadal Variability under Climate Change

IUGG-5224

The challenge for heat budget analysis of El Niño – Southern Oscillation processes

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El Niño – Southern Oscillation (ENSO) is fundamental to Earth's natural climate variability and impacts. Its environmental and societal significance demands appropriate approaches to quantifying ENSO variability, mechanisms and processes, to better diagnose and predict ENSO events. El Niño events are often diagnosed in terms of the amplitude and duration of the spatially averaged sea surface (or mixed layer) temperature anomaly in the equatorial central-eastern Pacific, within the NINO3 or NINO3.4 box. The important processes underpinning these events are often diagnosed by analysis of the component terms in the mixed layer heat budget equation that define the temperature tendency in this fixed region. In this paper, we examine the merits of this approach based on analysis of historical simulations and climate change projections across a suite of models from the Coupled Model Intercomparison Project Phase 5 (CMIP5). Both nonlinear and linear forms of the mixed layer heat budget equation will be considered. We find that the correlations between the NINO3 region temperature tendency and the main terms of the mixed layer heat budget in this box decrease over time through the 21st Century under the RCP8.5 climate change projections – with the residual becoming larger over time. This suggests that unresolved processes in the box (e.g. high frequency eddies and diffusion) are projected to become more important in future and/or this may correspond to a shift in the centre of action for ENSO feedbacks. Hence, climate change presents challenges to the interpretation of key ENSO processes based on fixed-region heat budget analysis.

M19p - M19 El NiNo / Southern Oscillation and Decadal Variability under Climate Change

M19p-504

Interdecadal variability of the mega-ENSO-NAO synchronization in winter

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Mega-El Niño-Southern Oscillation (ENSO) and the North Atlantic Oscillation (NAO), as two principal components of the global air-sea coupling system, may have synchronous or out-synchronous fluctuations during different epochs. Understanding such connection change is instrumental for climate prediction, particularly the decadal prediction. Results in this study show that mega-ENSO has experienced a notable inter-decadal change in its linkage with the winter NAO during the past 56 years: mega-ENSO was significantly correlated with the NAO during 1957-1981 (or synchronous epoch), while such correlation has broken down since 1982 (or out-synchronous epoch). This marked change might be attributed to a sea surface temperature (SST) forcing change in the North Atlantic, based on the observational and numerical evidences in this study. The synchronous epoch is concurrent with the anomalous tropical North Atlantic (TNA) SST forcing, whereas the out-synchronous epoch is associated with the anomalous extra-tropical North Atlantic (XNA) SST forcing. Two possible reasons may explain how the synchronous behaviors between mega-ENSO and the NAO were tied to the TNA SST anomaly (SSTA). There is a positive feedback between the TNA SSTA and the NAO-like atmosphere anomalies, which helps to 'prolong' the NAO impacts from the developing phase through mature phase of mega-ENSO. Additionally, the TNA SSTA itself may induce a NAO-like atmosphere anomaly. Since 1982, the TNA SSTA has been replaced by the XNA SSTA and the latter primarily favors a NAO-neutral state in the atmosphere, which ends the synchronous epoch.

IAMAS (Meteorology)

M19p - M19 El NiNo / Southern Oscillation and Decadal Variability under Climate Change

M19p-505

Global atmospheric oscillations and El Niño in dynamics of the recent climate

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The work confirmed, improved and extended the earlier hypothesis of the existence of intra-secular oscillations of the modern climate system thermodynamic characteristics. Use a composite analysis of observational data on planetary fields of hydro-meteorological parameters of ocean and atmosphere the quasi-cyclic oscillations have been detected in recent climate dynamics with periods of 3-5 years and 20-30 years. These fluctuations were found to appear in the most explicit form in terms of large-scale redistribution of atmospheric mass, accompanied by a significant enhancement of positive atmospheric pressure anomaly in the equatorial-tropical zone of the Earth and the formation of other major anomalies of different signs in different areas. The results obtained suggest that the known multimode regional fluctuations in dynamics of the climate system (North Atlantic, North Pacific, Southern and other so called fluctuations) are derived of the forenamed global atmospheric oscillations (GAO), which the time scales ranging from several years to decades. It was found that multi-decade GAO is followed by the phase transitions in the course of the recent climate change. On the background of identified evolution of thermodynamic index of large-scale processes in the climate system of the North Atlantic region it were defined the temporal characteristics of individual quasi-deterministic scenarios of the recent global climate. Analytical detection of intra-decadal GAO gave an opportunity to formulate a new concept of physical mechanism triggering ENSO process. On the basis of the study results it was shown that those well-known climatic events are far beyond the regional scale of the Pacific basin, but should be treated as a structural part of the global atmospheric oscillation.

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M19p - M19 El NiNo / Southern Oscillation and Decadal Variability under Climate Change

M19p-506

Two key parameters for the El Niño continuum allowing for a simple and reliable El Niño prediction?

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From NCEP-NOAA 1980-2013 reanalysis, we find that **El Niño** (EN) is a continuum that depends on two parameters: (1) 130E-160E Western Pacific 0m-250m subsurface oceanic **potential temperature anomaly** (PTA) about 1 year before the EN peak (typically Dec-Feb), (2) 140E-160W cumulative **zonal wind anomaly** (ZWA) between onset and peak of the EN event. In a framework separating ENs into **Central Pacific** (CPEN) and **Eastern Pacific** (EPEN), both are the end members of the continuum. Those in between are called **Hybrid** (HBEN). To create an EPEN, the Western Pacific must be in the recharged state. Strong and sustained westerly wind anomalies in Western Pacific can then trigger Kelvin waves propagating to the eastern Pacific. Both parameters constructively interfere. For CPEN, these parameters are much less important and Kelvin wave propagation is not involved. Central Pacific warming is caused locally by zonal advection feedback and local air-sea interaction as already demonstrated in previous studies. HBEN occurs when: (1) West Pacific is weakly charged, but strong westerly ZWAs reduce the equatorial upwelling in the Central Pacific, but the triggered Kelvin wave is too weak to have a significant effect; (2) Western Pacific is strongly charged, but only weak westerly ZWA develop and the resulting Kelvin wave cannot fully extend into the eastern-most Pacific.

ENSO prediction is simple and accurate using the two parameters. About 72% of the maximum sea surface temperature anomalies' total variance observed in different Nin~o regions can be explained already up to 6 months in advance. False-alarm rate (number of predicted EN / number of EN events occurred) is only 8.7% 10 months in advance.

IAMAS (Meteorology)

M19p - M19 El NiNo / Southern Oscillation and Decadal Variability under Climate Change

M19p-507

Composite analysis of the effects of El Nino Southern Oscillation events on Antarctica

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Substantial evidence exists for teleconnections associated with El Nino Southern Oscillation (ENSO) events throughout Antarctica and the Southern Ocean. These phenomena have been primarily viewed through the lens of comparing the opposite phases, El Nino and La Nina, of ENSO. This methodology has provided substantial understanding of regions where both phases have opposing effects. More recently analysis of the phases separately has become viable through comparison with neutral state conditions. Of interest for this poster are regions where only one phase has an effect, or regions not generally discussed in prior literature. Areas of specific interest generally associated with ENSO are the Amundsen Bellingshausen Sea, West Antarctica, and the Antarctic Peninsula. This work explores the differences throughout the atmosphere between the El Nino and La Nina phases with specific emphasis on La Nina as represented in the European Centre for Medium Range Weather Forecasts Reanalysis Interim (ERA-Interim) from 1979-2014. The focus is on regions affected outside of these areas that show significant variation. Of particular interest are variations seen throughout East Antarctica, which has commonly been attributed to the Southern Annular Mode (SAM), or through interactions between SAM and ENSO. The ENSO signal in the absence of interactions with SAM is briefly explored, indicating these East Antarctic teleconnections remain despite removing the SAM signal.

IAMAS (Meteorology)

M19p - M19 El NiNo / Southern Oscillation and Decadal Variability under Climate Change

M19p-508

Relative Importance of Tropical SSTA in Maintaining Western North Pacific Anomalous Anticyclone during El Niño to La Niña transition years

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This study investigates the relative importance of tropical Indian Ocean warming (IOW) and equatorial central to eastern Pacific cooling (EPC) in sustaining an anomalous Western North Pacific anticyclone (WNPAC) during the transition from an El Niño in the preceding winter to a La Niña in the subsequent summer through a suite of numerical experiments. The numerical results indicate that the WNPAC is maintained by a combined effect of IOW and EPC during the La Niña developing years. The contribution of IOW in maintaining the WNPAC sustains from spring to early summer, but appears to weaken after that as IOW decays. The role of IOW is via an eastward-propagating Kelvin wave induced Ekman divergence mechanism. The decay of IOW is because of reduction in downward solar radiation associated with above normal precipitation in situ. As the cooling develops over central to eastern Pacific from spring to summer, EPC starts to contribute to the maintenance of the WNPAC during summer through stimulating a Rossby wave response to its northwest. In this study, we have identified that the cooling over the central to eastern Pacific plays an important role in sustaining the WNPAC during La Niña developing summers. This finding may help to improve the prediction of the East Asian summer monsoon, which is closely associated with the WNPAC.

IAMAS (Meteorology)

M19p - M19 El NiNo / Southern Oscillation and Decadal Variability under Climate Change

M19p-509

The robust impact of El Nino on East Asian summer monsoon during the warm phase of Pacific Decadal Oscillation

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The robust impact of El Nino on East Asian Summer Monsoon (EASM) was observed during the warm phase of Pacific Decadal Oscillation (PDO), which was confirmed by the two numerical experiments with CAM3, i.e., PDO_run forced by PDO-regressed interdecadal SSTAs and PDO-ENSO_run forced by combined SSTAs of PDO-regressed interdecadal SSTAs and nino3-regressed interannual SSTAs. During the PDO warm phase, as revealed by both observations and simulations, the tropical Northwest Pacific became dryer than normal and the East Asian Subtropical Westerly Jet (EASWJ) moved southward with larger intensity. Thus, acting as the background of El Nino, the former tended to further suppress the convective activities occurred over the tropical Northwest Pacific, and then to induce a stronger southwestward shifted anomalous low-level Northwest Pacific anticyclone (NWPAC) appeared in El Nino decaying summer. At the same time, the intensified southward EASWJ favored the distinct meridional propagation of Rossby wave featured as East Asian-Pacific (EAP) or Pacific-Japan (PJ) teleconnection pattern, which in turn was initiated by the suppressed convection over the tropical Northwest Pacific. Finally, modulated by the PDO warm phase, the relationship between EASM and ENSO was greatly enhanced through its bridge, the intensified NWPAC in El Nino decaying summer.

IAMAS (Meteorology)

M19p - M19 El NiNo / Southern Oscillation and Decadal Variability under Climate Change

M19p-510

Evaluating consistency of ocean profiles in Equatorial Pacific Ocean

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Ocean profiles are essential to the study of El-Niño Southern Oscillation (ENSO) dynamics. However, subsurface scenario (such as evolution of an ENSO event) suggested could be different among ocean profiles. Furthermore, accuracy of subsurface parameters in ocean profile is hard to be estimated. As a result, choice of ocean profile for ENSO dynamics study could be a challenging problem. This study attempts to alleviate the difficulty by evaluating the consistency between six selected ocean profiles. These ocean profiles are compared with each other on Equatorial Pacific Ocean subsurface temperature and current to evaluate the consistency of scenario suggested by them. It is found that general consensus is not common among these ocean profiles. Instead, scenarios suggested by them can mostly be classified into groups. The findings imply that ENSO mechanism found in one group of profiles may be disagreed by another group.

IAMAS (Meteorology)

M19p - M19 El NiNo / Southern Oscillation and Decadal Variability under Climate Change

M19p-511

On solar variability and ENSO cycle

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At present there is almost no dispute that solar variability has influenced the paleo-climate, however, there is still debate over its role in climate variations on decadal timescale. Interestingly, comparisons between paleo-temperatures and solar activity reconstructions reveal, usually, time lag up to 30 years, but this fact is not taken into account during investigating modern climate variations depending on solar activity. On the other hand, at present there are already rather long instrumental data on both solar activity and climate parameters that allows one to investigate such relationship with taken into account rather long time lag. This report deals with monthly sunspot numbers (SSN) from 1755yr and southern oscillation index (SOI) from 1876yr. It is found that correlation between these parameters becomes more visible if SOI record lags SSN record at 34.8 years. More over, the 11 year ENSO pattern developed some years ago by White and Liu [2008] http://onlinelibrary.wiley.com/doi/10.1029/2008GL034831/abstract becomes more clear with taken into account such time lag. This finding, if it could be confirmed by other investigations, could allow one to predict warm and cold ENSO phases up to 30 years in advance. In any case, our results show that the closest El Niño events had to occur in 2014-2015 and 2019-2020 years.

IAMAS (Meteorology)

M20a - M20 The Ocean's Role in Climate Variability, Change and Predictability

IUGG-0421

Indo-Pacific warm pool area expansion, modoki activity, and tropical cold-point tropopause temperature variations

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The tropical cold-point tropopause temperature (CPTT), a potentially important indicator of global climate change, is of particular importance for understanding changes in stratospheric water vapor levels. Since the 1980s, the tropical CPTT has shown not only interannual variations, but also a decreasing trend. However, the factors controlling the variations in the tropical CPTT since the 1980s remain elusive. The present study reveals that the continuous expansion of the area of the Indo-Pacific warm pool (IPWP) since the 1980s represents an increase in the total heat energy of the IPWP available to heat the tropospheric air, which is likely to expand as a result. This process lifts the tropical cold-point tropopause height (CPTH) and leads to the observed long-term cooling trend of the tropical CPTT. In addition, our analysis shows that Modoki activity is an important factor in modulating the interannual variations of the tropical CPTT through significant effects on overshooting convection.

IAMAS (Meteorology)

M20a - M20 The Ocean's Role in Climate Variability, Change and Predictability

IUGG-1239

Pacific interdecadal variability driven by tropical-extratropical interactions

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Interactions between the tropical and subtropical Pacific at decadal time scales are examined using uncoupled oceanic and atmospheric simulations. An atmospheric model is forced with observed Pacific SST decadal anomalies, computed as the difference between the 2000-2009 and the 1990-1999 period. The resulting pattern has negative SST anomalies at the equator, with a global pattern reminiscent of the PDO. The tropical SST anomalies are responsible for driving a weakening of the Hadley cell and atmospheric meridional heat transport. The atmosphere is then shown to produce a significant response in the subtropics, with wind-stress-curl anomalies having the opposite sign from the climatological mean, consistent with a weakening of the oceanic subtropical gyre (STG). A global ocean model is then forced with the decadal anomalies from the atmospheric model. In the North Pacific, the shallow subtropical cell (STC) spins down and the meridional heat transport is reduced, resulting in positive tropical SST anomalies. The final tropical response is reached after the first 10 years of the experiment, consistent with the Rossby-wave adjustment time for both the STG and the STC. The STC provides the connection between subtropical wind stress anomalies and tropical SSTs. In our models, tropical SST decadal variability stems from the forcing of the Pacific STG through the atmospheric response to ENSO, giving rise to a possible mechanism for multidecadal ocean-atmosphere variability. The mechanism is consistent with the evolution of the Pacific STC for the period 1948-2007 and cooling trends in tropical SSTs. The natural mode of variability has implications for the evolution of equatorial SST in the coming decades under the concomitant effects of climate change.

IAMAS (Meteorology)

M20a - M20 The Ocean's Role in Climate Variability, Change and Predictability

IUGG-1251

A multi-model ensemble pattern regression method to correct the tropical Pacific SST change pattern under global warming

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This study develops a new observational constraint method, multi-model ensemble pattern regression (EPR), to correct regional climate change projected by multi-model ensemble (MME). The EPR method first extracts the leading inter-model modes in historical simulation using EOF analysis, then builds up the linear correlated patterns between historical bias and change bias in the models using multi-variant linear regression, and finally estimates the common change bias based on the historical-change correlated patterns and the common historical bias. Besides correcting common change bias, the EPR method implicitly removes the inter-model change uncertainty deriving from the inter-model diversity in background.

The EPR method is applied to correct the change pattern in the tropical Pacific SST with great importance and uncertainty using CMIP5 models. The common historical bias in the tropical Pacific SST including the excessive cold tongue, the southeastern warm bias and the narrower warm pool is estimated to induce a La Niña-like change bias. After the common change bias removed, the corrected SST change displays a pronounced El Niño-like pattern and much greater zonal gradient. This correction decreases around half inter-model uncertainty in SST change. The patterns of the corrected tropical precipitation and circulation change are dominated by the enhanced SST change pattern, displaying a pronounced warmer-get-wetter pattern and decreased Walker circulation with less uncertainty.

IAMAS (Meteorology)

M20a - M20 The Ocean's Role in Climate Variability, Change and Predictability

IUGG-2066

Revisiting the recent slowdown of upper tropospheric warming over the tropics

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Projected increase in tropical upper-tropospheric temperature (TTUT) is an important factor for climate feedbacks, changes in tropical atmospheric circulation, and tropical cyclone activity in a warming climate. Simulated increase in TTUT during the recent decades in atmosphere-ocean coupled general circulation models (AOGCMs) tends to be overestimated relative to radiosonde observations. The recent observation-model discord in TTUT variation is an underlying issue regarding the reliability of future climate projections based on AOGCMs.
To examine reasons for this bias, we conducted ensemble simulations using an atmospheric general circulation model (AGCM) forced by sea surface temperature (SST) both with and without anthropogenic influences. Historical and natural AGCM runs reproduced the upper-tropospheric cooling over the central Pacific found in radiosonde and satellite observations, while the multi-AOGCM mean did not. Recent tropical SST variability, characterized by eastern Pacific cooling, which is considered natural variability, accounted for half of the TTUT bias in the multi-AOGCM mean. The results of this study suggest that difficulties in simulating the recent 'upper-tropospheric warming hiatus' do not mean low reliability of AOGCM-based future climate projections.

IAMAS (Meteorology)

M20a - M20 The Ocean’s Role in Climate Variability, Change and Predictability

IUGG-2836

The madden-julian oscillation in a warmer world

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The Madden-Julian Oscillation (MJO) is the dominant pattern of atmospheric subseasonal variability in the tropics. Despite its global importance, affecting monsoons, tropical storms, extra-tropical weather, the MJO is not well understood or simulated by state-of-the-art climate models. Thus, great uncertainty exists in how global warming will impact the MJO: the increase in atmospheric moisture content could intensify it, while atmospheric circulation changes could weaken and alter its frequency. Here we assess global warming’s impact on the MJO using one of the few models capable in reproducing its key features. In a warmer climate predicted for the end of the century, the MJO increases in amplitude (by ~30%) and frequency, but retains its planetary wavenumber-one scale. Furthermore, eastward propagation is faster and more circumglobal. These changes result from an intensification of the frictional-wave CISK mechanism. During the deep convective phase, precipitation increase is roughly consistent with Clausius-Clapeyron scaling. The enhanced, deeper, zonally extended and meridionally confined diabatic heating drives a stronger forced Kelvin wave-like perturbation. This reinforces the frictional low-level convergence, leading to more efficient and timely preconditioning of the deep convection, and therefore to a faster development and enhancement of the deep convection in MJO.

IAMAS (Meteorology)

M20a - M20 The Ocean's Role in Climate Variability, Change and Predictability

IUGG-4833

Hiatus and accelerated global warming due to tropical Pacific natural variability

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Since the 19th century, global-mean surface temperature (GMT) has risen with notable interannual and interdecadal variability, suggesting internal variability superposed on the radiatively forced climate change. Tropical Pacific variability is known to be a major driver of internal GMT variability. We perform a long Pacific Ocean-Global Atmosphere (POGA) experiment dating back to the late 19th century, which forces tropical Pacific sea surface temperature anomalies to follow the observed history. When forced by historical and RCP4.5 radiative forcing, POGA reproduces annual-mean GMT variability with a correlation coefficient R = 0.96 and 15-year running GMT trend with R = 0.80 since 1870. We quantify relative contributions from the radiative forcing and tropical Pacific variability by comparing POGA with another experiment forced solely by the radiative forcing. The tropical Pacific variability was a major cause of global cooling from the late 1890s to around 1910, accelerated the first warming from the 1910s to 40s, advanced the beginning and delayed the end of the big hiatus for the mid-1940s to mid-70s, and accelerated the first half of the second warming for the mid-1970s to late 90s. POGA also captures observed regional trend of surface temperature for these periods with strong tropical Pacific influence, especially over the tropical Indian Ocean, Indian subcontinent, North and South Pacific and North America. Rate of the recent GMT decrease due to the tropical Pacific cooling is comparable with that occurred in the beginning of the 20th century, but the recent one is the longest for the past 150 years. The strengthening of the Pacific trade wind since the 1990s is at the fastest rate. In these regards, the recent hiatus is unprecedented in instrumental records.

IAMAS (Meteorology)

M20b - M20 The Ocean’s Role in Climate Variability, Change and Predictability

IUGG-0716

Intensified impact of tropical Atlantic SST on the western North Pacific summer climate under a weakened Atlantic thermohaline circulation

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The tropical North Atlantic (TNA) sea surface temperature (SST) has been identified as one of regulators on the boreal summer climate over the western North Pacific (WNP), in addition to SSTs in the tropical Pacific and Indian Oceans. The major physical process proposed is that the TNA warming induces a pair of cyclonic circulation anomaly over the eastern Pacific and negative precipitation anomalies over the eastern to central tropical Pacific, which in turn lead to an anticyclonic circulation anomaly over the western to central North Pacific. This study further demonstrates that the modulation of the TNA warming to the WNP summer climate anomaly tends to be intensified under background of the weakened Atlantic thermohaline circulation (THC) by using a water-hosing experiment. The results suggest that the weakened THC induces a decrease in thermocline depth over the TNA region, resulting in the enhanced sensitivity of SST variability to wind anomalies and thus intensification of the interannual variation of TNA SST. Under the weakened THC, the atmospheric responses to the TNA warming are westward shifted, enhancing the anticyclonic circulation and negative precipitation anomaly over the WNP. This study supports the recent finding that the negative phase of the Atlantic multidecadal oscillation after the late 1960s has been favourable for the strengthening of the connection between TNA SST variability and WNP summer climate and has important implications for seasonal prediction and future projection of the WNP summer climate.

IAMAS (Meteorology)

M20b - M20 The Ocean's Role in Climate Variability, Change and Predictability

IUGG-1420

The role of coastal mid-latitude air-sea interactions in exporting tropical energy to North America during summer

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Our recent publication in JGR describes and provides evidence for a partial mechanistic understanding of the North American monsoon (NAM). This presentation would focus on the oceanographic aspects of that research and relate them to the air-sea interactions (documented in our paper) that help transfer abundant moisture from the Gulf of California (GC) into northern Mexico, the USA and as far north as Canada. This moisture transfer and subsequent convection provides a source region for stationary Rossby waves that affect the large-scale circulation and precipitation patterns of over North America during summer.

Regarding the air-sea mechanism, an intrusion of tropical surface water (TSW) into the GC occurs during May-June that coincides with a slackening of the coastal wind field off Baja California and central Mexico. Satellite measurements of sea surface height (SSH) further show a reconfiguration of SSH fields and geostrophic currents at the time of this wind slackening, with TSW from the eastern Pacific warm pool directed poleward into the GC. Subsequently GC sea surface temperatures (SSTs) typically reach 29-30°C by mid-July, with this SST increase warming and humidifying the GC marine boundary layer (MBL) air, eroding the MBL inversion once SSTs exceed ~ 29°C. This allows the very humid GC MBL air to mix with free tropospheric air, producing a deep (several km) moist layer that can be advected inland to produce thunderstorms. This entire process may depend on the annual cycle of the North Pacific High. A NAM paleoclimate study (Barron et al., 2012), supported by these ideas, addresses the potential impact of a warming climate on the NAM.

IAMAS (Meteorology)

M20b - M20 The Ocean's Role in Climate Variability, Change and Predictability

IUGG-1512

Evidence for solar-induced AMOC variability from Greenland temperature records over the past 2000 years

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The abrupt Northern Hemispheric (NH) warming at the end of the 20th century has been attributed to an enhanced greenhouse effect. Yet, Greenland and surrounding subpolar North Atlantic remained anomalously cold in 1970s- early 1990s. A combined Greenland temperature record from two Greenland ice cores (using argon and nitrogen isotopes in trapped air in ice cores) over the past 2100 years indicates that stronger (weaker) solar activity produced negative (positive) temperature anomalies in Greenland relative to the NH temperature trend, consistent with earlier findings over the past 4000 years[1-3]. Analyses of proxy-based global gridded temperatures over the past 800 years and observational global gridded surface temperatures over the past 134 years suggest that the antiphase Greenland temperature responses to solar variability persisted across the subpolar North Atlantic, and occurred under increasing greenhouse gases during the 20th century. The spatiotemporal pattern of the temperature responses to multidecadal solar variability resembles modelled and observed changes of Atlantic meridional overturning circulation (AMOC), suggesting that solar variation induced AMOC variability. We hypothesize that an unusually high solar activity during the modern solar maximum (ca. 1950s-1980s) produced a cooling and thus a delayed warming over Greenland and subpolar North Atlantic in the late 20th century through the AMOC slow-down. The solar-induced AMOC variation over the past decades provides a plausible hypothesis on the origin of the global warming hiatus.

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2, Kobashi, T. et al., Clim. Past **9**, 583-596 (2013).

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IAMAS (Meteorology)

M20b - M20 The Ocean's Role in Climate Variability, Change and Predictability

IUGG-2531

European climate impacts of a slowdown of the Atlantic Meridional Overturning Circulation in a high resolution global climate model.

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We present the impacts from a hypothetical slowdown in the Atlantic Meridional Overturning Circulation in a state-of-the-art global climate model, with particular emphasis on Europe. This is the highest resolution coupled global climate model to be used to study the impacts of a slowdown of the overturning circulation so far. Many results found are consistent with previous studies and can be considered robust impacts from a large reduction or collapse of the Atlantic Meridional Overturning Circulation. These include: widespread cooling throughout the North Atlantic and northern hemisphere in general; less precipitation in the northern hemisphere midlatitudes; large changes in precipitation in the tropics and a strengthening of the North Atlantic storm tracks.

The focus on Europe, aided by the increase in resolution, has revealed previously undiscussed impacts, particularly those associated with changing atmospheric circulation patterns. Summer precipitation decreases (increases) in northern (southern) Europe and is associated with a negative summer North Atlantic Oscillation signal. Winter precipitation is also affected by the changing atmospheric circulation, with localised increases in precipitation associated with more winter storms and a strengthened winter storm track. Stronger westerly winds in winter increase the warming maritime effect while weaker westerlies in summer decrease the cooling maritime effect. In the absence of these circulation changes the cooling over Europe's landmass would be even larger in both seasons.

IAMAS (Meteorology)

M20b - M20 The Ocean's Role in Climate Variability, Change and Predictability

IUGG-3555

Impacts of midlatitude frontal sea-surface temperature gradients on the atmosphere as revealed in new Japanese reanalysis data

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Impacts of midlatitude frontal SST gradients on the overlying atmosphere are assessed through comparison of two products of a new Japanese reanalysis (JRA55). One is the main product of JRA55 in which observed data have been assimilated in a forecast system with horizontal resolution of ~60km and the COBE SST data with 1-degree resolution prescribed over 55 years. The other is an additional product (JRA55HS) with MGDSST data with a quarter-degree resolution only over 28 recent years. The comparison reveals substantial differences in midlatitude atmospheric processes around the western boundary currents and associated SST fronts. As a typical example, atmospheric response to variability of the Kuroshio Extension (KE) is examined. As in satellite observations, enhancement of cloudiness and precipitation in the mixed-water region east of Japan during the unstable regime of KE relative to its stable regime is represented well in JRA55HS but not in the main JRA55 product. The enhancement results from augmented heat/moisture release from the warmer ocean with more active warm-core eddies. This oceanic thermal forcing onto the atmosphere is manifested as positive correlation in anomalies between SST and heat/moisture release, which is represented only in the high-resolution MGDSST but not in the COBE SST. As another example, stormtrack response to meridional displacement of the Oyashio front is examined. Again, the positive correlation between anomalous SST and heat/moisture release is much stronger in JRA55HS, and so is the enhancement of convective precipitation over warm SST anomalies. Convective diabatic heating may be essential for the development of synoptic-scale cyclones, which may be the source of the sensitivity of a stormtrack to the variability of oceanic fronts.

IAMAS (Meteorology)

M20b - M20 The Ocean's Role in Climate Variability, Change and Predictability

IUGG-5285

Atmospheric response to sea surface temperature anomalies linked with oceanic vortices.

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Recent studies using high resolution coupled model showed a strong link between the extratropical sea surface temperature front and the storm track in the same latitudes (Minobe etal 2008, Nakamura etal 2008). Sea surface temperature front impact the storm track and the low frequency variability. The condition to see it is to use fine grid model (less than 50km). Other studies showed the impact of turbulent fluxes on the wind stress (Chelton etal 2004, Bourras etal 2004). The sea surface temperature fronts are full of mesoscale and submesoscale motions (vortices and filaments). Our present study assess their impact on the atmospheric boundary layer dynamics and their influence on the storm track. We perform different set of experiments using the WRF model in an idealised configuration forced by a constant sea surface temperature field. Very idealised set studied the impact of the wind strength on the atmospheric boundary layer answer.We showed that the two main mechanism described in the literature (Wallace etal 1989 and Lindzen and Nigam 1987) occurs for different wind strength and sea surface temperature anomaly orientations. We also addressed the influence of the addition of mesoscales eddies, in a sea surface temperature front, on the storm track dynamics. First results show an impact on the vertical temperature fluxes in the high troposphere.

IAMAS (Meteorology)

M20c - M20 The Ocean's Role in Climate Variability, Change and Predictability

IUGG-0693

Thermodynamic origins of the Atlantic Nino

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The equatorial Atlantic Niño is believed to be governed by dynamical ocean-atmosphere coupling; specifically, the Bjerknes mechanism similar to the Pacific El Niño. In this study, we challenge this view and show that the Atlantic Niño originates primarily from thermodynamic feedbacks and that ocean dynamics could be of secondary importance. By comparing two sets of numerical experiments—one with, the other without, dynamical feedbacks—we find that thermodynamic mechanisms could explain >70% of equatorial Atlantic variability. The Atlantic Niño warming is mainly driven by a weakening of the subtropical anticyclone, slackening of the trade winds slacken and consequently net heating over eastern equatorial Atlantic Ocean. The implications of these findings for the modelling and predictability of the tropical Atlantic sector will be highlighted.

IAMAS (Meteorology)

M20c - M20 The Ocean's Role in Climate Variability, Change and Predictability

IUGG-1378

Regional air-sea interaction and Indo-Pacific remote forcing in summer rainfall variability over the South China Sea

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The air-sea relationship over the South China Sea (SCS) displays remarkable seasonality and regionality. Atmospheric forcing is dominant in northern and central SCS during local warm season. During April-May-June, the atmospheric impact on the SST change features a prominent cloud-radiation effect in central SCS, a wind-evaporation effect in central and southern SCS, and a wind-driven oceanic effect along the west coast. Oceanic forcing is found in northern SCS during local cold season. During November-December-January, regional convection responds to the SST forcing in northern SCS through modulation of the low-level convergence and atmospheric stability. Co-existing atmospheric and oceanic forcing is identified in southern SCS during August-September. The air-sea relationship in the CMIP5 models has been evaluated.

The SCS summer rainfall is related to simultaneous SST in the equatorial central Pacific (ECP) and the North Indian Ocean (NIO). Positive ECP SST anomalies induce an anomalous low-level cyclone over the SCS-western North Pacific as a Rossby-wave type response, leading to above-normal rainfall over northern SCS. Negative NIO SST anomalies contribute to anomalous cyclonic winds over the western North Pacific by an anomalous east-west vertical circulation north of the equator, favoring more rainfall over northern SCS. These NIO SST anomalies are closely related to preceding La Niña and El Niño events through the "atmospheric bridge". Thus, the NIO SST anomalies serve as a medium for an indirect impact of preceding ECP SST anomalies on the SCS summer rainfall variability. The Indo-Pacific SST effects are confirmed by numerical experiments with an atmospheric general circulation model.

IAMAS (Meteorology)

M20c - M20 The Ocean's Role in Climate Variability, Change and Predictability

IUGG-2027

Phase locking of equatorial Atlantic variability through the seasonal migration of the ITCZ

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Equatorial Atlantic variability exhibits many similarities to El Nino-Southern Oscillation (ENSO) in the Pacific. Accordingly warm events in the Atlantic are accompanied by a relaxation of the equatorial trades over the western basin with subsequent deepening of the thermocline and rising SST in the east. In difference to ENSO, however, equatorial Atlantic variability is phase locked to boreal summer rather than winter. Analysis of observations and climate models suggests that this behavior is determined by the seasonal march of the Atlantic ITCZ and its influence on the surface winds. In particular the strength of the equatorial easterlies is closely related to the latitudinal position of the ITCZ, with the easterlies weakest when the ITCZ is farthest south. Climatologically, the ITCZ is farthest south in boreal spring and farthest north in boreal summer. Due to the ITCZ influence on the surface winds this rapid northward shift of the ITCZ is accompanied by an equally rapid intensification of the equatorial easterlies with attendant cold tongue development in the east. The year-to-year variation in the timing and intensity of this ITCZ shift is therefore one of the major factors controlling interannual variability. This explains why warm events develop in late spring and early summer. The rapid northward shift, however, also leads to the termination of events in late summer because precipitation anomalies invariably shift north of the equator along with the mean ITCZ. This limits the ability of the Bjerknes feedback to enhance the equatorial SST anomalies.

IAMAS (Meteorology)

M20c - M20 The Ocean's Role in Climate Variability, Change and Predictability

IUGG-2513

Alleviating the North Atlantic cold bias in the Kiel Climate Model

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The North Atlantic cold bias, associated with a too zonal path of the North Atlantic Current and a missing "northwest corner", is a major problem in coupled models. It affects the North Atlantic Sector climate mean state, variability and predictability, as this severe model error is located in the North Atlantic storm track region. In the standard model version of the Kiel Climate Model (KCM), like in many other climate models, the surface heat flux is reversed in the northwest corner; the ocean gains heat, instead of releasing heat to the atmosphere as observed.

The use of a Flow Field Correction (FFC) to adjust the path of the North Atlantic Current is investigated as well as additional corrections to the surface heat and freshwater fluxes. The FFC can be regarded as a means to correct for model error, e.g. associated with the deep water mass pathways and their impact on the circulation, and to parameterize unresolved processes such as eddy momentum flux convergence. The FFC does not depend on the state of the coupled model.

Results show that the FFC allows a northward flow into the northwest corner, largely eliminating the subsurface bias in the KCM. A cold bias remains at the surface but can be eliminated by additionally correcting the surface freshwater flux, without adjusting the surface heat flux seen by the ocean model. Sea ice and convection occurs in more realistic positions in the corrected model versions, connected to a more northward extension of the Atlantic Meridional Overturning Circulation (AMOC).

Using the corrected model versions, we explore the North Atlantic region climate variability with a focus on the AMOC and basin-wide North Atlantic sea surface temperature variability known as the Atlantic Multidecadal Oscillation or Variability (AMO/V).

IAMAS (Meteorology)

M20c - M20 The Ocean's Role in Climate Variability, Change and Predictability

IUGG-2998

Effects of warm pool SST warming on the atmospheric circulation in the Pacific

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It is obvious that the western-Pacific warm pool (hereafter, the warm pool) plays an important role in both the tropical and extratropical climate by modulating tropical convection. Furthermore, the warm pool sea surface temperature (SST) has gradually increased over time. We examine the effects of warming in the warm pool SST on the atmospheric circulation in the Pacific. By analyzing the outgoing longwave radiation (OLR), it is found that the sensitivity of convective forcing in response to anomalous warm pool SST variation significantly increases in recent decades. Because of this, the east-west zonal circulation has been modified, subsequently, mean descending motion is dominant in the central tropical Pacific, leading to a negative trend of both precipitation and OLR. Furthermore, the SST variations in the central tropical Pacific are closely associated with the Arctic Oscillation-like atmospheric circulation in the middle-to-high latitudes, indicating that the warm pool SST is able to modify the atmospheric teleconnections form the tropics to the middle-to-high latitudes.

IAMAS (Meteorology)

M20c - M20 The Ocean's Role in Climate Variability, Change and Predictability

IUGG-4991

Water cycle amplification inferred from broadening of the ocean's salinity distribution in observations and CMIP5 models

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The water cycle leaves an imprint on ocean salinity through Evaporation (E) and precipitation (P) and it has been proposed that observed changes in salinity could be used to infer changes in the water cycle. Here salinity is characterized by the distribution of water masses in salinity coordinates. Mixing acts to collapse the distribution, homogenizing salinity, while the water cycle (E-P) stretches the distribution, maintaining the contrast between water masses. A simple model is developed to describe the relationship between the mean deviation of the salinity distribution, the water cycle and mixing, the later being characterized by an e-folding (mixing) timescale. We tested this model in various CMIP5 model historical and 21st century RCP scenario runs where we have computed both the mixing timescale setting the quasi-steady balance in the pre-industrial climate and the time scale setting the response of ocean salinity to water cycle change. From observations, the mean E-P over the ocean of order 2.6 Sv maintains the mean salinity distribution with a mixing timescale of order 50 years. Using observed changes in salinity we computed a total fresh water displacement in salinity space of ~0.040-0.045 Sv over the last 60 years, which implies that the water cycle has increased by ~0.065-0.075 Sv (~2.5-3 %). The increase in salt mixing over that period has reduced the net stretching of the salinity distribution by about 40%. CMIP5 models tend to be more diffusive than observations, potentially explaining why they display weaker salinity amplification in response to warming.

IAMAS (Meteorology)

M20d - M20 The Ocean’s Role in Climate Variability, Change and Predictability

IUGG-0237

A connection between the tropical Pacific Ocean and the winter climate in the Asian-Pacific region

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The impact of the tropical Pacific sea surface temperature (SST) anomaly on the winter mean surface air temperature (SAT) in the Asian-Pacific region is investigated during the period from 1948 to 2008 using both observations and a linear baroclinic model (LBM). A singular value decomposition (SVD) analysis is conducted between the 500-hPa geopotential height (Z500) over the Northern Hemisphere and the SST over the tropical Pacific Ocean to obtain the large scale atmospheric patterns related to tropical Pacific SST. Focus is given to the second pair of SVD mode (SVD2) which bear some similarities in the Z500 field to the Arctic Oscillation (AO) over the North Atlantic sector and can impact the SAT over a larger area of Asian-Pacific. In the winter of a positive SVD2 the SAT over the mid-to high-latitude Asian continent, the Arctic Ocean, the Indian Ocean and the western subtropical Pacific Ocean tend to be warmer-than-normal while the North Pacific Ocean around the Bering Strait is abnormally cold, and vice versa. Examination of the associated surface general circulation shows that a positive SVD2 tends to shift the Siberian High northwestward and the Aleutian low eastward resulting in anomalous weak pressure gradient between the Asian continent the North Pacific and anomalous southerly wind along the east coast of the Asian continent. At the same time, the East Asian trough at mid-troposphere becomes weaker-than-normal and the East Asian westerly jet stream is shifted northward. The analysis of the wave activity flux and result of idealized numerical experiments show a possible influence of the western tropical Pacific SST forcing on the SVD2.

IAMAS (Meteorology)

M20d - M20 The Ocean’s Role in Climate Variability, Change and Predictability

IUGG-1423

Changes in the tropical India Ocean during pIOD events versus global warming

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Climate models project a positive Indian Ocean Dipole (pIOD)-like SST response in the tropical Indian Ocean to global warming. By employing the Community Earth System Model (CESM) and applying an overriding technique to its ocean component Parallel Ocean Program version 2 (POP2), this study investigates the similarity and difference of the formation mechanisms for the changes in the tropical Indian Ocean during the pIOD versus global warming. Results show that their formation processes and related seasonality are quite similar; in particular, the Bjerknes feedback is the leading mechanism in producing the anomalous cooling over the eastern tropics in both cases. Some differences are also found, including that the cooling effect of the vertical advection over the eastern tropical Indian Ocean is dominated by the anomalous vertical velocity during the pIOD while it is dominated by the anomalous upper-ocean stratification under global warming. These findings above are further examined with an analysis of the mixed layer heat budget.

IAMAS (Meteorology)

M20d - M20 The Ocean's Role in Climate Variability, Change and Predictability

IUGG-3388

Impacts of IOD and ENSO on the australian winter wheat yields and their seasonal predictability

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Influences of IOD and ENSO on the year-to-year winter wheat yield variations in Australia in the last three decades are investigated and their seasonal predictability is examined by the SINTEX-F1 seasonal prediction system. Results show that when the single linear regression is applied, both IOD and ENSO show significant influences on the wheat yields due to their strong influences on the Australian climate during the growing season generally from April to the subsequent January; the standardized linear regression coefficient with Sep.-Nov IOD indices is -0.63 ($p < 0.01$) and that with Nov.-Dec. Niño3 is -0.49 ($p < 0.01$). However, when the multi-linear regression is applied, the standardized multi-linear regression coefficient with Sep.-Nov IOD indices remain -0.56 ($p < 0.01$), while that with Nov.-Dec. Niño3 indices becomes -0.10 ($p > 0.60$). This indicates that IOD plays a more important role and the ENSO influences can be counted by the IOD due to their frequent co-occurrence. When the SINTEX-F1 is initialized on April 1st right before the sewing of wheat, the predicted Sep.-Nov. IOD indices can explain 15.3% of the Australian year-to-year wheat yield variances. This indicates a promising scheme to predict the wheat yield variations related to the IOD by using the seasonal climate prediction system and the simple linear regression method.

IAMAS (Meteorology)

M20d - M20 The Ocean's Role in Climate Variability, Change and Predictability

IUGG-4961

Characterizing the increase in regional U.S. precipitation

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U.S. annual precipitation has increased in recent decades, especially over the Northeast where totals have risen about 15% since 1901. Accompanying this increase in total precipitation have been increases in the frequency and intensity of very heavy precipitation events. In this presentation, the effects of various factors causing trends in very wet days are diagnosed in order to better characterize their recent change.

Long integrations of atmosphere and coupled atmosphere–ocean models are used to diagnose regional variability and change in U.S. heavy precipitation events. In particular, 2000-yr long equilibrium integrations of a coupled model are diagnosed, one that was subjected to radiative forcing of the late 19th century and the other to radiative forcing of the early 21st century. A large number of samples of regional precipitation are analyzed from each (1) to characterize the role of internally driven ocean-atmosphere climate variability, and (2) to compare the magnitude of that variability to the signal of externally driven mean change.

We ask if changes in weather statistics of heavy precipitation are reconcilable with a deterministic response to climate forcing. What is the nature of that forcing, and in particular what role has been played by global warming dynamics? Alternatively, we also ask if the observed changes in weather statistics of heavy precipitation reflect an extreme manifestation of internal variability, either of the atmosphere alone, or of the coupled ocean-atmosphere system.

Answers to these questions are central to knowing if changes in the statistics of weather-related precipitation extremes have been detected regionally, and what those changes tell us about extreme precipitation events in coming decades.

IAMAS (Meteorology)

M20p - M20 The Ocean's Role in Climate Variability, Change and Predictability

M20p-204

"Recent change of land-sea thermal contrast and its effects on summer rainfall in eastern China"

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Based on the analysis of zonal land-sea surface temperature difference between eastern mainland China and its adjacent seas, the zonal land-sea thermal contrast had significant inter-annual and inter-decadal periods, and obviously declined from 1957 to 2000 and rose after 2000 to the present. It may be due to the imbalance in the warming rate of the land-sea surface in eastern China and coastal waters. An anomalous anti-cyclonic atmospheric circulation was observed over the coastal China Seas due to a larger zonal thermal difference, and in contrast, an anomalous cyclonic atmospheric circulation emerged over the same area, which was caused by a smaller zonal thermal contrast. Besides, the zonal thermal contrast had a significantly negative relationship to summer rainfall in the middle and lower reaches of the Yangtze River, and a positive relationship to precipitation in Northeastern China. Numerical experiments give similar results, i.e., the atmospheric lower cyclonic circulation anomaly occurred over eastern China and coastal waters and the summer rainfall was below the normal, when the thermal difference was relatively smaller. Conversely, an anomalous anti-cyclonic circulation appeared and the summer rainfall was above normal, when the thermal contrast is relatively higher. It is therefore suggested that the zonal land-sea thermal difference between eastern mainland China and its adjacent seas is very likely to play an important role in regional climate change.

IAMAS (Meteorology)

M20p - M20 The Ocean's Role in Climate Variability, Change and Predictability

M20p-206

Decadal drought in Southwest China since 2000 and its atmospheric teleconnection

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The extreme drought in Southwest China during the winter 2009/2010 brought catastrophic losses to the state and people. In this paper, evidences have been presented that this drought event was not a single event, but a part of a decade-long drying period after 2000. Based on observed data from Chinese meteorological stations, we identified two distinct modes of winter precipitation in Southwest China: one was spatially in-phase change pattern and the other was east-west dipole pattern, both of which experienced a sharp decadal decrease since the late 1990s.The two modes are closely linked to two atmospheric circulation patterns induced by Arctic Oscillation (AO) and El Niño, respectively. The persistently deficient rainfall in Southwest China after 2000 was mainly derived from the decadal transition of AO toward its negative phases and from frequent El Niño, especially the central Pacific El Niño. The model experiments forced by SSTA patterns in the north Atlantic and tropical Pacific, respectively, could robustly reproduce rainfall anomaly in Southwest China and large-scale circulation pattern.

IAMAS (Meteorology)

M20p - M20 The Ocean's Role in Climate Variability, Change and Predictability

M20p-207

Sensitivity of Arctic Warming to Sea-ice Concentration in CMIP5

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We examine how the sensitivity of Arctic warming changes with respect to background sea-ice concentration (SIC) under greenhouse warming by analyzing the datasets of the historical and Representative Concentration Pathway 8.5 (RCP8.5) runs of the Coupled Model Intercomparison Project Phase 5 (CMIP5). Analysis of the relationship between the Arctic amplification (AA) trend and climatological mean SIC on moving 30-yr windows from 1960 to 2100 shows that the annual mean AA trend is highly variable and depends on the climatological mean SIC condition. In particular, some models show a clear nonlinear relationship between the AA trend and climatological mean SIC. In these models, the AA trend tends to increase remarkably until the climatological mean SIC reaches a critical level (i.e., 20 ~ 30%). However, the AA trend tends to decrease after that, indicating that Arctic warming may not amplify as much as before as greenhouse warming progresses further. Further analysis indicates that the nonlinear sensitivity of AA trend to the climatological mean SIC condition in these models is closely related to the changes in summer surface albedo feedback and winter turbulent heat flux feedback in the Arctic Ocean.

IAMAS (Meteorology)

M20p - M20 The Ocean's Role in Climate Variability, Change and Predictability

M20p-208

Observational evidence of the atmospheric response to Kuroshio Extension variability

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This study focuses on regional atmospheric response to the Kuroshio Extension using the combination of multiple satellite observations and reanalysis data during boreal winter for at least a decade long. A climate index is used for measuring the interannual-to-decadal Kuroshio Extension variability, which leaves remarkable meso-scale sea surface temperature imprints. Clear spatial coherence between the sea surface temperature signals and frontal-scale atmospheric variables including surface wind convergence, vertical velocity, precipitation and cloud is presented by linear regression analysis. In agreement with previous studies, we find the penetrating effect of the Kuroshio Extension variability in free atmosphere. The westward tilt of atmospheric response above the Kuroshio Extension near 500 hPa is revealed consistently among different datasets, which is possibly preconditioned by the effect of background flow. We suggest that background descending air resulting from the cold high pressure system limits the vertical development of atmospheric response, leading to mid-level horizontal divergence above surface convergence, and thereby anomalous vertical velocity and air temperature in the upper-level troposphere in opposite phase with their near-surface response. Remote large-scale atmospheric association with Kuroshio Extension variability is explored and is found to be sensitive to time periods selected. Possible reasons for the time-dependent remote large-scale atmospheric signal will be further investigated.

IAMAS (Meteorology)

M20p - M20 The Ocean's Role in Climate Variability, Change and Predictability

M20p-209

Seasonal variation characteristics of atmospheric duct over the xisha Islands

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This study aims to investigate the climatology of atmospheric duct around the central South China Sea. Based on the twice daily GPS sounding dataset observed in the Xisha station,where located at the middle of south China Sea ,from 2007 to 2011, the characteristics of seasonal variation of the strong atmospheric duct are statistically analyzed. The results are summarized as follows: the seasonal variation of the atmospheric ducts is obvious that the occurrence probability is higher in summer than in winter, but the magnitude of height, thickness and strength of duct are smaller in summer than in winter. The seasonal variation of duct is related to the vertical distribution of humidity, temperature. There exists a strong positive vertical gradient of relative humidity above 400m, which has a significant seasonal variation and a great contribution to the duct seasonal variation.

IAMAS (Meteorology)

M20p - M20 The Ocean's Role in Climate Variability, Change and Predictability

M20p-210

Roles of ocean initialization and wind bias correction on ENSO predictability

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El Niño and Southern Oscillation is one of the most well-known and important climate phenomena. Although the ENSO appears in the tropical Pacific, it interacts with climate variability over the world, which impacts the human life by various ways. KIOST has been developed an ENSO prediction system by applying the ocean data assimilation and wind bias correction to a fully coupled climate model, GFDL CM2.1. The ocean observation data are assimilated into its ocean component model through the data assimilation system of the KIOST (DASK) while other component models are freely integrated. Even though atmospheric observation variables are not assimilated, the wind bias of the DASK has been corrected through applying a simple wind bias correction when calculating the air-sea fluxes. We evaluated the variability of the ocean climate in the climate reanalysis by the DASK from 1947 to 2012. The DASK represents global temperature and salinity well, not only at the surface but also at intermediate depths in the ocean. The DASK's ocean climate variability also matches well with observations of the ENSO, Pacific Decadal Oscillation and Indian Ocean Dipole. The heat content of the DASK shows a good correlation with real-world observations. In this study, we use the reanalysis data from the DASK as an initial condition of our ENSO prediction system. To evaluate the ENSO prediction system, hindcast experiments have been conducted during 30 years from 1982 to 2011, which suggests that the ocean initialization and wind correction significantly improve the ENSO prediction skill. The sensitivity of the ENSO prediction skills to the ocean initialization and wind bias correction will be displayed in more detail in our study.

IAMAS (Meteorology)

M21a - M21 Decadal Climate Dynamics and Prediction

IUGG-0430

A delayed oscillator model for the quasi-periodic multidecadal variability of the NAO

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Wavelet analysis of the annual North Atlantic Oscillation (NAO) index back to 1659 reveals a significant frequency band at about 60 years. Recent NAO decadal variations, including the increasing trend during 1960–1990 and decreasing trend since the mid-1990s, can be well explained by the approximate 60-year cycle. This quasi 60-year oscillation of the NAO is realistically reproduced in a long-term control simulation with version 4 of the Community Climate System Model, and the possible mechanisms are further investigated. The positive NAO forces the strengthening of the Atlantic meridional overturning circulation (AMOC) and induces a basin-wide uniform sea surface temperature (SST) warming that corresponds to the Atlantic multidecadal oscillation (AMO). The SST field exhibits a delayed response to the preceding enhanced AMOC, and shows a pattern similar to the North Atlantic tripole (NAT), with SST warming in the northern North Atlantic and cooling in the southern part. This SST pattern (negative NAT phase) may lead to an atmospheric response that resembles the negative NAO phase, and subsequently the oscillation proceeds, but in the opposite sense. Based on these mechanisms, a simple delayed oscillator model is established to explain the quasi-periodic multidecadal variability of the NAO. The magnitude of the NAO forcing of the AMOC/AMO and the time delay of the AMOC/AMO feedback are two key parameters of the delayed oscillator. For a given set of parameters, the quasi 60-year cycle of the NAO can be well predicted. This delayed oscillator model is useful for understanding of the oscillatory mechanism of the NAO, which has significant potential for decadal predictions as well as the interpretation of proxy data records.

IAMAS (Meteorology)

M21a - M21 Decadal Climate Dynamics and Prediction

IUGG-1910

"Impact of observed North Atlantic multi-decadal variations to European summer climate: A quasi-geostrophic pathway"

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The observed central European summer temperature shows a prominent multidecadal variation during the last century. This multidecadal variation in the summer temperature is closely related to the Atlantic Multidecadal Variation. This work demonstrates a plausible mechanism by which the multidecadal variation in the central European summer temperature is governed by a quasi-geostrophic atmospheric response to the Atlantic Multidecadal Varaition related heat flux. The heat flux over the north-western Atlantic triggers a surface baroclinic pressure response of diabatic heating with a negative surface pressure anomaly eastward. Further downstream the quasi-geostrophic response induces an east-west wave like pressure anomaly. The east-west wave like response in the sea level pressure structure is independent from North Atlantic Oscillation and is the principle mode of variation during summer in multidecadal time scale over this region. This mode causes warming of the central European region through temperature advection and by creating atmospheric blocking. Our findings also suggest that this quasi-geostrophic mode is responsible for the multidecadal variation in precipitation over Britain and north-western Europe. These added understanding about the observed dynamics behind the multidecadal variation of European summer climate, would enable us to reach an enhanced decadal prediction skill over the Euro-Atlantic region during summer.

IAMAS (Meteorology)

M21a - M21 Decadal Climate Dynamics and Prediction

IUGG-2974

Potential sources of mutidecadal climate variability over southern Africa

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Potential sources of multidecadal climate variability over southern Africa are examined by conducting in-depth analysis of available data sets and coupled general circulation model (CGCM) results. Observation and reanalysis data in recent decades show a mutidecadal variability noticeable in the southern African rainfall with its positive phase of peak in 1999-2000. It is found that the rainfall variability is related to anomalous moisture advection from the southwestern Indian Ocean, where the anomalous Sea Level Pressure (SLP) clearly appears. The SLP anomaly is also accompanied with the anomalous Sea Surface Temperature (SST) and both anomalies slowly propagate eastward from the South Atlantic to the southwestern Indian Ocean. The analysis of mixed-layer temperature tendency reveals that the SST anomaly in the southwestern Indian Ocean is mostly due to the eastward advection of the SST anomaly, probably by the Antarctic Circumpolar Current. The eastward propagation of SLP and SST anomalies are also confirmed in the 270-yr outputs of CGCM control experiment, but in a sensitivity experiment, where the SST anomalies in the South Atlantic are suppressed by the model climatology, the eastward propagation of the SLP anomaly becomes unclear. These results suggest that the local air-sea interaction in the South Atlantic may influence the SLP variability in the southwestern Indian Ocean at mutidecadal timescale. Although remote effects from the tropical Pacific and Antarctica were widely discussed, this study provides a new evidence for the potential role of local air-sea interaction in the South Atlantic for the mutidecadal climate variability over southern Africa.

IAMAS (Meteorology)

M21a - M21 Decadal Climate Dynamics and Prediction

IUGG-4389

Evaluation of decadal predictions using a satellite simulator for the Tropical Rainfall Measuring Mission precipitation radar

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A satellite simulator for the Tropical Rainfall Measuring (TRMM) precipitation radar (PR) is developed for evaluation of the three dimensional structure of precipitation simulated by general circulation models (GCMs). The approach enables an evaluation in the instrument’s parameter space thereby reducing uncertainties on the reference side. The simulator is developed as an integrated part of the CFMIP Observation Simulator Package (COSP).

In a first step the simulator is applied to AMIP (Atmospheric Model Intercomparison Project) type simulations performed with two different GCMs, namely MPI-ESM (ECHAM6) and HadGEM2-A. Results are sensitive to the method used to distribute convective precipitation at sub-grid scales. Related uncertainties are constrained by a comparison with satellite based cloud type products, as for example retrieved from the CloudSat cloud profiling radar. HadGEM2-A shows slightly too frequent occurrence of strong precipitation events but the total number of precipitation events is slightly lower than obtained from observations. By contrast, MPI-ESM (ECHAM6) shows larger numbers of precipitation events with moderate radar reflectivities.

In a second step the simulator is applied to different hindcasts of the MiKlip (Mittelfristige Klimaprognosen) decadal prediction system which is based on MPI-ESM. The probabilistic verification approach requires the introduction of metrics for the comparison of the simulated and observed radar reflectivities. The focus is on the evaluation of the simulated tropical precipitation with respect to the mean state and the forecast quality of the hindcasts.

IAMAS (Meteorology)

M21a - M21 Decadal Climate Dynamics and Prediction

IUGG-4981

Assessing the decadal predictability of West African monsoon precipitation in a multi-model RCM downscaling experiment

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West African summer monsoon precipitation (WAM) is a promising candidate in the context of decadal predictability. WAM characteristics are closely connected to oceanic circulation patterns and specifically to long-term oscillations in Northern Hemisphere oceans. Besides ocean temperatures, West African climate is controlled by land-cover characteristics, as well as greenhouse-gas and aerosol concentrations which are consequently chosen as additional boundary conditions in the presented decadal RCM model experiments.
We dynamically downscale several realizations of global hindcast simulations (MPI-ESM-LR) for four decades (1966-1975, 1981-1990, 1991-2000, 2001-2010) using three different RCMs (COSMO-CLM, REMO, and WRF). In a second step, aerosol concentrations and land cover changes (LCCs) are implemented as additional boundary conditions in the RCMs. The performance of the global and regional simulations in reproducing observed precipitation characteristics and variability, as well as the respective decadal prediction skills and uncertainties are assessed on the basis of different observational data sets. The three sub-regions West Sahel, Central Sahel and Guinean Coast are in the scope of the investigations. We present potential decadal predictive skills of the GCM simulations and the added value of the SST-driven RCM simulations for the West African monsoon

region. While an added value from the RCM cannot be found for all simulations and regions, at least one RCM outperforms the GCM in the given test cases. The highest predictive skill can generally be found in the West and Central Sahel. Besides, we show results of first studies regarding the influence of the additional boundary conditions LCCs and aerosol concentrations on the decadal predictability of precipitation.

IAMAS (Meteorology)

M21a - M21 Decadal Climate Dynamics and Prediction

IUGG-5380

Decadal predictions of the North Atlantic with the high-resolution HiGEM model

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The North Atlantic, and especially the subpolar gyre region, has been shown to be one of the few regions where initialisation robustly improves near-term climate predictions. By examining decadal change case studies, it has been shown that the skill is not just due to persistence; the initialisation of the ocean dynamics is important to achieve skilful predictions. However, to date, these studies have been performed with low-resolution climate models, which do represent the all of the relevant processes in the North Atlantic Climate. Hence questions remain on the realism of the proposed mechanisms.

To understand the sensitivity of the predictions to model resolution we have examined predictions made with the HiGEM coupled climate model (a high resolution version of the Hadley Centre Global Environment Model 1), which has a nominal resolution of 90km in the Atmosphere, and 1/3° in the ocean. It is found that HiGEM decadal predictions exhibit significant skill in the North Atlantic, substantially outperforming the historically forced transient integrations and persistence. By focusing on the 1960s cooling and the 1990s warming shifts it is found that, as in previous studies, changes in ocean heat transports dominates the decadal change events, which brings further confidence to the veracity of the importance of the ocean for theses events. However, there are interesting differences in the mechanisms between the low and high-resolution prediction systems, related to the interaction of overturning and gyre changes, suggesting further understanding of the dominant mechanisms is needed. Finally, targeted sensitivity experiments, which examine the role of volcanic forcings in both events, have also been performed and results will be presented.

IAMAS (Meteorology)

M21b - M21 Decadal Climate Dynamics and Prediction

IUGG-1182

The connection between decadal variability in the Pacific Subtropical Cells and sea surface height in the western Tropical Pacific

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The role of the western Pacific sea surface height (SSH) anomalies and associated changes in the horizontal gyre circulation for the phase shift in the Pacific Subtropical Cells (STCs) and subsequent sea surface temperature (SST) in the tropical Pacific during recent decades is examined by using a CMIP-class OGCM simulation (1965-2006). The model represents decadal variations of the STCs concurrent with tropical Pacific thermal anomalies: the eastern tropical Pacific is warmer when the STCs are weaker and cooler when they are stronger. The spatial patterns of the SSH in the western tropical Pacific show different features, depending on events associated with decadal variability. During the warm phase (1977-1987), the SSH anomalies exhibit deviations from a meridionally symmetric distribution, with weakly positive (strongly negative) anomalies in the western tropical North (South) Pacific. Analysis of the heat budget in the upper tropical Pacific indicates that the termination of the warm phase around 1985 results from a poleward heat transport anomaly that is induced by a horizontal gyre associated with the SSH anomalies. During the cold phase (1996-2006), in contrast, the SSH anomalies are nearly meridionally symmetric, with positive anomalies in both hemispheres. Enhanced easterly wind anomalies contribute to the development of the cold phase after the late 1990s. These results suggest that heat exchange between the tropics and the subtropics plays a crucial role in the phase shift of the decadal variability around the mid-1980s. A sensitivity of the results to OGCMs of different horizontal resolutions is also examined.

IAMAS (Meteorology)

M21b - M21 Decadal Climate Dynamics and Prediction

IUGG-1862

Structure and dynamics of decadal anomalies in the wintertime midlatitude North Pacific ocean-atmosphere system

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The structure and dynamics of decadal anomalies in the wintertime midlatitude North Pacific ocean-atmosphere system are examined. The midlatitude decadal anomalies associated with the Pacific Decadal Oscillation are identified, being characterized by an equivalent barotropic atmospheric low (high) pressure over a cold (warm) oceanic surface. Such a unique configuration of decadal anomalies can be maintained by an unstable ocean-atmosphere interaction mechanism in the midlatitudes, which is hypothesized as follows. Associated with a warm PDO phase, an initial midlatitude surface westerly anomaly accompanied with intensified Aleutian low tends to force a negative SST anomaly by increasing upward surface heat fluxes and driving southward Ekman current. The SST cooling tends to increase the meridional SST gradient, thus enhancing the subtropical oceanic front. As an adjustment to the enhanced oceanic front, the low-level atmospheric meridional temperature gradient and the low-level atmospheric baroclinicity tend to be strengthened, inducing more active transient eddy activities that increase transient eddy vorticity forcing. The vorticity forcing tends to produce an equivalent barotropic atmospheric low pressure north of the initial westerly anomaly, intensifying the initial anomalies of the midlatitude surface westerly and Aleutian low. Therefore, it is suggested that the midlatitude ocean-atmosphere interaction can provide a positive feedback mechanism for the development of initial anomaly, in which the oceanic front and the atmospheric transient eddy are the indispensable ingredients. Such a positive ocean-atmosphere feedback mechanism is fundamentally responsible for the observed decadal anomalies in the midlatitude North Pacific ocean-atmosphere system.

IAMAS (Meteorology)

M21b - M21 Decadal Climate Dynamics and Prediction

IUGG-2623

Investigating tropical model initial drift in seasonal hindcasts

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Despite several decades of development, general circulation models are still affected by persistent, unresolved systematic biases, particularly in the Tropics. The problems caused by these biases are especially acute in seasonal and decadal forecasting, where any drift in the model can dominate a forecast. Fixing these biases requires correction algorithms for which the physical basis is difficult to justify.

In this study, we identify the causes of systematic biases present in the tropical Pacific in the ECMWF's seasonal prediction System 4 model, via the detailed analysis of the initial drift away from observations in retrospective forecasts ("hindcasts"). Specifically, we examine the chain of events that lead to the spurious northward displacement of the West Pacific intertropical convergence zone by a few degrees in operational seasonal hindcasts.

By comparing hindcasts both with a coupled ocean and sea-surface temperatures prescribed from observations, we are able to trace the source of this drift back to a pulse of easterly wind bias in the atmosphere component of the model that lasts for the first 40 days and extends over much of the western Pacific.

IAMAS (Meteorology)

M21b - M21 Decadal Climate Dynamics and Prediction

IUGG-4011

The impact of stratospheric aerosol on multiyear seasonal and decadal predictions

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The possibility of a large future volcanic eruption provides arguably the largest uncertainty concerning the evolution of the climate system on the time scale of a few years; but also the greatest opportunity to learn about the behavior of the climate system, and our models thereof. So the question emerges how predictable is the response of the earth system to future eruptions? And how strong will the volcanic perturbation effect seasonal and decadal climate predictions? To address these issues we performed hindcast simulations without stratospheric aerosol with the German MiKlIp prediction system baseline 1 from 1960 to 1991 and compared them to the corresponding simulations with stratospheric aerosol. Our results show that the consideration of stratospheric aerosol leads to a significant improvement in the prediction skill of surface air temperature. The prediction skill is improved in particular over the tropics and subtropics of the Northern Hemisphere in the first year and over the North Atlantic after 5 years. Gain of skill can be found in boreal winter especially over the North Atlantic and Scandinavia. Considerable improvements in the prediction skill due to stratospheric aerosol are also visible in Northern Hemisphere summer over the southern subtropical Atlantic and Indic. The results are strongly influenced by the three large volcanic eruptions during the time.

IAMAS (Meteorology)

M21b - M21 Decadal Climate Dynamics and Prediction

IUGG-4643

The Pacific decadal oscillation, revisited

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Since its identification in the late 1990’s, the Pacific decadal oscillation (PDO), the dominant pattern of North Pacific sea surface temperature (SST) variability, has been connected both to other parts of the climate system and to impacts on natural resources and marine and terrestrial ecosystems. Since then, however, studies have found that the PDO is not a single mode of climate variability but instead represents the combination of three groups of processes: (1) changes in ocean surface fluxes related to the Aleutian low, due to remote interannual to decadal tropical variability (largely El Nino) via the “atmospheric bridge” plus more rapidly varying, unpredictable weather “noise”; (2) oceanic memory processes, principally “re-emergence”, that act to integrate this forcing and thus generate added PDO variability on interdecadal time scales; and (3) SST anomalies along the subarctic front at about 40ºN in the western Pacific ocean, the surface manifestation of decadal changes in the Kuroshio-Oyashio current system forced by basin-wide oceanic processes. Thus, the PDO and its impacts represent the effects of different processes operating on different timescales, not all of which are driven by extratropical SST anomalies. This talk presents a synthesis of this current view of the PDO, and discusses corresponding implications for climate diagnosis, including of PDO climate impacts and predictability (both oceanographic and atmospheric); potential decadal 'regime'-like behavior; simulations of the PDO in climate models; PDO relationships with 'modes' in other ocean basins including the global trend; and the interpretation of paleoproxy multicentennial reconstructions of the PDO.

IAMAS (Meteorology)

M21b - M21 Decadal Climate Dynamics and Prediction

IUGG-5475

Where are we in understanding the early-2000s hiatus of global warming?

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Since 2000 there has been only a very small positive linear trend in globally averaged surface air temperature. This has been termed the hiatus (Meehl et al., 2011) or more generally the “early-2000s hiatus”, and has prompted some to say that global warming has stopped. The hiatus has raised more general and compelling science questions involving the nature of the relationship between internally generated and externally forced climate variability and change, and has prompted an intense research focus on the hiatus. What is known so far is that the small linear trend of globally averaged surface air temperature since 2000 is not unprecedented in either observations or climate model simulations. Analyses from models and observations have indicated that during such hiatus periods when greenhouse gases continue to increase and trap heat in the system, this excess heat is being sequestered in the deeper layers of the ocean, and ocean mixing processes in three areas of the world oceans are likely involved (the subtropical Pacific, near Antarctica, and in the North Atlantic). The negative phase of the Interdecadal Pacific Oscillation (IPO) drives not only ocean mixing processes in the tropical and subtropical Pacific but also the signal of globally averaged surface air temperature. The negative phase of the IPO can be simulated for the early-2000s hiatus in initialized decadal climate prediction experiments, thus pointing to the possibility that this technique could be used to provide information regarding when the hiatus may end.

IAMAS (Meteorology)

M21p - M21 Decadal Climate Dynamics and Prediction

M21p-232

Interdecadal variability of early summer monsoon rainfall over South China in association with Pacific Decadal Oscillation

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Interdecadal variability of the early summer monsoon rainfall over South China (SCMR) is investigated based on several long-term rainfall datasets from 1926 to 2013. Both correlation and composite analyses suggest a significant out-of-phase relationship between interdecadal fluctuations of SCMR and the preceding wintertime Pacific Decadal Oscillation (PDO), with negative (positive) PDO epochs favoring above-normal (below-normal) SCMR. The physical mechanism relating wintertime PDO to interdecadal variability of SCMR appears to be via atmospheric and oceanic teleconnections. The below-normal SCMR is characterized by an anomalous meridional wavelike teleconnection along East Asian–western North Pacific (WNP) sector with an anomalous cyclone and an anomalous anticyclone occurring alternately over South China Sea (SCS)-WNP, Yangtze Basin and Lake Baikal in the early summer, which may respond to the PDO-related warm sea surface temperature (SST) anomalies over SCS-WNP and tropical eastern Pacific. South China is just under the divergent moisture environment of anomalous northeasterlies between the anomalous cyclone over SCS-WNP and anticyclone over Yangtze Basin. Again, the below-normal SCMR is preceded by negative (positive) SST anomalies in midlatitude North Pacific (tropical eastern Pacific) associated with positive PDO in wintertime, with such anomalous SST pattern inducing an strengthened and northward-shifted upper tropospheric jet and an intensified and eastward-extended South Asian High, subsequently leading to significant upper tropospheric convergence over South China. This out-of-phase relationship between SCMR and wintertime PDO and related physical processes can be verified by coupled model (NCAR-CCSM4) simulations.

IAMAS (Meteorology)

M21p - M21 Decadal Climate Dynamics and Prediction

M21p-233

Helioclimatology of Japan (case study)

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Japan is an excellent test case given its remoteness from continents. Japan is surrounded on all sides by the sea. Isolation of Japan from continental landmass of Asia and warm and cold ocean currents creates a specific climate system of the archipelago.

In this study we examined relations between mean air temperature and sunspots. Our study show in a large part of Japan area the temperature change has a positive correlation with solar activity. The exception is the northern part of the island of Hokkaido.

Calculations of weather stations: Tokyo, Hiroshima, Hamamatsu, Kobe, Kanazawa, Izuhara, Matsuyama, Nagano, Nagaya, Kyoto, Nagasaki, Osaka reveal high correlation between air temperature and solar activity over the period 1878 – 1996.Correlation coefficients varies from 0,81- 0,95 for different stations.

The report presents basic conceptual framework underlying in background of study and methodology of calculation the solar influence on air temperature with forecasting of further temperature trends.

The source of data: NASA Surface Temperature Data.

IAMAS (Meteorology)

M21p - M21 Decadal Climate Dynamics and Prediction

M21p-234

Processes of Decadal Climate Variability

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The realistic representation of decadal climate variability in the models is essential for the quality of decadal climate predictions. Therefore, those processes important for the realistic representation need to be found and included or improved in the climate models. This is done in several projects within the German research program "MiKlip – Decadal Predictions" (http://www.fona-miklip.de/en/) for the following processes. A new parameterization of boundary layer processes over inhomogeneous Arctic sea ice is developed. A coupled global atmosphere-ocean-sea ice system with regional refinement in the Arctic is applied. The consideration of the full-physics subsurface hydrodynamics to account for the memory effect of soil moisture is tested for different regions in Europe. The air-sea interaction is analyzed over the North Atlantic Current and Gulf Stream. Stratospheric processes and their impact on the troposphere are analyzed including tropospheric and stratospheric chemistry. The effect of large volcanic eruptions is also taken into account.

IAMAS (Meteorology)

M21p - M21 Decadal Climate Dynamics and Prediction

M21p-235

Analysis and forecasting of climate variability on basis of solar activity.

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The Earth's climate system has constantly evolved throughout its geologic history. There have been periods of warming and there have been ice ages. It is believed, the large-scale climatic changes of the pre- industrial era were caused by natural causes, such as changes in solar energy, volcanic eruptions, and natural changes in greenhouse gas concentrations.

Since the mid-20th century climate change is considered as a result of human activity or imposition of human activity on the natural climate process.

The goal of this study is to identify a contribution of solar variations role in the background of climate change.

The source of virtually all the energy in the climate system is radiation from the Sun.Cloud cover,global wind patterns and precipitation are factors derived due to solar energy.
The averaged temperature on latitude 85–65° in Northern hemisphere and the 10.7 cm Solar Flux were studied to analyses the statistical relationship between temperature data time series over the period 1891-1986 and solar activity.

An empirical relationship between solar activity phases and averaged temperature in Northern hemisphere was found:

$T_{85\text{-}65°} = 257{,}795+0{,}0304F_{10,7} \pm 0{,}456$ °?

-where T 85-65° - averaged temperature on latitude 85–65° in Northern hemisphere,

257,795-air temperature, K;

0,0304- thermal conductivity coefficient of air on latitude 85–65° in Northern hemisphere for one solar cycle;

0,456 °?- a confidence interval (CI);

$F_{10,7}$ -10.7 cm Solar Flux.

This relationship can be used for analyses of temperature change in dependence from solar activity.

We recommend using the air temperature of months January and July or averaged annual temperature of any studied weather station to find the contribution of power of radio emission of the Sun in temperature change.

IAMAS (Meteorology)

M21p - M21 Decadal Climate Dynamics and Prediction

M21p-236

Results from different initialization strategies in the decadal prediction project MiKlip

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There is a growing need for reliable information on trends in weather and climate for time frames of years to decades, mainly because the
planning horizon of the economy, but also of politics and society, is on the order of ten years. The national German research project "Mittelfristige Klimavorhersagen" (MiKlip) aims at developing a decadal prediction system for operational use. We introduce the MiKlip project and present results from different initialization strategies, including different ocean reanalysis (ORAS4 and GECCO2), as well as initialization with full-fields versus anomalies. The impact of ensemble size and model resolution is also evaluated.

IAMAS (Meteorology)

M21p - M21 Decadal Climate Dynamics and Prediction

M21p-237

Volcanic forcing in decadal forecasts

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Volcanic eruptions can significantly impact the climate system, by injecting large amounts of particles into the stratosphere. By reflecting backward the solar radiation, these particles cool the troposphere, and by absorbing the longwave radiation, they warm the stratosphere. As a consequence of this radiative forcing, the global mean temperature can decrease by several tenths of degrees. However, large eruptions are also associated to a complex dynamical response of the climate system that is particularly tricky do understand regarding the low number of available observations. Observations seem to show an increase of the positive phases of the Northern Atlantic Oscillation (NAO) the two winters following large eruptions, associated to positive temperature anomalies over the Eurasian continent. The summers following large eruptions are generally particularly cold, especially over the continents of the Northern Hemisphere. Overall, it is really challenging to forecast the climate response to large eruptions, as it is both modulated by, and superimposed to the climate background conditions, largely driven themselves by internal variability at seasonal to decadal scales. This work shows the added value associated to volcanic forcing in climate simulations dedicated to seasonal to decadal forecasts. It could consist in a base for forecasts that would be performed in the context of a new large eruption.

IAMAS (Meteorology)

M21p - M21 Decadal Climate Dynamics and Prediction

M21p-238

Investigating causes of systematic model biases in the tropical Atlantic based on the seasonal hindcast of the EC-Earth model

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The climatology of the Tropics as represented in General Circulation Models (GCMs) is affected by significant systematic biases despite the huge investments in model development over the past 20 years. In this study, seasonal hindcasts performed with the coupled GCM EC-Earth are analysed to understand the evolution and infer the causes of the model biases in the tropical Atlantic . We use monthly- and daily-frequency ensemble-mean fields from 120 hind-casts, with 4 starting dates each year for the period 1981-2010, and compare them with atmosphere and ocean re-analysis datasets. Here we discuss the rapid development of a wet, westerly bias over the equatorial Atlantic in Spring, which occurs within the first 5 days of the forecast. We test the role of the wind error on the subsequent development of Equatorial and other tropical-Atlantic SST biases using wind stress correction in the coupled configuration of the model.

IAMAS (Meteorology)

M21p - M21 Decadal Climate Dynamics and Prediction

M21p-239

Decadal predictions with the high-resolution HiGEM coupled climate model

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Developing skillful and statistically reliable climate predictions on seasonal to decadal timescales is one of the grand challenges of climate science. Skillful seasonal to decadal predictions would have substantial socioeconomic benefits, informing investment across a wide range of economic sectors. To explore the question of how increased resolution might improve predictions at regional scales, a high resolution global coupled climate model, HiGEM, has been developed. This model is based on the Met Office Hadley Centre global coupled climate model, HadGEM1. In HiGEM the horizontal resolution in the atmosphere is increased to 1.25x0.83 degrees longitude by latitude, while the resolution in the ocean is increased to an eddy-permitting resolution of 1/3x1/3 degrees. Increasing the horizontal resolution results in an improved representation of a number of climate phenomena in HiGEM, including ENSO, Northern Hemisphere planetary waves and subtropical stratocumulus.

We have completed a set of decadal predictions using HiGEM following the CMIP5 protocol, producing an ensemble of 10 year predictions starting every five years from 1960 to 2005. The methodology for the HiGEM decadal predictions is based on that used in Met Office DePreSys system, where the ocean model is initialised using anomaly assimilation. A general overview of the prediction system will be presented including the skill of the HiGEM decadal predictions. In particular, HiGEM is capable of skillfully predicting the evolution of ocean temperatures in the North Atlantic subpolar gyre on lead times of up to four years.

IAMAS (Meteorology)

M21p - M21 Decadal Climate Dynamics and Prediction

M21p-240

Decadal climate forecasts and their evaluation of accuracy and spread in the MiKlip prediction system

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We show the evaluation of temperature and precipitation forecasts obtained with the MiKlip decadal climate prediction system. The combination of forecasts for the next years and its evaluation on lead years enables a clear assessment. These decadal hindcast experiments are verified with respect to the accuracy of the ensemble mean and the ensemble spread as a representative for the forecast uncertainty. The skill assessment follows the verification framework already used by the decadal prediction community, but enhanced with additional evaluation techniques like the logarithmic ensemble spread score. The core of the MiKlip system is the coupled Max Planck Institute Earth System Model. An ensemble of 10 members is initialized annually with ocean and atmosphere reanalyses of the European Centre for Medium-Range Weather Forecasts. For assessing the effect of the initialization and its added value, we compare these predictions to uninitialized climate projections with the same model system. Furthermore, we show that increasing the ensemble size improves the MiKlip decadal climate prediction system for all lead years.

IAMAS (Meteorology)

M22a - M22 Understanding and Predicting High-impact Weather and Climate Extremes

IUGG-1594

Attribution of extreme climate events

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There is a tremendous desire to attribute causes to weather and climate events that is often baseless from a physical standpoint. Indeed headlines in newspapers and other media are frequently misleading in attributing an event solely to either human-induced climate change or to natural variability when it is always a combination of both. Many attribution statements are merely a more complete description of the event. It is argued that instead a different framing is required to ask sensible questions about influences external to the atmosphere and why such extremes unfold the way they do. Specifically, it is more useful to regard the extreme circulation regime or weather event as being largely unaffected by climate change, and ask the question of whether the impact of the particular event was affected by known changes in the climate system's thermodynamic state in which there is more confidence. Some examples briefly illustrated include super storm Sandy in October 2012, and super typhoon Haiyan in November 2013 that devastated the Philippine Islands and, in more detail, the Boulder floods of September 2013, all of which were influenced by high sea surface temperatures that had a discernible human component.

IAMAS (Meteorology)

M22a - M22 Understanding and Predicting High-impact Weather and Climate Extremes

IUGG-2278

The timing of anthropogenic emergence in climate extremes

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Many extreme events can be attributed to anthropogenic climate change whilst others can not. This has motivated us to study the time of an anthropogenic emergence (TAE) of six indices representing temperature and precipitation extremes. We used multiple historical runs and RCP8.5 projections from six CMIP5 models. We define a quasi-natural variability for each of these indices at gridbox level and for sub-continental regions and the globe as a whole. We determine when an anthropogenic emergence occurs by comparing index distributions across moving windows and the quasi-natural variability. We also investigated how TAE compared for mean temperature and precipitation with extremes. We found earlier emergence of extreme temperatures in equatorial regions compared to other parts of the world and some seasonal variability in TAE. Spatial aggregation reduces variability in mean and extreme temperature and precipitation leading to earlier TAE values. Using limited observational datasets, the same TAE methodology was applied and signs of emergence found. Finally, using the CMIP5 models, we show the regions of the world where anthropogenic signals can already be detected in our temperature and precipitation indices to aid in the study of attribution of extreme events to climate change.

IAMAS (Meteorology)

M22a - M22 Understanding and Predicting High-impact Weather and Climate Extremes

IUGG-3933

Detection, attribution and extreme climate and weather events

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Climate change detection and attribution (D&A) research over the past decade has increasingly concerned itself with questions concerning changes in the frequency and intensity of rare, high impact weather and climate events (extremes). While D&A methods appropriate to extremes are not completely settled, the science consistently indicates that human influence is responsible for observed changes in the intensity and/or frequency of temperature extremes, and increasingly often, in precipitation extremes. A recent further development is a gathering interest in "event attribution", which is loosely defined as the identification of external factors that may have contributed to the intensity or likelihood of specific events, such as the European 2003 heat wave or the California drought. This talk will compare and contrast differences in the questions posed by D&A research (what are the causes of observed long-term changes in extremes) and event attribution (what are the causes of event that has just occurred), and in the methods that are used to answer these questions. Event attribution is challenging because of "selection bias", the need for timeliness, and the difficulty in identifying relevant controlling factors, but surmounting these challenges, coupled with ongoing D&A research on long-term changes in extremes and seasonal-to-interannual forecasting, could eventually lead to reliable short-term climate forecasts of variations in the likelihood of occurrence of extremes that also take into account long-term changes in likelihood and intensity that are caused by anthropogenic forcing of the climate system.

IAMAS (Meteorology)

M22a - M22 Understanding and Predicting High-impact Weather and Climate Extremes

IUGG-5045

Attribution of extreme temperature changes during 1951-2010

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An attribution analysis of extreme temperature changes is conducted using updated observations (HadEX2) and multi-model climate simulation (CMIP5) datasets for an extended period of 1951 to 2010. Compared to previous HadEX/CMIP3-based results, the current results provide better agreement with observations, particularly for the intensification of warm extremes. Removing the influence of two major modes of natural internal variability (the Arctic Oscillation and Pacific Decadal Oscillation) from observations further improves attribution results, reducing the model-observation discrepancy in cold extremes. An optimal fingerprinting technique is used to compare observed changes in annual extreme temperature indices of coldest night and day (TNn, TXn) and warmest night and day (TNx, TXx) with multi-model simulated changes that were simulated under natural-plus-anthropogenic (ALL) and natural-only (NAT) forcings. Extreme indices are standardized for better intercomparisons between datasets and locations prior to analysis and averaged over spatial domains from global to continental regions following a previous study. Results confirm previous HadEX/CMIP3 based results in which anthropogenic (ANT) signals are robustly detected in the increase in global mean and northern continental regional means of the four indices of extreme temperatures. The detected ANT signals are also clearly separable from the response to NAT forcing, and results are generally insensitive to the use of different model samples as well as different data availability.

IAMAS (Meteorology)

M22b - M22 Understanding and Predicting High-impact Weather and Climate Extremes

IUGG-0223

Application of strong wind statistics for disaster management related to wind hazards in South Africa

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For the estimation of accurate extreme wind statistics, the use of applicable statistical methods is imperative. This is particularly true for extreme value estimations from data which cover short time periods. In South Africa, time series of most wind measurement stations recording on a continuous basis are shorter than 20 years. This affects the confidence in the results from the application of the traditional Gumbel method. Appropriate estimation methods, e.g. the Peak-Over-Threshold method for the estimation of extreme values, that considers the maximum amount of usable data, are expected to provide more realistic results. In addition, the application of the method also makes the possibility of related statistics possible, which can be of value to disaster management. This is because a larger section of the strong wind profile is modelled by the distribution, i.e. all wind speed values stronger than a specific threshold e.g. 20 m/s, which falls in the near-gale wind speed category of the Beaufort wind scale. The National Disaster Management Centre of South Africa approached the South African Weather Service to provide measures of four wind hazard parameters, i.e. likelihood, frequency, magnitude and predictability, according to definitions widely used by the disaster management sector, as well as a relative measure of overall wind hazard. By application of the Peak-Over-Threshold method all these parameters could be estimated to a satisfactory degree, and relevant risk according to five relative categories, assigned to local municipal level.

IAMAS (Meteorology)

M22b - M22 Understanding and Predicting High-impact Weather and Climate Extremes

IUGG-0681

Distinguishing natural and anthropogenic influences on extreme fire danger in Australia

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In the aftermath of the 2013 Blue Mountains wildfires in New South Wales, Australia, the scientific community was faced with the challenge of quantifying the event's link to different causal factors, including human-induced climate change. While there are a number of recorded attribution studies for temperature and precipitation-related events, no such study exists for fire weather.

This study investigates how the likelihood of extreme fire weather in south-east Australia has been changed due to the competing influences of human-induced climate change and modes of inter-annual climate variability. Our analysis benefits from the use of the recently launched weather@home Australia-New Zealand distributed computing citizen science project to generate very large ensembles of regional climate model simulations over Australia. The likelihood of extreme fire weather is examined for different phases of the El Niño Southern Oscillation under present climate conditions and climate conditions with no human influences.

IAMAS (Meteorology)

M22b - M22 Understanding and Predicting High-impact Weather and Climate Extremes

IUGG-1538

Projecting climate extremes in Ireland using extreme value theory

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Changes in extreme climate events are of great importance to policymakers and the general public. But measuring changes in their frequency, intensity and duration is difficult, due to their rarity.

In this study, we create an extreme climate map of Ireland. We examine how climate extremes of temperature have changed in the recent past, and how they are projected to change in the future, using output from the latest high-resolution climate models.

Our data consists of: historical weather station observations; gridded datasets from those observations; and climate model output for historical and future periods. Learning from the models' historic extreme events is an innovative approach to improve our understanding of their future projections.

Our method involves inference on the parameters that uniquely define a Generalised Pareto Distribution, for a given set of extremes above an appropriate threshold. We construct a hierarchical model to reflect our assumption of an underlying spatial process. Observations are first compared to the gridded datasets in order to understand the inherent biases and assess levels of signal damping. We then focus on using this information to produce future projections of extreme events, along with covariates such as the historical and model values of the North Atlantic Oscillation, global surface temperature, and the particular climate models under consideration.

Using Bayesian inference to sample from the posterior densities of the statistical model parameters, we then estimate desired quantities such as return periods and associated uncertainty levels.

The result is a spatio-temporal map of Ireland showing projected changes in the distribution of the climate extremes of temperature. Our method will then be applied to precipitation and wind speed.

IAMAS (Meteorology)

M22b - M22 Understanding and Predicting High-impact Weather and Climate Extremes

IUGG-3353

"ensemble application for extreme weather/climate detection"

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In 2006, the post-processing of NCEP Global Ensemble Forecast System (GEFS) and North American Ensemble Forecast System (NAEFS) has been implemented to enhance probabilistic forecast through anomaly forecast of various weather elements. Anomaly forecast is one of NAEFS products from bias corrected forecast and reanalysis based climatology. It is measuring the forecast departure (bias–free) from climatology (observation). Based on NCEP/NCAR 40-year reanalysis, daily climatological distribution (PDF) has been build up for 19 atmospheric variables, such as height, temperature, winds and etc. The uncertainty information for anomaly by comparing forecast PDF to climatological PDF allows users to identify the extreme weather event easily. There are many applications in past years for extreme heat waves, winter storms and etc.

Later, a new daily climatology has been generated from latest Climate Forecast System (CFR) reanalysis. Apparently, CFSR has much improved analysis quality through various enhancements, such as the quality of observations, state-of-art model and assimilation system, and much higher spatial resolution. There will be a comparison of two climatological distributions in terms of their anomaly forecast for extreme weather/climate events. In the contrast, there is another way to build up anomaly forecast (or Extreme Forecast Index (EFI)) in the communities, that bases on raw ensemble forecast and model based climatology, such as ensemble reforecast (20 years). Therefore, a multi comparison of anomaly forecast for several extreme weather/climate events will be performance through out this study.

IAMAS (Meteorology)

M22b - M22 Understanding and Predicting High-impact Weather and Climate Extremes

IUGG-3413

Investigating extreme climate events of the past century

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A range of observational datasets that allow investigation of climatic extremes have recently become available. Some of these datasets cover the entire 20th Century and thus enable us not only to estimate long-term changes of extremes, but also to investigate individual events in a historical context.

Comparing datasets of gridded observations of temperature and precipitation extremes and extremes calculated from a century-long atmospheric reanalysis, this presentation will address the issue of uncertainties related to long-term trend analyses. On a global scale, time series of the different extremes indices compare generally well over the past 70 years but show larger differences before around 1940. However, in areas with good observational coverage, including North America, Europe and Australia, agreement remains strong also throughout the earlier decades of the 20th Century.

Furthermore, these datasets are used for case studies of specific events. Here, we focus on the 1930s US Dust Bowl as one of the most severe hot drought events of the early 20th Century that was associated with unprecedented hot extremes over large parts of North America. Using a combination of gridded observations and reanalysis data we investigate large-scale conditions associated with this climate event. We find that the unprecedented summer heat during the Dust Bowl years was likely exacerbated by land-surface feedbacks associated with springtime precipitation deficits. These deficits were associated with a superposition of anomalously warm North Atlantic and Northeast Pacific surface waters that is unique over the instrumental record, and a shift in atmospheric pressure patterns leading to reduced flow of moist air into the central US.

IAMAS (Meteorology)

M22b - M22 Understanding and Predicting High-impact Weather and Climate Extremes

IUGG-5294

Need for caution in interpreting extreme weather statistics

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Given the reality of anthropogenic global warming, it is tempting to seek an anthropogenic component in any recent change in the statistics of extreme weather. We caution, however, that such efforts may lead to wrong conclusions if the distinctively skewed and heavy-tailed aspects of the probability distributions of daily weather anomalies are ignored or misrepresented. Departures of several standard deviations from the mean, although rare, are far more common in such a distinctively non-Gaussian world than they are in a Gaussian world. This further complicates the problem of detecting changes in tail probabilities from historical records of limited length and accuracy.

A possible solution is to exploit the fact that the salient non-Gaussian features of the observed distributions are captured by so-called Stochastically Generated Skewed (SGS) distributions that include Gaussian distributions as special cases. SGS distributions are associated with damped linear Markov processes perturbed by asymmetric stochastic noise, and as such represent the simplest physically based prototypes of the observed distributions. We provide extensive evidence for the relevance of SGS distributions in extreme analysis. The tails of SGS distributions can also be directly linked to Generalized Extreme Value (GEV) and Generalized Pareto (GP) distributions. The Markov process model can be used to provide confidence intervals, and to investigate temporal persistence statistics. We illustrate the procedure for assessing changes in the observed distributions of daily wintertime indices of large-scale atmospheric variability in the North Atlantic and North Pacific sectors over the 1872-2011 period. No significant changes in these indices are found from the first to the second half of the period.

IAMAS (Meteorology)

M22c - M22 Understanding and Predicting High-impact Weather and Climate Extremes

IUGG-2586

High-impact, end-user focused forecasts and their verification during the Sochi 2014 Winter Olympics

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The weather forecasters of the Sochi Winter Olympics (February-March 2014) had a huge challenge to provide accurate and reliable forecasts of the high-impact weather affecting the highly time and space critical sports events in a complex terrain, at altitudes 500-2500 m, relatively close to the Black Sea. Forecast and Research in the Olympics Sochi Testbed (FROST-2014) was a related Forecast and Research Demonstration Project (FDP/RDP) that was initiated under the auspices of the WMO World Weather Research Program (WWRP). Many international partners (Austria, Canada, Finland, Italy, Norway, Russia, South Korea, USA) contributed to FROST-2014 by running their locally developed state-of-the-art deterministic and probabilistic now-casting and forecasting systems. Their forecast output was disseminated to a common database which was set up to serve the local Olympics forecasters who, consequently, interacted with the end-users. Forecast verification was an obvious, integral component to assess forecast performance of these various systems. Finnish Meteorological Institute adapted its in-house operational verification system for the Sochi environment and accomplished a comprehensive verification undertaking by performing high spatial resolution point verification utilizing c. 30 surface weather stations located at or close by the individual sports sites. The paper will give an overview of the FROST-2014 project, the various prerequisites that needed to be considered and the forecast verification framework. Illustrative results are presented on how the various forecast systems and components managed to forecast the high-impact weather events during the Olympics.

IAMAS (Meteorology)

M22c - M22 Understanding and Predicting High-impact Weather and Climate Extremes

IUGG-3598

Using advances in meteorology to build resilience to high impact weather

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Over the past ten years, the THORPEX project has produced impressive advances in synoptic scale weather prediction, the development of convection-permitting models has enabled the prediction of weather-related hazards, and technology has become available for more effective communication of forecasts and warnings to emergency managers and the public. The time is ripe to usse these capabilities to raise the level of resilience to weather hazards in all countries. Working alongside national and regional initiatives, the World Meteorological Organisation has launched the 10-year HIWeather project to facilitate international collaboration in solving the critical obstacles to achieving this across the physical and social sciences. My talk will demonstrate the new capabilities for hazard and impact prediction provided by recent advances in high resolution Numerical Weather Prediction. It will then describe the structure and objectives of the HIWeather project, focussing on the way in which decisions made by emergency managers and the public determine what information should be communicated, when and how, which in turn drive the challenges to the meteorological research community. Finally I will outline some early areas of work in the project that will begin to address these issues.

IAMAS (Meteorology)

M22c - M22 Understanding and Predicting High-impact Weather and Climate Extremes

IUGG-5265

Stochastic ensemble forecasts of precipitation and wind in storm events: dynamical downscaling and stochastic full-field fractal weather generators

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Dynamical and stochastic downscaling methods forced by operational global ensemble forecast systems (GEFS) are used to improve short-to-mid-range forecasts of storm events, focusing on the Iberian Peninsula.
Dynamical downscaling is performed by generating a large number of high-resolution nonhydrostatic WRF model simulations, by varying the initial and boundary conditions but also the physical parameterizations, hence accounting for observation and model uncertainties. Alternatively, a transient fractal based stochastic downscaling methodology recently developed by Nogueira et al. (2013); Nogueira and Barros, (2014) is used to generate high-resolution stochastic forecasts directly from the GFS. Such methods are demonstrated to rapidly produce plausible weather realizations, dynamically dependent on the atmospheric state that capture the correct statistical structure of the observed fields, opening a promising path to solve two major open problems in atmospheric sciences: downscaling and sub-grid parameterization of precipitation, clouds, wind and other geophysical fields.
The ability of both downscaling methodologies to provide useful and accurate (probabilistic) forecasts of wind and precipitation in storm events is investigated, taking into account the enhanced value from the forcing GEFS, the computational power and time required (a critical issue for operational forecasts).

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IAMAS (Meteorology)

M22c - M22 Understanding and Predicting High-impact Weather and Climate Extremes

IUGG-5499

Flood Foresight: Near real-time flood monitoring and impact assessment for the re/insurance and civil contingency sectors

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National scale flood maps are available in many countries, describing the risk of flooding from rivers, sea and intense rainfall. Global scale maps are also available, typically developed for the private re/insurance market so that large scale risk can be evaluated. These products report the extent or depth of inundation for a given return period event. The events they describe are therefore hypothetical, making them useful for planning and evaluating long-term flood risk, but not for understanding how a forecast event might unfold.

The Foresight approach is designed to re-use this flood map data in a way that enables the derivation of real-time and forecast event footprints, on a global scale. A range of disparate environmental datasets are mined to provide outputs that can be directly applied in flood response management.

The method presented uses outputs from high resolution Weather Research and Forecasting (WRF) model simulations, in combination with a statistical analysis of the Climatic Research Unit (CRU) 2.0 dataset, to obtain catchment scale rainfall recurrence intervals. Historical river flows are obtained for each catchment, and a regression model constructed to relate observed rainfall to observed flow. This regression model is applied in real-time to derive predicted river flow from precipitation forecasts, without the need for a fully distributed hydrological model. In a final step, a unique relationship is built between flood depths on a 1km grid and the flow at an associated river gauge. During an event, these relationships are called upon to generate flood depth maps, which can then be used to map the number of properties at risk across large areas. Applications are demonstrated, with particular reference to the re/insurance and civil contingency sectors.

IAMAS (Meteorology)

M22c - M22 Understanding and Predicting High-impact Weather and Climate Extremes

IUGG-5704

TIGGE-LAM ensemble datasets for the prediction of heavy precipitation events: first results at ARPA-SIMC.

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The TIGGE-LAM archive provides a unique opportunity to support research on ensemble prediction at high spatial resolution. In this contribution, different limited-area model ensemble prediction systems (LAM-EPSs) from the TIGGE-LAM archive are used to assess the predictability of a number of severe weather events recently occurred over Europe.
The added value of the multi-model with respect to the single-model approach is assessed by investigating the performance of the different LAM-EPSs over a 3-month period and a common overlap region. The skill of the TIGGE-LAM systems (either running in convection-parameterised or convection-permitting mode) is mainly studied in terms of probabilistic prediction of precipitation for forecast ranges up to day 5.The relative benefits of higher resolution and/or larger ensemble size are quantified over the verification period as well as for the individual case studies.

IAMAS (Meteorology)

M22d - M22 Understanding and Predicting High-impact Weather and Climate Extremes

IUGG-0701

The impact of urbanization on the extreme rainfall in Beijing in July 21st 2012

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The impact of urbanization on heavy rainfall in Beijing on July 21, 2012 is investigated using the new version Weather Research and Forecasting Modal (WRF3.6.1) coupled with Multi-layer urban canopy model (BEP). High-resolution land use data of Beijing in 2010 with modified urban parameterization were introduced into the model. Evaluation using china automatic stations mixing with CMORPH precipitation product shows that the simulation is generally well. Two sensitive tests with two different high-resolution land-use scenarios were employed to analyze the impact of urban expansion on this event. Simulation results address that urbanization plays an important role in precipitation distribution and intensity. The urbanization leads to total precipitation increasing in downtown as well the neighboring area in this extreme strong rainfall event. The start time of the precipitation is in advance and the duration is also become longer influence by urbanization. Moreover, the urban induces the precipitation become concentrated. The frequency of total precipitation above 250 mm and the precipitation intensity of 40-50 mm are increased. The impact of urbanization on frontal-type rainfall in current land-use scenario is also the most significant.

IAMAS (Meteorology)

M22d - M22 Understanding and Predicting High-impact Weather and Climate Extremes

IUGG-2855

Convection Initiation of a High-impact Squall Line on 3 June 2009 in East China

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This work examined the convection initiation (CI) of a severe squall line that occurred in east China on 3 June 2009 in front of a short-wave trough embedded in a quasi-stationary cold vortex through both observational analyses and numerical simulations. The strong disastrous wind associated with the squall line casued a fatality of 20. It was found that the convection initiation was triggered by lifting due to a mesoscale boundary collision between a surface convergence line and a series gust fronts (GF) generated by a pre-existing mesoscale convective system upstream of the CI location. Observational study showed that maximum horizontal convergence and upward motion formed near the two inflection points of a GF modulated by two fast-moving GFs behind it. Over these two locations, two convective cells were initiated and merged to form a convetcive line parallel to the convergence line which later on developed into a strong bow-echo. This CI process was successfully captured by a cloud-permiting numerical simulations with the Weather Research and Forecasting model (WRF) with a grid-spacing of 4.5 km. Based on the simulations, the three-dimensional kinematic and thermodynamic mesoscale structures of the CI as well as the boundary layer and the lower troposphere at relevant scales of CI forcing were examined.

IAMAS (Meteorology)

M22d - M22 Understanding and Predicting High-impact Weather and Climate Extremes

IUGG-2967

Diurnal Variability of Cloud-to-ground lightning over Hainan Island in the Warm Season: Impact of Sea-land breeze

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The main purpose of this study is to assess the predictability of cloud-to -ground (CG) lightning activity over Hainan island, where is located in the southernmost part of China, during the warm season. CG lightning data collected by Hainan Lightning Detection Network, and 10m surface wind data from Hainan high-density automatic weather stations from 2007-2012, are used to create lightning climatology and surface wind climatology. Synoptic scale background flows are grouped into four categories to investigate their interactions with sea-land breeze, and the resulting evolution of convergence zones. The relationships between the displacements of CG lightning and the convergence zones are then examined. Results show that lightning occurs most frequently over northern inland with a yearly maximum of 13 strikes per square kilometer. The second largest region of flash density is located at the southern coastal areas and their immediately offshore. The diurnal variations of Lightning activity are regulated by circulations of the sea-breeze and land-breeze. More than 90% of the lightning over land occur during the daytime except for southern and western coastal areas of the Island where more than 60% lightning happen at the midnight and early morning. Patterns of lightning evolution depend largely on the prevailing low-level synoptic flow. Different wind flows exhibit different sea-breeze convergence lines and therefore control the initiated locations of lightning and their migration path. The results could have practical applications for lightning short-term forecast and nowcastinig.

IAMAS (Meteorology)

M22d - M22 Understanding and Predicting High-impact Weather and Climate Extremes

IUGG-2997

Numerical prediction of local high impact weather with the K-computer

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A research on super high-resolution mesoscale numerical weather prediction with the K-computer is introduced. This research project is one of the five fields of the MEXT-funded national research project in Japan, the Strategic Programs for Innovative Research (SPIRE). Following three subjects are underway to show the feasibility of precise prediction of local high impact weather phenomena: 1) Development of cloud resolving 4-dimensional data assimilation systems, 2) Development and validation of a cloud resolving ensemble analysis and forecast system, and 3) Basic research with very high resolution atmospheric models.

In the presentation, development of advanced data assimilation methods (e.g., cloud resolving 4D-VAR, two-way nested LETKF) is introduced, and examples of high-resolution and super high-resolution data assimilation/ensemble experiments of high impact weathers (typhoon, torrential rain, and tornado) are shown. A realistic simulation of observed 3-dimentional structure of the sea-breeze front head with a nested building-resolving LES model will also be presented.

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IAMAS (Meteorology)

M22d - M22 Understanding and Predicting High-impact Weather and Climate Extremes

IUGG-5315

Monitoring of thunderstorm activity by super dense network with electromagnetic filed sensors

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It’s difficult to understand the inside structure and developing process of thunderstorm only with existing meteorological instruments or their networks since its horizontal extent of the storm cell is sometimes smaller than an order of 10 km while the densest ground network consists of sites located every an order of 10 km and the typical resolution of meteorological radar is 1-2 km in general. Here we suggest a thunderstorm monitoring system consisting of the network of sferics receivers and the super dense meteorological observation system with simple and low cost plate-type sensors that can be used for measurement both of raindrop and vertical electric field change caused by cloud-to-ground lightning discharge. Horizontal location, height and charge amount of each lightning discharge are estimated successfully based on the information of electric field changes at several observing sites. Moreover, it was found that the thunderstorm has a structure smaller than 300 m that cannot be measured by any other ways, counting the positive and negative pulses caused by attachment of raindrop to the sensor plate. We plan to construct a new super dense observation network in the north Kanto region as a test site, Japan, where the lightning activity is most prominent in summer Japan and surrounded by our VLF systems developed for detecting sferics from lightning discharge, distributing more than several tens of sensors at every 4 km or shorter, such as an order of 100 m at minimum. This kind of new type network will reveal the unknown fine structures of thunderstorms and open the door for constructing real time alert system of torrential rainfall and lightning stroke, which cannot be monitored by any other ways.

IAMAS (Meteorology)

M22e - M22 Understanding and Predicting High-impact Weather and Climate Extremes

IUGG-1510

Rapid increase in the risk of extreme summer heatin Eastern China

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The summer of 2013 was the hottest on record in Eastern China. Severe extended heatwaves a ected the most populous and economically developed part of China and caused substantial economic and societal impacts1. The estimated direct economic losses from the accompanying drought alone total 59 billion RMB (ref. 2). Summer (June–August) mean temperature in the region has increased by 0.82 C since reliable observations were established in the 1950s, with the five hottest summers all occurring in the twenty-first century. It is challenging to attribute extreme events to causes3–6. Nevertheless, quantifying the causes of such extreme summer heat and projecting its future likelihood is necessary to develop climate adaptation strategies7. We estimate that anthropogenic influence has caused a more than 60-fold increase in the likelihood of the extreme warm 2013 summer since the early 1950s, and project that similarly hot summers will become even more frequent in the future, with fully 50% of summers being hotter than the 2013 summer in two decades even under the moderate RCP4.5 emissions scenario.Without adaptation to reduce vulnerability to the e ects of extreme heat, this would imply a rapid increase in risks from extreme summer heat to Eastern China.

IAMAS (Meteorology)

M22e - M22 Understanding and Predicting High-impact Weather and Climate Extremes

IUGG-2665

Understanding trends in global heatwaves

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Since 1950, heatwaves have been increasing in their intensity, frequency and duration over many global regions. This includes the temperature "hiatus", where global average temperature did not significantly increase since 1998. In this talk, we present whether a hiatus occurred for regional heatwaves. Since we only have one "real world", we employ a 21-member ensemble of the Community Earth System Model (CESM) to determine a plausible range of trends that could have occurred over the hiatus period, which takes into account various states of internal variability of the climate system.

Results show that for many global regions there is a large range in plausible heatwave trends during the ~15 year hiatus period, thus inhibiting the robustness of any one estimate. We illustrate that such trends are largely dominated by modes of climate variability (e.g. El Nino/Southern Oscillation). Continuing to use the CESM ensemble, we explore the relationship between the length of time over which heatwave trends are calculated and the corresponding magnitudes. There is a clear relationship where increasing the temporal length of the trend results in a more robust estimate of trend magnitude, signified by high agreement among the 21 members. Lastly, using the long control run CESM provides (980+ years) we explore whether similar heatwave trends are possible without anthropogenic climate change. Similar to absolute changes heatwave intensity, frequency and duration, we conclude that the rate of change (i.e. trend magnitudes) in heatwaves since 1950 is primarily a result of human influence on the climate system.

IAMAS (Meteorology)

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IUGG-3304

Physical insights on future European summer heat waves and record-breaking temperatures

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Recent summer heat waves had strong socio-economic impacts in different parts of Europe. This highlights the need for improved understanding of key processes and feedbacks. We focus on the detection of an anthropogenic signal on record-breaking summer temperature using historical and 21st century simulations from a set of CMIP5 climate models. Results show that simulated and observed record evolutions follow the stationary climate theoretical record rate until the 1980s. They then diverge from the expected value, with an increase of the number of warm records and a decrease of the cold ones. These changes are shown to accentuate over the 21st century. The influence of internal variability based on control simulations is used to estimate an anthropogenic signal emergence time around 2030.

We then focus on a set of case studies of future heat waves. We analyze a high spatial resolution simulation (from 1950 up to 2100) of the ALADIN regional atmospheric model driven by the CNRM-CM5 model. Based on warm spell duration indices, we select a few intense events that occur in the second part of the 21st century. Heat waves are generally associated with quasi-stationary anticyclonic circulation anomalies that produce clear skies and warm air advection. They are often associated to anomalously dry land surface conditions. For each case study, we perform ALADIN sensitivity experiments by perturbing either the prescribed large-scale circulation and/or the initial soil moisture content. We then infer the dominant mechanisms and the feedbacks operating to amplify or mitigate the heat waves. We also perform a worst-case scenario where we try to generate an extreme heat wave in order to assess the associated temperature rise and its possible saturation due to negative feedback.

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IUGG-3829

The hottest historical summers will be the norm for more than half of the world's population by 2035

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Global mean temperatures are projected to increase by 4.9°C above pre-industrial levels by 2100 under the high-emissions RCP8.5 scenario (based on CMIP5), and by 3°C under the RCP4.5 a stabilization scenario. However, climate change affects different regions differently. We here investigate when the hottest historical summers are projected to become the norm (the time-of-emergence) for the regions defined by the IPCC SREX report. We provide probabilistic time-of-emergence estimates based on RCP4.5 and RCP8.5 simulations constrained by the observations during 1950-2012. More than half of the world's population is projected to experience the historical hottest summer of the past 63 years with a probability of 50% by 2035 and 90% by 2050, respectively, under the RCP4.5. In the absence of climate change policies (RCP8.5), the historical hottest summers are projected to be more wide spread, with over 80% of the population affected bythe hot summers with a 90%-probability by 2050. We also show that emergence appears first in the Mediterranean and Western Asia, the Sahel region, Western US/Canada and Central Asia. Even under the relatively strongly mitigated RCP4.5 scenario, more than 90% of summers are projected tobe hotter than the hottest historic summers by 2025 and 2035 for the Sahel and Mediterranean regions, respectively.

IAMAS (Meteorology)

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IUGG-3977

Two types of California Central Valley summer heat waves

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Understanding the mechanisms how Californian Central Valley (CCV) extreme hot spells develop is very important since the events have major impacts on the economy and human safety. Based on temporal and spatial changes of large scale meteorological patterns (LSMPs), 28 extreme summer hot spells during 1977 to 2010 are roughly divided to two clusters: one is locally formed hot spells with rapid development, and the other develops in Northwest America, has wider coverage and advects heat over the CCV region. Adiabatic heating of air by anomalous sinking motion and its horizontal advection is the main local heating mechanism for both clusters, but the spatial distribution of sinking and horizontal flow is often distinct. A ridge-trough-ridge LSMP spanning the North Pacific is built by wave activity flux traveling across North Pacific in the first group. In the second group the LSMP is in place but further north when sinking and advection expand the coast ridge south over the region. Trajectory analysis shows most air parcels sink from upper layers to the west of the CCV where prior work finds the largest temperature anomaly (northern California coast). However, the trajectory origins differ between the two groups: the first group from the far west, the second group often from the desert southwest. For this symposium, we test the robustness of the CCV hot spells clustering by comparing several reanalyses and we assess the relative contributions of diabatic and adiabatic processes in the two clusters of events.

IAMAS (Meteorology)

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IUGG-5059

Daily temperature records in a warming climate

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The ratio of daily record high maximum temperatures to daily record low minimum temperatures in the first decade of the 21st century was about 2 to 1. Previous model simulations also showed a comparable ratio, with projections of an increase in that ratio in the 21st century. Here we relate record highs and record lows to changing surface conditions in 1 degree and 0.5 degree resolution global coupled climate models for 20th and 21st century climate to address the issue of model resolution in simulating past and future changes of temperature extremes as represented by daily record highs and lows. We show that there is a nonlinear relationship between mean temperature increase and the ratio of record highs to record lows, with implications for heat extremes in the future.

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M22f - M22 Understanding and Predicting High-impact Weather and Climate Extremes

IUGG-0519

Dry summer over Southeastern Brazil in 2014- Part II: atmospheric patterns in ERA-Interim and simulated by CFSv2 and RegCM4 ensembles

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Southeastern Brazil (SEB) experienced a strong drought during the 2014 austral summer. Previous studies have related SEB dry summers with the South Atlantic Convergence Zone suppression. In these cases, the western sector of the Brazilian Northeastern Trough (BNT) remains over the southeastern and northeastern Brazil and the South Atlantic Subtropical Anticyclone (SASA) appears displaced westward compared to its climatological position. Indeed, these features were observed throughout JFM-2014 inhibiting the precipitation over SEB. In the work titled “Dry summer over Southeastern Brazil in 2014 - Part I: forecasted precipitation by CFSv2 and RegCM4 ensembles” we evaluated the precipitation forecasts from a 6-member ensemble of each model and described the simulations configurations. As the ensembles produced a large positive bias over SEB, the purpose of the present study is to verify differences in the simulated atmospheric circulation against ERA-Interim reanalysis. Both ensembles simulate the BNT axis near 20ºW and with its western sector over the ocean. Conversely, ERA-Interim shows the BNT axis around 40ºW and with its western sector over the continent. While in the reanalysis the BNT acts similar to a block because of its quasi-stationarity and westerly winds disruption over SEB, in the ensembles in the southwest sector of BNT there is wind acceleration over SEB. Regarding SASA, in the ensembles it is displaced to the east compared with ERA-Interim favoring lower pressure over SEB. To summarize, the low skill of the models in the precipitation forecast was associated with the poor performance in simulating the atmospheric patterns observed.

IAMAS (Meteorology)

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IUGG-1566

Atmospheric Rivers and Heavy Precipitation From a Hierarchy of Climate Simulations

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The western U.S. receives precipitation predominantly during the cold season when storms approach from the Pacific Ocean. The snowpack that accumulates during winter storms provides about 70-90% of water supply for the region. Associated with the warm sector of extratropical cyclones over the Pacific Ocean, atmospheric rivers (ARs) provide enhanced water vapor transport from the tropics. Upon landfall in the mountainous terrain along the U.S. west coast, ARs produce heavy precipitation that accounts for 25 – 50% of annual precipitation in the region. Due to the narrow structure of the ARs and the complex terrain along the west coast, simulations of ARs and the associated precipitation are sensitive to model resolution. Using a suite of idealized aqua-planet simulations and AMIP simulations at multiple resolutions ranging from 30km to 240km, we investigate the sensitivity of simulated AR frequency and heavy precipitation to model resolution and dynamical core. Additionally, the impacts of global warming on ARs and heavy precipitation are investigated using model outputs from the Community Earth System Model Large Ensemble Project (CESM-LE) and the multi-model ensemble of the Coupled Model Intercomparison Project Phase 5 (CMIP5) to evaluate the thermodynamical and dynamical contributions to changes in extreme precipitation.

IAMAS (Meteorology)

M22f - M22 Understanding and Predicting High-impact Weather and Climate Extremes

IUGG-1567

Increasing potential of biomass burning over Sumatra, Indonesia induced by anthropogenic tropical warming

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Uncontrolled biomass burning in Indonesia during drought periods damages the landscape, degrades regional air quality, and acts as a disproportionately large source of greenhouse gas emissions. The expansion of forest fires is mostly observed in October in Sumatra favored by persistent droughts during dry season from June to November. The contribution of anthropogenic warming to the probability of severe droughts is not yet clear. Here, we show evidence that past events in Sumatra were exacerbated by anthropogenic warming and that they will become more frequent under a future emissions scenario. By conducting two sets of atmospheric general circulation model (AGCM) ensemble experiments driven by observed sea surface temperature (SST) for 1960–2011, one with and one without an anthropogenic warming component, we found that a recent weakening of the Walker circulation associated with tropical ocean warming increased the probability of severe droughts in Sumatra, despite increasing tropical-mean precipitation. A future increase in the frequency of droughts is then suggested from our analyses of the Coupled Model Intercomparison Project Phase 5 model ensembles. Increasing precipitation to the north of the equator accompanies drier conditions over Indonesia, amplified by enhanced ocean surface warming in the central equatorial Pacific. The resultant precipitation decrease leads to a ~25% increase in severe drought events from 1951–2000 to 2001–2050. Our results therefore indicate the global warming impact to a potential of wide-spreading forest fires over Indonesia, which requires mitigation policy for disaster prevention.

IAMAS (Meteorology)

M22f - M22 Understanding and Predicting High-impact Weather and Climate Extremes

IUGG-2766

Untangling the cause of decadal-scale drought using climate model simulations: A case study in southeast Australia.

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Prolonged droughts on the order of a multiple years to a decade have recently afflicted many parts of highly populated regions around the globe, for example, the southwest United States and southeast Australia. However, the causes of these droughts remain unclear. A significant contribution from natural decadal-scale climate variability is likely, but there is also conflicting evidence of any contribution from anthropogenic climate change.

This work aims to untangle the causes of a 13-year drought in southeast Australia spanning 1997–2009. A suite of historical and control simulations from fully coupled GCMs contained in the CMIP5 archive are employed, and the potential contributions of random climate variability, SST forcing and anthropogenic forcing to the drought are examined.

It is likely that random, decadal-scale variability played a significant role in producing the prolonged rainfall deficits across southeast Australia. These were reinforced by several years with El Niño-like conditions, which commonly induce drought in the region, and a lack of La Niña conditions, which are more likely to bring rain. Evidence of contribution of anthropogenic forcing to the drought is limited.

IAMAS (Meteorology)

M22f - M22 Understanding and Predicting High-impact Weather and Climate Extremes

IUGG-3226

Case study on the band-shaped precipitation system causing heavy rainfall in Hiroshima, western Japan, on 20 August 2014

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On 20 August 2014, heavy rainfall exceeding 200 mm/3hour occurred in Hiroshima, located about 300 km south of a stationary front extending northeastward over the Sea of Japan, and brought some huge landslides that killed 74 peoples. The rainfall was caused by a band-shaped precipitation system with a hierarchical structure consisting of convective cells and band-shaped multi-cell clusters that stagnated for 4 hours. The band-shaped precipitation system had a back-building type formation, as well as the multi-cell clusters, in which new multi-cell clusters successively formed upstream of the pre-existing ones, and consequently extent northeastward with a width of 20~30 km and a length of about 100 km. Convective cells successively formed under instable atmospheric conditions that were enhanced by the inflows of mid-level colder air and low-level humid air. The colder air was produced through adiabatic cooling due to large-scale updrafts that existed south of the stationary front. The updrafts also brought a humid condition at the middle level that is favorable for the development of convective cells. The humid air was accumulated below a height of 1 km by the effect of Bungo Strait, located just south of Hiroshima. Both the sides of Bungo Strait have terrains exceeding a height of 1 km, which accelerated southerly winds from the Pacific Ocean that took along humid air. The effect of Bungo Strait also produced the upward pressure gradient force to transport humid air upward.

IAMAS (Meteorology)

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IUGG-4032

"Challenges in the prediction of droughts and heat waves on monthly to seasonal timescales"

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Improvements in climate models have led to better representations of the meteorological drivers of extremes of rainfall and temperature. However, the development of skilful and reliable forecasts of droughts and heat waves at monthly to seasonal timescales requires a deeper understanding of the underlying atmospheric dynamical processes responsible for the evolution of these high-impact weather events. Forecasting skill on these timescales is also limited by, for example, the inability of climate models to accurately represent processes such as anticyclonic blocking and storm track position.

Extremes of rainfall and temperature frequently exhibit some of the same meteorological drivers and/or weather regimes. By way of illustration, summer heat waves in Southeastern Australia and two recent multi-annual droughts in the United Kingdom are investigated to determine the underlying dynamics and drivers of these events.

These may include, for example, the position of the storm track, planetary-scale wave patterns, atmospheric blocking, and large-scale modes of climate variability such as the El Niño-Southern Oscillation, the Madden Julian Oscillation, and the Northern/Southern Annular Modes. Other meteorological drivers may include the impact of both sea surface temperatures and stratosphere-troposphere interaction on rainfall and circulation; and tropical-extratropical interactions, such as the effect of the MJO on the NAM.

IAMAS (Meteorology)

M22g - M22 Understanding and Predicting High-impact Weather and Climate Extremes

IUGG-1265

Extreme rainfall and floods in southern Africa in January 2013, associated circulation patterns and regional forecasting

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During January 2013, very heavy rainfall over central and southern Mozambique led to severe flooding more than 100 deaths, and the displacement of about 200, 000 people. The atmospheric and oceanic patterns associated with this devastating event are analysed. An active South Indian Convergence Zone (SICZ) in January 2013 was associated with the heavy rainfall event. The SICZ was sustained by a low-level trough, linked to a Southern Hemisphere planetary wave (wavenumber-4) pattern and an upper-level ridge over south-eastern Africa. The low-level trough and upper-level ridge contributed to the convergence of moisture over south-eastern Africa, particularly from the tropical South East Atlantic (specifically offshore of Angola in the so-called Benguela Niño region), which in turn contributed to the prolonged life span of the event. Positive SST anomalies (1–2°C) in the Benguela Niño region were favourable for the substantial contribution of moisture fluxes to the event from the South Atlantic Ocean. This contribution is of particular interest since previous work has tended to ignore this basin and regard the Indian Ocean as the most important moisture source for rainfall over south-eastern Africa. The guidance forecast issued by the Regional Specialised Meteorological Centre, Pretoria for the period indicated its likely occurrence with a lead time of 4 days; however, the magnitude was underestimated, which may be linked to the threshold system used in the forecast system.

IAMAS (Meteorology)

M22g - M22 Understanding and Predicting High-impact Weather and Climate Extremes

IUGG-1694

Heavy Rainfall Predictability : the THORPEX West Africa case study

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The African continent is afflicted by high-impact weather and climate extreme events with devastating consequences for local communities. A key question is to understand what determines the predictability of these events, both for individual cases and statistically. In the framework of THORPEX (THe Observing Research and Predictability Experiment) www.wmo.int/thorpex, THORPEX-Africa regional committee have selected few sub-regional based case studies related to flooding events to study the predictability of high impact weather.

This West African case concerns a wet spell that crossed the whole African Sahel during the last decade of August and first decade of September 2009, marked with heavy precipitation leading to floods in many Sahelian countries (261 mm at Ouagadougou).

This extreme event has been analyzed following different complementary approaches. First a forecaster exercise has been replayed using the WASA/F forecasting method. This step allowed a better understanding of this extreme event and to propose a conceptual model. Then we analyzed the skill of NWP global models, showing their ability to predict this event with a three-day lead time. A further modeling study at high resolution (4 km) with the French AROME operational model allowed a better forecast of this event both in term of intensity and location, up to three days in advance. Sensitivity tests and application of different diagnostics (tracking, budgets...) are underway to assess the predictability and to better understand the occurrence of such extreme events over West Africa associated with a moist mesovortex on the southern flank of the African Easterly Jet, and forced both by Rossby midlatitude waves and equatorial waves.

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IUGG-3520

Uncertainties in global land-based rainfall extremes estimates in observations and models

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Rainfall is fundamental to maintaining our water resources and sustaining life on our planet. Understanding how, where and why it rains, is vital for enabling sound decisions to be made by our planners and policymakers especially as it relates to extremes. However, the trends and variability of global daily rainfall are uncertain due to limitations in observational datasets and climate models. For this presentation we calculate a range of rainfall extremes using the standard set recommended by the Expert Team on Climate Change Detection and Indices (ETCCDI) which incorporate measures of rainfall intensity, frequency and duration. From this we show the wide-range of estimates of rainfall extremes over global land areas from in situ, satellite, reanalyses and merged products and discuss reasons for this related to data and methodological issues with each product. Results are then compared to the ETCCDI rainfall extremes calculated from CMIP5 model output. While the uncertainties in precipitation intensity across observationally-based products are as large as those across model simulations, long-term trends are remarkably similar across all products analysed indicating increases in rainfall extremes when averaged across the global land area. Ultimately it is hoped that this work will inform future model evaluation studies and feed into model strategies, laying the foundation for improvements in future rainfall projections to better inform decision makers.

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IUGG-4964

Could boulder's flooding rains of september 2013 be anticipated due to climate change, or were they predictable on shorter time-scales?

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Extremely moist air was pushed against the Colorado Front Range for one week in September 2013 to give Boulder its biggest rainfall event on record from daily to annual time-scales. A total of 10 fatalities and damages in excess of $3B place this flood near the top of historical Colorado disasters, comparable only to the flood of June 1965. While there was a similar synoptic set-up during the September 1938 flood in particular, the immediate questions raised were (1) how well it was predicted on different time-scales, and (2) to what extent climate change increased the odds for this kind of event.

With regard to the first question, this flood was preceded by more than a decade of prevalent drought conditions, and occurred during an ENSO-neutral season (El Niño has been shown to increase the odds of Front Range floods). Thus, there was no seasonal foreshadowing of an unusually wet month or season. On shorter time-scales, weather prediction models did anticipate a wet spell more than one week in advance, but missed out on the temporal and some of the spatial details as the event unfolded.

NASA's GEOS-5 model was used to evaluate whether the regional footprint of climate change (precipitable water (PW) increase) can be invoked to explain this event. This model does a reasonable job in modeling the probability density function of observed 5-day precipitation totals in northeast Colorado. Since the late 19th century, modeled PW has increased consistently with temperature increases, but modeled precipitation has not increased. Thus, high PW values are a necessary but not sufficient condition for extreme rainfall events in this region, perhaps

analogous to the role of high sea surface temperatures in the generation of hurricanes.

IAMAS (Meteorology)

M22g - M22 Understanding and Predicting High-impact Weather and Climate Extremes

IUGG-5148

Heavy precipitation in a changing climate: Does short-term summer precipitation increase faster?

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Consistent with the Clausius-Clapeyron relation, it is generally accepted that extreme day-long events will increase at a rate of about 6-7% per degree warming. However, recent studies suggest that sub-daily (e.g. hourly) precipitation extremes may increase at about twice this rate (referred to as super-adiabatic scaling). Conventional climate models are not suited to assess such events, due to the limited spatial resolution and the need to parameterize convective precipitation (i.e. thunderstorms and rain showers).

Here we employ a convection-resolving model using a horizontal grid spacing of 2.2km across an extended region covering the European Alps and its larger-scale surrounding from Northern Italy to Northern Germany. Validation using ERA-Interim driven simulations reveals major improvements with the 2km resolution, in particular regarding the diurnal cycle of mean and extreme precipitation, the representation of hourly extremes, and representation of observed super-adiabatic scaling.

Consistent with previous results, projections using an RCP8.5 greenhouse gas scenario reveal a significant decrease of mean summer precipitation. However, unlike previous studies, we find that both extreme day-long and hour-long precipitation events asymptotically intensify with the Clausius-Clapeyron relation. Here we will address these differences, and show that it is inconsistent to extrapolate from present-day precipitation scaling into the future. The applicability of the Clausius-Clapeyron scaling across the whole event spectrum is a potentially useful result for climate impact adaptation.

Ban, N., J. Schmidli and C. Scha¨r (2015): Heavy precipitation in a changing climate: Does short-term summer precipitation increase faster? GRL, doi: 10.1002/2014GL062588

IAMAS (Meteorology)

M22g - M22 Understanding and Predicting High-impact Weather and Climate Extremes

IUGG-5744

Latitude belt, convection-permitting simulation of extreme weather events using the WRF-NOAH model system

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We present and analyze what it to our knowledge the first latitude belt, convection-permitting simulation using the WRF-NOAH model system. The simulation covered the latitude belt from 20-65 N with a grid increment of 0.03 degrees, 57 vertical levels up to 10 hPa and 15 levels up to 1500 m, which corresponds to approximately 1 billion grid points, from July till August 2013. The model was forced by ECMWF analyses and SST data from the OSTIA project. No further data assimilation was performed in the inner domain. For comparison, a 0.12 degree resolution run with parameterization of deep convection was performed as well. The overarching research goal is the investigation whether a higher resolution of small-to-large scale interaction and land-surface-atmosphere feedback improved the simulation of convection initiation as well as of clouds and precipitating systems. We expect that these results are very instructive for the next generation of global weather simulations and climate projections.

The simulated period contained several high-impact weather events from which two are presented and analyzed in detail. The first event was taifun Soulik, which developed on July 10, 2013, and made landfall at the east coast of China north of Taiwan on July 12, 2013. Using the above mentioned driving data, the simulation of the development of the taifun was as accurate as 3 h and the taifun track was accurate within 200 km. Furthermore, a Rossby wave train event triggering strong convection over Europe is introduced and studied. Scale interactions between the coarse and the high-resolution runs are compared and discussed. The results indicate that particularly in the mid-latitude belt, convection-permitting resolution may improve the simulation of extreme weather events significantly.

IAMAS (Meteorology)

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IUGG-2069

Dynamic causes of Ural blocking biases and their implications on East Asian winter circulation in CMIP5 GCMs

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Winter Ural blocking (UB) is a potential trigger of cold extremes in the East Asia. In the past decade, its increasing frequency was a possible cause of some unprecedented cold events in the region, such as the persistent snowstorm and icy rains in southern China in early 2008. To better predict their occurrence under a changing climate, we need to better understand the underlying mechanisms of UB in observations and the causes of biases of UB in general circulation models (GCMs).

In this presentation, we will first explore the dynamic mechanism of UB using NCEP-NCAR reanalysis datasets. Then, we will look into the performance of 25 CMIP5 GCMs in simulating the blocking frequency, as well as the dynamic linkage between UB and the East Asian winter circulation. We will show that poor simulation of the basic state over the North Atlantic results in the biases of wave activities and blocking distribution over Eurasia. Afterward, we will discuss the effect of biases of UB on East Asia winter circulation. Finally, we will briefly present how the uncertainty of UB projections in RCP4.5 and 8.5 scenarios might cause an uncertainty of the East Asian winter circulation.

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M22h - M22 Understanding and Predicting High-impact Weather and Climate Extremes

IUGG-3218

Climatology of polar lows over the Japan Sea using the JRA-55 reanalysis

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Polar lows (PLs) are meso-alpha-scale cyclones over the high-latitude oceans during winter. We compiled climatology of PLs over the Japan Sea using the JRA-55 reanalysis, because a number of previous studies have reported PL formation in this region, which is associated with cold air outbreaks within the East Asian Winter Monsoon. JRA-55 uses a global-spectral model with horizontal grid spacing of ~60 km, which appears to reasonably resolve PL formation. PLs are detected by the minimum of sea level pressure in T40-T100-filtered fields, and are tracked using the algorithm of TRACK-1.4.3 (Hodges, 1995, 1999). Based on the methodology of Zahn and von Storch (2008) and Zappa et al. (2014), PLs are identified by a temperature difference equal or larger than 43 K between the sea surface and 500 hPa.
The above methodology is applied to 35 extended winter seasons (Oct-Mar) from Oct. 1979 to Mar. 2014. The detected PLs reach their maximum intensity off the Japan Islands, which is downwind of the northwesterly monsoon flow over the Japan Sea. Dominant moving directions of polar lows are southward and eastward, which is consistent with satellite observation. Composite analysis demonstrates that the southward moving PLs are steered by northerly flow associated with transient synopitic-scale cyclones on their eastern sides. On the other hand, the eastward moving PLs are steered by westerly flow of the climatological jet stream in winter.

IAMAS (Meteorology)

M22h - M22 Understanding and Predicting High-impact Weather and Climate Extremes

IUGG-3496

Future changes in extreme east coast lows

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Low pressure systems affecting the east coast of Australia are known as East Coast Lows (ECLs). Severe ECLs are responsible for the majority of damaging storm events in this region. How these severe ECLs may change in a future warmer climate is a major question for the area. The NSW ACT Regional Climate Modelling (NARCliM) project downscaled four global climate models with three regional climate models to a produce 12-member ensemble of high-resolution (50 km and 10 km) climate projections for southeast Australia. Using these projections, and several objective methods for identifying and tracking ECLs, future changes in severe ECLs are examined. The use of both a 12-member regional climate projection ensemble, and ECL identification methods with different strengths and sensitivities, allows an assessment of robustness for these future changes in severe ECLs.

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IUGG-3811

Atmospheric conditions associated with polar low genesis in the North-East Atlantic

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Polar lows are severe, maritime mesoscale cyclones, developing over the ice-free ocean at high-latitudes. Despite recent improvements in numerical weather prediction, polar lows still represent a major challenge for forecasting in polar areas. Hence, understanding the underlying dynamical pathway and identifying favourable atmospheric conditions is essential to make improvements in our forecasting skills.One way to improve our understanding is to climatologically assess the synoptic conditions in which they form. So far, climatologies mainly focussed on the large-scale atmospheric patterns associated with polar low events. Thereby, they did not resolve the sub-synoptic features of the ambient polar low environment. Furthermore, current classifications of polar lows are based on rather descriptive or spatial arguments. In this study, we utilise a dynamical feature of the sub-synoptic environment associated with the genesis of polar lows to distinguish between different dynamical pathways of polar low development and determine the characteristics of those environment.Using ERA-INTERIM reanalysis data, we calculate the angle between the thermal wind and the mean wind for polar lows from the STARS database provided by MET Norway. Based on the angle between the thermal wind and the mean wind, two subsets of polar lows are identified: forward-shear polar lows, where the thermal and mean wind are in the same direction, and reverse shear polar lows, for which the thermal and mean wind are in opposing directions. Both environments are nearly equally likely associated with polar low development. However, the environments exhibit distinctly different synoptic and sub-synoptic configurations, which we will illustrate and discuss.

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IUGG-4564

Unusual winter snowfall in Japan associated with western Pacific blocking

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The influence of large-scale atmospheric blocking over the northwestern Pacific on unusual (with 10-day time scales) snowfall events in the metropolitan area of Japan (Kanto area) and Northeastern Japan was examined through blocking case studies. The past 14 block cases over the Pacific, including the block during early- to mid-February 2014 that influenced a record-breaking snowfall over the Kanto area were analyzed using a long-term reanalysis dataset and local meteorological observation station data. Results reveal that blocks over the Pacific cause unusual precipitation over the Kanto area and Northeastern Japan (Pacific side of Japan) by shifting cyclone (storm) tracks towards the east coast of Japan from their usual course across the mid-Pacific via the south coast of Japan eastward. Excessive passing of cyclones caused unusually increased precipitation in the Kanto area and snowfall in Northeastern Japan. In the block cases with heavy snowfall events in the Kanto area, a strong southward cold-air inflow over Japan also existed in the lower troposphere originating from east Siberia, which initiated synoptic ground cold-air environments to the Kanto area.

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M22i - M22 Understanding and Predicting High-impact Weather and Climate Extremes

IUGG-1318

Double Rossby Wave Breaking in the North Atlantic and severe european windstorms

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Rossby wave-breaking has a profound impact on atmospheric circulation in the Northern Hemisphere, and is closely connected to the North Atlantic Oscillation. Specific patterns of wave-breaking, such as concurrent cyclonic and anti-cyclonic breakings (double wave breaking) over the North Atlantic, have been associated with severe weather conditions in Europe. The present study offers an overview of the dynamical features associated with double Rossby wave-breaking over the North Atlantic, thus also providing a deeper understanding of its role in favouring extreme weather over Europe. Objective automated algorithms for detecting Rossby wave-breaking and for determining the intensity, meridional location and direction of the jet stream are adopted.

The analysis focusses on the interplay between double wave-breaking and the phases of the North Atlantic Oscillation; the impact of the breakings on the jet stream and the implications of the above for the link with weather extremes. It is found that double wave-breaking events are equally likely to occur during strong positive and strong negative phases of the oscillation. Double wave-breaking also has important effects on the direction and intensity of the jet stream, but these are highly dependent on the geographical location of the breakings. Recent works have found that severe weather events over continental Europe are often associated with a positive NAO and a very zonal jet stream, and have linked these conditions to double wave-breaking. The results of the present study suggest that this link is more complex than previously hypothesised, and that the double wave-breaking is a favourable but not necessary condition for the development of the large-scale conditions associated with severe weather.

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IUGG-1346

Energy and helicity of convective vortices in the atmosphere

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Based on similarity assumptions, a simple model of steady convective tornado-like vortices has been developed which takes into account the vortex breakdown occurring at a certain height above the ground and relates the maximum azimuthal velocity in the end-wall vortex adjacent to the ground surface to the amount of convective available potential energy (CAPE) stored in pre-tornado conditions in the environmental atmosphere. The relative proportion is evaluated of the kinetic energy (helicity) dissipation (destruction) in the zone of 'vortex breakdown' and, accordingly, within the surface boundary layer beneath the vortex. These considerations form the basis of the dynamic-statistical analysis of the relationship between the intensity of tornadoes and the amount of CAPE in the surrounding atmosphere.

IAMAS (Meteorology)

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IUGG-2005

Effects of Multi-scale interaction on the simulation of Intraseasonal Oscillation and Tropical Storm Activities in WRF Regional Climate Model

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The heavy rainfall associated with typhoon has strong impact on the climate over the East Asia and Taiwan. Our recent research (Tsou et al., 2014) found that two-way interaction exits between the intraseasonal oscillation and tropical cyclones. Tropical cyclones activities are not only influenced by the large-scale circulation, but also provide energy upscale to the intraseasonal oscillation (ISO). The purpose of this study is to investigate the effect of multi-scale interaction between the monsoon circulation, ISO and tropical storms (TS) on the simulation of TS over the western North Pacific (WNP) in climate models. Numerical experiments with Weather Research and Forecasting (WRF) Regional Climate Model (RCM) at a large domain (45°E-180°, 20°S-40°N) including Indian Ocean and western North Pacific (WNP)) at 10-km, 30-km, 50-km and 100 km are conducted in this study.

The results show that model simulation at 100 km seriously underestimated the TS genesis frequency. This feature is similar to the majority of the GCM's simulation. As model resolution increased to 50 km, TS genesis frequency simulation was greatly improved, while the performance on the interannual variability of TS frequency remains poor. With the resolution increased to 30 km, the TS genesis frequency and Interannual variability of TS frequency are well represented in the numerical simulation. However, the category 4 and 5 Typhoons were not able to be simulated in 30 km resolution WRF regional climate model. These features indicate that multi-scale interaction associated with the modification of horizontal resolution may play an important role on the simulation of the climatology and interannual variability of TS.

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M22i - M22 Understanding and Predicting High-impact Weather and Climate Extremes

IUGG-3575

Statistical seasonal forecasting of tropical cyclone tracks and landfall in the north Indian ocean region

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Extensive damage and loss of life can be caused by landfalling tropical cyclones. In this study, we develop a seasonal forecasting model of tropical cyclone tracks and landfall for North Indian Ocean (NIO) rim countries based on a Generalized Additive Model (GAM) approach. Using tropical cyclone track observations (1974-2013), from the Joint Typhoon Warning Centre (accessed in the International Best Track Archive Climate Stewardship version6), the GAM model is fitted to the observed cyclone track velocities as a smooth function of location in each season. The distribution of genesis points is approximated by kernel density estimation. Trajectories are then simulated from the matrix of genesis points, and an array of stochastic innovations applied at each time step. Three hindcast validation methods are applied. First, leave-one-out cross validation is applied whereby the country of landfall is determined by the majority vote from the simulated tracks. Second, the probability distribution of simulated tracks is evaluated against observed tracks. Third, the distances between observed tracks and simulated tracks are compared and quantified. Overall, our model shows very good cross-validated hindcast skill for most NIO rim countries. For example, the probability distribution for four out of six countries shows only 13% difference (all together) compared to observations. Indices of climate drivers, including the Quasi- biennial oscillation (QBO) and El Nino - Southern Oscillation, are used as model predictors for interannual tropical cyclone track direction and landfall probabilities.

IAMAS (Meteorology)

M22i - M22 Understanding and Predicting High-impact Weather and Climate Extremes

IUGG-4208

Diagnosing interannual variability in tropical cyclone activity in high-resolution Community Atmosphere Model ensemble simulations

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High-resolution simulations of the Community Atmosphere Model version 5 (CAM5) have demonstrated the ability to represent reasonable global tropical cyclone activity – intensity, spatial distribution and frequency – in present-day climate. However, such simulations have also been shown to exhibit numerous regional biases in interannual variability and seasonal cycles. Due to computational constraints, previous studies have been limited to one, or at the most two, realizations of present climate. For this work numerous CAM5 simulations have been completed from 1994 to 2005. These represent 12-year uncoupled global simulations at 25 km horizontal resolution using prescribed sea surface temperatures and sea-ice extent. The ensemble is characterized by simulations with initial condition perturbations and by simulations with different CAM5 model configurations (e.g. the treatment of aerosols or dynamical core). This study will focus on the North Atlantic, East Pacific and West Pacific ocean basins. The high-resolution ensemble will shed new light on natural, including interannual, variability in cyclone activity in CAM5.

IAMAS (Meteorology)

M22i - M22 Understanding and Predicting High-impact Weather and Climate Extremes

IUGG-4221

Examination of Land-falling Tropical Cyclones in an IPCC extreme climate scenario

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Land-falling tropical cyclone (TC) properties are examined in an extreme scenario of future climate for the years 2098-2100 using a high-resolution, multiply-nested numerical weather prediction (NWP) model. The study is facilitated by taking pseudo-radiosonde observations from the NCAR Community Climate Model System 4 (CCSM4) and IPSL (CM5A) climate model simulations for the Representative Concentration Pathway (RCP) 8.5 scenario of the Fifth Climate Model Intercomparison Project (CMIP5). The pseudo-radiosondes are assimilated by the Navy 4DVAR Data Assimilation System (NAVDAS-AR) to create global analyses consistent with the future extreme climate for the Navy Global Environmental Model (NAVGEM). These future analyses are then used to drive a multiply-nested regional TC prediction model (the Coupled Ocean-Atmosphere Mesoscale Prediction System - Tropical Cyclones [COAMPS-TC]) at a cloud-resolving horizontal resolution (5km). The COAMPS-TC simulations are seeded using a Monte-Carlo approach and the results are examined with particular focus on the impact of land-falling TCs. Overall, the distribution of simulations exhibits a tail of distinctly higher intensity TCs than are observed in the present climate, reinforcing the idea that future extreme climates may support exceptionally strong TCs. Distributions and composites of TC properties including intensity, tracks, scale, structure, and precipitation will be shown. The results will offer a window into how land-falling TCs in a future climate may differ from those in the present climate.

IAMAS (Meteorology)

M22p - M22 Understanding and Predicting High-impact Weather and Climate Extremes

M22p-272

Potential influence of precipitation extremes on total water storage changes over the Ganges-Brahmaputra-Meghna basin

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Climate variability and change impose considerable influence on the variation of regional and global water storage changes. In this study, we investigated the impacts of precipitation extremes on water storage variations within the Ganges-Brahmaputra-Meghna (GBM) basin in South Asia, where groundwater resources are currently being over-exploited. The datasets used here include monthly total water storage (TWS) changes from the GRACE mission for the period 2003 to 2013, and daily precipitation products from APHRODITE (1951-2007), and TRMM (1998-2013) used to derive the precipitation extremes. In addition, terrestrial water storage (TeWS) changes derived from three different versions of GLDAS land model have been used to estimate groundwater (GW= TWS-TeWS) changes over the basin. Multiple linear regression and principal component analysis were jointly employed to relate various precipitation extremes to water storage changes that include GW and TWS of the basin during the period 2003 to 2013. Trend analysis was also performed to analyse the long-term (1951-2007) trend of the extreme events over GBM. From long-term rainfall data, a decreasing trend in the frequency of extreme rainfall (rainfall > 10 mm) events was apparent despite showing an overall increase in precipitation over the region, and thus likely contributed to the decline in TWS changes over the basin during 2003-2013. Increasing demand for drinking and irrigation water within the basin among others, coupled with decreasing trend in the frequency of heavy rainfall events call for new water management strategies within the region

IAMAS (Meteorology)

M22p - M22 Understanding and Predicting High-impact Weather and Climate Extremes

M22p-273

An assessment of drought frequency in Ukraine under the future climate conditions

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Droughts in Ukraine can be occurred in different seasons. Under the climate changes become important the estimates of future drought frequency, which is necessary for long-term economic decisions.

An assessment of drought frequency in the future years 2020-2050 was performed using data of CMIP5 (Coupled Model Intercomparison Project, phase 5). Analysis of spatial and temporal drought distribution was held using the index SPI. For its calculation has been used multimodel (32 models) monthly mean precipitation data for two boundary scenarios, which represents the RCP (Representative Concentration Pathways), experiment RCP2.6 and RCP8.5.

Under the scenario RCP2.6 surface air temperature anomaly in Ukraine until 2050 will be +0.7, +2.1^{o}C compared with a baseline period 1981-2010. According to the scenario RCP8.5 increasing of temperature can be up to +2.8, +3.1^{o}C. Precipitation will be slightly increased in both scenarios. The SPI7 analysis (April-October) showed that at the RCP2.6 total number of drought during the growing season will be several larger than at the RCP8.5. The frequency of weak and moderate droughts at the RCP2.6 averaged to 12-14 cases per 31 years, according to the RCP8.5 is 10-12 cases. Severe and extreme droughts under both scenarios are expected in 1 to 4 years, but not everywhere.

The SPI12 analysis for local points showed that at the RCP2.6 some significant dry periods will be observed in 2020's and 2040's, but at the RCP8.5 expected increasing the intensity and duration of drought episodes after 2035. The most severe drought is projected in 2042-2045.

IAMAS (Meteorology)

M22p - M22 Understanding and Predicting High-impact Weather and Climate Extremes

M22p-274

Synoptic-scale precursors of East Asia/ Pacific teleconnection pattern responsible for persistent extreme precipitation in the Yangtze river Valley

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Synoptic-scale precursors of typical East Asia/ Pacific (EAP) teleconnection responsible for persistent extreme precipitation events (PEPEs) in the Yangtze River Valley (YRV) are investigated. The results indicate that about one week prior to PEPEs, a blocking high develops near the Sea of Okhotsk owing to upstream energy dispersion and further strengthens markedly due to poleward energy dispersion. Subsequently, a meridional tripole structure of typical EAP pattern becomes well established by this blocking and a westward-migrated negative/positive anomaly at mid/lower-latitudes. In the lower troposphere, a westward-progressive anticyclone-cyclone pair can be identified up to about a week prior to PEPEs, contributing to greatly enhanced moisture transport towards the YRV with a magnitude anomaly over 3 standard deviations. An equatorward-displaced westerly jet associated with the EAP pattern and the eastward-extended South Asia High combine to provide favorable upper-level divergence. Correspondingly, strong ascent of low-level warm/moist air along a quasi-stationary front leads to PEPEs in the YRV. Additional contrastive analysis suggests that EAP-inducing PEPEs tend to occur in the YRV with the ridge of the anomalous anticyclone typically staying around northeastern quadrant of the South China Sea. This contrastive analysis also highlights the importance of the upstream pre-existing ridge to early strengthening of the Okhotsk blocking.

Actually, these precursors are mainly modulated by 10-30-day oscillations. The evolutions of the 10-30-day low-frequency circulations and the unfiltered fields are highly consistent. The low-frequency components may account for about 50% of PEPEs and are more predictable.

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M22p-275

Use of the World Wide Lightning Location Network for severe weather warning

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The lightning activity in a thunderstorm is related to the kinetic energy of the thunderstorm updraft. The updraft provides an environment conducive to mixed-phase microphysical and precipitation processes, associated charge transfer microphysics and cloud-scale separation of charge centers. Many studies over the past several decades have attempted to correlate trends in lightning to severe weather occurrence; because the total flash rate rapidly increases several minutes prior to the onset of severe weather.

This work presents a lightning jump algorithm (LJA) to detect severe weather; it is based on the algorithm presented by Schultz et al.(1). The lightning data used in this study came from the World Wide Lightning Location Network which is a real-time, world-wide and ground network. In this study, the lightning activity occurred during 2013 in the spatial window [30–40]S of latitude and [60–70]W of longitude was examined. This region was selected due to the most populous cities of Argentina are located inside this region and the severe weather occurrence data is reasonably well documented. The LJA was validated by using information of severe weather occurrence reported by the Servicio Meteorológico Nacional, newspapers, and radar data. The spatial and time distributions of lightning jumps were studied using different spatial and temporal scales.

The results show that the WWLLN data are may be useful specifically within the framework of developing a useful lightning-based severe weather warning decision support tool. It is of particular interest due to the WWLLN is a global network and can be used for nowcasting in remote regions not covered or sensed with meteorological instruments.

(1) Schultz, et al. (2011). Weather and forecasting, 26 (5), 744-755.

IAMAS (Meteorology)

M22p - M22 Understanding and Predicting High-impact Weather and Climate Extremes

M22p-278

Dry summer over Southeastern Brazil in 2014 - Part I: forecasted precipitation by CFSv2 and RegCM4 ensembles

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Southeastern Brazil (SEB) has a monsoon climate, i.e., the austral summer is rainy and the winter is dry. However, dry anomalies occurred in the summer of 2014 causing several water-supply problems to society. In this context, the purpose of this study is to assess how accurately a 6-member ensemble from the NCEP Coupled Forecast System Model Version 2 (CFSv2), a global model, and from the Regional Climate Model Version 4 (RegCM4), a limited area model, forecasted the dry summer over SEB in 2014. RegCM4 was nested in CFSv2 outputs and used a 30 km horizontal resolution with 18 sigma-pressure levels in the vertical. The domain covers a large portion of South America, with 190×240 grid points in the north-south and west-east directions, respectively. Among the physical parameterization schemes are the Biosphere-Atmosphere Transfer Scheme (BATS) and the Grell scheme with Fritsch-Chappell closure. To forecast the precipitation in the trimester January, February and March of 2014, the initial date of ensembles were 01, 05, 10, 15, 20 and 25 of November, 2013. Both global and regional model ensembles overestimate the precipitation over SEB (more than 300 mm) compared to Climate Prediction Center (CPC) analysis. The only value added by RegCM4 was in the center-south of São Paulo State where there was a smaller positive bias of approximately 150 mm (instead of 300 mm in the CFSv2). The physical reasons for the poor performance of the models in simulating de dry summer over SEB will be presented in part II of this work.

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Analog method and its application to extended range weather forecast

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According to the analog method, the surface elements' similarity relationship was used to make extended range weather forecast (10~30 day) by using the precipitation and wind speed data from 1960-2010 of 57 stations around Bohai Sea. The results of forecast for 2000 to 2010 show that: this method is applicable for application of rain day forecast in summer. The TS score is better than that of climate probability values in summer without considering the 27~30 day's forecasting results in August. The accuracy of moderate rain forecast is between 8% and 10%.The TS score is higher than the climatic probability value for forecast of heavy rain and torrential rain, which indicates the result is basically credible. Seasonal difference for wind-scale 0~2 forecast is obviously with the maximum value of 85% in summer and the lowest around 50%in spring. For wind scale 3~4 forecast, the TS scores fluctuates could be up to 10% in 8 months of one year. The accuracy of daily mean wind-scale above 5 forecast is between 7% and 10% from February to April. TS score between 18.5% and 39.1% shows that the forecast result of the maximum daily wind speed is superior to daily mean wind-scale above 5. A comparison of the wind speed forecast and previous results shows that the results in this paper is identical to forecast 4~10 day wind, which suggests the prediction of this method is basically credible. The attemption of analog method based on surface elements similarity relationship shows it has application value in extended range forecast.

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Sea surface temperature and extreme dry events in Southeastern Brazil: a numerical simulation

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A numerical simulation through a regional climate model was conducted in order to verify if a Sea Surface Temperature (SST) anomalies pattern found in some data analysis over the South Atlantic Ocean (SAO) which may be associated to dry events in southeastern Brazil can be reproduced and how important they are for them.

A previous observational study using daily rainfall data in southeast of Brazil and SST anomalies in SAO for 1982-2009 period, considering autumn, winter and spring seasons was carried out in order to build a conceptual model of synoptic and dynamic patterns for periods of dry extreme events in southeastern Brazil. The results indicated the following feature: tripole pattern (negative/ positive/ negative) for SST anomalies in SAO; increased (decreased) of moisture sources closed to positive (negative) SST anomalies; South Atlantic Subtropical High (SASH) positioned close to the continent; decrease in the number of frontal systems to latitudes further north.

A Regional Climate model (RegCM4.3) was used to simulate 1990 year which is considered to be the less dry year in the analyzed period. Simulations with modified TSM showed that there was a decrease of precipitation in southeastern Brazil and dry events with longer duration. For circulation in 850hPa an anticyclonic anomaly in SAO closed to Rio Grande do Sul coast was observed and in 200 hPa the Subtropical Jet appeared weakened. These features seem to have favored the negative bias of precipitation in the study area. These results agree with those found observationally.

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Verification of weather research and forecasting model in predicting heavy precipitation from tropical cyclone Gonu off the coast of Iran

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Application of the numerical weather forecasting model has a serious role in the predicting extreme events like tropical cyclones. Occurrence of cyclone Gonu, caused a huge damage on the Coast of Oman in Iran. Therefore predicting this storm and estimating its total amount of precipitation is necessary. In this investigation, the weather research and forecasting model was run for Gonu event that was formed on the first of June 2007 in the Arabian Sea and on 6th and 7th of June affected the Coast of Oman Sea and the results were compared with the observation. The model was run with two convective schemes (Kain-Fritsch and Grell-Freitas). The results of the model outputs for the first and the second 24 hours (6th and 7th of June) are compared with Chabahar synoptic station. The first simulation is closer to the observation value and in the second simulation is overestimated. The maximum core of precipitation in the first simulation is 140 mm, and in the second simulation reached 270 mm. The results show that the first simulation in the first 24 hours is underestimated and the second simulation is overestimated from the actual precipitation. But the second simulation results are closer to the observation. In the second 24 hours both of the simulations are overestimated. Although the simulation results are different from the observation, the model is sensitive to the convective parameterization and well predicted heavy precipitation on the Coast of Oman Sea in Iran.

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Data assimilation and simulation of high impact weather events by using WRF model

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The Assimilation of conventional (Synoptic, Upper Air, AWS) along with non-conventional observations (Doppler Weather Radar Data- radial winds and reflectivity) are useful for improvement of the numerical prediction of mesoscale weather events. The high impact weather events that form over northeast India and adjoining Bangladesh region during the pre-monsoon season (March to May) are studied employing observations from ground based radar, Tropical Rainfall Measuring Mission (TRMM) and synoptic stations. These Mesoscale convective systems (MCSs) are responsible for majority of the squall events and related natural hazards that occur over Bangladesh and surrounding region. DWR Data of Bangladesh Meteorological Department (BMD) are used to study the squall events through 3-dimensional variational (3DVar) data assimilation technique within the Weather Research Forecasting (WRF) modeling system. Two sets of experiments (CTRL and 3DVar run) on each case have been applied. The simulated sea level pressure, thermodynamic indices, 850 hPa wind fields, cloud hydrometeors from the experiments are presented in this study in order to analyze the observed and simulated features of the squall events. The model results are also compared with the Kalpana-1 satellite imagery and the India Meteorological Department (IMD) observations. Further, the intensity of the events, generated from the simulations is also compared with the in-situ meteorological observations in order to evaluate the model performance.

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"Changes in Patterns of the hottest cities in Eastern China since the 21th Century"

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An exceptionally large number of extreme heats in large and medium-sized cities around China have been observed under global warming, causing major human suffering and economic damage. The latest data rated by China Meteorological Administration showed that Fuzhou city in southeastern China had become the hottest "furnace city" called by Chinese media due to the largest number of high temperature days. This paper compares the extreme heat in Fuzhou with those frequently experiencing summer extreme temperature cities, such as Chongqing, Wuhan, Nanchang and Nanjing which are traditionally known as "four big furnace cities" in China. Based on the analysis of several extreme heat indices (EHI), e.g., high temperature days, extreme maximum temperature, mean high temperature and heat index, the results indicate that the extreme heat in Fuzhou was not notably obvious during periods of 1960 to 1970. However, Fuzhou has almost become one of the hottest cities in eastern China in the past decade. The EHI analysis also reveals Fuzhou city in summer was much hotter than the above mentioned "four big furnace cities" during the past decade. Moreover, the Fuzhou's EHI experienced an abrupt climatic change around 2000, which was associated with the decadal variability of atmospheric circulations over East Asian. It is also suggested that the lower horizontal and vertical temperature advections and westward extension of subtropical high could play a great role in the pattern changes of the hottest cities in eastern China, especially Fuzhou city suffered frequent extreme heat in the past decade.

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Evaluation of the summer precipitation over China simulated by BCC_CSM model with different horizontal resolutions during the recent half century

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The performance of Beijing Climate Center Climate system model with different horizontal resolutions (BCC_CSM1.1 with coarse resolution and BCC_CSM1.1m with fine resolution) in simulating the summer precipitation over China during the recent half century is evaluated and the possible underlying physical mechanisms related to the model biases are also further analyzed and discussed. Results show that increasing horizontal resolution does improve the summer precipitation simulation over most part of China especially in western China due to the more realistic description of the topography. However, the summer precipitation amount (PA) over eastern China characterized by monsoonal climates is much more underestimated in the finer resolution model. It’s also noted that the improvement (deterioration) of the summer PA over western (eastern) China in BCC_CSM1.1m model is mainly due to the better (worse) simulation of the moderate and heavy precipitation relative to BCC_CSM1.1 model. In addition, increasing model horizontal resolution can significantly improve the convective precipitation simulation especially over western China but shows very limited improvement in the large scale precipitation simulation. The much more underestimated summer PA over eastern China in BCC_CSM1.1m model relative to BCC_CSM1.1 model is due to the significantly reduced positive biases of the convective PA but with few changes in the negative biases of the large scale PA. Further mechanism analysis suggests that the underestimated land-sea thermal contrast and overestimated Western Pacific subtropical high resulted in much less northeastward water vapor transport and summer PA over eastern China in BCC_CSM1.1m model than in BCC_CSM1.1 model.

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Numerical simulation and diagnosis of the anomalous track of typhoon Muifa

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The anomalous track of Typhoon Muifa has been analyzed using daily NCEP reanalysis and TRMM data and conducting cloud-resolving model simulation employing a with WRF model. Muifa had recurvature twice after it formed at the east of Philippine on July 28, 2011. Our results show that different factors are responsible for the recurvatures. The recurvature from northward to westward propagation was affected by environmental circulations such as large-scale steering flows, subtropical high, twin typhoon interaction, and mid- and high-latitude atmospheric circulation. In addition to these environmental circulations, the recurvature to northward propagation was closely associated with convective processes over the inner core.

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A comparative study of the atmospheric circulations associated with rainy-season floods between the Yangtze and Huaihe River Basins

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Here we present the results from the composite analyses of the atmospheric circulations and physical quantity fields associatedwith rainy-season for the selected floods cases over the Yangtze and Huaihe River basins for the 21 years (1990–2010), usingthe daily rain gauge measurements taken in the 756 stations throughout China and the NCEP/reanalysis data for the rainyseasons(June–July) from 1990 to 2010. The major differences in the atmospheric circulations and physical quantity fields betweenthe Yangtze and Huaihe River basins are as follows: for flooding years of the Yangtze River Basin, the South Asia highcenter is located further east than normal, the blocking high over the Urals and the Sea of Okhotsk maintains, and the Meiyufront is situated near 30°N whereas for flooding years of the Huaihe River Basin, the South Asia high center is further westthan normal, the atmospheric circulations over the mid and high latitudes in the Northern Hemisphere are of meridional distribution,and the Meiyu front is situated near 33°N. In addition, there are distinct differences in water vapor sources and associatedtransports between the Yangtze and Huaihe River basins. The water vapor is transported by southwesterly flows from theBay of Bengal and monsoon flows over the South China Sea for flooding years of the Yangtze River Basin whereas by southeastmonsoons from the eastern and southern seas off China and monsoon flows over the South China Sea for flooding years ofthe Huaihe River Basin.

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Tendencies of change of atmospheric convective activity in Northern Eurasia

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Different criteria of convective activity in Northern Eurasia regions are analyzed for present climate and for projected climate in the 21st century based on meteorological observations, modern reanalyses data and CMIP5 climate model simulations with different anthropogenic scenarios. Particularly, convective activity is assessed based on analysis of occurrence of convective clouds (cumulonimbi and cumuli) and thunderstorm events. This analysis is accompanied with an evaluation of objective indices of convective activity (such as CAPE and 3D-index) and supported with a case study of tornadoes recently occurred in Northern Eurasia. A general increase of convective activity in Northern Eurasia was revealed for last four decades and can be expected for the 21st century climate.

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A New Perspective on Precipitation Trends during the 1979-2013 Warming

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Trends in precipitation are critical to water resources. Considerable uncertainty remains concerning the regional precipitation trends in response to global warming and their controlling mechanism(s). Here we use an inter–annual difference method to derive trends of regional precipitation from data of GPCP and MERRA reanalysis in the near–global domain of 60°S–60°N during a major global warming period of 1979–2013. We find that trends of regional annual precipitation are primarily driven by changes in the top 30% heavy precipitation which in turn are controlled by changes in precipitable water in response to global warming, i.e. by thermodynamic processes. Significant drying trends are found in most of the US and eastern Canada, the Middle East ranging from Libya to Iran, and eastern South America during this period, while significant increases in precipitation occur in northern Australia, southern Africa, western India and western China. In addition, as the climate warms there are extensive enhancements and expansions of three major tropical precipitation centers, namely the Maritime Continent (MC), Central America, and tropical Africa; leading to a significant strengthening of the global hydrological cycle.

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Flow-dependent predictability of summertime Euro-Atlantic weather regimes at medium-range timescale

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A weather regime is a persistent and/or recurrent large-scale atmospheric circulation pattern which is associated with specific weather conditions on a regional scale. Accurate simulations of weather regimes are important in weather and climate.

The predictability of Euro-Atlantic weather regimes at medium-range timescales (up to 384hr) are investigated for summer (June-August) in the periods 2007-2013 and 1985-2013 using operational ensemble forecasts at CMC (Canada), ECMWF (UK), JMA (Japan), NCEP (US), and UKMO (UK), available at the TIGGE database, and NOAA's second-generation global ensemble reforecast, respectively.

The positive and negative phases of the NAO (NAO+ and NAO-), Atlantic ridge (ATLR), and Atlantic low (ATLL) are detected as summertime weather regimes over the Euro-Atlantic region from the ERA-Interim data (97.2% significant). The summer NAO+ can be considered as blocking (BLCK). The models have common biases in the frequency of regime transitions. The Markov chain of transitions among regimes shows that the models prefer BLCK and ATLR to NAO- with lead time, compared with ERA-Interim. The models show small skill differences regarding deterministic and probabilistic regime forecasts, suggesting that the skills of regime forecasts strongly depend on atmospheric flows. The models show higher forecast skills when predicting NAO- and especially being initialised on BLCK or ATLR. In contrast, BLCK forecasts initialised on NAO- have the lowest skill, followed by ATLR forecasts initialised on ATLL.

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An empirical relation between Swiss hail occurrence and monthly environmental parameters

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Hail can develop in mid-latitude thunderstorms and cause serious damages to cars, buildings, crops and injure livestocks or people, making it one of the most costliest natural disasters.
The prediction of thunderstorms and in particular hail, is a challenging task for operational weather forecast models, due to often short temporal scale, the small spatial scale and the complexity of the involved processes. Moreover, most of the time, only short-term forecasts are possible. Due to the high risk potential associated with large hail and in perspective of a changing climate, the local probability and intensity of hail has gained interest, in particular for loss prevention and risk management purposes.

The aim of this study is to achieve an empirical relationship between environmental parameters and hail frequency in Switzerland, provide a framework for extended range forecasts of hail and study its long-term variability.
Previous studies (Huntrieser et. al, 1997, Weather Forecasting) identified the most important quantities that influence the occurrence of thunderstorms over Switzerland. Based on their findings, monthly averaged environmental parameters are calculated at 1° resolution form the ERA-Interim ECMWF reanalysis. Furthermore, hail-producing thunderstorms are detected using weather radar imagery for the months April to September 2002-2013, and for every month the number of days with hail occurrence is computed. Monthly environmental parameters and hail occurrence are fitted to a generalized linear model, similar to the method used in the study of Tippet et al. 2014 (Journal of Climate), resulting in an empirical relation between the environment and the number of hail days per month.

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Composite Maps for Extreme Rainfall in Indonesia

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We develop composite maps for studying large scale meteorological patterns of extreme rainfall in Indramayu, Indonesia. Such maps have been developed by Grotjahn and Faure (2008) to study the Extreme weather events (EWEs) in the California Central Valley, USA and they have robust mid-latitude meteorological patterns. Indonesia, with its tropical climate, may induce specific patterns which influence the robustness of the maps. Extreme dates have been identified using Peaks Over Threshold (POT) combined with series “declustering” to ensure no autocorrelation structure on the extreme data. Bootstrap nonparametric approach is applied to highlight the key features that are statistically significant in the maps during extreme rainfall events. The significance of the mean maps of several investigated fields (e.g. geopotential height, relative humidity and temperature) seems to be biased. One of the potential causes of the bias is because of limited periods taken into account in the statistical assessment (only rainy seasons considered). To overcome this problem, anomaly composite maps based on long term daily means have been developed to reduce the bias and improve the accuracy of the maps. Moreover, global significance tests have been conducted to assess the significance of the map globally.

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"Case study of the hailstorm event on 13 June 2014 in the Tokyo Metropolitan Area, Japan"

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This paper is described about the case study of the hailstorm event on 13 June 2014 in the Tokyo Metropolitan Area, Japan. The hail with a diameter of 3 centimeters and wind gust were reported with this event. This hailstorm was observed by multiple X-band polarimetric Doppler radar and a Doppler lidar, simultaneously. On that day, there was a cold low in the northern part of Japan and a trough was laid on the Tokyo Metropolitan Area. The duration of the hailstorm is about 3.5 hours (from 1000 LST to 1330 LST), and hail fell around 1210 LST. The analysis of the X-band polarimetric Doppler radar shows that the region of hail was located the southern edge of the storm and was indicated large specific differential phase (Kdp) value (~ 8 degree km-1) at 1 km AGL. This large Kdp region also corresponded to strong downdraft region (~ 4 m s-1) at 1 km AGL. The reported wind gust might be caused by this strong downdraft. The Doppler lidar, which was located on the warm sector of the hailstorm, completely succeeded to capture the radial velocity of the inflow toward the hailstorm. It is planed that this radial velocity of the Doppler lidar and wind field analyzed by multiple X-band polarimetric Doppler radar will be assimilated to improve the comprehension and forecast of this hailstorm.

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Future precipitation extremes are linked to changes in moisture flux anomalies

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Understanding the response of precipitation extremes to anthropogenic climate change is currently based on a simple thermodynamic link to future warming (Clausius-Clapeyron equation). While previous work has identified empirical links between observed flooding events and the occurrence of specific circulation patterns, often containing filamentary bands of anomalous moisture flux, the large-scale dynamics driving extreme precipitation remains poorly characterised. Here, we introduce a diagnostic measure of the explicit link between extreme precipitation events (>99.5thpercentile) and incoming moisture flux anomalies. This represents a significant development over previous methods which sought arbitrarily defined ‘atmospheric river’ events. Robust links are found between anomalous moisture flux and corresponding extreme 24-hour precipitation accumulations, with a particular significance placed on meridional moisture fluxes of tropical origin. Using this metric, we explicitly calculate future changes to the likelihood of precipitation extremes attributed to changes in large-scale moisture and wind fields. Preliminary results of applying this analysis to the CMIP5 ensemble under an RCP8.5 warming scenario are considered, particularly for mid-latitude regions.

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Influence of La Nina on high impact weather over Eurasia in summer 2010

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The dynamical causes of two extreme events (Russian heat wave and Northeast China flooding) are analyzed in more detail using ERA-Interim re-analysis data and observations.

The heat wave in summer 2010 was characterized by a long-persisting blocking high over Russia causing severe droughts and numerous forest fires. It is shown that the blocking high occurs as an overlay of a set of anticyclonic contributions on different time scales: (i) A regime change in ENSO towards La Niña modulates the quasi-stationary wave structure in the boreal summer hemisphere supporting the eastern European blocking. On climatology, La Nina summers are characterized by an increased blocking frequency over 30°-60° E and a double jet structure; (ii) Together with the quasi-stationary wave anomaly the transient eddies maintain the long lasting blocking; (iii) Three different pathways of wave action are identified on the intermediate time scale (about 10-60 days).

Northeast China had its worst seasonal flooding for a decade in August 2010. Summer precipitation is influenced by the western North Pacific subtropical high (WPSH), and is often associated with southeasterly low-level winds, transporting moist air into China. The intra-seasonal variability of the WPSH is partly affected by quasi-stationary wave trains propagating eastwards from the continent along the westerly jets. Two wave trains are important the Silk-Road wave train along the Asian midlatitudinal jet and the polar wave train along the sub-polar jet. The summer 2010 was characterized by the long-persistence of an anticyclone over Eastern Europe and Russia, whose influences the precipitation over China. In

August 2010 both wave trains modulate the northward and westward displacement of the WPSH.

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Attribution of the record high Central England Temperature of 2014 to anthropogenic influences

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In 2014, central England experienced its warmest year in a record extending back to 1659. Using both state-of-the-art climate models and empirical techniques, our analysis shows a substantial and significant increase in the likelihood of record-breaking warm years, such as 2014, due to human influences on the climate. It is very likely that anthropogenic forcings on the climate have increased the chances of record warm years in central England by at least 13-fold. This study points to a large influence of human activities on extreme warm years despite the small region of study and the variable climate of central England. Our analysis shows that climate change is clearly visible on the local-scale.

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Intrinsic predictability of the tornadic thunderstorm event in Oklahoma on 20 may 2013 at storm scales

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Using a high-resolution convective-permitting numerical weather prediction model, this study seeks to explore the intrinsic predictability of severe convective thunderstorms on 20 May 2013 in Oklahoma from initiation to dissipation, by ensemble forecasts with tiny initial ensemble perturbations representing uncertainties that is unable to be explicitly resolved by the employed model grid. It is found that differences that are smaller than current observational errors, although unable to modify the mesoscales convective conditions of environmental instability and moisture, will be rapidly amplified in moist convective processes through positive feedbacks associated with updrafts, phase transitions of water species and cold pools, thus greatly affect the appearance, organization and development of thunderstorms. The forecast errors remain almost unchanged even when the initial perturbations (errors) were reduced by as much as 90%, strongly suggest an inherently limited predictability for this thunderstorm event. Further scale decomposition of errors reveals error saturations in meso-γ scale in spite of the magnitude of initial errors and accompanying processes of upscale growth into meso-β scale with delays in time, which is consistent with peer-reviewed theories of error growth associated with convective weather systems.

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Ensemble forecast of beijing '07.21' flooding event at convective permit resolution and its comparison with global ensemble forecast

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On July 21, 2012, an extreme rainfall event occurred in the city of Beijing, capital of China. The average 24 hours accumulated rainfall in the city of Beijing was 190 mm which is the largest in the record history since the year of 1949. And the recorded maximum point of this event, as reported by news, is over 400 mm. Such excessive rainfall caused urban waterlogging and torrents. 79 people were dead, millions of people were afflicted and the evaluated financial losses were about RMB 16.2 billon.

In this study, an ensemble forecast system at convective permit resolution was established to study the predictability of this heavy rain event. The system consists of 22 members at 4 km grid spacing with a domain covers entire mainland China. Ensemble forecasts from two different global forecast systems were used as the initial and lateral boundary conditions (ILBCs). Here, the predictability of using different ILBCs will be compared and discussed. Additionally, the forecast at convective scale will be compared to global ensemble forecast (GEF). The predictability of different scale will also be discussed.

IAMAS (Meteorology)

M22p - M22 Understanding and Predicting High-impact Weather and Climate Extremes

M22p-300

Bayesian spatial-temporal additive modeling of climate extremes with nonparametric spatially varying regression effects and applications

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It has been observed that climate extremes are more variable than climate averages when responding to the climate change. Non-stationary modeling of climate extremes have therefore attracted significant attention in recent years. Generalized extreme value (GEV) distribution with distribution parameters μ, σ and ξ regressed to some time covariate t accounting for the non-stationarity is widely used for modeling block maxima. For simplicity and stability such models normally take the following form:

$\mu(t) = \alpha0 + \alpha1 * t$

$\log(\sigma(t)) = \beta0 + \beta1 * t$

$\xi = \gamma0$

Since observational series of annual climate extremes are usually very limited (several tens of years long), it is more desirable to pool all the extremes from a region together to reduce the model uncertainty. This requires the model to introduce extra effects to represent the spatial variability of climate extremes. Here a spatial-temporal additive GEV model is implemented as an extension of the above single-site model:

$\mu(s,t) = \alpha0(s) + \alpha1(s) * t$

$\log(\sigma(s,t)) = \beta0(s) + \beta1(s) * t$

$\xi(s) = \gamma0(s)$

where s is a set of 2-dimensional coordinates representing the locations where climate extremes were observed, $\alpha0(s)$, $\alpha1(s)$, $\beta0(s)$, $\beta1(s)$ and $\gamma0(s)$ are bivariate functions implemented by thin-plate smoothing splines. $\alpha0(s)$, $\beta0(s)$ and $\gamma0(s)$ are nonparametric terms serving as local constants for μ, σ and ξ; $\alpha1(s)$ and $\beta1(s)$ are nonparametric spatially varying coefficients of linear trend terms for μ and σ. The model can be inferred within Bayesian framework using Markov Chain Monte Carlo (MCMC) algorithm. As two applications the model is applied to annual maxima and minima of air temperature during 1951-2013 for China mainland respectively. Return levels of 2- and 40-year return periods for the two extremes are analyzed accordingly.

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M22p-301

Half-Hour Rainfall Retrieval based on multispectral geostationary satellite images

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A method for both precipitation area and intensity retrievals is developed based on multispectral geostationary satellite images. Satellite observation is instantaneous, whereas the rain gauge records accumulative data during a time interval, and thus, using the 10-min gauge rainfall data rather than 1-hr gauge rainfall data as the reference value, can obviously improve the accuracy of satellite rainfall retrieval.For this reason, a 10-min rainfall algorithm is established firstly. It includes two steps. 1) A Rainfall probability identification matrix (RPIM) is used to distinguish rainfall clouds from nonrainfall clouds. This RPIM is established by combining infrared brightness temperatures (BTs) with visible reflectivity at daytime and dual-channel brightness temperature differences (BTDs) at nighttime. It is more efficient in improving the retrieval accuracy of rainfall area than previous threshold combination screening methods. 2) the multispectral segmented curve-fitting rainfall algorithm (MSCFRA) is proposed to estimate the 10-min rain rates. Rainfall samples taken from June to August 2008 and 2010 are used to assess the performance of the rainfall algorithm. Assessment results show that the MSCFRA improves the accuracy of rainfall estimation for both stratiform cloud rainfall and convective cloud rainfall. These results are practically consistent with rain gauge measurements in both rainfall area division and rainfall intensity grade estimation. Furthermore, this study demonstrates that the temporal resolution of satellite detection is important and necessary in improving the precision of satellite rainfall retrieval.

IAMAS (Meteorology)

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M22p-302

The synoptic and dynamic structure of heavy snow event over southern coast of the Caspian Sea on February 2014

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A heavy snowfall occurred in Northern coast of Iran On February 2014, which was a rare event in its type. This heavy snow was caused huge social and economic impacts on the Iranian people and government. Although, this event was predicted, but its intensity was significantly underestimated. In this study, this extreme event is analyzed synoptically and dynamically. Synoptic station data and reanalysis data of NCEP/NCAR are used in this research. Sea level pressure, relative vorticity, geopotential height, and relative humidity in different levels and their anomalies are investigated and analyzed. Blocking index is a sign of an intense blocking of omega type in the region. The results showed that amplification of Siberian high pressure and its continuity over Caspian Sea were caused a heavy lake effect snow over Southern coast of the Caspian Sea. Analysis demonstrated that the heavy snow exhibited classic patterns of large-scale circulation combined with lake-effect. The results from this study will provide insights on how to improve forecasts for these kinds of extreme events.

IAMAS (Meteorology)

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M22p-303

Characteristics of TIGGE in representing forecast variability associated with extratropical transition

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The characteristics of the extratropical transition (ET) of tropical cyclones and its impact on the midlatitude flow are examined in the THORPEX Interactive Grand Global Ensemble (TIGGE) multimodel ensemble prediction system (EPS). Ten ensemble forecasts initialized prior to ET for five tropical cyclones in 2008 are investigated using an empirical orthogonal function analysis and fuzzy clustering methodology. Each forecast contains 231 members from eight different global EPS. The EPS contributing to TIGGE differ in their spread and their contributions to the different scenarios. Some of the individual EPS are generally confined to only a few scenarios, whereas others contribute regularly to almost all. TIGGE contains more development scenarios than European Centre for Medium Range Weather Forecast (ECMWF) EPS but the full range of development scenarios is only found with the ECMWF included in the multimodel EPS. By comparing the development scenarios with the corresponding analysis it can be shown that in some of the cases the multimodel approach is necessary to get the analysed development included in the ensemble forecast.

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M22p - M22 Understanding and Predicting High-impact Weather and Climate Extremes

M22p-304

Predictability of offshore wind energy and wave energy

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We evaluate forecast skill of the global offshore wind energy and wave energy based on ensemble forecast experiments with the third-generation wave model (WaveWATCH III) and near-surface wind forecasting of TIGGE. Wave energy is predicted by the wave model, while offshore wind energy is predicted at the hub height of 80m by taking into the consideration the effect of sea surface roughness predicted by the wave model. The forecast experiment is performed during boreal winter from 2007 to 2011. An "ERA forcing experiment" with the wave model is also performed by using near-surface winds derived from the ERA-Interim. Results of the forecast experiments are compared with those of the ERA forcing experiment. It is found that daily variation in wave energy is predictable in most of the basins at the forecast lead time of 2 days (the anomaly correlation exceeds 0.7). In addition, the forecast bias of wave energy is less than 10% in most of the regions at the forecast lead time of 2 days. The forecast skill of wave energy decreases particularly in the mid-latitudes with the increasing forecast lead time. We also find that the forecast skill of wind energy is generally lower than that of wave energy.

IAMAS (Meteorology)

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M22p-305

Present and future climatologies of polar lows over the Norwegian Sea

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Polar lows are low-level mesoscale cyclones that occur over high latitudes seas. They often cause significant damages offshore and along the coast, in particular in Norway. Therefore it is important to understand the climatic variability of polar low occurence. That is why several studies try to track polar lows with various methods and datasets. A good tracking is necessary to better understand the life-cycle of the polar lows which are known to have various formation and intensification processes, mainly associated with baroclinic instability and convective processes. Our obtained present-time set of tracks is compared to a polar low database compiled by Met-Norway. After evaluating the accuracy of the algorithm, we present climatologies based on ERA-Interim as well as high-resolution future climate simulations for the first and second half of the 21st century and discuss the changes in frequency and area of occurrence.

IAMAS (Meteorology)

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M22p-306

MJO dependency of summertime California Central Valley extreme hot weather

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The California Central Valley (CCV) is the most agriculturally productive area in the world. Extreme hot weather over the CCV area causes strong nationwide socioeconomic impacts since the heat wave influence on agriculture is tremendous. Previous studies found that certain Large Scale Meteorological Patterns (LSMPs) amplify heat over the regional scale CCV (Grotjahn and Faure 2008; Grotjahn 2011, 2013, 2015). During boreal summer season, tropical convection travels eastward through the Indian and Pacific basins as well as northward in the Eastern Hemisphere with the periodicity of 40–50 days, the so-called the Madden Julian Oscillation (MJO) [Madden and Julian, 1994]. Midlatitude Rossby wave source can be induced by tropical convection through upper level divergence and extra-tropical convergence (Rasmusson and Mo, 1993; Sardeshmukh and Hoskins, 1988). Our prior study showed that tropics-originated Rossby wave-type LSMPs are a prior condition of one type of summertime CCV hot spell (Lee and Grotjahn, 2015, in preparation). Therefore it is worthwhile to investigate the relationship between CCV hot days and MJO. In preliminary results, we calculate a metric that is the number of extreme hot days for individual MJO phases at 15 CCV stations. Interestingly, the Indian Ocean convection (Phases 1 and 2) is most frequent 5 days prior to hot days. The next highest frequency occurs when the tropical convection is closest to the CCV (Phase 8) without lead time. We will illuminate the dynamics of these MJO phase dependencies with further analyses.

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M22p-307

Variability of the relation of the North Atlantic Oscillation and European winter windstorms during the last millennium

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Winter windstorms are the most loss-relevant natural hazard for the European region. This study investigates winter windstorms using a comprehensive Earth System Model (ESM) with variable radiative forcing (e.g. solar irradiance, volcanoes, CO2) simulating the last millennium. This model run covers a broad range of natural variability. An objective methodology for the identification and tracking of windstorms is applied. Variability of storm activity is investigated in terms of its relation to the North Atlantic Oscillation (NAO). Results are compared with 20th century reanalysis (20CR).

Both, the ESM simulation and 20CR show maximum track density of winter windstorms over the North Atlantic. These storms are propagating towards Central and Northern Europe. The position of the windstorm track density is strongly correlated with the phase of the NAO. A positive NAO phase is related to higher storm frequencies, both in the North Atlantic and Europe, north of 45°N and lower frequencies south of it. The overall pattern of this correlation is stable during the last millennium, whereas its intensity varies between 0.6 and 0.75 and the exact positions of the maxima are ranging between Central Europe and the Eastern North Atlantic. The temporal variability of the NAO pattern is analysed, by means of the first EOF of the 500hPa geopotential height, for sub-periods of different length. Especially the southern centre of action, associated with the Azores High, shows variability in its position. This finding is discussed in relation to the variable position and intensity of the correlation between the NAO and winter windstorms.

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M22p-308

Assessment of past and projected future trends of precipitation in the Carpathian Region

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Precipitation is one of the most important meteorological elements, since (i) it has considerable effects on natural and cultivated vegetation, (ii) it plays a key role in transportation and outdoor human activities. Furthermore, precipitation-related extreme events may result in severe environmental damages and/or economical losses. In order to increase the adaptation capacity towards precipitation-related hazards, future trends must be appropriately estimated, for which physically-based projections are required. Moreover, analysis of past trends is also essential in order to better understand possible causes, feedback mechanisms, and potential connection chains.
To evaluate precipitation trends in the recent past, the homogenized, high-quality CarpatClim database (1961–2010) is used, which is available for 0.1° horizontal resolution. For investigating the future trends, regional climate model (RCM) simulations at 0.25° horizontal resolution from the ENSEMBLES project are used for the selected domain. Validation analysis showed that RCM simulations underestimate precipitation in summer, and overestimate it in the rest of the year. In order to eliminate these systematic errors, a quantile-based bias correction method is applied to the raw RCM outputs Then, time series of 18 precipitation-related climate indices are calculated for the entire 1961–2100 period. Average annual and seasonal changes by the mid- and late-century are estimated relative to the 1971–2000 reference period for five subregions within the Carpathian Region. Our results suggest that more intense precipitation is likely to occur in the future in general. However, drying trend is estimated for summer whereas more precipitation days are projected for winter, especially in the northern parts of the domain.

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M22p-309

Extreme value analysis and evaluation of indices using wind speed data sets for Hungary

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Homogenized wind speed (1975–2012), wind gust (1975–2013) measurements, and homogenised and gridded data sets of the CarpatClim (1961-2010) database are analysed in order to assess Hungarian wind climate trends, variability, frequency and intensity of extreme wind events. Extreme value analysis is applied to evaluate wind related extremes in a changing climate and to calculate return values and various wind climate indices for Hungary.
The annual daily maxima of wind speed and wind gust are determined on the basis of available time series fitted to the Generalized Extreme Value distribution at every station and grid cell. 50-year and 100-year return values are estimated from these fitted distributions. In addition, the threshold crossing technique is applied to examine the frequency occurrence and trend of moderate and strong wind days at the stations in the last few decades. Our results from the analysis of homogenised observed wind data show decrease in the annual mean wind speed, which is consistent with the reduced Pole to Equator meridional temperature gradient in a warmer globe.

IAMAS (Meteorology)

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M22p-310

Development of high wind now-casting system using X-band radar network and its implementation

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The improvement of the technique for monitoring and predicting high wind area is being required. However, it is difficult to predict a local and sudden high wind by physical model at present. On the other hand, the now-casting, which is a kinematic method to extrapolate temporally a spatial pattern, is based on a real-time data observed by radar, then the prediction accuracy for a few hours from initial time is good. This presentation introduces the developed method of high wind now-casting and the result of verification.

This method uses wind data observed by the X-band radar network, which is composed of the Doppler or Multi-Parameter radars operated by several organizations such as NIED etc. around Tokyo in Japan. The wind data cannot be observed in the area where rainfall particle doesn’t exist, then this blank area of wind data is spatiotemporally interpolated with GPV data calculated form the numerical weather prediction model of JMA. The movement vector of high wind area is calculated by using the wind velocity distribution of current and the latest 3 past time data, and high wind area for 1 hour is predicted. Finally, the calculated wind velocity at the altitude of 1,000m is corrected into the wind velocity above the ground by using the wind data observed at AMeDAS of JMA.

We extracted the events that a remarkable gusty wind is reported in from January, 2010 to December, 2014, and verified a precision accuracy. As a result, the prediction accuracy in the case of the typhoon and the passage of the front is good.

We carry out the experiment that the high wind prediction is provided through web site on real-time.

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M22p-311

The Tokyo metropolitan area convection study for extreme weather resilient cities (TOMACS)

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An unprecedented dense observation campaign and relevant modeling and societal studies have been conducted since April 2010 by the National Research Institute for Earth Science and Disaster Prevention (NIED), Meteorological Research Institute (MRI), and more than 25 national institutions and universities in Japan that target local high-impact weather (LHIW) in the Tokyo metropolitan area. The objectives of the project, the Tokyo Metropolitan Area Convection Study for Extreme Weather Resilient Cities (TOMACS), include the 1) elucidation of the mechanism of LHIW in urban areas (e.g., local torrential rain, flash flood, strong wind, lightening), 2) improvement of nowcasting and forecasting techniques of LHIW, and 3) the implementation of high resolution weather information to end-users through social experiments.
TOMACS was endorsed in 2013 as an international research and development project (RDP) of World Weather Research Programme (WWRP) of the the World Meteorological Organization (WMO) with the international partners including the Environment Canada (Canada), Bureau of Meteorology (Australia), Sao Paulo University (Brazil), University of Hohenheim (Germany), Pukyong National University (Korea), University Paris-Est (France), National Center for Atmospheric Research (USA) and Colorado State University (USA).

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Nakatani, T., Y. Shoji, R. Misumi, K. Saito, N. Seino, H. Seko, Y. Fujiyoshi and I. Nakamura, 2013: WWRP RDP Science Plan: Tokyo Metropolitan Area Convection Study for Extreme Weather Resilient Cities (TOMACS). WWRP report for Joint Scientific Committee, 26pp.(available online at

http://www.wmo.int/pages/prog/arep/wwrp/new/documents/Doc4_6_TOMACS_RDP_proposal_20130704.pdf)

IAMAS (Meteorology)

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M22p-312

Droughts in the Nortn Eurasian regions: Probability estimates for different El Niño / La Niña phases

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The strongest regional weather-climate anomalies are connected with the formation of long-living blocking anticyclones. We estimate the probability of regional climate anomalies related to the atmospheric blocking anticyclones and El Niño/ La Niña effects. In particular, we analyzed data from observations during 1891–2013 for anomalies of surface air temperature, precipitation and drought indices in spring-summer months for the East European (ERR) and West Asian (ARR) Russian regions.
The largest probability of drought conditions during spring-summer in ERR was detected for the years starting with El Niño events and with the transition to the La Niña events at the end of the year (EN–LN transition). It is associated with the largest probability of the extremely hot ERR temperature. Such conditions were realized for ERR in summer 2010 (Russian heat wave). Similar results were obtained for the ERR and for the larger East European region (ER) in mid-latitudes for the shorter period 1891–2010.
The largest probability of drought conditions in ARR for both periods 1891–2013 and 1891–2010 was detected for the years starting with La Niña events and with the transition to the El Niño events at the end of the year (LN–EN transition). The largest probability of drought conditions for the larger West Asian region (AR) in mid-latitudes for the shorter period 1891–2010 was obtained for the years starting with La Niña events and with the transition to the La Niña event at the end of the year. It is associated with the largest probability of negative anomaly for the AR precipitation.

IAMAS (Meteorology)

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M22p-313

Fingerprint of the 2010 Russian heat wave in tree-ring width chronologies of pine (Pinus sylvestris) and oak (Quercus robur)

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The extreme surface warmth over western Russia during July and early August of 2010 was mostly a product of the unusually persistent blocking episode. The heat wave and abnormal low precipitation rate resulted in severe drought and impacted terrestrial ecosystems, particularly by tree growth suppression. Tree rings are traditionally used to reconstruct the extreme hydroclimatic regimes even in the regions, where the climatic control of ring width is relatively low. In this study, we used 14 ring width chronologies of pine and 3 chronologies of oak in the central part of western Russia (55-60N, 35-45E) to assess their sensitivity to the 2010 drought and to other severe droughts of the 20th century (1936-1939, 1972). 2 oak chronologies and 10 pine chronologies demonstrated significant positive correlation with either precipitation, PDSI or Soil moisture index. In all cases the reaction of trees was in the subsequent year. The heat wave, which occurred in July and August 2010 in the central part of western Russia, is recorded in chronologies in Kostroma, Yaroslavl', Moscow and Kaluga regions in 2010 and 2011, however in the southernmost oak chronology (Tula region) both years were regular in terms of ring width. Three previous droughts (2003, 1939, and 1936) are recorded even more clearly in the ring width chronologies than the 2010 event. By the amplitude of growth suppression the years 1964, 1956, 1939, 1936, 1921, 1897, 1891, 1845, 1797, 1787, 1767 exceed those of 2010 and 2011. The results provide a useful methodology for extending records of meteorological droughts into pre-instrumental observation era and new insights into climate extremes.

IAMAS (Meteorology)

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M22p-314

Origins of large scale precipitation deficiencies in Europe and Africa

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In a recent study we assessed the predictability of meteorological droughts using precipitation fields provided by the ECMWF Ensemble prediction systems. It has been shown that 40% of droughts in Europe can be forecasted about one month ahead with a false alarm rate of only 25%. Following these results, the next goal is to assess potential improvements in forecasting large scale meteorological droughts in Europe and Africa by including atmospheric predictors that are generally better represented in atmospheric models.

To achieve this goal, the first step was to identify relevant atmospheric predictors. To do so meteorological droughts have been identified based on the large scale observed precipitation deficiencies as expressed in the Standardized Precipitation Index calculated for one month accumulation periods (SPI-1). The main spatial patterns of these meteorological droughts were then identified by Empirical Orthogonal Functions of the SPI-1 over Europe and Africa and the principal components were analyzed to depict recent climatological trends. These evolutions were related to weather type classifications calculated from ERA-Interim reanalysis data and to the temporal variabilities of the main components of the tropical circulation during droughts that occurred in Europe and Africa, respectively.

Results show that over several regions in Europe and Africa there is a significant relation between the evolution of the SPI-1 and atmospherical components, highlighting the potential interest of using predictors to better forecast meteorological droughts.

IAMAS (Meteorology)

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M22p-315

Numerical simulation of the explosive cyclone that caused a severe snowstorm in Hokkaido, Japan on March 2 2013

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Extratropical cyclones often develop rapidly in the cold season, called explosive cyclones, cause wide-ranging heavy snowfall and strong winds, which make enormous impacts on lifelines. Severe snowstorms associated with explosive cyclones occasionally cause fatal accidents. Therefore, better understanding of the development process of explosive cyclones leads to the improvement of weather forecast and disaster prevention in the cold season.
An extratropical cyclone occurred over the Japan Sea on March 1 2013 and passed through the Hokkaido Island in Japan developing rapidly, and then peaked over the Sea of Okhotsk on March 3. The severe snowstorm associated with the explosive cyclone caused a sudden whiteout in the eastern part of the Hokkaido Island and killed nine people on March 2.
To investigate the development process of the explosive cyclone, numerical simulations are performed using the Weather Research and Forecasting (WRF) model. The control simulation including full physical processes (denoted as CNTL) successfully reproduces the track and evolution of the observed cyclone, and the distribution of strong winds associated with the severe snowstorm. The simulation without diabatic heating associated with precipitation processes produces a weaker cyclone than CNTL, which indicates that diabatic heating associated with precipitation processes plays an important role for the cyclone development. On the other hand, the simulation without sensible and latent heat fluxes from the surface produces a stronger cyclone than CNTL. The sensible heat flux from the Sea of Japan reduces cold advection in the rear of the cyclone center, resulting in the smaller amplitude of the zonal temperature perturbation associated with the cyclone.

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M22p-316

The predictability of frontal waves and cyclones.

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The statistical properties and skill in predictions of objectively identified and tracked cyclonic features (frontal waves and cyclones) are examined in MOGREPS-15, the global 15-day version of the Met Office Global and Regional Prediction System (MOGREPS). The number density of cyclonic features is found to decline with increasing lead-time, with analysis fields containing larger numbers of weaker features which are not sustained past the first day of the forecast. This loss of cyclonic features is associated with a decline in area averaged enstrophy with increasing lead time. Both feature number density and area averaged enstrophy saturate by around 7 days into the forecast. It is found that the feature number density and area averaged enstrophy of forecasts produced using model versions that include stochastic energy backscatter saturate at higher values than forecasts produced without stochastic physics. The ability the MOGREPS-15 to predict the locations of cyclonic features of different strengths is evaluated at different spatial scales by examining the Brier Skill of strike probability forecasts: the probability that a cyclonic feature centre is located within a specified radius. The skill is found to be maximized for the most intense features, with the spatial scale at which skill is maximized increases with lead-time from 650km at 12h to 950km at 7 days. Forecast skill remains above zero at these scales out to 14 days.

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M22p-609

Spatio-temporal analysis of the annual maximum multi-day precipitation amounts in Croatia

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In this study maximum annual multi-day precipitation amounts (Rxn, n=1, 2, 3 and 5) are analyzed. The study comprises 137 meteorological stations in Croatia from the 1961-2010 period. Expected maxima for different return periods (2, 5, 10, 25, 50 and 100 years) have been estimated by the generalized extreme value distribution (GEV). Spatial distribution of the corresponding return values will be presented. Beside, the trend analysis is also performed. The results of this study will serve as a basis for the regionalisation of extreme precipitation amounts for the purpose of preparation of hazard and flood risk maps in Croatia. Part of this study was published at Cindric et al. (2014.).

IAMAS (Meteorology)

M22p - M22 Understanding and Predicting High-impact Weather and Climate Extremes

M22p-610

The extreme European cold spell in 2011/12 winter: Observed features and possible causes

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In midwinter of 2012, Europe suffered an extreme cold spell, and hundreds of people lost their lives under severe blizzard condition and extreme low temperatures. The present study offers an overview of the event and discusses its possible mechanisms, based on station observations and atmospheric reanalysis data. The initiation of the cold spell was triggered in mid-January by a quasi-stationary Rossby wave train emanating from the North Atlantic. Under positive feedback forcing from transient eddies, the wave train generated a cold upper-level cyclonic anomaly over Europe that led to surface cooling mainly through the reduction of downward long wave radiation. The development and mature stages of the cold spell in late January and early February, respectively, were characterized by a prominent blocking ridge and strong surface high over northern Europe and western Russia. The cold spell resulted from enhanced cold advection by the anomalous low-level easterlies associated with the high. The build-up of the blocking ridge was initiated by an incoming Rossby wave train over western Russia, and then the conversion of available potential energy from the climatological-mean flow contributed substantially to the amplification and maintenance of the anticyclonic anomaly whose structure became increasingly baroclinic. The westward spread of the coldness over Europe was also contributed to by gradual westward extension of the cold surface high, occurring with another upper-level blocking ridge developing over the northeastern Atlantic under feedback forcing by transient eddies. As its downstream effect, a cold upper-level cyclonic anomaly developed, setting a condition favourable for heavy snowstorms around the Mediterranean coasts.