Union Symposium

JV03d - JV3 Geophysical Imaging and Monitoring of Volcanoes (IAVCEI, IASPEI, IAGA)

IUGG-1559

Rapid fluid ascent from magma reservoir to surface revealed by strain data from Soufrière Hills Volcano (Montserrat, West Indies)

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Geodetic surveying of the andesitic dome-building Soufrière Hills Volcano (SHV) has been conducted for almost two decades. Evaluation of the recorded GNSS, tilt and strain data revealed a detailed image of the complex subsurface magmatic system that has found to consist of three sources of magma storage: a mid-crustal magma reservoir, an upper magma chamber and a shallow dyke-conduit system. We here show that pressure changes in each of the segments of the plumbing system generate a specific strain amplitude ratio that allows for distinction of the operating segments in the magmatic system in almost real-time during volcanic activity events. We apply this method to evaluate continuous (1 Hz) strain data from selected Vulcanian explosions and gas emission events that occurred at SHV between 2003 - 2012. Our results show that the events were initiated by a sudden contraction of the deeper magmatic system along with an inflation of the shallow feeder system. The initial phase lasts only tens to hundreds of seconds and is followed by a recovery of the system.
The time scales involved are far too short to be associated with magma transport and we instead propose rapid ascent of fluids to generate the pressure changes. A viable mechanism to provide pathways for such rapid fluid migration within the magmatic system is the propagation of tensile hydraulic fractures. The sudden onset of the fluid ascent events, together with the fast ascent speeds imply that large pockets of already segregated fluid existed in the magmatic system and were released by sudden destabilization. Our study demonstrates that geodetic observables can provide unprecedented insights into complex dynamic processes within a magmatic system commonly assessed by theoretical models and petrologic observations.

Union Symposium

JV03d - JV3 Geophysical Imaging and Monitoring of Volcanoes (IAVCEI, IASPEI, IAGA)

IUGG-1925

An overview of RSTVOLC perfomances in detecting volcanic hot spots by means of polar and geostationary satellite data

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The RST_{VOLC} algorithm, which is based on the largely accepted Robust Satellite Techniques (RST) multitemporal approach, has been developed for studying and monitoring active volcanoes from space. Such an algorithm, which uses two local variation indexes in combination to detect volcanic hot spots, was firsly tested on Advanced Very High Resolution Radiometer (AVHRR) data, to study the Mt. Etna (Italy) thermal activity, revealing a suitable trade-off between reliability and sensitivity of detection. After that, it was implemented on Moderate Resolution Imaging Spectroradiometer (MODIS) records and was compared to MODVOLC, showing a better capability in detecting subtle hot spots, like those occurring before the Mt. Asama (Japan) eruption of 1 and 14 September 2004. Recently, RST_{VOLC} has been exported on data provided by geostationary satellites, such as the Multi-functional Transport Satellite (MTSAT) and Spinning Enhanced Visible and Infrared Imager (SEVIRI), demonstrating a high potential in monitoring short-lived eruptive events, like those occurred at Shinmoedake (Japan) and Mt. Etna (Italy) in January 2011. In this work, an overview of RST_{VOLC} perfomances in monitoring active volcanoes, by means of polar and geostaionary satellite data, is then presented. Results achieved studying volcanoes located in very different geographic areas, such as Ol Doinyo Lengai (Tanzania) and Eyjafjöll (Iceland) are reported. Moreover, the successfull implementation of RST_{VOLC} in automatic elaboration chains for the operational monitoring of high risk volcanic areas (e.g., Taal, Philipphines) is also discussed here, evaluating advantages offered by such an algorithm, when used in the framework of automated early warining systems.

Union Symposium

JV03d - JV3 Geophysical Imaging and Monitoring of Volcanoes (IAVCEI, IASPEI, IAGA)

IUGG-3143

Monitoring of Sakurajima Volcano, Japan, using X-band SAR/InSAR data

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Sakurajima volcano is located in southwestern part of Japan, and currently one of the most active volcanoes in Japan. Eruptive activities from a Showa-crater have activated since 2009, and many explosive eruptions have occurred. To understand current condition and future unrest of Sakurajima, periodic monitoring is required. Although it is generally difficult to make a field observation in dangerous active volcanoes, a satellite remote sensing can make observations of even ongoing volcanoes periodically. Especially, Synthetic Aperture Radar (SAR) sensor is well-suited for monitoring active volcanoes because it can penetrate ash clouds and can observe targets like an active vent. Moreover, SAR data are applicable to use a Differential Interferometric SAR (DInSAR) technique to detect crustal movement associated with the magmatic activities. In this study, we used COSMO-SkyMed (CSK) data through JAXA-ASI co-operative research and tried DInSAR/PSInSAR processing.
We have been monitoring on Sakurajima volcano using CSK data acquired between 2010 and 2014 from both ascending and descending orbits. From amplitude images, we detected apparent changes of backscattering intensity probably due to an enlargement of the Showa-crater. Because enough coherence could be given by only short-term pairs and the crustal movement on Sakurajima is small, it was hard to detect signals from the DInSAR processing. Then we tried PSInSAR processing using StaMPS software [Hooper et al., 2007]. The results show 1cm/year uplift in north part of Sakurajima volcano between 2012 and 2014, and it corresponds to results from leveling survey.

Union Symposium

JV03d - JV3 Geophysical Imaging and Monitoring of Volcanoes (IAVCEI, IASPEI, IAGA)

IUGG-3720

Geodetic monitoring of volcanic activity of El Hierro (Canary Islands) and Fogo (Cabo Verde)

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Precise geodetic monitoring is essential in monitoring volcanic activities. We have been conducting continuous GPS observation in Canary Islands, Spain, since 2004 and Fogo, Cabo Verde since 2013. In July 2011, an active seismic swarm started in El Hierro, Canary Islands, and resulted in a submarine eruption off the southern coast of El Hierro from October 2011 to March 2012. We detected magmatic inflation and its migration by continuous GPS observation. There have been several major seismic swarms until 2014, and crustal deformation always accompanied seismic activity. The highest seismic and deformation event ocurred on June 2012, and it was associated to a new submarine volcanic activity observed off the western coast of El Hierro. One interesting characteristic of this activity is that the seismic swarm migrates in a different direction and the deformation pattern is always different. This suggests that previously intruded magma tube behaves as a barrier for new magma. Also it should be noted that we have not detected clear deflation signal in El Hierro.
In November 2014, after a seismic activity for weeks, Fogo started eruption accompanied by a massive lava flow. Surprisingly, crustal deformation before the eruption was only about 10mm. After the eruption started, we detected deflation signal up to 25 mm. The deformation slowed down in accordance with the volcanic activity at the surface. The observation indicates difference in the magmatic system of two volcanoes. Understanding of the structure and behaviors of the magmatic system is indispensable for monitoring of volcanoes.

Union Symposium

U07a - U07/JP02 The Potential for Carbon- and Climate-Engineering to Offset Global Change / The Potential for Carbon- and Climate-Engineering to Offset Global Change (IAPSO, IAMAS)

IUGG-2049

Climate model simulations of geoengineering: What we've learned from GeoMIP and what we might learn in the future

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Some of the most powerful tools in assessing the climate responses to geoengineering are climate models. Here I present some of the latest findings from climate model simulations of geoengineering, with a focus on results from the Geoengineering Model Intercomparison Project (GeoMIP), an international coordinated collaboration designed to determine robust climate model response to various geoengineering scenarios. I also discuss how the study of geoengineering is tightly coupled to more general investigations in climate science, and simulations of geoengineering can be used to better understand how the climate system works. I close with an evaluation of GeoMIP's successes, shortcomings, and possible future directions to increase it relevance to climate science and society as a whole.

Union Symposium

U07a - U07/JP02 The Potential for Carbon- and Climate-Engineering to Offset Global Change / The Potential for Carbon- and Climate-Engineering to Offset Global Change (IAPSO, IAMAS)

IUGG-2166

The role of iron during the open ocean dissolution of olivine in a simulated CO2 removal experiment

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One CO_2 removal mechanism proposed as geoengineering approach is enhanced silicate weathering. We here follow up on previous simulation experiments on the open ocean dissolution of olivine, a well-distributed magnesium-iron-silicate and focus on the role of iron. Olivine is known to contain a magnesium:iron ratio of ~9:1. Iron is a micronutrient and in various areas of the ocean marine biology is iron-limited. It is thus expected that olivine dissolution as a large-scale geoengineering application for CO_2 removal would increase the iron input into the ocean with implications for marine biology. With the numerical simulation of the marine ecosystem and biogeochemistry model RECOM-2 embedded in the ocean general circulation model MITgcm the potential changes in the marine biological productivity via associated iron fertilization were analysed. Since it is not clear how much of the iron contained in olivine will be lost by colloid formation and aggregation before becoming biologically available we show in sensitivity experiments that already the availability of 0.1% of the iron enhances the oceanic carbon uptake connected with the olivine dissolution by 20% compared to similar experiments in which the effect of iron is neglected. Results saturate at an increase in marine carbon uptake rate of 35% if 1% or more of the dissolved iron would be biologically available. For an addition of 3 Pg/yr of olivine with a 1% solubility the additional biologically available iron in the surface ocean would be 2.4 Tg/yr, which is 10x larger than the dissolved iron input by dust. The effect of such an iron fertilization would lead in certain areas to species shifts in the phytoplankton communities with diatoms being one of the winners and effects would be largest in the Southern Ocean.

Union Symposium

U07a - U07/JP02 The Potential for Carbon- and Climate-Engineering to Offset Global Change / The Potential for Carbon- and Climate-Engineering to Offset Global Change (IAPSO, IAMAS)

IUGG-5076

Cirrus Cloud Thinning - a Climate Engineering technique that targets longwave radiation

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Climate Engineering has been proposed as a potential approach to counteract global warming, especially in the case of a 'climate emergency'. Much of the research on climate engineering so far has investigated the possibility of balancing the longwave forcing by increasing greenhouse gas concentrations by enhanced reflection of solar radiation. Earth System Model Simulations indicate that such 'Solar Radiation Management' might succeed in suppressing the globally averaged temperature response, but only at the expense of the hydrological cycle, which is indicated to weaken. An alternative technique, 'Cirrus Cloud Thinning' - if feasible - might conceivably avoid such side effects, because it targets the longwave radiation, which is precisely the type of radiation that is being perturbed by greenhouse gases. We will explain the principle of Cirrus Cloud Thinning and then review recent research investigating the potential and side effects of this technique. One aspects that will be given particular attention is the hydrological cycle, e.g. as viewed from the perspective of atmospheric energetics. We will also discuss the possibility of confining Cirrus Cloud Thinning to certain latitudes and times of the year, as proposed in recent publications in the literature. Finally, we will address the question of how large a negative forcing it might be realistic to achieve by Cirrus Cloud Thinning alone.

Union Symposium

U07b - U07/JP02 The Potential for Carbon- and Climate-Engineering to Offset Global Change / The Potential for Carbon- and Climate-Engineering to Offset Global Change (IAPSO, IAMAS)

IUGG-1419

On the feasibility of cirrus cloud thinning: Dependence of homo- and heterogeneous ice nucleation on latitude and season

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While GCM testing of cirrus cloud climate engineering (CE) reveals some advantages over stratospheric aerosol injection, cirrus CE will not work when ice is primarily formed through heterogeneous nucleation for T < -38°C. Field campaigns have shown that ice in cold cirrus is generally produced heterogeneously, but these campaigns have not addressed the cirrus at high latitudes that would determine the effectiveness of cirrus CE.

A new understanding of thermal absorption in two split-window channels renders a reinterpretation of a standard CALIPSO satellite retrieval. 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) the ice particle number concentration/ice water content ratio, or 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 (and probably from Dec. – April) 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, implementing cirrus CE at high latitudes only when solar zenith angles are relatively low (i.e. seeding only 15% of the planet) may have a comparable cooling effect at high latitudes where global warming is most severe, and may have a mean global cooling of 1.4°K as shown in Storelvmo et al. (2014). These satellite findings indicate that cirrus CE is a real possibility.

Union Symposium

U07b - U07/JP02 The Potential for Carbon- and Climate-Engineering to Offset Global Change / The Potential for Carbon- and Climate-Engineering to Offset Global Change (IAPSO, IAMAS)

IUGG-1579

Is nature testing climate engineering for us?

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National commitments to reduce greenhouse gas emissions remain well below cutbacks needed to stabilize climate, increasing interest in the potential for counteracting their warming influences. Discussion has arisen, however, regarding the potential for unintended consequences, even during field testing. Examining the contributing causes of the recent slowed pace of global warming may provide insights for evaluating this potential. For example, Santer et al. attribute about 30% of the slowing to a volcanically induced increase in the stratospheric sulfate layer, not unlike proposals to increase the stratospheric aerosol loading. Similarly, the role of increased ocean heat uptake may emulate the 'ocean pipes' approach proposed by Lovelock and Rapley. Also, the extent to which a shift in the centroid of sulfur dioxide emissions from nations bordering the North Atlantic basin to nations in south and east Asia has shifted the cooling effects of tropospheric sulfate and the brightness of clouds may offer insights regarding the cloud brightening approach of Salter and Latham, (and the reduction in sulfate loading over the North Atlantic basin may be creating a useful inverse analog). On a regional basis, the storm-induced breakup of thin polar sea ice by super-typhoon Nuri may be akin to suggestions to use icebreakers to break up thin ice in the fall to increase transfer of oceanic heat to the atmosphere and space. With large-scale (and even small-scale) field programs to evaluate potential climate engineering approaches unlikely to gain early approval, expanding diagnostic studies of Earth system behavior might well provide a useful approach to gaining at least some of the insights needed to further evaluate potential approaches for slowing global warming.

Union Symposium

U07b - U07/JP02 The Potential for Carbon- and Climate-Engineering to Offset Global Change / The Potential for Carbon- and Climate-Engineering to Offset Global Change (IAPSO, IAMAS)

IUGG-1623

Atlantic hurricane response to geoengineering

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Devastating Atlantic hurricanes are relatively rare events. However their intensity and frequency in a warming world may rapidly increase - perhaps by a factor of 5 for a 2°C mean global warming. Geoengineering by sulphate aerosol injection preferentially cools the tropics relative to the polar regions, including the hurricane main development region in the Atlantic, suggesting that geoengineering may be an effective method of controlling hurricanes. We examine this hypothesis using 6 Earth System Model simulations of climate under the GeoMIP G3 and G4 schemes that use aerosols to reduce the radiative forcing under the RCP4.5 scenario. We use a temperature dependent Generalized Extreme Value statistical model callibrated by historical storm surges from 1923. We find that although temperatures are ameliorated by geoengineering, the numbers of storm surge events as big as that caused the 2005 Katrina hurricane are only slightly reduced compared with no geoengineering. As higher levels of sulphate aerosol injection produce diminishing returns in terms of cooling, but cause undesirable effects in various regions, it seems that stratospheric aerosol geoengineering is not an effective method of controlling hurricane damage.

Union Symposium

U07b - U07/JP02 The Potential for Carbon- and Climate-Engineering to Offset Global Change / The Potential for Carbon- and Climate-Engineering to Offset Global Change (IAPSO, IAMAS)

IUGG-2589

Is there a limit of sulfate injections for climate engineering?

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The climatic impact of climate engineered sulfate aerosols depends on the injected amount of sulfur. Different studies have been estimated the impact of sulfur injection up to 10 Mt(S)/y. But newly designed experiments for GeoMIP6 require stronger injection rates as stronger forcing scenarios under business as usual conditions come into focus.
Therefore we performed with a aerosol microphysical model a series of experiments with sulfur injection rates up to 100 Mt(S)/y. One aim of our study was to estimate an upper limit of sulfate injections, when the change in the ratio of increased injection strength to gained further radiative forcing becomes very small. This ratio follows an e-function. Therefore, for a strong solar radiation management scenario, like keeping temperature level under business as usual conditions at the level of the year 2020, would require injections 10 to 20 times the emission strength of Mt.Pinatubo eruption per year. We estimated the reliability of the given results by varying the injection strategy and relating the results to previous studies.

Union Symposium

U07b - U07/JP02 The Potential for Carbon- and Climate-Engineering to Offset Global Change / The Potential for Carbon- and Climate-Engineering to Offset Global Change (IAPSO, IAMAS)

IUGG-3396

Global agricultural impact from the G4 Specified Stratospheric Aerosols (G4SSA) GeoMIP Simulation using the CESM-CAM4 climate model

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In stratospheric sulfate geoengineering, as solar radiation is blocked by sulfate aerosol, reductions of temperature, precipitation and surface solar radiation, as well as surface ozone concentration changes, would have impacts on the global agricultural system. Here we present agricultural impact results of a new proposed geoengineering experiment "G4 specified stratospheric aerosols" (G4SSA) using the CESM-CAM4-chem earth system model and the CESM-CLM crop model. We first run 3 ensemble members of RCP6.0 from 2004 to 2090 as the reference run and 3 ensemble members of G4SSA from 2020 to 2090 using CESM-CAM4-chem. In G4SSA, geoengineering is applied in years 2020-2071 with a fixed prescribed stratospheric aerosol distribution assuming an emission of 8 Tg SO_2 per year. After 2071, the background aerosol forcing is used to simulate the termination effect of sulfate geoengineering. We then drive CESM-CLM-crop, incorporating plant responses to ozone, with 3-hourly output from the G4SSA and RCP6.0 simulations generated from CESM-CAM4-chem. Five crops are included in this crop model. Compared with the reference run, there are regional differences in crop production when G4SSA is applied. For example, in most maize production regions, temperature reduction in G4SSA comparing with RCP6.0 is the dominant climate change factor, and it increases maize yield. However, some regions also show a decreased maize yield as a result of enhanced ozone damage on crops. For example, in China and India, severe air pollution provides precursors for surface ozone, and enhanced surface ultraviolet radiation due to stratospheric ozone depletion provides a friendly environment for catalytic reactions to form surface ozone. These and other comprehensive impacts on crops globally will be presented.

Union Symposium

U07b - U07/JP02 The Potential for Carbon- and Climate-Engineering to Offset Global Change / The Potential for Carbon- and Climate-Engineering to Offset Global Change (IAPSO, IAMAS)

IUGG-3653

Will cirrus cloud seeding reduce warming ?

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It has been suggested that the seeding of cirrus clouds by the purposeful injection of heterogeneous ice nuclei (or IN) would reduce cirrus cloud ice water path, optical depths, and heating, and thereby lead to an overall cooling of the climate. However, the effectiveness of cirrus cloud seeding depends to a large extent on the choice of ice nucleation spectrum and the aerosol types active as IN in the unseeded atmosphere. Here, we use the IMPACT aerosol model to determine the ice nucleation spectrum and aerosol types. This model includes a detailed aerosol particle formation scheme for both secondary organic aerosols (SOA) and other aerosol types that is able to reproduce observed aerosol concentrations in the upper troposphere/lower stratosphere. The ice nucleation properties of these aerosol types are based on laboratory and field studies. Moreover, our predicted aerosols together with observed ice nucleation properties are able to reproduce observed background ice number concentrations. We report the effectiveness of the introduction of further IN into the atmosphere at cirrus levels based on this new validated model.

Union Symposium

U07p - U07/JP02 The Potential for Carbon- and Climate-Engineering to Offset Global Change / The Potential for Carbon- and Climate-Engineering to Offset Global Change (IAPSO, IAMAS)

U07p-576

Estimation of carbon budget change in South and North Korea using the VISIT model

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Carbon storage on earth consists of the atmosphere, ocean, terrestrial ecosystem, and rock. Of those, the terrestrial ecosystem is a major carbon reservoir most affected by human activities. Therefore, to quantify carbon budget is important to manage and reduce emission of carbon dioxide. This study aims to estimate carbon budget in the Korean peninsula over the past 30 years using a VISIT (Vegetation Integrated Simulator for Trace gases) model, and to calibrate the estimated carbon budget by applying forest growth rate. The result shows that (1) in North Korea net carbon flux is 10.72 ± 5.18 Tg C yr^{-1} in the 1980s, 3.00 ± 7.96 Tg C yr^{-1} in the 1990s, and -0.46 ± 5.13 Tg C yr^{-1} in the 2000s, which means that North Korea has changed from carbon sink to carbon source. In South Korea, net carbon flux is 10.55 ± 1.09 Tg C yr^{-1} in the 1980s, 10.47 ± 7.28 Tg C yr^{-1} in the 1990s, and 6.32 ± 5.02 Tg C yr^{-1} in the 2000s, showing the decrease of carbon uptake gradually. (2) Forest growing stocks of North and South Korea are revised by applying growth rate and devastated forest area to the model-estimated NPP. As a result, forest growing stock per unit area has the highest in the 2000s and the lowest in the 1990s in South Korea while it decreases gradually from the 1980s to 2000s in North Korea. Considering forest has been devastated in the Korean peninsula, the total growing stock is about 149×10^6 m^3/yr of the average for the past 30 years with 5.27% of growth rate in South Korea, and about 116×10^6 m^3/yr with 3% in North Korea.

Union Symposium

U01a - U1 Future Earth and Sustainability

IUGG-1585

Integrating GEC Study into Future Earth Initiative

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How to integrate the study of global environmental change (GEC) into the Future Earth initiative and thus to deliver knowledge in natural and social sciences to public and policy makers in developing countries is an important issue for global sustainable development. Attempts and progress have been made in China and can be taken as an example for further exploration.

Since 1980's, due to the rapid economy development, China is facing new challenges: rapid urbanization, energy consumption, population growth, land use and land cover change, and serious environment pollution, among others which are hampering the sustainable development of China.

A nationwide endeavor on ecological progression was initiated in 2012. An international workshop hosted by Chinese Association for Science and Technology (CAST) on "Future Earth in China" was held to explore a co-design pathway for sustainable development in China, a project "Co-design of Implementation Plan for Future Earth in China" was initiated by CAS, and a Chinese National Committee for Future Earth (CNC-FE) was established jointly supported by CAST, CAS, Chinese Academy of Social Sciences (CASS), and NSFC etc. A consultation project "Develop 'Future Earth in China' for promoting social sustainability" was also approved. This presentation will introduce the key issues concerning meteorology and GEC for Future Earth study and the ongoing efforts towards the SDG.

A national project "Land-air Coupling over the Tibetan Plateau and Its Climate Impact", an unprecedented Chinese effort running through 2023 will be presented to illustrate how the scientists, stakeholders, and funding agencies can work together for co- design and co- production so as to meet the facing challenges and to promote the social sustainable development.

Union Symposium

U01a - U1 Future Earth and Sustainability

IUGG-3232

Future Earth: Its importance and implications in Asia

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Future Earth is a global research platform designed to provide the knowledge needed to support society's transformation to a sustainable world. We seek to build and connect global knowledge to increase the impact of research and to find new ways to accelerate transitions to sustainable development. Future Earth will contribute to achieving the goals of the high level UN General Assembly resolutions on global sustainability, as articulated at the 2012 Rio+20 Summit and subsequently. Future Earth will work with partners in society to co-develop the knowledge needed to support decision makers and societal change by focusing on three Research Themes – Dynamic planet, Global sustainable development and Transformations towards sustainability.
Here, I would like to emphasize the important role of Future Earth particularly in Asia. This region as a whole is characterized by rapid population and economic growth and urbanization, where great disparities of wealth both within and between countries, and social and ecological vulnerability to the potential impacts of climate change are increasing. Associated with this rapid population & economic growth, this region has become a huge hot-spot of greenhouse gas increase, air and water pollutions, affecting regional to global climate change. In addition, this region is located in the midst of monsoon climate and the huge active tectonic zone. These natural conditions cause high frequency of natural disasters, but also provide rich natural resources for agriculture & fisheries. The science community and society should tightly collaborate particularly in Asia to form Future Earth in Asia initiative. I do believe that without achieving sustainable society in Asia we cannot achieve global sustainability.

Union Symposium

U01a - U1 Future Earth and Sustainability

IUGG-5707

Climate change and food security

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The world needs to nutritiously feed 9 billion people by 2050 in what will be a more challenging climate. A two degree warmer world will bring particular challenges for certain crops, farming systems and peoples, including adaptation that requires transformative changes. The increased variability of weather and the greater frequency and intensity of extreme events brings many challenges for food security. In addition to the adaptation challenge, the ecological footprint of agriculture must be significantly reduced. Agriculture and its value chains, including agriculturally-driven land cover change, account for about a third of global GHG emissions, but agriculture has many other consequences for global change.

The term climate smart agriculture (CSA) has been coined to address the triple challenge of adaptation, mitigation and food security. The overall aims of CSA are to support initiatives for sustainably using agricultural systems to achieve food and nutrition security, integrating adaptation and capturing potential mitigation. In response to the challenges, the Global Alliance on Climate Smart Agriculture has been launched, involving diverse stakeholders. The aim includes increasing the resilience of 500 million farmers by 2030. For this to happen, there is now a great deal of activity, involving researchers, policy makers, investors and implementers; to define what CSA should look like in different contexts and to ensure rapid implementation. This includes tool development, prioritisation processes and the fostering of new partnerships.

Meeting the challenges will require a major shift in research to better reflect the priorities of CSA. Science to support the agenda will cut across scales and disciplines, and will involve deep engagement with stakeholders.

Union Symposium

U01b - U1 Future Earth and Sustainability

IUGG-2576

Global change and global water emergency: a new vision for new solutions

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While the majority of the Earth surface is still in pristine conditions, the totality of the hydrological systems that are relevant to society are human impacted. In fact, the limited transferability of water in space and time implies that water withdrawals from natural resources take place where and when water is needed, thereby causing a direct perturbation of all water bodies that are relevant to society. The current trend of population dynamics and the current status of water systems are such that the above impact will be not sustainable in the near future. Therefore mitigation actions are urgently needed, whose planning needs to be based on improved interpretations of the above impact. Up to recent times, hydrologists mainly concentrated their research on catchments where the human perturbation is limited, to improve our understanding of pristine hydrology. Nowadays, the urgency of the above need to mitigate the global water crisis through improved water resources management calls for a research attempt to bridge water and social sciences. The relevant research question is how to build operational models in order to fully account for the interactions and feedbacks between water resources systems and society. Given that uncertainty estimation is necessary for the operational application of model results, one of the crucial issues is how to quantify uncertainty by means of suitable assumptions. This talk will provide an introduction to the problem and a personal perspective to move forward to set up improved operational models to assist societal planning to mitigate the global water crisis.

Union Symposium

U01b - U1 Future Earth and Sustainability

IUGG-5111

Future earth and disasters

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In 2015, three major international disaster-sustainability-climate change instruments will be coalesced: 1) the Hyogo Framework for Action on building resilience to disasters; 2) the Sustainable Development Goals; and 3) the 2015 climate agreement under the UN Framework Convention on Climate Change. This year (2015) is also the International Year of Evaluation. These events present the global science community with an almost unprecedented opportunity to align, harmonize and integrate efforts to provide the evidence-base for improved policy and practice in Disaster Risk Reduction. The governments of the world came to Sendai, Japan in March 2015 to take stock of the achievements and shortcomings of the Hyogo Framework for Action, and seek to put in place a successor strategy to serve the world's needs for the coming decade and beyond. Integrated Research on Disaster Risk programme (IRDR), which is co-sponsored by International Council for Science, International Social Science Council and UNISDR, has key roles to play in making sure that the results of integrated, interdisciplinary, relevant research are used by decision-makers at all levels. The IRDR Programme is working closely with "Future Earth" to build partnerships, expand networks and integrate efforts to contribute to reduce disaster losses.

Union Symposium

U01b - U1 Future Earth and Sustainability

IUGG-5731

Systems approach to future earth

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Narrowly focused, single-disciplinary science alone cannot adequately underpin policies and solutions to resolve major transitions and sustainability challenges. One example of the system's approaches is the IIASA'sGlobal Energy Assessment (GEA), multidisciplinary study, whose findings were released during Rio+20. The GEA links energy to climate, air quality, human health and mortality, economic growth, urbanization, water, land use, and other factors. The GEA scenarios find that energy access for all (by 2050) is possible with co-benefits of limiting warming to 2°C, improving air quality and human health, and stimulating economic growth within a green economy framework.

In addition to GEA, methodological approaches will be discussed along with examples of the fundamental science behind systems analysis, including climate and water systems, as well as game theory approaches for governance towards the governance of common goods as pursued at International Institute for Applied Systems Analysis (IIASA).

IIASA was created in the peak of the Cold War during the 1970's and it became a world leading institute for trans-disciplinary and cross-sectoral systems science applied towards multiple aspects of global and regional transformations ranging from environment, energy and climate to financial, economic and demographic transitions. IIASA is an independent, global international science and science to policy institute with currently 22 member countries and more than 2000 international staff, across the an entire range of disciplines, from mathematics to sociology. IIASA is partnering with and supporting the Future Earth by a number of large scale projects, among them the World 2050 study, which will provide integrated scenarios for global sustainable development.

Union Symposium

U01b - U1 Future Earth and Sustainability

IUGG-5734

Future directions for the world climate research programme

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The mission of the World Climate Research Programme (WCRP) is to facilitate the analysis and prediction of the earth system variability and change for use in an increasing range of practical applications of direct relevance and value to society. The programme is articulated around four core projects (Clivar, Gewex, Sparc and Clic) and six Grand Challenges that should provide actionable information to decision-makers. An increasingly important focus of the programme is the difficult problem of seasonal-to-decadal climate prediction because of its relevance to many different stakeholders. The effort to provide information to different sectors of the economy will be intensified by working together with established climate services.

The paper will review the strategic directions of the programme and identify areas where efforts coordinated with Future Earth should be developed.

Union Symposium

U01p - U1 Future Earth and Sustainability

U01p-241

Future Earth in the MENA region

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Interactions and feedbacks between rapidly increasing multiple pressures on water, energy and food security drive social-ecological systems at multiple scales towards critical thresholds in countries of the Eastern Mediterranean, the Middle East and North Africa (MENA Region). These pressures, including climate change, the growing demand on resources and resource degradation, urbanization and globalization, cause unprecedented challenges for countries and communities in the region. Responding to these challenges requires integrated science and a closer relationship with policy makers and stakeholders. Future Earth has been designed to respond to these urgent needs.

Future Earth will be administered by a globally distributed secretariat that also includes a series of regional hubs, which will be the nuclei for the development of new regional networks. The Cyprus Institute in Nicosia, Cyprus (CyI; www.cyi.ac.cy) has been selected as the regional hub for the MENA Region.

The CyI is a non-profit research and post-graduate education institution with a strong scientific and technological orientation and a distinctive regional, Eastern Mediterranean scope. Cyprus at the crossroads of three continents and open to all nations in the region provides excellent conditions for advancing the research agenda of Future Earth in the MENA Region. Given the recent and ongoing major political and societal transformation in the region, research and development that help prepare the MENA countries for anticipated global changes and advance the development of sustainable structures are not only meaningful, but also a quite challenging undertakings.

Union Symposium

U01p - U1 Future Earth and Sustainability

U01p-242

Water-energy-food nexus for sustainability in Asia-Pacific

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Demands of water, energy, and food resources are rapidly increasing because of increases of populations and changes in lifestyles. These intensive demands for three makes conflicts between resources due to tradeoff among three. Managements and policy of water, energy, and food resources were treated separately, however they should be considered as one integrated matter, because water-energy-food are connected and it makes nexus and tradeoff. The water-energy-food nexus at a local level in the Asia Pacific region are examined. Themes including geothermal power plants, heat pump, micro hydropower as energy developments, hot springs, groundwater pumping for melting snow, and aquaculture as water uses, and fishery productions as food are used to evaluate the water-energy-food nexus in the Asia-Pacific region. Potentials of ground heat storage, geothermal energy, micro-hydro power in Japan and Philippines were evaluated as the capacities for the tradeoff and the potential conflicts between water and energy. Relationships between fishery production and fishery diversity, and between diversity of the water discharged from land to the ocean and fishery production/diversity have been evaluated. Stakeholder analysis and social network analysis have been made to analyze the common interests/disputes among water-energy-food nexus and stakeholder behavior changes by using local stakeholder meetings as co-design and national level discussion by internet about water-energy-food nexus such as geothermal energy development and hot spring preservation.

Union Symposium

U01p - U1 Future Earth and Sustainability

U01p-243

Commuter exposure to black carbon particles on a public bus route

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Cities are hot spots of air pollution due to many anthropogenic activities occurring in and around their perimeters, such as motor traffic, industry and domestic fuel. Black carbon (BC) is an air pollutant that arises from the incomplete combustion of fossil fuels and biomass. BC is made up of nanoparticles with diameters of 10-50 nm which form a chain-like structure, and –when inhaled– carries toxic species adsorbed onto their surface to the lower respiratory tract. BC is also a short-lived climate pollutant that absorbs incoming solar radiation efficiently. In cities, BC particles are mainly due to traffic emissions and their concentrations depend on the configuration of urban elements, such as canyons and avenues. An accurate assessment of the human exposure to BC requires monitoring strategies that reach different microenvironments and modes of transportation. We monitored BC concentrations in a midsize Brazilian city using a payload consisting of an aethalometer and GPS on a public bus route crossing various microenvironments. 1-second BC concentrations ranged from 1.0 ug m^{-3} to 200 ug m^{-3}. We observed large concentrations not only in street canyons and highly trafficked avenues, but also at traffic lights and idling/queuing modes. Because buses stop frequently and open their doors regularly, a bus' own emissions enter the cabin and enhance the pollution levels inside. The environment would benefit from a shift from individual car use to public transportation. Nevertheless, from the public health standpoint, the commuters would still be exposed to the fumes from the tailpipes on certain drive modes, since in Brazil most buses run with open windows.

Union Symposium

U01p - U1 Future Earth and Sustainability

U01p-244

Weather, climate and food security

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Safety and Security, though almost synonymous opposites of "risk", can have different meanings. Thus, for example, food safety is only one of the nine attributes of food security.

To meteorologists, food security is dominated by the impacts of weather and climate on food systems. But the link between the atmosphere and food security is more complex. Extreme weather events such as tropical cyclones impact directly on agriculture, but they also impact on the logistical distribution of food and can thus disrupt the food supply chain, especially in urban areas. A holistic approach is required to understand the phenomena, to forecast catastrophic and to predict their societal consequences.

In the Food Security recommendations of the Rio+20 Forum on Science, Technology and Innovation for Sustainable Development it states that it is important "To understand fully how to measure, assess and reduce the impacts of production on the natural environment including climate change, recognizing that different measures of impact (e.g. water, land, biodiversity, carbon and other greenhouse gases, etc) may trade-off against each other..."

The International Union of Geodesy and Geophysics (IUGG), through its Union Commission on Climatic and Environmental Change (CCEC) is leading the WeatCliFS consortium of international scientific unions to examine weather, climate and food security as well as to look at the interaction of food security and geophysical phenomena. The following fundamental question underpins WeatCliFS: What technologies and methodologies are required to assess the vulnerability of people and places to hazards [such as famine] – and how might these be used at a variety of spatial and temporal scales? This poster will review the work undertaken to date.

Union Symposium

U01p - U1 Future Earth and Sustainability

U01p-245

Exposure to black carbon, ozone and particulate matter in different urban microenvironments and travel modes using mobile measurements

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Traditionally studies on the relationships between air pollution and health use measurements from fixed and sparsely located monitoring stations. This approach may misrepresent specific microenvironments, since the concentrations of pollutants in cities vary greatly within short distances from the source and depend on the configuration of urban elements. This is a major limitation to assess the human exposure to air pollution within acceptable margin of error. Particulate matter (PM), black carbon (BC) and ozone (O3) are pollutants commonly found in the urban air pollution matrix. Furthermore, BC and O3 absorb incoming solar radiation efficiently leading to the warming of the climate and are classified as short-lived climate pollutants. We measured PM, BC and O3 concentrations in two Brazilian cities using mobile platforms: Londrina (540 thousand inhabitants) and Itajubá (95 thousand inhabitants). A bicycle was instrumented with a portable aethalometer, nephelometer, O3 monitor and GPS, and a similar payload was used for collection on foot. We collected data simultaneously with both payloads along the same route and crossing different microenvironments. A pilot experiment performed in Itajubá revealed large daily spatial variability with PM concentrations ranging from 10 to 350 ug.m^{-3}, and instantaneous peaks of about 3400 ug.m^{-3}. In Londrina, BC concentrations as large as 150 ug m^{-3} were observed close to bus stops and busy crossroads. From the health standpoint, these hotspots found in relatively small cities are of concern and show that an accurate assessment of human exposure to air pollutants require monitoring strategies that reach a range of microenvironments.

Union Symposium

U01p - U1 Future Earth and Sustainability

U01p-246

Robert Mallet Foundation: from a participatory approach to a sustainable development model

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Sustainability and Resilience are concepts now becoming more common and unavoidable from each other; their understanding and emphasis is critical to act on the organizational and management models of social systems in order to make well-being of mankind and identify actions and policies needed not only for the overcoming of natural or anthropic extreme events, but also for their prevention and mitigation. A resilient territory that does not conform just to the problems raised by the effects of natural (earthquakes, floods, climate changes etc.) and anthropic hazards, but that turns, formulating environmental, economic and social responses.
It's in this context that the Fondazione di Comunità Lucana Robert Mallet (FRM) operates. The FRM is born as an initiative of the volunteer network of the Gruppo Lucano, the City of Viggiano and numerous public and private institutions of the Lucanian area. The FRM is based in the Val d'Agri, theater in 1857 of one of the most destructive earthquakes in Southern Italy and where there is one of the largest oil field in Europe. One of the essential elements of the FRM is the in-depth knowledge of the environmental history of the Lucanian area, its transformations, and the responses of the institutions and communities to the impact of extreme events.
The many aspects of environmental excellence of the Lucanian area, in stark contrast to some critical infrastructures in case of extreme events, make the FRM an ideal tool to promote and create a laboratory for sustainable and resilient mankind development models. The FRM proposes the start of innovative processes focused on the creation of a sustainable mankind development integrating the basic components of a territory: citizens, institutions and forms of solidarity of the third-sector.

Union Symposium

U10a - U10 Sea Level Change and Variability: Past, Present and Future

IUGG-1021

Glacier mass change between 1900 and 2100

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The global mass storage of glaciers, estimated to approximately 0.4 m sea-level equivalent (SLE), seems negligible compared to the mass storage of the Antarctic and Greenland ice sheets (approximately 65 m SLE). However, since glaciers are losing mass fast, they are contributing to present-day sea-level rise (SLR) with rates similar to Antarctica and Greenland combined (approximately 1 mm SLE/yr). During the past century, they have likely been the greatest source of SLR, and they will continue to contribute strongly throughout the 21st century.

In this presentation, we show that recent advances in reconstructing the 20th century contribution of glaciers to SLR have led to a reconciliation of the different methods. We highlight that there is substantial mass loss of glaciers which is already committed but not yet realized, and that this committed mass loss limits the influence of 21st century climate forcing on future glacier mass loss. Finally, we will review the projections of mass change during the 21st century.

Union Symposium

U10a - U10 Sea Level Change and Variability: Past, Present and Future

IUGG-5124

Contribution of the Antarctic and Greenland ice sheets to sea-level change from observations and glaciological modeling

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Continental ice sheets constitute the largest potential source of sea-level variations on a wide range of time scales. Compared to their total ice volume, their current contribution to sea-level rise is still modest, yet this contribution has increased over the last few decades and is moreover the largest source of uncertainty in future projections. Large ice sheets have a memory of millenia, hence the present-day ice sheets of Greenland and Antarctica are still adjusting to climatic variations extending back to the last glacial period. A correct interpretation of current ice-sheet changes therefore needs to address both the effect of contemporary surface mass balance changes as well as the ice-dynamic response to both contemporary and past atmospheric and oceanic forcing. Ice-dynamic responses are well understood when caused by changes in ice sheet geometry, but a solid body of observational evidence has also revealed badly understood fast flow variations at ice sheet margins that are likely transmitted inland through changes in basal conditions and longitudinal stresses. For the Greenland ice sheet, meltwater induced basal lubrication and ocean-induced changes of ice discharge at marine-terminated outlet glaciers have been suggested to play a role, while for the Antarctic ice sheet, such changes are attributed to melting and weakening of the floating ice shelves that surround it.

The presentation will give an overview of current observations of ice-sheet changes, mainly from a variety of remote-sensing platforms, and will discuss their interpretation with glaciological models for the surface mass balance, ice-ocean interactions, and ice dynamics. Modeling results pertaining to the future evolution of the Antarctic and Greenland ice sheets will also be discussed.

Union Symposium

U10a - U10 Sea Level Change and Variability: Past, Present and Future

IUGG-5726

Steric contributions to sea level change and variability: recent progress and future challenges

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The increasingly clear and well documented warming of the global ocean is contributing to both global and regional sea level changes via thermal expansion. While largely confined to the upper 1000m of the global ocean volume, in some regions warming is now being detected in the very deepest layers. Past ocean salinity changes are also being better documented, and they also drive regional sea level changes through halosteric contraction, in some places augmenting thermal expansion, while in others, offsetting it. Overlying longer term multidecadal changes, natural wind-driven variability strongly influences regional sea level at interannual and decadal timescales, complicating both the detection and projection of regional sea level rise. We will present recent progress in quantifying steric contributions to sea level and their attribution. We will also touch on the challenge of improving our ability to observe total steric sea level changes in the future.

Union Symposium

U10b - U10 Sea Level Change and Variability: Past, Present and Future

IUGG-2931

Sensitivity of estimates of sea-level rise and ice-sheet mass balance to uncertainties in vertical land movement

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Estimates of ice-sheet mass balance and sea-level rise both rely on accurate corrections for vertical land movement. Glacial isostatic adjustment is thought to be the globally-dominant signal of this kind, but more local-scale signals exist, such as related to elastic response to present-day changes in surface loading, aquifer extraction or post-seismic deformation. As such, models of glacial isostatic adjustment, even if perfectly accurate, do not fully account for all motion. Furthermore, the most commonly used models of glacial isostatic adjustment have uncertainties in their ice history and are typically represented by Earth models with an unrealistic spherically-symmetric Earth structure. In this talk I will outline evidence for substantial deviation from such models in Antarctica associated with ice loading changes over recent decades to centuries and lateral variations in Earth rheology, and show the importance of accounting for all vertical land movement, not just glacial isostatic adjustment, when validating altimeter drift and hence altimeter sea-level change estimates.

Union Symposium

U10b - U10 Sea Level Change and Variability: Past, Present and Future

IUGG-4166

What have we learned about global and regional sea level change in the satellite era?

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Variations in global mean sea level are a sensitive indicator of how the Earth is responding to climate change, but assessing the impacts of sea level change on coastal populations requires an understanding of the regional variations from the global mean. We now have a precise 22-year continuous record of sea level change from TOPEX/Poseidon, Jason-1, and Jason-2. Two more developments fundamentally improved our capability to study the causes of sea level change: the launch of the GRACE satellite gravity mission in 2002 and the establishment of the Argo network of profiling floats shortly thereafter. Together, satellite altimetry, satellite gravity, and in situ measurements have provided unprecedented insight into the magnitude, spatial variability, and causes of present-day sea level change. In addition, these datasets have allowed new insight into the ~100 year record of sea level change measured by tide gauges. When compared to the historical record of sea level change from the tide gauge network, the satellite record can be placed in context. The rate of sea level change observed during the altimeter era is roughly double the long-term rate observed by the tide gauges, but the causes of this are still being investigated. The satellite measurements also give a perspective on the spatial variability of sea level change not possible with only tide gauge measurements, and this has led to increased understanding of the spatial variability of sea level change and how it evolves over time. The recent advances in our understanding of global and regional sea level change due to these new measurement systems will be reviewed. In addition, the prospects for improving future projections of regional sea level change will be discussed.

Union Symposium

U10b - U10 Sea Level Change and Variability: Past, Present and Future

IUGG-4846

Quantifying internal variability of land-ocean mass exchange and global mean sea level

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The past decade has provided an unprecedented opportunity to assess variability in global mean sea level (GMSL) and associated land-ocean exchanges of mass. A main finding has been the fact that while interannual variability in GMSL is often related to ENSO, the relationship is complex and is modulated by other modes of variability and the influence of key land regions. Motivated by this complexity and the relative brevity of the satellite records of surface altimetry and mass, internal variability in GMSL's governing terms is explored using the NCAR CESM1-CAM5 Large Ensemble (LE), a 30-member ensemble of coupled simulations spanning 1920-2100. The LE shows that GMSL variability associated with ENSO is typically on the order of a few millimeters and that important asymmetries exist between both El Niño and La Niña events, and the individual contributors to GMSL during each. In the run up to El Niño, positive ocean heat content (OHC) anomalies emerge, increasing sea level and drawing deep convection and rainfall away from tropical land. As a consequence, decreases in terrestrial water storage (TWS) ensue and at the peak of El Niño, both OHC and TWS are important contributors to GMSL anomalies. Following the peak of El Niño, OHC decreases and TWS increases, resulting in sustained negative GMSL anomalies only a few months thereafter, a time at which La Niña conditions often begin to emerge. As during El Niño, OHC anomalies during La Niña generally lead those in TWS. Regional characteristics of these evolving OHC and TWS anomalies are discussed and changes in a warming climate are demonstrated. In relating simulated ENSO events in the LE to the observed record, the exceptional rarity of the observed 2010-11 sea level drop is underscored.

Union Symposium

U11a - U11 Early Career Scientists Symposium

IUGG-1020

Glaciers between Little Ice Age and Anthropocene: causes of the global meltdown

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By changing the seasonality of runoff, glaciers are important regulators of water availability in many regions of the world. Retreating glaciers lead to increased geohazards, e. g. from destabilized slopes and lakes dammed behind unstable, ice-cored moraines. Finally, even though the ice mass stored in glaciers seems negligible compared to the Greenland and Antarctic ice sheets, glaciers have contributed significantly to sea level rise in the past, and probably have been the biggest single source of observed sea level rise since 1900.

Glaciers respond to changes in the climate with a lag of decades to centuries, and thereby allow people to directly perceive changes of the climate system that otherwise would be overwhelmed in human perception by short-term weather fluctuations. Because of this property, and since glaciers form prominent features of many arctic and high mountain regions, shrinking glaciers have become an icon of climate change. At the same time, the lagged response of glaciers to climate change complicates the attribution of the observed changes to any particular cause, because glacier mass change at any time is in part an ongoing adjustment of the glacier to previous climate change.

In this talk we present strong evidence that most of the glacier mass loss of the past few decades is caused by human activities, and we estimate the impact that anthropogenic glacier mass loss has had on seasonal water availability in large, glaciated river basins.

Union Symposium

U11a - U11 Early Career Scientists Symposium

IUGG-1988

Melting glaciers: from process understanding to global impacts

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Mountain glaciers are highly sensitive to changes in climate forcing. In a global perspective, their anticipated retreat will pose far-reaching challenges to the management of fresh water resources and will raise sea levels significantly within only a few decades. However, the models for projecting global glacier changes mostly depend on strongly simplified, and often empirical descriptions of the driving processes hampering the reliability of the results. Thus, a transition from the physically-based mass-balance ice-flow models developed for single glaciers to the worldwide application is urgently needed. The challenges are manifold but can be tackled with the new data sets and methods that have emerged during the last years.

This contribution presents an overarching picture from observations and direct measurements of recent glacier retreat to past and future impacts at both the local and the global scale. Poorly understood feed-back mechanisms are identified and gaps in current cryospheric research are highlighted. The three-dimensional evolution of each of the 200,000 glaciers around the globe is computed until 2100 based on a new process-based model and climate scenarios. Future changes in global sea level due to glacier melt are discussed in the light of model uncertainties. Mountain regions are particularly vulnerable to changes in runoff. Model results indicate that the maximum rate of water release from glacial storage is subject to a high spatio-temporal variability. This crucial tipping point for sustained water supply will be reached in the near future.

Union Symposium

U11a - U11 Early Career Scientists Symposium

IUGG-2132

Human influences on climate: Representing climate-society feedbacks in models

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It is well known that human activities are influencing the climate in unprecedented ways, with implications for all sectors of the planet. Modern climate science has made great strides in understanding signatures of human-induced climate change and the impacts of these changes. However, an underexplored direction of research is how those climate changes in turn influence human behavior. This reciprocal effect is part of a climate-society feedback loop; instead of treating human activities as exogenous to the climate system, it is becoming more relevant in geoscience research to include more thorough treatments of the coupled climate-society system. In this talk, I discuss some of the work my colleagues and I have done to introduce these feedbacks into climate model simulations of geoengineering. I also discuss how this feedback methodology can be used as a new direction in conducting climate science research. I close with a brief discussion of how these simulations, themselves examples of sequential decision making, can be used to further advance the field of climate science and improve the relevance of climate models in assessing the impacts of human-induced climate change.

Union Symposium

U11b - U11 Early Career Scientists Symposium

IUGG-1453

The nonlinear local Lyapunov exponent method and its applications in predictability and ensemble prediction

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Based on nonlinear dynamical system theory, we developed a method using the nonlinear local Lyapunov exponent (NLLE). The nonlinear properties of the NLLE make it applicable to predictability problems involving different initial states and different finite-amplitude initial errors, thereby overcoming the limitation of traditional linear Lyapunov exponents. To apply the NLLE in studies of actual atmospheric predictability**,** an algorithm based on local dynamical analogues is devised to enable the estimation of the NLLE and its derivatives using experimental or observational data. Based on atmospheric observational or reanalysis data, the NLLE method has been used to investigate decadal changes in weather predictability, the temporal–spatial distribution of the predictability of monthly and seasonal means of climate variables, and the predictability limit of the Madden-Julian oscillation (MJO) and decadal-scale climate variability.

Recently, the NLLE was further expanded in a high-dimensional situation and the NLLE spectrum (NLLEs) was proposed to investigate the nonlinear evolution behaviors of initial perturbations along different directions in phase space. This group of orthogonal initial perturbations was defined as the nonlinear local Lyapunov vectors (NLLVs). NLLVs are a set of orthogonal vectors spanning the fast-growing subspace, and are proven to be a quick and efficient ensemble generation scheme. The performance of the NLLV method is compared comprehensively and systematically with other ensemble generation methods such as the bred vector (BV) and the random perturbation (Monte Carlo) methods. The results indicate that the NLLVs perform significantly better than the BVs in terms of reliability and the random perturbations in resolution.

Union Symposium

U11b - U11 Early Career Scientists Symposium

IUGG-2657

The atmospheric fate and effects of organic aerosol particles: An interplay between natural sources and human activities

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A significant fraction (20-90%) of atmospheric sub-micron particulate matter consists of organic compounds. The biosphere is thought to be the primary source of these particles, thus suggesting that organic aerosol would be an important component of the atmospheric composition even without any human interference. Knowing the sources, atmospheric processing and loss mechanisms of biogenic organic aerosol particles is thus important for defining the baseline to which the present day conditions are compared to when estimating the human effects on radiative forcing and climate. After being emitted, organic particles interact with inorganic aerosol constituents (such as sulfate, nitrate and sea salt) and cloud water. Understanding these interactions is necessary for accurate assessment of the consequences of political choices related to e.g. land-use change, urban air quality or agricultural emissions. I will present an overview of our work focusing on the interactions of atmospheric organic particles with inorganic aerosol constituents and cloud water – ranging from molecular simulations to macroscopic scale cloud modeling.

Union Symposium

U11b - U11 Early Career Scientists Symposium

IUGG-3306

Challenges and successes in ocean-atmosphere research over the past decade

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During my years as an early career scientist, notable changes have occurred in physical oceanography and the climate sciences: the global ocean has become much better observed, and our understanding of the processes driving upper-ocean variability and its interaction with the atmosphere have improved significantly. In this presentation I will discuss my experiences as an early career scientist in the context of these changes, focusing on recent scientific advances. An example is the growing consensus that the ocean's near-surface temperature and salinity structure are important for tropical cyclone intensification. Recent progress in this field will be described, emphasizing its value to society. Other emerging topics that will be discussed are the interaction of natural aerosols, such as African dust, with weather and climate, and attempts to trace open-ocean dust aerosols to their source regions using samples collected at sea. Throughout the presentation, common themes are the importance of long-term, continuous, and direct measurements of the upper ocean and atmosphere, from which climate variability and trends can be diagnosed, and the need for international collaboration in achieving these goals. Challenges and successes will be described, especially in relation to the establishment of new ocean observations and improvement of existing ones. The talk will conclude with thoughts and concerns about the future of physical oceanography and climate sciences.

Union Symposium

U11c - U11 Early Career Scientists Symposium

IUGG-1350

Imaging the Earth across the scales

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Seismic images of the Earth's interior play a key role in numerous applications with immediate social relevance. These include earthquake early warning and seismic hazard analyses, mineral and hydrocarbon exploration, and the monitoring of time-dependent systems such as fault zones, volcanoes and geothermal reservoirs.

Thanks to the deployment of dense seismometer arrays, advances in numerical wave propagation, and the fast growth of computational power, seismic imaging has progressed rapidly during the past decade. The assimilation of complete seismograms – from the first to the last oscillation – has become reality, blurring boundaries between traditional tomographic techniques. Modern Earth models capture structures over a wide range of scales, including shallow sedimentary basins and oceanic lithosphere subducting into the deep mantle. The resolution of today's seismic Earth models is unprecedented, and comparable to the resolution achieved in medical imaging.

Seismic tomographers have good reasons to look optimistically into the future, despite big challenges that remain to be addressed. While some of these are technical in nature, others are related to the way we conduct science in an environment that suffers from increasing publication and evaluation pressure.

In this talk I will defend the following two theses: (i) Regardless of any technological advances, the credibility and success of seismic imaging can only be maintained by improving the quantitative aspect of our inferences and their uncertainties. (ii) The reliance on existing methods and growing computational power will be far from sufficient to tackle rapidly increasing data volumes. The combination of computing and thinking remains essential.

Union Symposium

U11c - U11 Early Career Scientists Symposium

IUGG-1464

Hydrology: a science at the interface of atmosphere, biosphere and pedosphere

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Being the essence of life, the availability and distribution of water not only supports the Earth's ecosystem, our demands for drinking water, food, energy and industrial production but it is also an agent in many natural hazards, such as floods, droughts, landslides, land degradation or soil contamination. Strongly influencing many parts of the Earth's ecosystem with a wide range of societal impacts, hydrology, is a discipline at the interface of atmosphere, ecosphere, pedosphere and hydrosphere and the related sciences, such as climatology, ecology or biogeochemistry.
In spite of the central position of hydrology, it remained rather isolated for a long time as much of the research focused on specific aspects of the system, often only investigated in one or a few catchments, thus leaving fundamental aspects of the water cycle poorly understood. Only recently a growing understanding developed for the value of comparative studies and more systems-like approaches, which allow more efficient ways to identify fundamental patterns as well as feedback mechanisms that link hydrology to other parts of the co-evolving system. Some illustrative examples include the use of topographic information for model design, the value of climate data to infer root zone characteristics and the use of solutes to enhance understanding of transport processes underlying hydrological and water quality dynamics. These examples illustrate the importance of more holistic and robust system representations that in turn result in higher predictive power and limited uncertainty, an important prerequisite for the development of more sustainable management tools and policies.

Union Symposium

U11c - U11 Early Career Scientists Symposium

IUGG-3801

Contribution of consistent geodetic observations to Earth system sciences

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During the past two decades, the scope of geodesy extended from measuring the shape, rotation and gravitational field of the Earth towards providing reliable and accurate measurements of a highly dynamic and complex system Earth. This change of geodesy into a multidisciplinary science is based on the significant technological improvements of geodetic space techniques and the launch of various Earth observing satellites. The geodetic community recognized the need of incorporating the variety of sensor systems in space and on Earth into a common observing system and benefit from the strengths of each observation technique. Therefore, in 2007, the Global Geodetic Observing System (GGOS) was raised to a full component of the International Association of Geodesy (IAG). The aim of GGOS is to integrate the different geodetic observation techniques for a consistent monitoring of spatial and temporal changes of global surface dynamics in combination with an assessment of mass anomalies, transports and exchange processes. A fundamental role in this integration plays the global terrestrial reference frame.
The presented paper gives an overview of the current strategy to achieve the GGOS goals in future. In particular, the realization of the International Terrestrial Reference System (ITRS) and its accuracy is evaluated w.r.t. its impact on geodetic products. As a case study, Satellite Laser Ranging (SLR) observations to multiple satellites are used to realize a consistent estimation of the Earth's shape, rotation and gravitational field. Furthermore, selected geophysical applications are presented which emphasize the importance of consistent geodetic measurements for a reliable interpretation of global change phenomena.

Union Symposium

U11d - U11 Early Career Scientists Symposium

IUGG-1168

Proterozoic Supercontinent Nuna

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To understand processes occurring from the planetary interior to the surface environment, a robust paleogeography of tectonic plates is important. Paleomagnetism coupled with geochronology is the only quantitative methods for providing ancient latitudes and azimuthal orientations of continents. The Earth's continental crust is considered to have been assembled to form several supercontinents at different times. The three youngest supercontinents Pangea (320Ma to ca.180-160 Ma); late Neoproterozoic to Cambrian Gondwana and Rodinia (900Ma to ≥750 Ma) are widely accepted. The concept of pre-Rodinia supercontinents becomes more controversial as the age of the geological formations increases, due to paucity of paleomagnetic data and inherent dating problems. There is a general agreement that a tectonic 'core' of the Paleo- to Mesoproterozoic Nuna supercontinent incorporates Laurentia, Baltica, Siberia, and proto-Australia (e.g. Pisarevsky et al., 2014 and Pehrsson et al., in press). Advances in Nuna reconstructions will require more high quality paleomagnetic data for other cratons. This has been addressed by several recent and ongoing studies and a paleogeography of Nuna has started to form. A more robust paleogeogrphy can be used for studying possible secular changes at the rates of global plate motions and true polar wander during the Proterozoic, for studying the cycles and styles of supercontinental transitions, and for providing paleogeographic boundary conditions for models of Proterozoic paleoclimate and biological evolution (Evans, 2014).

Union Symposium

U11d - U11 Early Career Scientists Symposium

IUGG-1274

Numerical dynamo simulations and magnetic field observations of the Earth, Moon and planets to infer core dynamics

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In general, the global scale magnetic fields of the terrestrial planets are generated and maintained by dynamo actions occurring in their electrically conducting fluid outer core. Thus, the dynamo-generated magnetic field and its secular variation reflect many dynamical aspects of the deep interiors and thermal history of the planets, which we want to understand. For the purpose, we have two approaches: one is to use numerical simulations, while the other is direct magnetic field observations using orbiting satellites. In the last two decades, numerical dynamo modelling have greatly advanced. At present, dynamo modeling is evidently a very powerful tool to understand the dynamo action and core dynamics of the planets as well as in-situ observation of the magnetic field. In this talk, we summarize such efforts and show our latest results of geodynamo simulations such as dynamos driven by double diffusive convection, those with stably stratified layer below the core-mantle boundary, and also results of the lunar magnetic field observation by the Kaguya spacecraft to examine the ancient lunar core dynamo.

Union Symposium

U11d - U11 Early Career Scientists Symposium

IUGG-5131

Towards multidisciplinary and open-access Earth and Space sciences

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Since the origin of Earth sciences, the scientific world has suffered from an important and preoccupying atomization process. During the last decades, Earth scientists have become more and more specialized on particular topics, so each individual is an expert on a very detailed subject. This is an understandable phenomenon since it is very difficult that single scientists, either senior or early career ones, have the capability to simultaneously work and have broad expertise on completely different disciplines. However, this situation may have significant consequences. For example, when designing and carrying out mathematical models, where input data may be very diverse including: chemical compositions, geophysical signals, physical properties, etc. In most cases, the lack of dialogue and interaction between researchers of different disciplines, acts against the correctness of the results obtained and scientific progress. This recalls the need for scientific groups to become multidisciplinary and "open-minded " in the sense of being capable of integrating data and results coming from other scientific branches. Incorporating experts from the diverse disciplines into the same research group is crucial for ensuring the well development of innovative and high-quality science. Directly related to that is the need to go a step further and promote the open–access of data, databases, results, software, etc. so that these are accessible to any scientist around the world.

Union Symposium

U11p - U11 Early Career Scientists Symposium

U11p-129

Paleoenvironment of the East-European Platform during Maastrichtian time: new data on X-events

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The Maastrichtian stage is characterized by the series of X-events at the Cretaceous - Paleogene boundary. They are periodical changes in the relative sea level, changes in sedimentary modes and paleoenvironment, climate cooling, impact events, variations of the organic etc.

This work considers the conditions of the formation of deposits of the East-European Platform and its Southern frames (Precaucasus) and discusses the sections of Maastrichtian sediments in context of stratigraphy. It presents a detailed lithologic description of the sediments and describes their individual lithologic members and beds. Litho- and genetic types among the Maastrichtian sediments were recognized. These types allowed the facies zones to be delineated and cycles detected.

A detailed analysis of the lithologic and paleontological rock composition by different methods (petrographic microscope study; describe of the micro- and macrofossils such as foraminifers, Coccolithophora, belemnite; carbon- and oxygen-isotopic methods; geochemical analysis) has presented the more detailed subdivision of the Upper Maastrichtian – Terminal Maastrichtian.

These results can also help to characterize the distribution of water masses on the East-European Platform and its southern framing in more detail and determined the paleoenvironment reconstruction.

Union Symposium

U11p - U11 Early Career Scientists Symposium

U11p-130

Spherical screen and Orbus software as a new tool in geodata visualisation

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The main disadvantage of cartographic editions published in the form of paper maps is their lack of visual representation. One of the most advanced instruments for visualization and representation of georeferenced data is digital projection systems with a spherical display. Projection devices of this type are based on an innovation technology, which provides visualization of raster images, animation or video, converting them for projection on a spherical display in real time mode. The Geophysical Center of RAS has constructed a digital visualization complex with a spherical display. The Orbus software was developed to visualize any dynamic phenomena on the scale of all planet, for example earthquakes, tsunami, air pollution, global warming, magnetosphere etc. The software was primarily aimed at creating presentations based on online and offline data sets on the basis of GIS technologies with multidisciplinary approach. This equipment is intended for the visualization of the global phenomena. This demonstration complex is currently the unique device of this type in Russia. We use the digital complex for implementing various scientific tasks and as an efficient device for education purposes. The visualization of Earth`s dynamic systems, its interoperability and analysis is a successful example of the use of the complex for scientific research that takes education and modeling approaches to the new level.

Union Symposium

U11p - U11 Early Career Scientists Symposium

U11p-131

Urban heat island as a result of land use land cover changes

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Urban heat islands are a clear, well-documented example of an anthropogenic modification to climate that has an atmospheric, biological, and economic impact. This review shows how satellite-based and modeling studies continue to help unravel the factors that are responsible for urban heat island development and are providing a basis for the development and application of sustainable adaptation strategies.

As urban areas continue to expand as a result of land use land cover changes, there is a heightened awareness that scientific knowledge of the urban heat island must be more effectively communicated to architects, engineers, and planners and translated into intelligent urban design.

Green roof technology and greening of urban set up is a case in point. This and other technologies are being slowly adopted, and research published since 2003 suggests that the pace with which many practical applications are put into practice should accelerate.

Union Symposium

U02a - U2 Integrated Disaster Risk Science: Accounting for Extremes

IUGG-0413

The GGOS initiative to improve disaster early warning and response

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The Global Geodetic Observing System (GGOS) of the International Association of Geodesy has as its goal the development a next generation global geodetic network of 25 to 40 integrated core geodetic observatories and associated analysis centres, and the enhancement of current geodetic infrastructure. A significant component is the development and expansion of the IGS real time GNSS network that includes over 180 GNSS instruments.

The GGOS initiative will improve the network architecture, data distribution and timeliness of data analysis to address many scientific and societal needs including the mitigation of and response to natural hazards and natural disasters. Numerous studies have demonstrated the utility of this network in the first identification of slow slip seismic events at fault zones and the rapid estimation of earthquake moments and associated ionospheric response for ground motion, tsunami prediction and tracking. Orbiting GNSS occultation satellites provide all-weather atmospheric profiling for improved weather and climate forecasting. Ongoing development of GNSS reflectometry satellite missions will facilitate the estimation of wind stress and wave height for better predictions of severe storm tracks. The GGOS next generation geodetic network of instrumentation and data centres will also advance the capabilities of earth observation satellites such as satellite synthetic aperture radar imagery to map ground deformation across wide areas, and gravity satellites that can map temporal gravity changes due to fluctuating water storage in aquifers and basins, ice sheet loss, and other mass transport phenomena.

Union Symposium

U02a - U2 Integrated Disaster Risk Science: Accounting for Extremes

IUGG-4422

Integrating research to reduce risk and gain the benefits for development

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Across all countries there are challenges due to the increasing numbers of hazards creating disasters and impacting on people and property and limiting development. These impacts, in a relative sense relative to population and economy, are larger in developing countries and small island states. The Mission of the International Council for Science Mission is "to strengthen international science for the benefit of society"; it is important that it be for all societies and there is need to focus on how to deliver the benefits in developing countries. The issues of disaster risk reduction, sustainable development goals and climate change mitigation and adaptation are key global issues being addressed through international processes in 2015. It is important that internationally coordinated research, through programs such as Integrated Research on Disaster Risk, Future Earth: Research for Global Sustainability and Health and Wellbeing in the Changing Urban Environment, be supported and their research coordinated so the outputs are effective in policy development and can be used by all countries. A particular challenge is with regard to those extreme and relatively rare events that have huge impacts but societies are not yet effective in "making timely decisions and implementation of the hazard-associated preparedness measures to mitigate humanitarian and economic losses". The challenge for the scientific community is to work with stakeholder communities through a co-design, co-produce and co-deliver approach to enhance the relevance and effectiveness of our science.

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Union Symposium

U02a - U2 Integrated Disaster Risk Science: Accounting for Extremes

IUGG-5561

A call for improved disaster response through an international real time data network for data sharing

D. Green[1]
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The timely delivery of accurate warning, monitoring, and damage assessment is critical to the effective disaster risk management. This presentation focuses upon the growing utility of Interferometric Synthetic Aperture Radar (InSAR), (Global Navigation Satellite System) GNSS remote sensing data, new investments in ground, airborne and space-based observation platforms, and cooperative international data systems to improve disaster risk management.

Satellite InSAR has been used for several years to understand ground deformation however the latency and availability of these data limits the effectiveness of these data. Rapid data distribution and new analysis systems can improve damage assessment information essential to disaster response. GNSS occultation data provides cost effective and timely input to global atmospheric models for storm track predictions while GNSS reflectometry measurement of wind stress furthers understanding of air-sea interactions and improves extreme weather predictions for tropical storms and hurricanes. A well distributed real time ground network of GNSS receivers and analysis network provides cost effective prediction, tracking and warning for destructive tsunamis.

International cooperation on data sharing is essential to achieve the full benefits of these important technologies. A model for this sharing of resources is the GGOS initiative for the building of global infrastructure and real time data systems.

Union Symposium

U02b - U2 Integrated Disaster Risk Science: Accounting for Extremes

IUGG-1568

A hard rain's a-gonna fall - Changes in flood risk

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A holistic perspective on changing rainfall-driven flood risk is provided. Economic flood losses have greatly increased, worldwide. Climate change of direct relevance to flood generation (i.e. increase in precipitation intensity, decrease of snowpack) has been observed already. However, no gauge-based evidence has been found for a climate-driven, widespread change in the magnitude or frequency of observed annual maximum river discharges during the last decades. There are strong regional and sub-regional differences in the trends and only a minor part of them shows statistical significance. Moreover, it has not been generally possible to attribute rain-generated peak streamflow trends to anthropogenic climate change. The increase of flood damages and flood risk has been primarily attributed to increasing exposure and damage potential and not to climate change.

Physical reasoning suggests that projected increases in the frequency and intensity of heavy rainfall in the warmer world would contribute to increases in rain-generated local floods (flash floods and urban floods). Also less snowmelt flooding and earlier spring peak flows in snowmelt- and glacier-fed rivers are expected. However, there is low confidence in future changes in flood magnitude and frequency resulting from climate change. The impacts of climate change on flood characteristics are highly sensitive to the detailed nature of changes in relevant climatic variables that is presently uncertain.

Discussion of flood projections for the future is offered. Attention is drawn to the fact that over the last decade or so, projections of flood hazard in Europe have dramatically changed, hence interpretation of such changes has to be sought, related to both different climate scenarios and different modeling approaches.

Union Symposium

U02b - U2 Integrated Disaster Risk Science: Accounting for Extremes

IUGG-4236

Changing risks caused by severe weather events

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As extreme weather events affect the core business of insurance this industry has quite early addressed potential effects of natural climate cycles and global warming on natural catastrophe hazards. The analyses of Munich Re`s NatCatSERVICE data clearly show a high interannual variability, in some regions decadal oscillations, and a long term trend to an increase in the number of natural catastrophes around the globe, with ever growing losses. The trend curve indicating the number of loss relevant natural catastrophes worldwide reveals an increase by a factor of about three within the last 35 years.

The main contribution to the upward trend of the losses caused by natural catastrophes comes from socio-economic/demographic factors such as population growth, ongoing urbanization and increasing values being exposed. Prevention measures, especially flood protection programs, on the other hand have a high potential to even reduce losses while the hazard has increased.

Looking at trends of extreme weather events and their effects, natural climate variability has to be considered. Short term oscillations such as ENSO as well as decadal oscillations in hurricane or typhoon activity still play a dominant role on the variability of losses caused by weather extremes. As global warming will continue and most probably even accelerate in the coming decades, its contribution to increasing natural catastrophe losses will become more prominent.

There is no sensible way to interfere with natural climate oscillations influencing natural catastrophe losses. Humankind, however, still has the chance to avoid catastrophic increases of losses caused by global warming driven weather extremes by ambitious climate protection and adaptation measures.

Union Symposium

U02c - U2 Integrated Disaster Risk Science: Accounting for Extremes

IUGG-0258

Advanced seismic hazard assessment to cope with complexities of the largest seismic potential and risks for public safety

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Since 2000 to 2012, all 60 earthquakes with M≥7.5 were surprises for GSHAP, half of the cases big surprises. Fatalities were much higher than that projected from GSHAP maps, by two-three orders of magnitude. PSHA, in general, and GSHAP, in particular, betrayed the UN-IDNDR recommendations to endorse prevention and preparedness rather than recovery expenses. Given two sites prone to earthquakes with the same potential of M=7.5, all other conditions remaining the same, the site where sporadicity is higher appears preferable for new settlements, vice versa for retrofitting. Nevertheless the seismic design parameters must be equal at the two sites: the magnitude to face is the same (M=7.5). Advances in understanding earthquake physics and access to e-infrastructures allow for realistic numerical simulation of reliable hazard scenarios for use in preventing or reducing risks: neo-deterministic seismic hazard assessment (NDSHA) makes use of it. Contrary to PSHA, NDSHA does not reduce the tensor problem (wave generation and propagation) to a scalar one (GMPE) and naturally allows for time-dependent estimate. This tool to impact Society and Economy by creating a community with Disaster Resilient Society has been developed to exploit to its best the uniqueness of the existing earthquake archives for Italy taking advantage, at the same time, of the wealth of quantitative geological, structural, tectonic, and seismic knowledge quite homogeneously available for the entire national territory. NDSHA can be applied also to incomplete data at the cost of a decrease of reliability of the results to the level comparable with PSHA. A recommendation of the pertinent Parliamentary Commission to use both PSHA and NDSHA led to a parliamentary bill to exploit the uniqueness of Italy database.

Union Symposium

U02c - U2 Integrated Disaster Risk Science: Accounting for Extremes

IUGG-4736

Anticipating and addressing the global risk associated with very large volcanic eruptions

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Supported by the European Science Foundation, the Geohazards Community of Practice of the Group on Earth Observations prepared a white paper reviewing the risk associated with extreme geohazards. These low-probability, high-impact events have in common that their probability is not well known, direct experience is lacking, and the associated threats are largely underestimated. In the Holocene extreme events occurred that were much larger than those experienced during the last century. The modern globally interconnected society would be extremely challenged if it were exposed to such hazards. In particular, under today's circumstances, the largest volcanic eruptions that occurred during the Holocene could impact societal infrastructure, human health, supply of resources, transportation, and food and water security on global scale. Their potential impact on civilization is comparable to other possible mega disasters from extreme droughts, floods, pandemics, and asteroid impacts. It is recommended that (1) a global scientific framework for strategic extreme geohazard science be developed that is capable of delivering a tactical science response to inform warning, preparedness, mitigation and responses; (2) scenario contingency planning be used to better understand the threats; (3) a global monitoring system be put in place to provide early warning for emerging extreme volcanic eruptions, based on a core element of operational monitoring of solid earth surface displacements with major societal benefits besides the early detection of emerging extreme eruptions; (4) an informed global governance be developed that could respond to emerging global threats and coordinate global measures to increase preparedness and resilience and reduce the risk of global disasters.

Union Symposium

U02c - U2 Integrated Disaster Risk Science: Accounting for Extremes

IUGG-5763

Measuring community wellbeing during a disaster recovery: lessons following the 2010-2011 Canterbury earthquake sequence

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In 2010 and 2011, a sequence of destructive earthquakes caused 185 deaths, thousands of injuries and extensive building and land damage in Christchurch, New Zealand. In this paper we outline a multi-agency, multi-sector research collaboration led by the Canterbury Earthquake Research Authority (CERA). The CERA Wellbeing Survey (CWS) is a serial, cross-sectional survey that gathers self-reported wellbeing data to supplement the social recovery monitoring through CERA's Canterbury Wellbeing Index. The CWS provides the community with a broad indication of how the population is tracking in the recovery and informs agency decision-making. The CWS data-set promises to be equally valuable as further time-points are added. The collaborative process has helped establish the basis for a network of researchers across organizations and agencies. It is also hoped that the success of this collaborative cross-sector, multi-agency approach will constitute a valuable model for others, by adding to the body of disaster recovery monitoring literature.

Union Symposium

U02p - U2 Integrated Disaster Risk Science: Accounting for Extremes

U02p-384

Extreme energetic atmospheric events from comets/asteroids impacts: Actual global problem of the Earth's protection

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Extreme energetic atmospheric events such as the 1908 Tunguska explosion (energetics of the order of 4x10^24 erg = 20 megatons TNT equivalent, i.e. 1000 times the energy of the Hiroshima atomic explosion) and the widely known 2013 Chelyabinsk superbolide explosion (energetics around 400 kilotons TNT) are connected with entry of comet nuclei or asteroids (and their large fragments / meteoroids) into the Earth's atmosphere with cosmic velocities, i.e. more than 10-20 km/s. According to fully analytic approach developed in the last decades on the basis of classical physical theory of meteors for large bodies (bolides and superbolides / fireballs), these air explosions occur (in spite of tens possible hypotheses on the Tunguska event origin, from atomic explosion of a spacecraft up to interplanetary small mass black hole penetration) due to essential aerodynamic effects, namely aerodynamic crushing of large meteoroids in dense layers of the planetary atmosphere together with lateral expansion of the crushed mass, that lead to sharp aerodynamic deceleration / impulse thermalization of kinetic energy of supersonic flattening structure within a relatively very thin layer. The process will be terminated by known/observable phenomena: generation of very hot / intense photon emitting plasma along with strong 'blast' shock wave in the thin 'exploding' layer, near the end-point of the flight. Protection of the Earth from space threats, comets/asteroids impacts, is an actual global problem for strong international scientific-technical collaboration in our cosmic era.

Union Symposium

U02p - U2 Integrated Disaster Risk Science: Accounting for Extremes

U02p-385

Tsunami events and lessons learned - Environmental and societal significance

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Natural disasters like tsunamis cause enormous damage to infrastructure, the society and the environment particularly when these events are of large magnitude like the Chilean tsunami in 1960 and the Indian Tsunami in 2004 as well as the Great East Earthquake and Tsunami which occurred in Japan on 11 March 2011. As damage is enormous in terms of human life and wide spread destruction along the affected coastlines an urgent need for action to restore normality by the national and local authorities has been required. Provision of food and shelter, cleanup of debris and reconstruction of lifelines such as electricity, water and fuel as well as rebuilding roads amongst others become crucial as reconstruction and restoration works start. The multiplicity complicates reliable assessment of the major risks that is the necessary prerequisite for making implementation of the hazard-associated preparedness measures to mitigate humanitarian and economic losses (Kossobokov et al., 2014). The presentation is concentrated on post-tsunami hazard reconstruction and restoration issues covering topics such as coastal engineering and planning including risk and vulnerability, early warning systems improvement, coastal settlements and resilience as well as socioeconomic redevelopment, natural and induced coastal ecosystems recovery, restoration of affected agricultural lands, and coastal development amongst others. During the presentation we will bring specific examples from a variety of countries hit by tsunami events. The presentation participants can expect to benefit from the experiences, lessons learned and proposed measures aiming at increasing safety and resilience reduce and or ameliorate tsunami hazards in vulnerable coastal areas.

Union Symposium

U02p - U2 Integrated Disaster Risk Science: Accounting for Extremes

U02p-386

Determination of landslide and deformation with GNSS measurements, religious high schools, GÜMÜSHANE

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Today precise location is performed in real-time applications . These applications ; engineering purposes surveying, geodetic studies , cadastral purposes studies , meteorological measurements , the earth crust movement in the identification of and towards this earthquake prediction can be replaced with the surface of the resulting deformation is measured and analyzed to estimate the standard applications.TUSAGA determine the precise location of our country - Active system and is considering TUTGA points . Thus, determination of the deformation process is carried out with GNSS measurements . In this study, the application area and its surroundings as Gümüshane religious high schools were selected. This area , which is an old landslide area surrounding was triggered by blasting and excavation . In areas exposed to sudden changes in meteorological these changes has been another factor that caused the landslide . Periodically with the help of data collected was to determine the deformation in selected application areas . Religious high schools around gümüshane for the determination of deformation , which can represent landslides were appliqué to land 3 points . At this point with GNSS receiver in April 2012 and in January 2014 the second period , including measurements were carried out. Dimensions balancing based on static methods , deformation analysis were performed . Analysis of the results have been analyzed and applique compatibility of deformation was observed at the points .

Union Symposium

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U02p-387

Recognition of strong earthquake prone areas in the Caucasus, California and the Andes using clustering of epicenters

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The authors created a new method (FCAZ—Fuzzy Clustering and Zoning) for recognition of highly seismic areas, where epicenters of earthquakes with magnitude $M \geq M_0$ can occur. The magnitude threshold M_0 depends on the seismic activity of a region. The objects of clustering are earthquake epicenters. Suggested approach consists of two steps: clustering of known earthquake epicenters by the original DPS (Discrete Perfect Sets) clustering algorithm and obtaining highly seismic zones from clusters of earthquake epicenters by the original E^2XT algorithm.
Recognition of strong earthquake prone areas by FCAZ algorithmic system was carried out for the Caucasus ($M \geq 5.0$), California ($M \geq 6.5$) and the Andes ($M \geq 7.75$). The obtained results correspond well to the known instrumental and historical strong earthquake epicenters for all these regions. The reliability of recognized areas was confirmed by numerous control experiments.
The problem of strong earthquake prone areas recognition was studied since 1972 by I. M. Gelfand, V. I. Keilis-Borok, A. D. Gvishiani, A. A. Soloviev, V. G. Kossobokov and others. For this purpose a labor-intensive multidisciplinary method combining geological and geophysical parameters and recognition with learning was used. The recognition was done by the dichotomy with learning algorithms Crust-3 and Subclasses. In the scientific literature, this method was later called the EPA (Earthquake-Prone Areas recognition) method. Comparison of the FCAZ and EPA results in the three regions shows that the recognition of strong earthquake prone areas can be done easier and more reliably by the original FCAZ method.

Union Symposium

U02p - U2 Integrated Disaster Risk Science: Accounting for Extremes

U02p-389

Sea level prediction for the tsunami warning system

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The problem of the sea level prediction in the short period of time using the signal of hydrostatic pressure sensors is considered. The authors analyzed the frequency content of the signal level of the sea, developed an algorithm for constructing polyharmonic models to predict sea level and tested the results of the developed algorithm. The proposed solution of the problem of prediction, based on the construction of polyharmonic models, is aimed at ensuring the recognition of irregularity in the work of the sensors of the tsunami warning system.

Union Symposium

U02p - U2 Integrated Disaster Risk Science: Accounting for Extremes

U02p-390

Effects of geologic and geomorphic parameters on 2014 Hiroshima Landslides based on GIS analysis

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Landsliding is one of the most destructive earth surface phenomena. Geomorphic and geologic features, rock types and vegetative cover are important primary causes of the phenomena. Landslides are one of the most destructive geological hazards affecting Japan every year. Many landslides are triggered by heavy rain, like the ones that devastated Hiroshima prefecture at the western part of Honshu Island in 2014. This study focuses the relationship between geologic and geomorphic factors (elevation, slope, aspect and curvature) to landslide occurrence. The method contains the data integration and spatial analysis based on GIS. The data integration and analysis involves GIS based statistical analysis relating landslide occurrence to geological and geomorphological parameters. DEM are derived from GSI, and landslide distribution maps are derived from NIED and GSI. The highest peak of the study area 685 meters above the sea level. The geology of the site is characterized by late Cretaceous igneous rocks and Jurassic accretionary complex. This landslide type is debris flow with surface deposit. However, the landslides occurred in all rock types in the study area. However, the area with porphyritic rhyolite characterized by the presence of big boulders had more casualties and damaged to properties.

Union Symposium

U02p - U2 Integrated Disaster Risk Science: Accounting for Extremes

U02p-391

"Extreme multihazards and their cascading causes and effects"

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Extreme hazards are associated to long recurrence times and large potential effects, occasionally even at a global scale. However, the eruption of the Eyjafjallajökull volcano in Iceland in 2010 showed that today even a small and highly recurrent event may have worldwide impacts because the vulnerability increase of our modern societies due to their unavoidable dependency on technology. Despite this, the occurrence of extreme geophysical hazards (supereruptions, mega-landslides, earthquakes and tsunamis, ..), seems to be not controlled by the same variables than hazards with a much higher recurrence and lesser potential impacts, which may be predicted to certain extend. The difficulty in predicting extreme geophysical hazards make them to be not taking into account in hazard assessment. Most importantly, their potential cascading occurrence and effects are not considered because they may have unaffordable consequences. We analyse the predictability of some extreme hazards and their potential cascading causes and effects through the study of a few past examples found in the geological record and rise awareness on their potential occurrence in a near future.

Union Symposium

U02p - U2 Integrated Disaster Risk Science: Accounting for Extremes

U02p-392

Space hazard assessment: Characterization, simulation and classification of possible impact consequences

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One of the important steps in the prediction of impact threat to Earth raised by potentially hazardous asteroids is the understanding and modeling of processes accompanying the object's entry into the terrestrial atmosphere [1]. Such knowledge enables characterization, simulation and classification of possible impact consequences. Using dimensionless expressions, which involve the pre-atmospheric meteoroid parameters, we have built physically based parametrisation to describe changes in mass, height, velocity and luminosity of the object along its atmospheric path [2,3]. The developed model is suitable to estimate a number of crucial unknown values including shape change coefficient, ablation rate, and surviving meteorite mass. It is also applicable to predict the terminal height of the luminous flight and therefore, duration of the fireball [4]. Besides the model description, we demonstrate its application using the wide range of observational data from meteorite-producing fireballs appearing annually (such as Košice) to larger scale impacts (such as Chelyabinsk, Sikhote-Alin and Tunguska).

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Union Symposium

U03a - U3 Mathematics and Observations of Earth Systems

IUGG-3354

A 4-D earthquake cycle model for bounding seismic moment accumulation rate

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Simple elastic half-space dislocation models are commonly used with surface geodetic data to estimate fundamental quantities such as seismic moment accumulation rate and stressing rate in the seismogenic zone. However, these models do not accurately simulate the motions associated with the plate-like nature of the lithosphere. Full 4-D numerical plate models are computationally prohibitive especially when used to generate Greens functions for inversions of GPS and InSAR data. Over the past decade we have developed a semi-analytical approach for simulating complex fault dependence and realistic earthquake cycles for strike-slip fault systems. The most challenging aspect of the formulation is an analytic solution for the response of an elastic plate over a viscoelastic half space to a point load in space and time. The analytic solution is found by solving a 6x6 linear system using computer algebra to provide formulas for the 6 Boussinesq coefficients, as well as to generate the computer code for the computation. We use this approach to generate Greens functions for 2000-year earthquake cycle models and invert for the bounds on the present-day moment accumulation rate along the San Andreas Fault System.

Union Symposium

U03a - U3 Mathematics and Observations of Earth Systems

IUGG-3704

Imaging and monitoring seismic velocity in the Earth from records of ambient noise

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We present examples where the seismic noise records are used to image the Earth at various scales. We discuss the feasibility of using noise for the exploration of the deep Earth with body waves. Furthermore, noise records can be used to monitor changes of elastic properties of the crust in relation to dynamic processes like earthquakes or volcanic eruptions. We discuss why and how it is possible to perform high precision monitoring, even without a precise description of the noise. Our results suggest that high precision monitoring with fractional seismic wave variation of the order of 10^-4 or less can be performed in presence of a fluctuating noise. This can be achieved because of the properties of scattered waves. This type of analysis relies on the use of large data sets, the computations of numerous correlations functions and numerous time measurements. We illustrate the continuous monitoring with the case of the crust beneath Japan before, during and after the large Tohoku-oki earthquake. We also discuss the response of the seismic velocity to external forcing, including meteorological processes and Earth tides.

Union Symposium

U03a - U3 Mathematics and Observations of Earth Systems

IUGG-3873

The inference spiral of earthquake system science

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System science seeks to explain emergent phenomena at the system scale, such as global climate change or earthquake activity in California or Japan. The "system" is not a physical reality, but a hypothetical representation of nature, typically a numerical model or ensemble of models that replicates an emergent behavior and predicts its future course. I describe how earthquake system science is improving predictive models of fault rupture and wave propagation through a cyclical process of model formulation and verification, simulation-based prediction, validation against observations, and data assimilation. As we work models around and outward on this "spiral of inference", we alternate between constructionistic synthesis and reductionistic analysis, addressing model inadequacies with more data and better physics. Over the last decade, this development cycle has increased the computational demands of earthquake system science more rapidly than Moore's law, and current research to improve the system-level models are now taxing the capabilities of the largest supercomputers. I will discuss SCEC's efforts to develop and validate earthquake forecasting models based on the coupling of rupture simulators with ground-motion simulators, focusing on how we can use this modeling framework to pose interesting problems of contingent predictability as physics questions in a system-specific context. For example, more accurate earthquake simulations using realistic three-dimensional crustal models can reduce the aleatory variance of the strong-motion predictions by a factor of two relative to the empirical ground motion prediction equations in current use, which would improve the estimation of exceedance probabilities at high hazard levels by an order of magnitude.

Union Symposium

U03b - U3 Mathematics and Observations of Earth Systems

IUGG-1702

Spatio-temporal pattern recognition for large GPS data sets

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We introduce advanced methods for spatio-temporal pattern analysis and prediction to earth deformation problems. These methods have been developed in the climate sciences and widely applied but are new to the solid-earth geosciences.

GPS networks now record transient deformations of the Earth surface. These deformations are, however, difficult to extract from the background noise. They are also obscured by other geophysical signals, such as the seasonal oscillations in the mass of the atmosphere, the ocean and the hydrological reservoirs.

The proposed methodology includes singular-spectrum analysis (SSA) and its generalizations and modifications, such as multichannel SSA (M-SSA) and Monte Carlo SSA (MC-SSA); see http://web.atmos.ucla.edu/tcd//ssa/ and references there. Here we show that M-SSA can be used to extract transient deformations and the seasonal oscillations present in the GPS time series, without the use of a priori hypotheses about their spatio-temporal structure.

M-SSA is a multivariate nonparametric statistical method that exploits simultaneously the spatial and temporal correlations of geophysical fields. It allows one to define spatio-temporal empirical orthogonal functions (ST-EOFs) onto which the GPS time series can be projected. M-SSA also facilitates the extraction of common modes of variability shared by several time series. These modes correspond to oscillations and to nonlinear trends.

Dynamical system theory provides a convenient framework for the interpretation of M-SSA results, as applied to GPS time series analysis. We illustrate our results with examples from seasonal signals and micro-inflation-vs.-subsidence near an Aleutian Arc volcano.

This talk is based largely on recent joint work with E. Calais, A. Groth, D. Kondrashov and D. Walwer.

Union Symposium

U03b - U3 Mathematics and Observations of Earth Systems

IUGG-3159

Modeling the melt: What math tells us about the disappearing polar ice caps

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The precipitous loss of Arctic sea ice has far outpaced expert predictions. In this lecture we will explore the mathematical underpinnings of this mystery, and show how we are using the mathematics of multi-scale composites and statistical physics to study key sea ice processes. Our models are developed in close conjunction with measurements of sea ice properties that we have made during recent polar expeditions. This research is helping to represent sea ice more rigorously in climate models and improve projections of the fate of Earth's ice packs.

Union Symposium

U03b - U3 Mathematics and Observations of Earth Systems

IUGG-4464

Rigorous statistical methods for modeling paleoclimate and climate extremes

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We present new methods for high dimensional spatial paleoclimate reconstructions and for understanding climate extremes. In particular, we propose dimension reduction techniques which leverage recent advances in statistical and mathematical theory for the modeling of earth's climate, both past and present. We demonstrate that these methods can yield a better understanding of climate with reduced uncertainty. (Joint work with various co-authors)

Union Symposium

U03p - U3 Mathematics and Observations of Earth Systems

U03p-421

Investigation for spatial and temporal variations of daily mean temperatures of Black Sea Region, Turkey

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The correct determination of the spatial distribution of meteorological variables is as important as their measurement. Several methods have been employed to determine these variables. However, determining the variables that best reproduces actual conditions has been difficult. Many factors also affect the performance of spatial interpolation methods.

This study uses daily mean temperature data from 52 sophisticated topography and relatively variable latitude and elevational demonstration of meteorological stations covering the Black Sea Region, Turkey which has been the focus of little research. The Turkish State Meteorological Service recorded these data for a total of 32 years from 1981 to 2012. With regard to the spatial and temporal properties of data points, our study focuses on the performance of 9 spatial interpolation methods, namely, Inverse Distance Method (IDW) using Original Shaperd and Modified Shaperd weights, Lapse Rate Method, Simple Linear Regression Model and Multiple Linear Regression Model, Combined Simple Linear Regression and IDW, Combined Multiple Linear Regression and IDW (GIDS) and Combined Lapse Rate and IDW, Ordinary Kriging Method. We also aim to determine the optimum parameterization configuration of the three methods on the basis of root mean square error, mean absolute error, maximum of error, and minimum of error statistics. These statistical values are derived from the interpolation errors of the daily mean temperature data collected in the region from 1981 to 2012. The optimized parameterization options for the methods were determined by using a cross-validation method applied on 52 meteorological stations with data collected for 32 years.

Union Symposium

U03p - U3 Mathematics and Observations of Earth Systems

U03p-422

Matrix eigenvalue approach for solid-Earth free-oscillation calculations and superconducting-gravimeter-data inversion

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Deformations and changes of the gravitational potential of prestressed elastic bodies under free oscillations are described by means of the momentum equation, the Poisson equation and the constitutive relation. For the case of spherical symmetry spherical harmonic decomposition transforms the equations and boundary conditions into a series of eigenproblems for ordinary differential equations (ODEs) of the second order that yields eigenfrequencies and eigenfunctions of the oscillations.

We employ highly accurate pseudospectral schemes to directly discretize the ODEs on Chebyshev grids and a set of algebraic eigenproblems with almost block diagonal matrices is derived. Since constitutive relations of the reference Earth model (PREM) are frequency dependent, these eigenproblems are, in principal, non-linear. We solve the problem for several fiducial frequencies of PREM and interpolate the results to obtain eigenfrequencies and eigenfunctions for corresponding frequencies of PREM.

Both the modal frequencies and eigenfunctions are benchmarked against the Mineos software package based on Runge-Kutta integration techniques and used for inversion of superconducting-gravimeter data recorded after the recent megathrust events (2010 Maule, 2011 Tohoku, 2012 Sumatra double earthquake) to constrain their low-frequency centroid-moment tensors and quality factors of gravest radial and spheroidal modes.

Union Symposium

U03p - U3 Mathematics and Observations of Earth Systems

U03p-423

Stochastic Modeling of Decadal Variability in Ocean Gyres

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1. Decadal large-scale low-frequency variability of the ocean circulation due to its nonlinear dynamics remains a big challenge for theoretical understanding and practical ocean modeling. This paper presents a novel fully data-driven approach that addresses this challenge. We adopt non-Markovian low-order methodology with stochastic closure and data-adapative mode decomposition by multichannel Singular Spectrum Analysis. The multilayer stochastic linear model is obtained from the coarse-grained eddy-resolving ocean model solution, and it reproduces with high accuracy the main statistical properties of the decadal variability. The proposed approach does not depend on the governing fluid dynamics equations and geometry of the problem, and it can be extended to other ocean models and ultimately to the real data.

Union Symposium

U03p - U3 Mathematics and Observations of Earth Systems

U03p-424

Determination of the sensitive and important physical parameters combination within numerical models using a new approach

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An important source of uncertainty, which then causes further uncertainty in numerical simulations, is that residing in the parameters describing physical processes in numerical models. There are many physical parameters in numerical models in the atmospheric and oceanic sciences, and it would cost a great deal to reduce uncertainties in all physical parameters. Therefore, finding a subset of these parameters, which are relatively more sensitive and important parameters, and reducing the errors in the physical parameters in this subset would be a far more efficient way to reduce the uncertainties involved in simulations. In this context, we present a new approach based on the conditional nonlinear optimal perturbation related to parameter (CNOP-P) method. The approach provides a framework to ascertain the subset of those relatively more sensitive and important parameters among the physical parameters. The Lund–Potsdam–Jena (LPJ) dynamical global vegetation model was utilized to test the validity of the new approach. The results imply that nonlinear interactions among parameters play a key role in the uncertainty of numerical simulations in arid and semi-arid regions of China compared to those in northern, northeastern and southern China. The uncertainties in the numerical simulations were reduced considerably by reducing the errors of the subset of relatively more sensitive and important parameters. The results demonstrate that our approach not only offers a new route to identify relatively more sensitive and important physical parameters but also that it is viable to then apply “target observations” to reduce the uncertainties in model parameters.

Union Symposium

U03p - U3 Mathematics and Observations of Earth Systems

U03p-425

New fuzzy logic technique for studying geomagnetic secular acceleration using on-ground observations

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Secular variation (SV) models for the epochs before the space era are constructed basing on magnetic observatory data, which represent rough and noisy time series due to magnetic storms, anthropogenic spikes and gaps. The models are smoothed afterwards, so if an initial record is recovered, it does not conform with the real one. Particularly, SV models allow studying magnetic jerks, which are sharp changes in a core field behavior. Recent studies show that at least some of geomagnetic jerks observed at the Earth's surface emanate from increasing and decreasing phases of secular acceleration (SA) pulses at the core surface. The latter ones are direct manifestation of the dynamic processes taking place in the liquid core.
Being the most smooth and homogeneous in terms of geographical coverage, satellite data are widely used for modeling SA. However, it makes it difficult to study SA pulses before 2000, when satellite measurements of the Earth's magnetic field were not conducted. Herein we attempt to carry out similar studies basing on observatory data available for a longer period. The proposed method of SV modeling and recognition of secular acceleration (SA) pulses relies on a new technique of smoothing time series based on fuzzy mathematics. Comparison with the SV modeling results derived from satellite data has shown their high conformity with the proposed method. It was tested by the example of the last two known SA pulses, which took place in 2006 and 2009 in Atlantic and South Asian regions. The obtained results provide a basis for applying the method to retrospective historical data processing for a better study of SA pulses and magnetic jerks in the pre-space era.

Union Symposium

U03p - U3 Mathematics and Observations of Earth Systems

U03p-426

New approach to the time-frequecy analysis of acoustic emission signals

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This report is devoted to the development of a new approach of analysis of acoustic emission (AE) signals. Since 1999 investigation of AE of sound range at different stages of seismic activity has been carried out in Kamchatka peninsular. A typical AE signal is composed of a sequence of relaxation pulses with the duration of not more than 200 ms, amplitude of 0.1 – 1 Pa, with pulse excitation and frequency of filling from units to the first tens of kHz. Besides the pulses, AE signals may contain noises of different nature called acoustic noise. To solve the problems of description of signal inner structure, the authors applied the method of sparse approximation. In the course of the experiments it was shown that the most appropriate from sparse approximation algorithms for AE signal analysis is the Matching Pursuit (MP), suggested by Mallat S. and Zhang S. To improve the quality of AE signal approximation, a combined dictionary was developed which includes Berlage functions and Gauss functions. The choice of Berlage functions is based on the similarity of their structure with AE elementary pulses and, consequently, they approximate better the signal parts containing a pulse. In its turn, Gauss functions are appropriate for approximation of signal parts containing noise components. It is shown that application of the developed method in analyzing real data makes it possible to reveal the internal geoacoustic pulse structure caused by the features of their sources. The results can be used for diagnosing deformation processes in natural media.

Union Symposium

U03p - U3 Mathematics and Observations of Earth Systems

U03p-427

Optimal interpolation of spatially discretized geodetic data and its application to southern California GPS measurements

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We present an algorithm to calculate horizontal strains (or strain rates) through interpolation of geodetically derived displacements. This is an under-determined inverse problem to derive smoothly distributed strains using spatially discretized geodetic observations. A priori information, in the form of weighted smoothing, is required to facilitate the solution. At a given site, the horizontal displacement field in its vicinity is approximated by a bi-linear function and represented by rigid block translation, rotation, and strains. The displacement data in the neighborhood, after reweighting, are used to estimate the field parameters through a least-squares procedure. Optimal weightings are prescribed for the neighborhood data, based on their distances to the site and their spatial coverage. We apply this method to the Southern California GPS velocity field and derive the strain rate field. Our result shows that: (1) Distance dependent weighting can be optimally achieved by employing either a Gaussian or quadratic decay function, with the former offering a slightly sharper result than the latter. (2) Spatially dependent weighting is important to improve the interpolation, and can be done by invoking either an azimuthal weighting or a Voronoi cell areal weighting function. The result shows detailed strain rate pattern, and reveal present day tectonic activities and deformation styles in southern California.

Union Symposium

U03p - U3 Mathematics and Observations of Earth Systems

U03p-428

Refining the Flood Pulse concept: The role of non-river inundation water quality and river-derived particulate nutrients for floodplain vegetation patterns.

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The Flood Pulse Concept links the hydraulic river flood pulse to floodplain nutrient status and productivity. The moving littoral, or edge of inundation water, indicates the zone of wetting and drying and dynamic exchange of water and nutrients. We hypothesized presence of other water sources may influence inundation water quality, including nutrient concentrations, displaying a spatial zonation related to flow processes operating in the floodplain.

Nutrient input generally enhances plant productivity. Flood pulse related dissolved nutrient input has thus been related to zones of high vegetation productivity usually found close to the river. However, particulate nutrients are rarely measured, although those are the nutrients that stay behind in deposited sediment after the flood has receded. This sediment then provides a nutrient pool during the growing season. We therefore hypothesized deposition patterns of sediment-attached particulate nutrients will better explain floodplain vegetation productivity than dissolved nutrient patterns.

Cluster analysis revealed a spatial pattern of inundation water types linked to distinct flow processes in different parts of the floodplain. The zone of most productive vegetation was strongly related only to the river water flood zone. We therefore conclude the moving littoral is not necessarily a good indicator of the zone of high vegetation productivity.

Both dissolved and particulate nutrients generally decreased with distance from the river. However, suspended and deposited particulate nutrients showed higher significant correlations to vegetation productivity than dissolved nutrients. We conclude river-derived particulate nutrients may be more relevant to vegetation productivity than dissolved nutrients.

Union Symposium

U03p - U3 Mathematics and Observations of Earth Systems

U03p-429

Creation of digital terrain models using surface evolution

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In our contribution we discuss the creation of the digital terrain models using a surface evolution by the weighted mean curvature flow. To achieve this goal we have developed a discretization of the Laplace Beltrami operator using the finite volume method. This approach is based on an approximation of an arbitrary surface by triangular mesh and deriving the weak formulation for the Laplace-Beltrami operator on the manifold. A system of linear equations obtained by the finite volume approximation of the weak formulation is solved in each discrete time step by an iterative solver. The numerical experiments consist of theoretical ones, where we have tested the proposed approach by finding a minimal surface and a surface with a given mean curvature, and practical ones, where our aim was to create the digital terrain models obtained by using a remote sensing technology LiDAR.

Union Symposium

U03p - U3 Mathematics and Observations of Earth Systems

U03p-430

Nonlinear diffusion filtering of data on closed surfaces.

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We develop new nonlinear diffusion filtering method on closed surfaces such as Earth topography or satellite orbits. Our new model extends the regularized surface Perona-Malik model by including local extrema detector based on the mean curvature of processed data. The model is thus represented by a nonlinear diffusion equation which at the same time reduces noise and preserves main edges, local extrema and details important for a correct interpretation of real geodetic data. We define a surface finite-volume method to approximate numerically the nonlinear parabolic partial differential equation on closed surface. The closed surface is approximated by a polyhedral surface created by planar triangles and we use a piece-wise linear approximation of a solution in space and the backward Euler time discretization. We present numerical experiments related to nonlinear diffusion filtering of GOCE measurements and satellite-only mean dynamic topography data.

Union Symposium

U03p - U3 Mathematics and Observations of Earth Systems

U03p-431

Laboratory study of suspension filtration trough porous medium.

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The fluid filtration through porous media is considered in various aspects. In geophysics there are problems of fluid penetration into soil, groundwater filtration, fluid migration in porous rocks, drilling mud filtration through borehole walls and so on. In the proposed presentation, the results of laboratory experimental research of suspension filtration through porous media are considered. The experiments were made using transparent Hele –Shaw cells filled by porous media. The suspension flowed through that porous material under constant pressure difference, the suspension particles settled in the porous. The distribution of the settled particle concentration along the porous media was measured by optical method. The method was based on change of the medium transparency. The continuity equation for the suspension filtration and absorption was derived. The experimental variation of the volumetric filtration rate (which decreased monotonically with time due to permeability decreasing) and the concentration profiles of the particles settled in the porous media at different time were obtained. The model for estimation of the time variation of the concentration profiles of the settled particles was suggested and investigated. A good agreement between experimental and theoretical values of the particle concentrations as functions of coordinate and time was demonstrated. The model can be applied for evaluation of dynamic porosity of the rocks as well as their specific permeability variation due to suspension particle sedimentations.

Union Symposium

U03p - U3 Mathematics and Observations of Earth Systems

U03p-432

Estimating climate sensitivity from an ensemble of GCM configurations optimized to outgoing TOA radiation

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Multiple parameters controlling subgrid-scale physical processes in the version 3 of the Hadley Centre Atmosphere Model (HadAM3) were optimized to global mean outgoing longwave radiation and reflected shortwave radiation estimates from CERES and ERBE satellite observations. An ensemble of sucessfully-optimized model configurations were identified. Equilibrium climate sensitivity of each ensemble member was estimated using a statistical emulator, which had been trained on the 14,001-member ensemble of HadAM3 slab-ocean experiment simulated over the distributed computing platform of climateprediction.net. To produce an uncertainty estimate for the equilibrium climate sensitivity, likelihood for each model configuration was calculated by combining model-observational discrepancy arising from satellite measurements, observational radiation imbalance, total solar irradiance, radiative forcing, natural aerosol, internal climate variability, and the prescribed sea-surface temperature and that arising from parameters that were not varied. Combining different prior probabilities for model configurations with the likelihood for each configuration and taking account of uncertainty in the emulated climate sensitivity gives, for the HadAM3 model, a 2.5%-97.5% range for climate sensitivity of 2.7-4.2 K if the CERES observations are correct. The results rule out, at the 2.5% level for HadAM3 and several different prior assumptions, climate sensitivity greater than 5.6 K. The method has been recently extended to increase the number of parameters and climate variables and to optimize coupled GCM (HadCM3). Results from these will also be presented.

Union Symposium

U03p - U3 Mathematics and Observations of Earth Systems

U03p-433

On the spatial resolution of filters defined on the sphere

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Filtering a field defined on the sphere inevitably changes the spatial resolution of the field. In this contribution we ascertain the spatial resolution using a test field made up of two Dirac's delta functions defined on the sphere. Such a field provides the ideal spatial resolution of the filter, which is easily represented for the case of homogeneous isotropic filters by a single value. However, for the case of inhomogeneous and/or anisotropic filters the ideal resolution is a direction dependent curve, best represented in the polar form. A complementary metric to the ideal spatial resolution is the contrast, which is described by the modulation transfer function (MTF). It provides a glimpse of the real world behaviour of the filter. These concepts are explained by applying them on some commonly used filters in the processing of GRACE (Gravity Recovery and Climate Experiment) satellite data.

Union Symposium

U03p - U3 Mathematics and Observations of Earth Systems

U03p-434

"Transfer Entropy between South Atlantic anomaly and global sea level for the last 300 years"

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The possible connection between the geomagnetic field and the Earth's climate has been widely discussed from 70's. We have applied a recent information-theoretic tool, transfer entropy (and its generalization to mitigate the finite sample effects, the effective transfer entropy) to measure the possible information flow (and sense) between these two systems using the South Atlantic Anomaly (SAA) surface extent at the Earth's surface and the Global Sea Level (GSL) rise for the last 300 years. The results seem to support the existence of a link, with more information transferred from the SAA to the GSL than vice versa. This fact also seems reinforced by the cross-correlation between both time series (with a lag of 35 years of the GSL with respect to the SAA), as well as by the frequency spectrum from wavelets analysis, finding two dominant periodicities around 60 and 100 years, which are observed in both time series and could indicate a common origin. Considering the recent outcomes, we support as physical mechanism to explain this connection an internal mechanism as the most probable: the coupling would be due to a common internal cause, i.e., a convective dynamism in the outer core, which is reflected like a variation of the magnetic field on the Earth's surface, produces changes in the fluid pressure field acting at the core-mantle boundary (CMB) and elastic-gravitational deformations up to the Earth's surface.

Union Symposium

U03p - U3 Mathematics and Observations of Earth Systems

U03p-435

Detection and classification of acousto-elektromagnetic effects of the lithosphere based on wavelet transform

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An approach of formation of information features has been developed to detect and classify the acousto-electromagnetic effects of lithospheric processes caused by tectonic stresses. Applying this technique on the data obtained by the means of a borehole in a seismically active region of Kamchatka, confident detection of 4 classes of signals corresponding to near-surface and deep processes was realized. This approach may be applied for monitoring of tectonic activity necessary for earthquake forecast.

Union Symposium

U04a - U4 Data Science and Analytics in Geodesy and Geophysics - Research and Education Progress and Opportunities

IUGG-5751

ICSU World Data System (WDS): data preservation and accessibility without borders

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Research is increasingly international, transdisciplinary, and data-enabled, which requires scrupulous data stewardship, full and open access to data. New expectations on researchers from governments and funders to share data fully, openly, and in a timely manner present significant challenges and opportunities to improve quality, efficiency and accountability to society. Researchers should be able to archive and disseminate data, and civil society to scrutinize datasets. Trustworthiness of data services must be verifiable. In addition, the need to integrate large and complex datasets across disciplines and domains with variable levels of maturity calls for better coordination to achieve interoperability and sustainability.

WDS promotes long-term stewardship of, and universal and equitable access to, quality-assured scientific data. It coordinates and supports trusted scientific data services for the provision, use, and preservation of datasets to facilitate scientific research. It certifies its members—holders and providers of data—using internationally recognized standards, providing the building blocks of a searchable common infrastructure from which a data system that is both interoperable and distributed can be formed.

This presentation will describe more specifically activities developed by its Scientific Committee to:

- Improve and stimulate basic level **Certification for Scientific Data Services**, in particular through collaboration with the Data Seal of Approval.
- Identify and define best practices for **Publishing Data** and to test implementation by involving the core stakeholders i.e. researchers, institutions, data centres, scholarly publishers, and funders.
- Establish an open WDS **Metadata Catalogue**, **Knowledge Network**, and **Global Registry of Trusted Data Services**.

Union Symposium

U04a - U4 Data Science and Analytics in Geodesy and Geophysics - Research and Education Progress and Opportunities

IUGG-5753

The research data alliance—creating the culture and technology for an international data infrastructure

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All of society's grand challenges require diverse data to be shared and integrated across cultures, scales, and technologies. Data sharing, and the infrastructure that enables it, is fundamental to innovation, but creating that data infrastructure is a grand challenge in its own right. History shows that infrastructure is not planned or designed up front. It evolves through a staged process involving complex dynamics, unanticipated consequences, and significant friction between individuals, organizations, and systems. Collaborators may agree on general principles, but they do not necessarily have common goals. Coalition style politics emerge that can both ameliorate and exacerbate the friction, but it is through this multifaceted perspective that we achieve greater understanding.

The Research Data Alliance (RDA) embraces this complex dynamic. It has no specific plan or architecture, but it provides core principles and a "neutral place" that provide enough alignment to move forward while still recognizing the value of friction. The focus is on building and implementing bridges or gateways that connect disparate systems, organizations, and processes in order to create interconnection and increase data sharing.

RDA is an international member organisation. It is only two years old but has already made significant advances in bringing the community together, identifying key issues, and delivering the initial products that help bridge across cultures and systems. This talk will review the approach, operations, and products of the RDA and how they are advance us toward creating a global data infrastructure. How international unions and societies can enhance the adoption of RDA products and accelerate infrastructure development will be emphasized.

Union Symposium

U04b - U4 Data Science and Analytics in Geodesy and Geophysics - Research and Education Progress and Opportunities

IUGG-2579

Data Stewardship – Discovery, Delivery, and Citation Supporting the Next Generation Integrated Science

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The National Geophysical Data Center (NGDC) ensures the security and widespread availability of geophysical data through long-term stewardship. This mission has been reinforced and strengthened through participation in a variety of international programs, including hosting a World Data Service for Geophysics and hosting the International Hydrographic Organization's Data Center for Digital Bathymetry. While the mission to provide long-term scientific data stewardship ensuring quality, integrity, and accessibility has remained largely unchanged for more than 200 years, the methods and technologies used have changed drastically. We describe the overarching framework of data services, web applications, data management, and data citation used to ensure easy discovery of and access to a wealth of public scientific data.

Ocean mapping partners expend significant resources to survey our coasts and oceans. In order to enable scientific discovery and re-use, the data must be easily discoverable and readily accessible to numerous users and applications now and into the future. In addition, data need to be integrated across space and time. To meet these goals, NGDC draws on a variety of software technologies and strictly adheres to international data standards. The result is a geospatial framework built on spatially-enabled databases, standards-based web services, and International Standards Organization metadata. NGDC's suite of tools and services delivers over 40TB of marine geophysical data each year to a wide range of customers. By making the data more accessible to both human and machine clients, NGDC extends the use of, and therefore the value of, these data.The result is environmental information that enables informed decisions.

Union Symposium

U04b - U4 Data Science and Analytics in Geodesy and Geophysics - Research and Education Progress and Opportunities

IUGG-3440

Building a Google for data: The current state of the art

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Researchers are experiencing increasing pressure from agencies and professional societies to make all outputs of their science open and accessible. But a large percentage of scientists feel the need to maintain control of their data or lack an appropriate repository in which to deposit their data. Even when data are transferred to a repository, discovery of those data can be difficult due to the large number and dynamic state of repositories. Brokering services can provide harmonized discovery and access services on heterogeneous catalogs but populating and maintaining those catalogs has proven to be a challenge and will become more so as more researchers seek to deposit their data. There is a growing need for mechanisms that make it possible to discover and aggregate all data that is in repositories and registries, or is self-published on the web.

The National Snow and Ice Data Center has piloted a way for researchers to advertise their data by posting syndication-type metadata alongside their data, and have developed crawlers that find and aggregate these advertisements. We are now working on a crawler that is capable of discovering other types of documents describing data such as OAI-PMH, OpenSearch, OGC W*S, and THREDDS. Owing to the vast number of such documents on the web we are also developing a means to discriminate which of the discovered resources are applicable to specific scientific interests. The locations of these discovered resources could then be incorporated into discovery and access services such as those provided by GI-Cat/GI-Axe. In this talk the status of this and similar work in the US will be discussed and potential good practice guidelines for repositories and researchers in advertising their data holdings and services will be described.

Union Symposium

U04b - U4 Data Science and Analytics in Geodesy and Geophysics - Research and Education Progress and Opportunities

IUGG-5752

Citing dynamic data in the earth sciences: Challenges and solutions

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Earth Sciences, like many other disciplines, rely heavily on vast amounts of data as a basis. Specifically, and maybe more so than in other disciplines, these data are highly dynamic, being accumulated over potentially long periods of time, as well as measurement values being corrected/updated for data that had become available at earlier points in time. On the other hand, published studies need to be able to precisely identify the subset of data the results are based upon. In order to repeat an earlier study, to apply data from an earlier study to a new model, we need to be able to precisely identify the very subset of data used. While verbal descriptions of how the subset was created (e.g. by providing selected attribute ranges and time intervals) are hardly precise enough and do not support automated handling, keeping redundant copies of the data in question does not scale up to the big data settings encountered in many disciplines today. Conventional approaches, such as assigning persistent identifiers to entire data sets or individual subsets or data items, are not sufficient to meet these requirements.

In this talk we will review the challenges identified above and discuss the solutions and recommendations that are currently elaborated within the context of a Working Group of the Research Data Alliance (RDA) on Data Citation: Making Dynamic Data Citeable. These approaches are based on versioned and time-stamped data sources, with persistent identifiers being assigned to the time-stamped queries/expressions that are used for creating the subset of data. We will review examples of how these can be implemented for different types of data, reviewing several examples from the Earth Sciences, and see how this fits into the larger context of activities on Data Citation.

Union Symposium

U04p - U4 Data Science and Analytics in Geodesy and Geophysics - Research and Education Progress and Opportunities

U04p-438

Data management and service system for marine geology and geophysical data in Korea Institute of Ocean Science & Technology

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We established a data management and service system using database management system (DBMS) and geographic information system (GIS), respectively, for marine geology and geophysical data around Korea in Korea Institute of Ocean Science & Technology (KIOST). For the efficiency of data management and service, database is comprised of ARCHIVE DB and GIS DB. ARCHIVE DB stores the archived data as an original form for primitive data archiving tasks and GIS DB manages all the processed data and reproduction data for GIS application services. Relational data management system adopted for DBMS and open source GIS techniques applied for GIS services such as OpenLayers for user interface, GeoServer for application server, PostGIS and PostgreSQL for GIS database. A viewer program for geophysical data of which the data format is SEG Y were developed and provided. To keep the consistency of data management with annual updates, we set up standard operating procedures (SOPs) for data archiving, data processing, converting and reproducing, data quality controls, and DB uploading, etc.

Union Symposium

U04p - U4 Data Science and Analytics in Geodesy and Geophysics - Research and Education Progress and Opportunities

U04p-439

Lab stand for study of fluid layer response to dynamic impact

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The lab stand aimed at study of a fluid layer response to dynamic impact in flat radial problem set was constructed. Despite many evidences of post-seismic collectors response to seismic waves propagation such as fluid level variations, flowing of wells and oil wells output increase, currently there are no lab investigations that are pointed to full phenomenon theory creation. Including this lab set we have made the 'Signal' stand that let us register disturbance propagation in the permeable layer inside impermeable massif and the 'Permeability' stand for fluid layer permeability real-time control.

As a layer model we used a concrete disk with diameter of 270 mm and thickness of 20 mm made of cement, sand and expanded perlite that was placed in plasticine block with volume of 1.35 m^3 to the depth of 200 mm. Layer was taped with a wellbore with a diameter of 25 mm. For filling of the layer with fluid with used the distribution ring around the cylindrical disk surface. By the use of laser displacement sensors with the accuracy of 0.1 mcm massif and water surfaces oscillations could be recorded.

As a result of experiments with 'Signal' stand we found out that fluid oscillations significantly differs from initial wave parameters that is caused by layer deformation and fluid flow from layer to well and back.

Residual water level changes were found out. It is believed to be connected to slow hydrostatic equilibrium restoration after system deformation. Intensity and character of these effects depend on layer permeability and geometry. 'Permeability' stand allows us to found out that fluid layer permeability can be changed both by dynamic impact and significant amount of fluid flow through layer. Now experiments with layer mudding with clay particles are planned.

Union Symposium

U04p - U4 Data Science and Analytics in Geodesy and Geophysics - Research and Education Progress and Opportunities

U04p-440

Least-squares wavelet analysis

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The least-squares spectral analysis, an alternative to the classical Fourier analysis, was introduced by Vanicek in order to analyze unequally spaced and non-stationary time series in their first and second statistical moments. When a time series has low or high frequency and amplitude variation over time, however, both the least-squares spectral analysis and Fourier analysis are not appropriate tools for analysis. On the other hand, the classical short-time Fourier transform and the continuous wavelet transform do not consider the covariance matrix associated with a time series nor do they consider trends or datum shifts. Both, the short-time Fourier transform and the continuous wavelet transform are not defined for unequally spaced time series.

In this talk, we present a new method called the least-squares wavelet analysis that can analyze a non-stationary and unequally spaced time series with high frequency and amplitude variation over time by transforming the time series to the time-frequency domain. The least-squares wavelet analysis is a powerful method for analyzing an unequally spaced and unequally weighted time series with associated covariance matrix superseding the well-known wavelet analysis. Several examples from artificial and real time series will be presented to demonstrate the effectiveness of the method.

Union Symposium

U04p - U4 Data Science and Analytics in Geodesy and Geophysics - Research and Education Progress and Opportunities

U04p-441

Experiments for the mashup of heterogenous data systems using semantic web concepts

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This paper describes the efforts and lessons learned during experiments for the mashup of heterogenous data systems and server within the last four years. There are the European Union ESPAS data server based on OGC and ISO standards, the Japanese IUGONET data server using the SPASE data model, realized via DSpace, and the GFZ Potsdam Semantic Web based ISDC data server prototype. The architectures and the realizations of these data systems and servers are very different and are not interoperable. The experiments conceived and realized together with students of the faculty of information sciences from the UAS Potsdam cover following main topics:
- metadata (context data), data models and domain ontologies in geo and space sciences
- controlled vocabularies and terminological ontologies in geo, space and environmental sciences
- transformation of vocabularies, e.g. SPASE and GCMD science keywords into SKOS ontologies

- mapping and merging of domain and terminological ontologies (e.g. SPASE and ISDC ontologies)
- text mining and mashup of unstructured data resources from e.g AGU and EGU publications
- mashup of data managed by relational databases via D2R server and services (e.g. ISDC)
- using SPARQL, Virtuoso, D2R and Drupal for the design of Semantic Web based ISDC data server

The results of the experiments clearly show the potential of the Semantic Web approach for the mashup of heterogenous data systems and servers in the geo and space domain as well as the connection with appropriate data sources in open linked data.

Abbreviations:
ESPAS - near-Earth space data infrastructure project and data server
IUGOENT - Inter-university Upper atmosphereGlobal Observation NETwork
ISDC - Information System and Data Center
SPASE - Space Physics Archive Search and Extract project and data model

Union Symposium

U05a - U5 New Discoveries in Deep Interior of the Earth and Planets

IUGG-1323

Of mantle plumes and secondary scale convection: Insights from whole mantle seismic waveform tomography

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Many questions remain on the detailed morphology of convection patterns in the mantle. With the advent of numerical methods for accurate seismic wavefield computations, it is now possible to apply the tools of waveform tomography to better detect the presence, throughout the mantle, of slow velocity anomalies, previously 'hidden' by wavefront healing effects not captured by approximate wave propagation methods. Using waveform tomography based on the spectral element method (SEM), we have recently constructed a second-generation global, radially anisotropic, shear velocity upper mantle model (SEMum2, French et al., 2013) and have now extended it to the whole mantle by adding shorter period body waveforms (model SEMUCB-WM1, French and Romanowicz, 2014). These models reveal better focused, finer scale low velocity structures both in the upper and in the lower mantle. In the upper mantle, we observe quasi-periodic, low velocity structures with a wavelength of ~2000 km, elongated horizontally for thousands of kilometers in the direction of absolute plate motion (APM), most prominent in the depth range 200-300 km, but extending from the base of the lithosphere into the transition zone. While these upper mantle structures are elongated horizontally, the rest of the mantle low velocity structure is dominated by vertically elongated structures that form discrete 'columns' rooted at the base of the mantle, positioned in the vicinity of major hotspots lying over the large lower mantle low shear velocity provinces. The vertical conduits are quite straight from the base of the mantle to 1000 km depth, but wider (~1000 km) than expected from the standard 'plume' model. Their character changes above 1000 km depth, as they seem to become narrower and meander across the upper mantle.

Union Symposium

U05a - U5 New Discoveries in Deep Interior of the Earth and Planets

IUGG-1825

Insights into mantle dynamics and thermo-chemical structure through joint inversions of seismic and geodynamic data

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Global seismic tomography has made great strides during the past two decades with most models showing agreement in the large scale heterogeneity of Earth's mantle. However, the interpretation of the seismic models in terms of thermo-chemical structure and mantle dynamics is still controversial. To better understand mantle composition and dynamics we perform joint inversions of seismic and geodynamic data. The geodynamic data consist of the Earth's free air gravity, dynamic topography, plate motions, and the excess ellipticity of the core-mantle boundary. The geodynamic observations depend on the 3D distribution of density. Mineral physics scaling of seismic velocity and density under various assumptions, for example that heterogeneity is due to temperature variations alone, with appropriate uncertainties can be used to test hypotheses for the nature of the thermo-chemical structure of the mantle. Assuming temperature controls mantle heterogeneity, scaling seismic velocity to density using tomography models solely derived from seismic data results in poor fits to geodynamic observations. Jointly inverting seismic and geodynamic data, however, results in quite good fits to both data sets showing the non- uniqueness of the seismic data as well as the sensitivity of the geodynamic data to small changes in the seismic structure. We conclude that most seismic heterogeneity observed in the mantle can be explained by thermal variations. The misfit to data using our thermal model can mostly be explained by intrinsic low density in cratonic lithosphere and an intrinsic increase in density within the lower mantle Large Low Shear Velocity Provinces. We will discuss the sensitivity of our results to viscosity model as well as predictions and implications of our models.

Union Symposium

U05a - U5 New Discoveries in Deep Interior of the Earth and Planets

IUGG-2569

Mapping mantle electrical conductivity structure: progress status

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Electrical conductivity is one of the characteristic physical parameters of materials making up Earth's interior and is sensitive to variations of state-variables such as temperature, chemical composition, oxygen fugacity, water content, and melt. As a consequence, estimating mantle electrical conductivity structure is a potentially strong tool for mapping mantle chemistry, mineralogy and physical structure and presents a complementary method to seismic studies that seek to elucidate the elastic properties of the mantle. Deep electromagnetic (EM) induction studies, which provide information on the mantle electrical conductivity, have been the focus of increasing interest during the last years, mainly for three reasons. A primary reason is the recent growth in the amount of EM data available, especially from low-Earth orbiting satellite missions (Oersted, CHAMP, SAC-C, and Swarm). A second reason is the great interest in the characterization of the three-dimensional (3-D) properties of Earth's mantle on a global scale. Finally, growing interest in deep EM studies has also resulted from the significant methodological progress made during the last years both in data analysis and interpretation. In this talk I will present and discuss recent global and regional models of mantle conductivity structure derived from satellite and ground-based EM data. Topics for possible future research are also suggested.

Union Symposium

U05b - U5 New Discoveries in Deep Interior of the Earth and Planets

IUGG-1629

ULVZ locations can provide insight into their cause

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Seismic tomography reveals two large low shear velocity provinces (LLSVPs) in the lowermost mantle. Seismic studies also reveal much smaller-scale structures at the base of the mantle, ultra-low velocity zones (ULVZs), characterized by dramatic reductions in seismic velocity, high density, and possibly partial melting. The larger LLSVPs are hypothesized to be caused by primordial, compositional reservoirs (i.e., thermochemical piles) with slightly increased intrinsic density. The cause of ULVZs is widely debated, but hypotheses generally fall into two categories: (1) partial melting of normal mantle and (2) additional small-scale compositional heterogeneity. Here we examine how the positions and shapes of ULVZs are related to the much larger-scale LLSVPs. We explore whether the locations of ULVZs can provide insight into their cause. We perform numerical convection calculations in a partial sphere geometry, employing two sets of experiments; each of which includes thermochemical piles to represent LLSVPs. In one set of experiments, we simply examine the time-dependent locations of the hottest regions of the lowermost mantle. We find that the hottest regions, where partial melting could occur to explain ULVZs, are located well within thermochemical pile interiors. In the second set of experiments, we include an additional composition: a small volume of ultra-dense material to represent ULVZs. We find that the ultra-dense material accumulates within patches spotted along the margins of thermochemical piles. Both hypothetical causes of ULVZs lead to different morphologies and positions with respect to thermochemical piles, providing evidence that seismic observations of ULVZ location my provide insight into their cause.

Union Symposium

U05b - U5 New Discoveries in Deep Interior of the Earth and Planets

IUGG-1843

What can we learn about mantle dynamics using satellite gravity?

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Understanding the nature and the scales of mantle convection remains a debated question. Because they are driven by density anomalies and deflect interfaces, the flows are expected to contribute to gravity and topography variations. Information on the associated mass structure can thus be obtained using geodetic data, provided that these mantle signals have been identified in the datasets.

With the GOCE satellite mission, a new class of observations has become available to investigate Earth's mass distribution in a wide range of spatial scales: the small variations of the Earth's gravity vector. Highly sensitive to the geometry of the sources, these gravity gradients bring original information to decipher the Earth's dynamic processes, especially when the associated mass structure has a preferred orientation. Such oriented patterns can precisely arise from the deep flows and their interactions with lithospheric motions.

Here, we show how GRACE and GOCE satellite gravity data, including measured and reconstructed gravity gradients, can be analyzed in combination with bathymetric data, shear-velocity anomalies from global seismic tomography, and the distribution of volcanism, in order to understand how convective flows develop and interact at different scales within the Earth's mantle.

Union Symposium

U05b - U5 New Discoveries in Deep Interior of the Earth and Planets

IUGG-2295

East-west mantle geochemical hemispheres and its implications for a coupled supercontinent-mantle-core dynamics

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In order to decode the mantle geochemical structures in both spatial and compositional domains, a total of 6854 young basalt data consisting of five isotopic ratios of Sr, Nd and Pb from almost all tectonic settings (mid-ocean ridge, ocean island, arc and continent) have been statistically analyzed. It is found that the continental basalts are heavily concentrated in the eastern hemisphere, while other basalts are distributed evenly. Independent features hidden in the data have been extracted using multivariate analysis "Independent Component Analysis". Two independent components (IC1 and IC2) explain most of the sample variance (95%), and the third minor component (IC3) accounts for 4%. Therefore, almost all young basalts covering the whole globe plot on a single compositional plane, and can be explained by only two differentiation processes (i.e., melting and aqueous fluid-rock interaction). Of the two, IC2 represents 'anciently subducted aqueous fluid component' stored for 0.3 to 0.9 Gyr in the mantle, and defines the fluid component-rich (=positive IC2) eastern hemisphere. We have also found a striking geometrical similarity between the IC2 and the inner core hemispheric structures: the eastern hemisphere shows positive IC2 in the mantle and high seismic velocities in the inner core. Combining these constraints, we propose 'top-down hemispherical dynamics': focused subduction within and around the supercontinent has created a fluid component-rich hemisphere with a lower temperature, compared to the oceanic mantle. The colder hemisphere seems to have been anchored to the asthenosphere during the continental dispersal, and may affect the temperature and growth rate of the inner core, resulting in the coupled hemispherical structures in the mantle and the core.

Union Symposium

U05c - U5 New Discoveries in Deep Interior of the Earth and Planets

IUGG-2675

The geomagnetic field and life: New observations and insights

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The geomagnetic field that is generated by convection in Earth's outer core extends from Earth's interior into space and protects biosphere by shielding the surface from harmful solar particles and cosmic rays. Many questions, however, remain poorly understood and contentious. Such outstanding questions include whether the emergence of life on Earth was a consequence of the field's protection, how organisms respond to and utilize the direction and intensity gradient of the field, and how the field variation with time could impact the evolution of life on Earth. For examples, it was proposed that geomagnetic reversals/excursions might cause some genus and/or mass extinctions in the geological records; however, such links, whether causal or coincidental, are still debated. In the past decade, great efforts have been made to probe many of the above-mentioned complex and challenging questions, mainly through inter-disciplinary biogeomagnetism (fusing geomagnetism and biology), which investigates how representative organisms, from bacteria to animals, respond under known magnetic field conditions, as well as on geologic records as far back as the early Earth. Newly accumulated lines of evidence suggest that the geomagnetic field and its changes through time have directly and/or indirectly impacted the Earth's life and its evolution. In this talk, I will provide an overview of recent observations, progresses and potential breakthroughs in biogeomagnetism.

Union Symposium

U05c - U5 New Discoveries in Deep Interior of the Earth and Planets

IUGG-2972

Dynamos with no viscosity, an alternative to conventional dynamos

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We consider the inertia-free, inviscid model of the dynamo first proposed more than fifty years ago by Taylor as an appropriate model for the dynamical regime of the core. Estimates of the Rossby number and Ekman number for the Earth's core show that they are both tiny, and thus suggest that this regime is appropriate for the Earth's core. The resulting balance, termed magnetostrophic balance, must satisfy a special constraint first expounded by J. Bryan Taylor in 1963, namely that the longitudinal component of the Lorentz torque, when averaged over every cylinder coaxial with the rotation axis, must vanish. The technical nature of this constraint has hampered progress for decades. We report on our solutions for this system when mean-field dynamos are considered, in which the action of the small scales can be characterised by an alpha effect. We will reflect on the different characteristics of the solutions compared to dynamos in which viscosity plays a leading role.

Union Symposium

U05c - U5 New Discoveries in Deep Interior of the Earth and Planets

IUGG-3820

Imaging Earth's dynamo field from space

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Space-born measurements of the geomagnetic field started with the Soviet satellite Sputnik 3, very early on in the history of space exploration. But it took more than 20 years before reliable global maps of the geomagnetic field could be built, using such satellite data. The breakthrough came with the close-to-polar orbiting 1980 US MAGSAT satellite, which provided not only intensity, but also vector, measurements of the geomagnetic field. MAGSAT provided the first snapshot image of the Earth's dynamo field up to the highest spatial resolution with which it can be modeled, given the limits imposed by the overlapping field produced by rocks. Unfortunately MAGSAT flew only seven months and it took another 20 years before other similar models could be built. This eventually happened thanks to the very successful Danish Ørsted and German CHAMP satellites, launched in 1999 and 2000. These satellites made it possible to not only produce other high-resolution snapshots of the Earth's dynamo field in 2000, but also follow the detailed evolution of this field until beyond 2010, prompting considerable interest in the investigation of core field dynamics on decade and sub-decade time scales. Thanks to the launch of the next generation three-satellite Swarm mission of the European Space Agency on November 22, 2013, this dynamics can now be witnessed with even better spatio-temporal resolution. In this talk, we will review the progress made in imaging the magnetic field of Earth's dynamo from space over the past decades, with emphasis on the latest advances made possible thanks to the Swarm mission. We will also discuss what these advances could eventually bring to our understanding of the core dynamics.

Union Symposium

U05d - U5 New Discoveries in Deep Interior of the Earth and Planets

IUGG-1121

Vesta and ceres: Extant building blocks

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The simple paradigm describing the origin and evolution of the solar system is that about 1 million years after the beginning of the accretion of the solar system, a supernova explosion seeded the accreting material with ^{26}Al, whose half-life is 0.7 million years. Bodies that formed at this time trapped the heat of the radioactive decay of ^{26}Al, and this led to melting and differentiation of these bodies. Bodies that formed late after the ^{26}Al had decayed did not trap as much heat, remained cooler inside, and did not differentiate. These bodies remained wet. The accreted bodies constitute a set of dry and wet protoplanets of varying properties. These bodies are assumed to be the building blocks of the present-day terrestrial planets. The Dawn mission was designed to determine the properties of the two largest remaining intact building blocks, Vesta, a dry basaltic asteroid with a diameter of 530 km, and Ceres, a supposed wet hydrated silicate body with a diameter of 950 km. When Dawn arrived at Vesta, it discovered a body to first order as predicted from meteoritic evidence. Vesta was differentiated with an iron core of about 110 km radius and a eucritic crust, but no olivine mantle. This was not reason to discard the standard model, but rather to examine more carefully the processes by which such bodies evolve.

Dawn has now arrived at Ceres, our best example of a wet intact protoplanet. By the time of this symposium, we will have a zero-order assessment of the processes at work and have a measure of its physical properties. If, as we assume, these two bodies are the prototypical building blocks of the planets, they should better inform us of the starting material for the present day terrestrial planets.

Union Symposium

U05d - U5 New Discoveries in Deep Interior of the Earth and Planets

IUGG-2418

"Why Earth-mass planets are unlikely to be Earth-like (even when they are in the "habitable zone") "

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The explosion of exoplanet data has led to bodies approaching Earth mass and radius, some of which might even be close to the zone where effective temperatures are in the range of liquid water. The question arises as to whether these bodies are in fact “Earthlike” as many seem to be hoping. I will argue that this is unlikely because of the astonishing richness of phase space for planets: Radius, mass and orbital distance are vastly insufficient to characterize the nature of a planet. I will focus on two things in particular: the nature of an atmosphere and the amount of water present. In both cases, the particular amounts we have on Earth appear to be the outcome of a planetary formation process that is highly specific and unlikely to be similar in other planetary systems. For example, the amount of water delivered to Earth (of order a thousandth of Earth mass) could easily be either larger or smaller by a large amount in other systems. There coincidence of both ocean and dry land is a priori unlikely elsewhere. The atmosphere can similarly be highly variable both in mass and composition. Many other factors can also vary a lot, including whether the planet has a moon or a magnetic field (possibly related).

Union Symposium

U05d - U5 New Discoveries in Deep Interior of the Earth and Planets

IUGG-2885

Structure and dynamics of the Earth's inner core

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Inner core anisotropy was discovered more than 25 years using both seismic body wave and normal mode observations (e.g. Morelli at al, 1986, Woodhouse et al, 1986), finding cylindrical anisotropy with the fast axis aligned with the Earth's rotation axis. More recently, hemispherical anisotropy variations have been found in both body wave and normal mode data, with the west being more strongly anisotropic than the east (e.g. Tanaka & Hamaguchi, 1997, Deuss et al, 2010). However, it has proven difficult to reconcile both data types. Here, we try to reconcile body waves and modes, making a comprehensive model.

We find that a top layer with isotropic velocity of about 70km thick fits both the body wave and normal mode data. Hemispherical variations in isotropic velocity, with the west being slow and the east being fast, exist in the top 275 km of the inner core. Strong anisotropy starts below 70km depth, and only exists in a wedge in the western hemisphere, increasing in strength with depth. The location of the anisotropic wedge seems unrelated to the isotropic hemispheres found at the top of the inner core.

The isotropic hemispheres are most likely due to variations in solidification rate at the inner core boundary. The deeper anisotropic alignment of crystals is most likely due to a deformation process. Recent work fitting normal mode frequencies suggests that the top layer of the inner core may in fact be radially anisotropic with the fastest velocity perpendicular to the inner core boundary. Such radial anisotropy would be in line with the model proposed by Yoshida et al (1996) where the inner core grows preferentially near the equator, leading to a flow from the equator to the poles generating both the shallow radial anisotropy and deeper cylindrical anisotropy.

Union Symposium

U05p - U5 New Discoveries in Deep Interior of the Earth and Planets

U05p-377

Detection of slab-triggered mantle plumes in the Earth's lowermost mantle

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Mantle plume initiation in the lowermost mantle has long been discussed in Geodynamics. However, directly probing the plume origin in the lowermost mantle using seismic data has been a grand challenge. In this study, we detect a 350 km thick truncated cone-shape low-velocity structure in the Earth's lowermost mantle beneath Perm surrounded by a 240 km thick high-velocity D" structure, based on travel time analysis and forward waveform modeling of the observed anomalously broadened and azimuth-dependent S, S_{diff} waveforms in distance range from 95° to 110° from the seismic waves sampling lowermost mantle beneath Perm. The low velocity anomaly has diameters increasing from 400 km at the top to 800 km at the core-mantle boundary (CMB) and has velocity reductions varying from 0% at the top to -3.0% at about 240 km above the CMB and to -3.5% at the CMB. We suggest that the low velocity anomaly may represent a slab-triggered mantle plume in the lowermost mantle.

Union Symposium

U05p - U5 New Discoveries in Deep Interior of the Earth and Planets

U05p-378

New constraints on S-wave velocity structure near the western edge of the Pacific LLSVP

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S-wave velocity structure near the edge of the Pacific LLSVP has been examined by many researchers (He et al., 2006; He and Wen, 2009; Takeuchi et al., 2008; Idehara et al., 2013). They have mainly used the differential travel times of ScS-S observed by global or local broadband networks (e.g., IRIS GSN, F-net, CNDSN and so on). Here we add the new data of ScS–S and S–SKS travel time data obtained by NECESSArray and a temporal broadband ocean bottom seismograph network in the Philippine Sea by the Stagnant Slab Project (SSP-BBOBS) (Shiobara et al., 2005).

ScS–S anomalies observed by NECESSArray in conjunction with those by F-net, which covers the region beneath the eastern Micronesia, are roughly explained by the existing 3D S-wave models. However, S–SKS anomalies, which are affected by S-waves propagated near the base of the mantle beneath the western Micronesia and the north of New Britain Island, suddenly changes from positive in the eastern area to almost zero or slightly negative in the western, whereas all the models predict large positive anomalies without significant changes. To confirm this S-SKS observation, we further examined ScS–S anomalies observed by the SSP-BBOBS. Some data indicate nearly zero in the corresponding area although the data are scattered and still sparsely distributed. Since a low velocity anomaly beneath the New Guinea Island are confirmed by Takeuchi et al. (2008) and Idehara et al. (2013), our observation suggests that the Pacific LLSVP is separated beneath the north of New Britain Islands. The models of 3D mantle structure are possibly insufficient near the western edge of the Pacific LLSVP.
Acknowledgements. The authors are grateful to NECESSArray and SSP-BBOBS projects, IRIS and F-net for providing valuable data.

Union Symposium

U05p - U5 New Discoveries in Deep Interior of the Earth and Planets

U05p-379

Radial modes of the deep 2013 Okhotsk earthquake: Evidence for an implosive component in the context of transformational faulting

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We study the spectral amplitudes of the first two Earth radial modes, 0s0 and 1s0, excited by the Sea of Okhotsk earthquake of 24 May 2013, the largest deep event ever recorded, in the search for an isotropic component to its source. In contrast to the case of the 1994 Bolivian earthquake,we detect an implosive component of -6.9 E26 dyn*cm, equivalent to 2% of the full scalar moment, but 9% of the lone deviatoric component exciting the Earth's radial modes. This implosive component would be expected in the model of transformational faulting in which deep earthquake rupture nucleates and grows upon transformation of metastable olivine to ringwoodite in the cold subducting slab. This interpretation is confirmed by quantitative estimates (55 to 80 cm) of the thickness of the transformed shear zone, which scale favorably, relative to earthquake fault length, with the upper end of the range of laboratory results reported for ices, germanates and silicates.The resulting extent of the transformation in the metastable wedge is consistent with the local geometry of the deep slab, as recently determined by rupture modeling and aftershock distribution. Our results are in contrast to those for the two runner-up largest deep earthquakes, the 1994 Bolivian and 1970 Colombian shocks, for which a similar isotropic component could not be detected. We attribute this difference to variability in the ratio of isotropic to deviatoric components, which combined with the smaller size of the 1970 and 1994 events, would make any putative implosive component fall below detection levels, especially in the case of the 1970 Colombian earthquake for which only analog narrow-band records were available.

Union Symposium

U06a - U6 Data Assimilation and Inverse Problems in Geophysical Sciences

IUGG-1555

Data Assimilation: Past, Present and Future

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We introduce basic ideas and methods of data assimilation in meteorology and oceanography, and illustrates their progress from numerical weather prediction to ocean and climate studies. Novel applications to space physics and paleoclimate will be covered too.

We start with the best linear unbiased estimation of scalar temperature from several observations and show how to extend this to the typical situation of interest, in which one of the current "observations" is a prediction based on a dynamic model and past observations. We thus proceed from the scalar to the vector situation, and study information transfer from observed to unobserved variables. These simple steps are the basis of the sequential approach to combining information from models and observations; they include the

We next extend the models being used from systems of linear differential equations (Kalman, 1960) to systems of nonlinear partial differential equations governing planetary flows, and study advection of information from data-rich to data-poor regions. The duality of estimation and control — and thus of sequential and variational methods — is discussed, along with parameter estimation vs. state estimation.

Data assimilation for weather vs. climate is presented in discussing filters vs. smoothers (Wiener, 1949). Difficulties are emphasized, including strong nonlinearities; data availability, accuracy and diversity; as well as computing power and storage limitations.

Finally, we address paleoclimate issues, where the dates of the observations are as uncertain as their values. Bright perspectives for the future conclude the talk.

This introduction to data assimilation is based on joint work with many students and colleagues over three-and-one-half decades;
see http://web.atmos.ucla.edu/tcd//.

Union Symposium

U06a - U6 Data Assimilation and Inverse Problems in Geophysical Sciences

IUGG-2912

Snow data assimilation for numerical weather prediction

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Initialisation of land surface variables is a key component of Numerical Weather Prediction (NWP) systems. Current land data assimilation systems used to initialise NWP models include snow depth analysis, soil moisture analysis, soil temperature and snow temperature analysis. This paper presents the State-Of-The-Art snow data assimilation used for NWP. In the context of the European Cooperation in the field of Scientific and Technical Research on snow (COST action on snow, ES1404) an overview of the various snow observations used in NWP systems is given and the combined use of conventional observations and satellite data addressed. Based on the European Centre for Medium-Range Weather Forecast experience, a snow data assimilation method based on an Optimal Interpolation approach is presented. Using the ECMWF Integrated Forecasting System snow data assimilation impact is evaluated for different configurations of the snow data assimilation system. Results and impact on snow fields and NWP performance are presented and discussed. Both surface fields and low-level atmospheric variables are shown to be highly sensitive to the snow initialisation methods.

Union Symposium

U06a - U6 Data Assimilation and Inverse Problems in Geophysical Sciences

IUGG-3103

Scale-dependent ensemble covariance localization for ensemble-variational data assimilation

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An approach is presented for efficiently applying scale-dependent spatial covariance localization within an ensemble-variational (EnVar) data assimilation system. More severe localization is applied to small scales and less localization to large scales within the same single analysis procedure. It will be shown that such an approach leads necessarily to a reduction in the between-scale corrections. The approach is motivated by the challenge of assimilating all available observations in future high-resolution global NWP systems to simultaneously correct all scales resolved by the model and observations (i.e. from global scales down to convective scales). This is in contrast with most current operational systems that focus on either correcting only the relatively large scales or only the small scales. Examples will be given using an idealized 1-D system and a simple 2-D sea ice data assimilation system.

Union Symposium

U06b - U6 Data Assimilation and Inverse Problems in Geophysical Sciences

IUGG-0594

Time-varying gravity field and large-scale mass redistribution inferred from GNSS and Satellite Altimetry

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The low-degree gravity field can be inversed from Global Navigation Satellite Systems (GNSS) observations, but subjecting to large uncertainties due to effects of uneven GNSS distribution, less GNSS stations over oceans and higher-degree aliasing. In this paper, uncertainties and effects on low-degree estimates from global GNSS observations are investigated and assessed using different truncated degrees and selected GNSS network distribution based on different plate motion models. In addition, a Tikhonov regularization method is employed and compared. Results show GNSS networks have smaller effect on low degree estimates. Geocenter motion estimates from selected GNSS networks by different strategies are better with truncated degree 3, while C20 is best estimated from GNSS observations with truncated degree 4, and the Tikhonov regularization method is better than the usual least square method when compared to SLR solutions. Furthermore, since there are less or no stations over oceans, Global GNSS and ocean bottom pressure from satellite altimetry minus the temperature and salinity derived steric sea level change are jointly used to inverse the time-varying gravity field with up to degree 60 from 1998 to 2014. The characteristics of global larger-scale mass redistribution are addressed and compared with GRACE-based time varying gravity field. Some new results also are presented and discussed.

Union Symposium

U06b - U6 Data Assimilation and Inverse Problems in Geophysical Sciences

IUGG-1205

Twenty years of global seismic tomography using time domain waveform inversion: a review and recent progress.

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In the past 20 years, we developed several generations of global mantle shear velocity models based entirely on time domain waveform inversion. This implies computations of synthetic seismograms in 3D earth models. Until the advent of numerical wavefield computations, the method of choice relied on normal mode perturbation theory. I will describe how we built the framework of our imaging methodology in this context (e.g. Li and Romanowicz, 1995). Features of the method include, among others, windowing of waveforms to bring out contribution of weak amplitude phases, such as Sdiff, and a fast converging Gauss-Newton based inversion approach. With 3-component waveform data from several hundred globally distributed earthquakes, theresulting models achieved resolutions in the lower mantle at least equivalent to those using more standard approaches.

Recently, the Spectral Element Method (SEM) has been introduced to global seismology as a powerful numerical method to compute the seismic wavefield accurately in arbitrary 3D models (Komatitsch and Vilotte, 1998; Komatitsch and Tromp, 2002). Substituting the numerical SEM synthetics into our procedure was straightforward, the main drawback being the significantly increased cost of computation. We have therefore made choices, and introduced computational efficiencies, that have allowed us to construct three generations of mantle shear velocity models (SEMum, Lekic and Romanowicz, 2011; SEMum2, French et al., 2013; SEMUCB_WM1, French and Romanowicz, 2014). One of the advantages of the accurate wavefield computations is better resolution of low velocity regions in the mantle. I will describe the technical choices made and illustrate our latest results and current methodological improvements at the global and continental scale.

Union Symposium

U06b - U6 Data Assimilation and Inverse Problems in Geophysical Sciences

IUGG-3834

Variational assimilation of satellite observations and multiple river flow data in distributed flood forecasting modeling

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Data assimilation in distributed hydrologic presents many challenges: non-linear and discontinuous model structure, non-Gaussian/multiplicative errors, layers governed by different equations, complex topology of domains such as surface drainage and river networks. The variational approach, as compared to various Kalman and Montecarlo filters and smoothers, require much less restrictive hypothesis on model and error structures, but an adjoint model is to be build. This is also a peculiar task in hydrological modeling. We discuss the variational assimilation of gridded (land surface temperature LST and vegetation FAPAR) and point data (river flow at multiple locations) in the framework of an operational flood forecasting chain (Arno river, Italy). The model uses a coupled surface water/energy balance to link soil moisture to LST and FAPAR. Assimilation of these variables rather than soil moisture satellite estimates is here preferred because the higher accuracy and spatial resolution of the first and the need of substantial bias correction of the latter. Possible assimilation of new soil moisture products, upcoming from the SMAP mission, is also addressed. Two hindcast experiments are used for discussion. The first event, which in reality resulted in a false alarm, was a late summer very intense rainfall over quite dry soils. The batch assimilation of LST and FAPAR improves the flow prediction even at locations and lag-times where/when the flow data assimilation is not effective. The second event, with persistent winter rainfall on wet soils, resulted in the nearly flooding of the city of Pisa. The soil moisture update is not so relevant now, while the assimilation experiment highlights the extreme sensitivity to possible multiplicative biased errors in flow data.

Union Symposium

U06c - U6 Data Assimilation and Inverse Problems in Geophysical Sciences

IUGG-2296

Data assimilation in global mantle circulation models: theory and applications

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Data assimilation through fluid dynamic inverse theory allows geodynamicists to reconstruct the large scale heterogeneity structure of the Earth's mantle back in time. Although exceedingly demanding in computational terms, data assimilation thus opens powerful avenues for testing poorly known parameters in geodynamic models. Here we present the basic theory of the forward and inverse mantle convection problem, using the adjoint method as a computationally efficient way in computing the cost function gradient. We discuss geologic constraints, provide computational considerations relevant to the global mantle flow problem with about 1 billion finite elements, and explore the practicality of the method for use in high resolution mantle circulation models by restoring a representation of present day mantle heterogeneity derived from the global seismic shear wave study of Grand et al. (1997) back in time for the past 40 million years. An important result is our finding of a strong global minimum for the unknown initial condition, regardless of the assumed first guess for the initial heterogeneity structure, which we attribute to the uniqueness theorem by Serrin. Paleo mantle convection modelling will improve our ability to test our assumptions about the internal structure and dynamics of the Earth’s mantle against geologic observations.

Union Symposium

U06c - U6 Data Assimilation and Inverse Problems in Geophysical Sciences

IUGG-2757

Variational data assimilation in geomagnetism: Towards imaging the interior structure of planetary cores

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How should we best treat the rich record of geomagnetic and archaeomagnetic data? To date, most efforts are directed towards a parametric description of the data in time and space, with no reference to the internal fluid dynamics responsible for the changes in time (the secular variation). Beginning in 2007, the first efforts were made to couple the dynamics with the data analysis. Since then, various flavours of data assimilation have been developed, using either sequential or variational methods. For the pure prediction problem, relevant to meteorology, both methods are equally effective. But when the interest is in the interior structure of the planet, we find that the variational strand has its benefits.

In our work we seek to find a model of the magnetic field inside Earth's core that evolves in a way compatible with the observations of the field taken purely on the boundary. We need versions of the Navier-Stokes equation and the induction equation, that together determine the entire evolution of the system. To show how this can work under certain conditions, we will show the results of several end-to-end simulations in which exact boundary data are assimilated into a dynamical model. The unknown is the magnetic field configuration at the initial time, but by dint of the known forward problem, the magnetic field is known everywhere over all times. We will show the problems one may encounter with ambiguities that may exist in the inverse problem, and how they might be circumvented.

Union Symposium

U08a - U8 Geo-Monitoring in the 21st Century

IUGG-4275

Monitoring the dynamic Earth with geodetic observing systems

R. Gross[1]
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The Earth is a dynamic system---it has a fluid, mobile atmosphere and oceans, a continually changing global distribution of ice, snow, and water, a fluid core that is undergoing some type of hydromagnetic motion, a mantle both thermally convecting and rebounding from the glacial loading of the last ice age, and mobile tectonic plates. In addition, external forces due to the gravitational attraction of the Sun, Moon, and planets also act upon the Earth. These internal dynamical processes and external gravitational forces exert torques on the solid Earth, or displace its mass, thereby causing the Earth's rotation, gravitational field, and shape to change. Geodetic observing systems, both space-based and ground-based, provide the measurements of the Earth's rotation, gravitational field, and shape that are used to study the response of the Earth to these dynamical forces, thereby allowing inferences to be made about the internal structure and rheology of the Earth. In this presentation, the IAG's efforts to gain a better understanding of the dynamic Earth and its interacting systems through the use of geodetic measurements will be described, including the contributions of the IAG's measurement technique Services, scientific Commissions, and Global Geodetic Observing System.

Union Symposium

U08a - U8 Geo-Monitoring in the 21st Century

IUGG-5414

The challenges of atmospheric monitoring in the 21st century

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Over the last two decades our ability to monitor the atmosphere has taken some very significant steps forward, particularly in the area of satellite observations. New instruments and new measurement techniques have allowed us to have a much more nuanced and detailed view of the atmosphere and its processes. For some components we now have records that approach “climate length” and the list is growing, although not as fast as some people would like.

However there are new challenges on the horizon as the earth grapples with a very large industrialized population and the multitude of issues that come with that reality. We need to look ahead at the requirements of nations for their regulatory regimes as well as to the emerging issues of the science. We also need to better integrate the various measurement methods from space, aircraft, ships and the surface into a cohesive whole to round out the picture of the atmosphere.

This talk will give an overview of some of the emerging issues, with an emphasis on the space component, and see how we can move in the future to the needed view of the atmosphere.

Union Symposium

U08a - U8 Geo-Monitoring in the 21st Century

IUGG-5738

The role of geomagnetic field monitoring in understanding Earth system processes

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The geodynamo creates the Earth's main magnetic field, which permeates all parts of the solid Earth and extends through the atmosphere into space. Solar electromagnetic radiation creates the ionosphere, and the interaction of the main field with the solar wind plasma creates the magnetosphere. In both regions electric fields drive currents which are sources of magnetic fields which induce currents in the oceans and the solid earth, creating further magnetic fields. IAGA's science therefore extends to all parts of the Earth system and involves times scales ranging from millennia to milliseconds. The Earth has 'self-monitored' and recorded magnetic field changes in crustal rocks over much of the planet's history, and man-made fired materials containing magnetic minerals have preserved records of contemporary magnetic fields. Quantitative instrumental measurements of the magnetic field go back almost 500 years and modern instrumentation in the global network of permanent magnetic observatories and on-board satellites now provides data of excellent quality, geographical coverage and sampling rate.

We will discuss the evolution of geomagnetic observations into the 21st century, illustrating how they provide data for both research (e.g. reversals) and modern risks of societal concern such as space weather impacts. Answering many important questions in basic and applied research demands a multidisciplinary approach, and the ability to integrate different types of data. The challenges and opportunities will be illustrated by examples.

Union Symposium

U08b - U8 Geo-Monitoring in the 21st Century

IUGG-2866

Creating a federated European data center that serves the widest amount of seismic data

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The European Integrated Data Archive (EIDA; www.orfeus-eu.org/eida) is the federated Data Centre within ORFEUS, providing open access to high quality seismic data from data archives distributed across Europe. EIDA today connects 9 large data archives providing standard broadband seismic data from permanent networks across Europe, and is supplemented by a limited number of institutions that also provide access to temporary broadband deployments, accelerometric and infrasound data.

EIDA is core component of the Seismology part of EPOS (European Pate Observing System), which aims to coordinate Earth Science data in Europe. Within EPOS, EIDA will be used to collect and distribute a significantly increased set of seismological and related data. In particular, EIDA will provide comprehensive access to accelerometric data, with dedicated portals offering data selection targeted towards strong motion; temporary broadband seismic deployments across Europe (including experiments past eg TopoIberia and future eg AlpArray); OBS data recorded by European institutions; all seismic and infrasound data recorded by the EPOS Near Fault Observatory and Volcano Observatory communities; and accelerometric data recorded within structures.

EIDA is thus entering in a phase of rapid growth, in terms of the number of contributing data archives, the volume of these archives, the variability of the data, as well as the number of users and the volume of downloads. To deal with these

issues, we are developing the next generation EIDA (EIDA NG) software. EIDA NG must also serve more complex user requirements and offer extended services. This presentation documents the current extent of the EIDA archives, and highlights the vision for EIDA within EPOS, and the plan for developing EIDA NG.

Union Symposium

U08b - U8 Geo-Monitoring in the 21st Century

IUGG-5427

Gravitational geodesy as basis for geo-monitoring: progress in relativistic geodesy and gravimetry with quantum sensors

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Quantum sensors and advanced laser physics enable new measurement methods for geodetic geo-monitoring. The recently started Collaborative Research Center „Relativistic geodesy and gravimetry with quantum sensors (geo-Q)“ at Leibniz Universität Hannover is dedicated to develop sensors and modeling to increase the gravity field resolution and accuracy. The focus is on three complementary fields: laser interferometry systems for satellite gravimetry, atomic gravity sensors for the observation of regional and local mass variations, and atomic clocks in networks to explore perspectives for a relativistic gravity potential and height reference.

Union Symposium

U08b - U8 Geo-Monitoring in the 21st Century

IUGG-5785

Water spies in the sky

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Over the past decade, the hydrologic community has experienced a paradigm shift in water research, whichhas fostered an increased attention toward the comprehension of the physical processes underlying thewater cycle. Water processes are inherently complex to observe and model: they are characterized bymulti-scale and highly spatio-temporal heterogeneous phenomena, which demand sophisticated andversatile measurement techniques. Further, hydrological processes are highly dependent on geography andclimate and, therefore, knowledge of phenomena occurring in specific regions is difficult to extrapolate toungauged areas.Toward a better comprehension of water processes, recent efforts have been devoted to the design anddevelopment of novel strategies for hydrological data acquisition. This surge of novel observationalmethodologies has enriched the hydrological dataset by often resorting to water-unintended andhigh-tech devices. These innovative observational methodologies aim at overcoming informationscarcity and improving data quality through more detailed insight on hydrological phenomena atcompetitive costs.In this talk, we present a novel approach for the observation of surface waters. Leveraging onimage analysis, the approach aims at providing non-invasive, low-cost, and potentially continuoussurface flow observations at refined space resolution. Inspired from traditional optical techniquesfor flow measurements in laboratory environments, the approach consist of capturing images offlow processes and of reconstructing flow regime in small to large natural regions.Tested in an array of field experiments, the methodology has proved sufficiently accurate atestimating surface flow velocity. Toward the continuous monitoring of hydrological processes, apermanent measurement station has been installed on the Tiber River, Rome, Italy to test theapproach in low to high flow conditions. At the same time, considerable efforts have been devotedto the integration of image analysis techniques and Unmanned Aerial Vehicle technology todevelop an aerial sensing platform for surface flow observations. The platform allows for surveyingmedium to large scale areas that are potentially difficult-to-access with standard equipment orgeographically complex.This transformative approach is expected to considerably extend the sensing capability of ourcommunity by enabling unprecedented measurements in unexplored areas. Research fields thatare foreseen to highly benefit from the use of the methodology include: catchment dynamicsmodeling, erosion dynamics, sediment transport, landscape evolution, and water contamination.

Union Symposium

U08p - U8 Geo-Monitoring in the 21st Century

U08p-232

Vernal point in the study and monitoring of earth sciences phenomena

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For the study of the earth as a dynamic system, it was necessary to have a natural chronometer in order to coordinate and classify the observations i.e. synchronize the earth sciences phenomena (e.g. geology, geophysics, etc.). It was proposed that the natural chronometer on earth was the retrograde motion of the vernal point. It enters into the Aquarius Constellation (declination 11.5 °S) on March 20, 1940. On earth this entry was verify through: (a) Stability of the magnetic equator since 1940. (b) The greater intensity of equatorial electrojet (EEJ) in Peru and Bolivia since 1940. (c) In 1940 in the astrological sign of Taurus the conjunction of Jupiter and Saturn happened on August 7, October 19 and also on February 15, 1941. (d) In the solar eclipse of March 27, 1941, the conical shadow enters parallel from latitude 11 ° S to 13 ° S over the area where the magnetic Ecuador stabilizes in 1940. (e) Greater solar activity since 1940 (Usoskin Ilya G., et al. 2003). (f) Between 1915 and 2014 the minimum level (3806,48 m) of Lake Titicaca (Peru-Bolivia) was observed in 1942 (SENAMHI-Peru) (g) The phenomenon of El Nino of 1940-1942 was one of the strongest and most durable (NOAA, 1994); which generated a global climatic anomaly in the troposphere and stratosphere of the Northern Hemisphere (Bronnimann S, et al. 2004). (h) The variation of the temperature of the Earth between 1861 and 2014 had a rise in the year of 1940 to the zeros degrees; subsequently the temperature stabilizes and then ascends. Besides, there was evidence that the Incas studied the retrograde movement of the vernal point in the Temple of the Sun located in Ingapirca (Ecuador). A correlation between earth sciences phenomena and vernal point were found.

Union Symposium

U08p - U8 Geo-Monitoring in the 21st Century

U08p-233

WebGIS technologies for monitoring and analysis of natural processes

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We consider two geoinformation technologies for monitoring and analysis of natural processes: webGIS platform and web-GIS, integrated into the monitoring system.
The webGIS platform consists of two GISs: SeismoMap and GeoTime 3. SeismoMap is implemented as a thin client. It is designed for a wide range of users. SeismoMap daily calculates and publishes 3 types of spatio-temporal fields: the fields of background and current seismic activity and the field of seismic anomalies (change-point field). API Google Maps is used for displaying seismological data in geographical context. GeoTime 3 is designed for the study of geodynamic processes. It is implemented in client-server architecture and intended for Earth Science specialists. GeoTime starts with the same data as SeismoMap. GeoTime tools allow one to download and analyze additional spatial and spatio-temporal data from remote or local servers. The webGIS platform prototype is available at http://dcs.isa.ru/geo/2 (IITP RAS) and http://saltlab.emsd.ru/server2 (Kamchatka Branch of the Geophysical Survey RAS).
The second technology is implemented in webGIS GeoESIMO, which is integrated into the Unified System of Information on the World Ocean http://portal.esimo.ru/portal/. The input data are spatial and spatio-temporal vector and grid-based data on atmospheric and hydrological processes. GeoESIMO analytical tools support visual exploration with animated visualization of one or more processes, interactive measurements and spatio-temporal modeling. Demo version is available at http://www.geo.iitp.ru/esimo/.
Case studies of environmental analysis and decision support in critical situations are considered. The examples demonstrate that both technologies are efficient for monitoring and analysis of natural and man-made processes.

Union Symposium

U08p - U8 Geo-Monitoring in the 21st Century

U08p-234

Wavelet analysis of GRACE K-band range rate measurements related to Urmia basin in Iran

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Previous spaceborn approaches show the desiccation of Lake Urmia during the first decade of the present century. We present a wavelet based method to analyze GRACE level 1B K-band range rate time series corresponding to Urmia basin. On the one hand, direct corrected range rates between 2005 and 2009, related to the basin have been used to construct an unevenly spaced time series. On the other hand, monthly mean measurements of the same type create a uniform time series. So we introduce a wavelet based least-squares spectral analysis method as an alternative scheme of classical least squares spectral analysis, in order to access a time- (pseudo) frequency representation of irregularly sampled mentioned time series. At the same time classical wavelet transformation will be used to analyze uniform monthly averaged time series.
The results are in good agreement with analyzed modeled total water storage changes in Urmia basin and its corresponding recorded precipitation series as well as similar previous research findings.

Union Symposium

U08p - U8 Geo-Monitoring in the 21st Century

U08p-235

Analysis of the magnetic data from NEMO-SN1 cabled seafloor observatory (off-shore Eastern Sicily, Italy)

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The NEMO-SN1 cabled seafloor observatory deployed at around 2 km depth and 25 km off-shore eastern Sicily (Italy) is an important node of the distributed pan-European infrastructure EMSO (European Multidisciplinary Seafloor and water-column Observatory, www.e'EN-GB'>sensors, including a module with vector and scalar magnetometers displaced 10-m from the observatory main frame. The point of observation is of great interest because it lies in one of the most active tectonic and volcanic areas of the Mediterranean. Tectonic activity marks this area as a seismic district with the highest hazard exposition in Italy, while volcanic activity is mainly due to the presence of the largest volcanic edifice in Europe, Mt. Etna. We analyze 3 months of 2012 magnetic data in the frequency domain, and, through the reconstruction of a vertical pseudo-section of the apparent conductivity, we are able to estimate the crustal and lithospheric depths underneath the deployment site, confirming the values that were previously obtained by seismological studies. We thus propose our method for crustal and lithospheric thickness estimation complementary to usual methods in seismology and particularly interesting for applications to still poorly known areas like the seafloor.

Union Symposium

U08p - U8 Geo-Monitoring in the 21st Century

U08p-236

Satellite observations of enhanced trace gas emissions from wildfires during the 2010-11 La Niña across northern Australia

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The 2010-11 La Niña was one of the strongest events in Australia on record. As a consequence, large parts of northern Australia experienced higher than average rainfall peaking in late 2010 and early 2011 and resulting in one of the wettest "dry" season in this region. Due to extreme rainfall events, abundant vegetation growth resulted in exceptionally high biomass accumulation. In the following dry season, an unusual high number of wildfires with increased intensity were observed in this region. These fires released large amounts of trace gases and aerosols into the atmosphere.

In this study, satellite-derived information about vegetation, fire intensity, and selected trace gases (e.g. NO2, CO, HCHO) from different satellite sensors is used to quantify the effect of the 2010-11 La Niña on the release of trace gas emissions in northern Australia. The release of NOx, for instance, was about two times as large as it was the years before on average.

Union Symposium

U08p - U8 Geo-Monitoring in the 21st Century

U08p-237

Study of reservoir permeability using water level monitoring and pore-scale modelling based on X-ray microtomography scanning of the rock samples

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Precise multi-scale determination of the reservoir's permeability is an important and sometimes complicated task. In order to assess large scale permeability of the studied aquifer horizon we monitored water levels at 'Mikhnevo' geophysical observatory (located at Great Russian Plane). Moreover, seismic and meteorologic records were also performed during the same time period. During well drilling some core and drilling cut materials was collected and studied using X-ray microtomography method. Based on the segmented 3D images of the pore structure effective micro-scale permeabilities were determined by solving Stokes equation. In addition, we studied thin-sections and performed detailed geological survey of all aquifer's horizons, which resulted in detailed geophysical data along the well. Pumping test was used to determine upper (43-56 m) and lower (92-115 m) horizons' permeability. Permeability of the carbonate reservoir was also calculated based on phase shift analysis between daily tidal components. The latter were extracted from water level and surface variations using calculations with ETERNA 3.0 package. Unpressurized horizon mainly characterized by lunar-solar wave of type K_1. Pressurized horizon characterized with 8 different types of tidal waves among which lunar type wave M_2 is the most influential. Permeabilities determined using M_2 analysis result in permabilities varying from 250 to 450 mD and are comparable with pumping test and pore-scale estimations.

Union Symposium

U08p - U8 Geo-Monitoring in the 21st Century

U08p-238

Monitoring subsidence of railway network from InSAR technology

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One of the most dangerous geological disasters is land subsidence especially if it happens in urban areas. Railway network plays important role in modern life of more populated cities. This large scale man-made linear construction is vulnerable to land subsidence. Therefore they need to be monitored permanently. Satellite visibility and traffic jam issues are serious obstacles for GPS and other geodetic measurement techniques (point-base measurement techniques) respectively to monitor the subsidence of railway network in crowded urban areas. Furthermore these techniques mostly make point-based measurements. Interferometric Synthetic Aperture Radar (InSAR) provides permanent and high resolution area-based measurements during day and night in all-weather conditions. Sensitive to the terrain motion, InSAR is able to provide dense information related to the land subsidence efficiently, economically and effectively.

In this study we analyzed complex single look Advanced Synthetic Aperture Radar (ASAR) images of Envisat satellite recorded from 2003 to 2009 to estimate the land subsidence of railway network in Tehran. To do that, interferograms were formed from proper co-registered master and slave images. After removing the topography effect, phase differences of interferogram were unwrapped to be used for land subsidence estimation.

Our analysis from differential interferogam and coherence maps (orbit 378) shows the land subsidence between 2 cm and 6 cm over this period of time for different locations of the railway network. We validated these result internally by defining interferograms from orbit 149. We will validate our result externally against ground based data or against other satellite mission like TerraSAR-X.

Union Symposium

U09a - U9 Revolutions in Earth Sciences: from Different Spheres to a Common Globe

IUGG-4228

Geophysics, patronage, and national needs: IAGA from its founding to the cold war

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The International Association for Geomagnetism and Aeronomy, whose origins can be traced back before even the founding of the International Union of Geodesy and Geophysics [IUGG] in 1919, gained its current name in 1954. Its progression from an IUGG Section to a self-standing association reflected the traditional pattern of all scientific fields: increased specialization occurred when the research community grew large enough that new professional structures were needed to promote, nurture, and evaluate research in burgeoning subfields. But geomagnetism and aeronomy grew particularly rapidly in the second half of the twentieth century. One reason they did so was that nation-states gave strong support to these disciplines. In particular, operational requirements of national military establishments in leading scientific nations after World War II meant that engineers and researchers needed to understand the properties of the upper atmospheric and ionosphere in order to maintain essential military communications and to successfully operate nuclear-tipped ballistic missiles, a key weapons system during the Cold War.

How these developments unfolded--and how the experience of IAGA researchers compared to those in other branches of geophysics in this period--will provide the focus for this historical exploration

Union Symposium

U09a - U9 Revolutions in Earth Sciences: from Different Spheres to a Common Globe

IUGG-4341

Predicting the atmosphere and the progress toward Earth-system science

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Scientific knowledge about the atmosphere has advanced hugely over the past 40 years not least because of a revolution in making global observations (from space), in effectively using these observations to initialize predictions, in modelling the global system, and in forecasting the weather. A number of the techniques that have been developed are transferable to other components of the Earth system. Already global weather modelling systems are being extended into cognate areas such as atmospheric composition, hydrology, as well as land, ice and ocean interactions.

This talk will survey the key advances and set out avenues where further progress can be made towards a truly integrated Earth-system approach.

Union Symposium

U09a - U9 Revolutions in Earth Sciences: from Different Spheres to a Common Globe

IUGG-5211

From different spheres to the Global Geodetic Observing System

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Ideas of a spherical Earth go back to Pythagoras of Samos (ca. 570-500 BC); the first measurement of the Earth's radius was done by Eratosthenes of Cyrene (ca. 275-195 BC). After Claudius Ptolemy's Great Treatise (ca. 90-165 AD) with spherical coordinates of about 1000 stars and 8000 terrestrial points there was silence in geodesy until Nicolaus Copernicus (1473-1543) formulated the heliocentric system and Isaac Newton (1643-1727) postulated an ellipsoid as the Earth's figure. Recent geodesy started with J. J. Baeyer (1794-1885) who initiated in 1861 the measurement of deviations from an ellipsoid and founded the International Geodetic Association (1886).

Geodetic research focusses today on temporal variations of the geometry (surface shape) and gravity (mass displacements) in the System Earth providing the basis for studying the phenomena and processes of global change, including climate change and geodynamics. Three principal revolutions enable its precise measurement and representation: (1) the evolution of geodetic space methods (radio astronomy and satellite geodesy), (2) the development of precise clocks, replacing mechanical distance and gravity measurements by travel times, and (3) the availability of powerful computers allowing the processing of the extensive amount of data.

The International Association of Geodesy established the Global Geodetic Observing System (GGOS) for continuous, high precision, representation of geometric and gravimetric changes in the Earth System. A network of more than 1000 observatories is coordinated by 14 Scientific Services and the results available in the Internet provide findings on variation in the atmosphere (ionosphere and neutrosphere), hydrosphere, and solid Earth. Most important results are demonstrated in the presentation.

Union Symposium

U09b - U9 Revolutions in Earth Sciences: from Different Spheres to a Common Globe

IUGG-3808

The 140 year voyage of ocean discovery.

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The oceans' importance to life on earth has long been recognized. However, the challenges of observing and understanding that role have been, and remain, enormous. There have been three phases in addressing these challenges. The first, lasting almost 100 years, from the voyage of HMS Challenger in the 1870s to the advent of the micro-electronic age in the 1960s, slowly defined the global-scale distribution of physical and chemical properties. In turn these revealed the circulation and gave glimpses of the impact of physics and chemistry on marine life. In the latter part of the 20th century new technologies, (including satellite remote sensing and computer modeling), a variety of socio-economic drivers and a small number of ambitious international projects finally allowed us to consider the ocean as a global entity and to study its variability. Only in the 21st century have we have been able to observe and monitor the processes within the ocean that are crucial to understanding the oceans' role in the global earth system.

The talk will describe key ocean science developments in this 140 year period.

Union Symposium

U09b - U9 Revolutions in Earth Sciences: from Different Spheres to a Common Globe

IUGG-3831

Megatrends in hydrology: Projecting the future from lessons learned from the past

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If one traces the history of development of hydrology over the past one hundred years one can discern distinct eras in terms of research questions, methods and ideas. At the beginning of the 20th century national hydrological services were established to address questions of flood design and land management, and the methods used were largely empirical. To overcome that subjectivity the next era of hydrological research introduced a systems approach, but it was soon realized that it was constrained by what is in the data. The next era that followed therefore paid explicit attention to hydrologic processes. Over time came the realization that the hydrologic system is more complex than the mere addition of several small scale constituent processes, and this gave rise to a new era of interdisciplinary hydrologic research. Eventually, even this geosciences view was found wanting, in terms of its ability to fully capture the various feedbacks within the earth system. These deficiencies are accentuated with the advent of the Anthropocene, where the human footprint is dominant. Increasingly it was realized that humans must be treated as an integral part of the earth system and the feedbacks between humans and water need to be explicitly accounted for in framing the hydrological cycle and the design of data collection schemes. This talk will review these major eras of hydrological research in the 20th century and we will show that, in spite of differences in detail, some common features remained right through all of these major eras. From the prism of this understanding of the past, we will then provide an admittedly subjective outlook towards current and future research trends in hydrology.

Union Symposium

U09b - U9 Revolutions in Earth Sciences: from Different Spheres to a Common Globe

IUGG-5183

"how climate modelling changed a discipline: Epistemic authority and marginalisation in climatology, 1960s to 1980s."

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In the year 2000, the Geographical Institute of the ETH Zurich was renamed as «Institute for Climate Research». The renaming reflected the radical and international change of the discipline that dealt with climate. In the 19th and 20th Century, climatology was a field within geography, and climate was understood as a stationary condition of the atmosphere, associated with specific places and related to human sensation. This traditional concept was then challenged by a new notion of climate. A new generation of climate scientists, typically trained in Meteorology or Physics, depicted climate as a physical-mathematical and global variable, and began to use computer models as a tool to investigate climate, and to eventually predict its future changes. Climate modelling has fundamentally changed knowledge production and influenced perception and interest in climate. It thus raised the question: who had the epistemic authority in climate research.

The change of epistemic standards and the shift towards a modern climate science, though, was not a linear one. Traditional climatologists were skeptical and feared the marginalization of their own approach, while others were more open towards the new tools and tried to incorporate the new ideas. Others were more open towards the new approach and tried to incorporate it without turning away from the traditional ones. This paper will trace fundamental changes in climatology and the negotiation of approaches, directions and their epistemic authority for the case of Germany in the period from about 1960 to 1980. This study is part of a larger project investigating the rise of climate modelling and the controversies and negotiations it caused in its formative period from about 1960 to 1985 in the USA, Great Britain, Germany and Sweden.

Union Symposium

U09c - U9 Revolutions in Earth Sciences: from Different Spheres to a Common Globe

IUGG-2950

Revolution and continuity: Seismology in the 20th century

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Any scientific discipline has seen huge changes in the late 20th century as a result of computer and internet technology, and seismology is no exception. Computer power allows modelling exercises that could hardly have been dreamt of 100 years ago, and rapid exchange of data is particularly appropriate in studying the highly dynamic phenomenon of earthquakes. But it is interesting to see also how the fundamentals of observational seismology have followed a continuous thread since the start of modern seismology in 1889 with the first recorded teleseism by Rebeur-Paschwitz at Potsdam. Rebeur-Paschwitz's ideas for a global monitoring network were quickly realised by John Milne, with support from the British Association for the Advancement of Science. The "Shide Circulars", the first global earthquake bulletins, were published by Milne from 1899 until his death in 1913. The work of publishing bulletins of earthquake locations of global span then devolved upon the International Seismological Summary, with headquarters at Oxford, which evolved subsequently into the present International Seismological Centre, which recently celebrated its 50thanniversary.

In this period, two great advances occurred in understanding the causes of earthquakes. The first was Reid's work in California after 1906 on elastic rebound and the dynamics of faulting. This established the proximate cause of earthquakes, but the great advance in understanding the ultimate cause came with the plate tectonics revolution in the 1960s. This has led to the development of the science of seismic hazard. Seismologists today can actually make a contribution to protecting society from this most destructive of natural hazards.

Union Symposium

U09c - U9 Revolutions in Earth Sciences: from Different Spheres to a Common Globe

IUGG-4454

One science or many? Geophysics and the founding and evolution of the IUGG

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The Great War of 1914-1918 disrupted the organizational structure of many sciences and in the process opened a space for a new phase in the history of geophysics. Prior to the war, a plethora of international academies diffracted geophysics into numerous, separately isolated specialties: seismology, meteorology, terrestrial magnetism, geodesy, etc. Moreover, these specialties were treated as sciences in service to the state, such that national representatives to international bodies were almost always functionaries of state weather bureaus, geodetic surveying services, etc. Very few academic researchers could participate. After the war, a single international organization, the International Union for Geodesy and Geophysics, pulled many of these specialties together and used new means to involve a broader array of scientists. Nevertheless, IUGG was divided into half a dozen special Sections or Associations, leaving the question open: Just how much were the geophysical sciences unified? How much were they independent? In the decades since the founding of IUGG in 1919, this creative tension between unity and diversity has been ever-present. The history of IUGG evidences many instances of adapting to and encouraging research about the Earth in inherently interdisciplinary and flexible ways. Its history provides some of the best examples of the mutability of scientific fields in the 20th century.