IAHS (Hydrology)

HS01a - HS01 Changes in Flood Risk and Perception in Catchments and Cities

IUGG-0006

On correlation between urban development, land subsidence and flooding phenomena in Jakarta

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Jakarta is the capital city of Indonesia with a population of about 9.5 million people, inhabiting an area of about 660 square-km. It is located within a deltaic plain and passes by 13 natural and artificial rivers. In the last three decades, urban development of Jakarta has grown very rapidly in the sectors of industry, trade, transportation, real estate and many others, which has caused several negative environmental impacts. In turns Jakarta is then prone toward a few natural hazards, mainly land subsidence and flooding. In general, based on geodetic measurement methods (e.g. Leveling, GPS surveys, and InSAR), conducted since 1982 up to 2014, it is obtained that land subsidence in Jakarta exhibits spatial and temporal variations, with the typical rates of about 5 to 10 cm/year. In general, the impacts of land subsidence in Jakarta can be seen in the forms of cracking of permanent constructions and roads, changes in river canal and drain flow systems, wider expansion of coastal and/or inland flooding areas, and malfunction of drainage system. Several areas along the coast of Jakarta already have experienced tidal flooding during high tide periods. These coastal flooding usually occurs in the areas with relatively large subsidence rates. Subsidence in the areas along the rivers which are flowing throughout Jakarta will also worsen the impacts of riverine flooding. The changes in river canal and drain flow systems and malfunction of drainage system due to land subsidence will also aggravate the flooding. Land subsidence will have direct and indirect affects with the flooding in Jakarta, both in coastal or inland areas. This paper analyzes and discusses the characteristics of correlation between urban development, land subsidence and flooding phenomena in Jakarta.

IAHS (Hydrology)

HS01a - HS01 Changes in Flood Risk and Perception in Catchments and Cities

IUGG-0055

Urban flooding evolving and the drivers of Dongguan City in southern China

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Dongguan is a city in southern China whom has been observed the rapidest development in China since China's reforming and opening. Dongguan City, from a small agricultural county, has become a modern metropolitan with over 10 million population and over 80% urbanization rate in the past 3 decades. Unfortunately, with the rapid development, the urban flooding is getting worse and worse, the flood damages have been increasing. This paper, collected the observed flooding in the past decades, analysis the evolving of the urban flooding, and found that there are several obvious characteristics. First the urban flooding occurs more sensitive to precipitation, that means the threshold precipitation causing urban flooding is getting less and less, thus causing high frequent urban flooding and higher flood damages, and for this reason, Dongguan is now in a very situation that urban flooding is observed even if a medium precipitation. Secondly, the magnitude of the urban flooding has been increasing, including bigger inundation area and higher inundation water depth, thus causing more traffic jam. Thirdly the casualties decrease from the peak at ten years age, now the reported death toll is very low. The authors analysis the drivers caused this changes, and attributed them as increasing of the no-infiltration surface rate due to the rapid urbanization, higher intensity and more frequently extreme precipitation caused by the combed reason of climate changes and human activities, and the improved urban flood management.

IAHS (Hydrology)

HS01a - HS01 Changes in Flood Risk and Perception in Catchments and Cities

IUGG-0063

Influence of urban land cover changes for the exposure of European cities to flooding during high-intensity rainfall events.

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The extent and location of impervious surfaces within urban areas due to past and present city development strongly affects the amount and velocity of run-off during high-intensity rainfall and consequently influences the exposure of cities towards flooding. The frequency and intensity of extreme rainfall are expected to increase in many places due to climate change and thus further exacerbate the risk of pluvial flooding. Improved knowledge of the impacts of both urban land cover changes and climate change towards the risk of flooding in urban areas is needed when planning for climate proof cities. This paper examines the influence of recent changes in urban land cover, under present and future climatic conditions, on the exposure of cities to pluvial flooding. Eight European cities are included in the analyses, representing different climatic conditions and historical urbanisation trends within Europe. A combined hydrological-hydrodynamic modelling and remote sensing approach is used to simulate the occurrence of a range of extreme rainfall events under current and expected future climatic conditions, and for different levels of urbanisation, which corresponds to historical (1984) and current (2014) urban land cover. Landsat satellite imagery are analysed to quantify historical changes in impervious surfaces. The outputs of the remote sensing analyses are combined with regionally downscaled estimates of current and expected future rainfall extremes to enable 2D overland flow simulations and flood hazard assessments, and to compare the relative influence of land cover changes with that of expected climate change. Preliminary results confirm that recent land cover changes within major European cities can play a central role for the cities' exposure to flooding.

IAHS (Hydrology)

HS01a - HS01 Changes in Flood Risk and Perception in Catchments and Cities

IUGG-0071

Spatio-temporal changes of urban areas patterns and their impact on 100 urban catchments hydrology

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It is often argued that urban areas play a significant role in the catchments hydrology, but previous studies reported disparate results of urbanization impacts on stream flow. This might stem either from the difficulty to quantify the historical flow changes attributed to urbanization only or from the inability to decipher what types of urban planning is more critical for flows. In this study, we applied a hydrological model on 100 urban catchments in the United States and quantified the flow changes due to urbanization. Then, in a second step, we link these flow changes to spatio-temporal changes of urban/impervious surface, while often the fraction of urban area is used. We argue that these spatial changes of urban areas can be more precisely characterized by landscape metrics, which enable analyzing the patterns of historical urban growth. Landscape metrics combine the richness (the number) and evenness (the spatial distribution) of patch types represented on the landscape. Urbanization patterns within the framework of patch analysis have been widely studied but to our best knowledge previous research work has not linked them to catchments hydrological behaviors.
In this study, we show the relation between the long-term change on stream flow using hydrological model and different landscape metrics of urbanized catchments. The Patch analysis was used to quantify the fragmentation of urban landscape pattern. This analysis can help understand why the impact on catchment hydrology of the same urban growth rate can be so diverse according to its spatial distribution.

IAHS (Hydrology)

HS01a - HS01 Changes in Flood Risk and Perception in Catchments and Cities

IUGG-0092

Analyzing the effect of urbanization on flood characteristics at catchment levels

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It is increasingly recognized that the land-use change, especially urbanization has influenced hydrological attributes intensely. Flood characteristics variation could likewise increase flood risks and pose higher demand on water management. The paper aims to evaluate temporal and spatial processes of urbanization affecting flood events at catchment level. The study sites were Xiaoqinhe catchment and its sub-catchments, a part of lower Yellow river basin in northern China. Historic cities Jinan and Zibo in the area have experienced dramatic urban expansion in recent decades, about 5 percent growth of urban build-up area annually from 1980s to 2010s, and also pressed alarm for increasing flood disasters. In the paper, a HEC-HMS model was set up to simulate flood processes for different land-use scenarios. The possible effects of urbanization on flood characteristics were checked in study catchment and its sub-catchments. As expected, impervious area spread led to enlarged peak flow and reduced convergence time in flood events. However it showed different changing patterns and magnitudes for different scales and landscapes of sub-catchments.

IAHS (Hydrology)

HS01b - HS01 Changes in Flood Risk and Perception in Catchments and Cities

IUGG-0053

Flood protection effect of the existing and projected reservoirs in the Amur River basin: evaluation by the hydrological modeling system

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Hydrological modeling system was developed as a tool addressed supporting flood risk management by the existing and projected reservoirs in Amur River basin. The system includes the physically-based semi-distributed model of runoff generation ECOMAG coupled with a hydrodynamic MIKE-11 model to simulate channel flow in the main river. The case study was carried out for the middle part of the Amur River where large reservoirs are located on the Zeya and Bureya Rivers. The models were calibrated and validated using streamflow measurments in the different gauges of the main river and its tributaries for 14 years (2000-2013).

Numerical experiments were carried out to assess the effect of the existing Zeya and Bureya reservoirs regulation on 850-kilometer stretch of the middle Amur River stage. It was shown that in the absence of the reservoirs, the water levels downstream of the Zeya and Bureya Rivers would be 0.5-1.5 m higher than the levels measured during the disastrous flood of 2013.

Similar experiments were carried out to assess possible flood protection effect of new projected reservoirs on Zeya and Bureya Rivers. The simulation results are evaluated according to targets for reducing maximum water levels depending on planned schemes for locating waterworks and their characteristics. If the targets are not reached, then the algorithm of hydroinformatics support (in regional planning decision making) can be repeated with new options of the projected reservoir placement and their characteristics to achieve optimal performance on hydro-ecological safety and economic feasibility of reservoirs construction.

IAHS (Hydrology)

HS01b - HS01 Changes in Flood Risk and Perception in Catchments and Cities

IUGG-0062

Effectiveness of water infrastructure for river flood management: Part 1 - Flood Hazard Assessment using hydrological models in Bangladesh

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This study introduces a flood hazard assessment part of the global flood risk assessment methodology conducted with a distributed hydrological Block-wise TOP (BTOP) model and a GIS-based Flood Inundation Depth (FID) model under present and future climates. In this study, the BTOP model was developed with globally available data for the Ganges, Brahmaputra and Meghna (GBM) river basins and calibrated to observed river discharges in Bangladesh. The calibrated BTOP model reproduced important signatures of the GBM basins hydrology and was applied to produce 50-year and 100-year return period flood discharges at each BTOP cell. The use of the BTOP model allowed us to account for individual and cumulative dams' flood control effectiveness, which reduced the flood river discharge downstream of the dams' locations. For the flood inundation maps, the FID model used the BTOP simulated flood discharges in Bangladesh and produced cumulative flood inundation depth maps. The use of the FID model allowed us to consider levee effectiveness when producing flood inundation depth due to the extreme flood river discharges, which were compared to the inundation data collected in the field. For the climate change results, the flood hazard increased in both flood river discharge and inundation area for the 50-year and 100-year floods using the 20-km grid precipitation of the Meteorological Research Institute atmospheric general circulation model 3.2 (MRI-AGCM). From these preliminary results, the proposed flood hazard assessment methodology can alleviate the limitation of the data unavailability globally, especially in developing countries,

and produces flood hazard maps that can be used for the local flood risk assessment, which is presented in the flood risk part of this study.

IAHS (Hydrology)

HS01b - HS01 Changes in Flood Risk and Perception in Catchments and Cities

IUGG-0181

Understanding sensitivities along the flood risk chain

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Flood disaster risk results from the interaction of physical and socio-economic processes. Hence, the quantification of flood risk ideally considers the complete flood risk chain, from the atmospheric processes, through the catchment and river system processes to the damage mechanisms in the affected areas. Within a given flood risk system, a multitude of influences can occur with potential effects on the characteristics of the flood risk. This contribution discusses the state of knowledge about the sensitivity of flood risk to the perturbations along the risk chain: How do perturbations propagate through the risk chain? How do different perturbations combine or conflict and affect flood risk? A model framework representing the complete risk chain will be combined with observational data to understand how the sensitivities evolve along the risk chain.

IAHS (Hydrology)

HS01c - HS01 Changes in Flood Risk and Perception in Catchments and Cities

IUGG-0068

A European Flood Database: Facilitating research on flood processes and associated flood regime changes beyond catchment and country boundaries

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The present work addresses one of the key building blocks towards an improved understanding of flood processes and associated changes in flood characteristics and regimes in Europe: the development of a comprehensive, extensive European flood database. This results from cross-border research collaborations initiated with data collection and joint interpretation in mind. A detailed account of the current state, characteristics and spatial and temporal coverage of the European Flood Database, is presented.

At this stage, the hydrological data collection is still growing and consists at this time of annual maximum and daily mean discharge series, from over 7,000 hydrometric stations of various data series length. Moreover, the database currently comprises of data from 40 different data sources. The time series have been obtained from different national and regional data sources in a collaborative effort of a joint European flood research agreement based on the exchange of data, models and expertise, and from existing international data collections and open source websites. These ongoing efforts have been contributing to advancing the understanding of regional flood processes beyond individual country boundaries and to a more coherent flood research in Europe.

IAHS (Hydrology)

HS01c - HS01 Changes in Flood Risk and Perception in Catchments and Cities

IUGG-0070

Investigation into impacts of land-use changes on floods in the upper Huaihe River basin, China

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The Huaihe River Basin is one of seven major river basins in China, and lies in the warm temperature semi-humid monsoon region, which is a transition zone between the climates of North and South China, with a history of flooding over many centuries. With intensified human activities including land-use change in the basin, which has China's highest population density (662 persons per km^2), the rainfall-runoff relationship has been altered in terms of flood frequency and magnitude. This paper aims to evaluate impacts of land-use change in the upper Huaihe river basin above Xixian gauge station on its floods. The study area has a catchment area of 10 190 km^2, and was divided into grids with a size of 1km × 1km to consider the spatial unevenness of precipitation and underlying conditions. Based on three-phase (1980s, 1990s, 2000s) land-use maps, soil type map, and hourly rainfall and flow discharge data, the improved distributed Xinanjiang model, with potential evapotranspiration being computed by coupling a dual-source evapotranspiration model with a simplified plant growth model, was adopted to simulate rainfall-runoff processes over 1980-2008 on a 3-hour time scale, and then the effects of land-use change on flood peaks, flood volume, timing of flood peaks, the percentage of surface runoff component were investigated respectively. The results was interesting and indicated that impacts of land-use change on flood characteristics varied significantly with land-use types. The outputs could provide valuable references for flood risk management and water resources management in the Huaihe River basin.

IAHS (Hydrology)

HS01c - HS01 Changes in Flood Risk and Perception in Catchments and Cities

IUGG-0079

Potential of satellite rainfall products to understand and predict Niger river recent flood increase in Niamey

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A dramatic increase in the frequency and intensity of floods in the city of Niamey (Niger) has been observed in the last decade. Previous studies found out the evidence of the land use change role on the flood increase since 1970s; land clearing and soil crusting leading to increase the runoff and the endorheic ruptures. In the last decade, observations have raised the issue of a possible increase in extreme rainfall in the Sahel, which may had an important role in the last extreme floods of 2010, 2012 and 2013 in Niamey (higher discharge level ever recorded since 1920s). The study focuses on the 125000km^2 basin between Ansongo and Niamey, corresponding to the drainage area of monsoon rainfall leading to the rapid flow rise occurring between June and October. To understand the possible role of rainfall in this recent flood intensification, satellite rainfall estimates are an attractive alternative in this region sparsely covered by operational gauge networks. Six products (with their own spatial, temporal and intensity characteristics) are used in this study: a gauge only product (CPC), two gauge adjusted satellite products (3B42v7, RFE2), three near real time satellite only products (3B42RT, CMORPH, PERSIANN). On going work, focusing on the period 2000-2013, has already shown the potential of these products for understanding the flood generation through statistical analysis and hydrological modeling. It showed that a hydrological modeling based on these products is able to detect flooded years (Casse et al., 2014). Given these results we envisage to extend the period of analysis from 1970s (with reanalyzed product such as PERSIANN-CDR), in order to better understand the role and the timing of land use and rainfall regime changes in the observed flood regime evolution.

IAHS (Hydrology)

HS01c - HS01 Changes in Flood Risk and Perception in Catchments and Cities

IUGG-0125

Flood-rich flood-poor periods of the last 500 years in Europe: A recent overview

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Long-term ?ood series can be gained by combining evidence and systematic hydrological observations. Based on a broad European database of over 90 long ?ood chronologies we aim to provide an overview of the detected changes in ?ood regimes over the last 500 years, with respect to common break points. A further aim of investigations is to reveal the main causes (e.g. atmospheric, human) of these changes and study spatial and temporal variability of ?oods on a European scale.

In the presentation the following topics are discussed:

1) - present state, strength and weaknesses of long-term historical series in Europe; possibilities and limitations of defining flood-rich and flood-poor periods in the pre-instrumental period;

2) - applied methods in detecting common break points and in defining flood-rich and flood-poor periods on catchment and European level;

3) - overview of flood-rich flood poor-periods in Europe (presented on maps) - applying different methodologies.

IAHS (Hydrology)

HS01c - HS01 Changes in Flood Risk and Perception in Catchments and Cities

IUGG-0129

Changes in flood risk in lower Niger – Benue catchments

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Floods are devastating natural disasters with a significant impact on human life and the surrounding environment. Between July and October 2012, flooding in Nigeria pushed rivers especially the Niger and Benue Rivers over their banks and submerged hundreds of thousands of acres of farmland. This paper analyzes the 2012 extreme flood events of the Niger River; it observed changes in flood characteristics and flood risk and develops adaptation policy that would enhance early warning system for sustainable development of the area. Historical flow data (1960 to 2012) from Lokoja (Niger – Benue Confluence), 2008 and 2012 flow data from Jedere Bode (Niger) and Wurobokiri (Benue) were analyzed. Image from LANSAT Moderate Resolution Imaging Spectroradiometer (MODIS) on NASA's Terra satellite on October 20th 2008 and October 13, 2012, were used to map the normal flood (2008) and extreme flood 2012 respectively. Flood Plain Vulnerability Index (FPVI) based on three dynamics characteristics (Peak flow, Flood extent and Land use) was developed for the Lower Niger and Benue catchments. The result shows that Lokoja had a peak flow of 31,692 m^3/s (29/09/2012) which is about 50% above the historical average. The result of the FPVI revealed that most parts of the Niger River downstream of the confluence at Lokoja to the acute delta fall within the very high vulnerability class. A four levels hierarchical implementation adaptation strategy for sustainable agricultural practices along the rivers flood plain was proposed. The implementation hierarchy includes: Community Concern, Local Authority Concern, State Concern and National Concern.

IAHS (Hydrology)

HS01d - HS01 Changes in Flood Risk and Perception in Catchments and Cities

IUGG-0032

Actual and perceived changes in flood risk and its Implications in a wet zone catchment in Sri Lanka

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The Kalu Ganga basin, covering an area of 2688 km^2, lies within the Wet Zone of Sri Lanka receiving an annual average precipitation of 2900 mm. The basin has a steep gradient in the upper catchment area but has milder slopes (and is low-lying) further downstream. Certain parts of the basin are, on average, flooded once a year. A network of low-lying marshes, interconnected by streams and canals, act as natural retention ponds to store flood water, minimizing damage to people and property. However, an increase in the annual flood frequency (number of flood events per year) has been observed, especially in the lower part of the basin, in recent years. It is generally perceived that this growth in the number of flood events per year is caused by an increase in the frequency and intensity of extreme wet precipitation events. In order to test this hypothesis we gauged the opinion of 400 households within the basin on perceived changes in rainfall, and established actual changes through calculation and trend analysis of three seasonal precipitation indices, related to extreme wet events, during the period 1961 to 2010. We also carried out logistical regression analysis to establish precipitation thresholds triggering flood events, and their behavior during the study period. The results indicate that the increase in annual flood frequency may be more influenced by local land use changes, such as, reclamation of low-lying lands, and escalation of impervious areas due to urbanization, rather than climatic changes. Continuous maintenance of the flood retention functions provided by the low-lying lands may prove extremely important in safeguarding the lives and livelihoods of the inhabitants of the basin in the future.

IAHS (Hydrology)

HS01d - HS01 Changes in Flood Risk and Perception in Catchments and Cities

IUGG-0033

A metric-based assessment of flood risk and vulnerability of rural communities in the Lower Shire Valley, Malawi

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In response to the increasing frequency and economic damages of natural disasters globally, disaster risk management has evolved to incorporate risk assessments that are multi-dimensional, integrated and metric-based. This is to support knowledge-based decision making and hence sustainable risk reduction. In Malawi and most of Sub-Saharan Africa, however, flood risk studies remain focussed on understanding causation, impacts, perceptions and coping and adaptation measures. Using coupled IPCC-Sustainable Development Frameworks, this study has quantified and profiled risk to flooding of rural, subsistent communities in the Lower Shire Valley, Malawi. Flood risk was obtained by integrating hazard and vulnerability. Flood hazard was characterised in terms of flood depth and inundation area obtained through hydraulic modelling of the catchment with Lisflood-FP, while the vulnerability was indexed through analysis of exposure, susceptibility and capacity that were linked to social, economic, environmental and physical perspectives. Data on these were collected through structured interviews of the communities. The implementation of the entire analysis within GIS enabled the visualisation of spatial variability in flood risk in the valley. The results show predominantly medium levels in hazardousness, vulnerability and risk. The vulnerability is dominated by a high to very high susceptibility. Economic and physical capacities tend to be predominantly low but social capacity is significantly high, resulting in overall medium levels of capacity-induced vulnerability. Exposure manifests as medium. The vulnerability and risk showed marginal spatial variability. The paper concludes with recommendations on how these outcomes could inform policy interventions in the Valley.

IAHS (Hydrology)

HS01d - HS01 Changes in Flood Risk and Perception in Catchments and Cities

IUGG-0067

Dynamics of the Flood Response to Slow-Fast Landscape-Climate Feedbacks

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The dynamical evolution of the flood response to landscape-climate feedbacks is evaluated in a joint nonlinear statistical-dynamical approach. For that purpose, a spatiotemporal sensitivity analysis is conducted and a nonlinear dynamical model is built linking floods with climate, landscape and their feedbacks. These involve nonlinear scale interactions, with landform evolution processes taking place at the millennial scale (slow dynamics), and climate adjusting in years to decades (fast dynamics). The results show that floods are more responsive to spatial (regional) than to temporal (decadal) variability. Catchments from dry lowlands and high wetlands exhibit similarity between the spatial and temporal sensitivities (spatiotemporal symmetry) and low landscape-climate codependence, suggesting they are not coevolving significantly. However, intermediate regions show differences between those sensitivities (symmetry breaks) and higher landscape-climate codependence, suggesting undergoing coevolution. The break of symmetry is an emergent behaviour from nonlinear feedbacks within the system. A new coevolution index is introduced relating spatiotemporal symmetry with relative characteristic celerities, which need to be taken into account in hydrological space-time trading. Coevolution is expressed here by the interplay between slow and fast dynamics, represented respectively by spatial and temporal characteristics. The dynamical model captures emerging features of the flood dynamics and nonlinear landscape-climate feedbacks, supporting the nonlinear statistical assessment of spatiotemporally asymmetric flood change. This study ultimately brings to light emerging signatures of change in floods arising from nonlinear slow-fast feedbacks in the landscape-climate dynamics.

IAHS (Hydrology)

HS01d - HS01 Changes in Flood Risk and Perception in Catchments and Cities

IUGG-0123

Diagnosing possible anthropogenic contributions to Colorado floods in September 2013

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Unusually heavy rainfall occurred over the Colorado Front Range during early September 2013, with record or near-record totals recorded in several locations. It was associated predominantly with a stationary large-scale weather pattern (akin to the North American Monsoon, which occurs earlier in the year) that drove a strong plume of deep moisture inland from the Gulf of Mexico against the Front Range foothills. The resulting floods across the South Platte River basin impacted several thousands of people and many homes, roads, and businesses. A recent model-based study finds that, given an insignificant change in the weather pattern, there is an increase in atmospheric water vapour under anthropogenic climate warming leading to a substantial increase in the odds of heavy rainfall occurring over the basin in September 2013. Here we develop this work by including a hydrological modeling component in order to investigate any anthropogenic influence on the actual flood occurrence in the basin during that time. We use precipitation output from the Weather Research and Forecasting model – in both anthropogenic and non-anthropogenic configurations for September 2013 – to drive the Community Land Model (CLM) version 4.5 over the basin. The CLM is the land surface component of the Community Earth System Model, and includes elements of the Variable Infiltration Capacity model to generate river runoff. Thus by comparing changes in CLM peak runoff under the anthropogenic / non-anthropogenic driving conditions we assess any influence on the odds of flood occurrence. Integral to this, we test the sensitivity of our results to hydrological parameters, such as infiltration, base flow, and land use/cover.

IAHS (Hydrology)

HS01d - HS01 Changes in Flood Risk and Perception in Catchments and Cities

IUGG-0126

Paleoflood hydrology of the Colorado river system, Southwestern U.S. - Frequency and magnitude of the largest past floods

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The paleoflood record of the Colorado River basin was reconstructed at several sites using paleoflood hydrology. This method uses slack-water sediments and other paleo-stage indicators deposited in bedrock canyons to reconstruct past floods and their magnitudes. The paleo-record at the Upper Colorado River near Moab, Utah, includes 44 floods during the last 2000 years. The largest paleoflood at 15 m above water level (a.w.l.) had a peak discharge of 9200 m^3s^{-1} (Greenbaum et al., 2014, WRR), whereas the largest measured flood - 3540 m^3s^{-1}, occurred in 1884. The paleo-record indicates that large floods are much more frequent than can be extrapolated from the gaged record. The resulting flood frequency analysis assigns a peak discharge of about 4990 m^3s^{-1} for the 100-year flood, 7270 m^3s^{-1} for the 500-year flood and 8440 m^3s^{-1} for the 1000-year flood which is close to the calculated PMF (8500 m^3s^{-1}). These values are much larger than those based on the gaged record only. In the lower Green River - the largest tributary of the Colorado River, more than 32 paleofloods were reconstructed during the last 680±250 years (OSL ages). The highest flood deposits are at an elevation of about 13.5m a.w.l. had an estimated peak discharge of up to >8500 m^3s^{-1}. In Cataract Canyon downstream, paleofloods during the last <1000 year are up to 13m a.w.l.

These study results have important implications for the risk to water-resources infrastructure of the Colorado River system, which is the most important source of water for the arid southwestern U.S.

IAHS (Hydrology)

HS01d - HS01 Changes in Flood Risk and Perception in Catchments and Cities

IUGG-0134

Flood risk trends in coastal watersheds in South Spain: direct and indirect impact of river regulation

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Spain is one of the world's countries with a large number of reservoirs per inhabitant. This intense regulation of the fluvial network during the 20th century has resulted in a decrease in flood events, a higher availability of water resources, and a high development of the irrigated crop area, even in the drier regions. For decades, flood perception was reduced since the development of reservoirs protected the floodplains of river; this resulted in later occupation of soil by urban, agricultural and industrial uses. In recent years, an increasing perception of flood events is observed, associated to the higher damage associated to extreme events in the now occupied areas, especially in coastal watersheds. This work shows the change on flood risk in the coastal areas of three hydrographic basins in Andalusia (South Spain) during the reservoir expansion period: the Guadalete, Guadalquivir and Guadalhorce river basins. The results differentiate the impact of the regulation level on both the cumulative distribution functions of the fluvial discharge near the river mouth, for different time scales, and the associated damage related to the enhanced soil occupation during this period. The different impact on the final medium and long term flood risk is also assessed in terms of the storage capacity per unit area throughout the basins, the effective annual runoff/precipitation index, the frequency of sea storms, and the human factor (change in social perception of floods), for different intervals in the flood extreme regime. The implications for adaptation actions is also assessed.

IAHS (Hydrology)

HS01e - HS01 Changes in Flood Risk and Perception in Catchments and Cities

IUGG-0005

Flood risk changes over centuries in Rome: An empirical study

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Over centuries, the development of the historical city of Rome -close to one of the largest Italian rivers, the Tiber- has been intertwined with the magnitude and frequency of flooding events. The ancient Rome mostly developed on the (seven) hills, while the Tiber's floodplain was mainly exploited for agricultural purposes. A few small communities did settle in the riparian areas of the Tiber, but they had a relatively peaceful relationships with the frequent occurrence of flooding events. Instead, numerous people live nowadays in modern districts in the Tiber's floodplain, unaware of their exposure to potentially catastrophic flooding. The main goal of this research is to explore the dynamics of changing flood risk over the centuries between the aforementioned two pictures of the ancient and contemporary Rome. To this end, we carried out a socio-hydrological study by exploiting long time series of physical (flooding, river morphology) and social (urbanization, population dynamics) processes together with information about human interactions with the environment (flood defense structures). This empirical analysis showed how human and physical systems have been co-evolving over time, while being abruptly altered by the occurrence of extreme events. For instance, a large flooding event occurred in 1870 and contributed to the constructions of levees, which in turn facilitated the development of new urban districts in the Tiber's floodplain, while changed the societal memory of floods as well as the communities' perception of risk. These outcomes were also used to test

the hypotheses of recent-developed models conceptualizing the interplay between floods and societies and simulating the long-term behavior of coupled human-water systems.

IAHS (Hydrology)

HS01e - HS01 Changes in Flood Risk and Perception in Catchments and Cities

IUGG-0035

Integration of uncertainties in water and flood risk management

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Water management is challenged by hydrological and socio-economic change and hence often forced to make costly and enduring decisions under uncertainty. Thus, thinking beyond current acknowledged and known limits is important to consider these changes and the dynamic of socio-hydrological interactions. For example, reservoir management aiming at flood reduction and mitigation has to cope with many different aspects of uncertainty. The question is to what extent can, do and should these uncertainties have implications on planning?

If practice recognises uncertainties they frequently use risk based decision approaches to acknowledge and handle them by e.g. relating them to other decision relevant factors, while science is mostly preoccupied in reducing these uncertainties. Both views are of relevance and a risk focused approach is needed to bridge the different perspectives covering all significant aspects of uncertainty. Based on a review of various characteristics and perceptions of uncertainty, this paper proposes a new analytical framework where the various aspects of uncertainty are condensed and a risk perspective is added. It thus goes beyond a pure typology and provides an overview of neuralgic points and their location and appearance during the decision-making process. Moreover it supports a structured and evaluated knowledge assessment and knowledge transfer for informed decision-making and it points out potential fields of action and uncertainty reduction. Reservoir management targeting at flood prevention is used as an illustration to present the analytical framework, which is also amended by the needs and demands of practitioners, using first results of expert interviews and case study reviews. Additionally controversial views are brought up for discussion.

IAHS (Hydrology)

HS01e - HS01 Changes in Flood Risk and Perception in Catchments and Cities

IUGG-0155

Operational tools to help stakeholders to protect and alert municipalities facing uncertainties and changes in karst flash floods.

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Flash floods are often responsible for many deaths and involve a lot of material damages. When they occur on a Mediterranean karst aquifer, the complexity of the connections between surface and ground waters and the non-stationarity of the weather patterns increase the difficulties to warn and protect people. Furthermore, to manage flood risks, knowledge of the past floods is no longer sufficient (because of recent changes in land use and in extreme rainy events).Then, the worst realistic flood that could occur has also to be considered in addition.

Physically and processes-based hydrological models are considered among the best ways to forecast floods under various conditions. But they usually don’t match with the stakeholders needs. To face these technical difficulties, this study proposes two operational tools, derived from these models, to help stakeholders planning real time decisions with the little available, changing and uncertain information: i) A hydrological graphical tool (abacus) to estimate the peak discharge of the flood from the past state of the karst and the forecasted but uncertain extreme rainfall; ii) A GIS-based method (MARE) to estimate the potential flooded pathways and areas, from runoff and karst contributions, considering the changes in land use. Then, the outputs of these tools were put in front of past and recent floods and municipalities observations, and the impacts of uncertainties and changes on planning decisions were discussed. The validation on the recent 2014 observed events allowed ensuring the tools reliability for stakeholders.

This study was realized on French Mediterranean basins, in close collaboration with the Flood Forecasting Services (SPC Med-Ouest, SCHAPI, municipalities).

IAHS (Hydrology)

HS01f - HS01 Changes in Flood Risk and Perception in Catchments and Cities

IUGG-0034

Crash-tests for forward-looking flood control in the city of Zürich (Switzerland)

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Floods in the city of Zuerich (Switzerland) were already reported in the 13th century. The most severe threat are flash-floods from the Sihl river (a pre-alpine torrent with an artificial lake reservoir for hydropower in headwater region). Damages of several billions Euros including the complete flooding of the central railway station are possible. Authorities started a comprehensive program in order to adapt flood management to extreme flooding. Concerning early warning, a real-time hydrological ensemble prediction system has been established in 2008. More recently a series of studies has been completed to evaluate flood scenarios. 19 precipitation scenarios (target return periods of 100 and 300 years) and two antecedent soil moisture situations (wet and mean) were considered to generate flood scenarios. These scenarios identified considerable deficits for the safety of Zürich. For the improvement of flood management several options are possible: a) lowering of the artificial reservoir level, b) bypassing of water from the Sihl river to the lake of Zürich, c) increased diversion by the hydropower pipeline, d) diversion of water from a tributary river of the Sihl into the artificial lake, e) regulation of lake outflows in function of the discharge of the downstream rivers and f) change in the safety regulation of the artificial reservoir. Crash-tests with over 24’000 combinations of options have been completed using the tools that are also implemented in the operational forecasts. Data give insights and information to venture long-term infrastructural measures. Results in this respect with indications for adequate structural flood-control measures will be presented.

IAHS (Hydrology)

HS01f - HS01 Changes in Flood Risk and Perception in Catchments and Cities

IUGG-0036

Using subseasonal-to-seasonal (S2S) extreme rainfall forecasts for extended-range flood prediction in Australia

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Meteorological and hydrological centres around the world are looking at ways to improve their capacity to be able to produce and deliver skilful and reliable forecasts of high-impact extreme rainfall and flooding events on a range of prediction timescales (e.g. sub-daily, daily, multi-week, seasonal). Making improvements to extended-range rainfall and flood forecast models, assessing forecast skill and uncertainty, and exploring how to apply flood forecasts and communicate their benefits to decision-makers are significant challenges facing the forecasting and water resources management communities. This paper presents some of the latest science and initiatives from Australia on the development, application and communication of extreme rainfall and flood forecasts on the extended-range 'subseasonal-to-seasonal' (S2S) forecasting timescale, with a focus on risk-based decision-making, increasing flood risk awareness and preparedness, capturing uncertainty, understanding human responses to flood forecasts and warnings, and the growing adoption of 'climate services'. The paper also demonstrates how forecasts of flood events across a range of prediction timescales could be beneficial to a range of sectors and society, most notably for disaster risk reduction (DRR) activities, emergency management and response, and strengthening community resilience. Extended-range S2S extreme flood forecasts, if presented as easily accessible, timely and relevant information are a valuable resource to help society better prepare for, and subsequently cope with, extreme flood events.

IAHS (Hydrology)

HS01f - HS01 Changes in Flood Risk and Perception in Catchments and Cities

IUGG-0056

Simplified graphical tools for assessing flood-risk change over large flood-prone areas.

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Moving from the common perception that flood risk is dramatically increasing worldwide, we investigate the flood-risk evolution along the middle-lower reach of the River Po (the longest Italian river). To this aim, we propose and investigate the reliability of simplified graphical tools, which we term Hypsometric Vulnerability Curves, HVCs, for assessing flood vulnerability and risk over large geographical areas and for defining sustainable mitigation strategies. The tools rely on the use of inundation scenarios simulated by means of a quasi-two-dimensional (quasi-2D) hydrodynamic model that reproduces the hydraulic behavior of the floodable area outside the main embankment system of the River Po, which we set up for a river stretch of about 350 km. Referring to HVCs constructed on the basis of land use and census data relative collected during the last 50 years we assess the recent dynamics of the flood vulnerability and risk. We also combine flood-damage curves proposed in the literature with inundation scenarios simulated by means of fully 2D hydrodynamic models: TELEMAC-2D and HEC-RAS 5.0. The former is a widely employed and well known 2D finite-element scheme, while the latter is a recently released HEC-RAS version that enables users to perform coupled 1D and 2D unsteady-flow simulations (i.e. combining 1D reaches and storage areas with 2D flow areas schematized with finite-volume method). By means of these comparisons, we characterize the accuracy and consistency of the proposed simplified approach (i.e. quasi-2D model and HVCs) to flood-risk assessment over large geographical areas and, indirectly, we assess the inundation scenarios simulated by new HEC-RAS 2D against those resulting from TELEMAC-2D.

IAHS (Hydrology)

HS01f - HS01 Changes in Flood Risk and Perception in Catchments and Cities

IUGG-0076

Extensive Spatial-Temporal Assessment of flood events by Application of Pair-Copulas

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The perception of floods is strongly tied to their peak discharges. But a statistical classification of flood events that only depends on this peaks is not sufficient for flood risk assessments. Apart from “design floods” with pre-defined characteristics, the flood risk depends in reality on a variety of combined characteristics. In case of an extreme flood, the whole river basin is affected instead of single watershed. Because of this simultaneity, there will be superposition of peak discharges from adjoining catchments. These peaks differ in their size and timing according to the spatial distribution of precipitation and watershed-specific processes of flood formation. Thus the spatial characteristics of flood events are a stochastic phenomenon. Hence, there is a demand for a multivariate statistical approach to consider the spatial interdependencies between floods from different watersheds and their coincidences. The question, how this can be done most effectively is the subject of this contribution.

The aim consists in assessing a flood event not only with regard to its local conditions but as well according to its spatial-temporal patterns within the river basin. In this paper we demonstrate the stochastic description of contemporaneous floods by use of both trivariate Joe-Copula and pair-copulas. Their ability to link the marginal distributions of the variates while maintaining their dependence structure characterize them as an adequate method. Hence, extreme flood events and complex failures of overload can be evaluated with regard to the verisimilitude, which is very useful for the risk-based design of retention basins.

IAHS (Hydrology)

HS01f - HS01 Changes in Flood Risk and Perception in Catchments and Cities

IUGG-0172

Evaluating extreme flood characteristics in small mountainous basins of Northern Caucasus in past and future

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The probability of heavy rains and river floods is expected to rise in the future in the Caucasus region. Densely populated areas in valleys of small mountainous watersheds suffer from catastrophic peak floods caused by intense rains in higher altitudes. This study aimed to assess flood characteristics for past and future at several small watersheds, located at the Black Sea coast in the piedmont area of the Caucasus Mountains including ungauged Cemes River in Novorossiysk city.

The task is complicated by the sparseness of meteorological and hydrological observational network in the region. The Deterministic-Stochastic Modelling System (DSMS) developed by Prof. Vinogradov in the State Hydrological Institute of Russia was applied to assess current extreme rainfall and runoff characteristics and possible changes to these in the future. The DSMS consists of a deterministic hydrological model Hydrograph and a Stochastic Model of Weather (SMW). Deterministic Hydrograph model describes runoff formation processes in different landscapes and altitudinal zones while the stochastic weather model provides stochastic meteorological input and a framework to link future climate with land surface components. The verified

Verified at historical data the Hydrograph model was used to simulate long-term series of daily discharges with several stochastic meteorological inputs. Extreme runoff characteristics under historical, recent and future climate conditions were assessed. The results of deterministic-stochastic modelling are compared with the assessments made according to the Recommendations for engineering hydrological practice.

IAHS (Hydrology)

HS01p - HS01 Changes in Flood Risk and Perception in Catchments and Cities

HS01p-111

High resolution radar rainfall for urban pluvial food risk analysis and control

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Cities are particularly vulnerable to flooding induced by intense precipitation due to their high degree of imperviousness and concentration of high value assets. Urban floods are typically characterised by their rapid onset and localised nature. This implies that precipitation and catchment information need to be available at high resolution to reliably predict hydrological response and potential flooding. Thanks to recent advances in weather radar technology, precipitation can currently be measured at high temporal and spatial resolution, using polarimetric X-band radar. In the European RainGain project (EU-Interreg IVB NWE), two of these radars were purchased and tested in Paris and Rotterdam, and other radar configurations (single polarization X-band and C-band super-resolution) were implemented in London and Leuven. High resolution rainfall and hydrodynamic modelling techniques were implemented at seven different pilot sites to analyse catchment sensitivity to local rainfall peaks. Results will be used to identify critical flood risk locations to support water authorities in the project consortium to improve flood control schemes. Initial results of hydrodynamic modelling using high resolution precipitation inputs from polarimetric X-band radar will be presented for a range of events, followed by an analysis of differences in hydrodynamic response behaviour between the pilots. Implications for urban flood control at the pilots will be discussed in the light of modelling results as well as in the context of constraints set by water management strategies in the different cities.

IAHS (Hydrology)

HS01p - HS01 Changes in Flood Risk and Perception in Catchments and Cities

HS01p-112

A flood risk curve development for inundation disaster considering spatio-temporal rainfall distribution

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To manage flood disaster with an exceeding designed level, flood risk control based on appropriate risk assessment is essential. To make integrated economic risk assessment by flood disaster, a flood risk curve, which is a relation between flood inundation damage and its exceedance probability, plays an important role. This research purposes a method to develop a flood risk curve, which is converted from a probability distribution function of annual maximum precipitation through rainfall-runoff and inundation simulations so that risk assessment can consider changes in climatic and land use conditions.
A flood risk curve considering uncertainty of spatio-temporal rainfall distribution is estimated through the following processes: 1) to prepare typical extreme rainfall patterns; 2) to obtain a probability distribution of annual maximum rainfall from the past observed data; 3) to obtain relations between T-year annual maximum rainfall and the maximum inundation water depth through a rainfall-runoff and inundation model; and 4) the economic damage is estimated for each maximum inundation depth caused by the T-year annual maximum rainfall; These procedures are conducted for each typical extreme rainfall pattern. Finally, the relation between economic damage and its exceedance probability is obtained by taking an average of each inundation damage. This method requires many rainfall-runoff and inundation simulations, thus we developed a nesting inundation method to reduce computational costs.
The method was applied to the Yura-gawa river basin (1882 km2) in Japan, and we obtained a risk curve of economic damage in the basin. The annual economic benefit of an existing dam in the basin was successfully quantified by comparing risk curves with/without the dam.

IAHS (Hydrology)

HS01p - HS01 Changes in Flood Risk and Perception in Catchments and Cities

HS01p-113

Evaluation of glacier melt contribution to runoff in North Caucasus alpine catchments using isotopic methods and energy balance modeling

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North Caucasus is one of the most dangerous parts of Russia in terms of hydrological risks. The majority of the most extreme floods in North Caucasus are of mixed origin. They are arisen by combination of factors such as intensive melting and heavy rainfall. During last decades a rise in frequency and intensity of river floods is observed in North Caucasus that is considered to be caused by recent climate change. On the one hand a rise in mean annual temperature provokes an increase in glaciers melt rate, and on the other hand a rise in precipitation sum contributes to the process through more frequent rain flooding. According to this in order to predict possible future trends in extreme hydrological events in the contest of climate change it is essential to estimate contribution of different nourishment sources in rather complicated flow forming processes in the alpine part of North Caucasus.

A study was carried out for Djancuat river basin that was chosen as representative for Northern Caucasus during International Hydrological Decade. Simultaneous solution of water, isotopic and ion balance equations and energy balance modelling of ice and snow melt was used to separate Djancuat river hydrograph by such nourishment sources as ice melt, seasonal snow melt, rain precipitation, base flow. The study allowed to obtain new results on river runoff respond to glaciers melt regime, seasonal redistribution of melt water due to accumulation ability of the glaciers as a prerequisite of the formation of extreme hydrological events. A forecast of possible future changes in Djancuat glacier melting regime and related flooding danger according to predicted climate changes was conducted.

The study was supported by the Russian Science Foundation (grant No. 14-17-00700, 14-27-00083).

IAHS (Hydrology)

HS01p - HS01 Changes in Flood Risk and Perception in Catchments and Cities

HS01p-115

Actual problems with water resource management of Black Sea estuaries during the flood different origin

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In the north-west area of the Black Sea (as part of the Odessa region of Ukraine) are closed estuaries-reservoirs - Khadzhibey and Kuyalnik. They are unique in origin of a natural formation.

Modern hydrology of the Hadzibeevsky and Kuyalnitsky estuaries is due to natural and anthropogenic factors and characterized by their intense economic use:

- For Khadzhibey, since the beginning of the last century, there was an intensive discharge of municipal waters from Odessa (biological treatment plant 'North'). This led to a significant increase in the levels of water in the estuary, which threatened to destroy the dam that separates the estuary from the sea, with the possible flooding of residential areas and enterprises of the Peresip area (total area of ??25 km2), as well as the road, on the dam, especially in disastrously high water yield
- The ecological crisis of the Kuyalnitsky estuary is caused by the regulation the water flow r. Large Kuyalnik (since 1960 ears) a significant number of ponds and reservoirs now. They are designed to provide water to irrigation systems and management needs. This led to a catastrophic shoaling and silting of the reservoir estuary, reducing the water level and the depth, as well as an associated increase in water salinity.

The first task of study - an analysis of conditions of the Hadzhibeysky estuary in the presence of an exceptional the spring flood and rain floods of exceedance probability (P = 1%).

The main goal - is to develop a methodology for calculating and the long-term forecasting of filling of the Hadzhibeysky and Kuyalnitsky estuaries during the spring flood, which is the most abundant phase in the hydrological regime into the territory.

IAHS (Hydrology)

HS01p - HS01 Changes in Flood Risk and Perception in Catchments and Cities

HS01p-116

Changes in snow pack in mountainous basins in Slovakia due to climate change

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Monitoring and modelling snow accumulation and snow melting in mountainous catchments is rather complicated, especially due to the high spatial variability of snow characteristics and the limited availability of terrestrial hydrological data. An evaluation of changes in the snow cover in Slovakia, possible impact of climate change on the SWE and a validation of MODIS satellite images are provided in this paper. The analysis of the SWE was performed using a conceptual hydrological rainfall-runoff model; the upper Hron River basin with 23 stations with available measured snow data was selected as the pilot basin. The basin was divided into five altitude zones. The hydrological model used in this paper was the rainfall-runoff model Hron (zones), which was developed at the Department of Land and Water Resources Management, Faculty of Civil Engineering, Slovak University of Technology in Bratislava, Slovakia. The simulated values of the SWE for each altitude zone were compared with the available measured values of the SWE in the corresponding zones. Also, the satellite images were compared with the available measured data. The changes in the snow cover and the simulated snow water equivalent were estimated by trend analysis; its significance was tested using the non-parametric Mann-Kendall test. The analysis was provided for the period of 1961-2010. From the results, it is possible to see a decrease in the snow depth and the snow water equivalent in all the months of the winter season, and significant decreasing trends were indicated in the months of December, January and February, especially in the higher altitude zone.

IAHS (Hydrology)

HS01p - HS01 Changes in Flood Risk and Perception in Catchments and Cities

HS01p-117

Determination of Curve Number for snowmelt-runoff floods in a small catchment

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One of the widely used method for predicting flood runoff depth from ungauged catchments is the curve number (CN) method, developed by Soil Conservation Service (SCS) of U.S. Department of Agriculture. This method has been extensively used for a number of small catchment all over the world for rural as well, as urban catchment. The CN parameter can be computed directly from recorded rainfall depths and direct runoff volumes in case of existing data. In this investigations, the CN parameter has been computed for snowmelt-runoff events based on snow depth measurement. All required data has been gathered for a small agricultural catchment of Zagozdzonka river Central Poland. The CN number received from snowmelt-runoff events has been compared with CN computed from rainfall-runoff events for the same catchment.

IAHS (Hydrology)

HS01p - HS01 Changes in Flood Risk and Perception in Catchments and Cities

HS01p-118

Application of the model of the limiting intensity to determine maximum runoff in Dniester Basin

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The results of testing the modified model of limiting intensity on the example of rivers in the basin of the Dniester.

The calculation of maximum runoff characteristics is an actual problem for the regions of the Dniester River Basin, which often suffer from flooding caused by floods of different origin. On the territory of lowland rivers Dniester maximum flow of spring flood dominated by over expenditure of flash floods, so they are accepted as calculation.

In work were used data from 98 hydrological stations with a range of watersheds from 30 to 68900 km ^{2} and 53 meteorological posts. The observation period of 11 to 100 years (using data to 2010 inclusive).

Based on the analysis of the current state in the field of valuation characteristics maximum runoff, as a base formula is recommended, which can be attributed to the type of limiting intensity. From well-known formulas of this type, it differs in that it is realized not model a kind of 'black box' - 'precipitation - channel runoff', but the operator natural transformation scheme 'surface influx- the channel runoff'

For realization the proposed structure of the standard statistical processing conducted initial information obtained as a result of which the characteristics of runoff rows and rows of maximum snow storage, and also calculated the discharge and the layers of different frequency (1, 3, 5, 10 %).

Thus the structure of, which is proposed for the calculation formula maximum flow and its implementation on the example of river Dniester can be recommended for practical use. Also, the model is proposed which allows to introduce corrections to the calculated value of snow reserves in view of climate change.

IAHS (Hydrology)

HS01p - HS01 Changes in Flood Risk and Perception in Catchments and Cities

HS01p-119

STUDY CYCLICALITY MAXIMUM RUNOFF RIVERS OF CRIMEA IN CONDITIONS OF MODERN CLIMATE CHANGE

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River Mountain Crimea is characterized by frequent rain floods. Formation of rain floods origin associated with torrential rainfall character that cover a relatively small catchments area. After a large amount of precipitation in the river turn turbulent flows with the discharges, many times greater than the average value, which can lead to disastrous consequences.

Last official publication, which provides maximum design characteristics of runoff this territory dates back to 1973. Given the fact that over the past 40 years there has been climate change, both regional and global scale, of interest to investigate possible trends in the maximum flow of the rivers.

To analyse the possible temporal trends in the ranks of the high flow floods warm period built chronological charts connection and , with which you can identify patterns and trends of long-term fluctuations layers runoff and water discharges. Analysing the graphs, it can be noted that trend is virtually absent on the studied rivers of the Crimean Mountains (correlation coefficient $r = 0.014$ to 0.10).

To characterize the cycling fluctuation of discharges and maximum layers are constructed the difference integral curves for the rivers of the Crimean Mountains. In general we can say that the phase of water content of maximum runoff Crimean rivers are practically identical, and discrepancies in the flow can be explained by different exposure slopes with respect to moisture air masses and characteristics of the underlying surface (eg , the presence of karst).

IAHS (Hydrology)

HS01p - HS01 Changes in Flood Risk and Perception in Catchments and Cities

HS01p-120

Simulating hydrological responses with a physically based model in a mountainous watershed

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A physical and distributive approach was proposed by Reggiani et al. (1998) to describe the hydrological responses at the catchment scale. The rigorous balance equations for mass, momentum, energy and entropy are applied on the divided spatial domains which are called Representative Elementary Watershed (REW). Based on the 2nd law of thermodynamics, Reggiani et al. (1999) put forward several constitutive relations of hydrological processes. Associated with the above equations, the framework of a physically based distributive hydrological model was established. The crucial step for successfully applying this approach is to develop physically based closure relations for these terms and simplify the set of equations. In this paper, several closure relationships, expressing mass exchange fluxes as functions of relevant state variables in a physically reasonable way, were formulated in the upstream of Huangnizhuang watershed, which is a mountainous watershed located in the Huaihe River Basin of the east part of China. The paper showed how a theoretical hydrological model based on the REW method was applied to prosecute the hydrological response simulation for a watershed. The established model was used to carry on the short-term (runoff simulation of storm event) and long-term (daily runoff forecasting) hydrological simulation in the studied watershed and the simulated results were analyzed. These results and analysis proved that this physically based distributive hydrological model can produce satisfied simulation results and describe the hydrological responses correctly. Finally, several aspects to improve the model demonstrated by the results and analysis were put forward which would be carried out in the future.

IAHS (Hydrology)

HS01p - HS01 Changes in Flood Risk and Perception in Catchments and Cities

HS01p-122

Etude de l'évolution du régime hydrologique et des événements extrêmesdans le bassin de la Medjerda, Tunisie

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Many recent studies find that the evolution of climate over the last fifty years is marked by an exceptional global warming, accompanied by changes in different types of extremes phenomena. In the semi-arid Mediterranean area of Tunisia rainfall are highly spatially and temporally variable, which lead to a high variability of flows. This study focuses on the largest watershed in Tunisia: Medjerda with a surface of about 23600 km2. The large watersheds integrate the hydrological response to climate and environmental change (fluctuations in climate, rainfall, flow, sediment flows) to large spatial and temporal scales, but also changes in the physical environment due to anthropogenic causes, making it very difficult to identify the source of the impact of these changes on coastal areas.

The main objective of this work is to determine the hydrologic variability and climate fluctuations especially extreme events, from the rainfall data, water volumes released by the Sidi Salem dam in the river Medjerda, and flows at hydrometric stations in the pre-estuarine area, downstream of the dam. Thus, monitoring the flow of these major hydrological stations allows measuring the impact of the construction of large dams on hydrological regimes and the reduction of hydrological extremes: reduction in average rates, decrease in volumes yields, change in the seasonal pattern, and especially reduction of sediment transport, whose highest values are related to exceptional events.

The deficit of sediment supply to the sea is viewed as a major factor to be taken into account for better understanding of the dynamics of coastal areas in the context of global climate change and sea level rise.

IAHS (Hydrology)

HS01p - HS01 Changes in Flood Risk and Perception in Catchments and Cities

HS01p-123

Flood Monitoring and Mapping using Passive Microwave (ENVISAT-ASAR WSM) remote sensing for the Southeast Asia

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Space-based information is essential for the monitoring of flood events, preparing for proper mitigation and adaptation policy; and estimating of damage to structures and agriculture during floods. In particular synthetic aperture radar (SAR) satellites are very useful for the spatial characterization of floods because of their all-weather image acquisition capability with high accuracy. For flooded areas extraction of pre and post events, ENVISAT ASAR Wide Swath Mode (WSM) images were analyzed in this study by identifying threshold to classify water and non-water pixels and morphological operations such as dilation. Synthetic aperture radar-based time series of flood and inundation information were derived and analyzed for the time period 2007-2011 of the South East Asia. High spatial resolution (~70m) is another advantage of this data set which can be addressed the flood dynamics with high precision.

In this study, we showed which areas of the South East Asia are frequently affected by floods and how the flood propagates; and which regions remain dry all year round based on available spatio-temporal Envisat ASAR data sets. Furthermore, we also analyzed flood frequency of selected region like as the Mekong river delta, part of the Irrawaddy delta, and few parts of the Thailand etc. Flood events are well captured by the adapting procedure followed in this paper. It is essential to assess flood risk analysis of the fragile areas of the South East Asia as many parts of this region are frequently flooded and causes huge loss in terms of agricultural production, properties and human life. The results of the present study can be very helpful for the flood risk analysis in conjunction with other ancillary dataset.

IAHS (Hydrology)

HS01p - HS01 Changes in Flood Risk and Perception in Catchments and Cities

HS01p-124

Analysis of Hydrologic Variable Changes Related to Large Scale Reservoir Operation in Thailand

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Recently, global warming has been significantly affected various hydrologic processes. The large-scale multiple purposes reservoir is one of the countermeasures to manage and address both flood and drought problems. The objective of this study is to apply the Mann-Kendall statistical trend test to long daily historical record of reservoir operations data such as inflow to dam reservoirs, release from dam reservoirs, dam storage as well as precipitation and temperature for investigation the trend of hydrologic variable changes and better dam reservoir operation. The five large-scale dam reservoirs located in the northern, central and western parts of Thailand are selected to analyze the trend of the Ping River basin (Bhumibol Dam, 26,386 km^2), the Nan River basin (Sirikit Dam, 13,130 km^2), the Pasak River basin (Pasak Jolasid Dam, 12,292 km^2) and the Mae Klong River basin (Srinagarind dam, 10,880 km^2 and Vajiralongkorn dam, 3,720 km^2). Through the analysis, we found that the temperature and precipitation trends were increasing trends nevertheless Ping River basin. The water resources availability in term of inflow to Bhumibol Dam and Pasak Jolasid Dam were decreasing trend during dry season. The inflow of all reservoirs in rainy season had increasing trends. Dam release from the all reservoirs, generally increasing significant trends in dry season. Furthermore, water storage for Bhumibol dam found dramatically decreasing trends throughout the year while the Srinagarind dam detected decreasing trends. The study indicates that the increasing trends of water shortage in Bhumibol and Pasak Jolasid Dam and also raising the trend of flood in Sirikit dam and both dams in Mae Klong River Basin.

IAHS (Hydrology)

HS01p - HS01 Changes in Flood Risk and Perception in Catchments and Cities

HS01p-125

A process-based analysis of the suitability of copula types for flood peak-volume relationships

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The work aims at analyzing bivariate relationship between flood peaks and flood volumes, with a particular focus on the flood generation processes.

The target region is located in Austria, and consists of 72 small and mid-sized catchments. On the basis of discharge measurements with a times resolution of 1 hour from the period 1976-2007, flood events were identified, and were assigned to one of the following three flood type categories: synoptic floods, flash floods and snowmelt floods. Flood events in the given catchment are considered as independent when they origin from different synoptic situations.

In the first step, empirical copulas for different flood processes are compared at each site separately in order to verify whether flood processes are discernible in terms of the corresponding bivariate flood-peak relationships. This step is followed by a similar analysis, in which, for a given flood generation process, similarity of empirical copulas are examined in a regional perspective, i.e., between each combination of pairs of catchments. In the last step, nine frequently used copula types are fitted locally to the samples of data, and their goodness-of-fit is examined locally and in a regional scope.

It is concluded that (i) treating flood processes separately is beneficial; (ii) flood processes are discernible locally, and in accordance with the expectations, the most remarkable difference is observed between the flash floods and the other two flood types; (iii) spatial similarity of copulas is comparable with the similarity of different flood types at the same catchment; (iv) the Clayton copula shows

unacceptable performance for all three processes; (v) the rejection of the other copula types depends on the flood type and also on the sample size.

IAHS (Hydrology)

HS01p - HS01 Changes in Flood Risk and Perception in Catchments and Cities

HS01p-126

Modelling the Flood Risk Extent using LISFLOOD-FP in a Complex Watershed: Case study of Mundeni Aru Basin, Sri Lanka

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Flood risk management measures, such as flood hazard mapping require flood extent maps that derived from flood inundation modelling. Such flood inundation model can be developed at the watershed level using available historical data as well as through coupling with hydrological modelling system. In this work, we developed flood inundation model coupled with hydrological model to produce flood risk maps for different return periods in the rural area of Sri Lanka. Flood inundation model result was evaluated against SAR-Satellite flood extent map of same event in the area. The flood risk maps in terms of population density and land use types in particular by focusing on paddy area were produced. We found out that most paddy areas located near the middle and downstream part of the river basin are more susceptible to flood risk with even high frequent events of 1-in-20 year return period. Finally, possible counter measures were identified and then applied to the hydraulic model to produce flood extent maps with and without counter measures in the basin.

IAHS (Hydrology)

HS01p - HS01 Changes in Flood Risk and Perception in Catchments and Cities

HS01p-127

TO THE POSSIBILITIES OF WATERSHED PARAMETERIZATION FOR DESIGN FLOW ESTIMATION ON UNGAUGED BASINS

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Estimation of an appropriate design value of extreme flood events as water level, discharge, or runoff is one of the most important parts of the design process for large number of engineering projects and studies. Design flood estimates require consideration of geographic conditions, jurisdictional requirements, hydrological and meteorological data, and available estimation techniques and methods. For estimation design flood values we can use methods, which can be applied locally, or regionally. The significant problem may arise in small catchments that are poorly gauged or when no recorded data exist. To obtain the design values, single countries adopted different procedures and hydrological models that fit to the conditions and requirements of the countries. The SCS-CN method is a rainfall-runoff model developed for United States. Since the method was derived on the basis of the specific characteristics of selected river basins of United States, use of the method for the conditions of Slovakia raises uncertainty and can cause inaccurate results in determining the direct runoff. The objective of this study was to analyze the SCS – CN method further, subsequently derive the parameters of the method empirically and regionalize runoff curve numbers based on actual rainfall and discharge measurements for the conditions of Slovakia. Since there has been no appropriate methodology provided for empirical determination of SCS-CN method parameters in Slovakia, such as runoff curve number and initial abstraction coefficients (λ), presented work is important for the regionalization of the SCS-CN method for the conditions of Slovakia.

IAHS (Hydrology)

HS01p - HS01 Changes in Flood Risk and Perception in Catchments and Cities

HS01p-128

The Potential of Satellite Radar Altimetry in Flood Forecasting: Concept and Implementation for the Niger-Benue River Basin

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Flood forecasting in the downstream part of any hydrological basin is extremely difficult due to lack of basin-wide hydrological information in near real-time and the absence of a data sharing treaty among the trans-boundary nations. The accuracy of forecasts emerging from a hydrological model could be compromised without prior knowledge of day-to-day flow regulation at different locations upstream of Niger-Benue rivers. Only satellite altimeter monitoring allows us to identify the actual river levels upstream that reflect the human intervention at that location. This is critical for accurate downstream forecasts.

The present study is carried to demonstrate the capability of altimeter based flood forecast along the Niger-Benue River in Nigeria. The study includes the comparison of decadal (at every 10 days from Jason 2) or monthly (at every 35 days from Envisat/AltiKa) observation from 2002 to 2014 with historical in situ measurements from 1990 to 2012. The water stage from these sources shows a good correlation (0.7-0.9). After validation of hydrological parameters obtained from two sources a quantitative relation (rating curve) of upstream water stage and downstream discharge is derived. This relation then adopted for discharge calculation at observation points which is used to propagate the flow downstream at desired location using hydraulic river model. Results in this study from Jason-2 shows a promising correlation (R2=91% with NS coefficient 0.71) with 5-days ahead downstream flow prediction over Benue stream.

IAHS (Hydrology)

HS01p - HS01 Changes in Flood Risk and Perception in Catchments and Cities

HS01p-129

Rainfall-runoff modeling for flood forecasting in arid zones: Case of the watershed of M'Zab valley (South eastern Algeria)

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In Algeria, flooding is one of the most significant and prevalent natural hazards especially in arid and semi-arid regions. Flooding has become a major issue that has disrupted the social activities and economic growth in the country and can result in severe damage and loss of properties, and occasionally loss of human lives as can be seen in the October 2008 floods in Wadi M'Zab (Ghardaia) as well as the 2001 floods in Wadi Koriche (Algiers). Regional knowledge of surface runoff is indispensable for the study of flooding. However, the quality of the observed data (not available, discontinuous, vitiated by errors of measurement, etc ..) makes the determination of flow rates very difficult to achieve, only the use of Rainfall-Runoff Modelling can bring a solution to this problem. The main purpose of this study is to develop Rainfall-Runoff models to estimate rare frequency floods in arid region in absence of gauging. The Watershed of Wadi M'Zab, under Saharan climate, growing region, was chosen to conduct this study, considering its vulnerability to flooding and its importance. This work involves not only the identification of factors responsible for the flood generation in the study area but also the determination of an efficient model appropriate for this region. Two Rainfall-Runoff models are adopted for the construction of the flood hydrograph: i. the HEC-HMS model, a semi-distributed model based on SCS Rainfall-Runoff Model, ii. the global model of IRD (ORSTOM model), a classic purely deterministic model. Relationships between the characteristics of the flood and the catchment area were performed using the IRD model.

IAHS (Hydrology)

HS01p - HS01 Changes in Flood Risk and Perception in Catchments and Cities

HS01p-130

Impact analysis of the decline in agricultural land-use on flood risk and material flux in hilly and mountainous watersheds

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Agricultural land-use, especially rice paddy, has been reduced by mainly urbanization and devastation in Japan. While the land-use in hilly and mountainous areas has been changed to wasteland by abandon owing to retirement of old-aged farmers, the land-use near urban areas has been changed to residential areas. The decline in rice paddy may increase flood risk because it has an ability of flood mitigation. Especially, the change in flood risk affects not only human and economic damages such as inundation in the urban area but also material fluxes from watersheds such as sediment and nutrients which are eventually caused eutrophication in downstream. The objective of this study is to confirm the impacts of decline in agricultural land-use on the increase of flood risk and material fluxes using Soil Water Assessment Tool. The four watersheds, Takahashi River ($2670km^2$), Asahi River ($1810km^2$), Yoshii River ($2110km^2$) and Ashida River ($860km^2$) which drain into northern part of the Seto Inland Sea in western Japan, were targeted in this study. A result indicated that the effects of agricultural land-use changes on nutrient discharges indicated increases of runoff volume and discharges of sediment and nutrients in devastation scenarios. In urbanization scenarios, although increases in runoff volume and fluxes of dissolved inorganic nitrogen and dissolved inorganic phosphorus were indicated, decrease of fluxes of sediment, particulate nitrogen, and particulate phosphorus were indicated. Consequently, both of decline scenarios of agricultural land-use indicate increasing flood risk. Furthermore, it is suggested that sediment and nutrient flux are affected by the effects.

IAHS (Hydrology)

HS01p - HS01 Changes in Flood Risk and Perception in Catchments and Cities

HS01p-131

Evaluations of spatial distributions in groundwater recharge and flood discharge in an urban and suburban watershed of 1000km2 scale

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In coastal megacities, sever groundwater depression and land subsidence occurred. For sustainable groundwater use and risk management of flood, it is necessary to estimate not only groundwater recharge in upstream area of a megacity but flood discharge in subsidence area. In addition, spatial distributions of them would be especially expected in various annual precipitations. However, such estimations and predictions in future have not been fully done in previous studies. Therefore, we aimed to evaluate spatial distribution in groundwater recharge and flood discharge in an urban and suburban watershed of 1000km^2 scale including Osaka metropolitan city. We applied SWAT model to predictions of floods and groundwater recharge from 1990 to 2013 in Yamato river watershed. It was calibrated by the daily river runoff data from 2003 to 2004 in Japanese Ministry of Land, Infrastructure and Transport and it was validated the data from 2008 to 2009. The daily variation in river runoff in 2012 indicated the typical increase at the rainfall event with the amount above 100mm, especially it was one of the largest flood on the end of June in 2012. According to these results, the increase of the flood risk on the Osaka megacity was suggested. Based on the river runoff simulation, the spatial distributions in groundwater recharge were also evaluated. The urban area indicated the low recharge rate but forest area had the high rate. For the sustainable groundwater use and decline of flood risk, it was suggested that we should keep the present percentage of forest cover.

IAHS (Hydrology)

HS01p - HS01 Changes in Flood Risk and Perception in Catchments and Cities

HS01p-133

Flood hazards assessment using SWAT model into a GIS framework over Una River Basin, Pernambuco State, Brazil

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Many major floods have recently occurred in Pernambuco State, Brazil. The years of 2000, 2004, 2005, 2010 and 2011 presented events that were more dangerous than those ones of the decades ago. That was the case of the Una river basin, which had **high economic loss and human life**. Thus, this study evaluates the streamflow for Una River Basin (6,704 km²) by using the SWAT model for the study of land. The SWAT model provides alternative scenarios that contributes to the water infiltration into the soil, reducing runoff and attenuate peak flow rates. The model was validated by comparing simulated average monthly stream flow with observed long-term average monthly stream flow data between 1997 until 2008 from four fluviometric gauges were used (1997-2004 for calibration and 2005-2008 for validation). The calibration process for each streamflow station was satisfactory, in general, with values greater than 0.5 for Nash-Sutcliffe and R^2 for three runoff gauges. This study demonstrates the usefulness of distributed hydrologic studies and the potential of SWAT for application in flood analysis and prediction. A hydrologic modelling study of the Una River Basin using SWAT indicates the potential for application of the model in Brazilian watersheds to collaborate with policies of payments for environmental services, which are critical for detailed water resources studies.

IAHS (Hydrology)

HS01p - HS01 Changes in Flood Risk and Perception in Catchments and Cities

HS01p-134

Analysis of the temporal variability of the 100-year flood for multiple catchments in Serbia

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The flood recurrence interval, or return period, is still one of the most popular methods of evaluating flood magnitudes for purposes of structure design and risk analysis. Numerous guidelines, best practices, policies and even laws worldwide dictate the use of the 'T-year flood', obtained by flood-frequency analysis, as the design flood for flood risk management and design of major water resources structures.This paper deals with the '100-year flood' as probably the most commonly required flood magnitude. More than 20 small to mid-scale catchments were carefully selected throughout Serbia based on available data and catchment characteristics to conduct an analysis to depict the change in the 100-year flood over time, depending on the time period used for frequency analysis. The selected catchments include natural catchments (homogeneous time series), as well as those that have had major basin management works over the course of the time period of the data (heterogeneous time series).Multiple probability distributions were fitted to annual maximum flows for all selected gauging stations, and confidence intervals were estimated for different time periods to analyze and compare performances of the distributions over time.Included in the data are maximum discharges from the disastrous 2014 floods in Serbia, to show how such an event affected the value of the 100-year flood in different catchments.

IAHS (Hydrology)

HS01p - HS01 Changes in Flood Risk and Perception in Catchments and Cities

HS01p-135

Impact of climate change on the frequency and severity of floods in the Dalaki river basin, Iran

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Climate change has different impacts on extreme events such as flood and drought. This research was aimed to investigate maximum annual discharge that may occur due to climate change in Dalaki River Basin during 2040-2060. At first, monthly temperature and precipitation data of HadCM3 model under the SRES emission scenarios A2, B1, A1B were provided. Then, these data were downscaled spatially to Dalaki River Basin by proportional downscaling method. Comparison between computed and observed averaged data at baseline period (1979-1999), indicates B1 and A1B scenarios are suitable for precipitation and temperature simulation respectively. Therefore data of these two scenarios were downscaled temporally to study area by change factor downscaling method. Results showed that the temperature increases and the precipitation varies in 2040-2060 compared with baseline period (1979-1999). A semi-conceptual model (IHACRES) for simulation of daily runoff was calibrated. Downscaled temperature and Precipitation for future were introduced to IHACRES and daily runoff was simulated. Fitting of Probability distribution to maximum annual discharge series and comparing the frequency and severity of them at future with the baseline indicated that climate change affects on the regime of flood in the basin. Also, the analysis showed that the intensity of maximum discharges for the return period less than 10 year does not show any significant difference but by increasing the return period, the intensity decreases in future periods. Moreover, it was shown that the probability of maximum discharges with constant intensity will decrease in the future compared to the baseline.

IAHS (Hydrology)

HS01p - HS01 Changes in Flood Risk and Perception in Catchments and Cities

HS01p-137

Effectiveness of water Infrastructure for river food management: Part 2 - flood risk assessment and changes in Bangladesh

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This study presents a methodological possibility to be used for a case study in Bangladesh based on a global approach for assessing extreme flood risk and its changes considering flood hazard, exposure, and vulnerability. Up to date, many existing flood risk methodologies are not representing real risk phenomena in developing countries such as Bangladesh. Therefore, the aim of this study is to measure flood risk changes in terms of affected people and damaged rice crops by extreme flood events and to quantifying the effectiveness of water infrastructure in flood risk reduction by using an integrated GIS-based approach with local data. From the results of flood hazard assessment described in Part 1 of this study, we selected 50- and 100-year flood hazards as extreme events based on MRI-AGCM3.2S (SRES A1B scenario) precipitation for the Present (1979-2003) and Future (2075-2099) climates simulated with the BTOP model and the GIS-based Flood Inundation Depth (FID) model. For the flood risk assessment part, the focus is on estimating changes of affected people and damaged rice crops due to water infrastructure. The flood stage-damage curves are derived from the local data collected during the field surveys in Bangladesh to verify proposed global methodological possibility. The preliminary results shows that a propensity of extreme flood risk changes strongly depends on the increase of the temporal and spatial dynamics of exposure and vulnerability such as water infrastructure and stage-damage curves. This study provides a basis for appropriate policy and management decisions by government and international organizations towards the reduction of disaster impacts.

IAHS (Hydrology)

HS01p - HS01 Changes in Flood Risk and Perception in Catchments and Cities

HS01p-138

Extreme flood risk warning in North China region under climate change by implementing a coupled hydrological-hydraulic model

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North China is in common-sense water shortage area. Floods are rare; however, under the effect of climate change, extreme precipitation events in the North China region have been an increasing concern as they increase ?ood risks. For this kind of area, to provide the warning from the precipitation is very important as people are not always in good preparation because of less frequent occurring of floods. A new model tool is implemented for forecasting the extreme flood risk in North China region, by coupling Vegetation Interface Processes (VIP) hydrological model and New-Flood hydraulic model. The VIP model is a distributed eco-hydrology dynamic model, which shows robust ability of reproducing the hydrology cycle process. The New-Flood model is a two-dimensional shallow flow model which is capable to accurately and effectively solve complicated hydrodynamic problems in different flow regimes over complex domain topography. Forecasting via the coupling hydrological model and hydraulic model can provide the very detail information of flood time, extent, and velocity from precipitation. The study is innovative on how to take advantages of both models to not only simulate the flash floods in the whole view of hydrological cycle but also provide the two-dimensional information of flash floods, and on how to emphasise the importance of the effective extreme flood assessment in the North China region. The results expect to help the decision-makers in extreme flood warning for the region which is not always thinking about of floods due to being in water shortage status always but do face the risk of flash floods in the history and future.

IAHS (Hydrology)

HS01p - HS01 Changes in Flood Risk and Perception in Catchments and Cities

HS01p-139

Data mining of public databases to characterize urban flood risks in Amsterdam

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Dutch cities are challenged by increasing urban flood risks. Precise and realistic measures to reduce their impacts are required. Obvious flooding factors include sewer systems performance and urban topography. However, implemented sewer and topographic models do not provide realistic predictions of local flooding occurrence during heavy rain events. Assessing other factors such as spatially distributed rainfall and socioeconomic characteristics may provide further insights into urban flooding.

Several public databases were analysed: rainfall-related complaints, rainfall depths (15 min and 100 Ha spatio-temporal resolution), grids describing number of inhabitants, income, and housing price (1Ha and 25Ha resolution); and buildings age. Data analysis was done using Python and GIS programming, and included spatial indexing of data, cluster analysis, and multivariate regression on the complaints.

The cluster analysis, run for all the variables but the complaints, grouped part of the grid-cells of central Amsterdam into a highly differentiated group, covering 10% of the analysed area, accounting for 25% of registered complaints. The configuration of the analysed variables in central Amsterdam coincides with a high complaint count. Remaining complaints were evenly dispersed along other groups. An adjusted R^2 of 0.38 in the multivariate regression suggests that explaining power can improve if additional variables are considered. While rainfall intensity explained 4% of the incidence of complaints, population density and building age significantly explained around 20% each.

Data mining of public databases proved to be a valuable tool to characterise significant factors of urban pluvial flooding, though additional variables must be considered to further explain its risk.

IAHS (Hydrology)

HS01p - HS01 Changes in Flood Risk and Perception in Catchments and Cities

HS01p-140

Modelling of quality of natural waters case of the dam of Sidi M'HamedBenAouda in the watershed of the Wadi Mina

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Geochemical modelling is a tool to attempt to understand complex systems and phenomena and make decisions about the management of sites in order to minimize the impact of metal pollution (heavy metals). In the case of solutes and contaminants that are not reactive or who are conservative, the only physical process can be modelled, but most of the contaminants are reactive. In particular, in the case of metallic elements, chemical reactions significantly affect the concentrations in solution (transfer delay, processing into a more toxic species ...).

Dam of Sidi M'Hamed Ben Aouda was put water in 1978 on the main stem of the Wadi Mina with an initial capacity of 253 hm^3 but given the erosion phenomenon that hit the region, the dam currently suffers from siltation problem and its capacity is reduced to 153 hm^3, several factors come into play such as vegetation, topography, rainfall, water quality...

In this context, the study of dam water below was made by the physic-chemical data acquired by the National Agency of Water Resources. These data are collected over a period of 27 years (1985-2012) with the aim to characterize the physic-chemical state of water systems in relation to these waters. The study was initiated by doing classification dam water using piper diagram and see their subsequent evolution as a function of the study period.

Thus, the calculation of the speciation of the chemical species of water was carried through the PHREEQC geochemical model, which permitted to make a modelling pollutants index most threatening (PO_4, NO_3, NO_2) and at the end find the influence of dry residues and turbidity on siltation dam SMBA.

IAHS (Hydrology)

HS01p - HS01 Changes in Flood Risk and Perception in Catchments and Cities

HS01p-494

Extreme flood estimations on a small alpine catchment in Switzerland, the case study of Limmerboden.

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In Switzerland, 160 large dams (h>15 m according to the definition adopted by the International Commission on Large Dams) have been constructed in the past. This roughly corresponds to 20 dams per 5’000 km^2. In comparison, the dam density in China, the world leading hydroelectricity producer, is only 11.5 dams per 5’000 km^2. Due to this high dam density in Switzerland, flood safety is a critical topic for Swiss engineers and the Swiss Federal Office of Energy already initiated research projects on extreme flood issues some twenty years ago. In the context of this vast still ongoing issue, the project Cruex++ started in 2012 within the goal of improving extreme flood estimations in alpine catchments. In Switzerland, dam safety guidelines prescribe the estimation of the so called design flood, Q_{1000}, and the safety flood, estimated by $1.5 \cdot Q_{1000}$ or the PMF (probable maximum flood) for dam design. The design flood Q_{1000} has to be evacuated below the maximum operation level, even if the spillway with the highest capacity is out of order (“n-1 rule”). Concerning the safety flood, the dam has to withstand it without failure; all spillways are assumed to be operational for concrete dams and the “n-1 rule” is applied to embankment dams. In this framework, a case study on extreme flood estimations for the small Swiss alpine catchment, Limmernboden, with a large dam, is performed and presented in this paper. These estimations are achieved using statistical methods as well as rainfall-runoff simulations. The rainfall-runoff simulations are realized with a semi-distributed conceptual hydrological model developed for alpine catchments. The paper outlines the current procedures in flood estimation and discusses and compares the results in the selected case study of Limmernboden.

IAHS (Hydrology)

HS02a - HS02 Hydrologic Non-Stationarity and Extrapolating Models to Predict the Future

IUGG-0037

Accounting for hydro-climatic and water use variability in the assessment of past and future water balance at the basin scale

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This study aims to assess water stress at the 2050 horizon in river basins facing increasing human and climatic pressures, and to compare the impacts of a wide range of possible future socio-economic and climate trends. A modeling framework integrating human and hydro-climatic dynamics and accounting for interactions between resource and demand at a 10-day time step was developed and applied in two basins of different scales and with contrasted water uses: the Herault (2 500 km^2, France) and the Ebro (85 000 km^2, Spain) basins. Natural streamflow was evaluated using a conceptual hydrological model. A demand-driven reservoir management model was designed to account for streamflow regulations from the main dams. Urban water demand was estimated from time series of population and monthly unit water consumption data. Agricultural water demand was computed from time series of irrigated area, crop and soil data, and climate forcing. Indicators comparing water supply to demand at strategic resource and demand nodes were computed. This framework was calibrated and validated under non-stationary human and hydroclimatic conditions over the last 40 years before being applied under four combinations of climatic and water use scenarios to differentiate the impacts of climate- and human-induced changes on streamflow and water balance. 18 climate scenarios at the 2050 horizon were built based on nine GCMs and two RCPs. The baseline water use scenario for 2050 was based on demographic and local socio-economic trends. Results show that projected water uses are not sustainable under climate change scenarios. Adaptation measures will be necessary to achieve a sustainable balance between water use and availability.

IAHS (Hydrology)

HS02a - HS02 Hydrologic Non-Stationarity and Extrapolating Models to Predict the Future

IUGG-0041

Ability of a land surface model to predict climate induced changes in northern Russian river runoff during the 21st century

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The objective of the present study is to investigate the possibility of application of the Land Surface Model (LSM) SWAP and the Atmosphere–Ocean Global Climate Model (AOGCM) INMCM 4.0 to project climate change impact on northern Russian river runoff up to 2100. The study was performed for two rivers: the Northern Dvina River and the Kolyma River characterized by different climatic conditions. First of all, the ability of INMCM 4.0 to reproduces modern climate and the ability of both models to reproduce the observed river runoff were investigated.

To apply SWAP for hydrological projections, the robustness of the model was evaluated by means of calibration/validation on two historical periods with contrasted climate conditions: cold and dry years were used for model calibration, while wet and warm years for model validation. Analysis of the obtained results confirmed a fairly good model performance and robustness; it was concluded that SWAP can be applied for simulating changes in northern river runoff due to possible climate change.

The river runoff projections up to 2100 were calculated for two greenhouse gas emission scenarios: a high emissions scenario (RCP8.5) and a medium mitigation scenario (RCP4.5) prepared for the phase five of the Coupled Model Intercomparison Project (CMIP5). For each scenario, several hydrological projections were obtained using different models (INMCM4.0 and SWAP) and different post-processing techniques for correcting biases in meteorological projections (simulated by INMCM4.0), which served as inputs for SWAP. Differences among the river runoff projections obtained for the same emission

scenario and the same period illustrate uncertainties resulted from application of different models and different bias-correcting techniques.

IAHS (Hydrology)

HS02a - HS02 Hydrologic Non-Stationarity and Extrapolating Models to Predict the Future

IUGG-0087

On the effects of wind and other atmospheric drivers on transpiration in contrast to "potential evaporation"

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Transpiration, i.e. the water use by vegetation, is commonly conceptualised as a fraction of a potential maximum rate, driven by so-called 'atmospheric evaporative demand'. Therefore, atmospheric evaporative demand or „potential evaporation“ is generally used alongside with precipitation and soil moisture to characterise the environmental conditions determining plant water use. Consequently, increases in potential evaporation (e.g. due to climate change) are believed to cause increased transpiration and/or vegetation water stress.

In the present study, we investigated the question whether potential evaporation constitutes a meaningful driver for transpiration and compared sensitivity of potential evaporation to atmospheric forcing to that of leaf transpiration. For this purpose, we employed a physically-based leaf energy balance model that explicitly considers the feedbacks between leaf temperature and the different energy balance components and their dependence on stomatal resistance. Based on modelling results and supporting experimental evidence, we conclude that the effect of stomatal resistance cannot be parameterised as a factor relating transpiration to potential evaporation, as this factor does not only vary with stomatal resistance, but also with wind speed, air temperature, irradiance and relative humidity. Furthermore, the effects of wind speed and solar irradiance in particular imply increase in potential evaporation and hence „water stress“, but at the same time allow greater uptake of carbon dioxide for the same amount of transpiration, implying a decrease in „water stress“ at leaf scale.

IAHS (Hydrology)

HS02a - HS02 Hydrologic Non-Stationarity and Extrapolating Models to Predict the Future

IUGG-0097

Assessing evapotranspiration losses in a warmer climate

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Recent literature has suggested that rising temperatures are the cause of reduced soil moisture and inflows in the Murray Darling Basin, Australia, implying that increased temperatures lead to increased evaporation. This paper explores the relationship between temperature, evaporation and soil moisture using a planetary boundary layer (PBL) model. A simple convective PBL model coupled with the Penman–Monteith (PM) equation is used to estimate evapotranspiration. Following calibration and sensitivity analysis, the model was used to simulate the relative impact of dry and wet soil moisture conditions on daytime temperatures by changing the surface resistance parameter in the PM equation. It was found that the maximum temperature that can be reached during a day is constrained by the amount of soil moisture and the available net radiation, confirming previously published results. Higher temperatures can be reached with greater net radiation and dry soil moisture conditions. However, in this study, it is shown that an increase in temperature only has a minor influence on evaporation. The findings highlight an important weakness of climatological studies and climatological projections based on the assumption that increased temperatures are responsible for increased evaporation and lend more weight to the use of more physically realistic energy-balance models.

IAHS (Hydrology)

HS02a - HS02 Hydrologic Non-Stationarity and Extrapolating Models to Predict the Future

IUGG-0151

The need of the change of the conceptualisation of hydrologic processes under extreme conditions---taking reference evapotranspiration as an example

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What a hydrological model displays is the relationship between the output and input. In the case of climate or other environment change, the input of the hydrological model may show a gradual or abrupt change. There have been lots of documented studies to explore the response of output of the hydrological models to the change of the input with scenario simulation. Most of the studies assumed that the conceptualisation of hydrologic processes will remain before and after the change, which may be true for the gradual change. However, under extreme conditions the conceptualisation of hydrologic processes may have to be totally different. Taking the Allen's formula to calculate reference evapotranspiration (ET0) as an example of simple hydrological model, we calculate the long-term variation of ET0 from 1955 to 2012 for Chongling Experimental Station located in Hebei province, China based on such meteorological data as net radiation, air temperature, wind speed, saturation and actual vapor pressure. The comparison is made of the relationship between ET0 and the meteorological factors for the average, minimum (maximum) values at daily, monthly and annual scale respectively. It is found the extreme of the output can only follow the extreme of the input when their relationship is linear although the coefficient of determination is not high partly due to the contributions by multi-factors. For non-liner relationship, the extreme of the input cannot at all be reflected from the extreme of the output. Relatively speaking, extreme event at daily scale is harder to be shown than that at monthly scale. The result implicates that a routine model may not be able to catch the response to extreme events and some new conceptualisation is needed.

IAHS (Hydrology)

HS02b - HS02 Hydrologic Non-Stationarity and Extrapolating Models to Predict the Future

IUGG-0009

Scenario forecasting changes in the water balance components of the Olenek and Iindigirka river basins due to possible climate change

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The polar regions, largely controlling the hydrological processes and water resources, will undergo the earliest and the most profound changes in the case of climate change. The objective of this research is to assess possible changes in the water balance components of the two river basins of Yakutia (RF): Olenek and Indigirka in connection with various climate change scenarios. These rivers are located in the severe weather conditions in the northern part of Eurasia. For four IPCC global climate scenarios, namely SRES family scenarios for economic, technological, political and demographic development of human civilization, prognostic series of meteorological elements in the Olenek and Indigirka River basins for the 21 century were derived. Using these series, the calculations of possible changes in the components of the water balance in selected river basins until 2063 were obtained. A calculation technique was based on application of a physically-based model SWAP, which describes heat and mass exchange between the land surface and the atmosphere, as well as on a generator of climatic scenarios MAGICC/SCENGEN. The values of the water balance components were averaged for 22-24 years to illustrate changes in these values on a climatic scale. It is shown that all four climate change scenarios result in increase in all water balance components (precipitation, evapotranspiration and river runoff) by 2063. Quantitative differences between the results obtained for different climate change scenarios are relatively small. Changes in climatic values of runoff hydrographs for the selected rivers were also analyzed. It was shown that for the Indigirka River the shape of its hydrograph remains nearly constant, while for the Olenek River the peak of spring flood becomes sharper.

IAHS (Hydrology)

HS02b - HS02 Hydrologic Non-Stationarity and Extrapolating Models to Predict the Future

IUGG-0075

Assessing uncertainties in climate change impacts on runoff in various meso-scale catchments from the Western Mediterranean

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This paper investigates the uncertainties linked to climate change impacts on runoff in four meso-scale basins (910 to 1800 km²) from the Mediterranean. Runoff simulations were based on a daily conceptual model including a snow module. The model was calibrated and validated according to a differential split-sample test over a 20-year period and four competing criteria were used to represent model structural uncertainty based on the concept of Pareto optimality. Five regional climate models (RCMs) from the recent Med-CORDEX initiative were used to provide temperature and precipitation projections under RCP 8.5 by 2050. The RCMs' inability to realistically simulate reference climate (in particular precipitation) led us to apply a perturbation method in order to produce a range of climate scenarios. The structural uncertainty bounds obtained from the hydrological simulations over the reference period showed that the model was able to correctly reproduce observed runoff despite contrasted hydrological conditions within and in between the basins. Climate projections were shown to be convergent regarding temperatures, which could increase by about +1°C to 3°C on each basin. In contrast, no clear trends in precipitation could be put in evidence, some RCMs leading to a mean annual precipitation decrease (up to 64%), and others to an increase (up to 33%). The hydrological projections resulted from the combination of the hydrological simulation bounds with the range of climate projections. Despite the propagation of those uncertainties, the hydrological scenarios by 2050 agreed on a significant runoff decrease (2?77%) during spring on all basins. On the opposite, no clear trend in runoff could be observed for the other seasons.

IAHS (Hydrology)

HS02b - HS02 Hydrologic Non-Stationarity and Extrapolating Models to Predict the Future

IUGG-0142

Assessment and modelling fire impact on runoff formation processes in mountainous landscapes of Siberia and Far East of Russia

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Forest fires are widespread in Siberia and Far East of Russia. Though their impact on transformation of soil-vegetation cover are well-studied, their influence on hydrological regime which may lead to catastrophic flooding and even debris flows are still unknown in cold regions. In our study we conducted joint analysis of monthly gridded 500 m MODIS Burned Area Product (MCD45) on fire distribution across Eastern Siberia and Far East of Russia for 2000-2013 period and the series of observed daily discharges for 50 small and middle-size (from 12 to 16000 km^2) basins to detect fire impact on runoff. Preliminary results of hydrological and meteorological data analysis suggested that small basins with high burned area in case of strong rainstorms have quick and profound hydrological response to wildfire expressed in increased peak flow. Larger basins with lower burned rates show no significant short-term changes of runoff after the fire. Application of process-based distributed hydrological model Hydrograph to burned basins for assessment fire influence on variable states of watersheds and internal flow formation processes allowed to reveal the differences between watershed responses to fire depending on dominated landscape, especially in permafrost areas.

IAHS (Hydrology)

HS02b - HS02 Hydrologic Non-Stationarity and Extrapolating Models to Predict the Future

IUGG-0166

Using historical climatic signals to better predict the future: case of the water cycle in Central Sahel

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Rainfall and climatic conditions are the main drivers of natural and cultivated vegetation productivity in the endorheic region of Central Sahel. In a context of decreasing per capita cultivable area, understanding and predicting changes in the water cycle is vital. Yet, complex non-linear relationships, lack of consensus on the sign of future precipitation changes and the inability of climate models to simulate the West African Monsoon make it challenging to extrapolate current models to future climatic conditions.
The Sahel region has experienced strong climatic changes in the past 60 years which can provide a first basis to understand the response of the water cycle to non-stationary conditions in this region of the world. The objective of this study is therefore to better understand the response of the water cycle to highly variable climatic regimes in Central Sahel using the historical climatic records and two physically based models capable of simulating the Sahelian water, energy and vegetation cycles (SiSPAT and STEP). To do so, we rely on a reconstituted data series produced at Niamey, Niger, in which three precipitation regimes can be distinguished with a relative deficit exceeding 30% for the driest period. Three temperature scenarios (+0°C, +2°C and +4°C) consistent with future predictions are superimposed to this climatic signal to generate 9 hypothetical future 20-year climate series. Preliminary results with a zero increase in temperature show a

decrease in evapotranspiration in the driest scenario, while increased precipitation led to an increase in runoff and drainage. This study shows the potential of using the strong non-linear climatic signals of the past decades to better understand potential future climate variability.

IAHS (Hydrology)

HS02b - HS02 Hydrologic Non-Stationarity and Extrapolating Models to Predict the Future

IUGG-0176

Symmetry in performance of different streamflow prediction methods: effect of non-stationarity in catchment processes.

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Stationarity of hydrologic processes in a given catchment is implicitly assumed by the vast majority of current hydrological tools including models. However, there is growing evidence that a shift in climate might modify catchment behaviour. In this case, projections based on historical data become less reliable and are likely to be biased. To investigate the effect of non-stationarity in governing catchment processes we begin with an exploration of annual rainfall-runoff relationships. This simple relationship is a natural integrator of catchment processes on an inter-annual time scale, covering the range of typical catchment behaviour during wet and dry years. We compare this straightforward streamflow prediction method with a number of widely used conceptual rainfall-runoff models. Using a large dataset of catchments we demonstrate there is symmetry in model performance during prolonged dry periods. Whether projections are based on a simple rainfall-runoff relationship or on a conceptual model with many stores and parameters, we still overestimate the expected runoff. To understand this result we investigate catchment dynamics in case study catchments and explore the processes responsible for the modified behaviour. Our results have important implications for hydrological projections of climate change based on conceptual rainfall-runoff models, and also for water management and infrastructure design. Overall, we demonstrate that non-stationarity in hydrologic processes is the key factor related to model ability to predict under different climatic conditions.

IAHS (Hydrology)

HS02c - HS02 Hydrologic Non-Stationarity and Extrapolating Models to Predict the Future

IUGG-0078

Frequency of floods in a changing climate. A case study from the Red River in Manitoba, Canada.

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Spring flooding on the Red River is a recurrent issue in the Province of Manitoba, Canada, and has threatened the City of Winnipeg on numerous occasions. Although the city now is protected against a 700-year flood, flooding south of Winnipeg regularly cause inundation of agricultural land and roads with significant socio-economic costs. There have been a relatively large number of flood events in recent years, and climate change has occasionally been mentioned as a possible cause. This paper presents a relatively simple model for predicting changes in the frequency distribution of annual spring peak discharge as a response to increased GHG concentrations. A regression model has been used in the past by conservation authorities to predict spring peak flow from predictor variables that include antecedent precipitation in the previous fall, winter snow accumulation, and spring precipitation. Data from the Coupled Model Intercomparison Project - Phase 5 (CMIP5) are used to estimate changes in the predictor variables and this information is then used to derive flood distributions for future climate conditions. Most climate models predict increased precipitation during winter months but this is partly offset by a shorter snow accumulation period. The means and medians of an ensemble of 16 climate models do not suggest that the frequency distribution of floods on the Red River will change significantly in the future. However, the ensemble range is relatively large, highlighting the difficulties involved in estimating changes in extreme events.

IAHS (Hydrology)

HS02c - HS02 Hydrologic Non-Stationarity and Extrapolating Models to Predict the Future

IUGG-0145

Non-stationary hydrological frequency analysis based on the reconstruction of extreme hydrological series

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Abstract: At present, in terms of non-stationary hydrological frequency analysis (NSHFA), lager bodies of research works have been done. In this paper, after summarizing and comparatively analyzing the characteristics of present-typical methods, we propose a novel approach for NSHFA. The approach is due to the following consideration that the non-stationary series has three-possible-evolution-status in the unknown future. Taking a non-stationary series with increased trend as example, 1) increased trend detected at present continues to keep increased trend in the future, 2) increased trend stops and changes to decreased trend, and 3) increased trend stops and changes to stationary status. In this proposed method, an assumption is done that the variation hydrological series in a big time window owns an expected vibration center (EVC), which is a linear combination of the two mean values of the two subsample series obtained through separating the original hydrological series by a novel optimal segmentation technique (change rate of slope method). Then using the EVC to reconstruct non-stationary series to meet the requirement of stationarity, and further ensure the conventional frequency analysis methods is valid.

IAHS (Hydrology)

HS02c - HS02 Hydrologic Non-Stationarity and Extrapolating Models to Predict the Future

IUGG-0167

Floods in a non-stationary world

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There has been a surprisingly large number of major floods in the last years around the world which suggests that floods may have increased and will continue to increase in the next decades. However, the realism of such changes is still hotly discussed in the literature. In this presentation I will argue that a fresh look is needed at the flood change problem in terms of the causal factors including river training, land use changes and climate variability. Analysing spatial patterns of dynamic flood characteristics helps learn form the rich diversity of flood processes across the landscape. I will present a number of examples across Europe to illustrate the range of flood generation processes and the causal factors of changes in the flood regime. On the basis of these examples, I will demonstrate how comparative hydrology can assist in learning from the differences of flood characteristics between catchments both for present and future conditions. Focus on the interactions of the natural and human water system will be instrumental in making meaningful statements about future floods in a non-stationary world.

IAHS (Hydrology)

HS02c - HS02 Hydrologic Non-Stationarity and Extrapolating Models to Predict the Future

IUGG-0169

Non-stationary flood frequency analysis with time-varying moment POT (POT-TVM) for Dongjiang Basin, South China

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Time seriers of a flood extream feature is non-stationary under changing environment. Time Varying Moment (TVM) has been applied in non-stationary Flood Frequency Analysis (FFA) mainly basing on Annual Maximum Series (AMS). Aiming at expanding TVM application and exploring a non-stationary FFA for Dongjiang Basin, a highly reservoir controlled river basin in South China, this research adopted TVM with “peaks over threshold” (POT) approach, which took annual frequency of flood into concern, in non-stationary FFA for Longchuan and Heyuan gauging stations on mainstream of the Dongjiang river. On the other hand, the changing pattern of frequency, the magnitude and return period of flood, which were deeply impacted by the regulation of reservoirs, were also investigated. We used Poisson distribution in fitting annual threshold excess number (ATEN), Generalized Pareto for POT series and GEV for AMS series. When sampling with POT, we assumed mean of ATEN and the first two moments of POT series to be time-varying. The results indicated that: (1) non-stationarity existed in AMS, ATEN and POT series for both stations in the Dongjiang basin; (2) mean of ATENs in two stations had linear trends, while mean and Standard Deviation (SD) in Longchuan had parabolic trend, connected by constant Coefficient of Variation (Cv), and that in Heyuan had linear trend, also related by steady Cv; (3) when estimating with non-stationary approach, a traditionally defined 100-year flood had an increasing return period over time; (4) under the influence of reservoirs, upper tail of flood frequency curve became less steep, which meant that design flood value would be overestimated without taking altered environment into consideration.

IAHS (Hydrology)

HS02d - HS02 Hydrologic Non-Stationarity and Extrapolating Models to Predict the Future

IUGG-0010

Hydrologic non-stationarity and extrapolating models to predict the future

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This paper provides an overview of the IAHS session at IUGG2015 on 'hydrologic non-stationarity and extrapolating models to predict the future'. The session directly addresses a key issue in the IAHS 2013–2022 Panta Rhei Decade (Change in Hydrology and Society).

The term 'hydrologic non-stationarity' has been used to describe many things, ranging from climate and streamflow variability evident within a long hydroclimate time series to changes in climate-runoff relationships and dominant hydrological processes over time. Hydrologists have excelled in developing models for numerous applications but extrapolating the models to predict further into the future will become more challenging as streamflow will be increasingly influenced by higher temperatures and changed ecohydrological processes under higher CO_2.

The papers in this publication address the range of issues relating to hydrologic non-stationarity and challenges in extrapolating hydrological models to predict the future. This include papers on observed hydrologic non-stationarity, limitations in modelling through non-stationarity and adapting hydrological models or modelling methods to simulate the future. Modelling methods range from smart regionalisation, calibration and parameterisation against long hydroclimate records with changing climate-runoff relationship over time, improved conceptualisation of hydrologic processes under extreme conditions (e.g., different surface-groundwater connectivity through long wet and dry spells), to adapting and building models that may adequately simulate surface-atmosphere feedbacks and dominant ecohydrological processes in a significantly warmer and higher CO_2 world.

IAHS (Hydrology)

HS02d - HS02 Hydrologic Non-Stationarity and Extrapolating Models to Predict the Future

IUGG-0039

Quantifying the uncertainties of climate change effects on the yield and performance characteristics of the Pong multi-purpose reservoir, India.

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Climate change is predicted to affect water resources infrastructure due its effect on rainfall, temperature and evapotranspiration. However, there are huge uncertainties on both the magnitude and direction of these effects. The Pong reservoir on the Beas River in northern India serves irrigation and hydropower needs. The hydrology of the catchment is highly influenced by Himalaya glaciers and Monsoon rainfall; the changing pattern of the latter and the predicted disappearance of the former will have profound effects on the performance of the reservoir. This study employed a Monte-Carlo simulation approach to characterise the uncertainties in the future yield and performance of the Pong. Using a calibrated rainfall-runoff (R-R) model, the baseline runoff scenario was first simulated. The R-R inputs (rainfall & temperature) were then perturbed using plausible delta-changes to produce simulated climate change runoff scenarios. Stochastic models of the runoff were developed and used to generate ensembles of both the baseline and climate-change perturbed scenarios. The resulting runoff ensembles were used to simulate the behaviour of the Pong and determine "populations" of yields, performance characteristics (reliability, vulnerability, resilience and sustainability) and rule curves ordinates. Comparing these parameters between the baseline and the perturbed provided the population of climate change effects which was then analysed to determine the uncertainties. The results show that contrary to the usual practice of using single records, there is wide variability in the assessed impacts. Recommendations are then made regarding how the results can support decision making for climate-change proofing in reservoir management.

IAHS (Hydrology)

HS02d - HS02 Hydrologic Non-Stationarity and Extrapolating Models to Predict the Future

IUGG-0043

Progress in hydrological modelling of changing catchments: lessons from the common testing experiment at the 2013 IAHS general assembly

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This communication will present a summary of the outcomes of a workshop session held in Gothenburg (Sweden) during the IAHS General Assembly in 2013 on the topic of modelling of temporally-varying catchments, i.e. catchments that exhibit significant changes in their physical or climate conditions over a period of record. This workshop aimed at contributing to the Panta Rhei IAHS decade by offering a tribune to modellers to debate on hydrological modelling under change.

For this workshop, the participants had been invited to apply a calibration and evaluation protocol to their own hydrological models on a given set of changing catchments and to come to Gothenburg to present their results (Thirel et al., 2015a). It was recognized that this protocol, based on calibration and evaluation over contrasted periods, is an appropriate way of assessing the suitability of hydrological models to handle changing conditions.

Some modellers saw this exercise as an opportunity to confront their models to conditions different from their usual application area, or to use models to better understand hydrological changes. The crucial need for dedicated protocols to evaluate models under change was also stressed by some modellers who proposed complementary testing protocols (Thirel et al., 2015b). Several challenges for future research to improve the hydrological modelling of changing catchments were discussed during the workshop and will be presented.

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IAHS (Hydrology)

HS02d - HS02 Hydrologic Non-Stationarity and Extrapolating Models to Predict the Future

IUGG-0139

Generating non-stationary stochastic rainfalls by variable length block bootstrapping

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A monthly variable length block bootstrap model that is able to generate stochastic rainfalls for a normal, a drier, a wetter and/or a more variable climate is formulated and tested using a multi-site problem located in the Western Cape of South Africa. The rainfall ensembles for a changed climate can be generated as time-invariant (stationary) or time-variant (non-stationary) and the overall average mean annual precipitation of the ensembles can be matched to the mean annual precipitation projected by Global Climate Models or other methods. These abilities are achieved by biasing the selection of historic rainfall blocks based on their mean annual precipitation and by appropriately varying the intensity and temporal variation of this bias during block resampling. An approach for matching the average monthly fragments to those projected by global climate models or other approaches is also incorporated in the model. The variable length block model obtains stochastic rainfalls that possess the expected inter-decadal variability unlike global climate model projections. Furthermore, since the model generates rainfalls for existing rainfall stations, it could be used as a practical statistical downscaling method if matched to the overall mean annual precipitation and monthly fragments projected by global climate models. The variable length block model therefore incorporates two essential components of probabilistic water resources planning; natural climatic variability and the plausible long-term changes to rainfall due to climate change.

IAHS (Hydrology)

HS02e - HS02 Hydrologic Non-Stationarity and Extrapolating Models to Predict the Future

IUGG-0007

Modelling climate change impact on future runoff: uncertainty from climate projections, hydrological models and model calibration considerations

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The term ‘hydrologic non-stationarity’ has been used to describe many things, ranging from climate and streamflow variability evident in different periods within a long hydroclimate time series to changes in climate-runoff relationships and dominant hydrological processes over time. Hydrologists have excelled in developing models for numerous applications, through analysing and interpreting climate and hydrologic data to understand hydrologic processes, conceptualising the processes in hydrological models, and calibrating and testing models against observations. These models are particularly good in predicting streamflow response to changes in the climate inputs and catchment characteristics. In fact, practically all climate change impact on runoff studies use future climate series informed by projections from climate models to drive a hydrological model developed and calibrated against past hydroclimate data.

Interpreting results from these simulations will become more challenging as we extrapolate the models to predict further into the future where streamflow will be influenced not only by the changed climate inputs, but increasingly by higher temperature and changed ecohydrological processes under higher CO_2 not seen in the past. This paper will explore potential errors or uncertainty from different sources in current approaches using data from south-eastern Australia. Specifically, the paper will quantify the range of results in future runoff estimated using future climate change projections from the range of CMIP5 global climate models, using different hydrological models, and using parameters from models calibrated against entire historical data versus parameters calibrated using only historical periods that are similar to the future climate projections.

IAHS (Hydrology)

HS02e - HS02 Hydrologic Non-Stationarity and Extrapolating Models to Predict the Future

IUGG-0019

Scientific and practical tools for dealing with water resource estimations for the future

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Future flow regimes will be different to today and highly uncertain, the uncertainty related to imperfect knowledge of present and future climate variations, rainfall-runoff processes and anthropogenic impacts. If decisions are to be made about responding to change, practical and appropriate simulation tools are needed, which represent natural hydrology and various anthropological impacts on flow regimes. The models need to be sensitive to changes, able to assimilate different types of change information and flexible enough to accommodate improvements in our understanding of change. Above all, the tools need to include methods of representing uncertainty and generate outputs that are appropriate for uncertain decision-making. This paper presents some examples of the tools that have been developed to address these issues within the southern Africa region. The examples are based on realistic, but largely hypothetical uncertainty scenarios of different types of change. The examples will demonstrate methods of dealing with uncertainty in present day situations due to lack of understanding and data, using climate change projection data from multiple climate models, possible future catchment response changes due to both climate and development effects and land-atmosphere feedbacks related to changes in temperature and carbon regimes. The outputs of the different examples are examined in a context of uncertain water resources decision-making. The conclusions are that the tools and models are largely available and that what we need now is more reliable information to feed the models and generate appropriate information as well as methods of making decisions with such inevitably uncertain information.

IAHS (Hydrology)

HS02e - HS02 Hydrologic Non-Stationarity and Extrapolating Models to Predict the Future

IUGG-0024

Modifications to rainfall-streamflow models to handle non-stationarity: IHACRES model applied to Bani River catchment, Africa

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The Bani River catchment is a large catchment (area 130,000 sq km) in western Africa that has had declining streamflows since the 1970's. Originally, the catchment had a strongly perennial flow, with minimum flow between 1959 and 1970 of approximately 10 cumecs. By the mid 1980's the minimum flows had decreased to zero, while the peak flows decreased by a factor of almost 3. There has also been a decrease (by about 70%) in the runoff coefficient over the period of record. Modifications made to the IHACRES model include: adopting a Nash cascade to capture the very slow response of the catchment; and a loss term to capture the transition from perennial to ephemeral flows. Analysis of the model performance showed that potential evaporation alone cannot explain the decrease in minimum flows. Relating the loss to population growth gave a better result, suggesting that the transition to a ephemeral flow pattern is due to increase in water use through time.

IAHS (Hydrology)

HS02e - HS02 Hydrologic Non-Stationarity and Extrapolating Models to Predict the Future

IUGG-0072

Generalization of parameters in the storage-discharge relation for a low flow based on the hydrological analysis of sensitivity

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The accurate estimation of a low flow can contribute to better water resource management and more reliable evaluation of the impact of climate change on water resources. In this study we present the generalized parameters in the discharge-storage relations for a low flow by efficient sensitivity analysis using a hydrological model.

In earlier studies of low flow, the nonlinearity of the discharge Q associated with the storage S was expressed by the general power function Q=KSN, where K is a constant and N is the exponent value (e.g., Horton, 1936). Fujimura et al. (IAHS Publ. No. 363 & 364, 2014) carried out a wide-ranging sensitivity analysis of the two parameters in the discharge-storage relation Qg=AuNSgN and found that the optimum two parameters, Au and N, can be characterized by the power function Au=1/(?N?). Here, Qg is the groundwater runoff, Sg is the groundwater storage, Au is the fractal recession constant and ? and ? are constants. This study perform a sensitivity analysis of efficiency using a hydrological model, in which the exponent value N is varied between 1 to 105 along in the neighborhood of a line of the power function Au=1/(?N?). The study basins are four mountainous basins in Japan selected for their very different climatic and geological conditions. The hydrological data used in this study are 10 to 20 year periods in hourly time steps.

The results show that the constant ? was confirmed to be 1. The optimum value of the constant Au, therefore, is inversely proportional to N, namely Au=1/(?N). In addition, the optimum value of N in the range of 1 to 105 is a higher value, such as more than 100. The results obtained in this study may serve as a reliable and accurate estimation for a low flow by using the new discharge-storage relation.

IAHS (Hydrology)

HS02e - HS02 Hydrologic Non-Stationarity and Extrapolating Models to Predict the Future

IUGG-0173

Estimating inter-annual runoff variability from a global data set

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Hydrologic signatures are a promising methodology for constraining hydrologic models under changed or changing conditions. Signatures or indices of hydrologic interest can be estimated directly from observed data. However, where observed data are unavailable at a given location a theoretical or empirical relationship is required to estimate the signature value. Empirical signature relationships developed over a wide range of climate and catchment conditions offer scope for robust prediction of signature values in ungauged basins (PUB problem) and ungauged climates (PUC problem). Here we present empirical relationships for inter-annual runoff variability, represented by the annual coefficient of variation (RCv), developed from the analysis of a global data set of 588 catchments. Empirical RCv relationships are developed for the World, Australia and Southern Africa, the rest of the World, and catchments experiencing predominantly (≥75% catchment area) tropical, arid, temperature or cold climate types. The RCv relationships are established using catchment characteristics pertaining to precipitation, evaporative demand, vegetation and topography. Key variables that contribute to explaining RCv in each relationship are assessed to identify the dominant drivers of RCv and how the contribution of those drivers varies between regions and climate types. A comparison in performance between previously published RCv relationships and the empirical relationships presented here is also made. These empirical RCv relationships are indicative of the benefit than can be obtained from large-sample hydrology at the global scale.

IAHS (Hydrology)

HS02f - HS02 Hydrologic Non-Stationarity and Extrapolating Models to Predict the Future

IUGG-0082

Assessment of climate change effects on groundwater resource in transient conditions

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A sophisticated transient weather generator (WG) in combination with an integrated surface-subsurface hydrological model (HydroGeoSphere) are used for producing a stochastic generation of large numbers of equiprobable climatic time series, representing transient climate change, and assess impacts on groundwater resources in a probabilistic way. The modelling approach is applied for the unconfined chalky aquifer of the Geer catchment in Belgium. Biased-corrected climate change scenarios are applied as input of the hydrological model. The integrated model is used in combination with a stochastic daily weather generator (WG). This WG allowed generating a large number of equiprobable climate change scenarios representative of a full transient climate between 2010 and 2085. These scenarios enabled to account for the transient nature of the future climate change, and to assess the uncertainty related to the weather natural variability. The downscaling method considers changes in the climatic means, but also in the distribution of wet and dry days.
A general decrease of the mean groundwater piezometric heads is calculated. The approach allowed also assessing different uncertainty sources linked to: (1) the calibration of the hydrological model; (2) the global and regional climatic models, by using a multi-model ensemble; (3) the natural variability of the weather, by using stochastic climate change scenarios. 30 equiprobable climate change scenarios from 2010 to 2085 have been generated for each of 6 different RCMs. Results show that although the 95% confidence intervals calculated around projected groundwater levels remain large, the climate change signal becomes stronger than that of natural climate variability by 2085.

IAHS (Hydrology)

HS02f - HS02 Hydrologic Non-Stationarity and Extrapolating Models to Predict the Future

IUGG-0091

Would inclusion of peak rainfall intensity add value to runoff predictions?

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Most hydrological models such as SimHyd and GR4J for streamflow estimation require, as input, continuous daily precipitation and potential evapotranspiration. With the projected increase in mean surface temperature as a result of elevated level of CO_2 concentration in the atmosphere, hydrological processes, precipitation especially, are set to intensify irrespective of the underlying changes to the mean precipitation. The effect of an increase in rainfall intensity at the sub-daily time scale on the long-term water balance is, however, not adequately accounted for in the commonly used hydrological models. This study follows from a previous comparative analysis of a non-stationary daily series of streamflow of a forested watershed (River Rimbaud) in the French Alps (area = 1.4 km^2) (1966-2066). Non-stationarity in the recorded streamflow of the watershed occurred as a result of a severe wild fire in 1990. Four daily models (AWBM, SimHyd, GR4J, and SCS-CN) were initially calibrated using daily precipitation and potential evapotranspiration data only. Exploratory data analysis was undertaken to relate daily peak hourly precipitation and the discrepancy between the observed and modelled runoff. Preliminary results show that the effect of peak hourly precipitation on runoff prediction is significant, and runoff prediction would improve when peak daily precipitation is included. Daily hydrological models are modified generically embedding the peak rainfall intensity for better streamflow estimation.

IAHS (Hydrology)

HS02f - HS02 Hydrologic Non-Stationarity and Extrapolating Models to Predict the Future

IUGG-0098

Snowpack trends and variability at long-term stations in Northern Colorado, USA

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Long term analysis of snowpack trends use manual snow course data collected at the first of the month. Across the Western United States, April 1st is used to represent peak snow water equivalent (SWE). Various studies have illustrated a decrease in SWE along the Pacific Coast (Washington, Oregon and California) for the period from the start of measurements in the 1930s or so through the end of the century. The trend in continental climates has been less definite. Global temperature patterns indicate differing trends over this same time period with cooling from the mid-1940s through mid-1970s and then rapid warming since then. As such, data from individual snow course stations across northern Colorado were analyzed to determine if shorter trends existed, specifically for one period starting in the 1930s and another ending in the 2000s. Significant trends were found for these two time periods but not for the entire period of record. The manual snow course data collected by the Natural Resources Conservation Service also have the utility of being an average of 10 or more individual measurements. The individual measurements were also used to investigate trends in variability at each location using the same period of record. Variability trends were less clear, but the utility of using more than just the average of the individual measurements is highlighted.

IAHS (Hydrology)

HS02f - HS02 Hydrologic Non-Stationarity and Extrapolating Models to Predict the Future

IUGG-0137

Evaluation of drought impact on groundwater recharge rate by SWAT and Hydrus Model in an agricultural island, Western Japan

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Clarify the variations of groundwater recharge is important for efficiently managing the ground water resource, particularly in regions with limited precipitation which face with the risk of water shortage. However, the rate of aquifer recharge is difficult to evaluate under a changing non-stationarity hydrological process In case of the large annual-variation and increasing frequency of drought event in western Japan, we would like to simulated related groundwater recharge process, using the SWAT Model, validate the groundwater using the HYDRUS Model. Simulation time periods is 2000-2013, including warm up period of 2000-2003 and calibration period of 2003-2004. The reproducibility of daily discharge in calibration period by the model was found to be acceptable. The result shows annual average groundwater recharge comprise about 34% of total precipitation, however larger variation of groundwater recharge was found than river discharge fluctuated with annual precipitation variations, in high precipitation year of 2011 (1,527mm), groundwater recharge rate increased about 6 times than in low precipitation year of 2005 (781mm), the increasing of river discharge is at about 2.5 times. In spatial variations of groundwater recharge rate, the upstream is main surface water discharge area; middle and downstream area is the main ground water recharge area. By validation by Hydrus Model, the estimated and simulated groundwater level matched well in our research area. The groundwater level variation shows annual variation response quickly with the groundwater recharge rate and drought events. Consequently, it was estimated that large spatial and temporal variation of groundwater recharge rate would affected by precipitation uncertainty in future.

IAHS (Hydrology)

HS02f - HS02 Hydrologic Non-Stationarity and Extrapolating Models to Predict the Future

IUGG-0168

Assessing the reliability of conceptual model predictions in a cultivated, snowmelt-driven catchment of the semi-arid Andes

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This paper explores the reliability of hydrological model predictions in a cultivated, snowmelt-driven catchment of semi-arid Andes. Depending on water availability, a significant part of surface water resources are diverted to meet irrigation requirements. In return, these water withdrawals are likely to influence the hydrological catchment behavior. Natural climate variability also has considerable effects on the water supply capacity at both the interannual and interdecadal time scales. In the future, higher temperatures and lower precipitation are expected to affect both the volume and timing of hydrological events and irrigation requirements. Thus, the value of model-based analyses relies on our ability to adequately represent the complex interactions between hydroclimate non-stationarity, human-induced flow perturbations and crop evapotranspiration. To this end, the whole catchment (1512 km^2) was divided into three subcatchments to separate upstream natural flows from downstream influenced flows. Three conceptual models were combined and tested over different periods: a hydrological model including a snow module, a process-based phenological model and an irrigation management model. The periods were chosen so as to represent contrasted water-use and hydroclimate conditions over the last 30 years. Model results were analyzed using uncertainty quantification techniques to account for unavoidable errors in observations, model structures and inputs. Despite significant predictive uncertainty, this framework provided reliable model simulations in terms of the percentage of observations covered by the uncertainty bounds. Consequently, the models were also used to study the impact of climate variability on the capacity of natural flows to meet irrigation water needs.

IAHS (Hydrology)

HS02p - HS02 Hydrologic Non-Stationarity and Extrapolating Models to Predict the Future

HS02p-028

Non-stationarity driven by long-term change in catchment storage: Possibilities and implications

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“Non-stationarity” with reference to hydrology is a term applied to many situations. While climate change non-stationarity is often examined, these effects can provide a stern test for assumptions of runoff generation process encapsulated in rainfall-runoff (RR) models.

Observations from Southwestern Australia (SWA) over the past 40 years show a decline in rainfall and reductions in runoff. Q/P relationships in SWA show a significant shift over the past 40 years suggesting a change in runoff generation and catchment state. This has challenged the paradigm of assumed runoff generation process in SWA as well as the veracity of conceptual RR model structure.

We expand on some of the lessons learned from SWA and frame the climatic and geomorphic conditions that may make reasonable predictions of runoff very difficult with RR models calibrated in traditional ways. Catchment storage has a significant interaction with runoff generation and we examine the situations where this may change in the longer term. We suggest some strategies in terms of model structure and calibration that may improve predictive performance in such situations.

IAHS (Hydrology)

HS02p - HS02 Hydrologic Non-Stationarity and Extrapolating Models to Predict the Future

HS02p-029

Analysis on domestic water demand in Haihe river basin of China under future environmental changes

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A statistical model has been developed to predicting future domestic water demand in Haihe river basin of China in the context of climate change, population growth and technological development. Historical records of domestic water use, climate, population and available technologies are used to develop the model. The model is then used to project the possible impacts of climate and other changes on domestic water use in Haihe river basin. A suit of seven GCMs models namely, BCC-CSM1-1, BNU-ESM, CNRM-CM5, GISS-E2-R, MIROC-ESM, PI-ESM-LR, MRI-CGCM3 under various Representative Concentration Pathways (RCPs) adopted by Intergovernmental Panel for Climate Change (IPCC) are used for this purpose. Results showed that domestic water demand in different sub-basins of Haihe river basin will continue to increase with time. Under projected climate, population, water saving technological improvement, future domestic water demand in Haihe river basin is projected to reach maximum $136.22\times10^8 m^3$ by BNU-ESM model and minimum $107.25\times10^8 m^3$ by CNRM-CM5 model in 2030. In spite uncertainty in projection, it can be remarked that climate change and population growth will increase water demand and consequently, reduce the gap between water supply and demand in the basin. Water demand management should be emphasized for adaptation to ever increasing water demand and mitigate the impacts of environmental changes.

IAHS (Hydrology)

HS02p - HS02 Hydrologic Non-Stationarity and Extrapolating Models to Predict the Future

HS02p-030

Streamflow predictions in regulated river systems: Hydrological non-stationarity versus anthropogenic water use

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Streamflow in a regulated river system is highly influenced by storage regulations and anthropogenic water use in addition to climate variability. Thus, changes in climate-runoff relationships and dominant hydrological processes over time are difficult to quantify in a regulated system without partitioning influence of storage regulation and anthropogenic water uses. This requires a robust regulated river system model, which takes into consideration of both hydrological and man-made flow regulation processes, as well as anthropogenic water uses.

A large-scale river system (AWRA-R) model was developed and implemented for water accounting in Australia. The model includes major hydrological processes, anthropogenic water utilisation and storage routing that influence the streamflow in regulated rivers. It incorporates urban diversion and includes an irrigation model to compute water diversion for irrigation and an inundation model to compute overbank flow.

AWRA-R was used in the Murray-Darling Basin (MDB), a highly regulated basin with over 60 large storages used for irrigation diversion. This was undertaken with the aim to assess streamflow variability over a period from 1910-2014. This period includes rapid water resources development in the basin. The model was calibrated in different periods covering early years with limited water resources development and later years with high development. The calibrated parameters were used to simulate streamflow under current and pre-development conditions to analyse the streamflow variability and influence of climate change and anthropogenic development. This paper briefly introduces the model and the method used for assessing streamflow variability under natural and developed conditions and presents the results and findings.

IAHS (Hydrology)

HS02p - HS02 Hydrologic Non-Stationarity and Extrapolating Models to Predict the Future

HS02p-031

Scaling behaviour in the relationship between land use changes and flood regime

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Socio-economic activities taking place in a watershed produce changes in land uses that modify the behaviour of infiltration and its relationship with the generation of surface runoff. This study has two main objectives: a) determine the effect of the static storage (initial abstractions plus soil capillary retention) and saturated infiltration capacity variation on the flood magnitude, and; b) incorporate the scalability properties of fractal models to describe the flood variability with respect to changes in static storage. The study area corresponds to the Combeima River basin in Colombia, South America, where historic changes in land use between 1991 and 2007 were analysed, along with the watershed's hydrological response, modelled through a distributed hydrological model. A frequency analysis was carried out with the Generalized Extreme Value (GEV) and Gumbel probability distribution functions. Later, a joint estimation of scaling theory was implemented to synthesise regularities of flood behaviour using the mean watershed static storage and saturated infiltration capacity as scales. This scaling behaviour was found not only for the flood moments, but also for the probability distribution parameters. The obtained results were useful to determine that, through potential equations, it is possible to describe both the variation in static storage brought about by land use changes and the magnitude of flood quantiles.

IAHS (Hydrology)

HS02p - HS02 Hydrologic Non-Stationarity and Extrapolating Models to Predict the Future

HS02p-032

Advanced modelling of hydrologic non-stationarity and its role on improvement in biogeochemical cycle in inland water

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Recent research shows inland water may play some role in continental carbon cycling though its contribution has remained uncertain due to limited data (Battin et al., 2009). The authors have developed process-based National Integrated Catchment-based Eco-hydrology (NICE) model (Nakayama, 2008a-b, 2010, 2011a-b, 2012a-c, 2013; Nakayama and Fujita, 2010; Nakayama and Hashimoto, 2011; Nakayama and Shankman, 2013a-b; Nakayama and Watanabe, 2004, 2006, 2008a-b; Nakayama et al., 2006, 2007, 2010, 2012), which incorporates surface-groundwater interactions and can simulate feedback between hydrologic-geomorphic-ecological processes. NICE incorporates 3-D groundwater sub-model and expands from previous 1- or 2-D and steady state, and can clarify lateral subsurface flow has also important role on the hydrologic and biogeochemical cycles (Nakayama, 2011b; Nakayama and Shankman, 2013b), which extends traditional dynamic equilibrium with atmospheric forcing (Maxwell and Kollet, 2008). In this study, NICE was further coupled with biogeochemical model to incorporate the biogeochemical cycle including reaction between inorganic and organic carbons in biosphere including surface water and groundwater. This improvement in hydrologic non-stationarity and the coupling with biogeochemical cycle showed some effect on variations of CH_4 flux in wetland which is sensitive to fluctuations of shallow groundwater. The model also simulated CO_2 evasion from inland water in global scale, was relatively in good agreement in that estimated by empirical relation (Aufdenkampe et al., 2011). This advanced model would play important role of hydrologic non-stationarity on improvement in identification of greenhouse gas balance along terrestrial-aquatic continuum (Cole et al., 2007; Battin et al., 2009).

IAHS (Hydrology)

HS02p - HS02 Hydrologic Non-Stationarity and Extrapolating Models to Predict the Future

HS02p-033

Comparison of nonstationary generalized logistic models based on Monte Carlo simulation

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Recently, the evidences of climate change have been observed in hydrologic data such as rainfall and flow data. The time-dependent characteristics of statistics in hydrologic data are widely defined as nonstationarity. Therefore, various nonstationary GEV and generalized Pareto models have been suggested for frequency analysis of nonstationary annual maximum and POT (peak-over-threshold) data, respectively. However, the alternative models are required for nonstatinoary frequency analysis because of analyzing the complex characteristics of nonstationary data based on climate change.

This study proposed various nonstationary generalized logistic models including time-dependent parameters. The parameters of proposed models are estimated using the method of maximum likelihood based on the Newton-Raphson method or R package. In addition, the proposed models are compared by Monte Carlo simulation to investigate the characteristics of models and applicability of various method to estimate the parameters.

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IAHS (Hydrology)

HS02p - HS02 Hydrologic Non-Stationarity and Extrapolating Models to Predict the Future

HS02p-034

Drought Assessment and Trends Analysis from 20th Century to 21st Century over China

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Droughts are becoming the most expensive natural disasters in China and have exerted serious impacts on local economic development and ecological environment. The fifth phase of the Coupled Model Intercomparison Project (CMIP5) provides a unique opportunity to assess scientific understanding of climate variability and change over a range of historical and future 21st century (2001-2100). In this study, fine-resolution multimodel climate projections over China are developed based on 8 CMIP5 climate models under two emissions scenarios (RCP4.5 and RCP8.5) by means of Bilinear Interpolation and Bias Correction. The result of downscaled CMIP5 models are evaluated over China by comparing the model outputs with the England Reanalysis CRU3.1 from 1951 to 2000. Accordingly, the results from the output of downscaled models are used to forcing the VIC model. Time series of monthly precipitation, monthly total runoff from VIC models, and their ensemble median have been used to identify drought from 20th century to 21st century over China. The results show that, in spite of widespread precipitation increases, most areas of China are projected to become drier as a consequence of increasing evaporation driven by temperature increases under RCP4.5 and RCP8.5 scenarios. Detailed examination shows that drought is moderate or severe according to current climate standards will become the norm in the future. Not only will incidences of severe and extreme drought increase dramatically in the future, but extreme wet events will also become more probable.

IAHS (Hydrology)

HS02p - HS02 Hydrologic Non-Stationarity and Extrapolating Models to Predict the Future

HS02p-035

The evaluation of regional frequency analysis methods for nonstationary data

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Regional frequency analysis (RFA) is widely used to estimate more reliable quantiles of extreme hydro-meteorological events. The stationarity of data is required for its application. This assumption tends to be violated due to climate change. In this paper, stationary index flood (SIF) and nonstationary index flood (NSIF) methods were used to analyze the nonstationary regional data. Monte Carlo simulation was used to evaluate the performance of two methods for the generalized extreme value (GEV) model with time varying location/scale parameters and constant shape parameter. This paper also included the case study on precipitation data from South Korea. As the results, the stationarity of the data had more effects on the index flood than the growth curve and consequently the time varying parameters of the nonstationary model need to be formed considering the temporal pattern of the regional frequency estimates. The shape parameter of GEV distribution had little effects on the temporal pattern of the regional frequency estimates. Temporal change of the heterogeneity measure was not significant.

Acknowledgement

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IAHS (Hydrology)

HS02p - HS02 Hydrologic Non-Stationarity and Extrapolating Models to Predict the Future

HS02p-036

Characterization of the space-time variability of annual precipitations in the area of the upstream Boughezoul

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Abstract : The climate changes had important effects on rainfall and flows in Algeria presenting a remarkable disturbance of the rainfall mode to the level of all its areas. In this work, the rainfall mode is studied on an annual scale in the catchment area of Boughezoul, characterized by a semiarid climate with arid. The interannual evolution of the rainfall modules is represented by 33 rainfall stations installed on 12 sub basins. The statistical tests of homogeneity are applied to the series of the annual totals of the stations thus making it possible to detect ruptures over period 1970/71 to 2008/09 is 40 years of observations. Space and temporal analyses were undertaken. The first via the Analysis in principal component made it possible to extract the relations being able to exist between the elements of this system of resource whereas the temporal analysis made it possible to visualize the succession of the wet and dry years during the studied time series. To detect more information, a characterization of the drought starting from the SPI (Standardized Precipitation Index) was made and which led us to discover an alternation of various classes to knowing wet, normal and dry allowing to determine the climate dominating over the whole of the watershed. Variability climatic and more particularly rainfall in Boughezoul's watershed is a recurring phenomenon at the risk, which requires the setting in continuous observation for an early alarm and to draw up the plans of intervention in the event of water shortage.

Keywords: Watershed of Boughezoul Upstream, rainfall mode, tests of homogeneity of Khronostat, ACP (Analysis in Principal Component), SPI (Standardized Precipitation Index).

IAHS (Hydrology)

HS02p - HS02 Hydrologic Non-Stationarity and Extrapolating Models to Predict the Future

HS02p-037

Non-stationarity in extreme daily rainfall and its impact on nesign

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Stationarity in hydro-meteorological records is commonly investigated through an assessment of the mean value of the tested parameter. This is arguably insufficient for capturing non-stationarity and parameter variance can be more important. This study applies the Mann-Kendall linear and Mann-Whitney-Wilcoxon step change trend detection techniques to investigate the changes in the mean and variance of maximum annual daily rainfalls at eight stations in Dublin, Ireland, where long and high quality rainfall records are available. Design estimates are obtained from frequency analysis of annual maximum daily rainfalls using the Generalised Extreme Value distribution, identified from the Modified Anderson Darling Goodness of Fit criterion. Results indicate that while significant positive step changes were observed in mean values (1961 and 1997) at two of the eight stations, a significant and consistent shift in the variance was observed at all eight stations during the 1980s.

The study evaluates the impact of this non-stationarity in variance on rainfall design estimates. Two depth-frequency relationships for return periods from 5 to 100 years are derived at each station, the first based on the full rainfall record assuming stationarity and the second based on a partial record commencing in the year that followed the shift in variance. Increases in design rainfall estimates using the two curves ranging from 5% to 16% for the 5-year event and from 20% to 41% for the 100-year event were observed. Results illustrate that detected trends in higher order moments of hydro-meteorological variables can be important and should be considered in design estimates.

IAHS (Hydrology)

HS02p - HS02 Hydrologic Non-Stationarity and Extrapolating Models to Predict the Future

HS02p-038

Method of determining characteristics maximum spring flood runoff in Ukraine in view of global and regional climate change

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The authors of this study proposed method considering possible climate change as part of genetic model of maximum spring and rain floods operator type. The model proposed makes it possible to introduce 'climate amendment' directly to the maximum snow supplies and precipitation during the flood, as well as runoff coefficients.

To study the parameters of methods of calculating the maximum spring flood were used data of runoff on the 340 hydrological observation stations and posts of the State Hydrometeorological network within the plain territory of Ukraine, as well as a small part of Russia, on which the basins of the Desna, Sejm and the Seversky Donets. Also for spatial generalization spring flood factors were used observational data 229 meteorological stations and posts, which collected data on the maximum snow supplies the beginning of spring flood and precipitation for the period flood.

In order to obtain predictive values of temperature and rainfall in the plains of Ukraine in the study were using the results of modeling of two different global climate forecasting centers - HadCM3 model developed by Hadley Centre for climate research and forecasting (Meteorological Service UK MetOffice), and climate model (CCSM3) developed National Center for atmospheric Research (NCAR, USA). The next task was to study the relationship between the expected value (eg, annual precipitation) and calculated values - maximum snow supplies and precipitation during the flood. For the territory of Ukraine according to the data from 103 weather stations about snow supplies and 315 weather stations about precipitation got the depending that have relatively high correlation coefficients, indicating the possibility of direct incorporation of climate change on flood runoff.

IAHS (Hydrology)

HS02p - HS02 Hydrologic Non-Stationarity and Extrapolating Models to Predict the Future

HS02p-039

Evaluation of monotonic trends for streamflow in austral Amazon, Brazil: a case study for the Xingu and Tapajós rivers.

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This paper has the goal of evaluating monotonic trends in the Xingu and Tapajós river basins in the Austral Amazon region, Brazil, and their possible implications in hydropower generation. Non-parametric statistical tests such as Mann-Kendall, Bootstrap Mann-Kendall, Sen and Bootstrap Sen are applied on streamflow gauging stations data, to determine the magnitude and significance of possible trends. Data in these river basins is relatively scarce, with time series ranging from twenty to forty years, having many gaps. Former studies indicate a decreasing trend for both annual average and minimum streamflow values in the Tapajós river basin, with 99% confidence level, and a decrease in maximum values in the Xingu river basin, with 90% confidence level. However, past analyses have only used one station near the basin outlet. This study uses data from 9 gauging stations in the Xingu basin and 14 stations in the Tapajós basin. Results indicate opposite trends for different regions in the basins, and for different sections (minimum, average, maximum) of the flowrate distribution. A significant (95% confidence) decreasing trend was detected for the minimum flowrate at the Tapajós basin stations, whereas for the average and maximum flowrates increasing trends predominate. In the Xingu river basin, contrasting other studies, positive significant trends stand out.

IAHS (Hydrology)

HS02p - HS02 Hydrologic Non-Stationarity and Extrapolating Models to Predict the Future

HS02p-040

Non-stationarity of Owo River catchment in South Western Nigeria

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The Owo River is an important surface water source in Lagos particularly to the western section.It is the source of direct water intake for water supply by Lagos State Water Corporation to Amuwo-Odofin, Ojo and parts of Badagry Local Government Areas. This paper examine the complex interactions and feedbacks between many variables and processes within that catchment and analyses the future ability of this semi-urban watershed is sustaining water supply in the face of cumulative environmental change. Stationarity analysis on rainfall, change detection analysis and morphometry analysis were combined to analyse the non-stationarity of Owo River catchment. On rainfall trend analysis, since the Correlation Coefficient (0.38) with Test Statistic of 2.17 did not satisfy the test condition we concluded that there is trend and that rainfall in the watershed is not stationary. The dominant land use impacting on the bio-geochemical fluxes is built up area (including structures and paved surfaces) which grew from about 62.37 km^2 (5.32%) in 1984 to 365.38 km^2 (31.17%) in 2013 recording gain of 303.01Km^2 at average growth rate of 10.45 km^2 per annum. Total length of streams within the catchment reduced from 622.24 km in 1964 to 556 km in 2011, while stream density reduced from 0.53 in 1964 to 0.47 in 2011 an indication of shrinking hydrological processes. The observed trends in both natural and anthropogenic processes indicated non-stationarity of the hydrological fluxes within the Catchment and if this continues, the urban ecosystem services of water supply will be compromised

IAHS (Hydrology)

HS02p - HS02 Hydrologic Non-Stationarity and Extrapolating Models to Predict the Future

HS02p-041

Evaluation for the effect of non-stationary nutrient transport on the coastal seaweed cultivation in western Japan

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The coastal area such as estuaries is characterized by significantly high biological production and biodiversity where freshwater with higher nutrients meets saltwater. It is also an important area as coastal fisheries. The seaweed cultivation is significantly influenced by the nutrient transport through rivers. However, the river-derived nutrient supply is unsteady and is closely related to the environmental changes such as variation of precipitation and land use. Therefore, it is important to evaluate and predict the effect of non-stationary nutrient transport on the seaweed production for the sustainable coastal fisheries.

In the present study, the relation between the variation of the nutrient load and the seaweed yield was examined for the last 40 years in the coastal area of the Seto Inland Sea, western Japan. The Seto Inland Sea is the largest enclosed sea in Japan with large influence of freshwater inputs. However, decreasing trend in the yield of seaweed (nori) is one of the critical problems in the coastal fishery. The results show that seaweed yield was in the peak in early half of the 1970s, since then it has been on a decreasing trend. Both of the river inflow and concentration of nutrients in seawater totally show a decreasing trend since 1970s. Besides, the annual yield decreased significantly in the following dry year (<1,000 mm/y). These results indicate that one of the controlling factors of seaweed yield is land-derived nutrient in the study area.

IAHS (Hydrology)

HS02p - HS02 Hydrologic Non-Stationarity and Extrapolating Models to Predict the Future

HS02p-042

Detection of climate change using statistical tests in the Dorudzan Dam Basin, Iran

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In this research, in order to investigate climate change occurrence in the Dorudzan Dam Basin, At least 35 and maximum 45 years

observed data (1977-2012, 1966-2012) from the stations of the area were used and evaluated. To this regard, significant variations

values of maximum, minimum and average air temperatures as well as precipitations and relative humidity on both annual and seasonal

time series were analyzed. Various statistical tests including Man-Kendall, spearman, Pearson and Linear regression Tests have been

applied to recognize the probable trend of data. The results show that first: an increasing trend in seasonal maximum temperatures also

spring and annual average temperatures. Second: a decreasing variation in spring, summer and Annual relative humidity. Thus the

climate change is demonstrated in the basin. Of course, Values of precipitation did not show any significant trend in seasonal and

annual scale.

IAHS (Hydrology)

HS02p - HS02 Hydrologic Non-Stationarity and Extrapolating Models to Predict the Future

HS02p-043

Discrete wavelet transform coupled with ANN for daily discharge forecasting into Três Marias reservoir using TRMM data

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This paper proposes the use of discrete wavelet transform (DWT) to remove the high-frequency components (details) of input original signals, because the noises generally present in time series (e.g. streamflow and rainfall records) may influence the prediction quality. Cleaner signals could then be used as inputs to an artificial neural network (ANN) in order to improve the model performance of daily discharge forecasting. Wavelet analysis provides useful decompositions of original time series in high and low frequency components. The present application uses the Coiflet wavelets to decompose hydrological data, as there have been few reports in the literature. Finally, the proposed technique is tested using the inflow records to the Três Marias reservoir in São Francisco River basin, Brazil, and daily rainfall data from the Tropical Rainfall Measuring Mission (TRMM) for the period of 1998–2012, which is a joint mission between NASA and the Japan Aerospace Exploration Agency (JAXA) designed to measure rainfall for weather and climate research. These transformed signals are used as input for an ANN model to forecast inflows seven days ahead, and the error RMSE decreased by more than 50% (i.e. from 372.3245 to 178.7158).

IAHS (Hydrology)

HS02p - HS02 Hydrologic Non-Stationarity and Extrapolating Models to Predict the Future

HS02p-045

Effects of precipitation and potential evaporation on actual evapotranspiration over the Laohahe basin, northern China

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Problems associated with water scarcity are facing new challenges under the ambiguous impact of climate change. As one of main consumptions in water cycle, evapotranspiration plays a crucial role in regional water budget. In this paper, we employed two methods, i.e. hydrological sensitivity analysis and hydrological model simulation, to investigate the effects of climate change (varied precipitation and potential evaporation) on actual evapotranspiration (E_a) within the Laohahe basin. The results show that affected by combined impacts of decreased precipitation and PET, variation of annual E_a in most catchments of this region suffered a downward trend during 1980-2009, with a higher descending rate in northern catchments. At decadal scale, E_a showed significant oscillation in accordance with precipitation patterns. Northern catchments generally suffered more decadal E_a changes than southern catchments, implying the impact of climatic change on decadal E_a is more intense in semi-arid areas than that in semi-humid regions. For whole changed durations, a general 0-20 mm reduction of E_a was found in most parts of studied region, with larger reductions (more than 40 mm) in southwestern part of the Laohahe basin and certain increments (0-80 mm) in northern and eastern parts of Chifeng catchment, which was in good agreement with the spatial pattern of precipitation variability. For this water-limited region, E_a shows higher sensitivity to precipitation than to potential evaporation (PET), which confirms the significant role of precipitation in controlling E_a patterns, whereas the impact of PET variation would be negligible.

IAHS (Hydrology)

HS02p - HS02 Hydrologic Non-Stationarity and Extrapolating Models to Predict the Future

HS02p-046

Monitoring and modeling of slope processes in a dynamic watershed – combining hydrology, soil science, remote sensing and geomorphology

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Slope morphodynamics are repeatedly object to research from various fields of science. Hydrology, soil science, remote sensing and geomorphology have an interest in increasing knowledge about potential relationships between processes occurring on highly dynamic slopes. A combination of approaches from all sciences is established in a watershed in southern Bavaria in the northern limestone Alps. The Lainbach Valley (Bavaria, Germany), a right tributary to the Loisach River, is filled with unstratified glacial and lacustrine sediments and thus prone to recent erosion and small-scale landslide events. Major areas of the 7km² basin are already heavily affected delivering large quantities of sediment and debris of all sizes to the receiving waters encouraging flooding events in downstream villages. Due to a severe flooding in 1990 with damaged infrastructure and buildings, the torrent was subject to some flood control measures.

A combined methodology of terrestrial laser scans, unmanned airborne vehicle imagery, rainfall simulations and soil scientific analysis is applied to (1) monitor changes in morphology of the slope and (2) to generate input parameters for a physical based erosion model EROSION 3D. For summerly conditions, the model produces decent results while changes during winter remain difficult to reproduce, due to the original development of the model for agricultural areas. Three morphological active areas of the watershed are measured on a regular basis, one of them since 2009. A weather station records the required climatic parameters to run the model and digital elevation models are produced either from terrestrial laser scanning data or by applying Structure from Motion algorithms on the airborne imagery.

IAHS (Hydrology)

HS02p - HS02 Hydrologic Non-Stationarity and Extrapolating Models to Predict the Future

HS02p-047

Estimation of the climate change effect on the long-term variation in river water temperature in a temporal snow-covered watershed

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According to the effect of climate change such as global warming, it is possibly predicted that seasonal precipitation and snowfall increase in a watershed scale. It would increase the river water discharge and disaster risks. Climate change also influences on river water temperature and river ecosystem. Therefore, the estimation of climate change effect on river environment especially in a snow-covered watershed is important. However, it is not well examined using long-term records. Besides, the river discharge data which is directly observed these effects is limited because it is usually controlled artificially by dams and weirs in large-scale watersheds. It is important to make the application model to evaluate the variation of river environment using the simple observed data such as river water temperature.

In the present study, we examine the prediction of river water environment in future, based on variations of river water temperature observed one week interval up to decade in western Japan. As a result, it shows the totally cooling trend and the most cooling tendency are detected in spring season. Total snow depth in winter in the recharge area shows increasing trend. These results suggest that river water temperature was affected by the snow melt in recharge area. It is important result which suggests global warming cause decrease of river water temperature and change of ecosystem in the temporal snow-covered region.

IAHS (Hydrology)

HS02p - HS02 Hydrologic Non-Stationarity and Extrapolating Models to Predict the Future

HS02p-048

Land cover and climate change effects on streamflow and sediment yield: a case study of Tapacurá catchment, Brazil

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This study assess the impact of the land use and climate changes between 1967−2008 on the streamflow and sediment yield in Tapacurá catchment (Brazil) using the Soil and Water Assessment Tool (SWAT) model. The model was calibrated and validated by comparing simulated mean monthly streamflow and sediment yield with observed long-term mean monthly streamflow and sediment yield from runoff-erosion gauge records. The obtained R^2 and Nash-Sutcliffe efficiency values to streamflow and sediment yield were respectively 0.77 and 0.74 for 1967−1974, and 0.84 and 0.82 for 1995−2008. The results show that the land cover and climate change affected the catchment hydrology, decreasing the streamflow and sediment yield (1.82 m^3/s and 20.66 t/ha/year for 1967−1974 and 1.53 m^3/s and 7.67 t/ha/year for 1995−2008). The process changes are arising mainly due to the land cover/use variability, but, mainly due to the decreasing in the rainfall depth during 1995−2008 when compared with the first period analyzed, which in turn decreased the streamflow and sediments during the wet seasons and reduced the base flow during the dry seasons. The evaluation of the SWAT model response to the land cover and climate changes has shown that the mean monthly flow, during the rainy seasons of the studied period increased, since no significant climatic changes were observed in the basin for the period 1967−2008. Finally, the results of this study for the Tapacurá catchment provide the information and understanding necessary for systematically identifying effective changes in the streamflow and sediment yield, which can be used as a principle for water resources management strategies in the basin.

IAHS (Hydrology)

HS02p - HS02 Hydrologic Non-Stationarity and Extrapolating Models to Predict the Future

HS02p-049

Coupled regional climate and hydrological modeling system for analysis of climate hydrology interactions in mountainous watersheds in Northwest China

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High elevation and cold mountain ranges are the main sources of runoff for the downstream agricultural oases and desert ecosystems in the inland river (terminal lake) basins in Northwest China. Hydrological processes and water resource supplies are very sensitive to climate change in these regions. Yet, few studies are done to assess the impacts of climate change on hydrological processes at the watershed scale in the arid Northwest China. We have developed a Coupled Regional Climate and Hydrological Modeling System (CRCHMS) to evaluate the effects of climate change on water resources in the inland river basins in Northwest China. The CRCHMS consists of a regional climate model-RegCM3 (Regional Climate Model Version 3) with a grid spacing of 10 km, and a distributed hydrological model-DLBRM(Distributed Large Basin Runoff Model) with a grid network of 1 km^2. A parameterization scheme and spatially double-nested scheme of the RegCM3 were devised to improve the output resolution.

Simulation results show that the CRCHMS performed better than the stand alone DLBRM and other similar coupled systems, mainly because the output of the regional climate model provides much better spatial coverage of meteorological variables than the interpolation of the observed station data. Thus, the output of regional climate model can be used as supplements to meteorological data in areas lacking of observed data. Because the output of the RegCM3 was not bias-corrected in this study, the performance of the CRCHMS has much room to improve in the future. Currently, the feedback of the agricultural irrigation in the oasis to the regional climate system is being analyzed in the CRCHMS to better understand the future climate and hydrological patterns in the region.

IAHS (Hydrology)

HS02p - HS02 Hydrologic Non-Stationarity and Extrapolating Models to Predict the Future

HS02p-050

Influence of climate variability on large rivers runoff.

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In accordance with IPCC Report the influence of climate change on the water cycle will increase hydrologic variability by means of changing of precipitation patterns, melting of ice and change of runoff. Precipitation has increased in high northern latitudes and decreased in southern latitudes.

We investigated large rivers with period observation over 70 years for rivers with diverse geographical locations.

Temperature rise in the last century leads to different river flow trends for all rivers.

The rivers Amur, Danube and Amazonas flowing in sub latitudinal direction show stable decrease in runoff. The same trend was observed for the Yangtze and Ganges rivers runoff due to melting and shrinking of glaciers area.

The rivers Mississippi, Missouri, Rhine and Songhua Jiang show steady increase of their runoff.

Analysis of dynamics of water inflow to World Ocean (1921-1985) shows long term increase of rivers discharge in ocean.

Intensification of atmospheric circulation due to climate change makes the water cycle more intensive. In this way orography plays a crucial role in a change in atmospheric conditions caused by a change in elevation, primarily due to mountains. The mountain ranges intercept a mass transfer of evaporated water.

In accordance with NASA forecasting the solar cycles 24 and 25 will be very weak and that will lead to following: the global temperatures will be trending lower over the next 20 years. Rivers discharge will be change in dependence from geographical location.

The report analyzes the causes of this phenomena-variability of air temperature, precipitation and connected with these factors water formation process in dependence from solar activity.

IAHS (Hydrology)

HS02p - HS02 Hydrologic Non-Stationarity and Extrapolating Models to Predict the Future

HS02p-052

Modelling experiments to assess implications of hydrologic non-stationarity on model predictions

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The term ‘hydrologic non-stationarity’ has been used to describe many things, ranging from climate and streamflow variability evident in different periods within a long hydroclimate time series to changes in climate-runoff relationships and dominant hydrological processes over time. This paper presents runoff modelling results from catchments from different parts of the world which have experienced different types of non-stationarity. The catchments were used for investigating the issue of hydrological non-stationarity in the Hw15S1 session at the 2013 IAHS General Assembly in Göteborg, Sweden, in July 2013. Specifically, the modelling experiments here assess simulations from hydrological models using optimised parameter values from model calibration against daily streamflow from different five-year sub-periods. The results are then interpreted and the implications of hydrologic-non-stationarity on the reliability of model predictions are discussed.

IAHS (Hydrology)

HS02p - HS02 Hydrologic Non-Stationarity and Extrapolating Models to Predict the Future

HS02p-613

Investigating the responses of soil moisture to climate change in the 'Huang–Huai–Hai Plain' region of China

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The responses of surface soil moisture (SSM) to climate change within the 'Huang–Huai–Hai Plain' ('3H') region of China are evaluated by using the Common Land Surface Model. To discuss the maximal response of SSM to climate change over the '3H' region, the approach of conditional nonlinear optimal perturbation related to parameters (CNOP-P) is employed. The CNOP-Ps supply a possible climate change scenario as the CNOP-P-type scenario, which constrained by 22 global climate models from the Coupled Model Intercomparison Project Phase 5 (CMIP5) under two future emission scenarios (representative concentration pathway (RCP) 4.5 and RCP 8.5). For making comparisons between the variations of SSM under different types of climate scenarios, the hypothesized climate scenario is applied, which only considers the variation in climatology. Numerical results have suggested that SSM increases no matter which type of climate scenario is considered. Based on projections under the RCP 4.5 (RCP 8.5) scenario, the increase in SSM generally varies from 0.005 (0.006) to 0.024 $m^3\,m^{-3}$ (0.033 $m^3\,m^{-3}$) under the CNOP-P-type scenario and is no more than 0.017 $m^3\,m^{-3}$ (0.022 $m^3\,m^{-3}$) under the hypothesized scenario. Furthermore, the CNOP-P-type scenario induces greater soil moisture variation, especially over the semiarid region. This demonstrates that climate variability has significant effects on SSM over the semiarid region. By analyzing the components of surface water budget, the reasons for the difference of SSM variations between the two types of scenarios are investigated.

IAHS (Hydrology)

HS03a - HS03 Precipitation: measurements, instrumentation, statistics, modeling and predictions at all scales

IUGG-2549

Using model combination to improve rainfall estimates by merging radar and gauge measurements

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Radar reflectivity measurements show great promise in improving the spatial information about rainfall events available to hydrologists. However there remain a number of difficulties in converting reflectivity measurements to equivalent rainfall estimates on the ground. We argue in this presentation that some of the difficulties can be overcome with two new methods. The methods have been tested on a dataset of approximately 3 years of 30 minute rainfall and radar reflectivity data in Sydney, Australia.

Firstly a non-parametric reflectivity-rainfall relationship has been developed which can better capture the joint dependence structure of reflectivity and rainfall. The new approach is shown to outperform a calibrated power-law rainfall-reflectivity relationship due to the improved representation of small and medium rainfall rates in particular.

A dynamic model combination approach is then adopted to combine the radar-rainfall estimates with spatially interpolated gauge measurements. It is shown that the model combination is particularly useful in sparsely gauged areas where the combination is able to use the information from the radar measurements. Overall the combination approach leads to smaller errors in the leave-one-out cross validation at close to 60% of the gauges. Errors are reduced by approximately 20% compared to using the radar-reflectivity in a traditional power-law method.

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IUGG-4794

Drop by drop radar observations of a 50 x 50 x 50 m3 volume : a numerical experiment

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The findings on the rainfall field very small scales (mm to few tens of m) spatio-temporal structure, of the HYDROP experiment and a recent analysis of 2D video disdrometer data in a Multifractal framework, is used to generate a distribution of drops location in a 50 x 50 x 50 m3 volume. More precisely the Liquid Water Content (LWC) distribution is represented with the help a multiplicative cascade down to 0.5 m, below which it is considered as homogeneous. Within each 0.5 x 0.5 x 0.5 m3 patch, liquid water is distributed into drops according to a pre-defined Drop Size Distribution (DSD) and located randomly uniformly. Such configuration is compared with the one consisting of the same drops uniformly distributed over the 50 x 50 x 50 m3 volume.

Radar observations of this volume are computed by summing the electric field backscattered by each drop. This enables to take into account potential coherence effect due to inhomogeneous drop distribution (speckle effect). It appears that the sampling uncertainty between various realisations containing the same average LWC is high. The radar scanning strategy is also investigated through the computation of the temporal evolution of the intensity retrieved by a radar (considering the coarse assumption of a vertical ballistic evolution of drops over few seconds). The extreme variability of the signal is analysed and its consequences discussed. Finally the sensitivity of the results to the underlying multifractal parameters and chosen DSD is also quantified.

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IUGG-5000

Radars and multifractal precipitation variability: data uncertainties and nowcast predictability

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Recent radar technologies, in particular polarimetric X-band radars, provide precipitation data with unprecedented resolution and reliability. However, this resolution remains much larger than the internal scale of precipitation variability, i.e. the scale over which the homogeneity becomes relevant. The problem of small scale variability and resulting uncertainties is therefore not yet resolved. These uncertainties have many practical implications, for instance in risk management and in improving the resilience of our urban systems.

We first recall the so-called speckle effect or coherent backscattering due to "drop rearrangement" and how the resulting difference between the radar reflectivity and the effective reflectivity can be statistically estimated across scales with the help of multifractal techniques. We show that this approach is supported by empirical results of spectrometers or disdrometers and that this bias is far from being negligible for rain rate retrieval algorithms. We also quantify the resulting intrinsic predictability limits of forecasts based on these data. These results are used to theoretically evaluate the uncertainty reduction obtained with higher resolution data. This is tested on empirical data obtained in the framework of the projects EU/Interreg RainGain, Paris Region RadX@IdF and WMO/RDP/TOMACS.

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IUGG-5097

Weather system-wise evaluation of satellite precipitation observation

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Precipitation is the only influx of water from the atmosphere to the land surface. It is necessary to precisely estimate the spatiotemporal distributions of precipitation for investigating the global hydrological cycle. Since Tropical Rainfall Measuring Mission (TRMM) which is the first satellite mission dedicated to precipitation retrievals has successfully monitored rainfall near the equator for the past 17 years since launched at 28th November 1997. Because of the high spatiotemporal and vertical resolutions, it has been used in a broad range of researches in Atmospheric science and Hydrology. As the descendant, Dual-frequency Precipitation Radar (DPR) satellite has been launched at 17th February 2014 as the core observatory of the following Global Precipitation Measurement (GPM) with higher resolutions and larger global coverage and additional sensor of Ka-band radar. In this study, an objective validation strategy is proposed for those satellite precipitation measurements. Level-2 ground track data of TRMM and GPM are decomposed for different precipitation mechanisms, such as tropical and extratropical cyclone. Dynamically downscaled Japanese 55-year Reanalysis data is used as the reference for classifying the types of precipitation and intensity of background atmospheric mechanism trained by observational data including digitized weather charts and best tracks of tropical cyclones. Decomposed precipitation is validated with in-situ measurement and ground radar observations, and the results will have a potential to enhance the retrieval algorithms of precipitation radars for different weather systems.

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IUGG-5369

Dynamic bias correction of commercial microwave links by remote rain gauges

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Efficient urban storm water management relies on rainfall information of high spatial and temporal resolution which is unfortunately often not available. Commercial microwave links (MWLs) represent an alternative source of rainfall information which could aid in this regard. MWLs are point-to-point radio systems widely used in telecommunication. They operate at frequencies where rainfall represents a significant source of signal attenuation. This attenuation is conceptually easily available online and can be related to rain rate. Although, MWLs reflect very well spatio-temporal structure of rainfall fallen on an urban catchment (as they are very dense in urban areas and operate close to the surface) their rain rate estimates are often biased.

In this investigation we introduce a novel method to dynamically correct MWL bias using cumulative rainfall from remote rain gauges (RGs) with 1-hour temporal resolution, i.e. rainfall information usually provided by national weather services. We test this method on data set from experimental urban catchment in Prague-Letnany, where signal attenuation from 13 MWLs operating at 26, 32 and 38 GHz frequencies is being polled every 10 second and reference rainfall is recorded every minute. The MWL estimates are corrected using hourly rain rates from three RGs located outside of the catchment and compared against the reference rainfall.

We show that remote RGs with low temporal resolution can be still conveniently used to correct MWL bias. The corrected MWLs can provide significantly improved high-resolution rain rates corresponding very well to the areal rainfall fallen on the catchment.

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IUGG-5513

Can eastern mediterranean heat content predict precipitation over Israel?

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Israel is located in a semi arid area along the eastern coast of the Mediterranean Sea, where prediction of winter precipitation is socially and environmentally important. In 1982, Tzvetktov and Assaf suggested there is a connection between the fall heat content of the Eastern Mediterranean and the precipitation in the following winter over Israel. We revisit their work using continuous satellite derived sea surface temperature and elevation collected over the last 20 years. We derive the Eastern Mediterranean upper layer heat content from remote sensing parameters, under a reduced gravity approximation, and compare our calculations with hydrographic observations. Our results show correlation of R=0.6 between fall heat content in a northern region of the Eastern Mediterranean and precipitation in the north of Israel and correlation of about 0.4 with precipitation in central Israel. The depletion of heat content during winter is moderately correlated (R=0.43) with precipitation as-well. Therefore, according to our analysis, the Eastern Mediterranean upper layer heat content during summer or fall can not solely predict the amount of precipitation over Israel.

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IUGG-1684

Rainfall in the Andean Páramo—New Insights from High-Resolution Monitoring in Southern Ecuador

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In mountainous regions, rainfall plays a key role in water supply for millions of people. However, rainfall data for these sites are limited and generally of low quality, making it difficult to evaluate the nature, amount, and timing of rainfall. This is particularly true for the Páramo, a high-elevation grassland in the northern Andes that is a primary source of water for large populations in Ecuador, Colombia, and Venezuela. In this study, high-resolution laser disdrometer data and standard tipping-bucket rain gauge data were used to improve our knowledge of rainfall in the Páramo. For 36 months, rainfall was monitored in a high-elevation (3780 masl) headwater catchment in southern Ecuador. Average annual rainfall during this period was 1345 mm. Results indicate that (i) when input from very low intensity events (drizzle) is taken into account, rainfall is 15% higher than previously thought; (ii) rainfall occurs throughout the year (only approximately 12% of the days are dry); (iii) rainfall occurs primarily as drizzle (80% of rainfall duration), which accounts for 29% of total rainfall amount; and (iv) the timing and average intensity of rainfall varies throughout the year (shorter afternoon events are common from October to May, whereas longer night events—with lower intensities—are more frequent from June to September). Although some of these numbers may vary regionally, the results contribute to a better understanding of rainfall in the wet Andean Páramo.

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IUGG-2147

Orographic precipitation observation in Jeju Island, Korea

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To understand the spatial and temporal structure of rainfall associated with mountain, we performed intensive field observation around Mt. Halla in Jeju Island (33.21°N and 126.32°E, width 78 km and length 35 km) which is located at the southern part of Korea. We had a new observational in-situ dense network around Mt. Halla, including raingauges (14), automatic weather station, disdrometers (Parsivel 9; 2DVD 2), ultrasonic anemometer (3), and upper air sounding. Each disdrometer sites were located in a radial line from east to west, northwest to southeast, and northeast to southwest in Jeju Island. We analyzed microphysical properties and precipitation process using RDSD data and kinematic characteristics of precipitation by dual-Doppler radar analysis using S-band radars from Korea Meteorological Administration (KMA) which were located in Gosan (33.17°N 126.09°E) and Seongsan (33.23°N 126.52°E) in Jeju Island. We analyzed two precipitation cases on 6 and 9 July 2014, which were originated from the Changma front and Typhoon Neoguri, respectively. In both cases, the accumulated precipitation was recorded over 100 mm. However, there showed a different moving direction (case1-from west to east, case2-from southeast to northwest) and microphysical structures. The break up process was dominated near windward side, while coalescence process observed at leeside in case 1. On the other hand, the case 2 showed collision-coalescence was definitely observed.

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IUGG-3128

Precipitation trends as a basis for developing adaptation to increased flood risk from flash floods in Serbia

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The catastrophic floods that struck Serbia, Bosnia and Herzegovina and Croatia in May 2014 resulted from coincidence of unprecedented precipitation and highly saturated soils from antecedent precipitation. The floods caused enormous damage to the three countries and a high number of casualties. A question was often raised during the floods both in media and among the professionals whether this event is an indication of climate change impact in the region. This study investigates daily precipitation records in Serbia including the most recent events in order to identify precipitation anomalies by looking into trends in the rate of occurrence of precipitation events exceeding certain thresholds such as the nominal 100-year precipitation, while looking at the multi-decadal oscillations in the data that may explain the variability. Preliminary results show that the extreme precipitation events are not increasing at the stations considered and that the variability is more due to the background oscillation.

This study presents the base for looking into the outputs of the climate modelling for Serbia that would be based on GCM/RCM model chains ran under two IPCC/SRES gas emission scenarios (A1B and A2), first with an aim to verify the scenarios in terms of reproducing the extreme precipitation features, and then in order to estimate future climate tendencies and their impact on the medium-size basins in Serbia prone to flash floods, which suffered the heaviest consequences in the May 2014 floods.

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IUGG-3316

On the reproduction of correlation structure and extremes at high temporal resolutions by stochastic precipitation disaggregation models

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The correlation structure and extreme intensities in high resolution (10-min and less) rainfall are important features to be reproduced by stochastic disaggregation models particularly for a range of engineering problems. For climate change impact studies it is also important to understand whether short duration but high intensity rainfall may be increasing and how this dependence may be built into disaggregation models. In this paper we discuss three problem areas. First, we show that high-resolution correlation statistics (fluctuations) are strongly influenced by measurement. Tipping-bucket gauges show much higher fluctuations than electronic weighing gauges at high resolutions and this influences the estimation of breakdown coefficients in cascade-type models and their temporal dependence. For a typical canonical random cascade disaggregation model we show that the assumption of temporally independent (iid) cascade weights generally does not hold. Second, we show that a combination (nesting) of point-process models and cascade-based disaggregation models is a suitable approach which improves the performance of the stochastic model across a range of hydrologically relevant timescales (10-min to annual), including high resolution extremes. This nesting approach takes advantage of the best performance of each model at its appropriate scale. Third, on a large dataset in Switzerland we demonstrate that 10-min extreme rainfall intensities increase with air temperature by 7-14% depending on storm type (stratiform or convective), and slightly lower increases were also seen in 1-hr data. This feature is important for climate change analysis and can in principle be built into stochastic precipitation disaggregation models by conditioning model parameters on air temperature.

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IUGG-5004

Major precipitation patterns in Kochi, Japan by tropical and extratropical cyclones

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Kochi is known to be the prefecture where the annual precipitation is about 2500 mm and the most amounts in Japan. The present study aims to clarify the mesoscale convective systems (MCSs) such heavy rain and the relation between these MCSs and tropical cyclone or extratropical cyclone.

We classified MCSs causing heavy rain of more than 50 mm/h in hourly precipitation from the 2 km CAAPI radar echo patterns as follows; spiral rain band, fixed echo, streak on slope, quasi-stationary linear rain band, squall line and multi-cell types. The spiral rain band type is the convection system of tropical cyclone itself. The fixed echo type and the streak on slope are kinds of orographic rainfall. The quasi-stationary linear rain band and the squall line both show linear echo patterns but their moving directions are different with each other. The multi-cell type is the pattern that many convective cells distribute in wide area. We extracted 302 echo patterns for 25 years from 1986 to 2010. The tracks of tropical and extratropical cyclones when the MCSs appeared were also checked from the typhoon best track data and weather maps by JMA.

Major MCSs by tropical cyclones were fixed echo and streak on slope types. The orographic effect caused 70% of heavy rainfall due to tropical cyclones. We found that such MCSs can be predicted by using the location of tropical cyclones. On the other hand, the extratropical cyclones cause mainly quasi-stationary linear rain band and multi-cell types. These MCSs appear in the warm section and the center of extratroical cyclones.

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IUGG-5248

Using X band radar data for flooding management in urban areas

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Nowadays, flooding has become more frequent, severe and also less predictable. In urban areas, this is related to the high urbanization level, witch reduces infiltration and increases the catchment runoff. Various technical solutions and strategies have been implemented in urban areas. Alternative upstream water management techniques promote the retention of pluvial water and the soil infiltration while downstream, retention basins have been widely implemented.

The complexity of the situation in urban environments, particularly their very short response times, requires in addition to these technical solutions, the use of predictive models and real-time management system that are both crucial for urban flooding management and depend on reliable nowcast. Unfortunately, the high heterogeneity of urban catchments require to represent the variability of precipitation over the large range of involved space-time scales, which is neither provided by raingauge networks, nor the classical $1km^2$ radar products.

This work aims to analyze the rainfall resolution needs in urban hydrology for both forecasting and modeling purposes. The case study is a $2.15km^2$ urban catchment that has suffered in the past from several flooding events. The present management strategy operated in this catchment uses a real time radar forecasting based on C band radar data at $1km^2$ by 5min resolution. A new X band radar was implemented last year at Ecole des Ponts (10km from the case study) to provide radar high-resolution data (100m by 1min). We will present a detailed quantitative comparison between two modeling approaches (semi-distributed and fully-distributed) using radar data whose resolution ranges from 100m to 1km. We will emphasize the benefits obtained with the help of the highest resolutions.

IAHS (Hydrology)

HS03c - HS03 Precipitation: measurements, instrumentation, statistics, modeling and predictions at all scales

IUGG-0315

Modelling and prediction of rainfall in Kinshasa using Fourier Transform and Autoregressive Integrated Moving Average (ARIMA) model Techniques

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Precipitation is highly non-linear climate variable, which require sophisticated computer modelling and simulation to obtain an accurate prediction. Its forecast is of particular relevance, for example, to medicinal plants growth, water resource management and agriculture, which are significant economic activities in Africa. In this study, we present results of the daily precipitation estimation in Kinshasa. The used dataset consists of the daily rainfall amounts for the period from 1983 to 2010 provided by the Régie des Voies Fluviales (RVF) of Kinshasa. The precipitation estimation is based on two methods: the Autoregressive Integrated Moving Average (ARIMA) that is used to forecast rainfall amounts and the Fourier Transform used to assess the temporal distribution of rainfall in Kinshasa. The performance of the estimation (model) is evaluated using the mean square error, the mean absolute error and the criterion of Nash.

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IUGG-1414

One and a half centuries of precipitation variability over Africa

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Contrary to the common belief that the rainfall record for Africa is sparse, many parts of the continent have adequate rain gauge data to examine variability covering periods of 120 to 180 years. Although few stations continuously cover the entire period of record, a methodology for combining station records permits the derivation of these long time series. The series represent spatial averages over large regions. The sectors for which time series are evaluated and the length of record are the Sahel (160 years), East Africa (140 years), South African winter rains region (175 years), southern Africa summer rains region (170 years), the Kalahari (125 years) southwestern Africa (135 years), the Kalahari (120 years), Algeria (180 years), Egypt (145 years), western equatorial Africa (130 years), the Cape Verde Islands (140 years), the Benguela Coast (155 years), and the Guinea Coast (140 years). Wavelet analysis shows that the temporal structure of the variability is non-stationary, indicative in some cases of changes in the dominant forcing mechanism. The contribution of the various seasons to annual rainfall also changes on decadal time scales, a characteristic that also has implications for understanding decadal scale variability.

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IUGG-1981

Campus Precipitation Nowcasting using X-band Polarimetric Radar

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Well-developed thunderclouds cause local downpours. They sometimes bring hourly rainfall amounts that reach 100 mm in areas of a few square kilometers and cause flooding of small rivers, lowland inundation, and underpass damage. The Ministry of Land, Infrastructure, Transport and Tourisms deployed 38 X-band polarimetric radars in major city areas to monitor localized heavy rainfalls, each with a spatial resolution of 250m and a temporal resolution of 1 minute. The present paper describes the development of very short range nowcasting of localized heavy rainfalls using X-band polarimetric radar. This nowcasting is based on a correlation method that extrapolates rainfall distribution in a 1.8 km square area with a 250m resolution, every minute, and 10 minutes in advance. To assess the usefulness of this extremely short range rainfall forecast, an on-campus survey of faculty and students has been underway since April 2015 at Kagoshima University. In the experiment, 10 minute nowcasting information is distributed via digital signage, PCs, mobile devices, digital terminals, and cell phones to examine the usefulness of each device. In the signage experiments, additional data such as campus information and messages from past large–scale disasters, showing their mechanisms and countermeasures, are displayed automatically in accordance with a pre-set schedule.

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IUGG-2067

Development of rapid method for inland inundation risk using machine learning

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In urban areas, damages caused by inland inundation are more frequent and costly. According to the government statistics, flood disasters swept away $ 2 billion during 1999 to 2008, in Tokyo metropolitan. Of those, as much as 87 % are brought by inland inundations. Numerical models, which compute rainfall-runoff, overland flow and sewer flow processes, are often applied to assess the extent and depth of flooding due to a wide range processes. However, such approaches tend to be quite complicated and extremely time-consuming. They are the highly effective way to derive flood hazard map, but difficult to provide real-time risk information. Therefore, this study aims to develop a rapid estimation system to predict the urban inundation in real-time. The system is built based on the support vector machine (SVM) algorithm that shows high performance among machine learning classifiers. It classifies the area where it is raining into inundated, high risk or non-inundated zones, and visualizes the classification results on meshes as well as inundation hazard map. The SVM model is trained using the simulation results of the InfoWorks model and inundation records. And the input parameters for SVM consist of endogenous factors such as surface elevation ratio, slope gradient, catchment area etc., and exogenous factors including rainfall rate and several kinds of accumulation rainfall amount that are derived from X-band dual polarization radar observations. The spatial resolution of real-time estimated image is 50 meters by 50 meters, and the image is refreshed every 10 minutes.

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IUGG-5132

Uncertainty analysis in building ensemble of precipitation from RCMs in semiarid South East of Spain

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The Regional Climate Models (RCMs) improve the understanding of climate mechanism, however the projections of climate change in extreme rainfall events exhibit great divergence between RCMs. As a consequence, the rainfall projections and the estimation of uncertainties associated are better based on the combination of information provided by an ensemble approach from different RCMs simulations.

In the present work, two novel approaches based in the Reliability Ensemble Averaging method, for building RCMs ensembles of monthly precipitation have been applied. An uncertainty analysis is performed, in order to identify the more robust and parsimonious methodology for building plausible scenarios of precipitation as input to hydrological models.

The study area corresponds to semiarid South East of Spain, where rainfall presents a high variability. A long historical meteorological dataset (named Spain02), with spatial resolution 20 by 20 km for the time period 1961-2007, was considered. While the RCMs were provided by the ENSEMBLES European project, 25 by 25 km grids, for time period 1961-2100.

The assessment of RCMs goodness-of-fit in building of the precipitation ensemble, was based on empirical probability density functions (PDF) at each site. One of the ensemble methods is taking into account the seasonal and annual variation of rainfall from the PDFs, while the other is only based on monthly rainfall PDF. A sensitivity analysis was made considering the impacts of the variability of monthly, annual and seasonal rainfall in the building of the ensemble, for identifying the main factor that controls the rainfall in that semiarid area and the more appropriate ensemble method.

IAHS (Hydrology)

HS03p - HS03 Precipitation: measurements, instrumentation, statistics, modeling and predictions at all scales

HS03p-302

The impacts of climate change on the Discharge of Osse-Ossiomo River Basin, S. W. Nigeria

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The impacts of climate change of Osse-Ossiomo River Basin, S. W. Nigeria under different climatic Scenarios was investigated using information on rainfall - temperature for forty years (1961 - 2000). Discharge information of Osse and Ossiomo rivers was from 1989-1994. A number of water resources development schemes including hydroelectric and water supply projects have been planned in the southwestern river system of Nigeria. Results revealed fluctuating rainfall pattern with great uncertainties in the mid-1980s. Temperature shows increasing trend and the highest temperature of $37^{o}C$ was obtained in 1998 during the 40-year period. There is a strong evidence of global warming using the index of temperature in the drainage basin. River discharge also indicated fluctuating trends from year to year in the decades with available discharge records. It was concluded that the river discharge pattern of Osse-Ossiomo River Basin, S. W. Nigeria exhibited similar behaviors as other drainage basins of the world. Climate change has impacted on the river discharge of Osse-Ossiomo River Basin, S. W. Nigeria. This has implication for sanitation and health of the inhabitants in the river basin. Most people were forced to resort to various sources for the numerous uses of water. This had a negative impact on water security and consequent health and sanitation. Statistical tests showed that the changes in rainfall and temperature and rainfall and dischatge were significant at the 5% level.

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HS03p-303

Tipping-bucket Rain Gauge Inter-Comparison Quantifies Deficiencies in Precipitation Monitoring in the Ecuadorian Andes

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Accurate measurements of precipitation are inherent in hydrological studies. Efforts to correct precipitation measurements have been ongoing for decades, but are scarce for tropical highlands with their own climate conditions. Tipping-bucket (TB) rain gauges commonly used in the Andean mountain region were compared—one with 0.254 mm resolution, one with 0.2 mm resolution, and two with 0.1 mm resolution (respectively with and without an Alter-type wind screen). The performance of these rain gauges, installed side by side in a headwater microcatchment at an elevation of 3780 masl, was assessed with respect to the TB with the highest resolution (0.1 mm), used as reference. The effect of rain intensity and wind conditions on gauge performance was estimated as well, using 2-year precipitation data. Results reveal that (i) the precipitation amount for the reference TB is on average 5.6 to 7.2% higher than what is measured with the rain gauges having a resolution ≥0.2 mm; (ii) the commonly used TBs underestimate precipitation during low-intensity rainfall—a maximum deviation with the reference TB of 11% was observed for rain intensities ≤1 mm hr^{-1}; (iii) typical precipitation intensities cannot be determined accurately for timescales shorter than 30 minutes; and (iv) the Alter-type wind screen does not offer any benefit for wind speeds ≤4 m s^{-1}, but avoids overestimation of the precipitation for higher wind speeds—at least 7% in unshielded gauges. Noteworthy findings are the key role of the rain gauge resolution to accurately measure precipitation in Páramo landscapes, and the correction factors for more accurate and homogeneous precipitation data throughout the Andean highlands.

IAHS (Hydrology)

HS03p - HS03 Precipitation: measurements, instrumentation, statistics, modeling and predictions at all scales

HS03p-304

VALIDATION AND INTERCOMPARISON OF SATELLITE RAINFALL PRODUCTS OVER GUIANA SHIELD

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Four satellite-based rainfall estimation algorithms TRMM-TMPA 3B42 V7 (Version 7), RT (Real Time), PERSIANN and CMORPH- are evaluated at daily time scales, and a spatial resolution of 0.25°. These products are particularly useful in regions with sparse gauge distributions, as it is the case in Guiana Shield. The reference data come from to 93 rain gauges over French Guiana and North Brazil. Products comparison is conducted with quantitative and qualitative statistical analysis. Results are discussed in terms of products accuracy, sensitivity to climate variability, and differences between products. Products validation and intercomparison are provided for the whole region, as well as for more specific climatic zones of the area. Validation results are reasonably acceptable with a good match in spatial distribution. However, the relative performance of each product depends on which aspects of the rainfall regime are being considered. Convective rains are better estimated with TMPA-V7 (bias much lower compared to other products for all regions). Moreover TMPA-V7 is the product best suited to estimate the stratiform rain. Nevertheless bias characterizing the stratiform rains is lower than through convective rains. Error calculations on time series corresponding to the 99 percentile show a weakness in the estimation of heavy rainfall for the four products. The occurrence of rainfall is better estimated than rainfall amounts. This study, analyzing the capacity of products to reproduce the different rainfall characteristics, will lead to an appropriate use of these products in order to improve the understanding of hydroclimatic variability in this area.

IAHS (Hydrology)

HS03p - HS03 Precipitation: measurements, instrumentation, statistics, modeling and predictions at all scales

HS03p-305

Analysis of precipitation trends and its distribution over the eastern Slovakia

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The objective of this study was to investigate precipitation trends in chosen climatic stations in Slovakia. We investigated 17 20 climatic stations in the eastern Slovakia. The studied period was from 1981 to 2010. Monthly precipitation trends were detected by nonparametric Mann-Kendall statistical test. Positive trends of monthly precipitation were found in the analyzed rainfall gauging stations in Slovakia. March was observed to have the decreasing trends. All other months displayed increasing trends. Geographical information system were used for presentation of the results.

IAHS (Hydrology)

HS03p - HS03 Precipitation: measurements, instrumentation, statistics, modeling and predictions at all scales

HS03p-306

Classification of range overlaid echoes in the polarimetric measurements

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The Ministry of Land, Infrastructure and Transport (MOLIT) of Korea operates two S-band dual-polarimetric radars, as of 2013, with a purpose of water resources management through quantitative rainfall estimations at the surface level. However, the radar measurements suffer from range ambiguity, mainly due to their short unambiguous range (100 km or 150 km). In order to mitigate the range ambiguity causing by their short unambiguous range, the MOLIT radar observations are conducted using an option of RVP8 of Vaisala Sigmet that a fixed phase from a klystron tube artificially modulates into a random phase for each pulse. Nevertheless, the MOLIT radars produce too severe range overlaid echoes to estimate accurate rainfall amounts. In this study, an algorithm based on fuzzy logic is developed to identify range overlaid echoes using seven inputs of SD(ZDR), SD(DP), SD(HV), SD(SWD), HV, SWD, and DP. An examination of the algorithm's performance shows that these echoes can be well identified, and that echoes strongly affected by second-trip are highlighted by high probabilities over 0.7, echoes weakly affected have probabilities from 0.4 to 0.6, and those with low probabilities below 0.3 are assigned as echoes without range ambiguity. A quantitative analysis of a limited number of cases using the usual skill scores shows that when the probability of 0.4 is considered as a threshold for identifying the range overlaid echoes, they can be identified with a probability of detection of 88%, a false alarm rate of 7%, and a critical success index of 83%.

IAHS (Hydrology)

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HS03p-307

Improving precipitation estimation using radar data via random mixing

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The spatial estimation of precipitation is still a challenging task. The high variability as well as the sparse observation networks, often combined with insufficient measurement quality, lead to high uncertainties of the estimations. Those uncertainties need to be described reasonably and methods need to be found that improve the spatial precipitation estimation.

One possibility to increase the information content and with that to improve the estimation is to use external information like radar data. Weather radar provides precipitation data with large spatial and temporal resolution. Such data could be coupled with ground-based measurements to improve the precipitation estimation.

On that account a new developed conditional simulation technique called random mixing will be presented. This technique allows the incorporation of radar data as additional conditioning constraints. Different information, like knowledge on dry areas, can be extracted from the radar data und used as additional constraint for the precipitation estimation. Random Mixing is based on linear combinations of independent spatial random fields; the spatial dependence structure is described with the help of a copula.

As example precipitation estimations for a certain region in Baden-Württemberg will be shown. Different radar constraints are used and the results are compared to kriging interpolations.

IAHS (Hydrology)

HS03p - HS03 Precipitation: measurements, instrumentation, statistics, modeling and predictions at all scales

HS03p-308

"Intercalibration of the X-band Radarnet-Sur in Southern Ecuador"

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The land-surface complexity of mountain regions strongly affects rainfall processes and this in turn makes the quantitative precipitation estimation very difficult. Rainfall has countless implications on human activities and may spatio-temporally differ due to longer-term atmospheric variability (e.g. ENSO phenomenon). Unfortunately, spatially well-distributed rainfall data in mountain regions are scarce. To improve our understanding of the spatio-temporal rainfall variability in the Andean mountain range of South Ecuador, this study uses a new observational network primarily comprised of 3 X-band weather radars combining two technologies (1 x LAWR and 2 x Rainscanner) which differ in signal recording and calibration abilities regarding radar reflectivity. One of the Rainscanner radars will be installed at 4400 m a.s.l., making it arguably the highest in the world. Instruments of different resolution will be employed in calibration and rain retrieval (conversion from dBZ to rain rate) process. This calibration will be done by two disdrometers and a vertical radar by inferring the Z-R relationship parameters. Advection algorithms will be implemented to overcome the influence of the altitude. Raingauges will be used as validation points for the calibrated images. Afterwards, an intercalibration of the technologically different radars will be performed by using machine-learning techniques because direct calibration and rain retrieval is only possible for the rainscanner systems. First results on Z/R relations for different altitudes and precipitation zones are presented. Practical applications of the intercalibrated images include identifying precipitation patterns of storm events, calibration of RCMs, researching rainfall-triggered landslides and flood forecasting.

IAHS (Hydrology)

HS03p - HS03 Precipitation: measurements, instrumentation, statistics, modeling and predictions at all scales

HS03p-309

Spatial variability of rainfall and its correlation with discharge in five micro-catchments in the Southern Amazon

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The understanding of rainfall spatial and temporal variability is a well-known demand in hydrological processes analyses. Its comprehension allows better instrumentation planning in order to reduce the process-related uncertainties. In this study, we analyse the spatial variability of rainfall in five micro-catchments (< 1 km²) in Southern Amazon. The micro-catchments (three in the Cerrado biome and two in the Amazon biome) were selected based on different land use types, including one covered with rainforest vegetation. Each catchment was instrumented with three tipping bucket rain gauges with data loggers, recording the precipitation in 10 minutes intervals and 0.2 mm resolution, from October 2012 to September 2014. Additionally, the rainforest catchment was instrumented with two throughfall tipping bucket rain gauges. Regression analysis was done using the daily amounts of rainfall for all rain gauges within the same micro-catchment. This analysis was extended using the rainfall daily values and the maximum daily discharge in order to quantify the correlation of each rain gauge with the catchment outlet's discharge. The results show a high correlation between the rain gauges ($r > 0.9$). However, for such a small-scale approach, there were still coefficients of determination under 0.85, which show a moderate spatial variability. Furthermore, the discharge showed a better correlation with the rain gauge closest to the catchment's outlet. The results of this study support the importance of micro-scale analysis of the rainfall spatial variability and its relation to other hydrological processes.

IAHS (Hydrology)

HS03p - HS03 Precipitation: measurements, instrumentation, statistics, modeling and predictions at all scales

HS03p-310

A new tool to investigate the influence of the tropical Atlantic Ocean on the pluviometry of Brazilian Northeastern coastal region

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The strong contrast in the spatial and temporal distribution of precipitation in Northeast Brazil deeply affects local socioeconomic conditions. Thus, the current knowledge of the Atlantic Ocean surface conditions can be very important for the development of tools for climate predictions that contribute effectively to the regional socio-economic planning.
This work presents results of the direct influence of the tropical Atlantic ocean on the pluviometry of Brazilian Northeastern coastal region. To do this a new tool was developed in GUI for characterization of events related to possible influences of the wind, temperature and evaporation of the adjacent ocean surface with the precipitation in Brazilian northeastern coast. The input of data can be made from global model weather forecast as NOOA, ECMWF, OAFlux, etc., or even from other regional models made available to the scientific community while precipitation data can be used from gauge stations.
Applications for this tool were made using oceanic data from ECMWF-Europe Center for Medium Weather Forescasts, and the rainfall data were obtained from a meteorological gauge station localized in Natal city situated in the Brazilian northeast coast.
The analysis shows an inverse correlation between the annual seasonal normalized for the wind and rainfall signals by considering a significance level of 0.05. The most promising months for precipitation occur in periods related to lower wind

speeds.
Meanwhile, the correlations of both the temperature and evaporation present direct relationships with the rainfall. In addition, seasonal maps generated by the tool show good correlations between temperature, evaporation and ocean surface winds with rainfall in the analyzed region.

IAHS (Hydrology)

HW01a - HW01 Exchange Processes at Aquatic Boundaries and Their Effects on Ecosystems

IUGG-0363

Finite element modelling to assess the spatial and temporal variation in subsurface flow across the coast north of Chennai, india

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The objective of this study is to assess the spatial and temporal variation in exchange of water between the sea and aquifers in the Arani-Koratalaiyar river basin, north of Chennai, India. A three dimensional finite element groundwater modelling of this region comprising an upper unconfined and lower semi confined aquifer was carried out using FEFLOW. Transient state calibration of the model was accomplished for the period from January 1996 to December 2004. The model was validated with the observed data for the period from January 2005 to December 2012. Then the model was used to estimate the flux of water along the coastal boundary between the aquifers and the sea. The computed flow across the coastal boundary varies significantly with respect to space and time and a considerable quantum of seawater enters into the aquifer. The inflow of seawater was very high in the central part of the coastal boundary due to relatively high hydraulic conductivity of the aquifer. During the period from 2000 to 2012 the influx of seawater to the aquifer during June (summer) has increased from about 17000 m^3/day to 24500 m^3/day due to the over exploitation of groundwater from the lower aquifer. However, quantum of seawater inflow into the lower aquifer has reduced from the year 2006 due to the termination of pumping from the well field nearer to the coast. The model was used to explore various options of managed aquifer recharge to mitigate the problem of seawater influx into this coastal aquifer.

IAHS (Hydrology)

HW01a - HW01 Exchange Processes at Aquatic Boundaries and Their Effects on Ecosystems

IUGG-0407

Nutrients in groundwater and associated processes in the coastal zone of the Pearl River Delta, China

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Rapid urbanization has occurred in the Pearl River Delta since 1980s, resulting in tremendous accumulation of population and material in an area of around $1.1x10^4$ km^2. Massive nutrients were released to the coastal zone either via the Pearl River or the aquifer, and effects of these nutrients on ecosystem and drinking water supply are a big public concern. Field campaigns to collect groundwater samples were implemented in rainy (April- September) and dry seasons (October – March) during the period of 2005-2014, and samples were analyzed for major ions, nutrients, multiple isotopes, N_2O and microbiological DNA. Seasonal and spatial pattern of nutrients from the recharge to the discharge zone in two case study areas were identified and compared regarding relevant N transformation processes. Main sources of nutrients in groundwater and major mechanisms, e.g. denitrification, nitrification and etc., involved in these processes were raised by integrating microbiological, isotopic and geochemical evidences. Driven forces of the change in nutrients in the past 10 years were investigated based on statistical data, and total nutrient load in groundwater in the delta was estimated.

IAHS (Hydrology)

HW01a - HW01 Exchange Processes at Aquatic Boundaries and Their Effects on Ecosystems

IUGG-3123

Prediction of saltwater-freshwater interface in the coastal region of the eastern Niger delta of Nigeria

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Ground water resources in many coastal communities in the Eastern Niger Delta of Nigeria have been impaired by saltwater intrusion thereby making access to potable groundwater water in such communities difficult. A combined study using geophysical methods (I-D vertical electrical soundings & 2-D Electrical Resistivity Imaging), borehole drilling and physic-chemical analysis of groundwater samples was undertaken to determine the freshwater/saltwater interface and develop an empirical relation for predicating freshwater/saltwater interface in the region. A total of sixty five (65) I-D vertical electrical sounding, twelve (12) 2-D electrical resistivity imaging data were acquired while thirteen (13) water samples were obtained from drilled boreholes. Interpretation of the results revealed that saltwater has intruded freshwater aquifers in several locations (eg, Opobo, Bonny, Okrika, Ikuru, Oyorokoto, Buguma, Borikiri, etc) where the range of resistivity values is 0.129?m - 49.95?m whilst the values of chloride, TDS and conductivity are generally above 24mg/1; 990mg/1 and 997us/cm respectively. Groundwater type in the study area varies from fresh through slightly fresh, moderate, slightly saline to saline. Depth to freshwater interface can be predicated using the empirical relation z=0.103x+0.045, with coefficient of determination R^2 = 0.77, (r = 0.88) where z is depth to fresh/saltwater interface and x is distance to the saltwater body. The depth to fresh/saltwater interface varies from ≤2.5m to more than 150m within the region.

IAHS (Hydrology)

HW01a - HW01 Exchange Processes at Aquatic Boundaries and Their Effects on Ecosystems

IUGG-3255

Characterization of groundwater and surface water interactions along Kirmir Stream using field measurements and thermal remote sensing

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The exchange processes between surface water and groundwater have recently received attention due to the important implications on the basin-scale water management as well as biogeochemical and ecological status of watersheds. We investigated the exchange processes between Kirmir Stream – a controlled stream nearby the city of Ankara, Turkey - and groundwater using a hierarchical multi-scale approach incorporating catchment physical characteristics (geology, geomorphology, DEM etc.), water quality field parameters as well as in-situ and remotely sensed measurements. Geological and geomorphological information pinpointed potential stream reaches where the interaction could occur. The identified reach was then investigated through in-situ measurements including differential discharge measurements, temperature measurements at different depths (temperature sticks), as well as remotely-sensed thermal images to identify discharge variations and temperature anomalies. Nested piezometers were then installed at possible discharge locations to investigate the variation in the vertical hydraulic gradient over time. Temperature probes (i-buttons) installed at various depths into the streambed for a period of time and helped to quantify temporal variations in vertical flow components. Basic water quality field parameters collected along the Kirmir Stream and nearby springs were investigated through Cluster Analysis to identify potential source areas. This hierarchical, multi-scale methodology provided an efficient and effective way to determine the locations and the direction of groundwater and surface water exchange processes. It was found that geology and channel modification exerted strong controls on the exchange processes.

IAHS (Hydrology)

HW01a - HW01 Exchange Processes at Aquatic Boundaries and Their Effects on Ecosystems

IUGG-3646

Eco-hydrological modelling of wetland processes in a restored river system in Denmark

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Denmark has one of the most intensive and export-oriented agricultural sectors in the world and eutrophication of surface waters due to diffuse pollution from agriculture is recognized as one of the most important challenges to achieving 'good ecological status' as required by the European Water Framework Directive. The restoration of wetlands continues to be an important measure for reducing nutrient loads in Danish river basin plans. The effectiveness of riparian wetlands in providing both improved ecological conditions while reducing nutrient loads depends not only the water quality processes but also on the hydrological processes. As wetlands act as buffer zones for the river system intercepting both surface and subsurface flows, their functioning depends on the interaction between surface water and groundwater particularly during flooding of the wetland. To improve our understanding of the influence of these different processes on the functioning of a restored riparian wetland we have developed a detailed eco-hydrological model representing the flow, transport and water quality processes within a restored riparian wetland on the Odense River in Denmark. The ability of this model to capture both the surface and subsurface processes is verified using measurements of flows and water levels in the river and wetland system including groundwater levels in profiles during both dry and wet periods. Examining the water balance indicates that the exchange between the river, wetland and groundwater during flooding is dynamic and this controls the path of nutrients through the restored system in particular the nitrate reduction processes.

IAHS (Hydrology)

HW01b - HW01 Exchange Processes at Aquatic Boundaries and Their Effects on Ecosystems

IUGG-0697

Impact of exchange and evolution process across aquatic and marine boundaries on coastal Wetland ecosystems

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The Kolleru Lake, one of the largest fresh water lakes of India and a designated Ramsar site is located on the east-coast of India.The conspicuously shallow lake is influenced by distinct coastal, near shore and fluvial processes apart from attracting international faunal community and harbouring a wide range of bio-diversity innumerable varieties of flora and fauna. In recent years the lake and its surroundings have undergone massive changes in geometry, land use- land cover, hydrology and ecology due to anthropogenic activity including industrialization, urbanization and aqua cultural. Further the lake, once used to act as a balancing reservoir to handle the hydrological dynamics no more receives similar fluvial inputs. A synergistic behavior of estuarine and lake environments characterized by coastal, near shore and hydrological processes is clearly reflected in the behaviour of Upputeru connecting the ocean and the lake. Over the years, the lake has shrunk in size and turned highly eutrophic with deformed hydrological, ecological and coastal aquifer characteristics. The simulated water balance components of different hydrological response units clearly indicate the impact of land use and soil type on the water yield of the catchment. Results of near-shore oceanographic studies substantiate the changing Upputeru mouth at the confluence. A multi-disciplinary geospatial approach encompassing geomorphological, sedimentlogical, hydrogeological, hydrological, biological, biogeochemical and near-shore oceanographic studies have not only provided an insight into the evolutional, ecological, hydrological and biogeochemical changes of the lake, but also lead to the development of scientific strategies for the restoration of Kolleru lake ecology.

IAHS (Hydrology)

HW01b - HW01 Exchange Processes at Aquatic Boundaries and Their Effects on Ecosystems

IUGG-2233

The Spatio-temporal Dynamic Analysis of Wetland Evolution Process in Chongming Dongtan Using Remote Sensing Data

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Located in the far east of Chongming island, at the mouth of Yangtze river, Dongtan wetland is formed by deposits taken by Yangtze river from its upper reach. As an estuarine alluvial island in the outskirts of Shanghai, Dongtan also faces many common ecological problems, such as sea level rise resulting from climate change, inundation of sea water, invasion of alien species, loss of species habitat, fresh water shortage. With the increase of development intensity and human activities, this island suffers from increasing environmental pressure. In addtion,the mudflat wetland as the eastern beach of Chongming extends further each year, which made the island become a rapid developed and rare ecosystems. It is an ideal place for studying several scientific problems. Therefore, monitoring the wetland spatio-temporal change and analyzing the interplay between wetland evolution process and human activities is a frontier research problem. Meanwhile it can play an important role in the management and protection of Dongtan wetland.

In this paper, we use eight Landsat images from 1986 to 2013 to study the spatio-temporal changes of land-use and of coastline of Dongtan based on an optimal SVM image classification and edge detection. We show that the optimal SVM has higher classification accuracy and is more effective to analyze the spatio-temporal change of Dongtan. Furthermore, we apply land-use dynamic indicators to analyze quantitatively the interactions of the wetland succession and human activities. Finally we use a Pressure-State-Response model to calculate environmental assessment indicators, and map the ecosystem health assessment chart.

IAHS (Hydrology)

HW01b - HW01 Exchange Processes at Aquatic Boundaries and Their Effects on Ecosystems

IUGG-3074

The transport of suspended matter in estuarine zones

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Estuarine area forms a transition zone between river and ocean environments. This zone is characterized by a removal of the main part of riverine dissolved and suspended matter. Usually the removal mechanisms are characterized as a combined process of coagulation and flocculation leading to the enlargement of fine particles. The contribution of each of the above processes to the fate of riverine matter is poorly understood. The aim of our investigation is the study of different factors affecting coagulation and flocculation of riverine suspended matter. River water is a rather complicate object, so we carried out the investigation using laboratory experiment. Aggregative stability of colloidal dispersions of clays and ferric(III)hydroxide was studied under different salt concentrations and the results were compared with natural systems (aquarium and sea water).

It was shown that flocculation is the main mechanism for removal of kaolinite at low concentrations of chitosan and its derivatives (<1 mg/l), but montmorillonite was determined to flocculate in a wide range of concentrations of chitosan (0.5-10 mg/l). The increase of hydrophobicity of chitosan derivatives leads to more effective flocculation of montmorillonite. Flocculation activity of chitosan increases when clay particles were modified by humic acids. Humic acids play the role of anchors between clay particles and chitosan in aggregates. The experiments with micro-plankton show the decrease of clay and ferric (III) hydroxide stability under less salinity compared with the systems without living organisms. Probably the substances released by micro-plankton under saline stress conditions may be flocculants. That fact may confirm an idea of Vernadsky about the existence of biogeochemical interactions in nature.

IAHS (Hydrology)

HW01b - HW01 Exchange Processes at Aquatic Boundaries and Their Effects on Ecosystems

IUGG-3098

Spatial and seasonal fluxes of greenhouse gases in the River Tay, Scotland: Hotspots of emission

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River networks are now recognised as important interfaces between terrestrial, aquatic and atmospheric systems for global budgets of the greenhouse gases (GHGs) - carbon dioxide (CO_2), methane (CH_4) and nitrous oxide (N_2O). However there is still great uncertainty in GHG fluxes from rivers. We investigated the spatial and temporal dynamics of CH_4, CO_2 and N_2O in the River Tay catchment, Scotland, over a two year period. Spatial and temporal hotspots and hot moments in GHG saturation and emissions were observed in the river catchment.

Estimated CH_4 emission density ranged from 1720 to 15500 µg C m^{-1} d^{-1}, and in general decreased from upland to lowland sites. Emission peaks in a lowland tributary and at the outflow of a lowland loch are attributed to allochthonous inputs from gas rich soil waters and in-stream production in fine grained carbon rich sediments. CH_4 production also varied seasonally, with temperature and variation in sediment quality the predominant driving factors.

Estimated CO_2 emission densities ranged from 517 to 2550 mg C m^{-1} d^{-1} and generally increased from upland to lowland sites. CO_2 emission density was highest in late summer and autumn and lowest in winter at most sites, highlighting the role of seasonal environmental controls such as temperature, light, and substrate availability.

Estimated N_2O emission densities also showed considerable spatial and seasonal variation, ranging from 176 to 1850 µg N m^{-1} d^{-1}. Emission densities were highest in the lowland tributaries related to elevated nutrient concentrations associated with more intensive agricultural activity.

Results highlight the combined effect of seasonal climate variability, hydrology, channel geomorphology and human activities (especially land use) in determining freshwater GHG fluxes.

IAHS (Hydrology)

HW01b - HW01 Exchange Processes at Aquatic Boundaries and Their Effects on Ecosystems

IUGG-3144

Monitoring water stress and flood impacts on riparian vegetation in an Alpine river by terrestrial photography

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Water stress and flood disturbance are the major hydrological factors impacting riparian vegetation on river floodplains in Alpine gravel bed braided rivers. Low groundwater levels and sediment moisture supply as well as frequent and erosive flooding are both detrimental to riparian vegetation establishment and growth. In this paper we demonstrate the feedback between hydrology and vegetation erosion/growth in the Maggia River in Switzerland on the basis of a new terrestrial camera monitoring system with near-infrared sensitivity and 2d hydrodynamic modelling of floodplain inundation. First, we demonstrate the sensitivity of a customer-grade digital camera to objectively separate different surfaces (gravel, water, vegetation) and to quantify vegetation photosynthetic activity by the normalized difference vegetation index (NDVI). Second, we show the progression of vegetation activity measured by NDVI through three years of our monitoring, where water stress is evident in periods with low precipitation and streamflow. We also show that such effects are difficult to see on an individual plant scale by studying tree ring growth increments. Third, we quantify the immediate response of riparian vegetation to five largest floods in our monitoring period on three distinct floodplain units. We find both a negative (damage) and positive (enhancement) response of vegetation within 1 week following the floods, with a selective impact determined by pre-flood vegetation vigour, geomorphological setting, and intensity of the flood forcing. We conclude that vegetation response to flood disturbance may be effectively monitored by terrestrial photography with near-infrared sensitivity, with potential for long-term assessment in river management and restoration projects.

IAHS (Hydrology)

HW01p - HW01 Exchange Processes at Aquatic Boundaries and Their Effects on Ecosystems

HW01p-312

Integrated surface water and groundwater modelling of flooding in the Lower Murrumbidgee River, Australia

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Flooding can result in significant social, economic and environmental damages, however regular flooding is important to the health and functioning of river wetland ecosystems. Integrated catchment management must therefore address the risks posed by floods while protecting freshwater ecosystems. The dynamics and extent of flooding are controlled by a number of factors such as the magnitude of the event, vegetation and land use distribution, the floodplain topography, channel and river bank geometry. However processes like the exchange between surface and groundwater and losses via infiltration and evapotranspiration may also be important particularly for riparian wetlands. In this paper we present an integrated modelling tool capable of simulating flooding in both urban areas and riparian wetlands. The model captures the hydraulic processes in the river, the dynamic surface water-ground water interactions, and the infiltration and evaporation effects on flooding.
One of the most important challenges in simulating flood behaviour for catchment management is the need to verify the reliability of these models. Traditional observation data are limited to flows or water levels within the river channels and few observations are found in the floodplain areas of interest. Satellite imagery and aerial photography of flood extent are used here to assess the simulated flooding behaviour in the Lower Murrumbidgee River, between Carrathool and Maude Weir. Our investigations show that while evapotranspiration is important, spilling in the upstream urban area affects both the local flooding and the wetland dynamics downstream which in turn is strongly controlled by local channel and river bank geometry.

IAHS (Hydrology)

HW01p - HW01 Exchange Processes at Aquatic Boundaries and Their Effects on Ecosystems

HW01p-313

Presence of nitrous oxide hotspots in the coastal upwelling area off central Chile; a time series study

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Seasonal and inter-annual variability of biogeochemical variables, including nitrous oxide (N_2O) an important climate active gas, were analyzed during monthly observations between 2002 and 2012 at the COPAS Ocean Time-Series station in the coastal upwelling area off central Chile (36° 30.8’ S). Oxygen, N_2O, nutrients and chlorophyll-a (Chl-a) showed clear seasonal variability associated with upwelling favorable winds (spring-summer), and also inter-annual variability, which in the case of N_2O was clearly observed during N_2O hotspot occurrence with saturation levels of up to 4849%. The hotspots consistently occurred during the upwelling-favorable period in years 2004, 2006, 2008, 2010 and 2011, below to the mixed layer (15-50 m depth) in waters with hypoxia and specific NO_2^- accumulation. They displayed a 3 times greater apparent N_2O production (ΔN_2O) than the average monthly anomalies (2002-2012). Estimated relationships of ΔN_2O vs. apparent oxygen utilization (AOU) and ΔN_2O vs. NO_3^- suggest that aerobic ammonium oxidation (AAO) and partial denitrification are the processes responsible for high N_2O accumulation in subsurface water. Chl-a levels correlated fairly well with the presence of the N_2O hotspots, suggesting that microbial activities, facilitated by a higher availability of organic substrates, trigger high N_2O levels. This in turn results in a huge efflux into the atmosphere of up to 260 μmol m^{-2} d^{-1}. N_2O hotspots are transient events or hot moments, which may occur more frequently than they are observed. If so, this upwelling area is producing and emitting greater than expected amounts of N_2O and resulting in an important source of N_2O that should be considered in the global atmospheric N_2O balance.

IAHS (Hydrology)

HW01p - HW01 Exchange Processes at Aquatic Boundaries and Their Effects on Ecosystems

HW01p-314

Impacts of Chencun reservoir on flow regimes based on ecohydrological indices at various time scales

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Chencun reservoir which is the largest one in Anhui Province in China is a hydropeaking dam with diel flow patterns. Dam operation for daily peaking hydroelectric production alters the preimpoundment riverine habitat by changing both seasonal and sub-daily flow patterns. Such subdaily flow fluctuations create highly unnatural river habitat characteristics and health of river ecosystems could be degraded. The method is based on a modified Indicators of Hydrologic Alteration (IHA), in which a set of biologically relevant hydrologic parameters based on post-dam hourly flow data, including magnitude and duration of baseflow, magnitude and duration of peaking flows, frequency of peaking flows and ramping rates were supplemented specifically to depict subdaily flow pulses and water condition changes induced by hydropeaking at the subdaily time scale. The results show the hydrologic perturbation characteristics affected by Chencun Reservoir at subdaily to monthly time scales. In particular, the monthly distribution of those ecohydrological indices at the hourly time scale provides detailed information on ecologically significant features of the subdaily flow variation induced by hydropeaking operations of Chencun Reservoir.

IAHS (Hydrology)

HW02a - HW02 Hydrological Model Intercomparison for Climate Impact Assessments

IUGG-1787

Evaluation of three hydrological models with respect to simulation of floods and droughts in three large-scale catchments

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The risk of extreme events is likely to be amplified by climate change and it raises an increasing interest in climate impact studies focusing on extremes. As the focus topic of ISI-MIP2 (The Inter-Sectoral Impact Model Integration and Intercomparison project, phase 2) an intercomparison of flood and drought projections under climate change is the ultimate objective for the regional-scale hydrological group. Before doing an investigation on future projections, it is important to evaluate the model performance with respect to extremes, which is usually ignored in hydrological calibrations. This study aims to investigate the representation of floods and droughts in simulations by three regional hydrological models: SWIM, VIC and HBV for three large catchments of similar size on three continents: the Rhine in Europe, the upper Niger in Africa and the upper Yellow in Asia. The simulated floods and droughts are compared to the observations in the historical period 1961- 2000. Five indices are chosen for floods: discharge at the 95th and 99th percentiles, 10-year, 30-year and 50-year floods. The drought characteristics are measured by annual minimum 7-day mean flow, number of droughts, their duration and intensity. The results from the hydrological models, separately and on average, will be analyzed and compared with indices estimated for observed time series. Such evaluation provides an essential basis for further application of regional-scale hydrological models for impact assessment on extremes.

IAHS (Hydrology)

HW02a - HW02 Hydrological Model Intercomparison for Climate Impact Assessments

IUGG-1854

"Analysis of hydrological extremes along a hydro-climatic gradient under present and future conditions"

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Climate change is expected to have a strong impact on water resources on the local, regional and global scales. In an effort to understand and quantify potential impacts of climate change, the ISI-MIP experiment was launched to assess impacts across scales through common input datasets, future scenarios and focus regions. ISI-MIP phase 2 now focuses on model evaluation with respect, in particular, to variability and extreme events, while Reg-MIP focuses on regional impacts. In here, we investigate hydrological extremes (i.e. high and low flows) under the present and future climatic conditions driven by the WATCH data for the present climate and an ensemble of future climate projections available within ISI-MIP. The future projections are based on two GCMs (HadGEM2-ES and IPSL-CM5A-LR) and two emission scenarios (RCP2.6 and RCP6.0). Unlike the global ISI-MIP project, here we analyse results from the HYPE, VIC, SWIM and mHM hydrological models optimized to simulate five river systems, i.e. the Rhine, Tagus, Lena, Niger and Ganga. The use of different impact models and future projections allows for the assessment of the uncertainty of future impacts. The analysis of extremes is conducted at four different time horizons: present-day (1980-2010), near-term (2005-2035), mid-century (2035-2065) and end-century (2069-2099). In addition, Sen's non-parametric estimator of slope is used to calculate the magnitude of trend in high flows (99^{th} percentile) at all river systems, whose statistical significance is assessed by the Mann–Kendall test.

IAHS (Hydrology)

HW02a - HW02 Hydrological Model Intercomparison for Climate Impact Assessments

IUGG-3141

Multi-model climate impact assessment and intercomparison for three large-scale river basins on three continents

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A systematic intercomparison of climate impacts is suggested, done for representative regions using state-of-the-art models. Only a few such studies are available until now with the global-scale hydrological models, and our study is intended as a step in this direction applying the regional-scale models. The impact assessment presented here was performed for three river basins on three continents: Rhine in Europe, Upper Niger in Africa and Upper Yellow in Asia. For that, climate scenarios from five General Climate Models and three hydrological models: HBV, SWIM and VIC, were used. Four 'Representative Concentration Pathways' covering a range of emissions and land-use change projections were included. The objectives were to analyze and compare climate impacts on future river discharge and to evaluate uncertainties from different sources.
The results allow drawing some robust conclusions, but uncertainties are large and shared differently between sources in the studied basins. Robust results in terms of trend direction and slope and changes in seasonal dynamics could be found for the Rhine basin regardless which hydrological model or forcing GCM is used. For the Niger River scenarios from climate models are the largest uncertainty source, providing large discrepancies in precipitation, and therefore clear projections are difficult to do. For the Upper Yellow basin, both the hydrological models and climate models contribute to uncertainty in the impacts, though an increase in high flows in the future is a robust outcome assured by all three hydrological models.

IAHS (Hydrology)

HW02a - HW02 Hydrological Model Intercomparison for Climate Impact Assessments

IUGG-3475

Climate change impact on large-basin water regime and hydrological extremes: modeling and uncertainty issues

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A physically-based semi-distributed hydrological model ECOMAG was applied within the ISI-MIP framework for assessing climate change impact on water regime of the Lena River basin (the catchment area is 2 488 000 km^2). The model describes processes of snow accumulation and melting, soil freezing and thawing, water infiltration into unfrozen and frozen soil, evapotranspiration, thermal and water regime of soil under the influence of permafrost, overland, subsurface and channel flow. Most of the model parameters were assigned from the global and regional datasets. Calibration and validation of the model were carried out against the available long-term streamflow records at the Stolb and Krestovsky gauges. The calibration was made in two steps: firstly using meteorological observation data, and then re-calibrating to reanalysis data. Four reanalysis datasets provided by the project organizers were used for historical runs. The calibration and validation sub-periods were of 10 years (2000-2009) and 14 years (1986-1999), respectively. The model was evaluated through its ability to reproduce daily streamflow hydrograph and hydrological extreme characteristics for multi-year period and demonstrated good performance, when using both observational and the bias-corrected reanalysis data. Opportunities of the ECOMAG model application for deriving hydrological projections from the climate model outputs were investigated with emphasis on the projection uncertainty issues. An approach was proposed for assessing internal atmospheric variability effect on the ECOMAG-based simulation uncertainty. The internal atmospheric variability was reproduced through ensemble climate model experiment and considered as the lowest level of uncertainty achievable in climate impact studies.

IAHS (Hydrology)

HW02a - HW02 Hydrological Model Intercomparison for Climate Impact Assessments

IUGG-4369

Modelling and intercomparison of climate impacts simulated by regional-scale hydrological models in eleven large river basins

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The Inter-Sectoral Impact Model Intercomparison Project (ISI-MIP) is a community-driven modelling effort bringing together impact modellers across sectors and scales to create more consistent and comprehensive projections of the impacts of climate change. An overview of current state of the regional-scale hydrological modelling in ISI-MIP will be given. The scope of the modelling includes eleven models applied to the chosen eleven large-scale river basins worldwide (not every model is applied to every of eleven basins). The modeling tools include: ECOMAG, HBV, HBV-light, HYPE, LASCAM, LISFLOOD, mHM, SWAT, SWIM, VIC and WaterGAP. The river basins included in the study are: the Rhine and Tagus in Europe, the Niger and Blue Nile in Africa, the Ganges, Lena, Upper Yellow and Upper Yangtze in Asia, the Upper Mississippi and Upper Amazon in America, and Murray-Darling in Australia. The drainage areas range between 67,490 km^2 (Tagus) to 2,460,000 km^2 (Lena). The model calibration and validation was done using WATCH climate data for all cases, also checking the high and low percentiles of river discharge. For larger basins, also intermediate gauge stations were included in the calibration. The results, evaluated with the Nash and Sutcliffe efficiency and percent bias, are mostly satisfactory. After that, climate change impacts were simulated and analyzed using climate scenarios from five ESMs: HadGEM2-ES, IPSL-CM5A-LR, MIROC-ESM-CHEM, GFDL-ESM2M and NorESM1-M. An overview of this collaborative experiment and current state of the regional-scale modelling for water sector in ISI-MIP will be presented.

IAHS (Hydrology)

HW02b - HW02 Hydrological Model Intercomparison for Climate Impact Assessments

IUGG-2009

France-wide future evolution of discharges for the next decades: a multi-RCP/GCM/hydrological model and calibration exercise

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In order to provide new insights for hydrology in France, we assess the impact of climate change on discharge module, high and low flows for over 800 river points in France. The last CMIP5 projections are used for the periods 2021-2050 and 2071-2100. This country-wide evaluation, a compromise between basin-based and continental studies, is of the utmost importance due to the numerous interconnections of water uses inside France.

For this work, the 4 IPCC Representative Concentration Pathways (RCPs) were utilized to drive part or all of 27 Global Circulation Models (GCMs) or versions of GCMs, for which one to ten different runs were available. This represents a total of 183 climatic projections that were then downscaled using the Advanced Delta Change (ADC) method, a statistical method calibrated between a past reference period and the two future periods.

We applied the ADC to an 8x8 km 52-year meteorological reanalysis over France. Six global conceptual hydrological models (GR4J, GR5J, GR6J, MORD6, TOPMO, HBV0) were used to produce the projections, allowing the representation of uncertainty in hydrological modelling. Moreover, one of the hydrological models was calibrated with several objective functions and over contrasted climatic periods. By having several methods or models for every step of the modelling chain (except regarding the downscaling method), we aimed at representing the uncertainty in all the components of the modelling chain.

We will present the future evolution of climate and discharge over France. Regarding discharges, we will focus on several indicators dedicated to high and low flows, discharge module and regimes. The intensity of the sources of variability from the different components of the modelling chain will possibly be quantified.

IAHS (Hydrology)

HW02b - HW02 Hydrological Model Intercomparison for Climate Impact Assessments

IUGG-3401

Hydrological model intercomparison for climate impact assessments of two typical catchments of China

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Uncertainty is a major issue in climate impact assessment. The sources of uncertainty include emission scenario, general circulation models (GCMs), downscaling techniques, as well as hydrological models. Taking the Xiang River catchment located in the central China and the Kuye River catchment situated in the north China as cases, the performances of three hydrological models (including SimHyd model, SWBM model and VIC model) used for climate impact assessments were investigated. Results show that the three hydrological models could simulate monthly discharges well with Nash-Sutcliffe coefficients exceeding 70% and average relative errors falling in range of ±3% for both catchments. The projected changes in water resources are associated with different hydrological models and climate scenarios. Annual water resources of the Xiang River catchment and the Kuye River catchment over the period of 2021-2050 will be expected to decrease by 2.76% (ranging from-7.81% to +7.40%) and to increase by 3.4% (ranging from-5.47% to +12.60%) relative to 1970—2000. The differences between water resources changes produced by different hydrological models fall in ±2.2%. The projected changes in water resources mainly rely on climate scenarios used in water resources assessment. GCMs are major drivers of uncertainty in climate impact assessment.

IAHS (Hydrology)

HW02b - HW02 Hydrological Model Intercomparison for Climate Impact Assessments

IUGG-4424

Intercomparison of energy balance and hydrological models to simulate monthly evapotranspiration of the Blue Nile basin.

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Evapotranspiration is globally the largest output component in many basins. Nevertheless, hydrological catchment models tend to be calibrated and evaluated on discharge data. Discharge is relatively easy to be measured and it provides information on the catchment as a whole. However, discharge data may not provide the necessary information to characterize the hydrological processes in distributed hydrological models. These models have become popular tools in hydrology for simulating land use change analysis or to map water fluxes (e.g. groundwater recharges or evapotranspiration) at grid, land use or landscape element level.

In the past decades, more and more products estimating evapotranspiration are derived from remote sensing data. These data are typically derived from energy balance models using thermal remote sensing data can be mapped following the resolution of the thermal data sources.

Here, a comparison is done using several distributed hydrological catchment models and ensemble remote sensing product. The hydrological models (SWAT, SWIM and mHM) have been calibrated using the WATCH data for inter-comparison purposes within the Reg-MIP initiative which is part of Inter-Sectoral Impact Model Intercomparison Project (ISI-MIP) (www.isi-mip.org). The ensemble remote sensing product is generated using multiple ET products including (MOD16NBI, SSEBop, ALEXI, CMRSET, and GLEAM). The ensemble remote sensing products have been collected for the water accounting project (www.wateraccounting.org). The preliminary results for the Blue Nile basin show high differences among the different models.

IAHS (Hydrology)

HW02b - HW02 Hydrological Model Intercomparison for Climate Impact Assessments

IUGG-4629

Characterizing and reducing uncertainties in hydrologic projection of Columbia river basin using objective multiple climate and hydrologic models

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The uncertainties raised from Global Climate Models (GCMs) and hydrologic model structures are investigated using multi-modelling and post-processing of simulated streamflows. For that, we used an ensemble of 10 statistically downscaled GCMs from two CMIP5 datasets, i.e. Bias Corrected Statistically Downscaled (BCSD) and Multivariate Adaptive Constructed Analogs (MACA), for historical period and two future scenarios, i.e. RCP4.5 and RCP8.5. This climate data is used as input for the three hydrological models, i.e. VIC, SAC-SMA, and PRMS. The models were calibrated at 1/16 degree resolution and the simulated streamflow was routed to the sub-basin outlets of interest. The simulations from each hydrologic model were post-processed, and then combined using Bayesian Model Averaging (BMA) based on their performance in the historical period. We compared simulated streamflow from individual models with multi-model averages for three different 30 year blocks (2010-40, 2040-70 and 2070-99), which are of importance to reservoir management in the Columbia River basin. The simulated streamflows from BCSD products are, in general, higher than those from MACA. The results show that hydrologic model uncertainty is mostly smaller than uncertainty from GCMs and pathways. The application of post-processing along with BMA enabled accounting for two major sources of uncertainty more realistically, i.e. model input and structure, which can also lead to more accurate and reliable streamflow projections.

IAHS (Hydrology)

HW02b - HW02 Hydrological Model Intercomparison for Climate Impact Assessments

IUGG-4806

Bridging the global and regional hydrological scales in climate impact assessment

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Policy relevant information on climate change impacts is available from global and regional impact assessments. The global model results are often used by policy makers for the global-scale assessments. They can also form the boundary conditions for regional modelling studies, while information from the regional scale, which is applicable for creating regional adaptation strategies, can help to improve global simulations. Ideally, the results from both scales should agree in trend direction and strength of impacts. However, this implies that the sensitivity of impact models from both scales to climate variability and change is comparable. In this study we compare hydrological results simulated by global and regional impact models for the water sector in different climate regions under reference and scenario conditions. The aim is to start the discussion on how to bridge the global and regional scales for impact assessment in order to provide more reliable information on future projections for the global and regional decision makers.

IAHS (Hydrology)

HW02b - HW02 Hydrological Model Intercomparison for Climate Impact Assessments

IUGG-5371

Variability of eco-hydrological elements simulated with an eco-hydrological model integrating remotely sensed product from 1981 to 2012 over China

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Reliable estimation of regional eco-hydrological elements will enable us to improve regional ecosystems and water resources management. A process-based Vegetation Interface Processes (VIP) eco-hydrological model integrating remote sensing vegetation index is used to simulate the spatiotemporal variations of the elements over China from 1981 to 2012. The model is validated with the eddy covariance flux measurements of evapotranspiration (ET) and gross primary production (GPP) and basin water balance derived ET over the study domain. The simulation showed that there is a great spatial variability for ET and GPP with mean CV (coefficient of variation) of 70.8% and 95.5% respectively, but their temporal variability is much lower with CV being 2.8% and 4.3% respectively. Over the whole area, the temporal trends vary considerably with a noticeable increase in East China and Tibet Plateau and decreasing in west of Northeast China and Southwest China. Although precipitation and net radiation are slightly decreasing, annual ET and GPP are increasing significantly ($p<0.01$), which is consistent with the global trends. As a consequence, ET to precipitation ratio is raised while runoff to precipitation ratio is reduced. The simulated soil moisture is slightly decreasing, confirmed by the decrease of land water storage from GRACE satellite data from 2002 to 2013. It is illustrated that global warming is intensifying the hydrological and carbon cycling, and the drought condition may occur more severely and frequently on the mainland of China.

IAHS (Hydrology)

HW02c - HW02 Hydrological Model Intercomparison for Climate Impact Assessments

IUGG-0726

Consideration and interpretation of multiple sources of uncertainty in modelling future hydroclimate in south-eastern Australia

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This paper provides a synthesis of the relative sources of uncertainties in predicting climate change impact on water resources and hydrological characteristics, based on extensive studies in south-eastern Australia over the last decade. This large region is an interesting case study because of the large variation in hydroclimate spatially (from temperate to arid) and temporally (large inter-annual variability and the recent unprecedented 1997–2009 Millennium Drought).

The paper presents multiple lines of evidence pointing towards a drier winter in the region, but the uncertainty in future climate projections remain very large. Weighting future projections on a subset of the ‘better’ GCMs can provide a false sense of reduced uncertainty because the use of different criteria to assess the GCMs often results in different model choices. Limited downscaling runs present the same problem and different downscaling models may show different results. The uncertainty in hydrological modelling can also be as large as the uncertainty in the climate projections, as we extrapolate hydrological models developed and calibrated using past observations to predict a future in a significantly warmer and higher CO_2 world.

Despite the large uncertainties from various sources, the paper explains that, for many parts of the world including south-eastern Australia, we can project likely changes in key hydrological characteristics like long-term average streamflow, seasonality and security of water supply. Predicting the tails of the distribution and changes to extreme hydrologic metrics will remain difficult. It is therefore important to adopt an integrated climate-hydrology modelling and interpretation tailored specifically to the impact assessment and adaptation being considered.

IAHS (Hydrology)

HW02c - HW02 Hydrological Model Intercomparison for Climate Impact Assessments

IUGG-1658

Climate change impacts on the seasonality of low flows for multiple catchments with different discharge regimes

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Impacts of climate change on the seasonality of low flows were assessed for 134 sub-catchments of the River Rhine basin. Three seasonality indices for low flows were estimated: the seasonality ratio (SR) related to the discharge regime, the weighted mean occurrence day (WMOD) related to the timing of low flow events and the weighted persistence (WP) related to the variability in timing of low flow events. The three indices were estimated from: 1) observed low flows; 2) simulated low flows by a semi-distributed HBV model using observed climate as input; 3) simulated low flows using simulated inputs from seven combinations of General Circulation Models (GCMs) and Regional Climate Models (RCMs) for the current climate; 4) simulated low flows using simulated inputs from seven combinations of GCMs and RCMs for the future climate including three different greenhouse gas emission scenarios. Significant differences were found between cases 1 and 2. The HBV model overestimates SR, underestimates WP and simulates very late WMODs compared to estimated WMODs using observed discharges. Comparing the results of cases 2 and 3, the smallest difference was found for SR, whereas large differences were found for WMOD and WP for the current climate. Finally, comparing the results of cases 3 and 4, we found that SR decreases considerably for the future climate in all seven sub-basins of the River Rhine. The lower values of SR indicate a shift from winter to summer low flows in the two Alpine sub-basins. The WMODs tend to be earlier than for the current climate in all sub-basins except for the Middle Rhine and Lower Rhine sub-basins. The WPs are slightly larger, showing that the predictability of low flow events increases as the variability in timing decreases for the future climate.

IAHS (Hydrology)

HW02c - HW02 Hydrological Model Intercomparison for Climate Impact Assessments

IUGG-2630

Frequency Bias Correction (FBC) - A new approach for correcting low frequency bias for water resources climate change impact assessment

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Addressing systematic persistence related biases in GCM simulations is being increasingly recognised as a first step in any hydrological climate change impact assessment. This is in contrast to many bias correction procedures that focus on correcting biases in moments without focussing on persistence, an option that has significant implications for water resources assessments. The current options for addressing persistence biases comprise of the Nested Bias Correction (NBC) or its recursive variant, the Recursive NBC (RNBC), which correct lag 1 autocorrelation biases across specified nesting time scales. While these represent the only alternatives available to correct persistence biases (and hence are of considerable use in storage related applications in hydrology), the assumption of pre-defined time scales and a focus on the lag 1 autocorrelation limits their generality in representing persistence. Here we present the Frequency Bias Correction (FBC) as an alternative to the NBC, that aims to correct for biases in the spectral representation of the data. By focussing on the entire spectrum instead of a handful of time-scales allows a more comprehensive treatment of any persistence related biases that may exist in the GCM simulations being assessed. The FBC is tested for MIROC5 precipitation simulations across the Australian land mass and compared to the empirical quantile mapping (EQM) and RNBC in terms of its ability to maintain distribution and persistence related attributes. Results indicate that the FBC corrects distributional and dependence attributes relevant in hydrological design and operation of water storage systems.

IAHS (Hydrology)

HW02c - HW02 Hydrological Model Intercomparison for Climate Impact Assessments

IUGG-3916

Hydrological sensitivity analysis to statistically downscaled climate values on Western Mediterranean catchments

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This study analyses the sensitivity of a hydrological model to different methods to downscale climate values on four Western Mediterranean basins along a North-South axis facing various hydro-climatic conditions. The comparison was conducted over a common 20-year period (1986-2005) so as to capture different climatic conditions in the basins. Streamflow was simulated in the basins using the GR4j conceptual model. A cross-validation procedure showed that the model was able to correctly reproduce runoff in various climatic conditions when using high-resolution observed climate forcings. Those simulations thus served as a reference for testing the ability of the various downscaled datasets to correctly reproduce various aspects of the hydrograph. Three different statistical downscaling techniques were considered: analog weather typing (ANALOG), cumulative distribution function transfer (CDFt) and stochastic weather generator (SWG). These techniques were applied to downscale precipitation and temperature high-resolution data from NCEP/NCAR reanalyses and two GCMs outputs over the reference period. A sensitivity analysis of the hydrological model to these various downscaled data was thus conducted. Results underlined that the ANALOG method globally performed better than the other downscaling techniques in reproducing mean seasonal streamflow, interannual runoff volumes as well as low/high flow distribution. They also point out mismatches between downscaling method and climate data, which may result from incompatibilities between large-scale predictors and climate data observations. More generally, our approach provides a guideline to select the downscaling model outputs to be used according to the needs of climate change impacts studies.

IAHS (Hydrology)

HW02c - HW02 Hydrological Model Intercomparison for Climate Impact Assessments

IUGG-5186

Using data-based elasticity estimates to assess the capacity of hydrological models to predict the hydrological impact of climatic changes

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This presentation will discuss the climate elasticity of streamflow, i.e. the sensitivity of the changes in streamflow related to changes in a climate variable (Schaake and Liu, 1989). Elasticity e can be defined as e = DeltaQ / DeltaX , where DeltaQ represent the streamflow anomalies and DeltaX the climatic variable anomalies.

The past has seen a wealth of elasticity studies based on models (i.e. based on flows simulated by a hydrological model fed with different inputs). But elasticity can be directly derived from data (see e.g. Sankarasubramanian et al., 2001; Coron et al., 2014), provided that long-term records are available. We wish here to discuss the differences between the two estimates, by using models of increasing complexity over a range of catchments.

The fact that all the models we tested had a tendency to underestimate the observed elasticity leads to questioning whether hydrological models do not systematically underestimate the hydrological impact of climate change. We discuss possible solutions to “force” models to better represent data-based elasticity.

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IAHS (Hydrology)

HW02p - HW02 Hydrological Model Intercomparison for Climate Impact Assessments

HW02p-141

An analysis of projected impacts on climate change of river Nisava in Serbia

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In this paper, a comparative analysis of projected impacts of climate change on water resources from two types of models, ACR-VNC model and catchment scale hydrological simulation model is presented. The ACR-VNC model is developed at the Institute for the development of water resources “Jaroslav Cerni” and is based on determination of linear auto cross regressive dependences of standardized variables, different combinations of cause-effect relations between hydrologic and meteorological time series. Another model which was used for analysis is the Hydrologic Modeling System (HEC-HMS) developed US Army Corps of Engineers, Institute for Water Resources. The model is designed to simulate the precipitation-runoff processes of catchment systems.

Models are calibrated according to observed hydrologic and meteorological data of the Republic Hydrometeorological Service of Serbia for the period 1961-2012. In order to simulate the effects of climate change, the calibrated hydrological models were run with time series of monthly precipitation, air temperature, evaporation and humidity that were results of integration of a downscaled global model SX-G to the regional level associated with the coupled atmosphere and ocean model EBU-POM. Integration covers the period 1961-2100 year. Future hydrologic projections are given for two future scenarios which were selected in accordance with concentrations of greenhouse gases determined by the IPCC. For the period 2013-2100 A1B scenario is selected as average, and the A2 scenario as the most extreme.

Analyses are conducted for the Nisava river basin in Serbia. Time periods that are considered are: 1961-2012 as a control, 2013-2050 represents near future and 2051-2100 represents far future.

IAHS (Hydrology)

HW02p - HW02 Hydrological Model Intercomparison for Climate Impact Assessments

HW02p-142

River salinity on a mega-delta, an unstructured grid model approach.

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With an average freshwater discharge of around 40,000 cubic metres the BGM (Brahmaputra Ganges and Meghna) river system has the third largest discharge worldwide. The BGM river delta is a low-lying fertile area covering over 100,000 square km mainly in India and Bangladesh. Approximately two-thirds of the Bangladesh people work in agriculture and these local livelihoods depend on freshwater sources directly linked to river salinity.

The finite volume coastal ocean model (FVCOM) has been applied to the BGM delta in order to simulate river and coastal salinity under present and future climate conditions. Forced by a combination of regional climate model predictions, and a basin-wide river catchment model, the 3D baroclinic delta model can determine salinity under the current climate, and make predictions for future wet and dry years. The river salinity demonstrates a strong seasonal and tidal cycle, making it important for the model to be able to capture a wide range of timescales.

The unstructured mesh approach used in FVCOM is required to properly represent the delta's structure; a complex network of interconnected river channels. The model extends over 300 km inland in order to capture the full extent of the tidal influence, but also well offshore to fully cover the continental shelf. At the open boundaries the model is coarse (of the order 20km) but grid resolutions of 10s of metres are required to represent narrow inland river channels. The use of FVCOM to simulate both the coastal dynamics and river flows on the delta is a novel challenge, which also requires knowledge of the shape and cross-section of the river channels.

IAHS (Hydrology)

HW02p - HW02 Hydrological Model Intercomparison for Climate Impact Assessments

HW02p-143

Comparison of conceptual and distributed rainfall-runoff models for climate change impact assessment

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Since the early 2000s, various studies with respect to climate change impact assessment have been individually conducted in the Republic of Korea. However, research considering various fields of study simultaneously using the recently published AR5 climate change scenarios is needed. There are various rainfall-runoff models with different complexity, and the accurate and less uncertain results from the models are important because they are applied to other research fields as basic water resources data. This study compares two well-known and simpler conceptual rainfall-runoff models, IHACRES and GR4J, and a more complex SWAT model by investigating the efficiency and accuracy using historical data. In addition, this study predicts the future water resources scenarios in a catchment on the Korean peninsula.

The results of this study shows that the conceptual models requires less computational time and presents better model performance, higher than 0.8 of Nash-Sutcliffe efficiency, compared to the SWAT model. The differences between the two conceptual models are minor whereas the differences between the conceptual and SWAT models are large. In addition, the SWAT results from this study differ greatly in comparison to the SWAT results of a previous studies because of the different conditions used. Additionally, considering the widely known structural uncertainty in more complex models, simpler rainfall-runoff models with less structural uncertainty are more appropriate for this study. The water resources forecasts with RCP4.5 scenario is predicted to be increased to around 22.2% and 44.0% for 2040s and 2080s respectively, whereas the RCP8.5 scenario predicted 16.4% and 22.3% for 2040s and 2080s respectively due to less rainfall and higher evapotranspiration loss.

IAHS (Hydrology)

HW02p - HW02 Hydrological Model Intercomparison for Climate Impact Assessments

HW02p-144

Quantifying Contributions of Climate Change and Human Activities to Runoff Decline in Upper Reaches of the Luanhe River Basin

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Climate change and human activities were regarded as the two main factors for runoff change. Using observed stream discharge, there was a statistically significant decreasing trend for annual and monthly runoff detected by Mann-Kendall's test, in the upper reaches of Luanhe River basin (URLRB), 1954-2000. With the break point analysis, the whole time series were divided into two periods: "natural period (1954-1970) and "impact period" (1971-2000). "Natural runoff" from 1954 to 2000, was reconstructed by variable infiltration capacity (VIC) model, in which the model parameters were calibrated in "natural period" representing the natural land cover conditions without the impact of human activities. By comparing the difference between observed stream flow and "natural stream flow", the contribution of climate change and human activities was quantitatively separated. The results indicated that climate change and human activities accounted for 49% and 51%, respectively, of the annual runoff decrease in URLRB. That meant the contribution of climate change on runoff was equal to it caused by human activities. Monthly, climate change decreased the stream flow in every month; otherwise, human activities increased the stream flow in four winter months: December to March, and reduced the stream flow in other eight months. The results could be a reference for water resources projection and management in URLRB and others catchments in northern China.

IAHS (Hydrology)

HW02p - HW02 Hydrological Model Intercomparison for Climate Impact Assessments

HW02p-146

Estimation of flood and storm surge complex disaster in Japan for adaptation

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In recent years, climate change has gained significant attention among the professionals and the communities, mainly towards the increasing impacts of climate change on natural disasters. Focusing on two water-related disasters, such as flood and storm surge, we found that the potential damage costs were high in areas affected by these two disasters in each Japanese prefecture. In order to estimate the amount of potential damage costs and evaluate complex disasters correctly, the damage costs caused by flood, storm surge and complex disaster of flood and storm surges were expressed quantitatively in the form of map. Flood and storm surge are likely to occur at the same time in coastal areas. Therefore we assumed that complex disaster of flood and storm surge was caused by low atmospheric pressure at the time of a tropical cyclone. We estimated the strength of flood and storm surge from the low atmospheric pressure when two disasters happened at the same time. We evaluated which disaster was potentially most dangerous in each prefecture. The potential damage costs of flood in whole Japan was 1.03 trillion USD, of storm surge was 0.52 trillion USD and complex disaster of flood and storm surge was 0.87 trillion USD. The damage amount costs of flood were maximized compared to storm surge and complex disaster. However, when we estimated the damage costs in each prefecture, there were some areas where the damage costs of storm surge or complex disaster were maximized. Out of 46 prefectures, the damage costs of flood were maximized in 37 prefectures. Additionally the damage cost of storm surge and complex disaster were maximized in 1 and 8 prefectures respectively.

IAHS (Hydrology)

HW02p - HW02 Hydrological Model Intercomparison for Climate Impact Assessments

HW02p-147

Propagation of biases in humidity in the estimation of global irrigational water

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Future projections on hydrological environments under a changing climate are highly dependent on meteorological data derived from general circulation models (GCMs). Since climate projections include biases, bias correction is widely used to adjust meteorological elements, such as the atmospheric temperature and precipitation, but less attention has been paid to biases in humidity. In this study, we examined how the biases remaining in the humidity data propagate into results of impact assessment of future climate change. We mainly focused on impacts on the estimation of irrigational water using the global hydrological model (GHM) H08. To determine the effects of humidity bias across GCMs, we used meteorological data sets to which a state-of-the-art bias correction method was applied except to the humidity.

We found that differences in the monthly relative humidity of 11.7 to 20.4 %rh from observations across the GCMs caused the estimated irrigational water abstraction from rivers to range between 1217.7 and 1341.3 km3/yr for 1971-2000. Differences in humidity also propagate into future projections. We also performed another set of experiments to examine whether bias correction of the humidity can reduce uncertainties in irrigational water across the GCMs. The results showed that bias correction, even with a primitive methodology that only adjusts the monthly climatological relative humidity, helped reduce uncertainties across the GCMs.

Although the GHMs have different sensitivities to atmospheric humidity because of the implementation of different types of potential evapotranspiration formulae, bias correction of the humidity should be included in hydrological analysis, particularly for the evaluation of evapotranspiration and irrigational water.

IAHS (Hydrology)

HW02p - HW02 Hydrological Model Intercomparison for Climate Impact Assessments

HW02p-148

Assessing climate change and land use impacts on runoff variation by SWAT model in upper reaches of Zhanghe River, China

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It is one of hot and difficult topics of water science to attribute impacts of climate change and human activities on hydrological processing, and one of urgent issues for related adaptation and mitigation decision-making. Zhanghe River was decisided as the study case here allowing for the characteristics of environmental condition. It identified the break piont of runoff series by addressing Mann-kendell method, then divided the historical data into natural period and impacted period. SWAT model was imported into this study as a hydrological model, which was calibrated using daily data of natural period. The impacts of climate change and human activities could be separated in terms of differences between the simulated runoff and observed one. Meanwhile, based on the resampling method, the climate natural varaibility was modeled, and the effects of climate natural varaibility and human-induced climate change also were discussed. It employed the latest projections of RCP2.6, RCP4.5, RCP8.5 from IPCC5 to predict the runoff trends in future ages of 2050s and 2080s. The results indicated that the human-induced effects domintated the runoff changes in study case, the imbalance between water supply and demand would show more highlighted.

IAHS (Hydrology)

HW02p - HW02 Hydrological Model Intercomparison for Climate Impact Assessments

HW02p-149

Evaluating robustness of conceptual rainfall-runoff models under climate variability in Northern Tunisia

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Climate change is likely to have significant impacts on runoff in the Southern rim of the Mediterranean basin that already suffers from scarcity of water resources. To investigate how hydro-climatic conditions could evolve in this region, not only future projections of climate are necessary but also robust rainfall-runoff models that are able to be fairly reliable under changing climate conditions. This study thus aims at assessing the robustness of two conceptual rainfall-runoff models (GR4j and IHACRES) under long-term climate variability on eight basins covering the main hydrographic characteristics in Northern Tunisia (High Medjerda, Zouaraâ, Ichkeul and Cap bon). The catchment areas are between 81 km² and 418 km². The streamflow regime of the basins can be considered as natural since these basins are located upstream from storage-dams and withdrawals. A 30-year common period (1970-2000) was considered to capture a large spread of hydrological conditions. The models were calibrated and validated using various goodness-of-fit criterions: NSE, KGE and Bias. Their efficiency was evaluated according to a 10-day time step using three differential split sample tests that aimed at assessing the models under various precipitation and PE conditions. Results showed that the two models were able to correctly reproduce runoff from the basins with a good agreement of the hydrograph shapes, of the high and low flows as well as the water volumes. However, the models prove a limited transferability of their parameters under contrasted climate conditions in almost all basins. Consequently, many parameter sets will have to be considered to represent the hydrological uncertainties associated in the assessment of possible climate change impact on runoff in the basins.

IAHS (Hydrology)

HW02p - HW02 Hydrological Model Intercomparison for Climate Impact Assessments

HW02p-150

"Uncertainty by model process description and parameter estimation under present and future conditions"

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As it is well known, the modeling of physical processes brings with it different sources of uncertainty. When the aim of the models is to make projections into the future, a quantification of this uncertainty is of major importance. This work aims to provide an estimation of the uncertainty associated with the processes description and parameter estimation in hydrological modeling for different catchments, under present and climate change conditions. The first issue will be addressed by considering different hydrological models, namely LASCAM, HBV and HYMOD. This will be performed in both calibration and projection based on General Circulation Models. The second issue is addressed based on the equifinality thesis. As different (quasi) optimum parameters give different results, a set of well performing parameter vectors will be considered. We will apply these parameter sets under current conditions as well as future projections. In this way, a range of equally likely projections of climate change impacts will be assessed for each scenario. A statistical analysis of the distribution of these assessments will be carried out and a comparison with the outcomes from a single-valued optimization algorithm will be performed. As not only the uncertainty estimation but also the reduction of this uncertainty is important, a robust parameter estimation will be considered. Finally an interesting analysis will be the comparison of the different sources of uncertainties in different periods. This means, uncertainty because of model structure, parameter estimation and (climate change) scenarios

IAHS (Hydrology)

HW02p - HW02 Hydrological Model Intercomparison for Climate Impact Assessments

HW02p-151

Assessing the impacts of climate change on hydrology in the Yellow River Source region using climate projections and VIC model

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Variation of Precipitation, Temperature and runoff in Yellow River Source Region was analyzed with Mann-Kendall and Spearman method over past 63 years from 1951-2013. Based on the seven climate scenarios from CMIP5 climate models under three Representative Concentration Pathways (RCP2.6, RCP4.5 and RCP8.5), responses of hydrological process to climate change were simulated using the Variable Infiltration Capacity model. Results indicated that recorded Temperature in the Yellow River Source Region presented significant increasing trend during over past 63 years. The daily minimum temperature presents higher increasing trend than the daily maximum temperature. Yearly gross precipitation presents minor increasing, and the year runoff present minor decreasing. The runoff and soil moisture will likely undergo decreasing trend and the heterogeneity on Runoff Process will be increase in the future. Much more drought may threaten the social development in this region in the future.

IAHS (Hydrology)

HW02p - HW02 Hydrological Model Intercomparison for Climate Impact Assessments

HW02p-152

A multi-model ensemble method preserving variability in various temporal scales for climate change impact assessment

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Ensemble simulation has been suggested as an efficient approach reduces simulation uncertainty in various numerical experiments. In particular, multi-model ensemble approach has been broadly used to assess the impact of climate change considering the uncertainty of projections derived from the difference climate models of Climate Model Intercomparison Project (CMIP). However, a typical method, arithmetic averaging in temporal domain, is not appropriate, in particular, when the temporal scale of target analysis is shorter than a decade, because representations of relatively short-range natural phenomena in different models are not completely in phase each other. In order to reduce such an artifact from smoothing high-frequency signal in simple multi-model ensemble average, a sophisticated multi-model ensemble method is devised, which preserves variability in various temporal scales of each ensemble representations. New method averages statistical distributions of each climate model output (Probability Domain Averaging). The ensemble statistical distributions are calculated for both future and historical period, and the changes of the ensemble distributions from historical to future are merged into the reference historical climate. PDA method successfully reflects the temporal characteristics of the projection by each climate model. In addition, the range of uncertainty in the projections is estimated in the process of averaging statistical distributions.

IAHS (Hydrology)

HW02p - HW02 Hydrological Model Intercomparison for Climate Impact Assessments

HW02p-153

Modeling water cycle change in the U.S.: Climate versus human drivers

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There is mounting evidence of profound hydrologic changes over the past century when instrumented records began, but to make correct attributions for the causes of the observed change, and to integrate and make sense of the changes in different branches of the water cycle and in different water stores, large-scale hydrologic models play an irreplaceable role. However, most of the existing large-scale water cycle models do not yet explicitly represent the anthropogenic forces which can no longer be neglected because the water cycle today is not natural anymore. In this study, an integrated modeling framework of continental-scale water cycle, with explicit representation of climate and human induced forces (e.g., irrigation, groundwater pumping) is developed and used to reconstruct the observed water cycle changes in the past and to attribute the observed changes to climatic and human factors. The new model builds upon two different previously developed models: a global land surface model called the Human Impacts and GroundWater in the MATSIRO (HiGW-MAT) [1,2] and a high-resolution regional groundwater model called the LEAF-Hydro-Flood [3]. The model is used to retro-simulate the hydrologic stores and fluxes in close dialogue with in-situ and GRACE satellite based observations at a wide range of river basin scales over the U.S., with a particular focus on the changes in groundwater dynamics in the High Plains and the Central Valley regions.

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IAHS (Hydrology)

HW02p - HW02 Hydrological Model Intercomparison for Climate Impact Assessments

HW02p-154

The ensemble hydrological forecasts of spring flood in terms of future climate change

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In the last decade on the territory of Ukraine is often seen as an abnormally warm winter with the lack of stable snow and cold snowy winters with a decrease in temperature to minus 30º? and below. In this case it is possible occurrence of catastrophic floods in the rivers that lead to flooding areas.

The ensemble long-term forecasts of hydrological characteristics of the spring flood of flat rivers based on the principle of distribution of totality of years on water content groups by complex of the hydrometeorological factors forming of spring flood using linear discriminant function. These include the total amount of water (snow, rainfall, frost depth and soil moisture, temperature in winter-spring season).

The territorial forecast is represented in the form of maps of expected modular coefficients of spring flood layers and maximum water discharge, the timing of its passage as well as the probability of occurrence of floods in the perennial period.

The calculations of climate scenarios (COMMIT, A1B, A2, B1) suggest the following increasing surface air temperature in all seasons, with the highest rates of growth in winter

To use the model ensemble long-term forecast characteristics of spring flood in consideration of future climate change depending on meteorological factors found spring runoff are vector predictor discriminant function of scenario characteristics of air temperature and precipitation

IAHS (Hydrology)

HW03a - HW03 Multivariate Analysis in Hydrological Modelling

IUGG-2618

The internal dose calculation based on the lumped hydrologic method

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In this paper, we propose a readily-understandable internal dose calculation based on the lumped hydrological method. While the internal dose calculation which includes complex computational reproduction of the human body is accepted as an accurate method, we provide uncomplicated understanding of health effects of radioactivity. The human body is treated as a single vessel schematically. The conservation of radioactivity in the human body is described by the continuity equation, which is the first order ordinary differential equation. We can get time-dependent radioactivity in the human body analytically. The internal dose is obtained by time integral of radioactivity in the human body. The radiation energy absorbed into the human body per one radioactive decay event is estimated from the decay scheme based on the Fermi theory of beta decay. The effective dose is calculated from the internal total exposure and the radiation energy per one radioactive decay event. We demonstrate the accuracy of our method comparing with previous research. The merit of our method is not to need complex computational calculation for internal dose calculation. Our method to calculate radioactivity can be applied to not only the human body but also the soils and agricultural products. We calculate that the internal dose caused by the intake of radioactivity on agricultural products derived from fallout as an example. Considering the difference of radioactivity in the human body by individuals, the time evolution of probability density of radioactivity is calculated by re-formalization of the continuity equation into the stochastic differential equation. In summary, our method provides an understanding of the influence of radioisotopes for general technologists.

IAHS (Hydrology)

HW03a - HW03 Multivariate Analysis in Hydrological Modelling

IUGG-4233

How can we best utilize spatially distributed data for the calibration of physically-based hydrologic models?

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Spatially distributed and physically-based hydrologic models have been promising tools for hypothesis testing and for prediction, but have also, so far, suffered from at least two problems. Firstly, they do not perform well in an uncalibrated state when parameters are simply estimated from information about soils or vegetation. Secondly, calibration to specific variables, mainly streamflow, generally does not sufficiently constrain other parts of the model domain that are important for understanding catchment function, e.g. internal variability of storage behaviour. And there are of course more issues such as overparameterisation, model structural error or the noncommensurability of modelled and observed state variables. In this presentation we would like to revisit the topic of model calibration for physically-based models – and especially how we make best use of available data in this context. Our premise is that the direct calibration to observations almost always leads to an overfitting of the model to this type of information, while other aspects of model behaviour get ignored. Here we propose to use the observations (and any other available information) only to guide the development of an explicit perceptual model, which contains information about what behaviour we believe can be expected to occur in the catchment or not. Our efforts are then focused on making the perceptual and the numerical model consistent with each other, rather than satisfying some measure of optimality. We believe that this strategy is more likely to yield numerical models that are hydrologically acceptable than traditional calibration strategies, and that the value of our data is better recognized.

IAHS (Hydrology)

HW03a - HW03 Multivariate Analysis in Hydrological Modelling

IUGG-4698

Toward reduction of model uncertainty in operational hydrologic forecasting within a bayesian framework: A combination of multivariate analysis and multi-modeling

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The commonly used Bayesian Model Averaging (BMA) method provides probabilistic estimation of forecast variable given the predictions of different models. The method develops a linear weighted average to the posterior distributions of individual models to account for importance of individual models, hence reducing the uncertainty induced by model selection in hydrologic predictions. In the original form of BMA, the posterior distribution of forecast given each model prediction is assumed to be a particular probability distribution (e.g. normal, gamma, etc.). In this presentation, we demonstrate the integration of a group of multivariate functions, the so-called copula functions, to approximate the posterior distribution of forecast given individual model predictions. Here we introduce a copula-embedded BMA (Cop-BMA) method that skips the iterative procedure in the EM algorithm and also relaxes any assumptions about the shape of conditional PDFs. Both BMA and Cop-BMA are applied to hydrologic forecasts from different rainfall-runoff and land-surface models. We consider the streamflow observation and simulations of ten river basins provided by the Model Parameter Estimation Experiment (MOPEX) project. Results from BMA application shows that the predictive distributions are generally overconfident by having insufficient spread. In contrast, the post-processed forecasts by Cop-BMA are shown to be more accurate and reliable. In addition, Cop-BMA outperforms standard BMA in the river basins with poor initial forecasts (e.g., dry regions).

IAHS (Hydrology)

HW03b - HW03 Multivariate Analysis in Hydrological Modelling

IUGG-0321

Copula-Based seasonal Flood Frequency Analysis (FFA) - for dependant seasonal maxima

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In flood frequency analysis flood events are mainly characterized by maximum annual peak flow. In the regions where the peak flow series are mixture of summer and winter flows the seasonal approach is necessary. However, the classical model of annual maxima distribution defined as the product of seasonal distributions is not valid when seasonal maxima are dependent.
In this study, a methodology is developed to derive bivariate joint distributions of the summer and winter peak flows using the concept of copula and traditional (multivariate normal distribution) approach. Among different copula families Elliptical and Archimedean copula are applied and compared using statistical and graphical tests. The parameters of copula are estimated using maximum likelihood and simulated method of moments. The resulting distributions of annual maxima are analysed and compared to show the differences in design quintiles estimates. They are also compared with product model in order to assess the impact on design quintiles while dependency is ignored.

IAHS (Hydrology)

HW03b - HW03 Multivariate Analysis in Hydrological Modelling

IUGG-1120

Multi-fidelity stochastic collocation of a groundwater model

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A high degree of uncertainty is typically associated with the inputs, parameters, and calibration data of groundwater models. These uncertainties may be represented by multivariate distributions, and propagated to the model outputs and calibrated parameters by statistical integration techniques. However such methods are often computationally infeasible due to the large number of model runs required to accurately sample multivariate distributions. The situation is exacerbated by the slow runtimes of complex groundwater models exhibiting a high degree of spatial and temporal variability. One solution is to approximate complex models using a simpler surrogate which captures their salient features. Low fidelity surrogates reduce computation time by employing lower spatial resolution, lower accuracy time-stepping methods, ignored physics, or computational simplifications. However, such surrogates have been shown to provide misleading results when used in place of the complex model for statistical analysis. In order to take advantage of both the accuracy of complex, 'high fidelity' model and the speed of the lower fidelity model, approaches have been developed to combine the two. We employ a recently developed multi-fidelity stochastic collocation method to quantify uncertainty in a transient, spatially distributed groundwater model. We use a lower fidelity model with a coarse spatial discretization to select collocation points at which to evaluate the higher fidelity model. The approach is non-intrusive, so can be applied to legacy black box models.

IAHS (Hydrology)

HW03b - HW03 Multivariate Analysis in Hydrological Modelling

IUGG-2194

Spatio-temporal synthesis of long continuous precipitation series for urban hydrological applications

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Long and continuous rain series in a high temporal resolution are required for designing and operating urban drainage systems. As data available for urban hydrology is often short, i.e. for temporal and regional required resolutions, it is advantageous to develop a precipitation model to allow for the generation of long synthetic series.
A stochastic model is applied for this purpose, involving an alternating renewal (AR) process describing a system which can be in one of two possible states: wet or dry spells. Spells are described by their duration and amount of rainfall. The former variables belong to the external structure and are generated stochastically, whereas the internal structure describes the distribution of the rain within the wet spell. Stochastic generation of rainfall time series using AR models is straight forward for single site simulation. The aim of this work is to present a possible extension of the model to spatio-temporal simulations. To generate several spatially correlated time series a methodology is proposed which consists of a hybrid model to define in which locations rainfall events are occurring simultaneously and a multivariate copula model to generate synthetic events in the different locations.
Rainfall series registered in several stations located in the cities of Hamburg and Braunschweig in the north of Germany are used to develop and test the proposed methodology. Results are compared with an existing method in which long independent time series of rainfall events are transformed to spatially dependent by permutation of the order of events following an optimization scheme. The combination of the hybrid model with the multivariate copula shows to perform as a satisfactory extension of the AR model for multiple sites simulations.

IAHS (Hydrology)

HW03b - HW03 Multivariate Analysis in Hydrological Modelling

IUGG-3431

Dimension reduction techniques in multivariate hydroclimatic forecasting models

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The process of developing statistical hydroclimatic forecasting models is often faced with the problem of large numbers of potential input variables such as spatially distributed ocean-atmospheric state variables. In multivariate regression-type models, high dimensionality of predictors poses the risk of calibration overfitting and subsequent poor validation. This study overviews several different methodologies of dimensionality reduction in forecasting models.

Firstly, the LASSO (Least Absolute Shrinkage and Selection Operator) is mentioned as one of a family of regression-type prediction models which eliminate uninformative predictor variables. The reduced models tend to have good validation performance from the resulting simpler predictive expressions. The LASSO is a linear model, however, and may fail to detect potentially useful non-linear relations between response and predictor variables.

Secondly, a brief evaluation of selected data mining methods is considered. Data mining as a general exploratory tool has some advantage in that there is no reliance on assumed continuous functional relationships between causes and effects as with multiple regression models.

A preliminary application of the respective methods seeks to identify variables associated with river inflows to hydropower lakes in the Waitaki catchment, New Zealand. The aim here is to isolate predictor variables for season- and month-ahead inflow forecasting, extracting predictors from seasonal and monthly-averaged gridded Pacific variables.

IAHS (Hydrology)

HW03p - HW03 Multivariate Analysis in Hydrological Modelling

HW03p-102

Simulating hydrological processes of a cold catchment in north China with a Water Balance Model

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Conceptual hydrological models are believed useful in assessing environmental change impact on hydrology. Hydrological characteristics of the Xilin River catchment, a dry cold catchment located in the Inner Mongolia of China, were analyzed with data series over 1963—2010. A water balance model was applied to the catchment for monthly discharge simulation. Results indicate that Runoff yield in the Xilin River catchment is dominated by both snowmelt and heavy rainfall storm. Recorded runoff at Xilinhaote hydrometric station and areal average precipitation of the catchment over 1963—2008 both presented decline trends. The water balance model performed well for simulating monthly discharge rates. Nash–Sutcliffe efficiency criterion (NSEs) in the calibration and verification periods were 83.6% and 72.7%, respectively, while he relative errors of volumetric fit (REs) in the both periods were less than 5%, which illustrates the water balance model could be applied to cold catchments for hydrological modeling and climate change impact assessment.

IAHS (Hydrology)

HW03p - HW03 Multivariate Analysis in Hydrological Modelling

HW03p-103

A multivariate smoothed bootstrap approach for specification and simulation of climate change scenarios with spatially correlated hydrological variables.

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Hydrological variables are typically correlated in space. Any data-based specification of climate change should therefore preserve some spatial correlation structure. One approach is presented here, for simulating correlated data in climate change scenarios.

Suppose K recorded time series of length N are available, with spatial correlation between the series but negligible serial correlation. With no climate change, a smoothed bootstrap data simulation views the data of each year as a vector of K correlated random variables generated from an independent K-variate normal distribution, with the respective component means corresponding to the data values of that year. The matrix of correlations and standard deviations needs to be specified by the user. Data is simulated by first randomly selecting any past year with constant probability 1/N. From the K-variate normal distribution for that year, a random vector of K variables is generated. This two-step process is then repeated as required.

A climate change scenario is now specified as some years in the record being more likely than others. That is, some years now have selection probability exceeding 1/N while other years have less. The simulations then proceed as above. The simulation mechanics are straightforward, requiring only generation of random variables from K-variate normal distributions.

There is no preservation of moment properties from the original data as climate change makes this unknown in any case, although the general correlation structure is preserved. The method allows arbitrarily large K, which would give rise to difficulties when simulating multivariate correlated data from copulas.

IAHS (Hydrology)

HW03p - HW03 Multivariate Analysis in Hydrological Modelling

HW03p-104

Simulating hydrological processes of a cold catchment in north China with a water balance model

G. Wang[1], *C. Liu*[1]
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Conceptual hydrological models are believed useful in assessing environmental change impact on hydrology. Hydrological characteristics of the Xilin River catchment, a dry cold catchment located in the Inner Mongolia of China, were analyzed with data series over 1963—2010. A water balance model was applied to the catchment for monthly discharge simulation. Results indicate that Runoff yield in the Xilin River catchment is dominated by both snowmelt and heavy rainfall storm. Recorded runoff at Xilinhaote hydrometric station and areal average precipitation of the catchment over 1963—2008 both presented decline trends. The water balance model performed well for simulating monthly discharge rates. Nash–Sutcliffe efficiency criterion (NSEs) in the calibration and verification periods were 83.6% and 72.7%, respectively, while he relative errors of volumetric fit (REs) in the both periods were less than 5%, which illustrates the water balance model could be applied to cold catchments for hydrological modeling and climate change impact assessment.

IAHS (Hydrology)

HW04a - HW04 Hydrological Change in Statistical Perspective

IUGG-0314

Statistical exploration of changes in rainfall in parts of Northern Nigeria

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This study examined the existence of changes in the statistical properties of rainfall at 5 locations within the water stressed sudano-sahelian region of northern Nigeria. Distribution-free statistical testing approach was used to test for changes in the rainfall time series of the study locations. Test for trend detection between 1960 and 2010 showed that except for Kaduna which exhibited a trend ($z = -2.19$ for Kendall Rank Correlation Test; $p = 0.031$ for Mann-Kendall Test) no trend was exhibited at the other locations. Pettitt test for change showed that Kaduna is the only location that exhibited a step change which occurred in 1997. Test for randomness revealed that annual rainfall at all the locations were random in their occurrence which further suggest that rainfall within the selected locations have been relatively stationary and future statistical properties of rainfall can be inferred / modelled from the past rainfall characteristics. Conclusively, rainfall characteristics (frequency, amount, duration and intensity) are the needed data to support non-stationary approach to implying level of uncertainty of rainfall in Northern Nigeria.

IAHS (Hydrology)

HW04a - HW04 Hydrological Change in Statistical Perspective

IUGG-0667

Predicting runoff under changing climatic conditions: using Pareto approaches to identify robust models

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Hydrologic models are useful tools in planning for future variability in climate. They allow us to project the impact that changes in climatic variables, such as rainfall, might have on water availability for human consumption or environmental needs. However, it appears that the current generation of hydrologic models are not sufficient for this task. Simulations of real-life case studies such as the recent Millennium Drought in South East Australia indicate that the models tend to underestimate the sensitivity of runoff to a given change in rainfall. While some authors have assumed that the models themselves are to blame, this research examines more closely whether robust models can be found using non-standard techniques. We use an approach based on the concept of Pareto dominance to explore tradeoffs between model performance in different climatic conditions. Compared to standard calibration techniques, this approach allows a more thorough exploration of the capabilities of hydrologic models under a changing climate. Preliminary results, suggesting that there may be scope for improvement of traditional calibration techniques, will be presented and discussed.

IAHS (Hydrology)

HW04a - HW04 Hydrological Change in Statistical Perspective

IUGG-2279

Should the design flood change in a global warming scenario? Design intensities, spatio-temporal patterns and antecedent conditions revisited

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There is sufficient empirical evidence to show that short-duration rainfall intensities are increasing with higher temperatures as has been long expected by scientists the world over. But are these the only changes of importance in design flood estimation likely to occur with higher temperatures? We show here using a rich observational precipitation dataset that along with increases in the extreme short-duration rainfall, the very structure of the extreme storm is modifying in both space and time. We show that storm temporal patterns are changing with a consistent shift towards non-uniformity observed at all locations analysed. We show that the storm spatial pattern is changing with a general peaking of the storm structure leading to a shorter radius the storm stretches over. These changes directly impact the estimation of the design storm for use in ascertaining the design floods in a warmer climate. We also show that in addition to direct changes in the design storm, the future holds markedly different pre-storm or antecedent wetness conditions, that will require consideration in any design flood estimation exercise. A strategy for how such changes can be modelled and new design flood estimation guidelines formulated is proposed.

IAHS (Hydrology)

HW04a - HW04 Hydrological Change in Statistical Perspective

IUGG-3292

Optimal adaptation level in current and future climate

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More intense and frequent rainfalls have increased the number of urban flooding events in recent years, prompting adaptation efforts. Economic optimisation is considered an efficient tool to decide on the design level for adaptation. The costs associated with a flooding event to the T-year level and the annual capital costs of adapting to the T-year level are described with log-linear relations. The total flooding costs are developed as the expected annual damage of flooding events above the T-year level and the corresponding annual adaptation capital costs. The value of T that corresponds to the minimum of the sum of the two costs will then be the optimal adaptation level.

The change in climate, however, is expected to continue in the next century, which calls for expansion of the above model. The change can be expressed in terms of a climate factor, which is assumed to increase linearly in time. Also, the log-linear cost relation is expected to increase linearly with the 100-year climate factor. It is further anticipated that the adaptation is carried out in year t*. Thus, a search for the minimum costs should be sought by varying both T and t*. A comparison of the different options should be done in terms of the net present value of all incurred costs. The optimal set of (t*, T) providing minimum total net present value can then be identified and its sensitivity to the chosen model parameters analysed.

IAHS (Hydrology)

HW04a - HW04 Hydrological Change in Statistical Perspective

IUGG-3888

Assessing impacts of environmental change on hydrological cycle in terms of three-sources and uncertainty evaluation in catchment scale

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It is one of hot and difficult topics in water science, and one of urgent issues of mitigation and adaptation related decision and actions that how separate and define impacts on hydrological processes by climate change and human activity. This study made a survey of research progress on assessment methods for climate change and human activity affecting hydrology. It presented methodology of identifying climate change and human activity impacts on hydrological elements in separated manner. Changes in hydrological processes brought by environmental reasons should be attributed into three sources: climate natural variability, human-induced climate change and human activity, and a framework was presented. Due to the complex uncertainties in the hydrological processes under environmental change, uncertainty factors in hydrological processes under changing environment were explored, thus common quantitative and qualitative uncertainty evaluation approaches were summarized. Moreover, the Info-Gap theory was addressed to solve the problem of qualitative uncertainty (Knightian uncertainty) estimation. Finally, to enhance the ability of mitigation and adaptation for environmental change, it pointed that in future studies environmental change impacts should be strengthened in terms of climate natural process, human-induced climate change and human activity. Uncertainty analysis should be an original part of environmental modeling rather than additional or dispensable component. In the impact assessing uncertainty estimation should be fully stressed. Further uncertainty information application and catchment-scale risk management should be facilitated in catchment-scale management decision-making.

IAHS (Hydrology)

HW04a - HW04 Hydrological Change in Statistical Perspective

IUGG-5544

A characteristic of estimated downward short wave radiation by general circulation model in Japan

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A downward short wave radiation is a key driving force for land surface hydrologic cycle. It was reported that observed downward short wave radiation shows increasing trend for the last several decade. Therefore, it is important for a research on climate change impact to reproduce both annual and/or monthly value and increasing trend for downward short wave radiation by general circulation models. In this study, a downward short wave radiation output from MRI-AGCM3.2S is evaluated on a whole of Japan. There are 70 observing stations where downward short wave radiation is observed in Japan. In this research, 30 stations are selected because there are more than 5 days missing period per month in the rest of stations. By the T-test with 5% significant level, annual short wave radiation by observation shows increasing trend with statistical significance at 21 stations. On the other hand, that by GCM output shows slightly decreasing trend with statistical significance at some points. Moreover, a shortwave radiation by MRI-AGCM3.2S is 2.25 MJ m-2 larger than observation on average. Thus, the output of short wave radiation by MRI-AGCM3.2S doesn't have no increasing trend and have a bias which must be corrected. In addition, rainy days and a short wave radiation on only sunny days were also evaluated. A number of rainy days is not so large difference between MRI-AGCM3.2S and observation. However, a short wave radiation on sunny days by MRI-AGCM3.2S is 4.33 MJ m-2 larger than observation. It is assumed that a process of absorption or reflection of short wave radiation in the atmosphere might be not adequate.

IAHS (Hydrology)

HW04b - HW04 Hydrological Change in Statistical Perspective

IUGG-0992

Analysis on the joint distribution of low flows based on the Kendall distribution function under a changing environment

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The risk analysis approach based on Clayton copula and Kendall distribution function is used to analyze the joint distribution of low flows between Xijiang River in Makou and Beijiang River in Sanshui, which are connected through the Sixianjiao waterway in Guangdong, China. Using samples with seven consecutive average minimum flows of Makou gauge and the corresponding low flows of Sanshui gauge during the hydrological years 1959–2010, the “OR,” “AND,” and secondary return period of the joint distributions of low flows between 1959 and 1985 (referred to as Sample A) and between 1986 and 2010 (referred to as Sample B) of the two rivers were calculated using the Clayton copula and Kendall distribution function, respectively. The main conclusions of this study can be summarized as follows: (1) The design quantiles of the low flows of Makou in Sample B are less than the design quantiles for the corresponding return periods of Sample A, while the design quantiles of low flows significantly increased in Sanshui. (2) The encounter probabilities of low flows between Xijiang River and Beijiang River were significantly reduced, with the same frequencies of Samples A and B since 1985. (3) The cumulative frequencies calculated using the secondary return period represent the risk possibilities between Xijiang River and Beijiang River low flows with specific design frequencies. (4) The $Q_{7d,T = 20a}$, $Q_{7d,T = 10a}$, and $Q_{7d,T = 2a}$ of the most likely design quantiles calculated using the secondary return period for the Makou and Sanshui gauges may be more suitably used as the design reference for water supply planning of the West River Delta during the low water season.

IAHS (Hydrology)

HW04b - HW04 Hydrological Change in Statistical Perspective

IUGG-1770

Comparison of different approaches to trend analysis of flow and precipitation in Polish and Norwegian conditions

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This work investigates methods of trend detection in hydrological variables using novel and traditional tools addressing the problem of seasonality and interannual variability. We analyse streamflow time series from several gauging stations located in Poland and Norway for a period 1951–2010. The stream-flow and precipitation time series were analysed using four methods: linear regression, modified Mann-Kendall test taking into account autocorrelation, Dynamic Harmonic Regression (/www.lancs.ac.uk/captain) and wavelet analysis. The first two methods are used in standard statistical tests for trend analysis. The DHR method is based on the unobserved component approach, and combines the data analysis in frequency domain with the time domain. The method allows the estimation of low frequency variation (trend) and other seasonal/cyclic frequency components. Together with the estimates of components, the uncertainty of the estimates is also calculated. In addition we apply nonparametric method of trend detection using wavelets. The outcomes from the DHR and wavelet analysis are compared with the trends calculated using traditional approaches. The results indicate that predicted changes are consistent in sign of the trend but differ in intensity of the estimated changes. The results of DHR and wavelet analysis show that hydrological extremes are characterized by oscillatory behaviour at different time scales. Apart from raw data, we apply the analysis to smoothed over several years observations within a moving time-window. Comparison of changes of flow at gauging stations with changes in climate data (precipitation and air temperature) allows to separate changes caused by climatological forcing from those caused by land use and water management.

IAHS (Hydrology)

HW04b - HW04 Hydrological Change in Statistical Perspective

IUGG-3626

The role of time-dependence in return period estimation

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The return period is the most popular concept in statistical hydrology also used in many other disciplines (such as seismology, oceanography, geology, etc.), with an emphasis on engineering practice. The popularity of this concept, which gives an indication on critical event rareness, is because it is very simple to compute and easy to understand. The strength of the return period concept relies on some basic assumptions that should be satisfied for a correct application of this statistical index.The hypotheses of independence and stationarity are commonly assumed as necessary conditions to proceed with conventional frequency analysis in hydrology. The main issue explored in this work is the role of the independence condition. We demonstrate that, under the stationarity hypothesis, the independence condition is not necessary for applying the classic equation of return period (i.e. the inverse of exceedance probability). At the same time, we show that time-dependence influences the shape of a distribution function of which the return period represents only the first order moment. This implies that, in the context of time-dependent processes, the return period might not represent an exhaustive measure of the probability of failure, and that its uncritical application could lead to misleading results in both design and risk assessment problems.

IAHS (Hydrology)

HW04b - HW04 Hydrological Change in Statistical Perspective

IUGG-4489

A non-stationary Bayesian clustering framework for Identifying regional hydro-climate trends from large scale data

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Trends and climate effects in extreme precipitation and flood can have high variability locally, thus preventing robust detection. Spatially incorporating information among different stations can better identify these effects. Hierarchical Bayesian models are useful for modeling hydro-climatic trends and teleconnections with a formal approach to characterizing and reducing estimation uncertainties. However, their response in large areas, such as a country or a continent, can be spatially heterogeneous, thus the choice of the spatial regression model in large space is not intuitively obvious. We develop a new non-stationary hierarchical Bayesian clustering model to seek the potential homogeneity of response in the data sets, through a multi-component mixture model. This model is applied to the annual maximum daily stream flow data over Germany to study the potential trends. The results show that the clustering model can identify better the trends compared with the traditional at-site analysis. Significant large positive trends are detected in the gauges of the Upper Danube River Basin and River Rhine Basin in the southern and western of the country.

IAHS (Hydrology)

HW04p - HW04 Hydrological Change in Statistical Perspective

HW04p-105

Hydrological drought in Transcarpathia

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The study considered the drought conditions and related minimal rivers runoff, which were observed during period of 1950-2011 for Transcarpathian region in Ukraine. For analysis was used the drought index SPEI (Standardized Precipitation Evapotranspiration Index), which is based on monthly data of precipitation and potential evapotranspiration. The SPEI calculated for different time scales and the long time periods (from 12 months) are associated with the parameters of streamflow and water storages, therefore it used to monitoring of hydrological droughts.

Transcarpathian region is the small territory of west part in Ukraine, which belong to the Carpathian foothills and characterized by distinctive climatic conditions. The main rivers of Transcarpathia are mountain, therefore runoff of different rivers varies greatly depending on precipitation sums.

Time series of the SPEI on scales 12, 18 and 24 months shows that for all points were observed from 12 to 16 episodes of drought with the duration more then one year. The most important dry episodes occurred in region from autumn 1961 to summer 1965, from summer 1971 to summer 1974, from spring 2000 to spring 2005. In this periods hydrological drought reaches up to strong and extreme criteria in some points and years. From summer 1983 to summer 1998 was observed the continuous consecutive period with predominantly moderate dry conditions, when intensity of drought only one station (Golatin) and one time (spring 1997) reach up to extreme value.

The main wet periods occurred from autumn 1974 to summer 1983 and from summer 1997 to summer 2002. In first decade of current century observed the trend to strong increasing the intensity of wet period in mountain station Yasinya and smaller trend west along the Carpathian ridge.

IAHS (Hydrology)

HW04p - HW04 Hydrological Change in Statistical Perspective

HW04p-106

Probability Distribution of Long-term Annual Rainfall Erosivities in Korea

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Frequency Analysis is the scientific method to estimate the frequency of occurrence of hydrologic data stochastically. This study is focused on stochastic distribution of long-term annual rainfall erosivities in Korea for 30 years. FARD (Frequency Analysis of Rainfall Data) 2013 program included 16 types stochastic models were used to analyze the frequency of annual rainfall erosivities for 10 stations. Rainfall erosivities for individual storms were calculated and combined for one year. Goodness-of-fit tests such as χ^2, Kolmogorov-Smirnov(KS), Cramer Von Mises(CVM), and Probability Plot Correlation Coefficient tests were conducted to examine the appropriate stochastic distribution. The result showed that Gumbel distribution is the best proper probability distribution for annual rainfall erosivities in Korea.

IAHS (Hydrology)

HW04p - HW04 Hydrological Change in Statistical Perspective

HW04p-107

Hydrologic risk analysis according to extreme drought applying a climate change scenario

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Drought is one of the biggest climatic disasters along with flood, but due to its characteristics, it is hard to see how it starts or ends clearly. Its damage appears extensively unlike that of flood that is temporary and local, even though various forms of drought indexes have been suggested; thus, it is fairly difficult to perform quantitative analysis and investigation on it. Therefore, this study analyzed the regional characteristics of extreme drought events in each of the mid-watersheds in Korea using the Standardized Precipitation Index (SPI), one of the typical drought indexes. We also suggested a methodology of quantitative analysis on hydrometeorological drought risk in each of the watersheds in consideration of the probability of exceedance of entire observed streamflow data. According to the analysis results, there are distinct regional characteristics, and especially spring droughts are expected to be more serious nationwide. In addition, drought risk applying the climate change scenario is getting reduced significantly in the entire area of the Korean Peninsula. In some of the watersheds including Nakdong River's, however, the climate change scenario of RCP8.5 is being applied, but they will be vulnerable to extreme droughts. The findings of this study are expected to be utilized as foundational material to forecast droughts in Korea according to the climate change and also build up realistic coping strategies for extreme droughts.

IAHS (Hydrology)

HW04p - HW04 Hydrological Change in Statistical Perspective

HW04p-108

Design discharges in Slovenian rivers and climate change.

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Climate change or climate variability is an important topic in many geophysical studies including hydrology. The data-based approach was selected to investigate the impact of climate variability on the flood risk in Slovenia, Central Europe. More than 3,000 years of discharge data from 55 Slovenian gauging stations with catchment areas between 10 and 10,000 km^2 were used. First, annual maximum series method (AM) was used to define samples, then data sets were divided into 30–years period based on the 10 years mowing window. For each data–set, which contained 30 AM events, the flood frequency analyses (FFA) were performed. The distribution parameters were estimated with the method of L-moments. Changes in the design discharge values with 100 years return period were observed between two periods: 1961–1990 and 1981–2010. These changes were than compared with the Mann-Kendall test results.
Results show that no generalization is possible about the positive or negative change in the design discharge values in Slovenia. Similar conclusions can be made using the Mann-Kendall test results. Furthermore, for only 15 % of gauging stations the trend was positive and statistically significant with chosen significance level 0.05. Likewise, also the Mann-Kendall trend results were generally not consistent with the changes in the design discharge values with 100 years return period. The results indicate that variability in discharge series in Slovenia is present, however no uniform (positive or negative) trend/change can be observed in the analysed data–sets.

IAHS (Hydrology)

HW04p - HW04 Hydrological Change in Statistical Perspective

HW04p-109

Quantification of the effect of forest harvesting versus climate on streamflow cycles and trends in an evergreen broadleaf catchment

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A new method known as Unobserved Component - Dynamic Harmonic Regression (UC-DHR) was applied to a 39-yr record of rainfall and streamflow for three sub-catchments of the Sarukawa Experimental Watershed in southwestern Japan. Some 25% of the timber was harvested from one of the sub-catchments in May-July 1982 and the objective was to quantify the magnitude of this effect relative to the effects of climate cycles (e.g. Southern Oscillation Index). The observed effects of inter-annual climate cycles (i.e., 0.89-1.36 mm/day) were seen to be comparable (i.e., 0.70-1.17 mm/day) to the effects of harvesting 25% of the standing timber. This result underlines the importance of always quantifying the effect of climate on streamflow response when harvesting impacts are studied.

IAHS (Hydrology)

HW04p - HW04 Hydrological Change in Statistical Perspective

HW04p-110

Investigating the hydrological seasonality of the upper Zhang River catchment in a changing climate

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To gain insight into hydrological regimes of the upper reaches of the Zhang River, a first level tributary of the Hai River, China, monthly runoff data series recorded at the five hydrometric stations over the period of 1960-2010 were employed to investigate changes in runoff seasonality. Intra-annual coefficient of variation and concentration degree of runoff, occurrence period of peak discharge, and seasonal patterns were analyzed. Results show that (1) Intra-annual coefficient of variation are commonly large than 1; Concentration degrees tend to be greater than 0.6. (2) Peak discharge mainly occurred in the period from July to October, particularly in August. (3) Seasonal pattern of runoff hydrograph could be classified into mono-peak, bi-peak, multi-peak and irregular patterns, with mono-peak pattern accounting for a big percentage. (4) Concentration degrees are highly correlated to peak discharges and hydrograph patterns, i.e. a higher concentration degree suggests a higher peak discharge normally corresponding to a mono-peak hydrograph pattern. (5) More intensive autumn rainfall has a certain influence on the hydrograph pattern of next year which tend to shift flood season early.

IAHS (Hydrology)

HW05a - HW05 Societal Relevance of Groundwater: Ever Increasing Demands on a Limited Resource

IUGG-1209

Theoretical perspectives on flexible and adaptive institutions for effective peri-urban groundwater management

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Rapid urbanization within the Ganges delta has put increasing pressure on groundwater resources, particularly within the peri-urban areas of Khulna, Bangladesh and Kolkata, India. The challenge in groundwater management stems from fragmented institutions with poor capacity to address the needs of this transforming socio-economic landscape. The result is seasonal scarcity, high salinity, arsenic contamination and increasing competition between users producing conflicts at the local level. This research adopts an institutional lens to account for the important role of actor interactions and decision-making on groundwater resources within this context. A review of literature on flexible and adaptive institutions is presented, resulting in the identification of key determinants for the ability of existing institutions to ensure sustainable groundwater management in peri-urban areas. A specific focus is on how this flexibility in institutions can help local actors deal with the uncertainty in managing groundwater resources. Here, uncertainty is regarded as both resulting from a limited knowledge base about the groundwater resource, as well as from socio-economic changes as a result of urbanization. This then, helps to better position the contribution of further groundwater research into a broader set of conditions for sustainable local groundwater management. Findings are illustrated for peri-urban communities within Khulna using conceptual frameworks from literature suited for the analysis of institutions within this context.

IAHS (Hydrology)

HW05a - HW05 Societal Relevance of Groundwater: Ever Increasing Demands on a Limited Resource

IUGG-1432

Transboundary aquifer mapping and management in Africa – an on-going process

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Recent attention to transboundary aquifers (TBAs) in Africa reflects the growing importance of these resources for development in the continent. However, relatively little research on these aquifers and their best management strategies have been published. This presentation recapitulates progress on mapping and management frameworks for TBAs in Africa since the beginning of this century. The 2013 map published by IWMI included 80 shared aquifers and aquifer systems superimposed on 63 international river basins and showed that TBAs represent approximately 42% of the continental area and 30% of the population. This map has been used for the world map on transboundary aquifers published by IGRAC in 2014 which identified 83 TBA systems in Africa. A brief review of current international law, specific bi- or multilateral treaties, and TBA management practice in Africa reveals little documented international conflicts over TBAs. The existing or emerging international river and lake basin organisations offer a harmonised institutional base for TBA management, particularly where TBAs intersect with international river basins, while alternative or supportive models involving the regional development communities as well as national and local management bodies are also required. Finally, a case study of the Ramotswa aquifer, shared by Botswana and South Africa, is presented to illustrate and emphasize the need to understand the bio-physical and socio-economic environment of areas overlying and dependent on TBAs in order to improve their management.

IAHS (Hydrology)

HW05a - HW05 Societal Relevance of Groundwater: Ever Increasing Demands on a Limited Resource

IUGG-1598

Global Food Production: the Contribution of Groundwater and Depleting Aquifers

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Groundwater provides significant input to irrigation and food production around the world. Previous studies have estimated that 10 to 40% of global food production is derived from groundwater, indicating high uncertainty in these numbers. However, intensive use and depletion of groundwater are increasingly threatening food security as well as environmental sustainability. This research estimates for the first time the contribution that depleting groundwater resources make to global food production. By integrating distributed data from three different global datasets on: global food production (42 crops), groundwater abstraction and depletion, and area equipped for groundwater irrigation, it is estimated that 44% of the global irrigated crop production is derived from groundwater irrigation, out of which 33% is from unsustainable abstraction. Out of total global crop production (including rainfed), about 4%, and out of irrigated crop production, about 14% is based on depleted groundwater. South and East Asia are responsible for the largest share of food production from depleting groundwater. While significant regional variability is apparent, the crop groups that dominate in the depletion of aquifers are cereals and sugar. The depleting crop production occurs particularly in the larger contiguous aquifers in the semi-arid parts of the world, like the central and South-western USA, North China plains, the Middle East, Northern Africa, the Indus-Ganges Basin, Central Asia and some regions in Southern India. Such estimates imply the critical importance of analyzing and developing congruent policies at multiple levels that account for the nexus between groundwater and food security.

IAHS (Hydrology)

HW05a - HW05 Societal Relevance of Groundwater: Ever Increasing Demands on a Limited Resource

IUGG-2703

Impacts of coal mining and coal seam gas extraction on groundwater in Australia

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Being the driest inhabited continent, groundwater in Australia is frequently utilised for irrigation, stock watering, industrial uses, and human consumption. In places, this has led to over development of groundwater resources. Development of coal resources through coal mining and coal seam gas extraction can place additional stresses on groundwater resources by dewatering coal seams and using extracted water for industrial uses. In Australia an Independent Expert Scientific Committee has been established to provide scientific advice to federal and state government regulators on the impact that coal seam gas and large coal mines may have on water resources. This advice is provided to enable decisions to be informed by the best available science about the potential water-related impacts associated with these developments. To support this advice a three-year programme of research termed 'bioregional assessments' has been implemented to investigate these potential impacts. A bioregional assessment is defined as a scientific analysis of the ecology, hydrology, geology and hydrogeology of a bioregion with explicit assessment of the potential direct, indirect and cumulative impacts of coal seam gas and large coal mining development on water resources. These bioregional assessments are currently being carried out across large portions of eastern Australia underlain by coal reserves. Further details of the program can be found at http://www.bioregionalassessments.gov.au. Here, the methodology for undertaking bioregional assessments will be described and the application of this methodology to six priority bioregions in eastern Australia will be detailed. Results of the programme to date will be provided with a focus on the results of numerical groundwater modelling.

IAHS (Hydrology)

HW05a - HW05 Societal Relevance of Groundwater: Ever Increasing Demands on a Limited Resource

IUGG-5712

Protection of the groundwater tappings from qualitative point of view in Romania – legislative issues and principles

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The groundwaters represent an important source of water supply for lots of human communities both in the urban environment and in the rural one. At European level, water is given a great importance, the Water Framework Directive no. 60/2000/EC and Directive for the groundwater protection against pollution and deterioration no.118/2006/EC, establishing clear objectives that all waters, including groundwater, must achieve 'good status' by 2015 so as to ensure their sustainable use. In this context the sanitary protection of the grounwater tapping is very important.

In Romania the legal basis for the concept and size of protection areas of groundwater tapping is given by the 'Water Law' (Law no. 107/1996), ' The Law regarding the amendment and completion of Water Law no.107/1996” (Law no.310/2004) “The Decision for the approval of special rules type and the size of the sanitary and hydrogeological areas (GD no. 930/2005) and Order no.1278/2011 of the Minister of Environment and Forests for approval of “Instructions on designation of sanitary protection areas and hydrogeological protection perimeter”

GD no. 930/2005 sets out that in order to protect the groundwater tapping from qualitative point of view there are established in the field three areas of protection with various degrees of risk from pollutants, namely sanitary protection area with severe regime, the sanitary protection regime restriction and hydrogeological protection perimeter.

The paper presents some legal issues and principles for determining the protection areas of the groundwater tapping in Romania.

IAHS (Hydrology)

HW05b - HW05 Societal Relevance of Groundwater: Ever Increasing Demands on a Limited Resource

IUGG-0011

Performance evaluation of percolation tanks in groundwater recharge using hydrogeochemical tracers and environmental isotopes

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India’s rural communities have followed a policy of conserving rainwater for subsequent use through innumerable tanks, managed by the local people through community organizations. Since tanks are neglected and remain devoid of water for most part of the year, recharge is a problem. The Sulur watershed is a part of the Noyyal River basin and is surrounded by mountains which has dry climate that affects the availability of water. Since the surface water source is limited, they depend mainly on the ground water sources. This has made the situation unsustainable which needs a detailed study on rechargeable conditions of the Sulur watershed. Two existing tanks (big and small tanks) in sulur village are maintained effectively to recharge groundwater sources. In this paper, a detailed study using environmental isotopes to assess the dynamics of the water availability has been reported. Also the hydrochemical analysis was made to assess the groundwater quality. 34 samples from in and around the Sulur tanks were analysed for water quality parameters using conventional methods. Hydrochemical analysis was carried out and the spatial distribution of different water quality parameters and groundwater level was mapped using ArcGIS. The samples were analysed for environmental isotopes of composition (deuterium (hydrogen-2) and oxygen-18) using Mass Spectrometer The interaction between the two percolation tanks and groundwater resources towards sustainable development of the study area was analysed. From the isotopic footprints of O-18, Deuterium, hydrochemical parameters and the spatial distribution mapping of groundwater quality and quantity data, , it was observed that the groundwater recharge is mainly due to contribution from two existing percolation tanks.

IAHS (Hydrology)

HW05b - HW05 Societal Relevance of Groundwater: Ever Increasing Demands on a Limited Resource

IUGG-0298

Geogenic sources for fluoride rich groundwater and induced recharge through dug well for mitigation

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The objectives of this study are to investigate the geogenic sources for fluoride in groundwater and the use dug well recharge system for mitigation in the Vaniyar river basin, Dharmapuri district, Tamil Nadu, India. People living in this region are affected by fluorosis due the use for groundwater for drinking purpose. Groundwater samples were collected once in two months wells between 2011 and 2014. The fluoride concentration in the groundwater of this region ranges from 0.15 to 6.14 mg/l. Out of 641 samples analysed, the fluoride concentration of 426 samples exceeded the maximum permissible limit of 1.5 mg/l suggested by the Bureau of Indian Standards for drinking water. The use of the fluoride-rich groundwater for drinking has caused dental and skeletal fluorosis in many people residing in this area. The major sources of fluoride in the groundwater of this area are fluoride-bearing minerals, i.e., biotite and hornblende, in rocks present in the study region. The fluoride leaches from these minerals into the groundwater, causing the high fluoride concentration. Study of temporal variation of fluoride concentration indicates that it decreases when the groundwater level increases at locations where the depth to the water table is shallow. One such location having groundwater with high fluoride concentration was chosen and the dug well recharge system was implemented. This has lead to decrease in concentration from 3.1 mg/l to 1.4 mg/l. This study confirms that regions with shallow water table are ideal for induced recharge to reduce fluoride concentration in groundwater.

IAHS (Hydrology)

HW05b - HW05 Societal Relevance of Groundwater: Ever Increasing Demands on a Limited Resource

IUGG-1431

Mapping irrigation potential from renewable groundwater in Africa – a quantitative approach

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Groundwater provides an important buffer to climate variability in Africa. Yet groundwater irrigation contributes only approximately 1% of the cultivated land as compared to 14 % in Asia. As opposed to previous country-based estimates, this paper derives a continent-wide, distributed (0.5 degree resolution) map of groundwater irrigation potential, indicated in terms of fractions of cropland potentially irrigable with renewable groundwater. The method builds on an annual groundwater balance approach using 41 years of model data, allocating to groundwater irrigation the groundwater recharge in excess after satisfying other current human needs and environmental requirements, while disregarding any socio-economic and physical constraints in access to the resource. Due to high uncertainty of groundwater environmental needs, three scenarios, leaving 30, 50 and 70% of recharge for the environment, were implemented in a conservative estimate of the potential. In addition, current dominating crops and cropping rotations and associated irrigation requirements in a zonal approach were applied. Results show an inhomogeneously distributed gross groundwater irrigation potential across the continent, even within individual countries, reflecting recharge patterns and extent of cropland. Results further show that average annual groundwater available for irrigation ranges from 708 to 1669 km^3 depending on scenario. The total area of cropland irrigable with groundwater ranges from 44.6 to 105.3 million hectares, corresponding to 20.5% to 48.5% of the cropland over the continent. Accounting for existing groundwater irrigation, residual irrigation potential remains high and relevant for poverty alleviation in the Sahel and Eastern Africa region.

IAHS (Hydrology)

HW05b - HW05 Societal Relevance of Groundwater: Ever Increasing Demands on a Limited Resource

IUGG-1470

Estimating groundwater availability at catchment scale using streamflow recession and instream flow requirements of rivers in South Africa

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Groundwater is an important resource for multiple uses in South Africa. Setting limits to its sustainable abstraction while assuring basic human needs is required. Due to prevalent data scarcity related to estimation of groundwater availability, the present work presents a novel method for determining allocatable groundwater at the catchment scale through information on streamflows. Using established methodologies for assessing baseflows, recession flows, and instream ecological flow requirements, the study develops a combined stepwise methodology to determine annual groundwater storage volumes at the catchment scale using linear reservoir theory.

The approach was trialled for twenty-one perennial and relatively undisturbed quaternary catchments, with longterm and good streamflow records. Using the Desktop Reserve Model, maintenance low instream flow requirements necessary to meet present ecological state of the streams were determined and, baseflows in excess of these flows were converted into allocatable groundwater storages on an annual basis. Results show that groundwater development potential exists in nineteen of the catchments, with upper limits to allocatable groundwater volumes ranging from 0.01 to 1.58 MCM/yr over the catchments. With a secured availability of these volumes 75% of the years, variability between years is assumed to be manageable. A significant (R^2 = 0.86) correlation between baseflow index and the drainage time scale for the catchments underscored the physical basis of the methodology and also enables the reduction of the procedure by one step, omitting recession flow analysis. The method serves as an important complementary tool for the assessment of the groundwater part of the Reserve and the Groundwater Resource Directed Measures.

IAHS (Hydrology)

HW05b - HW05 Societal Relevance of Groundwater: Ever Increasing Demands on a Limited Resource

IUGG-5587

Cross comparison of groundwater quality in coastal parts of Cauvery river basin, India and Mhlathuze river basin, South Africa

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Surface water resources are limited to meet the water demand in countries like India and South Africa. Dependence on groundwater in day today life is increasing in these countries. Assessment of groundwater quality is important to manage the available resources properly. The present study was carried out in the coastal parts of Cauvery, India and Mhlathuze river basins, South Africa with the objective of assessing the groundwater quality and to understand the possible impact on it due to the projected climate changes. Groundwater samples from representative wells in the Cauvery and Mhlathuze river basins were collected and analysed. Based on the inferences made from the major, minor and trace elements, it is observed that the groundwater quality is poor near the coast. The effect of projected rainfall due to climate changes on the groundwater resources and quality was also assessed. Phosphate, ammonium and nitrate concentrations are generally higher in Cauvery basin due to agricultural and aquaculture activities. The concentration of major ions like calcium, magnesium, sodium and potassium were high in inlands due to rock-water interaction and concentration of chloride, bromide and lithium were high in the coastal regions due to seawater intrusion in both these study regions. The groundwater quality in the Richards bay region of South Africa is affected by the mining and industrial activities.

IAHS (Hydrology)

HW05p - HW05 Societal Relevance of Groundwater: Ever Increasing Demands on a Limited Resource

HW05p-111

How do sugarcane irrigation system affects ground water quality (HW05)

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Malawi is generally considered relatively rich in water resources which are stored in form of lakes, rivers and aquifers. There are two main aquifers in Malawi the Precambrian weathered basement complex and quaternary alluvial aquifers of the lower shire valley area which is high yielding aquifers which are mostly used by sugarcane growers for irrigation.

The Geology of the lower shire valley area is alkaline geology due to source of sediments which are from alkaline magmatic rocks that happens due to intrusion that cut across sedimentary rocks. Naturally the water quality is high in salinity due to hydro-geochemistry of the area but sugarcane irrigation system which covers 80.6 % of water use in the area has increased the salinity of the ground water. And 11.6% is surface irrigation which is not good for water quality since its arid climate area the average temperature is 35 degrees Celsius and when these water are in one place for long time they evaporate and form saline ponds which infiltrate into soils and increase water salinity and since the aquifer is alluvial these saline solution infiltrate direct to ground water. As years are going the salinity of the area is increasing exponentially due to surface irrigation and some fertilizer chemicals used in the area which are high in sodium and potassium. Borehole Installation and development in the area has affect water supply since are shallow boreholes almost surface water.

IAHS (Hydrology)

HW05p - HW05 Societal Relevance of Groundwater: Ever Increasing Demands on a Limited Resource

HW05p-112

Improvement of drinking water (surface and ground) quality Beneficial to human use

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Drinking water has received considerable attention recently. However, misuse and mismanagement have resulted in a rapid and widespread decline in source-water quality and supply. Water quality guidelines can be used to identify constituents of concern in water, to determine the levels to which the constituents of water must be treated for drinking purposes. Membrane technology for the water cycle plays an important role in the provision of safe water supply and treatment. The aim of this paper is to improve the water quality to be valid for domestic purposes through minimizing the health risks associated with either direct or indirect use of water. The need for standards and guidelines in water quality stems from the need to protect human health. The results revealed that there were several areas polluted chemically by some heavy metals (Ni, Cd, Pb, Mn and Fe) and microbiologically by (Entamoeba Histolytica, Amoeba, Egg of Nematodes and Total count of Bacteria). We conclude and recommended that water treatment could see better membranes with both higher permeability and tighter cutoff. Removal of some chemical constituents must be done and sewage system projects are implemented in all towns and villages.

IAHS (Hydrology)

HW05p - HW05 Societal Relevance of Groundwater: Ever Increasing Demands on a Limited Resource

HW05p-113

Renewable groundwater resources of European Russia

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The water resources (groundwater and surface water) are determined based on the available information about the modern conditions of water formation, their spatial distribution, transformation over time, rational use, and protection. The new situation requires a revaluation of the renewable water resources because of changes in climate characteristics. Regional estimates along with the analysis of water resources distribution in European Russia, obtained by the authors, show the space and time dynamics of the surface and subsurface components of river runoff.

The work was based on up-to-date scientific and methodological principles of statistical processing and examining the time distribution of the mean annual, dry-season, and minimal water resources and their space distribution over some regions, river basins, and the constituent entities of the Russian Federation. The solution of those problems was largely facilitated by the authors' studies, which have been carried out since 2007. Those studies have provided a theoretical and methodological basis for establishing modern formation conditions of groundwater resources characteristics.

The objective of the study was to assess the current resources of fresh subsurface and surface waters in different regions. The problems solved in the study are as follows:

– the distributions of specific water availability characteristics for territories and population were evaluated;

– the absolute and specific amounts of water resources for the constituent entities of the Russian Federation were calculated, as required for the rational use and protection of water resources with estimates of their changes in the recent 30 years.

IAHS (Hydrology)

HW05p - HW05 Societal Relevance of Groundwater: Ever Increasing Demands on a Limited Resource

HW05p-114

Nonlinear baseflow recession analysis for karst watersheds

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Karst aquifers are very different from other aquifers with their specific complex characteristics. Water circulates through and is stored in in the porous and cavitated rock formations. Karst aquifers are important for the water supply of a large part of the Mediterranean region. For an accurate water resources assessment and management, information about the storage and conduction properties is needed. It can be obtained by the analysis of outflow hydrograph analysis, i.e. of rivers in karst catchments. Numerical analysis of recession limbs of hydrographs from karstic basins provides insight into hydrological processes in karst drainage systems and their water storage. In this study, nonlinear baseflow recession analysis is used to separate baseflow from time series of total flow from karst watersheds in the Mediterranean Region of Turkey. Numerous springs exist in the study region, most of them perennial. Their discharges are essentially baseflow. The objective of this paper is to assess baseflow and related groundwater / karst water recharge and their seasonal variation. It is expected that the analysis in this study will help in regulating the demand and pressure on groundwater resources in karst watersheds.

IAHS (Hydrology)

HW05p - HW05 Societal Relevance of Groundwater: Ever Increasing Demands on a Limited Resource

HW05p-115

Accelerating surface and ground water interactions to augment sub-surface storage in the Ramganga sub-basin of the Ganges

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Analysis of data over a period of 11 years (2002-2010) show that the groundwater storage is depleting at a rate of 1.6 Billion M^3/year in the Ramganga sub-basin of the Ganges. And the projections show increasing water demand for humans use allocation for environment. Lack of storage facilities is a critical issue for meeting water the increasing demand for humans, and tackling issues of water quantity and quality deterioration in river during the dry period. Augmenting sub-surface storage (SSS) is one of potential solution for storage dilemma facing Ramganga sub-basin. This paper illustrates how to augment the sub-surface storage (SSS) by accelerating the interactions of surface water and groundwater in the basin. The paper employs a semi-coupled groundwater and surface water modelling framework by developing fully processed and physically based numerical models of MODFLOW and Soil and Water Assessment Tool (SWAT) for the Ramganga sub-basin. The SWAT and MODLFOW models simulate surface runoff and groundwater recharge and discharge of 27 sub-catchments in the Ramganga sub-basin. The modelling framework show the technical feasibility of creating additional SSS by pumping more groundwater before the monsoon for irrigation and other uses and subsequently recharging during the monsoon by means of natural and artificial recharge mechanisms. This increased pumping-irrigation-recharge-pumping cycle could improve the livelihoods of hundreds of million people in the basin.

IAHS (Hydrology)

HW05p - HW05 Societal Relevance of Groundwater: Ever Increasing Demands on a Limited Resource

HW05p-116

Augmenting sub-surface storage for sustainable eco-systems services in the Ganges basin

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The Ganges basin has abundance of water resources. Yet, inadequate access to water is a major impediment for sustainable intensification and productivity increases of agriculture in the basin. Hydrology of the basin is highly seasonal. Water accounting of the basin shows that more than 80% of the surface flow is generated by the monsoon rain during June and September. Estimates of water use accounts show that most monsoon-generated surface flow in the basin is unused, while water stresses during non-monsoon period are increasing. The process depletion from irrigation is about 150 Billion m^3, of which 95% is consumptive water use (CWU); much of the CWU (75%) is in non-monsoon period between October and May, and the majority of that (75%) is also from groundwater. Moreover, the river flow during the non-monsoon period (about 45 Bm^3) is hardly adequate to meet the minimum water requirement to manage the river under a reasonably acceptable level of environmental management. And the water demand for human consumption and environmental allocation is increasing everywhere in the basin. However, the topography, demographic pressures and environmental concerns limit prospects for surface storage in the basin to buffer the water variability to improve supply. Therefore, augmenting sub-surface storage (SSS) is one of potential alternative solution for storage dilemma in the densely populated and poverty rampant Ganges Basin. This paper also shows potential sub-basins for SSS by conducting hydrological simulations using the Soil and Water Assessment Tool (SWAT) developed for the Ganges basin.

IAHS (Hydrology)

HW06a - HW06 Socio-Hydrology: The Dynamic Interplay between Water and Human Systems

IUGG-3588

Optimizing phosphorus flows in a two-sector economy

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Phosphorus is used in households, agriculture and industry, and resource management measures, calculates, and controls these flows. In this paper we combine resource management and economics in a socio-hydrology model. More specifically, we embed the anthropogenic phosphorus cycle in a dynamic economic optimization model.
The economy consists of three decision makers: the households, farmers in the crop production and farmers in the animal husbandry. The households maximize their utility function, taking into account their consumption. Both types of farmers optimize a profit function. Since households can consume both crops and animal products, and farmers sell their products to the households (or crops to animal production), we face two markets: the market for animal products and the more complex market for crops, used as consumption good or as intermediate good (fodder). In addition to the three decision makers we include the waste water treatment sector, which recovers phosphorus from the households with a certain technology and sells it to the crop production sector, and an industry sector selling phosphorus mineral fertilizers. Moreover, waste water treatment and the crop fields lose phosphorus into the environment, which negatively affects the quality of environment.
The dynamic economic optimization model is solved analytically to point out the most important mechanisms that influence the decision makers. We find the price level of mineral fertilizer compared to recycled phosphorus where farmers stop buying mineral fertilizer. In addition, we identify the consumption behavior of the households, taking into account the different technologies, different time preference rates and environment.

IAHS (Hydrology)

HW06a - HW06 Socio-Hydrology: The Dynamic Interplay between Water and Human Systems

IUGG-4321

Spiral Co-evolution of Humans and Water: A Case Study of Irrigation Efficiency Paradox in Bayingola, Xinjiang, China

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Along with fast development of human society, more and more natural resources are consumed. In arid and semi-arid areas like Xinjiang, northwestern China, water is one of the natural resources facing severe shortage that constrains socio-economic development. With full awareness of water scarcity, the local government has taken actions for coping with water shortage. However, during the study period (1998-2010), the total water consumption still increased even as irrigation efficiency has been dramatically raised. Although this phenomenon, generally called Irrigation Efficiency Paradox (IEP) or Jevons Paradox, could be interpreted as a rebound effect of economics, the specific interactions between social demand and the natural environment are not yet explicitly identified and discussed. In this paper, we have identified the key elements of irrigation land growth, water-saving technology improvements, community sensitivity to water scarcity change and social decision-making constitute a dynamic system, in which the social decision-making element drives the pendulum swing process. The socially feasible options of the pendulum swing are summarized as: i) irrigation land use (total water) control; and ii) water-saving system application. A conceptual socio-hydrologic model is built and applied to verify the processes and the emergence of the irrigation efficiency paradox. Preliminary findings of the conceptualization of irrigation efficiency paradox in Bayingola give us the idea that the co-evolution of humans and water is following a spiraling process in that the pendulum swing theory captures the selecting interaction as the vertical section,

while the Taiji-Tire theory captures the circulating interaction as the transverse section of the human-water spiral.

IAHS (Hydrology)

HW06a - HW06 Socio-Hydrology: The Dynamic Interplay between Water and Human Systems

IUGG-4572

Conceptualising human-flood interactions through models: comparison to data

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Changes in flood risk occur because of changes in climate and hydrology, as well as changes in societal exposure and vulnerability. Research on flood risk has demonstrated that the mutual interactions and continuous feedbacks between floods and societies has to be taken into account to better support flood risk management. We have recently provided some examples on the importance of these feedbacks and developed a socio-hydrological model that conceptualises the evolution of a human settlement located in the proximity of a river, whereby part of the community develops in flood-prone areas. The model has been used to formulate and communicate hypotheses on the floodplains as human-water systems, as well as explore long term dynamics emerging from flood-society interactions. The model reproduces the dynamic co-evolution of five variables: flooding, wealth, distance from the river, level of structural protection , and community memory of floods. As some of these variables are not easily observed, we present here a reformulation of the socio-hydrological model, which substitutes two of the variables (namely community wealth and distance from the river) with the population density in the floodplain, for which data are more easily available for real world case studies. Even though the model does not always account for all the factors determining the dynamics of floodplain population density (as this is not its aim), comparison between simulated and observed dynamics allows evaluation (verify or falsify) of the hypotheses made on the interactions and feedbacks between floods and societies.

IAHS (Hydrology)

HW06a - HW06 Socio-Hydrology: The Dynamic Interplay between Water and Human Systems

IUGG-4909

Roots and branches of adaptive delta management

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Under the moniker of Adaptive Delta Management (ADM), adaptive policy making moved from science to practice within 10 years. This fast uptake of scientific work in policy analysis, was enabled by the development of the Dutch Delta Program that incorporated ADM as its main conceptual framework from its inception in 2010. The rapid absorption of ADM by the Delta Program was initiated and sustained by a close and ongoing cooperation between scientists of the faculty of Technology, Policy and Management of Delft University of Technology, Deltares and the professional staff of the Delta Commissioner. The application of ADM in the Delta Program and active dissemination, both national and international, by the delta Program, mainstreamed ADM into professional organizations related to delta management and, as a consequence, professionals took the lead in the further development and application of ADM. An inventory of publication on ADM in Scopus and a Google searched on ‘adaptive delta management’ reveals that only two scientific publication referring to ADM are available, while Google delivers 1450 hits. This indicates that ADM is firmly rooted in advisory reports and policy documents, while its penetration into the scientific literature is limited. Further inspection of the professional literature indicates that the theoretical constructs underlying ADM lost connection with their founding scientific work and as a consequences lacks a clear orientation for further development. This research aims to structure developments in ADM and reconnected them to their scientific roots in order to support their further development and application.

IAHS (Hydrology)

HW06b - HW06 Socio-Hydrology: The Dynamic Interplay between Water and Human Systems

IUGG-2001

On modeling social dilemmas and interplay in sociohydrological systems

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Most modeling efforts for coupled natural-human systems focus on humans and the natural resources. In reality, however, humans rarely interact with these resources directly; the relationships between humans and resources are mediated by infrastructures. In sociohydrological systems, these include, for example, dams, irrigation canals, and various institutions. These infrastructures have important characteristics such as threshold behavior and/or a separate entity tasked with maintaining them. These characteristics influence social dynamics within the system, which in turn determines the state of infrastructure and water usage, thereby exerting feedbacks onto the hydrological processes. Systematic characterization of these feedback loops in sociohydrological systems is lacking, however. Contributing to this pursuit, we mathematically operationalize a conceptual framework proposed by Anderies, Janssen, and Ostrom (2004). Specifically, we develop a simple model based on the framework and report some preliminary results. The model results highlight the structure of the social dilemmas and interplay as well as their consequences on the system's sustainability. The model offers a platform to explore how the system may respond to external shocks from globalization and global climate change.

IAHS (Hydrology)

HW06b - HW06 Socio-Hydrology: The Dynamic Interplay between Water and Human Systems

IUGG-2154

Change in vulnerability of companies in Germany

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Due to expected further increases of flood damage, many countries reconsider their policies for flood risk management and develop integrated, adaptable concepts which rely on precautionary measures besides structural flood protection. However, despite the growing importance of private coping capacity and precautionary measures, quantitative information about their state of implementation are hardly available.

Therefore, vulnerability data from companies affected by recent floods in Germany were analyzed to gain quantitative information about changes in vulnerability during the last decade and how these changes are linked to flood experience and other physical and social drivers.

Preliminary results reveal that in the case of a flood event, most companies undertake emergency measures. The effectiveness of these measures is increased by recent flood experience, emergency plans, reliable warnings with long lead times, and low water levels. Additionally, larger companies that own their buildings seem to be more efficient in undertaking emergency measures. Additionally, many companies undertake precautionary measures after a flood, but still much more could be done. Perhaps the diversity of responsibilities in businesses and the institutional structure create hurdles as well as the level of uncertainty regarding which actions are most cost-effective and will provide significant damage reduction.

IAHS (Hydrology)

HW06b - HW06 Socio-Hydrology: The Dynamic Interplay between Water and Human Systems

IUGG-4134

Socio-hydrological dynamics in the Lake Chad District in Chad – outlining hydrological vulnerabilities of the agricultural economy

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The Lake Chad Basin has gone through extensive hydrological changes since the 1960s. In this period, the surface area of Lake Chad has shrunk from 25,000 km^2 to 3,000 km^2 and its volume has decreased by nearly 60% (WMO, 2005; Musa et al. 2008). The livelihoods in this area are based on agropastoral and fishing activities and are directly dependent on hydrological factors such as rainfall, freshwater availability, and soil moisture.

Hydrological variations are common in this area and human societies have generally adopted flexible livelihood strategies to adapt to this (Mortimore, 2010). However, there are signs that this adaptive capacity has been reduced lately due to increased population, poverty, and prolonged environmental stresses (FAO & LCBC, 2009). This reduction in adaptive capacity, together with expectations of increased hydrological variability due to global climate change, puts the local communities in an increasingly difficult situation.

This paper aims to improve the knowledge on the relationships between large-scale hydrological variations and the agricultural economy in the Lake Chad District in Chad. It does so by using multivariate statistical analysis of data sets spanning the past 25 years and qualitative assessments of each agricultural season from a local development organization. The quantitative data sets cover agricultural production, demographics, market prices, and hydrology for the specific area. Several of these data sets have not been coupled before. By coupling and analyzing these data sets this paper is able to outline hydrological vulnerabilities of the agricultural economy. Together with hydrological forecasts and regional socio-economic scenarios, this body of knowledge can be used to conduct risk analyses for future food security.

IAHS (Hydrology)

HW06c - HW06 Socio-Hydrology: The Dynamic Interplay between Water and Human Systems

IUGG-0584

Understanding the dynamics interplay between hydrological and social processes in the southwest coastal region of Bangladesh

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Bangladesh lays in a densely populated delta where flooding is a frequent event, which plays a remarkable role on social dynamics. Hydrological and social processes interact very significantly in Bangladesh, but the dynamics emerging from this interplay are still poorly understood and largely unexplored. This paper presents an empirical study of the interactions between human and water systems in the southwest coastal region of Bangladesh. Social responses to hydrological changes were explored. In particular, hydrological, climate and demographical data were used to understand the hydrological and demographical trends of this region and their interrelationships. To identify the factors influencing the social responses with the hydrology, interviews and focus group discussions with households mainly with farmers and fishers were carried-out.

Results show that reduction of upstream fresh water supply and increase of sea level rise, has led to increased salinity in this area. Furthermore, the construction of polders caused amplification of tides. Tidal water levels variation is increasing which enhancing chances of overtopping tidal surges inside the polders during extreme cyclonic events. These extreme events led to suffering people, damaged human lives, buildings, homesteads, agricultural products and triggered migration in some instances. Migration is resulting from the interactions between hydrological and biophysical changes processes and social and political dynamics.

IAHS (Hydrology)

HW06c - HW06 Socio-Hydrology: The Dynamic Interplay between Water and Human Systems

IUGG-2045

Bringing together methodologies and epistemologies: Experiences of joint research in the Cordillera Blanca region, Peru

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Since warming climate has been identified to alter water availability, recent societal processes and future scenarios around competition and conflict for access to water are framed as socio-environmental phenomena within climate change discourses. In this context, science faces societal and political exigencies to analyze the interdependencies between precipitation and glacier changes, water availability, and vulnerability of societies and economies for tempering risks of conflicts. Yet, the physical sciences are hampered in modeling meltwater and precipitation in complex topography and climate regimes of concern due to the lack of measurements for model calibration and evaluation at the required spatiotemporal resolutions. The social sciences, in turn, have to section highly complex and dynamic mutual interdependencies of, and hierarchies between user groups of diverse vulnerabilities and resiliencies. It is an enormous challenge to contextualize climate change not only as a physical science phenomenon, but also as a discursive field, structured by unequal power relations and injustice. To understand both the complex behavior of water availability and the socially imparted knowledge about water availability requires a broad set of methodologies in physical as well as in social sciences. Intersecting positivist and constructivist epistemologies demands for compounding qualitative with quantitative information, different spatiotemporal scales, different understandings of validity and representativeness, different ways of dealing with uncertainty and significance etc. Based on the experience from our study on “Vulnerability to Water Scarcity and Glacier Fed Water Availability in the Tropical Callejón de Huaylas, Peru” we show steps towards possibly reaching this goal.

IAHS (Hydrology)

HW06c - HW06 Socio-Hydrology: The Dynamic Interplay between Water and Human Systems

IUGG-5329

"Of dikes, tides and rice - co-evolution of a vulnerable African community and its environment into an intricate socio-hydro-eco-technological system"

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This is a story of a Diola community located in the mangrove forests of the Casamance estuary, Senegal, that has been able to make the mangrove soils (acid sulphate soils, also known as cat clays) productive. They cultivate African rice (Oryza glaberrima), farm fish, produce salt and distil palm wine. They sell the salt and distilled wine to other communities. They made their lands productive through reclaiming the mangrove lands that surrounds the sandy islands on which they live by building dikes and sluices. They developed a systematic soil and water management system in order to ensure that the soils never dry up (upon drying cat clays turn irreversibly acid, unsuitable for agriculture). They thus gained knowledge on soils, salt and fresh water, tides, rice, and developed technological tools (spade, dikes, new rice cultivars).

Knowledge and tools, however, are not equally distributed in the community but along age and gender. Land is owned by male lineage elders, young men cultivate the lands and build and repair dikes with a particular spade, while rice is the domain of women – they plant and harvest, but also maintain the many rice cultivars with their different characteristics (e.g. taste, salt tolerance), and breed new ones. The specific rice cultivars, the lay-out of the land with its dikes and sluices, and the spade, are technological manifestations of the co-evolution of social and biophysical processes. Power relations based on age and gender can be understood likewise. This is thus a socio-hydro-eco-technological system (SHETS).

Recent developments, for example outmigration by the youth, have put this SHETS under stress. Monitoring how it evolves will improve our understanding of the feedbacks between social and biophysical processes underlying this system.

IAHS (Hydrology)

HW06p - HW06 Socio-Hydrology: The Dynamic Interplay between Water and Human Systems

HW06p-117

A socio-hydrology perspective of the agriculture industry in the Murrumbidgee, Australia: The "Pendulum Swing" in water resource management and sustainabillity

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Freshwater security poses a major challenge in the 21st century, with the uncertain future supplies due to climate change and increasing demands from growing populations, and as ecosystem services become increasingly valued. Human impacts on water resources and ecosystems have increased, but the ability of freshwater sciences to understand and model interlinked human and hydrologic systems has not. Hydrological models treat human impacts on water systems as exogenous, complex, and place-specific issues. Socio-hydrology framework explores the coevolution of humans with water resources using case study approach. This paper explores the issue of environmental water and its competing pressure on other productive uses and human coevolution within the Murrumbidgee River, located in south-eastern Australia catchment. Irrigation in the valley uses much water and reduces the share of the environment, although important in its vital role in ensuring food security. This has influenced land use in the region in the past 150 years, significantly altering the natural distribution and condition of the vegetation cover leading to environmental degradation. The challenge in the Murrumbidgee is to cater for the environmental customer without severely impacting on the irrigation sector. This was studied through different data analysis and numerical modelling. Data relating to various aspects of agriculture production were examined to investigate the interrelations between them, and their significance. A model based on the data analysis that could simulate the dominant drivers in the Murrumbidgee as it relates to agriculture production, the use of water and the impact on the environment was developed.

IAHS (Hydrology)

HW06p - HW06 Socio-Hydrology: The Dynamic Interplay between Water and Human Systems

HW06p-118

Characterising and quantifying water demands in mountain tourist resorts

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In the context of integrated water resources (and uses) management studies, this work focuses on the monitoring of water demands in mountain tourist resorts. Three issues are addressed, right at the interface between human and water systems:

1) The complexity of water use systems in highly developed mountainous areas, characterised by inadequate distribution of resources and demands over both space (water demand concentration, remote from resources) and time (higher demands during winter, the low flow period). This has lead to the development of heavy hydraulic infrastructures (interbasin transfers; storage reservoirs; networks for artificial snowmaking, drinking water supply, irrigation and hydropower production). Moreover, there are significant tourism-related demand pressures. In this work, spatial and temporal scale issues are addressed from a conceptual (concepts of water use system and water use regime) and cartographic (using GIS) perspective.

2) The need for continuous and long-term water use data. There is a strong contrast between water resources, which are almost systematically monitored, and water demands for which direct measurements are rare and insufficient. To address this lack of data, we set up an observatory of water demands in two Alpine resorts for two major uses: drinking water (in Megève, France and Montana, Switzerland) and irrigation (Montana).

3) The need to better understand water demand drivers, belonging to the socio-economical sphere and the water cycle state. Proxies commonly used for the estimation of water demand (e.g. needs per capita) are here compared with our direct measurements.

IAHS (Hydrology)

HW06p - HW06 Socio-Hydrology: The Dynamic Interplay between Water and Human Systems

HW06p-119

Assessment of severity levels of Damaging Hydrogeological Events in Calabria (Southern Italy)

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A Rainfall Event and a subsequent Damage Event, resulting from floods and landslides triggered by rainfall, are the two components which characterize a Damaging Hydrogeological Event (DHE). Since the same rainfall amount can cause different degrees of damage, depending on both rivers and slopes conditions, both Rainfall and Damage Event characteristics are related to climatic, geomorphological and anthropogenic factors. Moreover, as to what concerns the damage, and specifically the damage occurrence, this also depends on the geographical distribution of damageable elements such as population, lifelines and urbanized sectors.

In this paper, a methodology for the classification of the severity of the DHEs, which have been recorded in a region of southern Italy (Calabria), is proposed. The applied methodology was based on a chart which considers some indicators of both the Damage (D_{score}) and the daily Rainfall values (R_{score}) recorded in the study area; the chart was applied to a series of 30 DHEs which occurred between 1981 and 2010. As a result, four types of events have been identified: ordinary events, obtained by low D_{score} and R_{score} values; extraordinary events, with high R_{score} values but low D_{score} values; catastrophic events, characterized by non-exceptional rainfall (low R_{score}) and severe damage (high D_{score}); major catastrophic events, having high D_{score} and R_{score} values. Given that, media accounts and first or second-hand personal accounts fail to provide an objective classification, the aim of this study was to provide an objective classification of the severity of the DHEs through the production of a chart.

IAHS (Hydrology)

HW06p - HW06 Socio-Hydrology: The Dynamic Interplay between Water and Human Systems

HW06p-120

"Relationship between flooding and Net Primary Productivity in the downstream basin of the Mekong River"

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Floodplains are the most productive and valuable ecosystems in the planet. Their role in providing services such as biodiversity and agriculture is disproportionally high. There are many researches on the relationship between vegetation, agriculture and flooding, but not any research on relationship between land productivity and flooding. Land productivity can be measured in terms of Net Primary Productivity (NPP). Clarification of relationship between NPP and flooding helps to clarify the essence of the relationship between vegetation, agriculture and flooding. Specifically, it is very important to clarify such relations at Mekong River basin in Cambodia. This is because agriculture is very important in Cambodia and is dependent on flooding and land productivity. And land development in Cambodia is currently in its fast pace,which does notfollow any order and lacks index. So, it is needed to clarify the relationship between NPP and flooding at Mekong River basin in Cambodia.

10km×10km Global NPP data from NASA EARTH OBSERVATIONS is used as input data. Then, flood duration, water depth and nutrition distribution in Cambodia are simulated using the flood models and field survey. By using these data, the relationship between NPP and flood duration is studied.

Result shows that there are strong relationships between flooding and NPP. NPP has clearly marked peak value when it is flooded from 7 to 8 months annually. It is also found that the flood limits land development and increases NPP in flood plains.

This study provides fundamental knowledge needed to understand the land productivity in flood plain. And this study will be helpful for land development not only in Cambodia but also in similar flood plains around the world.

IAHS (Hydrology)

HW06p - HW06 Socio-Hydrology: The Dynamic Interplay between Water and Human Systems

HW06p-122

Flood victims, what we could learn

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Floods not only induce vast economic damages but also pose a great danger to human life. In Slovenia, floods rank as number one on the scale of damage magnitude. Different factors external to the hazard of flooding influence the gravity and extent of the impacts. A comprehensive collection and analysis of the information related to the understanding of causative factors of human impacts can substantially contribute to the mitigation and the minimization of fatalities and injuries. With the dataset of the 10 severest flood events and 73 causalities that happened in the years between 1926 and 2014, a detailed collection and review on human impacts was made in Slovenia. The focus was on demographic aspects (age and gender) of fatalities and analysis of the circumstances of loss of life. Based on a description of activities of the victims during flood events and repetitive patterns, we have made a categorisation of fatalities. Complexity of the factors that contribute to the loss of life probability imply a need for a different, interdisciplinary approach.

IAHS (Hydrology)

HW06p - HW06 Socio-Hydrology: The Dynamic Interplay between Water and Human Systems

HW06p-123

Assessing the impacts of Land Cover Change on Surface Water Sources in Southwestern Nigeria: The Role of Communities' Local Experts

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In this study, we investigated whether water stress in the woodland savanna and rain forest zones of Southwestern, Nigeria as observed by the rural communities' local experts' can be used to evaluate LCC in the region. LCC was conducted using orthorectified Landsat multi-temporal imagery for 1970/1972, 1986/1987, 2000/2001 and 2006 using maximum likelihood classification and change detection techniques. The results showed a decrease in the forest area and an increase in built-up and cultivation/others (open space, bare land, grassland) areas. Between 1972 and 2006, forest reduced by about 50% while built-up areas increased by about 300%. A social survey (Participatory Learning Approach PLA) involving local experts between the ages of 50 to 70 was conducted to assess their observations in the region on (i) LCC and (ii) the causes of water stress, and (iii) the associated risk and adaptation/recommendation. The communities' local experts are generally reported that changes in climatic condition (e.g. decreasing rainfall), continuous deforestation in the last 30 years and diversion of rivers and streams into surface storages (earth dams and reservoirs) are the major factors responsible for water stress and scarcity in the region. There is thus, a good correlation between the results of remotely sensed data of LCC assessment and the communities' local experts' observations of land cover changes and changes in surface water resources in the region. The study inferred that LCC map products could be used in a participatory approach involving the communities to assess the impact of environmental change on an important service of ecosystems such as fresh water resources.

IAHS (Hydrology)

HW06p - HW06 Socio-Hydrology: The Dynamic Interplay between Water and Human Systems

HW06p-124

Constraints to public participation in the Pitimbu River Basin Committee, Brazil

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As a democratic forum in which representatives take decisions about collective issues, the River Basin Committee relies on public participation to decide and resolve questions involving water management. Public participation provides insight that can foster supported decisions. However, effective public participation in the decision making process is contingent on enabling factors and can be seen as an ideal situation. This paper discusses some questions involving the public participation experience within the Pitimbu River Committee. The Pitimbu River basin is located in the Brazil's Natal region and is subjected to intense urbanization. It supplies potable water to approximately 280 000 people. With the aim of analysing public participation in the decision-making process, semi-structured interviews were held with selected stakeholders. Obtained results indicate that the quality of participation is unsatisfactory and is related to the following factors: a) Financial constraints and thus lack of prioritization of implementation of public participation. b) Engagement and interest in participatory forums is poor, reflecting the low political importance of water and the lack of use of the forums' output by state agents. c) Lack of sufficient technical capacity of some actors to take decisions, which can generate unbalanced decisions. d) State Administration ignores Committee land use policy recommendations, indicating that an effective inter-institutional implementation model is necessary. e) Water use in the basin is not adequately measured and controlled, indicating that water governance is poor or lacking. Finally, this paper presents some basic recommendations that could progressively improve water governance within the basin.

IAHS (Hydrology)

HW06p - HW06 Socio-Hydrology: The Dynamic Interplay between Water and Human Systems

HW06p-125

An ecohydrologic framework for modeling stream-fed irrigation in dryland environments

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The climatological conditions common in drylands – greater potential evapotranspiration than rainfall and high variability in total rainfall over the growing season – pose challenges for farmers in making decisions about crop type and planted area. These challenges are magnified in developing countries where, in the absence of sufficient storage and pipe networks, irrigation water is often taken directly from rivers. Because both soil moisture and river flow are dependent on recent precipitation, high irrigation demand coincides with periods of low flow. To better understand these dynamics, we built a numerical model to simulate both flow production and irrigation withdrawals in an agricultural catchment. This model was used to explore the effects of total irrigated area on the distribution of both river flow and crop yield. Optimum irrigated area was determined using a simple economic return function based on crop yield, water costs, and overdraw penalties. We will apply a similar economic analysis to multiple irrigation communities in the same catchment in order to investigate strategies to manage competing upstream and downstream water users in dryland agricultural settings.

IAHS (Hydrology)

HW06p - HW06 Socio-Hydrology: The Dynamic Interplay between Water and Human Systems

HW06p-128

Understanding the Socio-Hydrology System of the Kissimmee River Basin, Florida

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This study is to develop a conceptual socio-hydrology model for the Kissimmee River Basin. The Kissimmee River located in Florida was channelized in mid-20 century for flood protection. However, the environmental issues caused by channelization led Floridians to conduct a restoration project recently, focusing on wetland recovery. Hypothetically, the major reason to drive the system from channelization to restoration is that the community sensitivity towards the environment has changed from controlling to restoring.

The model developed in this study includes 5 components: water balance, flood risk, wetland area, crop land area, and community sensitivity. Urban and rural people in the basin have different community sensitivities towards the hydrologic system. The urban people are more sensitive to wetland restoration; while the rural people, who live closer to the river are more sensitive to flood protection. The power dynamics between the two groups and its impact on management decision making is described in the model.

The model results confirm the study hypothesis that the focus of community sensitivity in the Kissimmee area has changed from flood protection to wetland restoration in the past 60 years. There are two main reasons for the community sensitivity change. Firstly, people's flood memory is fading because of the effective flood protection, while the continuously shrinking wetland and the decreasing bird and fish population draw more and more attention. Secondly, in the last 60 years, the urban population in Florida drastically increased compared with a much slower increase of rural population. As a result, the community sensitivity of urban population towards wetland restoration has more weight than the rural population's towards flood protection.

IAHS (Hydrology)

HW06p - HW06 Socio-Hydrology: The Dynamic Interplay between Water and Human Systems

HW06p-129

Converging stakeholders' climate change adaptation visions through hydrologic modeling

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The Pedieos river in Cyprus flows from the forested hillslopes of the Troodos mountains through the rural Mesaoria plain to the capital Nicosia. A dam with a 2.8-Mm^3 reservoir captures the water from the steep upstream watershed. The dam protects the mid- and downstream area against flooding and provides water for domestic supply for nearby rural communities. The dam's waterbody has also become a biodiverse recreational area. However, climate change is threatening the watershed. Projections of Regional Climate Models show a drier and warmer Pedieos watershed in the near future (2020-2050).

A dialogue has been started with a diverse group of stakeholders for the development of a climate change adaptation plan for the watershed. Environmental-minded stakeholders suggested to demolish the dam and to return the watershed to its natural state and the water to the downstream ecosystems. Agricultural producers would also like to see the return of stream flows, such that they can divert or impound the water for irrigation. Community leaders similarly prefer stream flows for the recharge of the alluvial river aquifer, allowing them to abstract more groundwater for community water supply. On the other hand, flooding is a main concern for the downstream authorities. The usually dry river bed serves as the drainage of the urban agglomeration of Nicosia and has been identified as an area of potentially significant flood risk for the EU Flood Directive.

Hydrologic modeling is ongoing to simulate and visualize the water management options proposed by the stakeholders. Observations, climate change projections and hydrologic models facilitate the development of sustainable adaptation solutions. However, it may be more complex to reconcile the diverging visions of the stakeholders.

IAHS (Hydrology)

HW06p - HW06 Socio-Hydrology: The Dynamic Interplay between Water and Human Systems

HW06p-130

Inter-model comparison of industrial and domestic water demand under consistent future socioeconomic scenarios

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There remains an ever-increasing interest and challenge for the sustainability of water resources. Previous studies suggest expected intensification of water stress - an imbalance between water supply and demand- over various regions due to both climate and socioeconomic change. Although many studies have focused on change in supply side, further understanding of water demand and its future change are indispensable for robust water resource assessment.
This study, the global model-inter-comparison of water demand under consistent future socio-economic scenario, compares the different approaches of globally simulated water demand. The purpose of this study is to understand the current status of demands for industrial and domestic water use using a model inter-comparison approach. Three leading-edge global water models (H08, PCR-GLOBWB and WaterGAP) simulate water demand on grid-based level (0.5°×0.5°), and their disparities and their cause were argued. Three scenarios related to social change, that affects industrial and domestic water demand, were applied based on the Shared Socioeconomic Pathways (SSPs).
From the preliminary results, spatial distribution of regions where uncertainty of estimation tends to be large, i.e. hot spots of uncertainty, were revealed. It was found that uncertainties in these regions are significant compared with the

ensemble mean. Moreover, this study showed the pronounced difference among models, particularly in temporal evolution of future water demand projection. Although the simulated variations include the sign of change, their trends differ according to assumptions of models. Reflecting these findings to improve modeling in future studies would give better insights into water demand, and therefore sustainable water use under changing world.

IAHS (Hydrology)

HW06p - HW06 Socio-Hydrology: The Dynamic Interplay between Water and Human Systems

HW06p-131

Modeling as a tool to predict bargaining over scarce water resources in Israel and Palestine

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Interaction between water availability and value of water is studied for the socio-hydrology of Mountain Aquifer that is shared by Israel and Palestine. Continuous water negotiation between the two countries influences the sustainability of the aquifer and vice versa, one of the many two-way feedbacks that shape the local reality.

In this study we apply the Rausser-Simon bargaining model to explore the effect of selected scenarios for the water system on bargaining for water between the two states. The scenarios serve as means to understand the socio-hydrological dynamics in piecemeal fashion. The Rausser-Simon model simulates the non-cooperative bargaining process between two or more agents (in our case Israel and Palestine). The 'power' of Israel and that of Palestine to influence the outcome of a bargaining process is also formalized in the model. Finally we assume that the agents rationally negotiate over economic benefit from the Mountain Aquifer.

The results suggest that equal powers of Israel and Palestine can explain current water allocation. The small size of the Palestinian economy compared to the Israeli economy appears to be the main reason for this outcome. If the economies of the two states are allowed to grow equally, Palestinians appear to gain a larger share of the aquifer. And lower desalination costs, as technology may improve in the future, only affects the bargained outcome if the reduction in cost is sufficiently large.

The model clarified the interaction of bargaining behaviour and water availability. Yet several improvements are desirable. Several assumptions such as money metric value of water and rationality of agents will be relaxed. Future development also envisages inclusion of additional parties such as Jordan.

IAHS (Hydrology)

HW06p - HW06 Socio-Hydrology: The Dynamic Interplay between Water and Human Systems

HW06p-132

Le risque inondation: l'issu des interactions et rétroactions entre rivières et sociétés. L'exemple de la ville de Tecuci (Roumanie)

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Les dernières décennies, dans le monde entier, les dommages socio-économiques engendrés par les inondations, ainsi que leurs coûts, ont augmentés significativement. Par conséquent, la diminution du risque inondation est devenue un défi pour les sociétés, à différentes échelles spatiales. Afin de diminuer ce risque, étant donné qu'il résulte de la combinaison de l'aléa et de la vulnérabilité, des approches systémiques, qui permettent de comprendre les interactions et rétroactions complexes et dynamiques entre rivières et sociétés, s'avèrent nécessaires. Ce travail, qui est à la fois conceptuel et applicatif, a pour but d'analyser le risque inondation dans la ville de Tecuci (environ 35 000 habitants, qui, à cause de son emplacement à la confluence de deux rivières, le longue du temps a été touchée plusieurs fois par des inondations dommageables) à travers le prisme des interactions/rétroactions entre les rivières qui la traversent et le développement de la ville. Le travail englobe des analyses portant sur l'aléa (analyse des fréquences et d'intensités des crues) et sur des aspects socio-économiques (extension spatiale, dynamique démographique et économique, développement de mesures structurelles et non structurelles de diminution du risque inondation) illustrant la vulnérabilité. Sous aspect conceptuel, le travail essaye de synthétiser la complexité dans le temps et dans l'espace des relations entre la rivière et la ville et leur rôle dans la dynamique du risque inondation.

IAHS (Hydrology)

HW06p - HW06 Socio-Hydrology: The Dynamic Interplay between Water and Human Systems

HW06p-133

The interplay between groundwater-agriculture hydrosystems and their societal implications for managing arid coastal regions

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Groundwater-agriculture hydrosystems in arid coastal regions are particularly at risk due to limited potential for groundwater replenishment and increasing water demand caused by continuously growing population. Excessive use of groundwater for irrigation in agriculture leads to declining groundwater levels and saltwater intrusion into the aquifer systems. Using this increasingly saline water for irrigation destructs the agricultural resources, which are the economic basis for the farmers and their communities. Further consequences are abandoned farms and migration into cities. The limitation of resources (water and soil) and the feedbacks of human interventions with water quality in arid coastal regions require societal adaptation and management strategies for a transition towards stable and sustainable future hydrosystem states. Besides a more general description of the hydrosystem dynamics, the contribution seeks for a more specific evaluation of management options and policies based on results of empirical surveys about stakeholders' behaviour and opinions on possible management interventions and physically based modelling of the groundwater-agriculture hydrosystem interactions. The study is exemplarily investigated for the south Batinah region in the Sultanate of Oman, which is affected by saltwater intrusion into a coastal aquifer system due to excessive groundwater withdrawal for irrigated agriculture.

IAHS (Hydrology)

HW06p - HW06 Socio-Hydrology: The Dynamic Interplay between Water and Human Systems

HW06p-134

Integrated hydrological modeling system: A platform for flood risk management support

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OGC Open Modeling Interface (OpenMI 2.0) standard was used to develop an integrated hydrological modeling system, which combines the semi-distributed hydrological model ECOMAG with the hydrodynamic model Stream-2D. The OpenMI is a data exchange protocol to facilitate communication of numerical models operating at different time-spatial scales, databases and visualization tools. The ECOMAG model describes hydrological processes at a river basin scale including the processes of snow accumulation and melting, soil freezing and thawing, water infiltration into unfrozen and frozen soil, evapotranspiration, thermal and water regime of soil, overland, subsurface and groundwater flow. The Stream-2D model is based on two-dimensional hydrodynamic equations and describes spatial distribution of water flow velocity and depth, flood inundation dynamics and other processes within a floodplain-channel system. In this study, we demonstrated ability of the developed modeling system to be used as a flood risk management tool for analyzing flood protection effect of large reservoirs and large-scale hydro-technical constructions (such as dikes and bank reinforcements) on populated floodplains. The case study was carried out for the middle Amur River where large reservoirs are currently located on the Zeya and Bureya tributaries. The system was calibrated and validated against the available observation data at the study basin and demonstrated good performance. Numerical experiments were carried out with the modeling system in order to reproduce flood regime near the city of Blagoveshensk under different scenarios of location of existing and projected flood protection infrastructures.

IAHS (Hydrology)

HW06p - HW06 Socio-Hydrology: The Dynamic Interplay between Water and Human Systems

HW06p-561

Differentiating the social in socio-hydrology: The dynamics of land use changes in Southwest Bangladesh

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This presentation contributes an observation of interactions and feedbacks between physical and social processes in the coastal area of Southwest Bangladesh, in the Brahmputra/Ganges Delta. The impacts of flood management infrastructure (polders) on hydrological processes in this delta are well understood: research has documented increases in water and soil salinity, sedimentation of river bed, subsidence of flood plain area in polders. What is less examined is the subsequent influence on various social processes (economic, demographic, politics), and differentiation in social outcomes. We present the results of recent research identifying the different social processes related to changes in water: noting both consolidation in land ownership and shifts in land use to aquaculture (and back), international and local economic changes, alongside processes of displacement, and out-migration by small scale farmers. We call attention to the relations of power and governance processes mediating societal responses to changes in water quantity and quality; socio-hydrological process are not power neutral, but produce both winners and losers in new human-water landscapes. We call for more attention to the differentiation in social outcomes as a result of socio-hydrological processes, and attention to power dynamics shaping these differences.

IAHS (Hydrology)

HW07a - HW07 Control of Water Resource Systems

IUGG-1586

Climate Change Impact on Water Resources Vulnerability and Adaptive Water Management in Major River Basins in China

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China, as a larger developing country in the world, in facing to bigger challenges than before on wisely managing water resources to support rapidly socio-economic development in 2020 and beyond. China has a vast area of 9.6 million km^2 and relatively abundant water resources with ranked sixth in the world in terms of absolute amount of annual runoff. However, China has a very low per capita amount (about one quarter of the world average) of water resources and, is therefore one of the countries with the most severe shortage of water in the world. Water Resource Vulnerability under impact of both climate change and human activities are rather significantly. This presentation will focus on two issues: (1) how to screening climate changes impact to water sector, and how to quantify water resource vulnerability related to impact of climate change and human activity ? (2) how to take adaptation & wisely manage water to changing environment on existing water projects and new water programme & water policy in China? A screening process for climate impact to water sector in North China was proposed. A new study on quantifying water resource vulnerability, based on three practical and workable, i.e., the use to availability ratio, water crowding and per capita water use, were developed. Four case studies in China are given as explanation of this study. The concept on good water governance was discussed. It was shown that: (1) climate change and human activity are two big issues to water sustainable use. Science & technology will play a key role on understanding & reduce risk; (2) Water policy, in China will had to shift from water quantity management into water quality management, and water supply management into water demand management.

IAHS (Hydrology)

HW07a - HW07 Control of Water Resource Systems

IUGG-2032

The effect of establishing boundary on Genetic algorithm (GA) for optimising reservoir operating rule curves

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Evolutionary genetic algorithms (GA) optimisation have long been recognized, and widely applied, to provide the optimal solutions when deriving reservoir rule curves. One of the main challenges in GA, however, is establishing the initial boundary of the feasible region to search for the optimal solution: too wide a boundary will increase the computational time while too narrow a boundary may lead to the solution missing the global optimum. Thus, the aim of this study is to investigate the effect of specified boundary on the performance of GA. Two variants of GA were considered: the standard GA (SGA) and a newly developed dynamic GA (DGA) that uses reducing-search-space techniques. The fitness function was the cumulative squared deficits. The Ubonratana reservoir in north-eastern Thailand was selected as test case. Two boundaries were investigated: (a) boundary formed by the Ubonratana existing (un-optimised) rule curves, as guide (B1); and (b) boundary formed by the top and minimum water levels (B2). Thus B2 is much wider than B1. Both the SGA and DGA benefited from using the narrower B1 especially in the computational times, which were 66.7% and 47% respectively lower than the corresponding values for B2. The average computational time of using B2 in DGA was less than 28% of time taken by SGA. The results of the optimisation in SGA gave the minimum fitness values over 30 repetitions as 6854 and 6862, respectively using B1 and B2. The corresponding values for the DGA were 5989 and 5995, respectively, both representing improvements over the SGA.

IAHS (Hydrology)

HW07a - HW07 Control of Water Resource Systems

IUGG-2428

Simulation of multisite daily inflows for reservoir systems considering climate change

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For the optimal planning and derivation of operation rules for multi-purpose reservoir systems long time series of daily streamflows are required. Stochastic streamflow models can provide these data. The synthesis of daily flows at multiple sites is a challenging task especially if non-stationarity in streamflow conditions is expected. Recently, nonparametric k - nearest neighbor resampling techniques have been applied successfully for the generation of daily streamflows at multiple sites. The objective of this study to employ k-nn resampling for the simulation of multivariate daily streamflows considering changes in climate conditions.

Observed daily streamflows are resampled conditioned on observed and simulated climate variables from regional climate models considering past and future scenarios. The resampling is done in a three step-procedure: 1) seasonal flows for an index station representing the flow sum over all considered gauges are generated; 2) the flow sum is spatially disaggregated by resampling station flow proportions from observed data; 3) the individual seasonal flows for all gauges are temporally disaggregated to daily data by resampling daily flow proportions.

The method is applied for a reservoir system in the Harz mountains in Germany comprising five streamflow gauges with long daily observations. Climate data from observations and from the regional climate models REMO and WETTREG are used for conditioning. The method is parsimonious, easy to understand and very fast. It simulates all observed statistics well and provides significant change signals concerning future flows.

IAHS (Hydrology)

HW07b - HW07 Control of Water Resource Systems

IUGG-2932

Development of operating rules for Hluhluwe Dam, South Africa

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Hluhluwe Dam, with a 30 million m^3 reservoir that supplies water for irrigation and Hluhluwe municipality in Kwa Zulu Natal Province, South Africa, was consistently experiencing low storage levels over several non-drought years since 2001. The dam was operated by rules of thumb and there were no records of water releases for irrigation - the main user of the dam. This paper describes an assessment of the historical behaviour of the reservoir since its completion in 1964 and the development of operating rules that accounted for: i) the multiple and different levels of reliability at which municipal and irrigation demands need to be supplied, and ii) inter-annual and inter-decadal variability of climate and inflows into the dam. The assessment of the behaviour of the reservoir was done by simulation assuming trigonometric rule curves that were optimized to maximize both yield and storage state using the SCE-UA method. The resulting reservoir behaviour matched the observed historical trajectory reasonably well and suggested that the dam has been operated at a demand of 10 million m^3/annum till 2000 when the demand suddenly rose to 25 million m^3/annum. The operating rules were derived from a statistical analysis of the base yields from simulations of the reservoir using 500 5 year-long stochastically generated sequences of inflows, rainfall and evaporation. After the implementation of the operating rule in 2009, the storage state of the dam has improved and is matching those of other reservoirs in the region that had established operating rules.

IAHS (Hydrology)

HW07b - HW07 Control of Water Resource Systems

IUGG-4943

Drowning by numbers: excess water distribution in the Gezira irrigation scheme

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The Gezira Scheme is located between the Blue and White Niles south of Khartoum. In 1925, Gezira started with 300,000 acres; currently it covers close to two million acres. Managing Gezira was done by inspectors from the British firm Sudan Plantations Syndicate. In 1950, the Sudan Gezira Board took over management. Water flowed from Sennar through main and major canals, controlled by the Sudan Irrigation Department. Minor canals were the responsibility of SPS inspectors.
A Gezira tenancy included one field of cotton, one with sorghum, and one fallow. Crops rotated over the fields each year. Fields with the same crop would be in the same Number. Every Tuesday, an inspector would send his request in cubic meters of water per feddan per day for his Block to the SID.
However, rain in a Block meant that irrigation water asked could not be used on the field, but all the water asked for on Tuesday would still flow to the inspector's area and had to be used by it until the irrigation engineers could adjust canal settings upstream. With the total amount at his disposal being the same, an inspector could balance flows between Numbers, by opening or closing pipes. In case of acute danger of drowning a cotton plot, a fallow Number could be used as an escape. Drains were not supposed to be escapes for canal water.
For a given week the system is modeled as a graph where each node has a preference order for the use of limited capacity links to other nodes and a preference order for acceptance of flow along links from other nodes. There is a graph theoretical algorithm that calculates "stable flows" for such a graph. The historical decisions on where to send the surplus water are compared with those of the algorithm.

IAHS (Hydrology)

HW07b - HW07 Control of Water Resource Systems

IUGG-5389

The use of general irrigation calendars under different climate conditions

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In this contribution a stochastic simulation optimization framework for decision support for optimal operation of irrigation systems under limited water is presented. To treat the climate uncertainty within a simulation optimization framework for irrigation management it is necessary to formulate a tractable probabilistic framework which avoids the considerable computational effort of Monte Carlo simulations. This is even more the case for ensuring food security since higher quantiles (90% and above), which for achieving convergence require large evaluation sets, are of interest. This study demonstrates the efficiency of a stack-ordering technique for generating high productive irrigation schedules which are based on statistically appropriate sample sizes and a reliable optimal management. Those general irrigation schedules can be applied in practice as simple irrigation calendars and are evaluated in the study for different climate conditions.

IAHS (Hydrology)

HW07p - HW07 Control of Water Resource Systems

HW07p-053

Vulnerability assessment of drinking water production facility to chemicals from watershed

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The objective of this study is to assess the vulnerability of a drinking water production facility to chemicals produced, transported, and discharged in a river watershed. The facility is located in the delta of the Nakdong River, South Korea and employs Aquifer Storage Transfer and Recovery (ASTR), in which river water is injected to the aquifer, stored and pumped for sustainable supply of higher quality water. Vulnerability is evaluated based on the amount of chemicals transported in the watershed and the distance between the cities and the facility. The frequent transportation of chemicals will incur the potential risk of accidents, while the long distance from the facility will contribute to the attenuation of risk through the mechanisms such as absorption of the leached chemicals to the surrounding medium or evaporation to the atmosphere. We analyzed top-ten chemicals managed in the watershed. Vulnerability index was calculated as a summation of functional values accounting for the transported amount and the distance. For calculation, the re-scaling method adjusted to time factor was applied to normalize the amount of chemicals transported. As a result, a vulnerability map was created and the correlation was analyzed between the vulnerability index and the geographical distribution of industries handling the chemicals.

IAHS (Hydrology)

HW07p - HW07 Control of Water Resource Systems

HW07p-054

Downstream accentuation of hydrological alterations by dams in heavily regulated basins of Catalonia, Spain.

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Dams induce deep modifications to the downstream hydrology by altering the natural river regimes and often by the diversion of river flows for different water uses. In this study, we use long-term (1950-2013) river flows and climatic series to analyze the downstream cumulative effect of dams on the alteration of the natural river regimes and the disassociation between climate and runoff evolution in the Segre and Ter basins, with a drainage area of 13000 and 2955 km^2 respectively. Both basins have their headwaters in the Catalan Pyrenees and they have been highly regulated by numerous dams in the second half of the twentieth century. River flows of the Segre basin are mostly used for irrigation, whereas the reservoirs of the Ter basin supply water for domestic and industrial use to the Barcelona metropolitan area. Long-term monthly averages of upstream and downstream sectors are compared, as well as the relation between climatic and hydrological time series. Analyses have shown how the progressive increase of impounded ratio enhances the disassociation between climate and runoff. It leads to a marked downstream reinforcement of the negative trend in runoff that cannot be explained only by climatic factors. Moreover results evidence that the use of the reservoirs lead to contrasted magnitude in the observed decline of the runoff between both basins, and also to a different seasonal alteration of the natural river regimes.

IAHS (Hydrology)

HW07p - HW07 Control of Water Resource Systems

HW07p-055

Application of controlled breaching scenarios in flood risk management

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Flood risk management requires specification of flood risk and choice of tools that would be most effective in reducing the risk. Flood risk maps are used to specify the area of highest risk, but equally important are the maps of socio-economic volnurability. In this paper we present a study on the application of controlled breaching scenarios for the reduction of potential flood losses. The aim of the study is an estimation of sensitivity of water levels at the cross-section of the river with the highest flood hazard, including volnurability, to breaching of the river embankments upstream. The 1-D flow routing model MIKE11 is used in the scenario analysis. The solution of a flow routing model depends on the model structure simplifications, the initial and boundary conditions and estimates of model parameters which are usually identified using the inverse problem based on the available noisy observations. In our analysis we take into account both parametric and input model uncertainty. We test breaching under various conditions. We take into account different widths of breaching (50m, 100m and 150m), different time formation of breaching (1h, 3h, 6h) and different lengths of time of water levels exceeding the height of the embankment base. The choice of the location of the controlled breaching also plays an important role both in the effectiveness of the action and its cost.

As the study area Tarnow reach of the River Biala Tarnowska, south-east of Poland, is used. We apply pseudo-Bayesian methods of uncertainty estimation and Global Sensitivity Analysis as the main methodological tools. The results of this study will be used in the development of adaptation measures to floods in this area under present and future climatic conditions.

IAHS (Hydrology)

HW07p - HW07 Control of Water Resource Systems

HW07p-056

Determining the soil layer depth of a green roof

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A green roof is a roof of a building that is partially or completely covered with vegetation and a growing medium, planted over a waterproofing membrane. There are two types of green roof: intensive roofs can support a wider variety of plants but are heavier and require more maintenance, and extensive roofs lighter than intensive green roofs, and require minimal maintenance.In this presentation, a simple model for intensive green roof is developed and its hydrological performance with respect to soil layer depth is investigated. Optimal soil layer depth based on the hydrological performance of the green roof will be determined.The model results show that 85% green roofs can capture 0.55 ~ 0.96 of runoff and reduce 1.7 - 36.2 % of the peak runoff in the usual design criteria of 3 – 20 cm soil layer depth. Pollutant removal efficiency in BOD can be expected to be 37 - 49 %. Soil layer depth is optimized as the value of 8.1 cm using the law of diminishing returns in the sense of non-point sources pollutant reduction efficiency.

IAHS (Hydrology)

HW08a - HW08 Water Security in a Changing World

IUGG-0334

Key challenges for water security and conflicts between human and environmental water needs in China

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Water is central to all our development goals. Water issue is also rather complex due to its system behaviors under the climate change and socio-economic development. There are multiple impacts and challenges on climate change and human activity. Water security has become the most important issue on global water strategies, which involves water shortage, water pollution, water disasters and ecosystem degradation etc. This paper addresses three key issues, based on China case studies on water security and conflicts between human and environmental water needs. Some of points and discussions are given as follows: (1) water security Strategy is one of the most important reality and middle-long term water strategies in the world. However, for water security, there are different means for different water sector problems/issues, such as the conflict between water supply & water demand, water disaster (floods & droughts), water pollution issue for drinking & water supply, and the trans-boundary water issue and international water and so on. What the most important for water security is to develop the global & regional water security strategies that should be higher than the traditional understanding on water security with the perceptiveness, scientific foundation support and comprehensiveness; (2) building up the vision system for water security issue, i.e., assessment system for water security, coordinating & guaranteeing system for global & regional water security and its policy ;(3) science & technology will play a key role on water security issue. China Government is processing national policy, namely, Ecological Civilization Construction, which will fully support and improve water security issue in China.

IAHS (Hydrology)

HW08a - HW08 Water Security in a Changing World

IUGG-3386

Investigating impacts of climate change on water resources in the Yellow River basin and identification of adaptation strategies

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Climate change has been a currently major environmental issue which will increase the challenge of sustainable water resources management. Taking the second largest river in China, the Yellow River basin as a case, variation trends of recorded stream flows during 1950-2010 were detected. Using the VIC model and climate projections produced by 18 GCMs, the impacts of climate change on water resources and adaptation strategies were investigated. Results show that the recorded stream flows have been decreasing with significant reduction occurring on the middle and lower reaches. During the next decades, temperature in the Yellow River basin tends to increasing with decadal rising rate of 0.066—0.470?/10a. Precipitation will likely undergo a slightly increase. Climate change will probably enhance the situation of water shortage for the Yellow River basin. Water resources over 2021—2050 are expected to change by -10.7% to 7.6% relative to 1960—2000. The effective adaptation measures and strategies to climate change are to reduce the vulnerability of water resources and mitigate the conflicts between water supply and demand.

IAHS (Hydrology)

HW08a - HW08 Water Security in a Changing World

IUGG-4154

Groundwater security issues of over-exploited and urbanised crystalline watershed: Groundwater balance as an indicator

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Crystalline aquifers in hugely populated, semi-arid regions are very hard to manage because of their different groundwater issues like less recharge and high groundwater withdrawal. These issues often make such aquifers vulnerable to undesired changes in storage like negative groundwater balance. In such cases, groundwater sustainability indicators can prove useful in designing effective management policies while locating the key priorities and issues in such watersheds. In our study, we used groundwater withdrawal as a pressure indicator and projected groundwater balance as a state indicator to evaluate the sustainability of fast urbanizing over-exploited watershed. This study was carried out in the Maheshwaram watershed, Southern India. We used different landuse scenarios to project the impact of high groundwater withdrawal on groundwater balance and sustainability. The behaviour of the state indicator in two groundwater withdrawal scenarios reveals that groundwater storage is generally declining because of over-exploitation and urbanisation. This indicator also shows that groundwater levels will continue to decline with the current withdrawal practices. Such a trend is dangerous groundwater sustainability in semi-arid over-exploited regions with limited means of recharge. With rapid urbanisation and over-exploitation in a watershed such as Maheshwaram, this indicator may be used to locate priority zones where immediate watershed interventions are required to address groundwater management issues, such as withdrawal reduction or managed aquifer recharge.

IAHS (Hydrology)

HW08a - HW08 Water Security in a Changing World

IUGG-4703

Hydrological ecosystem service delivery in the upper umngeni catchment – water security from ecological infrastructure

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The uMngeni catchment, located in the province of KwaZulu-Natal, South Africa, is a rapidly growing centre of economic activity. The catchment houses several major dams, which supply the thriving cities of Durban and Pietermaritzburg. Economic and population growth in the catchment is increasing, placing significant pressure on the catchment's natural resources. Water is arguably the most important of these, and the risks to water security from population and economic expansion in terms of water quality and quantity are already more than evident.

Funded by the Development Bank of South Africa's Green Fund, the University of KwaZulu-Natal in partnership with the South African National Biodiversity Institute (SANBI) is undertaking a project to assess whether achieving water security in the catchment is possible through investment in "ecological infrastructure" i.e naturally functioning ecosystems that produce and deliver valuable services to people. This implies the securing or rehabilitation of the catchment's extensive grasslands, riparian areas and wetlands. Recent land cover data and a daily-timestep hydrological model are used to identify priority areas in terms of delivery of hydrological ecosystem services such as dry season baseflow. The process attempts to translate hydrological model outputs into results which are both visually accessible and useful for investment guidance. This will inform decision makers as to where to invest in catchment rehabilitation or protection.

Results indicate that higher altitude grassland areas should be secured for water supply through purchase or stewardship mechanisms, and that there are several opportunities for rehabilitation activities such as reducing grazing or removal of alien plants, particularly in the riparian areas.

IAHS (Hydrology)

HW08b - HW08 Water Security in a Changing World

IUGG-0838

Water security at southeast coastal zone in Vietnam by managing coastal aquifers

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This report presents results of the project “Adapting to climate change: Solutions for managing coastal aquifers in the context of climate change' in Ninh Thuan Provinces, Viet Nam. The purpose of this project is to evaluating impacts of sea level rise by climate change on coastal zone in Ninh Thuan, proposing solutions for managing aquifer recharge to improve groundwater quality in coastal zones. In this work, authors focus in change of groundwater quality in time and their causes .

The coastal province of Ninh Thuan, due to its disadvantaged geographic location, unfavorable climate conditions and the limited social and economic development is among those more likely to be affected by climate change impacts such as sea level rise. One of the potential effects of sea level rise in these areas is the risk of saline water intrusion into fresh water coastal aquifers.

To understand the hydrogeological asset of the coastal aquifers, hydrogeological, geophysical investigations, drilling exploratory wells and monitoring of groundwater physio-chemical parameters (EC, pH, Salinity, TDS) were carried out. The results show that there are two types of aquifers: intergranular aquifers in the cover sediments: qh and qp and fractured aquifers in the metamorphic bedrock. Water level, EC and Temperature changes in each of these aquifers were recorded with continuous monitoring devices. The transects for monitoring groundwater quality at these aquifers include 8 wells: NH1, NH3, NH4 and NH5 for the intergranular aquifers and NH2 for the fractured aquifer.

Results of chemical and stable isotope analysis of water samples as well as monitoring data at a monitoring well network showed that the groundwater quality changes in time and MAR is a chosen solution to resolve these problems.

IAHS (Hydrology)

HW08b - HW08 Water Security in a Changing World

IUGG-3023

Exploring implications of climate, land use and policy intervention scenarios on water resources, livelihoods and resilience.

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Integrated modelling methodologies have a greater potential than purely disciplinary approaches to support comprehensive assessment of social, economic and biophysical aspects of complex natural resource management such as the Indian governments' program of watershed development schemes. Climate and recharge estimates drive predictions assessment of the availability of surface and groundwater resources as impacted by watershed development, climate and land use (i.e. water extractions). Water availability, land use mix and crop productivity influence who has access to the available water resources, how these resources can be used and consequently, the decisions and resilience of households. This presentation will describe an integrated modelling approach to explore possible impacts of selected climate, land use, the Integrated Watershed Management Programme and other policy interventions on surface and groundwater resources, agricultural productivity and people's livelihoods and resilience.

IAHS (Hydrology)

HW08b - HW08 Water Security in a Changing World

IUGG-3024

Exploring pressures applied on water resources in a changing socio-hydrological context. Case of the Vaud canton (Western Switzerland).

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Switzerland's description as Europe's water tower might evolve by the mid-century as its western and alpine region should undergo significant hydro-climatic changes. In the past 15 years, these areas already met water shortage episodes during which water withdrawals and supplies had to be restricted, notably in the Vaud canton (Western Switzerland). These droughts highlighted increasing competition among water users and new water management issues arose. This study explores the current and future state of freshwater resources and of urban, irrigation and livestock water needs in the Vaud canton. An integrated modeling framework was developed to assess water stress under climatic and/or anthropogenic changes. Climatic changes were derived from Swiss scenarios relying on ten regional climate models downscaled to the Swiss meteorological station network. Regarding water needs, a population growth scenario was provided by the canton while a business-as-usual scenario was considered for irrigation and breeding trends. Currently, the canton experiences moderate water stress from June to August except in its alpine region where no stress is noted. By the medium-term, temperatures should increase causing a higher ratio of liquid precipitation in winter and less snowmelt in spring thus leading to more severe low flows. In addition, water needs should significantly increase from April to July, mainly due to higher irrigation (+25%) and urban (+40%) water needs. In light of these changes, the canton should undergo moderate to high water stress from May to September and water needs could reach more than 80% of rivers' total runoff in July and August. This study is a first step towards a broader impact study including water management and water quality issues in western Switzerland.

IAHS (Hydrology)

HW08b - HW08 Water Security in a Changing World

IUGG-4178

Water dependency and water exploitation at global scale as indicators of water (in)security.

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A water dependency index has been developed indicating the dependency of water consumption from upstream sources of water, sometimes across (multiple) national border. This index is calculated at global scale using the 0.1 global LISFLOOD hydrological modelling system forced by WFDEI meteorological data for the timeframe 1979-2012. The global LISFLOOD model simulates the most important hydrological processes, as well as water abstraction and consumption from various sectors, and flood routing, at daily scale, with sub-timesteps for routing and subgrid parameterization related to elevation and landuse. The model contains also options for water allocation, to allow preferences of water use for particular sectors in water scarce periods. LISFLOOD is also used for the Global Flood Awareness System (GloFAS), the European Flood Awareness System (EFAS), continental scale climate change impact studies on floods and droughts. The water dependency indicator is calculated on a monthly basis, and various annual and multiannual indicators are derived from it. In this study, the indicator will be compared against water security areas known from other studies. Other indicators calculated are the water exploitation index (+), which is a commonly use water security indicator in Europe, and freshwater resources per capita indicators at regional, national, and river basin scales. Ongoing forcing the LISFLOOD global water resources model with climate scenarios will indicate future trends in water security.

IAHS (Hydrology)

HW08p - HW08 Water Security in a Changing World

HW08p-155

Effect of not considering water quality issues on soil and agricultural plants

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The present work has been developed within the framework of the Panta Rhei Research Initiative of the International Association of Hydrological Sciences (IAHS) by the Working Group "Sustainable Water Supply in an Urban Change".

The impact of climate change, increasing water demand through industrialisation and population growth in Iran significantly reduce available water resources. In such conditions the most attention is paid to water supply but not enough to the quality of water. For example, the use of industrial waste water for irrigation can become one of the solutions for solving water supply issues. On the other hand, not considering water quality can cause many problems in the future. In this study we have measured the Cu concentration in soil and different parts of barley and wheat (root, stem and grain) which were irrigated by the waste water of Alborz industrial city in the Qazvin Province. The results have been compared with the samples' from the near field, which was irrigated by the clean water. The amount of Cu in the wheat soil, barely soil, grain of wheat and barley in the waste water irrigated field was 2.3, 1.04, 1.7 and 1.32 times more than permissible level, respectively. The ratio of the measures of Cu concentration in soil, root, stem and grain of barley and wheat in the waste water irrigated field to those of the clean water has been calculated. This ratio for soil, root, stem and grain of wheat is 5.67, 1.31, 3.5 and 4.41 and for barley 2.3, 3.28, 2.21 and 2.08, respectively. Although at the time of sampling the waste water had a good quality, the results have shown a significant difference between two fields because of the polluted soil. This proves that quality issues should be taken into account along with quantity.

IAHS (Hydrology)

HW08p - HW08 Water Security in a Changing World

HW08p-156

Water security at spratly islands in context of climate change: Managing of groundwater quality

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This paper presents results on impacts of climate change to groundwater quality of the Project “Studying the impact of the sea level rise by global climate changes of Spratly archipelagos” and some adaptive solutions such as rain-water harvesting or infiltration galleries for protecting and managing groundwater quality.

The study area includes very small coral islands with their elevations are from 2 to 6 m a.s.l . The upper geological structure of these islands are the same: the surface layers are mainly composed of friable coral, the rainwater will be osmotic into the deeper layers, it only a bit can make small flow on the surface layer. The geology structure affects strongly the rain-water collection and accumulation. The hard coral structure can’t osmotic and storage rain-water, only the friable coral sand and the crumbing coral have a certain porosity which can observer and accumulate rain-water. The ground water only can be found at the friable coral layer or weathering-coral have a big porosity, distributing from the surface to the depth of 6-8 m. The form of ground water occurs in the form of ‘freshwater lenses’, static water level fluctuates from 0, 4-1,5 m, depends on the season and tidal regime.

Based on results of chemical and stable isotope analysis of water samples, hydrogeological and geophysical investigations characteristics of water resources and situation of groundwater quality at Spratly islands shown that: salinity in the groundwater is increasing and water type also changed.

Amount of rain-water will be harvested around 100,000 – 120,000 m^3/y, that is a very precious source as artificial recharge or supplying domestic needs on these islands.

IAHS (Hydrology)

HW08p - HW08 Water Security in a Changing World

HW08p-157

Evaluation on adaptive capacity of water resources to climate change in Haihe River basin, China

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Over the past century, global climate change has become warming, which is affecting the water resources security especially in the water shortage areas. A framework of adaptive capacity of water resources to climate change evaluation based on hydrologic model droved by climate change scenario is outlined and applied in Haihe River basin. The evaluation indicator system is identified and categorized including the area water resources factors, social and economic development factors, infrastructure factors and emergency management factors, as well as engineering measures and non-engineering measures. The weight of each indicator is calculated using the method of Analytic Hierarchy Process(AHP), and adaptive capacity grade is calculated using fuzzy mathematics. Results show that the adaptive capacity of water resources in Haihe River basin is low under the current situation. With the future climate changes and human regulation including inter-basin water transfer, water-saving etc. although the water demand is increasing, the grade of adaptive capacity to climate change is general for the 2020 scene. Respectively, the results imply that the regulation and control measures can improve the water resources conditions of Haihe River basin.

IAHS (Hydrology)

HW08p - HW08 Water Security in a Changing World

HW08p-158

Sustainability of contaminated aquifers and virtual groundwater loss

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Aquifers in semi-arid regions with higher exploitation rates are most vulnerable to storage depletion and quality degradation. There are numerous studies assessing of groundwater storage but very few are available integrating impacts of both the storage depletion and quality deterioration. In this study, we assessed the impact of contamination on a highly over-exploited watershed as well as virtual loss of groundwater from the aquifer system. This study is carried out in the Maheshwaram watershed, a typical representative of hard rock watershed in Southern India having geological structures like dolerite dykes, pegmatite and quartz veins, granite outcrops. This is an over-exploited watershed, experiencing a fast land use change and urbanization. The watershed is divided into three homogenous zones as analysed from the bore well study, providing a better estimate of groundwater budgets and avoids distortions. The methodologies used are process based auto-regressive method for water level prediction, lithologically constrained rainfall method for estimating recharge, double water table fluctuation for estimation water balance and dilution equation for estimating contaminated groundwater volume. The long term groundwater balance (~20 yrs) is assessed. The volume of the fluoride contaminated groundwater is also quantified, and used to re-assess the groundwater balance and estimate the virtual loss of groundwater from the system due to quality degradation. The revised groundwater balance acts as an indicator to analyse the combined effects of groundwater over-exploitation and contamination on the groundwater resource. The study shows that assessment of virtual groundwater loss can act as a key factor in securing and managing over-exploited contaminated aquifers.

IAHS (Hydrology)

HW08p - HW08 Water Security in a Changing World

HW08p-159

Analysis of the water supply and demand under drought conditions in the Guayllabamba river basin, Ecuador

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The upper part of the Guayllabamba river basin is located between 1000 masl and 5890 masl. Its water resources are used for hydropower generation, agriculture and drinking water for the city of Quito (Ecuador), which has a population of about 2.5 million people. Agriculture currently represents 70% water consumption of the basin. Climate change is expected to increase the frequency of warm and dry conditions over the tropical Andes. The basin has experienced drought conditions in the past, but in the future such conditions will be more difficult to deal, due to increase the demand linked to population growth, so that the implementation of agricultural development policy is required to reduce the vulnerability of agricultural and ecological systems. Under this physical and socio-economic development scenario, we present an analysis of historical and future drought conditions in the basin, considering the evolution of the demand in time. This allows us quantify its impact over the different water use sectors that compose the Guayllabamba system. It is paramount to represent in the model the monthly regime of the agricultural requirements into the basin, and also to explore the impact of future climate scenarios obtained from GCMs over the water distribution in the system. The results obtained in this study can provide useful information for water practitioners who have to plan how to deal with extreme drought condition into the future.

IAHS (Hydrology)

HW09a - HW09 Hydrology Education in the Classroom

IUGG-0012

Hydrology education through national science foundation project: The boat of knowledge in science classroom

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The Boat of Knowledge in Science Classroom (BooKS), funded by National Science Foundation, aims to enhance and broaden science and engineering education of graduate fellows at Ohio University and improve STEM (Science Technology Engineering Mathematics) education in high schools. Each year, nine graduate students will work with nine high school teachers to conduct on-boat hydrological samplings and experiments related to their research along the Ohio River from Marietta to Gallipolis in Ohio. Inquiry-designed activities have been documented to build a virtual Boat-of-Knowledge for environmental and hydrological education. Through activities of the project, the graduate students and the participating school teachers will engage in real-world interactions with environment and develop sustaining enthusiasm in hydrology. The participating high school students will experience increased interest and effectiveness of learning in science courses by hands-on water sampling on the river boat and activities of the virtual Boat-of-Knowledge. The project has resulted in significant impacts on the hydrological science education of high school teachers and students in the economically and educationally depressed region of the Ohio River by bringing their most familiar environment, a neighboring river, to their classrooms. We have strengthened the graduate education at Ohio University to sustain partnerships with local school districts. We plan to make this as a model for the learning community on both graduate and high school education.

IAHS (Hydrology)

HW09a - HW09 Hydrology Education in the Classroom

IUGG-0195

Water policy and legislation in malawi education system (HW09)

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University of Malawi has been long standing institution which offer undergraduate degree in water engineering and management. This program has for so long known to be only for engineers and scientist like hydro-Geologist and hydrologist without policy makers involved and has resulted in poor water management.

Though this programme was offered water problems seems not to disappear this was so since many water engineers and scientist were only trained in how to develop water systems and irrigation systems and borehole installation and development. The water engineers and scientist didn't recognise water policies and legislation .result many agricultural irrigation system were set up which but were only design just to make profit without considering water policies and legislation not because they had knowledge but they didn't learn it in classroom and they fail to advise agricultural companies on how develop agricultural system depend on legislation which government has put in place.

Second thing is make water engineers in government department that looks on issue of water management are not trained in water policies but they are employed to enforce laws and legislation on water policy result they are not properly managed. So it's very important for hydrology education has to include Water law and legislation as part of curriculum from undergraduate as a compulsory module.

IAHS (Hydrology)

HW09a - HW09 Hydrology Education in the Classroom

IUGG-2943

Sand-box model as a toll to enhance the knowledge of groundwater dynamics

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The knowledge about groundwater dynamics between people that are not professionally deal with geology is weak. It has turned out that knowledge is mostly based on the experience than on understanding of a regional groundwater dynamics. Therefore, we believe that it is worth to start a systematic education on groundwater dynamics and pollution not only for geologists but also for general public. In cooperation with Geological Survey of Slovenia we developed an educational sand-box model of the Ljubljana polje aquifer, which will be used to spread knowledge on ground- and drinking water.

The model of an inhomogeneous and anisotropic intergranular aquifer has predominately a two-dimensional water flow. It enables visualisation of natural features and anthropogenic on the quantity and quality state of the stored groundwater. It can be used to explain hydrogeological phenomena on various levels of knowledge, from simple visualisation to more complicated mathematical descriptions.

We recorded a movie, which shows the operation of the model and it could be presented on 26th IUGG general assembly.

IAHS (Hydrology)

HW09a - HW09 Hydrology Education in the Classroom

IUGG-3317

Are female students less self-confident in their skills and what can we do about it?

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In the past three years the first author has conducted a self-assessment test at the end of his written examinations in the MSc level course Fluvial Systems with the aim to understand if students correctly perceive their level of knowledge and thereby to improve my teaching. The course covers theoretical, conceptual and modelling concepts of sediment production, transfer, and landscape change from hillslope to river network scales, and is representative of the expectations in a typical graduate level course in hydrology and earth sciences at any university. The results brought up a number of unexpected findings, most importantly a significant signal that female students underestimate their own skills and performance compared to male students, despite the fact that their actual performance is practically identical. A review of psychology and education literature showed that this is in fact a known problem, a general lack of self-confidence in women which manifests itself in many ways in society and in particular the professional world. We are wondering: Are we doing our best as educators to promote self-confidence in female students? What are the education tools available to reach this goal (e.g. gender-mixed group work, peer-discussion, better testing methods, etc.)? In other words, how do we ensure that female graduates in hydrological programmes truly enter the working world as confident and self-aware candidates for their jobs, which they are. In this paper we will present the data collected from the self-assessment exercise at ETH and the analysis thereof; and then we will present some thoughts on possible solutions to promote self-confidence with simple, easily implementable tools in the classroom, as a basis for discussion.

IAHS (Hydrology)

HW09a - HW09 Hydrology Education in the Classroom

IUGG-4625

Establishing the cathedral peak research catchments, South Africa, as a living laboratory

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Given the uncertainty surrounding environmental change and its related impacts on hydrological responses there is an imperative to improve our understanding of the movement of water within catchments and the effect of changes in the drivers of the hydrological system and to ensure that a new generation of hydrologists benefit from this understanding. This will enable the development of resilient and adaptive water management strategies to minimise the risks to and maximise the benefits from the potential impacts of environmental change.
In South Africa,the South African Environmental Observation Network (SAEON) have recently re-established the monitoring of four long term research catchments at Cathedral Peak in the important water producing mountains of the Drakensberg. Working in collaboration with several local organizations, these historic research catchments have now been established as living laboratories for long term monitoring and hence understanding of water movement, and provide a focus for training for undergraduate through to postgraduate students.
Progress on the reestablishment of monitoring, use of the catchments in teaching and training in hydrological process studies, state of the art monitoring techniques (such as the Cosmic Ray Soil Mositure probe) and the planned long term research will be highlighted in the paper

IAHS (Hydrology)

HW09p - HW09 Hydrology Education in the Classroom

HW09p-160

Development and application of Hydrologic Climate change Assessment Tool (HydroCAT)

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With the Intergovernmental Panel on Climate Change (IPCC) publishing Climate Change Assessment Reports containing updated forecasts and scenarios regularly, it is necessary to also periodically perform hydrologic assessments studies on these scenarios. The practical users including scientists and government people need to use handy tools that operate from climate input data of historical observations and climate change scenarios to rainfall-runoff simulation and assessment periodically. We propose HydroCAT (Hydrologic Climate change Assessment Tool), which is a flexible software tool designed to simplify and streamline hydrologic climate change assessment studies with the incorporation of: taking climate input values from general circulation models using the latest climate change scenarios; simulation of downscaled values using statistical downscaling methods; calibration and simulation of well known multiple lumped conceptual hydrologic models; assessment of results using statistical methods. This package is designed in an open source, R-based, software package that includes an operating framework to support wide data frameworks, variety of hydrologic models, and climate change scenarios. The use of the software is demonstrated in a case study of the Geum River basin in Republic of Korea.

IAHS (Hydrology)

HW09p - HW09 Hydrology Education in the Classroom

HW09p-161

On the future of hydrology education in the engineering classroom

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A thorough understanding of the hydrosphere is crucial for the sustainable evolution of human society and the ecosystem in a rapidly changing world. This understanding can only come from well-trained professionals in the field of hydrology working in research and practice. In civil and environmental engineering, this knowledge is the basis for the design of infrastructure and for its management. The twentieth century was characterized by the establishment of a vision for hydrology education as a distinct formal program of study in the 1950s and 1960s, and its consolidation in the 1990s. In recent years, different educators have expanded this traditional vision of hydrology education. This recent literature emphasizes formalized approaches to hydrology education, including community-developed curricular resources, data-based and modeling-based curricula, formally assessed pedagogies, and formalization of nontraditional pedagogies. Several challenges for hydrology education in the 21st century emerge from these findings. Central themes of these challenges for hydrology education are the development of international hydrology education communities and networks, shared learning technologies—partially driven by the need for a more mechanistic approach to engineering hydrology, formalized and validated pedagogies, and adaptations of international best educational practices to regionally specific hydrology and socioeconomic context.

IAHS (Hydrology)

HW09p - HW09 Hydrology Education in the Classroom

HW09p-162

Assessing climate station accuracy across Canada: A study in climate science and student involvement

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Over the past 20 years, the numbers of climate monitoring stations used for weather forecasting across Canada has declined from ~9000 (in the early to mid-1980's) to ~1500 stations. This has reduced forecast accuracy in many parts of Canada, which is of grave concern as weather events and anomalies are predicted to become more severe with increases in atmospheric energy and climatic warming. In light of this, the Canadian Federal Government (January 2015) decided to fund the re-instatement of new climate stations over the next few years. The objectives of this study are two-fold: 1) to monitor divergence between measured and predicted weather over a one-week period at sites throughout Canada in the form of a residual grid (per day and via a cumulative index) prior to increased federal spending; and 2) to enlist the help of undergraduate students within a long-term monitoring project spanning years to decades. The results of this study will form a baseline from which future student-based involvement studies in weather forecasting can be compared. Further, analysis of gridded residuals provide a visual assessment of spatial patterns that are easily recognisable to both students and scientists. Finally, it is hoped that this type of exercise will promote interest and awareness in physical geography and environmental science and will empower students to think critically about their place in the environment and their contribution to science.

IAHS (Hydrology)

HW10a - HW10 The Role of Sediment as an Indicator of Hydrological and Societal Change

IUGG-0199

Sediment transport due to hydroclimatic development and anthropogenic impacts: case study of Selenga-Baikal catchment

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The present research considers the unregulated Selenga River which contributes about 50 % of the total inflow into Lake Baikal. Elevated sediment-associated chemical concentrations reported for the area tend to fall into one of two categories: those associated with soil/petrologic anomalies or those associated with anthropogenic inputs. The latter is related to mining, industrial and agricultural activities within the Selenga drainage basin which affect sediment transport. At the same time, the region is reported to experience the water runoff decrease with acceleration since the 1970s. The key question for the understanding regional environmental change is to disentangle the influence of climate change from that of other changes in catchment.

The study is based on novel screening campaigns were conducted in June–August 2011-2014. Discharge and suspended sediment concentration (SSC) data were combined to yield estimates of daily and monthly water discharges, suspended load averages at more than 150 locations. All samples (suspended and streambed sediments and filtered water) were analyzed for 62 elements by inductively-coupled plasma mass spectrometry ICP-MS (ICP-AES). Results indicate that high sediment loads were reported both for altered and natural rivers. Reported multi-decadal declines in sediment loads in the downstream part of Selenga River can be attributed to the abandonment of cultivated lands and changing hydroclimatic factors. Elemental composition of the mass flows mostly relate to the soil/petrologic conditions. With the exception of small impacted rivers where water quality impacts associated with mining were found, the formation of elemental compositions and sediment-associated chemical constituents generally reflects catchment characteristics.

IAHS (Hydrology)

HW10a - HW10 The Role of Sediment as an Indicator of Hydrological and Societal Change

IUGG-0859

Flash floods: the laws of origin, dynamics and distribution

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Flash flood is one of the less-explored natural hazards over the world. Though there is already a number of studies conducted in different areas to investigate local factors and basic characteristics of the process itself. Most works focus on special hydrologic features distinguishing flash flood from the other flood types, and on local sediment redistribution due to this extreme event. At this moment there is a need to compare and unite the available information for better understanding flash floods factors, process dynamics, distribution and risk assessment over the globe. There is also a possibility to start solving this problem as the necessary database is already collected. This work is mainly a review and generalization of accessible flash flood studies conducted and published up till now by different scientific groups worldwide. A classification of flash floods triggered by various patterns of factors was made. There are also correspondences between local conditions and the process intensity, frequency and dynamics found. The generalized map of flash flood distribution was made, and the most susceptible territories distinguished over the world. A significant part of our study was focused on the role flash floods play in sediment redistribution in different areas. Special attention was paid to flash floods in Russia where by now this process is almost not studied at all. The first results of our field studies of the processes factors and mechanisms are discussed for the mountainous humid subtropics of the Black Sea coast with a comparison of local types of flash floods with the other types of the process.

IAHS (Hydrology)

HW10a - HW10 The Role of Sediment as an Indicator of Hydrological and Societal Change

IUGG-1533

Seasonal variations of rainfall-runoff erosivity and soil erodibility in the Muskingum Watershed in Ohio, USA

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This study utilized geographic information system to estimate soil erosion in the selected months to examine seasonal effects of rainfall-runoff erosivity and soil erodibility for the Muskingum Watershed in Ohio, the United States of America. The Revised Universal Soil Loss Equation (RUSLE) is popular for the estimate of annual soil erosion average for a watershed based on six parameters including rainfall-runoff erosivity (R) and soil erodibility (K). This study applied the RUSLE model in the Muskingum Watershed using monthly R and K values to estimate selected monthly erosion values and compare them with annual average estimates that were previously studied in the same watershed. It further developed and identified monthly erosion hotspots and compared them with their annual counterparts. From the results of this study, it was discovered that effects of rainfall-runoff erosivity and soil erodibility are significantly varied from month to month for the estimation of watershed erosion. Monthly erosion estimates for the Muskingum Watershed are 0.28, 0.27, 0.05, and 0.02 kg/m^2, respectively, for May, June, September, and October, while the annual average estimate was 0.29 kg/m^2. Based on the definition of erosion hotspots developed, it was further found that the monthly erosion hotspots were mostly located at the same region of the annual erosion hotspots.

IAHS (Hydrology)

HW10a - HW10 The Role of Sediment as an Indicator of Hydrological and Societal Change

IUGG-1599

Human impact on the global sediment budget

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The land-ocean sediment flux provides a key measure of land denudation. It also exerts an important control on global geochemical cycling. It must therefore be seen as an important component of the Earth system. There is increasing evidence that the sediment loads of the world's rivers are changing in response to a number of human-induced drivers which can result in both increases and decreases in sediment load. Changes will also have occurred in the past in response to human impact. The extent to which the land-ocean sediment flux and the associated global sediment budget have been perturbed by past and recent changes in river sediment loads in response to human impact remains uncertain. Existing attempts to establish the global sediment budget provide conflicting evidence regarding the likely magnitude of the perturbation. Current estimates of the amounts of sediment currently being sequestered behind dams differ by an order of magnitude or more. This in turn introduces uncertainty regarding the extent to which the sediment flux has been increased over the background of 'natural' level. These uncertainties will be explored further.

IAHS (Hydrology)

HW10a - HW10 The Role of Sediment as an Indicator of Hydrological and Societal Change

IUGG-1624

Using 137Cs and 210Pbex to explore the effects of climate change on sediment redistribution within two catchments in Southern Italy

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In recent years, increasing attention has been directed to the impact of human activity and climate change on the hydrological response of drainage basins, including sediment fluxes. Changes in sediment flux can have important implications for river channel stability and reservoir sedimentation, as well as for aquatic ecology. It is frequently difficult to separate the impacts of human activity and climate change and new approaches are required to assist with this. This contribution reports a study where the aim was to isolate the effects of climate change from those of other human impacts and to establish the importance of recent climate change in causing changing in rates of soil redistribution within two small catchments in Southern Italy. Measurements of the fallout radionuclides ^{137}Cs and $^{210}Pb_{ex}$ have been used to document sediment redistribution rates in two forested catchments where no significant change in land use has been documented since the early 1950s. Comparison of the results provided by the two fallout radionuclides provides a basis for identifying recent changes in soil redistribution rates. For the Alaco catchment (14.8 km^2), the results provided by the $^{210}Pb_{ex}$ measurements indicate higher soil redistribution rates than those documented using the ^{137}Cs measurements, suggesting that soil redistribution rates have increased in recent years. These findings are consistent with the trend of increasing annual erosivity documented in that area during the last 20 years. In contrast, no significant change in erosion rates was found in the Melito catchment (41.3 km^2), where no trend in rainfall erosivity was detected.

IAHS (Hydrology)

HW10a - HW10 The Role of Sediment as an Indicator of Hydrological and Societal Change

IUGG-3307

Sand sheets as part of fining upwards sequences as indicators of hydrological and societal change in the Sydney basin, Australia

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Fining upwards sequences up to 1 m thick of a basal sand sheet capped by a muddy sand bed form a large part of Holocene fluviatile sediments in the northern Sydney Basin, Australia. This is illustrated for Wollombi Brook and Macdonald River. The area is characterised by high flood variability by world standards and the basal sand sheets are formed by deposits of a single large flood whereas the superposed muddy sand units are formed by many succeeding smaller floods. Occasionally large channel-fills are formed by channel incision of the fining upwards sequences and backfilled by thick cosets of trough cross-laminated granular coarse sands. These fining upwards sequences have continued to form since European settlement. While Aboriginal firing has been invoked as a potential cause of valley infilling with sand, the sand sheets are almost charcoal free and have been formed in essentially fire-free environments. The recurrence of repeated large floods throughout the Holocene indicates that this area has been sensitive to flood impacts throughout the last 10000 years at a time of Aboriginal intensification. Further sedimentological and geoarchaeological research of these valley fills is required to explain the interactive effects of Aboriginal fire, Aboriginal intensification and catastrophic floods.

IAHS (Hydrology)

HW10b - HW10 The Role of Sediment as an Indicator of Hydrological and Societal Change

IUGG-3480

Long term impacts of severe wildfire and post-fire salvage logging on sediment production in the Oldman River Basin, Alberta

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There is increasing global awareness of large scale landscape disturbance by wildfire and its impacts on hydrological processes that influence the mobilization, transport and fate of sediment in terrestrial and aquatic environments. Here we report on the long term impacts of the Lost Creek wildfire on sediment production in the headwater regions of the Oldman River Basin, Alberta. Seven small watersheds with varying levels of land disturbance (burned, post-fire salvage logged, unburned) were instrumented and monitored for ten years to measure stream discharge, sediment concentration and sediment yields for a range of dominant flow periods characteristic of the region (baseflow, spring melt, and stormflow). Annual and seasonal stream flow are related to runoff regimes that are characteristic of precipitation patterns in high relief physiographic settings. Over the ten year study period, both suspended sediment concentrations and yields were significantly higher in burned and post-fire salvage logged watersheds compared to reference (unburned) watersheds. Topographic and hydro-climatic controls strongly influenced sediment production. In burned and post-fire salvage logged watersheds, sediment availability was significantly higher than in reference watersheds but it also varied strongly with flow condition (baseflow, storm flow, snowmelt freshet). While several previous studies indicate recovery in sediment production within a few years post fire, no recovery has occurred in the headwater regions of the Oldman River Basin impacted by wildfire.

IAHS (Hydrology)

HW10b - HW10 The Role of Sediment as an Indicator of Hydrological and Societal Change

IUGG-4128

Gully erosion responses to past and current land management in a tropical savannah

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The morphology of drainage channels can be highly responsive to upstream land management, resulting in long-lasting changes in the magnitude and dynamics of catchment sediment yield. In particular, gully erosion is a dominant sediment source in many catchments following landuse intensification. Understanding the behaviour of gullies can indicate their significance as a land management issue. Gully sediment yield can decay as the catchment area upslope of incised channel headcuts declines through network extension. However, as the area of gully features grow, increased rill and side-wall mass failure can counteract declining yield from headcuts. Thus there is a need to understand the sediment yield trajectories of different gully systems at decadal scale. Land management also affects ongoing gully sediment yields at event to annual timescales by influencing surface vegetation cover and runoff volumes.

We investigated the decadal erosion rates of established gully networks in a tropical river catchment in northeast Australia over 65 years using air photo interpretation. We also investigated the dependence of annual gully sediment yields on surface runoff by monitoring headcut and sidewall retreat over 10 years. Results indicate that gully erosion can remain an important sediment source for decades to centuries following landuse intensification. In gullied landscapes the hydrological effects of land management are amplified in the sediment yield signal. Ongoing sediment yields of established gully systems can be highly dependent on surface runoff volumes, contributing to river basin sediment load dynamics. Managing surface runoff may thus be a way to influence sediment yields in gullied landscapes.

IAHS (Hydrology)

HW10b - HW10 The Role of Sediment as an Indicator of Hydrological and Societal Change

IUGG-4239

Importance of tile drainage and tillage practices in modifying phosphorus losses from agricultural fields in temperature climates with severe winters

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Agricultural systems are a source of pollutants to downstream water bodies, leading to the degradation of water quality in these systems. This has implications for the environment, human health and the economy. Excess phosphorus (P) levels have been associated with increases in the frequency of Harmful Algal Blooms in many freshwater lakes. Changing land management practices such as tile drainage, tillage and P application method and timing can affect the transfer of both dissolved and sediment-bound P in the environment during runoff events. This is particularly important during the spring snowmelt period in regions with severe winter conditions. The objective of this presentation is to demonstrate the impacts of tile drainage, tillage practices and P application on runoff and dissolved and particulate P mobilization from agricultural fields in the Great Lakes region of Canada. Results demonstrate that annual losses are dominated by winter thaws/spring snowmelt period, although spring and autumn storms can also be significant, particularly following P application. Sediment-P losses in tile drain effluent are reduced and dissolved P losses are unaffected under no-till management relative to tilled plots at our sites. Although we observed P losses in tile drain effluent at our sites, these losses were very small in comparison to P losses in overland flow. These findings are important as they shed light on the role of various agricultural management practices in affecting sediment and dissolved P losses in temperature climates with severe winter conditions.

IAHS (Hydrology)

HW10b - HW10 The Role of Sediment as an Indicator of Hydrological and Societal Change

IUGG-4745

Sediment storage in slope buffer zones – filling the gaps in sediment budgets and indicating land use changes

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Despite the several decades of successful application of a sediment budget concept, there are still some gaps requiring attention. One is sediment storage in slope buffer zones which separate boundaries of arable fields from each other or from uncultivated valley sides. The most widespread is plough terrace formed along the lower field boundary initially by aggradation of soil from mechanical translocation of plough layer by tillage implements. Other widespread types of buffer zones include forest belts, hedgerows and stone walls. Sediment storage in such zones is difficult to model. It is therefore in most cases considered in very general terms during sediment budget construction. This work presents an approach using both field-based techniques and remote sensing for filling this gap. In addition, investigating sediment storage in buffer zones can add a new perspective for land use change reconstructions. For example, remnants of plough terraces are often visible. However, how long the particular field boundary existed is difficult to determine. Investigations of sediments stored within the buffer zone can bring some insight on duration of the particular plough terrace active existence. Under certain circumstances previously existing boundaries of smaller parcels remain detectable within the enlarged field, allowing reconstruction of the previously existing structure. It is also possible that in some cases sedimentation changes in buffer zones can indicate climatic events. For example, large plough terraces can be cut or overflown only by runoff formed by extreme events, indicated by sediment fans or aprons formed in such cases. Several examples of the situations described above and general outcomes of those are discussed.

IAHS (Hydrology)

HW10b - HW10 The Role of Sediment as an Indicator of Hydrological and Societal Change

IUGG-4841

The impact of urban processes on suspended sediment transport systems: a challenge for the 'First-Flush' model

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Over 50% of the world's population urbanised, and projected to rise to 60% by 2020. It is vital, therefore, that we develop understanding of how urban processes and hydrological change impact on water and sediment transport dynamics and pollution systems. However, little is known of the dynamics of storm-event sediment and pollutant transport to urban rivers. It is often assumed that most pollutants are delivered early in the storm – the 'First-Flush' effect, an idea also embedded in some numerical models.

This paper addresses these research gaps and challenges the First-Flush Model, by presenting high-resolution hysteresis analyses of key water quality datasets, including storm-event Turbidity, Sediment Concentration, Ammonia, Conductivity and stream power for the highly-urbanised (42% urban) River Tame basin in Birmingham – UK's second-largest city. Two water quality monitoring stations (upstream / downstream) generated one of the most detailed fluvial water quality monitoring programmes ever established. A simple Hysteresis Index was developed to quantify the magnitude and direction of hysteretic response patterns for 73 events.

Peak turbidities were high for urban rivers. Crucially, in 90% of storm events, turbidity peaks occurred after river flow peaks - anticlockwise hysteresis - contrary to the First-Flush model. Of 10 hypotheses tested, 3 are especially focused on here: (a) Combined Sewer Overflow surcharges; (b) delayed bed sediment destabilization effects (with a new BASS - Biofilm Adhesion of Sediment Supplies model); (c) road-derived particulates generated by some of the heaviest traffic loads in Europe. This unusual storm behaviour suggests that urban impacts are much more significant and complex than thought, as discussed in a 'Senile Cities' model.

IAHS (Hydrology)

HW10b - HW10 The Role of Sediment as an Indicator of Hydrological and Societal Change

IUGG-5078

Transformation of suspended sediment yield under the influence of volcanic eruptions (Kamchatka, Russia)

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Volcanism is a unique factor of suspended sediment yield formation in Kamchatka. Volcanic eruptions are the constant source of friable volcanic deposits such as ash, pyroclastic deposits in river basins. They influence on variability of suspended sediment yield characteristics (such as suspended sediment concentration, suspended sediment flux, specific suspended sediment yield and grain-size of suspended sediments) in diurnal, seasonal and long-term spatial-temporal scales. The main goal of this research is the study of volcanic activity impact on suspended sediment yield characteristics variability in different spatial-temporal scales. The study is based on sediment discharge monitoring in Kamchatka rivers under the influence of volcanic eruptions. It also includes fieldwork data in 2003 – 2012 in selected rivers draining the flanks of active volcanoes.

The main factors of suspended sediment yield formation in rivers of volcanic regions are water flow, catchment area and distribution of friable volcanic deposits. Regions of modern volcanic activity in Kamchatka are characterized by maximum values of potential soil loss, mean annual suspended sediment concentrations and specific suspended sediment yield. Volcanic eruptions have substantial influence on suspended sediment flux of rivers and can lead to its increase up five-fold after eruptions. Seasonal fluctuations of suspended sediment yield characteristics depend on water regime. Diurnal variability of these characteristics in rivers draining flanks of active volcanoes is defined by snow melt and precipitation. Water regime of rivers is characterized by periodic extinction of surface flow and significant underflow because of high infiltration rates into friable volcanic deposits there.

IAHS (Hydrology)

HW10p - HW10 The Role of Sediment as an Indicator of Hydrological and Societal Change

HW10p-163

Area-storage capacity curves of Mosul Dam, Iraq using empirical and semi-empirical approaches

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The storage capacity of the reservoirs is gradually reduced due to sediment accumulation that causes shifting in area-capacity curves (or stage-water surface area curve and stage-storage capacity curve). The area-capacity curves are very important for many aspects. Determination and shifting prediction of these curves are an important issue for planners, designers and operators of dams. Many empirical and semi-empirical approaches were suggested for determining these curves. In this study four methods were reviewed and presented to determine the area-capacity curves of Mosul reservoir that is the biggest hydraulic structure on the River Tigris, north of Iraq. The dam was start in operation in 1986 with storage capacity 11.11 km^3 and water surface area 380 km^2 at normal operation stage 330 m a.s.l. The results of these methods evaluated by testing against observed bathymetric survey data that have be conducted after 25 year of dam operating.

IAHS (Hydrology)

HW10p - HW10 The Role of Sediment as an Indicator of Hydrological and Societal Change

HW10p-165

Overbank sedimentation as indicator of antropogenic influence on the river environment

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It is well-known that floodplain sediments deposited during overbank floods has been used to reconstruct past changes in sediment sources, to provide information on changing sediment fluxes and to evaluate the antropogenic influence on the river basin. This presentation reports the use of sediment cores collected from the River Niida floodplains to provide information on evaluation of human impact on sediment and sediment-associated pollutants redistribution and river environment in River Nitta basin affected by radionuclide contamination in the NE part of Honshu Island in Japan after Fukushima Dai-ichi NPP accident in 2011. Detailed study of ^{137}Cs vertical distributions curves in floodplain soils were carried out at different levels of the floodplain to 7 sections, located across the River Niida fluvial network. The River Niida drains a mountainous region with mostly forested slopes in the upper and middle parts of basin and piedmont plain near the Pacific Ocean in the lower part of basin. Wide valley bottoms of the upper part of the basin are mainly used as paddy fields. After radionuclide contamination of upper part of the basin, all rice fields were abandoned and the recent work carried out on decontamination. The lower part of the basin is still being used in agriculture. In the upper part of the basin river streams were canalized, and the earthen levees were built along the streams in the lower part of the basin. Floodplain deposition rates are significantly controlled by human influence and may explain the local impact of natural and anthropogenic factors on the environment of the river. Finally it is discussed the differences of human activity impact on the river environment between the River Niida and the River Plava, located in the Chernobyl contamination zone

IAHS (Hydrology)

HW10p - HW10 The Role of Sediment as an Indicator of Hydrological and Societal Change

HW10p-166

Grain-size distributions of debris flows deposits at the Motozintla basin, Mexico: An evidence of natural hazard for the town

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Alluvial deposits as fans and terraces develop in diverse regions responding to different climatic conditions and tectonic environment. The Motozintla basin is located in the State of Chiapas, southern Mexico. The evolution of the Motozintla basin is related to intense erosion by hydrometeorological events, fault movement and anthropogenic activity. Recent catastrophic floods affected Motozintla in 1998 and 2005 induced by extreme hydrometeorological events. This study deals with the granulometric analysis and geomorphology of the alluvial plain of Motozintla that exposes 31 alluvial fans. Fourteen of these are exposing their internal stratigraphy made of debris flow deposits, paleosols, fluviatile beds, and pyroclastic fallouts. The reconstruction of the stratigraphy assisted by radiocarbon geochronology suggests that at least 10 events have been recorded at the fans´ interior during the past ~1840 years. Therefore, we analyzed the internal structure of these fans with particular interest in the granulometric distribution of the samples to understand their genesis. The parameters calculated for these analyses include: the median (Md), mean (M), sorting ($\sigma\varphi$), skewness (sk) and kurtosis (k). The debris flows have a Md between -5φ and -1φ, and a standard deviation ~2.8 (very poorly sorted). Instead, hyperconcentrate flow deposits have a Md between 1φ and 8φ and a standard deviation ~0.4 (well sorted). These parameters are similar with respect to the 1998 and 2005 flood events and similar from typical volcanic counterparts. Our results suggest that Motozintla has been exposed to several hydrometeorological events during the past ~1840 years that nowadays represent a serious hazard and threat to the inhabitants of the region.

IAHS (Hydrology)

HW11a - HW11 Fingerprinting Techniques: Evaluating Methodological Approaches, Problems and Uncertainty

IUGG-0204

Sediment fingerprinting: not quite ready for prime time!

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Sediment fingerprinting is used to identify the provenance of actively transported sediment; it also is used to target remediation to reduce erosion and subsequent sediment delivery to rivers. The expansion of the discriminatory properties used for source ascription may improve the results, but also increases the application costs. Even so, the uncertainties associated with fingerprinting are substantial (frequently ±100%), and may make this approach no better than best professional judgement.

Current fingerprinting evaluations indicate several factors that contribute to the causes of the large errors/uncertainties associated with the method. These need systematic investigation to determine their relative significance. Obvious sources of uncertainty include: 1) sampling errors; 2) analytical imprecision; 3) the potential non-conservative nature of the properties used in source ascription whilst sediment moves through a fluvial system; and 4) the various statistical/modelling approaches used to generate source ascription. These investigations may be possible using data sets available from prior fingerprinting exercises. Regardless, a systematic evaluation of the sources of error/uncertainty associated with the technique is long overdue.

The reliability of the method also is confounded by: 1) a lack of long-term monitoring data to evaluate source apportionment and/or the efficacy of targeted remediation; and 2) errors associated with hydrologic monitoring are typically ±20%, hence, declines in erosion have to exceed that range to ensure a significant

improvement. As detectable improvements may take years, evaluations of remedial measures based on fingerprinting require a long-term commitment to post-application hydrologic monitoring and repeated source apportionment.

IAHS (Hydrology)

HW11a - HW11 Fingerprinting Techniques: Evaluating Methodological Approaches, Problems and Uncertainty

IUGG-0696

The identification of uncertainties when using mineral magnetic signatures to fingerprint historically deposited sediment sources in the Karoo, South Africa.

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Mineral magnetic signatures have been shown to discriminate between sediment sources on the basis of geology, soil formation processes, anthroprogenic activity and post-depositional alterations. However, published literature has shown magnetic signatures to be sensitive to the particle size of soils and sediments, introducing potential uncertainty to their use. The relationships between magnetic signatures and particle size are often complex and processes of magnetic mineral ingrowth and dissolution in soils have been indicated to be particle size specific, Additional uncertainties can arise during sediment transport and storage due, for example, to biogenic and dissolution processes.

This presentation introduces a novel approach to identifying the causes of tracer non-conservatism in historically deposited sediment. Relationships were established between magnetic signatures and seven particle size fractions of potential sediment sources in a semi-arid Karoo region dominated by dolorites and shales. The basis for magnetic discrimination between sources was investigated. The ability of magnetic signatures to discriminate between sediment sources was found to be highly particle size dependent. Strong correlations were found between paired magnetic signatures for soil samples but these were particle size dependent. These relationships were examined for sediment cores taken from farm reservoirs to account for particle size related uncertainty and determine the degradation on the detrital magnetic signature by biogenic and dissolution processes.

IAHS (Hydrology)

HW11a - HW11 Fingerprinting Techniques: Evaluating Methodological Approaches, Problems and Uncertainty

IUGG-1358

Towards identifying and shortlisting potential tracers for sediment source ascription

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The application of sediment source tracing procedures (sediment fingerprinting) has risen dramatically in recent years due to the need to manage/remediate a variety of erosion and subsequent fluvial and lacustrine sediment issues. A growing number of research outputs have tested various tracer groups, statistical tests, numerical modelling algorithms, and corrections/weightings, but the development of generic guidelines for tracer pre-selection for different environments (e.g. fluvial, lacustrine) warrants further attention. Conservatism and strong discriminatory efficiency are two fundamental requirements for sediment source tracers. Accordingly, tracer datasets assembled for various previous research projects have been re-analysed to assess: 1) consistencies in tracer conservatism, and 2) surface and sub-surface source discriminatory ratios (between source group: within source group variance). In combination, these tests provide one means of developing some preliminary guidelines for helping end users with tracer selection for different environments.

IAHS (Hydrology)

HW11a - HW11 Fingerprinting Techniques: Evaluating Methodological Approaches, Problems and Uncertainty

IUGG-1564

Characterizing the fingerprints of surficial sediment sources: Some potential problems and their implications

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Most sediment source tracing protocols assume that it is possible to define characteristic fingerprints for a range of potential sources. In some cases mean values for individual fingerprint properties associated with a given source are used, whereas in others the likely spatial variability of the properties across a given source is explicitly recognised by considering their probability distributions. These approaches effectively assume that fingerprint properties are randomly distributed across a given source. Where systematic variation occurs this can introduce further complexity. This contribution examines the potential problems introduced where fingerprint properties are themselves influenced by the soil redistribution rate at the sampling point and where individual fingerprint properties are correlated. The study focuses on a small (7 ha) cultivated field in Devon UK and explores the complexities involved in defining the fingerprint of its surface soil. A range of potential fingerprint properties, involving both fallout radionuclides and geochemical indicators are considered. The extent to which fingerprint properties directly reflect the soil redistribution rate at the sampling point and are themselves inter-correlated is established. The wider implications of the findings are explored.

IAHS (Hydrology)

HW11a - HW11 Fingerprinting Techniques: Evaluating Methodological Approaches, Problems and Uncertainty

IUGG-1612

Effects of different sampling strategies when using 137Cs and 210Pbex to fingerprint sediment sources in a catchment in southern Italy

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Establishing the relative importance of the primary sediment sources within a catchment is an important requirement for designing and implementing an effective sediment control strategy. Sediment source fingerprinting techniques offer considerable potential for providing such information, particularly when involving the use of the fallout radionuclides (FRNs) ^{137}Cs and $^{210}Pb_{ex}$, which commonly offer a valuable means of discriminating surface and subsurface sources. However, in order to obtain reliable results, it is important that the fingerprints of individual potential sediment sources should be accurately characterized. When FRNs are used as source fingerprints it is necessary to take account of the spatial variability of surface activities. This is particularly the case for uncultivated soils, where activities are commonly inversely related to the erosion rate. Use of random spatial sampling to characterize the fingerprint of surface sources can result in biased source fingerprints and unreliable estimates of source contributions. These issues are explored for a small (41.3 km^2) catchment located in Calabria, Southern Italy, where existing work employing^{137}Cs had already documented the spatial variability of surface erosion rates within the catchment. The impact of using different sampling strategies on defining the fingerprints of surface sediment sources and on the resulting estimates of source contribution are investigated.

IAHS (Hydrology)

HW11a - HW11 Fingerprinting Techniques: Evaluating Methodological Approaches, Problems and Uncertainty

IUGG-4295

Signals of climate variability in sediment fingerprints from a large river basin

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Fingerprinting is a way to monitor variations in sediment source contributions through climate cycles, to improve the understanding of erosion and transport processes. Such information can help to constrain process-based models of sediment transport, and target catchment management actions to reduce sediment yield at a comparable cost to flux monitoring. Once robust source fingerprints are defined, the dynamics of source contributions can be defined by repeated monitoring at only a downstream location of interest. Through multiple fingerprinting studies involving fallout radionuclides in northeast Australia, we have found that the contribution of surface soils is smaller after periods of above-average rainfall than after periods of below-average rainfall, consistent with the effect of variations in vegetation ground cover on erosion processes. This research also developed methods to improve fingerprints using ancillary data on spatial gradients in modelled soil erosion rate.

A geochemical fingerprinting study from the same region has demonstrated the potential to monitor changes in source contributions from different tributary catchments. This study defined seasonal tributary contributions to river basin export comparable to that provided by a network of suspended solids monitoring stations across multiple tributaries, and at comparable levels of uncertainty. By targeting fine sediment fractions, geochemical fingerprinting has improved our understanding of sediment delivery through large dams.

In the age of big data, sediment fingerprinting can play an important role in environmental monitoring networks. It continues to deliver new understanding of erosion and sediment transport processes, and its use to constrain catchment sediment models is becoming more widespread.

IAHS (Hydrology)

HW11b - HW11 Fingerprinting Techniques: Evaluating Methodological Approaches, Problems and Uncertainty

IUGG-0200

Distinguishing sediment sources in a New Zealand catchment using sediment fingerprinting approaches

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Suspended sediment forms an important component of the fluvial channel by changing the chemical, physical and ecological character. It is important to understand what the key sediment sources are within a river catchment, how they are characterized and how they may change in the future. Extensive landuse conversion has occurred in the Manawatu River Catchment from indigenous forests to pastoral agricultural which has changed sediment yields and patterns. This has influenced slope stability and caused widespread mass movements, soil erosion and an increased sediment supply to the river. Discriminating sediment sources within a sedimentary dominated catchment where unique sources are not spatially restrictive provides challenges for classification. Sediment fingerprinting provides an approach capable of directly quantifying sediment delivery through differentiating between sediment sources based on their inherent geochemical signature. In this research discrimination function analysis and principal component analysis of bulk geochemical concentrations of major, minor, trace and rear earth elements using X-Ray Fluorescence and Laser Ablated-Inductively Coupled- Mass Spectra have been employed to differentiate between and understand key sediment sources in the Manawatu River Catchment.

IAHS (Hydrology)

HW11b - HW11 Fingerprinting Techniques: Evaluating Methodological Approaches, Problems and Uncertainty

IUGG-0202

Sediment sources and ages of channel sediment by combining short-lived radionuclides with the sediment fingerprinting approach

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Sediment fingerprinting offers a tool to quantify the relative proportion of sediment contributed to a point of interest in a watershed. However, the sediment-fingerprinting method is limited because it does not determine what the temporal aspects of the sediment may have been. For example, it cannot determine whether surface-derived sediment was mobilized in the sampled event or had been in sediment storage for a period of time.

Atmospheric-derived cosmogenic radionuclides (7Be, 210Pbex) have been shown to differentiate between surface and non-surface (streambanks and in-channel storage) derived sediment. The technique has also been used to date sediment. By combining the sediment-fingerprinting approach with short-lived radionuclides it may be possible to determine the sources and ages of suspended sediment and stored sediment.

A study was designed in the Smith Creek Watershed, Virginia, U.S.A., to determine the sources of fine-grained sediment (<0.063 mm) in suspended sediment and in-channel storage. At 3 sites in the watershed, sediment was collected from two different channel deposits: 1) channel-margin deposits were sampled by coring and 2) gravel substrate sampled by stirring the bed and pumping the slurry into a container. The sediment was analyzed for elemental composition (ICP-OES, ICP-MS), stable isotopes (delta C13 and delta N15), and radionuclides (7Be, 210Pbex, 137Cs). This presentation will discuss the results of the sediment-source apportionment and age of sediment for storms that occurred from 2013 through 2014.

IAHS (Hydrology)

HW11b - HW11 Fingerprinting Techniques: Evaluating Methodological Approaches, Problems and Uncertainty

IUGG-0338

Uncertainties of using the CSSI technique to indentify sediment sources in three pond catchments , Three Gorge Area, China

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The CSSI technique(combined specific stable isotopes) has been recently applied for identification of sediment sources. This new technique was tested to identify sediment sources in three pond catchments, Three Gorges Area in 2012. Total 27 surface soil samples from nine types of land and 9 surface sediment samples from three ponds were collected. Analyses of $\delta^{13}C$ of fatty acids were undertaken in Institute for Plant Production and Agroecology, University of Hohenheim. 29 types of fatty acids exist in source soils in T1+2 catchments with 3 types of land and 39 types in T3 catchment with 6 types of land , respectively. The mean $\delta^{13}C$ values of the fatty acids vary between -28.74‰ and -36.28‰ in the soils and sediments. 9 types of fatty acids are detected in the sediments of T1 and T2 ponds and 12 types in T3 pond, respectively, which are much less than 29 types in the source soils in T1+2 catchments and 39 types in T3 catchment, respectively. The reduction of the fatty acid types from the source soils to the pond sediments demonstrate that parts of the fatty acids have been lost by washing out of the organic detritus during the erosion-transportation processes from the eroded source soils or by post-depositional decomposition of the organic matters in the pond sediments. To reduce the uncertainties caused by the organic detritus losses in the sediments during the erosion-transportation-deposition processes, it is recommended that the soil and sediment samples should be treated by wet sieving.

IAHS (Hydrology)

HW11b - HW11 Fingerprinting Techniques: Evaluating Methodological Approaches, Problems and Uncertainty

IUGG-1145

Identification of sediment sources using sediment fingerprinting methods in small catchments in the Kruger National Park, South Africa

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Sustainable land use requires contemporary information on the dynamics of the environment for management objectives to successfully combat the global problem of soil erosion. For effective management it is important to identify and analyse the source of the sediment, allowing for informed decision making and context specific management approaches to be introduced. Sediment fingerprinting can be used to identify sediment sources. Kruger National Park, a conservation area since 1898, provides a suitable environment for assessing near natural erosion rates in a semi-arid savanna ecosystem that can provide a bench mark against which to evaluate rates in more degraded areas. This study aims to create a sediment fingerprint using environmental magnetism and radionuclide tracing (^{137}Cs and ^{210}Pb) for potential sediment source areas in seven small catchments in Kruger National Park. The final aim is to apply the sediment fingerprinting techniques to assess the relative contribution of potential catchment sources to sediment deposited in small reservoirs. Surface samples were taken from as many geological zones and soil types as possible. Subsurface samples were taken in gullies and channels. One core was taken in the deepest area of each reservoir. Preliminary results for the Hartbeesfontein catchment shows the sediment fingerprinting can be used to discriminate between different geologies.

IAHS (Hydrology)

HW11b - HW11 Fingerprinting Techniques: Evaluating Methodological Approaches, Problems and Uncertainty

IUGG-1712

Changing suspended sediment dynamics over two flood events: an application of sediment source tracing in the Vuvu River, South Africa

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Sediment tracing was used to interpret sediment source changes during flood events in the Vuvu River, a headwater tributary of the Mzimbubu River, South Africa. The geology of the 58 square kilometer catchment comprises two distinct formations: basalt in the upper catchment with a characteristically high magnetic susceptibility; shales with a low magnetic susceptibility in the lower catchment. Application of a mixing model showed that low-frequency magnetic susceptibility (Xlf) provided a means to assign the proportion of each geological province contributing to the river's sediment load. Water samples were collected at twenty-minute intervals during flood events for subsequent analysis of suspended sediment concentration and magnetic susceptibility of the filtered sediment. A level logger was used to record water stage at twenty-minute intervals, which was converted to discharge using a rating curve developed for the site. The results are presented for two floods. The first represents a significant event at the start of the wet season; the second was a smaller flood that occurred a month later. The sediment dynamics during the two floods were quite different. In the first the sediment concentration was high, peaking after the flood peak. The Xlf value increased during the event, indicating that basalt in the upper catchment dominated the sediment load during the recession limb. In the second, smaller flood the sediment peak coincided with the flood peak. Low Xlf values indicated that shales in the lower catchment soils dominated the sediment load through the entire flood event. Sediment tracing was thus used effectively to study changing sediment sources during a flood event in a catchment with source areas having strongly contrasting magnetic signatures.

IAHS (Hydrology)

HW11b - HW11 Fingerprinting Techniques: Evaluating Methodological Approaches, Problems and Uncertainty

IUGG-4426

Exploring the use of fallout radionuclides to identify sediment sources in a small experimental catchment in southern Italy

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A catchment sediment budget, which integrates information on soil and sediment redistribution rates and sediment sources can provide a valuable tool for informing the design and implementation of effective sediment control strategies. However, as it has been frequently indicated, it is often difficult to obtain the necessary information to construct a meaningful sediment budget, particularly using traditional techniques. The use of fallout radionuclides as sediment tracers offers considerable potential in this context, since they can be used to both document soil and sediment redistribution rates and to trace the source of mobilised sediment. If estimates of the output flux can be obtained, these can be linked to both the estimates of soil redistribution rates and the information on sedimernt source to provide an improved understanding of the source, transfer, storage and output continuum. A detailed investigation of sediment and sediment-associated ^{137}Cs and $^{210}Pb_{ex}$ fluxes has been initiated in a small (1.38 ha) experimental catchment located in southern Italy. Recent work has assembled information on radionuclide activities in soils and sediment for some recent storm events. Source fingerprinting techniques, based primarily on radiometric fingerprints (^{137}Cs, $^{210}Pb_{ex}$, and ^{7}Be) have been used to establish the primary sediment sources within the catchment, where independent information on the spatial pattern of surface erosion rates derived using ^{137}Cs and $^{210}Pb_{ex}$ measurements was available. The results of this study are consistent with a previous investigation undertaken in this catchment and provide a useful demonstration of the potential for using FRNs with different half-lifes to identify sediment sources areas.

IAHS (Hydrology)

HW11p - HW11 Fingerprinting Techniques: Evaluating Methodological Approaches, Problems and Uncertainty

HW11p-167

Ascribing geomorphic landform soil erosion to river sediment yield using 137Cs tracer and sediment fingerprinting mixing model

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In recent decades soil erosion have been increased in catchments of Iran and there are necessitates to understand soil erosion process and sources to combat this problem. Geomorphic landform plays important role in influencing the water erosion and ascribing geomorphic landform soil erosion to river sediment yield using ^{137}Cs tracer and sediment fingerprinting mixing model could be useful for soil and sediment management to decrease off-site effects related to downstream sedimentation area. The main objectives of this study are to apply ^{137}Cs tracer to determine relative contributions of geomorphic landforms sediment sources including summit, shoulder, backslope, footslope and toeslope using a Bayesian-mixing model and to estimate the uncertainty in sediment fingerprinting in a mountainous catchment of western Iran. In this analysis, ^{137}Cs tracer were measured in 32 different sampling sites from four sediment sources (summit, shoulder, backslope, footslope and toeslope) and four sediment samples from river sediment at outlet of catchment. Using the mixing model, the median contribution from summit, shoulder, backslope, footslope and toeslope sources was 10%, 79.5%, 4.7% and 2.5%, respectively. Sediment source fingerprinting was used to explore the uncertainty in the contributions of sediment from the three sources. Uncertainty is considerable, as the range of probable values was wide: 0.8-33.4% for summit, 58.6-91.7% for shoulder, 0.4-16 % for backslope and 0.2-9.8 % for toeslope, respectively. The mixing model based on ^{137}Cs tracer estimated the highest contribution of soil erosion in shoulder component landform that may be useful for soil and sediment control management strategies.

IAHS (Hydrology)

HW11p - HW11 Fingerprinting Techniques: Evaluating Methodological Approaches, Problems and Uncertainty

HW11p-168

Selecting the optimum composite fingerprint by an approach with virtual sample mixtures to identify sediment sources in a Pyrenean catchment

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Fingerprinting studies with a large number of tracer properties require statistical tests to identify an optimum composite fingerprint to discriminate between sediment sources. The selection of the most effective statistical test for each specific application can be time-consuming and complex. Here, an auto-evaluation of composite fingerprints obtained by different statistical tests using 1000 virtual sample mixtures is proposed to support a verifiable decision to apply the fingerprinting procedure for the study catchment. Surface soil samples from different land uses from a Spanish Pyrenean catchment were used to characterise the sources for the fingerprinting procedure and for the generation of the virtual sample mixtures. The approach involved testing the composite fingerprints obtained by different commonly used statistics tests as the Kruskall Wallis H-test or the principal component analysis for the dataset. The options were tested solving the contributions for all generated virtual sample mixtures by a Monte Carlo method designed to test the entire parameter space providing the optimal solution for each mixture. The accuracy of the assessed composite fingerprints to solve the virtual sample mixtures was characterised by the averaged root mean squared error between the predicted and known apportionments used to generate the virtual sample mixtures for each un-mixing case. Results of the evaluated options enable us to select the optimum composite fingerprint that generate source ascriptions with the highest accuracy to apply the fingerprinting procedure for real mixture samples from the study catchment. The proposed approach provides an enhanced basis for selecting the optimum composite fingerprint with the best discriminatory capacity for the studied catchment.

IAHS (Hydrology)

HW12a - HW12 Using Environmental Observatories in Catchment Studies and Management

IUGG-0018

Remote sensing and GIS contribution to the investigation of karst landscapes in W-Morocco

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Remote sensing and GIS methods have been used for karst research in the coastal areas of W Morocco in order to identify karst landscapes, to describe karst features, and to detect geological structures relevant to karst development. The aim of this study is to investigate the use of different satellite data such as ASTER and SRTM derived digital elevation models (DEMs) for the analysis of karst features, especially of karst depressions. Sinkholes were identified by combining the morphometric analysis, and visual interpretations based on LANDSAT, RapidEye- and IKONOS satellite imageries and aerial photographs. Digital image processing of the satellite data, such as deriving vegetation and water index images, helps to identify regions with relatively higher surface water input, where karstification processes might be more intense than in surrounding areas. Lineament analysis based on the different satellite data contributes to the detection of surface-near fault and fracture zones with potential influence on dissolution processes in sub-terrain waterways.

IAHS (Hydrology)

HW12a - HW12 Using Environmental Observatories in Catchment Studies and Management

IUGG-1460

A novel optical-based measurement station for the observation of flood events in the Tiber River

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The first implementation of a permanent measurement station for the estimation of surface flow velocities from digital video acquisitions is presented. The station is located on the Tiber River at Ponte del Foro Italico, in the center of Rome, and has been designed and realized in collaboration with CAE S.p.A. based on Mhas (multi hazard system) technology.

Based on preliminary experimental tests described in [Tauro et al., Water Resources Research 2014], the measurement station comprises a Mobotix FlexMount S15 video system and two laser modules for remote image calibration.

Activated since January 2015, the measurement station will allow for noninvasively monitoring the discharge of the Tiber River in real time. In particular, captured videos will be analyzed through large scale particle image velocimetry (LSPIV) to develop surface velocity maps. Such maps will then be combined with information on the bathymetry of the river section to provide discharge data. Notably, the pilot measurement station is located next to an existing ultrasonic meter and a radar flow meter that are currently operated by the Agenzia Regionale di Protezione Civile, Centro Funzionale Regionale at Regione Lazio, Italy. We expect to compare estimates from the pilot station to such more established measurement equipment during a flood event.

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IAHS (Hydrology)

HW12a - HW12 Using Environmental Observatories in Catchment Studies and Management

IUGG-1697

Monitoring of water level variations of inundation areas within the Pantanal Wetland

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The Pantanal is one of the largest wetlands worldwide. It is located in South America and comprises an area of about 400 by 250 km. The region is located within tropical climate, exhibits a marked wet season between November and March and is affected by strong seasonal inundation and desiccation.
In-situ gauging stations for monitoring the water level are rare. We use satellite altimetry to determine absolute water level heights of rivers and inundation areas within the region. Radar altimetry had been designed to provide high accurate measurements of sea surface heights over open oceans on a global scale. However, nowadays, satellite altimetry provides also inland water level heights, mainly for lakes, reservoirs, and rivers. It can also be used to monitor wetlands such as the Pantanal.
We divided the area of investigation in small grid cells and compute one water level time series for each grid cell. The data processing is based on various altimeter missions and comprises waveform retracking, robust outlier detection, terrain correction (in order to account for changing land elevations within one grid cell), and complete error propagation. Most of the derived time series show a clear annual behavior. In case of low water the formal errors are higher due to land contamination of the waveforms. Comparisons with selected near-by in-situ gauging stations reveal RMS differences of about 0.4 m. In addition, the altimeter data also shows a good consistence to GRACE total water storage time series.
In this contribution we will show how altimetry can be used to derive accurate and reliable water levels of wetlands with sub-meter precision. The technique can provide unique and highly valuable information for hydrological research, especially in remote inundation areas.

IAHS (Hydrology)

HW12a - HW12 Using Environmental Observatories in Catchment Studies and Management

IUGG-2148

Land use/land cover dynamics and future implications on environmental resource in Epe, Nigeria

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For this study, LANDSAT multi-temporal data of 1984, 2000 and 2011 were processed and classified into five – built-up, forest, agricultural land, wetland and waterbody using the maximum likelihood classification method. Markov Environment modelers was used to generate a transition probability information matrix and prediction map for the year 2050 with associated land use/land cover statistics. The results show that between 1984 and 2011 there had been changes in agriculture, forest and waterbody with a reduction of 163.2%, 12.2% and 8.3% respectively, while built-up land and wetland increased by 968.2% and 136.3% within the same period. The result of the probability assessment reveals that built-up, forest, agriculture, wetland and waterbody have 0.54, 0.12, 0.74, 0.09 and 0.89 chances respectively to retain their present sizes, and 0.46, 0.88, 0.26, 0.90 and 0.11 chances respectively to change to other classes in the year 2050. The CA Markov modeler for LULC projection revealed 20.44%, 6.09% and 16.15% proportions of the total land area as the potential sizes for built-up land, wetland and waterbody in 2050 as against 1.51%, 1.94% and 18.22% in that order in 1984. Forest and agriculture will have 51.50% and 5.82% in 2050 as against 65.95%, and 12.39% respectively in 1984. As population increases, these results revealed serious implications on future per capita holding (PCH). The population PCHs will reduce by 47.2%, 38%, 24% and 13.02% in 2050 for forest, agricultural land, wetland and waterbody. This study, therefore, suggested that there is the need for sustainable management and assessment of human immediate land use/land cover changes to maximize the benefits of environmental resources.

IAHS (Hydrology)

HW12a - HW12 Using Environmental Observatories in Catchment Studies and Management

IUGG-3573

Low flow regime description and its dependence on monitoring timing for the Ciciriello experimental catchment

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The aim of the present study is to understand the relative role of runoff generation processes and to identify a relevant optimal monitoring technique for the T. Ciciriello catchment, a 3km^2 watershed located in the Cilento, Vallo di Diano and Alburni European and Global Geopark (Southern Italy). Particular interest is addressed to the baseflow index and the flow duration curve. Low flow indices have to be computed from observed streamflow data indeed, but monitoring campaigns are time and cost consuming activities and the opportunity for a monitoring program cost-benefit trade-off is challenging. To the scope, the hydro-chemo-graphical dataset recorded at the T. Ciciriello experimental catchment have been analyzed. To initially focus on the role of groundwater resources within the studied catchment, different hydrograph filtering algorithms (digital filter and mass balance methods) have been applied and compared. Subsequently to stress the importance of the monitoring time step resolution on low flow processes description, a fictitious monitoring experiment has been performed, sampling the observed daily time series at different multiple-day time steps. Main global statistic are computed for the different fictitious series and compared to the daily series. The baseflow patterns, filtered with the use of a mass balance method, which appear to be the more consistent and physically based, appear substantially and statistically similar and the differences in terms of low flow indices fall within a 10% range. The results obtained through the analysis of high frequency collected data for the Ciciriello experimental catchment provide useful indication about the possibility to plan low frequency monitoring campaign in a similar hydro-geomorphological context.

IAHS (Hydrology)

HW12a - HW12 Using Environmental Observatories in Catchment Studies and Management

IUGG-3768

Implementation of the Fourier series model to study the impact of evapotranspiration on discharges during dry periods

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Catchments can be considered as dynamic systems where evapotranspiration data can be assessed either from the measurement of climate-meteorology output data, or from the measurement of stream-flow fluctuation and free water evaporation. The latter procedure is connected with the recent development of high resolution (sensing) equipment for measuring discharges. Using a short time step (DT = 60 min) on small catchments enables the measurement of stream-flow fluctuation diurnally during 24 hours (day/night) in a harmonic wave, taking also into consideration the impact of actual evapotranspiration of a vegetation cover. In parallel, we have measured the water evaporation as well as the soil moisture content nearby. We have implemented the harmonic analysis of the discharges by the Fourier series model (FSM). This model provides computed discharges data which need to be estimated through the harmonic coefficients as the results from FSM. Using measured data of water evaporation and soil moisture content we can compute the actual evapotranspiration from the catchment vegetation as the final output of the FSM model. This study was carried out in the experimental catchment of the Starosuchdolsky Brook in the vicinity of the Czech University of Life Science Prague campus. The catchment area is small. The outcomes of this harmonic analysis is interesting and the methodology innovative. This hydrological methodology can substitute to a certain extent the expensive procedures of evapotranspiration assessment made by classic plant physiology methods.

IAHS (Hydrology)

HW12b - HW12 Using Environmental Observatories in Catchment Studies and Management

IUGG-3015

Estimating periphyton dynamics in a temperate catchment using a hydrological simulation

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This research aims to build a model to estimate spatio-temporal distribution of stream algae in a basin scale by integrating an existing dynamic periphyton model into a distributed hydrological model. We estimated daily periphyton biomass throughout the Natori River basin located in north-eastern Japan using daily inputs of discharge and water temperature computed using the hydrological model and light intensity estimated by daylight hours. We also carried out observations of algae on 9 reaches in the same catchment from July to November in 2014 to calibrate the model and examine its capability of spatial extrapolation. We quantitatively collected the algae attached on 9 streambed gravels at each site. Then periphyton biomass was determined by assaying chlorophylls a with 80% aqueous acetone. With estimated 6 parameters in line with the measured biomasses (survey number = 5) at 3 of 9 sites, the model could explained temporal variations of periphyton biomass (R=0.54-0.97). Subsequently, we estimated the periphyton biomass at the other 6 sites (survey number = 3) with the same parameters. The estimated and observed biomasses are similar at 2 upstream sites of the 6 sites, suggesting limited spatial applicability of the model. Marked differences in the predictions at middle and downstream sites probably arise from man-made influences on variation of water quality such as point and non-point source pollutions.

IAHS (Hydrology)

HW12b - HW12 Using Environmental Observatories in Catchment Studies and Management

IUGG-3116

Quantifying ecosystem resilience to climate change in the Western Boreal Plains

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This study examines the impacts of more than two decades of atmospheric drying on changing vegetation trends within six watersheds of the Western Boreal Plains region, Alberta. Watershed characteristics vary between permeable till moraines with upland forests and deep valleys to relatively flat clay/silt sublayer and organic peatlands on poorly drained soils. Watershed sensitivity is determined using an index of annual evapotranspiration (ET) (evapotranspiration index (EI)) (actual ET / precipitation) vs. dryness index (DI) (potential ET / precipitation) per water year. Watersheds with large variability in EI are presumably more sensitive to climatic anomalies, whereas those that have relatively stable EI are more resilient. The effects of basin resilience is determined by testing ecosystem response to periods of drought extending beyond one year using the Normalized Difference Vegetation Index (NDVI) over 23-years of Landsat TM data.

The results of this study indicate that watersheds containing high proportions of peatlands have small ranges in EI and low dynamic deviation (maximum range in EI), despite high elasticity (maximum range in DI). Watersheds containing high proportions of till moraine and conifer/broadleaf forests have significantly larger dynamic deviation and low elasticity. This indicates increased sensitivity to climate anomalies in upland basins compared with wetland-dominant basins. Significant declines in vegetation productivity (browning trends) occur in watersheds containing till uplands. Greatest changes to ecosystem vegetation production has occurred in low lying, resilient watersheds. Extensive greening (positive NDVI trends) is prevalent in wet areas, indicating potential succession to shrubland/forest and wetland loss with warming and drying.

IAHS (Hydrology)

HW12b - HW12 Using Environmental Observatories in Catchment Studies and Management

IUGG-3546

Evaluation of CryoSat-2 performance over inland water bodies

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The Synthetic Aperture Interferometric Radar Altimeter (SIRAL) mounted on CryoSat-2 senses the Earth's surface in three modes. The Low Resolution Mode (LRM) covers land, ocean and flat ice sheets. This radar measures coastal zones and sea-ice areas in the Synthetic Aperture Radar (SAR) mode. SIRAL uses SAR Interferometry (SARIn) mode over mountain glaciers. SAR and SARIn modes also operate in a few other testing areas.

In spite of advances with respect to previous altimeters, SIRAL still has a relatively large cross-track footprint size (~3 km). Therefore return waveforms may be contaminated by environmental effects. These corrupted waveforms need to be retracked to obtain accurate water level variations. The quality of water level measurements from each mode does not only depend on the retracking but also on the retracking algorithm.

In this study we analyzed L1B, L2I and L2 data of CryoSat-2 to retrack water level variations of different inland water bodies, e.g. Qinghai and Nasser lakes and Caspian sea. To this end, we performed full and sub-waveform retracking based on empirical (OCOG and threshold) and physical retrackers (SAMOSA3, Brown and β-parameter model). We validated the result against available in-situ gauge and other satellite altimeter data.

Our analysis shows that for Qinghai lake, covered by LRM, full waveform retracked by 5β parameter retracker, is the best retracking scenario with an RMS of 17 cm. In the case of Nasser lake, observed with SARIn mode, retracking the first detected sub-waveform by 5β parameter (with 44 cm RMS) produces the most accurate water level measurements. Over the northern part of Caspian sea covered by SAR mode, SAMOSA3 retracker provides an RMS of 13 cm for full-waveform retracking.

IAHS (Hydrology)

HW12p - HW12 Using Environmental Observatories in Catchment Studies and Management

HW12p-135

Variability of stream flows for the Xiang River under a changing environment

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Stream flow plays a crucial role in environmental, social and economic contexts. Variability of recorded discharges at three key hydrometric stations on the Xiang River and their responses to environmental change were investigated. Results show that recorded annual discharges at Laobutou (upper), Hengshan (middle), and Xiangtan (lower) stations have been insignificantly increasing over the period of 1960-2010 with linear increasing rates of 7.0 m^3s^{-1}/10a, 45.7 m^3s^{-1}/10a, and 47.5m^3s^{-1}/10a respectively. Variations of the recorded discharge series presented an non-strict periodicity of approximately 16 years with three visible phases of 1960—1975, 1976—1992, and 1993—2010. The second phase is a relatively dry period with mean discharge anomaly ranging from -5.52% to -6.73% relative to the baseline of 1960—2010. Annual discharges are highly correlated to annual catchment mean precipitations and weakly correlated to annual mean temperature for all three catchments. Change in land use does not alter runoff amount as well as seasonal pattern significantly. Change in precipitation is a major driver of stream flow variability. It is therefore essential to consider potential impact of climate change in future water resources management, particularly impact of change in precipitation.

IAHS (Hydrology)

HW12p - HW12 Using Environmental Observatories in Catchment Studies and Management

HW12p-136

Sharing water-related information to tackle changes in the hydrosphere – for operational needs (SWITCH-ON)

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Recently, a collaborative EU project started called SWITCH-ON (EU FP7 project No 603587) coordinated by SMHI to support the INSPIRE directive and the Open Data Strategy. The overall goal of the project is to establish a “one-stop-shop” web portal for easy access to European water information. The project will use open data, provide infrastructure for sharing and collaboration, and add value to society and research by repurposing and refining data from various sources.

The SWITCH-ON project http://www.water-switch-on.eu/ will establish new forms of water research and facilitate the development of new products and services based on principles of sharing and community building in the water society. The SWITCH-ON objectives are to use open data for implementing: 1) an innovative spatial information platform (SIP) to find, bind, transform and publish data, 2) entirely new forms of collaborative research organised in a Virtual Water-Science Laboratory, open for any research group, 3) fourteen new operational products for water management and awareness, 4) outreach facilities for new water business and knowledge in line with the Europe’s smart growth and environmental objectives.
Contact: waterswitchon@gmail.com

IAHS (Hydrology)

HW12p - HW12 Using Environmental Observatories in Catchment Studies and Management

HW12p-137

Extreme event measurement with ADCP: comparison, lessons learnt and way forward for the Madeira River, Amazon Basin, Brasil

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The Madeira River is one of the main tributaries of the Amazon River, with an average discharge of 18.000 m^3/sec. In February/March/April 2014 the highest flood in 47 years was recorded at Porto Velho gauging station, using the ADCP, with the highest measured discharge ever of 60.066 m^3/sec on 28/03/2014, at level stage 19,66 meters. The CPRM - Geological Survey of Brazil accompanied all this flood event ever recorded using the ADCP measurements, we used two ADCP equipments to get Q - the discharge values: a Sontek-M9 and Rio Grande. Moving bed test was also performed in order to correct discharge data, and due the high sediment transportation of the river and moving bed at the bottom. The results obtained with these two equipments have been compared, and recommendations for extreme high flows measurements are provided here.

IAHS (Hydrology)

HW12p - HW12 Using Environmental Observatories in Catchment Studies and Management

HW12p-138

Stream flow velocity measurement with smartphones: a technique for citizen observatories, decision-making, and water management

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Stream flow velocity may be used for estimating discharge. Given the relative scarcity of direct stream flow and discharge measurements, surface velocity measurements can provide useful information for flood warning, hydropower production, hydrological science in general and water resource management. Some recent research efforts attempt involving the population in environmental sensing to complement existing static monitoring networks with alternative, spatially dense environmental information. Given the availability of sensing and the advances in image processing techniques (smartphones), there is a large potential to obtain hydrologically relevant data through motivated citizens. In this study, we investigate the feasibility of stream flow surface velocity measurements from movie clips taken by (smartphone-) cameras based on specifically adapted image processing techniques. Results from movie-clip derived velocity information is presented and compared to reference measurements from standard flow meters in various field experiments. The application of this technology in the context of so-called Citizen Observatories is expected to have a significant impact on hazard warning, forecasting, decision-making and water governance.

IAHS (Hydrology)

HW12p - HW12 Using Environmental Observatories in Catchment Studies and Management

HW12p-139

Land-atmosphere interactions in cold environments (LATICE): the role of atmosphere - biosphere – cryosphere – hydrosphere interactions under climate change

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Climate change is impacting the high latitudes more rapidly and significantly than any other region of the Earth because of feedback processes between the atmosphere and the underlying surface. Yet many studies rely on one-way coupling between the atmosphere and the land surface, thereby neglecting important interactions. The observation, understanding and prediction of such processes from local to regional and global scales, represent a major scientific challenge that requires multidisciplinary scientific effort. The successful integration of earth observations (remote and in-situ data) and model development requires a harmonized research effort between earth system scientists, modelers and the developers of technologies and sensors. LATICE aims to advance the knowledge base concerning land atmosphere interactions and their role in controlling climate variability and climate change at high northern latitudes. LATICE addresses critical knowledge gaps in the current climate assessment capacity through: i) Improving parameterizations of processes in earth system models controlling the interactions and feedbacks between the land (snow, ice, permafrost, soil and vegetation) and the atmosphere at high latitudes, including the boreal, alpine and artic zone. ii) Assessing the influence of climate and land cover changes on water and energy fluxes. iii) Integrating remote earth observations with in-situ data and suitable models to allow studies of finer-scale processes governing land-atmosphere interactions. iv) Addressing observational challenges through the development of novel observational products and networks. The poster presents the LATICE concept, its main research areas and activities.

IAHS (Hydrology)

HW13a - HW13 Hydrological Predictions in Ungauged Basins

IUGG-0031

Monitoring water levels by integrating optical and synthetic aperture radar water masks with lidar DEMs

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The ability to map and monitor wetland and lake open water extent and levels across the landscape allows improved estimates of watershed water balance, surface storage and flood inundation. The study presents open water classifications over the wetland dominated Sheppard Slough watershed east of Calgary in western Canada using parallel temporal imagery captured from the RapidEye and RadarSat satellites throughout 2013, a year of widespread and costly flood inundation in this region. The optical and SAR-based temporal image stacks were integrated with a high-resolution lidar DEM in order to delineate regions of inundation on the DEM surface. GIS techniques were developed to extract lidar-derived water surface elevations and track the spatio-temporal variation in pond and lake water level across the watershed. Water bodies were assigned unique identifiers so that levels could be tracked and linked to their associated watershed channel reach. The procedure of optical image classification through to merging of individual water bodies into watershed channel topology and extracting reach water levels has been automated within python scripts. The presentation will describe: i) the procedures used; ii) a comparison of the SAR and optical classification and water level extraction results; iii) a discussion of the spatio-temporal variations in water level across the Sheppard Slough watershed; and iv) a commentary on how the approach could be implemented for web-based operational monitoring and as simulation initialisation inputs for flood inundation model studies.

IAHS (Hydrology)

HW13a - HW13 Hydrological Predictions in Ungauged Basins

IUGG-0206

Modeling of seasonal river–aquifer interactions in a tropical coastal area controlled by tidal sand ridges

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Water exchanges between streams and aquifers influence the quantity and quality of water in both domains. Seasonal river–aquifer interactions were investigated in a tropical coastal area where tidal sand ridges control river discharge to the sea. The study site is located in a poorly gauged catchment in southwestern Nicaragua, dominated by humid tropical hydro-climatic conditions. Connectivity between the river and the aquifer influences water quality and water availability for humans and for the downstream estuarine ecosystem. The effect of stream stage fluctuations on river–aquifer flows and pressure propagation in the adjacent aquifer was investigated analyzing high temporal resolution hydraulic head data and applying a numerical model (HYDRUS 2D). Tidal sand ridges at the river outlet control the flow direction between the river and the aquifer. Surface water accumulation caused by these features induces aquifer recharge from the river. Rupture of the sand ridges due to overtopping river flows causes a sudden shift in the direction of flow between the river and the aquifer. The aquifer behaves as confined, rapidly transmitting pressure changes caused by the river stage fluctuations. However, the pressure wave is attenuated with increasing distance from the river. Therefore, we concluded that a dynamic pressure wave is the mechanism responsible for the observed aquifer responses. The model provides a useful tool for protecting water resources for social and ecological uses in this poorly gauged tropical region.

IAHS (Hydrology)

HW13a - HW13 Hydrological Predictions in Ungauged Basins

IUGG-1169

Estimation and prediction of an ungauged basin using satellite remote sensing and a state space model: test case Aral Sea.

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Over the last few decades satellite remote sensing has proven to be the best alternative for the continuous monitoring of poorly gauged inland water bodies. The four dimensional information derived from the combination of satellite altimetry (water stage) and Landsat images (water extent) of a lake, promises a step forward for the improved estimation of volumetric variations and surface water management.

We assess the dynamics of the Aral Sea volume in monthly resolution from three independent methods. Firstly by intersecting water level time series generated from altimetry observations with a digital elevation model (DEM), secondly by intersecting the temporal evolution of the water extent from Landsat images with the DEM, and lastly by combining water level with the respective surface area of the basin to get volumetric variations using a pyramidal frustum volume estimation method. All three methods are characterized by unknown uncertainties due to inaccuracies of the DEM and errors in the satellite measurements. For improved estimates of the volume dynamics, a state space model (SSM) is fitted over the three data sets. The SSM has robust capability in dealing with trends, seasonality, interventions like construction of dams etc within the given period and uncertainties in the data. The model result for the volume trend of the Aral Sea is finally predicted over the next five years under the assumption of a continuation of the present scenario.

IAHS (Hydrology)

HW13a - HW13 Hydrological Predictions in Ungauged Basins

IUGG-1899

Hydrological characteristics predictions in ungauged basins in the Czech Republic

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Hydrological characteristics predictions in ungauged basins have long-term tradition in the hydrological service of the Czech Republic. Predicted characteristics, called the base hydrological data, are then used for many purposes, e. g. for water resource management commonly, dimensioning of weirs, culverts or bridges, flood protection etc. They contain basin area, long-term annual mean precipitation height, long-term annual runoff, specific quantiles of flow duration curve and specific quantiles of flood frequency curve. Base hydrological data, except for flood frequency curve, are always derived for specific reference time period. Currently the characteristics for the period 1981–2010 are being provided to the public. New and modern approaches have been used not only for observed data processing, but for the extrapolation of hydrological characteristics to ungauged sites in the river network as well. These new approaches are based on extensive using of GIS. Several tools have been developed by the authors, e. g. terrain dependent interpolation of point measurement. Work procedures contain also massive using of linear and non-linear regression methods. Theoretical flow duration curves are constructed from log-normal statistical distribution with five parameters, what is also original idea. Extrapolation of hydrological characteristics from gauged to ungauged sites is based on a combination of the results from regression analysis and composing of flow frequency curves in river network junctions. As hydrological regime is less or more influenced by anthropogenic activities, time series of withdrawals and waste water draining, had to be used in the data processing.

IAHS (Hydrology)

HW13a - HW13 Hydrological Predictions in Ungauged Basins

IUGG-2190

Global maps of streamflow characteristics based on observations from several thousand catchments

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Streamflow (Q) estimation in ungauged catchments is one of the greatest challenges facing hydrologists. Observed Q from three to four thousand small-to-medium sized catchments (10–10,000 km2) around the globe were used to train neural network ensembles to estimate Q characteristics based on climate and physiographic characteristics of the catchments. In total 17 Q characteristics were selected, including mean annual Q, baseflow index, and a number of flow percentiles. Testing coefficients of determination for the estimation of the Q characteristics ranged from 0.55 for the baseflow recession constant to 0.93 for the Q timing. Overall, climate indices dominated among the predictors. Predictors related to soils and geology were relatively unimportant, perhaps due to their data quality. The trained neural network ensembles were subsequently applied spatially over the entire ice-free land surface, resulting in global maps of the Q characteristics (0.125° resolution). These maps possess several unique features: they represent observation-driven estimates; are based on an unprecedentedly large set of catchments; and have associated uncertainty estimates. The maps can be used for various hydrological applications, including the diagnosis of macro-scale hydrological models. To demonstrate this, the produced maps were compared to equivalent maps derived from the simulated daily Q of four macro-scale hydrological models, highlighting various opportunities for improvement in model Q behavior. The produced dataset is available via http://water.jrc.ec.europa.eu.

IAHS (Hydrology)

HW13a - HW13 Hydrological Predictions in Ungauged Basins

IUGG-2869

CRUCIAL: Cryosat-2 Success over Inland Water and Land: Full Bit Rate Altimetric Heights and Validation

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CRUCIAL is an ESA/STSE funded project investigating innovative land and inland water applications from Cryosat-2 with a forward-look component to the future Sentinel-3 and Jason-CS/Sentinel-6 missions. The high along-track sampling and resolution of Cryosat-2 altimeter in SAR mode (18 KHz) offers the opportunity to recover high frequency signals over much of the Earth's land surface, enhancing the inland water height retrieval capability. To perform this study we use the samples of SAR Full Bit Rate (FBR) data from Cryosat-2 acquired over a few of these land surfaces; however, for Sentinel-3 the SAR mode will be deployed widely over land. This paper will summarise the CRUCIAL aims and objectives and present the theoretical approach to analysis of the FBR L1A Doppler beams to form a product using ground cell gridding, beam steering and beam stacking from which inland water heights are derivable from the retracked Cryosat-2 altimetric waveforms. Retracking will use the BER1 retracker developed for SAR waveforms. Results over the Amazon will use the along-track rms as a measure of consistency across the river with further validation against in situ and other satellite data where possible.

IAHS (Hydrology)

HW13b - HW13 Hydrological Predictions in Ungauged Basins

IUGG-0208

Simulation of hydrologic responses to landuse and climate change in Lower Bhavani River Basin using soft computing technique

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Understanding the responses of hydrological processes to landuse and climate change is critical for developing appropriate mitigation and adaptation strategies for sustainable water resources management and protection of public safety. Climate variability has both direct and indirect effects on the hydrologic cycle. Land use change alters the hydrologic cycles by affecting evapotranspiration, soil infiltration capacity, and surface and subsurface flow regime. Since the hydrologic conditions vary from regions to region, the influence of local hydrological processes are likely to differ. Also the study of the impacts of climate variability and change on hydrologic response is complex because the parameters driving the climate change are coupled nonlinearly at local and regional level and therefore those impacts cannot be readily assessed. The present study aims to assess the impacts of landuse climate change on hydrology in Lower Bhavani basin of India using Artificial Intelligence Techniques. The regional climate data were used for the current study. The streamflow in ungauaged stations was predicted using artificial intelligent techniques. Four different ANN models were developed and trained with 20 input parameters (landuse, groundwater level and climatic factors) to predict the streamflow. The validation was carried out using measured, historic, long-term daily stream flow. Finally the sensitivity of streamflow to climate change was analysed using the predicted values.

IAHS (Hydrology)

HW13b - HW13 Hydrological Predictions in Ungauged Basins

IUGG-0209

Modelling of snow dynamic of an andean watershed using a distributed energy balance model

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Depending on the relative altitude and ambient temperature, Andean watersheds present important snow coverage during winter season. Snowpack stores significant amount of water which is released to surface runoff and groundwater when solar radiation increases, mainly during the spring and summer season, controlling the shape of the annual hydrograph and affecting the water balance at monthly and shorter scales. Field measurements of snow cover in those areas are difficult to perform due to adverse climatic and topographic conditions. Therefore, it is useful to support the hydrological characterization of watersheds located in the high mountains with models representing runoff from melting, i.e. based on the energy balance of the snowpack. The objective of this work is to characterize and quantify the energy flows that control the accumulation and melting of snow cover, using a distributed energy balance model. The work was done on the upper Malleco watershed, which is located in the Andes Mountain Range (38°20'– 8°41'S and 71°13'-71°35'W) and has an area of 27 km^2, elevations vary between 900 to 1789 m a.m.s.l. The distributed energy balance model was developed considering local conditions and data availability. Two weather stations were installed in the study area, which recorded data every 15 minutes. The model was calibrated and validated using data for two periods one for accumulation and the other one during melt season. Both of them were selected considering the most consistent and complete data set during 2010 and 2012. Results were compared with measured snow depth and flow and outlet of the watershed.

IAHS (Hydrology)

HW13b - HW13 Hydrological Predictions in Ungauged Basins

IUGG-0332

New insights for analysing projected changes in the water cycle

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One tends to think of the hydrologic impacts of climate change in terms of change in rainfall and temperature. One of the main sources of climate change projections is global climate models and it is important to understand the physical basis for the rainfall and temperature predictions and projections. One poorly understood aspect of the climate model projections that underlie current climate change scenarios is that much of the additional longwave (greenhouse) forcing at the surface is dissipated by an increase in outgoing longwave radiation with virtually no change in any of the other surface energy balance terms. It is important to fully comprehend the physical meaning and the hydrologic implications of this projected change. For example, the climate models are projecting an increase in surface (and air) temperature with virtually no change in net radiation. However, when we analyse the hydrologic properties of different catchments, the warmer catchments usually have a higher net radiation. In short, the variations expected under climate change are very different from those inferred by studying catchments in different places. The implication is that we cannot use space for time substitutions to study climate change. Instead we must deal with space and time explicitly. In this presentation we use examples to demonstrate the underlying principles and show how this is relevant to Predictions in Ungauged Basins.

IAHS (Hydrology)

HW13b - HW13 Hydrological Predictions in Ungauged Basins

IUGG-4501

An analysis of the relative roles of catchment dispersion mechanisms through numerical experiments

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Relevant dispersion mechanisms in natural catchments are broadly divided, based on their nature, into geomorphological and kinematic. Their relative role is crucial for understanding and modelling rainfall-runoff processes in gauged and ungauged basins. In this work we perform an exhaustive investigation aimed at making clear under which conditions each dispersion mechanism dominates the travel time distribution and if the prevailing mechanism changes with scale. We adopt a framework which is based on the geomorphological theory of the hydrologic response, embedding different aspects of the rainfall-runoff process. Our objective is to investigate changes in dispersion dominance trying to make our results as general as possible. Instead of representing detailed characteristics in specific basins, we base our analysis on a statistical characterization of basin hillslope and channel lengths. Doing so, we obtain a simplified model for the derivation of the main features of travel time distribution; this "virtual laboratory" provides quantification of the dispersion coefficients as function of a few physically meaningful parameters: the ratio g between channel and hillslope length (a surrogate of basin scale), the ratio q between channels and hillslope velocity and the correlation r between the two length distributions. Results show that i- flow conditions over hillslopes are dominant for small basins where g<100; ii- at larger scales, hillslope role can be still significant, depending on q; iii- negative correlation r enhances the role of hillslope kinematic dispersion; iv- basins are asymptotically dominated by network geomorphology for g >1000; v- when correlation r is positive, hillslopes always increase total catchment dispersion.

IAHS (Hydrology)

HW13b - HW13 Hydrological Predictions in Ungauged Basins

IUGG-5566

Prediction of basin-scale runoff using an Ensemble Kalman Filter framework based on global hydrometeorological datasets

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The hydrological community has to face a significantly shrinking number of terrestrial observation stations for the most important water cycle variables. This alarming development led to a growing need for alternative methods e.g. by using satellite based data for estimating runoff. In this work, we thus present an approach, which allows us to derive runoff from poorly or irregularly gauged basins. We apply widely used global hydrometeorological datasets for precipitation (GPCC, GPCP, CRU, UDEL), evapotranspiration (MODIS, FLUXNET, GLEAM, ERA Interim, GLDAS), and water storage changes (GRACE, WGHM, GLDAS, MERRA Land) within an Ensemble Kalman Filter setup. In the context of runoff, we make use of in situ data from the GRDC and satellite altimetry derived estimates. We follow a least-squares prediction that exploits the joint temporal and spatial auto- and cross-covariance structures of precipitation, evapotranspiration, water storage changes and runoff.

Our in-depth analysis comprises 29 large river basins of different climate regions, with which runoff is predicted for a subset of 16 basins. Comparing the predictions to observed monthly runoff shows correlations larger than 0.5, relative biases lower than 20%, and NSE-values larger than 0.5. We further compare our estimates with a simple empirical predictor, which exploits the relationship between runoff and precipitation, with satellite altimetry derived runoff estimates, and with estimates from a runoff-water-storage-relationship.

In total, the proposed method is able to provide runoff estimates for nearly 100 poorly gauged basins covering an area of more than 11,500,000 km^2 with a freshwater discharge, in volume, of more than 125,000 m^3/s.

IAHS (Hydrology)

HW13c - HW13 Hydrological Predictions in Ungauged Basins

IUGG-2170

Regional model for flood prediction in river basins characterized by poor or null information

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A regional probabilistic approach for the estimation of medium-high return period flood quantiles is presented. The analysis is based on the identification of main mechanisms of runoff generation controlling the flood frequency distribution, by means of theoretically derived flood frequency distributions. In particular two different threshold mechanisms associated with ordinary and extraordinary events are identified exploiting the general model called TCIF; based on at-site model calibration in several basins of Southern Italy, a regional analysis is performed obtaining satisfactory results for the estimation of flood quantiles for return periods of technical interest; results are exploited in order to investigate heterogeneities and homogeneities, finding interesting correlations between model parameters and geomorphological river basin descriptors. The proposed research focuses on the possibility to expand the use of the proposed methodology to river basins characterized by poor or null information, using basin descriptors; in this context an independent validation of the proposed regional model is obtained, exploiting a new set of discharge data from two gauged sections that were not available for the implementation of the regional model.

IAHS (Hydrology)

HW13c - HW13 Hydrological Predictions in Ungauged Basins

IUGG-2692

New morphometric properties for channel networks comparison and classification using the graph theory and DEMs

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The channel network controls the spatial pattern of hydrological processes within a catchment. Hence the identification of key hydrological features characterising the channel network can contribute to a rational classification of networks for PUB applications. This presentation aims to identify “similar” channel networks, referred as “twins”, which have the same topological structure and consequently similar surface runoff transfer function for lumped modelling applications. The graph theory was used in order to calculate morphometric properties from DEM. The contributing drainage area has properties of a scale free network, and was subsequently characterised by highly connected nodes called hubs. The method involves ranking the hubs of a channel network according to the contributing drainage area and the distance to the outlet. These hubs’ characteristics were used to compare and classify channel network. Applications were conducted on 788 French catchments with the same area of 100 km². Two ways of classifications were proposed, the first one according a supervised procedure based on 8 types and a second one according a nested hierarchy considering the main hub as the key factor of the classification. For this latter, various classification methods were compared using increasing number of hubs’ characteristics, from 3 to 12 indices. Both approaches enabled to identify twelve twins networks among the 788 studied. Results showed also that the knowledge of six morphometric indices of hubs’ morphometric characteristics were sufficient for channel network comparison and classification.

IAHS (Hydrology)

HW13c - HW13 Hydrological Predictions in Ungauged Basins

IUGG-3350

Large-scale predictions of multiple ungauged basins, using open data and process-based modelling across continents

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To characterize the present status and to explore potential changes of the future water resources, we have developed a concept for setting up a hydrological model for multi-basins at the large-scale. Using the best practices of PUB modelling at the single catchment-scale (Bloeschl, et al., 2013) we came up with a modified best practice for PUB in multibasin settings. In this way we combine bottom-up and top-down analysis to improve process understanding and model reliability. So far, we have applied the concept on the following geographical domains with different resolutions (number of subbasins within brackets): Sweden (37 000), Europe (35 000), Arctic Sea basin (30 000), La Plata River (6 000), Niger River (800), Middle-East North-Africa (31 000), and the Indian subcontinent (6 000). In the applications, most of the subbasins are of course ungauged, while the model is evaluated in some 40-2000 gauged basins across each model domain. This gives us a large sample to test our hydrological hypotheses and performance of the model concept.

In this presentation we will: firstly, describe the work process along the six steps suggested for best practices in the PUB book and how it can be interpreted when setting up a process-based model with multi-basins at the continental scale; secondly, exemplify discrepancies and errors in some commonly used global databases; thirdly, show different ways to constrain parameters when using large samples and multiple data sources, and fourthly, give examples of useful evaluation methods and metrics. Finally, we will show how we distribute our results to the public through a dedicated web site: www.hypeweb.smhi.se, showing present conditions, model performance and climate change impact for each model domain.

IAHS (Hydrology)

HW13c - HW13 Hydrological Predictions in Ungauged Basins

IUGG-3515

Improving the bayesian joint inference through the inclusion of hydrological state variables in the residuals dependence model

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In hydrological modeling, the mixture of an unsuitable error model with the input errors and the hydrological model structural deficiencies is the main cause of yielding biased calibrated parameters and hydrological models which can seemingly works well but not for the right reasons. Biased parameters are an obstacle for proper regionalization processes with the aim of predicting the response at **ungauged sites**.

This research focuses on the **Bayesian joint inference** (BJI) of both the hydrological and error model parameters, considering a general additive (GA) error model that allows for correlation, non-stationarity (in variance and bias) and non-normality of model residuals. The joint inference approach presented here deviates from previous researches in two main points: i) non-stationarity in errors variance and bias is modeled, taking into account the **Total Laws**; ii) it is considered the possibility that the residuals contain some information which may be correlated with state variables of the hydrological model. This correlation would be caused by model structural problems which hinder the proper processing of the Forcing signals by the hydrological model. In this way, a multiple correlation analysis, embedded in the residuals autoregressive model (**ARX model** in literature), allows the extraction of remnant information from residuals, giving us clues of which processes (or state variables) can be responsible of the unprocessed information.

The results of this research show that the application of BJI with a GA with ARX error model (GAARX) outperforms the hydrological **parameters robustness** and improves the reliability of the streamflow **predictive distribution**, in respect of the results of GA error model which not take into account the dependence residuals-state variables.

IAHS (Hydrology)

HW13c - HW13 Hydrological Predictions in Ungauged Basins

IUGG-5312

Regional patterns of water balance variability across the United States: a newtonian-darwinian synthesis

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Patterns of variability of catchment water balances across the United States are explored over a range of time scales, through a combination of data analysis and conceptual modeling. Catchments are grouped into clusters of similar behavior on the basis of key signatures of the water balance variability. The resulting clusters have a strong relationship to regional patterns of several climate drivers (in a Newtonian sense) but also with regional ecosystem, soil, and vegetation classes (in a Darwinian sense). In this sense, the study has identified a deeper sense of similarity evident in observed space-time variability of water balances that also reflects the co-dependence and co-evolution of climate and landscape properties. Approaches to a synthesis of these two alternative approaches will be discussed, their potential for their validation and implementation in other regions of the world, and their usefulness for predictions in ungauged basins through the choice of appropriate model structures.

IAHS (Hydrology)

HW13d - HW13 Hydrological Predictions in Ungauged Basins

IUGG-1903

Liuxihe Model and applications in catchment flood forecasting

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Liuxihe Model is a physically based distributed hydrological model, which derives model parameter from terrain data, and also as it sets up the model structure by using freely downloaded terrain property data, including the DEM, soil types and vegetation types, so it could be used in data-poor or no-data catchment, which is particularly useful for developing countries including China. In this study, results of the Liuxihe Model's applications in catchment flood forecasting have been presented. The first application is its application in small and medium sized catchment(SMC) with drainage area ranging from 200 to 3000 square kilometers that is usually data-poor catchments. For this application, the model parameters are derived directly from the terrain properties, and the model shows reasonable performances in several catchments. The second application is its application for reservoir flood forecasting. In this application, as there are usually some observed flood hydrographs, so the model parameters are further optimized with the observed hydrographs by using the Particle Swarm Optimization(PSO) based on the preliminary values derived from the terrain property, results in several catchments show the model performances have been improved. The third application is its application in large river flood forecasting by coupling with meteorological forecasting products, and application have been done in North River Basin with a drainage area over 40,000 square kilometers and West River Basin with a drainage area over 60,000 square kilometers. In this application, parallel algorithm has been developed to execute the computation deployed in high performance computer. The coupled precipitation is forecasted by WRF, and the results are acceptable.

IAHS (Hydrology)

HW13d - HW13 Hydrological Predictions in Ungauged Basins

IUGG-2038

A new physically-based analytical model for the prediction of stream temperature in ungauged basins

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Stream temperature is a hydrological factor which affects the habitat suitability of many aquatic species, and is therefore of great concern in the actual context of climate change. Its prediction in ungauged basins is usually based on statistical approaches, such as multi-linear regression models or machine learning techniques. These models typically predict temperature metrics corresponding to yearly aggregates, such as the popular annual maximum weekly mean temperature (MWMT). As a consequence, they are often unable to predict the annual cycle of stream temperature, nor can the majority of them forecast the inter-annual variation of stream temperature. This study presents a new model to estimate the monthly mean stream temperature of ungauged rivers over multiple years in an Alpine country (Switzerland). Contrary to the current statistical approaches, this model rests upon the analytical solution of a simplified version of the energy-balance equation over an entire stream network. This physically-based approach presents some advantages, among which the possibility to interpret the model coefficients from a physical point of view, hereby enabling the restriction of their calibration ranges. The evaluation of the model over a new data set shows that the monthly mean stream temperature curve can be reproduced with a root mean square error of 1.3°C, which is similar in precision to the predictions obtained with standard multi-linear regression models. We illustrate through a simple example how the physical basis of the model can be used to gain more insight into the stream temperature dynamics at regional scales.

IAHS (Hydrology)

HW13d - HW13 Hydrological Predictions in Ungauged Basins

IUGG-5184

Baseflow index regressed on hydrometeorological variables for ungauged hydrological subcatchments

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This study examines a regression expression between baseflow and the physiographical, topographical, meteorological and hydrological properties of watersheds. The expression is derived using multiple regression approach to calculate baseflow, and baseflow index as the ratio of baseflow to the total flow in the river channel. The United Kingdom Institute of Hydrology smoothed minima method (UKIH) is used for comparison purposes by using daily streamflow data gauged at hydrometric stations in the watershed. Regression equation is developed by minimizing the difference between the dependent variable of the regression model and the UKIH method. Application made on 29 subwatersheds of the Euphrates, the Sakarya and rivers in the Western Black Sea region in Turkey show that the developed regression model is suitable for estimating baseflow of the watershed. The regression model can also be used for subcatchments where streamflow is usually ungauged.

IAHS (Hydrology)

HW13d - HW13 Hydrological Predictions in Ungauged Basins

IUGG-5374

Simulating stream runoff by the VIP eco-hydrological model for data-scare basins in Tibet Plateau

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The process-based eco-hydrological model Vegetation Interface Process (VIP) model is employed to simulate the streamflow in Lhasa (with the basin area being 26,235 km2) and Gongbo (with the basin area being 6,417 km2) with elevation being from 4700 to 5300 meters in Tibet Plateau. The model is run at a daily time step and 1 square km spatial resolution with meteorology data at only 14 meteorological stations available and a few year hydrological data available just from recently. With the distributed physical-based features of the VIP model to avoid heavy work of calibration as lumped conceptual models will do, with the aid of remote sensing and global and regional information datasets to acquire the information of elevation, soil texture, land cover and glacier distribution, with a considerate handling of vertical variation in the interpolation of atmospheric driving forces, by using comparative idea for the two basins, VIP model catches the hydrograph well with the Nash-Sutcliffe modelling efficiency reaching 0.78. It shows a general pattern that runoff simulation performs better at monthly scales than at daily scales. The experiences in the basins provide an good example for Predictions in Ungauged Basins in Alpine area.

IAHS (Hydrology)

HW13d - HW13 Hydrological Predictions in Ungauged Basins

IUGG-5567

Parameterization of rainfall-runoff models for almost ungauged catchments

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Catchments that are almost ungauged, i.e. in which only a small number of point flow measurements are available, lie between the cases of ungauged and gauged catchments. Therefore it can be expected that blending model parameter estimation methodologies adapted to each of these two opposite cases may answer the problem of parameter estimation on almost ungauged catchments. The proposed method combines regional information (parameter sets of neighboring gauged stations) and local information (brought by the point measurements) in a framework where the relative weight of each source of information is made dependent on the number of point measurements available. This approach is tested with two different hydrological models on a set of 609 catchments. The results show that even a single measurement can improve the simulation's efficiency, while ten measurements reduce more than 50% of the performance gap between the gauged and ungauged situations. The issue of possible information redundancy will be discussed.

IAHS (Hydrology)

HW13p - HW13 Hydrological Predictions in Ungauged Basins

HW13p-169

Flow predictions in ungauged basins at the Niger River using the SWAT hydrological model

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In West Africa, many drainage basins are completely ungauged or poorly gauged. Prediction of discharge at ungauged basins is, therefore, an important priority for water resources management. The main goal of this study was to first setup the hydrological SWAT model at the Bani catchment then test its transferability feasible to different ungauged basins at the Upper Niger River. The Bani catchment drains an area of about 101, 000 km^2 at the outlet of Douna. The climate is tropical, humid to semi-arid from the South to the North with an average annual rainfall of 1050 mm. Global datasets used from USGS hydrosheds DEM, USGS LCI GlobCov2009 and the FAO Digital Soil Map of the World. Daily measured rainfall from nine rain gauges and maximum and minimum temperature from five weather stations covering the period 1981-1997 were used for model setup. Sensitivity analysis, calibration and validation were performed within SWATCUP using GLUE procedure. Model parameters were calibrated at daily time step for the period 1983-1992, and then validated for the period 1993-1997. Calibration and validation results are good at the catchment's outlet (Nash and R^2 equal to 0.76 and 0.79 for calibration, 0.84 and 0.87 for validation). These statistics suggest that the model performance can be judged as satisfactory, especially considering limited data condition and a high climatic gradient characterizing the Bani catchment. The most sensitive parameters (CN2, OV_N and SLSUBBSN) are related to surface runoff reflecting the dominance of this process on the streamflow generation.

IAHS (Hydrology)

HW13p - HW13 Hydrological Predictions in Ungauged Basins

HW13p-170

Development of hydrometeorological information database and application technology for monitoring water resources over ungauged basin in Korea peninsula

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Due to population growth, urbanization and climate change, the world has been damaged constantly by water-related hazards, and this leads to the major challenge for managing the water resources facilities, in particular over ungauged basin with lack of datasets and analysis tools (Barthold et al., 2008; Winsemius et al., 2009). Korea water resources corporation (K-water) has been focused on developing techniques for preventing from hydrological disasters as well as securing water supply. In 2014, K-water and Korea Meteorological Administration have been established the Hydrometeorological Cooperation Center (HCC) to accomplish more effective water management for scarcely gauged river basins, where data are uncertain or non-consistent. HCC aims to interconnect between weather observations and forecasting information, and hydrological model over sparse regions with limited observations sites in Korean peninsula, specifically ungauged basins located near the border such as Imjin River. The Hydrometeorological database management system via data visualization based on Geographic Information System so called “Hydrometeorological Portal System over North Korea” is built for data sharing by constructing a web based on quality assured data through various statistical and empirical quality control tests into one database for enhanced application of collected data that were among several governmental research organizations. To manage the optimal flood and drought control over the ungauged river section, we applied the quality-ensured data products to grid based rainfall-runoff model i.e., K-water Distributed Rainfall RUnoff Model (K-DRUM).

IAHS (Hydrology)

HW13p - HW13 Hydrological Predictions in Ungauged Basins

HW13p-171

Employing hydrologic fingerprints for regional parameter estimation of a conceptual model for hydrologic predictions in ungauged basins

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The aim to feasibly predict hydrologic fluxes such as streamflow dynamics or simulate the long-term water balance is an important hydrologic challenge. To ensure a reliable model performance effective parameters are needed and have to be estimated by calibration e.g. with the help of observed streamflow data. This procedure is substantially complicated in cases of poorly or completely ungauged river catchments and anthropogenically altered hydrologic regimes. In these catchments, regionalization techniques are usually employed to ensure parameter transfer to sites deemed to behave hydrologically similar. A common problem of these methods is the high degree of uncertainty associated with their results. For these reasons invariant descriptors of mesoscale catchments (e.g. weighted elevation gradients or soil porosity) and normalized hydrologic state variables (e.g. soil water storage or average residence time) are derived as scale relevant hydrologic indicators (i.e. fingerprints) to reasonably constrain the parameter space of a conceptual hydrologic model. We used the multiscale Hydrologic Model (mHM), which is based on a simultaneous multiscale parameter regionalization technique (MPR) and we employed the Fourier Amplitude Sensitivity Test (FAST) to determine a suitable range of global model parameters. This model was selected to show the capability of the approach to constrain (model calibration) the field of global model parameters via hydrologic fingerprints in a meaningful way. The predictive capacity, i.e. the transferability of the identified parameter ranges to ungauged locations within mesoscale headwater catchments of the river Ruhr and its tributaries of the low mountain range is tested and assessed (validation) in the context of human-impacted reaches.

IAHS (Hydrology)

HW13p - HW13 Hydrological Predictions in Ungauged Basins

HW13p-172

Regionalization of Watersheds for Regional Flood Frequency Analysis in Lake Tana Basin, Ethiopia

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Extreme environmental events, such as floods and droughts have severe consequences for human society. Estimates of their return periods and design values are of great importance in weather-related emergencies, design of civil engineering structures, etc. Regional flood frequency analysis resolves the problem of estimating the extreme flood events for catchments having short data records or ungauged catchments. This paper is the first of its kind in the study area and presents new plotting position formula for generalized extreme value and generalized logistic distribution by optimizing the parameters using the data in the tail distribution since all plotting position relationships give similar values near the center of the distribution. The derived plotting position formula was found to be useful for the study area. This paper analyzes annual maximum peak flood discharge data recorded from 5 stream flow gauging sites in Lake Tana Basin, Ethiopia, in order to derive regional flood frequency curves. On the basis of the L-moments and using mean annual rainfall pattern with elevation of the study area, the entire region is subdivided into three hydrologically homogeneous regions and whose homogeneity is tested using the L-moments based heterogeneity measure. Based on the L-moment ratio diagram and goodness-of-fit test, generalized logistic distribution for region-II & region-III and generalized extreme value distribution for region-I are identified as the robust distribution.

IAHS (Hydrology)

HW13p - HW13 Hydrological Predictions in Ungauged Basins

HW13p-173

Hydrological Assessment of Basin Development Scenarios Impacts on the Tonle Sap Lake in Cambodia

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Haphazard construction of hydraulic structures may alter the hydrologic regime of the Mekong River Basin, and also the Lower Mekong basins are directly affected by developments of large dams along the main stream of the Mekong River. Many scientific reports have pointed out that dams along the Mekong River lead to serious problems: not only hydrologically but also a decline of agricultural productivity due to a decrease of sediment supply in the Mekong Delta and a change of fish amount due to drastic change of the water environment. Cambodia and Vietnam, located in the lowest Mekong basin, are gravely affected by radical changes of hydrologic regime due to Mekong River developments. In particular, the Tonle Sap Lake in Cambodia is very sensitive to the flood cycle and flow variation of the Mekong River as well as inflow water quality from the Mekong River. More than 50% of Cambodian GDP depends on the primary industries such as agriculture, fishing, and forestry, and the Tonle Sap Lake plays an important role to support the national economy in Cambodia. In addition, Cambodian people usually take nourishment from the fish of Tonle Sap Lake. This research aims to assess the impacts of basin-wide development scenarios from MRC (Mekong River Commission) on the hydrologic regime of the Mekong River - Tonle Sap Lake. We proposed the rainfall-runoff-inundation modeling system based on CAESER-LISFLOOD for integrated water resource management in the Tonle Sap Basin and then analyze both monthly and yearly variation of flood inundation patterns of the Tonle Sap Lake due to the scenarios. Furthermore, the simulated inundation maps were compared to MODIS satellite images for model verification.

IAHS (Hydrology)

HW13p - HW13 Hydrological Predictions in Ungauged Basins

HW13p-174

The Fiumarella of Corleto experimental basin: new analyses

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The understanding of hydrological behaviour of a basin needs the measurements of several parameters at various spatial and time scales. In facts, while little scales are required to identify homogeneous areas for the measurement of a single hydrological parameter, on the other way the evaluation of the discharge flow at the outlet has to take in consideration all the basin heterogeneity. In this work the experimental research activity on the Fiumarella of Corleto basin is presented. The basin (32 km^2), were data are collected by more than 15 years, is located in Southern Italy. The experimental campaign started with basic hydrological measurements of precipitation and discharge flows at the outlet, with a light preliminary knowledge of the soil distribution. The sensors were gradually integrated for meteorological measurements (temperature, solar radiation, wind velocity, etc.) to estimate the most significant parameters for water balance at basin scale. More recently, the attention was turned to smaller scales by monitoring a gated subbasin too, where a TDR station was installed, for soil moisture measurements, along a transect. In this work, part of the experimental research activity is presented with particular regard to the information provided at different scales. Local and basin hydrological responses are also commented.

IAHS (Hydrology)

HW13p - HW13 Hydrological Predictions in Ungauged Basins

HW13p-175

Climate influence on baseflow index across climate and catchment properties gradient

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The baseflow indices prediction in ungauged basins has been essentially based on the use of catchment physiographic attributes as dominant variables. Additional studies have used modelling of the baseflow process to identify the dependence on mentioned physiographic parameters. In a context where changes in climate are more and more evident, it appears interesting to study how such slow component is additionally potentially affected by climate. In a combined study, based on analysis of daily rainfall patterns and hydrological modelling simulation exercises, which were validated with observational data, we aim to illustrate the impact of the climate variability on the baseflow process. About 15 catchments, spanning from south to north Europe and ranging from arid Mediterranean to maritime temperate climate conditions, have been analysed. The relative amount of baseflow is summarized by the BFI, the impact of climate properties can be investigated with the intra-storm period (l) and a measure for catchment effects is the catchment slow response delay time (K_s). On an empirical base it is possible to identify a threshold ratio l/K_s making a distinction between "poorly-drained" and "well-drained" catchments. In contrast to poorly drained catchments, well-drained ones, characterized by small l/K_s ratios and large BFI values, appear to be more sensitive to the length of the inter-storm period, with a steep rate of BFI decrease for increasing l. This means that longer dry spells decrease the baseflow contribution more in well-drained catchments compared to poorly-drained ones. The modelling exercise allows to simulate catchment response for a wider range of l/K_s ratios, estimating at which extent the catchments features are able to mitigate the climate variability.

IAHS (Hydrology)

HW13p - HW13 Hydrological Predictions in Ungauged Basins

HW13p-176

On the hydrological similarity of hillslopes

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Hydrologic similarity as a unifying organising principle is an ongoing field of research in hydrology. We understand similarity as a dynamic and scale-dependent measure related to the response or the state changes of a hydrological system. Recent studies proposed that this functional similarity is nothing static, but emerges at different scales depending on the prevailing forcing conditions and system states. While it is reasonably self-evident that comparable physiogeographic characteristics in combination with likewise hydro-climatological forcing lead to comparable system responses, quantitative understanding of these relationships is scarce.

To overcome this limitation, we analyse hydrological similarity using a virtual landscape approach based on a spatially explicit hydrological model. We simulate a 6-km² research catchment represented by 169 2-d hillslopes, each of which was parameterised individually according to its characteristics (e.g., topography, soil type, land use). In this setup, the individual contributions of each hillslope to the catchment’s runoff response is analysed by dynamical grouping of the hillslopes during the model period according to their responses, namely discharge, state changes, evapotranspiration fluxes, and quantify the differences in their physical landscape descriptors.

These results provide insights about which attributes of hillslopes are particular suited to address hydrological similarity, on what time scale grouping of model elements needs to be done and how grouping differs in context of different hydrological responses. Furthermore, we analyse how many hillslopes and therefore spatial complexity is at least necessary to simulate or observe a catchment’s behaviour within a certain level of confidence.

IAHS (Hydrology)

HW13p - HW13 Hydrological Predictions in Ungauged Basins

HW13p-177

Global-scale regionalization of hydrological model parameters using data from many small catchments

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Numerous regional studies have demonstrated the effectiveness of parameter regionalization in improving the streamflow (Q) estimates of hydrological models. However, current macro-scale hydrological models tend to rely on a priori parameterizations and thus may not reach their full potential in terms of Q estimation performance. Here we used a large set of 3328 small catchments (<10,000 km2) around the globe to set up and evaluate a model parameter regionalization scheme at global scale. The Hydrologiska Byråns Vattenbalansavdelning (HBV)-light model was chosen to test the scheme because of its flexibility and average complexity. The catchments were calibrated against observed Q using an objective function incorporating both behavioral and goodness-of-fit measures, after which the catchment set was split into subsets of donor and evaluation catchments based on the calibration performance. The calibrated parameter sets of the donor catchments were subsequently transferred to grid cells with similar climate and physiographic characteristics, thereby producing parameter maps with global coverage. The regionalized parameters produced markedly better Q estimates than spatially-uniform parameters, even in evaluation catchments located >900 km away from the closest donor catchment. There was an overall lack of suitable donor catchments for mountainous and tropical environments which should be addressed in future studies. Two current (uncalibrated) macro-scale hydrological models performed relatively poorly, suggesting that there is considerable merit in regionalizing the parameters of such

models. The produced HBV-light parameter maps including ancillary data are freely available via http://water.jrc.ec.europa.eu.

IAHS (Hydrology)

HW13p - HW13 Hydrological Predictions in Ungauged Basins

HW13p-178

Process based design flood estimation under parameter uncertainty: A case study in Southern Italy

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Design flood estimation is usually carried out by using statistical approaches or rainfall-runoff transformation, the latter being particularly affected by a high uncertainty in parameter estimation when ungauged catchments, which represent the majority in practical applications, are considered. In this work, for a predefined rainfall-runoff model, a Bayesian procedure is applied that allows for the assessment of posterior parameters distribution, using the estimate of "hydrological signatures" available in ungauged basins (Bulygina et al. 2009; 2011). Several catchments located in Calabria region (southern Italy) are analyzed, and the regionalized first three L-moments of annual streamflow maxima, whose regressions are available from previous studies for the investigated area (Biondi et al. 2012; Laio et al. 2011), are considered as signatures. Specifically, i) the effects of the model parameter conditioning using the selected hydrological indices and ii) the role played by uncertainty in their regional estimates, are investigated with specific reference to the application of rainfall-runoff models in design flood estimation. To this purpose, both event-based and continuous simulation approaches are used and compared to purely statistical methods, in a number of basin treated as ungauged. The obtained results highlight the relevant impact of uncertainty in regional estimates of hydrological signatures on posterior parameters distribution and on uncertainty bounds of simulated peak discharges.

IAHS (Hydrology)

HW13p - HW13 Hydrological Predictions in Ungauged Basins

HW13p-179

"prediction of rainfall in un-gauged basins with remote sensing from satellite technology and ground-based radar"

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PREDICTION OF RAINFALL IN UN-GAUGED BASINS WITH REMOTE SENSING FROM SATELLITE TECHNOLOGY AND GROUND-BASED RADARS

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KEY WORDS: spatial rainfall,

Rainfall measurement in a sparse network is a problem for disaster monitoring, prediction and mitigation. Rainfall estimation from space is new technology for Thailand, where unprecedented large amount of rainfall caused catastrophic flood in 2011, influenced by monsoons and tropical storms. The merit of TRMM PR which launched in 1997 is to effectively observe vertical rain profile from the top of cloud and propagate until surface. The relationship between rainfall intensity and cloud top temperature can achieve primary estimator using Bayes Theorem. Precipitation Index (PI), achieved from Look Up Tables (LUTs) which derived from probability of rain occurrence and mean rain rate in split windows using infrared images, shows an achievement of rainfall intensity associated with brightness of temperature bright band (TBB). The results have significance, represents local effects, dynamics and characteristics of rain patterns. The uncertainty of peak events in mesoscale convective complexes (MCCs) and separation between rain and non-rain pixels in thick cirrus remain to be dominated. The application of stochastically multifractals in shorter temporal and spatial distribution will be combined with 1-h automatic telemetry systems for calibration and verification with 3-h composite rainfall map. The correlation coefficient of

monthly area-averaged in sparse network (1 gauge/10,000 sq.km.) is 0.59.

IAHS (Hydrology)

HW13p - HW13 Hydrological Predictions in Ungauged Basins

HW13p-180

Development of an event-based rainfall-runoff model in a small tropical catchment with hydroelectric dams in Tahiti (French Polynesia)

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The inactive volcanic island of Tahiti, in French Polynesia, is exposed to heavy rainfall, up to 10 m per year. The whole island is deeply dissected by erosion and the catchments are small and elongated. These characteristics induce flash-floods which may cause heavy damages. The aim of this study is to elaborate a rainfall-runoff model for the small Titaaviri catchment of about 15 km², crossed by two hydroelectric dams. The Titaaviri River, located in the southeastern part of Tahiti, has been recently equipped with a rain-gauge and pressure sensors recording water level. This study uses the dataset recorded during the first year of observation. Forty main flash-floods have been identified and are characterized by a rapid stream rise with a response time between 20 and 50 min. This event-based model includes three main steps. The first one eliminates the evapotranspiration budget which is high in Tahiti, due to the tropical climate. The second one is an infiltration function, which cannot be neglected in the fractured volcanic complex. Finally the third one is a cascade of linear reservoirs including a man-made dam. The inputs of the model are rainfall, evapotranspiration as well as dam parameters (water level, leaks and turbine inflow).

IAHS (Hydrology)

HW14a - HW14 Advancing Water Quality Prediction at the Catchment Scale: New Theories and Approaches

IUGG-1935

Assessment of climate change impacts on water quality of the Geum River, Republic of Korea

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Over the past decades a changing climate, land use shifts, socio-economic development and political decisions have had a tremendous impact on water supply and water quality. Especially, impacts on water supply of changes in temperature and rainfall have received much attention, yet little is known about the variations of water quality. This study is designed to evaluate and enhance our understanding about the future potential impact of climate change on water quality and the modeling approach. The study will be conducted in the Basin of Geum River, one of the major rivers in South Korea. A conceptual hydrological and water quality model will be developed to simulate the effect of the changing climate on runoff. Concepts and methods of existing models will be used analyze the quantity and quality of water in a basin scale to simulate introduction of pollutant load to the Geum River. Data required in this study included digital elevation data, soil properties, land use, land cover, and source of pollutants. Our study aims to provide information on water quantity and quality to surface water for South Korea under future climatic conditions to provide information on human health, ecological health, agricultural activities, forest and coastal area for the effect.

IAHS (Hydrology)

HW14a - HW14 Advancing Water Quality Prediction at the Catchment Scale: New Theories and Approaches

IUGG-3412

Land use induced pattern of continues in-stream assimilatory nitrate uptake rates from high frequency sensor measurements

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River ecosystem nutrient cycling and export are closely tied to the metabolic activity of primary production. Recently developed in situ nutrient sensors can potentially be used to quantify autotrophic assimilation. We used high frequency in situ measurements of nitrate (NO3) and dissolved oxygen (DO) in the Bode River system of the TERENO Bode hydrological Observatory to i) evaluate seasonal variation and river scale dependency of GPP and to ii) generate independent estimates of assimilatory nitrogen demand. We analyzed 2 year continues data (15 min interval) from four measurement stations ranging from the Selke stream in the lower mountain range to the lowland Bode River.

We are able to show that GPP follows a clear seasonal variation with highest values of up to 3.5 $gO_2m^{-2}d^{-1}$ in spring and an additional second peak during litter fall in autumn in the small forested stream. The lowland river shows a similar but less pronounced pattern with distinct higher GPP values of up to 5 $gO_2\ m^{-2}d^{-1}$. Surprisingly this two modal behavior was not found for the mid sized arable stream with higher light availability. GPP strongly corresponded to the day length in the growing season showing the highest GPP of up to 7 $gO_2\ m^{-2}d^{-1}$ in summer. This may be caused by high periphyton growth due to low dense riparian vegetation. A clear relationship of GPP and dial amplitudes of nitrate concentration could be observed in all streams. Corresponding correlations (R^2) ranged between 0.5 and 0.7. The results show that high frequency in situ measurements potentially allow quantifying GPP and assimilatory nutrient uptake and may help to better calculate nutrient retention in rivers.

IAHS (Hydrology)

HW14a - HW14 Advancing Water Quality Prediction at the Catchment Scale: New Theories and Approaches

IUGG-4204

Cross-fertilisation between process and data-based approaches for modelling sediment load dynamics

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Elements of both process and statistical modelling approaches are useful to estimate temporal dynamics and spatial patterns in suspended sediment and nutrient loads, and to help identify options for catchment management. Process and statistical models have been developed and tested in parallel in the tropical rivers of north-east Australia. The statistical Loads Regression Estimator (LRE) used a generalised additive model based on current and recent discharge, to represent antecedent seasonal conditions. This out-performed rating curves based on current discharge alone but did not represent post-drought spikes in annual concentration well. Annual dry-season ground cover across the river basin was added as a process-based predictor variable, improving prediction of annual loads. In contrast, separating rising and falling limbs of the hydrograph did not improve prediction and that term was removed.

The process-based model Dynamic SedNet has been developed to simulate landuse scenarios. It includes empirical sediment rating curves nested into gully and riverbank erosion terms to constrain predictions with daily runoff or streamflow. Differences in model performance between basins have helped to identify weaknesses in process understanding. The process model has under-performed LRE in predicting TSS load dynamics. This may be due partly to poor quality input datasets.

Correctly representing the dynamics of both source and storage in a process model is difficult. An approach being considered is to calibrate these components together using load estimates from the statistical model. Alternatively, a Bayesian hierarchical framework has been trialled to assimilate statistical-derived load estimates with process models based on the parameter uncertainty in both models.

IAHS (Hydrology)

HW14a - HW14 Advancing Water Quality Prediction at the Catchment Scale: New Theories and Approaches

IUGG-4976

Assessing catchment-scale benefits of best management practices: An integrated modelling approach with field observations and remotely sensed data.

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The Chesapeake Bay (CB) is the largest and most productive estuary in the US. However, the Bay's ecosystems have been greatly degraded and high nitrogen (N) input to the Bay is the foremost water quality concern. In the CB, groundwater contributes more than half of total annual streamflow, and groundwater N loads account for about half of the total annual N load of streams entering the Bay. Nitrate leached to the groundwater has substantial residence time on the order of 5-40 yrs. The implementation of best management practices (BMP), such as winter cover crops or restoration of wetlands, has been emphasized with supports from federal and state government. However, the catchment-scale benefits of these management practices have not been fully assessed. This study presents a new modelling approach to assess the catchment scale water quality benefits of these management practices. We illustrate an integrated modelling approach that combines field survey, remotely sensed data, and newly improved simulation features developed in Soil and Water Assessment Tools (SWAT), to accurately simulate plant growth and nutrient cycling for winter cover crops, and wetland hydrology. This new modelling framework will be applied to two agricultural watersheds in the Coastal Plain. This paired-watershed study is designed to better understand the importance of underlying catchment system dynamics and human impacts on water quality. Different management scenarios relevant to policy-making will be considered and the results will be synthesized to assist decision making to improve the efficiency of these BMPs and target critical source areas.

IAHS (Hydrology)

HW14a - HW14 Advancing Water Quality Prediction at the Catchment Scale: New Theories and Approaches

IUGG-5121

Assessment and prediction of river runoff, water quality and sediment contamination in the Selenga-Baikal basin

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The Selenga River is the main artery feeding Lake Baikal. It has a catchment of ~450.000 km² in the boundary region between Northern Mongolia and Southern Siberia. Climate, land use and socioeconomic changes go along with rising water abstractions and contaminant loads originating from mining sites and urban waste water. In the future, these pressures might have negative impacts on the ecosystems of Lake Baikal and the Selenga River Delta, which is an important wetland region in itself and forms the last geobiochemical barrier before the Selenga drains into Lake Baikal.

Our study aims to evaluate the impacts of climate and land use changes as well as point and non-point contamination on the hydrology and water quality in the Selenga River Basin. We are combining data and model-driven approaches to assess the current and future threats and identify the most relevant stressors. Key steps of the study involve (a) assembling all currently accessible data on discharge and water quality in the Selenga River Basin in an online geodatabase; (b) characterizing recent changes in the hydrology and contaminant loads due to climatic developments and human impacts and (c) assessing different hydrological and water quality models (particularly WaterGAP and ECOMAG) with regard to

their ability to predict future trends in hydrology and water quality given the current data availability.

IAHS (Hydrology)

HW14a - HW14 Advancing Water Quality Prediction at the Catchment Scale: New Theories and Approaches

IUGG-5784

A model framework for simulating water quality evolution within complex aquatic landscapes

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It is well established that aquatic environments such as lakes, rivers and estuaries display complex system properties in response to anthropogenic forcing. Whilst our ability to characterize these dynamics and model them has advanced considerably for ideal systems, it remains difficult to investigate them across more complex aquatic landscapes. New model approaches are required that are able to accommodate spatial heterogeneity, connectivity regimes between terrestrial and aquatic sub-systems, and that are suited to capture the complex feedback and co-evolution processes that shape the signatures we observe in biogeochemical cycles. New approaches and software frameworks are required to facilitate the integration of the diversity of models of ecohydrology and aquatic system dynamics, and to allow their assessment against new streams of data. Here we report on the "Aquatic Ecodynamics" (AED) model framework being applied on the lower Murray River, Australia, that integrates models of riparian dynamics and surface water biogeochemistry with different hydrological and hydrodynamics drivers. Through validation with sensor network data the model system is used to quantify biogeochemical budgets and signatures that characterize individual sub-systems within the landscape, but also to identify thresholds and how the landscape as a whole responds to multiple stressors. Whilst such a coupled system is complex and many uncertainties exist, several theoretically relevant metrics of ecosystem function are being used to guide model assessment.

IAHS (Hydrology)

HW14p - HW14 Advancing Water Quality Prediction at the Catchment Scale: New Theories and Approaches

HW14p-315

Spatial/temporal variation of groundwater composition (2004 – 2014): quality transformation and recovery in a low latitude crystalline basement, Southwestern Nigeria

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Groundwater composition varies considerably from one location to another because of flow paths in diverselithologyand biogeochemical reactions. In this study, change in groundwater composition as it flows through different catchments of varied subsurface geology, geomorphology, human activity/anthropology and land use in crystalline basement complex of Ogbomoso North, Southwestern Nigeria was investigated between the periods of 2004–2014. This is in order to study temporal and spatial transformation in groundwater quality and hydrochemical facies; obtain the pattern of variation of physicochemical components of groundwater; develop a stochastic technique for prediction and modeling; and identify the major factors responsible for variation through models perturbation.

The direction of flow obtained from groundwater flow map constructed from wells inventory data was delineated into three catchments of low, high and low population based on population density and satellite map of the area. Samples of groundwater collected from each catchment were analysed in situ and laboratory work was performed for physical and chemical parameters respectively. Piper diagram was constructed for each catchment in each sampling year to identify hydrochemical facies constituting each phase. Breakthrough curves plotted to obtain trajectories were subsequently modeled to constrain physicochemical parameters through the catchments in each sampling year.

The results obtained from the Piper-Hill diagram suggest two hydrochemical facies namely $Ca(Mg)HCO_3$ and $Ca(Mg)Cl(SO_4)$ and is directly related to the geomorphology of the area. However, there was increase in concentrations of all analytes, except HCO_3^-, PO_4^{3-} and Ca^{2+}that decrease in concentration while turbidity remains unchanged over the period.

IAHS (Hydrology)

HW14p - HW14 Advancing Water Quality Prediction at the Catchment Scale: New Theories and Approaches

HW14p-316

Integrated stormwater management system using SWMM hydrological model, automatic monitoring system and on-site treatment facilities on urban catchment scale

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Increase in impervious area and storm sewer system in urban basin leads to more efficient introduction of pollutant loads and surface runoff to receiving waters. This effect has been causing serious water quality and quantity problems especially in urban streams. This study aims to develop integrated stormwater management system to assist efficient urban stream water quality and quantity control using information from SWMM urban watershed model using weather forecast, real time monitoring system and automatic treatment facility control system. SWMM model was calibrated using hydrograph and pollutograph obtained from field data using automatic monitoring system at study site during rainfall events. The SWMM simulation using the weather forecast can provide data on quantity and quality of surface runoff and can provide information for optimal design and efficient operation methods of stormwater treatment and detention facilities on catchment scale. An underground stormwater detention and treatment system using gravity flow and simple filtration system along with automatic monitoring system was developed. The system will be installed in a test bed in Gwanpyung-cheon stream in Daejeon, Korea and will be verified for its effectively on treatment and storage of stormwater for urban stream environment.

IAHS (Hydrology)

HW14p - HW14 Advancing Water Quality Prediction at the Catchment Scale: New Theories and Approaches

HW14p-317

Riverine nitrogen concentrations under different bioenergy crop management practices in central Germany

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In central Germany, expansion of bioenergy crops such as maize and rape for ethanol production during the last decade led to increasing of fertilizer application rates. To examine the effect of these changes, surface water quality of a drinking water reservoir catchment was investigated for more than 30 years. The Weida catchment (99.5 km^2) is part of the Elbe river basin and has a share of 67% agricultural land use with significant changes in agricultural practices. For the period 2004-2012, the share of maize and rape has been increased by 52% and 20%, respectively, for enhancing bioenergy production. The semi-distributed hydrological water quality HYPE (Hydrological Predictions for the Environment) model was calibrated for discharge and inorganic nitrogen concentrations (IN) during the period 1997-2000 at the Weida catchment. Then, the HYPE model was successfully validated for discharge prediction (with lowest performance of NSE = 0.78 and PBIAS = 3.74%) at three different periods 1983-1987, 1989-1996 and 2000-2003, which are charaterized by different fertilizer application rates. Also, the IN concentrations were well reprsented by the model for the same periods. Results showed that the HYPE model reproduced reasonably well the IN daily loads for the period 1983-2003. In addition, the HYPE model was evaluated successfully to predict the discharge and IN concentrations for the period 2004-2012, where detailed input data in terms of crops management (field-specific survey) have been considered. Land use and crop rotations scenarios, with high hypothetical percentage of acceptance by the farmers, revealed that continuous conversion of agricultural land into bioenergy crops, will most likely, lead to an enrichment of in-stream nitrogen, especially after spring storms.

IAHS (Hydrology)

HW14p - HW14 Advancing Water Quality Prediction at the Catchment Scale: New Theories and Approaches

HW14p-318

Evaluation of Nonpoint sources pollution contribution and its Best Management Practices with SWAT model in Jialu river basin

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Nonpoint sources (NPS) pollution has been an important cause for water quality impairment worldwide. For effective water environment management, It is necessary to comprehend its characteristics and contribution to river water body pollution. The Jialu river basin is selected as study area, which is located in the north of China with water shortage and water quality deterioration. On the GIS platform, the SWAT model is calibrated and validated with the ulitization of hydrological data and water quality data. The simulation results show that the relative error of monthly discharge are 11.70% and 6.61% respectively in calibrated period and validated period. The relative error of monthly ammonia nitrogen is -6.17% in simulated period. Then the SWAT model is applied for NPS pollution spatial distribution analysis and Best Management Practices (BMPs) scenario evaluation. The results show the nitrate nitrogen load, ammonia nitrogen load and organic nitrogen load are 1554.63t/a, 1128.64t/a and 1216.58t/a in 2008 over Jialu river basin. The evaluation of BMPs scenario demonstrate that fertilizing amount reduction and land use type change are most effective for NPS pollution decrease.

IAHS (Hydrology)

HW15a - HW15 Tracer Methods for Understanding the Response of Hydrological Systems to Transient Contamination Inputs

IUGG-1686

Spatial and temporal variation of surface water effect on groundwater recharge in Taihang Mountains, North China

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Groundwater recharge variations in time and space are crucial for effective water management especially in the low-precipitation regions. In order to reveal comprehensive groundwater recharge processes in a catchment with a large topographical relief and seasonal hydrological variations, intensive field surveys were undertaken at 4 times in different seasons (June 2011, August 2012, November 2012, February 2014) in the Wangkuai watershed, Taihang Mountains, which is a main groundwater recharge area of the North China Plain. The groundwater, spring water, stream water and reservoir water were taken, and inorganic solute constituents and stable isotopes of oxygen-18 and deuterium were determined on all water samples. The stable isotopic compositions and inorganic solute constituents of the groundwater were similar to those of the surface water at the mountain-plain transitional area and vicinity of the Wangkuai Reservoir. Additionally, an inversion analysis and simple mixing model were applied for constructing a groundwater flow model in the Wangkuai watershed, which specifically suggested the reservoir water and stream water in the mountain-plain transitional area plays an important role of groundwater recharge. Finally, the estimated contribution rate of precipitation and surface water to groundwater recharge was clearly higher in the beginning of rainy season (June) than that of mid-rainy season (August), even though August is the most humid season. The result seems to show an importance of hydrological unsteady phase between the seasons for groundwater recharge in the low-precipitation regions.

IAHS (Hydrology)

HW15a - HW15 Tracer Methods for Understanding the Response of Hydrological Systems to Transient Contamination Inputs

IUGG-2256

From precipitation to groundwater recharge: Challenges in estimating transit times using environmental isotope approaches

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Stable isotopes of water can provide integrative information about water flow and transport processes. Therefore, they are frequently used in combination with mathematical models to determine transit times of water in different compartments of the water cycle. Of particular importance for groundwater vulnerability assessment are transit times in the unsaturated zone. However, the transient nature of flow in the unsaturated zone as well as structural heterogeneities makes it so difficult to estimate water transit times. Hence, the application of water isotope approaches is challenged by transient and heterogeneous conditions in the unsaturated zone and its transitions with the atmosphere and the groundwater. The objective is to summarize these challenges and how they can be solved. One of the major challenges is to determine the correct isotope input concentration of the recharging water which not necessarily equals the isotope concentration in precipitation; particularly in snow dominated regions or if evapotranspiration is a crucial part of the water balance. Further, spatial heterogeneities can be considered by estimating not only mean transit times but transit time distributions of water additionally giving information about different flow paths. Stable water isotopes can also help to quantify preferential flow. Still, all these parameter are only representative for the observation time being analyzed and may change though. Additionally, changes can be induced by climate and land use changes; the latter being of main importance for the estimation of transit times at the catchment scale. Therefore, more advanced approaches superimposing transit time distributions and additionally giving information about time variability of these distributions are required in future.

IAHS (Hydrology)

HW15a - HW15 Tracer Methods for Understanding the Response of Hydrological Systems to Transient Contamination Inputs

IUGG-2775

Transport of ideal tracers in highly heterogeneous porous media at different flow velocities in a laboratory scale experiment.

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Highly different hydraulic conductivities of two sediment layers in one aquifer cause immobile water regions containing nearly stagnant water. Solutes can diffuse into immobile water regions which effects its retention time. Heterogeneity and the percentage of immobile water are often unidentified in natural aquifers. Hence, the mathematical simulation of solute transport taking regions with immobile water into account remains challenging. The objective of this study was to find a simple analytical model approach which allows quantifying properties of mobile and immobile water regions in a highly heterogeneous porous system at laboratory scale. Therefore, the Single Fissure Dispersion Model (SFDM), which takes into account diffusive mass exchange between mobile and immobile water zones, was applied to model conservative transport in well-defined saturated dual-porosity column experiments. Direct and indirect model validation was performed by running experiments at different flow velocities and using conservative tracer characterized by different molecular diffusion coefficients. In all setups the tracers' concentration curves within one experiment showed difference in peak, tailing and mass recovery according to their diffusion coefficients. These findings were more pronounced at lower flow rates (larger flow times) indicating the dependency of diffusive mass exchange into immobile water regions on tracers' molecular diffusion coefficients. The SFDM simulated all data with high model efficiency and successful model validation supported the physical meaning of fitted model parameters. This study showed that the SFDM, developed for fissured aquifers, is applicable in porous media and can be used to determine properties of mobile and immobile water regions.

IAHS (Hydrology)

HW15a - HW15 Tracer Methods for Understanding the Response of Hydrological Systems to Transient Contamination Inputs

IUGG-4689

Use of deuterium excess in hydrological studies of arid regions

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The deuterium excess, derived from deuterium (δ^2H) and oxygen-18 ($\delta^{18}O$) composition of water, has shown significant potential in hydrological studies for tracing the water cycle processes of arid regions in particular. Deuterium excess is primarily subject to the mean relative humidity of the air masses formed above the ocean surface, and it is not affected by the precipitation processes. Thus, the deuterium excess is considered as a good indicator of the water vapour origin or the source of precipitation. Considering that recycled moisture has high values of deuterium excess if the proportion of moisture, evaporated from the ground by surface water and/or soil is accordingly high in evapotranspirated moisture, the deuterium excess can be used to calculate the ratio of recycled moisture. Taking the arid Urumqi basin as an example, we found an average recycling ratio of 8%. Since deuterium excess decreases during evaporation and is unrelated to the isotopic composition of the initial water, it is a potential tool for determining the contribution of the evapoconcentration of a given water body using the relationship between deuterium excess and salinity rather than between δ^2H or ($\delta^{18}O$) and salinity. Using deuterium excess, we found that mineral dissolution contributes most of the salinity (67–77%) for Boston Lake and the Kongque and Tarim rivers. The next challenge for the application of deuterium excess is on the interpretation of hydrological processes based on the continuous monitoring data at a finer scale (such as hourly and daily).

IAHS (Hydrology)

HW15a - HW15 Tracer Methods for Understanding the Response of Hydrological Systems to Transient Contamination Inputs

IUGG-5711

Some isotopic investigation of water sources situated along the border Romania – Bulgaria, in the danube area

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The isotopic methods are an integral part of modern hydrology. Isotopic investigations contributes to the possibility of getting a detailed insight into the water cycle. Measurements of the environmental isotopes enable observations of hydrological systems in extensive geographical scales and time scales. In the case of groundwater flow, environmental isotopes are of particularly used for identification and quantification of involved groundwater or surface components and their elements, which, in most cases, cannot be achieved by classical methods.

This paper aims to present the results obtained in the study called 'Research and detailed analysis of groundwater located along the border RO / BG using environmental isotopes", as part of the project „Danube WATER integrated management".

Environmental isotopes used in this research are: Tritium (^{3}H), Deuterium (^{2}H,D) and Oxygen-18 (^{18}O). It were performed: isotopic analysis of spatial distribution, isotopic analysis of statistical terms, correlation, zonal and water types analysis, temporal evolution, on isotopes and water types, mean residence time (MRT) groundwater calculation and hydrogeologic context classification results.

This study/research provided a database of 400 values, the current state of environmental isotope contents and it can be used as a reference for assessing developments natural changes caused by environmental factors and impacts of anthropogenic effects.

IAHS (Hydrology)

HW15b - HW15 Tracer Methods for Understanding the Response of Hydrological Systems to Transient Contamination Inputs

IUGG-1857

Analyzing trace element information from a regional hydrogeological system (Empordà basin, NE Spain)

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Hydrochemical studies of regional hydrogeological systems usually rely on major components and isotopes. Nevertheless, minor or trace elements are usually analyzed, yet the meaning of their occurrence and concentration is not always straighforward to complement the information derived from major components. In this contribution, we explore the relationship of distinct trace elements in the frame of a regional system in a two-fold way: 1) looking at their association to major groundwater hydrochemical facies and its relationship with water-rock interaction or with human pressures, and 2) searching which information about the flow dynamics can be derived from them.
A dataset consisting on 60 groundwater samples obtained from supply wells at diferent depth (from 25 to 240 m) was created to characterize the regional groundwater flow system in the Empordà basin (NE Spain). Many geological units are involved in the system, consisting in igneous, metamorphic and sedimentary rocks. Major hydrochemical facies are Ca-HCO3, Ca-SO4, and Na-HCO3. Results indicate that trace elements can be hardly assigned to any specific geological unit, and they show a sparse geological distribution that difficults their use as tracers of geochemical processes at a regional scale. PCA analysis helps relating their occurrence with the major observed hydrochemical facies, so some useful information about the system dynamics can be inferred. This information points out potential exploitation strategies to avoid groundwater quality problems for human supply.

IAHS (Hydrology)

HW15b - HW15 Tracer Methods for Understanding the Response of Hydrological Systems to Transient Contamination Inputs

IUGG-3058

Groundwater ages and hydrogeological dynamics in the Empordà basin (NE Spain)

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Regional aquifers usually show complex dynamics that can be described using hydrochemical and stable isotopes, which give a snapshot description of the flow system. The use of radioactive tracers, as radiocarbon and tritium, permit estimating travel times within the aquifer, presenting a complementary understanding of flow-paths. In this contribution, radiocarbon and tritium data from the Empordà basin aquifer system, located in NE Spain, are presented and discussed to distinguish groundwater origin in distinct formations showing similar hydrochemical facies.
The Empordà basin, covers an area of ca. 1200 km2, which lays between the Pyrenees and the Mediterranean Sea, and it has a tectonic origin. Regional, large scale flow systems developed within the fault zones allow a vertical recharge from the aquifer basement towards the most shallow aquifers, in particular, the fluvio-deltaic formations of the Ter and Fluvià-Muga Rivers.
Radioactive tracers indicate flow-paths among the distinct geological units which can not be distinguished without groundwater dating methods. Moreover, they help to explain the occurrence (or lack of occurrence) of nitrate pollution in some deep aquifer layers; pointing out some clues about the migration and appearance of nitrate at specific locations.

IAHS (Hydrology)

HW15b - HW15 Tracer Methods for Understanding the Response of Hydrological Systems to Transient Contamination Inputs

IUGG-3236

Hydrograph separation using ionic concentration measurement

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The method of hydrograph separation considered for this study is a method to distinguish old and new water in a stream. This method is based on the fact that the ion content of the water depends on the time water has spent in the soil structure – there is a difference in the ionic composition between the groundwater (old water causing the base flow) and that of a given storm (new water). Groundwater has a greater content of Na^+ ions than that of K^+ ions, which is caused by a greater sorption of K^+ ions in the soil and by subsequent uptake of K^+ ions by plants. This means that in the storm water the ratio of Na^+ and K^+ ions is significantly lower than that in the ground water. Other quantities that are expected to vary with the ratio of the base flow to the storm runoff are contents of particular dissolved solids. These manifest themselves by variation of the electrical conductivity of water. It follows that a hydrograph can be separated into a new- and old-water part by means of measuring of the electrochemical properties of out-flowing water – Na^+ and K^+ ion content, electrical conductivity, provided that these quantities in the storm water are known. In dry and warm period, the age of water flowing into the stream can be quantified, since in the period when the flow rate decreases, also decreases the content of potassium ions in the water flowing from the soil into the stream. This is because consumption of potassium in the soil water by transpiring plants. Therefore, the age of the soil water can be measured by the concentration of potassium ions in the water flowing from the basin.

IAHS (Hydrology)

HW15b - HW15 Tracer Methods for Understanding the Response of Hydrological Systems to Transient Contamination Inputs

IUGG-3380

Effects of surface water on groundwater with high salinity during flood season in Tay Island region, Mekong Delta, Vietnam

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Predominant distribution of high salinity groundwater in the shallow aquifer and frequent floods during the rainy season are serious regional issues on water in the Plain of Reeds, north of the Mekong Delta. To investigate the spatial distribution of groundwater salinity, and evaluate the effect of surface water on the groundwater recharge during the flood season, the present study was performed in Tay Island region, using multi-tracers approach of the stable isotopes of Hydrogen (δ^2H) and Oxygen ($\delta^{18}O$) and solute ions concentrations in the groundwater, river water and channel water. The geochemical compositions of groundwater in the 1st aquifer distributed at the depths of 10 to 40 m is characterized by Ca-HCO_3 type. In particular, the groundwater in Tay Island showed similar stable isotopes compositions as that of the Mekong River, and showed the highest Ca-HCO_3concentrations, indicating that it seems to be recharged by the river. The groundwater in the 2nd aquifer distributed at the depths of 40 to 80 m showed the high Na-Cl concentrations being similar to that of fossil water, and the concentration decreased with a distance from the river toward to the inland region, whereas, the δ^2H and $\delta^{18}O$ increased with that. These results indicate that the groundwater of the 2nd aquifer in the inland region seems to be dominantly recharged by the groundwater in the 1st aquifer especially in the vicinity of the river. Additionally, the $\delta^{18}O$ of channel water in the inland region were enriched to the values ranging from -1 to -1.5 ‰ with decreasing of flow in the channel, suggesting that the channel water may recharge the groundwater in the inland region during the flow.

IAHS (Hydrology)

HW15b - HW15 Tracer Methods for Understanding the Response of Hydrological Systems to Transient Contamination Inputs

IUGG-3483

Dynamics of radio cesium released by Fukushima NPP accident in groundwater, surface water and spring water in the headwater catchments

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We have monitored dissolved radio cesium concentration in the rainfall, soil water, groundwater, spring water and stream water in headwater catchments covered by grass, forest and crop at intervals of one hour during rainstorms to a few weeks during rainless periods since May 2011. Also, inorganic solute concentration, stable isotopes and tritium concentration have been observed.

The results show that concentration of dissolved cesium in stream water fluctuated between 0.12 and 1.18 Bq/L in 2011 with decreasing to below 0.1 Bq/L after 2012 during rainless periods, whereas it increased up to 0.52 Bq/L at maximum during rainstorms. End member mixing analysis suggests that hydrological dominant sources in the stream in the rainstorms are groundwater and soil water, whereas the sources of high dissolved cesium seem to be rainfall / litter in the forest.

IAHS (Hydrology)

HW15b - HW15 Tracer Methods for Understanding the Response of Hydrological Systems to Transient Contamination Inputs

IUGG-3508

Investigation the polluting effect of heavy elements on underground water in Behbahan Plain, south west Zagros

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Ground water as an essential part of natural resources seems to be an important issue in environmental engineering so preservation and purification of it can have a critical value for any community. This paper investigates the concentration of elements of Pb, Cd, As, Se for ground water in Behbahan (a city on south west of Iran), to this purpose a group of 30 wells were studied to examine the concentration of the elements of Pb, Cd, As, Se and also to determine PH, EC, TDS, temperature and the ions of HCO_3^{2-}, SO_4^{2-}, Cl^-, Na^+, Mg^{2+}, Ca^{2+},K^+ for the wells. Results of the analyses show that the concentration of the elements of Pb, As and, Cd in 33, 13, 56 percent of the wells respectively and Se in all the samples were greater than normal range of WHO. Since there is a low correlation between Pb and major ions of (HCO_3^{2-}, SO_4^{2-}, Cl^-, Na^+, Mg^{2+}, Ca^{2+}, K^+) it can be revealed that Pb overconcentration caused by human contamination. Relative great correlation between Se and the ions showed that Se derived from Gypsum and Dolomit. The big correlation between As and major cations and onions, imply that As can originate from dissolution and liquidation of mineral evaporation in the zone. The high rate of cadmium concentration in urban sewage water is due to the small industries, workshops and, mills wastewater.

IAHS (Hydrology)

HW15p - HW15 Tracer Methods for Understanding the Response of Hydrological Systems to Transient Contamination Inputs

HW15p-319

Contamination of groundwater by intrusion of sea water of Tsunami on March 11 in 2011 in Tohoku of Japan

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On March 11 in 2011, we had a huge Tsunami wave generated by incredible earthquakes in Sanriku of Tohoku in Japan. The water supply systems in many cities and towns on the Pacific coast in Sanriku were destroyed and down. Many wells were perfectly flooded with Tsunami and plenty of sea water entered into groundwater that was flowing in the alluvial deposits. Consequently, groundwater was heavily contaminated. We have been carrying out on-site-measurements of the water table depth and water quality once and/or twice per a year since June in 2011, and also sampling groundwater for analyses of inorganic chemistry and isotopes. As a result, we obtained the important observation results of the high and abnormal values of EC (electric conductivity), Cl, Na, Ca, and heavy metal ions of groundwater of study wells in Tsunami affected areas in Sanriku. However, all these elements have gradually decreased with time since the sea water brought by Tsunami on the ground surface has perfectly flowed to the sea. In March in 2014, although the values of Cl ion and EC (as tracers) of groundwater of a study well (Sukezukuri well) in Minamisanriku-cho reached approximately those of groundwater of wells in the area without the intrusion of the Tsunami sea water, the values were slightly higher and still fluctuated. This fact suggests that it takes more than three years for perfect recovery of groundwater in the Minamisannriku-cho area at least.

IAHS (Hydrology)

HW15p - HW15 Tracer Methods for Understanding the Response of Hydrological Systems to Transient Contamination Inputs

HW15p-320

Evaluation of substances coexisting with volatile organic compounds in contaminated groundwater as a tracer for identifying the pollutant source

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During our annual groundwater monitoring program, we sometimes come across groundwater contaminated by toxic substances such as heavy metals and volatile organic compounds (VOCs). Although, from a legal point of view, the person responsible for the contamination must remove the contaminant, this is extremely difficult to implement in real life because there is no way to track groundwater flow. Therefore, if tracer compounds, specific to or reflective of the type of industry or tangible products, can be detected from the contaminated groundwater, it could help in tracking the source of the contaminant. Therefore, this study focused on coexisting compounds that can be detected during VOC determination as candidates of tracer compounds. We selected prominent but unidentified peaks in the GC/MS chromatogram and compared their mass spectrums with the ones in the mass spectrum database (NIST) to identify these compounds. Our results show that these compounds mainly consisted of plasticizing agents, fragrances (especially food fragrance), dyes, surfactants, and cleaning solvents. The data on the groundwater sampling well (latitude and longitude, the concentration of VOCs, detected tracer candidate compound) were listed in a table, and were converted into GIS data. In conjunction with the data of surrounding wells and factories, we discussed the availability of the identified compounds as a tracer compound.

IAHS (Hydrology)

HW15p - HW15 Tracer Methods for Understanding the Response of Hydrological Systems to Transient Contamination Inputs

HW15p-321

Characterization of preferential flow path in the fractured rock using nano-iron tracer

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Preferential flow is important for the study of groundwater flow and contaminant transport in the fractured rock. It is often difficult, however, to find the exact location of permeable fractures in a borehole. Characterization of preferential flow path through permeable fractures between adjacent boreholes is even a more challenging task. In this study, we conducted a series of field tests at an experimental well station in the fractured formation. Two multiple-well pumping tests were implemented to confirm hydraulic connection between wells A and C, but poor connection between wells A and B or wells C and B. This is followed by heat-pulse flowmeter measurements, detecting permeable fracture zones in wells A and C. While a few fracture zones in rock core or televiewer imaging are found permeable, most fracture zones are not really permeable. Then the nanoscale zero-valent iron solution was used as a tracer to inject into well A. The fluid conductivity recorded at the depth of 23.6 m in well C began to increase rapidly shortly after the injection, indicating the arrival of the nano iron solution. All of the nano-iron absorbed on the magnets in the observation well is distributed between the depth of 22.9 and 24.0 m, which is consistent with a highly permeable fracture zone detected by the flowmeter. Our study result indicated that nano-iron tracer test in conjunction with the flowmeter measurement could be a potential technique for characterizing preferential groundwater flow path in the fractured rock.

IAHS (Hydrology)

HW15p - HW15 Tracer Methods for Understanding the Response of Hydrological Systems to Transient Contamination Inputs

HW15p-322

"Impact of a rainfall intensity on water flow and solute transport through unsaturated zone: a lysimeter study"

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The impact of a rainfall intensity on water flow and solute transport in unsaturated zone remains a challenge in groundwater vulnerability assessments. The objective of this study was to identify such impact basing on the results of two artificial tracer experiments performed at the lysimeter station located in Krakow, Poland. Four bare soil lysimeters with lengths of 1 m (lysimeter A) and 1.5 m (lysimeter I-III) and surface areas of 1.0 and 0.28 m^2 respectively were used. They were filled with three types of sand of similar grain-size composition but different mineralogical composition. All lysimeteres were instrumented to collect the percolating water for chemical and tracer analyses. Lysimeter (A), was weighable which yielded the cumulative water content in the soil as a function of time. The first experiment started in September 2008 when KBr solution was injected in all lysimeters. Bromide concentration in lysimeter A and I-III was respectively ~2000 and ~1500 mgBr/L. The experiment was repeated in August 2011 with slightly minor bromide concentration (lysimeter A ~1250 and I-III ~1350 mgBr/L). Mathematical modeling of bromide tracer breakthrough curves using the Variable Flow Dispersion Model has shown that flow through the lysimeters is generally characterized by two components with different velocities varying between soils and depended on term of injection. Differences in residence time distribution between the experiments for the same lysimeter indicate that the variations in rainfall intensity during the two first weeks after tracer injection had a dominant influence on water flow.

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IAHS (Hydrology)

HW15p - HW15 Tracer Methods for Understanding the Response of Hydrological Systems to Transient Contamination Inputs

HW15p-323

Use of environmental tracers to assess vulnerability of a high mountain karst system (Tatra Mts., Poland)

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High mountain environment, such as Tatra Mts. (Poland), is a very attractive tourist destination. This area protected as a national park has been influenced by mass tourism since the 60s with almost three million visitors per year. Tourist infrastructure such as tourist lodges are crucial point sources of water pollution. Tatras oligotrophic waters are especially sensitive to any nutrient enrichment. Use of the isotopic and chemical tracers helps to identify the pathways of contaminants and to evaluate residence time of groundwater between the source areas and receptors of pollution.

The study was performed in the Olczyski Creek catchment (4.7 km^2) located in the Tatra Mts. between 890 and 1642 m a.s.l. The geology of the catchment comprises crystalline granitic rocks, karstified limestone, dolomite and Quaternary glacial sediments. Vaucluse spring water in the catchment was sampled once a month from June 2010 to May 2011. The spring with the mean discharge of 0.5 m^3/s drains both karst carbonate rocks and fissured granitic aquifers. Electrical conductivity, pH, main ions, tritium, $\delta^{18}O$ and δ^2H, $\delta^{13}C$ of dissolved inorganic carbon were measured. Samples of precipitation were collected twice a month in the high mountain recharge area of the spring at the elevation 1520 m a.s.l.

Time series of tritium concentrations spanning four decades were fitted to the lumped parameter dispersive model giving the mean water residence time (MRT) of 19.5 years. However, quick responses of the physico-chemical and isotopic characteristic of spring water to high rainfall or snowmelt events indicate contribution of faster flow components. The springs are thus potentially vulnerable to the anthropogenic pollution despite lack of nutrient contamination in the springs found in this study.

IAHS (Hydrology)

HW16a - HW16 Observations and Modelling of Land–Atmosphere–Society Interactions in Hydrology

IUGG-0211

Environmental risk of climate change and groundwater abstraction on stream ecological conditions

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A doubling of groundwater abstraction rates has been proposed in selected areas of Denmark to meet water resource demands. Combined with projected climate change, which is characterised by increased annual temperature, precipitation, and evapotranspiration rates for the country, the impacts to low flows and groundwater levels are of interest, as they relate to aquatic habitat and nitrate leaching, respectively. This study evaluates the risk to stream ecological conditions for a lowland Danish catchment under multiple scenarios of climate change and groundwater abstraction. Projections of future climate from 11 ENSEMBLES climate models are first bias corrected with a distribution based scaling method and then used to force hydrological simulations of stream discharge, groundwater recharge, and nitrate leaching from the root zone. Hydrological modelling utilises a sequential coupling methodology with DAISY, a one dimensional crop model describing soil water dynamics in the root zone, and MIKE SHE, a distributed groundwater-surface water model. The relative and combined impacts on low flows, groundwater levels, and nitrate leaching are quantified and compared to assess the water resource sensitivity and risk to stream ecological conditions. We find low flow and annual discharge to be most impacted by scenarios of climate change, with high variation across climate models (+/- 40% change). Doubling of current groundwater abstraction rates reduces annual discharge by approximately 20%, with higher reductions to low flows seen around 40%. Climate change has a greater relative impact on groundwater levels (+/- 25%) than the groundwater abstraction scenarios (+/- 5%) alone, though the combined impacts can change groundwater levels up to +/- 35%.

IAHS (Hydrology)

HW16a - HW16 Observations and Modelling of Land–Atmosphere–Society Interactions in Hydrology

IUGG-4322

Water, energy and carbon balance research: Recovery trajectories for oil sands reclamation and disturbed watersehds in the western boreal forest

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The Oil Sand Region (OSR) of North-Central Alberta, Canada exists within the sub-humid climate of the Boreal Plains ecozone, with a slight long-term moisture deficit regime. Much recent work in the Plains Region of the Western Boreal Forest suggests that on average it is the wetlands that supply moisture for the productivity of upland forests in this region. Thus, water use of reclaimed forests in decommissioned oil sands mine areas is going to be a critical factor determining not only the sustainability of these system but also adjacent wetlands. Water Use Efficiency (WUE), which links photosynthesis (Gross Ecosystem Production (GEP)) with water use (Evapotranspiration (ET)), provides a useful metric to compare ecosystems and evaluate their utilization of resources. 41 site years of total growing season water and carbon flux data over 8 sites (four reclamation, four regeneration) were evaluated using eddy covariance micrometeorological towers. WUE shows clear discrimination among ecosystem types as aspen stands assimilate more carbon per unit weight of water than conifers. WUEs also change with time as ecosystems become more effective at transpiring water through plant pathways compared with bare-soil evaporation, which allows an assessment of ability to limit water loss without carbon uptake. In addition, clonal rooting systems allow aspen forests to recover quicker after disturbance than reclamation sites in terms of their WUE. For reclamation sites, there is considerable variability in GEP and ET associated with vegetation establishment, with enhanced ET losses over-riding any significant changes in C uptake, suggesting that long-term mine water management must consider ecosystem pathways if down-gradient wetlands and end of pit lakes are to be sustained.

IAHS (Hydrology)

HW16a - HW16 Observations and Modelling of Land–Atmosphere–Society Interactions in Hydrology

IUGG-4639

The consideration of land–atmosphere–society interactions in large scale agricultural developments in sub-saharan Africa

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Many parts of Africa are being targeted for agricultural development by both local and international investors because of the availability of large areas of seemingly suitable land. However, in Africa, society is largely dependent upon that land for its survival, and plans for production of Food, Fibre, Fodder and now Fuel both nationally and internationally mean that the land is subject to huge pressures. Utilising a variety of crops many African countries have already instigated and accepted direct foreign investment, often at the scale of 1000’s of hectares. However, in these highly seasonal and largely semi-arid environments, the interaction between these societal decisions which result in major changes in land cover and thus hydrological fluxes and the impacts of water resources are little understood and largely ignored in these developments.

In this paper, an African perspective on Land-Atmosphere-Society apects of large scale agricultural development is provided. We highlight the reality that much of Africa is subject to extremely high rainfall, very high evaporation and hydrological variability and has a large proportion of rural smallholder famers. The implications of this for both the sustainable production of crops, the direct and indirect impacts on water resources and it’s societal implications are explored.

Drawing on hydrological field studies of sugar cane, various other biofuel feedstocks and teak from South Africa, where various policies and laws specifically address streamflow reduction arising from high evaporation crops, and Tanzania, where extensive tracts of land are being developed, lessons for developing countries and investors are provided.

IAHS (Hydrology)

HW16a - HW16 Observations and Modelling of Land–Atmosphere–Society Interactions in Hydrology

IUGG-4747

Hydrological sensitivity of land use scenarios for climate mitigation

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Bringing atmospheric concentration to 550 ppm CO_2-e or below by 2100 will require large-scale changes to global and national energy systems, and potentially the use of land (IPCC, 2013). The Danish government aims at reducing greenhouse gas emissions by 40 % in 1990-2020 and energy consumption to be based on 100 % renewable energy by 2035. Strategies developed to reach these goals require land use change to increase the production of biomass for bioenergy, further use of catch crops, reduced nitrogen inputs in agriculture and establishment of permanent grass fields. Currently, solar radiation in the growing season is not fully exploited for biomass production, and it is expected that biomass production for bioenergy can be supported without reductions in food and fodder production. Impacts of climate change on the hydrological sensitivity of biomass growth and soil carbon storage are however not known. The present study evaluates the hydrological sensitivity of Danish land use options for climate mitigation in terms of crop yields for wheat, barley, maize and clover under current and future climate conditions. Hydrological sensitivity was evaluated using the agrohydrological model Daisy. Simulations during current climate conditions were in good agreement with measured dry matter, crop nitrogen content and eddy covariance fluxes of water vapour and CO_2. Climate scenarios from the European ENSEMBLES database were downscaled and used for simulating water, nitrogen and carbon balance for 2071-2100. Due to warmer climate and longer growing season, the biomass growth potential generally increase, but water stress also increases in strength and extends over a longer late-summer period, thereby increasing sensitivity to water availability fluctuations in the future.

IAHS (Hydrology)

HW16a - HW16 Observations and Modelling of Land–Atmosphere–Society Interactions in Hydrology

IUGG-5061

Eco-hydrological responses to climate variability and management over the North China Plain

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Insufficient water resource is a major constraint on sustainable development of agriculture and socio-economy, and an imminent threat to national food supply security. Strategy and policy of regional water management demand reliable prediction of areal evapotranspiration (ET) and water use efficiency (WUE). Here the process-based VIP eco-hydrological model integrating remote sensing information is applied to predict regional eco-hydrological responses to climate variability and management over the North China Plain (NCP) from 1981 to 2012. Results show that latitudinal gradient pattern was quite noticeable for both ET and GPP distribution, especially in winter wheat growing season. With respect to water resources deficits, it is revealed that fields with ET higher than precipitation are mainly located in the north of Yellow River, while the southern NCP showed a rainfall surplus at annual level. It is found that both annual ET and GPP are increasing during the study period. Affected and regulated by both climatic variability and crop responses in terms of vegetation growth and phenology, both ET and GPP illustrate noticeable inter-annual variability. The contributions of climate change, atmospheric CO_2 enrichment and human activities to ET and GPP trends are separated. The estimated ET and water use efficiency (GPP/ET) are used to assess the suitability of crop system under the current conditions of climate and water resources availability, and some adapted cropping pattern and systems are suggested for policy decision.

IAHS (Hydrology)

HW16b - HW16 Observations and Modelling of Land–Atmosphere–Society Interactions in Hydrology

IUGG-0921

Large scale water budget of the Ganga River Basin, India

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We have constructed a regional hydrological model of water budget of Ganga river basin, India using Soil and Water Assessment Tool (SWAT) and satellite based datasets, such as DEM, LULC, soil etc. Simulated model is validated with in-situ river gauges level and discharge as well as groundwater level data measured in the wells. The simulated model provides a synaptic view of spatial and temporal variability of water storage over entire Ganga basin, which is crucial for understanding the anthropogenic impacts on terrestrial hydrological cycle and also useful for water management in river basin scale. Furthermore, we utilized monthly data from the GRACE gravity mission to estimate the changes in vertically integrated Terrestrial Water Storage (TWS) over Ganga basin. The simulated results of TWS from hydrological model compare well with GRACE derived TWS with more than 95% confidence level. The groundwater storage (GWS) over entire basin is estimated from GRACE data and hydrological model and found comparable with well observations. Both, hydrological simulated model and GRACE derived results show consistent decreasing trend in water storage over Ganga basin over last decade.

IAHS (Hydrology)

HW16b - HW16 Observations and Modelling of Land–Atmosphere–Society Interactions in Hydrology

IUGG-1392

Coupled component modelling for inter- and transdisciplinary climate change impact research: Dimensions of integration and examples of interface design

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In hydrological research the importance of interfaces between the traditional knowledge fields in natural and social sciences is increasingly recognized. By means of coupled component modelling, the process of developing interface designs supports communicative, social and cognitive integration between representatives of different knowledge fields. The task of integration is thereby not merely an additive procedure but has to be considered as important part of the research process itself. In our application, the development of a coupled component model facilitates an integrative assessment of the impact of climate change on snow conditions and skiing tourism in a typical Austrian ski resort. We elaborate the integration on two abstraction levels, a theoretical one and an applied one related to our case study. Other than model output, results presented here relate to the inter- and transdisciplinary development of the coupled component model and its interface design. We show how scientists from various disciplines and representatives from diverse societal fields jointly designed the interface tools. We identify joint model development - taking into consideration the different dimensions of integration - and recursive modelling as keys for successful inter- and transdisciplinary integration. Such integrative interface research can provide new insights which go beyond the sum of what can be learned from its disciplinary components.

IAHS (Hydrology)

HW16b - HW16 Observations and Modelling of Land–Atmosphere–Society Interactions in Hydrology

IUGG-3154

Modelling framework for regional climate adaptation in the Nile River Basin.

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Flows in the Nile are a critical resource for the economy of the region as agriculture, energy and livelihoods depend on the river flows. The strong dependence on rain-fed and irrigation-based agriculture makes the Nile Basin region highly vulnerable to climate variability. Faced with dramatic population growth, increasing water demands and a changing climate, floods and water scarcity are pressing issues for the Nile Basin countries. Managing and developing the water resources within the basin must also address the trade-off between developments upstream, water use downstream, between different countries and sectors (agriculture vs. energy, environmental quality vs. agriculture). An important knowledge gap, therefore, is the lack of tools and information to assess climate adaptation measures at the regional scale and to prevent negative trans-boundary impacts, while sharing benefits and risks in an equitable manner.

In this paper we present a modelling framework to support climate adaptation on a regional scale. The methodology exploits a novel perturbed physics ensemble of climate models and a systematic procedure to identify a representative sub-set from a larger Global Climate Model ensemble based on the ability of the members to reproduce the key climatic processes in a number of regions of Africa while representing the range of outcomes of the full ensemble. Downscaled regional climate model projections are then used, together with a regional hydrological model, to assess the impacts of climate change on flow extremes and water scarcity. In this paper we present both the framework and results of climate changes on the flow characteristics in the basin for 2020-2049 and 2070-2099.

IAHS (Hydrology)

HW16b - HW16 Observations and Modelling of Land–Atmosphere–Society Interactions in Hydrology

IUGG-3217

Co-innovation and co-development for improved water management outcomes – A case study

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In New Zealand, rainfall is uniformly distributed, and thus agricultural practices such as irrigation and nutrient application can be, or should be, scheduled around it. However, poor access to reliable current and forecast weather data seldom allows farmers scheduling farm activities based on weather. Irrigation and nutrient applications are often scheduled before large rainfall events, leading to loss of water, and leaching of nutrients via drainage. Our project is designed to explore the use of a co-innovation approach that combines biophysical and social sciences. The approach involves a range of stakeholders in co-developing solutions for better water and nutrient management. For this project, a selection of farmers (including a farmer from indigenous Maori culture) from an irrigation scheme are being provided with farm-specific observed hydrological and meteorological data on current rainfall, soil moisture and temperature, drainage and evapotranspiration, and region-specific 2-, 6- and 15-day weather forecast. Every day, the data are emailed as easy-to-read graphical plots, accessible via smart phone. Based on current soil conditions and forecast weather, farmers may make informed irrigation and nutrient scheduling or stock transfer between fields. At the end of each growing season, participant farmers, irrigation scheme managers, regulators and scientists gather for a semi-formal meeting to discuss the management decisions taken over the season and analyse the drivers and impacts. These meetings enable listening and learning from everyone’s experience and appreciating others’ perspective in a congenial atmosphere. The proposed workshop talk will highlight the challenges for successful dissemination and uptake of scientific data among non-science users.

IAHS (Hydrology)

HW16b - HW16 Observations and Modelling of Land–Atmosphere–Society Interactions in Hydrology

IUGG-4453

Quantifying the effects of climate and landuse changes on the hydrology in the subtropical Africa: A process-based distributed modelling approach

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Current projections of the future climate and socio-economic development indicate that both will have a significant impact on hydrological processes and available water resources, leading to the urgent need to develop efficient and sustainable adaptation strategies. In order to properly quantify the impacts of changing climate and land-use on water resources in subtropical Africa, the presented research offers a methodology that allows to properly quantify the impacts of changing climate and land-use on water resources of representative areas in subtropical Africa and to identify evidence-based, optimized adaptation and mitigation measures.

The presented research is being done in the catchment of the Luanginga River, a tributary of the Upper Zambesi with an area of about 33000 km². Ranging from the Angolan highlands to the floodplain of the Zambesi River, the catchment is characterized by an annual flow regime and extensive wetland areas. Due to its annual flooding with peak times in April, the area features exceptionally fertile soils with high agricultural production and is further known for its rich cultural heritage, making it especially sensitive to changes of hydrological conditions. For the assessment, a process-based distributed modelling approach is used to adequately represent hydrological processes and to address key water resources management issues at sub basin levels. Due to a special wetland extension, the model allows to represent the annual flood regime of the system and thus to address the effect of climate change and upstream land use changes on flow regimes in the downstream watershed.

We will give an overview of the study area and related water resources management problems, present the intended model structure and encouraging preliminary results.

IAHS (Hydrology)

HW16p - HW16 Observations and Modelling of Land–Atmosphere–Society Interactions in Hydrology

HW16p-140

Modeling of Okavango sub-catchments with JAMS in different spatiotemporal resolutions

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The Okavango River Basin (ORB) in southern Africa is exposed to a number of climate-related and socio-economic changes such as population growth, increasing irrigation agriculture, deforestation and reservoir construction. While hydrological models can be valuable tools to assess the current and projected conditions of river basins and to develop evidence-driven water resources management strategies, data scarcity often hampers their application. Due to the civil war in Angola during the last decades, nearly no current hydrological and only very few climatological data are available after the beginning of the 1970s especially for the upper part of the basin.

In order to deal with this lack of data, the JAMS framework was used to (i) build process-based, hydrological models of representative sub-basins of the ORB and (ii) to transfer the identified model parameters to other tributaries by the use of spatial upscaling techniques. The JAMS/J2000g simple water balance model was used to analyze the main tributaries of the Okavango, the Cubango and the Cuito using monthly resolution. On a daily resolution, the Cuebe catchment - a sub-basin of the Cubango catchment - was investigated and modelled using the fully-distributed, process-based JAMS/J2000. While the Cubango is characterized by a dense, impermeable underlying geology, the Cuito tributary is covered by thick Kalahari sand layers, leading to tremendous differences in natural flows and modelling requirements. Results however show that even though only short time series were available for calibration, the models are able to represent the natural flow conditions and differences in the tributaries with a satisfying degree of accuracy.

IAHS (Hydrology)

HW16p - HW16 Observations and Modelling of Land–Atmosphere–Society Interactions in Hydrology

HW16p-141

Evaluating the impact of changing land use and farm dams on the Gaborone dam catchment: a process-based distributed modelling approach

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One of the major challenges of hydrological modelling in semiarid areas is the high spatial and temporal variability of rainfall and subsequent associated hydrological processes, coupled with an inherent non-linearity of response between rainfall and runoff. The problem often gets worse due to a lack of spatially well distributed instrumentation, leading to increases in input errors and uncertainties through the use of rainfall estimates made from limited observations being used as input to rainfall-runoff models. This particular problem is well documented for many catchments in the world, including the semi-arid southern Africa. The Gaborone dam catchment located near Gaborone city in Botswana has been experiencing challenges of reduced inflows into the dam, despite some recorded heavy storms in the headwater streams and within the catchment. Recent studies indicate that there are more than 200 farm dams spread across the 400 km^2 catchment area which may have led to reduced inflows into the dam, which is a main source of water supply to the greater Gaborone area. However, due to insufficient rainfall recording instruments and flow gauging stations in the catchment, no studies have been able to adequately address runoff generation processes and associated inflow dynamics in this important catchment.

The presented study uses land use and land use change products as input to the process-based distributed hydrological model JAMS/J2000 in order to estimate the impact of land use change with special emphasis on the development of farm dams. Another focus is on improving the modelling results by changing land use inputs to further enhance the understanding of rainfall-runoff processes in greater Gaborone area.

IAHS (Hydrology)

HW16p - HW16 Observations and Modelling of Land–Atmosphere–Society Interactions in Hydrology

HW16p-142

Structure and initial application of a decision support system for hydrological systems analysis

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The South African Science Service Centre for Climate Change and Adaptive Land Management (SASSCAL) was founded with the aim of providing a regional centre for knowledge and expertise regarding climate change and environmental management. The SASSCAL Information System (IS) has been set up with the aim of providing a data storage and exchange platform, in particular for use in activities linked to Integrated Land and Water Resources Management (ILWRM) in the region. The hydrological modelling of a selection of catchments in the region using the models from the Jena Adaptable Modelling System (JAMS) software package is one of these activities. A further SASSCAL task is aimed at creating and applying a decision support system (DSS) for use within the SASSCAL region. The core of this system will initially be composed of the IS, the data storage and management platform, and a server based setup of the JAMS models. Additionally, a user-based selection process of scenarios and conditions to be modelled is added, occurring prior to the data selection and model run processes. These conditions could range from global climate scenarios to the alteration of land use within a catchment, with the goal of seeing how the hydrological dynamics in the catchment could change under such conditions. Following the modelling process, the output of the model is stored on the IS, and presented in such a way as to be easily understood and interpreted by the user. In this way, untrained users can easily adapt catchment conditions to assess related environmental impacts without the need of a technical expert. Once completed, this DSS will ideally be expanded to apply the same process to other models and other thematic areas. Here, the concept, structure, and initial application will be presented.

IAHS (Hydrology)

HW17a - HW17 Hydrological Forecasting and Predictive Uncertainty: Advances and Challenges of Transferring Science into Operational Practice

IUGG-0215

Rainfall–runoff–inundation analysis of the 2011 Sri Lanka flood in the Mudeni Aru River basin

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Sri Lanka has suffered a devastating flood disaster in 2011. In the Mundeni River basin of Eastern Province (1,300 km^2), large-scale riverine and flash floods caused destructive damage that affected more than 1 million people. This study analysed rainfall–runoff and inundation in the Mundeni River basin with a newly developed model that simulates the processes of rainfall–runoff and inundation simultaneously based on two-dimensional diffusion wave equations. The simulation results showed a good agreement with an inundation map produced based on ALOS PALSAR for riverine flooding. In addition, the study carried out flood control and uncontrolled measures by proposing storage measures to address risk reduction and improving the livelihood of people living the downstream. The study also provides assessment related to impact on agriculture and population at risk by integration various spatial layers for flood risk assessment. Since the model is designed to be used even immediately after a disaster, it can be a useful tool for analysing large-scale flooding and to provide supplemental information to agencies for relief operations.

IAHS (Hydrology)

HW17a - HW17 Hydrological Forecasting and Predictive Uncertainty: Advances and Challenges of Transferring Science into Operational Practice

IUGG-0812

Assimilation of remote sensing data into a conceptual rainfall-runoff model for hydrological forecasting applications

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Remote sensing information has extensively developed over the past few years and spatially distributed data for hydrological applications has now become available at high resolution. The implementation of these products in operational flow forecasting systems is still an active field of research, where data assimilation plays a vital role on the improvement of initial conditions of flow forecasts. Most data assimilation methods have focused on the implementation of Kalman filters. As an alternative, we present a variational method based on Moving Horizon Estimation (MHE) to assimilate streamflow data and remote sensing information obtained from the Satellite Application Facility on Support to Operational Hydrology and Water Management (H-SAF) community, namely Snow-Covered Area, Snow Water Equivalent and Soil Moisture. This approach enables a highly flexible formulation of distance metrics for the introduction of noise into the model and the agreement between simulated and observed variables.

The application of MHE on data assimilation is tested in two data-dense test sites in Germany and one data-sparse environment in Turkey. Results show a potential improvement on the performance of the forecasted discharges when using perfect time series of state variables generated through the simulation of the conceptual rainfall-runoff model HBV. The implementation of H-SAF products into the assimilation results in a reduction of the performance of the forecasted discharges compared to the assimilation using only the agreement of discharge data. However, other forecasted quantities such as the snow water equivalent or soil moisture get improved. Therefore, the assimilation provides a more complete description of the forecasted variables.

IAHS (Hydrology)

HW17a - HW17 Hydrological Forecasting and Predictive Uncertainty: Advances and Challenges of Transferring Science into Operational Practice

IUGG-1565

Ensemble forecasting of snowpack conditions and avalanche hazard

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Ensemble forecasting is increasingly used for hydrology applications but has not been applied to avalanche hazard forecasting hitherto. However, the large sensitivity of the snowpack to meteorological conditions makes its prediction challenging especially in mountain regions. Until now, the SAFRAN–SURFEX–MEPRA (S2M) numerical models are used in France to provide an objective assessment of the past and future snow conditions including mechanical stability. The input in terms of meteorological forecast comes only from the deterministic numerical weather prediction model ARPEGE. Here we introduce an ensemble forecasting system using the 35 members of the ensemble version of ARPEGE as input to the S2M chain. S2M ensemble forecasts produced using archived ARPEGE ensemble forecasts were evaluated through statistical comparisons with the deterministic prediction and the analysis of snow conditions, in terms of elevation of the rain-snow limit, fresh (less than 1 day old) snow thickness and a regional scale natural avalanche hazard index. We followed evaluation methods used for ensemble hydrological forecasting applications. Results indicate that accounting for the uncertainty in meteorological forecast improves significantly the skill and the usefulness of the modelling chain, regardless of the prediction lead time. The predictability of snowpack conditions remains good at a 4 day lead time. This now allows building probabilistic estimates of avalanche hazard level in support of operational avalanche hazard warning activities. The necessary but challenging synthesis for the forecasters of the large amount of data provided by the ensemble is in progress. Our system may also help in a near future to produce ensemble hydrological forecasts in Alpine basins sensitive to snowmelt.

IAHS (Hydrology)

HW17a - HW17 Hydrological Forecasting and Predictive Uncertainty: Advances and Challenges of Transferring Science into Operational Practice

IUGG-2061

Data assimilation of satellite-derived surface water extent into a global rainfall-runoff model

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In hydrological forecasting, data assimilation techniques are employed to improve estimates of initial conditions to update incorrect model states with observational data. However, the limited availability of continuous and up-to-date ground observational data is one of the main challenges for real-time applications such as global flood forecasting models. Remote sensing has been recognised as a valuable alternative source of observations of land surface hydrological fluxes and state variables due to its global coverage, open data policy and the advantage of being available at frequent temporal intervals and shortly after the satellite image retrieval. The main disadvantage of remotely sensed information, however, is that an additional model is required to transform the raw satellite signal into observations that can be assimilated into a hydrological model.

In this study, we present first results of assimilating remotely sensed surface water extent into the global hydrological LISFLOOD model using ensemble Kalman filter (EnFK) and its potential to improve the timing of the flood peak. We use the merged product from Global Flood Detection System (GFDS) that employs both AMSR-E (Advance Microwave Scanning Radiometer – Earth Observing System) and TRMM (Tropical Rainfall Measuring Mission) to derive water extent as used in the GFDS. This satellite-derived water extent signal is assimilated into LISFLOOD for selected catchments and results are compared to baseline initial conditions (without data assimilation). Validation is done based on ground-based discharge observations. Furthermore, we discuss the post-processing and data assimilation strategies of satellite data within a global hydrological model.

IAHS (Hydrology)

HW17a - HW17 Hydrological Forecasting and Predictive Uncertainty: Advances and Challenges of Transferring Science into Operational Practice

IUGG-4135

Exploration of Ensemble Kalman filter streamflow assimilation in snow dominated watersheds

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Data assimilation holds considerable potential for improving hydrologic predictions as demonstrated in numerous studies. Because hydrological models are imperfect, hydrologists need to continuously update the state variables of their model in order to adapt to day to day situations. The probabilistic assimilation method EnKF (Ensemble Kalman Filter) was implemented on a semi-distributed hydrological model (Hydrotel) to improve the initial conditions of the hydrological ensemble predictions (HEP) for different climatic conditions. In the case of snow-free period on Québec watersheds, the verification of the quality of the HEP showed a considerable improvement in both performance and reliability in comparison to the results of model without assimilation. Manual assimilation provides performance similar to the EnKF, but with much less reliability. The 1000-member HEP obtained from the EnKF can be reduced up to 50 members without any loss of reliability or performance. Similar results were obtained for snow accumulation and melt periods, especially when updating the snow water equivalent in addition to the soil state variables explored in the snow-free period, namely the snow water content and the overland routing reservoir. The application of the EnKF perturbation to the open-loop scenario improved the spread as much as the EnKF, indicating that the perturbations enhanced spread and that the state variables adjustments improved performance.

IAHS (Hydrology)

HW17a - HW17 Hydrological Forecasting and Predictive Uncertainty: Advances and Challenges of Transferring Science into Operational Practice

IUGG-5537

Assessment of ensemble forecast uncertainty with multi-models for a mountainous basin in Turkey

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Streamflow forecasting necessitates special effort in the mountainous basins due to complex snowmelt physics and harsh topographic conditions. These basins are generally in the upstream of large reservoirs for which hydropower, irrigation and flood mitigation tasks must be simultaneously ensured. The assessment of streamflow predictive uncertainty includes meteorological and hydrological uncertainty. There is always a challenging part of using various models in the same forecasting system. Advances is expected in the predictive skill of forecasting system by incorporating better representations of physical processes and using different independent plausible model structures. In this study, conceptual and artificial neural network types of models are utilized with necessary enhancements in their general calculation methodologies. Conceptual models are simplistic representation of a physical system, but they require multiple continuous input data, whereas neural network is capable of mapping complex nonlinear relationships using different input combinations without describing physical relationships. The models are tested for a mountainous test site having 10000 km^2 area at the headwaters of Euphrates River in Turkey where snowmelt runoff is of great importance as it constitutes approximately 2/3 in volume of the total yearly runoff during spring and early summer months. In both models, Ensemble Prediction Systems (EPS) generating probabilistic medium range (up to 10 days) products are preprocessed and used as input. Instead of a single deterministic prediction as does in traditional hydrological modeling approach, ensemble forecasts from both models are compared to reduce and estimate hydrologic predictive uncertainty; thus pros and cons of the models become prominent.

IAHS (Hydrology)

HW17b - HW17 Hydrological Forecasting and Predictive Uncertainty: Advances and Challenges of Transferring Science into Operational Practice

IUGG-0214

Verification of ensemble inflow forecasts for decision support on the sediments flushing of aimores hydropower dam

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In the present study we investigate the use of medium-range scenarios of reservoir inflow for a decision making procedure related to a hydropower reservoir operation in the Doce River basin, Brazil. The main location of interest for hydrological forecasting is the reservoir of the Aimorés Hydro Power Plant (HPP) with a drainage area of 63,000km². This reservoir acts as a "trap" to the sediments that originate from upstream regions. A cleaning process called "pass through" must be executed periodically to remove the sediments from the reservoir. The sediment flushing operation is triggered if an inflow larger than 3000m ³/s is issued within a forecast horizon of 7 days. This inflow forecast highly depends on Numerical Weather Predictions (NWP) models that generate Quantitative Precipitation Forecasts (QPF). The dependency on medium-range weather predictions creates an environment with high uncertainty to the operators, since the meteorological uncertainty of the QPF is usually a key factor in streamflow forecasting.

To support the decision making related to executing the flushing process at Aimorés HPP, we developed an operational hydrological forecasting. It uses a large scale hydrological model capable of generating ensemble streamflow forecasts based on QPF forcing from meteorological Ensemble Prediction Systems . This work has the objectives of investigating the benefits of the scenarios given by the ensemble forecasts as input to this specific decision making problem. The QPF data used in this study was derived from the TIGGE database. To verify the proposed objectives we used metrics to evaluate the forecast skill. Core results of the analysis point out the added value of the use of ensemble forecasts in comparison to deterministic ones for the flushing process.

IAHS (Hydrology)

HW17b - HW17 Hydrological Forecasting and Predictive Uncertainty: Advances and Challenges of Transferring Science into Operational Practice

IUGG-2042

Assessing the use of reforecast climatology in global flood forecasting

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The Global Flood Awareness System (GloFAS) is an experimental flood early warning system designed to detect upcoming severe flood events worldwide, on the basis of ensemble discharge forecasts and warning thresholds derived statistically from a simulated climatology. The streamflow climatology is obtained by forcing a global hydrological model with different meteorological inputs. In this work, streamflow climatologies derived from two global meteorological inputs were compared and their impacts on flood forecasting were assessed. The first climatology is based on bias-corrected reanalysis data (ERA-Interim) which is currently used in the operational GloFAS forecast. The second climatology is derived from atmospheric reforecasts which are routinely produced at the ECMWF using the latest forecasting model. As reforecasts are only produced once a week the climatology is composed of data with mixed lead times ranging from 1 to 7 days.

The comparison results indicate that: 1) flood thresholds derived from the two datasets have substantial dissimilarities with varying characteristics across different regions of the globe; 2) the differences in the thresholds have direct impact on the severity classification of a flood; and 3) ERA-Interim produces lower probability of flood threshold exceedance (and flood detection rates) than the reforecast for several large rivers at short forecast lead-times, where the uncertainty in the meteorological forecast is minimal. Overall, we found that the use of reforecasts, instead of ERA-Interim, marginally improves the flood detection skill of GloFAS operational forecasts. In this presentation, we also highlight the recent updates to the hydrodynamic model such as a changes in river network and river width.

IAHS (Hydrology)

HW17b - HW17 Hydrological Forecasting and Predictive Uncertainty: Advances and Challenges of Transferring Science into Operational Practice

IUGG-2098

Testing a real-time operational procedure for rapid risk assessment in Europe

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We describe the development and testing of a real-time procedure for rapid flood risk assessment based on the operational flood predictions issued by the European Flood Awareness System (EFAS).

The daily forecasts produced by EFAS for the major European river networks are translated into flood hazard maps using a large map catalogue derived from high-resolution hydrodynamic simulations, based on the hydro-meteorological dataset of EFAS.

Flood hazard maps are then combined with exposure and vulnerability information, and the impacts of the forecasted flood events are evaluated in terms of flood prone areas, potential economic damage, affected population, infrastructures and cities.

An extensive testing of the operational procedure has been carried out, to evaluate the reliability of hazard and risk estimates against experimental data in recent flood events. The assessment of the procedure has included a comparison of several alternative approaches for hazard mapping and risk assessment, in order to meet the requests of EFAS users. The tests provided good results and showed the potential of the developed real-time operational procedure in helping emergency response and management.

IAHS (Hydrology)

HW17b - HW17 Hydrological Forecasting and Predictive Uncertainty: Advances and Challenges of Transferring Science into Operational Practice

IUGG-3481

Improved use of weather and climate information in managing wine, fish, and water in California's Russian River Basin

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A clear understanding of the context in which water resource management decisions are made in California's Russian River Basin is critical to guide the production of scientific knowledge that is readily understandable and immediately applicable. We have applied a decision calendar framework to identify entry points and opportunities for the use of advances in weather and climate information that can be used to maximize the availability of water to meet a spectrum of potential uses in the Russian River Basin. Our analysis focuses on flood control, water supply, vineyard and fisheries management decisions that could potentially benefit from improved use of weather and climate information given the episodic nature of precipitation in the region. Maximizing the availability of water stored in reservoirs to meet the full spectrum of potential uses is complicated by the multi-use of many reservoirs for both flood control and water supply. Our study focuses on Lake Mendocino as one of two major reservoir projects used to manage water supply for Russian River watershed, providing water for agriculture, municipal and industrial uses, and to maintain required minimum stream flows to support river-related recreation and fish habitat and passage for three endangered salmonid species. We describe how decisions at different lead times benefit from improved forecasts across weather and climate time scales of the location and duration of extreme precipitation events and persistence of drought with lead times from hours to decades. We also identify entry points for enhanced weather forecast and climate prediction capabilities that can inform management practices, leaving more water in the river and support efforts to restore threatened and endangered fish populations.

IAHS (Hydrology)

HW17b - HW17 Hydrological Forecasting and Predictive Uncertainty: Advances and Challenges of Transferring Science into Operational Practice

IUGG-5305

User-defined development priorities for global scale flood forecasting

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Forecasts of an increased probability of a hazard are rarely acted upon to trigger preventative humanitarian action. However, advances in the skill of Hydrological Ensemble Prediction Systems (HEPS) mean that a forecast of an imminent flood could give the public, civil contingency and the humanitarian response communities time to implement measures to reduce the risk to lives and livelihoods.

Providing flood forecasts for the resource-poor nations of the Global South (where national forecasting capabilities may not exist) and to the humanitarian organisations that operate there means that the development priorities for global scale flood forecasting will vary from those of national or catchment scale modelling carried out by national forecasting agencies. We highlight the current forecasting science barriers and state the key development priorities to ensure that HEPS are fit-for-purpose for the humanitarian community. We draw on the experiences of humanitarian organisations who are at the forefront of the use of ensemble flood forecasts for anticipatory humanitarian action.

Despite our emphasis in this work on the forecasting science, the adoption of HEPS by humanitarian organisations is not solely related to the forecast skill; there are multiple barriers unrelated to developments in forecasting science that have precluded their use. We conclude by focussing on how scientists need to work with humanitarian users and social scientists to break down these barriers.

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HW17c - HW17 Hydrological Forecasting and Predictive Uncertainty: Advances and Challenges of Transferring Science into Operational Practice

IUGG-1065

Towards real-time post-processing and online verification of HEPS in a small-scale Swiss basin

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It is well known that hydro- meteorological forecast systems are prone to errors caused by a variety of uncertainties like mathematical and physical model approximations and inaccurate measurements. In order to capture some of these uncertainties Ensemble Prediction Systems (EPS) have been developed and its usefulness for operational forecasters and decision makers manifests in a steadily increasing number of applicants. The combination of such ensembles of meteorological forecasts with hydrological models and their intrinsic uncertainties result in a Hydrological EPS (HEPS), which, however, possibly show significant bias and dubious uncertainty spreads. In order to improve the quality of such a HEPS various post-processing methodologies have been developed. The degree of complexity of such methods may varies from simplified autoregressive approaches to methodologies using different modern statistical tools like Wavelet Transformations and machine learning methods and combinations of these approaches incorporating Bayesian principles.

The Swiss Federal Institute WSL developed a probabilistic flood warning system for the city of Zurich. The hydrological model PREVAH is driven by meteorological forecasts of COSMO-LEPS consisting of 16 members and with a lead-time of 5 days. A long series of consistent forecasts and corresponding observations have been archived since 2010 and can now be used for testing different post-processing methods and establishing near real-time evaluation tools. The gain of information applying these methods in real-time has been evaluated analysing different skill scores. Results concerning the operational HEPS of the city of Zurich will be shown.

IAHS (Hydrology)

HW17c - HW17 Hydrological Forecasting and Predictive Uncertainty: Advances and Challenges of Transferring Science into Operational Practice

IUGG-1964

Improved post-processing of operational precipitation forecasts in hydrologic catchments based on NCEP GEFS reforecast data

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Operational hydrologic forecasts require improved skill in the operational quantitative precipitation forecasts (QPFs) and probabilistic QPFs (PQPFs). At the National Centers for Environmental Prediction (NCEP), the frequency matching method (FMM) is used to post-process the operational QPFs and PQPFs. This study discusses the limitations of such adaptive frequency matching method (AFMM), and proposes improved post-processing methods based on the NCEP Global ensemble forecast system (GEFS) reforecast data during the 24-year (1985-2008). For hydrologic forecasts, heavy precipitation events are critical. However, AFMM adopts the Kalman filter method and the decaying weight depends on different regions and seasons. Therefore, AFMM shows limited skill in the calibration of heavy precipitation events and capturing the regime transition. In order to improve 24-hr precipitation forecasts, especially heavy precipitation events in hydrologic catchments in China, the reforecast FMM (RFMM) is tested by pooling more temporal samples using the GEFS reforecast data. The gridded FMM (GFMM) is designed to catch the gridded bias information with temporal samples, while AFMM can only use regional bias information to generate daily accumulative frequencies by expanding spatial samples. The real-time daily precipitation analysis from China National Meteorological Information Center over Mainland China (MC) during 2009-2013 is used as the verification data. Compared to the optimized AFMM, RFMM can only slightly improve the performance of QPFs and PQPFs, while GFMM significantly improves various verification metrics of precipitation forecasts and thus may better the precipitation forcing in the distributed hydrologic models.

IAHS (Hydrology)

HW17c - HW17 Hydrological Forecasting and Predictive Uncertainty: Advances and Challenges of Transferring Science into Operational Practice

IUGG-4062

Bayesian modeling of rainfall-runoff uncertainty to improve probabilistic forecasts

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Probabilistic forecasting aims at producing a predictive distribution of the quantity of interest instead of a single best guess point-wise estimate.
With regard to river flow forecasts, the main sources of uncertainty are due (a) to the unknown future rainfalls and temperatures (input uncertainty), (b) to the inadequacy of the deterministic model mimicking the rainfall-runoff transformation (hydrological uncertainty).
Following Krzysztofowicz's ensemble Bayesian forecasting system, we model them separately and then integrate them together into the total uncertainty, which is quantified in terms of a predictive density function. We aim at producing forecasts as sharp as possible while guaranteeing marginal and temporal calibration.
Input uncertainty can be taken into account using ensemble forecasts as inputs to the rainfall-runoff model (RRM). However ensemble forecasts are often biased and overdispersed. To postprocess them, we develop a model based on the hypothesis of exchangeability, a key property when dealing with ensemble members.
To quantify hydrological uncertainty, a joint model for the time series of RRM errors has to be developped. As in Krzysztofowicz's Bayesian river stage forecasting system, we rely on a Bayesian approach, first considering the prior behavior of the river flows and then updating their predictions with the likelihood of RRM's outputs. We moreover establish a classification of time periods with RRM state variables as explanatory variables of a Probit model. Conditioning on such a classification yields a mixture model for the RRM errors.
Our work focuses on series of river flow forecasts routinely issued by two hydro-electricity producers in France and in Québec. We finally compare the results to their present operational forecasting systems.

IAHS (Hydrology)

HW17c - HW17 Hydrological Forecasting and Predictive Uncertainty: Advances and Challenges of Transferring Science into Operational Practice

IUGG-5070

A new post-processing approach to generate ensemble precipitation forecast for hydrologic applications

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Reliability and accuracy of the forcing data are of vital importance in hydrologic predictions skill. Currently, Numerical Weather Prediction (NWP) models are generating ensemble weather forecasts across spatial and temporal scales. However, the raw products of the NWP models are prone to biases at the basin scale. Statistical post-processing (SPP) is a common approach to generate calibrated predictive distribution of weather forecasts which relies on the joint distribution of the observation and single-value precipitation forecasts. Here we present a new Bayesian approach based on the Copula functions to develop an ensemble weather forecasts from the conditional distribution of the single value precipitation forecasts. Unlike current SPP methods with Gaussian assumption in marginal distributions of the observed and modeled climate variables, Copulas are capable of modeling the joint distribution of two variables with any level of correlation and dependency. Precipitation forecasts from the Climate Forecast System (CFS-V2) has been used to generate the ensemble precipitation forecasts as the forcing data to the hydrologic model. Through case studies we demonstrate the strength and applicability of the method over few river basins in the Western US within the Community Hydrological Prediction System (CHPS).

IAHS (Hydrology)

HW17c - HW17 Hydrological Forecasting and Predictive Uncertainty: Advances and Challenges of Transferring Science into Operational Practice

IUGG-5526

A real-time, automated demonstration and evaluation of short to seasonal range streamflow forecasting in US watersheds

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Managing water resources sustainably will require adapting short-term water operations to increasingly variable weather and climate, and the associated floods and droughts. It will be critical to realize potential improvements in streamflow forecasting that have been demonstrated in the weather and hydrologic research communities. These include new methods, models and datasets that are applicable across the various stages of the forecasting workflow – e.g., monitoring and data verification, historical weather analyses, ensemble weather and climate forecasts, physically-oriented models, automated assimilation to improve watershed initial conditions, and streamflow forecast post-processing. Yet many intriguing forecast research results of the past decade have yet to transition into public operational forecasting services, in part because research approaches tend to feature an automated 'over-the-loop' forecasting paradigm that is incompatible with traditional operational forecasting practice in which forecasters manually interact with the forecast data and models. As a result, we lack experience with the actual performance of new research in an integrated operational workflow. To address this knowledge gap, the US National Center for Atmospheric Research, the University of Washington, the US Bureau of Reclamation and the US Army Corps of Engineers are developing a real-time, automated streamflow forecasting experiment to apply state-of-the-science short to seasonal range forecasting advances for a selection of US watersheds. We describe the system implementation and assessment results to date, focusing particularly on intercomparisons of streamflow hindcasts based on downscaled ensemble weather and climate inputs.

IAHS (Hydrology)

HW17c - HW17 Hydrological Forecasting and Predictive Uncertainty: Advances and Challenges of Transferring Science into Operational Practice

IUGG-5709

Preserving temporal-spatial structure in ensemble precipitation predictions based on a modified empirical copula method

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It has been widely acknowledged that using ensemble precipitation prediction (EPP) as input to hydrological models to produce ensemble streamflow forecasting is a promising attempt for improving the forecasting lead-time and skill. Due to the existence of various uncertainties, such as initial condition, model structure and model parameters, statistical post-processing methods are commonly applied to correct the raw ensemble precipitation prediction (REPP) in terms of mean and dispersion. However, univariate bias correction usually ignores the temporal-spatial structure of precipitation, which reduces the accuracy of streamflow forecasting. In this study, a modified empirical copula method (MECM) is proposed, which is based on the empirical copula coupling (ECC) method. In MECM method, the first step is to bias correct the REPP and obtain the calibrated predictive distribution (CPD) of precipitation. The second step is to sample from the post-processed predictive distribution by Latin Hypercube sampling (LHS) technique. LHS method has the ability to ensure that the sampled series better represent the CPD characteristics even if the length of the sample is very limited. The third step is the same as in the original ECC method, to rearrange the sample to make its rank structure the same as in the raw ensemble to obtain the post-processed ensemble.

IAHS (Hydrology)

HW17d - HW17 Hydrological Forecasting and Predictive Uncertainty: Advances and Challenges of Transferring Science into Operational Practice

IUGG-0217

Ensemble forecasts of monthly streamflows out to 12 months using climate forecasts as inputs

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We describe a new model for generating forecast guided stochastic scenarios (FoGSS) of streamflow. Monthly rainfall forecasts are generated by: 1) calibrating rainfall forecasts from a coupled ocean-atmosphere seasonal forecasting model; 2) establishing statistical ‘bridging’ models that use forecasts of sea-surface temperature to forecast rainfall; and 3) merging the calibrated and bridged forecasts with quantile model averaging. Bridging adds skill to the calibrated rainfall forecasts, while the calibration and model averaging produce highly reliable forecast ensembles. Rainfall forecast ensembles are then run through a monthly rainfall-runoff model and a staged hydrological error model that updates forecasts and quantifies hydrological uncertainty. This results in forecasts of monthly streamflow volumes out to 12 months, in the form of ensemble time series. As forecast skill decreases with lead time, the forecasts become more like stochastic scenarios that follow the historical variation in streamflow.

We test the streamflow forecasts on 20 Australian catchments. Overall, forecasts are only skilful at short lead times (< 3 months) for most catchments. However, forecasts for some locations and seasons can be skilful for many months ahead. Forecasts of cumulative streamflow are much more skilful than forecasts of individual months. Forecasts of monthly streamflow and cumulative streamflow are both statistically reliable. The method is able to represent the rainfall forecast uncertainty, hydrological uncertainty (other than rainfall forecast uncertainty), persistence in streamflow, and propagate uncertainty up to 12 months ahead. Each ensemble member has realistic temporal characteristics, allowing water managers to run forecasts directly through water management models.

IAHS (Hydrology)

HW17d - HW17 Hydrological Forecasting and Predictive Uncertainty: Advances and Challenges of Transferring Science into Operational Practice

IUGG-2728

Assessing the performance of ensemble streamflow forecasts produced by the rainfall forecasts from Australian numerical weather prediction models

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Through the water information research and development alliance (WIRADA) project, CSIRO is conducting research to improve flood and short-term streamflow forecasting services delivered by the Australian Bureau of Meteorology. WIRADA aims to build and test systems to generate ensemble flood and short-term streamflow forecasts with lead times of up to 10 days by integrating rainfall forecasts (QPFs) from Numerical Weather Prediction (NWP) models and hydrological modelling. Here we assess the performance of such ensemble streamflow forecasts.

Ensemble QPFs from NWP models have a wide range of applications, and are used routinely by experts and the general public to prepare for weather conditions in coming days. However, raw output that is publicly available from Australian NWP models is deterministic and often contains systematic error. We apply post-processing method for deterministic QPFs to produce calibrated QPF ensembles which are bias free, more accurate than raw QPFs and reliable for use in streamflow forecasting applications. The method combines a simplified version of the Bayesian Joint Probability (BJP) modelling approach and the Schaake shuffle. The BJP modelling approach relates raw QPFs and observed precipitation by modelling their joint distribution to correct biases and to quantify uncertainty. The Schaake shuffle is then employed to produce calibrated QPFs with appropriate space-time correlations.

The calibrated QPF ensembles are then used to force a semi-distributed conceptual rainfall runoff model to produce ensemble streamflow forecasts. The performance of the ensemble streamflow forecasts is evaluated on a number of Australian catchments and the benefits of using calibrated QPFs are demonstrated.

IAHS (Hydrology)

HW17d - HW17 Hydrological Forecasting and Predictive Uncertainty: Advances and Challenges of Transferring Science into Operational Practice

IUGG-3378

E-HYPE: How variations in continental scale precipitation affect pan-European forecasts for flood warning, seasonal anomalies and inflows to seas.

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The E-HYPE model was first set up in 2008 as a research tool testing if open data can be used to predict spatial variation of runoff across Europe. Improved model versions have since been made operational to make deterministic predictions of inflows to seas, seasonal forecasts and for the European Flood Awareness system. Although, the latest version (3.0) is calibrated to WFDEI data, initial state simulation for each application: flood forecasting, seasonal forecasting and sea inflows, is made using a different data set, as is the forecast, e.g. the flood forecast application uses high-resolution interpolated observations for spinup to the initial state, whereas the sea inflows application uses atmospheric model data from MESAN Europe. Forecasts are then made using yet other atmospheric forecast models. What is the change in model performance when forced with a reanalysis, an interpolated gauge data set or forecast data? Potential forecast biases arising from biases in precipitation data sets from various sources and at various stages in forecast production are explored. In a continental scale model system, these biases vary spatially as does the ability of the hydrological model to predict in each region. The spatial distribution of the biases can change from the hindcast, through the nowcast and forecast depending on ability of the precipitation data set to capture relevant regional processes, particularly where modeled precipitation is used. Can prior knowledge of these biases improve forecasting uncertainty? By comparing biases in the precipitation fields for each of these production phases, better knowledge is gained of the how precipitation uncertainties propagate through the forecast and affect the use of forecasts for each of the three E-HYPE applications.

IAHS (Hydrology)

HW17d - HW17 Hydrological Forecasting and Predictive Uncertainty: Advances and Challenges of Transferring Science into Operational Practice

IUGG-4078

Comparisons of Probabilistic Flood Prediction based on the ensemble weather prediction

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A flood warning system incorporating into numerical weather predictions can increase forecast leading times from a few hours to a few days. However, a single NWP forecast from a single country forecast center is not enough as involving respectable non-predictable uncertainties and can lead to a considerable missed or false warnings. Multiple ensemble prediction from various weather centers implemented on catchment hydrology can improve early flood warning significantly. The study shows that based on the precipitation and temperature data obtained from THORPEX (The Observing System Research and Predictability Experiment) Interactive Grand Global Ensemble (TIGGE) and the rain gauge data, the three-layer variable infiltration capacity land surface model was employed to carry out probabilistic hydrological forecast experiments over the upper Huaihe River catchment from 20 July to 3 August 2008. The study also indicates that precipitation input uncertainties dominated and propagated through the cascade chain. The performance of the ensemble probabilistic prediction from single prediction center is better than that of the deterministic prediction. Especially, the 72-h prediction has been improved obviously. The ensemble spread goes widely with increasing lead time and more observed discharge is bracketed in the 5th-99th quantile. The accuracy of river discharge prediction driven by the ECMWF is higher than that driven by the Chinese forecasting center and NCEP, and the grand-ensemble prediction is the best for hydrological prediction using the VIC model. A probabilistic discharge and flood inundation forecast is provided as the end product to study the potential benefits of using the TIGGE database.

IAHS (Hydrology)

HW17d - HW17 Hydrological Forecasting and Predictive Uncertainty: Advances and Challenges of Transferring Science into Operational Practice

IUGG-4774

Hydrologic ensembles based on COSMO-DE-EPS precipitation forecasts for flash flood warnings at ungauged basins

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Flash floods, which are typically triggered by severe rainfall, are difficult to monitor and predict at the spatial and temporal scales of interest due to large meteorological and hydrologic uncertainties. In France, the AIGA discharge-threshold flood warning system ingests the operational radar-gauge rainfall grids into a simplified distributed hydrologic model at a 1-km² resolution to provide flash flood warnings for small-to-medium (from 10 to 1000 km²) ungauged basins. AIGA produces real-time peak discharge estimates along the river network, which are subsequently compared to regionalized flood frequency estimates of given return periods to characterize the severity of ongoing events.
To increase warning lead time while accounting for precipitation forecast uncertainty, AIGA is currently being enhanced to ingest precipitation ensembles from the convection-permitting COSMO-DE-EPS system from the Deutscher Wetterdienst. The 20 precipitation ensemble members of a 21-h horizon at a 2.8-km resolution were ingested in the hydrologic model to produce flow ensembles and probabilistic flash flood warnings for the Meuse and Moselle river basins and for significant events of the 2010-2013 period. The evaluation showed significant improvements in terms of flash flood event detection and effective warning lead-time compared to warnings from the current deterministic AIGA setup, as well as improved forecast skill compared to single-valued persistence benchmarks. Planned enhancements include ingesting other probabilistic products from Météo-France's convection-permitting AROME model, accounting for hydrologic uncertainties, as well as developing comprehensive observational and post-event damage database to determine decision-relevant thresholds for flood magnitude and probability.

IAHS (Hydrology)

HW17d - HW17 Hydrological Forecasting and Predictive Uncertainty: Advances and Challenges of Transferring Science into Operational Practice

IUGG-4959

Seasonal hydrological ensemble predictions over Europe

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Seasonal forecasts have potentially an important socio-economic in hydro-meteorological forecasting. Important applications are for example hydropower management, spring flood prediction and water resources management. The latter includes prediction of low flows for navigation, water quality assessment, droughts and agricultural water needs. Traditionally, seasonal hydrological forecasts are done with observed discharge from previous years, so called ensemble streamflow predictions (ESP). Recent development of seasonal meteorological forecasts has increased the incentive for hydrological applications.In this study the ECMWF's System 4 seasonal forecast (SYS4) was used as input to the hydrological model LISFLOOD, which was setup over the European domain, with a spatial resolution of 5 km. The forecast used were the SYS4 hindcasts from 1990 until present, and these are issued once a month with a lead time of seven months. The hindcasts have 15 ensemble members, which is extended to 51 members every three months. SYS4 was compared with an ESP of modelled discharge using observations as input. The ESP forecasts comprise 15 ensemble members to serve as benchmark.The SYS4 hindcast were evaluated using a diverse set of verification metrics over several time-scales and for each season. The evaluation focussed on of several aspects of seasonal forecasting, such as limits of predictability, timing of high and low flows, exceedance of percentiles, aimed at showing the spatial distribution and timely evolution of the limits of predictability.

IAHS (Hydrology)

HW17p - HW17 Hydrological Forecasting and Predictive Uncertainty: Advances and Challenges of Transferring Science into Operational Practice

HW17p-188

Artificial Neural Networks based modelling for flood hazard zonation in response to mitigation of extreme hydrological events in Ilorin, Nigeria

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In recent times, floods have become major hydrological hazards in Nigeria and each year these are responsible for enormous loss of human lives and properties worth millions of US dollars. Floods occur due to complex interaction of several geo-environmental and anthropogenic parameters such as land use, meteorological events, hydrology and topology of the land. Attempts have been made in this work to integrate these factors to produce flood hazard zonation map showing relative susceptibility of a given area to flood hazards using artificial neural network (ANN). Causative parameters were derived from interpretation of satellite images, topographic maps and field surveys in Ilorin, north-central Nigeria. These parameters were taken into consideration while using the back-propagation of neural network method. The weights obtained from the trained network were consequently utilized for map integration and classification. The resulting susceptibility zonation map delineates the area into three classes: High, Moderate and Low. The early results are very encouraging and attempts are being made to further improve the training and classification results. The outcome of this work would assist policy makers in the mitigation of extreme hydrological events in Nigeria.

IAHS (Hydrology)

HW17p - HW17 Hydrological Forecasting and Predictive Uncertainty: Advances and Challenges of Transferring Science into Operational Practice

HW17p-189

Ensemble streamflow simulations based on multiple parameter sets in the Huaihe River basin

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This study explores the feasibility of constructing hydrologic ensemble simulations based on model parameter uncertainty by introducing the integrated quantile method. Several sets of ensemble experiments using the Variable Infiltration Capacity(VIC)model have been implemented for the upper region of the Bengbu hydrological station in the Huaihe River basin, China. The uncertainty of the VIC model parameters is estimated using the Generalized Likelihood Uncertainty Estimation (GLUE) method. On the basis of calibration and uncertainty analysis, ensemble simulations are generated using multiple parameter sets. The simulations using the integrated quantile method are verified and compared with the simulations using the calibrated parameter sets (control simulations) or uniform quantile parameter sets. The integrated quantile method shows great advantages in reducing the relative error of the ensemble mean as well as further improvement in Nash-Sutcliffe coefficient of the adjusted ensemble mean, and providing generally better probabilistic simulations than the control simulations and the sample climatology. Additionally, the influence of the training period length on the performance of ensemble simulations is analyzed. Sensitivity experiments of the training period length indicate that shortened training period can be adopted to save computing resources without much degrading the results.

IAHS (Hydrology)

HW17p - HW17 Hydrological Forecasting and Predictive Uncertainty: Advances and Challenges of Transferring Science into Operational Practice

HW17p-190

Identifying useful Information in climate indices oscillations by means of Ensemble Empirical Mode Decomposition to improve precipitation forecasting

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Whether climate indices oscillations on various time scales contain some information to be useful to hydrological forecasting is worth investigating. The purpose of this study is to select climate indices that help seasonal precipitation forecasting. To this end, it is suggested to adopt the Ensemble Empirical Mode Decomposition (EEMD) method as an algorithm for extracting modes of variability (IMFs) associated to climate indices and to compare them to precipitation IMFs. Moreover, we used a significance test for assigning statistical significance of information content for resulting IMF components. A Forecasting model is then developed with a nonlinear autoregressive network with exogenous inputs using each IMF of selected indices, with lag times varying from 1 to 12 months, as inputs to forecast each IMF of precipitation. To make forecasts operational, we reconstruct precipitation by summing of all forecasted IMFs to make comparison with observation. Four climate indices on the monthly time scale from 1950 to 2011 are studied: Southern Oscillation index (SOI), Multivariate El Nino Southern Oscillation index (MEI), North Atlantic Oscillation (NAO) and Mediterranean Oscillation index (MOAC) forming the database of inputs. It is found that IMFs of MEI and SOI indices can be distinguished from a white noise at the 95% level. NAO and MOAC components on medium time scales (IMF3, IMF5) with 0 and 6 months delay time can also provide useful information to forecasting. Six rainfall stations are used to validate the model. All IMFs are very well forecasted (Nash exceeding 0.8) for most Stations except IMF1 even if statistically significant. EEMD allows extracting significant components to help reducing predictive uncertainty as well as improving forecasts of a narx model.

IAHS (Hydrology)

HW17p - HW17 Hydrological Forecasting and Predictive Uncertainty: Advances and Challenges of Transferring Science into Operational Practice

HW17p-191

A Demonstration of BNU Hydrological Ensemble Prediction System in the Yalong River Basin

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The Hydrological Ensemble Prediction System developed at Beijing Normal University (BNU-HEPS) is designed to be an end-to-end hydrological forecasting system that links meteorological forecasts with hydrological forecasts with lead-times ranging from two-weeks to nine months. BNU-HEPS is equipped with a graphical-user-interface and GIS capability, and contains many modeling tools including various hydrological models and statistical/mathematical toollets. It includes the following major functions: (1) statistical pre-processing for meteorological forecasts (e.g., precipitation and air temperature forecasts); (2) the hydrological modeling system simulating rainfall-runoff processes; (3) model parameter calibration; (4) statistical post-processing for streamflow forecasts. In the future we will add data assimilation function to the system. In this talk we will demonstrate the different functionalities of BNU-HEPS in the Yalong River basin, a major tributary of the upstream Yangtze River in China. We will show how medium-range meteorological forecast products (e.g., NCEP GEFS) and seasonal climate forecast products (e.g., NCEP CFSv2 and NMME) are combined seamlessly through the BNU-HEPS pre-processor and are used to drive the hydrological models to generate ensemble hydrological forecasts. Our results will show that hydrological forecasts forced by meteorological forecasts have demonstrable advantage over the forecasts based on the climatology (i.e., historical observations).

IAHS (Hydrology)

HW17p - HW17 Hydrological Forecasting and Predictive Uncertainty: Advances and Challenges of Transferring Science into Operational Practice

HW17p-192

Ensemble river flow prediction by coupling a distributed hydrological model and an analogue-based ensemble meteorological prediction system

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A hydrological ensemble prediction system is developed by coupling the distributed hydrological model WaSiM-ETH with a meteorological ensemble prediction system based on analogues. The analogue method is used to issue an ensemble of daily precipitation and temperature predictions with a horizontal resolution of 1 km and lead times of up to three days. This information is then used as input to WaSiM-ETH to produce a hydrological ensemble prediction. The system is evaluated over a period of five years, on two river catchments located in Northern Iceland. Results indicate that the analogue method produces reliable prediction intervals and provides a better deterministic weather prediction than persistence or climate. The hydrological ensemble prediction system is capable of predicting river flow with reasonable accuracy. The uncertainty of the hydrological predictions depends both on the uncertainty of the meteorological predictions and the hydrological modelling. A simple iterative correction procedure improves the discharge predictions, but its use in an operational environment will be conditioned by the quality and availability of real-time flow observations. This system is planned to be made operational at the Icelandic Meteorological Office.

IAHS (Hydrology)

HW17p - HW17 Hydrological Forecasting and Predictive Uncertainty: Advances and Challenges of Transferring Science into Operational Practice

HW17p-193

An inverse algorithm to identify inundation zone triggered by dam failure

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Floods triggered by earth-dam failure can lead to devastating disasters with tremendous loss of life and property. Often a numerical modeling approach is used to construct a flood hazard map to identify probable inundation zones. The analysis of an earth-dam failure is divided into two primary tasks; One is the outflow hydrograph released from the reservoir and the other is the routing of the outflow through the downstream valley. If the outflow hydrograph to be routed downstream could be prescribed, it is easy to run a routing model downstream in relative terms. However the outflow hydrograph is directly related to breach growth that is one of the most important parameter in building the reservoir outflow hydrograph, observations for breach growth are rarely available during earth-dam failure. Whereas lake level data is readily obtained during the dam failure on the real time basis and they may capture the characteristics of breach formation. Thus this study starts from a time series of lake level data during the dam failure. Then a simple inverse method is developed to reproduce breach growth. The new method uses an optimization scheme as a primary tool. The retrieved breach progression curve by the suggested inverse algorithm is linked with a parametric dam failure model to compute outflow hydrograph, and then the constructed outflow hydrograph goes to FLO-2D to route the downstream valley for the test site. The newly suggested algorithm is validated with on-site investigation of the inundation zone. The disparity between the estimated and investigated is about 7~8% and the water depth is ignorable with 0.03~0.10m. In terms of the inundation zones the new method is promising in that it provides reasonable accuracy in the test site.

IAHS (Hydrology)

HW17p - HW17 Hydrological Forecasting and Predictive Uncertainty: Advances and Challenges of Transferring Science into Operational Practice

HW17p-194

Research and operational efforts to face the challenge of providing forecasts with uncertainties in France in 2015

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Currently, the French flood forecast network provides hourly observed stage and discharge data through the website www.vigicrues.gouv.fr. If a flood is likely to happen, these observations are completed with a vigilance warning which consists in a short text about the forecasted trend for the next 24 hours and some quantitative forecasts if available. However, forecasts are not graphically displayed today. An improvement of the general public website is planned for late 2015, with the forecasts plotted further to the corresponding observations. The local services are used to deal with deterministic models and the national center for flood forecasting (SCHAPI) decided that forecasts should only be provided with the associated uncertainties. In order to achieve this goal, two actions were conducted: a research project to develop a scientifically sound and operational method to quantify predictive uncertainty in hydrological models and brainstorm sessions gathering flood forecast experts to define the implementation strategy as well as the specifications of the tools to visualize and communicate forecasts and uncertainties. Several relevant questions were raised during these discussions: How can we find the compromise between automatic calculation and human expertise to estimate uncertainties? How can we find the balance between sharpness, reliability and utility of the uncertainty bounds? This communication show cases how recent research results and inputs from the experts' group were translated into a post-processing operational tool designed for a multi-hydrological/hydraulic model platform as well as the main lessons learned during this paradigm shifting process within the French flood forecast network.

IAHS (Hydrology)

HW17p - HW17 Hydrological Forecasting and Predictive Uncertainty: Advances and Challenges of Transferring Science into Operational Practice

HW17p-195

Severity-duration-frequency analysis of droughts: A planning tool for post-mining ecosystem restoration.

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Eastern Australia has considerable mineral and energy resources and areas of high biodiversity value co-occurring over a broad range of agro-climatic environments. Water is the primary abiotic stressor for (agro)ecosystems in many parts of Eastern Australia. In the context of mined land rehabilitation quantifying the severity-duration-frequency (SDF) of droughts is crucial for successful ecosystem rehabilitation to overcome challenges of early vegetation establishment and long-term ecosystem resilience.

The objective of this study was to quantify the SDF curves of drought events of 11 selected locations across a broad range of agro-climatic environments in Eastern Australia by using three drought indices at different time scales: the Standardized Precipitation Index (SPI), the Reconnaissance Drought Index (RDI), and the Standardized Precipitation-Evapotranspiration Index (SPEI). Based on the indices we derived bivariate distribution functions of drought severity and duration, and estimated the recurrence intervals of drought events.

Similarly to intensity-duration-frequency (IDF) analyses of rainfall events, we propose to apply SDF analyses of droughts to make decisions on the design of critical ecosystem components such as landform, soil, or plant community composition in post-mining lands. Together with design rainfalls, design droughts should be used to assess rehabilitation strategies and ecological management based on drought recurrence intervals, thereby minimising the risk of failure of initial ecosystem establishment due to ignorance of fundamental abiotic and site-specific environmental barriers.

IAHS (Hydrology)

HW17p - HW17 Hydrological Forecasting and Predictive Uncertainty: Advances and Challenges of Transferring Science into Operational Practice

HW17p-196

Evaluating the effects of lake and reservoir parameterization in a global river routing model on uncertainty of daily river discharge.

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Hydrological model predictions are affected by uncertainties from meteorological forcing, initial and boundary conditions, parameterization, calibration data, and model structure. These uncertainties can be a substantial source of errors that propagate through the model and affect the subsequent decision-making process. Here we evaluate how parameter uncertainty of the lake and reservoir modules affects the global river discharge simulations with the aim of improving flood forecasts of the Global Flood Awareness System (GloFAS).

The global river routing in the GloFAS is performed by a distributed hydrological model, LISFLOOD, with a spatial grid of 0.1° and daily time steps. Discharge simulation results are evaluated by comparing historical in-situ observations for more than 1600 stations around the world. We parameterize (newly incorporated) lake and reservoir routines of LISFLOOD with available global datasets, and with simulated river discharge statistics. We use pseudo Monte Carlo simulations to propagate uncertainty from model parameters of lake and reservoir modules, as well as selected river routing and groundwater parameters, on the outputs of interest such as daily river discharge and performance measures. Furthermore we perform global sensitivity analysis in order to identify the parameters that should be evaluated with greater caution or used for future model calibrations in order to minimize uncertainty of river discharge predictions downstream of lakes and reservoirs.

IAHS (Hydrology)

HW17p - HW17 Hydrological Forecasting and Predictive Uncertainty: Advances and Challenges of Transferring Science into Operational Practice

HW17p-197

Probabilistic hydrological forecasting on the Rhône River: How to ensure spatial and temporal coherence?

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Compagnie Nationale du Rhône (CNR), France's leading producer of exclusively renewable energy, operates 18 hydropower plants along the French part of the Rhône River. The 3000 MW installed capacity is of "run-of-the-river" type, with limited storage capacities. To optimize the sale on the electricity market, while ensuring a strict adherence to a rigorous hydraulic safety framework, CNR has developed since 2002 an integrated hydro-meteorological forecasting chain. The system provides deterministic hourly streamflow forecasts with a prediction horizon of 4 days. Each step allows added-value expertise of the input and output by a team of hydro-meteorologists. Different sources of meteorological information are compared, including deterministic precipitation forecasts from operational numerical weather prediction models and probabilistic quantitative precipitation forecasts from analog downscaling, in order to generate a single deterministic precipitation forecast. This is then used as input of conceptual and seasonal ARX rainfall-runoff models at the Rhône's tributaries scale. Hydraulic modeling is finally used to propagate forecasted streamflow along the Rhône River.

As uncertainties are hidden, the use of such a deterministic forecasting chain makes the end-user over-confident and risk analyses more difficult. Therefore, CNR aims at providing unbiased probabilistic streamflow forecasts all along the Rhône River. Because industrial and civil safety is particularly sensitive to tributaries concomitant flooding, current developments focus on ensuring spatial and temporal coherence at a large watershed scale, within a probabilistic framework. The poster will give an overview of the current CNR forecasting chain and discuss methodological challenges to achieve this goal.

IAHS (Hydrology)

HW17p - HW17 Hydrological Forecasting and Predictive Uncertainty: Advances and Challenges of Transferring Science into Operational Practice

HW17p-198

A long-term simulation of regional climate model using three reanalysis datasets and its evaluation with river runoffs in Japan

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Reanalysis data necessary to climate modeling research are numerous available now. In this study, we checked the performance of river discharge simulation by using a regional climate model output produced with NCEP/NCAR (ds090.0), ERA-Interim and JRA25 reanalysis datasets in two decades, 1980s and 1990s. The Weather Research and Forecast model (ver. 3.2.1) was used in this study. The horizontal resolutions were 18km and 4.5km for outer and inner domains, respectively. The period of simulation is 20-year from Oct. 1980 to Oct. 2000. Four river basins (Mogami River, Agano River, Jinzu River and Tone River) were selected to compare the observed and calculated river discharges.

IAHS (Hydrology)

HW17p - HW17 Hydrological Forecasting and Predictive Uncertainty: Advances and Challenges of Transferring Science into Operational Practice

HW17p-199

Development of a drought forecasting system and reservoir management model for water supply: Case-study of the Arzal Dam (Brittany, France)

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The IAV is in charge of the management of the Arzal dam located in Brittany (France), which, in summer periods, supplies drinking water for 1 million people. The implementation of an operational hydrometeorological forecasting system is considered a priority for the next years. Such a system is expected to add value to recent research developments and open opportunities for new products in operational water-reservoir management. The Arzal dam regulates a 50 Mm^3 single reservoir downstream the Vilaine River Basin (10,000 km^2) in the Northwestern part of France. Built in 1970 to avoid flooding due to the concomitance of a flood in the river and high sea level, it has gained in importance over the years in the regional water management system. Today its water reservoir plays a central role in water supply for drinking and irrigation, sailing and fish by-passing. During summer periods, conflicts among water users may arise. The development of a low-flow forecasting and reservoir management model to improve management decisions started in 2013 within the framework of the Interreg IVB NWE project DROP. It includes a drought forecasting model, a reservoir water balance model, and the development of an efficient visualization of the forecast outputs to support decision making in seasonal forecasting and to anticipate water use conflicts. The results obtained so far will be presented and illustrated in this communication. Particular attention will be given to the performance of raw and bias corrected seasonal precipitation and streamflow forecasts, as well as to the first assessment of reservoir management variables.

This study is partly funded by the Interreg IVB NWE programme of the European Union, project DROP (Benefit of governance in DROught adaptation)

IAHS (Hydrology)

HW17p - HW17 Hydrological Forecasting and Predictive Uncertainty: Advances and Challenges of Transferring Science into Operational Practice

HW17p-200

Hydrological model complexity as stability of underlying system representation

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The essential need of modelling in hydrology triggers the need for a formal definition of complexity. We study two, though related, paradigms of complexity. One is based on Vapnik-Chervonenkis generalization theory and the other based on stability of hydrological system representation. We use the former paradigm on a class of k-nn models and quantify complexities of MOPEX catchments in eastern United States. These complexities “optimally” trade off finite sample model performance with model complexity. We use the latter paradigm on SAC-SMA models for the same catchments. These models are based on parameters that are deemed optimal for the basins but model complexity is not considered in such a model selection exercise for MOPEX catchments. We quantify complexities of these SAC-SMA models based on the second paradigm. The results of the first paradigm demonstrate that not only basin complexities are related to hydrological characteristics of the catchments but also wet (dry) catchments are identified as the ones with low (high) complexities. The results of the second paradigm demonstrate that basins with high (low) recession parameters and low (high) storage capacities have high (low) complexities. We compare and contrast these results to provide insights into physics based interpretation of model complexity.

IAHS (Hydrology)

HW18a - HW18 Advances in Remote Observation of Snow

IUGG-1534

Using terrestrial laser scanner to analyze snow depth distribution at very long distances: validation and identification of drivers of variability

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Snow dynamics in mountain terrain is highly variable in space and time. In the last years terrestrial laser scanner has raised as a useful technique to obtain detailed information on snow depth distribution. In most of the cases TLS has been used to monitor snowpack at short or medium distinces (up to 1000 mts), but rarely is applied to longer distances due to technical limitations of the majority of the scans, but also because it is expected large uncertainty at longer distances. This work presents the particularities of applying LiDAR technology in mountain terrain to measure snow depth at very long distances (1200 to 3000 metres) in a Pyrenean catchment. Obtained information is used to assess the accuracy of this technique at different distances, and also to apply random forests and statistical equation models to identify the main topographic factors to explain snow distribution during three different years at various times of the accumulation and melting periods. Results indicate the need to apply a careful protocol to achieve reasonably good representation of the snowpack distribution at this distance. Different validation procedures (manual measurements, time lapse photography, and the use of invariant elements of the landscape) demonstrate the feasibility to measure snow depth even at the longer distances in areas of thick snowpack, with errors that generally does not exceed 50cm of error at the longer distances. Provided snow data from TLS allows identifying the elevation, curvature and snow redistribution by avalanches as the main drivers that explain the snow distribution in the analysed catchment.

IAHS (Hydrology)

HW18a - HW18 Advances in Remote Observation of Snow

IUGG-2472

Airborne laser scanning: a basis for hydrological model studies in glacierized catchments

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Lateral redistribution of snow has a strong effect on glacier mass balance and the seasonal regime of runoff in glacierized catchments. Therefore, the spatial and temporal snow depth distribution in the complex topography of glaciers and adjacent ice-free terrain was investigated using airborne laser scanning (ALS) data. ALS surveys in a catchment of approx. 36 km² including the glaciers Hintereisferner and Kesselwandferner (Ötztal Alps/Austria) allow to analyse the snow pattern for 5 different accumulation seasons since 2001. The data provide useful information on spatial variability of snow depth in relation to topographic features and ice cover. Simple linear regressions for snow depth with DEM-derived openness/shelteredness parameters were used to simulate the observed snow distribution for snow-hydrological modelling. The resulting simulated snow pattern was in good agreement with the ALS data. Small features of extreme accumulation, e.g. avalanches, could not be reproduced due to their inherently higher random component. A multi-objective model calibration study shows that the basin-wide SWE calculated from ALS-derived snow depth patterns is better suited than snow covered area to constrain model parameter ranges. The integration of ALS-derived SWE maps in the calibration and validation of physically-based snow-hydrological models improved the results not only for runoff simulations, but also for the long-term volume changes of the glaciers in the mountain region of the Ötztal Alps.

IAHS (Hydrology)

HW18a - HW18 Advances in Remote Observation of Snow

IUGG-2910

Snow depth mapping via UAV borne laser scanning

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In snow and avalanche research, laser scanning is used increasingly to accurately map the snow depth distribution. Laser scanners emit a pulse of light in the near-infrared spectrum. The pulse hits the terrain or snow surface and is reflected. A photodiode in the scanner detects the returning pulse and determines the distance to the surveyed point from the travel time of the pulse. Typically, laser scanning acquisitions are conducted using either airborne or ground-based instruments, and target positions are geolocated by coupling the laser scanning system with a high-precision GPS (ground-based) or GPS/inertial measurement unit (IMU) (airborne) system. Differencing co-registered maps from two dates (snow-off from snow-on) allows the calculation of snow depth with sub-decimeter vertical uncertainty and high horizontal spatial resolutions. In this work we present for the first time data from a UAV borne laser scanning campaign of spatial snow depths. We used the UAV RiCopter in combination with the RIEGL VUX-1 laser scanner, including GPS/IMU, measuring with 550 kHz in a flight altitude of up to 300 m above ground. The UAV borne laser data was compared to data gained by terrestrial laser scanning using the RIEGL VZ-6000 at our mountainous test area in Lech am Arlberg, Austria. We discuss the process of data acquisition, necessary post processing steps and precision of acquired results as well as the comparison to the terrestrial laser scanning data. In summary we conclude that UAV borne laser scanning is a new flexible method to measure spatial snow depths especially for terrain that is flat, covered with vegetation or inaccessible.

IAHS (Hydrology)

HW18a - HW18 Advances in Remote Observation of Snow

IUGG-5101

Mapping thin snow cover from small aircraft with LiDAR and SfM photogrammetry.

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A long-standing goal in snow hydrology has been to map snow cover in detail, either mapping snow depth or snow water equivalent (SWE) with sub-meter resolution. Airborne LiDAR and photogrammetry have been applied to this problem. Digital elevation models (DEMs) are made from 1) snow-free acquisitions in the summer and 2) snow-covered acquisitions in winter, and these DEMs are then differenced to arrive at snow thickness. Vertical accuracy and precision of each DEM is on the order of +/-30 cm and +/- 8 cm, respectively. The accuracy of the derived snow depths can be made to approach that of the precision if suitable snow-free ground control points exists and are used to finely co-register summer to winter DEM maps.

We tested the accuracy and precision of snow depths measured using these approaches with a comparison to extensive on-the-ground measured snow depths. Study areas include 1) Trail Valley Creek near Inuvik, NWT, Canada, 2) Imnavait Creek, Northern Alaska, and 3) Minto Flats near Fairbanks, Alaska. Final snow depth accuracy from our series of tests was on the order of ±15 cm. Both LiDAR and SfM data were acquired simultaneously during these campaigns, and their independently derived DEMs were closely compared. The SfM photogrammetric processing is directly georeferenced using commercially available Structure from Motion (SfM) software and does not require ground control points. Outside of areas with forests or brush, the SfM approach is found to produce snow depth maps with much higher resolution and better precision than LiDAR. This result, combined with inexpensive, off-the-shelf hardware, suggests promise for the SfM photogrammetric approach to snow depth mapping.

IAHS (Hydrology)

HW18a - HW18 Advances in Remote Observation of Snow

IUGG-5695

Optimizing a high resolution snow redistribution model in sub alpine terrain using multi-temporal airborne lidar

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In natural mountain environments snow depths can vary significantly over small length scales, thus affecting the performance of hydrologic models for estimating snow accumulation and melt. An empirical model for redistributing snow was developed to supplement the Isnobal physically-based energy- and mass-balance snow model, and has been presented extensively in the literature. This work examines a method for optimizing the terrain parameters of the redistribution model at a 1-km^2 intensive study area in Northern Colorado, USA using airborne lidar-derived, high resolution snow depths acquired throughout multiple seasons. The observed interannual consistency of the snow depth spatial distributions is used to classify pixels as drift or scour locations, along with locations of neither drift nor scour, within the 5-meter resolution digital surface model. These delineated regions, along with nearly constant in-storm wind directions at this experimental site, enable parameter optimization of the redistribution model. At a nearby 1-km^2 control site, the optimized redistribution model is implemented to predict the drift and scour patterns observed by lidar.

IAHS (Hydrology)

HW18a - HW18 Advances in Remote Observation of Snow

IUGG-5701

Quantifying snow depth uncertainty in repeat terrestrial laser scanning of avalanche starting zones

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The distribution of snow depth in avalanche starting zones strongly influences avalanche potential and character. Extreme depth changes over short distances are common, especially in wind-affected environments. Snow depth also affects avalanche triggering, with avalanche reduction efforts often being more successful when shallow areas near deeper slabs are targeted with explosives or ski cutting. Our pilot study explores the use of high resolution, LiDAR-derived snow depth and depth change maps to quantify loading patterns for use in control planning and evaluation.
We present results from our initial work at Arapahoe Basin Ski Area and Aspen Highlands Ski Resort in Colorado, USA. Both ski areas have many large avalanche terrain features both above and below treeline. Mapping multiple times during the snow season allowed us to produce time series maps of snow depth and snow depth change at high resolution to explore depth and slab thickness variations. We conducted surveys before and after loading events and control work, allowing the exploration of loading patterns, slab thickness, shot and ski cut locations, bed surfaces, entrainment, and avalanche characteristics.
While methods for computing volume from terrestrial LiDAR point clouds are well documented, a rigorous quantification of the volumetric uncertainty has yet to be included in the analysis. Using our avalanche terrain surveys, we demonstrate the propagation of TLS point measurement and cloud registration uncertainties into 3D covariance matrices for each point. The point covariances are then propagated through two volume computation methods to produce spatial maps of snow depth uncertainty and computed volumes. Results from the two volume methods are compared and the influence of LiDAR point density examined.

IAHS (Hydrology)

HW18b - HW18 Advances in Remote Observation of Snow

IUGG-3259

Improving snow canopy interception modelling using aerial LiDAR data

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Forest snow interception can account for large snow storage differences between open and forested areas and can also lead to large variations in sublimation, with estimates varying from 4% to 50% worldwide. Most current interception models utilize canopy cover and leaf area index to partition interception efficiency (interception divided by precipitation in the open), typically modelled as an exponential decrease with increasing precipitation. However, these models can show limited utility quantifying interception dynamics under heterogeneous canopy. This study paired field measurements of snow interception (10000 measurements from 2012 to 2015) to aerial LiDAR data in efforts to improve the current state of interception modeling within Norwegian Spruce dominated forests. Existing and novel canopy metrics within the field areas (1932 surveyed points surrounding Davos, Switzerland) were developed using a high resolution LiDAR data set. These included estimates of leaf area index, canopy closure, under canopy incoming solar radiation, distance to tree measurements, aerial gap fraction measurements and various tree size parameters. The snow measurements and LiDAR derived canopy metrics were then integrated to formulate an improved representation of interception. Leaf area index was replaced for a basic open area and distance to canopy metric due to a ~21% correlation improvement with the snow measurements. The standard exponential decay framework was modified based upon interception efficiency distributions seen from this study which showed a clear initial effeciency increase before a decay is seen. This new conceptual model gave a ~27% increase in the R^2 and a ~40% reduction in root mean squared error for both calibration and validation data sets.

IAHS (Hydrology)

HW18b - HW18 Advances in Remote Observation of Snow

IUGG-4047

Snowmelt dynamics and streamflow response in an alpine catchment

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Snowmelt processes are crucial components of the hydrologic cycle in mountain regions. Proper understanding of the relationships between snowmelt output at point and slope scales and the hydrological response of alpine catchments is important for its accurate representation in hydrological models. Here, we combine local and spatially distributed measurements during the snowmelt season at the Dischma River Basin (~40 km^2) near Davos, Switzerland, to study the link between these processes at varying scales and the hydrological response of the catchment. At the point scale, snowmelt dynamics are captured at 5 stations where snowmelt output, vertical snow temperature profiles and soil moisture are continuously measured. At the slope scale, the snowmelt pulse is captured using weekly terrestrial laser scans of the snow surface to quantify the differential depletion of the snowpack at high resolutions (~1 m). The hydrological response is captured at 3 streamflow gages isolating the response of the catchment and subcatchments. These measurements are integrated to establish relationships between some of the controlling processes and basin morphological characteristics, and the catchment hydrological response. Results from the first-year measurement campaign (Water Year 2015) will be presented, with an outlook to the subsequent measurements and their integration with simulations at the catchment scale using the physically-based Alpine3D model.

IAHS (Hydrology)

HW18b - HW18 Advances in Remote Observation of Snow

IUGG-4162

"Multi-sensor observation of snowfall during CLACE 2014 in the central Swiss Alps"

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The cloud and aerosol characterization experiment (CLACE) is a series of campaigns conducted in the Swiss Alps by research groups from many countries, focused on aereosol-cloud activation and ice nucleation.

During CLACE 2014, the X-band dual polarization Doppler radar (MXPol) of the Environmental Remote Sensing laboratory (LTE) of EPFL, Lausanne, was deployed at an altitude of 2065 m at the Kleine Scheidegg pass. Close-by, a scanning wind lidar with depolarization channel was deployed by the University of Manchester, while at the Jungfraujoch observatory (3471 m) multiple cloud particle probes and imagers. These sensors sampled 13 cloud and precipitation events during the exceptionally cyclonic months of beginning 2014.MXPol observations allow to formulate hypothesis about shape, density, type and concentration of the ice particles constituting snowfall while the lidar and in-situ probes provide the content of ice and liquid water in mixed phase clouds. In this work we aim to relate the in-situ data with the radar and lidar measurements. We focus on the relation that liquid water in the clouds and wind intensity have with respect to the characteristics of snowfall. Additionally, radar retrievals are compared with local snow accumulation measurements. The comparisons indicate that riming is a recurring ingredient for a significant accumulation of snow. For the sake of completeness the events are also evaluated taking into account the synoptic conditions and high-resolution reanalyses conducted by means of the operational numerical weather model COSMO.The present database is a valuable example of the complementarity of remote sensing, in-situ, and numerical tools for the understanding of snowfall in complex terrain, a necessary step to better understand snow accumulation.

IAHS (Hydrology)

HW18b - HW18 Advances in Remote Observation of Snow

IUGG-4291

Quantifying the sub-pixel relationship between terrain roughness, remotely-sensed fractional snow covered area and snow depth

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Snowmelt is the primary water source in the Western United States and mountainous regions globally. Forecasts of streamflow and water supply rely heavily on snow measurements from sparse observation networks that may not provide adequate information during abnormal climatic conditions. To this end, we have developed a method that is not expected to depend on repeated climatic conditions because it considers the snow holding capacity of the ground based on small-scale terrain roughness. Snow depth is estimated from remotely-sensed fractional snow covered area (fSCA) and a digital elevation model (DEM). A temporal analysis of fSCA near peak SWE derived from Landsat TM/ETM+ for 2000-2007 in Green Lakes Valley, Colorado (Jepsen et al 2012) yields an r2 = 0.56 when relating the median fSCA and average basin snow depth. Spatial analysis of fSCA utilizing a Light Detection and Ranging (LiDaR) dataset from 2010 from Green Lakes Valley, Colorado, USA (Harpold et al. 2012) was used to relate snow depth, fSCA and the sub-fSCA-pixel terrain roughness. The pixel terrain variability is calculated as the standard deviation of slope. Thirty meter pixels of snow depth are modeled by regression with 30m fSCA pixels, categorized by terrain variability. Relative MAE ranged from 39%-58% of the measured snow depth, with higher errors in less rough terrain. Future analysis includes improving the quantification of potential wind redistribution and applying the proposed relationship to other research basins in California and abroad. The utility of these relationships is such that snow depth could be estimated above treeline for any set of climatic conditions and could have far-reaching implications for understanding snow distribution and water forecasting.

IAHS (Hydrology)

HW18b - HW18 Advances in Remote Observation of Snow

IUGG-4377

Combining ground-based observations, distributed models, and remotely sensed data for real-time SWE estimates

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Estimates of snow water equivalent (SWE) are a critical component of forecasting water supplies because it controls the magnitude of spring and summer runoff in the mountains. Uncertainty in the distribution of precipitation in mountainous regions hinders the development of physically-based water supply and streamflow forecasts. Real-time distributed SWE estimates have traditionally been obtained by interpolating ground-based observations or operational hydrologic modeling. This research aims to combine retrospectively reconstructed SWE estimates, for which satellite images of snow covered area are coupled to energy balance modeling to reconstruct peak snow mass, with ground data from the SNOTEL network of the western United States in a blended real-time product. A geostatistical blending of reconstructed SWE in the Sierra Nevada, CA showed an average 19% decrease in RMSE when validated against independent snow surveys (Guan et al. 2013). A regression-based blending in the Upper Colorado River Basin has similarly resulted in 5% - 20% decrease in RMSE for the months of March, April and May (Schneider et al. 2012). Progress is being made to utilize the ensemble of reconstructed SWE estimates in a real-time framework by leveraging these past spatially explicit patterns of SWE within a statistical framework. Multiple regression models for the Upper Colorado River basin of the past 12 years indicate r2 improvements of 31% to 156% when including the SWE reconstruction compared to interpolation models of just physiographic variables. Multiple distributed SWE estimates derived from SNOTEL measured SWE, physiographic variables, and past reconstructed SWE will be created for 2001-2012 and assessed for use as a real-time SWE product.

IAHS (Hydrology)

HW18b - HW18 Advances in Remote Observation of Snow

IUGG-4939

Using time-lapse photography to investigate processes related to avalanche release

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One of the most striking properties of snow is its color. Snow wouldn't be snow if it wasn't white. Once snow falls on the ground, it can therefore easily be distinguished from the surface on which it fell. Time-lapse photography (TLP) is thus an attractive method to investigate snow related processes, and can be used to monitor large areas. We have used TLP to monitor glide-crack expansion, by counting the number of dark pixels in an area around a glide crack. Gliding rates can thus be monitored in several start zones, and potentially provide insight into when, or if, a glide-snow avalanche will release. We also used TLP to investigate processes involved in wet-snow avalanche release. By correlating avalanche occurrences with local meteorological data we found a lag of a few hours between the rise in snow surface temperature and the onset of avalanching. Furthermore, based on accurate wet-snow avalanche occurrence data from six winter seasons, we computed wet-snow probability maps for Switzerland, which compared well with observed wet-snow avalanche activity patterns. Finally, we used TLP to monitor the growth of a cornice, using a method to automatically track the horizontal extent of the cornice based on converting the images to a binary format. Cornice growth only occurred during periods of moderate to high winds during or soon after snowfall. Furthermore, observed cornice extent showed excellent agreement with a wind drift index calculated by the numerical snow cover model SNOWPACK, suggesting that the SNOWPACK wind drift index can be used to quantify regional cornice growth. Overall, our results show that time-lapse photography can be used to improve our understanding of processes related to avalanche release, and ultimately improve avalanche forecasting.

IAHS (Hydrology)

HW18c - HW18 Advances in Remote Observation of Snow

IUGG-2337

Evaluating the above-ground cosmic-ray neutron sensor for measuring snow water equivalent at a multi-sensor snow research site (Kaunertal, Austrian Alps)

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To improve both process understanding and modelling of the spatial and temporal dynamics of snow accumulation and melt, the snow research site Weisssee in the Kaunertal (2480 m a.s.l., Tyrol) was upgraded in 2014. Additionally, a Hydroinnova CRS-1000 above-ground cosmic-ray neutron sensor, whose potential for soil moisture monitoring was shown recently, was installed to evaluate its capability for measuring snow water equivalent (SWE).

Since the cosmic-ray sensor is mounted above ground, it covers an area of around 600 m in diameter and potentially closes the gap between point scale measurements, hydrological models and remote sensing. However, while it is generally known in the literature that neutrons counted by the sensor are moderated not only by water in soil or organic matter but also by frozen or liquid water in the snow pack, there is only limited knowledge of its actual use for SWE monitoring.

The standard configuration of the Weisssee site consists of a fully equipped meteorological station (including all sensors for measuring the surface energy fluxes), two ultra-sonic snow depth sensors and a Snow-Pack-Analyser for measuring snow density, liquid water content and snow temperature at different levels in the snow pack. In addition, terrestrial LiDAR measurements are conducted at a monthly basis to provide snow depth patterns in the cosmic-ray sensor

footprint. Mass and energy balance are simulated applying the snow-hydrological model SES at the point and hillslope scale.

This contribution highlights both potential and limitations of cosmic-ray based snow pack monitoring in alpine environments. Future research will include the use of cosmic-ray derived mean SWE values for assimilation, calibration and validation of snow pack models or remote sensing products.

IAHS (Hydrology)

HW18c - HW18 Advances in Remote Observation of Snow

IUGG-3126

Progresses of monitoring snow covered area by observing effective solar UV albedo

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Previous studies have shown that ground-based retrievals of daily effective solar ultraviolet (UV) albedo correlate strongly with the decline in snow covered area (SCA) during snowmelt. Thus, effective UV albedo observations display an alternative method for remotely sensing SCA from one single point measurement. This study presents the progresses of further work in the interdisciplinary field of atmospheric UV radiation and detection of snow coverage in mountainous terrain.

First, the temporal evolution of UV albedo obtained with a Brewer double monochromator placed in the valley bottom of Davos, Switzerland, is compared with daily modelled SCA during spring in the period from 2007 to 2014. The model results are based on a spatially distributed snow cover model which integrates local snow measurements using data assimilation.

Second, the UV albedo retrievals are compared with SCA observed by satellite. The analysis revealed that the best congruence between UV albedo and modelled or satellite based data of SCA is obtained when including grid cells within a radius of approximately 20 km. However, due to the different approaches of deriving SCA, the three datasets showed differences in their daily course.

Furthermore, in season 2014 the effective UV albedo was retrieved using broadband UV measurements in the valley bottom of the Dischma valley near Davos, as well as with two instruments at different altitudes in Davos. This additional datasets supports the finding that the effective albedo varies depending on the development of the SCA around the measurement sites. Implications for further studies using broadband UV measurements for SCA detections are presented.

IAHS (Hydrology)

HW18c - HW18 Advances in Remote Observation of Snow

IUGG-3939

Measurement of snow properties using upward-looking GPR applying (1) a combination with GPS technology and (2) full-waveform inversion

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The temporal evolution of the mountain snow cover is important for avalanche forecasts and flood predictions. So far, it was hardly possible, especially in complex alpine terrain, such as avalanche starting zones, to derive continuous information on snow parameters in a non-destructive manner. We have demonstrated the feasibility to quantitatively derive snowpack properties and monitor their temporal evolution using an upward-looking ground penetrating radar (upGPR) that was buried underneath the snow. To determine additional snowpack properties, we still needed additional information such as independently measured snow height. To overcome these limitations, we present two promising methods: First, we combined the upGPR travel-time information with tomographic GPS signal strength losses using a GPS antenna that was also buried underneath the snowpack. This combination allowed determining liquid water content, snow height and snow water equivalent from beneath the snow cover without requiring data from above snow sensors. The snow parameters derived from the upGPR and GPS data are in good agreement with conventional sensors, such as laser distance gauges or snow pillows. As the GPS sensors are low cost, they can easily be installed in parallel with upGPR systems. Second, to fully exploit the information content of upGPR data, we applied full-waveform inversion (FWI) techniques. We

refined the model of the snowpack by repeated forward modeling of the waveforms and updating the model parameters to match it with synthetic data. This allowed us to determine the density and the liquid water content for each layer in the snowpack. Both approaches have promising potential for application in mountain hazard management.

IAHS (Hydrology)

HW18c - HW18 Advances in Remote Observation of Snow

IUGG-3960

Continuous and non-destructive snow information for remote areas based on the Global Navigation Satellite System (GNSS)

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Information on snowpack properties is highly relevant for avalanche warning systems, flood predictions and hydropower management within alpine regions influenced by seasonal snow cover. However, snow measurements are often scarce and labour-intense and it is still challenging to monitor snow parameters with sufficient temporal and spatial resolution, especially in remote complex terrain. Since 2012, we are running three low-cost GPS (Global Positioning System) receivers at the high-alpine study site Weissfluhjoch in Switzerland. The sensors record the globally and freely broadcasted GPS L1-band data continuously above and underneath the snow cover. Snow liquid water content and daily melt-freeze cycles were successfully calculated based on GPS signal strength losses, complex permittivity models and external snow height information. The results show high accordance with meteorological and snow-hydrological data. The evolution of liquid water content derived by GPS agrees very well with simultaneous non-destructive upward-looking ground-penetrating radar (upGPR) measurements from below the snow cover. Moreover, we aim to determine further snow properties by analysing temporal changes in the received GPS carrier-to-noise-power-density ratio and carrier phase information for all 32 GPS satellites, whereof preliminary results will be presented, too. Due to its non-destructive, low cost and low power setup, networks of these in-situ GNSS (Global Navigation Satellite System) sensors can be used for applications in remote areas, for instance to cover a better geographical distribution of snow measurements aiming to support users in the water supply and hazard management sectors.

IAHS (Hydrology)

HW18c - HW18 Advances in Remote Observation of Snow

IUGG-4257

Measuring snowmelt rates using a mobile GPR setup

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Terrestrial and airborne laser scanning of snow has significantly increased our understanding of the spatial variability of snow depth. However, methods to provide corresponding datasets of snow water equivalent, particularly during the melt phase, are yet unavailable. In the recent past, ground penetration radar (GPR) has become more accessible to snow researchers and is already successfully being used in the context of snow hydrological studies.

GPR systems can be used and set up in different ways to measure snow properties. In this study we elaborate on a mobile GPR system that allows simultaneous estimation of snow depth, density, and water equivalent in a snow survey setting. For this purpose we have built a GPR platform around a sledge system with four antenna pairs set up as a common-mid-point array. This system has been used to retrieve SWE along given transects. Careful repetition of these measurements along the same paths following several days of snowmelt provided corresponding data on snowmelt rates. Further, manual snow samples were collected during the field campaigns for validation purposes.

After specifying the setup of our GPR system we will present SWE data collected during the past two winter seasons. System accuracy and the feasibility of using our current GPR system to derive spatially-distributed snowmelt rates will then be addressed.

IAHS (Hydrology)

HW18p - HW18 Advances in Remote Observation of Snow

HW18p-324

Mapping snow cover extent (MODIS Terra) and snowmelt dynamics (QuikSCAT) in the Hindu Kush Himalayan region

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The changes in seasonal snow covered area in the Hindu Kush-Himalayan (HKH) region have been examined using Moderate – resolution Imaging Spectroradiometer (MODIS) 8-day standard snow products. The average snow covered area of the HKH region based on satellite data from 2000 to 2010 is 0.76 million sq.km which is 18.23% of the total geographical area of the region. The linear trend in annual snow cover from 2000 to 2010 is −1.25±1.13%. This is in consistent with earlier reported decline of the decade from 1990 to 2001. A similar trend for western, central and eastern HKH region is 8.55±1.70%, +1.66%±2.26% and 0.82±2.50%, respectively. A melt detection algorithm previously described for this region (Panday et al., 2011) was used for mapping and analyzing the timing of freeze/thaw events and duration of annual melt seasons for the western Himalaya region. Enhanced resolution QuikSCAT scatterometer data with horizontal polarization from 2000 to 2008 period were used to melt detection. The average melt onset for the western Himalaya region (elevations > 3500 m) is May 24±11 days, and the average freeze-up for this region is September 26±8 days for the 2000–2008 period. As a result, the average melt duration for elevations greater than 3500 m is 149±11 days (~ 5 months). The combined two satellite sensors provides better understand on the snow cover extent and snowmelt at a longer time horizon for assessing water resources, as well as larger-scale global environment monitoring.

IAHS (Hydrology)

HW18p - HW18 Advances in Remote Observation of Snow

HW18p-325

"Intra-seasonal variability of snow spatial patterns on glaciers and the potential of Unmanned Aerial Vehicle photogrammetry"

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The winter phase of snow accumulation on glaciers has been little investigated as compared to melt processes, and in mass balance models, simple assumptions for snow redistribution are still common. The challenges lie in the remote environment as well as the constantly changing reference surface due to ice flow and firn settlement. The characteristics of snow spatial distribution have often been investigated with different methods such as in-situ measurement, ground-penetrating radar, or differentiation of digital elevation models derived from light detection and ranging. However, previous studies restricted their investigation at the peak-of-winter.

Our study investigates the temporal evolution of snow accumulation during the winter season. For the analyses, we use snow-depth data collected repeatedly in two quadrants on Haut Glacier d'Arolla during winter 2013 and semi-variogram analysis. Our results show that the snow distribution exhibits different patterns within the two investigation sites, but that those characteristics remain similar over the winter season. This suggests that correctly representing the snow distribution at the peak-of-winter is sufficient for calculating glacier accumulation, and asks for adequate winter survey strategies. Here we present first experiences collected with the deployment of a small unmanned aerial vehicle as a platform for close-range photogrammetry, discuss the encountered challenges, and report the lessons learned.

IAHS (Hydrology)

HW18p - HW18 Advances in Remote Observation of Snow

HW18p-326

Spatio-temporal estimation of snow in a mountainous region using a time-lapse camera network and unmanned aerial vehicles (UAVs)

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In cold-mountainous regions, it is quite difficult to obtain meteorological data for hydrological model simulations. It is mainly due to the lack of available meteorological stations in the high mountainous areas. In the case of the Tedori river basin in Japan, there are only two ground observation stations in a basin area ($809km^2$). Furthermore, they are located in relatively low elevations. Therefore, by using these data as an input for hydrological simulation, we could not evaluate the influence of snow in the high mountainous areas. In order to overcome these problems, we installed various observation systems such as a time-lapse camera network with a small temperature and RH sensors in the 5 different elevations from 50 m to 2500 m (asl) within a basin. These monitoring data and field observation data (snow depth, surface temperature, and sky openness) were used for model validation of a rain/snow determination, snow depth and snow duration period. Then, we quantified spatial distributions of snow cover and its depth by a small unmanned aerial vehicle with a compact digital camera (DJI Phantom 2 vision+) and latest 3D model softwares (Pix4D and Photoscan). Finally, we applied these updated models into a distributed hydrological model and validated its performance by comparing observed river discharge. The result obtained in this study will contribute to improve our understanding of snow processes in a cold mountainous region.

IAHS (Hydrology)

HW18p - HW18 Advances in Remote Observation of Snow

HW18p-327

Airborne measurements of snowpack properties

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Spatially continuous information on snowpack properties such as snow depth or snow grain size is the basis of investigations in numerous snow-related research fields. Such parameters have traditionally been measured at discrete point locations by automated weather stations or observers in the field, with the drawback of insufficiently capturing the high spatial variability of snow in alpine terrain. Remote sensing techniques allow gathering spatially continuous information over large areas (up to more than hundred km2), without the necessity of having personnel in potential avalanche terrain. Technical advances and a rising number of data and system providers have eased remote sensing data collection and availability throughout the past decade. Today they are widely available and affordable for research and practical applications.

In this investigation, we present the potential of airborne optical sensors to map snow depth and different snow types such as windblown snow at the surface with high spatial resolution (5 – 200 cm) in the mountainous region of Davos, Switzerland. We discuss advantages and disadvantages of different available measurement and data processing approaches. A key for mapping snowpack properties with optical sensors is the application of near infrared bands (wavelength 780 – 1400 nm). In these wavelength snow absorbs more solar radiation than in the visible wavelength (380 – 780 nm) and is sensitive to snow grain size. This is an advantage for the generation of digital surface models (DSM) using structure-from-motion photogrammetry. We validate the remotely sensed snow depth maps using independent snow depth measurements generated by hand probing and terrestrial laser scanning.

IAHS (Hydrology)

HW18p - HW18 Advances in Remote Observation of Snow

HW18p-328

Multispectral airborne LiDAR observations of the McMurdo Dry Valleys

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Field observations have documented dramatic changes over the past decade in the McMurdo Dry Valleys of Antarctica: extreme river incisions, significant glacier loss, and the appearance of numerous thermokarst slumps. To date these observations have been sporadic and localized, and have not been able to capture change on a valley-wide scale. During the 2014-2015 Antarctic summer season, specifically between December 4th, 2014 to January 19th, 2015, we undertook a widescale airborne laser mapping campaign to collect a baseline digital elevation model for 3500 km^2 area of the Dry Valleys and other areas of interest. The airborne LiDAR observations were acquired with a novel multi-spectral LiDAR sensor with active laser observations at three light wavelengths (532 nm, 1064 nm, and 1550 nm) simultaneously; which not only allowed the generation of a high resolution elevation model of the area, but also provides multispectral signatures for observed terrain features. In addition to the LiDAR data, high resolution (5-15 cm pixels) digital color imagery were collected. During the six week survey campaign of the Dry Valleys a total of 30 flights were performed, in which about 20 billion LiDAR returns and 21,000 60-Mpixels images were collected. The primary objective of this project is to perform a topographic change detection analysis by comparing the recently acquired dataset to a lower resolution dataset collected by NASA in the 2001-2002 season. This presentation will describe the processing and analysis of this significant mapping dataset and will provide some initial observations from the high resolution topography acquired.

IAHS (Hydrology)

HW18p - HW18 Advances in Remote Observation of Snow

HW18p-329

Multi-source testing of distributed snow models

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The main objective of this study is to demonstrate a potential of using multi-source snow dataset for tuning and validation of distributed snow model (DSM). The methodology is evaluated in Rax and Hochschwab regions (Austria). Existing snow cover there is a significant source of the natural water storage, which is important for the water supply system of Vienna.

In the study, a DSM was used to simulate spatial and temporal changes of snow water storage. It was calibrated and validated against a range of different sources of snow observations. Six types of comparisons were performed:

1) Comparison of DSM and satellite MODIS snow cover in terms of its spatial statistics. This type of comparison indicates potential biases of the model.

2) Comparison of snow depth observations obtained from time lapse photography at 5 snow gauges. The advantage of this comparison is that it allows to examine hourly variability as well as small scale spatial variability over the 100x100m plot.

3) Snow courses evaluations. This is an important test of the model from a practical perspective and interest in water resources management.

4) Evaluation of MODIS snow cover patterns. This test allows to compare spatial snow variability as well as the seasonal depletion of snow cover .

5) Test against satellite SPOT images that have better spatial resolution but a lower temporal frequency than MODIS.

6) Comprison of the model and oblique photographs at 3 camera locations. Also, the oblique photographs can be used to test the interception model against the appearance of snow in the canopies.

Results demonstrate a strong potential of multi-source datasets for validating snow simulations, particularly for operational applications.

IAHS (Hydrology)

HW18p - HW18 Advances in Remote Observation of Snow

HW18p-330

Towards the assimilation of MODIS reflectance into the detailed snowpack model SURFEX/ISBA-Crocus.

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Numerical simulations of snow on the ground are used for numerous scientific and operational applications such as avalanche hazard forecasting. Although the chain of models used in French mountain ranges for meteorological analysis and forecast (SAFRAN) and detailed snowpack modeling (SURFEX/ISBA-Crocus) usually perform reasonably well, significant differences with snowpack observations are common and are primarily attributed to the uncertainties in meteorological input and to the heterogeneity of snowpack conditions at all scales.

So far, no snow observation is assimilated into this model chain, so that simulation errors can accumulate over the winter season. Current efforts are devoted to the assimilation of data from visible and near-infrared imagers into the snowpack model. These efforts rely on the recently developed “TARTES” optical scheme that computes reflectances at various wavelengths using the vertical profile of the physical properties of snow predicted by the snowpack model.

In a first step, we performed ensemble simulations by perturbing the atmospheric forcing consistently with its estimated uncertainty. These experiments showed that the simulated snowpack evolution is extremely sensitive to this uncertainty, and that the assimilation of observations can greatly improve model results.

In a second step, we performed assimilation experiments using synthetic imager observations and a particle filter. The experiments were carried out for the location of Col du Lautaret area (French Alps) over 5 hydrologic seasons. They provide a good insight about the potential and limitations of assimilating imager data to improve the representation of the snowpack.

IAHS (Hydrology)

HW18p - HW18 Advances in Remote Observation of Snow

HW18p-332

Estimating the spatial-temporal distribution of snow depth in a forest catchment

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It is still difficult to measure snow depth in forested catchments located in high mountainous areas. In this study, we evaluated the applicability and robustness of a snow depth measurement approach based on temperature observations. We found that a standard deviation method is suitable and robust to estimate snow depths. Then, we observed snow depths at many points in a forested catchment. We investigated the relationships between snow characteristics and topographical information (e.g., elevation, slope, and aspect) and forest properties (e.g., canopy openness). Based on the results of these investigations, we constructed a multiple regression model that could predict data such as daily snow depths, snow duration, and snow disappearance days. In many cases, canopy openness was a significant variable that helped to explain the outcomes for daily snow depths, snow duration, and snow disappearance days. Overall, we found that it was possible to estimate the snow depth using the constructed equations and that this approach was quite effective for characterizing the spatial-temporal distribution of snow in a forested catchment.

IAHS (Hydrology)

HW18p - HW18 Advances in Remote Observation of Snow

HW18p-333

Use of various satellite snow products in short term hydrological forecasting

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Monitoring Snow Covered Area (SCA) and modeling snowmelt is the mainstay of the forecasting studies for the mountainous areas where snowmelt dominates runoff. Since the data limitations in combination with snowpack heterogeneity prevent a detailed understanding of the dynamics of snowmelt, satellite images provide an opportunity to supplement ground measurements for snow cover and runoff predictions. With the development of remote sensing, various data series with different source of acquisition and resolutions are acquired via satellites. In this study, some of the operational (MODIS, IMS and MSG) satellite snow products are analyzed on a mountainous headwaters of Euphrates River Basin, Turkey. The test site has an area of 10250 km2 and the elevation ranges in between 1125-3500 m. Each of the snow products has different properties which add value in the suitability assessment of them through hydrological modeling.

The selected hydrological model is SRM which is well-known in the literature and used world-wide especially for snowmelt modeling studies. The products are compared on average as depletion curves of the pilot area for each melting season, which is one of the main inputs of the hydrological model besides temperature and precipitation.

An operational hydrologic forecast system is implemented together with a deterministic numerical weather prediction data of Weather Research and Forecast (WRF) model. Therefore, runoff predictions are obtained for short (1-2 days) range which provide benefits to operational management of water structures located in the downstream of Upper Euphrates Basin.

IAHS (Hydrology)

HW19a - HW19 Remote Sensing Retrievals of Precipitation and Evapotranspiration

IUGG-0219

Statistical assessment and bias correction of remotely-sensed precipitation products: Case studies over South Asia and the African Continent (1998-2012)

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Accurate and reliable measurement of precipitation is crucial for monitoring water resources. However, lack of dense observational networks and existing gaps in the precipitation records over most regions of South Asia and Africa impose substantial problems in estimating rainfall variability. Considering the growing number of remotely-sensed precipitation products during the last decade, we evaluated seven satellite-based precipitation estimates (ARCv2, CHIRP, CMORPH, GSMaP, PERSIANN, TAMSAT, and TRMM) over the African continent (2003-2010) and the Himalayan region of Bhutan (1998-2012), whose climatological regimes and topographical features are very different. A bias estimation-correction method, based on the gamma-distribution technique was applied to assess the satellite-only products (e.g., CHIRP) against in-situ observations. Principal component analysis was applied to assess the dominant modes of variability of various products over the study regions. Our results indicated that all satellite-based products are able to adequately capture the spatio-temporal modes of rainfall variability over both regions including some aspects of precipitation extremes. While they generally agree very well with gauge-based in-situ observations, we found their accuracies to be widely different over the two regions. All satellite-based products underestimated monsoon rainfall over Bhutan, while they systematically overestimated convective rainfall over central parts of Africa. The gauge-adjusted TRMM data (3B43 v7) was found to be more consistent with in-situ observations over Bhutan. Various statistical measures (e.g., RMSE, biases, and correlation) employed over Africa indicated that PERSIANN is well suited for monitoring African rainfall, followed by the regional product ARCv2.

IAHS (Hydrology)

HW19a - HW19 Remote Sensing Retrievals of Precipitation and Evapotranspiration

IUGG-2617

The quest for an improved remotely sensed global soil moisture dataset: A model combination approach

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A number of microwave-based remotely sensed soil moisture products have been used in various fields of Earth sciences in the past decades. However, significant uncertainties exist, with soil moisture values for a given location and time step using the same satellite sensor deviating from each other if different retrieval algorithms are used. In our quest to derive a better global soil moisture product, two datasets from the Advanced Microwave Scanning Radiometer 2 (AMSR2), retrieved by the Japan Aerospace Exploration Agency (JAXA) algorithm and the Land Parameter Retrieval Model (LPRM) are assessed and structural errors noted. The main findings are: 1) The JAXA algorithm generally underestimates the ground soil moisture, whereas LPRM algorithm tends to overestimate soil moisture. 2) Correlation coefficients between AMSR2 products and ground measurements decrease when the mean temperature decreases below approximately 290K. 3) In general the LPRM correlations increase as the surface becomes rougher whilst the JAXA correlations decreases. 4) The performance of JAXA is affected in areas with dense vegetation, particularly for mean EVI greater than 0.30. 5) Distributions of bias and RMSE of LPRM are relatively insensitive to variation of mean ground soil moisture; however JAXA performs better in dry condition. As it is found that the two products are complementary under the various conditions, a combinatorial approach is presented for improving the accuracy of soil moisture dataset. The approach attempts to ascertain the optimal combination weight between the two products, taking into account the cross-correlation the two exhibit for each location and the time-window under consideration. An initial assessment of the improvements that result are presented.

IAHS (Hydrology)

HW19a - HW19 Remote Sensing Retrievals of Precipitation and Evapotranspiration

IUGG-2705

On the use of satellite data to implement a distributed dynamic vegetation model in a Mediterranean catchment

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It is important to consider that the Mediterranean region is recurrently confronted with the scarcity of the water. The issue of climate change is aggravating this situation. The vegetation plays a key role in the catchment's water balance particularly for semi-arid areas as Mediterranean region is.

However, many of the dynamic vegetation models are quite complex. To cope with the difficulty of estimating a large number of parameters, the authors focused on the use of a parsimonious model called LUE-model. This model is based on the amount of photosynthetically active radiation absorbed by green vegetation and the Light Use Efficiency index (the efficiency by which that radiation is converted to plant biomass increment).

It has been applied in a Mediterranean catchment located in La Hunde (East of Spain) and it has been implemented using remote sensing data. The satellite information used was Normalized Difference Vegetation Index (NDVI) included in the products MOD13Q1 and MYD13Q1. After implementing the model using only satellite data, the results were tested against field measurements (soil moisture and transpiration data).

In this way, the main objectives of this work were: use the satellite data to calibrate a parsimonious dynamic vegetation model and prove that the obtained results are consistent with field observation, and check the capability of the model to reproduce the vegetation dynamic and hydrological behavior.

The obtained results suggest that this parsimonious model is able to adequately reproduce the dynamics of vegetation and also reproduces reasonably well the soil moisture variations (Nash-Sutcliffe index equal to 0.61 and 0.65 respectively). The

obtained results also suggest that satellite data can be used to implement this parsimonious model.

IAHS (Hydrology)

HW19a - HW19 Remote Sensing Retrievals of Precipitation and Evapotranspiration

IUGG-4347

Uncertainty analysis of a nonparametric approach for satellite retrieval of terrestrial evapotranspiration with multi-temporal and multi-sensor data

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The combination theory of evaporation has been developed comprehensively to describe terrestrial evapotranspiration (ET). It involves complicated parameterization of aerodynamic and surface resistances, which prevents its application in accurate retrieval of ET from satellite remote sensing, especially with multi-temporal and multi-sensor data. A nonparametric approach has been recently proposed to circumvent the problem (Liu et al. A nonparametric approach to estimating terrestrial evaporation: Validation in eddy covariance sites. Agricultural and Forest Meteorology, 2012, 157, 49–59). This approach requires surface net radiation, soil heat flux, land surface temperature and emissivity, and surface air temperature, all of which can be readily available or estimated from satellite remote sensing. For multi-temporal and multi-sensor remote sensing, this study analyzes the uncertainties of the nonparametric approach relevant to temporal influences including sun-target-sensor geometry, atmospheric status, sensor-to-sensor difference and sensor degradation. Furthermore, multi-temporal images of Landsat ETM+ and the Advanced Spaceborne Thermal Emission Reflection Radiometer (ASTER) are used to retrieve ET over a subtropical region with the nonparametric approach. The retrieved ET generally agrees well with eddy covariance observations. Comparative analysis shows that the largest uncertainty comes from surface net radiation, followed by land surface temperature, air temperature, soil heat flux, and sensor-to-sensor difference. Effects of sensor degradation can be significant on the ET retrieval for the period experiencing sharp changes. Overall, the nonparametric approach may offer merits for satellite retrieval of ET from multi-temporal and multi-sensor data.

IAHS (Hydrology)

HW19a - HW19 Remote Sensing Retrievals of Precipitation and Evapotranspiration

IUGG-4393

Use of remotely sensed actual evapotranspiration to parameterize a SWAT model for a basin in East Africa

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This study investigates the use of actual evapotranspiration (ET) data estimated by the Simplified Surface Energy Balance (SSEB) approach, to parameterize a Soil and Water Assessment Tool (SWAT) model of the Mara River Basin (13,400 km^2). For this trans-boundary basin, only a limited amount of hydro-meteorological observations are available. Bias corrected daily CMORPH rainfall data are used as inputs for the SWAT model. A monthly SSEB ET time series from 2001 to 2006 and observed monthly discharges from 2005 and 2006 are used for the model calibration and validation. The SWAT parameters related to the ET calculations, such as the soil evaporation compensation factor (ESCO), the canopy storage (CANMX) and the soil depth (SOL_Z), are adjusted manually in order to fit the SWAT simulated ET to the SSEB ET at basin scale. As it turns out, the calibrated SWAT model results a Percentage of Bias (PBIAS) of -5.6% and a Coefficient of Determination (R^2) of 0.5 in simulating monthly ET during the calibration period (2001-2004). While validating the fairly optimized model from 2005 to 2006, an improved model performance (PBIAS = -7.7% and R^2 = 0.7 for monthly basin ET) is noted. .. However, when considering the monthly flows, a large bias is observed (-42%). A further study is planned to improve the performance of the model using a multi-objective automatic optimization algorithms using flow and ET from SWAT and SSEB at sub-basin and at HRU scale. In general, these preliminary results show the potential of spatially and temporally varying remotely sensed rainfall and ET products in data poor catchments for water balance analysis.

IAHS (Hydrology)

HW19a - HW19 Remote Sensing Retrievals of Precipitation and Evapotranspiration

IUGG-5768

Interpolation of daily rain gauge data for hydrological modeling in data sparse regions using pattern information from satellite data

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In order to cope with a severe reduction of the rain gauge network in the Great Ruaha River Basin over the past 30 years, an interpolation scheme using spatial patterns from satellite images as covariate has been evaluated. The regression based interpolation attempts to combine the advantages of accurate rainfall amounts from rain gauge records with the unique spatial pattern information obtained from satellite based rainfall estimates. A spatial pattern analysis reveals that the simple interpolation of the sparse current rain gauge network compares very poorly to the pattern originating from the much denser historic network. In contrast, the rainfall data sets that include patterns from satellite data show good correlation with the historic pattern. The evaluation based on hydrological modeling, showed similar and good performance for all rainfall products including rain gauge records, whereas the purely satellite based product performed poorly.

IAHS (Hydrology)

Hw19b - HW19 Remote Sensing Retrievals of Precipitation and Evapotranspiration

IUGG-0678

Estimation of actual and potential evapotranspiration using remote sensing in northern Tunisia

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Accurate quantification of the amount and spatial variation of actual evapotranspiration is a key task in water balance prediction. Satellite remote sensing offers the opportunity such assessment. This study aims to present a tentative of spatial and temporal estimation of actual evapotranspiration AET in northern Tunisia using satellite imagery and evaluating the Surface Energy Balance System (SEBS) model.
The sources of data were 8 ground meteorological stations covering the study area. It is also taken advantage of satellite products from the European organization for the exploitation of meteorological satellites on land surface analysis and satellite application facility (EUMETSAT LSA SAF).which have an imaging-repeat cycle of 15-30 minutes and a 3 km resolution.
On the other hand, the performance of the Land Surface Analysis Satellite Application Facility (LSA SAF) SAF AET was evaluated and compared to SEBS AET estimations. Subsequently, the SEBS AET and the SAF AET have been compared with reference ET0 calculated using the Penman-Monteith equation. Comparisons of SEBS AET and SAF AET results show a good agreement and compare comprehensively with reference ET0.

In order to validate the results of actual evapotranspiration, a balance water model named BBH is used. This model used the precipitation, runoff, potential evapotranspiration and 8 parameters as input data. After calibration and validation of results, AET is evaluated.

Furthermore, temporal and spatial droughts were analyzed of the region. The temporal variations and the drought observed were possible by integrating hydro-meteorological variables (e.g. AET, rainfall and potential Evapotranspiration (PET), vegetation performance and drought indices).

IAHS (Hydrology)

Hw19b - HW19 Remote Sensing Retrievals of Precipitation and Evapotranspiration

IUGG-0819

Merging and correction of Satellite rainfall estimate with in-situ data for the Northern of Tunisia

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Satellite products have been widely used in the estimation of extreme rainfall events. This study aims to investigate statistical correction methods applied the Tropical Rainfall Measuring Mission TRMM 3B42 rainfall daily estimates. 16 heavy rainfall events interpolated using 318 rainfall stations in Northern Tunisia are studied here. They were observed during 2007, 2008 and 2009. We mean by heavy event the rain exceeding 50 mm/day for at least one station of the study area. The Pearson's correlation coefficient between satellite estimations and ground maps reached 0.75 for some events but were non significant for other events. Firstly, a bias correction procedure was implemented. It resulted in an improvement of the Pearson's correlation coefficient between corrected maps and ground maps. One drawback of the bias correction method is that it needs in-situ observations to be achieved. Thus, a quantile-quantile correction procedure was applied. To this end, two fitting curves were calibrated for each studied event: one for quantiles smaller than the 87th percentile and another for greater quantiles. Then, for both situations, an ensemble mean was estimated and its resulting estimates fitted using new average fitting curves. The firtt part (< 87th map percentile) was adjusted by a linear curve and the second part by a power curve. Applying this two fitting equations to

estimate the corrected TRMM maps didn’t improve the Pearson’s correlation coefficient within the interpolated in-situ data. Thus, the quantile correction procedure needs more statistical tools to achieve an improvement of TRMM rainfall map.

IAHS (Hydrology)

Hw19b - HW19 Remote Sensing Retrievals of Precipitation and Evapotranspiration

IUGG-1708

Climatic water balance analysis of the Zala River Basin

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In Hungary under semi-humid climatic conditions, about 90% of the precipitation evaporates and only 10% runs off. Evapotranspiration (ET) is a very effective vehicle for mass and energy transfer between the land- or vegetation surface and the ambient atmosphere. Therefore, it is essential to determine more accurately the amount of ET for better knowledge of energy balance and hydrological cycle.

The Zala River provides the largest inflow of the Lake Balaton, which is the biggest lake in Central Europe. Water balance of Zala River Basin was analysed using remote-sensing based evapotranspiration maps (Calibration-free Evapotranspiration Mapping CREMAP 1 km2 spatial resolution) for Hungary over the 2000-2008 period (Szilágyi and Kovács, 2011).

For climate change impact analysis a climate water balance model was used in spatially-distributed mode. The parameter of the Budyko-model (alfa) was calculated for pixels without surplus water. For the extra-water affected pixels a linear model with beta-parameter (actual evapotranspiration / pan-evapotranspiration) was estimated. Alfa and beta parameters were validated for the Zala River Basin using historical precipitation and streamflow measurements. By using the two parameter maps and future data of climate models (mean annual temperature and precipitation) evapotranspiration and runoff have been predicted for three periods (2011-2040, 2041-2070, 2071-2100).

This research has been supported by AGRARKLIMA.2 VKSZ_12-1-2013-0034 project.

Reference:

Szilágyi J., Kovács Á. (2011) A calibration-free evapotranspiration mapping technique for spatially-distributed regional-scale hydrologic modeling, J. Hydrol. Hydromech., 59, 2011, 2, 118–130.

IAHS (Hydrology)

Hw19b - HW19 Remote Sensing Retrievals of Precipitation and Evapotranspiration

IUGG-4503

Big river flood forecasting by coupling quantitative precipitation prediction with distributed hydrological model

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Precipitation is the critical driver of river basin flood in many regions of the world, but in many river basins, there are not dense precipitation observation network that prevents a reasonable river basin flood forecasting, particularly in some big rivers in the developing countries, which may need long lead-time forecasting products for flood warning. Development of quantitative precipitation estimation and prediction in the past decades provides new product for river flood forecasting, thus having the potential to forecast floods of big river with no ground observation of precipitation with long lead-time. This paper has done some preliminary works on this method in Southern China. The WRF, a quantitative precipitation prediction model, is employed to predict the precipitation over the Liujiang River in southern China with a drainage area of 60,000km^2 with a spatial resolution at 20km, and a temporal resolution at 1 hour with 48 hour lead-time. Liuxihe model, a physically based distributed hydrological model is developed to predict the flood by coupling the WRF predicted precipitation. Preliminary results show the flood of Liujiang River could be forested reasonably. Forecast uncertainty still exists, that is a big challenge for the operational use of this method.

IAHS (Hydrology)

Hw19b - HW19 Remote Sensing Retrievals of Precipitation and Evapotranspiration

IUGG-5767

Remote sensing of evapotranspiration: a review of models and applications

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Evapotranspiration is a significant process in the water balance of watersheds. In addition, its transpiration component is directly correlated to agricultural biomass production and crop yield. Over the last two decades, several models have been developed to retrieve surface evapotranspiration using remotely sensed inputs. These include water balance approaches in agricultural areas using reflectance-based crop coefficients as inputs; energy balance models that use the thermal infrared band of satellite sensors to retrieve spatially distributed evapotranspiration such as the Two-source model (TSM), SEBAL/METRIC, SEBS, ALEXI-DISALEXI and, hybrid approaches that combine water and energy balance approaches (SETMI, HIDROMORE). This presentation will summarize the state-of-the-art in evapotranspiration retrievals, presenting models and several application examples.

IAHS (Hydrology)

HW19p - HW19 Remote Sensing Retrievals of Precipitation and Evapotranspiration

HW19p-143

Validation of evapotranspiration and its long-term trend over the Yellow River source region

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Evapotranspiration (ET) is a key process of regional water cycle. In this investigation, daily mean ET products for the period 2010 are compared to the eddy covariance observations at the Maqu wetland station in the Yellow River source region. The deployed datasets include reanalyses (ERA-Interim, NCEP/DOE AMIP-II Reanalysis), satellite-based MODIS global ET product (MOD16), and the first emerging off-line SEBS ET datasets. In general, slopes of the least-squares line in the scattering plots of these datasets versus observational values show differences, with ERA-Interim, NCEP-DOE, MOD16 and SEBS ET product slopes ranging among 0.88±0.05, 0.63±0.06, 0.66+0.17 and 1.71±1.47, respectively. Reanalysis data from ERA-Interim was found to agree well and therefore to have a good representative of ET in the Yellow River source region. The Sen's slope estimator test and Mann–Kendall (MK) test were applied to quantify the significance of trend shift while the moving T test and the Sequential Mann–Kendall (SQMK) test were derived to characterize the abrupt changes, respectively. The results showed that the Yellow River source region is experiencing a statistical rise on the north and decrease of ET on the south from 1979 to 2014 at rates around 1.65mm/a, -0.50 mm/a respectively. Trend shift in annual ET is more pronounced than those in growing season ET, and abrupt changes detected in the 1985. The impacts of meteorological variables on temporal trends of ET showed that precipitation was the most dominant factor affecting ET variation whereas land surface temperature is the least. It suggested that these results are to be used as baseline ET values for reanalysis data and satellite image-based ET mapping research in the Yellow River source region.

IAHS (Hydrology)

HW19p - HW19 Remote Sensing Retrievals of Precipitation and Evapotranspiration

HW19p-144

Satellite calibration and validation for NOAA and other precipitation products

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The NOAA/NESDIS/Center for Satellite Applications and Research (STAR) is responsible for the calibration and validation (Cal/Val) of remotely-sensed products produced by NESDIS. Various projects are helping to insure both the quality of satellite radiance data and satellite-derived products. Also included in STAR's Cal/Val effort is the WMO based Global Space-based Inter-Calibration System (GSICS), for which STAR is the international leader.

Validation of NOAA STAR rainfall products is conducted at the end of each meteorological season (Dec-Feb, Mar-May, Jun-Aug, and Sep-Nov). Validation is conducted over the contiguous United States. Daily rainfall amounts are validated using rain gauge data as “truth” over both regions, and radar data also are used to validate composites of hourly swath rainfall products (MiRS and MSPPS) over the U.S. The purpose of this activity is to provide STAR rainfall algorithm developers with feedback on the performance of their algorithms, which will help to guide decisions on whether to divert resources toward algorithm improvement or perhaps to investigate the reasons for recent algorithm behavior (good or poor).

In addition, we expand our Cal/Val efforts to several exciting new rainfall estimates including JPSS GCOM AMSR-2, ATMS MiRS, and the products from newly launched GPM. The results of these validation efforts will be shown and discussed in detail.

IAHS (Hydrology)

HW19p - HW19 Remote Sensing Retrievals of Precipitation and Evapotranspiration

HW19p-145

Assessment of an energy-balance model for evapotranspiration mapping over the Andean páramos

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Understanding of evapotranspiration (ET) processes over mountain environments is crucial, particularly due to the fragility of pristine ecosystems like the high and humid grasslands in the Andean cordillera of South America. The present study aims to assess the applicability of satellite-based evapotranspiration retrievals over tropical mountain landscapes, including calibration with meteorological and flux data. We implemented the energy-balance based model METRIC (Mapping EvapoTranspiration at high Resolution with Internalized Calibration) with Landsat 7 ETM+ (landscape scale) and MODIS imagery (2013 ~ 2015) for the Andean páramo (neotropical alpine grassland, 2800 to 3900 m a.s.l.) in Southern Ecuador. Besides the basic implementation of the model, suitable algorithms that account for the topography and latitude of the Andean valleys were included (i.e. refinement of incoming radiation considering the slope and aspect of the terrain, temperature lapse corrections, roughness length and wind speed adjustments). First results of METRIC ET (Landsat-based) estimates show a good agreement with the widely applied FAO-56 based ET estimates retrieved from an weather station network (installed along two altitudinal gradients), which support the plausibility of the model. Ongoing work includes the installation of an eddy covariance flux tower, among other measurements for validation of the satellite-based ET maps.