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Water Diplomacy in the Mekong River Basin

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Water diplomacy should be understood as one coin with two sides: the benefit sharing side and conflict prevention/management side. In the international literature and practice, water and hydropower is usually focused much on dialogue and conflict prevention. At the MRC, we have both mechanisms in place: the Basin Development Planning (BDP) process through the 5 yearly Basin Development Strategy which tries to optimise basin wide benefits and the agreed basin-wide Procedures for water utilisation that acts as a platform for water cooperation and conflict management. The BDP process so far has produced a comprehensive cumulative impact assessment of the countries plans, involving multiple stakeholders at basin and national levels, following which negotiation by senior officials were conducted and agreed on the Basin Development Strategy. The Strategy, updated in 2015, prioritised the need for joint projects of cost and benefit sharing to address long term water security needs (water, energy, food, and flood). The MRC Procedures, also agreed by riparian countries at the ministerial level, deal with data sharing, notification and prior consultation on national projects, maintenance of flows, maintaining water quality, and monitoring water use. The BDP and the Procedures support one another in the overall water diplomacy work at the MRC.

Water diplomacy issues in the Lower Mekong Basin – some comments

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Of the 60 million people who live in the lower Mekong Basin, 80 percent rely directly on the river system for their food and livelihoods. The different development status of the main riparian countries and different priorities in the utilization of the rivers´ manifold potentials are sources of potential disagreement and conflict. Major uses of the river include inland navigation, fishery, irrigation, sustainable rice growing in the Mekong delta and hydropower-development. Amongst a number of sector specific programs, the Mekong River Basin Development Plan has a cross-sectoral approach and relies on strategic plans and approaches for the further development of the basin taking into account rapid changes in demographic development and impact of climate change on the hydrologic river regime and means of adaptation. The Joint Committee of the Mekong River Commission (MRC) has recently endorsed the Strategic Plan 2016-2020 that envisages further developing and making use of measures in water diplomacy. Strategic engagement and water diplomacy are core activities of MRC to ensure the equitable and sustainable development of the Mekong River Basin. The presentation comments on some of the most pressing issues in basin development on the basis of strategic approaches and the use of water diplomacy.

A regional approach to climate adaption in the Nile Basin

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The Nile Basin is one of the most critical and most important shared basins in Africa, hosting 25% of Africa's population (SEDAC, 2010) while accounting for 10% of its landmass. Agriculture, energy production and livelihoods all depend strongly on the flows. Managing and developing the water resources within the basin must not only address different water uses but also trade-off between developments upstream and water use downstream, often between countries. The distribution of precipitation can be categorised into two distinct regions; the Equatorial (or East African) lakes and the Ethiopian highlands. Furthermore, there are significant differences in the wet and dry period distribution with some areas in the tropical region of the Nile basin having two rainfall seasons. The significant inter-annual and inter-decadal variability, which also has important implications for the management of water resources in the Nile (Conway, 2005). In addition, the region is facing rising levels of water scarcity, high population growth, watershed degradation and loss of environmental services (UNEP 2010). Many past studies have demonstrated that modelling current and future changes in river runoff presents a number of challenges; the large size of the basin, the relative scarcity of data, its geographical location and the corresponding dramatic variety of climatic conditions and diversity in hydrological characteristics. On top of these hydrological challenges, the climate projections are inherently uncertain. Nevertheless decision-makers in region need to evaluate and implement climate adaptation measures. Such climate adaptation measures can be implemented at the local, sub-basin or national scale. However within trans-boundary basins like the Nile the implementation of such measures locally may have important impacts regionally particularly downstream of those measures. Therefore tools and information are required to understand climate change and adaptation impacts at the regional scale.

We present a regional scale approach to support climate adaptation on a regional scale developed with the UNEP project "Adapting to climate change induced water stress in the Nile River Basin", funded by SIDA, for assessing climate change impacts and adaptation potential for floods and droughts within the basin. The project exploits a novel perturbed physics ensemble of climate models recently developed at the UK Met Office. A selection procedure was followed to identify a representative sub-sample from a large GCM ensemble of the whole distribution based on the ability of the members to reproduce the key climatic processes in a number of regions of Africa. These high-resolution simulations were bias-corrected and are being used together with a regional hydrological model to assess the impacts of climate change on the floods, droughts and water scarcity. This regional hydrological MIKE HYDRO model includes sub-basin based conceptual rainfall-runoff, where the basin size depends on the availability of climatic and hydrological data as well simple linear reservoir routing along the main river reaches and facilities to represent reservoirs, irrigation systems and general water users. In this paper, we present both the methodology and results of climate changes on the flows and water balance in the region.

Keywords: Climate change, regional scale modelling, regional scale adaptation, Nile River basin, floods, droughts, water scarcity

Conflict resolution in Euphrates basin by Bankruptcy Method

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Mismanagement, water scarcity and its uneven distribution would lead to or increase conflict and tensions among riparian countries. Redistribution and allocation of water between riparian countries is an important issue on conflict over utilization from shared water resources. The bankruptcy theory is a cooperative game theory method used when the amount of demand of riparian states is larger than the available water. In this study, we survey the application of six methods of bankruptcy theory including Proportional, Adjusted Proportional, Constrained Equal Awards, Constrained Equal Losses, Piniles and MO in allocation of the Euphrates river which is shared between 3 riparian countries: Turkey, Syria and Iraq. The Proportional rule leads to equal percent achievement for all 3 riparian countries. Iraq achieves more than two other riparian countries by Adjusted Proportional rule, Constrained Equal Losses rule and MO rule by 71%, 77% and 77%, respectively. However by Constrained Equal Awards rule the Turkey would obtain about 94 percent of its claim which is most achievement between other 5 rules, while by the Piniles rule Syria achieve more than two other riparian countries about 74 percent.

Keywords: Euphrates River, shared water resources, Conflict resolution, Bankruptcy theory

Post conflict water management: learning from the past for recovery planning in the Orontes River basin

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Current human - hydrosystem interactions are shaped by past water uses, hydraulic development and hydro-social configurations (Swyngedouw 2009). Historical reconstruction of water use is considered a powerful approach to identify drivers of changes in human-water relationships in order to design realistic future water management scenarios (Grouillet et al 2015; Lu et al 2015). While general trends such as population growth or increase of irrigated areas have been considered as major drivers of changes, little attention was paid to radical changes, for example in the case of armed conflicts.

The transboundary Orontes (Al Asi) River basin, shared between Lebanon, Syria and Turkey, is representative of the global changes in water use that impacted hydrosystems during the last century in the southern and eastern parts of the Mediterranean basin. Since the 1950s and especially in the 1990s, the area witnessed an intensive surface and ground water development, mostly for agricultural purposes, leading to a sharp decrease of the Orontes river discharge in its middle course; the drying up of numerous springs and localized groundwater overexploitation in several areas (Zwahlen et al 2014). After 2011, the study area became a key region in the Syrian conflict (Haj Asaad and Jaubert 2014) and witnessed a drastic spatial redistribution of the water consumption and thus a radical reconfiguration of surface and ground water flows. As a consequence of the decrease of water use and consumption in the middle reach, the Orontes River discharge of the basin increased by two-fold at the Syrian-Turkish border in 2014; whereas water use increased in “shelter” areas, where displaced populations take refuge.

This study aims to provide guidance for recovery planning in a post-conflict perspective in the Orontes River basin by identifying, through a historical water balance assessment, the socioeconomic drivers (Reynard et al 2014) of spatialized long term and radical changes at a regional catchment level. The adopted interdisciplinary approach consists of assessing the human-hydrosystem coevolution through the calculation of a water balance at two scales for four representative periods in terms of water use and consumption: the 1930s; 1970s; 2000s and post-2011. The lack of accurate and comprehensive long term datasets is tackled by confronting different estimation methods of historical surface and ground water flows: literature reviews, historical records, statistical analysis, expert interviews, maps and satellite images analysis to assess land use changes. Water balance as a synthesis tool allows checking the plausibility of the estimated parameters.

This study is part of the Orontes River Basin Research Program led by the Graduate Institute of International and Development Studies (Geneva) with the support of the Swiss Development and Cooperation Agency, which aims to provide baseline elements to support emergency interventions and post-conflict planning in Syria and to contribute to coordinated and sustainable management of the Orontes River Basin’s shared water resources in the long term (Jaubert et al 2014).

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Water Resources Assessment and Seasonal Prediction: To what extent do they sway decision making in water management in Australia?

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At a time when the reliability of freshwater resources has become highly unpredictable as consequences of climate change and increasingly frequent droughts, the role of science – as evidenced based policy – in decision-making points to the need to constantly improve our capabilities to forecast the availability of seasonal water. Australia in one of the driest inhabited continents where freshwater availability is highly variable, which poses unique problems for the management of the nation's water resources. Under Australia's federal system, water management challenges have been progressively dealt with through political institutions that rely on best available science in policy making. However, it could be argued that evidence based policy making is an impossible aim in a highly complex and uncertain environment and that such a pursuit is far from attainable in a world of competing values and vested interests across stakeholders. This article demonstrates that, while science has a fundamental role to play in effective water resources management, the reality *on the ground* often diverges from the intended aim and does not always reflect efforts at reform. This article briefly reviews the Water Act 2007 and comments on how policy makers need to manage rather than try to eliminate uncertainty in order to promote change.

Water resources observation using satellite altimeters and future capabilities with the SWOT satellite

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Rivers and lakes are a key component of the continental hydrological cycle. The storage and amount and dynamic of water stored in lakes, reservoir and wetlands globally is known only crudely. Over rivers, surface water stage and slope are a key measurement for derivation of streamflow. Although river discharge and lake water storage are critical elements of land surface hydrology, they are poorly observed globally. Freely available stream gauge networks cover only a few river basins. They record water surface elevation at fixed points along river channels. Since the beginning of the 1990s, numerous in-situ networks have declined or stopped working, because of political and economic factors.

Remote sensing techniques can be used to monitor components of the water balance with a geographical coverage, a good spatiotemporal sampling and continuous monitoring with time. Satellite altimetry is able to give a systematic monitoring of water levels of large rivers, lakes and floodplains and can be used in addition of in-situ data. At each intersection of the altimeter track with the river can be build a so-called virtual station. The LEGOS and the French Space Agency, CNES, has developed HYDROWEB, a database based on altimetry data. It contains time series and fluctuations over water levels of large rivers, lakes and flood plains all around the world. At present, HYDROWEB gives the level of 235 lakes and 1400 virtual stations over 20 great watersheds and level, area and volume of 100 other lakes. The accuracy is around 2 cm over lakes and varies from 10cm to 1m over rivers larger than 100m. This database is evolving in 2015 to an operational service with data available in near real time with a downloaded from the THEIA land data center managed by the CNES.

The French Space agency is working with NASA on a new technical concept mission: the Surface Water and Ocean Topography (SWOT) satellite, based on wide-swath interferometric altimetry. Compare to conventional altimetry that gives water elevation only at virtual stations, SWOT can be considered as a revolution in hydrology science by providing the first global survey of Earth's surface water. With a launch date scheduled for late 2020, SWOT will allow mapping surface water extent and elevation of rivers wider than 100 m with a goal at 50m. It will estimate the global change in river discharge at sub-monthly, seasonal and annual time scales. SWOT will inventory a majority of medium to large lakes (approximately 250m^2 and larger) and estimate 65% of the global lake storage change lakes larger than ~0.06 km^2. These unprecedented measurements will support scientific research for a better understanding of the global water cycle on land, to study the dynamics of floodplains and wetlands, which have important impacts on flood control and the balance of ecosystems. It will also open up a new avenue for scientific research and at the same time create a new operational sector, particularly in hydrology where space observations are developing.

Monitoring changes in groundwater storage over East Africa using satellites and models

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In the face of climate change and increasing water demands from population and development pressures, effective water resources monitoring and management calls for a good understanding of the resource with a fair degree of accuracy. The East African community (Kenya, Uganda, Tanzania, Rwanda and Burundi) largely derives its home and industrial water from the under-sampled groundwater resource. Understanding the drivers of changes in this resource and its behavior through time is important for water resources management. In this study, we use a simple water balance model with inputs from the Gravity Recovery and Climate Change (GRACE) satellite, Lake Altimetry and land surface models, to estimate groundwater storage changes over East Africa. The capacity of the GRACE satellite to capture changes in groundwater storage is evaluated using insitu groundwater observations from monitoring wells over Uganda. The results show that GRACE-based groundwater estimates and insitu observations are highly correlated (rs = 0.64). Piecewise trend analyses for the GRACE-groundwater estimates reveal significant negative storage changes that are attributed to groundwater use and climate variability. Our results prove the utility of applying GRACE in monitoring groundwater resources in hydrologically complex regions that are under-sampled and where policies limit data accessibility. Such results can be readily applied to regional water resources management tools to interpret local-scale water resources availability.

The new portfolio of global precipitation data products of the Global Precipitation Climatology Centre suitable to assess and quantify the global water cycle and resources

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The Global Precipitation Climatology Centre (GPCC) collects and assures quality of world-wide observational in-situ data from rain gauges in order to provide gridded high-quality and high-resolution land surface precipitation analyses as mandated by WMO's World Climate Research Program and the Global Climate Observing System (GCOS). Based on over 25 years of operation the GPCC gridded data products are built on base of the world-wide largest archive of quality controlled in-situ precipitation data. All gridded GPCC data products are public available in OGC compliant netCDF format to the community (ftp://ftp-anon.dwd.de/pub/data/gpcc/html/download_gate.html)

Depending on the climate related application and service aspired, there is a large variety of user needs in terms of timeliness, homogeneity, resolution and accuracy which cannot be addressed by one data product. As a consequence GPCC has issued a suite of products that contains near-real-time as well as non-real-time products in monthly and daily resolution. Data from national meteorological and hydrological services, regional and global data collections are mainly used to calculate these products, as well as WMO-GTS data. In order to provide the user with a sufficient level of documentation and long term accessibility, all GPCC products issued since year 2011 are referenced by digital object identifiers (DOIs), allowing also for reproducibility and repetition of data utilizations even decades after primary data accesses.

Most recently updated versions of the Full Data Reanalysis (V7) and Climatology (V2015) were released, replacing their predecessors issued in 2011. The updates are enhanced by almost 8,000 additional stations that were added to the quality assured data base of the GPCC. Furthermore the data records of existing stations were extended by the most recent years. All in all, the new versions are based on about 75,100 stations with records exceeding 10 years instead of 67,200 stations reprocessed in year 2011. Due to the additional stations and precipitation data, it was possible to detect errors invisible so far and to improve the analysis in particular across Indonesia, Mexico, Brazil and some other regions. Moreover a new land-sea mask has been introduced, adding many grid cells across islands/atolls that had been missing (sea cells) before. The GPCC Full Data Reanalysis Product is the most recommended for quantitative assessments of the global water cycle and resources with regard to the precipitation over land (Schneider et al., 2014)

Schneider, U., A. Becker, P. Finger, A. Meyer-Christoffer, M. Ziese, and B. Rudolf, 2014: GPCC's new land surface precipitation climatology based on quality-controlled in situ data and its role in quantifying the global water cycle. *Theoretical and Applied Climatology* **115**, Issue 1-2, pp 15-40.

Rainfall as proxy for evapotranspiration predictions

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Land-use or land-cover change and climate variability are two important factors that can lead to changes in hydrological variables, particularly river discharge. This changes may have positive and negative impacts on society and it is desirable to separate the effects of those two causes in order to analyze their relative impacts.

Hydrological models are often used as tools to assess the impacts of climate variability on historical streamflow time series. Input data include precipitation and variables needed to estimate evapotranspiration, such as temperature, solar radiation and wind speed. The need of other meteorological variables in addition to rainfall usually limits how much the streamflow can be extended into the past. This occurs because rainfall monitoring started earlier in the past than other meteorological variables. This is true for Brazil, where rainfall time series in several places started during the 1940´s, while operational nation wide monitoring of the variables needed to calculate evapotranspiration usually started during the 1960´s.

To extend potential evapotranspiration time series into the past, we investigated the relationship between potential evapotranspiration and precipitation using data from 290 meteorological stations of the Brazilian Meterological Institute (INMET).

Results show that potential evapotranspiration tends to be lower during rainy periods and vice-versa. We assessed this relationship through the evaluation of the meteorological variables needed to run the Penman-Monteith equation, trying to obtain physical explanations for the relationship of each variable. Rainy days tend to present lower radiation (which is the main driver of evapotranspiration), higher humidity (increasing water vapour pressure) and lower air temperature, all of them causing a decrease in evapotranspiration. In fact, these three variables explain most of the negative relationship between evapotranspiration and precipitation. For air pressure and wind velocity, correlations are weaker.

We also adjusted seasonal curves between monthly evapotranspiration and precipitation for each meteorological station. We believe these relations can be useful for extending time series to the past for the assessment of climate variability impacts on streamflow, as well as other applications such as reservoir design, irrigation management and hydrological forecast and prediction.

Can Ensemble Empirical Mode Decomposition extract useful information to improve precipitation forecasts of a neural network model

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Long-term precipitation forecasts can provide valuable information to help mitigate some of the consequence of floods and to best water manage. Whether climate indices oscillations contain some information to be useful to hydrological forecasting is worth investigating. The purpose of this study is to select significant information from climate indices that help seasonal precipitation forecasting. Data preprocessing procedures such as Ensemble Empirical Mode Decomposition (EEMD) method are suitable tools for extracting modes of variability, called intrinsic mode functions (IMFs), associated to climate indices. To this end, it is suggested to adopt a significance test for assigning statistical significance of information content for resulting IMF components. A long-term precipitation forecasting model is then developed with a nonlinear autoregressive network with exogenous inputs (narx) using each IMF of selected indices, with lag times varying from 1 to 12 months as well as precipitation IMF, 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 observed precipitation in the Medjerda river basin located in north Tunisia. 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) are well correlated to precipitation components with 6 months delay time. This implies that an oscillatory forcing coming from the Atlantic influences the precipitation in the Mediterranean basin. These components can also provide useful information to precipitation forecasting. Monthly forecasts are made on the period 2003 to 2011. While from 1950 to 2002 is the training and the validation period. The performances of the model evaluated using the Nash coefficient as well as RMSE. Six rainfall stations are used to validate the model. The forecast results indicate that 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.

Keywords: Forecasting, precipitation, climate index, EEMD, significance test, narx

Crystal Balls into the Future: Are Water Balance Models Ready

Balázs M. Fekete, Dominik Wisser and Jacon Schewe

Climate and direct anthropogenic changes altering the water cycle has called into question the traditional water management planning that relies on past records of water resources as a means to characterize the likelihood of extreme conditions affecting water availabilities. The alternative is complex water balance simulations driven by projected climate forcings from global circulation models.

Growing number of hydrological models intended to support water managers and policy makers offer new capabilities to assess future resources. Model inter-comparison exercises like Water and Global Change (WATCH) and Inter-Sectoral Impact Model Intercomparison Project (ISI-MIP) shed lights on how these models in combination with state-of-the-art global circulation models perform.

Unfortunately, global circulation models have large uncertainties projecting changes in key climate variables (e.g. air temperature and precipitation) and those uncertainties are further exaggerated by the impact assessment models. Hydrological models tested in the afore mentioned inter-comparison studies gave disturbingly wide range of projected changes in water resources based on the same forcing data. These uncertainties are beyond what is normally accepted in the water management community to establish design criteria for water infrastructure management and planning.

Our presentation, we will focus on challenges in relying on Earth system modeling for water management and planning. We will show results form the ISI-MIP experiments and we will highlight some of the key characteristics of the tested GCM forcing data (considering five different bias corrected models, and four future scenarios) in the context of Water Balance/Transport model (WBMplus) maintained by the CUNY Environmental CrossRoads Initiative team using. We will also summarize the results from other hydrological model simulations contributed to the ISI-MIP project.

We will demonstrate the challenges of applying climate model driven hydrological models in regional studies. We use a set of regional climate models to drive WBMplus in West Africa to estimate water stress under changing climate and changing water demand drivers and demonstrate the uncertainties along the modeling chain. Uncertainties in water resources assessments are dominated by the uncertainties in input data and highlight the need to improve existing monitoring networks that can help reduce these uncertainties through validation of modeling approaches.

We will demonstrate the need for new approaches that can combine projected changes according to model simulations with trajectories of changes derived from traditional observational records to provide more realistic assessment of the anticipated changes that can form the basis for “no regret” policy making in water managements. No regret policies recognize that investing infrastructures to prevent disasters that never materialize is just as much of a loss than leaving the infrastructures vulnerable.

Development of Dynamic Water Resources Assessment System

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Since the stationarity of hydrological data is not valid owing to climate change, the traditional water resources assessment also becomes not valid. To consider characteristics of dynamic climate, dynamic water resources assessment should be practiced instead of the static traditional water resources assessment. By using stochastic water cycle analysis based on continuous short-interval (monthly or less) data and modeling, trend and variability of water resources assessment can be accounted.

This paper describes methodologies and application results for development of the dynamic water resources assessment system. The developed system can analyze water cycle for a watershed or water management unit with runoff, evapotranspiration, water use and water supply. In addition, future water cycle can be predicted by using the results of stochastic modeling of components of the water cycle, in aspect of space and time.

For water cycle analysis, the developed system uses CAT (Catchment hydrologic cycle Assessment Tool) which is a conceptual hydrological model with physical parameters. The system is linked to the water use and availability information system, and results of application can be compared with the observed or it can be used for ungagged area. As the system is also linked to an open GIS tool, and the physical parameters of the system can be searched and optimized conveniently.

The developed system is applied to the mid-sized water management unit in Republic of Korea.

Variations of global and continental water balance components as impacted by climate forcing uncertainty and human water use

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When assessing global water resources with hydrological models, it is essential to know the methodological uncertainties in the water resources estimates. The study presented here quantifies effects of the uncertainty in the spatial and temporal patterns of meteorological variables on water balance components at the global, continental and grid cell scale by forcing the global hydrological model Water Global Assessment and Prognosis (WaterGAP) with five state-of-the-art climate forcing input data-sets. While global precipitation over land during 1971-2000 varies between 103 500 and 111 000 $km^3\ yr^{-1}$, global river discharge varies between 39 200 and 42 200 $km^3\ yr^{-1}$. Temporal trends of global water balance components are strongly affected by the uncertainty in the climate forcing (except human water abstractions), and there is a need for temporal homogenization of climate forcings (in particular WFD/WFDEI). On about 10 – 20% of the global land area, change of river discharge between two consecutive 30yr periods was driven more strongly by changes of human water use including dam construction than by changes in precipitation. This number increases towards the end of the 20th century due to intensified human water use and dam construction. The calibration approach of WaterGAP against observed long-term average river discharge reduces the impact of climate forcing uncertainty on estimated river discharge significantly. Different consistent climate forcings lead to a variation of Q of only 1.6% for the 54% of global land area that are constrained by discharge observations, while estimated renewable water resources in the remaining uncalibrated regions vary by 18.5%. Uncertainties are especially high in Southeast Asia where Global Runoff Data Centre (GRDC) data availability is very sparse. By sharing already available discharge data, or installing new streamflow gauging stations in such regions, water balance uncertainties could be reduced which would lead to an improved assessment of the world's water resources.

Impact of climate change and anthropogenic pressure on the water resources of India: Challenges in management

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Major challenges associated with the management of water resources in India are the abnormalities in climate and the impact of anthropogenic activities. With changing climate, increasing water demands in the domestic, agricultural and industrial sectors, and fast deterioration of the water resources, India is heading towards a water crisis. Life of millions living in climate sensitive river basins and wetlands make India one among the countries highly vulnerable to the impacts of climate change. Drylands are potentially threatened by desertification. Abnormalities in rainfall seriously affect freshwater availability, agricultural production, and thus the national economy and life of millions of rural poor. Extreme hydrological conditions affect hydropower generation and industrial development. Increasing rainfall seasonality in certain parts reduces groundwater recharge and summer water availability. Changes in the intensity, frequency and tracks of storms increasingly salinate coastal aquifers. In the Western Ghats region, increasing intensity of rainfall results in erosion and sedimentation, reducing reservoir capacity and summer flow in rivers. Retreat of Himalayan glaciers will soon affect the runoff in the rivers of north India. Anthropogenic pressure adds to the impact of climate change. Water resources are being fast deteriorated and depleted because of pollution, overuse and encroachment. Due to the destruction of wetlands, sand quarrying and overextraction, groundwater level all over India is fast declining. Water related health issues are worsening. Vector-borne and water-borne diseases extend into new areas. Even the heavy rainfall zones face serious water shortage as a result of drawbacks in water conservation and management. Falling availability of reliable water leads to socio-economic issues such as water disputes, migration, pricing of water that is unaffordable to millions and large investments for the adaptation and mitigation. Present economic growth is likely to be haltered. India's preparedness for the effects of climate change is poor. National policies are only guidelines and they lack information on the effective implementation. Progress of the initiatives in the water sector as part of adaptation such as cleaning of major rivers, protection of wetlands, groundwater recharge and introduction of water efficient technologies in agriculture and industries is slow because of issues like lack of coordination of departments, weak and corrupt administrative mechanism, social issues and vested political interests. Vulnerable groups are often neglected in decision making and policy development. Projects lack transparency and accountability. India urgently needs appropriate policies and strategies and an efficient implementation mechanism to face the challenges in water sector. A mix of traditional, environment-friendly methods and modern technologies in water conservation and quality improvement could perform better. This paper assesses the impact of climate change and anthropogenic pressure on the water resources of India and its reflections on different sectors. Changes in water availability in two decades from now under an altered climate have been estimated using hydrological model, based on the projections from climate models. Existing policies and adaptation strategies have been critically reviewed to suggest guidelines for adaptation and mitigation measures in the water sector to face the impending water crisis.

Integrated Climate and land Use Change Scenarios for Water Resource Assessment in Ta Chin River Basin, Thailand

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Water is one of the crucial resources for local livelihoods. Freshwater available is traditionally a major problem in developing countries, especially in the river basin scale. Nowadays challenge of accessing to good water quality in sufficient quantity goes beyond security issue. Impact of climate change on freshwater resources has been evidenced through intensification of changing hydrological cycle, which will entail more frequent and intense precipitation as well as longer dry spell periods. Although many stakeholders have increased awareness in climate change threat to freshwater availability in the river basin, it is critical not to lose sight of the impacts of human activities on water balance. The effects of other anthropogenic interventions are very difficult to separate from the effects of climate variations and need to be integrated into water resource assessment by means of comprehensive approach. A clearest example is the effect of land uses change on water demand and supply.

It is, therefore, important that human activities can exacerbate negative impacts of climate change by increasing vulnerability of water resources along with climate change. The aim of paper is to understand future scenarios of climate and land use change as input variables for freshwater availability in river basin. In order to ensure that all socioeconomic aspect will be truly captures as much as possible, three scenarios are devised with consultation with related stakeholders at the early stage and extensively analysed by using land use model. Three future land use scenarios will be separately by dividing into business as usual (BAU), rapid economy change REC), and green growth scenarios (GGC) to ensure that all possible socioeconomic factors will be taken into consideration. Projected temperature, precipitation, land use change will be used as the input into water model in order to calculate how much of the precipitation that falls in the particular area ends up as run-offs into stream, recharge to groundwater or evapotranspiration to vegetation and finally water budget (demand and supply). Result reveals limited access to sufficient quantity of water in REC scenarios, while GGC scenario provide sufficient water to be viable in response to estimated demand and supply. To involve with all related stakeholders, they will be contacted and informed at research preparation stage in order to communicate, consult and to brainstorm different ideas of current adaptive capacity and future adaptation plan related to freshwater availability for agriculture, domestic sources of supply and suitable adaptation identification. Results can be useful in term of future water balance, including mitigation and adaptation measure in the river basin resources.

Keywords: Climate change, land use, water resource assessment, Ta Chin river basin

Water resources monitoring in Germany - current status and challenges

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In a global perspective the German river catchments including their international upstream parts - representing a major part of Central Europe - are usually not mentioned among the regions facing water ressource problems. However, given the fact that the socioeconomic systems in that area are optimised to relatively high and stable water resources, the region is nevertheless vulnerable to changes of availability, seasonality and interannual variability. For example, the abmormal low flow situation of summer 2015 is limiting various river functions, among others inland waterway transport.

Water resources are countinously monitored and reported on a national level and forwarded to the European and global environmental monitoring programmes. These data serve as a basis for decision processes facilitating sustainable river basin management against the background of climate variability and change as well as current and future anthropogenic pressures. This presentation gives insight into the institutional framework providing water resource information in Germany. Furthermore, selected input data, methods, products and ongoing developments are highlighted.

Integrated water resource assessment for the Adelaide region, South Australia

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Water is one of South Australia's highest priorities. Historically, the State has relied on three rain-dependent sources of water – the River Murray, Mt Lofty Ranges and groundwater. However, like much of the southern regions of the continent, many areas of South Australia have experienced a decline in surface water flows and groundwater levels over the past decade compared to long term averages.[i] This has resulted in an increased threat to the security of water supplies for regional communities, industry and the environment.

In the future this threat is unlikely to ease. It is projected that a decrease in annual rainfall in South Australia can be expected[ii], which is likely to further increase water scarcity. At the same time, South Australia's population is expected to grow from the current 1.67 million people to reach 1.79 million by 2016 and 2.28 million by 2036[iii], increasing the demand on water supplies.

To combat this threat, the State established The Goyder Institute for Water Research – a partnership between the South Australian State Government, the Commonwealth Scientific and Industrial Research Organisation (CSIRO), Flinders University, University of Adelaide and University of South Australia. The Goyder Institute undertakes cutting-edge science to inform the development of innovative integrated water management strategies to ensure South Australia's ongoing water security and enhance the South Australian Government's capacity to develop and deliver science-based policy solutions in water management.

There are a number of key research investments that have been targeted to inform integrated water management in State Government water planning and policy development. This new science will be presented in the context of the government policy and development drivers, with a focus on the following key research areas:

- Adelaide Plains Groundwater

This project has built upon existing knowledge to provide a thorough assessment of the groundwater resources beneath Adelaide, and the impacts of current and future extraction and climate change. It is the first study to provide an integrated assessment of the groundwater resources of the entire Adelaide metropolitan region.

- Optimal Water Resources Mix

A key product of this project is the development of methods for determining trade-offs between the multiple objectives of water security, economic efficiency and environmental benefits of water supply options that are consistent with the city's social values. The trade-offs analysis methodology developed also provided a framework that could be applied to other cities/regions to inform the development of total water cycle management plans.

- Managed Aquifer Recharge and Stormwater Use Options

This project assessed a range of potential uses of stormwater including via managed aquifer recharge at various locations around Australia and overseas. The project addressed the health risk assessment of uses for public open space irrigation, third pipe non-potable supplies to households and industry and for drinking water supplies. For several of those uses prototype risk management plans were developed. The economics of some specific options were also considered taking account of environmental impacts, and surveys of public acceptance of the more novel options that were considered.

- Mt Lofty Ranges Catchment

The Mt Lofty Ranges catchments are the source of surface water for Adelaide reservoirs. This project built on existing knowledge, management and monitoring systems in the Mt Lofty Ranges to understand environmental water needs, patterns of flow and water quality within the catchment. To support decision making, a tool has been developed that brings together all the information needed to make robust decisions on water allocations and assess the potential outcomes of alternative management options. The research has also involve collecting important hydro-ecological data and water quality assessments that support development of water allocation plans for the region, including installing monitoring equipment in high priority regions to measure water flow and quality and the subsequent ecological response from fish, vegetation and macro-invertebrates.

- SA Climate Ready

SA Climate Ready is the most comprehensive set of downscaled climate projections data ever available in South Australia. Data is available for six climate variables (rainfall, maximum and minimum temperature, areal potential evapotranspiration, solar radiation, and vapour pressure deficit), using two emission scenarios (intermediate and high "representative concentration pathways") through to 2100. The data can be used in future planning decisions. For example, to ensure that planned future infrastructure such as roads, bridges, farm dams and mine tailings dams, are designed to take into account; the impacts of climate change enable water resource and catchment managers to assess the security of future water supplies and protect water supplies for all water users; and anticipate changes in extreme heat and fire risk to inform planning for South Australia's emergency, health and social services sectors.

- Stormwater Interventions – linking catchment actions to coastal water quality

The government of South Australia is developing an Integrated Urban Water Management Plan (IUWMP) for Greater Adelaide that will embrace all available water sources including stormwater and wastewater. Currently, investment in stormwater and wastewater infrastructure is made or guided by state and local government agencies of South Australia. This does not currently include an evaluation of the relative effectiveness and efficiency of the investment (separately or in combination) in achieving goals such as water supply security, flood management and improved receiving water quality. In addition, there is a lack of understanding on catchment-scale implications of water sensitive urban design (WSUD) interim targets. While previous work has partially addressed some of the knowledge gaps more information is required to address the most efficient and cost effective way to manage stormwater and wastewater discharges to improve coastal water quality. This research has brought together the available information and tools to enable the assessment of stormwater interventions in the catchment to coastal water quality and other benefits.

These research investments are being drawn together in the peri-urban area north of Adelaide, the capital city of South Australia. This is a growing region for urban development, industry and agriculture. All require access to reliable, fit-for-purpose water supplies. The Goyder Institute is leading a program to coordinate the existing knowledge, including the latest science from the Goyder Institute's research portfolio and the specific water infrastructure projects undertaken by local authorities and state government. This coordination will bring together the best available assessment on the available quantity and quality of the northern Adelaide water resources including groundwater, surface water, stormwater and wastewater recycling, desalination, inter-basin transfers and projected demand to deliver an integrated water resource assessment now and into the future to support sustainable development.

This presentation will focus on the integrated water resource assessment of the northern Adelaide region, including the key research investments in water and climate, and how this information is being utilised by decision makers in the region.

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Rivers water resources of the Russian Federation and their changes

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Mean annual renewable water resources of the Russian Federation are 4350 km^3/year including 200 km^3/year coming from the neighboring countries. Total river runoff resources are 30 thousand m^3/year per capita. However, spatial distribution of surface water resources over the country is extremely irregular. For instance, water resources of the European part of Russia where 80% population of the country is concentrated are only 21% of the whole water resources. River runoff of the four largest rivers of the Asian part of Russia (the Yenisei, Lena, Ob and Amur rivers) amounts to 48% of the total.

The characteristic feature of water resources is a significant interannual changes. Currently investigations of long-term dynamics of water resources and particularities of runoff formation conditions are a major preoccupation of Russian scientists in view of modern climate changes. According to the estimates of Roshydromet there has been significant climate warming over the territory of the Russian Federation during the last decades. Affected by the current warming water resources of the country have become slightly higher than before. For example, annual river runoff over the period of 1981-2014 averaged out at 4472 km^3/year which is 213 km^3/year higher in comparison with those during the 1936-1980 period. In a great measure an increasing of river runoff took place for the rivers discharging to the Arctic Ocean.

It should not be left unmentioned that an amount of extreme water resources' events in the basins of some largest Russian rivers and some parts of the country has increased during last decades in comparison with the long-term period. For instance, annual river runoff of the Yenisei River was the highest in 2011 and the minimal during the entire period of observation in 2012. The same events happened in the Amur River basin in 2013 and 2008 years, respectively. Year to year amplitude of annual river runoff capacity was 235 km^3 in the Yenisei and 300 km^3 in the Amur.

Climatic changes have a considerable impact on intra-annual distribution of river runoff. There has been an increase of winter runoff over the large part of the Ciscaucasian Russia during more than the last thirty years. Water content of the majority of the European part of the country has increased up to 50-120%. The reason of this increase is winter air temperature warming which leads to decreasing of soil freezing depth and increasing of drainage properties of soil, increasing of number and duration winter thaws during which snowmelting, groundwater resources recharge and surface runoff formation occur. As the result river runoff during winter time increases and snow water equivalent at the beginning of spring is reduced which creates conditions for reducing of spring flood runoff.

In accordance with the results obtained by specialists of the State Hydrological Institute based on CMIP-5 data water resources of the Russian Federation will increase in the nearest future over the entire territory of the country except the south and south-west parts of the European Russia.

Water resources assessment and monthly runoff forecasting in China

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Water resources assessment in China, whose evaluation index including precipitation, surface and ground water quantity and quality, can be classified into three kinds: comprehensive water resources assessment, annual water resources assessment, and industrial projects water resources assessment. Comprehensive water resources, normal water resources and frequency distribution of water resources are assessed in basin and provincial regions. Two comprehensive water resources assessment have been carried out, in 1980 and 2003 in China. For the annual water resources assessment, water resources of last year are assessed in basin and provincial regions. For the industrial project water resources assessment, its water resources situation has to be assessed before the construction of industrial projects.

In past years, to address the changing of climate and environment, several studies of water resources assessment in China are undertaken. Distributed Xinanjiang model is used for the studies to assess normal water resources quantity changes caused by precipitation and temperature changes. The changes of precipitation and temperature were taken as input of hydrological model and the runoff amount changing is simulated as the model output, and the potential evapo-transpiration is correlated with temperature in the model.

In this paper, the trend method was presented as a statistical approach of water resources assessment in order to address the environment changes. The trend of data series was analyzed, runoff data series is divided into trend party and random party. The trend party represents the environment changes and this party is changing with time. Usually, this party is treated as a function of time. Parameters of the random party are taken as temporal constant. The method is suitable for underlying surface gradually changing basins, such as changing of land usage, groundwater level declining due to human excessive extraction, and changing of runoff situation year by year.

In China, most of low flow season monthly forecasting methods are based the flow recession curve, i.e. exponential equation. In this paper, a low flow season forecasting in north east China Nenjiang is presented.

Since last decade, the rainfall runoff ESP has been widely studied in monthly runoff prediction in humid regions. Usually, in humid regions hydrological models can produce reliable forecast and the initial soil moisture condition has more determinative effect on the runoff generation. The ESP used Xinanjiang model in Danjiangkou reservoir was thus presented in this paper. This reservoir is an important water source for the local region, and the special significance of the reservoir is that, it is the source of water for the south-to-north water diversion project which diverts water from south China to north China.

The conditional probability method in the monthly runoff prediction was also presented. Conditional probability means future runoff probability is under a fixed initial condition. By using initial condition, the mean quadratic error of probability distribution of the predicted monthly runoff is reduced, and accuracy of prediction can thus be improved. Two dimensional log-normal probability distribution functions are adopted for conditional probability study. In general, large basins have longer memories with good correlations between initial condition and future runoff. An example of this method in Songhua river basin was demonstrated.

A tentative discussion on the monitoring of water resources in China

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With the continuous development of economy and the progress of social civilization, Chinese government is dedicated to improve the ecosystem environment conditions. More efforts have been paid to solve water problems through the implementation of the most strict water resources management system. Thus, monitoring of water resources has been strengthened, becoming a main content of the hydrology work in recent years.

Compared with the traditional hydrological monitoring, in the work of water resources monitoring, more attention has been paid to the quantity and quality variations of water, reflecting the water resources carrying capacity in river basins and administrative regions. In this paper, an overall layout and the basic status of hydrometric network in China is introduced, the demand of work on water resources monitoring is analyzed, principles of monitoring network planning is put forward, methods of water resources monitoring which are commonly applied in the country is summed up, and technical requirements are put forward to meet the needs of water resource management.

Taking the hydrometric network planning on trans-boundary rivers as an example, summary of the main outcome of the planning at trans-boundary cross sections of the administrative regions is presented. The planning results can meet the need of water resources management at administrative divisions. It can be used to guide the work on water resources monitoring for trans-boundary rivers of administrative divisions.

Conjunctive operation of river facilities for integrated water resources management in Korea

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With the increasing trend of water-related disasters such as flood and drought due to climate change, integrated water resources management is getting more important recently. Korea is preventing disasters caused by flood, drought and managing water resources efficiently through conjunctive operation of river facilities such as dam, weir and agricultural reservoir. This has been pursued to enable everyone to enjoy the benefits of water resource utilization by preserving the function of river, improving its usefulness and reducing the damage of water quality degradation caused by flood and drought. At the same time, conjunctive operation is being conducted for multi-purpose dam, hydro-electric dam, weir, agricultural reservoir and water use facilities (water intake facilities of over 100,000㎥/day). This is to guarantee the right of facility managers within the limit of neither infringing upon public interest nor interrupting water management.

Conjunctive operation of river facilities is classified into flood season, drought season and water quality of river. During flood season, facility managers should comply with restricted water level of flood season for each facility. They obtain prior approval from the flood control office (FCO) within the jurisdiction in case of the need of gate operation for flood control. If the FCO within the jurisdiction judges that it is needed to issue flood watch or warning for river, or if flood-related damage is likely to happen, the FCO takes necessary measures considering overall flood situation of watershed such as climate and river condition and storage condition of dam and weir. For example, the FCO directs facility managers to use storage space of each facility down to the lowest operating water level for flood control.

During drought season, facility managers operate facility according to conjunctive operation plan. With regard to the sites of instream flow announcement that can represent the situation of river discharge, the FCO instructs facility managers to take necessary measures in case the FCO judges that drought situation might happen. For this, the FCO considers water balance situation of entire watershed such as climate and river conditions, storage of dam, weir and agricultural reservoir and water usage condition. In addition, storage is also used to secure clean water including the improvement of river water quality.

Once annual conjunctive operation plan is formulated, the followings are established separately quarterly or monthly: matters concerning target water level and drainage plan of facility, actual and planned water usage of water intake facilities, and matters concerning water surface condition and water surface management plan of dam and weir. Data needed to establish conjunctive operation plan is being collected and utilized jointly by related organizations. The conjunctive operation plan can be modified through the resolution of conjunctive operation council if there is a change in climate, river, electricity and intake conditions or there is request of modification from related organizations.

KEYWORDS: conjunctive operation, drought, flood, water quality, water balance, water management

Applied water monitoring software through a practical exampel:

Development and Implementation of a monitoring and information system for increasing water use effiency in arid and semi-arid areas in Limarí, Central Chile.

Erich Berger, CEO; David Balmert, CTO

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The growing world population, the rapidly increasing demand for high quality food and for water for agriculture use, the need to secure the provision of drinking water demands innovative and holistic solutions and products to increase the water use efficiency.

Especially in arid and semi-arid areas are these solutions required. Additional factors such as economic development, population growth and climate change deteriorate the situation. Therefore the longtermin, sustainable resource management at river basin level requires a complete , standardized and for all stuff members operable management system. Such complex challenges demand holistic and interdisciplinary solutions, which the WEINconsortium develops and implements in the region in Limarí - Cental Chile.

Our aim is, to capture holistically the scarce water resources in order to control the water assignment for agriculture irrigation efficiently, on-demand and transparent. Shortly: We want to optimize water usage and ensure the agricultural production.

The monitoring and information system is based on the optimized SEBA sensor systems which detects relevant climate and water runoff data. On this basis, the water availability is quantified and modeled on catchment level. On irrigation system level, the channel outflow and reservoir lakes are sized continuously, in order to capture losses in time and space. The estimation of future water availability and demand is made through an integrated review of the measurement results, historical hydro-meteorological and socioeconomic data in combination with the use of hydrological models.

To account the available resources holistically, an extensive, continuous collection of data is required.
The innovative and customized sensor technology ensures this. The surface water and irrigation channels are monitored by newly developed, robust and cost-effective water flow and water level sensors. Rainfall and the lack of infrastructure - especially in the mountain region of the Anden - require a special adaptation of the installed sensors. Beside the problem of data transmission, rainfall and snowfall sensors have to work without an external power supply. The development of an energy-efficient and maintenance-free sensor combination which stands the rough climate conditions, is needed.

In addition to the measurements an accounting for the farmer's water rights has to be managed. Orders for irrigation quotas are sent via Smartphones by the farmers and have to be edited. All relevant data (measurements, monitoring data, irrigation quoates,..) are automatically deployed and processed in the modular software system based on resource management system GW-BASE. Individual software modules are customized for the special usage scenarios and applications (e.g. water authorities, farmers, irrigation associations). For the first time, a monitoring and management system is available, which provides the possibility to use all relevant data for a holistic water management.

The collaborative product development will cover the worldwide rapidly increasing demand ideally. Based on already developed products and solutions, this project will develop an innovative system, which leads internationally and is oriented to market needs.

The Project was commissioned by the Federal Ministry of Education and Research (BMBF | Berlin, Germany).

Developing Hydro-Sources for Environment and Sustainability in Turkey: The Southeastern Anatolia Project (GAP) As a Case Study

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The Republic of Turkey has a special palace in the Eurasian and Middle East from the respects of both its social-economic structure and its geo-politic and geo-strategic importance. It is also the best model for the Islamic World by combining the traditional and modern life styles.

In the recent years, there have been many opportunities flourishing through the development of Turkey. One of these is unvalued rich agricultural and hydro-sources in the Southeastern Anatolia Region. Turkey, which has been trying to make use of these resources for years, reached a certain stage today.

The Southeastern Anatolia Project (GAP), one of the most important development projects in the world, focuses on the sustainable development of the land and water resources, as to develop, sustain and increase the production of hydroelectricity and the output of agriculture. Since initiation, the GAP Project underwent several changes, and most importantly in its course new aspects such as human sustainability and participation, in addition to environmental sustainable, were added. When the GAP Project is completed, the Upper Mesopotamia, home of many civilizations, will regain its importance as it had in ancient times. Taking into consideration the shortages in water supply the world will be facing, the importance of the Southeastern Anatolia Project will be doubled.

The GAP Project has been considered as a regional development projects through years, but the dimensions of sustainability, protection of environment and participatory have been attached to the master of the project in recent years. The GAP Project which take the responsibilities of some important tasks and functions in the future's Eurasian World and Middle East is giving hopes and coming fertility to its region. In addition, the project will provide some contributions in the respect of water sources and agricultural development in the Eurasian and Middle East.

The aim of this study is to introduce this region having rich natural hydro and agricultural resources and the GAP Project. For this reason, firstly, the natural potential of the region will be introduced. Second, the GAP Project aiming to make the country use of these natural resources, especially water resources will be presented in detailed way.

In the third stage, the projects being processed for protecting the natural sources and environment, making use of water will be analyzed. In the last stage, strategies and policies to develop and to protect the water of the region in short, mid, and long terms will be proposed for the Turkey's and the Eurasian's benefits as well as Middle East.

JEL Codes: Q2, Q3, N55, O53

Keywords: Natural and Hydro Resources; Environmental Economics and Sustainability; Southeastern Anatolia Region and Southeastern Anatolia Project (GAP).

Construction and evaluation of a toolbox for the formulation of the hydrologic component of the basin management plans in Colombia

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In 2010, the Colombian Ministry of Environment, Housing and Terrirorial Development issued the Policy for Integrated Water Resource Management which articulates new national guidelines for planning and management of water resources. A key component of this policy is the formulation of Basin Management Plans (POMCA) with the main purpose of land use planning and sustainable management of renewable natural resources.

Since the expedition of the policy, there has not been a considerable advance in the formulation of the POMCAs because of Colombia has had the need to generate knowledge and the necessary information to support the planning, management and sustainable use of water. The work is focused to the construction of a Toolbox that supports the formulation of the hydrologic characterization of the basins in the country, aiming to allow the understanding of the climatic variability of the country and the predictions in ungauged basins.

The use of the toolbox was illustrated and evaluated through its application in three pilot basins (Pamplonita, Gualí and Ceibas river basins) each with different level of available information of field monitoring of the hydrologic and climate variables, in order to give a reference framework that supports the use of the Toolbox.

Hydrology and water resources in Caspian Sea

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Precipitation is the main driver of variability in the water balance over Space and time, and changes in precipitation have very important implications for hydrology and water resources. Hydrological variability over time in a catchment is influenced by variations in precipitation over daily, seasonal, annual, and decadal time scales. Flood frequency is affected by changes in the year-to-year variability in precipitation and by changes in short-term rainfall properties. Desiccation of the Caspian Sea is one of the world's most serious ecosystem catastrophes. Framework Convention do not directly refer to any set of rules pertaining to a single type of body of water. However, it must be noted that the framework of the Convention is also its greatest weakness, for the Framework Convention's successful practical application requires signing of a number of protocols by the parties. Taken as a whole, the Framework Convention can be seen to mark a step forward in the littoral States' effort to preserve the particularly fragile maritime environment of the Caspian Sea and to accomplish a general understanding of the issues affecting the Caspian Sea. The Framework Convention is a part of the progressive development of international legislation on environmental protection. However, the adequacy of the Framework Convention will be judged by its ability to protect the marine environment of the Caspian Sea.

The purpose of this paper is to examine the significance of the Framework Convention and to argue that the Convention plays an important legal role in the protection of the water resources in the Caspian Sea. To achieve these purposes, the rules regarding the prevention, reduction and control of pollution, as well as the protection, preservation and restoration of the water resources of the Caspian Sea, are identified and described.

Keywords: Caspian Sea, Hydrology, water

Development Seasonal Flow Outlook Model for Ganges-Brahmaputra Basin in Bangladesh

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INTRODUCTION

Bangladesh is criss crossed by three main river systems: Ganges-Bramaputra and Meghna (GBM) and their branches and tributaries. The rivers are mostly originated from world Himalayan highest mountain range. The pattern of river flow from the Himalaya, its timing and intensity, is governed by the quantity and distribution of precipitation, its form (rain or snow) and seasonality (ICIMOD, 2009). Monsoon precipitation is the major source of river flow of these rivers. Low flow condition prevails during dry period. Thus temporal variation has significant impact on the different water usages such as irrigation, urban water supply, hydropower generation, navigation etc. Seasonal flow outlook can play important role in various aspects of water management like agricultural planning, disaster management.

Long range rainfall variability is influenced by different climatic drivers. Many authors have studied effects of climate drivers in rainfall variability of Indian subcontinent and Indian Ocean (Schott et al., 2009; Ashok and Saji, 2007; Saji and Yamagata, 2003). For instance, It is well known that there is a strong link between the inter-annual variation of Indian summer monsoon rainfall (ISMR) and the El Niño and Southern Oscillation (ENSO) (Sikka, D. R., 1980; Pant, G. B. and Parthasarathy, B., 1981; Rasmusson, E. M. and Carpenter, T. H., 1983). These climatic variables have significant effects on seasonal flow of Ganges-Brahmaputra river system.

Hydrological model is used to generate flow using various inputs like rainfall, temperatures, soil moisture, evapotranspiration etc.

There are some initiatives to predict medium to long range flow prediction using climate data. Flood Forecasting and Warning Center (FFWC) in Bangladesh issues 10 days forecast along the major river systems using ECMWF medium range forecast (FFWC, 2013). Webster, P. J., & Hoyos, C. (2004) predicted river discharge on 15–30-day time scale in the Brahmaputra and Ganges Basin in Bangladesh using ECMWF data.

This study focuses on the application of HYDROMAD model using ECMWF seasonal rainfall, temperature forecast data to generate flow for two big river basins. This study also highlights possible dissemination aspects of seasonal forecast among the water users in Bangladesh.

STUDY AREA

The study area consists of two big river basins which are known as Brahmaputra and Ganges. Figure 1 shows location of the study area with respect two national boundary of Bangladesh through which river is discharged into sea. Table1 shows the individual and total area in sq.km of these two river basins and the area in the co-riparian countries.

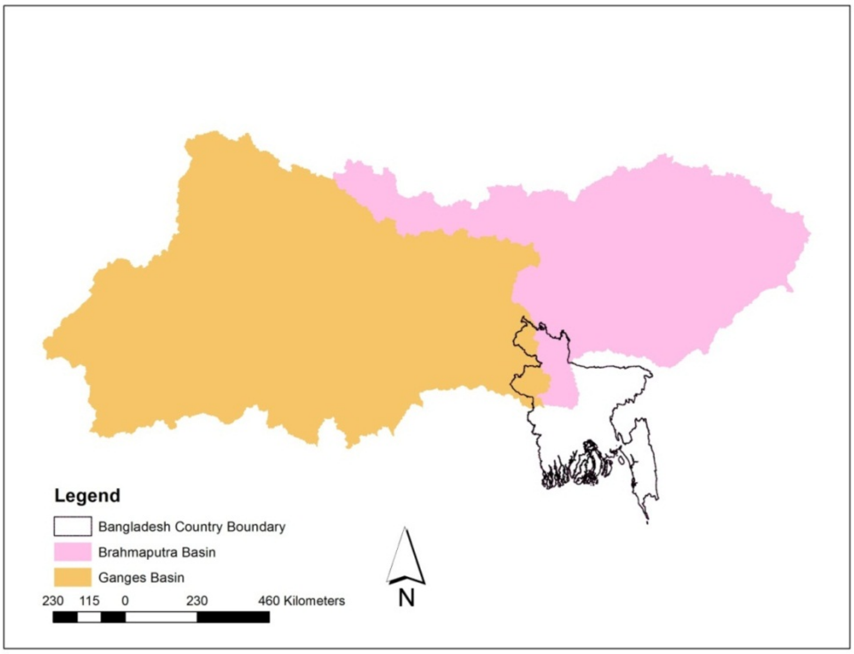

Figure1: Ganges–Brahmaputra Basin map

Table 1: Catchment Areas of Brahmaputra and Ganges River

River Basin	Total catchment area (Sq.km)	Catchment Area (Sq. km.)				
		India	Nepal	Bhutan	China	Bangladesh
Brahmaputra	552000	195000	-	47000	270900	39100
Ganges	1087300	860000	147480	-	33520	46300

(Source: Joint River Commission Bangladesh)

DATA AND METHODOLOGY

Data

The HYDROMAD model needs rainfall, temperature and potential evaporation to simulate and observed flow data for calibration. The present study uses ECMWF seasonal ensemble forecast of rainfall and temperature for the Ganges and Brahmaputra basins. This is Ensemble forecast with 40 members, and it is the output of Atmospheric, Wave and Ocean models (Persson, A., 2011 ; Persson, A. and Grazzini, F., 2011)**.** The observed river discharge of the two basins has been taken from Bangladesh Water Development Board (BWBD) for calibration and validation.

Modeling Techniques

Hydromad is a spatially lumped model, and it do not explicitly represent spatial variation over the catchment area (F.T. Andrews *et al*., 2011). The modeling framework is presented in Figure 2.

The modeling framework in the HYDROMAD package is based on a two-component structure: (1) a soil moisture accounting (SMA) module; and (2) a routing or unit hydrograph module (Figure 2). The SMA model converts rainfall and temperature into effective rainfall- the amount of rainfall which eventually reaches the catchment outlet as stream flow. The routing module converts effective rainfall into streaflow, which amounts to defining the peak response and shape of the recession curve.

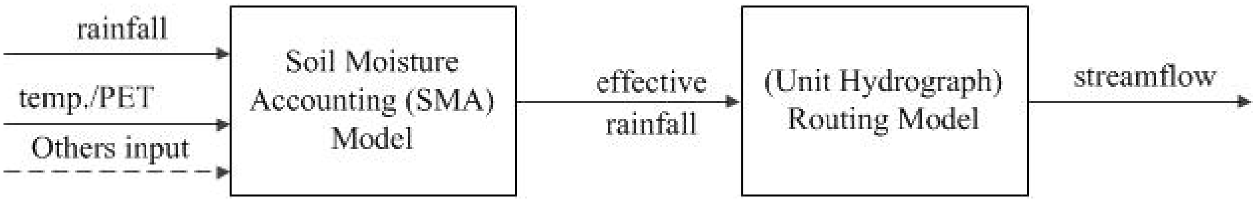

Figure 2: The modelling framework in the hydromad package

RESULT

The model was run for 2012-2014 period. The result was shown in figure 3. The preliminary result shows good conformity in terms of during the dry or low flow period.

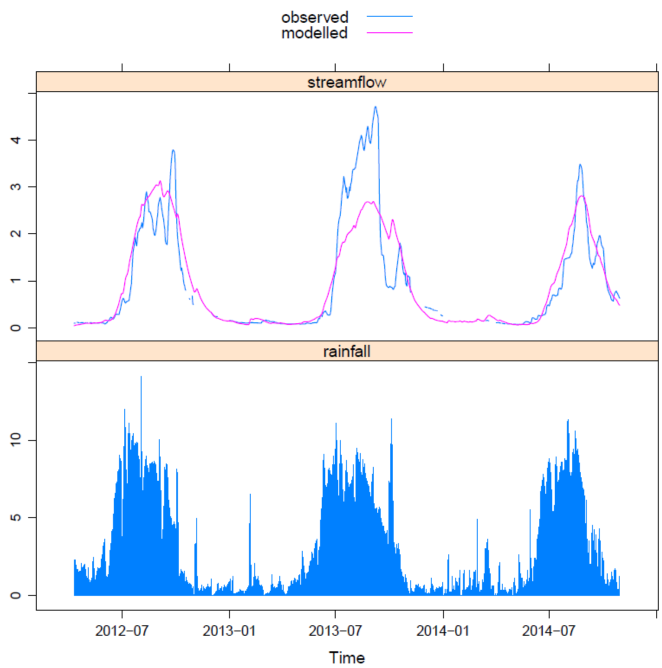

Figure 3: Observed and simulated discharge of Ganges

CONCLUSION

Probabilistic seasonal flow outlook generated by utilizing ECMWF ensembles data which may be better approach in agricultural planning. The preliminary result of the present study shows very promising prospect to use hydrological modeling in seasonal prediction. The output of hydrological model depends on the accuracy of rainfall forecast. As long range rainfall forecast affected by various climate drivers, so it is important to consider of those factors in using climate forecast in Hydrological model.

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East African wetland-catchment data base for sustainable wetland management

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Wetlands cover an area of approx. 18 Mio hectares in the East African countries of Kenya, Rwanda, Uganda, and Tanzania, indicating a tremendous increase from non-used or traditionally extensively used areas to intensive mainly small-scale agriculture in recent decades. Besides presenting potential agricultural production hotspots, wetlands provide a range of other valuable ecosystem services. Current upland agricultural use intensification in these countries due to demographic growth, climate change, and globalization effects are fostering the over-exploitation of the resource base and the agricultural use of wetlands. The main hydro-geomorphic wetland types in Sub Saharan Africa are alluvial floodplains and inland valleys. In the East African countries of Kenya, Rwanda, Uganda, and Tanzania these wetland types sum up to an estimated area of 17 million hectares and represent the focal wetland types of our study. In Sub-Saharan Africa still a variety of hydrological processes and mechanisms occurring within many wetlands under site/ -and use specific conditions are not fully understood, especially due to a lack of time series information related to water fluxes and water balance. We aim on translating, transferring and upscaling knowledge on experimental test-site wetland properties, small-scale hydrological processes, and water related ecosystem services under different types of management. This information gained at the experimental wetland/catchment scale will be embedded as reference data within an East African wetland-catchment data base including hydrological time series, soil properties, land use information and a regional wetland inventory serving as a base for policy advice and the development of sustainable wetland management strategies. One of the main challenges is the limited hydrological data availability for East African catchments and a harmonized East African wetland map applying a common wetland definition and classification with a joint land use/land cover classification. Within the GlobE: Wetlands in East Africa project a region-wide wetland map will be created using multitemporal remote sensing data and techniques. The East African wetland-catchment data base will further compile the global freely available hydrological, meteorological and land properties data sets. Working on a multi-scale test-site based approach with reference data on the wetland-catchment scale for experimental test sites we will further discuss the limitations and challenges of a regional approach for national and regional wetland management.

The Relationship between Agricultural Drought and Irrigation Water Demand in the Yellow River Basin

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The drought occurred more frequently with increasingly intensity and severe aftermaths in the Yellow River basin under global changes. Study on the relationship of agricultural drought and irrigation water demand can provide technical support for the irrigation water preparing so as to reduce losses caused by drought. Suitable drought index had been selected to analyze occurrence and evolution regularity of drought in the five typical irrigation districts since 1950. The typical irrigation district including the qingtongxia irrigation district, Yellow River irrigation districts of Inner Mongolia in the upper reaches of the Yellow River, the Fen river irrigation district and the Wei river irrigation district in the middle reaches of the Yellow River and the irrigation districts in the lower reaches of the Yellow River. A very sophisticated irrigation water demand model which considering changes of soil moisture and full use of atmospheric precipitation was constructed to calculate the irrigation water demand in each typical irrigation district. The relationship of agricultural drought and irrigation water demand in each typical irrigation district was studied using cluster analysis method. The results showed that the irrigation water demand of irrigation districts in the upstream, middle and downstream of the Yellow River basin presenting different response degrees to drought. The irrigation water demand increased 130 million m^3 with the drought increasing one grade in the qingtongxia irrigation district and Yellow River irrigation districts of Inner Mongolia. The irrigation water demand increased 170 million m^3 with the drought increasing one grade in the Fen river irrigation district and Wei river irrigation district. The irrigation water demand increased 680 million m^3 with the drought increasing one grade in the downstream of Yellow River irrigation districts.

Keywords: agricultural drought; irrigation water demand; response relationship; typical irrigation districts; The Yellow River basin

Water Balance, an Important and Simple Concept with Practical Complexities (Case Study: Jovain Watershed, Iran)

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Water balance computation has a wide application in all fields of studies, management and policy making of water resources. Although the water balance equation has a very simple concept, its application actually needs very considerations. The parsimony of this equation against the numerous affecting factors in its background cause excluded errors or serious complexities in practical purposes. So the present of an accurate description of water circumstances in a region with this parsimonious equation is beyond a general computation and should be considered as an art. Water balance computations are practically used in five separate categories: watersheds, groundwater aquifers, farms, urban water distribution networks and Particular areas such as glaciers and land fields. This paper is to concentrate on some specific matters relating to water balance computations in above mentioned areas which their ignorance lead us to less reliability on water balance and misunderstandings of actual situations. Studying on Jovain watershed in north-east of Iran presents some practical limitations on water balance calculations in this country.

Keywords: water balance, time scale, spatial scale, computation accuracy, surface water and groundwater interaction, Jovain watershed.

The limits of seasonal forecasting for the maximal runoff

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Introduction. The connection between precipitation and discharges have been executed in a cold climate. There are two types of maximal runoff. The maximal melt runoff is formed in every year. There is not the maximal rain runoff in certain years because of the absence of rains. Only the regular annual hydrological phenomena were a basis for the frequency analysis.

Methodology. The mean monthly precipitation and the mean monthly discharges at the same month are analysis. The period of observation has made 79 years. A long period ensures the representative results.

Five gradations have been used for the analysis of connection: "anomalous dry" month, "dry" month, "normal humid" month, "humid" month, "surplus humid" month. These gradations represent the departure from the norm in percentage (%). These gradations are standard. The long-term weather forecasts use such gradations.

Result. The Influence of precipitation on the river maximal discharges is not univocal connection in a cold climate. The extreme monthly humidity and the extreme river discharge of same month are appeared simultaneously only in 6.1 % and 5.5 % of cases from all period of observations. It is means, that the climatic factors and environmental factors can form the greatest discharge without the extreme precipitations in this current month. There are three reasons.

The first reason is the water content of soil in late autumn. Therefore, the limits of seasonal forecasting for maximal runoff are displaced into the last hydrological year (October-November).

The second reason is the freezing ground depth. As a result, the overland flow has the small loss of water by infiltration into the soil because of the freezing soil.

The third reason is the long accumulation of precipitation (snow) before the beginning of the maximal melt runoff. Therefore, the limits of seasonal forecasting are increased by cold period (November-April). This is the parameter "precipitation of cold period" (water equivalent of snow cover).

Conclusion. It is necessary to consider the parameters "water content of soil in late autumn", "freezing ground depth" and "precipitation of cold period" in a cold climate. There are not such parameters for the seasonal forecasting of maximal runoff in a warm climate. These features are embedded in the global water balance and reflect the functioning of geo-hydrosystem.

Seamless Water Forecasting for Australia

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Australia has experienced marked climate extremes over the first decade of the 21st century. Its streamflow regime can go through prolonged periods of droughts such as the “Millennium drought” that occurred between 1997 and 2009 across eastern Australia. This extreme dry period was followed by back-to-back La Niña years during 2010-11 and 2011-12, when Australia experienced severe flood events. This variability in extremes has a profound impact on the management of water resources in Australia. The Australian Bureau of Meteorology is working actively and cooperatively with all key stakeholders and end users to develop, implement and deliver end-to-end seamless water forecasting services to minimise the impacts of climate variability. These water forecasting services include Flood Forecasting and Warning service (up to a few hours to days), 7-day, 1-month and seasonal (3 month) streamflow forecasting services and long-term trends in water availability outlooks.

Seasonal Forecast of Kharif Flows from Upper Jhelum Catchment

Wolfgang Bogacki, Muhammad Fraz Ismail

A reliable forecast of seasonal flows at the beginning of Kharif season (April – September) is essential for the planning of irrigation area actually taken into command in the Punjab Province of Pakistan. The flows of the upper Jhelum catchment originate mainly from snowmelt in Early Kharif (April – June), while Late Kharif flows are dominated by monsoon events.

An operational hydrological forecast model was developed based on the snowmelt-runoff model (SRM) temperature index approach which was ported to an Excel application. Besides the input variable temperature, the degree-day factor is the most important parameter controlling the amount of daily snowmelt. The degree-day factor generally shows an increasing trend with the progress of the melting season and is also depending on altitude. General degree-day factor functions have been derived from a set of calibrated parameters for a series of years that are subsequently used for seasonal flow forecasting.

Although significant improvement in long-range weather modelling and forecasting has been achieved the last years, for a six month seasonal forecast generally only a rough indication of "warmer" or "cooler" respectively "drier" or "wetter" compared to the average conditions is specified. This level of detail is by far not adequate to sufficiently predict the depletion of the snow-covered area and associated snowmelt. On the other hand, the application of a scenario approach in which historical temperature and precipitation data of different years is used, gave very acceptable forecasting results. Based on SRM's modified depletion curve approach a representative curve according to the actual depletion of snow-covered area at the end of March is chosen and applied to all elevation zones. Daily temperature and precipitation of a series of historical years are applied to these depletion curves and the statistics of resulting flows is evaluated giving most likely as well as the range of minimal and maximal seasonal (Kharif) flow volumes to be expected. Hindcasts by this forecasting procedure for the years 2000 – 2011 show an average error in predicted seasonal flow volume of only 7% with all years but 2010 (200 years flood) below 10% error.

While at present different sources of medium-range weather prediction are evaluated to test their suitability for 10-daily forecasts that up-to now are also carried out using the scenario approach, it is not expected that long-range weather forecasts will be suitable for precise seasonal (six-monthly) forecasts in the near future.

KEYWORDS: Kharif, Snowmelt, SRM, Degree-day factor, Scenario approach

A snow and ice melt seasonal prediction modeling system for Alpine reservoirs

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The timing and the volume of snow and ice melt in Alpine catchments is crucial for management operations for reservoirs and hydropower generation. Moreover, a sustainable reservoir operation with respect to flooding is important for downstream communities. Forecast systems typically provide predictions only for a few days in advance. Reservoir operators would benefit if lead times could be improved in order to optimize the reservoir management. Current seasonal prediction products as provided by, e.g., the NCEP (National Centers for Environmental Prediction) coupled forecast system model version 2 (CFSv2) enable such seasonal forecasts up to nine months in advance given that the accuracy decreases as lead time increases.

We present a coupled seasonal prediction modeling system that runs at monthly time steps for a small catchment in the Austrian Alps. Meteorological forecasts are obtained from the CFSv2 model. Subsequently, these data are downscaled to the regional hydro-climatological snow model AMUNDSEN predicting snow water equivalent and snowmelt at a regular grid. Reservoir inflow is calculated taking into account various runs of the GFS model and these simulations are compared with observed inflow volumes for the melting period 2015.

Monthly and Seasonal Forecasting of Rhine water-levels and streamflow based on hydrologic, atmospheric and oceanic data

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A key element of the water management problem is to find out how much water will be available in the underlying water resources system during the following months, seasons and year. The analysis presented herein focuses on water levels and streamflow forecasting on monthly and seasonal time scales over the Rhine River catchment area. The forecast scheme for monthly and seasonal Rhine River streamflow is based on a methodology similar to that used for seasonal prediction of spring Elbe streamflow (Ionita et al., 2008, 2015). The basic idea of this procedure is to identify regions with stable teleconnections between the predictors and the predictand. The streamflow and water-levels are correlated with the potential predictors from the previous months in a moving window of 21 years. The results remain qualitatively the same if the length of the moving window varies between 15 to 40 years. As such, the streamflow and water-levels predictability of Rhine River, based on a statistical multimodel approach that uses as predictors precipitation, temperature, soil moisture, geopotential height at 700 and sea surface temperature from the previous months, has been investigated.

Overall, our analysis reveals the existence of a valuable predictability of the water levels and streamflow at monthly and seasonal time scales, a result that may be useful to water resources management. Given that all predictors used in the model are available at the end of each month, the forecast scheme can be used operationally to predict extreme events and to provide early warnings for upcoming floods or low flows. Although the analysis is restricted to a particular basin and is site-specific, the conceptual basis and lessons learned could be transferable to other catchment areas, which might lie under different climatological and/or hydrological background.

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Territorial long-term forecasting of spring flood characteristics in the present climatic condition

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Climatic changes that occurring over the past decades, do not stop worry the scientists, public organizations and governments around the world. The most authoritative international organization today is the Intergovernmental Panel on Climate Change (IPCC), which deals with the assessment of global and regional changes in climate of the past, present and future.

Modern global climate warming will resulting to increase recurrence of adverse meteorological processes in Ukraine, occurring the change in the regional hydrological cycle, reducing the amount of snow and ice, which greatly affects to the spring flood runoff.

The actual task of research is spatial long-term forecasting characteristics of spring flood at forecasted climate scenarios, allowing their premature to determine of any rivers area, including not been studied in hydrological terms.

In the paper was studied conditions temperature of winter and spring seasons, the maximum of snow reserves and date when they are coming, precipitation, maximum depth of the freezing soils, flowing spring flood characteristics (flow layers and maximum waters flow). The long course of meteorological factors and the characteristics of spring flood runoff indicates that, the growing air temperature of winter and spring seasons, there is a recurrence of fluctuations in the marked downtrend in the last decade. The correlation coefficients are significant (in the number of years of observation from *n* from 33 to 96) and reach to 0,62-0,71.

Methods of long-term forecasts of the flow layers and maximum waters flow is based on the regional dependencies of these variables from amount of moisture in the basin expressed in modular coefficients, that means in relation to the average long-term values. The peculiarity of the technique is that the water content type of the next spring is installation carried out discriminant function. In vector predictor of features included (in the modular coefficients) - total incomes flow of water on the river basin (maximum snow reserves and precipitation of spring flood period), the index of moisture and maximum depth of freezing soils.

Forecast of layers flow or maximum waters discharge of spring flood are realize for the sign of discriminant function (type of flood is set as the highest close or lower than normal). Obtaining values of the flow layers and maximum waters flow are modular by multiplying their term average coefficients value.

The form of presentation is the annual forecast cartographic generalization predictive values (coefficients of modular layers flow and maximum waters discharge) on the territory. The technique involves the installation of stochastic characteristics of spring flood in the long run (if using three-parameter gamma distribution curve by S.N. Krytskiy and M.F. Menkel) and their presentation in cartographic form.

The revealed correlations between the factors and variables spring flood temperature and precipitation for different periods. All links correlation coefficients are significant and range from 0,69 to 0,95, giving rise to the use scenario of meteorological parameters in the forecast maximum flow diagram of spring flood on the plains of rivers in the future.

Assessment of water resources and seasonal prediction of rainfall in India

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Water is indispensable for life and health and currently it is used in five major sectors: domestic (including drinking water), agriculture, industry, hydropower generation and ecosystem conservation. As a result, sustainable access to safe water and improved sanitation has become an urgent issue in many countries of the world including India. We know that rainfall brings water to the land and the occurrence of rainfall can be considered to be a process of weather systems. Moreover, the rainfall in a given area is not the same every year and it may range from half of the normal in one year to twice the normal the next year. This causes either too much of water from high rainfall or too less water from low rainfall resulting in droughts. The rainfall therefore is one of the most irregular climatic variables and this inter-annual variability in rainfall makes rainfall prediction very important for policy makers.

India with one sixth of the world's population and diversity of topography, soils, climate, etc., has always been facing challenges in the area of water availability received from the southwest (June-September) and northeast (October- December) monsoons. For example, the water availability per capita in India was over 5000 m^3 per annum in 1950, it now stands at about 1900 m^3 per capita. With every increase in population, there is a corresponding decline in per capita availability of water. Obviously, judicious use of water resources requires a detailed account of various characteristics of weather systems and the quantitative distribution and variability of rainfall provided by them over different states of the country, India is union of 29 states and 7 union territories. The source of all fresh water in the different states is rainfall brought by the southwest monsoon between June and September. The objective of this paper therefore is to provide comprehensive assessment of water resources that is how much water from rainfall is received by each state of the country and what the estimates are of surface water and groundwater for utilization so that the information can be useful to manage this important resource in a sustainable manner as also to solve water sharing issues and disputes between the states.

The inter-annual variability in rainfall in India is caused by some meteorological factors which have the largest influence over rainfall. If these meteorological factors that control the rainfall of any region are identified then they can be used to provide a forecast of the behavior of rainfall well in advance. For example, there is the association between the southwest and northeast monsoon rainfall over Tamil Nadu. A correlation analysis between the two rainfall series revealed that the southwest monsoon (June- September) rainfall is negatively correlated with that of the northeast monsoon rainfall. That is, an excess or deficit of southwest monsoon rainfall over this region is generally followed by an opposite tendency in the northeast monsoon rainfall. The negative rainfall relationship can be a useful tool in forecasting the northeast monsoon rainfall over Tamil Nadu which is of considerable economic importance for this region.

Comparison of cross-validation and bagging for building a seasonal runoff forecast model

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Developing data driven models is commonly applied in four steps: (1) predictor screening, (2) fitting of models, (3) model selection, and (4) model validation. Steps 1 - 3 are referred to as model building whilst step 4 is needed to estimate the final models ability to generalize. In case of seasonal runoff forecasting often it is not feasible to perform each step on different data subsets due to scarce observations. Additionally, weak predictor-predictand relationships can lead to quite different model versions dependent on the data subsets used in steps 1 - 3. Thus resampling (e. g. cross-validation or bootstrapping) is often used.

In this study we evaluate a forecast experiment where the period 1980-2009 is used for model building and the period 2010-2014 for model validation. Doing so, we simulate more or less a simple operational forecast system. Target values are mean runoff during 30, 60 and 90 days, date of prediction is every 1st and 16th day of a month. Main objective is the comparison of forecast skill when a regression model is built by using resampling in two different ways:

1. using leave-one-out cross-validation for a \best guess" model and
2. drawing bootstrap replicates of the data to get different model versions. The final model is then obtained by averaging these different models (so called bootstrap aggregating or \bagging", see Breiman 1996)

Here we use leave-one-out cross-validation for the reason of a fair comparison of both approaches: During bagging, the data points not included in model fitting can be used to test the model version in question. If the predictions for these data points are finally averaged, we get virtually a leaveone-out estimate of prediction error for the final "bagged" model.

The regression model itself is conceptually a persistence model, i. e. weather or climate forecasts are not considered. Predictors are restricted to antecedent precipitation, temperature and runoff derived from daily time series. Technically we screen these series by means of correlation to estimate appropriate aggregation periods; the regression coefficients are estimated using Partial least squares (Mevik and Wehrens 2007). To account for seasonal variation in aggregation periods and regression coefficients we fit separate models for each target value and date of prediction within the calendar year.

We present the comparison of the two resampling approaches for the validation period 2010-2014 and discuss their differences in terms of forecast skill as well as confidence band estimation. Overall 20 Swiss meso-scale catchments with diverse physiography are examined.

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Work resources assessment and seasonal prediction

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Mountains are essential sources of fresh water over the world but their role in global water resources could be significantly altered by climate change. The "Third Polar Ice Cap" extends over the mountain regions of Hindu Kush, Karakoram and Himalayas (HKH) of our planet, play the role of "water bank". Major amount of melted water is available for irrigation, drinking purpose and hydro power generation. Recent studies under climate change regime shows that mostly glaciers in HKH have been retreating and losing their mass balance and are a serious threat to food security, water reservoir and environment of the country.

Increase in population and decrease in per capita water, resources are under stress. Decline in water reservoir storage, the impact of salinity and water logging and over-abstraction of ground water to cover the domestic demand, leads to less water availability for power generation and irrigation.

The impact of climate change on upper Indus is divided / considered into three regimes. A rival regime (dependent on melting of winter snow), a glacial regime and a rainfall regime (dependent on concurrent rainfall). Historic trends particularly shows the decline in summer temps with no strong evidence in favour of marked reduction in water resources, where as evidence for change in trans – Himalayan glacier mass balance is mixed. Hence an understanding of hydrological regimes for three key basins (Hunza, Astore and Khankhwar) of Mountain Rivers followed by regional analysis of twelve small basins is essential for water resources management in Pakistan.

It is accomplished that efficient management of mountain water resources immediately requires more detailed regional studies and analysis the linkage of climate, glaciology and run off studies. Further the study on mountain water resources must become more integrative by linking the relevant disciplines.

Atmospheric Teleconnection based Seasonal Prediction for Hydro-meteorological Variables over the Korean Peninsula

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In this study analyzed non-linear behavior links with atmospheric teleconnections between hydrologic variables and the climate indices using statistical models over the Korean Peninsula (KP) with the ocean-related major climate factors such as ENSO (El Niño-Southern Oscillation) and IOD (Indian Ocean Dipole) mode in the tropical regions. The SSTA (Sea Surface Temperature Anomaly) was divided into different conditions such as Warm Pool (WP) El Niño and Cold Tongue (CT) El Niño, La Niña and positive (+) and negative (-) IOD phases. The analysis of the low frequency analysis for time series data was performed by principle component analysis (PCA) using a singular spectrum analysis (SSA), and the joint probability density function has estimated by kernel density estimation. Additionally, the SSA results are used to analysis the atmospheric teleconnections derived from linear and non-linear lag time correlation by the Mutual Information (MI) techniques. Results of the correlation analysis between hydrological variables and the climate indices came out with a high correlation for non-linear correlation analysis using the MI technique more than linear correlation analysis. In case of ENSO indices show that there are lag correlations of several months, but for the case of IOD index shows direct correlation over the KP. As a result of this study, extreme climate pattern changes and their hydrologic local impacts over the KP, show a statistically significant increasing tendency during the WP El Niño decaying years, while during the CT El Niño years it shows significant decreasing tendency. During the La Niña years shows maintained the average state compared to the normal years based on the 10% significant level in the Student's *t*-test. In addition, during the positive and negative IOD years for hydrologic variables were clearly decreasing tendency and similar to the normal year state, respectively.

A review on climate-model-based seasonal hydrologic forecasting

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Climate-model-based seasonal hydrologic forecasting (CM-SHF) is an emerging area in recent decade due to the development of coupled atmosphere-ocean-land general circulation models (CGCMs) and land surface hydrologic models, and increasing needs for transferring the advances in climate research into hydrologic applications within the framework of climate services. In order to forecast terrestrial hydrology at monthly to seasonal time scales, a CM-SHF system should take advantage of important information from initial land surface conditions (ICs) as well as skillful seasonal predictions of atmospheric boundary conditions that mostly rely on the predictability of large scale climate precursors such as the El Niño Southern Oscillation (ENSO). The progresses in the understanding of seasonal hydrologic predictability in terms of ICs and climate precursors are reviewed, and future emphases are discussed. Both the achievements and challenges of the CM-SHF system development including multimodel ensemble prediction, seamless hydrologic forecasting, dynamical downscaling, hydrologic post-processing, and seasonal forecasting of hydrologic extremes with the hyper-resolution modeling framework that is able to address both the climate change and human water resources management impacts on terrestrial hydrology, are presented. Regardless of great strides in CM-SHF, a grand challenge is the effective dissemination of the information provided by the seasonal hydrologic forecasting system to the decision makers, which cannot be resolved without cross-disciplinary dialogue and collaboration.

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Seasonal forecast of Nile Flood Over Ethiopian Plateau

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Nile River is the main source of water for Egypt to the scarcity of rain-fall as a result of Egypt's position in the desert belt in subtropical region. As the Nile River originates from outside the borders of Egypt and that the most important source, not only for the numerous sensitive sectors such as agriculture, industry but also drinking water and human needs. it's necessary for us to examine the nature of the changes and climatological factors, which dominates the headwaters areas and control in the amount ood and playing role to use it to forecast Nile ood and amount of water which resulting from it Before its occurrence by suitable lead time. We use Ethiopian data from NMHS to examine the inter-annual and inter-seasonal variability with dominated oscillation like El Nio Southern Oscillation (ENSO), Indian Ocean Dipole (IOD) and Atlantic Equatorial Mode. we use statistical techniques to determine which climate regimes (spatial classiffication) and its seasons(temporal classiffication) contribute by main amount for Nile ood . The seasonal classiffication of the region over Ethiopia, is from February to May, June to September and October to January called Belg, Kiremt and Bega, respectively. Here, more emphasis is given to Kiremt (JJAS) seasons. We utilize also different statistical models to make seasonal forecast like Multiple linear regression(MLR), Principal component regression(PCR), Canonical correlation analysis (CCA) to examine both benefits and exclude disadvantage for each. ENSO predictability was stand as a great barrier in our target but we use statistical techniques to use Previous Researches to overcome that obstacle. Finally, we elected the best Multivariate Statistical model (CCA) to make Seasonal Forecast using May SST after examine the skills of each different statistical model.

Development of Integrated Method for Long-term Water Quality Prediction Using Seasonal Climate Forecast

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APEC Climate Center (APCC) produces climate prediction information based on a multi-climate model ensemble (MME) technique. In this study, four different downscaling methods in accordance with the degree of utilizing the seasonal climate prediction information were developed in order to improve the predictability and refine the spatial scale. They include: 1) the Simple Bias Correction (SBC) method which directly uses the APCC's dynamic prediction data with 3 to 6 month lead time, 2) the Moving Window Regression (MWR) method which indirectly utilizes the dynamic prediction data, 3) the Climate Index Regression (CIR) method which predominantly uses the observation-based climate indices, and 4) the Integrated Time Regression (ITR) method which uses the predictors selected from both CIR and MWR. Then, sampling-based temporal downscaling using Mahalanobis distance method was conducted in order to create daily weather input to the Soil and Water Assessment Tool (SWAT) model. Long-term predictability of water quality within the Wecheon watershed of the Nakdong River Basin was evaluated. According to the Provisions of Water Quality Prediction and Response Measures of the Ministry of Environment, modeling-based predictability was evaluated by using 3-month lead prediction data issued in February, May, August, and November as model input of SWAT. Finally, we presented an integrated approach that takes into account various climate information and downscaling methods for water quality prediction which can be used for preventing potential problems caused by extreme climate in advance.

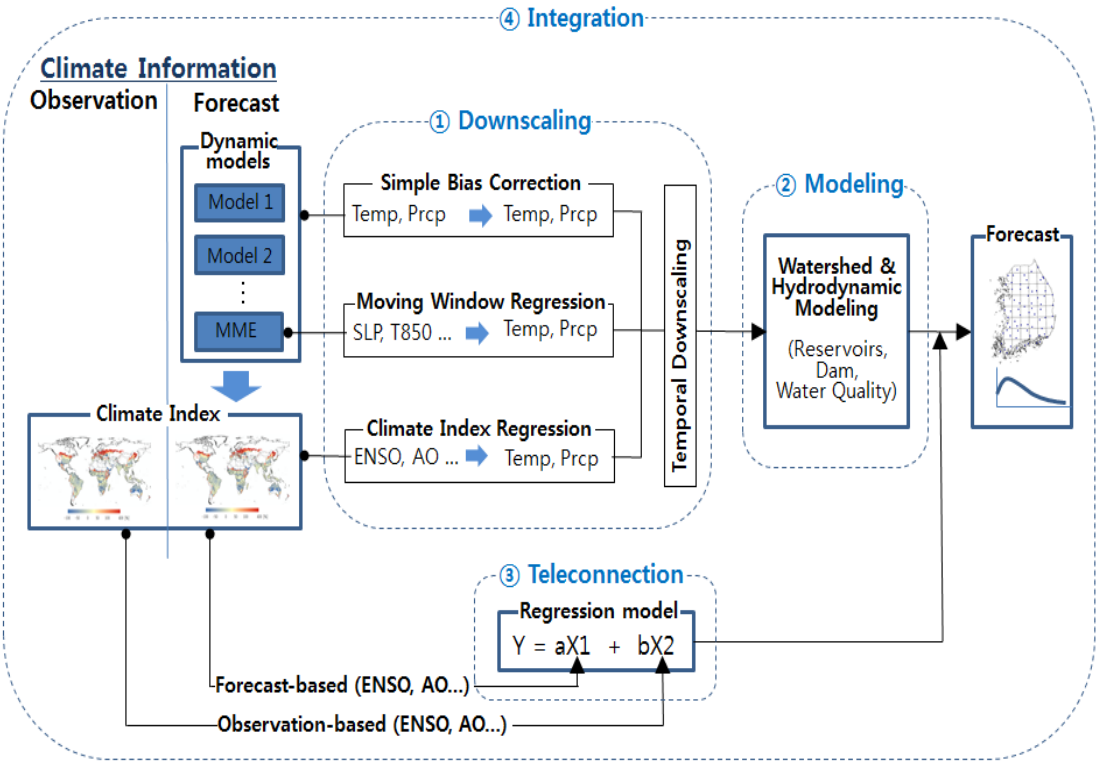

Figure 1. Schematic diagram of the study.

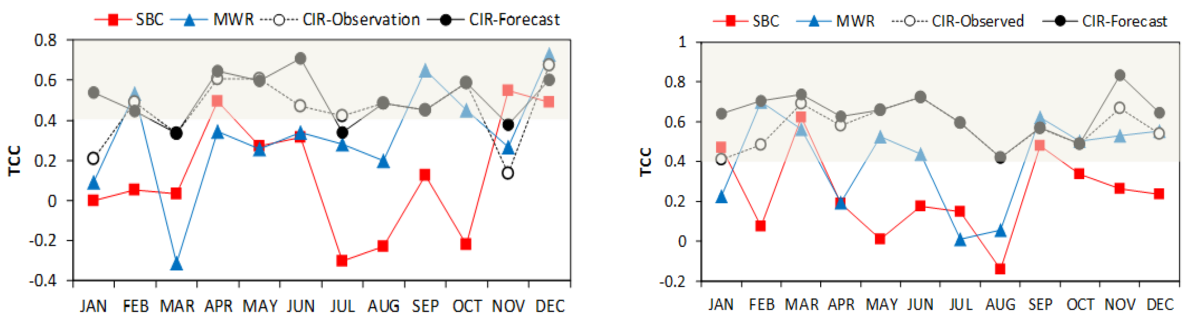

Figure 2. Monthly predictability of SBC, MWR, and CIR downscaling methods for precipitation (left) and average temperature (right). Shaded area means significant temporal correlation coefficient (TCC) which is higher than the critical value at 0.05 of significant level.

Space based, harmonized water quality monitaring services for inland and coastal waters

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Water quality is a global issue, therefore monitaring is needed for a wide range of governmental and industrial entities. Characterizing the actual status of rivers and inland waters, identifying trends or understanding ernerging problems over the huge number of inland water bodies is not possible only with traditional in-situ methodologies. Harmonized, trans-boundary remote sensing methodologies and services support these requests nowadays with a number of relevant water quality products, such as turbidity, organic and inorganic components or Chlorophyll.

Lakesand rivers smaller than 100m in diameter are recorded continuously by an increasing number of capable satellites - several times per week and with adequate spatial resolution. State-of-the-art physics-based and senser-independent retrieval of the water products ensures that the measures are inter-comparable for any location worldwide, independent on ground truth data.

The validity range and the limitations of the information products was investigated and is demonstrated for a large number of different water bodies on several continents.

For an easy access to the huge amount of spatio-temporal water quality information and for time series analysis, the access and data aggregation within online Web applications is presented. User friendly geospatial tools allow to understand the consistency of products in space and time, and to analyze various processes in inland and coastal water bodies.

A number of uses cases and perspectives of the services for a number of water agencies and industries incorporating water quality monitaring services are presented and shall be discussed.

Several environmental conditions such as clouds create temporal and spatial data gaps, with seasonal and geographical variations. However, the information gain on harmonized water quality information is significant with the new technology. Continental distributed water bodies, that could not be observed over years or decades, can now be monitared several times per month,or even up to daily under good weather conditions.

River water quality modelling under drought situations. The Turia River case

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Drought and water shortage effects are normally exacerbated due to collateral impacts on water quality, since low streamflows affect water quality in rivers and the uses depending on them. One of the most common problems during drought situations is maintaining a good water quality while securing the water supply to demands.

In this research, we analysed the case of the Turia River Water Resource System in Eastern Spain. This system counts with two upstream reservoirs, several agricultural demands in the medium and lower river basin, and the urban demand of Valencia City. The intake of the urban demand is located at the final part of the river, where streamflows are very low during droughts. As a result, concentrations of pathogens and other contaminants increase, compromising the water supply to Valencia City.

In order to define possible solutions for the abovementioned problem, we developed a water quality model for the medium-lower part of the Turia River, considering Nitrates, and Total and Fecal Coliforms. Due to the limited availability of data, we estimated the pollution entering the system from different sources by using a Monte Carlo approach. The water quality model was built with the software GESCAL (Paredes et al., 2010), which simulates the water quality evolution for a whole water resource system under process-based or mechanistic.

Among other possibilities, the Turia River model allows predicting how releases from the upstream reservoirs affect water quality at the Valencia intake site. With this method, we can define environmental flows downstream the reservoirs based on the water quality improvement in the river. However, there are other demands which rely on the Turia River, mainly agricultural, whose reliability decreases in drought situations and it could worsen with new environmental flow requirements. To address this problem, we used the water management model SIMGES (Andreu et al., 1996) in order to assess the increase of agricultural deficits due to the establishment of environmental flows. SIMGES solves the management of complex water resources systems with surface and groundwater storage, intake, transport, artificial recharge, use and consumption elements.

From the assessment, a balanced solution is proposed which maintains the reliability of the supply to the existent demands while improving the water quality in the Turia River and, especially, at the Valencia City intake location.

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Decadaal oscillations of the aquatic chemistry of river waters in Latvia

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Water quality changes of surface waters can be used to access human impact intensity, but of importance is to consider also impacts of climate change/variability and naturally occurring changes of environmental quality. In Latvia during recent decades a major reduction of anthropogenic pressure has happened due to restructuring of economy and industrial production, resulting in major decrease in loading of many groups of pollutants. However trends and driving factors for other groups of substances has not been much studied. Long term (1980-2014) results of hydrochemical monitoring performed in rivers of Latvia are analysed. During this study in a connection with long term sets of hydrological, meteorological, hydrogeological and heliophysical data, using standard statistical approaches. Our results shows that variation of some hydrochemical values, for example COD and total Fe shows clearly visible decadal oscillated character, while variation of some other values, for example phosphate P and total P, shows some individual characteristics of decadal oscillations. These results indicate a presence of large scale, geochemically and geophysically significant process: multiannual pulse of catchment impacts, driven by variation of solar irradiance through complex interactions between global atmospheric circulation, groundwater and surface waterbodies. The process described in our study is significant from geochemical point of view and must be taken into account in prediction of water quality and quantity. Impacts of natural processes should be considered at planning of environmental policy.

Water Quality in Reservoirs: Assessment and Seasonal Prediction

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Introduction

Considerations within the framework of the Panta Rhei Research Initiative of IAHS allow investigating the seasonal factor for water quality dynamics in reservoirs.

Creation of dam changes the ecosystem characteristics of the regulated part of the river not only quantitatively but qualitatively. In this regard more universal approaches should be used than the traditional statistical analysis of previous data. For example, it is necessary to move from phenomenological water quality models to simulation of nutrients biogeochemical cycles transformation and the calibration should be carried out on the data for reservoir-analogue.

Runoff regulation

Reservoirs are traditionally used for runoff regulation for the needs of power engineering and water economy, especially during the flood and period of low water. Ecological consequences of external changes outside of exploitation regime for reservoir were forecasted and compared for different seasons.

For the best providing of needs of municipal economy a few scenarios of water regime were proposed with the decline of water level near a dam on below than level of dead volume. It was required to estimate influence of such changes on water quality in the Novosibirsk reservoir for different seasons.

For environmental forecasting the simulation of biogeochemical transformation for nutrient compounds cycles was executed for the aquatic ecosystem of this reservoir on the basis the original model "Biogen". The seasonal prediction of regime changes for the Novosibirsk reservoir in winter (1-3 m lower than a level of dead volume) was executed and analyzed. It gives opportunity to formulate the conclusion in accordance with of sanitary-hygienic norms on water quality in case of realization of corresponded regimes for this reservoir.

Later this aquatic ecosystem model "Biogen" was used for ecological expertise of designing projects for a few Siberian and Far-Eastern reservoirs creation.

Pollution desilter

Widespread variant of the use of reservoir in industrial agglomerations is as a desilter for pollution. Since the reservoir transient region the river flow velocity is essentially slowed. As a result suspended and sorbate on river sediments contaminations subside on a bottom. Thus river stream become more "lighted" up.

However this water "purification" is often only seemed. As a result of resuspension and convective-diffusive release the "secondary pollution" of reservoir is appeared from a bottom. In the reservoir biocenosis production processes intensity increases as compared to a river ecosystem. It is accompanied by the accumulation of toxic substances in the trophic chains of aquatic organisms.

For environmental forecasting of reservoir creation consequences in similar cases it is important to simulate the seasonal dynamics of contents and substances streams in all components of ecosystem. Such research was executed for the project variants of the Krapivino reservoir exploitation for all seasons for different hydrological years.

The conducted simulation showed that seasonal behavior of aquatic ecosystem for designed the Krapivino reservoir in comparison with real reservoir (the Novosibirsk) from the point of ecological safety view.

Poster presentations

Variation Features and Effect Factors of the Yellow River Runoff over the Past 50 Years

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The variation of Yellow River runoff shows the features of non-linear, complexity and significant differences in terms of temporal and spatial distribution, due to the double impact of climate change and human activity. The temporal and spatial variation features of Yellow River runoff are analyzed based on the time series data (1956~2000) of the main hydrological stations on the mainstream and branches of the Yellow River. Multiple methods are used in the analysis including Mann-Kendall's rank correlation method, cluster analysis, maximum entropy principle and wavelet analysis. The results indicate that: ①The variation of Yellow River runoff has the periodicity of long term, medium term and short term. ②The Yellow River runoff shows the trend of decrease in the long term, but the trend varies in different reaches. The runoff reveals no trend in variation in the source area of upper Yellow River, while it shows significant decrease in the middle reach, and moderate decrease in the lower Yellow River. The impact of climate factors and factors of human activity on the variation of Yellow River runoff are analyzed quantitatively. The factors of climate considered are rainfall and air temperature, and that of human activity are groundwater（exploitation）, coal mining, soil and water conservation, hydraulic engineering. The contribution of each factor to the runoff variation is calculated, and the results demonstrate that human activity is the main contributor.

Keywords: Yellow River runoff, variation, difference of temporal and spatial distribution, affecting factor, quantitative analysis

Hydrological modeling on multiple scales in a data scarce catchment in East Africa

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The Kilombero floodplain in southwest Tanzania covers an area of about 6.650 km² and a catchment size of 40.240 km². It belongs to the Rufiji river basin and is one of the biggest Sub-Saharan floodplains. The Kilombero floodplain is framed by the Udzungwa Mountains in the northwest and the Mahenge Highlands in the south and is characterized by distinctive dry and wet seasons followed by the inundation of the floodplain. Hydrological data is scarce due to the challenges given by the highly dynamic river system. Beside the rarely existing discharge data the coverage with climate stations is not sufficient to adequately represent climate variability within the catchments varying topography. The Kilombero floodplain is one of the focal areas of the GlobE: Wetlands in East Africa project which emphasizes on reconciling future food production with environmental protection in East African wetlands. The GlobE Wetlands project covers multiple hydrological scales from the plot scale up to the regional scale including Kenya, Rwanda, Tanzania and Uganda. This study concentrates on wetland-catchment interactions in Kilombero Valley which is envisaged by governmental plans as the Southern Agriculture Growth Corridor (SAGCOT) to comprise large scale rice production in the forthcoming years.

We follow a two-step modeling approach with the application of various hydrological models and data sets on multiple scales. On the wetland scale (~30 km²) the SWATGRID model will be applied and the SWAT model will be used to simulate the boundary conditions of the surrounding catchment (~40.240 km²). On the wetland scale the hydrological monitoring setup follows a transect gradient from Kilombero river up to the fringe of the floodplain measuring soil moisture and ground water fluctuations under different hydrological conditions and various agricultural treatments. Additional a climate station is installed measuring precipitation, temperature, wind, radiation and humidity and soil physical properties are analysed for the entire transect. A drone flight campaign was conducted for the hydrological transect to develop a high resolution DEM. On the catchment scale we mainly rely on climate and discharge data provided by local partners like the Tanzanian Meteorological Agency (TMA) and the Rufiji Water Basin Office (RBWO) due to the large size of the catchment. Our database is supplemented by freely available global geodata. This data comprises climate data from multiple sources such as satellite data and reanalysis data. Furthermore we evaluated diverse soil and land use datasets to adequately represent the study sites characteristics. In summary the poster focuses on the challenges of small and large scale hydrological modeling in a data scarce region with emphasis on availability of different climate and runoff data and the challenges of collecting data in a highly dynamic floodplain system.

Comprehensive Regulation of Water Resources Sustainable Utilization in Water Shortage Area in the Northwest China

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Rich minerals resources but with poor water resources and deteriorate ecosystem in the Northwest China, the main problem is how to coordinate the relationship of water resources utilization, ecology protection and economic development. Point at the main problem of water resources utilization in water shortage area of Northwest China, We put forward the concept and tactics of resources comprehensive regulation. Aim to promote the harmonious capacity of the huge system of resources and economic, We set Ordos as type area, establish frame system of water resources comprehensive regulation from five aspects, such as， industry, sources, water usage and management, take the industrial selection and scale control of economic, surface water, ground water and unconventionality water multi-source unite dispatching, the strictest management of water usage and supply as the regulation measures. Through the implement of water resources comprehensive regulation measures, We optimize the reasonable economic scale and structure which is matching to the capacity of the regional resources, establish a mode of water resources utilization which involve multi-source complementary and spatio-temporal equilibrium, put forward the scenario of water resources protection which maintain the rational groundwater table and water quantity in stream, work out administrative institution which mainly include the ideal of water resources comprehensive management. From the effects of the regional water resources comprehensive regulation, We can get the conclusion that efficiency of water resources utilization can be enhanced, the abilities of water supply and allocation can be raised, the level of environment can be improved and the water resources sustainable utilization can be achieved. This paper gives a good case for water resources sustainable utilization in water shortage area.

Keywords: Water Shortage Area, comprehensive regulation, harmonious capacity, multi-source, spatio-temporal, equilibrium

Hydrological observing system of Russia - the main source of water resources and hydrological regime data

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Hydrological observing system of Russia (HOS) is a single technological complex established at national level to ensure all stages of receiving, collection, distribution and processing of hydrological information as well as for information product generation and delivery. The modern HOS technological complex comprises three interrelated subsystems of data receiving, data collection, and data processing and product generation.

The basement of data receiving sybsystem are observation stations of main and specialized hydrological networks. The main network includes river, channel, lake and reservoir observing sites. The specialized network includes swamp and water balance sites as well as water surface, soil and snow cover evaporation observing sites.

Now the main hydrological network of Russia consists of 2719 river sites and 352 lake and reservoir sites. Main observations include stage, discharge observations, observations of discharge and grain-size composition of sediments, water temperature, ice phenomena and ice thickness observations. Observations are made using standardized methods and certified instruments and equipment. Observation data are used by many sectors of economy, scientific community, to implement environmental protection measures and for other purposes.

Technological modernization and automatization of the Russian hydrological observing network began in 2008. In the first stage, hydrological networks in the Oka, Kuban and Ussuri river basins were upgraded to enhance the reliability of flood forecasts. In 2015, the second stage has been launched aimed at complex modernization of the whole system of hydrological observations in the Volga basin. Rehabilitation and modernization of observing sites at both main and specialized network in the Volga basin, automatization of collection of all types of observation data as well as technical and technological modernization of data processing centres are foreseen in this stage.

Hydrological network modernization is also implemented in the framework of the Federal targeted programme “Development of the Russian water management complex until 2020”. One of the objective of the programme is to restore 900 sites and upgrade 2700 sites of the main hydrological network in the Russian Federation until 2020.

Within data processing and product generation subsystem two technological complexes are operated by 23 regional branches of Roshydromet for processing observational data from rivers and lakes throughout the country. These complexes provide computer processing of observation data at all stages (data entry, multi-step quality control, computations, generation of graphics and tables and preparation of information for archiving in the State Fund).

With regard to provision of hydrological information to users, a new annual publication of the Water Cadastre “Rivers and lakes of Russia” is planned to be issued in the coming years providing general information on the hydrological regime and water quality of more than 150 rivers and 100 lakes of the Russian Federation in addition to the currently issued hydrological yearbooks, multiannual data syntheses and state inter-agency annual publication “Surface and underground water resources, their use and quality”.

The report represents more detailed information about the hydrological observing system of Russia and its future development.

Mountain Block X - a novel hydrologic model for a distinct seasonal water resources assessment in semi-arid mountain regions

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In distinct environments with recharge controlled groundwater flow regimes as for example in arid climates, considerable uncertainties are inherent to common approaches for water resources assessment on the global scale. For mountain catchments are the major contributer to the total renewable water yield in (semi-)arid regions, a distinct, well adapted assessment is essential for this hydrogeologic setting.

Hydrologic modelling in semi-arid mountain regions is subject to limitations, either due to an inadequate process representation (implying the need for a usually lacking empiricial reference) or due to a lack of an adequate data base for largely process based approaches. Approaches based on groundwater data, however, mostly integrate over time and space. Hence, they cannot provide prognostic and seasonal estimates. Against this background, the proposed hydrologic model aims at rainfall based, spatially distributed and seasonal water budget estimates in semi-arid mountain regions. Following the ideas of parsimony or simplicity, it aims at considering the main processes and mechanisms and at the same time using a minimal number of model parameters.

For distinct response units and seasons, functional relationships between rainfall and groundwater recharge describe the hydrologic response. Their derivation is based on a mass balance and considers the principal recharge mechanisms. In opposite to topography controlled flow regimes with effluent hydraulic conditions, where groundwater recharge is often considered to be a remainder of the water balance, surface runoff is the remainder in this consideration.

To avoid a continuous soil moisture accounting with the respective number of model parameters, a mean seasonal soil moisture status is assumed instead. This simplification implies, that the model is especially usable in regions with pluvial hydrologic regime and shallow soils. Based on an extensive sensitivity analysis it is concluded, that the model provides physically reasonable results.

The proposed approach was applied on the large scale in a semi-arid karst mountain range in northern Oman. Its results are in good agreement with inversely computed inflow to a steady state groundwater model for the adjacent basin aquifer, and also with the APLIS-approach for estimating groundwater recharge in carbonate regions. The results show that less intense winter rainfall contributes mainly to groundwater recharge in this study area.

The low number of model parameters and the grid based architecture support an efficient application on the large scale including the consideration of parameter uncertainties.

Study the methods on water management aimed for natural sturgeon reproduction in Caspian Sea

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Sturgeon are one of the ancient fishes on the Earth and it is likely that due to this their caviar is renowned for its good taste and food quality. The Caspian Sea basin is the most important fishery water body in the country. Over 70% of the world catch of Sturgeon are harvested here, and more than 60% of large ordinary fish of their total in Russia. They underwent many cataclysms on the Earth sharp climate changes large fluctuations of the Sea level and borders. The fisheries in the basin develops under the influence of complicated interactions of natural and anthropogenic factors which necessitate the elaboration of a system of purposeful measures providing conservation and rational exploitation of bioresources.In its turn the definition of the most effective measures is possible only if based on an analysis of conditions formed during a period of theme, assessment of priorities in change of ecological situation and productivity of the water body. The state of the Sea level and river flow is of special importance among the natural climatic factors forming the ecosystem of the Caspian Sea. Transgression of this Sea level, started in 1978, radically changed the conditions of bioresources formation and exploitation and determined the need for assessment of changes .In order to stabilize the Sea level and to provide conditions for natural sturgeon reproduction under conditions of regulated flow of rivers a number of measures was proposed:

- Reduction of loss of consumed share of the Caspian water balance(construction of a dividing dam between the northern and middle Caspian, isolation of eastern shallow waters of the Northern Caspian.
- Relation utilization of the Volga waters (elaboration of operation regime for the cascade of the Volga reservoirs, construction of a dividing dam in the Volga delta, amelioration of spawning grounds, dredging and cleaning of fish way canals).
- Replenishment of water resources of the basin through supplies from the other regions (transfer of part of flow of the northern rivers and the Black Sea water .

Keywords: Sturgeon, Caspian Sea , Water management

Evaluating TRMM and CFSR dataset performance over West Africa using a hydrological model

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Water is one of the most valuable natural resources and the modelling of the water balance is recognised as being an important tool to aid in the management of this precious commodity. The most important atmospheric driver for hydrological models is precipitation. However, ground-based observation networks, especially in developing countries, are sparse and a further decrease in density is observed due to the deterioration of stations. In ungauged river basins, or basins with insufficiently available precipitation data, satellite precipitation measurements such as the Tropical Rainfall Measuring Mission (TRMM) or reanalysis data, such as the Climate Forecast System Reanalysis (CFSR) products may be used in the modelling process instead of ground based observations. However, uncertainties of these datasets over Africa are not well examined.

In order to validate remotely-sensed or reanalysed precipitation data, these are traditionally compared to in-situ ground measurements. A recently adopted method compares different datasets by utilizing hydrological models, thus no longer requiring ground-truth precipitation data. In a hydrological evaluation, data quality can be assessed by running a hydrological model with different precipitation products and comparing the streamflow generated for each dataset with observed streamflow. These comparisons may be run in a "raw" simulation without the need to calibrate the model. While previous independent assessments of TRMM (available since 1998, 0.25° resolution) and CFSR (available since 1979, 0.31° resolution) products generally suggest both products to perform well, CFSR performed better than TRMM when directly compared, e.g. in Ethiopia. Applicability of rainfall products has not only to be tested using simple lumped models, but also physically based distributed model systems which are able to consider landscape properties and feedbacks between hydrological processes.

One of the objectives of this research project is to improve hydrological modelling at the regional scale by assimilating space-borne data into dynamic models of the terrestrial hydrological cycle. In a first step, TRMM and CFSR products will be analysed for the research area in West Africa located between 24° North, 18° West, 3° South and 16° East and encompassing, among others, the Senegal, Volta and Niger river basins, using the hydrological evaluation method. In order to achieve this, a hydrological model will be set up including information on elevation, land-use and soil and will be run with both precipitation products. The streamflow generated by each product will then be compared to actual measurements in order to assess the quality of these products.

Estimating Relationship between Groundwater Level Recovery and Rainfall for Shallow Unconfined Aquifers in North West Region of Bangladesh

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A comprehensible knowledge on the ground water (GW) recharge mechanism promises a better future prediction of highly dynamic shallow aquifer system in Bangladesh. However, due to the scarcity of data in the Bengal basin simplifications must be adopted in estimating groundwater recharge. Hence, a simplistic analytical approach of ground water recharge assessment has been done based on water table fluctuation hydrographs and rainfall records with the assumption that a strong relationship exists between these two variables particularly in case of shallow unconfined aquifer. But, the method do not consider impact of other factors like soil condition, top soil characteristics or some local effects (such as pumping, stream leakage effect etc.) In this technique, the recession part of the groundwater hydrograph is extrapolated to intersect the vertical line drawn perpendicular to the abscissa crossing the rising limb of the hydrograph to get recovery of groundwater level (ΔH). At the same time, the amount of rainfall causing the ground water table risen up during the recharging period is taken as wet period rainfall, R_t. Finally, a relationship is developed between ΔH and R_t by means of computing regression equations for water years (April-March) from 1968-2012.

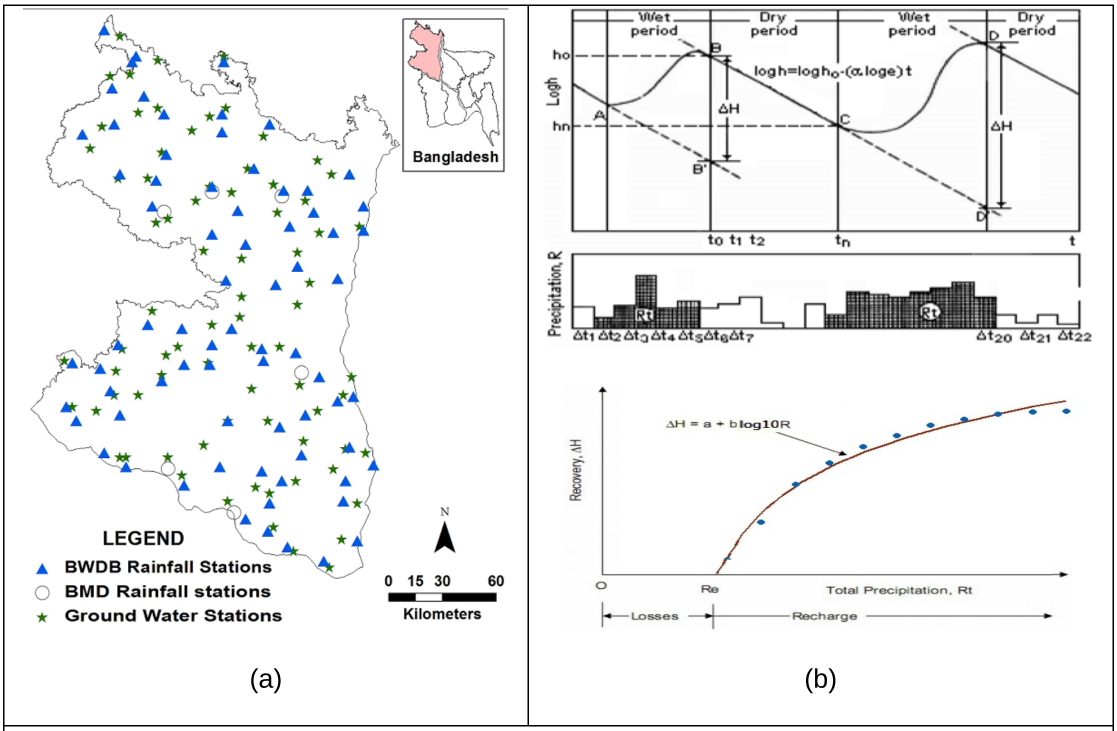

Figure 1.1 (a) Locations of rainfall stations and corresponding groundwater monitoring stations that are considered for the proposed approach and (b) graphical representation of the basic theory and hypothesis of the proposed methodology applied

For the purpose of the study, long term available daily rainfall data of 74 BWDB (Bangladesh Water Development Board) stations and 4 BMD (Bangladesh Meteorological Department) stations of North West of Bangladesh have been selected. The data period used for BMD stations are 1968-2012 and for BWDB stations are 1966-2006. Corresponding 78 weekly GW monitoring stations have been chosen depending on (a) distance not exceeding 15 km from rainfall stations, (b) missing data not exceeding 15%, (c) number of observation points not less than10, and (d) correlation, $r > 0.4$. Eventually, water table response to rainfall is investigated using the equation $\Delta H = a + b \log_{10}*R_t$ where, 'a' and 'b' are the regression coefficients. Graphical presentation of the process in **Figure 1.1 (b)** indicates that the precipitation intercept, R_e for zero recovery GW level (ΔH=0) is the effective rainfall. Therefore, R_e represents the amount of surface runoff and evapotranspiration for the same period. Finally, the recharge (Q) is estimated by subtracting R_e from the computed total precipitation, $(R_t)_{computed.}$

Assessment of recharge, where shortest possible data and information are available, is normally subject to large uncertainties and errors. Therefore, the accuracy of the derived equations totally depends on the high correlations between ΔH and R_t for any particular aquifer. In this paper, an attempt has been taken to establish a data conservative approach of estimating GW recharge in any shallow unconfined aquifer. Subsequently, this research detects different zones of recharge potential for the North West of Bangladesh and compares the results with the previous national studies. However, poor statistics are found in the cases where natural recharge condition might be absent due to the strong influence of irrigational abstraction of GW or the closer proximity of an influent river. Finally, such study, if continued further for whole Bangladesh territory, will open a window of opportunity for any sorts of initial level assessment of recharge potentiality of GW resources in shallow unconfined aquifers of the Bengal Basin.

Keywords: Groundwater level recovery; Rainfall; North West Region of Bangladesh

AssesSment of Ground Water Quality around Tummalapalle Uranium Mining, Cuddapah Basin, India

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Underground water (UGW) constitutes fresh water available in the world. Because of the inherent purification by soil, groundwater is generally considered a very good source of drinking water. Although groundwater is more protected naturally than surface water from pollution, human activities tend to alter the composition of groundwater. Ground water is one of the most important sources of drinking water in India. Apart from the exploitation of surface water resources, an estimated amount of 180Km^3 of ground water is being used annually for domestic, irrigational and industrial use. It is further estimated that the ground water requirement likely to increase to 350Km^3 by 2025 A.D. The adverse effect of ground water quality are the results of human's activity at ground surface, unintentionally by agricultural and industry, unexpectedly by sub-surface disposal of sewage and industrial waste and solid waste dumps (aglasem.com). The quality of ground water is the resultant of all processes and reactions that act on the water from the moment it is condensed in the atmosphere to the time it is discharged by a well or spring. This paper gives an insight on assessment of water quality in and around Tummalapalle Uranium deposit which is one of the largest Uranium deposits in the world. However, due to mining activity the chemical quality of underground water in this area is getting altered. A total of 19 samples are collected in and around mining area and the chemical parameters are analyzed by using Inductively Coupled Plasma –Mass Spectroscopy (ICP-MS) which is widely accepted as a powerful technique for chemical analysis. The chemical element values from ICP-MS are compared with the Bureau of Indian Standards (BIS). Correlation coefficients were calculated to establish inter – element relationship and T- Test is conducted to find out significant correlation between the elements. It is noticed that some chemical concentrations are present beyond the permissible limits of BIS and inferred that the ground water in and around the Tummalapalle area is not that safe for the domestic purposes. The present study area is of global interest because it is one of the largest Uranium Deposit in the world with 49,000 tons and expected even three times more than conformed reserves, which is located in Tummalapalle village Kadapa district, Andhra Pradesh, India. This domestic uranium finding would not only boost India's nuclear energy plans but also help to reduce costs by switching from expensive sources of power like coal. The present paper aims to evaluate the assessment of water quality in and around world's largest Uranium deposit i.e., Tummalapalle uranium which is located in Kadapa district, India. The mining activity in Tummalapalle area is in budding stage, due to continues mining in this area may leads to contamination of Underground Water in near future. This study recommends periodic monitoring of ground water quality in and around Tummalapalle area.