Table of Contents: UPDATE of PRINTED VERSION, later published via conference web site

Abstract number 3 - GIS-BASED HYDROCHEMICAL VULNERABILITY MAPPING OF QUATERNARY AQUIFER IN NORTHEASTERN COSTAL ZONE ON NILE DELTA, EGYPT

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The area of study lies at the northeastern part of Nile Delta. The global shoreline regression and sea level rise have their own-bearing on the groundwater salinization due to seawater intrusion. An adopted approach for vulnerability mapping using the hydrochemical investigations, geographic information system and multi-criteria decision support system (MCDSS) was developed to determine the trend of groundwater contamination by seawater intrusion. Six thematic layers were digitally integrated and assigned different weights and rates. These have been created to comprise the most indicative criteria used for the delineation of groundwater degradation due to seawater intrusion. These criteria are represented by total dissolved solids, well discharge, sodium adsorption ratio, hydrochemical parameter (Cl/HCO3), hydraulic conductivity and water types. A weighted MCDSS modeling was tried, where a groundwater vulnerability map with four classes ranging from very low to high vulnerability was gained. The map pinpointed the promising localities for groundwater protection, which are almost represented by the very low or low vulnerability areas (53.69 % of the total study area). The regions having high and moderate groundwater vulnerability occupy 46.31 % of total study area, which designate to a deteriorated territory of groundwater quality, and needs special treatment and cropping pattern before use. However, the moderate groundwater vulnerability class occupies an area of about 28.77 % of the total mapped area, which highlighted the need for certain management practices to prevent the saltwater intrusion from expanding further to the south. There is a good correlation of the constructed vulnerability map with the recently gathered water quality data and hydrochemical facies evolution. The plotting of water quality data on Piper trilinear diagram revealed the evolution of freshwater into the mixing and the saline zones as an impact of seawater intrusion, which validates the model results.

Abstract number – 12 APPROPRIATE ADAPTATION AND MITIGATION STRATEGIES FOR INTEGRATED WATER RESOURCES MANAGEMENT: IN CASE OF TSURUMI RIVER WATERSHED, NEAR TOKYO, JAPAN

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The rapid urbanization was occurred in a watershed during the high economic growth period of Japan around 1960s and 1970s. Tsurumi river watershed located near Tokyo with an area of 235 km2 and its maximum length of 42.5 km, crossing regional administrative boundaries including 2 local governments and 4 cities, is one of examples of such a rapid urbanized city river in Japan. The urban area of the watershed was only 10% in 1958. However, this reached 60 % in 1975 and 85 % in 1990. This rapid urbanization has caused many sever environmental problems regarding waters in the watershed such as

decrease of river flow rate and increase water pollution. For overcome these environmental problems regarding waters of the watershed, the Tsurumi river was designated as a "Specified River for Comprehensive Improvement" in 1980 by the National Government. This designation means that the river is controlled with not only embankment works as a hard type countermeasure but also reserves water retention and storage areas within the watershed as a soft type countermeasure. These countermeasures rather succeeded to control the river water and thus water resources in quantity. However, more advanced integrated water resources management including improvement of water quality and establishment of sound water cycle in the watershed, has been raised up in recently. For accomplish this, the Water Conference (WC), which is the cooperation organization among different stakeholders in the watershed, has been established in 2004. In the same year, the WC made the "Water Master Plan of Tsurumi River Watershed", of which target period is around 30-yrs including the basic schemes such as water management during flood time and water management in ordinary time. Moreover, they made the "Action Plan" for each basic scheme to proceed the master plan more effectively. Action plans are proposed by citizen, NPO, company and administration, respectively and the target period of each action plan is 3 to 5-yrs. Each action plan is evaluated by the PDCA (Plan, Do, Check, Action) management cycle. On the other hand, the Ministry of Land Infrastructure and Transports (MLIT), Japan has introduced the "Act on Countermeasures Against Flood Damages of Specified Rivers Running Across Cities" in 2003 as the National Law of No. 77. The Act requires waters management of a watershed with a watershed boundary (watershed unit) not a regional administrative boundary (local government unit), and also requires the permission and countermeasures for actions to damage rainwater infiltration by causing land use and cover changes depending on the principle of Corporate Social Responsibility (CSR). The Act was applied firstly in Japan to the Tsurumi river watershed in 2005 and is proceeding well as an integrated watershed and water resources managements for transboundary waters. Those processes and mechanisms in the Tsurumi river watershed will be presented in detail.

Abstract number – 15 EVALUATIONG THE EFFECTS OF SIMULATED LAND USE MEASURES ON PEAK OF A CATCHMENT ADJOINING A ROAD

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The consequences of heavy rainfall and other extreme weather events are strongly influenced by land use within watersheds. The tested catchment consists of arable land, forest, living areas, and a creek which crosses a main road at the bottom of the catchment. The theoretical hydrological responses to

different land use changes and four different extreme events were quantified by model simulations using MIKE-SHE. Land use composition and configuration was found to affect discharge; clear-cutting on 30% of the catchment area produced a 60% increase in peak discharge and a 10% increase in total runoff during a 50-year summer event. There were only small effects on peak discharge during smaller storms. Reforestation of 60% of basin area was the most effective measure to reduce peak flow, mainly for smaller (2-, 5- and 10-year) storms. Grassed waterways reduced water velocity in the stream and resulted in a 28% reduction in peak flow at the catchment outlet with the same 50-year event. A smaller degree of reforestation (30%) of the basin area was the most efficient measure to decrease total runoff. Hence different measures may be the most efficient for peak discharges and total runoff from the area. The specific effect of land use measures on catchment discharge depends on their spatial distribution and on the size and time of storm events.

Abstract number - 16 TEMPORAL DYNAMICS OF WATER AGES AND WHAT THESE REVEAL CATCHMENT INTEGRATED PROCESSES

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In conceptual models it is key represent the temporal dynamics in the activation and deactivation of the dominant catchment flow generation processes in a realistic way. Only a correct representation of these dynamics ensures adequate predictive power of a model. Tracer data can help to gain crucial insights into these internal processes of catchments and thus help to reduce misrepresentations of the process dynamics. In this study we use long term (< 16 years) tracer data sets at relatively high resolution (1 week) for three contrasting catchments (~ 2 - 10 km2) in the Scottish Highlands together with parsimonious conceptual models and three different mixing assumptions to get a better understanding of the dynamics of catchment internal processes and of how changes in these processes are directly related to variations in external forcings and system states. Tracking the tracer fluxes through the models allowed on the one hand assessing the age distribution of water at the catchment outlet depending on the antecedent wetness conditions and the characteristics of individual precipitation events. Besides that it could be shown how the age distribution of water varies between the individual flow paths under different conditions, depending on which pools of water in the system sustain these flow paths, such as groundwater or evaporation, at a given time. On the other hand, flux tracking also allowed investigating changes in patterns of how water is routed through the system. These changing patterns, i.e. time variable transit time distributions, were then linked to antecedent wetness conditions, as given by the system states, facilitating the development of a simple classification framework for hydrological response patterns. Furthermore, the dynamics in water age as well as transit time distributions of the individual flow generation processes were compared for the three catchments in order to identify catchment characteristic dependent patterns of change in dominant flow generation and tracer translation processes.

Abstract number – 17 STREAM FLOW TRENDS AND ITS ASSOCIATIONS TO EL NINO SOUTHERN OSCILLATION (ENSO) IN THE TONS RIVER BASIN

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Tons River is a tributary of the Ganges flowing through the States of Madhya Pradesh and Uttar Pradesh in central India. In order to analyse the stream flow trend at Tons River Basin over the past 31 years (1978-2008) two hydrological stations (Satna and Meja road) has been selected. Tons river is intermittent at Satna station and becomes perennial at Meja road station. The non-parametric Mann–Kendall test and Theil–Sen approach are used to identify the trends in the annual and seasonal stream flow (i.e. winter (December-February), pre-monsoon (March-May), monsoon (June-September) and post monsoon (October-November)). The observed trends in the time series are statistically evaluated at 99 percent confidence level. Due to the influence of rainfall, the stream flow is centralized in the monsoon season accounting 91% of the annual stream flow. The maximum stream flow is 201 cumec at the Meja road station and 189 cumec at the Satna station in the month of August. The results of Mann Kendall test show the significant increasing trend in annual, winter, pre-monsoon and post monsoon at the Meja road station. However, at Satna station winter and pre-monsoon seasons show the significant decreasing trend. The increase in annual discharge is 571 cumec per decade at Meja road station and 29.4 cumec per decades at Satna station. Further, the correlation between stream flow and climatic variables (precipitation, temperature and evapotranspiration) is calculated using the Pearson correlation test in annual and monsoon basis. The result shows that the stream flow in the Tons River is more sensitive to changes in precipitation than temperature and potential evapotranspiration. It is also found that discharge is positively related with precipitation, minimum temperature and dew point temperature and negatively related with maximum temperature and evapotranspiration. Further, monthly values of the Nino 3.4 Sea Surface Temperature (SST) anomalies, from the NOAA Climate Prediction Center, are used to evaluate the relationship between stream flow and ENSO indices. Comparison of standardized flow with Nino 3.4 SST anomaly shows that dry years are likely to occur during El Nino years and wet years are likely to occur during La Nino years. Through further analysis, a positive correlation coefficient (CC) is found in annual, winter, monsoon and post-monsoon season between stream flow and Nino 3.4 indices whereas the negative CC is observed in pre-monsoon season. The results of above analyses will be helpful to the managers, planners and agricultural scientists to work out water management options for the study region.

Abstract number - 18 IMPLICATIONS OF CLIMATE CHANGE ON MAINTENANCE DREDGING FOR NAVIGATION CHANNELS

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Dredging of navigation channels is a key activity to sustain international commerce. Its scope depends on economic considerations: the benefits from allowing for larger vessel droughts must overcome the cost of dredging. This economical trade-off can be significantly modified by Climate Change. In fact,

sedimentation in navigation channels depends on the prevailing hydrodynamic conditions (hydrologic regime) and the characteristics and quantity of available sediment. The hydrologic regime is critical in the case of rivers, while sediment provision is usually the most relevant issue in the case of estuaries. Climate Change can produce significant variations in both the hydrologic regime of rivers, and in sediment provision to estuaries, thus affecting the sedimentation rate and the consequent need for dredging. In this paper, a methodology is applied to determine the influence of potential changes in the flow regime, due to Climate Change, on sedimentation in a stretch of the navigation route of the Paraná River, in Argentina, a key transportation waterway for export of grains, the main source of economic wealth of the country. A river stretch where dredging activities are significant ('Paso Borghi') was selected, for which a data base of dredging volumes distributed along the stretch, and throughout a whole year, was made available by the Navigation Waterways Authority. A 2D horizontal (vertically averaged) hydrodynamic model was implemented based on bathymetric data obtained through an ad-hoc survey. It was validated through comparison between calculated and measured current velocities. Its results were used to feed a 2D vertical (laterally averaged) sediment transport model to calculate sedimentation in different reaches of the dredged navigation channel. This model was validated through comparison with dredged volumes data. Climate Change scenarios were defined through potential variations in the mean river discharge. Due to uncertainties in the future evolution of the hydrologic regime, as both historical records and theoretical approaches (from GCMs) do not indicate a definite trend, the effects of both increment and decrement of the river discharge were considered. Regarding vessel drought, two possibilities were studied: maintaining the present channel bottom elevation (thus implying larger or smaller vessel drought), and maintaining the present vessel drought (implying lower or higher channel bottom elevations). The relative changes in sedimentation (thus maintenance dredging) in relation to relative changes in river discharge were obtained, which constitutes the key input for an economic evaluation.

Abstract number – 23 CHANGE OF HYDROLOGICAL PARAMETERS BY URBANIZATION

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The social change, especially urbanization gives affect the flood runoff. But it is the difficult problem how to change the hydrological parameters after urbanization. The most important factors are rainfall runoff relation, flood runoff ratio and concentration time of flood. These analyses need highly precisely hydrological data. So the hydrological data are used from the experimental basins. The basin include many kind of different developed basin and different surface geology and installed precise rain gages and discharge stations. The number of the basins are selected as the objective basins of fifty three basins in whole Japan. Then the surface geology classified by permeable rock, for example, volcanic rocks, weathered rocks, Quaternary rocks and impermeable rock, for example, Tertiary rocks. The urbanized basin also classified by the area of percentages occupied by residential area more than 20 percent and the natural basin defined by the forest area more than 70 percent. First, the relation between the total rainfall loss and the total rainfall is analyzed. The result shows that the difference of the total loss between the natural basin and the urbanized basin is very large. Second, analysis is carried out between flood runoff ratio and urbanization and surface geology. The data of this analysis is up to two hundred of objective basins in the whole Japan. The result shows that runoff ratios change by urbanization. But the surface geology affect more than change of land use, that is urbanization. If pervious basin in geology becomes urbanization then runoff ratio largely change than impervious basins

become urban area. Third, model parameters are analyzed. The parameter of the storage function change to twice value for called "k". The concentration time of flood runoff, using experimental equation, are shortened, change one-third by urbanization.

Abstract number - 24 A REINFORCED MULTI-STEP-AHEAD ONLINE LEARNING ALGORITHM FOR RECURRENT NEURAL NETWORKS

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Considering the accurate label feedback can not be available at every time step in an online learning algorithm for multi-step-ahead forecasts, a reinforced multi-step-ahead real-time recurrent learning(RTRL) algorithm for recurrent neural networks (RNNs) is proposed to adjust weights in the learning process by incorporating the antecedent forecasted values and observed values into consecutive temp networks. Furthermore, because the residuals of model predictions often provide variable information rather than randomness, which indicates an additional residual analysis can be obtained by the chaos theory after examining the presence of chaotic behavior to enhance the model performance. To demonstrate the reliability and effectiveness of the proposed strategy, the multi-step-ahead forecast and residual analysis are derived by RNN with the reinforced RTRL algorithm and are investigated in two famous benchmark chaotic time series and a reservoir inflow in Taiwan. In comparison with the original RTRL algorithm and LRN, the results demonstrate that the proposed methodology with a reinforced multi-step-ahead RTRL algorithm can adequately forecast the theoretical time series and can significantly improve the precision and accuracy of streamflow forecast with an effective mitigation of the time-lag problem.

Abstract number - 25 INTELLIGENT WATER ALLOCATION STRATEGY: A CASE STUDY IN NORTHERN TAIWAN

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The growing water scarcity and threats of climatic change increase water stress and cause a decrease in water allocation for irrigation use in Taiwan. The drought conditions concerning the relation between initial reservoir storage and inflow are firstly presented; then a determination process of the discount on irrigation water supply is proposed for decision makers to pre-experience the water allocation outcome. The growth periods of the first paddy crop during 1965 to 2008 in northern Taiwan were used as a case study, and a number of drought years, during which decision makers made decisions to adjust water allocation, were further investigated. The analysis of drought conditions indicates that the initial reservoir storage plays an important role, and the drought condition becomes more and more serious

when the reservoir storage over the exceedence probability Q75. Moreover, the amount of inflow would also influence the level of severity. Besides, three-month probabilities of precipitation provided by Taiwan's Central Weather Bureau are useful information for reservoir inflow predictions. A large number of system simulations based on reservoir storage, upcoming three-month inflows and the discounts on irrigation water supply calculated by exceedence probabilities are used as inputs to train and validate the adaptive neuro-fuzzy inference system (ANFIS) for obtaining relevant deficiency levels so that suitably determine the discount on irrigation water supply and provide information on both public and irrigation water shortage. The estimation of model performance indicates the ANFIS is much better than the comparative model, linear regression. In sum, drought conditions can be preliminary reflected based on initial reservoir storage, and the proposed ANFIS model can be a useful tool to estimate the deficiency levels for public and irrigation use water and provide valuable information to the management of water allocation.

Abstract number - 29 MULTI-MODEL HYDROLOGIC PREDICTION UNCERTAINTIES ANALYSIS USING PARAMETER OPTIMIZING AND BAYESIAN MODEL AVERAGING

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Modelling uncertainties (i.e. input errors, parameter uncertainties and model structural errors) inevitably exist in the hydrological prediction. Much attention has recently been focused on these, of which parameter optimizing and multi-model ensemble strategy are the two most popular methods to demonstrate the impacts of modelling uncertainties. This paper focuses on multi-model uncertainties analysis using parameter optimizing and Bayesian model averaging (BMA). The Xin'ananjiang model, Hybrid rainfall-runoff model and HyMod were applied to the Mishui Basin, south China, for daily streamflow simulation. The three models were firstly calibrated by two parameter optimization algorithms, namely, the Shuffled Complex Evolution (SCE-UA) and the Shuffled Complex Evolution Metropolis method (SCEM-UA); next, the simulation sets calculated from the three models were combined using BMA; finally, the prediction intervals for the signal model and merged simulations were estimated and compared. The results show that both the two parameter optimization algorithms generate good streamflow simulations, specifically the SCEM-UA can imply parameter uncertainty and give the parameters' posterior distribution. The BMA combination does not only improve the streamflow prediction precision, but also quantificationally give the uncertainty bounds for the simulation sets. The calculated 95% prediction interval from the merged simulations of SCEM-UA is excellent, with 93.66% and 93.70% ratios of coverage for the calibration period and validation period, respectively; while the calculated 95% prediction interval from the merged simulation of SCE-UA using monte carlo combination sampling is worse, with only 75.23% and 75.27% containing ratios for the calibration period and validation period, respectively; however, it is still much better than that of corresponding singe model. These results suggest that considering the model parameters uncertainties and doing multi-model ensemble simulations are very practical for the streamflow prediction and flood forecast; from which we can generate more precision prediction and more reliable uncertainty bounds.

Abstract number - 32 ENSEMBLE SIMULATIONS FOR CLIMATE CHANGE ADAPTATION OF THE SWEDISH GUIDELINES FOR DESIGN FLOODS FOR DAMS

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A method for climate change adaptation of the Swedish guidelines for design floods for dams has been developed. This includes a method for adjusting regional climate scenarios used as input to a hydrological model, the so called DBS method. A production system has also been developed, which facilitates cost-effective processing of a large number of climate scenarios for hydrological simulations. Simulations of future changes in floods in Category I (high hazard dams) according to Swedish guidelines have been calculated for a sample of 11 basins which are relevant for the hydropower and mining industries. The simulations are based on 16 regional climate scenarios. Simulations of changes in the 100-year floods have been carried out in 1001 basins thus facilitating mapping of the effects of climate change for all of Sweden. The calculations of future design floods for high hazard dams (Category I) show variable tendencies depending on local conditions. This is mainly due to changes in precipitation, snow packs and evapotranspiration in a warmer climate. The analysis has therefore to be carried out on a case by case basis. The calculated changes in the 100-year floods shows a marked boundary through Sweden along a line approximately at the latitude of Stockholm city. To the north of this line a decrease is observed with the exception of the extreme northwest which shows a clear increase. The calculated 100-year floods generally increase in southern Sweden except for in a few smaller areas. The progress of the project was closely monitored by a Swedish task force on climate change and dam safety set up jointly by national authorities, the hydropower industry and the mining industry. In this process the climate uncertainty was also discussed in perspective of other uncertainties in a design study for high hazard dams. The task force delivered its final report in late 2011. The presentation will highlight the main findings of the project and also the experience from the close dialogue with the industry which has led to the adoption of joint recommendations on climate adaptation of the Swedish dam design flood standards to a changing climate.

Abstract number - 33 FLOODS IN THE M' ZAB VALEY (SOUTH ALGERIA) : GENESIS AND PREDICTION

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Floods and the inundations they cause, constitute in Algeria the recurring cause of fatal catastrophes, those of Wadi Koriche (Algiers) in November 2001 and of Wadi M'zab (Ghardaïa) on October 2008 testify of it and remain in the populations memory. The regional knowledge of surface flows is essential to study the floods. However, the quality of the observed data, (unavailable, discontinuous, spoiled by measurement, etc…) made the quantification of flows difficult to realize. Only rain-flow hydrological modeling can bring a solution to this problem. The aim of this study is to develop effectives rain-flow models to estimate rare frequency floods in arid region in absence of gauging. The Wadi M'Zab basin,

under Saharan climate, which is an area in full expansion, has been the subject of this study, considering its vulnerability floods, its importance from the socioeconomics, cultural and touristic point of view. The choice concerned two models, which showed their robustness and their performance on an international basis: The semi-distributed model HEC-HMS, easy to apply, based on a functioning SCS type, and the global model of IRD, purely determinist. The choice of these two models is justified by several criteria. The application of these models in the study area related to creation, organization and generation of input data by using a GIS then the evaluation of the results. The two models give satisfactory results and allowed the construction of the typical flood hydrographs. The model HEC-HMS shows itself easier to configure and implement. Nevertheless the flow obtained by the IRD model, has the advantage of being connected to the other flood characteristics which are evaluated by this same model. This work was based not only on the identification of the topographic, geomorphological, lithological, hydrographic, climatic and even anthropic flood factors, but also on a history of floods. The search for rain-flow models, adaptable to climatic and morphological specificities of the study area made it possible to establish relations connecting abatement coefficients – surfaces and runoff coefficients– surfaces, based on the basin physical characteristics. Also, the 100 year flow obtained by model HEC-HMS is used like entry in HEC-RAS model, which is a 1-D hydrodynamic model based on the equation of energy resolution, in order to simulate the flows in flood periods. This model has been applied to a section of the Wadi M' Zab. The hydrodynamic modeling of this section made it possible to study the behavior of the stream water profile, to consider the mean velocities and to identify the zones vulnerable to floods.

Abstract number - 34 MULTI-STEP-AHEAD INFLOW FORECASTING FOR RESERVOIR OPERATION AND MANAGEMENT IN MOUNTAINOUS AREAS

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Typhoons hit Taiwan during the summer period between June and November every year, which bring heavy rainfall in mountainous areas and deliver a huge amount of floodwater into reservoirs. It is of particular concern in the high mountains and steep slopes of Central Taiwan where reservoirs could be inundated within a few hours. This particular hydrologic feature makes reservoir management and operation very difficult. Important decisions on the timing and amount of reservoir releases must be made within a matter of hours by the controlling agency during each typhoon period. Therefore, a on-line multi-step-ahead short-term reservoir inflow forecasting model plays a crucial role in reservoir operation and management. To achieve this, anovel approach to combine spatial and temporal information using radar rainfall and DEM data for long-term inflow forecasting in Shihmen reservoir catchment was proposed. In this approach, the spatial segmentation was derived by the DEM data based on GIS analysis and the time lag between rainfall and inflow was derived by correlation analysis. We presented a case study of inflow forecasting by Adaptive network-based fuzzy inference system (ANFIS) and the results suggested that radar rainfall providing spatial information and greatly increased the accuracy of long term, longer than 3 hours, inflow forecasting.With the inflow forecasts for 3, 4 and 5 hours horizons, a reservoir outflow simulation was conducted based on several operation constraints and strategies. Using eight typhoon events as the test data set, the outflow simulation results showed that the suggested operation strategies worked well and no overflow occurred based on the suggested operation strategies. Furthermore, the higher accuracy of long-term inflow forecasting provided valuable information for decision makers to determine the proper outflow earlier and, therefore, reduced the danger of overflow.

Abstract number - 36 IMPACT OF WARMING CLIMATE ON THE RUNOFF COMPONENTS OF A MOUNTAINOUS CATCHMENT OF THE KASHMIR HIMALAYA IN INDIA

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The spatial and temporal distribution of δ18O and δD measurements of precipitation and stream waters were used to distinguish and quantify various sources and components of stream flow in a snow dominated mountainous catchments of Kashmir Himalaya. Water budget model was used to simulate the runoff components for last three decades. The catchment, Liddar watershed lie between the latitudes 33° 34′ N and 34° 15′ N and longitudes 74° 04′ E and 75° 29′ E and covers an area of about 1,243 Km2. The elevations in this watershed range from 1600m above mean sea level (amsl) to > 5000m amsl. The area experiences a temperate climate characterised by cold winters, warm summers and clear seasonality, with average annual precipitation of about 1200 mm (the average value represents two decades from1990 to 2009). There is great variability of temperature, which ranges from 37oC in summer to -15oC in winter. March normally receives the maximum rainfall of the year (183 mm) and November the least (36 mm). The precipitation is dominantly in the form of snow in winter and rain in rest of the seasons. A marked spatial and seasonal variability of stable isotopes of oxygen and hydrogen was observed in precipitation with δ18O and δD varied from -12.98‰ to -0.58‰ and -74.45‰ to -11.12‰, respectively, during the whole monitoring period. The seasonal changes in stable isotopes of precipitation with depleted and enriched 18O and 2H in winter/spring and summer/autumn, respectively at each site are found to be triggered by seasonal changes in ambient temperature, precipitation and airmass trajectory. The mean altitude effect of -0.23‰ and -1.2‰ per 100m change in elevation for δ18O and δD, respectively, was observed based on amount weighted mean precipitation isotopic composition data. Unlike precipitation, less variability of stable isotopes of streams was found with δ18O and δD ranging from-11.56‰ to -6.26‰ and -65.40‰ to -36.39‰, respectively, the more negative values being observed in the headwaters of the streams/tributaries. The results suggest that the winter precipitation in the form of snow fall dominantly contributes the annual stream flow with average snowmelt contribution of about 33% in early spring, 73% in late spring, 68% in summer and baseflow contribution of 47% in autumn season. The contribution of rainfall is higher (67%) in early spring season than in summer (32%) and autumn (53%) seasons. The study revealed that the warming climate has changed the timing of runoff components. The contribution of annual snow melt to the stream flow has decreased and the early spring snow melt has increased for last 30 years.

Abstract number - 38 VULNERABILITY THE AQUIFER OF THE OUM EL BOUAGHI (NORTH – EST ALGERIA)

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The water is very important for the human being and its environment. The demographic growth in the region is constantly increasing what have an influence on water need. In this work we make a description of the geometry and the structure of hydrogeological system using geophysical methods system, which shows that the superficial aquifer layer is constituted of conglomerate, lakeside limestone, clay and marl. The substratum is represented by the conductive marls. The measures of

electrical conductivities are the high and are an indicator of the influence of chotts. The interpretation of piézométric maps shows that the general appearance of curves varies only enough little partner to the other one. The hydrochemical analysis defines several facies; the most important is chlorinated sodic and chlorinated calcic resulting evaporates. The rates of nitrate are over the WHO standards for the drinking water because of agricultural activities. Maps of vulnerability established using GOD method shows that the aquifer of the Souk Naamane, Bir Chouhada and Ouled Zouai regions have moderated vulnerability moderated. We have made a classification of the social and economical domains that depend on water needs. Key words: aquifer, vulnerability, hydrogeological

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Abstract number - 40 ENSEMBLE MODEL TO RECONSTRUCT PALAEOCLIMATE AND PREDICT INDIA'S GROUNDWATER CHALLENGE AND THE WAY FORWARD

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In many parts the world, water consumption and pollution increased due to rapid growth of population and aspirations for economic development, and freshwater crisis is ascribed usually to the parameters governing climate. Despite debate on magnitude of climate induced anticipated warming, evidences of weather fluctuations and influence on hydrological processes exist. However, uncertainties and knowledge gaps in climate models and limited understanding of the factors controlling climate change are unable to assess the probable impacts on water availability in tropical regions. In this background, ensemble model has been developed, based on δ18O and δD signatures in rainfall and groundwater, 3H- and 14C- ages of groundwater and 14C-age of lakes sediments, and δ18O in air-CO2 and water vapour; reconstructed palaeoclimate and long-term processes on recharge in the North-west India; and future groundwater situation predicted. The annual mean temperature trend indicates both warming/cooling in different parts of India in the past and during 1901–2010. Neither the GCM nor the observational record suggests any significant change/increase in all-India average monsoon rainfall over the last century, and climate change during the last 1200 yrs BP. In much of the North-West region, 450-500 m deep GW (14C-age of >40,000 yr BP) and 60-250 m deep waters (14C-age <2,000 - 22,000 yr BP), with depleted δ18O (-4.2‰ to -7.6‰) than the present day rainfall δ18O (–2‰ to –6‰) indicate GW-renewal from past relatively humid climate, and slow flushing rate in the dry-arid last Interglacial period. Shallow (30 –50 m) GW 3H-age (<50 yrs) with δ18O and δ2H similar to that in the present day rainfall suggest a significant component of modern recharge also. The δ18O values and14C-ages of groundwater clearly indicate vertical stratification. Low mean recharge (<8-20% of annual rainfall) indicates limited storing and renewal potential of the GW reservoir over the past decades after decades. It is not certain how individual water catchment areas may respond to anticipated change in temperature and rainfall. El Nino years are associated with weak SW-monsoon and enriched rainfall δ18O. A warmer climate with delayed and/or uncertain onset of monsoon will have more anthropogenic-stress on water. Different timescales of recharge can help in devising strategies by creating an integrated system of water supply. To make water management to be more responsive to climate change, the gaps in the science of climate change need to be bridged based on investigations specific to the hydrological system in each area.

Abstract number - 43 STOCHASTIC OPERATION AND MANAGEMENT OF DAMS ON PERU

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One of the main problems for management and Operation of water resources on the mountain range from the "Andes" in regulated watersheds with reservoirs is the uncertainty of the future water availability of the basin since the operation is planned to the future. The Objective this paper is: oForecasting of the water offer of the basin with stochastic models. oWith forecasting of water doing simulation to the future of the Condoroma Dam (4155.00 meters above sea level) operation, within the Majes-Siguas hydro system –Peru (See Fig. N°1). Formulation of the operating rules for the Condoroma Dam. First, consists on predicting with stochastic models the flows and future rains, with this information a simulation of the operation dam and operation rules for the hydro system are obtained as a result, these “rules must satisfy the demands of water in the appropriate moment and quantity”. The work is applied to Condoroma dam (Arequipa-Peru), which is the greatest infrastructure of the Special Majes-Siguas Irrigation Project. The main objective of the project is irrigation of 45,000 hectares of new lands in “Majes Irrigation”, the amplification of the irrigation in approximately 1920 hectares in Colca Valley and the improvement of 4928 current irrigated hectares in the Siguas and Colca valleys. The hydraulic system of the Majes Irrigation Project begins in Condoroma dam with 280 million m3, located in the highlands of the Colca river basin. The stored water is then derived to the Colca River, for where it goes until Tuti derivation water inlet. Later on the water is to derivate to new basin, across the mountain range by a 34 m3/sec capacity with 80 km length tunnel and 180 km of channel, located in the left riverbank of the Colca canyon. Then the water is driven by the Siguas river; until Pitay derivation water inlet (1350.00 meters above sea level); from where the water is driven by the derivation channel, located in the right riverbank of the Siguas river going into in “Majes Irrigation” to irrigate 45,000 hectares (see Fig. N° 1). In general, they can be distinguished three sub basic systems: o Condoroma. Sub system on the mountain range from the Andes ("basin 1"-4155.00 meters above sea level) o Tuti terminal tunnel adductor Sub system o Pitay-Majes derivation Sub system o Irrigation Majes ("basin 2"-1350.00 meters above sea level Fig N°.1 Hydraulic schemes to the System for simulation operation to the system Colca, Majes, Camana and Siguas.

Abstract number - 47 THE ECOSYSTEM APPROACH TO PREDICTION OF SPILL EFFECTS

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The most common type of contaminants of the hydrosphere are hydrocarbons. The environmental effects of the recent accidents of oil spills from the tanker "Prestige" (Spain, 2002), in the Kerch Bay (Russia, 2008) and in the Gulf of Mexico (USA, 2010) are well known as disastrous. The first assessment of oil spill effects is often done by such visual indicators as the oil slick spread, the death of hydrobionts and pollution of coastal beaches. Although the distribution of hydrocarbons in the aquatic environment is well-studied, their physical, chemical and toxicological properties still raise many questions related to ecological risks. Effects, recorded on the first days and weeks after an anthropogenic accident are considered real ecological risk. Potential ecological risks that appear several years after also constitute great threats for the functioning of ecosystems. Studies of biotransformation

of persistent hydrocarbon at the biogeochemical barriers such as water-shore, water-bottom and the mixing zone of marine and fresh waters become very important. Long-term transformations of hydrophobic polycyclic aromatic hydrocarbons (PAHs) produce water-soluble and sometimes even more toxic substances. They cause long-term environmental consequences for biodiversity. Studies of the evolution of ecosystems under oil pollution should develop additional scenarios of their behavior. This can be achieved through experimental modeling of transformations of crude oil and PAHs using destructors from different habitats. We used bacterioplankton and bacteriobenthos of the Amur River collected in the zone of influence of major tributaries and in the direction of the distribution of river flow in the Okhotsk and Japan Seas. Transformation products were identified by gas chromatography and GC-MS. According to one scenario regardless of the season (including at 2 ° C) microbial transformations of aromatic hydrocarbons with different structures (naphthalene, phenanthrene, crude oil), produced methylated derivatives of benzene (toluene, xylene). Hydrocarbon decomposition mechanisms depended on the areas of their transformation. Thus, in areas of chronic pollution of river bottom sediments secondary butanol and isopropylbenzene were identified as degradation products of PAHs, which often come with industrial wastewaters. In forecasting oil pollution effects in the mixing zone of marine and fresh waters the qualitative composition of toxic products depended on the co-substrates. During 55-day destruction of the oil film acetone, butyl acetate, benzene and methylbenzene accumulated in water. These intermediates of hydrocarbons constitute risk factors for fish, mussels, marine animals and birds as causing secondary contamination of the environment and danger to the stability of water ecosystems.

Abstract number - 53 CONTINUOUS HYDROLOGIC MODELLING STUDY OF EVROS RIVER BASIN

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Continuous hydrologic modelling accounts for the synthetic analysis of a basin's response to multiple precipitation events and their cumulative effects over a period of time, thus allowing for different physical hydrologic phenomena affecting the soil water balance. In the present paper, a continuous hydrologic simulation of the transboundary basin (Bulgaria, Turkey and Greece) of Evros River is developed. Therefore, the twelve-parameter Soil Moisture Accounting algorithm, incorporated in the Hydrologic Modelling System (HMS) program by the Hydrologic Engineering Center (HEC), was employed. The values of the parameters of the intricate soil moisture accounting model were derived from readily available geospatial databases and were subsequently calibrated by means of seasonal parameterization. Thus, the combined effect of both wet and dry conditions can be more accurately interpreted in parametric values. Ultimately, using continuous precipitation data over a period of two years (October 2004 to September 2006), continuous hydrographs were computed at the outlets of the river sub-basins and compared to available measured mean daily values of water discharge. The model output indicated that the developed continuous modelling and parameterization methodology could be satisfactorily implemented to simulate the hydrograph components and river flow.

Abstract number - 54 QUANTIFYING SUSTAINABLE GROUNDWATER EXPLOITATION IN AQUIFER SYSTEMS: APPROACH USED FOR THE AQUIFERS IN FLANDERS (BELGIUM)

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Rising water consumption in many regions in the world has lead to an increased need for groundwater use and consequent intensification of exploitation of aquifer systems. Lowering of groundwater levels with related droughts, impact on ecosystems and deteriorating groundwater quality are much encountered side effects of overexploitation practices. Determination of a sustainable exploitation rate has become an important issue while developing management strategies for groundwater reserves in the future. Sustainable exploitation should find a balance between the economic profit from groundwater as a natural resource, the social importance and context of water supply and the hydro-ecological impacts of lowering water levels. In a hydrogeological sense it can be defined as the maximum amount of groundwater that can be pumped within prescribed limits of hydrogeological impact like drawdowns or baseflow reduction. In this paper, the methodology is presented that will be used in Flanders (Belgium) to quantify a sustainable groundwater exploitation rate for its aquifer systems. It has been tested on two different aquifers and will be further applied to all other systems. The method is based on simulations with regional groundwater flow models. A set of models exist in Flanders that cover the whole region and contain all aquifer layers. These are collected in the "Flemish Groundwater Model". For each aquifer, sets of maximal allowed impact are defined in terms of heads, drawdowns or baseflow reduction in rivers and streams. The problem is stated mathematically as a linear programming (LP) problem that maximizes pumping rate within the given constraints of impact. Therefore, response functions for each constraint are calculated with a regional model. This provides the coefficients in the LP equation set. These response functions are non-linear, but are used to eliminate the need that the LP solver and the model simulations should both be contained in an iterative loop for updating the LP coefficients, with the risk that the model does not converge and halts the iterative procedure. Therefore, a series of simulations with increasing pumping rates are performed, and non-linear respons functions are derived. The model area is subdivided into a number of compartments (up to a few tens), each containing a number of wells, and the total pumping rate of each compartment is the parameter that will be maximized by the LP routine. Each compartment's total is distributed over its containing wells using the initial well pumping rates as the proportionality factor. This approach has the advantage that all necessary simulations are performed in advance and can be checked thoroughly on their validity and consistence. The optimisation part by the LP solver is very fast, so lots of different constraint sets can be optimised separately and the resulting exploitation rates evaluated. Different obtained solutions can be compared using a defined sustainability index SI, a measure for the minimized hydrogeological and environmental impact, and an exploitation index EI, a measure for the maximized economical value of the pumped water. Application and results of the method will be shown for some aquifer systems of the Flemish Groundwater Model.

Abstract number - 55 INCREASING FLOOD PREPAREDNESS BY WARNINGS BASED ON MODELLED SOIL MOISTURE CONDITIONS

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The soil moisture condition is an important factor in the initiation of river floods. High soil moisture conditions decrease the storage capacity of the subsurface and in combination with high rainfall intensities, this can lead to floods. Real time information on soil moisture conditions in the river catchment therefore can be used as indicator for potential future floods, hence as input for awareness raising and increasing the preparedness of flood crisis management bodies for potential future floods. This requires the soil moisture data to be assessed/quantified, mapped and communicated. However, the soil moisture is very variable in time, space and depth, depending on the evaporation, the vegetation water demand, the groundwater level, rainfall (intensity and quantity) and soil type. To obtain a sufficient spatial soil moisture coverage, in situ measurements are inadequate. Hydrological models however are commonly used in flood forecasting systems, converting rainfall and evaporation predictions in runoff. Most of these hydrological models, in operational use, are lumped conceptual models, which contain storage elements, representing the soil moisture content. Depending on the relative content of these storage elements and rainfall and evapotranspiration inputs, rainfall-runoff estimates are generated together with the different runoff subflows (overland flow, interflow and baseflow). In this research more than 200 NAM models, covering most of the Flanders region in Belgium, are used. The model parameters are calibrated by evaluating peak flows, low flows, cumulative volumes and empirical extreme value distributions for both the peak and low flow extremes, after advanced time series processing, which allows the generation of physically consistent and conceptually accurate parameter sets. The relative content of the storage element that represents the relative soil moisture condition of the unsaturated zone (L/Lmax) and the baseflow are used as indicators of the soil moisture conditions. A procedure has been developed where actual L/Lmax and baseflow values are compared with different L/Lmax and baseflow quantiles to identify the severity of the indicator. The quantiles are calculated after statistical processing of long term time series of almost 60 years of model simulation results. In a second study an optimal trigger for flood warnings is searched by combining the relative soil moisture estimation and rainfall predictions. It has been found that such combined variable making use of the relative soil moisture condition estimated from model simulations forms a good basis for such an indicator of potential future floods, hence to initiate warnings and increase preparedness of flood crisis management bodies.

Abstract number - 57 ASSESSMENT OF UNCERTAINTY IN FLOOD FLOWS UNDER CLIMATE CHANGE - THE UPPER THAMES RIVER BASIN (ONTARIO, CANADA)

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The assessment of climate change impacts on frequency and magnitude of flood flows is important for flood risk management. It is recognized that existing methods for the assessment of climate change impacts are subject to various sources of uncertainty (choice of climate model, choice of emission scenario, course spatial and temporal scales, etc.). This study investigates the climate change related uncertainty in the flood flows for the Upper Thames River basin (Ontario, Canada) using a wide range

of climate model scenarios. Fifteen different climate model scenarios from a combination of six Atmosphere-Ocean Global Climate Models (AOGCMs) and three emission scenarios "A1B", "B1" and "A2" out of the family of emission scenarios are used to determine an uncertainty envelope of future estimated flood flows. The use of large number of climate models and scenarios also permits a probabilistic assessment of future flood flow uncertainty. In this study, AOGCM data is downscaled using the change factor approach for 30-year time slices centered on years 2020, 2050 and 2080. To estimate natural variability, a stochastic weather generator is used to produce synthetic time series for each horizon and for each climate change scenario. The weather generator is also used to perturb historical data so that a number of realizations can be produced for the 1979-2005 baseline. A continuous daily hydrologic model, calibrated for the basin, was then used to generate daily flow series for the 1979-2005 baseline period and the 2020, 2050 and 2080s. A peak-over-threshold (POT) modeling approach with Generalized Pareto Distribution is used to produce flood frequency distributions for the four time horizons. The uncertainty involved with the POT modelling is also considered. The results indicate that frequency and magnitude of flood flows in the Upper Thames River basin will most certainly change in the future due to climate change. Inherent uncertainties associated with different AOGCMs are quantified by a simple Gaussian approach. The resultant scenario indicates change in flood magnitudes for all return periods. Use of a probability based frequency curve is encouraged in order to apply the flood magnitude-return period relationship with high level of confidence.

Abstract number - 58 Recent variation of snow as a water resource in the Japanese Alps

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The region of Japan that lies along the Sea of Japan is known to experience some of the heaviest snowfall in the world. In this region, precipitation brought by snowfall is more important as a water resource than rainfall. Recent studies have reported that the amount of snowfall in Japan will decrease as a result of global warming. However, these studies used data observed at low altitudes. The question arises whether the same theory can be applied to high-altitude mountain areas. Therefore, in this study, we discuss the relationship between temperature and the amount of snow using observation data for the Japanese Alps region and present the results of some meteorological observations we carried out at high-altitude sites in the Japanese Alps region. A relatively large part of the Japanese Alps region is within the altitude range of 1,000–3,000 m and the snowfall there serves as a vital water resource. Therefore, the effect of global warming on snow accumulation in mountain areas is a crucial issue. At places with high altitude in the Japanese Alps, it is rare for the air temperature to rise to around 0 ºC at the current levels of temperature increase. An increase in winter precipitation should lead directly to an increase in snow accumulation in the high altitude area. Under the present circumstances, the role of the mountain regions as a system for purification of water and air that is essential for human beings' existence is not duly recognized and is undervalued. However, there is no doubt that we need to understand the response of mountain regions to global-scale environmental change in the near future. To achieve that, we need to discuss the matter based on proper observation data. We therefore plan to continue our meteorological observations at high altitude mountain regions.

Abstract number - 62 MEASURING GREEN ROOF EVAPOTRANSPIRATION USING A NOVEL MODIFIED LYSIMETER METHOD: IMPLICATIONS FOR THE ROLE OF ET IN GREEN ROOF STORMWATER DISCHARGE MITIGATION

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Urban development extensively replaces permeable surfaces with impervious ones, thereby altering the natural hydrologic cycle. Impervious surfaces accentuate stormwater runoffs and diminish groundwater discharge, especially under high intensity rainfalls. Since such runoffs could often become massive in volume and concentrated in time, they can overwhelm urban stormwater systems and cause overflow, producing detrimental effects on built-up areas and receiving water bodies. In sustainable urban stormwater management like the Low Impact Development (LID), green roof is a source-reduction control that mimics the pre-development hydrologic functions of storing and gradually releasing rainwater. A growing body of research has shown that green roof can retain and detain stormwater as well as delay and suppress peak stormwater discharge. Another hydrological benefit of green roof is its compensation for the reduced evapotranspiration (ET) caused by expansion of impervious surfaces. Other than discharge drainage, ET is a key exit pathway by which water can leave the green roof system. Thus, its relation with water retention and discharge characteristics may well be intimate and dynamic. However, few studies focus on the effect of ET on green roof stormwater performance, owing to the difficulty of measuring ET. Most studies hitherto have employed indirect methods such as simulation model and calibrated Thornthwaite ET formula to estimate ET. While useful, the computation of ET is no easy task since it requires a large number of weather parameters. Moreover, such models usually require local calibrations as they are not applicable to locations with a different climate. This study develops a novel modified lysimeter method, a well-established ET measuring device used in hydrology and soil science to monitor the ET of green roof plots in a rooftop urban environment. With continuous hourly measurements, this study provides insights into ET characteristics both during and between rainfall events. Moreover, ET's dynamic relationships with precipitation, soil moisture, and discharge are also explored to ascertain its role in green roof stormwater mitigation.

Abstract number - 63 A NEW CONCEPT FOR IDENTIFYING A SCALE OF POTENTIAL PREDICTIVE CAPABILITY OF SPATIALLY DISTRIBUTED MODELS

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Nitrate load from agricultural land to lakes and coastal water in Denmark has during the past 20 years been reduced by about 50% by government regulations imposed on agricultural practice. The EU Water Framework Directive (WFD) will require an additional reduction of nitrate load by 50%, which economically will be very painful for the agricultural sector. The regulations imposed until now have been uniform, i.e. the same restrictions for all areas independent on the subsurface conditions. Studies have shown that on a national basis about 2/3 of the nitrate leaching from the root zone is reduced naturally in the subsurface before reaching the streams. This implies that if a uniform agricultural regulation reduces nitrate leaching by 100 kg N, the nitrate load to surface water will only be reduced by 33 kg N. Therefore it is much more cost-effective to identify robust areas, where nitrate leaching through the root zone is reduced in the saturated zone before reaching the streams, and vulnerable areas, where no subsurface reduction takes place, and then only impose regulations/restrictions on the

vulnerable areas. Distributed hydrological models can make predictions at grid scale, i.e. at much smaller scale than the full catchment. Hence these models have a potential for being able to differentiate between robust and vulnerable areas. However, in all previous studies we have seen, distributed models do not have predictive capability at scales much smaller than catchment scale. A constraint in this respect is that distributed models often do not include local scale hydrogeological heterogeneities that are known to be important for reactive transport. In the NiCA research project (www.nitrat.dk) we are developing tools for assessing nitrate reduction in the subsurface between the root zone and the streams and methodologies for assessing at which spatial scales such tools have predictive capabilities (see the enclosed figure). A new instrument has been developed for airborne geophysical measurements, MiniSkyTEM, dedicated for identifying geological structures and heterogeneities in the upper 30 m. The geological heterogeneity and uncertainty will be analysed by use of TProGS which can generate stochastic geological realisations that are soft conditioned against the geophysical data. Finally, the flow paths will be simulated in the catchment by use of MIKE SHE for each of the geological models generated by TProGS and the prediction uncertainty will be characterised by the variance between the predictions of the different models.

Abstract number - 65 POTENTIAL IMPACTS OF CLIMATE CHANGE ON FOREST DEVELOPMENT AND FOREST WATER BALANCES IN THE WAIDHOFEN A.D. YBBS REGION (LOWER AUSTRIA)

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Potential impacts of climate change on forest development and water balance of forest sites important for drinking water supply have been assessed in four catchments of the Waidhofen a.d. Ybbs region. The investigations were done in the frame of the Interreg South East Europe Transnational Cooperation Programme CC-WaterS. Runoff characteristics and infiltration behaviour were analyzed at 6 sites representative for wider parts of the investigated catchments by use of a transportable spray irrigation installation on 50 m² large plots, precipitation of 100 mm per hour was applied. Further investigations comprised the characterization of the soil physical characteristics at the irrigated sites, the description of forest conditions and the development of surface runoff coefficient maps for the actual state in the catchments in question. Based on field data and daily values of precipitation and temperature (taken from the RCM-data provided in the frame of the CC-WaterS-project) forest water balances have been simulated with the hydrological model BROOK-90 for different tree species on two soil types and two different aspects respectively. Water balances for the time periods 2001-2010 and 2091-2100 have been compared. Several endangerments for the investigated stands and the different tree species with effects on water supply have been recognized: So the soils at the investigated sites show a high erosion potential, loss of ground cover will increase the danger of drinking water contamination. The number of months per year with a water deficit will increase till the end of the 21th century but differently in dependency of the tree species; e.g. the increase of the number of months per year with a negative water balance for Beech-Larch and Scots Pine-Beech stands will be lower in comparison to other stands. Especially south exposed slopes will be affected, the mean time of water shortage will increase up to

the double. The annual water balance (excess or surplus water available for deep-seepage) in the different stands will decrease about 25% at the end of 21th century. The model results suggest an increase of the range of the annual water balance at the end of the 21th century but the available amount of water during the vegetation period will decrease. The predicted climate change may enforce these risks, but there are also adaptation strategies for ensuring future drinking water supply available: Reduction of size of cuttings - group cutting; intensification of natural regeneration, reduction of sites covered by Norway Spruce, promotion of mixed forests, reduction of technical impacts (e.g. due to road construction, etc.).

Abstract number - 68 CLIMATE CHANGE PROJECTED IMPACTS IN THE HYDRO-ELECTRICAL POTENTIAL GENERATION IN RUN OF THE RIVER POWER PLANTS IN A CHILEAN CENTRAL-LOCATED BASIN

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As the Chilean economy foresees constant and sustained growth for the next years, the demands for energy of the country itself are also expected to rise above the actual scenario. In Chile, the hydro-generated electricity plays a key role for the Center-South power supply grid, representing approximately over the 45% of the total consumption. It is also known that due to the local geography, the southern latitudes of the country present high potential for hydropower generation, from which the country could benefit. However, this natural resource and its relationship with climate change still has to be studied and analyzed. Recent studies foresee a general rise in the average temperatures varying from 2°C to 4°C in the central valleys as well in the Andes mountains, bringing consequences upon the hydrological processes and regime of many basins in the area, among others impacts such as changing the position the snow line and therefore, the storage amount of rainfall as snow cover. To asses more specifically the impact of climate change in the hydro-electrical power generation, a WEAP model is developed of the Alto Cachapoal Basin, where run of the river power plants have been operating for almost a century and with some more plants currently at the design stage. Located in the central region of the country, this catchment represents a good case of study since it represents fairly well the expected characteristics of a typical basin of the area. The model is calibrated and validated at daily level using elevation bands as catchments on each of the sub-basins, using as forcing conditions those defined by the model ECHAM5 properly downscaled through the PRECIS methodology, under the scenario A1B. Appropriate corrections in the spatial and temporal scale were performed to the meteorological restrains to fit the study area. The calibration and validation of the model were performed for the period 1980-2010, using representative flow gauges located close to the places where the intakes of the existing and projected power plants are positioned. The water resources availability is analyzed for the intakes of the power plants for the period 2041-2070 and this leads to a comparison between the potential generable energy limited by the restrictions because of the installed capacity and to those defined by the water availability. This situation is later compared to the actual situation to evaluate the estimated potential impact.

Abstract number - 72 GROUNDWATER MANAGEMENT IN THE UPPER KLAMATH BASIN, OREGON AND CALIFORNIA, USA: BALANCING THE BENEFITS OF GROUNDWATER FOR AGRICULTURE AND WILDLIFE

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Water resources in the upper Klamath Basin (located in southern Oregon and northern California in the western United States) are managed to achieve a variety of complex, often interconnected purposes. Over the past decade, balancing the benefits of water for agriculture and ecological needs has proven difficult. Since 2001, the United States' Endangered Species Act has required irrigators to limit surface-water diversions in order to protect habitat for endangered fish. This shift in water-management priorities has resulted in substantial reductions in the amount of surface water diverted for irrigation and significant increases in the demand for groundwater, particularly in drought years. Water and environmental managers in the basin need methods to determine reliable groundwater development strategies that augment surface-water supplies while avoiding adverse impacts of pumping on aquatic habitat and groundwater levels. To address this need, we have developed a decision framework that links groundwater simulation and optimization to identify groundwater-management practices that meet the complex set of goals and constraints associated with groundwater development in the basin. These include (1) determining groundwater-withdrawal patterns that meet the spatially and temporally varying water demands for irrigation and aquatic habitat, (2) ensuring that pumping-generated reductions in groundwater discharge to surface water (streams, lakes and the agricultural drain system) are within allowable limits, (3) ensuring that drawdown due to managed pumping does not exceed limits allowed by water law, and (4) identifying the impacts of climate variability on groundwater availability. Groundwater-management alternatives are described using optimization-model sensitivity analyses that provide information on the nonlinear tradeoffs among groundwater-pumping decisions, water-demand constraints, groundwater-discharge constraints, drawdown constraints and climate variability. The sensitivity analyses demonstrate to water managers the importance of identifying constraint limits in order to better define the suitable amount and distribution of groundwater pumping for the basin. These analyses indicate that changes in the groundwater-discharge, drawdown and demand constraints could result in substantial changes in the optimal groundwater-management strategy, with total pumping increasing or decreasing by up to a factor of two as these constraint limits are relaxed or tightened. The impacts of climate variability on groundwater pumping were tested using historic data from 1970 – 2004, a period that included multiple drought years. The results indicate that the groundwater system will be able to meet demand in many years; however, significant irrigation shortages can be expected during extended (5 – 10 year) drought cycles when the demand for supplemental groundwater is highest.

Abstract number - 76 FLOOD HAZARDS ANALYSIS OF JEDDAH CITY, WESTERN SAUDI ARABIA

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Flash floods are among the most catastrophic natural extreme events that present a potential threat to both lives and property. They occur immediately after heavy and short rainstorm duration. Jeddah City, located in the middle part of the Red Sea coastal plain of Western Saudi Arabia, has received an unexpected amount of rainstorm in 25th November, 2009 and 29th Jan 2011 that has never happened in the last 5 decades. Flooding events in this city, in fact, often result form the integration of several factors, including rainfall intensity, surface runoff, infiltration, topography and land use. These factors contribute an important role in flood generation. This study represents an integrated approach of remote sensing, Geographic Information System (GIS) and hydrological models, which will be utilized to identify, asses, and categorize the vulnerable areas in Jeddah City. Nevertheless, this study will help the decision makers for any future planning and for the better management of sustainable development of Jeddah environment. Keywords: Flood hazards; GIS; Vulnerable areas; Jeddah; Saudi Arabia

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Abstract number - 77 ASSESSMENT OF IMPACTS OF LANDCOVER CHANGES ON INFLOWS INTO LOWER KIHANSI HYDROPOWER RESERVOIR IN TANZANIA

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The study aimed at assessing impacts of landcover changes on inflows into the Lower Kihansi reservoir (Capacity: 1.616 Mm3) located in the catchment of River Kihansi in the southwest highlands of Tanzania. This stems out of operational design of the almost run-of-the-river Lower Kihansi Hydropower Plant that generates 180 MW at 3-turbines total flow of 25 m3/s (or 8.33 m3/s per turbine). This Kihansi output power represents about 35% of total hydropower generation in Tanzania. The assessment involved statistical analyses for seasonal variations and multi-year variability that provide best periods for hydrological modelling (SWAT) that investigated impacts of changing landcover on streamflows. Seasonal variations were analyses by long-term daily and monthly averages while multi-year variability analysis involved visual analysis of time series plots, linear trend and change-point analyses. Results of statistical analyses indicated two tributaries of River Kihansi joining some 2.8 km upstream of the inflow gauging station, the large western sub-catchment of River Upper Kihansi and the small eastern sub-catchment of River Ruaha representing 67% and 33% of total catchment area respectively. Seasonal flow regime is characterised by a well-defined peak during the long rains (March-May) with daily flows over 20 m3/s and lowflows in September-late November when daily flows below 5-7 m3/s have been recorded, which are lower than rated discharge of a single turbine. The contributions of the large and small sub-catchments to reservoir inflows are high in October-March and April-May respectively. Analysis of inflows record indicated consistent declining average inflows into the Kihansi reservoir since the early 1990s, which were reflected in declining low flows while flood flows remained relatively unchanged in magnitude and period of occurrence. Annual minimum discharge has declined from 9 m3/s in the early 1980s to 7 m3/s in the mid 1990s to below 6 m3/s in the 2000s with the lowest value of 4.97 m3/s in December 2005 and January 2006. Declining flows were

reflecting identified similar declining trend in rainfall amounts. SWAT simulation of historical hydrological between 1979 and 1995 indicated reduction of 4.5% (average flow), 21.6% (minimum), 3.7% (Q70) and 7.9% (Q95) contributed only to changes of landcover in the Kihansi catchment between 1979 and 1995. However, results were affected by unavailability of a series of landcover at short intervals (e.g. 5 years) and streamflow records before January 1974. More studies are therefore recommended to develop landcover and streamflows for early decades (1950s-1970s) for use in revised studies.

Abstract number - 79 CLIMATE CHANGE AND DESIGN FLOOD CALCULATION FOR DAMS IN NORWAY

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The design flood for large dams in Norway, which is a 1000-year flood, is calculated by using historical flood and precipitation data. Requirements for flood calculation for dams are given in the Dam Safety Regulations and practical guidance on how to perform calculations and use the results for safety evaluation of dams are given in separate guidelines. Climate change studies indicate that much of Norway will probably experience more extreme rainfall and more frequent rainstorms in the future. Projected increases in temperature will, however, simultaneously contribute to a reduction in the magnitude of snowmelt flooding. Thus, the impact of climate change on extreme flooding will vary between regions and between catchments in the same regions. The Norwegian Water Resources and Energy Directorate has performed a study as to how the expected changes in climate will affect floods all over the country, in particular design floods for dams and land use planning. The study is based on ensemble modeling using multiple climate scenarios and methods for interpreting these so that some of the uncertainties underlying projected changes can be quantified. The study has resulted in recommendations for taking account of climate change impacts in design flood calculations. Recommendations are given for six different regions of Norway and for different types of catchments within each region. The recommendations are based on three categories for projected change: 0%, 20% and 40%. Results from this climate change study have affected the recent revision of the guidelines on flood calculations for dams. The guidelines recommend that sensitivity analyses are performed for certain dam types in regions and catchments where major changes in design flood are expected. In cases where the projected changes in design flood will affect the safety of a dam, the dam owner should consider to account for climate change when reassessing the safety of a dam as part of a regular reassessment according to the dam safety regulations.

Abstract number - 82 WATER QUALITY MODELING USING ARTIFICIAL NEURAL NETWORK AND DECISION TREES

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The water quality at ground zero in a given region largely depends on the nature and the extent of the industrial, agricultural and other anthropogenic activities in the catchments. Undeniably, ensuring an efficient water management system is a major goal in contemporary societies, taking into account its importance to the living organisms health and the need to safeguard and to promote its sustainable use. However, the assessment of the data quality of a dam`s water is being done through analytical methods, which may be not a good way of such an accomplishment, due to the distances to be covered, the number of parameters to be considered and the financial resources that will be spent. Under these circumstances, the modelling of water quality in reservoirs is essential in the resolution of environmental problems, and has lately been asserting itself as a relevant tool for a sustainable and harmonious progress of the populations. This work describes the training, validation and application of Artificial Neural Networks (ANNs) and Decision Trees (DTs) to forecast the water quality of the Odivelas reservoir, located in the south region of Portugal, over a period of 10 (ten) years. Two different strategies were followed to build predictive models for water quality. One of them used chemical parameters data (strategy A) while the other one used hydrometric and meteorological data (strategy B). In terms of the former strategy, the input variables of the ANN model are Chemical Oxygen Demand (COD), Dissolved Oxygen (DO), Oxidability and Total Suspended Solids (TSS), while for the DTs one the inputs is, in addition to those used by ANNs, the Water Conductivity and the Temperature. The performance of the models, evaluated according to the coincidence matrix, created by matching the predicted and actual values, are very similar for both models; the percentage of adjustments relative to the number of presented cases is 98,8% for the training set and 97,4% for the testing one. Following the strategy B, the input variables of the ANN model are humidity, wind speed, air temperature, precipitation, radiation, volume of water stored in reservoir and the pH, while for the DT model the inputs are pH, wind speed, precipitation, humidity and air temperature. The performance of the models, evaluated in terms of the coincidence matrix, are 91,1% for the training set and 91,7% for the testing one for the ANN model and 89,3% and 88,0% for the DT model.

Abstract number – 83 WATER RESOURCES VULNERABILITY TO CLIMATE VARIABILITY AND CHANGE IN BENIN-OWENA RIVER BASIN, S.W. NIGERIA

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Water Resources vulnerability to climate variability and change was investigated in the Benin-Owena River Basin of S. W. Nigeria. Meteorological information was gathered on the rainfall, temperature and evaporation of some major stations in the basin for a period of forty years (1961-2000). Information was also gathered on flooding (1990-2006), irrigation activities (1990-2000) and erosion (1990-2000) in the drainage basin. Results revealed a fluctuating trend in the rainfall distribution of the basin and an increasing trend in the temperature regime and evaporation of the basin. Reduced precipitation led to increased irrigation activities in some instances while incidences of increased flooding was observed in

other instances. Increasing temperature and fluctuating sporadic rainfall attenuated the incidences of flooding and erosion in Edo, Ondo and Ekiti States of the river basin. Mitigative measures to these activities in the drainage basin are highlighted.

Abstract number - 84 PROBABILISTIC DROUGHT FORECASTING FOR A BASIN SCALE WATER RESOURCES OPERATION

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Water resources management involves coping with the variability in the climate systems. Reliable analysis of climate variability can improve the management of water resources systems from economic, social, and environmental points of view. Understanding the relationship between streamflow anomalies and changes in large-scale climatic patterns, has led to improvements in planning and operation of water resources systems. This research uses a systematic approach to analyze the climate induced components of a water resources system for the purpose of improving the process of water resources operation. The sea surface temperature (SST) anomalies of the seas not only affect the nearby lands but also the ones in the far distance. This paper aims to choose main locations from the eastern Mediterranean Sea, which apparently have significant effect on the western part of Iran and to investigate their monthly mean SST's for being predictors of Karoun and Dez streamflow in the Karoun Basin, Iran. These rivers are placed in the southwest of Iran, which are two of the country's main rivers. The goal of operating water resources system of Karoun basin is to supply domestic, industrial, and agricultural water demands as well as hydropower generation. A model based on K-nearest neighbourhood method is used to forecast drought in a probabilistic manner, getting benefit from the derived predictors. The results of the study demonstrate that the selected predictors are better than those of common ocean-atmospheric signals like Pacific Decadal Oscillation, North Atlantic Oscillation and El-Nino Southern Oscillation in forecasting droughts with a 3-month lead time. The research develops an algorithm for selecting strategic operating rules for the water resources of the basin considering the risk of drought. The results show a significant improvement in benefits of water resources of the basin in case of dealing with the drought forecasting system.

Abstract number - 86 ASSESSING THE HYDROLOGICAL IMPACTS OF "GRAIN FOR GREEN" POLICY IN THE LOESS PLATEAU OF NORTHERN CHINA

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Rehabilitation of vegetation system over large scale is essential for maintaining terrestrial ecosystem services and ensuring regional economic vitality. During the past decade, China has implemented a large scale "Grain for Green" program to return hilly cropland to forest and grassland in the loess plateau of northern China, one of the most serious soil erosion regions in the world. But how is the

program affecting the ecohydrological processes of the region? This collaborative research adapts the Distributed Large Basin Runoff Model (DLBRM) to the Yanhe Watershed in the loess plateau to assess the hydrological impacts of the "Grain for Green" program. The DLBRM divides the Yanhe Watershed into over 7,000 1- km2 grid cells. Each cell of the watershed is composed of moisture storages of the upper soil zone (USZ), lower soil zone (LSZ), groundwater zone (GZ), and surface. Multiple databases of DEM, land cover, climate, soil, hydrology, and hydrography are collected and processed to derive the input variables for each of the over 7,000 grid cells. The model simulates the spatial and temporal distribution of watershed hydrological processes and routes cumulative surface and subsurface flows downstream. The DLBRM is first calibrated against the observed streamflow data and then used to simulate the hydrology of the Yanhe Watershed prior to (2000) and after the implementation of the "Grain for Green" program (2008), respectively. Preliminary simulation results show that the "Grain for Green" program has produced significant effects on the hydrology of the Yanhe Watershed. Such results, once verified with field data, may be applicable to similar watersheds.

Abstract number - 88 INCORPORATING CLIMATE CHANGE PROJECTIONS INTO WATER SUPPLY-DEMAND PLANNING IN VICTORIA, AUSTRALIA

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Projections of future water availability are required by water managers in order to adapt to the potentially negative impacts of climate change on water supplies in the urban, agricultural and environmental sectors. However, in order to do this, these projections must have some level of confidence associated with them, and the research community must make the data and/or information available in a format that is directly usable by water managers. This presentation presents results from a water availability study recently carried out across south-eastern Australia as part of the South Eastern Australian Climate Initiative (SEACI). We will also show how the results of this study have been used in defining a range of plausible future streamflow scenarios to be used by water resource managers in the state of Victoria in far south-eastern Australia in updating their Water Supply-Demand Strategies for the next 50 years. Climate change projections for this region were summarised by creating 'dry', 'wet' and 'median' future runoff scenarios for 2030 and 2060 based on the 2nd driest, 2nd wettest and median global climate model (GCM) results. These results were then averaged across 27 catchments covering Victoria so that they could easily be used by urban and rural water corporations in their future water planning. Of the 27 catchments covering Victoria, reductions in mean annual runoff (relative to the long term historical average) of between 8% and 34% are projected for all 27 under both the 'dry' and 'median' future climate scenarios for 2030 and 9% to 58% in 2060. Under the 'wet' future climate scenario, only 5 catchments in the far north and east of the State are projected to have an increase in runoff. The projected reductions in runoff by 2060 are generally of the order of, or smaller than the observed reductions in streamflow during the recent drought (1997-2009). Given that climate research indicates that this drought appeared to be at least partly linked to global warming, water corporations are also being asked to consider a "return to dry conditions" scenario in their planning processes. In areas such as Victoria where there is near-unanimous agreement among GCMs as to the direction of climate change impacts on rainfall, along with theoretical understanding consistent with changes in

large scale circulation in a warmer world, projected changes in water availability can be used by water resource planners to assist them in better planning for future changes in supply.

Abstract number - 91 FUSION OF MULTIPLE PRECIPITATION INFORMATION BY ENSEMBLE ARTIFICIAL NEURAL NETWORKS

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Precise simulation of rainfall-runoff mechanism is the key issue for flood mitigation. The accuracy of flood forecasting driven by hydrological models is usually dependent on whether the precipitation information is sufficient. As far as the spatial distribution of precipitation is concerned, remote sensing data provide more useful information than ground measurements, especially in mountainous areas. In this study, the effectiveness of fusing gauge-, radar- and satellite-derived precipitation products is investigated by the ensemble artificial neural networks and the contribution of individual precipitation product to the fusing process can also be identified according to the performance in forecasting hydrological responses. The results indicate that all three precipitation products are biased and can be appropriately adjusted with an improvement rate, in terms of their contribution to flood forecasting in the testing phase, of about 9% for gauges, 17% for radars and 17% for satellites, respectively. The study demonstrates that the ensemble technique integrated into artificial neural networks not only provides a stable and reliable way to fusion procedure but also has the capability to remove both bias and random errors which might exist in any of these three precipitation products.

Abstract number - 95 ASSESMENT OF THE INFLUENCE OF CLIMATE CHANGE ON GROUNDWATER RECHARGE IN SEMI-ARID REGIONS (SERRAL-SALINAS SE SPAIN)

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In this paper we present a methodology to generate future groundwater recharge scenarios in a water resources system from information available about regional climate change scenarios generated in some European projects. This is applied in “Serral-Salinas” aquifer, which suffers an important deficit in its water budget. The proposed procedure involves generating future precipitation and temperature series by modifying the monthly means and standard deviation of the historical series in accordance with an estimation of the increment or decrement produced by climate change (which is obtained from the differences between the control and future series provided by Climate Regional Models (CRM)). Then,

the corresponding future groundwater recharge series are generated by simulating the new precipitation and temperature in a calibrated rainfall-runoff model. For the Serral-Salinas aquifer system, daily rainfall and temperature series were generated for the period (2071-2100) under 2 emission scenarios [A2, A1B]. This procedure was made based on the available information for the simulations realized for the same period, using several CRM previously developed within the European projects PRUDENCE [2004] and ENSEMBLES [2009]). The recharge was evaluated with a rain-runoff model developed with the Visual Balan code [Samper et al., 1999]), which resolves, at a daily scale, the hydrological balance. The results show an important variability of the recharge depending on the CRM used. Furthermore, significant differences have been observed when generating future rainfall and temperature time series imposing only the change in the mean, in contrast with also incorporating the effect of the change in the standard deviation. A methodology, based on multi-objective analysis, is proposed to assemble predictions by giving more value to the information obtained from the best calibrated models (those that provide better approximations to the historical period). This ensemble of predictions estimates a reduction in mean annual recharge of 14,0% for the scenario A2 and 57,7% in the scenario A1B. The future rainfall and temperature series obtained by modifying the monthly means and standard deviations of the historical series provides higher mean annual recharge than the cases defined by forcing only the mean values (reductions of 14,0% and 21,8% respectively for scenario A2; and 65,8% and 57,7% in scenario A1B). This is due to the higher number of extreme events predicted by modifying the future standard deviation of the rainfall series, despite having the same mean precipitation values. ACKNOWLEDGEMENTS: The study has been supported by the Plan Nacional I+D+I 2008-2011, projects CGL2009-13238-C02-01 and CGL2009-13238-C02-02.

Abstract number - 96 GROUNDWATER QUALITY AND ITS USE FOR DRINKING WATER SUPPLIES

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In the Middle-Amur artesian basin waters of alluvial deposits in river valleys and in basin mantle have been investigated and are currently used to provide drinking water to population (the cities of Birobidzhan, Komsomolsk-on-Amur and Khabarovsk). The major aquifer in this basin, used for these purposes is confined to Pliocene-Quaternary alluvial deposits. Water mineralization in the aquifer is 150 – 250 mg/l. Groundwater redox potential (Eh) is within the range from minus 100 to plus 100 mV (mainly from minus 50 to plus 50 mV). The composition of gases dissolved in the aquifer is the following: CO2 – 68-80%, N2 – 16-26%, CH4 – 0.7-1.9%, and their total volume is 66 – 110 cm3/dm3. Along the vertical profile of the artesian basin and across the aquifer extent area groundwater chemical composition does not significantly vary, except for iron and manganese and some increase of silicon concentrations with the depth. The following parameters of groundwater quality in the aquifer of Pliocene-Quaternary alluvial deposits do not conform to accepted standards: total iron (from 12.3 to 24 mg/dm3), manganese (from 0.38 to 1.46 mg/dm3) and silicon (from 11.2 to 19.3 mg/dm3). Low water pH (5.2 – 6.1) and high concentrations of dissolved carbon dioxide (220 – 250 mg/dm3) are also complicating factors. The next aquifer down the basin profile is confined to Eocene-Miocene carboniferous deposits. It has been studied up to the depth of 200 – 400 meters. Groundwaters of this complex are fresh waters with mineralization 580 – 640 mg/l. Their chemical composition is of sodium-bicarbonate type or of mixed cation composition. Water pH fluctuates within 7.1 - 8.92. Iron concentrations do not exceed 1 mg/l. Silicon dioxide is 6.4 - 26.6 mg/dm3. Increased concentrations of lithium from 0.03 to 0.15 mg/l, fluorine from 3.2 to 4.6 mg/l and boron from 0.8 to 2.4 mg/l were recorded. The dissolved gas composition is of nitrogen (48%) – methane (25%) – carbonate (21%) type. These groundwaters need drinking water treatment. In Khabarovsk and Komsomolsk-on-Amur new

intakes are planned to be provided with SUBTERRA water treatment, a German technology of water treatment in the aquifer. The pilot project of 3 wells, implemented at the Tungussky intake in 2007 – 2011, proved this drinking water treatment method reliable and effective.

Abstract number - 99 UNCERTAINTY ASSESSMENT OF UP-SCALED SUBSOIL PARAMETERS BY PROPAGATION OF THE COMPLETE PROBABILITY DENSITY FUNCTIONS

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When creating numerical groundwater models much information is needed like time depended driving forces (precipitation, abstraction, river stages etc.) and the structure and properties of the subsoil. All these data are subject to uncertainty. Building a groundwater model the individual geological layers have to be up-scaled and aggregated to layers in the groundwater model. If the uncertainty of the geological structure and parameter values is known, in principle, the uncertainty of the up-scaled model layer can be evaluated. The most common way to assess the uncertainty of the geological structure and parameters of the groundwater model is to use methods like Monte Carlo simulation. If many parameters are involved this is a time consuming process, which yields not always a useful result. We propose a method to perform the uncertainty propagation of the subsoil parameters by taking into account the complete probability density function (PDF) of all individual parameters. This method does not rely on a specific type of distribution function of the PDF's and can therefore widely be used. In the Netherlands, like in many other countries, we have a large database containing borehole data. Interpretation of these data involves assigning hydraulic conductivity values to all the identified thin geological layers. These conductivity values, derived from all kinds of tests, are not fixed values but are represented by a certain range that can be described by a (lognormal) PDF. Beside the uncertainty of the conductivities also the layer depth and thickness are subject to uncertainty and can be described by PDF's. When doing the interpolation of the borehole point data to the desired groundwater model grid the PDF's of the conductivities and layer depths are used throughout all calculations instead of only their mean values. In this way the complete PDF of the conductivities of every grid cell of the groundwater model is known and can be used for further analysis. In the poster we will illustrate the proposed method by a real world example.

Abstract number - 101 INVESTIGATION OF THE EFFECT OF CLIMATE CHANGE ON WATER RESOURCES USING HILBERT-HUANG TRANSFORM

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Climate change has become one of the most critical global issues. Global climate change impacts water resources in many ways: changing the temporal and spatial distribution of water resources, changing the demand and supply of water resources. The purpose of this work is to identify drought and flood

changes due to climate change. This work use HHT (Hilbert-Huang Transform) technique to analyze the streamflow and precipitation and identify the effect of climate change on streamflow and precipitation of local area. The HHT method, consisting of empirical mode decomposition (EMD) and Hilbert spectral analysis, for analyzing streamflow and precipitation can reveal the nonlinear and nonstationary nature of these two phenomena. The EMD can decompose any time series into a collection of intrinsic mode functions (IMF) and Hilbert transform can obtain a physically meaningful time-frequency-energy description of a time series. To investigate the alternations of drought and flood, we designed four cases in Shihmen Reservoir watershed, North Taiwan: annual maximum daily flow/rainfall, maximum intension of flow/rainfall, total flow/rainfall in the dry season, maximum drought days. Through hypothesis test, the results show that streamflow and precipitation are statistically significantly related to climate change. Comparison with Fourier analysis shows that the HHT method offers much better trend and frequency information.

Abstract number - 102 METEOROLOGICAL AND HYDROLOGICAL DROUGHT IN SOUTHERN AREA OF ROMANIA. CASE STUDY: IALOMITA RIVER BASIN

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The hydrological drought manifests itself by maintaining a deficit of water resources during a relatively long and continual period. The Southern area of Romania in which lies the studied basin – the Ialomita River Basin is often affected to different kinds of droughts (meteorological, hydrological or pedological), as the entire extra-Carpathian space in which the excessive characteristics of the temperate-continental climate strongly manifests. Recent studies have shown that droughts have frequently occurred in some or more parts of the country. In this paper, spatial characteristic of the meteorological droughts were studied in the southern area of Romania based an Angot index. This index, also known as the monthly rainfall coefficient, applied on series of data that refer to the mean daily rainfall quantities from the 1961-2007 period, is used to identify the characteristics of the annual variation of precipitation and moreover to identify the types of this variation during the year. In order to identify and characterize the hydrological dry periods, we have used the method of establishing the periods with liquid discharges lower than a specific threshold considered to be the onset of drought. We analyzed the liquid mean daily minimum discharges from several hydrometric posts in Ialomita River Basin. Maria Zelinskaia (1971) shows that from a hydrological point of view, the most appropriate periods to be considered dry are the periods in which the liquid discharges drop below a threshold represented by the mean daily minimum annual liquid discharge taken into consideration for the entire functioning period of the hydrometric post. In the end we have provided correlations between the rainfall amounts and the mean daily minimum annually liquid discharges and we have identified their tendencies. Key words: Angot index, mean daily minimum annually liquid discharges, meteorological and hydrological drought, Ialomita river basin.

Abstract number - 103 TREATING AN ARTIFICIAL CATCHMENT AS UNGAUGED: INCREASING THE PLAUSIBILITY OF AN UNCALIBRATED, PROCESS-BASED SVAT SCHEME BY USING ADDITIONAL SOFT AND HARD DATA

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The 1-D process-based model SIMULAT was applied to the 6 ha large artificial catchment "Chicken Creek" in Lausatia, Germany. Within the framework of a model intercomparison study, data availability was improved step by step, starting from sparse data conditions. Initially, the model was parameterised based on transfer functions (e.g., soil hydraulic properties were estimated from pedo-transfer functions) and literature (e.g., plant parameters, boundary conditions), only. Then parameterisation was revised based on field inspection and additional quantitative data (e.g., from point measurements). Finally, soil moisture data were used for validation and calibration purposes. During this parameterisation process, model results became increasingly plausible although calibration and validation against observed discharge were not feasible because discharge data were not available to the modellers. Simulated discharge dynamics changed from an initially base flow-dominated and continuous flow regime to a system in which different flow components contribute similarly to the event-based total discharge, better conforming to the hydrological process understanding with respect to the development of a gully network. Qualitative information (=soft data) gained from a field visit particularly contributed to this improvement in process understanding towards a flow regime dominated by surface runoff, while additional quantitative information on system characteristics rather served the purpose of verifying (or revising) of model parameterisation and defining appropriate initial conditions. An evaluation of simulated surface runoff rates based on event-based discharge information for a subcatchment revealed that the model overestimated the surface runoff generation for all advanced modelling steps. A final validation of model results is not yet feasible as continuous discharge data at the catchment outlet are not available so far. However, the model application indicated that integration of soft and quantitative information can considerably increase the plausibility of model results in the case of poorly gauged basins while applying transfer functions developed under natural conditions might fail in artificial catchments.

Abstract number - 104 MODIFICATIONS TO MODFLOW-LGR FOR A DEEPER INVESTIGATION OF THE INTERACTION BETWEEN VADOZE ZONE AND GROUND SURFACE

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This work is part of a larger project, named SID&GRID, funded by Regione Toscana (Italy) under the POR-FSE-2007-2013 programme. The project aims at developing a hydrological modeling environment based on a GIS platform with embedded pre- and post-processing tools. As GIS interface, the open source gvSIG framework (Asociación gvSIG, 2011) was selected, operating with a geodatabase for the storage of input/output data. Concerning the hydrological models, we selected MODFLOW-2005 (Harbaugh, 2005) groundwater code, along with the Local Grid Refinement (LGR) capability (Mehl and Hill, 2005) endowing the following tools (originally developed during the SID&GRID project): 1) The flow package Variable Saturated Flow - VSF (Thoms et al., 2006) was modified in order to be compliant with the LGR method. This allows to solve a full 3D unsaturated flow domain only in selected zones. Here, all the VSF boundary conditions modeling the interactions at the ground surface (roots uptake, ponding events, soil evaporation and seepage flows) can be successfully considered, but

thanks to the LGR method, the dramatic increase of the solution time is avoided. 2) A new MODFLOW package, named Cascading Flow (CFL) has been defined and implemented, to account for the computation of all the water volume resulting from the ground surface saturation, for both Hortonian and Dunnian processes. The package simulates the flow on the ground surface as well (the so-called overland flow). 3) New subroutines were implemented to compute the net rainfall rate, namely the actual volumetric flow of water available for infiltration after the effect of the canopy interception and direct evaporation. This subroutine was included as scripting extension in the gvSIG platform. During this talk we are going to present the major features of the original algorithms and codes developed within the project.

Abstract number – 107 ESTIMATION OF APPROPRIATE INSTREAMFLOW FOR THE URBANIZED NAMCHEON WATERSHED IN KOREA

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The objectives of this study are to estimate the appropriate instreamflow and to examine the alternatives to secure instreamflow of the Namcheon watershed in Korea. The flow duration curves in the present and the ideal hydrologic cycle were estimated by using SWMM_GE model. The present situation was simulated by using the land use and the groundwater withdrawal in 2000 and the ideal situation was simulated through the land use before 1975 and no groundwater withdrawal. In this study, the drought flows in the ideal condition was assumed as the intreamflow, and the difference between the present and ideal drought flows was supposed as the shortage of water in the river. As a result, the instreamflow was 0.305 m3/sec, and the shortage of water was 4,200,000 m3/year. and the alternatives to secure instreamflow for Namcheon watershed were proposed as reservoir repairing, permeable pavement, rain storage facilities, and controlling groundwater use.

Abstract number – 108 CLIMATE CHANGE AND WATER MANAGEMENT STRATEGIES FOR HAIHE RIVER, NORTH CHINA

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As the largest water system in northern China, Haihe River is the political, economic, and cultural center of China, and it is extremely important to China's economic development and society safety in the past years. In the context of climate change and human activities in recent years, an increasing tendency of serious water shortage has happened in most part of the River. Therefore, it is imperative to take necessary initiatives to deal with water shortage under changing environment. In this paper, the impact of climate change on water consumption in Haihe River are analysised through the data during the past year, and the potential implications of climate change on future water security problems also

discussed. The study envisaged that water shortage will be more challenging in future due to the continuous growth of population and economy, and the possible change in climate. Finally, according to the situation of water utilization in Haihe River, we proposed that water demand management, particularly increasing efficiency in water use and imposing quota to control total water demand as an efficient way for future water management, this will be possible way to realize harmony relationship between water, environment, ecology and human-being in the whole basin.

Abstract number – 109 A MULTI-CRITERIA APPROACH FOR FLOOD RISK MAPPING EVALUATION USING DEPTH-DAMAGE CURVES. THE ALGÉS STREAM CASE - PORTUGAL.

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This paper presents the main conclusions of the application of multi-criteria analysis to assess flooding risk, using depth-damage curves. The methodology for the evaluation of flooding risk is the result of research conducted in the context of an ongoing doctoral thesis in urbanism. This thesis is provisionally entitled “City, climate change and floods. A contribution to the urban resilience study in a context of extreme precipitation” and is being developed under the project “Floods and Flood Risk Maps in Climate Change Scenarios” (CIRAC) in collaboration with the Portuguese Insurance Association. The evaluation is carried out in the catchment area of Algés characterized by its small size, strong urban occupation and where torrential rainfall occurs with some frequency. Taking into account the exploratory studies performed during the definition of the EU Directive 2007/60/EC on the assessment and management of flood risks, depth-damage curves were used for this risk evaluation. A set of depth-damage curves were selected from reference European studies (e.g. MERK-study - Germany), according to their suitability to the study area. Those curves were complemented with three others, estimated using flood data (e.g., water height, velocity) obtained by hydrological modeling of historical flooding episodes and the respective material losses recorded by insurers during the last 11 years. The data included in this study was provided by an inquiry done to Portuguese insurance companies, corresponding to a universe of 57% of the total national floods related insurances. In total, seven depth-damage curves for different categories from other studies are considered. The estimated curves were evaluated in terms of uncertainty using the Monte Carlo method to determine the confidence intervals for each curve. The damage categories analyzed correspond to tangible, direct, primary damage (e.g. walls, contents, and inventory) and the estimated curves refer to walls, home and commercial/services contents. The pairwise comparison method for multiple decision makers was applied to cross the different categories of damage used in the final flood risk map. The weights given by this method and the correspondent matrix were obtained by the method of Delphi surveys. The risk analysis covers different return periods and is complemented by a functional assessment of buildings exposed to flooding. It remains to note that this is a pioneering work in Portugal as it adopts depth-damage curves as methodology to create risk mapping. In the future the same methodology will be used to assess flood risk in climate change scenarios and compared with the study presented here.

Abstract number – 110 OBSERVED AND FUTURE CLIMATE AND HYDROLOGICAL TRENDS IN SERBIA

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Considerable pressures regarding future water supply security, like in many parts of the world, are expected in Serbia. According to differences in Climate Change (CC) and human activities, the different climate and hydrological trends were obtained for the different regions of the country. For the national CC analyzes, 26 temperature, 34 precipitation and 18 hydrological stations were analyzed. This paper presents the past longterm temperature, precipitation and river discharge trends in Serbia, on both an annual and monthly basis. The period selected for analysis is from 1949 to 2006. This period is convenient because it is relatively long (58 years), data are available from numerous monitoring stations, and they exhibit a close similarity to estimated longterm temperature and precipitation trends, and particularly river discharge trends in Serbia. All the obtained trend charts were generated using Surfer software, based on data recorded at analyzed temperature, precipitation or hydrological stations, removing the stochastic component by regional averaging. The aim of the research, in addition to determine longterm trends, is to assess and forecast average relationships between an increase in air temperature and changes in river discharges and precipitation. The results indicate that the longterm average yearly trends are about: temperature +0.6°C/100 years, precipitation 0%/100 years (but its spatial distribution varies), and the river discharge -35%/100 years. Another conclusion is that all the selected hydrological stations exhibit an inversely proportional correlation between annual temperatures and average annual river discharges. On average, a 1°C increase in average annual temperatures roughly corresponds to a 20% reduction in average annual river discharges, and a 7% reduction in average annual precipitation. It was shown that an average annual temperature increase of 2°C will very likely result in half the river discharge in Serbia, on average. Some of these results have been compared with the results of other similar investigations in South-East Europe. The majority of them are similar, but there is also some important differences, particularly in intraannual trend distribution.

Abstract number – 111 SPATIAL DIFFERENTIATION AND SEASONAL VARIABILITY OF BASIC PHYSICO-CHEMICAL WATER CHARACTERISTICS OF SMALL URBAN CATCHMENT (SOKOLOVKA RIVER CASE)

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The Sokolovka river catchment is located in the north part of the city of Lodz (in the centre of Poland). Drainage area covers 19,2 km2 and the length of the main stream – 11,8 km (whereof almost 1,5 km are closed up). In the investigated area, human interference with the environment, extensively transformed its original features in a short time. The basin of the Sokolovka river and of its single tributary, i.e. Brzoza river, were turned into concrete troughs, which were partly closed and connected with the

rainwater drainage system. Within this area, the river is over three times longer than the length of a natural river network. The upper part of the catchment holds a dense residential estate of single-family buildings, and industrial development dominates in its middle section. Natural sediments, which are usually characterized by good infiltration, were covered up with a layer of anthropogenic cover (such as debris, slag, asphalt and concrete) of variable filtration conditions. Only the lower part of the catchment has maintained a suburban nature, with a significant share of arable land. In the paper spatial differentiation and seasonal variability of a few physico-chemical water characteristics of the small urban stream were shown. The analyses were based on the five-year time series. They were recorded mainly every two weeks (sometimes three times per month or more often). The obtained data was recalculated to one-week, homogenous series based on the rectangle integration rule method. This allowed to compute multiyear monthly step series of the investigated parameters and their statistics like: average, coefficients of variation, skewness and kurtosis. Special attention was paid to time variation and spatial variability along the Sokolovka river. All the examined water parameters demonstrated a seasonal changeability especially, in water temperature but also in electrical conductivity (SEC) and pH. It is interesting that seasonal variability concerns not only average and variation coefficient but also skewness and kurtosis which indicate that both quantity and data structure are changing. In the next step, seasonal decomposition of all the water physico-chemical characteristics have been made and the results compared. Also the diversity along the river may be good seen. All the characteristics show that the water quality improves in the lower course, so the catchment is divided in two different parts (urban and suburban). In the upper part (strongly urbanized), higher water temperature and a pollutant concentration have been observed, especially in the summer. The results may be used to modelling of water pollutant displacement and the river self-purification process.

Abstract number - 112 USE OF WATER QUALITY INDEX METHOD FOR RIVER CLASSIFICATION

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It is important to monitor water quality over a period of time in order to investigate spatial and temporal changes. Traditionally, water quality data is summarized in technical reports that are very valuable to individuals who understand the technical content. However, this information is not always useful to non-technical individuals. The objective of a water quality index-WQI is to turn complex water quality data into information that is understandable and useable by the public. WQI a single number that expresses overall water quality at a certain location and time based on several water quality parameters. The method has been in use since early 1970's by water authorities worldwide (Canada, India, etc.).The WQI can be used to investigate water quality changes in a particular region over time, or it can be used to compare quality between various locations. The National Sanitation Foundation Water Quality Index NSF Index was developed in 1970 by the U.S. National Sanitation Foundation. It provides a standardized method to compare the relative quality of various water bodies. Nine water quality variables are used for the index (dissolved oxygen (DO), fecal coliform, pH, biochemical oxygen demand (BOD) (5-day), temperature change, total phosphate, nitrate, turbidity, total solids). Similarly Universal Water Quality Index-UWQI has been developed by studying the European Community Standard (75/440/EEC) and aimed to classify water quality based on the referenced standard. Index determinants of the UWQI are cadmium, cyanide, mercury, selenium, arsenic, fluoride, nitrate-nitrogen, DO, BOD, total phosphorus, pH and total coliform. In both methods the mathematical equations

transforming the actual concentration values into quality indices have been formulated: The objective of the study was integration of both methods to assess appropriateness of water quality for water supply and investigate spatial differences in quality in the case of Gediz River Basin, Turkey. In this scope European Standard "concerning the quality required of surface water intended for the abstraction of drinking water in the Member States (75/440/EEC)" was referenced. Categorization scheme of NSF Index was modified to assign water quality into one of the four quality classes defined by the standard. Spatial differences in quality were determined by comparing index scores and results were validated using statistical techniques. Results showed that overall quality cannot support use of the source for drinking water supply. On the other hand water quality was heavily affected to different degrees by discharges in different locations. This approach is believed to assist authorities to evaluate appropriateness of water by classifying river based on the quality defined by the legislation.

Abstract number - 113 THE IMPACT OF CLIMATE CHANGE ON WATER SUPPLY

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The study area, Tseng-Wen Reservoir catchment in southern Taiwan, is a catchment prone to suffer droughts since it receives temporally uneven rainfall. Only fifteen percent of annual rainfall occurs during dry season. To ensure a firm water supply, the surplus water has to be kept in the reservoir during the wet season. Generally speaking, Tseng-Wen Reservoir plays a critical role in water resources system for southern Taiwan. This study aims to assess the impact of climate change on reservoir inflows and further analyze the water shortage of reservoir system. For this purpose, the study used the downscaling results provided by Taiwan Climate Change Projection and Information Platform Project (TCCIP) (Lin et al., 2010), weather generator, hydrological model and reservoir system analysis to analyze the reservoir situations under different emission scenarios. Firstly, the downscaling results were integrated with the weather generator to synthesize daily rainfall data under scenarios. Secondly, the generated rainfall data were input into the hydrological model to simulate scenario inflows of the reservoir. After deriving the reservoir inflows, a continuity equation was used to simulate the water supply process of the reservoir. Thirdly, some indicators (e.g., shortage index, reliability, resilience and so on) were used to analyze the water shortages of the reservoir under future scenarios. Then, the impact of climate change can be assessed by comparing the water shortages under future scenarios with the historical situation. Finally, this study will further address the uncertainty caused by different general circulation models and green house gas emission scenarios. Lin, L.Y., Liu, S.C., Hsu, H.H. Chen, C.T., et al. (2010): Taiwan Climate Change Projection and Information Platform Project. Research Project, National Science Council, Republic of China.

Abstract number – 116 FUTURE WATER USE DEMAND IN THE CRANS-MONTANA-SIERRE REGION (SWITZERLAND)

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Crans-Montana-Sierre is an Alpine touristic region located in the driest area of Switzerland (Rhone River Valley, Canton of Valais), with both winter (ski) and summer (e.g. golf) tourist activities. Climate change as well as societal and economic development will in future significantly modify the supply and consumption of water and, consequently, may fuel conflicts of interest. Within the framework of the MontanAqua project (www.montanaqua.ch), we are researching more sustainable water management options based on the co-ordination and adaptation of water demand to water availability under changing biophysical and socioeconomic conditions. This work intends to quantify current water uses in the area and consider future scenarios (around 2050). We have focused upon the temporal and spatial characteristics of resource demand, in order to estimate the spatial footprint of water use (drinking water, hydropower production, irrigation and artificial snowmaking), in terms of system, infrastructure, and organisation of supply. We have then quantified these as precisely as possible (at the monthly temporal scale and at the municipality spatial scale). When the quantity of water was not measurable for practical reasons or for lack of data, as for the case for irrigation or snowmaking, an alternative approach was applied. Instead of quantifying how much water was used, the stress was put on the water needs for irrigating agricultural land or on the optimal meteorological conditions necessary to produce artificial snow. We analysed the variation in water demand for the 11 concerned municipalities in regard to drinking water, irrigation, snowmaking and hydroelectricity. We formulated a hypothesis about water demand variation in relation to the major consumption peaks. Using WEAP (the Water Evaluation And Planning system) model, we estimated the future water demand of the Crans-Montana-Sierre region. This hydrologic model is distinct from most similar models because of its ability to integrate climate and socio-economic scenarios (Hansen, 1994). The results obtained using WEAP show the probable evolution of the water demand from the present to 2050 pointing out possible water conflicts between water uses at the spatial and temporal scale. This work aims to allow anticipating water conflicts through the development of new water management strategies at the regional scale. The collaboration with local and regional authorities and stakeholders will contribute to development of solutions that are practicable and acceptable, and that can be implemented in other dry regions around the world.

Abstract number – 118 THE IMPACT OF A2 MOTORWAY ON BASIC PHYSICAL AND CHEMICAL WATER CHARACTERISTICS OF A SMALL SUBURBAN CATCHMENT IN CENTRAL POLAND

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The motorways are one of the most important anthropogenic factors of water contamination. The main motorway in Poland (A2), goes through the Dzierzazna drainage basin – a small suburban catchment near city of Lodz (A=42,9 km2). This catchment is the research area of the Department of Hydrology and Water Management at the University of Lodz, where monitoring of water resources has been started at 1998. The studies involved investigation spatial and temporal variability of basic physical and chemical parameters of surface water, like temperature, pH, specific conductivity and dissolved oxygen. The paper presents the changes of water quality, before and after the A2 motorway was built. It is also

an attempt of prediction in investigated parameters. Since few years, the A2 motorway drainage system is a great impact to transformation of conductivity and alkali level of water. Motorway waters reflects clear seasonality where sever pollution occurs in winter season, which depends on winter road maintenance. Water outflow from the motorway is supposed to reach the retention ponds or the rivers. Supplying by road sewages, in the investigated period, caused changes in quality of waters. During studies, there was analyzed the impact of the road sewages to natural characteristics of river which is observed since 2006. Investigations involved statistical significance of relationship between changeability of natural and artificial water parameters. There was estimated a linear trend equation and the level of anthropogenic transformation. Results lead to conclusions that conductivity demonstrate an increasing tendency as well as seasonal fluctuations. Similar remarks relate to alkali level. The program of motorways network building in Poland is still continued. Therefore more intensive traffic and higher pollution rate may be expected. In the long-term scale it may lead to the further degradation of aquatic environment and to decrease of suburban areas attractiveness. There may be also expected other negative effects of A2 motorway in the nearest future.

Abstract number – 120 ASSESSMENT OF MEASURES FOR ADAPTATION TO PRESENT CHANGES IN CLIMATIC CONDITIONS IN A CENTRAL BOHEMIA CATCHMENT

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This contribution results from a research project on possible adaptation to recently experienced negative impacts of climate change with respect to water resources in the Rakovnický potok catchment (302 km2), central Bohemia. The project was initiated by local farmers and financially supported by Ministry of agriculture. The case study in the Rakovnický potok catchment supports the application of the guidance document aimed at the design of adaptation measures in catchments with similar problems, which was developed within the project. The analysis of trends revealed that air temperature has increased significantly since 1980s. This increase is reflected by the increase in actual evapotranspiration (provided the water is available in the catchment) and since the precipitation amount remains stable, the catchment runoff decreases significantly, especially in spring and summer. This is in contrast with the rest of the Czech Republic, where the increase in actual evapotranspiration is compensated by the increase of precipitation. Present hydrological conditions at a sub-basin level were assessed using existing data in combination with extensive measurements of stream discharges and groundwater well levels and inspection of old mines or assessment of the interaction between river flows and groundwater. Water balance was modelled for present and several scenario conditions, considering outputs of climate models for different time horizons in the 21st century. Several adaptation measures were designed and their effectiveness was estimated using hydraulic and hydrological modelling in combination with expert judgement, especially with respect to the potential increase of river discharge or groundwater recharge and flood wave transformation. The agriculture measures, characterized by changes in landuse and farming techniques, would improve soil conservation and ecological state, but have no substantial effect on catchment water storage. The same applies to river restoration. The next considered measure was represented by a set of eight small reservoirs. This option would have significant effect and has advantage in operative building of reservoirs according to changing climate, but it would not be sufficient in the case of very high temperatures (projected for the second half of 21st century) or in the case of increased water demand, especially for irrigation purposes.

However, as a primary adaptation measure, a most suitable reservoir for adaptation purposes was identified. Transfer of water from adjacent catchment is supposed to be the most reliable measure, its costs are comparable with the costs of the whole system of reservoirs. Alternatively, water could be transferred within the catchment.

Abstract number - 122 A COMPARATIVE STUDY BETWEEN ANFIS AND HBV MODELS IN CAPTURING THE RAINFALL-RUNOFF PROCESS

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Modeling of Rainfall-Runoff (R-R) process is one of the important problems in hydrology. Nowadays, two very different, but widely held, physical and theoretical views of modeling are included in different hydrologic projects, e.g. flood forecasting. In this project, a conceptual model (HBV) and an Adaptive Network-based Fuzzy Inference System (ANFIS) served as two different modeling approaches which are based on physical processes and pure statistical assumptions, respectively. A comparison between ANFIS and HBV is the intent based on a common database representing catchment of Rönne basin in Sweden. From the 43 years available data, 19 years (1961-1979) were chosen for training, 17 years (1986-2003) for validation, and 6 years (1980-1985) for testing. Appropriate rainfall, runoff, and temperature antecedents were chosen as inputs to predict runoff up to three days ahead in ANFIS. On the other hand, HBV used precipitation, temperature, and potential evapotranspiration (PET) as input, and a set of acceptable parameter was chosen and used to reflect the physical process in basin. The results show that the selected neuro-fuzzy-computational technique (ANFIS) is comparable to HBV in R–R modeling. In addition, ANFIS is found to be better at peak flow estimation compared to HBV. However, HBV can describe the ongoing physical process in the study area without knowing about specific field characteristic and will have a potential for good long time prediction. Furthermore, this study demonstrates the promising potential of neuro-fuzzy tools and HBV in runoff forecasting. A suggestion of combining these two kinds of models to make a hybrid model is made.

Abstract number – 123 LINKING CLIMATE CHANGE, HYDROLOGY AND WATER RESOURCES SYSTEMS IN IMPACT ASSESSMENT STUDIES

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Impact assessment studies on water resources should integrate the hydrological response to climate changes with the response of water resources systems (e.g. irrigated agriculture, hydropower production) and environment. This is recognised as a key issue to constitute the knowledge base for discussion among decision makers, managers, and stakeholders in order to define effective adaptation measures. To integrate the water-related perspective in impact studies, the modelling chain, which usually includes downscaling and hydrological modelling only, should be extended to include the description of the socio-economic sphere, i.e., the management policies of the water system facilities and the quantification of the stakeholder perspectives by performance indicators. This task is difficult because of the co-evolutionary nature of environment and socio-economic systems, i.e. the feedbacks between the socio-economic, the hydrological, and the climatic systems. Moreover the exact quantification of impacts is a challenge because future hydro-climate projections are uncertain and climatic conditions are expected to evolve gradually in the future. In this work we analyse the real-world case study of lake Maggiore, a regulated Alpine water system. We use time series analysis to demonstrate that increase in temperature and reduction in snow cover occurred in the last decades. We analyse the reflections of these patterns into the hydrological regime and two water-resources interests, i.e., flood protection on the lake shores and irrigation downstream the lake. To this purpose we use a lumped model of the catchment, a physical based model for the reservoir, and a decision model reproducing the water system management. The same simulation tools are used to estimate impacts over future time period. To account for the non-stationarity of the climate, we consider an ensemble of climate change scenarios from two different RCM models, amounting to 100 equiprobable simulations for each of the decades from 2010 to 2050. To preserve the multi-objective nature of the water system, the analysis focuses on a set of Pareto-optimal policies describing the lake regulation. The main advantage is that it allows to evaluate not only variations in the indicator values but also tradeoffs among conflicting objectives. Results are represented through impact maps, a visualisation tool which shows impacts in the space of performance indicators. We discuss the efficacy of the proposed time series analysis, modelling, and visualisation tools to obtain a robust assessment of climate change impacts considering both modelling uncertainty and climate interannual variability.

Abstract number - 126 HYDROPSO: A MODEL-INDEPENDENT R PACKAGE FOR CALIBRATION OF ENVIRONMENTAL MODELS

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HydroPSO is an R package implementing an enhanced version of the canonical Particle Swarm Optimisation (PSO) algorithm. PSO is a powerful population-based stochastic optimisation technique

that shares few similarities with other evolutionary techniques such as Genetic Algorithms (GA). In PSO, however, each individual of the population, termed particles in PSO terminology, adjusts its flying trajectory on the multi-dimensional search-space according to its own experience (best-known previous position) and the one of all particles in the swarm (best-known global position). PSO has low memory and CPU requirements for the optimisation of complex problems and presents a reduced number of adjustable parameters. Albeit these advantages PSO may still get trapped into sub-optimal solutions, experience swarm explosion, or convergence problems and as such the development and enhancements to the canonical PSO are active areas of research. In this work we present hydroPSO, a model-independent R package implementing several enhancements to the canonical PSO that we consider of utmost importance to bring this algorithm to the attention of environmental scientists and practitioners. hydroPSO interfaces any model code with the PSO-based calibration engine without having to invest considerable efforts in customizing the calibration engine. Some of the enhancements included in hydroPSO are: 4 alternative topologies, several types of inertia weight schemes, time-variant acceleration coefficients, time-variant maximum velocity, regrouping strategy when premature convergence is detected, and different types of boundary conditions among others. Additionally, hydroPSO implements recent PSO variants such as: Improved Particle Swarm Optimisation (IPSO), Fully Informed Particle Swarm (FIPS), and weighted FIPS (wFIPS). Finally, an advanced sensitivity analysis using the Latin Hypercube One-At-a-Time (LH-OAT) method and user-friendly plotting summaries facilitate the interpretation and assessment of the calibration/optimisation results. We validate hydroPSO against the standard PSO algorithm (SPSO-2007) employing five test functions commonly used to assess the performance of optimisation algorithms. Additionally, we illustrate how the performance of the optimisation/calibration engine is boosted by using several of the fine-tune options included in hydroPSO. Finally, we use hydroPSO to calibrate a semi-distributed hydrological model for the Ega River basin in Spain using SWAT-2005 and to calibrate a groundwater flow model for the regional aquifer of the Pampa del Tamarugal in Chile using MODFLOW-2005. Results illustrate the capabilities of hydroPSO to calibrate complex surface water and groundwater models. Based on the flexibility of hydroPSO, however, we believe this package can be implemented to a wider range of models requiring some form of parameter estimation.

Abstract number – 129 THE IMPACTS OF CLIMATE CHANGE ON RIVER REGIMES IN THE CROATIAN PART OF THE DANUBE RIVER BASIN

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Global climate change/variability in the last 30 years has been manifested mainly through average annual temperature rise, resulting in evapotranspiration and precipitation pattern change. Those changes have spatially different impact on river (discharge) regimes. An analyze of changes in discharge and discharge regimes of rivers in the Croatian part of the Danube river basin. The research area covers around 60 % of Croatia with around 2/3 of total number of inhabitants. The area has a very well developed surface drainage network with major rivers Danube, Sava, Drava, upper part of Kupa flowing marginal. To assess the change in regimes, comparison of module (Pardé) coefficients between the standard thirty years time period (1961-1990) and the last twenty years period (1990-2009) was done for selected 16 stations with homogeneous data series. In addition, Kendall-Theil (Sen) non-parametric trend test was carried for the yearly and seasonal values of discharge for the 50-year and 20-year period. Results show changes on all analyzed rivers and stations. In the last fifty years all analyzed rivers have a decrease in mean annual runoff (exceptions are Ilova and Bijela river with the moderate increase). There is an evidence of redistribution of discharge throughout the year, increase of autumn and winter

discharge (especially on rivers dominantly fed by snowmelt) and decrease of summer values of discharge. In addition, we detected the change in the month of the appearance of discharge maxima and minima. This is more evident on smaller lowland rivers. In most cases above mentioned changes can be described through changes in regime of climate elements (temperature, precipitation, evapotranspiration). We also found some signals of intensification of processes in the last 20 years. Further analyzes should focus on the catchment scale in order to assess all relevant natural and antropogenic factors influencing changes in the discharge regime of each river.

Abstract number – 130 INVESTIGATING THE IMPACT OF CLIMATE VARIABILITY AND LAND-USE CHANGE ON HYDROLOGICAL PROCESSES IN THE ELBOW RIVER WATERSHED, ALBERTA, CANADA

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Climate change is one of the most important concerns for the sustainability of water resources. It has the potential to reduce the availability of water through impacts on the hydrological components such as evapotranspiration, soil moisture, groundwater, and stream flow. The Elbow River watershed in Southern Alberta is subjected to considerable pressure from urban development and agricultural activities, and as a result, along with the effects of climate change, water availability is becoming a critical issue. This study was undertaken to investigate the combined impact of climate variability and land-use change on the hydrological processes of the watershed from the year 2006 to 2031. MIKE-SHE/MIKE-11, a distributed, physical-based hydrological model was calibrated for the period 1981-1991 and validated for the period 1991-2008 using a rigorous procedure. The goodness-of-fit was evaluated by comparing simulated and observed stream flow and total snow storage; an average NSE value of 0.6 and a correlation coefficient of 0.8 were respectively obtained. A cellular automata land-use change model was calibrated using a semi-interactive procedure based on a set of historical land-use maps generated at the spatial resolution of 60 m. Simulations of land-use changes were performed from 2006 to 2031 at a five year interval. Information about the changes in hydrological parameters such as the spatial distribution of leaf area index, root depth, saturated hydraulic conductivity, and surface roughness were extracted from each simulated land-use map and incorporated into MIKE-SHE/MIKE-11. The simulations of the impact of land-use changes over hydrological processes carried out during 2001-2031 revealed a reduction in base-flow (13%), infiltration (2%), and total river flow (4%) and an increase of overland flow (7%) as urbanization increases (65%). To understand the combined effect of land-use change and climate variability, forecasted climate data (precipitation and temperature) from

five climate change scenarios (pertaining to: warmer and drier, cooler and drier, median, warmer and wetter, cooler and wetter conditions) were directly incorporated into MIKE-SHE/MIKE-11, whereas the required evapotranspiration (ET) rates were calculated using the Hargreaves-Samani temperature-based ET estimation model. The climate change scenarios were generated from downscaled climate data predicted from five global climate models (NCARPCM -A1B, CGCM2-B2(3),HadCM3-A2(a), CCSRNIES-A1FI, and HadCM3 B2(b)). This research provides a comprehensive understanding of the impact of both climate and land-use change over the hydrological responses, and how each hydrological component varies with each simulated scenario in the watershed. This understanding is crucial for decision makers to ensure water resource sustainability.

Abstract number - 136 ENSEMBLE FORECASTS TO SUPPORT DECISION MAKING AT BASIN SCALE DURING HEAVY PRECIPITATION

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This work introduces an ensemble approach to consider the inaccuracy of the quantitative precipitation forecast (QPF) to be reflected at decision support systems for flood control. The evaluation of recent forecasts with real time in situ measurements is used to determine the prediction bias from previous time steps. A penalty weighting scheme is presented to analyze the spatial variability of the bias. The evaluation of the QPF encompasses areas larger than the watershed to detect miss-location. The noise perturbation of the ensemble members is performed considering those penalty weights and semi-random numbers. The generated precipitation spread is done at each computing cell of a distributed hydrological model. Then, the ensemble member forces the model generating an ensemble stream flows at control locations within the river network. The mean and the standard deviation of the ensemble river discharge are considered for structural or nonstructural flood control measures. This approach was employed to Tone River basin in Japan with dam reservoir system and in Huong River basin in Vietnam for early flood warning. The results from both applications showed the advantage of incorporating ensemble forecasts in decision support systems extending lead-time and providing information related to uncertainty.

Abstract number - 140 ONEGA RIVER WATER REOSOURCES IN CONDITIONS OF MODERN CLIMATE CHANGES

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The Onega River watershed basin is one of the major basins in Barents Region (Northern part of Russian European territory), its catchment area is about 57000 km2. Onega River is 416 km long, its average annual water runoff is 16 km3/year. To assess the dynamics of the Onega water resources over the XXth century and currently, an analysis was carried out to assess the changes in the hydrological regime and climate, including instrumental observations. The analysis focused on the main characteristics of the Onega hydrological regime: the dynamics of the average, maximum and minimum water runoff, and an assessment of the changes in interannual runoff redistribution. Further, based on meteorological observation and results of re-analysis, climatic parameters over the Onega river basin were analyzed. As a result, correlations have been revealed between the hydrological and main climatic parameters (precipitation at the catchment area and air temperature). It was shown that Onega River hydrological regime undergoes minimal anthropogenic impact and that the water runoff within the basin is being formed by natural factors, with climatic ones dominating. The obtained results and identification of correlations between hydrological and climatic parameters enable forecasting of short-term dynamics of the Onega River water resources based on possible climate change scenarios in the Barents Region.

Abstract number – 143 GLOBAL WATER USE AND AVAILABILITY: WHAT MIGHT THE FUTURE BRING?

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Dams, built for water storage, and water withdrawals, e.g. for irrigation purposes, directly change the dynamics of the water cycle. Climate change is expected to alter the water cycle additionally, which will subsequently impact water supply and demand. Here, a comprehensive study of climate change and direct human interventions on the terrestrial water cycle is presented. Four global hydrological models (H08, LPJmL, VIC and WaterGAP) have been run both with and without taking direct human interventions into account, using forcing data from 3 climate models (ECHAM, CNRM and IPSL) and 2 emission scenarios (A2 and B1) for the period 1960-2100. Several water use sectors, e.g. agricultural, domestic, and manufacturing water use are considered, but the main focus here is on agricultural water demands and use at annual and seasonal time scales. Preliminary results indicate that irrigation water requirements at the global scale will be higher at the end of the century than today, when taking only the effects of climate change into account (e.g. irrigated areas are kept constant). When comparing potential

irrigation water use (water is assumed available) and actual irrigation water use (water availability is taken into account), areas where the relationship between availability and demand is likely to increase or decrease in future projections can be identified. Based on a subset of the simulation ensemble, the results show that 55 percent of current agricultural water demands can be met (30-year running mean), decreasing to about 48 percent at the end of the century (groundwater extractions not taken into account). The results also indicate that the differences between water demands and availability are particularly large in parts of Southern and Eastern Asia, and are expected to become even larger in the future. There are, however, large differences in the model estimates of current and future water demands and availability, both at the annual and seasonal level.

Abstract number – 144 MODELLING SURFACE RUNOFF TO MITIGATE IMPACT ON SOIL EROSION. CASE STUDY TREBSIN

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The link between soil erosion and its redistribution on land strictly depends on the process of surface runoff formation during intensive rainfall. Therefore, interrupting and reducing continuous surface runoff, using adequate remedial measures, may be implemented in order to reduce the shear stress values of flowing water. This paper describes the outcomes of the KINFIL model simulation in assessing the runoff from rainfall on hill slopes. The model is a physically based and parameter distributed 3D model that has been applied at the Trebsin experimental station in the Czech Republic. This model has been used for the first time to simulate the impact of surface runoff caused by natural or sprinkler–made intensive rains on seven different experimental plots. The plots contain a variety of soils which are covered with different field crops. At this stage, the model parameters comprise saturated hydraulic conductivity, field capacity, sorptivity, plot geometry and surface roughness. These parameters were calibrated and then verified for the next group of observed data. All seven plots had the same slope angle, but some of them manifested vulnerable surface runoff conditions, due to their soil hydraulic parameters, i.e. their hydraulic conductivity. There were rapidly increasing depths and velocities which subsequently caused a higher shear stress for splashing soil particles downstream. The paper provides further information and data concerning the relationships between the depth of water and its velocity on the slopes of certain roughness due to different soil surface and vegetation. It also provides information concerning shear stress and shear velocity values, compared with their critical values depending on the soil particles distribution. These experiments can be extended from local to regional scale, respecting hydrological and soil parameters. This approach is more physically based than the traditional method of Universal Soil Loss Equation (USLE). The USLE method provides data on the average yearly soil loss, regardless of how significant the rainfall – runoff event is. On the other hand, the KINFIL model, in spite of its uncertainty, simulates the processes physically, on the basis of the design rainfall–runoff events. Thus, the KINFIL model reflects the process principles much better. As land use change and farming practice play an important role in this process, the simulation model can quantify water related changes caused by direct man made intervention.

Abstract number – 145 SEDIMENT TRANSPORT MODELING NEAR COASTAL AREA OF ISE BAY INCLUDING KISO RIVER

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It is necessary to evaluate the long term change of total amount of the sediment transport from rivers to ocean, in order to keep the sustainable water environment near the river mouse and coast. Sediment transport is one of the key processes of the coastal erosion and the ecosystem hazard. In order to research the mechanism of the sediment transport process, integrated water environment modeling from rivers to ocean is necessary. In this study, we developed the integrated water environment model which couples river discharge and ocean circulation model including advective-diffusion model. A distributed Hydrological River Basin Environment Assessment Model (Hydro-BEAM) and RIAM ocean circulation model (RIAMOM) are used. These two models are connected at the river mouse through the boundary conditions of river outflow, water temperature and sediment amount. Sediment amount are estimated from the experimental relation between observed suspended solids (SS) and river flow. The sediment transport model was verified against observed SS distribution data by satellite. In the case of 27/Apr/2003 simulation, maximum river flow of Kiso river exceeded 4,500 ton/s. Calculated sediments were transported to southward along the west coast with anticlockwise circulation of Ise Bay. The calculated results correspond well with the satellite data of Aqua MODIS image. By using this model, future long term change of total amount of sediment transport from Kiso river to Ise Bay will be discussed.

Abstract number - 146 A MULTI-OBJECTIVE EVOLUTIONARY ALGORITHM FOR OPTIMIZING RESERVOIR MANAGEMENT UPON HUMAN AND ECOSYSTEM NEEDS

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Hydrology plays a key role in structuring and maintaining habitats and flow regimes that influence ecological sustainability. Flow regime assessment in Taiwan has been facilitated by the Taiwan Eco-hydrologic Indicator System (TEIS). This study presents an idea of considering the relation between ecological flow regime and fish communities and then applies the gradient analysis technique in quantitative ecology theory to the ecological response model by using fish abundance and the TEIS. We build hybrid artificial neural networks to categorize stream flow data and estimate the diversities of fish families in river ecosystem by using the TEIS and then establish a multi-objective evolutionary

algorithm, the non-dominated sorting genetic algorithm (NSGA-II) for river flow management using the Shih-Men Reservoir in North Taiwan as the study case. One of the multi-objective, the ecosystem needs, is to reach fish species optimal and maximize the biodiversity index through searching the optimal operating strategies. The other one, the human needs, is to provide a lower Generalized Shortage Index (GSI) and minimize the number of water shortage months. We demonstrate that the proposed method could obtain better operational strategies than the original ones. The results indicate that the NSGA-II is a promising approach that offers a number of diversified alternative strategies for the reservoir system. The wide spread of pareto-front (optimal) solutions allow decision makers to facilely determine the best compromise through the trade-off between reservoir operational strategies for human and ecosystem needs, which makes the method more attractive to the fields of water resources management and river restoration. Keywords: Reservoir operation, Ecological flow regime, Taiwan Ecohydrology Indicator System (TEIS), Non-dominated sorting genetic algorithm (NSGA-II)

Abstract number - 147 JOINT EFFECT OF CHANGES IN CLIMATE AND LAND USE ON RUNOFF PROCESSES IN SELECTED BASINS IN SLOVAKIA

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The interaction between potential changes in climate and anthropogenic land use changes, and their joint effect on river runoff processes and the water balance in selected mountainous catchments in Slovakia were evaluated using two different hydrological models - conceptual spatially-lumped rainfall-runoff model HBV and fully distributed hydrological model WetSpa. The selected basins for the study are significantly affected by local climate conditions, and the need for high resolution climate studies is particularly important here. Therefore, to predict such changes the regional climate model ALADIN–Climate that was developed within the Sixth Framework Program CECILIA (Central and Eastern Europe Climate Change Impact and Vulnerability Assessment) was applied. The ALADIN-Climate regional model has a very high spatial resolution – 10 km and the outputs of climate characteristics, such as precipitation totals, air temperature and relative air humidity, are simulated in a daily time step. Both hydrological rainfall-runoff models were calibrated in the daily time step with data from the period of 1981-1995 and validated with data from the next 10 years period. Based on the outputs of the ALADIN-Climate model and projected changes in land use, possible changes in the runoff for the time horizons of 2021-2050 and 2071-2100 were estimated for the selected mountainous catchments located in Slovakia. We focused mainly on the changes in seasonality of runoff and its components, changes in extremes (floods and droughts) and changes in occurrence and duration of droughts and extreme runoff periods.

Abstract number – 156 DISTRIBUTED ADAPTIVE CAPACITY BUILDING TO REDUCE CLIMATE CHANGE IMPACTS ON WATER SUPPLY SYSTEMS

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Effective and flexible adaptation measures for water supply systems are crucial to reduce vulnerability and increase resilience. Climate change can significantly impact on water supply systems being consequent on changes in hydrologic cycle and water availability. It is urgent to develop suitable adaptations to reduce vulnerability in different regions which have various characteristics. However, climate change study always has high uncertainty to hold adaptation actions. Thus, flexibility is also very important for developing adaptation measures. The purpose of this study is to propose a framework to strengthen water supply systems by distributed adaptive measures, which can effectively reduce vulnerability and have high flexibility. To begin with, this study aims to establish a procedure to evaluate the spatial distribution of vulnerability of water supply systems as well as make vulnerability maps for a study area. The procedure includes downscaling methods, a streamflow model, a water supply system dynamics model, and water allocation models. Secondly, the method to screen and select possible distributed adaptation measures is proposed. Centralized water resources measures, such as building a new reservoir, are effective but more difficult and less flexible. For example, it is more and more difficult to build a new reservoir in the study area, southern region of Taiwan. Distributed measures or small systems, such as rainfall harvesting system, groundwater, water recycling system, etc., may be considered to strengthen existing centralized water supply systems. With the vulnerability maps, hot spots can be easily identified and then appropriate distributed adaptation measures can be utilized for each hot spot to reduce its vulnerability. The results indicate that following the proposed framework to identify hot spots and then to choose proper distributed adaptation measures can reduce vulnerability and enhance resilience of water supply systems. Besides, a distributed system can be relatively easier to expand or shrink its components, which brings flexibility to face uncertainty of climate change impacts.

Abstract number – 159 COPING WITH SPARSE DATA IN EVALUATING A MULTITUDE OF WATER SAVING MEASURES FOR DROUGHT MANAGEMENT IN A COASTAL WATERSHED IN NORTH-EASTERN CHINA

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In Integrated Water Resources Management, a conjunctive consideration of hydrological processes and human influences is essential. Even though a large variety of models are available for this purpose;

application of these models is often hampered by insufficient data and information. A second obstacle for an objective analysis is the sheer abundance of measures, techniques and policies to alleviate deficits in water supply, which makes it impossible to calculate all combinations. Solutions for both obstacles are presented here. Economical and especially societal information of all sectors is often difficult to obtain. This is particularly the case for agriculture, a major user of water resources. However, current agricultural structure can be seen as the result of a multitude of factors, some of which can be determined like e.g. investment costs, soil suitability, water availability. Other influencing factors like crop or irrigation change feasibility, market's uncertainty and drought risks are hard to quantify or even unknown. To include these uncertain constraints in a planning system, a likelihood assessment characterising the diversion from the current situation is introduced. The tangible effects of different measures (water demand, yield etc.) are estimated with a deterministic model. A Monte-Carlo simulation ensures the generation of a multitude of win-win solutions: reducing water use without net yield loss. The likelihood assessment is then used as a threshold to specify combinations which are more probable than others to be realised. Pareto-optimality is used to specify this decision space and select optimal measures for the agricultural sector. The second obstacle was the objective and area-specific comparability of water saving measures across different sectors. To solve this problem a metadata modelling approach in form of a dynamic water balance was used, incorporating model-based analyses of the hy-drological conditions and human impacts based on socio-economic statistics as well as on detailed studies of water utilisation in agriculture, industries and settlements. Interlinks of the human and the natural systems were categorised by water fluxes. These fluxes are modified within the planning process with the aim of attaining a sustainable groundwater balance. To reach this goal a large number of combined strategies were evaluated on basic criteria that define cost efficiency, e.g. groundwater recharge versus costs. The best water saving solutions were then localised, according to spatial priorities, opportunities and possibilities. This methodology was applied for water management planning in a coastal region of China, which is strongly affected by climate variability and overuse of water resources.

Abstract number - 162 DEVELOPMENT AND INTERPRETATION OF NEW SEDIMENT RATING CURVES CONSIDERING THE EFFECT OF VEGETATION CHANGE IN THE DA RIVER BASIN

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Suspended sediment concentration and water turbidity of a river can provide very important perspective on erosion or soil loss of river basin. The changes of land use and land cover, such as deforestation or afforestation, affect sediment yield process of a catchment through changing the hydrological cycle of the area. A sediment rating curve can describe the average relation between discharge and suspended sediment concentration for a certain location. however,the sediment load of a river is likely to be under simulated from water discharge using least squares regression of log-transformed variables and the sediment rating curve doesn't consider changes of vegetation cover monthly or yearly. The Normalized Difference Vegetation Index (NDVI) can well be used to analyze the status of the vegetation coverage well. Thus Long time monthly NDVI data was used to detect vegetation change in the past 19 years in this study. And monthly suspended sediment concentration and discharge from 1988 to 2006 in Laichau station were used to develop and interpret one new sediment rating curve. Compared with the common ediment rating curve, the new curve can simulate and predict the suspended sediment concentration better in the Da river basin. The new curve can describe the relationship among sediment yield, runoff and vegetation, it can be the basis for sustainable land cover management and soil conservation.

Abstract number - 163 CLIMATE CHANGE AND FLOOD FREQUENCY: THE CRITICAL ROLES OF PROCESS AND SEASONALITY

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Hydrological projections for flood frequency under a future climate have been developed and published for Norway. These projections are derived from ensemble modelling based on several GCM/RCM combinations representing three emission scenarios (A1B, A2 and B2). Uncertainty derived from hydrological model parameterisation and from flood frequency analysis has also been included in the ensemble of simulations. Although there is a large spread in the ensemble results for individual catchments, the regional patterns of directional change for medium to large catchments are considered robust. Regional patterns of decrease vs. increase in future flood magnitudes reflect dominant flood-generating processes and differentiate regions dominated by high flows during the spring and early summer snowmelt season from areas where autumn and winter pluvial floods comprise the annual maximum flood series. Projected increases in winter temperature, reduced snow storage and earlier peak flows contribute to an overall reduction in the probability of the largest events relative to today's climate in inland regions and in the northernmost region of Norway. In western Norway and along most of the coast, the frequency of the largest events is projected to increase due to increases in seasonal and extreme rainfall. There are, however, significant portions of Norway which are currently or will come to be dominated by mixed regimes in which both snowmelt-dominated and rainfall-dominated events contribute to flood hazard. This transition is also associated with a change in seasonality from spring/early summer to the autumn/winter period. There is, however, significant uncertainty in the projections for catchments in these areas, reflecting not only differences between climate model projections, but also as a consequence of local adjustment/bias correction techniques, hydrological model parameterisation, and flood frequency analysis techniques. To further explore the transition from a snowmelt-dominated to rainfall-dominated flood regime, seasonal flood frequency analyses were undertaken. Rainfall-induced peak flows were analysed using a peak over threshold (POT) series for each catchment, and the changes in the 50 and 100-year return period for rainfall floods were estimated based on the Generalised Pareto Distribution. In virtually all regions, an increase in the magnitude of rain-induced floods is projected, and in some areas the magnitude is only slightly less than the spring snowmelt peak flow of a similar return period. This result highlights the importance of robust analyses of changing patterns of precipitation in climate impact analyses.

Abstract number – 167 DEVELOPING AN ADAPTATION STRATEGY TO CLIMATE CHANGE: THE EXAMPLE OF A PORTUGUESE WATER SUPPLY COMPANY

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In southern Europe, water availability and water stress are already a concern. In Portugal a trend has been observed in the 20th century towards drier conditions, with decreases in rainfall and more frequent and persistent drought episodes, leading to higher water consumption rates. Climate change will further affect both water availability and water consumption in this area. The project ADAPTACLIMA is

promoted by EPAL, the largest Portuguese Water Supply Utility, responsible for the extraction, treatment, transport and distribution of 34 municipalities, with population total of about 3 million inhabitants. It aims to provide the company with an adaptation strategy to reduce their system vulnerabilities to climate change. In the first stage of the project, climate change impacts in water availability and quality were estimated for EPAL's area of interest, which includes the surface and subterranean water resources located in the Portuguese basin of Tagus River, the municipalities served direct or indirectly by EPAL and potential new aquifers. The possibility of saline intrusion in water abstractions located in the Tagus estuary, due to sea water level rise was also studied. Impacts were estimated for surface and subterranean resources using physical and empirical hydrological models, driven by downscaled climate and water use scenarios, for 2011 to 2100. Uncertainties were assessed qualitatively, according to two criteria: their level of evidence and level of agreement with previous studies. The generated climate, water availability, quality and consumption time series were compiled into several indices according to environmental, legal and operational standards and used to identify current and future vulnerabilities of the EPAL system. In parallel, EPAL's organizational structure and correspondent decision process as well as the measures and plans presently being implemented were analyzed to determine the company's current vulnerability, i.e. the ability to cope with climate related impacts. Stakeholders, including not only EPAL but also related institutions such as the Portuguese Water Institute (INAG), were involved throughout the project. Their participation, through periodical meetings, personal interviews and joint workshops, provided an important insight in several project stages such as the vulnerability assessment and the definition of the criteria for a successful adaptation. The final adaptation plan will consist of a diagnosis of EPAL's current and future vulnerabilities and a set of adaptation solutions and respective appraisal, derived from stakeholder involvement and a benchmark analysis with other case studies. Those solutions will finally be incorporated into an integrated implementation plan designed to assess which adaptation options or sequences of options (pathways) are able to better cope with the current and future vulnerability in different scenarios.

Abstract number - 172 IMPACT OF WATER ABSTRACTION ON STORAGE AND BREAKDOWN OF COARSE ORGANIC MATTER IN MOUNTAIN STREAMS

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Water abstraction is increasing worldwide as a result of rising human population, which demands higher and higher amounts of energy and water. The impacts of water abstraction on river ecosystem functioning are still poorly understood, especially those produced by low dams. Here we assess the impact of water abstraction by small hydropower schemes on storage and breakdown of coarse organic matter in 5 unpolluted mountain streams. We performed three consecutive decomposition experiments in a reach upstream and a reach downstream from each dam, and we also measured the storage of benthic organic matter. For the decomposition experiment, freshly fallen alder leaves were collected, air dried and enclosed in 5 mm mesh bags (5 g per bag). Bags were incubated in riffles. Regularly the material was retrieved (5 replicates per site), dried (70 °C, 72 h), ashed (500 °C, 5 h), weighed, and breakdown rates calculated following the negative exponential model. To determine storage of organic matter, 10 Surber samples (30 x 30 cm, 5 mm mesh) were randomly collected per reach, sorted

categories, and ash free dry mass was calculated by combustion. We also measured channel geometry, water velocity, and water physico-chemical characteristics. Water abstraction did not affect water quality, but strongly reduced discharge, drying almost completely the downstream reaches during low-flow periods. We detected no evident change in storage of benthic organic matter in grams per square metre of wetted channel, but because the wetted perimeter was so much reduced, the amount stored per linear metre of channel was reduced below dams. Also, there was a trend for organic matter to break down slower below dams. Together the results suggest water abstraction to affect storage and breakdown of organic matter, and thus, to affect stream ecosystem functioning.

Abstract number – 175 LAND USE CHANGES IN FORESTRY IN DRINKING WATER PROTECTION ZONES BY ADAPTATION TO SITE CONDITIONS AND TO CLIMATE CHANGE

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Forestry is the predominant land use category within several drinking water protection zones (DWP) in Austria. It is generally regarded as unproblematic within the context of drinking water supply, as it does not involve the use of fertilizers or pesticides like given in agriculture. Despite this fact problems with water quality in forested catchments were reported after wide spread wind-throw events or huge clear-cuts. During the last decades the focus on the purpose of integral source water protection by the application of adequate forest management practices became increasingly important within DWP. The most important feature for forest ecosystems and forest stands within DWP is stability in the sense of resilience and resistance towards disturbances. Only stable forest ecosystems can protect the soil and humus layers which are of crucial relevance for water protection purposes. This requirement is not fulfilled in many forest areas of the European Alps, as during the last century homogeneous Norway spruce (Picea abies Karst.) plantations were cultivated on several different and contrasting forest sites. However, the improvement of forest stand stability can only be achieved if the tree species set of the potential natural vegetation (PNV) is established on the differing forest sites and if natural regeneration can evolve. By the way PNV also involves a higher degree of biodiversity for the specific forest stands. Within the DWP of the city of Vienna in the North-Eastern Limestone Alps of Austria, the GIS-based forest hydrotope model (FoHyM) was developed, providing the stratification of the DWP into operational units for forest management which is based on the continuous cover forest management model. The hydrotopes were defined using the specific set of PNV as stratification level. Hence FoHyM can be applied as tool for forest management in DWP, as it defines the most stable tree species composition and forest stand structural parameters for each forest site. This provides the basic requirements for adaptive forest management regarding site conditions and climate change. The tree species set of the PNV is an important data base for any climate change adaptation within a forest hydrotope, which was fulfilled by the integration of climate change scenarios and eco-physiological characteristics of tree species. The adaptation to the climate change conditions described by the climate change scenarios involves both natural regeneration and artificial recruitment management. The overall purpose of adaptive forest management is the improvement of the water protection functionality of forests within DWP.

Abstract number – 176 HOW A MORE CONSCIOUS EUROPEAN CONSUMPTION CAN INFLUENCE GLOBAL WATER FLOWS

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The water footprint (WF) and virtual water (VW) concepts provide the opportunity to link the use of water resources to the consumption of goods. The consumption of agricultural products is responsible for the largest fraction of the WF of consumption of the European Union. The total WF of consumption of the EU27 and Croatia adds up to 857 km3, of which 636 km3 as green, 66 km3 as blue and 155 km3 as grey water. The consumption of agricultural goods accounts for 89% of the total WF, i.e. 636 km3 green, 53 km3 blue and 70 km3 grey water (total 760 km3). With a total population of 505 million people in 2010 (7.3% of the world population), this consumption of agricultural goods represented 9.7% of the total worldwide WF of agricultural goods consumption. Apart from intra-European virtual water flows between EU nations, the EU is an extra-European net virtual water importer. This means that it imports more virtual water than it exports. Especially the consumption of commodities like coffee, cocoa, cotton and animal feed results in a net import. The population of the EU is projected to remain stable, but in the wake of a growing world population, increasing urbanisation, an increase in living standards with changes in food diets (e.g. more animal products) as well as a changing climate, the pressure and competition on water resources for food production will only grow. About half of the WF of consumption of agricultural products in the EU relates to animal products. Extreme high values are attributed to the consumption of bovine meat (84 km3 or 479 l/cap/day), pork (82 km3 or 465 l/cap/day) and milk (100 km3 or 568 l/cap/day). With a total annual per capita meat consumption of 85 kg in 2005, the EU is well above the global average (39 kg). A healthy diet is by different authors defined as a daily intake of 3000 kcal per person with a 20% animal protein share. The per capita daily consumption in the EU was 3466 kcal in 2005. From the average daily protein intake of 105 grammes, 42% came from crop products and 58% from livestock products. Additionally European households waste about 76 kg of food per capita yearly. This paper explores where substantial reductions in the WF of consumption of the EU can be made. Such reductions could have a massive impact on water resources management in a changing global context.

Abstract number – 177 HYDROLOGICAL PREDICTIONS FOR SUSTAINABLE URBAN PLANNING (SUDPLAN)

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New tools for assessing water-related changes due to climate change are now available from the EU FP7 SUDPLAN (Sustainable Urban Development Planner for Climate Change Adaptation) project. The tools offer urban downscaling for intense rainfall, river flooding and air quality in addition to web based

climate scenario information on the European scale. This interactive climate service offers an improvement of simulation results if the user includes local data, which may help local decision makers around Europe to get access to hydrological predictions. The hydrological service in SUDPLAN provides information on river discharge, local runoff, relative soil moisture, relative groundwater level, temperature and precipitation. The predictions use the Hydrological Predictions for the Environment (HYPE) model, which is an integrated, process-based catchment model. In SUDPLAN we use the pan-European model setup E-HYPE 2.0. The presentation will give examples of model-performance evaluation for water-discharge predictions using regional calibration. To improve the results locally, the user can select their basin of interest from the pan-European model. The user may add locally observed time-series of water discharge at a point within this basin. This data can be used for producing improved hydrological model results (as compared to the pre-calculated E-HYPE results) by optimizing the model calibration to the available local river discharge stations. For this purpose an automatic calibration routine has been implemented that builds on well-established numerical methods. The calibrated model can be run with climate scenarios which have been dynamically downscaled and bias corrected for the hydrological modelling. For intensive rainfall, which is of major interest for urban planning, the precipitation is downscaled towards observations in a specific point with 30 min temporal resolution. By extreme value analysis, the RCM data will be used to estimate future changes in short-term precipitation extremes and in particular the Intensity-Duration-Frequency (IDF) curve which is widely used in urban hydrological design. Moreover, continuous rainfall time series with particular relevance for e.g. treatment plant loads and sewer overflow can be calculated. By analyses of continuous RCM precipitation time series, future changes in the frequency distribution of short-term intensities as well as precipitation occurrence will be estimated. The services are developed in close cooperation with end users through a number of pilot applications. The applications are evaluated for the cities of Wuppertal, Linz, Stockholm and Central Bohemia.

Abstract number – 179 CONDITIONING RAINFALL-RUNOFF MODEL PARAMETER SPACE AND REGIONALISING OF CONSTRAINTS ON STREAMFLOW INDICES TO REDUCE PREDICTION UNCERTAINTY IN UNGAUGED BASINS

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Streamflow is one of the most important elements for water resources planning. However, many river catchments remain ungauged and this poses a challenge to hydrologists to estimate streamflow with high accuracy and low uncertainty. Problems common to ungauged basins involve data availability, data quality, rainfall-runoff model suitability, and prediction uncertainty. This paper attempts to improve the estimation of streamflow in ungauged basins and reduce associated uncertainties using the approaches of constraining and conditioning prior parameter space. The upper Ping River basin, Thailand is selected as a case study and the spatially lumped IHACRES model is applied for simulating streamflow. Monte Carlo algorithm is used to sample model parameter values from prior parameter space. The modelled streamflow and three indices, including rainfall-runoff elasticity, base flow index (BFI), and runoff coefficient, are calculated and then compared with the regionalised streamflow indices that are estimated through regression equations developed from the relationship between physical catchment

characteristics and streamflow indices at gauged sites. Constrained parameter space is defined by the regression at 95% confidence level, while conditioned parameter space is determined by Gaussian error distribution depending on how close the modelled indices to the regionalised indices. The objective functions, 1-NSE and 1-log(NSE) , calculated for daily and monthly timesteps, are used to assessed the performance of the model in fitting high and low flow accordingly. Ability to capture streamflow and reduction in prediction uncertainty is judged by reliability and sharpness. The ensemble prediction ranges obtained from constrained and conditioned parameter space usually overestimate high flows and underestimate low flow. However, constraining and conditioning approaches are proved useful for reducing streamflow prediction uncertainty. The reliability obtained from constrained and conditioned parameter space is high ranging between 73-99%, but the sharpness is low, 7-31%. Achieving both high reliability and sharpness is favourable results but difficult to obtain as there is a trade-off between these two values. The potential for improving quality of predictions through using more streamflow indices and combinations of indices are being continued with an attempt to reach higher reliability and sharpness.

Abstract number – 180 ENSEMBLE STREAMFLOW PREDICTION IN WESTERN NORTH AMERICA: EXPERIENCE, DEVELOPMENT, AND QUESTIONS

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Ensemble streamflow prediction is becoming a common forecasting technique for western North American water resources management. Historically, statistical models have been used to predict seasonal streamflow volumes (including error bounds) based on snowpack, precipitation, and other measurements. While these streamflow volume forecasts may suffice for many simple planning purposes, they are insufficient for complex systems and management objectives. Ensemble streamflow prediction is the alternative methodology that can provide fuller hydrologic information for these more complex decisions. Such techniques are finding increasing use in western North America. Ensemble techniques, however, require orders of magnitude more effort than statistical models, and they are subject to several additional sources of uncertainty. These sources include initial conditions, model parameters, model structure, and future meteorological forcings. Efforts are being made to quantify each of these sources explicitly. While this directly addresses the issue, it comes at the expense of very complex modelling systems and high computational cost. Questions remain as to the ability of forecast agencies to support increasingly complex hydrologic modelling systems due to extensive resource requirements. Another less costly alternative is post-processing to ensure that the ensemble is unbiased and has the proper dispersion. These methods are under development as well. It may be that some combination of these two methodologies is best. At present, both statistical and ensemble prediction methods are used together. None of these ensemble systems, however, incorporates all sources of uncertainty, and none has a formal post-processing system. It is therefore unknown whether these forecasts are unbiased and have the proper dispersion. There are also instances -- especially in very wet or dry years -- where seasonal volume forecasts from statistical models and from ensemble prediction systems differ substantially. The reasons for this are unclear. There is therefore work yet to be done in developing robust ensemble prediction systems and in understanding forecast uncertainty. Continued work is also needed in the incorporation of forecast uncertainty into decision making. Some progress has been made in educating managers of simple agricultural irrigation systems in using error bounds around seasonal volume forecasts. For complex river basin reservoir systems, however, there is still a long way to go for decision makers to know how to understand and incorporate uncertainty in ensemble

streamflow forecasts. Clearly, there are several areas of continued development and learning necessary to achieve a robust and supportable streamflow forecasting system in western North America.

Abstract number – 181 AUTOCALIBRATION FEASIBILITY AND URBANIZATION DIMENSION INTEGRATION IN REGIONAL HYDROLOGICAL MODEL METQUL

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Regional hydrological models become more and more essential in changing land use and climate conditions. In Latvia after II World War hydrological research were developed by professor Ansis Ziverts. He developed two hydrological models: METUL for groundwater level modelling (Krams, Ziverts 1993) and METQ (Ziverts, Jauja, 1999) for runoff modelling. Both models shoved very good precision in regional scale. Early versions of these models were developed in FORTRAN programming language and were quite complicated to use. Users had to prepare complex input files manually. Also there was no possibility to autocalibrate and missing graphical interface. This paper presents first version of integrated METUL and METQ models named MET-Q-UL with auto calibration feasibility and graphical interface which allows preparing the input data for model use and visualizes model results. Early versions of models were developed for pure natural areas. However, by fast urbanization of natural areas there is a necessity to extend hydrological models with such land use dimension. A new option which allows to model runoff in urbanized areas is added to this model MET-Q-UL. To find the best approach to auto calibration Nelder-Mead; Genetic; Levenberg-Marquardt; Quasi-Newton (BFGS); Quasi-Newton (DFP); Conjugate gradient (Fletcher) and Conjugate Gradient (Polak) optimisation methods were tested. First results of applied auto calibration methods showed that Nelder-Mead optimization method is most effective and precise for chosen data set modelling both groundwater levels and runoff.

Abstract number – 183 INTEGRATED WATER RESOURCES MANAGEMENT OF AGRICULTURAL COASTAL REGIONS USING SIMULATION BASED OPTIMISATION

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For ensuring an optimal sustainable water resources management in arid coastal environments, we develop a new simulation based integrated water management system. It aims at achieving best possible solutions for groundwater withdrawals for agricultural and municipal water use including saline water management together with a substantial increase of the water use efficiency employing novel optimisation strategies for irrigation control and scheduling. To achieve a robust and fast operation of the management system, it unites process modelling with artificial intelligence tools and evolutionary optimisation techniques for managing both, water quality and water quantity of a strongly coupled groundwater-agriculture system. For modelling the aquifer behaviour (inclusive the dynamics of the seawater interface) we use an artificial neural network (ANN) which was trained by means of a database containing the responses of a numerical density depended groundwater flow model for all

realistically feasible abstraction scenarios. The behaviour of high productive agricultural farms is simulated by a database of generated stochastic crop water production functions (SCWPF). These functions describe the relationship between the crop yield, the salinity of the irrigation water and the water amount for irrigation assuming an optimal water application. The SCWPF are derived by employing soil-vegetation-atmosphere-transport (SVAT) models together with optimal irrigation scheduling and control algorithms. Considering the stochasticity of the climate variables using a whether generator together with Monte-Carlo simulations, the SCWPF allow for a prognosis of crop yields with certain reliability. Finally we apply a simulation optimisation technique together with the SCWPF-database and the groundwater ANN for determining optimal groundwater abstraction and cropping patterns which provide a sustainable and most beneficial use of groundwater for crop production over a long-term period. Due to contradicting objectives like profit-oriented agriculture vs. aquifer sustainability a multi-objective optimisation is performed. We demonstrate our methodology by an exemplary application of the south Batinah region in the Sultanate of Oman which is affected by saltwater intrusion into the coastal aquifer due to excessive groundwater withdrawal for irrigated agriculture. Based on a generated database of crop water production functions for several predominant crops in the Batinah region we show the effectiveness of our methodology for the evaluation and optimisation of different irrigation practices, crop pattern and resulting abstraction scenarios. The results of several optimisation runs indicate that only a multi-objective optimisation can provide sustainable solutions for the management of the water resources in respect of the environment as well as the socio-economic development.

Abstract number – 184 DOES WATER STORAGE COINCIDE WITH NATURE OBJECTIVES? A FAST EVALUATION TOOL

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In the past, water policy focused on a rapid discharge of water by straightening rivers, constructing of bank revetments and flood control. With a changing climate, precipitation regimes and extremes will lead to higher flow differences and increased peak discharges in rivers leading to higher flood risks. To prevent such floods, the Flemish government introduces the principal of 'retain-store-discharge' by maximizing water retention in upstream river sections. Alternatively, if upstream river sections fail to retain water, river valleys need to provide water storage facility. Water storage and flooding are important boundary conditions in nature policy and conservation. Conservation practitioners need to understand the tolerance of habitats to flooding when allowing flooding in Special areas of Conservation (SAC). From an integrated water management view point, natural flooding areas that are able to buffer high discharge of rivers are believed to prevent flooding of urban regions that are usually located downstream. As most of the natural flooding areas are situated in agricultural, nature or forest zones, the government needs a framework and tool to assess the impact of active design of floodplains in such areas. As little is known about the effects of flooding on vegetation, most decisions are based on expert judgement. The report on "multifunctionality of water storage areas" of De Nocker et al. (2007) contains tables of the degree of tolerance of vegetation types to flooding. These tables were used to evaluate whether a habitat present in SAC's can occur in combination with the expected flood regime. The flood regime was defined in terms of season, frequency, duration and depth. A GIS-based tool (OverTol) was developed to evaluate if the nature conservation goals matches the flood regime. Because of the limited knowledge about flooding tolerance and a number of uncertainties, this tool has

to be seen as mainly explorative. It, therefore, only permits a first and rapid screening of the situation, but it does not replace a detailed eco-hydrological study. Since 2011, the Research Institute for Nature and Forest (INBO) started a new project to investigate the influence of 10 years of active flooding on different vegetation types. The results of this project can be used to improve the OverTol-tool in the future.

Abstract number - 185 WATER RELATED CHANGES AFTER INTENSIVE BOREAL FOREST HARVESTING

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The availability and quality of water are strongly influenced by forests. Climate change associated disturbances in the hydrological cycle are increasing and mitigating these impacts creates the need to strengthen the study on forest and water relationships. This is important in the boreal forests where the intensive wood harvesting is strongly increasing and likely can cause progressive changes in the character of the forests. The wide intensive study was carried out in three phytogeographical areas in Finland representing southern, middle and northern boreal forest zone to understand hydrological cycle in respect to climate change. Altogether 249 wells were set before cutting in 2006 after the radar scanning of the groundwater table to monitor groundwater. The effects of intensive wood harvesting were studied by using different harvesting treatments which were 1) Uncut control, 2) Clear cutting, 3) Clear cutting with 70 % logging residue removal, 4) Clear-cutting with 70 % logging residue and stump removal retaining 25 stumps/ha and 5) Harvesting all stumps and logging residues. The results are evaluated in respect to earlier groundwater study after waste wood harvesting since 1985, which is the longest monitoring data of groundwater quality after regeneration cutting in Finland. Groundwater catchment areas from north-eastern Finland were also implemented into the project in 2010. Clear-cutting and subsequent harvesting leads nitrate leaching into the ground water more than other elements. Increased leaching started a year after harvesting and is still increasing five years after treatments. Earlier study showed the water quality effects over 25 years. In addition to leaching, hydrological processes are now evaluated with the precipitation-runoff models applied to the catchment areas. In the conference the experimental layout and results in context of utilizing boreal forests will be discussed.

Abstract number – 187 IMPACTS OF CLIMATE CHANGE ON THE WATER RESOURCES AND ADAPTATION MEASURES IN THE DANUBE RIVER BASIN

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Global Change will have regional impacts on the water resources in Europe. The Danube River Basin as Europe's second largest catchment with a total area of 801,500 km² provides water resources for 83 million people in 19 countries. In this region, water is used in various ways, ranging from agriculture to energy production and navigation. Despite these important water use functions, the Danube River Basin is characterized by a wide range of different natural conditions and contains several highly valuable ecosystems. Climate change impacts will cause changes in mean water availability, water temperature, water quality and in extreme hydrological events like floods and droughts, which consequently trigger changes in all water related areas. In order to provide a basis for the development of appropriate adaptation measures and strategies to be prepared for future changes in the Danube River Basin, a study, funded by the German Federal Ministry for the Environment, Nature Conservation and Nuclear Safety, was carried out in close cooperation with the ICPDR as well as local experts and stakeholders. During the study all important basin-wide climate change impacts on water-related issues were identified by analysing ongoing and finalized research and development projects. Moreover, adaptation activities such as National Adaptation Strategies were analysed in order to find communalities, options for cooperation and challenges among the 19 countries of the Danube River Basin. Firstly, an overview of climate change impacts on the different fields of water availability, water quality, extreme hydrological events, biodiversity and forestry as well as of water supply, water demand and different water uses will be given for the entire Danube River Basin and its sub-regions. Secondly, according to the analysis, possible win-win and no-regret adaptation measures will be identified for each impact field. Communalities among the measures, options for an international cooperation within the Danube River Basin, and measures, where challenges in reaching a common understanding might arise, will be discussed.

Abstract number – 189 ASSESSMENT OF SURFACE WATER-GROUNDWATER INTERACTION IN THE ENGLISHMAN RIVER WATERSHED USING GEOCHEMICAL AND STABLE ISOTOPIC PARAMETERS

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The Englishman River Watershed in Parksville, BC is over 50% reliant on groundwater. Increasing development pressures have raised local, provincial and federal government concerns over sustainability of water resources. The Englishman River is a significant water source to support future growth and economic development. Managing long-term sustainable use of this resource is imperative

for both ecologic health and economic prosperity. As water demand pressures grow, it has been recognized that surface water and groundwater are not two independent water sources that can be managed separately. Sustainable water management requires new knowledge of the degree of groundwater-surface water interaction within a watershed. New methods to assess this seasonal interaction are required. Developing geochemical tools that can place constraints on these complex systems will aid development of hydrogeological models, which can be used to support decision makers in water allocation. The objective of this study is to assess the extent and nature of seasonal surface water-groundwater interaction using geochemical and stable isotope tracers. Stable isotope and geochemical analyses of precipitation and groundwater will provide geochemical and isotopic signatures for these sources. The precipitation data will yield a Local Meteoric Water Line (LMWL) for the study area. Geochemical and isotopic data will provide fingerprints of end-member water sources. Analyzing the observed seasonal surface water values, alongside the precipitation and groundwater values will provide relative source contributions to surface water. This will allow for a quantitative assessment of groundwater-surface water interaction of the Englishman River Watershed. Preliminary results reveal that in summer the discharge is predominantly baseflow derived (fed by groundwater) due to seasonal dry conditions. In contrast during the fall and spring seasons, discharge is comprised of both rainfall and groundwater, and in the winter, discharge is fed predominantly by rainfall. Interestingly, the chemistries remain constant throughout the year despite varying sources, suggesting that rainwater must travel through groundwater pathways before it is discharged into the river.

Abstract number – 190 APPLICATION OF INUNDATION MODEL TO IDENTIFY THE INUNDATION CHARACTERS AFFECTING THE SEDIMENTATION PROCESSES IN THE FLOODPLAIN

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In the recent years, numerous studies underlined the influence of inundation on floodplain morphology. However, less focus was given on the quantification of its influence. The aim of our study is to introduce an inundation model that calculates frequency, duration and shear stress in overbank flow channels for given input data. The calculated information can serve to identify and possibly quantify how inundation characters affect the sedimentation processes in the floodplain. In the following study, a reach of 12.7 kilometers located on the upper Rhône river, near Brégnier Cordon (southeast of France) is studied. The inundation model based of LiDAR and rating curves provides the frequency, the duration and the intensity of the inundation for each pixel of the floodplain for given time steps of discharge. For calculation of the intensity, the average and maximal discharge in the studied period of time was chosen. The error of calculation was estimated as a sum of LiDAR's precision and precision of hydrologic data. The outcome of model is compared with sedimentation rates provided from previous field campaigns for predicting floodplain evolution using multivariate statistical methods.

Abstract number – 194 NEURO-FUZZY MODELLING OF LAND-USE CHANGES

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Land-use changes are considered as one of the most important factors affecting groundwater resources by changing groundwater recharge conditions. The forecast of such important variable is required to develop of groundwater management and protection strategies. Land-use changes largely result from economic growth; therefore, it is proposed the construction of fuzzy logic models based on the dynamics of Gross Domestic Product. An analysis has been conducted in the area of the Main Groundwater Reservoir No 326. The aquifer is located in southwest Poland. It serves as drinking water resource but due to geologic conditions the aquifer is vulnerable to diverse sources of pollution. Models were developed for 6 communes lying in the case study area. The land-uses are divided into: arable land, forest, meadow and pasture, orchard and others. Simulations of land use changes for each commune were done by application of fuzzy models in Takagi-Sugeno's architecture. Assessment of relationships between input and output variables was done on the basis of historical data by using an Adaptive Network based Fuzzy Inference System. The Toolbox Function ANFIS (MATLAB, The MathWorks Inc.) was adopted to create fuzzy models. On the basis of the economic growth, presented in National Strategy of Regional Development 2010-2030, and the developed fuzzy models the land use changes in communes were forecasted. Because neuro-fuzzy models are built on the basis of the trends observed in the past, these trends are transferred to the future by forecasts. In urban communes and in some rural communes the further growth of urban areas is projected at the expense of agriculture areas. In typical rural communes, where the development of the agricultural land-use was observed, forecast shows a further increase in arable land. Changes are not linear, because the input variable (the growth rate of GDP) varies in the forecast period; it is higher in the period 2010-15 and lower in 2016-30. It causes that land use changes could be more significant in the first period and milder in 2016-30 for some kinds of land use.

Abstract number – 197 QUANTIFYING THE ROBUSTNESS OF COASTAL POLDER AREAS TO METEOROLOGICAL DROUGHTS: A CASE IN HOLLAND

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For many delta areas, climate change is a trigger to reconsider current strategies for flood and drought risk management. In the western polder areas of the Netherlands, intensive agriculture demand fresh water supply from the large rivers during summer. This fresh water is needed for irrigation, but more importantly to flush the irrigation network that suffers from salt groundwater seepage. Partly due to climate change, the fresh-water demand is expected to increase in the future. At the same time, the fresh-water inlets from rivers may be closed more often because of too high chlorine concentrations in the rivers. These occur when river discharges are too low to counteract salt intrusion from the North Sea into the open estuaries. Water managers are therefore considering new measures to enhance the balance

between fresh-water demand and supply. Deciding between measures requires insight into the functioning of the drought risk system, and especially into the system's robustness to meteorological variability. We consider a drought risk system as the combined physical and socio-economic system. This paper describes the analysis of the robustness of a drought risk system in the Netherlands. We followed a three-step procedure. First, we defined the system and divided it into subareas, based on geography, land use, and average surface water level. Next, the agricultural damage in the relevant subareas was calculated for a number of meteorological years in the past: an average year, a moderately dry year, and an extremely dry year. To select an appropriate drought indicator, various common indicators were compared (e.g., the Standardized Precipitation Index). An agricultural damage model was used to estimate the drought damage in these years. From the results we established a relationship between drought severity and agricultural damage. The shape of this response curve reveals the system robustness and allows quantification of three key robustness criteria: the resistance threshold, the response severity and the response proportionality. Finally, we analysed how hypothetical events affect the system response, for example a dry summer preceded by a very dry spring or an extremely low river discharge during a dry summer. The study reveals which uncertainties influence the relationship between drought and agricultural damage most. These should be taken into account when selecting measures to enhance the drought risk system's robustness.

Abstract number – 201 ASSESSING THE IMPACTS OF CLIMATE CHANGE AND URBAN DEVELOPMENT ON WATER-RELATED ECOSYSTEM SERVICES ACROSS MULTIPLE SPATIAL SCALES

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Climate change and urbanization are rapidly changing the provision, use, and value of water-related ecosystem services (WES), such as flow regulation, drinking water supply, flood mitigation, and temperature regulation, on rural-urban fringe landscapes. Forecasting potential shifts in such WES is critical to identifying the form and magnitude of likely impacts on watersheds. An interdisciplinary team of scientists is using two ecosystem services assessment models (Integrated Valuation of Environmental Services and Tradeoffs – InVEST and Counting on the Environment - COTE) to quantify expected changes in WES provision, use, and value in the Northwestern Lower Willamette Valley of Oregon. A landscape level model InVEST is compared with empirical site level COTE model at multiple spatial scales. Additionally, InVEST hydrologic model outputs are compared to BASIN-SWAT (Soil Water Assessment Tool) and SWAT-Temp at a sub-basin scale. Local Index of Spatial

Autocorrelation (LISA) measures identified spatial clustering of WES. Based on multiple methods, we analyzed the provision, use, and economic value of water yield, nutrient and sediment retention on the current landscape at the plot scale and the sub-basin scale and how the current level of WES will spatially shift under the combination of multiple climate change and land development scenarios. We are determining what areas, if used less intensively or conserved, would most cost-effectively prevent any expected declines in the value of WES on the landscape where cost-effectiveness is measured as WES value generated per economic opportunity cost of conservation. We have been engaged with policy stakeholders in the analysis to explore the interaction of WES science, scale, and complex policy negotiations. This project will deliver essential decision-relevant information for improving the WES provision. This research will thus illuminate the unexplored area of tradeoffs and complementarities among multiple WES shifts and spatial targeting for land conservation to sustain ecosystem services in a rapidly growing metropolitan fringe.

Abstract number - 203 MODELLING THE FUTURE – ARE OUR MODELS FIT FOR THE PURPOSE?

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Different types of models are frequently used tools to make quantitative estimations for possible future scenarios. Surprisingly often some form of stationarity assumption is made either explicitly or implicitly despite the fact that simulations are performed for changed conditions. The commonly used split sample test does not allow to test whether a model, or model chain, is suited for the purpose of providing reliable simulations under changed conditions. Therefore, here differential split sample tests were used for two different cases. Firstly, it was tested how hydrological models of different complexities perform, when they are used for conditions that differ from calibration conditions. Secondly, it was studied how bias-correction methods, which are needed when regional climate model (RCM) simulations are used for hydrological impact studies, perform, when they are used for simulations that differ from those used for parameterization of these methods. The main conclusion is that differential split sample tests are challenging tests, which highlight problems in our ability to provide reliable simulations for future conditions. At the same time, only such challenging tests allow to move forward toward models, and model chains, which are fit for the purpose of simulating future conditions.

Abstract number – 206 CLIMATE CHANGE IMPACTS ON WATER RESOURCES IN YEMEN

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Climate change impacts on water resources are expected to be significant in Yemen. Efforts have been made to understand the expected changes and develop mitigation possibilities for the expected scenarios for a future sustainable use of resources and mitigation of expected impacts. The work described in this paper addresses this issue with the overall objective to quantify the impacts of climate change and variability on the water resources in Yemen. The paper describes the development of a detailed baseline

database and the assessment of climate change and variability impacts on water resources over the 2030, 2050 and 2080 time horizon on a Yemen-wide scale. Based on downscaled Global Climate Model data, a range of scenarios were established, representing potential Mean, Warm & Wet and Hot & Dry conditions as derived by evaluating worst case scenarios from the ensemble of the global models for the specified years. An Excel spreadsheet approach was used to model the climate scenarios and related impacts. The water balances are calculated on averaged, mean monthly values as well as a yearly basis with each Wadi catchment representing a hydrological unit. The model calculates potential evaporation, considers land use classes with crop factors and estimates initial losses to calculate evapotranspiration. Together with the number of rain days and the precipitation, the rainfall excess is computed. Surface runoff and baseflow is then calculated per catchment with an incremental area approach, taking into consideration local geology, slope, overland- and channel flow velocity. Infiltration was calculated from precipitation minus evapotranspiration and total runoff. The results of the model include an estimated runoff coefficient, monthly quantities of rain, runoff, infiltration and evaporation representing the water balance in the different catchments. Analysis of the different evaluated scenarios shows that in the Mid and Warm and Wet scenario the hydrological components are generally higher than in the baseline scenario. For the Hot & Dry scenario, runoff, infiltration and evapotranspiration are decreasing due to the decreasing precipitation and increase in temperature. The relative changes in runoff are strongest. The general climatic circulation pattern is kept in all scenarios. The rainy season in July and August results in relatively constant infiltration and runoff for the Mid scenario and an increase in infiltration for the Warm & Wet scenario until the 2080s. The Hot & Dry scenario however, shows an overall decrease in these parameters for the rainy season. A change to the baseline pattern can be observed for March and June for all scenarios in all years. The climate is getting wetter in these periods, leading to higher evaporation, infiltration and runoff.

Abstract number – 208 HYDROMORPHOMETRIC STUDY FOR SOME DRAINAGE BASINS ON SABER MOUNTAIN, TAIZ, YEMEN

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The present study aims to analyze the hydromorphometric properties for some drainage basins in the area of study. To achieve the mentioned goals, it has been relied on some research approaches, they are the descriptive approach, spatial analysis approach, and the quantitative experimental approach, which were applied in the present research, depending on GIS programs in the various stages of the research, as well as machinery methods that had been used in order to take advantage of this technique to process and analyze the data entered into the computer to produce digital maps. ArcMap9.3, WMS8.1 and other programs were used to construct drainage patterns and basins in the area of study, and the production of formal qualities (morphometric) of the basins. We also studied the density of drainage influence on the velocity of runoff during rainfall storms. Selected drainage basins gave an integrated database on geomorphological characteristics and, therefore, can be utilized to develop a comprehensive view of the possibility of suggesting appropriate technologies for water harvesting.

Abstract number – 209 CONTRIBUTION OF DAMS IN UAE TO THE RECHARGE OF SURFACE AQUIFERS

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Contribution of Dams in United Arab Emirates to the Recharge of Surface Aquifers Prof. Dr. Riadh H. AL-Dabbagh Ajman University of Science & Technology The UAE is divided into two distinct zones: the larger low-lying zone and the mountains zone. The first covers over 90% of the country's area, extending from the northwest to the eastern part of the country where it is truncated by mountains zone. The low-lying zone ranges in altitude from the sea level up to 300 meters. Its major part is characterized by the presence of sand dunes which rise gradually from the coastal plain reaching their highest elevation of 250 m above sea level (amsl). Along the coast of the Arabian Gulf, the low-lying land punctuated by ancient raised beaches and isolated hills which may reach up to 40 m in some locations .Due to the recharge-discharge imbalance, a distinctive depletion of groundwater table has occurred in most aquifers in UAE. The existing imbalance has originated as a consequence of lack of natural recharge and extensive discharge. Groundwater recourses in the UAE have been over exploited to meet the increasing water demands, especially for agricultural purposes, during the last two decades. Detention dams are designed to retard the flow velocities and allow appropriate time fore the recharge process to take place. Retention dams are designed for water storage with large quantities and relatively high hydraulic heads. On the other hand, water might be used directly from the storage for irrigation purposes. During the last two decades the UAE government has built more then hundred dams. In addition to the numerous dams, several observation wells have been installed to monitor the subsurface water levels as well as changes in water quality. The main objective of this study is the evaluation the effectiveness of dams in recharging shallow groundwater aquifer.

Abstract number – 210 ANALYSIS OF IMPACTS OF IRRIGATION IMPLEMENTATION ON THE HYDROLOGY OF LERMA GULLY (ZARAGOZA, SPAIN)

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Irrigation surface has increased considerably during last decades and it trends to continue growing to feed a major population and better live standards all around the world. Little is known regarding the hydrological impacts of irrigation implementation, especially regarding temporal evolution of affected variables. This work assesses hydrological effects in a gully after the change to irrigation of its hydrological basin. With this purpose, flow, electrical conductivity and nitrate concentration were recorded in Lerma gully (Zaragoza, Spain) for 8 hydrologic years, i.e. before, during and after implementation of irrigation. Non-parametric statistical treatment was applied to the data set in order to understand relationships and trends in flow, water quality parameters and exported loads of pollutants. Results showed how median flow was highly correlated with irrigation, mass of salts and nitrates exported, although no significant relationship with precipitation was detected. Implementation of irrigation supposed an increase in flow (3.2 l/s year), decreasing salinity (-0.38 mS/cm year) in the

gully, but it has been detected an increase in nitrate concentration (5.4 mg/l year), increasing the exported loads of contaminants (salts and nitrates, 193 Mg/year2 and 8.0 kg/year2 respectively) to receiving water bodies. Results provided an insight on hydrological changes of implementation of irrigation and its temporal evolution, which are important to understand to achieve an adequate environmental and water resources management.

Abstract number – 216 FUTURE WATER CHALLENGE OF CENTRAL ASIA

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The region is under influence of a number of dynamic factors shaping potential water supply and depending on the balance of demand and resources. Traditionally, the resource side was characterized by flow variations and from side of demand population growth and industrial production, and, accordingly, of water demand in terms of quantity, quality, and service degree by all water users. The current situation is exacerbated by new circumstances: • irregularity of flow formation between upstream and downstream countries and interdependence of the countries in terms of water; • most main water sources are of transboundary nature and consequently competing aspirations and actions of the countries; • change in character and orientation of water demand; • worsening of water measurement in transboundary sources and in the countries; • weakening of financial capacities of the governments and water users and as a result, worsening of water supply reliability. Forecast of future situation prepared for period 2010 -2035 in different combination of climatic, hydrological, socio-economic and water management scenarios for basin of two principal rivers: Amudarya and Syrdarya. Analyze had done for most typical 6 scenarios. Recommendations concluded next: - principal attention should be done to Amudarya river with biggest expected deficit; - reassessment of present practice season and multiyear regulation in direction of establishment of combine regime of flow with equal account of interest of irrigation, hydropower and ecology; - interstate program water saving and improvement management on the base implementation IWRM; - enforce mechanism of trust between states as set of political, legal and institutional measures. Performed modelings complex ASBMM2 created by SIC ICWC together with IHE UNESCO will give to decision-makers to assess and find own solution adaptive to riparian states.

Abstract number - 217 IMPACT OF HUMAN ACTIVITY ON AGRICULTURAL LAND IN UKRAINE: SOIL DEGRADATION, WATER AND EROSION-HYDROLOGICAL PROCESSES IN CATCHMENT AREAS

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Social and economic transformations of land relations in Ukraine stimulated development of a number of negative processes that caused diminishing of agricultural lands biological potential and intensive Ukrainian soil cover degradation. Land privatization and large land massifs re-allotment caused general violation of agricultural crops growing agro technology, crop rotation nonobservance, dramatic decrease of organic fertilizer application dosage and stubbing of field forest shelter belts. Decrease of soil fertility and development of erosion processes has become the consequence of that. According to land cadastre data 13.3 mln. Ha of arable land is influenced by water erosion and 2.0 mln. Ha is influenced

by both water and wind erosion. Level of soil degradation based on quality values characterizes this process as close to desertification. The issue of regulating spending one of the principal natural resources – water has become topical in this relation. As well as the need to rationally use agro technical and organizational factors to avoid loss of liquid runoff and soil loss as the basis of management strategy of erosion-hydrological process in agro landscapes. Patterns of melt and storm water runoff are one of the most important issues in investigating erosion-hydrological processes of catchment areas. Interrelated understanding of qualitative side of this process is given by hydrological station observations in the small river basins and outlets of gully and elementary catchment areas. The attempt has been made in the process of investigation to justify the principles of forming soil and water protection ecologically balanced agro landscapes using the patterns of erosion-hydrological processes in the system: small river basin – gully catchment area – elementary catchment area. The landscape-hydrological method was used aimed at identifying the interrelation between principal factors determining the nature of water erosion display in small river basins and gully catchment areas. Landscape-ecological catchment area characteristics Landscape components and erosion-hydrological factors Small river basins 1 2 Catchment areas km2 37-7160 63-3700 Tillage degree, % 45,2-86,9 45,2-84,4 Forest coverage (State forest fund and hydrographic network), % 1,22-19,8 1,50-19,30 Agricultural land forest coverage, % 2,10-4,20 2,10-6,20 Other soils (infrastructure), % 0,10-10,00 8,40- 55,40 Natural forage lands, % 10,90-26,90 1,20 - 19,30 Average annual precipitation total, mm 442-535 432-583 Average weighted slope angle, degrees 0,013-0,066 0,01-0,05 Catchment area length, m 1000-6000 1500-7000 Area ruggedness, km/km2 1,65-3,45 1,76-2,74 Average annual river discharge, m3/sec 18,00-259,00 6,24-101,00 Area erosion ratio 1,11-1,20 1.03-1,20 1 – North Steppe; 2 – South Steppe

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Abstract number – 218 QUANTIFYING UNCERTAINTY AT DIFFERENT CATCHMENT SCALES ARISING FROM THE INPUTS TO LARGE-DOMAIN HYDROLOGICAL MODELS

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Large-domain hydrological models are used for flood forecasting across Europe, continental and global water resource estimates and for making continental predictions of future climate impacts on discharge and other hydrological variables. Because it is unfeasible to collate local data to set up such models, readily available regional and global databases are usually used to provide input data. This study shows that the errors arising from the use of regional and global scale databases are catchment scale dependent and may be significant at smaller scales. A pan-European application of the HYPE model, E-HYPE was used to evaluate subbasin delineation and precipitation input data. The E-HYPE model simulates hydrological and nutrient transport variables for the European continent in subbasins with a median resolution of 215 km2. Flow is routed between catchments so both local runoff and accumulated discharge and nutrient variables can be calculated. First, the errors in subbasin delineation and linking from the HYDROSHEDS database were evaluated using 832 discharge gauges situated in independent catchments ranging from 200 km2 to 482000 km2 as validation points. At each of these points, the upstream catchment area in subbasins delineated from the HYDROSHEDS grid was compared with the published upstream catchment area from each gauge. It was shown that HYDROSHEDS was useful for delineating catchments > 5000 km 2, but for catchments in the range 500 to 5000 km2, only about 60 % could be correctly delineated and results were worse for catchments < 500 km2. This has large implications for extracting medium to high resolution outputs from a large-scale hydrological model. The second large uncertainty in large-scale hydrological models comes from choice of precipitation data for forcing the hydrological model. In setting up the E-HYPE model, a number of the current state-of-the-art gridded precipitation products, both interpolated and reanalysis data, were used to simulate

discharge across Europe using a subbasin resolution of 215 km2. As well as inter-comparison of the precipitation products and comparison to more detailed national data sets, the error in simulated discharge in the E-HYPE model indicated regions where the precipitation products were poor. All of the precipitation products evaluated were poor in at least one region of Europe, usually related to the availability of precipitation gauge data in that region when creating the precipitation product. This lead to large errors in simulated discharge, particularly in smaller catchments where the local precipitation was incorrectly estimated. Despite the errors in both catchment delineation and precipitation, it is necessary to use these regional or global scale databases to set up and run large-domain hydrological models. It is therefore important to be aware of the uncertainty in the model as a result of these errors. This was shown to be catchment scale dependent for both subbasin delineation and precipitation, so a threshold catchment scale for which results from large-domain models are useful can and should be defined as a result of input data validation.

Abstract number – 220 REGIONAL RAINFALL FREQUENCY ANALYSIS USING L-MOMENTS APPROACH FOR CHELIFF BASIN, NORTH WEST ALGERIA

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Extremely great floods are among environmental events with the most disastrous consequences for the entire world .Estimates of their return periods and design values are of great importance in hydrologic modeling, engineering practice for water resources and reservoirs design and management, planning for weather-related emergencies, etc .Regional flood frequency analysis resolves the problem of estimating the extreme flood events for catchments having short data records or ungauged catchments. Regional frequency analysis uses data from a number of measuring sites. A region is a group of sites each of which is assumed to have data drawn from the same frequency distribution. The analysis involves the assignment of sites to regions, testing whether the proposed regions are indeed homogeneous, and choice of suitable distributions to fit to each region´s data. Three statistics useful in regional frequency analysis described: (i) a discordancy measure , for identifying unusual sites in a region; (ii) a heterogeneity measure , for assessing whether a proposed region is homogeneous; and (iii) a goodness-of-fit measure, for assessing whether a candidate distribution provides an adequate fit to the data and (iv) estimation of precipitation quantiles corresponding to various return periods. The final procedure allows for the estimation of these quantiles at sites where no precipitation information is available.

Abstract number – 221 APPLICATIONS OF HILBERT HUANG TRANSFORM (HHT) AND EMPIRICAL MODE DECOMPOSITION (EMD) IN HYDROLOGY AND CIVIL ENGINEERING

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The objective of this study is to build a stochastic model to simulate hydro-meteorological variables, which typically contain nonstationary oscillations (NSO). At present, the literature contains very few stochastic models that adequately reproduce the NSO processes. In the current study, we illustrate a stochastic simulation model based on the Empirical Mode Decomposition (EMD). The model procedure is to decompose the observed time series and then to simulate the decomposed components with an NSO resampling (NSOR) technique. The proposed model has been tested to simulate a number of test functions containing NSO as well as the North Atlantic Oscillation.

Abstract number – 225 SURFACE-GROUNDWATER INTERACTIONS AND NONSTATIONARITY OF LOW FLOWS; A CASE STUDY IN THE UPPER NAMOI RIVER, AUSTRALIA

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It has long been established that the surface and groundwater (SW-GW) systems are connected with continuous exchange of water between rivers and aquifers. Low flow periods pose an extra challenge to water managers, who must balance competing demands for water. The paucity of surface water during dry periods leads to a higher demand for groundwater, which eventually depletes river and causes further declines in surface flow during dry periods. In this paper, we focus on these aspects using a case study in the Namoi River catchment located in New South Wales, Australia. The work involves two components; the first is a numerical groundwater modelling component, and the second is a statistical analysis of low flows. The numerical modelling showed that during a hypothetical extended drought period, the predominantly gaining Boggabri-Narrabri reach of the Namoi River turned into losing; the extended drought condition resulted in significant declines in water levels especially away from the river. The sensitivity of the groundwater model showed that the SW-GW fluxes are most sensitive to groundwater pumping and the RBOT parameter of MODFLOW during drought conditions whereas the model was more sensitive to the hydraulic conductivity and specific yield during flood periods. The low-flow analysis highlighted the nonstationarity of low flows. A general downward trend in the log-transformed baseflow (LTB) was noted, which clearly reflects a declining groundwater contribution to the river. The 10th percentile LTB exhibited a much steeper downward-trend than the higher percentiles during drought conditions, which highlights the effects of increased groundwater pumping in the region. The trend was steeper in the Boggabri data than the Narrabri data, since groundwater pumping has increased more significantly upstream of Boggabri during the drought. The collective knowledge acquired from the three modelling approaches conducted in this study leads to a better understanding of SW-GW interactions in the Namoi thus leading to improved water management especially during low flow conditions.

Abstract number – 226 STREAM FLOW MODELLING UNDER GLOBAL CHANGE: ON STABILITY AND SPATIO-TEMPORAL CONTINUITY OF MULTIDIMENSIONAL RESPONSE SURFACES

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Global change and changes in land use inevitably, apart from other issues, lead to increasing uncertainty of the runoff modelling and forecasting caused by significant transformation of the overall shape and topography of multidimensional response surfaces, which are directly or indirectly analyzed to identify the optimum parameters of multi-parameter hydrological models. As a result, previously calibrated models become less reliable. To resolve this problem, additional analysis of stability and spatio-temporal continuity of the model response surface is required. In particular, stability of local optima of the response surface defines reliability of the model parameters, while patterns of its spatio-temporal continuum define their transferability to ungauged and poorly gauged catchments. All the necessary tools for such analysis have been developed and implemented in the Russian State Hydrometeorological University. The presented studies were supported by the Federal Purpose-Oriented Program on the Priority Directions of Scientific and Technological Development (Ministry of Education and Science of the Russian Federation, contract #P1103, 02.06.2010).

Abstract number – 230 THE HYDROCHEMICAL CHARACTERISTICS AND EVOLUTION OF WATER RESOURCES IN THE WESTERN PART OF THE RIVER NILE, EL MINIA GOVERNORATE, EGYPT

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A combination of major and trace elements have been used to characterize surface- and groundwater in El Minia district, Egypt. Surface water versus groundwater chemistry data enabled geographical zonation and chemical types to be differentiated. The main target of this research is to investigate the groundwater quality and hydrochemical evaluation. The situation is further complicated by contamination with lithogenic and anthropogenic (agricultural and sewage wastewaters) sources and low plan exploitation techniques. The investigated Pleistocene aquifer is composed of sand and gravel of different sizes, with some clay intercalation. The semi-confined condition was around the River Nile shifted to unconfine outside the floodplain. The groundwater flow generally from south to north and

locally diverts towards the western part from the River Nile. Fiftysix, 11, five, and two water samples were collected from the Pleistocene aquifer, River Nile, Ibrahimia canal, and Al Moheet drain, respectively. The collected water samples were analyzed for major and trace elements. The toxic metal concentrations of Al Moheet drain are higher than those in the River Nile and the Ibrahimia canal. Cr, Hg, As, and Cd concentrations in the River Nile and Ibrahimia canal are fluctuated above and below the WHO drinking standards. Se concentration in River Nile and Ibrahimia canal is below WHO drinking and irrigation guidelines. Total dissolved solid content in groundwater is generally low, but it is increased due to the western part of the study area. The geographic position of the River Nile, Ibrahimia canal, and Al Moheet drain impact on the groundwater quality. The PHREEQC confirm the high mixing proportions from the River Nile into the groundwater and decline away from it. In addition to the thicknesses of the Pleistocene, aquifer and aquitard layer enhance the River Nile and agricultural wastewaters intrusion into the aquifer system. The toxic metal concentrations (Pb, Cd, Cr, PO4, Se, Mn, As, Hg, Ni, Al, Fe, and SIO2) in groundwater were increased mainly in the northwestern and southeastern part (far from the River Nile). It is attributed to anthropogenic, high vulnerability rate (unconfined), and partially to lithogenic. In most localities, the groundwater are unsuitable for drinking and irrigation purposes with respect to Se concentration, while they are unsuitable for dinking according Mn, As, and Hg contents. There are some Cd and Pb anomalies concentrations, which cause severe restriction if used in irrigation. The results suggested that significant changes are urgently needed in water use strategy to achieve sustainable development.

Abstract number – 232 IHACRES MODEL OPTIMISATION BY GENETIC ALGORITHM TECHNIQUE AND SENSITIVITY ANALYSIS

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IHACRES model optimisation by Genetic algorithm technique and sensitivity analysis IHACRES is a lumped hydrological model for simulating streamflow by rainfall and temperature (or evapotranspiration) data. The core of IHACRES consists of a number of parameters which must be estimated by a calibration method. In the latest version of IHACRES, a grid searching scheme has been embedded as a calibration scheme which requires an upper bound, a lower bound and a step value for each parameter. Estimating the best range and step value for each parameter is tricky but very important on the precision of the obtained parameters. During the current study, it was found that, the IHACRES grid searching scheme can be trapped in to a local optimum. Also, defining wrong ranges for parameters can lead to a long computational time for deriving the optimal parameters. Hence, GA was investigated as an alternative calibration method to find the IHACRES parameters. The performance of GA was compared with the grid searching model by using the Root Mean Square Error (RMSE) coefficient. For this purpose, two different data sets were selected to evaluate the obtained parameters in terms of calibration and validation process. In another attempt, the computational time was compared for two optimisation schemes to find out which method achieves an optimum parameter set faster. After investigating about the calibration methods, it was confirmed that, GA can achieve more reliable IHACRES parameters. Also, GA tends to spend less computational time in comparison with the IHACRES grid searching scheme to derive the IHACRES parameters. An accurate and well calibrated rainfall-runoff model can be mentioned as a first point of flood forecasting studies. Obviously, an ideal flood simulation can lead to a more accurate flood forecast in future. After finding the IHACRES parameters, the model was analysed for checking the parameter sensitivities by the Generalised Likelihood Uncertainty Estimation (GLUE) technique for model updating as a method to improve model predictions.

Abstract number – 234 RAINFALL-RUNOFF MODELLING ANN: ITON RIVER

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The rainfall-runoff relationship is often a complex system at basin scale. This is even more complex with hydrogeological behavior (karstic system). Non-linearity is often arising from spatiotemporal variation of rainfall and karstic feedback also temporal variation of runoff. In this hydrogeological context, flood forecasting becomes hard to prevent society from flood damages especially for early warning alert to local authorities. Nevertheless non-linearity of rainfall-runoff is a principal cause which limits classical modeling tools. Our contribution focus on ANN modeling applied to the Iton watershed (northwest France). The Iton River has a 1035 sq.km catchment (at the Normanville hydrometric station) with topographic amplitude of 283 m. During the low water period, each year the Iton surface flow is subject to limited or total dewatering for 5 to 8 km which is locally named "Sec-Iton" (i.e. Dry Iton). These karstic phenomena act have a complex storage system providing a buffering capacity for winter floods. Since the late 19th century (i.e. 1881 flood) and in the downstream of Iton River, few hydrological events have been seen. It can be a subject to easily understand that Iton downstream floodplain communities depends on the possibility to prevent major flood event by early warning based on robust flood forecasting. This is why this research is conducted in close collaboration with the French flood warning service of Normandy (i.e. SPC 76). Our contribution addresses the ANN potential to forecast the Iton flood peak at different lag time (i.e. +6h, +12h, +24h, and +48h) based on rainfall-runoff response data set. Our results clearly demonstrate through classical ANN benchmark indicators (i.e. RMSE, MARE, Nash and Persistence criteria) both in training and validating phases that ANN modeling offers a very good flood peak prediction. Moreover ANN model of Iton is hundred percent meeting the needs of early warning levels estimations used by the French flood forecast service which is divided in four classes (i.e. from safety green conditions to red flood alert conditions). Our ANN model is thus successful both for flood forecasting and early warning decision making.

Abstract number – 235 CHANGE PRESENCE DETECTION USING A REGIONAL MODEL FOR UNGAUGED BASINS

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A simple two parameter model for ungauged basins is developed within the revision process of existing methodology for generating mean monthly flows at ungauged basins based on multiple nonlinear correlation. The proposed model requires hydrological and geo-morphological input data only. The

model is regional and as such it envisages formation of separate pools of donor catchments for model parameter estimates. Potential donor catchments are selected among available time series at hydrologic stations by Nash-Sutcliffe's model efficiency coefficient (NSE). The paper examines a potential of the regional model for detecting presence of a change in observed hydrologic series through identification of changes in model parameters. Since spatial interpolation from a gauged to an ungauged basin is possible only from hydrologic stations with undisturbed flow, at this stage of model development, detection of changes presence is crucial in the data preparation process. The proposed methodology was verified using the monthly runoff data sets from hydrologic stations in Serbia. Nash-Sutcliffe's model efficiency coefficient (NSE) was used to assess quality of the proposed model with 'observed' model parameters at forty hydrologic stations. These are the stations with systematic flow observations during the period 1961-2005, divided into three subperiods. Change in observed model parameters and in NSEs at stations within these subperiods is examined. A significance of change as a tool for verification is discussed, based on an example of known human induced impact within the basin (i.e. reservoir construction), in which conventional testing of series for homogeneity and randomness independence is also performed. Also, a potential of the proposed model for climate change detection at hydrologic stations is discussed.

Abstract number - 236 ASSESSING CONCEPTUAL MODEL UNCERTAINTY OF HYDROLOGICAL IMPACT OF CLIMATE CHANGE

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Predictions of hydrological models are by definition uncertain. In the case of prediction of climate change impacts on hydrology, uncertainty due to climate change scenarios is strongly exacerbated. The estimation of conceptual uncertainty of hydrological models is however mostly not determined. This study focuses therefore on the contribution of conceptual uncertainty of hydrological models in the assessment of the hydrological impact of climate change. For a lowland catchment in Belgium the climate of the reference period (1960-1991) is compared with plausible climate scenarios for 2066-2095. The uncertainty of the climate change is described by low, mean and high hydrological impact climate change scenarios as simulated by a perturbation tool. These scenarios summarize, based on their hydrological impact, the climate change for the region as derived from the PRUDENCE and IPCC-AR4 databases. The climate change scenarios are used to drive four distributed physically based hydrological models of the Kleine Nete catchment: a SWAT, PRMS and a semi- and fully distributed WetSpa model. Because all four models are calibrated with four different objective functions the hydrological model ensemble consists of 16 models. The uncertainty bounds due to the hydrological model ensemble is assumed to give a first indication of the importance of the conceptual hydrological model uncertainty. The results show that for both average monthly discharge as well as extreme peak and low flows the different hydrological models show large differences. During the winter and summer season the uncertainty on average monthly discharge is mainly determined by the climate change scenario while during spring and autumn the main uncertainty originates from the hydrological models. For the low impact scenario the uncertainty range on the mean monthly runoff is comparable to the range of the

reference period, for the mean and high impact scenarios however this range is significantly larger. For the extreme high flows the mean and high impact scenarios predict an increase in peak discharge, while the low impact scenario predict an increase in peak runoff only for peak events with a return period larger than 1.6 years. All models predict for every scenario a decrease of low flows, except for SWAT models with mean scenarios. As it is rather difficult to compare objectively the differences between the concepts of models, it is difficult to trace the origin of the demonstrated conceptual prediction uncertainty. Hence, there is a need for testing conceptual hydrological process uncertainty contribution with more flexible hydrological models.

Abstract number – 237 WATER REGIME VULNERABILITY DUE TO CLIMATE CHANGE IMPACTS ON SNOW COVER BUDGET AT MOUNTAINOUS BASINS OF THE MEDITERRANEAN

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In this presentation, the coupling of a climate change model data with a distributed hydrological model was developed in order to explore the impact of climate change on snow cover and consequently on water resources availability at the river basin level. Firstly, data from the Regional Climate Model (RCM), developed by the Max Planck Institute for Meteorology in Hamburg, Germany, were used to provide boundary conditions for the spatially distributed hydrological model MODSUR-NEIGE (MODélisation des transferts de SURface en présence de NEIGE, in French), developed by the School of Mines, Paris, France. Secondly, the snow melting process based on the degree-day approach was analysed in order to study the water flow vulnerability due to climate change impacts.The methodology is illustrated for the Mesta/Nestos river basin, which is shared between Bulgaria and Greece and is part of the worldwide UNESCO-HELP initiative. The upstream northern part of the basin (Mesta) is in Bulgaria, and the downstream part (Nestos) is in Greece. The topographic relief of this basin located in the northern Mediterranean zone, has highly mountainous morphology in the upstream and extensive valleys and deltaic areas in the downstream area. In conjunction with the trajectories of the weather systems it results on not having a single climatic type throughout the watershed extend. The practically alpine climate in the mountainous parts, in controversy to the coastal Mediterranean one, is differentiated by large periods of snow cover and is of particularly importance with the water releases during the thawing period to be vital to the environment, the irrigation schemes and patterns, the potable water infrastructures and the hydropower installations. According to observed and projected changes in climate as they related to water, phenomena such as the temperature augmentation and consequently the acceleration of the evapotranspiration process and the snow cover alterations in terms of distribution, thickness and days per year are bound to be dominant during the current century. Changes in water quantity and quality due to climate change are expected to affect food availability, stability, access and utilisation.

Abstract number - 239 ESTIMATION OF AVERAGE AREAL RAINFALL IN MOUNTAINOUS WATERSHED

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Determination of the average areal rainfall on a watershed is a fundamental requirement for many hydrologic studies. Though some new techniques such as raider system have been developed, it might be still difficult to estimate the average areal rainfall (AAR) over a whole basin. Especially in a mountainous area, the methods which reflect the influences of the local topography, slope and exposure of a relief on rainfall should be required instead of the traditional and conventional methods such as arithmetic and Thiessen method. The observed watershed is typical mountainous area in Japan, altitude ranges from 100 to 1900 m and area is 197 km2. Rainfall data have been collected at five gauging station and a new station was recently installed at higher elevation. The rainfall data at other station outside the watershed were used for analysis along with the stations inside. Annual AAR was calculated by using (1)the arithmetic mean; (2)the Thiessen polygon; (3)elevation regression method; (4)Isohyet method, and (5)combine method. Combine method is new method which is proposed by us in order to take consideration of horizontal and vertical distribution of areal rainfall which is given by a equation: Pcomb= r2.Pelev + (1-r2).Rh , where r2 is determination coefficient of elevation regressive method and Rh is AAR estimated by arithmetic, Thiessen polygon or Isohyet method. Before estimation of AAR, the relations between rainfall and elevation were investigated by using monthly data. As result, it could be concluded that the relations were effective to estimate the rainfall at higher elevation. After prediction of higher elevation rainfall, AAR of whole watershed area was calculated by the traditional and proposed methods. The consideration from water balance concept showed that annual AAR by arithmetic and Thiessen method were under estimation, while Isohyet, elevation regressive, and combined method gave reasonable values for annual AAR. Estimated daily AARs by the three methods were used as input data into a hydrologic model to calculate the daily discharge of research area. Furthermore, the snowfall and snowmelt sub-model was developed using the Degree Day Factor. Calculated values of discharge by two type of a runoff model, first which included the snow sub-model and other one did not include it, were compared with measured discharge along winter and spring season, in purpose to test reliability of the sub-model and reliability of AAR estimation methods. It could be concluded that the estimated AAR were reasonable as input data for the model and the snowfall and snowmelt sub-model also gave better result for result for daily runoff modeling.

Abstract number – 240 FROM DATA ASSIMILATION TO MULTI-TEMPORAL UNCERTAINTY PROCESSORS TO IMPROVE REAL TIME FLOOD FORECASTING AND EMERGENCY MANAGEMENT

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In water resources management, and more specifically in flood emergency management, decisions, which may generate dramatic social and economical consequences, must be taken on the basis of variables such as water stages, discharges, water volumes, etc. without perfect knowledge of the future evolution of the hydro-meteorological phenomena. This lack of knowledge or uncertainty on future occurrences is commonly called "predictive uncertainty". A possible definition of predictive uncertainty is: "Predictive uncertainty is the expression of a subjective assessment of the probability of occurrence a future (real) event conditional upon all the knowledge available up to the present (the prior knowledge) and the information that can be acquired through a learning inferential process". From this definition, the need emerges for using hydrological model forecasts in order to reduce the predictive uncertainty, usually expressed in terms of a probability density (or probability distribution) function, "conditional" upon the available observations and hydrological model forecasts, which are now seen as the available, although uncertain, extensions into the future of observations. In other words, hydrological model forecasts are a way to complement the prior belief of the decision maker in order to reduce "his" prior uncertainty within the frame of the decision making process. Data assimilation into initial conditions and in predictive models to improve their performances or on model outputs in order to match the latest observations can also be considered part of the predictive uncertainty problem since it tends to reduce the uncertainty bandwidth. Unfortunately the improvements provided by data assimilation tend to rapidly vanish with the lead-time. Recent approaches aim to assess and reduce predictive uncertainty via uncertainty processors, such as the Bayesian Model Averaging or the Model Conditional Processor that allow combining several model forecasts, as well as several members of forecasting ensembles, to provide a single and more reliable forecast in terms of the expected value of the predictand (water level, discharge or water volume), together with a measure of its uncertainty, conditional on all the models and all the members of the ensembles. Noticeable advances have been made in the last decade in predictive assessment. The latest research developments deal with multi-temporal predictive uncertainty assessment to allow answering two questions that are essential to the flood emergency managers: (1) Which is the probability of flooding (or more in general of overtopping a threshold) within the next N hours? (2) At which time interval the flooding (or the threshold overtopping) event is more likely to occur?
Starting from data assimilation the presentation will discuss alternative approaches to predictive uncertainty assessment with their pros and cons and, through a number of examples taken from real world cases, will show the improvements that can be obtained when using the multi-temporal approach.

Abstract number – 241 MODELLING TIME SERIES OF WATER TABLE DEPTH TO PREDICT EXTREME LEVELS IN A WATERSHED LOCATED IN OUTCROP AREA OF GUARANI AQUIFER SYSTEM (GAS)

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Predictive modeling of water table depths provides useful information for groundwater management. To support effective actions on water management, it is necessary to monitor water resources, to model hydrological processes, and to simulate the effects of policy measures. In this direction the knowledge about the spatio-temporal dynamics of the water table is important to optimize and balance economic and ecological interests, a main issue to Brazilian police makers and stakeholders. In this study a transfer function-noise model, the so called PIRFICT-model, is applied to estimate the dynamic relationship between water-table depth and precipitation surplus/deficit in a watershed located in a Guarani Aquifer System (GAS) outcrop area. Time series modeling is an elegant way to treat monitoring data without the complexity of physical mechanistic models. Time-series model predictions can be interpolated spatially, with the spatial differences in water table dynamics determined by the spatial variation in the system properties and the temporal variation driven by the dynamics of the inputs into the system. Time series analysis combined with geostatistics can model the dynamic behaviour of the water-table levels in the Onça Creek watershed, municipality of Brotas/SP, Brazil, resulting in maps with possible water-table levels for specific dates. The results are demonstrated for the wet season in the area, when extreme shallow water-levels can be a problem for agriculture and plan development. The final results in the form of maps can subsidize the decision making processes in groundwater management and long-term water policy.

Abstract number – 242 IMPACT OF LAND USE CHANGE ON HIMALAYAN HYDROLOGY, A MODELLING APPROACH

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The impact of land-use changes on the hydrological dynamics of a monsoon dominated Himalayan river system is analysed in the Dudh Kosi river basin (3,711 km2). The total forest cover is 41% and shrubland, grassland and agriculture occupy 18%. The rest is bare land (25%) and glacier (14%). Two land-use change scenarios have been parameterised in the basin. In Scenario 1, a more realistic scenario has been perceived where the forest area up to 3,000 m, adding up to about 28% of the total forest, has been converted into shrubland due to deforestation. It is assumed that the forest cover will be replaced by other vegetation types such as bushes in case of clearance. In Scenario 2, a worst case scenario is assumed where all forest area is converted into bare land realizing a total deforestation of the 41% and

converting the latter to bare land. In the modelling context, it is assumed that the infiltration is reduced in the case of bare land than forests.
The process oriented distributed hydrological model J2000 has been applied to understand the impact of the land-use change on hydrology. The model showed satisfactory results in simulating the hydrological basin dynamics between 1985-1997 and is defined as the baseline for change detection. In scenario 1, streamflow is increased by 1% showing that there will be very minimum impact on hydrology by converting forest to shrubland. Evapotranspiration (actET) is decreased by only 4% because the shrubland evaporates at a lower rate than the forest. In scenario 2, actET is decreased by 24% and streamflow is increased by 7% in total compared to the baseline condition. The bare land will produce less evapotranspiration from a soil surface due to lack of vegetation. The deforestation scenario has more influence on different runoff components. Due to less infiltration in bare land areas, the precipitation quickly drains the ground surface as overland flow. The scenario analysis of deforestation was carried out by producing ensemble runoff for different infiltration scenarios. This analysis indicated that the overland flow could be increased up to 32 % compared to the baseline period. The maximum increase was observed to lower infiltration condition. On the contrary, the baseflow could decrease up to 20 %. This is because of the less infiltration which causes less groundwater storage and associated flows. In the monsoon dominated Himalayan river systems, the role of vegetation in transpiration is partly overshadowed during the monsoon season due to intense rainfall and prevailing saturated soils. Due to enough water content in the soil, a higher amount of actET is expected without vegetation also. This study shows that the likely land-use change scenario has minimum impact on hydrology. However, in the case of worst case scenario, the flooding events might be increased.

Abstract number – 249 RAINFALL PATTERN IN IBA OKU RIVER BASIN, AKWA IBOM STATE AND ITS IMPLICATION ON STREAM FLOW REGIMES

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Available records of daily rainfall data at Uyo recorded for a period of 34 year (1977- 2010) was subjected to rigorous statistical analysis such as measures of central tendency and variability, time series analysis, Spearman's Rank Order statistics etc. The results indicate annual rainfall ranges from 1599.5mm in 1983 to 3855.5mm in 1977, (recorded between 1977 and 2010) with a mean of 2466.6mm: unimodal monthly distribution (with no pronounced August break)): concentration of rainfall in the months of April –October, mostly high intensity prolonged rainstorms: downward trend in annual rainfall in a cyclical pattern and the regression equation Y = 8.159x + 563. Field survey/measurement, focus group discussion and in-depth interview confirm the incidence of dried streams, particularly order-1 streams which drains the University of Uyo town campus. Other streams have shrunk to mere trickles of water in their channels. This study justifies the need for flood/erosion control, particularly in un-gauged basins.

Abstract number – 250 CLIMATE CHANGE IMPACTS ON THE FLOOD REGIME OF AN ALPINE WATERSHED

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The complex process of runoff genesis in Alpine watersheds results from a combination of higher precipitation induced by orographic effects, reduced evapotranspiration rates caused by relatively low mean temperatures, and temporary storage in form of snow and ice. Global climate change may lead to a modification of these factors and thus may have considerable impacts on flood characteristics of Alpine catchments. The objective of this investigation is to assess the impacts of climate change on the flood regime of the Alpine Lech watershed. The Lech catchment covers an area of ~1,000 km² and is located in the northern limestone Alps. The impacts of climate change are assessed by following a classical 'one-way' approach from global to local climate information, and eventually to the hydrological model. Two General Circulation Models (GCMs) are used to simulate current (1971-2000) and future (2071-2100) climate. In order to bridge the gap between the coarse GCMs output and the needs for local climate information, downscaling methods are usually applied. However, most methods are able to reproduce the mean behaviour of the variables and only a few techniques are reported to reasonably downscale extreme events like floods. In this study the Expanded Downscaling (EDS) technique is applied. EDS is a further development of the multiple linear regression concept and is particularly suited to the simulation of extreme events like floods. EDS is calibrated and validated on the basis of observed atmospheric fields taken from the European Centre for Medium Range Weather Forecasts (ECMWF) data set and local climate data. The downscaled climate data is then used to drive the semi-distributed hydrological model HQsim to examine possible changes in flood hazards. When forcing the hydrological model with downscaled climate data from the ECMWF dataset, a good agreement between observed and simulated average and extreme runoff is detected. Changes in flood hazard potential are assessed by comparing simulated runoff series for future times with the control period. Projected shifts in the occurrence of peak flows during winter and summer will be presented and the resulting changes in the frequency-magnitude relationship of floods will be discussed. An analysis of the uncertainties in the projections will show the reliability of the obtained results.

Abstract number – 253 RIVER INFLOW FORECASTING FOR RESERVOIR REGULATIONS: THE CASE OF NAMAKHVANI HPPC ON R. RIONI, GEORGIA

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The main issue addressed in the paper is related to river inflow forecasting for hydroelectric power system management and reservoir regulations. The case of Namakhvani Hydro Power Plan Cascade (HPPC) on river Rioni in Georgia is illustrated. The Namakhvani HPPC is one of several large to medium hydro power generation facilities planned to use the large hydro power generation capacity of rivers in western Georgia. Accurate time and site-specific forecasts of stream flows and reservoir inflow are required for effective hydropower reservoir management and scheduling, as the part of planning and optimization of country and region power system. Forecasting reservoir inflow is needed for water management and operational planning over periods from a few hours to several months ahead. In the past few decades, a wide range of hydrologic models has been proposed for this purpose. This is not easy task, as the rainfall-runoff relationship is one of the most complex hydrologic problems to understand and model, because of the uncertainty of hydrological and meteorological parameters and

scarcity of adequate records. Artificial neural networks (ANN) can be an efficient way of modeling stream flow processes as it is capable of controlling and modeling nonlinear and complex systems and does not require describing the complex nature of the hydrological processes. In this study, two ANN models, a Multi Layer Perceptron (MLP) network and a Radial Basis Function (RBF) Network, were implemented to forecast weekly reservoir inflow for Namakhvani HPPC on river Rioni. The two employed input parameters were antecedent precipitation and antecedent runoff. As output, the networks were trained to generate current runoff. Multiple evaluation statistics have been employed to estimate the accuracy of predicted flow. The results have shown that ANN could provide high training and testing accuracy and could generate significantly good results. The RBF models have the advantage that they can be developed and implemented with much less time compared with the MLP models and require less knowledge about the functioning of ANNs. The results of the presented study have demonstrated the potential of ANNs in inflow forecasting. The ability of ANNs to cope with missing data and to update model in real time makes it an attractive alternative to conceptual models. The results show that ANNs can be successfully applied to forecast runoff using rainfall time series for the studied catchment.

Abstract number – 258 PREDICTING ECOLOGICAL RESPONSES TO A CHANGING CLIMATE

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The management of freshwater ecosystems is usually achieved through the regulation of water quantity (limiting diversions and providing environmental flows) and quality (setting limits or targets for constituent concentrations). While considerable effort has been invested in predicting water quantity changes as a result of future climate scenarios and management actions, we know considerably less about potential water quality and ecological responses. Central to our lack of understanding is the lack of integrated quantitative tools for predicting the relationship between future climate scenarios, human activities, water quality and ecological responses. Predicting the ecological responses is particularly challenging because of the feedback inherent between climate change, water quality, water volumes, human use and biota. An innovative hierarchical modelling approach is being developed to predict the effects of climate change on water quality and ecological responses in the Upper Murrumbidgee River Catchment (NSW, Australia). Bayesian networks are being used as the high level framework to elicit, capture and express our knowledge by integrating the hydrological, water quality and ecological domains. This approach allows the power of traditional modelling techniques (such as hydrological modelling) to be linked to less well developed models of water quality and ecological response. The ecological endpoints are being considered in terms of threshold changes in community structure, rather than attempting to model the full range of responses. A combination of published studies, historical data sets, and expert opinion is being used to define the thresholds of changes in macroinvertebrate, fish and macrophyte communities. Preliminary work using macroinvertebrate community responses

demonstrates the importance (and challenges) of identifying appropriate thresholds, particularly in Australia where ecosystems have adapted to a high natural variability in both stream flows and water quality. Nevertheless, the focus on key ecological outcomes has advantage for defining the level of effort being invested in modelling both water quality and flow metrics, thus managing the complexity of the task. Beyond the direct implications for the Upper Murrumbidgee catchment, the work is expected to demonstrate a transferrable scenario-based framework for integrating knowledge from climate science, hydrology, water management, stream ecology to support climate adaptation policies.

Abstract number – 260 ASSESSMENT OF POSSIBLE CHANGE OF DESIGN FLOOD CHARACTERISTICS IN MOUNTAINOUS PERMAFROST BASIN CAUSED BY GLOBAL WARMING

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While the climate warming in the Arctic is a generally recognized fact, its impact on hydrological processes is still unresolved issue. The Russian Arctic has great potential for the development of hydropower industry which would require reliable assessment of design flood characteristics in changing conditions as a base for effective management and environment safety in future. Traditionally in Russia the frequency analysis of observed runoff characteristics is used within the tasks of engineering and design. Those statistical methods developed on the basis of assumption of hydrological processes stationarity do not include the comprehension of physical processes in a catchment and may lead to erroneous assessment of runoff characteristics under present and future climate change conditions. The alternative method is the application of a process-oriented hydrological model coupled with the data of global climate models as sources of forcing meteorological data. The Kankunskaya hydropower plant is being constructed on the Timpton river which is located at the upstreams of the Lena river in southern Yakutia. The basin is characterized by mountainous relief and severe climate conditions. It is covered by discontinuous permafrost which greatly affects its hydrological regime. The aim of the study is to assess possible changes in runoff characteristics of the Timpton river at the Kankunskaya dam location by 2035, 2050 and 2100 using the CMIP5 projections and the hydrological model Hydrograph. The Hydrograph is a distributed deterministic model of runoff generation processes developed in State Hydrological Institute (St. Petersburg, Russia). The model parameters are observable properties of soil and vegetation and require minimum of manual calibration. Therefore it has a high potential to be applied in the tasks of climate change impacts assessment. The ensembles of meteorological data for the Hydrograph model were derived from the CMIP5 results. The design flood characteristics of the Timpton river were assessed based on simulated daily flows corresponding to different scenarios of climate in 2010-2100. The runoff characteristics calculated by i) the traditional method ii) the Probable Maximum Flooding (PMF) approach and iii) using deterministic hydrological modelling combined with the outputs of global climate models would be compared and analyzed. Analysis of the results and the recommendations of designed dam characteristics will be presented.

Abstract number – 261 MODELLING EXPERIMENTS IN RESERVOIR OPERATION MANAGEMENT: ESTIMATION OF POSSIBLE CLIMATE PRESSURE ON THE KAMA RESERVOIR, RUSSIA

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Assessment of climate change impacts on hydrological cycle and its individual processes is a prerequisite for the development of new strategies to mitigate environmental risks and adapt the reservoirs and hydropower plants operation rules to future conditions. The aim of this study was to estimation of possible impact of hypothetical climate change on water inflow to the Kama reservoir (catchment area of 168,000 km2). The Kama reservoir is located at the foothills of the Ural mountains in the European part of Russia. Most of the catchment area is covered by the spruce and pine forests. The Kama reservoir and hydropower plant is a source of water and energy for the large industrial area. The distributed hydrological model Hydrograph developed under the supervision of Prof. Vinogradov in the State Hydrological Institute (St. Petersburg, Russia) was applied in the study. The Hydrograph model describes the processes of runoff formation in the catchment area including the heat and water dynamics in the soil that significantly influences the formation of spring floods depending on soil freezing depth and water saturation. The model was adjusted to the conditions of studied area and validated against runoff and variable states at several watersheds within the catchment of the Kama reservoir. The total inflow to the reservoir was simulated for the period 1970-1996. The main factors determining formation of maximum spring floods were investigated and defined as following: SWE at the end of winter sums of positive air temperature in spring, liquid precipitation in previous autumn and depth of frozen soil. Exaggerated to different extent those factors were combined to form the ensemble of hypothetical scenarios of climate change. The results of modelled water inflow to the Kama reservoir according to hypothetical climate change scenarios will be presented. The recommendations for the adaptation of the reservoir operational rules to future conditions will be suggested.

Abstract number - 262 PREDICTING ENERGY AND WATER CYCLE RESPONSE TO CHANGING CLIMATE AND LAND COVER CONDITIONS IN THE CULTIVATED SAHEL

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In the dry tropics in general and in the African Sahel in particular, hydrosystems and agro-ecosystems are very sensitive to climate variability and land management. In this region, a pluri-decadal drought has coincided with large-scale vegetation clearing, leading to a still ill-understood, spectacular increase in surface and ground water resources. It is also generally thought that soil moisture, vegetation and surface fluxes produce substantial feedback effects on rainfall generation. Therefore, it is of prime importance to understand and to model the dynamics of the soil-plant-atmosphere continuum in response to contrasted meteorological and terrestrial conditions in this area. The objective of this study is to produce a process-based model of water and energy transfers in the soil and land-atmosphere interface for the main Sahelian land cover types. This development is based on a comprehensive 5-year dataset acquired for crop and natural vegetation fields in South-West Niger (Wankama catchment, AMMA-CATCH observatory, part of RBV network). It includes atmospheric forcing, seasonal course of vegetation phenology, soil properties and model validation variables (net radiation, turbulent fluxes, soil temperature and moisture profiles). The SiSPAT physically-based model(*), used for this study, solves the mass and heat transfer system of equations in the soil, with vapour phase, coupled with a two-component (bare soil and one vegetation layer) water and energy budget at the surface-atmosphere interface. Main questions raised in this modeling exercise were, whether such a model could be adequately calibrated and validated for the studied sites, using physically-realistic parameter values and, what uncertainty would result for model outputs (surface fluxes and soil heat/water profiles). The model was calibrated over a 2-year period and then validated over the other three years, for a millet field and a fallow-savannah field. In both cases, observations are reproduced about as well for the two periods. The variations in water and energy variables, over the five contrasting years and between land covers, are highlighted. Multi-year, field-based estimations of land surface water and energy budgets are hence produced, with associated uncertainties, for the first time in this area to our knowledge. Given model performances, it is felt that it can be applied with reasonable confidence to much longer periods, reflecting the strong variability that characterizes the Sahel climate.

Abstract number – 266 VALIDATION OF NUMERICAL MODEL TO ESTIMATE THE STREAM FLOW REDUCTION UNDER A SEASONAL VARIATION

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The scarcity of water resources accepts now global scales. Rational use of water supplies requires "conjunctive use water resources", implying groundwater and surface water are utilized jointly. Seasonal pumping in low-water periods is one of the methods of conjunctive use, called combined use. Near-stream groundwater pumping occurs in high-water period, when reduction of stream flow or depth doesn't reach permissible levels. During low-flow periods of the year groundwater pumping is used for compensation the deficiency of surface water resources. Numerical modeling of compensation pumping has special features: the periodic solution, the seasonal changes in the boundary conditions and the importance even small drawdown of stream level. Usually pumping simulation calculates in two-step procedure. Natural conditions, an aquifer system is in an approximate dynamic equilibrium, describe by steady-state model. A steady-state solution provides an initial heads, a set of flows through boundaries, and used as initial state for transient solutions, when pumping is imposed on an aquifer system. The transient solutions provide the total change in flows through the boundaries. A difference between the transient and steady-state solutions estimate the capture and the stream flow reduction. When seasonality is a modeling feature, this approach leads to mistaken values of flow reduction. In this case steady oscillatory solutions (SOS) are used as initial conditions for transient model. Investigations of compensation pumping well simulation are dedicated to: • estimation error of stream flow reduction caused by using non-periodic solution (NPS)for transient model, • quantity of cycles required to reach SOS, For this study seasonal analytical model was constructed using ModTECH 2.3. When the steady–oscillatory solution is achieved, seasonal heads and fluxes begin to repeat from cycle to cycle. Closure criterion for termination of the cycles is chosen: • convergence of groundwater heads • convergence of streambed fluxes Is was realized, satisfactory accuracy is reached when difference between heads shouldn't exceed 0.001 m, ratio of streambed fluxes convergence to pumping rate - 5·10-5. Considerable error is imposed on the calculation of stream flow reduction when NPS is used, miscalculation exceed 70 percent and more. Simulation of compensation pumping well calculates in "drawdowns" (initial conditions are zero drawdown) in lieu of two-step procedure, in this case capture and stream depletion are estimated at once.

Abstract number – 271 HYDROLOGICAL ANALYSIS OF WATER RESOURCES REDUCTION AS ARISING OF DEFORESTATION PROCESSES IN THE NORTH ZONE AND EAST ZONE OF EL SALVADOR, CENTRAL AMERICA

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The research carried out is about the hydrological analysis and implications of the current reduction of subsurface water resources in northern and east zones of El Salvador, which is a result of severe deforestation processes in essentials areas to water recharge, that supply tributary rivers and water fountains which are also sources of drinking water for local people. Initially, the flows from different water fountains in certain seasons were measured and related with the percentage of existing forests areas in the watershed by mean correlation equations, taking into account also the kind of edaphological

soil and physiographic conditions. The curve and correlation index between water yields (liters/Ha) and percentage (%) of existing forest land currently were obtained. Different scenarios about "the abstraction" or "infiltration" of surface runoff (mm) were determined by mean to apply the method "Soil Conservation Service (SCS)" and Hydrological Model (rainfall-runoff) IHMS, taking in count the kind of soil and currently land uses. It was found, on average, that watersheds, which have gradually lost over the years their permanent cover forest from 60% to 15%, have submitted correspondingly, a decrease in water springs of 85% compared to their initial conditions until a few decades ago. It was found that an increase in the forest land use in upland watersheds, reaching on average 50% of the watersheds extension (ha), would be possible to obtain on average a decreased from 14% - 20% of surface runoff, in relation to surface runoff (mm) under current conditions and a decrease in the runoff equivalent to 50% of precipitation (mm) used for the analysis. From the result, was proposed a recovery strategy by raising the "abstractions or infiltration" in order to increase the water potential of the springs and generate a decrease in surface runoff. There is in El Salvador a gradual process of severe deterioration of water resources and springs due to the progressive deforestation and land use change. From the results obtained, it proposes as a strategic action in rural areas, implementing a comprehensive plan that articulates a new approach about energy development, food production, water conservation and uses, and community organization; taking in count the essentials aspects of hydrologic cycle.

Abstract number – 272 IMPACTS OF LAND USE CHANGES ON SURFACE RUNOFF IN THE ARENAL MONTSERRAT CATCHMENT, SAN SALVADOR CITY - EL SALVADOR

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This paper presents an analysis of impacts on surface runoff due to land use changes from 1992 to 2009 in the Arenal Montserrat catchment, which includes the San Salvador city, capital of El Salvador, Central America. Due to social and especially economic pressure, the upper catchment has been affected constantly by land use changes. From 1992 to 2009, about 25% of forest and coffee land use have changed to impermeable areas in large malls and residential areas. Land use change, together with the construction of drainage works that accelerate the water speed in channels, and the no requirement for projects with zero hydrological impact, has lead new flood areas in the middle and lower catchment, which has a high population density. In addition to the above mentioned, the surface runoff has increased about 45%, while the lag time has reduced by 15%. Also the speed water at different sections of the channel shows an increase of 8%. The hydrological modeling was done using the HEC-HMS hydrometeorological model, and the hydraulic modeling using the software HEC – RAS in six points located along the river, with calibration point at the "Belloso" telemetric station. The modeling was conducted for three specific events: the first one, a storm with a return period of 1 year; the second event was a precipitation occurred on July 3rd 2008, which produced flood in an area in which not happen frequently, resulting in 32 persons dead; and the last event, was presented on November 7th 2009 (a combination of the Hurricane IDA in Caribbean Sea with low pressure in Pacific Ocean), in which a precipitation with a return period exceeding 100 years for a duration of 3 hours, flooded several areas of San Salvador city. Besides this analysis, a field inspection has been developed, updating on a map the flood risk areas, which have been classified as low, medium and high risk, and also a network of local actors has been formed as part an early warning system in the basin.

Abstract number – 278 IMPACTS OF CLIMATE CHANGE ON SPRING WATER AVAILABILITY: A CASE STUDY ABOUT RELIABILITY OF THE WATER SUPPLY OF CITY OF VIENNA

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The objective of this paper is to analyse the possible impacts of climate change and related land use changes on fresh water resources, especially on drinking water. The bias corrected outputs from two Regional Climate Models (Aladin-Arpege and RegCM-ECHAM5-r3) are used to drive a water balance model for the period from 1971-2100. To assess changes of spring discharge, which is the main source for drinking water of the city of Vienna, the main components of the water balance are analysed in an Alpine karstic catchment. Water balance simulations were carried out with a continuous conceptual hydrological model with a spatial resolution of 1x1 km. The RCM outputs with a spatial resolution of 25 x 25 km had to be downscaled to the 1 x 1 km grid by a high resolution meteorological model to reflect the climatic conditions in an alpine environment appropriately. The hydrological model was calibrated for the baseline period from 1971 to 1990. The development in the land use pattern was taken into consideration over the whole simulation period. The outputs from the downscaling procedure, in our case these refer to time series of daily rainfall and temperature, provide the input to the hydrological model. In comparison to the baseline period, the two RCMs show small but opposite changes in mean annual precipitation. Both models show an increase in temperature, which is more pronounced in the Aladin-model than in the RegCM3 data. Due to higher temperatures evaporation rates rise as well as snowmelt driven runoff occurs at an earlier time in the year, being shifted from May to April. Runoff increases in wintertime because of a change from snowfall to rainfall, especially at lower altitudes. To estimate the future development of the spring discharges and thus the water availability, runoff duration curves of the simulated baseflow component were examined. Particularly the RegCM3-calculation results show an increase in spring discharge as from 2071, whereas Aladin simulates a decline. Further mainly the RegCM3 results show that the discharge is to be expected more uniform during a hydrological year. With respect to mean annual water yield, no significant changes are expected but low flow periods will be more pronounced and extended. This should be considered and compensated by increasing the storage capacity or by supplementary drinking water sources. The expected changes in the vegetation cover had a minor impact on spring discharges.

Abstract number – 279 THE ROLE OF EVAPOTRANSPIRATION IN ESTIMATING WATER BALANCES IN ALPINE CATCHMENTS

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This contribution presents uncertainties in water balance modelling in alpine catchment originating from different evapotranspiration calculation methods. Substantial differences are found between temperature and energy balance-based methods for estimating evapotranspiration. The differences increase with catchment elevation. Many large rivers of significance for water resources management in lowlands, including the Danube, Rhine, Rhone or Po, have their sources in the Alps. High precipitation

sums, together with low winter temperatures inducing snow accumulation in the headwaters lead to high runoff-rates in spring and summer, with the Alps contributing up to 80 % of the total water amount in downstream regions. Therefore a better understanding of the hydrological system in alpine catchments is of relevance, not only on a local scale, but also for the over-regional, or even continental scale and on the timescale to understand possible future changes due to the impact of climate change. In this study the focus lies in the often neglected third water balance component, the actual evapotranspiration. Meteorological datasets with a high spatio-temporal resolution (1 km² and 60 min) are used to estimate the potential evapotranspiration after the temperature methods of Hargreaves and Thornthwaite and the energy balance-based technique of ASCE-Penman-Monteith, which in many studies has been shown to be superior compared to other (simpler) methods. These different potential evapotranspiration realisations are used as input into a conceptual rainfall-runoff model. Other inputs, temperature and precipitation, and model parameters stay unchanged and the effects on runoff predictions are evaluated. Compared to the Hargreaves and Thornthwaite methods the ASCE-Penman-Monteith approach yields substantially higher potential evapotranspiration rates. Mean annual values of high lying basins are up to 27% higher compared to the temperature-based methods. High solar radiation rates and wind speed, as well as lower relative humidity values at high altitudes explain the comparable higher potential evapotranspiration rates when applying the ASCE-Penman-Monteith method. These higher potential evapotranspiration sums originate from considerably higher values in autumn, winter and spring months compared to the temperature-based methods. Calculating potential evapotranspiration as a function of temperature only seems to be insufficient, as the evaporative effect of other meteorological parameters is not considered. The actual evapotranspiration rates differ up to 17%, with the temperature based methods yielding lower values. The largest differences in runoff simulations for individual catchments lie around 9% on an annual basis. Considering the differences in runoff the often applied correction factors for precipitation for compensating undercatch and deficiencies in the interpolation methods need to be revised. Results are shown for the Upper Enns basin located in the north central Austria Alps.

Abstract number – 280 RUNOFF-RAINFALL MODELLING: PREDICTING AREAL PRECIPITATION FROM RUNOFF OBSERVATIONS

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Precipitation exhibits a large spatio-temporal variability in Alpine areas. Additionally the density of the monitoring network is low and measurements are subjected to major errors. The most reliable hydrological information which is available refers to runoff gauging stations. Therefore, this contribution presents a method to predict catchment precipitation from runoff observations with a high temporal resolution of 60-min. Observed runoff from a closed catchment is the integral of precipitation over a certain period, considering evapotranspiration losses and water storage differences. Rainfall-runoff models represent the catchment responses to rainfall, considering the interplay between the temporal variability of precipitation, the physical catchment characteristics and antecedent hydrological conditions. An inverse rainfall-runoff model ("backwards hydrology") is developed to estimate temporally disintegrated rainfall input. A conceptual rainfall-runoff model is embedded in an iteration algorithm, in which for every time step a catchment precipitation is determined, which results in a simulated runoff value that corresponds to the observed value ("runoff-rainfall model"). To test the runoff-rainfall model virtual experiments were performed with synthetic runoff inputs generated by the conventional rainfall-runoff model with known boundary conditions and without any noise or uncertainty concerning input and model. An exact reproduction of precipitation input and system states

of the conventional rainfall-runoff model was successful, enabling the consideration of a real world case study. For parameter calibration areal precipitation fields from the nowcasting- and analysis system INCA of the Austrian Central Institute for Meteorology and Geodynamics (ZAMG) with a high temporal and spatial resolution is used. For further evaluations a precipitation observation in the catchment, which is not included in the INCA-system, is used. The correlations between INCA and predicted areal precipitation values are low at high temporal resolutions. Temporal aggregation of precipitation (2h-, 6h-, 12h-, 24h-sums) leads to higher correlation values. The correlation between the ground observation in the catchment and the modelled precipitation is significantly higher than the correlation between modelled precipitation and INCA precipitation. Furthermore, at the modelling time step of 60-min, the correlation between INCA and station data is lower than between the modelled precipitation and ground observation. Results are shown for the Schliefau catchment located at the foothills of the Northern Austrian Alps.

Abstract number – 282 ASSESSMENT OF UNSTEADY INFILTRATION IN GDE AREAS OF WIERCICA RIVER CATCHEMENT

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Groundwater dependent ecosystems may strongly depend only on shallow waters, where is a strong relation with precipitation, changing groundwater levels and with humidity of aeration zone. Flow through the aeration zone was simulated with the help of the piston model of unsteady infiltration (PM). Computer model consists of two sub-programs: i) PM – piston model of infiltration, ii) hydrological model of net precipitation. PM model was applied to follow current states of GDEs in a sense of prediction of groundwater recharge, which is crucial for biotopes functioning. This might be made for short (seasonal) and long term (climatic) changes of meteorological conditions, as well as for various anthropogenic pressures (land cover, position of groundwater table). The model can be used to determine increasing or decreasing of soil moisture as a result of precipitation and evapotranspiration, which then allows to estimate the dynamics of groundwater recharge. Net precipitation model is a separate module used for calculation of the portion of precipitation penetrating into soil cover. Simplified model of evapotranspiration based on the Turc's equation was selected, with the following input data: radiation, local average temperature, precipitation height, plant cover in a sense of evapotranspiration capacity and local depth of rizosfera. To simulate changes of water content the classical Green-Ampt model for a sharp front is applied together with the piston model of unsaturated infiltration and the Morel-Seytoux model of moisture redistribution. The model has been elaborated for Wiercica river basin in southern Poland. The beginning of Wiercica river is formed by several springs, the yield of which is affected by unsteady conditions of groundwater recharge. Good water quality as well as specific climatic conditions are favourable for existence of mosaic of biotopes: in dry and warm conditions some southern species can be found, while in wet and cold - mountain and boreal ones. The obtained results show precipitation infiltrations for different soil types in research area. For strongly permeable soils the whole precipitation infiltrates into ground, directly recharging groundwater. Along the profile low moisture is maintained, shortly after the precipitation event (rain) soil gets dry. There may be no enough moisture left for more water consuming plants. For medium permeable soils condition can be different. Although whole precipitation infiltrates into ground, significant content

remains for a few days after the rain, in approx. 2 cm subsurface layer. There is quite large seasonal moisture content remaining in deeper layers, with good availability for plants.

Abstract number – 283 SWIM MODEL FOR RESILIENT WATER RESOURCES MANAGEMENT UNDER SCARCE DATA

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The SWIM (Soil and Water Integrated Model) holds a prominent place among the many existing models used for climate change impact studies, especially at the regional scale, where the impacts are manifested and adaptation measures take place. The model, constructed by Dr Valentina Krysanova (PIK) based on SWIM and MATSALU codes and developed over the last two decades under her leadership, has proven itself versatile and capable of being applied for unprecedented conditions of future climate projections. This physically-based model belongs to a broader category of SWAT-family of models. It has been applied in a range of situations, from well gauged areas like Germany, to developing countries, where the data do not exist or are virtually impossible to access (e.g. in international river basins, where the neighbor countries do not wish to share the data). The model serves as the principal tool used in PIK in hydrological modeling at the catchment scale and above, as a stand-alone tool, or in combination with other models, to cover the interface between hydrology and agriculture, economy, flood protection, forestry, environment, etc. Since the model is firmly anchored in physical principles that hold also in changing climate, one can have confidence that the uncertainty introduced by hydrological modeling, on top of the climate modeling, is tolerable. Hence, using this hydrological transfer function, a range of climate scenarios can be transformed into a range of impacts, such as river flow, groundwater level, nutrient and carbon cycling, plant growth, crop yield, and erosion. The model has been successfully tested to mimic both mean conditions and hydrological extremes – floods and droughts. The present contribution will provide introduction to SWIM model and will review results of its applications is a variety of conditions, worldwide.

Abstract number – 285 SAMPLING VARIABILITY VS. CLIMATE CHANGE: HOW DOES IT AFFECT HYDROLOGIC DESIGN?

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Sampling variability and climate variability and change pose significant challenges to the definition of design parameters for hydraulic structures, land use planning and risk management. In this work it will be discussed that, even in the presence of relatively long historic records; there are significant uncertainties that need to be accounted for in the determination/prediction of future flood peaks for gauged basins. This is true even in the absence of anthropogenic climate change. But in addition to sampling variability, climate variability and change should also be considered in decision-making and design. However, there are significant challenges in separating climate variability from climate change

and the result will always be an educated guess. Several studies using Global and Regional Climate Models have found that in the US Southwest, while average precipitation will decrease, precipitation extremes will increase. However, even if climate science predicts an increase in the (frequency?) and magnitude of extreme precipitation events, research is needed to see how increases in the magnitude of extreme precipitation events translate into changes in the magnitude of flood events. Strong non-linearity in rainfall-runoff transformations and increasing temperatures play an important role controlling how variability in precipitation events influences the variability of flood events. In this paper these variabilities will be analyzed and their impact on the design values of hydraulic structures in two case studies will be determined, one in the Verde basin a semi-arid snow-fed basin in the United States Southwest and the other in a tropical region, the Upper Senegal river basin in Africa. The paper will concentrate in hydrologic extremes, particularly in design floods both for floodplain management (100-yr) and for large hydraulic structures (i.e. 10,000-yr flood used in some countries as the PMF). Statistically and dynamically downscaled GCM data will be used to drive hydrologic simulations of flood events. In addition alternative approaches to represent future climate change using paleorecords will also be employed. The variability and uncertainty of flood estimates will be evaluated and the impact on the design will be determined.

Abstract number – 286 MOSAICC: AN INTER-DISCIPLINARY SYSTEM OF MODELS TO EVALUATE THE IMPACT OF CLIMATE CHANGE ON AGRICULTURE

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Climate change poses a great challenge to agricultural productions systems, potentially threatening those who particularly depend on local food production for their livelihood. Information on the impacts of climate change forms a primary tool for policy makers to cope with climate change. Studying the impact of future climate change on the hydrological cycle is of primary importance, as it strongly affects crop production. This affects directly the local economy, but might even affect the macroeconomic situation of a whole country. However, accurate trans-disciplinary assessment on the effects of climate change are difficult to achieve, as information is often scattered, incomplete or specifically focused on one scientific domain. An innovative multidisciplinary approach combining knowledge from the different domains would therefore be an ideal way to evaluate the impact of climate change on the hydrological cycle, coupled with its impact on agricultural production systems and socio-economic variables. The Food and Agriculture Organization of the United Nations (FAO), in partnership with European research institutes, has developed an integrated package of models for assessing the impact of climate change on agriculture at a national level. The MOdelling System for Agricultural Impacts of Climate Change (MOSAICC) is based on a generic methodology defined to assess the impact of climate change on agriculture, using climate data downscaling, crop yield projections, water resource estimations and economic models. All models are connected through a common spatial database and interconnected in terms of input and output. All models and databases are platform independent and can be hosted on a central server. Multiple users can access the MOSAICC toolbox simultaneously through a web interface, making data exchange easy, transparent and efficient.

MOSAICC is unique and innovative as it combines a web-based interactive and integrated model environment together with tools and materials for capacity building and technology transfer to institutions and scientists. The specific design allows for inter-disciplinary working groups to stimulate cooperation and foster knowledge exchange. Currently, the MOSAICC toolbox is under validation in Morocco and will be implemented afterwards in other countries. This paper describes the MOSAICC modeling system with a focus on the hydrological model STREAM. Examples are given on its utilization and performance under a range of different climate scenarios.

Abstract number – 287 TRANSFORMING CLIMATE VULNERABILITY ASSESSMENTS INTO OPERATIONAL WATER MANAGEMENT DECISIONS, PLANNING AND UPDATED ENGINEERING DESIGN STANDARDS

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Water managers have passed the point of undertaking hypothetical and speculative 'vulnerability assessments' based on GCM modelling. There is great pressure now, in many nations to directly incorporate climate change impact analysis into real decisions – operational, planning and design of hydraulic structures. The problem is that the GCM models are not yet 'ready for prime time' (Kundzewicz and Stakhiv, 2010). There are three main areas of emphasis for water management that must be addressed in any pragmatic approach to decisionmaking: operational decisions related to regulation of hydraulic infrastructure; changes in planning and evaluation frameworks for decisions related to investment choices for future infrastructure; and the concordant development of a new family of risk-based hydraulic design criteria. There are numerous initiatives underway both internationally and specifically in a few nations such as Japan, Netherlands and the U.S. to begin developing a new generation of methods that could better deal with the uncertainties inherent in climate variability, as well as the broader categories of model uncertainties introduced through the application of GCMs. E.g. there has been a long progression of international conferences and resolutions focusing on disaster risk reduction (DRR), culminating with the Hyogo Framework for Action (HFA) 2005-2015. The UN International Strategy for Disaster Reduction (ISDR) is the main coordination body within the UN system for implementing the HFA plan. The World Bank established a Global Facility for Disaster Reduction and Recovery (GFDRR) in 2006 to support HFA implementation. The UN World meteorological Organization (WMO) initiated an International Flood Initiative (IFI) and International Drought Initiative (IDI) to develop information on more effectively dealing with all aspects of floods and droughts and compile the information from various UN agencies into one data base. The International Upper Great Lakes Study (IUGLS) will be used as the practical case study for outlining the series of practical actions and methods that were developed to deal with climate uncertainty in a real decisionmaking setting (IUGLS, 2012). The decisions revolve around developing a new L. Superior regulation plan under climate uncertainty; the consideration of new hydraulic regulatory structures to deal with climate extremes; and the development of a new planning framework for incorporating climate uncertainty. A process was developed and applied for decisions regarding the future regulation of the Upper Great Lakes that looked at various sources of information, including paleoclimatic information and General Circulation Models to help the IUGLS Board select the most robust regulation plan.

Abstract number – 288 GUIDANCE MODEL FOR RESILIENT WATER RESOURCES PLANNING AND DESIGN

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Non-stationarity is a potential challenge to water infrastructure investments. Decisions need to be made now regarding whether and how to account for climate change in planning and design to provide robust integrated water resources management solutions. To address this issue, a partnership has been established consisting of water resources practitioners that include the World Bank, Conservation International and the U.S. Army Corps of Engineers to develop guidance. This presentation will provide initial findings from the hydrology and climate modeling perspective. The drive for this work is two-fold. First, water resources agencies are required to consider climate change but have no clear guidance to implement. Second, data is lacking and down-scaling often results in greater uncertainties in many parts of the World, such as the tropics or mountainous regions that are of special interest in international development. This ongoing work builds on existing planning methods by providing guidance to evaluate and distinguish between anthropogenic and climate change induced impacts on integrated water resources systems. We propose that decision making for resilient water resources management starts by understanding the relevant climatic and socio-economic forcings, data and tools available, and integrating this information into model development. In other words, resilient modeling begins by identifying the problem scope. We define and identify the 'breaking point' of the existing system when stressed by both climatic and socio-economic factors. This model development is coupled with a framework to assess the credibility of available climatic, hydrologic, and socio-economic data and how it is incorporated into model calibration and use. This work provides the elements to assist water resources practitioners in assessing the resilience of the system to anthropogenic and/or climatic factors based on the system breaking point identified and the credibility of the calibrated model and data. The goal is to help transform institutional climate science guidance and add to the dialogue for effective planning and design under the added uncertain of climate change.

Abstract number – 289 RISK-INFORMED DECISION MAKING WITH A CHANGING CLIMATE

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The missions of the U.S. Army Corps of Engineers (USACE) are water resources management, coastal management and ecosystem restoration. A changing climate has the potential to affect all USACE missions, but the magnitude of potential changes and the rates of change are only partially understood. USACE is developing a risk-informed decision framework to incorporate climate change considerations into its decision making. The risk management framework provides a structured approach to incorporate climate uncertainty into decision making. The decision context includes the identification of multiple stressors on the system of interest, not just climate. Risk analysis is based on evaluating the

consequences and likelihood of future conditions and events. However, with a changing climate, the probabilities of future conditions may not be well defined by a probability distribution. Alternative plans are formulated to address a wide range of plausible changes. Plan selection may consider different criteria than the optimization of economic benefits. Plans should also address residual risk to better manage consequences if plan thresholds are exceeded. The risk-informed decision framework would be implemented throughout the project life-cycle. Potential future adaptations can be planned and implemented sequentially as more information becomes known. The complexity and uncertainty associated with decision-making in the context of a changing climate will often mean that the possible set of solutions fall under the authority of multiple agencies and levels of government. The risk management process therefore needs to include a wide range of stakeholder and agency participation throughout the process.

Abstract number – 290 CLIMATE RISK ASSESSMENT FOR WATER RESOURCES DEVELOPMENT IN THE NIGER RIVER BASIN

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The Niger River Basin has a history of marked climate variability with significant socio-economic and environmental impacts. Understanding the possible effects of current and future changes in climate on existing and planned infrastructure is crucial for its development planning. We have used a bottom-up, risk-based framework to assess future risks of climate change to the water resources and associated development sectors of the Niger Basin. Because of the broad uncertainty associated with climate projections for West Africa, the methodology focused first on identifying climate hazards through a sensitivity analysis of economic performance indicators to changes in river runoff, and the ability of the Basin's water resources system to withstand climate variability. Subsequently we used climate projections to assess the plausibility of such climate hazards. An existing Mike Basin water resources model for the Basin was used to investigate the impact of changes in runoff on the performance of planned development infrastructure, mainly the planned Fomi, Taoussa and Kandadji dams and associated irrigation infrastructure (over 300Kha). Hydrological modeling and analytic hydrological techniques were used to estimate the climate elasticity of runoff across the Basin, and to translate projected relative changes in annual temperature and precipitation into relative changes in annual runoff. An ensemble of 38 climate projections for the 21st century was used to estimate the probability distribution of identified risk levels for key performance metrics, such as hydro-energy generation, irrigated agriculture, navigation, flooding and the sustenance of environmental flows. Climate projections show rather small positive and negative changes in precipitation and increasing temperature. The result is a projected mean runoff that is essentially constant over the 21st century at an average of 5% below the 20th century mean. A runoff decrease of 20% beyond 2050 was identified as the worst case hydrological scenario. However, while the variability of rainfall and runoff has been high across

the Basin in the last century, GCM projections offer no guidance on future variability. Due to current water allocation rules and prioritization, irrigated agriculture is insensitive to decreased runoff caused by possible climate changes. Potential impacts on hydro-energy, navigation and flooding are projected to be mild to moderate (less than 20% decrease), with a runoff elasticity of 1 or less. Impacts on minimum streamflows during the dry season may be severe, but can be remedied by moderate reductions in dry season irrigation. Overall, the interventions planned under the Strategic Development Action Plan for the Niger Basin are considered to be a good adaptation to future climate risks.

Abstract number – 291 MODELLING THE INDIVIDUAL AND CUMULATIVE IMPACTS OF ANTHROPOGENIC ACTIVITIES AND CLIMATE CHANGE ON WATER RESOURCES IN DATA-RICH AND DATA-POOR REGIONS

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Rivers are essential to aquatic ecosystem and societal sustainability, but are increasingly impacted by human water withdrawals, land use change, and climate change. The individual and cumulative effects of these stressors on continental river flows remain difficult to predict due to complex interactions and feedbacks. Tools that can identify, separate, and quantify the impacts of a wide variety of human interventions and climate change on water resources are sorely needed to support water management decision making, particularly in regions with limited data and technological resources. In this paper, we present the Water Supply Stress Index (WaSSI) model and demonstrate the utility of the model to predict relative and cumulative changes in runoff and river flows as a result of human and climate perturbations across the conterminous U.S. (a data-rich region) and across three African countries including Rwanda, Zambia, and Tanzania (data-poor regions). WaSSI is an integrated monthly water balance and flow routing model that is sensitive to vegetative land cover type and urban impervious cover, and water withdrawals and return flows are explicitly accounted for throughout the river network. Both evapotranspiration and runoff predictions have been tested against eddy flux and stream gauge measurements, respectively. For the U.S., we evaluated the impacts of impervious cover, water withdrawals, and future climate change as predicted by Global Circulation Models on river flows by 2060. For Rwanda, we evaluated the impact of forest conversion to agriculture on water yield and the sensitivity of water yield to hypothetical changes in climate. Our results suggest that impacts of climate change in the U.S. will overwhelm the potential gain in river flow due to increases in impervious cover and will add to the potential reduction in river flows from withdrawals by 2060. However, increases in impervious cover may offset the impact of climate change during the growing season in some watersheds. Large water withdrawals will aggravate the predicted impact of climate change on river flows, particularly in the western U.S. For the Rwanda case study, we found that historic air temperature increases have resulted in a decline in river flow, which may explain the observed loss of wetlands in Rwanda. We conclude that WaSSI is an effective tool for evaluating the individual and combined impacts of human and climate induced change on water resources, and can be easily adapted to different regions and scales to answer a variety of water resource questions.

Abstract number 296 – MODELS OF TRITIUM BEHAVIOUR IN HYDROLOGICAL SYSTEMS

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Tritium has been a very powerful hydrological tracer since the 1960's because of its global distribution resulting from atmospheric testing of nuclear weapons. Even though "bomb pulse" tritium has largely decayed away, it is still a very useful tracer that can provide important insights about the dynamics of groundwater and surface water systems that are difficult to obtain otherwise. In this presentation we will discuss how lumped parameter models of tritium time series can be used to understand basin-scale residence times in complex, large river/groundwater systems and we will use the upper Danube as an example. Such information is vital for understanding how pollutants and nutrients cycle through a system and for quantifying when mitigation or pollution prevention schemes will result in meaningful reductions in concentrations. The lumped parameter approach is also useful for other tracers such as stable isotopes. Thus, the Danube tritium discussion will serve as a good introduction of how to model hydrological systems whenever good time series of conservative tracer data are available. We will also discuss how tracers like tritium can be used to understand mixing of tributary and main river channel flows. Such information has important consequences for environmental sampling in river systems where mixing zones can extend over much longer distances than many people appreciate. Finally, we will describe the use of "age dating" tracers such as tritium to establish the importance of long-residence time flowpaths that can be a significant, but often underappreciated, component of baseflow to streams and rivers.

Abstract number – 303 CONCEPT: THE USE OF RED SEA AS A NATURAL DAM FOR ERITREA,

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With a per capita income of only about $ 230, Eritrea is considered one of the world's poorest countries. Eritrea is an arid and semi-arid country and is not endowed with rich water recourses. Furthermore being part of Sahel Africa it has been the victim of recurrent and devastating droughts. Rainfall in Eritrea is torrential, is of high intensity over a short duration, very unpredictable and occurs sporadically. Subsistence Agriculture of crop production and cattle keeping are the two important economic activities in Eritrea. However, the traditional farming system contributes heavily to land degradation. Desertifications due to overgrazing and soil erosion are common in many parts of the country. Energy requirement puts a lot of pressure on the environment as large quantities of wood and trees are needed for energy generation. The paper explores Red Sea as a Natural Dam to be used for hydroelectric power source for electricity and fresh water source for Eritrea. Cheap hydroelectric source

can help the country to achieve water and food security to a rapid industrial development; that can break the vicious cycles of poverty and underdevelopment. When water resources of Eritrea are listed, a potentially major resource, the Red Sea, seems to be overlooked by local and international experts. Unlike most countries with access to sea and oceans in the world, Eritrea is one of few countries endowed with natural hydro-dam because of its geographical location and topography. With the Danakil Depression situated only a few kilometers inland and about 100 meters below sea level, this concept explores Eritrea's ability to develop electricity and potable water generation capacity from the Red Sea. If the electrical generation potential from the Red Sea can be realized, then it may be feasible to transform the electric energy into heat energy, and then use the heat energy to convert the sea water into steam. When the steam cools it becomes potable water that will be dependable and clean water to supplement the erratic water supply from rain and ground water resources. Another possibility of desalination of Red Sea water for Eritrea would be Reverse Osmosis method where seawater is forced to pass through a membrane using gravitational force based on the elevation difference between the sea and the Danakil Depression. The desalinated water can be pumped inland to higher elevations and distributed to cities and towns across the country.

Abstract number – 316 VIRTUAL WATER TRADE INSIDE IRAN, SAVING WATER POLICIES

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Increasing water scarcity has posed a major constraint to sustain food production in many parts of the world. To study the situation at the regional level, we took Iran as an example and analyzed how an intra-country "virtual water trade strategy" may help improve cereal production as well as alleviate the water scarcity problem. Data from 1990–2004 were used to account for yearly fluctuations of water availability and food production. Five scenarios were designed aimed at maximizing the national cereal production while meeting certain levels of wheat self-sufficiency under various water and land constraints in individual provinces. Based on different scenarios in ASCP, we calculated that 31% to 100% of the total wheat shortage in the deficit provinces could be supplied by the wheat surplus provinces. As a result, wheat deficit provinces would receive 3.5 billionm3 to 5.5 billionm3 of virtual water by importing wheat from surplus provinces.

Abstract number – 320 STUDY OF THE PHENOMENON OF GROUNDWATER LEVEL RISE IN SOUTH EL QANTARA SHARK AREA, ISMAILIA, EGYPT

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The 'rising groundwater level' in the new reclaimed areas has become a major concern all in Egypt. Due to the increasing level of groundwater, it is not only endangering the structures and properties but also causing major environmental problem affecting the health of the area, habitats, and the biotic of the

land community. The groundwater level gets seriously affected due to increasing pressure of various man-made activities. Once the natural flow of the groundwater is affected, it can result in raising the level or lessen the level creating large number of environmental problems. The authors propose an interdisciplinary planning strategy to deal with the issue of rising groundwater level. In the concerned area, fifteen peizometers are drilled to investigate the rising in groundwater level. Detailed topographical and brief hydrogeological analyses had been carried out. The strata supplying groundwater in the area are the Quaternary strata (Holocene and Pleistocene). The Holocene shallow sandy aquifer dominated the area of study, where all drilled peizometers tap this aquifer. The daily seepage from excess irrigation water may represent the main contributor of groundwater rising in the shallow aquifer. Moreover, seepage from south El Qantara canal and the municipal water supply system leakages further raise the groundwater level. The groundwater exists in the south at depth of 9 m below the ground surface and sometimes the water appears on the surface causing water logging especially in the north and northeastern parts of the area The groundwater quality grades from fresh to brackish water where the total dissolved solids ranges from 1019 mg/l to and32000 mg/l . The dewatering system in the study area may be suggested as a solution to overcome the problem.

Abstract number – 326 ADAPTATION POTENTIAL FOR AGRICULTURAL WATER USE TO CLIMATE CHANGE CONDITIONS IN NORTHERN AUSTRIA

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Water use for agricultural production in Austria constitutes only about 7 % of total water use whereas 31 % of water withdrawals are used for households and about 62 % for industry. However, this seemingly small proportion necessary for agriculture is mainly caused by its blue water footprint whereas the largest proportion of the footprint for plant production usually is green water (>90 %). Future climate change conditions presumably will enforce a significant shift in the water footprint structure, increasing especially the blue footprint for crop production. For rural areas with limited access to groundwater or usable surface water resources a competition between the water uses for agriculture and households/industries is expected to arise. Future climate conditions will induce rising private water demands and increasing irrigation demands for agricultural or horticultural crops. This might be critical in areas where the quality of groundwater for drinking purposes is already compromised by nitrate or pesticide contamination. To develop strategies how to escape from a growing competition between the water use of different sectors under climate change conditions, we have analysed case studies in Northern Austria with different regional cropping patterns. The results presented in this poster are based on current agricultural water use calculated with evapotranspiration models, the consideration of future climatic scenario outputs and the assessment of potential adaptation measures. The groundwater recharge was calculated as mean precipitation minus mean evapotranspiration and the average direct runoff. The Central Institute for Meteorology and Geodynamics provided meteorological data and the annual hydrographical book supplied discharge data that were complemented with on-site measurements. Additionally, the effects of different crops and cropping methods on the soil water content were evaluated with AquaCrop software. These results were complemented by the Water Footprint Assessment that provides data of the green, blue and grey water consumption of various crops. Interviews on trends and expectations were conducted with chief officers

on the community level to assess future scenarios of water availability and distribution. Vegetable cropping is widespread in Northern Austria's regions Eferdinger Becken and Machland. According to the chief officers of those communities, the demand for water is expected to rise due to expansion of vegetable cropping that needs intensive irrigation. Further population growth will put additional pressure on water resources. Adaptation measures to cope with this situation will be developed in cooperation with the regional water authorities.

Abstract number – 331 EVALUATION OF CLIMATE CHANGE IMPACTS ON HYDROPOWER PRODUCTION OF MANICOUAGAN, QUEBEC, WATER RESOURCES SYSTEM

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Climate change will have impacts on water resources, on their availability and utilization; a better knowledge of the nature of climate change impacts will allow water resource managers to make better planning and operation decisions to mitigate the negative impacts and capitalize on potential opportunities. In snow-dominated regions, hydropower production is more concerned by climate change, because of snow accumulation, which is the major source of inflows into reservoirs, is likely to change in both magnitude and timing. This research is interested on the performance of the Manicouagan River water resources system with existing water resources system infrastructure under climate change projections uncertainties. Climate change projections showed significant increase in mean temperature during winter throughout the future climate period, and a part of winter precipitations will fall as rain instead of snow. There will be an increase of temperature during summer compared to present climate as well. Future climate projections of precipitation and temperature of an ensemble of climate change scenarios have been forced into a hydrological model to simulate future climate hydrologic regime. The climate change impact on the hydrologic regime will be a decrease in snowpack at the end of winter, an earlier timing of snowmelt runoff and spring flood, an attenuation of spring peak flow, larger winter flows and an increase of the total annual runoff volume. A reservoir optimization algorithm, Sampling Stochastic Dynamic Programming, was used to derive weekly operating rules for optimum hydropower production of the existing water resources system subjected to future climate projections. Results show an increase of future power production and increase of unproductive spills. The operating policy of the water resources system and the existing facilities should be adapted to capitalize on the impacts of climate change. Results also helped to quantify the uncertainty regarding future water availability and give an overview on possible adaptation measures for future climate. Climate change evaluation should be integrated in the process of long-term planning and management of systems water resources.

Abstract number – 332 RESEARCH ON A REAL TIME URBAN DRAINAGE MANAGEMENT SYSTEMS

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Research on a Real Time Urban Drainage Management Systems （Purpose） In recent years, flood damage due to rainfall exceeding capacity of stormwater drainage and probable maximum precipitation, have an enormous impact on human life and function in urban area . As main countermeasures to reduce these phenomenon , stormwater pump, stormwater by-pass sewer and stormwater sotorage pipe have been established, though all these implacements are both cost and time consuming.Thus, it is necessary to promote non structual measures, such as to applying rainfall forecast at the same time. This study is intended to build Real Time Urban Drainage Management Systems,used for effective facilities management and operation to flood control and CSO control,and for advanced stormwater management utilizing online real-time analysis,such as provision of information to promote self-help and support and assistance of residents （Results）（1）Construction of systems and confirmation of the stability operation It was confirmed that reliable real-time analysis and data distribution could be done with data from Japanese rainfall radar, rainfall, water level and flow meters. （2）Distributed contents The distributed contents were overall monitoring, pump operation at stormwater pumping station, operation of drainage pumps at stormwater storage pipe, inundation simulation and inspection of past data. The operator could browse the delivery information via the internet and can confirm the measured/forecast data and analytical value by a graph from the past two hours to six hours ahead. （3）Evaluation of introduction effects In the evaluation of the effects of introduction of the system, the “operational improvement of stormwater storage pipe and drainage pump,” “provision of inundation prediction information,” “concurrent use of storage pipes for flood control measures and CSO control” and “high-water level operation of intercepting pump” were verified to be applicable to the research field. The total introduction effect was 2.8 times as much as the introduction/operation cost.

Abstract number – 334 WAVELET ANALYSIS OF THE VARIABILITY OF MONTHLY DISCHARGE AND SUSPENDED SEDIMENT LOAD - CASE STUDY FOR 3 GS ON THE RIVER SAVA

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Continuous Wavelet Transform (CWT) is powerful technique that enables analyzing periodic localization of hydrological time series. In this study CWT is used to analyze multi-scale variations in monthly discharge and suspended sediment load on 3 Gauging Station on the River Sava for the period

from January 1979 to December 1995. River Sava is one of the most important rivers for water management in Croatia and better understanding of variation in discharge and suspended sediment has practical relevance in better understanding of anthropological impacts and climate variation on fluvial processes.

Abstract number – 344 WATER RESOURCES MANAGEMENT UNDER UNCERTAINTY

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All water management decisions are made under uncertainty, from design of facilities to regional and national plans and international agreements. The calculated performance of a pump-pipe-reservoir system involves some (albeit modest) uncertainty associated with imperfectly known pump and pipe properties and consumer demands. Flood protection has to deal with the uncertainties associated with climate, hydrology and the performance of drainage systems. Operation of a water distribution system faces uncertainties associated with the topology and properties of the network, with demand forecasts and their real-time realization. In this presentation we shall focus on development and management policies for regional water supply systems, fed by a range of sources, which are operated over years and decades to meet the needs of various consumers, with effects that cross sector and institutional boundaries. Uncertainties abound: hydrology and production capacities of the natural and man-made sources (including sewage effluents) and the potential effect of climate change, population growth and geographical distribution, forecasts of demands and their response to laws, to regulations and to pricing policies, changing social values and public participation norms, considerations of adjacent economic and political domains, and, right at the top, shifting institutional, legal and political governance systems. How should planners act to generate plans that can be termed sustainable, that result in least future regret, or, better, most satisfaction, plans that will convince decision makers to approve and implement them. This presentation suggests approaches and methods, and uses the case of Israel's recently approved national Master Plan to illustrate how professional expertise and experience can support WRMuU. The national Master Plan spans the time horizon to 2050. A range of approaches and methods have been used, from policy and scenario formulation and analysis to stochastic simulation of uncertain future drivers on the supply and demand side that generate the capacity expansion required to satisfy a selected supply reliability. The Plan presents recommended strategies, policies and plans for consideration and adoption by the decision-making bodies, which are then used as a basis for long-term and near-future capacity expansion and management plans. The process has been supported by professional, public, institutional and political hearings and consultations, and led to the adoption of the Master Plan.

Abstract number – 345 RISKS OF WATER SUPPLY SCHEMES ORIGINATING FROM CLIMATE CHANGE AND LAND USE CHANGES: THE CC-WATERS PROJECT

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The central tasks of this project referred to the assessment of possible climate change impacts on water availability and quality and the identification of adaptation measures of management of drinking water supply and land use. The CC-WaterS project involved 18 partners from 9 countries in South Eastern Europe (SEE-initiative) and it integrated three types of partners such as (a) governmental bodies, (b) research institutions and (c) end users from 25 different regions. Quite different water resources utilised for drinking water supply were considered at different spatial scales ranging from local supply to the water supply of large cities. The analysed period included the observation period of about 1960 to 2005 while the simulation period extended over the whole 21st century. The major sources of uncertainty referred to the climate change signal and the trends of land development in the water intake areas. Climate change studies were based on three different Regional Climate Models (RCMs) with a spatial resolution of 25 km. In heterogeneous terrain like mountain areas climate data required further statistical downscaling to represent the spatial variability of temperature and precipitation. Especially for precipitation, but to a lesser degree also for temperature, a larger bias in the RCM data were identified by comparing the simulation with observations from the control period 1961-1990. Hence, bias correction of the simulation data was carried out by applying a quantile mapping approach. In Greece and Serbia, consistent trends of decreasing precipitation were detected in all seasons while in Romania, Croatia and Slovenia a decrease was mainly found in summer. With respect to temperature there are rather consistent predictions of an increase of between 3 °C and 3.6 °C in the mean annual temperature towards the end of the 21st century. Especially in the countries in Southern Europe, the highest temperature increase is expected for summer. The land use changes were described by storylines based on climate induced impacts on the vegetation and changes in water demand of different sectors. Low or insignificant vulnerability of the water resources towards climate change was identified in the case of water resources in Austria, Slovenia, and some regions in Romania. Karstic resources in Croatia, Serbia and Greece, and furthermore the surface water resources in Eastern Hungary and Serbia and groundwater in Bulgaria were classified as medium vulnerable. Groundwater resources in Eastern Hungary and Serbia, karstic springs in Bulgaria and the surface water resources in Bulgaria and Greece were classified as the most vulnerable ones. Water management alternatives were assessed by a fuzzy multi-criterion framework trading-off costs versus water supply safety.The most selected management options regarding water quality were the application of best practices (mainly in agriculture and forestry), water treatment and in some test areas also implementation of drinking water protected areas. Hence cooperation among management authorities in the field of water supply companies, land users and governmental bodies and representatives of public interests needs to be improved to implement adaption measures.

Abstract number – 346 WHAT CAN WE LEARN BY INTEGRATING WATER RESOURCES WITH A GLOBAL MODEL OF THE SOCIAL–ECONOMIC–ENVIRONMENTAL SYSTEM

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Awareness of increasing water scarcity has driven efforts to model global water resources for improved insight into water resources infrastructure and management strategies. Most water resources models focus explicitly on water systems and represent socio-economic and environmental change as external drivers. In contrast, the system dynamics-based integrated assessment model employed here, ANEMI (Greek gods of the four directional winds), incorporates dynamic representations of these systems, so that their broader changes affect and are affected by water resources systems through feedbacks. Sectors in ANEMI therefore include the global climate system, carbon cycle, economy, population, land use and agriculture, and novel versions of the hydrological cycle, global water use and water quality. Since the model focus is on their interconnections through explicit nonlinear feedbacks, simulations with ANEMI provide insight into the nature and structure of connections between water resources and socio-economic and environmental change on a global scale. Of particular interest to water resources researchers and modelers will be the simulated effects of a new water stress definition that incorporates both water quality and water quantity effects into the measurement of water scarcity. Five simulation runs demonstrate the value of wastewater treatment and reuse programs and the feedback-effects of irrigated agriculture and greater consumption of animal products on a global scale.

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