Nordic Water 2014

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ABSTRACTS

"The Nordic Hydrology Model" - Linking science and practice

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Preface

Nordic Water 2014 - The XXVIII Nordic Hydrological Conference - is arranged at Royal Institute of Technology (KTH), Stockholm, Sweden from the 11th to 13th of August 2014. The conference is organised by the Department of Sustainable development, Environmental science and Engineering, Division of Land and Water Resources Engineering on behalf of the Nordic Association for Hydrology (NHF).

Nordic Water is a conference series focusing on water resources, hydrology and related sciences. Providing good solutions to our water resources requires an interdisciplinary approach. The aim for the conference is bring together scientists, managers and decision makers to talk about recent trends in water research and water resources management.

Scientifically based hydrological knowledge is becoming more and more important in today's society and in the future. It is applied in legislation, for instance through the various EU directives related to water, and planning and decision making at all levels of society, by authorities, private and public organisations and enterprises, and by us individually. Challenges are of course related to expected future climatological and hydrological changes: but also in present conditions and at shorter time scales, we need hydrological information and knowledge to enable decision making and planning related to daily, weekly, seasonal or inter-annual perspectives.

Nordic Water 2014 will present recent scientific progress from many fields of hydrology. The overall theme of the conference is “The Nordic Hydrology Model" - Linking science and practice, and is intended to put the focus on applied sciences and scientifically based decision making, and how this is manifested in the Nordic and Baltic countries. Is there a certain identifiable "Nordic hydrology model" that links science and practice, uniting the Nordic and Baltic countries in this respect?

We thank all the contributors that have made the conference possible, including scientific and organizing committee. We also would like to thank the authors who submitted either oral or poster presentations.

Especially we would like to thank the four invited keynote speakers: Alvina Reihan (Estonia), Bjørn Kaare Jensen (Denmark), Oddbjørn Bruland (Norway) and Sten Bergström (Sweden).

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Abstracts

Groundwater – surface water interactions in esker aquifer determined with fully integrated groundwater flow modeling and novel field methods

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Groundwater is a major factor affecting water quantity, chemistry and ecology of surface water bodies such as streams, lakes and wetlands. Understanding of these interactions is needed in efficient management of water resources due to increasing pressures from land use, water abstraction, and climate change. More research is especially needed to better establish the link between groundwater bodies and surface water ecosystems or terrestrial ecosystems directly dependent on groundwater.

In this work groundwater – surface water interaction at Rokua esker aquifer is studied using a fully integrated groundwater flow model HydroGeoSphere. The code allows water to flow and partition into different components overland and stream flow, evaporation, infiltration, recharge and subsurface discharge into surface water features in a physically-based way, which is needed in simulating groundwater surface water interaction in a complex aquifer system. The constructed model is validated with innovative field observations of groundwater surface water interaction. The model performance in transient simulations is first examined using measured time series data for lake and groundwater levels and stream discharge. Secondly, locations of groundwater discharge to lakes at Rokua area is mapped with areal infrared imaging, and the spatial patters of observed discharge are compared to simulated discharge locations. Finally groundwater component in the lake water balance is estimated using lake water isotopic composition (H2 and O18), and the estimate is compared with simulated values.

The novelty of work is in identifying and quantifying groundwater-surface water interaction in esker aquifer using several field based methods and state of the art modeling approach. The study provides new information regional flow processes and water fluxes at GW-SW interfaces, which are needed in integrated management of water resources and related ecosystems in esker aquifers.

Modeling of Water Temperature in a Small Pond with Multiple Regression Techniques

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Temperature plays a crucial role in the processes affecting the water quality of water bodies. As such, it is very important to predict temperature in the water environment in order to simulate reaction mechanisms. In this study, the temperature structure of the Borabey Pond in Eskisehir, Turkey, is examined and regression models relating water temperature at various depths to atmospheric variables are established. The pond lies, at 900 meters above sea level, embedded into the hills to the north of the city of Eskisehir which is situated in the northwestern part of Inner Anatolia Region of Turkey. The pond has a volume of 1.4 Mm^3 with a surface area of 0.16 km^2 at maximum water level. It has been created by damming a small creek draining an upstream agricultural watershed. Its waters are used for irrigation purposes downstream. The watershed of the pond measures 8.5 km^2 and the very vicinity of the pond is a protected area with limited access.

A meteorological station has been established close to the pond to serve the purposes of this study where all meteorological variables relevant to the construction of regression models are measured. Temperature is measured in the pond at two locations. One location is at the shore near where the ephemeral creek draining the watershed enters the pond. At this location, the temperature is measured 20 cm beneath the surface 2 meters away from the shore. The second location is in the middle of the lake where maximum depth occurs. Here, the temperature is measured at three depths, namely at the surface, one meter below the surface and one meter above the bottom. At both locations, the measurements are taken at 15 minute intervals, synchronized with the measurements at the meteorological station. For the measurements, Hobo pendant temperature data loggers are utilized. The meteorological station and the water temperature measurement locations are very near (within 300 meters) and at nearly the same elevation, so that the interactions between the water temperatures and the driving forces behind them are undisturbed by possible outside factors.

The multiple regression models to be used have water temperature as the criterion variable and a number of predictor variables. The predictor variables are minimum, maximum and average air temperatures, dew-point temperature, solar radiation, wind velocity and autoregressive components. Several regression equations are developed for different seasons, and categorical meteorological conditions like completely clear sky conditions, rainy periods, and day and night differences. Aggregate (hourly or daily) variables are also utilized.

The models are intended to predict water temperatures with a small number of easily measurable meteorological variables available at all meteorological stations. The model equations can be used as stand-alone tools to predict water temperatures, or can be integrated into hydrological and water quality models to provide the water temperature needed. Such data is especially important in water quality models in which many chemical and biological process rates are temperature-dependent. Moreover, the effects of persistently changing meteorological conditions as might be experienced as a consequence of climate change can be predicted and examined.

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Slussen in Stockholm - a multidisciplinary challenge

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In December the year 2000 it became evident that the discharge capacity of Lake Mälaren was inadequate, resulting in a critical flood situation. Already in the 1990's it was evident that the outlet structure, the Stockholm landmark Slussen, has to be replaced due to aging since its completion in 1935. The vulnerability of Lake Mälaren and its shore-lines, including parts of central Stockholm, was highlighted in 2007 by the Swedish Commission on Climate and Vulnerability.

On behalf of the city of Stockholm, SMHI has since 2007 been deeply involved in the hydrological, hydraulic, oceanographic, meteorological, statistical and climate calculations that are central in the reconsideration of the outlet structure and the whole regulation scheme of Lake Mälaren. The objective to propose a new regulation scheme for Lake Mälaren was carried out in close co-operation with regional authorities and other interests. The scientific basis is a number of simulations using a model that describes the function of the gates and sluices and calculates the lake water level and discharge through each of the eight outflow channels. The model also considers the hindering effect of the sea level on the discharge capacity.

A starting point was to determine the need for present and future discharge capacity. This step includes hydrological flood design calculations, statistical calculations of sea levels for different seasons as well as climate adaptation of the calculations. The new planned discharge capacity is approximately 2000 m^3/s, more than a doubling compared to the present capacity of about 800 m^3/s. This is needed to protect the city of Stockholm and other municipalities around the lake from flooding from the lake during the 21st century. Such increase in discharge at central Stockholm will of course have an effect also on water velocities in and around the outlet channels. SMHI has performed multidimensional hydraulic calculations to support the environmental impact analysis on erosion and sediment transport in a number of studies.

As the new conditions are planned to prevail for about 100 years, climate change is an integral part of all considerations. Climate factors which have been considered are changes in inflow from rivers, sea level rise, isostatic rebound of land and possible change in the wind climate causing denivellation of the lake and extreme sea level episodes. Sea levels are assumed to rise by 1 meter in 100 years but half of this is compensated by isostatic rebound. The overall conclusion is that the proposed new regulation of Lake Mälaren will safeguard the system for at least 100 years to come.

Preparations for the construction work have now started, even though there still are ongoing legal negotiations. The reconstruction is planned for the period 2015 to 2022, when the new sluice and channels will be finished.

Which factors have impacted the changes in the runoff of the Vienziemīte river?

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The Vienziemīte river basin is located in the Piebalga hillock of Vidzeme Upland in Latvia. The area of the basin equals 5.92 km^2. The goal of the present research was defined as identification of the major factors that have impacted the changes in the runoff of Vienziemīte River. The major factors included the changes in the land-use, the drainage of the basin in 1974 and the global warming of the climate. For the purpose of studying of the changes in the river runoff, the data row of the daily discharge during the period from 1946 to 2002 was used and processed by application of statistics methods.

For the purpose of the analysis of the changes in the land-use, topographic maps with scales 1:25000 (1951), 1:10000 (1973) and 1:50000 (1998), as well as Land Corine 2000 and 2006 were digitalised. The analysis of the data demonstrated that the changes in the land-use within the river basin were not essential.

In 1974 the Vienziemīte basin was drained by 50%. Therefore, two data sets of ten years prior to (1964-1973) and following (1975-1984) melioration works were compared. The research showed that following the drainage, the annual mean and minimum discharge increased. Changes are a statistically significant at the $p<0.05$, and the minimum discharge during summer months from July to August also increased at a statistically significant rate. No changes in the maximum discharge were identified.

In the analysis of the impact of the climate warming, the two following data sets were used: 1975 – 1987 when there was no essential climate warming and 1988 – 2002 when there was essential climate warming. The research showed statistically significant changes in the runoff in some cases. In this case, it could be explained by the fact that the data rows were not long enough for providing more justified results.

When longer time periods before the drainage of the Vienziemīte River in 1946 – 1973 and following the drainage of the Vienziemīte river in 1975 – 2002 were analysed, the following results were obtained. During the time period 1975 – 2002 there has been a statistically significant increase in the annual mean discharge and the mean discharge in January and March. There has also been a statistically significant increase in the annual minimum discharge and the minimum mean discharge in January, February, April and June. The maximum discharge has increased from January to March. It should be noted that prior to the drainage, the Vienziemīte has been drying up mainly during the summer-autumn month during a period of 14 years, however, following the drainage this phenomenon was only observed during one year, i.e. in 1999 (July - August).

Mann-Kendal test for the time period of 1946 – 2002 presented the following results: there are statistically significant trends in the mean, minimum and maximum discharge at the $p<0.05$ from January to March, and there has been a decrease in April and an increase in May and June. A statistically reliable positive trend is also presented by the annual mean flow and the winter 30 days minimum discharge. There is a positive trend in the annual maximum and the summer 30 days minimum discharge, however, it is not statistically important.

Long-term changes in the phonological observations of the Daugava ice regime and the impact of hydro power plants

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The research analyses the long-term changes in the phenological observations of the Daugava ice (the freeze-up date, the break-up date and the duration of ice cover) and the impact caused by hydro power plants (HPP) upon these observations from the winter season of 1919/20 to 2011/12. The long-term changes in the phenological observations of the Daugava River have been determined by two major factors: the global climate warming at the turn of the 20th and the 21st centuries and the anthropogenic impact after 1939 when the first Ķegums HPP was built. Mann-Kendall test showed that the long data rows up to the winter season of 2011/12, i.e. at the hydrological monitoring stations (HMS) Daugava-Piedruja, Daugava-Daugavpils, Daugava-Jersika un Daugava-Jēkabpils, show the following trends: the ice freeze-up date date is later, the ice break-up date is earlier and the duration of the ice cover is shorter. It should be noted that these changes are statistically significant at the $p < 0.05$. The long-term changes in the phenological observations at these HMS were determined by the trends of the global climate warming.

In order to analyse the impact caused by the Daugava HPP cascade on the changes in the ice phenological observations, two sets of data rows were compared, i.e. twenty years prior to and twenty years following the construction of the HPP. The first HPP, in particular, the Ķegums HPP on the Daugava was constructed in 1939, followed by Pļaviņas HPP in 1968 and Rīga HPP in 1974. The research showed that in the water reservoir up the dam the ice freeze-up date takes place earlier and the ice breaks up later, the duration of the ice cover is longer. However, a contrary process can be seen down the dam where the ice formation is later and the ice breaks up earlier, the duration of the ice cover decreases. The number of days depends on the location of the HPP, i.e. further away from the dam, the impact of the HPP on the changes in the ice phenological observations is lower. They are mainly statistically significant at the $p<0.05$. This can be explained by the fact that when a water reservoir is formed in the Daugava, the stratification of water layers in compliance with the season takes place. In summer it is the direct temperature stratification and during the coldest time of the year it is the inverse water stratification. This is a major determinant of the thermal and ice formation regimes of the water down the HPP dam.

Reconstructed model improvements, when going from S-HYPE 2008 to 2012

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The HYdrological Predictions for the Environment (HYPE) model (Lindström et al., 2010) is a semi-distributed dynamic model. It integrates landscape elements and hydrological compartments along the flow paths with nutrient emissions, turnover and transport. Calculations are made on a daily time-step in coupled subbasins. The code is up-dated continuously and released in new versions.

The model set-up for Sweden (S-HYPE) covers the country and more than 450 000 km^2. This model system produces daily values of several hydrological variables and nutrient concentrations in 37 000 catchments from 1961 and onwards. The model is used for decision-making linked to water status, climate change adaptation and safety of floods, droughts and fire. The model system is also used for research and hypothesis testing. The first version was launched in 2008 (Strömqvist et al., 2012), but S-HYPE is continuously improved and released in new versions about every second year.

Model performance has increased over time, going from an average NSE (401 sites) of 0.56 to 0.7 between the versions 2010 and 2012. The model performance changes with process descriptions, input data and model parameters (Arheimer et al., 2012). Efforts to improve the model are done continuously, by using an iterative and incremental model development approach. It can be difficult to compare NSE-values between model versions as time period and river gauges may differ. Therefore, controlled reconstructions were made in an experiment, to explore the impact of changes made and relative importance of different model components for the overall model performance.

In the experiment one factor at a time was removed from the model system. For each withdrawal, new NSE values were calculated for all 401 sites with water gauges. The order of withdrawal was reversed to the order of inclusion during the model development, to reconstruct the changes made. In total eight types of model improvements were analysed. Their impact on model performance was quantified across sites and scales for the whole model domain.

The results of the experiment show that for the 40 catchments without lakes, a general model without spatial distribution of catchment characteristics could explain 50% of the NSE, while such a general model only explained 26% when considering all 401 catchments. For catchments without lakes, spatial distribution of soil and vegetation and local recession parameters had more impact than in catchments with lakes. For catchments including lakes, regulation routines and local lake-rating curves were the outstanding most crucial factors for improving the model results. This is important knowledge for hydrological modelling in the Nordic countries, which are rich in surface water. Poor model performance in specific catchments were analysed to identify causes of errors. Often nutrient concentrations could help in finding local errors or alternative model structures.

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National and local predictions of hydropower impact on Swedish river flow

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The most radical anthropogenic impact on water systems in Sweden remains from the years 1900–1970, when the electricity network was developed in the country. Lakes and rivers became regulated as numerous dams were constructed to meet the societal needs of electricity for railways, industries and households. The hydropower development was a major contribution to the industrialization of Sweden and amounts today to half of the electricity supply for the country. There are ~1800 hydropower plants in Sweden. The total annual production varies from 50 to 75 TWh due to water recharge, with an average of 65 TWh/year. River flow in Sweden is highest during spring, but winters in Sweden are long, cold and dark; therefore there is a need for storing water from spring and summer for hydroelectric production in the autumn and winter.

The environmental problems linked to hydropower were recognized during the 1960s and are today considered as the major causes of aquatic ecosystem degradation in Sweden (HaV 2013) and heavily modified waterbodies in Europe (EEA 2012, Künitzer 2013). The EU Water Framework Directive (WFD) therefore demands regular reporting on the level of hydro-morphological alterations for all water bodies (EEA 2012) and that hydro-morphological pressures should be reduced. To improve the situation, the Swedish Water Authorities have recently introduced three new hydro-morphological indicators for monitoring: (i) hydrological regime, (ii) morphological status, and (iii) connectivity between waterbodies (HaV 2013). For these, SMHI was asked to provide such time-series to the Swedish water authorities, and in addition, to estimate baseflow indices, volume and degree of regulation, change in storage volume and flow. This information is needed for the new WFD indicators and for efficient allocation of measures to achieve good ecological potential.

To achieve scientifically based decision making, a general method to predict river regulation by hydropower was first validated for the assessment. The method is part of the national multi-basin model system covering Sweden, called S-HYPE (Strömqvist et al. 2012). Thereafter, a method to simulate natural conditions was tested and applied for all major dams in Sweden. The methods show good agreement with analysis based on observations. The results show that the average redistribution of water during a year due to regulation is 19% for the total discharge from Sweden. A distinct impact was found in seasonal flow patterns and flow duration curves. Finally, we quantified the model skills in predicting hydropower impact on flow. The median NSE for simulating change in flow regime was 0.71 for eight dams studied independently. Results from the national modelling are readily available for the public with a local resolution in 37 000 sub-basins across the country at http://vattenwebb.smhi.se/, and will be used by the Swedish water authorities for reporting hydro-morphological indicators to the EU and for guiding the allocation of river restoration measures.

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Sharing Water-related Information to Tackle Changes in the Hydrosphere – for Operational Needs (SWITCH-ON)

Berit Arheimer[1] and the SWITCH-ON project consortium[2-15]

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Recently, a collaborative EU project started called SWITCH-ON (EU FP7 project No 603587) coordinated by SMHI to support the INSPIRE directive and the Open Data Strategy. The overall goal of the project is to establish a “one-stop-shop” web portal for easy access to European water information. The project will use open data, provide infrastructure for sharing and collaboration, and add value to society and research by repurposing and refining data from various sources.

The SWITCH-ON project http://www.water-switch-on.eu/ will establish new forms of water research and facilitate the development of new products and services based on principles of sharing and community building in the water society. The SWITCH-ON objectives are to use open data for implementing: 1) an innovative spatial information platform (SIP) to find, bind, transform and publish data, 2) entirely new forms of collaborative research organised in a Virtual Water-Science Laboratory, open for any research group, 3) fourteen new operational products for water management and awareness, 4) outreach facilities for new water business and knowledge in line with the Europe’s smart growth and environmental objectives. Contact: waterswitchon@gmail.com

Hydrological forecast system for Lake Mälaren

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Lake Mälaren is Sweden's third largest lake and perhaps the most important, by means of infrastructure. It is the drinking-water supply for almost two million people, including Stockholm city. The lake is also important for shipping and it's ecological and recreational values should not be forgotten.

In order to control the water level, Lake Mälaren is a regulated lake by law since 1941. The regulation has an impact on boat traffic, infrastructure and salt intrusion, as well as the ecology. The regulation is made by managing eight different floodgates and culverts at four different sites. The site Söderström, also known as Slussen, is currently subject to extensive reconstruction plans. The potential reconstruction of Slussen has been an ongoing discussion for years and concern many stakeholders.

In order to provide better overview of the hydrology of Mälaren, a real-time forecasting tool was developed at SMHI. The tool will be used as a support in the regulation of Mälaren, at present, during the reconstruction of Slussen and in the future.

The forecasting system uses inputs, consisting of water level observations from Mälaren and sea level observations from Skeppsholmen. Two hydrological models and one oceanographic model, developed and operationally used at SMHI, calculate the forecasted inflow to Mälaren and the sea water level over a forecast period of nine days. A model describing the function of the gates and culverts calculates the forecasted lake water level and discharge through each of Mälaren's eight outflow channels. The calculations are based on the last recorded lake water level and sea water level, as well as, the forecasted inflow and sea water level.

The calculations are made using an iterating script, which compares the current water level to a regulation strategy, to determine the status of each of the eight channels. Alongside the forecast results given by today's legislation of regulation, the system also calculates forecasts, using two alternative regulation strategies. These will probably be used during the reconstruction of Slussen, as today's strategy, legislated in 1941, would then have to be neglected.

The forecast system is implemented into SMHIs system for real-time hydrological production and runs automatically once per day to generate the latest forecasts. The forecasts and observations are presented in a web-based interface called WebHyPro, which visualizes the results as graphs and numbers connected to geographical points on a map.

Stockholm and Lake Mälaren in a changing climate – an example of the future for Nordic hydrologists

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The city of Stockholm and Lake Mälaren offer a challenging hydrological problem. The lake is the freshwater reservoir for some two million people and its average level exceeds average sea levels by merely 70 cm. In addition the discharge capacity of the lake has proved inadequate, putting infrastructures along its shorelines at risk. Finally the outlet structure, the Stockholm landmark Slussen, needs to be replaced due to aging since its completion in 1935.

As a consequence the regulation scheme of Lake Mälaren is presently subject to review. The plan is to increase the total capacity to evacuate water by more than 100% and to formulate a scheme that meets the requirements from a number of partly conflicting interests, such as areal planning, agriculture, infrastructure, water supply, navigation, biodiversity and recreation. Effects caused by climate change and other long-term factors are also considered, such as changing inflow from rivers, sea level rise and the isostatic rebound of land, which is about 5 mm per year in Stockholm. As this project means a major investment that will change the appearance of the centre of Stockholm, there is also considerable public interest and an intense debate is ongoing. The plans are presently subject to deliberations in the environmental court.

The engagement in the new regulation scheme for Lake Mälaren has meant a new, and unusual, role for hydrologists at SMHI. Not only have we been forced to consider climate change effects on sea levels and river runoff simultaneously, we have also appeared in court and have responded to difficult questions raised during this debate. Media attention has also been quite intense, at least in Stockholm.

The Stockholm example may very well be symptomatic for the future of hydrology. With increased urbanisation, exploitation of shore-lines and more concerns about the effects of climate change we can expect more complex problems where hydrologists play a key role in the development of our metropolitan areas. We have a similar situation in the city of Gothenburg, where a major infrastructural project, the new railway tunnel, entails deep considerations about future sea levels, river flows and cloudbursts. In this case the dramatic and very costly rainfall in Copenhagen on July 2, 2011, has been very helpful. It increased the awareness of the importance of rigorous design of the drainage of the city.

Outside the Nordic area we can follow similar discussions. During last winter's floods in England we noticed the importance of the Thames barrier and a new barrier is now available outside Saint Petersburg in Russia. Some years ago this kind of solution may have been looked upon as a curiosity by Swedish hydrologists, but today similar solutions are seriously considered as long-term solutions for both Stockholm and Gothenburg.

With the growth of metropolitan areas and climate concerns, hydrologists have to adapt to new challenges. This means new opportunities but it also demands a broader perspective, which includes climate impacts on rivers, future sea levels, cloudbursts and the whole complex of possible technical flood protection of a large city.

Revitalizing ancient mythology in an Open Source framework to enhance innovation, interdisciplinarity and academia-industry cooperation

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ENKI is an OpenSource hydrological toolbox named after the ancient Sumerian god of sweetwater, wisdom and magic. ENKI is developed by SINTEF on the basis of previous PhD studies carried out at NTNU, the Norwegian University of Science and Technology. The development of ENKI is financed by Statkraft in the purpose of improving hydrological forecasting for hydropower scheduling. A principal goal of this development is that ENKI shall become the future hydrological toolbox for hydropower companies and a preferred tool in water resource education and management.

Statkraft is Norway's largest hydropower producer, currently maintaining more than 200 HBV models on a daily basis to schedule production in a deregulated electricity market. The economic consequences of poor predictions are large, leading to high interest in keeping the operational forecast models up to date with recent innovation.

Since 2002, Statkraft has supported the development of a modern model framework providing an ability to readily modify subroutine modules and physics for distributed models. The resulting tool ENKI is now in a pre-operational state as a hydrological forecast engine. It is released as Open Source under the GNU LPGL license.

The open-source license and modular design makes it easy for students, scientists and other model developers to implement, exchange, and test single routines and various model compositions in a fixed framework. As this also facilitates rapid dissemination of new methods to operational water resource management institutions, ENKI provides a mechanism to enhance cooperation between academia and the industry, reduce time to market of innovation and ensure state-of-the-art tools in industry. When industry, educational, and research communities work on and develop tools on a common platform, the transaction cost when employing students from the universities or of deploying new developments from master or PhD work can be significantly reduced. This should also make it easier for research communities to approach the industry and other financial sources, as the road to practical application of the scientific results is well defined.

The modular design makes the ENKI framework ideal for interdisciplinary work and development. Hydropower systems can be complex and hydrology is one of several prerequisites for optimal use of water resources. Hydraulic and environmental restrictions and concerns along the watercourse also have a significant influence. In ENKI these disciplines can play together interactively and give a consistent schedule where all input and restrictions are handled by different modules in the same framework. In addition to improvements in production schedules, this will further increase the understanding and cooperation between disciplines.

Nevertheless all good intentions and arguments, to conquer the world, ENKI has to live up to the wisdom of the god it is named after. To compete in a market of water resource software and with hard core hydrology software developers, probably some magic will also be useful. But the first steps are taken and the invitation to cooperate to develop ENKI further is open to all.

Monitoring Snow Water Equivalent using X-band radar satellite data in a Norwegian hydropower catchment

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Monitoring snow packs and its characteristics is important for the management of our water resources and their impact on floods and avalanches. Especially for the hydropower industry, the most important snow parameter is the Snow Water Equivalent (snow depth multiplied by density) as it translates directly into melting water in the spring that will end up in the hydropower basins.

Today SWE measurements are performed using manual measurements such as point measurements and Ground Penetrating Radars. It is not feasible to perform measurements covering large areas as it would be time consuming and costly and therefore SWE estimations made today are inaccurate and uncertain. To retrieve detailed measurements of SWE across catchment areas it is highly desirable to measure SWE using satellites since the mapping potentially could cover all points in the hydropower basin, not only a few stretches. The mapping could also be performed several times during the winter, leading to more accurate and up-to-date results.

In October 2013, Globesar and the research institution Norut initiated, a two-year long demonstration project, named "SWEX", to evaluate the applicability of a new technology being able to retrieve SWE values by inverting a physical model for radar backscatter from X-band radar satellite data. The radar backscatter is sensitive to changes in SWE, and the result is a high-resolution SWE map (10 m spatial resolution for the most accurate satellite modes) that captures the natural variability in snow depth much better than previous satellite derived SWE products (typically 25 km spatial resolution for passive microwave instruments such as AMSR-E and SSM/I). The test area is located in Sør-Trønderlag, Norway and covers catchment areas of several hydropower companies. The objective of this study is to investigate the technical possibilities and limitations of this method using X-band radar satellite data. In order to validate and study the accuracy of retrieved SWE values from satellite measurements correlation with meteorological, hydrological and field data, will be performed. We will present the preliminary results from the first year of data from the project, including 50 satellite images spread throughout the winter season 2013/2014.

Flood frequency estimation in ungauged catchments using a distributed hydrological model and regional flood frequency analysis. A case study for Iceland

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Extreme flood events may have serious social, economic and environmental consequences. Estimating flood quantiles is therefore required in risk assessment studies and for the design of various hydraulic structures. Often, this information is needed at sites where observed streamflow series are either too short to allow a robust estimation, or where no data is available at all. Two different approaches can typically be used to deal with these requirements, i) regional flood frequency analysis and ii) continuous hydrological simulation.

The work presented here explores the possibility of taking vantage of both approaches, in regions with limited data availability. The distributed hydrological model WaSiM-ETH, is calibrated on a gauged catchment and used to simulate daily streamflow series at different ungauged locations within this catchment. Annual maximum daily streamflow series simulated at these locations are then used to develop a regional flood frequency analysis which is used to derive daily flood quantiles at gauged sites belonging to independent catchments, treated as ungauged. Reference and estimated quantiles are compared. The same principle is then applied to infer instantaneous flood quantiles at ungauged sites after applying a flood-duration-frequency (QDF) model to the simulated daily streamflow series.

The method was tested on six gauged catchments in northern Iceland. Two catchments were used to simulate the streamflow series and develop the regional flood frequency analysis, which was then used to predict flood quantiles at the other catchments, treated as ungauged. Preliminary results indicate that the combined method has the potential to provide a credible solution for estimating flood quantiles at ungauged catchments, in data sparse regions.

How to better describe the spatial variation of snow over Sweden… and does it matter?

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Forecasts of spring flood timing and volume are crucial for optimization of hydropower reservoir management in Sweden, where snow melt is one of the most dominating hydrological processes. It is important that hydrological models used for such forecasting can handle the large scale variability of snow pack seen in nature. The aim of this study is to improve the precipitation pattern in the forcing data as well as the modelling of the snow accumulation and melting processes to better capture that variability. Besides a better description of the runoff generation process, a better description of the snow pack can in combination with observations lead to a constrain of model parameters and open up for various data assimilation methods.

A database called PTHBV has been in operational use since 2004 to force hydrological models at SMHI. The database contains daily data on precipitation and temperature on a 4x4km^2 grid covering all river basins in, and flowing to, Sweden. The precipitation, which we focus on in this study, is interpolated from some 700 ground based precipitation stations. As a first guess for the interpolation a background field, derived from a statistical relationship between wind, topography and precipitation, is used (Johansson and Chen, 2003, 2005). The influence of the background field is greatest in areas with large precipitation gradients where station locations do not represent the full spatial variability. In Sweden such areas often coincides with regions were most of precipitation falls and most of the runoff to hydropower is generated.

The idea for this study was to examine how using current wind information (instead of long term mean) could influence the distribution of precipitation in PTHBV and so the interannual variation in modelled snow pack. For this, U- and V-winds at 850hPa was extracted from the ERA-Interim database at 6h temporal resolution and used in the interpolation of the background fields. The snow model used was further developed by introducing more snow classes and incorporating daily wind information. The snow classes were introduced to better describe the melting of snow whereas the wind information was used in combination with a local topography index to describe the small scale redistribution of snow. The snow model was then used in a hydrological model and the calculated discharge compared to observations. One hypothesis is that the combined effect of the improved precipitation and snow model will give a better description of the interannual variability in runoff.

Results from running the model for 2000 to 2010 show that both changes in the precipitation interpolation and in the snow model have an effect on the distribution of the modelled snow pack. The results have been compared to observations of the snowpack as well as runoff and improvements can be seen in both variables. The improvements in runoff are smaller than for the snowpack, as the effect of the redistributions tends to even out at a larger scale.

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Effect of Groundwater Flow on Heat Exchange Efficiency of Geothermal Boreholes: Porous vs. Fractured Media

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Using borehole heat exchangers (BHEs) for space heating and cooling is becoming progressively more popular as they are energy efficient and sustainable, and globally implementable. Consequently, the concerns for thermal, environmental and economic sustainability of their design and application are rising, especially in interaction with groundwater flow.

Heat transport in the subsurface is one of the factors that significantly affects performance and sustainability of BHE systems. The advective heat transport regime by groundwater flow has not been well integrated in the design and regulatory environments (Dehkordi and Schincariol, 2014b). For instance, the majority of BHE design software assume the heat transport by groundwater flow to be negligible.

For modelling the BHEs, FEFLOW® – a fully-coupled variable density, finite element, flow and energy transport code – is used here. Loop temperatures are used as an indicator to compare the thermal performances, i.e. heat exchange. The effect of groundwater flow interaction with a BHE is studied. In porous media, at fluxes above 10^{-7} m s^{-1} an effect on BHE's heat exchange performance is observed, versus no groundwater flow conditions; this thresholds is as low as 10^{-8} m s^{-1} during thermal recovery periods, when the BHE is shut down and ground temperature is returning to its initial value (Dehkordi and Schincariol, 2014a). Groundwater at higher fluxes, e.g. 10^{-6} m s^{-1}, is ranked amongst the top factors impacting the thermal performance of BHEs. Groundwater flow in fractured media can also have a similar influence. There are, however, multiple fracture features affecting the heat exchange process, e.g. aperture, distance or depth of intersection, orientation, number and connectivity (Dehkordi et al., 2014).

The study confirms the significance of groundwater flow in certain conditions. The results are applicable for improving the thermal and economical sustainability of design methods and regulatory guidelines in a hydrogeological context.

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Adapting to climate change: Regulation strategies during extreme flood in the Kokemäenjoki watershed, Finland

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Many of the current Finnish lake regulation practices are forecast to become impractical due to climate change. Hydrological regime is forecast to change and extreme events to become more frequent, which raises a need to look for alternative regulation strategies. The aim of this study is to facilitate a dialogue between scientists, policy makers and key interest groups on acceptability of different kinds of regulation practices in response to changing hydrological conditions.

The case study area is the Kokemäenjoki watershed (area 27 046 km^2) in Southwest Finland. It includes a chain of regulated lakes upstream and the River Kokemäenjoki downstream. Along the River Kokemäenjoki two significant flood risk areas, the cities of Pori and Huittinen, have been identified.

An extreme winter flood was simulated with the hydrological model Watershed Simulation and Forecasting System (Vehviläinen 1994). The flood event included components expected to become more frequent according to climate change scenarios (Veijalainen et al. 2012): large discharge in winter, frazil ice formation, and high sea water level. Three different regulation schemes were applied to this flood event.

In the first scheme, lakes were regulated according to their current regulation rules, avoiding raising water levels to harmful levels by using large outflows. Downstream a frazil ice jam causes the water level to rise over the flood banks in the city of Pori causing enormous flood damages. In the second scheme, the total flood damage in the watershed was minimized by using an optimization model to calculate lake outflows. Discharge in the River Kokemäenjoki was thus reduced to promote formation of ice cover that prevents frazil ice formation. This involved raising lake water levels significantly over the damage levels. Estimated total monetary damage, however, decreased from the magnitude of hundreds of millions euros to tens of millions euros. In the third scheme, the optimization model was used as in the second scheme, but additionally the lakes were prepared for a winter flood by lowering lake water levels already in autumn. With this scheme the total damage was further reduced.

The simulated regulation schemes were presented and discussed in a stakeholder event in May 2013. Minimising the total damage was considered as an acceptable approach and preparation for winter floods reasonable. However, more reliable information on impacts of the measures was called for. Decision-making in an extreme situation involves uncertainty, risks and conflicting views. Therefore, the strategies should be simulated, discussed and agreed by stakeholders in advance.

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Groundwater balance in hard rock terrains with limited soil cover: The importance of spatial data

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Groundwater management is difficult in recently glaciated, hard rock terrains due limited glacio-fluvial deposits, lack of a significant weathered layer and extreme heterogeneity in the fracture network. While the Swedish climate has sufficient annual precipitation to meet the needs of the population, several phenomena occur which can lead to localized and regional groundwater scarcity. Large volumes of meteoric water are lost to surface water bodies including the Baltic Sea due to a high runoff coefficient and fracture plugging during rain events (Spence and Woo 2002). Elevated evapotranspiration rates during the summer period lead to limited recharge, forcing residents to rely on local groundwater reserves. However, these are often limited to isolated soil pockets with low kinematic porosities such as till or clay and the bedrock fracture network which has porosity values orders of magnitude lower. Low horizontal hydraulic conductivity values in the subsurface limit indirect recharge, leading to the primary source of recharge occurring directly from meteoric water. Proximity to saline water bodies such as the Baltic Sea increases the risk for salinization of groundwater reservoirs, which are already at risk due to the presence of relic salt water from the last period of glaciation (Olofsson 1994). Finally, increasing permanent residency in coastal areas increases the demand on groundwater resources. It is vital that decision-makers have access for tools which can quantify sustainably and equitably extractable groundwater resources, and which can identify areas where environmental stresses are likely to occur in order to allocate resources for mitigation.

Groundwater balance models have been shown to be useful in hard rock terrains with limited soil cover (Olofsson 2002), but often do not account for spatial distribution of well extraction which is exceedingly important in areas with primarily single-household drilled wells, nor do they account for the limited storage characteristics of the reservoirs. A new method has been developed which was based on a simple groundwater balance methodology, but accounts for both of these concerns. The method uses readily available data such as geological and well data from the Geological Survey of Sweden, topographical data from the Swedish Land Survey, and climate data from the Swedish Meteorological and Hydrological Institute. The model was run in several locations and for several climate and land-use scenarios, and compared to some more traditional groundwater balance methods. The method was shown to be capable of identifying areas which are at risk for over-extraction and increased environmental stress. Results indicate that this new methodology could prove very useful for regional and local planners in managing limited groundwater resources. Benefits of the model include: (a) reliance on readily available data, (b) execution in a GIS environment which allows for non-hydrological experts to implement and understand it and (c) a robust and adaptable framework which allows for modelling of different climate and land-use scenarios.

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Regionalisation of the Parameters of the Rainfall-Runoff Model PQRUT

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PQRUT is a simple, three-parameter event-based rainfall-runoff model which is used for design flood analyses. The model is primarily applied to ungauged or regulated catchments for which it is not possible to calibrate a more complete hydrological model, such as HBV. In addition, the model is well suited for the analysis of peak flows for which a sub-daily temporal resolution is required. Currently, the three model parameters are estimated based on three catchments properties (estimated annual runoff, effective lake percentage and a measure of the steepness of the catchment) using empirical formulas derived using a stepwise multiple linear regression analysis undertaken over thirty years ago (Andersen, et al., 1983).

The reasons for re-evaluating the empirical equations for the estimation of the PQRUT parameters are the availability of suitably long timeseries of high resolution discharge data and the development of newer methods for regional statistical analysis. In this study, the PQRUT model was calibrated for 63 catchments distributed across Norway. Precipitation data with a three-hour temporal resolution, representing a temporal disaggregation of daily gridded data using the HIRLAM model (Vormoor & Skaugen 2013) was used to drive the model. Event-based calibration was performed for the 50 highest flows for each catchment, representing peak flows generated by rainfall only. Snowmelt floods were excluded due to the uncertainty associated with quantifying the snowmelt contribution at a subdaily timestep. The calibrated parameter values were divided into regions by using PCA (Principle Component Analysis) and cluster analysis. Multiple linear regression was used to develop regression equations for estimating the parameter values at ungauged catchments.

The use of different regression coefficients in the identified regions was compared to using the same set of regression coefficients for the entire country. The performance of the proposed regionalization method was also compared to the regression equations developed by Andersen, et al., 1983. The results highlight the importance of considering the spatial variability in the parameters when developing regression equations for ungauged or poorly gauged catchments across a large, inhomogeneous study area.

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Multidimensional flow measurement point-clouds: moving beyond transects.

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The use of Acoustic Doppler Current Profilers (ADCP) for measuring flow and discharge is becoming increasingly widespread. Until now, most flow mapping has focused on measurements along a series of transects in a channel. Here we present a new method that takes flow measurements beyond transects. We achieved multidimensional spatial flow measurements by deploying an ADCP on a remotely controlled boat, combined with Virtual Reference Station Global Navigation Satellite System (VRS-GNSS) and locally monitored water level data. We processed this data into a point cloud of 4D flow measurements that allows the visualisation of flow velocities, directions and channel morphology in 3D space. We demonstrate how this allows monitoring changes of flow patterns with a time-series of flow point-clouds measured over the period of a spring flood Finnish Lapland.
This work expands on our previous methodological developments relating to high-resolution modelling of river environment topography (Flener et al. 2013) by focussing attention on high resolution modelling of the water flowing through and acting upon that topography (Laamanen et al. 2014)

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Long term variability of seasonal river runoff in Sweden in past, present and future climates

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This work, which builds on previous work presented at NHC 2012 (Foster et al. 2012), looks at how future climates may affect the longterm variability in seasonal runoff in Sweden.

A cluster analysis of runoff data from 73 observation stations, with unregulated flows, divided Sweden into five homogeneous regions based on monthly runoff and a composite runoff time series was constructed for each region. A linear regression model that employs an SVD approach (singular variable decomposition) was trained using these composites and large scale circulation variables from climate models from the CORDEX project. This statistical model is then forced with both historical (1850-2005) and projection (2006-2100) data from these climate models to give a recreated historical and projected runoff time series to perform analyses on.

Spectrum analyses, both Fourier and wavelet, was performed on the time series to identify any changes in the decadal variability of hydrology across Sweden for past climates, present climate and future climates. These results were compared to results from spectrum analyses performed on data from a hydrological model forced by climate data from the ensembles project. The reason for this was to see if there is consensus in the different generations of climate models and to extend the ensemble of data for a more robust result.

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Connecting large scale circulation patterns to seasonal runoff – understanding the engines that drive hydrology to improve seasonal hydrologic forecasts

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The importance of seasonal forecasts cannot be overstated, especially in the hydropower industry where they are indispensable in the planning of operations. The aim of this work is to build an understanding of how large scale circulation patterns are connected to seasonal runoff in Sweden. The hypothesis is that by understanding this connection, the physics that connect the phenomena as well as their timing and persistence, it is possible to improve hydrologic seasonal forecasts.

A cluster analysis of runoff data from 73 observation stations, with unregulated flows, divided Sweden into five homogeneous regions based on monthly runoff and a composite runoff time series was constructed for each region. Principle component analysis was used to identify significant connections between different hydrological seasons and large scale circulation pattern indices that represent different lead times and persistence. Next the physics that underpin these connections were investigated to ensure that these connections had real world explanations and were not the random result of the statistical methodology.

These connections and the understanding of the physics behind them allow us to improve on existing forecast systems and or to develop new forecast system that not only improve forecast results but extend the forecast horizon too.

Hydrological modelling: River runoff modelling of large River basins in Estonia.

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In the last years there has been a progressive approach to the hydrological rainfall run-off modelling which can be used as primary method to evaluate the basin response to the most important modelling parameter- precipitation in both forms, liquid and snow.

Hydrological rainfall-runoff models often require some degree of calibration and validation to achieve adequate basin representation of the study area. This is, however, only possible for gauged basins. There are many basins for which there are not monitoring discharge data available, it makes quite difficult the modelling but this disadvantage can be minimized extrapolating model parameters obtained through calibration of gauged basins to ungauged basins to simulate runoff.

The aim of the present study was to implement, calibrate and validate a hydrological model to simulate the spring peak runoff, in gauged and ungauged basins of Pärnu River and Emajõgi River with a total area of 6910 km2 and 9960 km2 respectively (Loopmann A. 1979).

Both River basins are covered by forest and agricultural landscapes, most of the land is considered flat, under 5 percent of slope and the hydrologic soils are mainly well drained to moderately drained. The climate of this region follows the pattern of Northern regions of Europe with an annual average temperature of about 4,3 °C and 6,5 °C, but the temperature usually falls down to negative centigrade during winter . Total annual average precipitation is 550– 750 mm with an evapotranspiration rate of 420 mm annually.

The application of the model requires specific information about weather sources, daily max and min air temperature and precipitation recorded at the Estonian meteorological network, topography, soil characteristics and land use.

Model performance was evaluated using the Nash-Sutcliffe coefficient and Regression Coefficient was also used. During the calibration and validation periods the model is able to represent satisfactorily silhouette, volume, and peak of observed flow hydrographs and perform better some stations than others, it is shown by the variations in the results of Nash and R2 coefficients. All the model evaluation results during the different periods are over the values to be considered acceptable NASH > 0, 65 or good NASH >0, 75 and (R2) > 0, 5. (Moriasi D. N. et al 2007)

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Management planning as a tool for water regime restoration in protected areas of Lithuania

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According the article 6 and Annex IV of Water Framework Directive (WFD) all Member States shall ensure the establishment of a register of all areas lying within each river basin district which have been designated as requiring special protection under specific Community legislation for the protection of their surface water and groundwater or for the conservation of habitats and species directly depending on water (Directive…, 2000). Four river basin management plans for river basin districts of Nemunas, Dauguva, Lielupė and Venta were prepared and approved by Lithuanian government in 2010. Register of protected areas (PAs) was presented here. Now updating river basin management plans in Lithuania is going on within the project "Updating of river basin districts management plans and programmes of measures", and impact to PAs of water bodies not meeting with criteria of good status will be evaluated.

Natura 2000 network consisting of territories important for the conservation of birds and habitats covers more than 12 % of Lithuanian territory. The general aim of creating of Natura 2000 network is to ensure the protection of the natural habitats and species mentioned in the Habitat directive (HD) annexes. The directive also states that PAs that were established as a part of the Birds Directive (BD) are also included in the Natura 2000 network. The special aim of the HD is to maintain, and if needed, restore natural habitats, wild flora and fauna of Community importance at a favourable conservation status.

The research (Povilaitis et al., 2011) showed that the water regime of different types of landscape has been transformed since long-ago. During 100 years of land reclamation in Lithuania 47 % of the country's area were drained. Land reclamation has reduced biodiversity. The area of bogs and shrubs in the drained territories has been rapidly shrinking and intensive transformation of cultivated lands has taken place. In 1955–1995, there disappeared almost 50 000 ha of bogs. Today wetlands in Lithuania occupy 9.6 %, peat bogs (peat layer is more than 30 cm) – 7.8 % of the country's territory. The greatest number of peat bogs is characteristic of the Dauguva River basin (13.8 %). The number of bogs in the Nemunas, Venta and Lielupė basins is close to the country's average.

One of the most important tasks in nature management of protected wetlands is to restore natural (or semi-natural) water regime in valuable habitats. Optimal measures should be chosen for protection and management of wetland habitats. All PAs with administrations in Lithuania has approved management plans (as documents of territorial planning) where special restoration measures could be designed. Also more than 110 nature management plans (as strategical planning documents) are prepared for Natura 2000 sites. Analysis of water regime restoration measures which are foreseen in planning documents and implemented in reality will be presented during the presentation.

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Simulation of changed transpiration due to groundwater drawdown in infrastructure projects as proxy for effects on crop: Case study – Road and railway junction in Skänninge, Sweden.

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In a few recent Swedish infrastructure projects stakeholder concerns have been raised regarding groundwater drawdown and negative impact on crop. According to the Swedish environmental code, which regulates groundwater drawdown, the developer has the evidential burden. In the legal process the developer has to show proof of possible impacts and eventually compensate the stakeholders for crop yield loss. This study shows how measurements of groundwater levels before and after construction of a road and railroad junction is used for simulation of altered transpiration and how it is used as proxy for effects on crop. The study site is located in Skänninge, Sweden.

Simulations of changes in transpiration have been conducted in the process-based COUP-model (Jansson & Karlberg, 2004) which calculates storage and flow of water in a vertical layered soil-plant system. Compared to previous studies with the same approach, the hydrogeological conditions in Skänninge demanded a modification of the model. The COUP-model can only process a single groundwater level. An aquifer system is located in the study area with an open aquifer containing silt and fine sand above a glacial till aquifer confined by a less permeable layer of clay and loamy silt. Measurements prior to groundwater drawdown only exist from observation wells established in the confined aquifer. The ground water table in the confined aquifer has been permanently lowered by approximately 2 meters in the area close to the junction.

The lowered level in the confined aquifer is used as a lower boundary condition for calculation of leakage between the aquifers. For simulation of continuous time series a storage based groundwater model was set up with the measurements used as a calibration dataset. Driven by climate data, the model calculates the transient change in water balance between storage in snow and in the aquifer. Values to independent parameters were assigned by calibration with Monte Carlo simulations. To improve the accuracy of the ground water model data assimilation was conducted with an ensemble Kalman filter. The purpose of the data assimilation was to successively update the simulated groundwater level with observations to correctly represent the impact of the road construction.

The Penman-Monteith's equation was applied to calculate changes in the crop's transpiration and water-uptake for potential transpiration as well as actual transpiration. The crop was represented by a single big leaf.

The results show that the risk for reduction of transpiration and hence loss of crop is less than 1% with a 95% confidence level. The sensitivity analysis shows that if the top layers were more coarse-grained the negative impact would increase. On the other hand, with higher content of fine-coarse silt and clay, increased drainage could have a positive effect on the crop due to less limitation in transpiration due to saturated conditions in spring. Both positive and negative effects are however strongly dependent on the permeability of the confining clay layers.

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The role of long-term monitoring for understanding the impact of water on carbon fluxes of boreal forest ecosystems

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The response of carbon fluxes in boreal forests to climatic and biogeochemical conditions such as temperature, water and nutrient availability are keys to improved understanding of the role of these ecosystems in the climate systems and the on-going climate change. Datasets with long-term measurements of carbon, heat and water fluxes are now available from many sites all over the world, sometimes covering two decades or more. In this study we are evaluating the role of long-term datasets for improving understanding of the impact of water availability on carbon fluxes in boreal forest ecosystems. The objectives are first of all to evaluate to what extent the importance of water on photosynthesis and respiration can be separated, respectively, and if the importance of water can be separated from other factors such as temperature and nutrient availability. A parallel objective is to evaluate in what respect the long-term monitoring data were informative for the calibration of a process-based ecosystem dynamics model and for the identification of the role of water for the carbon fluxes.

Two types of long-term datasets from the Norunda forest site in South-eastern Sweden are included in the study: on one hand, 15 years of hourly eddy-covariance measurements of land surface-atmosphere exchange of heat, water and carbon, and physical conditions in the soil including groundwater fluctuations; and on the other hand annual observations of carbon storage in the tree biomass and soil. The datasets were used in a Monte-Carlo calibration of the CoupModel, simulating coupled water, heat and carbon fluxes in a soil-plant-atmosphere system. Parameters regulating photosynthesis and respiration were calibrated by selection of parameter combinations fulfilling different criteria for the models ability to represent the observed fluxes and states in terms of absolute levels and temporal variability at within-day, daily, seasonal and inter-annual timescales. The analysis is focused on the link between identifiable parameters and type of criteria and type of data.

The results show that a double criteria to make the model in agreement with both long-term trends in tree biomass and eddy flux is not possible to satisfy with current understanding. Single criteria on eddy-flux measurements can be fulfilled provided that we are draining the soil and enhancing decomposition. On the other hand, with criteria focusing more on temporal variability and less on long-term balance it is possible to demonstrate the impact of water and temperature on shorter time scales for photosynthesis, and the impact of groundwater fluctuations on respiration on longer timescales.

Dam safety assessment in a changing climate - from SRES to RCP emission scenarios

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In Sweden there are over 10.000 dams of which approximately 200 are classified as high hazard dams, implying dam safety as a subject of national interest. Design floods is a keynote in dam safety and efforts to encompass design discharge in course of climate change is made by a joint committee between industry, responsible agencies and research. A recognized method for the climate adaptation of the Swedish guidelines for design floods for dams has been developed. The method for adjusting regional climate scenarios used as input to a hydrological model, the so called Distribution Based Scaling (DBS) preserves much of the climate signal from regional climate models while bias is removed. A rational production system has also been developed, which facilitates cost-effective processing of a large number of climate scenarios for hydrological simulations. Two ensembles of regional climate scenarios were used in order to assess earlier work and compare with more recent climate models and emission scenarios. The dual ensemble approach holds two different generations of climate projections; the so-called SRES-scenarios (Nakićenović et al, 2000) and the Representative Concentration Pathways scenarios, RCP (Moss et. al, 2010. The SRES-ensemble represents Assessment Report 4 (AR4) published in 2007 and the RCP-ensemble represents Assessment Report (AR5) published 2013. Climate adaptation of infrastructure is a long-term engagement and robustness in anticipated hydrological trends is a necessity to justify large-scale investments. It is of significant value to compare earlier climate impact simulations and put them in a modern context. Simulations of future changes in floods in Category I (high hazard dams) according to the Swedish guidelines for hydrological spillway design are shown for a selection of 7 basins, which are relevant for the hydropower and mining industries. The simulations are based on altogether 36 regional climate scenarios. The calculations of future floods in Category I show tendencies towards decreasing levels in many areas. This is mainly due to decreasing design snow pack but also increasing evapotranspiration in a warmer climate.

This project was initiated and financed by ELFORSK. The findings will be adopted operationally in future dam safety reviews.

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Hydrological Response to Land Use Changes at a Small Watershed in the Hilly and Gully Area of the Loess Plateau

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In order to study the relationship between human activity, land-use change and hydrological processes, a typical small watershed in the hilly and gully region of the Loess Plateau was chosen to use the CULE-S and SWAT model to analyze changes of land use and its corresponding hydrological processes. The two future changes of land use were set based on economic development and eco-environmental protection policy of China government, assumed the area of forest, farmland, and orchard will increase with the decreasing grassland cover by 2020. and the annual average surface runoff in the simulated period (2009–2020) was 51% less than the observed value of 1986–2004. As a result of soil and water conservation in vegetation and terracing, the future land-use structure should lead to remarkable benefits in both soil and water conservation. In this work, economic and policy factors are combined with land use and hydrological processes by coupling the **CLUE-S model with the SWAT model**, and this provides a basis for decision-making in the coordinated development of the economy and environment.

Key words: Economic and policy factors; Land-use change; SWAT model; Hydrological response.

Modelled runoff sensitivity to snow parameterization - A case study for Upper Beas basin in Himachal Pradesh, India

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For rivers with headwaters in the high mountains of Himalaya, snow and glacier melt are large contributors to river discharge. The timing and size of melt flow is important for the availability of water in these basins, especially for years with low precipitation during the summer monsoon. Hydrological models are used to assess the availability of water resources under current and future climate, and within these models, there are different methods used to calculate snowmelt. The aim of this study is to evaluate the sensitivity in the simulated water balance components, runoff in particular, to different complexity in the snowmelt routine of a hydrological model. For this purpose three specific tasks were defined. 1) Establish a gridded hydrological model for the Upper Beas basin including subbasins, based on local and global datasets, 2) Preform a systematic analysis of model sensitivity in terms of runoff and snow/glacier covered area, for three models with a varying complexity in the snowmelt routine and 3) Analyze the variability in the seasonal runoff pattern across the Upper Beas basin.

A gridded hydrological model with spatial resolution 1 km operating on daily time resolution was applied to the basin. Three models were used for calculating snow melt; a temperature-index model, an enhanced temperature-index model including a radiation term and an energy balance model. The input data were precipitation, relative humidity, temperature, wind and short wave radiation. In order to evaluate the differences between the snow melt routine, we kept all parameters but those related to snow melt constant for the three models, and we calibrated the snow melt parameters for each individual model. The models were evaluated for several sub-basins with different degrees of glacier covered areas.

The three models showed rather similar behavior. Evaluation of simulated runoff shows high correlation coefficients for all subbasins, high Nash-Sutcliffe efficiencies for the calibration period, lower for the validation period. For the validation period there were large volume errors. All models had problems simulating the negative trend in observed discharge in the high elevation subbasins with the largest glacier cover. This might be explained either by the precipitation interpolation routine or that none of the models has a glacier mass balance model. In all models the interpolation routine results in high precipitation at high elevation. A main challenge that high runoff occurred in the lower parts of the snow accumulation areas. For specific years, a storage reduction up to 6000 mm might explain the overestimation of runoff. In all models the glaciers are an infinite storage of water and do not account for an eventual reduction in glacier covered areas.

None of the models were found to be the best in all sub basins and for all evaluation criterions. For annual evaluation the enhanced temperature-index model simulated the highest runoff for most basins except for Tirthan were the full energy model had the highest over estimation.

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Impact of Climate Change on River Flow in Central Taiwan

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This study proposes an assessment of the impacts of climate change on river flow in central Taiwan including four river basins. The study area is 10503 km^2 comparing to 36192 km2 of the total area in Taiwan. The GCM (General Circulation Model) models including CSMK35、GFCM21、MIMR、MPEH5 and MRCGCM were used to project the future monthly climate data under climate change. For the five GCM models, the monthly downscaling rainfall data to the four river basins were prepared by TCCIP which funded National Science Council in Taiwan. The weather generator is then used to synthesizing daily rainfall based on the monthly downscaling data. A rainfall-runoff model GWLF is used to compute the runoff from the synthesized daily rainfall. The simulations results varied among different GCM models. Summarizing the results of the five GCM models for the A1B, A2 and B1 emissions scenarios from SRES (Special Report on Emissions Scenarios) during 2020~2039, the average runoff of the wet season (between May to October) varied between -1.33% to 10.33%, -3.22%~12.1% and -1.02% to 8.32% respectively for the three scenarios, and the average runoff of drought season (between November to April) varied between 1.33% to -9.32%, -0.82%~-22.31% and 2.23% to- 12.32% respectively. The results also indicated that the trend of discharge is increasing during wet season and decreasing during drought season. The variation of the projected river flow is mainly caused by the variation in the spatial patterns of climate change between climate models. The study results are important references for the decision making of the water resources adaption policies in centre Taiwan.

Keyword: Climate Change, Weather Generator, GWLF

Drought dynamics of central Finland in response to atmospheric circulation patterns: 1959-2009

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Using Standardized Precipitation Index (SPI), this study investigated drought phenomena in central Finland and its linkage to atmospheric circulation patterns. The SPI values at monthly (SPI1), seasonal (SPI3) and annual (SPI12) time scales were computed based on daily precipitation data collected from 1959 to 2009 at three meteorological stations in the region: Ähtäri (62°32'N; 24°13'E), Jyväskylä (62°24'N; 25°40'E) and Vieremä (63°50'N; 27°13'E). Statistically significant ($p<0.05$) trends in SPI1, SPI3 and SPI12 time series were detected using the Mann-Kendall non-parametric test. The spearman correlation coefficient (rho) was applied to determine relationships of the SPI1- 3 and 12 values with a number of atmospheric circulation patterns in the northern Hemisphere. The longest drought period was 4 years from 1963 to 1966. In general, increases in all of annual, seasonal and monthly SPI values, i.e. declines in drought, were found in central Finland during studied period (1959-2009); August was only month in which SPI1 values showed a drought increase. Besides, meteorological wetness was more frequent than drought, particularly at extreme level. The drought dynamics was positively linked to the North Atlantic Oscillation (NAO), while negatively associated with Scandinavia (SCA) and the East Atlantic/West Russia (EA/WR) patterns.

Shifts in Timing of Spring Flood Discharge in Northern Finland Rivers: 1967-2011

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Spring flood discharges resulting mainly from snowmelt runoff are currently considered as the largest flood in northern regions, including Finland. Climate change extensively influences both quantity and temporal characteristics of Nordic river discharges by impacting the snow accumulation and melt processes. Previous studies have reported decreasing trends in snowpack accumulation and consequently less snowmelt runoff over many parts of Finland during the last century. This study analysed 45-year daily discharge records (1967-2011) of 3 natural rivers (Torniojoki, Simojoki and Kuivajoki) over northern Finland, to determine shifts in timing of spring flood discharge over a year manifesting temporal changes of peak snowmelt runoff. The Mann-Kendall non parametric test was used to detect significant trends ($p<0.05$), and the Spearman's correlation coefficient (rho) to indicate relationships with different atmospheric circulation patterns. In general, the spring flood discharge in all selected rivers was found to be occurring significantly earlier in the year, approximately by 10.6 days per 45 years. In average, the timing of spring flood discharge was around 23rd of May in the Torniojoki River located at the highest latitude, while around 6th of May in both Simojoki and Kuivajoki Rivers. The East Atlantic (EA) pattern was negatively ($p<0.05$) associated with variations in the timing of spring flood discharges in all selected rivers, with rho between -0.42 and -0.36. As well, the North Atlantic Oscillation (NAO) and Arctic Oscillation (AO) showed negative relationships with the timing of spring flood discharge in both Simojoki and Kuivajoki Rivers ($p<0.05$). The results highlight expected changes in temporal characteristics of snowmelt hydrology in Finland by indicating clear shifts in timing of spring flood discharge.

Hydrological feasibility of flood barriers to protect the Gothenburg (Sweden) during the 21st century - an initial assessment

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Climate change due to increasing of greenhouse gas emissions to the atmosphere will cause mean sea level to rise about +1 m by 2100. To prevent coastal floods resulted from the sea level rising, different flood control structures have been built and showed acceptable protection levels at least so far; e.g. Thames Barrier in London, UK. Gothenburg city on the south-west coast of Sweden, with the Göta älv River running through it, is one of vulnerable cities to the accelerated sea level rise. Besides, a high tide in southern Sweden will be increased to +2 m above the current sea level by 2100. Hence, most parts of Gothenburg will experience flooding events during the 21st century, even the City Planning Office of Gothenburg suggests +2.5 m above the current sea level as the safe level for setting the shelter of especially important facilities by 2100. Developing water level model by MATLAB, we investigated the hydrological feasibility of using flood barriers in the Göta älv River to protect the Gothenburg city against flooding events during this century. One flood control barrier at the river upstream (upstream barrier) in the Gothenburg region and a sea barrage (Göta älv barrage) at the entrance point of the river to the North Sea were suggested by this study. Considering three operational scenarios for these barriers, the highest sea level was estimated to +2.95 m above the current mean sea level by 2100. To prove flood protection against such high sea levels, both barriers have to be closed. In order to prevent high water levels in the Göta älv reservoir due to the runoff generation from rainfall, the barriers would be open when the sea level is low. This preliminary assessment concluded the suggested sea and flood barriers would successfully protect the Gothenburg city from flooding events during the 21st century.

The resurrection of a biologically dead lake – monitoring and remedial measures

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The catchment of Lake Hornträsket hosts three abandoned mines. The fish has gradually been lost and in a test-fishing in 2006 only less than a handful of perches were caught in a part of the lake that received a better water quality. The investigation of the aquatic fauna in terms of macro-invertebrates showed a massive depletion compared with a neighbouring lake. An inventory of the chemistry in streams and drains showed that heavy metals and notably copper was the culprit (Bossuyt and Janssen 2004) and that this mainly derived from one of the three mines lying close to the lake shore. However, sizeable amounts of zinc were also coming from forest ditches after a subsidized campaign for forest drainage in the 90-ies. The closing of the mine was done in a way that coarse sulphidic waste rock was bulldozed into the open pits which allowed flow of groundwater through the permeable material and oxidation of the sulphides. The short distance to the lake meant that no sinks for the released metals were present.

The remediation included diversion of upstream water by construction of a ditch system around the mining area. In that way about 50 % of the through-flow was diverted from passing the filled up open pits. The next step was to inject mesa-chalk, a waste material from the nearby paper and pulp industry. This was successful in part of the mine area, notably in the filled up open pits. A flat area filled up with coarse rock and used for parking and storage resisted the treatment. By a dense network of piezometers and water sampling some hot spots of acidity and high sulphide contents could be detected. It was found to be heaps of high grade sulphidic material which was dug away and stored elsewhere in a safe place. This turned out to effective. The areas was then covered by sewage sludge and a silty till and vegetated by grass to start with.

During the process from 2006 until present the lake water and the drains into the lake has been monitored and a gradual increase in pH and lowering of the metal contents have been seen. The lake is monitored by the use of DGT sensors during the late winter period. It turns out the copper content has now gone below 10 μg/l, a level at which even sensitive species survive. To assess the bioavailability of the metals filtering and in situ dialysis of the lake water has been performed recently by the use of two dialysis membranes with 10 respectively 1 kDa of pore sizes (Vsyukova et al. 2011; Jacks et al. 2013). The dialysis showed clearly below toxic levels of copper, the most aquatoxic heavy metal.

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Subsurface dams for sustainable water resources development

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Improved water resources management increases the economic development, and contributes considerably to poverty alleviation. Global economies are highly dependent on rainfall variability; and there is a positive correlation between water storage capacity and economic growth. One of the problems with arid and semi-arid regions such as Pakistan is that the rainfall is usually restricted to short and intensive events followed by long dry periods. On the other hand, in previously glaciated humid regions such as Sweden, groundwater storage prospects are generally not very encouraging because of the unfavourable geology. Many Swedish coastal areas are developing at a high rate with newly constructed houses and conversion of existing summer cottages into permanent residences. This will likely result in increased groundwater problems, qualitatively as well as quantitatively. Over exploitation of the groundwater resources leads to declining groundwater levels and to quality problems, such as salinity of the drinking water due to seawater intrusion. Therefore, there is a need to develop some methodologies for water resources management in regions with erratic rainfall (e.g. monsoon) as well as in the coastal areas of glaciated terrains.

One of the methods to increase water supply is to increase groundwater storage through construction of subsurface barriers i.e. subsurface dams. Groundwater storage has many advantages over surface water storage, i.e. negligible evaporation, no submergence of valuable land and generally lower microbiologically contamination concerns. Subsurface dams proved to be quite sustainable in various parts of the world with very few reported environmental impacts. Japan is a leading country in this regard and has constructed some huge subsurface dams with individual storage capacities exceeding 10 million cubic meters which are being used for water supply and agriculture purposes. Existence of these dams have been reported in many countries, i.e. Japan, India, Ethiopia, Burkina-Faso, Kenya, South Korea, China, Brazil and USA. Therefore, groundwater storage through subsurface dams seems promising in dry climate of Pakistan as well as in south eastern humid islands of Sweden.

There are nevertheless, several examples of subsurface dams which have not been successful due to lack of planning and not being located on suitable sites. Locating suitable sites for construction of subsurface dams requires detailed field investigations and integration of multiple physical, socio-economic factors. However, for early planning stages, spatial multi-criteria analysis (SMCA) where GIS plays a role in analyzing spatial data and MCA provides procedures to structure decision problems; can provide an efficient decision support tool for water resources management; through identifying potential sites for construction of subsurface dams, using commonly available digital datasets.

Science- and knowledge-based water management in Denmark – linking science and practice

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Denmark has a long history of managing water and developing sustainable water solutions and technology. With a water resource law dating back to the 1920s, Denmark was the first country to establish a Ministry of Environment (MoE) in 1971. Thus, there has been a political call for knowledge and innovation on water issues from early on, and this understanding was fully embedded in the administrative system at all levels, which led to the launch of several applied research programmes within MoE from the 70ties and onwards, addressing topics like NPO emissions, pesticide degradation and ecotoxicology, groundwater remediation, etc.

These initiatives in the MoE were followed up by the Ministry of Higher Education and Science (MES) with the Strategic Environment Research Programme, lasting from 1992-2004 http://info.au.dk/smp/index.html. Within this program a number of strategic water research centres were established, all addressing major issues within the water cycle and feeding directly in to a number of large management programmes in MoE on monitoring, groundwater mapping, pesticides, etc.

So for many years there has been clear focus and funding for nearly all parts of the innovation chain within water management. While in the early years priority was given more on the back end innovation, basic and strategic research, the focus has changed during the later years - governed by a political paradigm shift towards economic growth - to front end innovation and technology programmes, including demonstration and testing of technology and system solutions, and taking-to-market programmes.

Another very significant feature of the Danish strategy has been the well-developed co-operation across the water sector. Denmark also has a long tradition for co-operation between research, production, engineering and management, and many water sector organisations have contributed to the cross-sectorial co-operation by various knowledge sharing and facilitation activities, i.e. the Danish Water Research and Innovation Platform and Danish Water Forum (DWF).

This cross-sectoral co-operation is also reflected by the fact that several ministries have contributed jointly to the development of water management tools and technology. Basic and strategic research is funded by MES, the applied research of a joint foundation (VTU) supported by MoE and the water companies, and the downstream RTD by a number of funding sources from different ministeries. As a new innovation facility, a Testing Centre for Water Technology has been established by MoE providing space and funding for testing new technology.

The latest organisational development is the Innovation Fund http://www.innovayt.eu/node/288. This is a merger in MES of the Council for Technology and Innovation (RTI), DSF and the Advanced Technology fund (HT) in one organisation, thereby enabling better co-operation between the research community, the private sector and the public users.

There is a very good climate in Denmark for bringing science to practice. This is best done by bringing the different stakeholders together in concrete triple helix arrangements, where public end users and practitioners, private technology and knowledge providers and academia work closely together. A very good example of such a strategic partnership is Water in Urban Areas http://www.vandibyer.dk/english/, involving some 150 public and private stakeholders from across the sector.

A new MODFLOW LID process for simulating near-natural stormwater management strategies in an urban-hydrological context

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Applied on a broad scale, near-natural stormwater management approaches, which is named Low Impact Development (LID) in the US, is potentially an efficient measure to restore an urbanised catchment's hydrologic and ecologic function and adapt to future climate changes. LID involves infiltration, evapotranspiration, delaying, and/or reuse of stormwater which at the same time reduces the amount of runoff to the sewer system and the demand for abstracting natural water resources. However, some groundwater related issues must be eluded before LID can be enrolled on a broad range. A shallow groundwater table (which might be the consequence of stormwater infiltration itself) is known to affect the behaviour of infiltration devices and may mobilize pollutants, cause damage to buildings and infrastructure, etc.

A new USGS Modular Groundwater Flow Model (MODFLOW) LID Process was developed to simulate the urban hydrological water cycle and LID features in an integrated manner. The LID process can simulate runoff from semi- and impervious surfaces, the mitigation effect of LID's, the two-way interaction between infiltration devices and groundwater and the associated change in the water balance. A number of typical SUDS features (such as green roofs, rainwater tanks, swales, infiltration devices) can be represented and routing rules can be specified to move water from one LID feature to another. The package is implemented in MODFLOW-LGR (Mehl and Hill, 2013) which enables the simulation of higher-resolution child grids (covering suburbs with infiltration devices) within a coarser-grid parent model (covering the remaining catchment). The process simulates the water balance in the LID-features in so-called LID time steps (typically with the length of minutes) of which there can be multiple within a single MODFLOW (groundwater) time step. Stormwater related output (such as overflow from LID-elements) can be given as input to sewer pipe models.

The developed MODFLOW LID process was demonstrated for case-areas in the city of Odense, Denmark, which is located at the sea, has 190.000 inhabitants, and covers 78 km^2. The case-areas (each 250.000 m^2) was represented by MODFLOW-LGR child models in a 1×1 m grid and combined with a 9 km^2 MODFLOW-LGR parent model in a 100×100 m grid (representing the catchment). Climatic data from the period 1990-2010 was used to simulate the urban hydrological water cycle in different LID-scenarios. Special attention was given to the simulation of infiltration devices supplied with an overflow drain to the sewer system in shallow groundwater settings to manage "sustainable infiltration" in terms of both maximizing the infiltration, minimizing the risk of a shallow groundwater table underneath buildings, and delay stormwater runoff to the existing sewer system. The MODFLOW LID process was found useful in the analysis of such alternative stormwater scenarios.

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Climate change impacts on Lithuanian river water temperatures

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The thermal regime of a water body is of major importance because many of the chemical, physical, and biological characteristics of water are affected by water temperature. Water temperature directly affects water quality (especially influences the amount of dissolved oxygen in water) and ecological processes in aquatic ecosystems (the rate of photosynthesis of aquatic plants, sensitivity of aquatic organisms to diseases and parasites et al). Water temperature influences composition of aquatic communities as most of aquatic species (especially fish) live in their preferred water temperature range which can tolerate and need different water temperature at different stages of life. For many aquatic species, water temperature serves as a signal for migration and spawning.

Despite the importance of thermal regime, the dynamics of river water temperature is poorly investigated in Lithuania. Most studies have focused on ice cover regime and water surface temperature of lakes or thermal regime of rivers below impoundments.

The climate is changing. It is apparent from the review of climate trends in Lithuania over the past some decades that there has been a shift to warmer air temperatures from 1980s.

The aim of this work is to assess temporal variability of Lithuanian river's water temperature due to climate change using hydrological monitoring database.

Over the years since water temperature monitoring began in Lithuania in the 1945, water temperature was measured at 174 water gauging stations (WGS) which have been established on 84 rivers and streams. Currently water temperatures are measured at 75 WGS in 51 rivers. The data series of monthly river water temperature of these WGS and the methods of statistical analysis were used for analysis.

To characterize the thermal regime of the rivers, water temperatures of warm season (May-October), of spring warming period (May-July), of autumn cooling period (August-October), the average water temperature of hottest month (July) as well as maximum annual water temperature were determined. It was evaluated how these values change over the time using long term data of water temperatures from the whole period of observations (1945-2011) and the most recent period, 1980-2011, when the warming effect of climate change in Lithuania has been defined in the literature.

For temperature of whole observation period (1945-2011) no statistically significant trends were found for majority of rivers. The strong positive trends of water temperature were found only for some warmer rivers and strong negative trends – only for some cold rivers.

The most extensive changes in water temperature trends are assessed in the recent period of 1980-2011. The most intensive positive trends were found for the water temperature of whole warm season (May-October) and spring warming period (May-July) for majority of rivers.

The analysis of Lithuanian rivers water temperature revealed that the river water temperature mostly increased during the last three decades.

INVESTIGATION OF FLOW STRCUTURE OVER FLUVIAL FORMATIONS–A COMBINED APPROACH OF REMOTE SENSING AND 3D CFD

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Fluvial formations, such as dunes and bars, are products of certain 3D flow structures interacting with the river bed. Their appearance, locations in the river bend, sizes and shapes may have major differences between years and rivers, but also within a reach. Investigating the dynamics of flowing water and the morphological units is essential in the protection of fluvial environments, in river restoration or in riverine engineering. Thus, detailed investigations of the fluvio-morphological processes in natural environment are required to be able to understand the river channel evolution. However, previous studies concerning the meso- and microform –scale riverine fluvio-morphology have been usually lacking either spatial or temporal resolution, which may have led to subjective or incomplete interpretation of the phenomenon.

A combined approach of multi-temporal mobile laser scanning (MLS) and 3D computational fluid dynamics (CFD) allows us to dissect very detailed morphological change data in parallel with spatially and temporally extensive flow field data. The CFD is validated with field measurements of Acoustic Doppler Current Profiler (ADCP) by comparing the measured and modelled flow velocities and directions. In addition, UAV (unmanned aerial vehicle) –based high resolution photographs from low water stage enable the interpretation of the bed-forms more comprehensively and the grain size distribution over the reach is used to analyze the movement of the sediment over a flood event.

In this study, the formations caused by one snow-melt-induced flood event over a sand-bedded meandering reach of 1700 m are observed and associated with specific quantified flow characteristics (e.g. flow velocity, direction, stream power, turbulent kinetic energy) of different phases of the flood produced by a three-dimensional CFD.

Water Quality in a Small Pond in Relation to Atmospheric Inputs and Watershed Processes

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In this study, the water quality of the Borabey Pond in Eskisehir, Turkey is examined and relationships to atmospheric inputs of contaminants and watershed processes are established. The pond is situated in a hilly region to the north of Eskisehir, a city in the northwestern part of Inner Anatolia Region of Turkey and lies at 900 meters above sea level. The pond has a volume of 1.4 Mm^3, a surface area of 0.16 km^2 at maximum water level and is an earthen-dammed water body intended to be used as a source of irrigation water to farmlands downstream. The pond receives drainage water from an upstream agricultural watershed and is burdened principally by runoff from fields containing suspended solids, phosphorus and nitrogen from fertilizers and pesticides. The water body serves as a habitat to small flocks of water birds and is well-stocked with fish. The close vicinity of the pond is a protected area and belongs to the Anadolu University.

To serve the purposes of the study described here, a meteorological station has been established in the watershed close to the pond where also precipitation sampling is carried out. The 8.5 km^2 watershed is drained into the pond by a single ephemeral creek on which a weir has been established to measure water discharge where also water quality sampling is done. Monthly depth-averaged sampling has been carried out in the pond at two locations in the 2012-2013 water year.

From the analysis of the bulk samples, the amount of solids, chlorides, sulfates, nitrogen and phosphorus species, organic carbon and major cations like calcium, magnesium, sodium and potassium settling on the watershed by dry and wet deposition have been determined for the 2012-2013 water year. Turkey receives sporadically large amounts of wind-blown dust from the Saharan desert. Such an event of high Saharan dust amounts in the atmosphere has been observed once during the sampling period and the effects of this event on the atmospheric settling have been observed. The consequent change in the water quality of the pond by direct settling on the pond surface and by surface runoff has also been determined.

The effects of agricultural activities like field plowing which releases high amounts of particulates to the stream and consequently to the pond and fertilizer application which increases the release of nitrogen and phosphorus species to the pond have also been examined. The pond has been found to be a phosphorus-limited water body in relation to eutrophication which is an expected result as it almost exclusively receives contaminants from nonpoint agricultural sources. The ponds trophic status has also been determined as mesotrophic based on phosphorus, nitrogen, chlorophyll-a and Secchi-disc depth.

The summarized results above are thought to aid management strategies to preserve and improve the quality of the water of the pond for its intended uses which in future might include domestic use by nearby small communities, besides irrigation purposes. The region is a drought-prone one and extreme care is warranted for the protection of the already scarce water resources.

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Modelling an Aquifer Thermal Energy Storage (ATES) system

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An Aquifer Thermal Energy Storage (ATES) system provides energy for cooling and heating of buildings and infrastructure. The technology has a potential to cut energy consumption and thereby obtain lower CO2 emissions to the atmosphere. Even though the ATES technology has developed to an industry standard during the last decades, the technology is still affected by a number of problems mainly related to chemical precipitation and bacteria growth in the production wells. Aquifer physics and geochemical conditions giving these problems are well known, but there is still a challenge to describe the feedback between physical variables and the bio-geo-chemical conditions in terms of coupled partial differential equations. In this project, we explore the opportunities of linking different processes at different scales together in the object oriented software platform COMSOL MULTIPHYSICS. A sensitivity analysis of the local boundary conditions with respect to the large scale groundwater flow, indicated a robust well configuration close to the groundwater divide. Validation of the numerical implementation where done by comparing the numerical results to analytical solutions. Since this is a work in progress, we focus first on the physical coupling between flow parameters, temperature and flow conditions. An important modelling result so far is calculation of an optimal energy efficiency coefficient for a given ATES system. Due to a significant retardation of the temperature front, the temperature contamination of the aquifer is limited to the close vicinity of the production wells. The second phase, which remains to be solved, is the bio-geo-chemical coupling between change in temperature, and the geochemical condition of the aquifer.

Analysis of floods on the Lielupe River

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The problems of floods are addressed on different temporal and spatial scales. Floods are one of few natural hazards Latvia is exposed to. Different scale floods and inundations are natural phenomena on the rivers of Latvia. Riverine floods can be caused by wind induced storm surges, by rainfall generated flood waves on rivers, but mainly the most dangerous situations arises springtime, when water levels are raising due snowmelt and ice jams.
Climatic conditions of Latvia are changing. Winters are getting warmer and the spring high water period start earlier and tend to be longer.

Flood peaks during spring high water periods are caused by intensive water supply from watershed, ice jams may contribute to high water levels. Depth and density of snow cover are main factors which determinates how much water is stored into snow cover. The most dangerous are so called “rain and snow” events.

The occurrence of many extreme events in hydrology cannot be forecasted on the basis of deterministic information with the sufficient skill and lead-time as those decisions, which are sensitive to their occurrence. In such cases probabilistically approach is required in order to incorporate the effects of such phenomena into decisions. Hydrological phenomena that are commonly described by frequency analysis are storm precipitation and annual flood maxima.

All flood peaks above threshold were analysed and separately annual maxima were also considered. The use of annual-maximum series is very common in probabilistically analysis. Flood waves and flood peaks were assigned to the three categories: snow, mixed and rain. Snowmelt induced flood waves, when snowmelt causes the given flood, rainfall induced floods – flood waves in warm period of year and floods of mixed origin, when peak is induced from snowmelt and additional heavy rainfalls.

Flood origin, duration and modality were analysed in this paper for more than 50 years long period. Length of the analysed data series is sufficiently long for statistical analysis. Meteorological data were used only as qualitative indicators. Mixed peaks by origin were dominating. Also mixed floods by its duration are longer than other types.

Serious conflicts in the use of groundwater and mineral resources.

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The extraction of aggregates in gravel deposits as well as mineral resources in hard rocks has sometimes caused conflicts with the use of groundwater resources. Springs at the front of glaciofluvial deposits, e.g. eskers, with great capacity and good water quality have been of great importance for water supply of many towns since the Middle Ages, e.g. in Skara, Uppsala and Visby and in Modern Era in Gothenburg, Kalmar, Lidköping and Nyköping. But when the population and the water consumption increased very much after the Second World War wells had to be localized and constructed inside the deposits and later on also as basins with artificial recharge of groundwater in sand and gravel. During the same time the need of aggregates for construction of new roads and buildings increased very much and most of the aggregates were extracted in the same gravel deposits as the wells for water supply of the towns. Later on the interests of preserving valuable objects in the environment e.g. wetlands and springs, due to their specific habitats increased, sometimes manifested by EU protection as Nature 2000 areas.

Hereby some conflicts arise in the disposal of the deposits, related to mineral or water resources as well as being of great interest as natural reserves. Rules had to be developed to regulate the conflicts, before all the Environmental Act.

Several conflicts occurred since the 1950s e.g. in the largest esker in SE Sweden called Nybroåsen, which was the main supplier of aggregates to the region but before all is the base for the water supply of the towns (Kalmar and Nybro) and some villages. A serious conflict was in 2005 – 2006 when a company, which had produced aggregates at a gravel pit in the esker since 1950 now applied for a new site nearby. But in an old regional plan for the water supply of Kalmar a site for a well was marked on a map in the same area. Despite that investigations and borings showed that the hydrogeological conditions were unfavourable for a big well, the Environmental Law Court as well as the High Law Court denied the exploitation application. Likely, no new well has so far been constructed.

During the same time an intricate conflict commenced between exploitation of high quality limestone and drinking water as well as nature preservation in Nature 2000 areas on the island of Gotland, SE Sweden. Different court levels have come to different decisions during the eight years process, not yet finalized despite seven court trials and enormous work load among all parties.

How can the decisions and handling be so different and how is it possible that the process can extend for such enormous long record? The courts usually have a very limited specific know-ledge except interpretation of the laws despite the different conflict parties often have their specific experts presenting more or less different aspects and views of the problem. This presentation discusses the conflict between water and mineral exploitation within the framework of Swedish and EU laws. In order to reduce such conflicts in the future we suggest an advisory impartial expert group being formed, which can give expert judgements as advisory within complex and intricate conflicts between water and exploitation interests. Such an un-biased group of ecological, hydrogeological and legal experts will not interfere into the process but can give an early warning whether a project is at risk of conflicts or not.

Scaling based approach to IDF curves estimation in Slovakia

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Rainfall intensity-duration-frequency (IDF) characteristics, or the design values of extreme rainfall are of very great importance in engineering hydrology, such as input data for hydrological modeling, for the prediction of flood events, or for planning and design in water resources management. However the lack of rainfall data with sufficient temporal resolution does not generally allow for constructing maps of extreme short-duration rainfall with the desired spatial resolution. A solution to this problem offers the simple scaling model, which has proved its applicability in various regions of the world (Menabde et al., 1999; Yu et al., 2004). Using the scaling hypothesis, it is possible to estimate design values of rainfall of selected recurrence intervals and durations shorter than a day by using only the daily data. These data are usually available from a considerably denser network having long series of measurements.

The aim of this study was to apply the simple scaling theory in the whole territory of Slovakia for the estimation of the intensity-duration-frequency characteristics of short duration rainfall. For the analysis the data series in one minute time step from 61 rainfall gauging stations were used. Two methodologies are combined to estimate T-year rainfall quantiles of sub-daily duration at ungauged sites: the local concept of simple scaling and the regional index value approach. The second approach is used to estimate the quantiles of 1-day rainfall maxima in the warm season, supposing that the so called index value can be estimated locally and the dimensionless quantiles (the regional growth curve) can be derived by means of regional frequency analysis. The atsite approach was used to estimate the local IDF curves by downscaling the T-year quantiles of 1-day rainfall maxima using the regionally estimated scaling exponent. Finally the derived IDF curves for analysed stations are compared with those which are nowadays applied in engineering hydrology in Slovakia.

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Fuzzy logic for estimation of streamflow under ice-affected conditions

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Today there are 162 discharge stations in the national network in Finland that are based on a rating curve. This method is reliable when discharge is dependent on stage alone. However, if hydraulic properties of the stream change, estimated streamflows may be strongly biased. This is the case especially during winter seasons when effect of ice on hydraulic properties of the channel is considerable. Such ice-covered season can last for over six months in northern parts of Finland.

Pelletier (1990) provides a thorough review of techniques used by northern countries for measurement and computation of streamflow under ice conditions. In Finland this estimation is currently done by a hydrologist with the aid of graphical interface developed at SYKE. This process contains subjective decisions although it is well known that hydrologists estimating winter streamflows for same sites can end up with hydrographs having significant differences (Melcher and Walker, 1992; Hamilton et al., 2000). As this graphical process is also time-consuming, estimation process is carried out only twice a year and thus there is no reliable near real-time data of the discharges during winter season for stations needing ice correction.

This study is to improve the current estimation of winter streamflows by developing a fuzzy model to mimic judgments of a hydrologist during the process. Fuzzy rules are developed for utilising actual discharge observations, stage observations, winter season rating curve, simulation results of a conceptual hydrological model, temperature and precipitation observations and both freeze-up and ice break-up observations. Use of such model would not only speed up the estimation process considerably and might enable real-time estimation of streamflows but would also lead to more sound and consistent procedure. The model calibration is based on the comparison of the official estimates of Finnish Environment Institute for five sites for winters 2010-2011 and 2011-2012. The validation is based on the comparison of the model results and official estimates for winters 2008-2009 and 2009-2010.

Preliminary results show that fuzzy model is a promising tool for estimation of winter observations. However, model parameters are dependent on local conditions and thus calibration of the model should be done separately for each station. Although the model might not give the final estimate of the winter discharges in practise it seems to be a valuable additional tool to systemize ice reduction with respect to different years, stations and hydrologists.

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Evaluation of mixing zones in Latvian-Lithuanian transboundary river basin

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Latvia (LV) and Lithuania (LT) should use common water assessment methodologies and measures for water management in the transboundary rivers. However, there are no national and local legislative acts describing how to harmonise water policy and activities for good water status at cross border level. One of the main tasks of Latvia–Lithuania Cross Border Cooperation Programme project „Towards a harmonised water quality and pollution risk management" (HOTRISK) is to propose practical measures for harmonisation of assessment of transboundary river water quality and management of chemical pollution risk in the cross border region by evaluation of mixing zones. The mixing zones are areas adjacent to the point of discharge where concentrations of one or more substances may exceed the environmental quality standard if they do not affect the compliance of the rest of the water body. According to Article 4 of Directive 2008/105/EC, there is no obligation for Member States to designate mixing zones. Therefore the States could calculate mixing zones using "Technical guidelines for the identification of mixing zones".

Nowadays mixing zones are not applied in practice neither in Latvia nor in Lithuania. In the project HOTRISK the designation of mixing zones is settled for priority/polluting substances in the transboundary Venta river basin district (RBD). The geographical region of the project covers international Venta RBD on its cross border sides in LV (15 625 km^2) and in LT (6 278 km^2). A monitoring and modelling based approach was used for evaluation of mixing zones in LV-LT border region. Initial assessment of water quality status in Venta RBD was done using analysis of monitoring data and permits for waste water treatment services. Priority/polluting substances were selected as limiting parameters of ecological quality in Venta RBD. We compared priority/polluting substances concentrations in discharged effluents with concentrations according to environmental quality standards. The sites with exceedance of the concentration are potential sites of "hot spots", where mixing zones are calculated. Five most dangerous "hot spots" were selected in the both sites: LT and LV.

The "Discharge Test" software was used for calculation of mixing zones in the rivers from the point of dischargers. This test is based on the widely used "Fischer" equations. The input data of Test is discharger data (flow and total concentration of the pollutant in the effluent), and river data (flow, dimensions, bed-roughness and the upstream-concentration of the pollutant). Joint field measurements were used for model calibration and verification. The calculations were carried out to determine mixing zones in the Venta RBD for five sites both in LT and LV, and the character of mixing (plume or jet-mixing) was identified. The mixing factor was calculated as a function of the distance to the point of discharge.

Sum up of joint investigation is evaluation of possibility of integration of mixing zones to the overall transboundary water body for harmonisation of water quality management.

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Evaluation of convective and stratiform precipitation in an ensemble of regional climate model simulations

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Regional climate models (RCMs) are tools widely used for modelling regional climate change. While many studies dealt with evaluation of precipitation characteristics in RCM outputs, little attention has been paid to ability of RCMs to reproduce basic properties of convective (sub-grid) and stratiform (large-scale) precipitation that are simulated separately through cumulus and large-scale precipitation parameterizations. One of the reasons is the lack of long-term series of precipitation data disaggregated according to their origin into convective and stratiform.

We apply a recently proposed algorithm for disaggregating station precipitation data into predominantly convective and stratiform (Rulfová and Kyselý, 2013), and evaluate biases in characteristics of convective and stratiform precipitation (annual cycle, proportion of convective and stratiform precipitation, dependence on altitude, and extremes) in an ensemble of 11 high-resolution (25 km) RCM simulations for the recent climate in Central Europe. All RCM simulations are driven by the ERA-40 reanalysis. We find that characteristics of total precipitation are usually much better simulated compared to those of convective and stratiform precipitation evaluated separately. Although the separation of large-scale and convective precipitation may differ between RCMs and observations, the biases suggest that the examined ensemble of current RCMs suffers from substantial deficiencies in reproducing precipitation processes. This has to be taken into account when interpreting also possible climate change scenarios and their uncertainties.

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Influence of river ice on water levels and erosion potential of sediments now and in the projected hydro-climatic conditions

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The influence of ice on erosion potential of an alluvial river and on water levels has been studied. We apply a 1 dimensional hydrodynamic model HEC-RAS (Brunner, 2010) that allows us to estimate the effects of an ice cover or wide river ice jams on shear stress and water levels. Additionally the possible impact of climate change on sediment processes and water levels of an icy river during the winter months December-February are simulated and analysed.

The study area is the lower reach of Kokemäenjoki River running into the Baltic Sea in SW Finland. The catchment area of the river is the fourth largest in Finland. The lower part of the river is flood prone area and severe winter floods have taken place e.g. in January 2005 when frazil ice packed into the river mouth and caused water levels to rise into alarming levels. The river estuary is also under constant change as fine clay and silt material deposits to the Pihlavanlahti bay.

The presence of river ice has a great influence on water levels. The HEC-RAS model allows users to include into the simulations a stationary floating ice cover or an ice jam to a certain river stretch. In case of an ice jam the model solves ice jam force balance equations to calculate the ice jam thickness in an equilibrium state. Ice reduces the channel conveyance, by increasing the wetted perimeter and modifying the effective channel roughness and also by making a portion of the channel cross section area unavailable for flow. The backwater associated with river-ice may be significant especially in the case of a thick and rough ice jam.

The sediment processes under ice cover are not fully understood partly because ice and especially ice jams mean some extra challenges to perform field examinations. The shear stress measures the resistance of sediments to flow and can be simulated with a hydrodynamic model. When the critical shear stress of sediment particles on the river bed is exceeded particles move.

The performed simulations are forced with present mean and extreme winter time hydro-climatic input as well as with projected hydro-climatic conditions. We quantify the backwater associated with ice by comparing open water simulation results to simulations where river-ice exists. We also analyse the variations of shear stress in open water and ice conditions along the longitudinal profile of the Kokemäenjoki River.

The initial results indicate that ice diminishes the shear stress or increases it depending considerably on the thickness and roughness of the ice cover. Relatively smooth and thin ice cover is decreasing the erosion potential of the river bed. In contrast ice jams may cause local scouring and high upstream water levels.

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Adapting to future sea level rise and extreme precipitation in an expanding urban area

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The city of Aarhus is expanding towards the sea and exchanging harbour areas with water front spaces and public buildings. The future rising sea level challenges existing buildings and the construction of roads and railways behind the harbour. A second challenge is the thread from behind from precipitation and river water fed from urbanised hill slopes.

The combination of future high sea level and extreme river flow has forced decision makers to plan for one of Denmark's biggest pumping stations in connection with a sluice, The Environmentalist (2012). The accepted level of security towards the sea is calculated from statistical extreme events and the expected future sea-level. It has been decided that a level of 2.5 metres above sea level offers an acceptable level of security. 2.5 meters above sea level equals a 100 year event in year 2100. The function of the sluice had to meet two demands. The urban area behind the harbour, which is drained by the river, must not be flooded by sea water or river water and fish must be able to pass the river mouth as much of the time as possible. The demands were met by closing of the sluice gates only when sea level rises above 1,4 meters and constructing a pumping station with a capacity of maximum 20 m^3/second which ensures that river water can be pumped to the sea when the gates are closed.

Another primary gain from the construction of the sluice and pumps, the river, and low lying areas next to the river, can store about 40.000 m^3 at an 10 to 20 year precipitation event and about 55.000 m^3 at an 40 to 100 year event. The combined effect of the storage capacity during closed sluice gates and active pumps secures that future precipitation events will not lead to flooding of the city. The large storage capacity on the other hand has led to reduced future investments in rain water reservoirs saving the sewage company millions of Euro.

The project is part of a major construction project Urban Mediaspace Aarhus owned by the City of Aarhus and financed by the Municipality of Aarhus and Realdania and Realdania Byg.

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Long-term changes in the water temperature of Latvia's rivers

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The research analyses the monthly mean water temperatures (from May to October) and the annual maximum water temperatures of the surface waters of Latvia's rivers during the time period from 1945 to 2000. The research covers 20 hydrological monitoring stations (HMS) located on the biggest rivers of Latvia and 18 HMS located on the smallest rivers of Latvia. The monitoring data were obtained from the data archives of the Environment, Geology and Meteorology Centre of Latvia. The data rows were processed by means of mathematic statistics methods.

The research results demonstrated that the mean water temperatures during the monitoring period from May to October were higher in the biggest rivers of Latvia (from 13.6 ^{o}C at the Gauja-Velēna HMS to 16.1 ^{o}C at the Lielupe-Jelgava HMS) and there were lower temperatures in the smallest rivers (from 11.5 ^{o}C at the Amata-Melturi HMS to 15.6 ^{o}C at the Mūsa-Bauska HMS). Similar trends can be seen when the maximum water temperatures are analysed: in the big rivers from 22.7 ^{o}C at the Gauja-Sigulda HMS to 25.7 ^{o}C at the Lielupe-Mežotne HMS, and in the small rivers from 20.8 ^{o}C at the Amata-Melturi HMS to 25.8 ^{o}C at the Mūsa-Bauska HMS. Generally, lower water temperatures can be seen in rivers with a high rate of inflow of underground water, for example, in the rivers of the Gauja basin, in particular, in the Amata River.

Mann-Kendel test results demonstrated that during the monitoring period from May to October, a positive trend was mostly characteristic of the mean water temperature (in 18% of the cases the trend is statistically significant at $p<0.05$). However, when the annual maximum temperature is analyses, a prevailing negative trend was obtained (in 55% of the cases the trend is statistically significant at $p<0.05$).

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Long-term changes in the ice regime of Latvia's rivers

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Water resources present a major natural wealth of Latvia because the uneven terrain, humid climate and also the geological structure has created beneficial conditions for a vast network of rivers to get developed in Latvia. The climate change and the climatic conditions nowadays are closely related to changes in hydrological processes. Several recent researches have proven that the increase of the global ambient temperature can cause essential changes in the global hydrological cycle and its processes (Yang et al., 2010; Thorsteinsson and Björnsson, 2011), also including in the Baltic Sea catchment area. Besides, the seasonal data of rivers, for example, the freeze-up date, the break-up date and the duration of ice cover, as well as the maximum ice thickness are good indicators for assessing the climate change, in particular, in relation to long-term climate change (Beltaos and Burrell, 2003).

The goal of the present research is to analyse the long-term changes in the ice regime of Latvia's rivers and their regional peculiarities. Data of the freeze-up and the break-up date collected at 44 hydrological monitoring stations and data on the ice thickness collected at 39 hydrological monitoring stations during the time period from 1945 to 2012. The data were obtained in the data archives of the Environment, Geology and Meteorology Centre of Latvia.

As regards the freeze-up date, there is a positive trend, which means that the ice formation in Latvia's rivers starts later. In the Eastern part of Latvia, the ice formation takes place 2-5 days later per 10 years, and in the Western part it is 3-7 days later. Besides, in 31.8% of the cases the trend is statistically significant. As regards the ice break-up date, there is a statistically significant negative trend (in 93.2 % of the cases at $p<0.05$), which indicates an earlier ice break-up date, which, in turn, correlates well with the increase of the air temperature. The reduction of the period with ice cover is also taking place (a statistically significant negative trend in 86.4 % of the cases at $p<0.05$). The ice cover at the rivers of the Eastern and Northern part of Latvia lasts for 75-105 days on average, while in the Western part of Latvia it is 30-60 days. In approximately 60% of the cases, a statistically significant decrease of in the ice thickness can be seen. When regional differences are evaluated, it can be concluded that the maximum ice thickness in the rivers of the Eastern part of Latvia can be seen in March and in the rivers of the Western and central parts it is in February. The assessed winter severity index demonstrates the development of warmer winters during last twenty years and also regional differences.

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Urbanisation, water abstraction and climate adaption
Surface and ground water interaction in the Municipality of Odense?

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The city of Odense has developed from a small borough of 11.000 people, covering only 2,5 km^2 in the 1850's to it`s current 170.000 inhabitants, covering an area of 78 km^2. This paper contains some of the important man-made historic influences on natural water levels and groundwater flows within the City of Odense. The study is part of a VTU-project* Development of a 3D geological/hydrogeological model as basis for understanding of the urban water cycle in which the geological and hydrogeological conditions are considered as being a new tool in city planning.

During the first 100 years of city expansion, the drinking water supply was primarily based on several local groundwater abstraction sites. Today, most of the groundwater abstraction within the urbanized areas no longer takes place and the water level within the city limits has risen dramatically over the past 25 years. Today, the water level is close to the water level at the turn of the last century (early 1900's).

The areas that are drained and urbanized are becoming increasingly waterlogged again. This is of increasing concern for the inhabitants and constitutes a major conflict of interest. The development in urbanization also causes other challenges. The natural attenuation of rain seeping in to the ground is drastically reduced due to the increase in impermeable surface areas.

Historically, sewage pipes were established as common sewage systems for both rain run-off and raw sewage. Expanding sewage pipe systems to accommodate future heavy rains/sea-level rise/climate change is highly expensive and sometimes an almost impossible task. Interests in reducing the amount of rain water entering the sewage/treatment system are also increasing. The need for artificially/naturally enhanced infiltration of rainwater in urban areas is growing. This, again, - is putting further strain on the water level and saturation beneath the cities. New large scale infrastructure projects like tunnels, underground parking facilities puts further strain on the groundwater saturation challenge.

The data for modelling of our urban areas deviate from other areas. It has to deal with the most important artificial data information on pipelines, buildings, tunnels etc., that impact infiltration and groundwater flow. In densely urbanized areas, underground information is also often limited due to very few borehole data. Some areas have plenty shallow geotechnical boreholes with information, but this information is often not public domain. Access to these shallow data points will supplement the small amount and sparsely distributed data such as boreholes/water level measurements are not feasible as a basis for the evaluation of possibilities for infiltration, groundwater flow and problematical areas. Old maps and knowledge of the historic development of the residential areas and lack of registration of past and present topological changes can provide valuable information to administer and take action on these matters of conflict.

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Impacts of Climate Change on Water Resources in Himalayan basins

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As the largest cryospheric component outside of polar Regions, the Himalayan glaciers are of concern to both scientific research and public communities. These glaciers are reported to retreat at an increasing rate due to climate change (Bolch *et al.*, 2012). A consequence of reduced glacier ice volume in the Himalayas is that water availability in the future is at risk, especially in melting season. These glaciers are the source of many river systems supporting more than 800 million people. Changes of the glaciers will lead to change in the water cycle (Barnett *et al.*, 2005). However, the hydrology of this region is not well understood.

Hence, the purpose of this work is to establish the water resources scenarios in the Himalayan regions for the near future. The general procedure is to force hydrological models by climate data generated by global or regional climate models under selected scenarios. Therefore, the CMIP5 scenario data from the ESG server and the Weather Research and Forecasting (WRF) modeling system are used to build the future climate scenarios. A hydrological model coupled with a glacier retreat model (Li *et al.*, 2014) is used to finally construct the water resources scenarios.

The selected basins are the Beas catchment in the Northern India and the Kurichhu catchment in the eastern Bhutan. Their areas respectively are 4883 km^2 and 660 km^2 with considerable glacier coverage. The changes in the areas under glaciers are expected to significantly influence the total runoff volume and the temporal distribution of runoff. Differences between two catchments at present and in future are quantitatively analysed with respect to water resources, such as annual runoff and seasonal distribution.

This work will not only improve the understanding of the hydrological regime in high altitude cold mountain areas in the Himalayas, but will also be useful for hydropower planning and water resources management. It may, however, be highlighted that the impacts of climate change on Himalayan glaciers may be quite different depending upon a number of factors. Thus, there is a need to undertake similar studies in a number of catchments to broadly understand the impact of climate change on flow regimes of Himalayan rivers.

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Performance evaluation of the large-scale GSM-WASMOD glacio-hydrological model at different resolutions and uncertainity analyses of model predictions and parameters: Case study- Beas river basin, India

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Accurate estimation of runoff from snow and ice melt in glacierized mountain regions is desired for efficient management of water resources. Hydrological models are often applied for this purpose. However, model results can be easily biased due to, among others, inadequate snow and glacier routines, and wrong scale choice. Thus, model prediction and parameters uncertainty analyses are recommended to generate useful information for both the modelers and end-users.

A large-scale glacier-hydrological model (GSM-WASMOD) which couples the well established large scale hydrological model WASMOD with a Glacier and Snow Melt (GSM) module using glacier mass-balance approach is applied for the glacier-fed Beas river basin in India. Scale is a central issue in the GSM-WASMOD since it uses model equations developed at catchment scale. The GSM-WASMOD is set-up and calibrated at two different spatial resolutions, 50 km and 10 km, using a decade long gauged data. The model performances were assessed based on Nash-Sutcliffe efficiency (NS) and absolute value of the volume error (VE). The uncertainties associated with the model predictions and model parameters are assessed using the generalized likelihood uncertainity estimation (GLUE) procedure. Moreover, the contribution of snow and glacier melt to the total discharge is quantified for the Beas river basin.

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Lake water levels for calibration and updating of the S-HYPE model

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Sweden is a country that is rich in surface water, and there are about 100 000 lakes with a surface area > 0.01 km^2. The SMHI measures water levels in the six largest lakes and reports these on the internet. In addition to this, water levels in natural lakes are also measured with the primary purpose of estimating discharge through established rating curves. The raw water level data is usually not used for other purposes. Water level data is, for instance, not quality controlled and corrected for e.g. ice jams in the same way as discharge data. The S-HYPE hydrological model covers all of Sweden in high spatial resolution (Strömqvist et al., 2012). It is based on the HYPE model code (Lindström et al., 2010). The present S-HYPE version has about 37000 sub-basins with a median area of 7 km^2. Water level variations are modelled explicitly for about 9000 unregulated lakes. Rating curves in the model are either simplified from observations in the SMHI data base, or generalised. Traditionally, hydrological models in Sweden, both the HBV model and the HYPE model, have been calibrated and updated using discharge data. Lake water levels have mainly been considered as intermediate data for estimating discharge.

However, the cost of measuring water levels is low, compared to establishing and maintaining a traditional discharge gauging station. A large number of discharge measurements are usually required, at low, medium and high flow situations, before a reliable rating curve can be established. It is furthermore in practice difficult to capture and measure discharge at high flow situations that occur rarely. Rating curves are thus often extrapolated for high flow situations, whereas the use of water level data does not imply the same problems of extrapolation. The objective of this study is to test if water levels can be used directly for calibration and updating of the HYPE model as a cost-effective complement to existing techniques.

The regionally calibrated S-HYPE model is used as the starting point for the study. The regional model is adjusted by local calibration of key parameters. Firstly, discharge measurements are used, and secondly, only water level measurements are used. Discharge stations where water levels are actually measured in a lake were used, and the raw water level data is for some events corrected manually. The model performance is tested for a number of basins, calibrated in the two alternative ways, and evaluated with independent data.

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Frequency Analysis of Precipitation in Taihu Basin, China, based on Regional L-moments Approach

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With the change of climate, storm flood is now becoming one of most serious natural hazards in China. And Taihu Basin, as the richest basin in China, flood control planning in this region is of much significance. And for this purpose, precipitation analysis, as a basic work of flood design, should be accurate and precise. And at present, regional L-moments frequency analysis (Hosking and Wallis, 1997), which has been applied in many fields, is one of the most useful and effective method of regional extreme precipitation frequency studies. Therefore, with the annual extreme precipitation series of 96 sites in Taihu Basin, regional precipitation frequency analysis based on L-moments approach has been carried out in this study.

The procedures of regional precipitation frequency analysis based on L-moments are as follows: (1) Screening the data and discordancy measure, (2) Identification of homogeneous regions, (3) Choice of a frequency distribution, (4) Estimation of the frequency distribution. The L-moments based discordancy measure (Di) has been used to screen the data in each site. Homogeneity of the region is tested using the L-moments based heterogeneity measure (H) with Monte Carlo simulation method. Based on this, it is observed that the whole region is divided into 7 sub-regions (Liang et al. 2007). In order to find the most suitable distribution for quantile estimation in each sub-region, a goodness-of-fit statistic test is used. Hence, specific distributions are identified as the robust distribution for 7 sub-regions. The annual extreme precipitation of various return periods at each site is estimated. In addition, the results from L-moments and from conventional moment method are compared, which shows the superiority of L-moments.

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River channel morphodynamics caused by ice in a sub-arctic natural state stony river – a case study based on laser scanning data

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For decades, there has been discussion about the importance of the ice and the effects of cold-region processes on river channel morphology, but only lately a general consensus on their importance has been emerging (Turcotte et al., 2011). River ice cover, anchor ice, frazil ice and ice jams may scour the channel bed and banks, and also pick up, transport and deposit sediments, pebbles and stones during winter, but especially during spring ice breakup period. There is still insufficient knowledge of the interactions between channel morphology and ice processes, particularly in rockier river reaches.

The lack of highly accurate data with sufficient extent has been hindering the quantification of reach scale patterns of channel forms and their relationships to processes (Legleiter, 2014). Terrestrial Laser Scanning (TLS), which has a high resolution and survey frequency, has been lately applied successfully in natural river environments. Despite its high accuracy, TLS measurements are more time consuming than mobile laser scanning (MLS). Even though the absolute accuracy of MLS is less than of TLS, MLS provides accurate data over spatially larger areas. Thus, fast and highly accurate multi-temporal measurements and analysis of morphodynamics caused by river ice are now possible in stony rivers.

The aim of this study was to enhance the knowledge of the river ice impacts on channel morphodynamics in sub-arctic rivers based on laser scanning data of both river bed and ice. TLS and MLS measurements were performed in 2012–2013 from Tana River, Northern Finland. Both TLS and MLS were highly accurate and applicapble in detection of volumetric changes of the river bed, stone sizes and stone movement. More importantly, also the ice surface, thickness and its decay during spring were captured with laser scanning methods. New information of the one-year morphodynamics caused by river ice and related forces were gained. The results can also be applied in enhancement of riverine planning in sub-arctic environments.

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Climate induced warming of Finnish and Swedish springs

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Scientific interest in climate change effects on groundwater resources has increased during the last decade. The mechanisms reducing groundwater quantity and quality have been thoroughly reviewed, but the role of climate change on groundwater-dependent ecosystems, such as springs, has received limited attention and is thus poorly understood. We studied long-term (> 20 yrs) water temperature trends in 67 Finnish and Swedish springs. Springs were mostly connected to glaciofluvial aquifer or moraine formations. A majority (> 90 %) of the studied springs exhibited an increasing trend in water temperature, 82 % of those being statistically significant. Spring temperature was associated to mean annual air temperature and, given different climate change scenarios, ca. 2-3 °C increase in spring water temperature is expected by 2100. Our results also suggest that springs associated with larger aquifers could be more tolerant to climatic influence compared to smaller aquifer springs. In addition, intensified water abstraction and land use that modify catchment hydrology may accelerate the climate-induced warming of particularly smaller springs and should be taken into account on protection land use planning surrounding these springs. Considering the focal role of water temperature in regulating water chemistry and ecology of spring ecosystems, the predicted warming may have irreversible and detrimental ecological changes in these vulnerable and threatened ecosystems.

Differences in Water balance between grassland and forest watersheds using long term data and two different models

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The current ongoing climate change is leading to alteration in the behaviour of the surrounding environment. Changes are occurring regarding the interaction between physical and biological processes. To have a better understanding of the role of land cover on the impact of climate change, a focus on the response of the run-off due to climate variations in Plynlimon in England was studied, The main objective is to describe to what extent the impact of land-use changes can be identified and supported by the long term monitoring data of runoff using two different hydrological models. The CoupModel platform (Jansson, 2012) was used to set up two different models originating from Richards equations (RE) or from a simplified compartment structure (SCS). Data was used from the Plynlimon study watershed in UK, on the mid-Wales coast that represent two neighboring watersheds with different land covers that have been exposed to the same climate conditions for 50 years data. The differences may be comparable with the results obtained by Gustafsson et al (2004) based on flux measurements between different sites.

The grass land showed the higher run off and lower evapotranspiration compared to the forested dominated watershed. Thus, the land-use changes play an important role in the water balance changes in Plynlimon catchment, indicated by increasing run-off along with the decline of vegetation cover (Marc & Robinson, 2007). It is of high interest to understand to what extent the difference in the water balance originates from any specific impact on the evaporation that is related to the plant cover or to any other characteristics of the watersheds.

Possible changes during the study period and differences between years were detected by Monte Carlo based calibration method. Various criteria to obtain the behavioral ensembles were applied to observed and simulated daily discharge data in the period of 1992 - 2010. Good performance was obtained for both the RE and SCS approaches and watershed with respect to the dynamics and mean values. Differences in the obtained parameter distributions suggested that changes between the watersheds were with respect to both plant cover and soil related factors. Comparing the outcomes of the two approaches showed both different and similarities. The common plant cover was assumed for both approaches with respect to potential transpiration and interception evaporation. In addition to this, the RE approach assumed also direct evaporation from soil surface. The actual evaporation was in the SCS approach regulated by a field capacity parameter and in the RE approach by a physical description of the root distribution. The surface runoff, soil evaporation, interception and soil hydraulic conductivity showed a tendency to be constrained by the data in the RE approach whereas the field capacity and interception evaporation showed similar tendencies for the SCS approach.

The discrepancies between the simulated and measured values showed similar tendencies with respect to the time for both models and watersheds. The suggested explanation for the lower runoff from the forested watershed depends to a large extent on the model used and the assumptions made for the criteria. Similar difference in the water balance could be suggested by actual evaporation, declining markedly in both main and sub-catchments.

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Monitoring of ice break up in Torne and Tana River using earth observation satellites in the Copernicus project CryoLand

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The Copernicus project CryoLand (2011-2015), see Nagler et al. (2012) has the focus on satellite monitoring of the cryosphere components seasonal snow, glaciers and lake/river ice. For river ice we want to demonstrate that remote sensing satellites can contribute to near real time monitoring by providing timely data for waste areas which can augment the situational awareness of the hydrological agencies. The project has used both optical and radar satellites to monitor the timing of the river ice break up in large rivers in the Nordic region in the years 2013-2014. Satellite data and in situ data from hydrological agencies were used from the years 2010-present to develop methods for the monitoring service.

The ability of remote sensing satellites to map river stretches is largely depending on the spatial resolution of the sensors (which should be 30 m or better for unambiguous classification of river ice) and the spatial extent that the sensor can map. Usually the field of view/swath width is limited for high resolution satellites. Due to limited capabilities satellite images over river stretches has been quite limited up to now. However, with the new and more operational era of satellite remote sensing that we now enter, with the launch of Landsat-8 in 2013, Sentinel-1A in 2014 and Sentinel-2 in 2015, this lack of data will change dramatically. In the future, we can expect close to daily coverage with sufficient quality when we combine optical and radar sensors.

In the current project we demonstrate some of the capabilities we can expect using Radarsat-2, TerraSAR-X and Landsat-8. We show that by combining data from each sensor, we obtain a densely sampled time series, which enables the users to monitor the ice breakup along a river stretch along Torne River from Torneo/Haparanda to Pello (110 km). The project also has provisions for rapid high resolution data acquisitions in the case of an emergency event such as a river ice jam followed by flooding. During the spring of 2014, the project aims to also monitor the Tana River in Norway which usually has ice break up in late May.

As a part of the CryoLand project, we have also interviewed users about their needs and requirements for a river ice monitoring service, and developed products and automatic classification algorithms that can be used within a river ice monitoring service.

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Factors controlling daily oscillations of springs discharge

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The western Poland belongs to the lowland regions shaped during the Pleistocene glaciations. It has resulted in relatively variable landscape with relatively thick cover of Quaternary deposits. The latter are composed mostly of sands and gravels, serving as a groundwater aquifer, intercalated by glacial tills. These conditions caused that groundwater outflows in form of springs and seeps are relatively frequent in this area. Preliminary monitoring of spring water discharge by very precise measurements of water level changes in streams draining headwater zones with group of springs revealed a clear daily pattern. Thus, a detail study was conducted to reveal the range of these daily oscillations as well as to determine likely controlling factors (water and air temperature, air pressure, evapotranspiration).

Observations of water levels were carried out in the years 2012 - 2014 in four headwaters, nearby Gryżyna, western Poland. In each of them water level oscillation were measured on a stream draining a group of springs. The measurements were taken at sites located a few meters downstream from the springs, where measuring weirs were installed, which enabled installations of diver type dataloggers. The divers automatically recorded changes in water level and water temperature. Simultaneously, barodiver was used for recording air temperature and atmospheric pressure, necessary for the compensation of the water-level divers results. In addition, spring water temperature was measured in situ using an automatic HOBO recorder.

The results showed that the diurnal fluctuations in water level in the headwaters ranged from 2 to 4 centimeters (approximately 10% of the total water depth). These oscillations revealed a very good correlation with the changes of atmospheric pressure. The correlations with the air temperature and water temperature were weaker. The evapotranspiration, which may vary over a daily cycle, has been problematic for the precise measurements.

We conclude that the observed water level oscillation may result from spring water discharge changes, as well as from processes taken place already in the headwater. The good correlation with atmospheric conditions (pressure and temperature) suggests control by daily topoclimatic changes. On the other hand relation with water temperature, suggests that the oscillation are also due to changes in water viscosity, which depends on temperature, and thus due to diurnal changes of hydraulic conductivity in hyporheic zone (the region of contact between stream water and stream bed). The lack of precise measurements of evapotranspiration, which is known to change in daily cycle, does not allow to assess the influence of this factor on spring water discharge. It is likely that the daily fluctuations of the water level in streams next to their headwater zones are controlled by a number of factors, possibly linked by feedback effects. Further field observations including monitoring of more factors is planned to resolve the problem.

Comparing passive microwave observations of snow water equivalent with in-situ data from Finnish snow courses

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Snow water equivalent (SWE) tells how much water (mm=kg/m^2) is contained within snowpack. Information on SWE is needed, among other things, for climate research, modelling of river systems, forecasting of floods during spring melts and for regulating the water level of power plant reservoirs.

Traditionally this information has been obtained from in-situ observations or by interpolating data from weather stations and other gauging networks. Interpolations from weather data for this purpose tend not be precise enough and gauging networks are usually limited and have relatively large spatial resolutions. Additionally, information on SWE on daily basis can be obtained from satellite microwave radiometer observation. So far however, errors inherent in interpreting these observations, both random and systematic, have been too large (rmse >30mm) for purposes of operational hydrology in Finnish Environment Institute. To better quantify and understand the differences, SWE maps produced from radiometer data were compared with in-situ measurements from the Finnish snow course network and maps interpolated from observation data.

SWE-maps were produced with observation from Special Sensor Microwave Imager (SSM/I) and Advanced Microwave Scanning Radiometer for EOS (AMSR-E) sensors, using Helsinki University of Technology (HUT) snow emission model (Pulliainen et al 1999), and corrected with weather station snow depth information, using assimilation method described by Pulliainen (2006).

These maps were compared with i) in-situ SWE, snow depth and snow density observations from snow courses and ii) daily SWE values interpolated from these observations with data from weather stations and iii) maps derived thereof. Data for three winter/spring periods from 2011 to 2013 were analysed.

A strong seasonally changing bias was discovered. Microwave radiometer-based technique tends to overestimate SWE during early- and mid-winter accumulation period and severely underestimate it once spring melt has started. We also identified several sites, where difference between radiometer and in-situ observations remains high and consistently biased throughout the seasons and between years. First type of bias can be mostly tracked to spatially and temporally changing attributes of snow cover. Latter cases point to presence of some systematic error source such as sparseness of gauging network, quick changes in elevation or wrongly interpreted terrain type.

Correcting SWE values with local values of snow density and depth was investigated. Results were promising with rmse-rates considerably reduced. More research on how to best include this data to the assimilation process itself is needed.

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Mapping groundwater vulnerability in Denmark – Challenges and achievements of a mega-project

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Mapping of Denmark's groundwater is one of the most comprehensive projects to for the description of the country's water environment. The nationwide project that started in 1998 and will be finished in 2015, aims to collect the necessary knowledge to provide the key decision basis for targeted protection of drinking water resources. Comprising an area of 43,000 km^2, Denmark is among the few countries in the world where drinking water almost exclusively is based on groundwater. The survey, performed on area covering 41 % of the country, constitutes an essential prerequisite to ensure that the Danish drinking continually is to be based on the simple purification of groundwater. Water consumers finance the mapping program by paying 0.04 € per cubic meter of consumed water i.e. about € 4 per family per year, which sums up to a total amount of approx. 360 000 €.

The Main objective of the paper is to provide an overview about the national mapping project, its background, challenges and achievements, including technical and organisational methods.

Uniformity in mapping has been challenged particularly by differences in geological and hydrological conditions and by the fact, that mapping methods have evolved significantly during the more than 15 project years. Various administrative guidelines have been established to ensure a unified workflow across the country and a professionally documented basis for decision, a uniform reporting and transfer to municipalities, and that the collected data are reported consistently and correctly to the national databases at GEUS.

From the beginning the work has been performed in close cooperation between the administrative units, the national geological survey of Denmark and Greenland, and private engineering companies.

Each single mapping project starts with the assessment of current knowledge of groundwater conditions in the survey area to identify the field work activities to be undertaken in order to establish a complete picture of how well protected the aquifers in the area are. Field work comprises borehole drilling and various geophysical and chemical measurements. Based on all geological, hydrological and chemical data available, geological, hydrological and chemical models are established to identify the location of the aquifers, their hydrogeochemical protection and the catchment areas of the well fields in the mapping areas (Thomsen et al., 2004). Finally the areas for which municipalities have to prepare action plans are delineated. The data and mapping results generated are not only applied by the state and municipalities, but provide also important planning tools for e.g. regions and water companies. A large number of different mapping methods have been developed. These methods along with the associated expertise and cooperation experience between the involved organisations and companies provide a toolkit with strong export potential.

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The impact of roads on hydrological responses during extreme events as simulated using high resolution topographic data

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Roads are among the most common geomorphological alterations in watersheds and natural river sections. They influence hydrological responses by changing the connectivity within fluvial systems and shortening of stream flows especially during extreme events when surface flow processes dominate the hydrological response. The impact of the road was investigated by using physical based model combined with high resolution topographic information. The alterations excreted by road topography on the outflow from a number of watersheds simulated and the results showed that roads changed both the flow duration and the timing of the flow.

Geographic Information System (GIS) and high resolution elevation data (2 meter) was used to allocate roads and delineate watersheds in the study area of Western Sweden, near Karlstad City that have experienced several extreme flooding on roads (Nickman, 2014). Twenty watersheds with approximately similar physical characteristics were selected. Roads were eliminated from the elevation data and missing values were interpolated to resemble landscapes without roads. HEC-HMS (Davis, 1993) was used to model surface and near surface hydrological responses of watersheds with roads and without roads in response to three storms with different intensities. The storms were designed based on a recorded extreme rainfall event which caused severe damages to the watersheds in the study area.

Flow duration curves (FDCs) were used to display the flow characteristics of streams in each watershed in the range of the simulated discharges. To compare flow duration curves between watersheds with roads and without roads, L-moment ratios estimators (L-skewness and L-kurtosis) were calculated and their distributions were considered.

In general the peak outflow rates were higher and the delay times were shorter in watersheds with roads. An increase in peak flow and reduced delay time occurred with increased storm intensity. Although the impacts of removing the topographic features as created by the roads were generally small, the alterations were considerable bearing in mind that roads occupy small portions of the watersheds. The generally small alteration may be because the model did not consider additional coupled soil and vegetation properties. Results also showed that variations of the L-skewness and L-kurtosis ratios were larger in larger watersheds. The results are useful to gain a better estimating of the effect of road topography in hydrological processes and responses especially in storms with high intensities

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Radar-observed precipitation and high-resolution flood forecasting in Sweden

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In Sweden, operational flood forecasting is currently performed with a 1-day time step. A key reason for having a daily resolution is the limited availability of historical sub-daily observation-based precipitation products suitable for hydrological model calibration and simulation on a national scale. On the daily scale, a long-term (since 1961), gridded (4×4 km) product based on interpolated station data is available (PTHBV). A 1-day time step is sufficient for describing the temporal changes in the main rivers, with their large catchments, but not for capturing the variability in smaller and "hydrologically faster" catchments.

In the most recent set-up of the hydrological HYPE model for Sweden, S-HYPE, the country is divided into ~40 000 sub-catchments with a mean size of ~10 km². Thus the spatial resolution is sufficient for resolving also the small, fast catchments. Also the process descriptions in HYPE, with different soil layers and explicit flow paths, are designed to represent flow dynamics also on short time scales. The requirements for sub-daily hydrological modelling and forecasting are thus met in terms of model availability; what is missing are input data for model calibration and initialisation, most critically precipitation.

In an on-going research project, the possibility of utilising radar-observed precipitation for producing the sub-daily products required is being investigated. The main source of radar data are hourly gauge-adjusted accumulations on a 2×2 km grid from the NORDRAD network. One activity is to develop routines for quality control and error correction. To obtain a historical, gridded sub-daily product, the prospect of temporally disaggregating the daily PTHBV data base into an hourly time step based on radar data is being explored. The different products are evaluated with respect to their applicability for hydrological model calibration and simulation in S-HYPE catchments. Flood forecasting further requires real-time updating of model state, based on the most recent observations, as well as high-resolution forecasts. Concerning the latter, radar-based nowcasts are being evaluated with specific focus on their accuracy of estimating intense precipitation.

An overview of the various activities will be given and selected results presented, focusing on assessments of different radar-based precipitation products; their characteristics and, in particular, their applicability for high-resolution flood forecasting. The performance of different sub-daily time steps will be evaluated and discussed. Future developments, including full-scale, quasi-operational, sub-daily S-HYPE forecasting, will be outlined.

Noble crayfish *Astacus Astacus* in rivers of western Estonia islands: Do low flow period influence the stock of crayfish?

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Fishing of noble crayfish had a significant role in local food industry at the beginning of twentieth century. Now, there are few water bodies left on mainland Estonia, where food fishing is worthwhile. However, the crayfish is more abundant on Western Estonia islands Saaremaa and Hiiumaa.

Many factors have been considered determining crayfish stock in Estonia like over-fishing, illegal fishing, crayfish plague, predators (mink and otter; predator fish), loss of suitable habitats because of basin drainage. Low flow as a factor of abundance decrease, has not observed until 2002 when decline of crayfish stock was linked to drought of 2002-2003.

The 2002 drought in Estonia was considered the most severe since 1961 and brought about administration restrictions for harvesting crayfish for years 2003 and 2004 to guarantee recovery of the stock in rivers.

Rivers on islands are small, unregulated but may be affected by beaver dams. Precipitation amount tends to be lower on coastal areas than on mainland Estonia. Drying up of smaller rivers during low flow periods is not exceptional occasion, especially in rivers of Western Estonia islands.

The paper presents results of analysis of river low flow periods on Western Estonia islands and crayfish population response on water shortage.

Characteristics of wind-induced loss of solid precipitation derived from a Norwegian field study

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Solid precipitation measurements are known to be plagued by under-catch in windy conditions. Adjustment techniques, either based on a dynamic relationship between under-catch and measured determinants or static corrections, are then typically invoked. Such adjustment procedures, especially if the adjustment algorithm is unfit, introduce notable uncertainties that impact hydrological modelling in snow-dominated regions.

In 2010, a test-site was established at a mountain plateau in Haukeli, Telemark, Southern Norway. Precipitation data of automatic gauges were compared with a precipitation gauge located in a Double Fence Inter-comparison Reference (DFIR) wind shield construction that served as the reference. A large number of sensors were additionally monitoring supportive meteorological parameters.

The study presented in this poster considers data from three winters that were used to study and determine the wind-induced loss of solid precipitation. A general model framework was proposed, and Bayesian methods were used to objectively choose the most plausible sub-model to describe the loss ratio – wind speed – temperature relationship from the Haukeli data. The derived adjustment function is continuous and accounts for measurements of all types of winter precipitation (from rain to dry snow).

The analysis shows a non-linear relationship between the loss ratio and wind speed during significant precipitation events, and there is a clear temperature dependency, believed to be mostly related to the precipitation type. The data also displayed a distinctive scatter that is believed to be an artefact mainly caused by neglecting the varying aerodynamic characteristics of the precipitation particles (for a given temperature) as a determinant. The adjustment formula allowed for the first time to derive an adjustment function with a data-tested validity beyond 8-9 m/s and proved a stabilisation of the wind-induced precipitation loss for higher wind speeds. Preliminary tests of the adjustment function show promising results when adapting to different time periods: 1, 12 and 24 hours, which is data resolutions commonly used in hydrological applications.

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Assessment of the hydrokinetic energy resources of the medium sized lowland rivers in Lithuania

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The Law on renewables has been recently introduced in Lithuania. Regarding the hydropower sector, a priority is dedicated for the hydrokinetic (in-stream) technology. Lithuania has a vast network of the rivers that likely contain significant potential for power production from the running waters, although the size of this resource has never been assessed. This is consistent with most industrialized countries with some exceptions in North America (EPRI, 2012). Note, so far this hydrokinetic technology has neither technical maturity nor market value even in the highly industrialized countries (Khan et al., 2008).

An ongoing research project has been initiated by the Lithuanian Research Council to quantify Lithuania's hydrokinetic resources. Some preliminary results of the evaluation of hydrokinetic power characteristics of a large country's river are given in Punys et al. (2013).

This paper describes the methodology and provides results of the assessment of hydrokinetic resource of the selected medium-sized rivers in the country. Two independent methods were used to assess the hydrokinetic resource: hydrological and hydraulic. The latter based on modelling procedures is more detailed. To apply the hydrological method, the long term records of gauging stations were used. In the result, relationships among the river flow or stage on the one hand and mean velocities or cross sectional areas, on the other hand, were constructed.

The one-dimensional hydraulic model HEC-RAS 4.1 was used with the GIS extension GeoRAS to perform river hydraulic calculations. A high-resolution digital elevation model of the streambed was employed. The model calibration to adjust the Manning's coefficient was performed after the stream surface slope and discharge were measured.

Once the model was calibrated, the simulations of the mean annual, bankfull and low flows were used to identify the key hydraulic and geometric variables at the cross sections: the mean velocity, the flow geometry (the width, the mean depth, and the cross sectional area), and the specific stream power. The modeled parameters were compared to the independent dataset. The validation indicates that the hydraulic geometry can be modeled satisfactorily at the selected river cross-sections. Based on this data, the theoretical hydrokinetic power and the power density along the river (100 cross-sections spacing) were determined.

The technically recoverable resources were also evaluated. This procedure required a number of assumptions regarding the energy extraction by installed turbines, the acceptable spacing between the installed turbines along and across the river, and the natural environmental conditions.

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Environmental impacts on soil and water from a new highway section: Long-term resistivity results

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The hydrology of roads in operation is difficult to study, especially the distribution of moisture, infiltration and percolation processes. A huge tracer experiment is on-going on major roads in the Nordic countries due to use of large amounts of deicing salts during winter maintenance (Lundmark and Olofsson 2007). Permanent monitoring systems of electrodes have been shown to be effective in monitoring highways by mapping electrical resistivity changes over time (Olofsson and Lundmark 2009).Initial effects of highways on soil and groundwater have been studied (Earon et al. 2012) at the test site E18, Sweden, with three permanent electrode lines. This data will be compared with current resistivity measurements at the field site in order to assess long-term hydrological and environmental impacts.

The case study discussed in this paper is located at the test site on E18 highway between Västerås and Enköping (www.testsitee18.se). During construction of this test site and road section, three resistivity lines were installed under the highway for monitoring purposes. Initial measurements carried out by Earon et al. (2012) from 2010 to 2011. New measurements were collected twice per month since November 2013. Old and new collected data are combined and analyzed using Res2DINV software and with statistical analyzes. Initial results show that the electric resistivity at initial period of construction was uniform for the road layers. And the resistivity for entire section is decreasing especially for the road layers the ranges of resistivity changed due to moisture, pollutants from road and winter maintenance. Results show similar behavior regarding infiltration of runoff from the road surface between initial and current results, with distinct differences regarding depth and extent of contamination. The results imply that a major hydraulic path way is created during construction of the roadway, and that constant infiltration of highly contaminated runoff is a source of environmental stress from highways. Results confirm initial conclusions presented by Earon et al. (2012).

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Streamflow modelling experience in Estonia

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Estimation of the river runoff is very important for a sustainable water management and water related risks reduction. Provision of sufficient quantities of water to satisfy the demand in fastly growing economic sectors e.g. agriculture, industry and society development is becoming more relevant in the future. The question is in which direction to focus the efforts to ensure the viability of human society and ecosystems on earth under all anthropogenic and natural impacts? There are only few methods to determine river runoff: on-site measurements, morfometrical method and modelling. The importance of modelling is rapidly increasing thanks to the development of information technologies.

In Estonia, the modelling of river runoff as a scientific and practical activity has been initiated already several decades ago. Models were used to calculate the river runoff, pollution loads, filling gaps in the observational series, for quality control and the runoff forecast. Nowadays challenges faced worldwide are mainly related to the impacts of climate change on water resources. Hydrological regime of Estonian rivers is highly sensitive to climate change. About 40% of river runoff is formed by the snow melt in the spring time. Observed mean air temperature in spring has increased by more than 3^{o}C in 1955-2007 (Russak, 2009). The projected air temperature in the winter-spring seasons will continue rising by 1-2^{o}C leading to increasing precipitation in the form of the rain during milder winters. Therefore, the recent modelling aims at estimation of the seasonal and temporal trends in the river runoff following different climate scenarios (Järvet et al, 2000). The paper presents more recent results from various studies of the runoff modelling in Estonia. In addition, initial assessment results based on the complex simulation of atmosphere, coupled circulation and ecosystem, wave and river runoff models from the ongoing project „Assessment of possible changes of Estonian climate and environmental status on the basis of dynamical modeling of atmosphere, ocean and river runoff" are presented. Finally, the paper provides a brief history of the past and current situation of hydrological monitoring system in Estonia, considering the importance of the high quality *in vivo* hydrological data for calibration and validation of models.

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The most applicable methods for environmental flow estimation in small rivers of Estonia

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The implementation of the environmental flow calculation methods is very relevant and important, not only because of the Water Framework Directive (e.g. WFD) requirements to protect water bodies by mitigating and preventing the negative environmental impacts to achieve good status (GS) of surface and ground waters by 2015, but also for reducing social and economic implications on a river-system scale. In Estonia, rivers are small and therefore very sensitive to any impacts. The runoff of many rivers is regulated and anthropogenically affected by dams or other impoundments, which causes great effects on valuable fish communities (like salmonids). Hence, it is necessary to maintain an adequate water flow in a downstream, to meet human needs and to preserve the natural ecosystem headed by valuable fish species in rivers. Therefore it is very important and actual to provide an environmental flow in distinct river systems for different seasons. The aims of this study are: i) to estimate a low flows magnitude, frequency and duration for the monitored rivers in warm and cold seasons; ii) to compare it with the rates calculated by different methods; iii) to find the most applicable method for determination of the environmental flow, as setting the appropriate environmental flows is a key step in achieving Good Status (Acreman et al, 2004). Data from 34 cross sections over Estonia were used for the analysis. Depending on a station's observing period, different estimated data series have been used: the earliest from 1902 until year 2011.

Despite a large number of the existing methods (Tharme, 2003), based on the previous analysis, the ecological Tennant Method (10%, 20%, 30% and 40% percentage of the mean annual runoff (MAR) and the hydrological Index method Q95 and Q75 (the mean monthly minimum flow with 95% and 75% excess probability), and Q9530 (30-days minimum mean flow with 95% excess probability) were used. Depending on the hydrological regime and taking into account the aspects of fishing importance, rivers were divided into three categories. For the rivers of the first and the second categories, mainly salmon rivers with a shorter period of low flow, the Tennant 30% and 20% of MAR respectively are recommended. For the third group of rivers, with periods of a longer low flow, the mean monthly minimum flow with 75% excess probability is proposed to be used. For the rest of the rivers the mean monthly minimum flow with 95% or 90% excess probability is recommended. All outcomes from the research were taken into account in the Estonian legislation.

Keywords: Estonian rivers, environmental flow, magnitude, Tennant Method, hydrological Index method, small rivers.

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Hydrogeochemical characteristics and interpretation of Gauja aquifer in Latvia

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Gauja aquifer belongs to the Middle Devonian Gauja formation and mainly consists of fine-grained sandstones. It is distributed in almost entire territory of Latvia and in many cities serves as major drinking water source. Although the geochemistry of Gauja aquifer is well known, detailed investigations related to groundwater evolution and origin is sparse.

The aim of the study is to determine processes affecting the quality of groundwater in Gauja aquifer. To investigate the geochemical processes controlling the variability of major chemical composition classic geochemical methods (ionic ratios, Piper diagram) together with statistical methods (Principal Component Analysis, Cluster Analysis) were applied.

The data set used includes data from Latvian Environment, Geology and Meteorology Centre (ranging from National monitoring programs to groundwater resources prospecting projects) and data from previous studies investigating the quality and trace element content of groundwater (Levins and Gosk, 2007; Retike et al., 2012).

Results show that some parts of aquifer are influenced by intrusion of deeper, more mineralised groundwater or to a lesser extent by sea water intrusion. It is also possible to identify links between surface water and groundwater based on conservative ions such as chlorine. Initial few characteristics of trace elements in various ground water types have been identified, for example, elevated fluorine and strontium concentrations can be mainly associated with Ca-SO_4 water type, but highest barium concentrations are found in sulphate low, Ca-Mg-HCO_3 carbonate type waters.

The groundwater composition data including trace element concentrations originating from heterogeneous sources were processed and analyzed as a part of a newly developed geologic and hydrogeological data management and modelling system with working name “GeoVipum”.

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The need for re-mineralization of drinking water after treatment with Reverse Osmosis

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The last decades, drinking water has not been considered a source of minerals. However, studied waters in Sweden showed the following contributions to the daily intake (2 Liters): Ca 0-72 %, Mg 0-69 %, Na 0-65 % (Rosborg 2005). The drinking water minerals are especially important if the diet does not cover nutritional needs. Growing populations, increasing water use and drought cause water shortage. Thus, in the Middle East and Western Asia more than half of the drinking water is produced by Reverse Osmosis.

RO treatment causes completely de-mineralized water, which is corrosive and may cause elevated Cu and Pb levels, and lacks all essential minerals. Inclusion of remineralizing cartridge in household RO units proved to be ineffective, as Ca in re-mineralized RO water only increased to 2.64 mg/l, Mg 0.64 mg/l, and conductivity 2.64 mS/m, which was much lower than in the original tap water (to be published at NordicWater, Stockholm, August 2014)

Infants whose drinks were prepared with low-mineral water experienced brain oedema, convulsions and metabolic acidosis, and hyponatremic shock. "Water intoxication", or delirium, may occur following intense physical efforts and ingestion of several litres of low-mineral water. National Institute of Public Health registers a number of cases of people who developed pathologic symptoms of acute magnesium and probably also calcium deficiencies (muscular cramps, abnormal fatigue and weakness, cardiovascular disorders) after several weeks or months drinking RO water, which disappeared again shortly after switching on normal tap water (Kozisek 2005).

Quality standards for desalinated water in Israel are: 80-120 mg /L Ca, and >80 mg/L alkalinity (Brenner & Tenne 2010); minimum of Mg 20-30 mg/L is under discussion. Suggested ranges as presented in a future publication are Ca 20-80 mg/L, Mg 10-50 mg/L, HCO3 100-300 mg/L, SO4 50-250 mg/L (Rosborg et al “Drinking water minerals and mineral balance –importance, health significance, safety precautions”, Springer Verlag, to be published 2014).

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Measuring snow water equivalent with gamma radiation sensors (CS 725)

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One third of the annual precipitation in Norway is snow. Snow is a major contributor to annual spring floods in Norway and has major impact on hydro-power production and production planning. Measurements of snow and snow water equivalent (SWE) is also important for e.g. calibration and validation of snow models, for dimensioning of roof constructions, in snow avalanche forecasting, in recreation, etc.

Since 2009, Norwegian water Resources and Energy directorate (NVE) have been testing different methods for automatic in-situ monitoring of SWE in order to retrieve more and better data than provided by the existing snow measurement methods. At our research site at Filefjell (~1000 masl, 61 degrees N, 8 degrees E), snow scales, snowpillows, gamma radiation sensors (Campbell CS 725, from Campbell Scientific) and snow depth sensors are being tested (Stranden and Grønsten, 2011, Fjeldheim and Barfod, 2013). In addition, NVE is monitoring snow temperature, meteorological parameters and soil and ground water measurements at the same site. Many of these instruments are also tested in more coastal climates (Anestølen in Sogn, 430 masl, 61 degrees N, 7 degrees E) and (Vikafjellet, ~1000 m asl, 61 degrees N, 7 degrees E). Measurements at the latter site are provided by Statkraft.

Preliminary results are promising for the gamma radiation sensor when compared with snow pillows and snow scales. The measurement area is far larger with the gamma radiation sensor than with snowpillows and snowscales, and the gamma radiation sensor is not influenced by layers of crust and ice in the snowpack, which is a common problem using snow pillows (Ree et al, 2011). Nevertheless, we have seen that the gamma radiation sensors may be affected by increasing ground- and soil water caused by snow melt. When the groundwater level increases above a certain limit, the SWE from the gamma radiations also increases rapidly. However, preliminary results from Vikafjellet, indicates that the gamma radiation sensor gives reliable results also above the limit of 600 mm SWE given by the manufacturer.

Our conclusions based on the work done prior to this winter, show that 1) snow pillows work well in alpine conditions, 2) snow scales give reasonable data in several types of climate and 3) gamma radiation sensors give promising results in both coastal and alpine climate. Results from testing the gamma radiation sensor at Vikafjellet this winter will hopefully give us further information about the range of application for this sensor.

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Water quality for Sweden – from hydrological modelling to decision makers

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The European Union has addressed the issue of water quality within the Water Framework Directive. In this directive the member states are commissioned to characterize the status of their water resources and make a plan for improving water status. In Sweden SMHI is responsible for providing data on discharge and water quality to the reporting authorities and other decision makers.

Simulated data for fresh water and water quality is provided by the hydrological simulation model HYPE (Hydrological Predictions for the Environment). The HYPE model simulates the flow of water and substances (nitrogen and phosphorus) through soils, in rivers and in lakes on their way to the river outlet. The geographic area to be modelled consists of one or several river catchments and each catchment is divided into subbasins. S-HYPE2012 is the HYPE model application for Sweden. This model setup consists of around 35000 subbasins derived from the Swedish Water Archive database. For each subbasin different properties relevant for water and water quality is described. This includes for example soil properties and land use. For agricultural land we describe the distribution of crops and how they are managed. All relevant sources of nitrogen and phosphorus are considered including point sources and atmospheric deposition. The model is calibrated and evaluated against observations for a high number of monitoring sites. This has enabled a unique model setup for Sweden with high geographic resolution and simulation results with high accuracy..

Results on water quantity and quality from S-HYPE2012 are presented for the reporting authorities and other users on vattenweb.smhi.se. The presentation and the tools on the site have been developed in close cooperation with its users. For water quality the site includes input data relevant for simulation of nitrogen and phosphorus as well as simulated time series of nutrient concentrations. The site includes measured time series as well as a tool that allows the user to assess the accuracy of the simulated values. Among other results presented we can mention estimates of nutrient retention and source appointment for each of the 35 000 modelled subbasins. Source appointment is available for current nutrient load and for non-anthropogenic background load. To further explore this data the site includes an interactive scenario tool that allows the user to investigate the downstream effect of a hypothetic change of nutrient load of an upstream source.

The model data together with the different provided tools on the site offers a very powerful toolset for the end users to understand the validity of simulated data and how they can be used. The value of the information on the site is shown by continuous feedback from the users. In many cases this feedback and other information from users is a valuable source of local knowledge which can be used for further development of the site and model.

Regional versus local calibration of the S-HYPE model for prediction at ungauged sites

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Hydrological catchment models are commonly used in assessment of water quantity and quality. Results usually extend to places where no observations are available for calibration and validation of the model (predictions in ungauged basins, PUB).

A national model for water quantity and water quality (nitrogen and phosphorus) has been set up for Sweden (S-HYPE) using the HYPE model (Lindström et al., 2010). Many of the parameters in the HYPE model are linked to either soil type or land use. A step-wise calibration strategy, described in Strömqvist et al. (2012), was used for the calibration of S-HYPE, in which a small subset of river discharge gauging stations and nitrogen and phosphorus monitoring sites was used. Much observational data was therefore withheld from calibration and could serve as independent validation data. This gives a good base for PUB assessment but also means that much information is not used that could potentially improve the general accuracy and usefulness of the model application. Since S-HYPE is used operationally there are requirements on good model performance.

To make better use of all available data, a final step of the calibration procedure was employed in which the model domain was split into parameter regions. A few "super parameters" that act within parameter regions were developed. The super parameters govern local deviations in either one parameter at a time or modify a set of related parameters in a systematic way. They can either control the level or dynamics of a specific predictand. The use of a few super parameters is a compromise between a fully regional model set-up and local calibration, while keeping down the number of local parameters.

In two parallel experiments we test how this calibration strategy may improve results in ungauged basins. The results can give some indication and guidance on where in space additional monitoring efforts are best located. For selected test regions the monitoring sites are split into smaller (<200 km^2 contribution area) and larger basins. In the first experiment (up-scaling), half of the small basins in each region were used for calibration and the remaining sites were used for independent evaluation. In the second experiment (down-scaling), only the outlet stations (or monitoring stations furthest down-stream in a basin) were used for calibration. The models were evaluated for the independent sites in terms of levels and correlation for nitrogen and phosphorus concentration and volume and Nash-Sutcliffe Efficiency for river discharge.

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Challenges and opportunities of integral water management in Switzerland – Conclusions from the National Research Programme 61

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With its annual average precipitation of > 1'500 mm and its massive alpine glaciers storing 57 km^2 of water, Switzerland has been termed "water tower of Europe". However, climate, landscape and socioeconomic change are expected to impact on both the water resources and the water use in future. In order to assess these impacts and enhance our preparedness, a National Research Programme (NRP 61) including 16 projects was run from 2010 to 2013. Here, we present the programme synthesis (Björnsen Gurung and Stähli, 2014) illustrating our current knowledge of present and future water resources in Switzerland and their use.

The study showed that in the alpine part of Switzerland (representing ~60% of the total area) the annual water availability will remain constant to the end of the century, but the seasonal variability will change considerably. Overall, snow storage and glaciers will strongly diminish which will pose a challenge to hydropower industry. Alpine hydropower plants will have to be operated in a different way than in the past, and the importance of pumped storage and a clever sediment management will increase. As a consequence of glacier retreat new alpine lakes will emerge providing new opportunities for a multiple use for tourism, hydropower and flood protection, but entailing equally new natural risks.

With regard to the Swiss plateau (~30% of total area), where a rapid extension of the residential area is ongoing, NRP 61 highlighted the importance and risks of groundwater. It was concluded that groundwater yield potential is often overestimated given technical, economic, ecological and legal restrictions. There is a need for better quantitative knowledge about the sustainably usable groundwater volume, both in space (regional extent) and particularly for drought situations.

Overall, the quality of Swiss water resources is high and the input of nutrients and contaminants to the rivers has been reduced due to a technical and legal interventions. But for the sustainability of water resources a healthy ecosystem along our streams and lakes is equally important. This means that future long-term studies of water resources have to extend beyond quantity and quality measures, but needs to include morphological and ecological indices.

NRP 61 also showed that Switzerland has a wealth of data on water resources, which is an asset for a sustainable water management. However, at the interface between land use and water quality and with regard to water consumption, data gaps have been identified that need to be closed. Also, a country-wide soil moisture monitoring programme is an open issue of high priority for many aspects of water management (e.g. agriculture, flood prevention, drought forecast).

Finally, 40 km^2 of water are delivered as runoff to the neighbouring countries every year. This implicates a great responsibility to Swiss water users and the need for a transnational water resource strategy.

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Seasonal and spatial variations in hydrochemistry of spring water in formerly glaciated areas of western Poland -contribution of natural and anthropogenic factors

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The formerly glaciated areas of the Polish Lowlands (European Plain) are covered by thick glacial and glacifluvial deposits. They serve as voluminous groundwater aquifers. However, due to complex geology and porous character of the sediments the groundwater emerging in form of groundwater outflows (springs and seeps) often is influenced by interaction of groundwater and locally infiltrating surface waters.

In order to assess this interaction, as well as local anthropogenic impact, the seasonal and spatial changes in hydrochemistry of 20 springs was studied in the western part of Polish Lowlands. The spring waters were sampled every 3 months in the period from November 2011 to October 2013. The analyzes included major cations (Ca^{2+}, K^{+}, Mg^{2+}, Na^{+}, NH^{4+}), anions (Cl^{-}, HCO_3^{-}, NO_3^{-}, NO_2^{-}, PO_4^{3-}, SO_4^{2-}) and trace elements (Cd^{2+}, Cr^{3+}, Cu^{2+}, Fe, Mn^{2+}, Pb^{2+}, Zn^{2+}). Moreover, water temperature, electrical conductivity and pH were measured in the field. In addition, for 5 springs were made isotopic analyses of nitrates.

The results revealed that for most of the studied elements the water composition was similar and stable discharge along with small amplitudes of water temperature suggest that the spring water comes mostly from regional groundwater aquifers. However, in case of Fe, Mn^{2+}, Pb^{2+} and nitrates the spatial and seasonal variations were relatively significant. The average concentration of total iron ranged from 0.1 to 3.6 mgFe/L and in 70 % of springs it was found to be in excess of the Polish legal limits for drinking water (0.2 mgFe/L). The concentration of manganese in spring water exceeded the Polish legal limits for drinking water (0.05 mg Mn/L) in 85 % of the springs. High variability was found also in concentration of Pb^{2+}, in some periods the concentration of this metal in the analysed waters was 10 times bigger than the Polish legal limits for drinking water (0.01 mgPb/L). In some springs, elevated nitrate concentrations were found with maximum of 74 mgNO_3/L, which is also in excess of the legal limits (50 mgNO_3/L).

The seasonal high concentrations of Fe and Mn^{2+} are considered to be related to natural geo- and hydrochemical changes due to processes likely taking place in the infiltration zone. However, the high concentrations of Pb^{2+} and nitrates point to anthropogenic pollution and admixture of the groundwater with locally infiltrating water in the areas relatively close to the springs. The nitrates come from agriculture activities, while Pb^{2+} may come from several sources.

The results show that spring water may be affected by local seasonal changes due to supply from infiltrating waters nearby. The hydrochemical monitoring of them must thus consider seasonal variations as the water properties may be for some periods not permitting to use them for instance for drinking purposes.

Modeling hydropower potential shift with SWAT in North-Estonian rivers, considering future climate change

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Climate change is altering the impact of various hydrological processes in different regions of the world. The purpose of this study is to analyze the possible influence of climate change on hydropower production potential in North-Estonian rivers. In Estonian rivers, energy comes mainly from water volume and not from the head of water. Thus, changes in discharges are related to changes in hydropower.

Soil and Water Assessment Tool (SWAT) was selected to model discharge change in four North-Estonian rivers (Kunda, Vihterpalu, Keila and Valgejõe). Model was calibrated with a program SWAT-CUP, with Sequential Uncertainty Fitting (SUFI-2) method. Climate model GFDL-R30, composed by Geophysical fluid Dynamics Laboratory (GFLD) was used. Emission scenario A2 was selected, which assumes rapid population growth and increase in regional differences. Model efficiency was evaluated with the coefficient of determination (R^2) and Nash-Sutcliffe efficiency coefficient (NS). Coefficient of determination indicated a strong correlation (R^2>0.70) between observed and simulated discharges, ranging from 0.73 to 0.76 for calibration and from 0.66 to 0.70 for validation. Nash-Sutcliffe efficiency coefficients ranged from 0.71 to 0.75 during calibration, which indicates a "Very good" model (Moriarsi et al., 2007). During validation NS values ranged from 0.61 to 0.70 for different rivers, rating the model performance from "Adequate" to "Very good".

Hydropower potential was calculated from modeled river discharges. Results showed over 10% overall increase in hydropower potential from period 2010 to 2100. Current results are in agreement with previous study (Lehner et al., 2005), where a 10-25% hydropower potential increase was modeled. According to A2 emission scenario, spring flood will decrease and the hydrograph peak will shift earlier. Secondly hydropower potential in winter and early-spring will increase remarkably. No significant change in hydropower potential was modeled in summer. A slight hydropower potential decrease was modeled in autumn. Installing additional small turbines to North-Estonian hydropower plants could be beneficial.

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Simulating the water balance under climate change in northern Mongolia

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In recent years, Mongolia has experienced an increased pressure on the water resources. The problems are mainly related to increased water withdrawal, pollution and environmental changes. To address the changing conditions, one of the objectives of the IWRM MoMo project (Integrated Water Resources Management in Central Asia: Model Region Mongolia) has been to monitor the hydrological fluxes within the country. The conducted research has focused on the Kharaa River basin which is important for the fresh-water resources of northern Mongolia. In this study, the hydrological conditions and the water availability of the Kharaa basin were addressed by complementing climatic observations starting in the 1980s with recent observations from extended field studies. The data were used as input for the hydrological model HBV-D which was calibrated with observed discharge. It was demonstrated that the high inter-annual runoff variability is linked to climatic fluctuations. As an example, a sudden runoff decrease in the middle 1990s was shown to be related to several years of below normal precipitation. The first model application relied on data from a limited number of climate stations. In a following analysis, additional data from Global Climate Models (GCMs) were utilized in order to increase the amount of data, and to extend the study period both into the past and future. When the HBV-D was applied on WATCH forcing data for the period 1901-2000, a rise in temperature could be identified along with oscillating precipitation. As a result, a highly variable mean annual runoff was simulated. Thereafter, WATCH scenario data for 2001-2100 were applied. The data consisted of three GCMs driven by two IPCC emission scenarios. Analysis of the projections revealed that the rise in temperature is expected to continue whereas precipitation is expected to slightly decrease. As a consequence, the model results show decreases in mean annual runoff. The finding can be explained by increased evapotranspiration and changes in the precipitation regime.

Capacity optimization study of small scale hydropower plant in Mozambique river

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The current energy utilization in Mozambique shows that about 10% of the entire households with a total population of 23 million have access to modern energy sources in the form of electricity. The remaining 90% rely on traditional energy sources derived from biomass. The use of energy from thermal power plants depends on imported fuel which is expensive, and contributes to environmental pollution. Moreover, the rural areas are poorly or not all served with grid electricity (Maria de Fátima and Bryan, 2011). The situation is not expected to change in the foreseeable future. Hence, there has been a renewed interest on the development of energy resources from small scale hydropower potentials, which are considered to be a possible option for supplying energy to the rural and isolated areas. Besides, small scale hydropower systems are considered to be environmentally friendly and of low cost compared to large hydropower systems. The studies that are done in Mozambique show that there is an existence of a number of untapped small hydropower sites with an approximate overall capacity of about 300 MW. In this study, a low head (less than 3 m) hydropower plant, situated along the Pungwe River at Sofala. The flow duration curve was plotted based on cumulative flow rain curve (Mohammadi et al.,2006). Based on the net annual energy from the flow duration curve, optimal design discharge was established as 4.9 m^3/s for Francis, Kaplan, Propeller, and Banki turbines. Water wheel and Archimedes screw turbines optional discharge was 6 m^3/s. Power potential that can be generated was determined as 50 kW for Propelle, 55 kW for Francis turbine, 58 kW for Waterwheel, 61 kW for Kaplan and 64 kW for Archimedes screw turbine.

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Hydraulic factor as criterion for alluvial stream channel stability assessment

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Flow regime in stable channels represents a dynamic equilibrium in which average channel dimensions remain more or less constant, despite the ongoing both the bed and the bank erosion and sedimentation, meander cut offs and lateral migration. Moreover, stable river bed is also necessary to ensure the sustainability of aquatic ecosystems in the stream. Thus, alluvial stream channel stability assessment is very important and hydraulic factors were used for that. This report presents the results of investigation on bed stability both in natural and regulated streams and their self-regulation issues in Lithuania. It was found that the river bed equilibrium patterns presented by Lane principle were observed in small natural beds, while such balance was disturbed in the regulated ones. The state of flow dynamic equilibrium was evaluated by flow stability parameter *a*, which determine minimal potential expenditure of hydraulic loss depending on sediments discharge (Q_s) and bottom sediment particle mean diameter (D_{50}) as well as on the average stream discharge (Q_w) and the longitudinal gradient of the river bed (*S*).

$$a = \frac{Q_s D_{50}}{Q_w S}$$

It was found that flow power parameter *a* varied from 1.6 to 11.6 in small rivers, it was significant smaller (a – 0.004-0.134) in the bigger ones. This demonstrates the aggradation and degradation processes in observed rivers respectively. Energy distribution and geomorphology conditions in natural and regulated river channels were evaluated having in consideration Grishanin's beds' hydrodynamic stability criterion *M*.

$$M = \frac{d(gb)^{1/4}}{Q^{1/2}} = \left[\frac{d}{b}\frac{1}{Fr^2}\right]^{1/4}$$

where: *d* – average bed depth in river cross section, m; *b* – river bed width in river cross section, m; *Q* – bankfull discharge, m^3/s; *g* – acceleration due to gravity, m/s^2; *Fr* - dimensionless Froude number, characterizing river flow's kinetic and potential energy ratio in measured cross section.

According to this criterion the stability of some natural researched channel sections is not sufficient yet (0.81 - 0.87<0.92). Meanwhile the values of *M* vary from 0.68 to 0.81 in the regulated ones. The findings show that these drastically canalized river sections in the past 25- 30 year is very unstable and it is under intensive bed recovery process till now. Adapting to these naturally occurring river adjustments processes and using the extensive channel maintenance techniques, it is possible to force the hydrodynamic equilibrium self-recovery process and achieve rehabilitation of biodiversity in small regulated streams.

Regional groundwater model of Estonia and its hydrological developments

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A regional 3D digital model of the Estonian artesian basin was created in 2002 (Vallner 2003). Model is based on codes of Visual MODFLOW Classic and Flex allows performing sophisticated simulations of the transient density-dependent groundwater flow and transport. The model enfolds the whole territory of Estonia, the surrounding coastal sea, Lake Peipsi with the Lake Pihkva, border districts of Russian Federation, and Latvia, all together about 88,000 km^2. The model layers include all main aquifers and aquitards from ground surface to as low as the impermeable portion of the crystalline basement. The model has been profoundly calibrated against groundwater heads observed, and groundwater discharges in streams measured by gauging stations.

Spatial distribution of groundwater heads, flow directions, velocities and rates as well as transport characteristics can be simulated by the model. Detailed regional or local groundwater flow and transport budgets can be completed. The model is continuously used to elucidate the problems of Estonian regional hydrogeology. Thereat criterions of optimal consumption of groundwater resources proceeded from the EU Water Directive have been investigated (Gavrilova et al. 2010; Marandi and Vallner 2010). A series of regional paleohydrogeologic reconstructions from 22 until 0.1 ka BP based on water isotope data has been performed.

The simulated groundwater discharge into streams is an important output of the model. In periods of an insignificant precipitation the simulated groundwater discharge must be close to statistical low flow rates determined on the ground of long-term measurements of river gauging stations. If this requirement has been achieved then it is possible to postulate that the simulated groundwater discharge into surface water bodies should be practically equal to the base flow. Model simulations enable to distinguish sundry genetic components of the base flow and to establish their quantitative relationship with geologic and climatic factors. The branches of the base flow discharging into streams, lakes and seas can be separated and particularize in the space-time. Simulation of the base flow by the regional well-calibrated hydrogeological model is more informative and convincing than groundwater separation on runoff hydrographs.

The net infiltration input in the model following general climatic data was corrected until the areal distribution of the base flow controlled by river gauging stations was achieved. This way the most authentic data about territorial distribution of net infiltration were obtained. Furthermore, the model renders possible to simulate the evaporation from the groundwater table depending on its depth from the ground surface.

The inputs and outputs of the regional groundwater model should be functionally and statistically connected with other hydrological and meteorological data (runoff, precipitation, temperature, etc.). It might be attained by coupling of all water and climatic models created in Estonia with existing data bases. An integrated digital model of the Estonian hydrosphere should be created.

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Water scarcity and drought in Finland – status quo and future implications

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Water scarcity is a man-made phenomenon. It is a recurrent imbalance that arises from an overuse of water resources, caused by consumption being significantly higher than the natural renewable availability. Drought, contrary to water scarcity, is a natural phenomenon. It is a temporary, negative and severe deviation along a significant time period and over a large region from average precipitation values, which might lead to meteorological, agricultural, hydrological and socioeconomic drought. (Schmidt G. et al. 2012) Both droughts and water scarcity can cause economic losses in key water-using sectors and environmental impacts on biodiversity, water quality, deterioration and loss of wetlands, soil erosion, land degradation and desertification (European Commission 2012).

Water scarcity and drought are rather unknown concepts in Finland due to the fact that Finland is a water rich country. This is not the case in most parts of Europe where concerns about drought events and water scarcity have grown within past decade. One of the most widespread droughts in Europe occurred in 2003 affecting over 100 million people, a third of the EU territory, with a cost of at least € 8.7 billion (European Commission 2012). Also Finland was affected by this drought causing economic losses worth € 100 million.

Water scarcity is also getting worse in Europe. In 2007 at least 11% of the EU population and 17% of its territory had experienced water scarcity (European Commission 2012). According to water scarcity indicator used in EU (Water Exploitation Index plus or WEI+), water scarcity does not occur in Finnish river basins on an annual basis. However seasonal water scarcity occurs in Southwest Finnish small agriculture intensive basins with few lakes during summer periods (Ahopelto L. 2013). Climate change and water use development are expected to aggravate this seasonal water scarcity in the future by decreasing water resources availability and increasing water use.

One focus of the EU Blueprint to Safeguard Europe's Water Resources' is the integration of water quantity issues into the Water Framework Policy. One way towards this is to develop water assets accounting in member states. Better accounting of water abstraction and use by different sectors is important also in Finland. This information is needed to raise awareness of the decision makers and public about the vulnerability of water resources, especially in those basins that are affected by seasonal water scarcity, and to improve water resources management and drought risk management.

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Changing flow characteristics and their impacts on river systems in the Arctic: a combined approach of multi-temporal Landsat image change detection and flow simulation methods

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Arctic rivers are sensitive and yet quite unexplored river systems, the fluvial geomorphology of which is not well known. The reasons for this inscrutability have been the wideness and remoteness of the watersheds, difficulties to achieve, and the problems with data availability. Our research is enabled by the wide collaborative spatial databases in hydrology, development of the computing resources, and cooperation with the Swedish Meteorological and Hydrological Institute (SMHI), that has been active in the Arctic with Arctic-HYPE (HYdrologic Predictions for the Environment) hydrological catchment model.

The main research objective is to increase the understanding concerning the flow magnitude changes and the impact of the observed changes on the Arctic river system dynamics. The preliminary findings and detailed research plan are introduced. The research is conducted based on multi-temporal Landsat data of 7 Arctic watersheds during the last 25–30 years. The chosen study watersheds are situated in Canada, the USA, Russia, Finland and Norway and hence represent extensively the Arctic river systems.

Extensive Arctic river environments are studied by combining remote sensing data, wide hydrological datasets and flow simulation methods, such as SMHI's Arctic-HYPE model. The research delineates and develops satellite-based morphological indices describing the watershed, stream network and river channel, and the change detection of the morphological indices delineated. Remote sensing based river bathymetry delineation and also modelling of the past, present, and future river dynamics by using hydraulic modelling and cellular modelling are applied and developed. The impacts of flow conditions and prevailed climate parameters on the observed fluvial processes are also delineated. Thus, the understanding of the past and present river dynamics is possible to be developed and improved. This increasing knowledge is a precondition for the research of future processes in the Arctic watersheds. By using satellite-based methods applied and developed in our research, it is possible to understand and describe the Arctic river dynamics, its changes, and causation of changes better than earlier. The significance of our research will be emphasised by the growing population, increasing tourism, and economic actions in the Arctic mainly due to the ongoing climate change and technological development.

Flood frequency analysis – does the use of historical data improve estimates?

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The estimation of high flood quantiles is performed by fitting a parametric distribution to a dataset of high flows comprising either annual maximum values or peaks over a selected threshold. Estimates of high quantiles are needed for many applications, .e.g. dam safety assessments are based on the 1000 years flood, whereas the dimensioning of important infrastructure requires estimates of the 200 year flood. These estimates are often based on a limited amount of data compared to the desired flood quantile, with the estimated flood magnitudes therefore being based on a high degree of extrapolation. The longest time series available in Norway are around 120 years, and as a result any estimation of a 1000 years flood will require extrapolation. One solution is to extend the temporal dimension of a data series by including information about historical floods before the stream flow was systematically gaugeded (Benito et al., 2004; Parent and Bernier, 2002). Such information could be flood marks or written documentation about flood events.

The aim of this study was to evaluate the added value of using historical flood data for at-site flood frequency estimation. The historical floods were included in two ways by assuming: (1) the size of (all) floods above a high threshold within a time interval is known; and (2) the number of floods above a high threshold for a time interval is known. We used a Bayesian model formulation, with MCMC used for model estimation. This estimation procedure allows us to estimate the predictive uncertainty of flood quantiles (i.e. both sampling and parameter uncertainty is accounted for). To evaluate the possible benefit of using historical data, we investigated the reliability and stability of predicted flood quantiles (Renard et al, 2013). The procedure was tested for two cases. For the first we used a 120 year long streamflow time series and investigated the effect of having several shorter series' which could be supplemented with a limited number of known large flood events. For the second we chose a a site with historical information. The results show that the uncertainty and stability of flood frequency estimates are improved when historical data are used.

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Aspects of river typology from the view of mixing zones calculation in transboundary river basin region (LT – LV Project HOTRISK)

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In order to use the Latvian and Lithuanian water quality standards for the modelling of zones for mixing of effluents with receiving waters, a harmonized system for river water typology will be considered. The typology of rivers will be revised on geographical, geological, hydrological and hydrogeological background. It would facilitate the harmonisation of river classification for further target-based cross-border cooperation. Therefore one of the main tasks of Latvia-Lithuania Cross Border Cooperation Programme project „Towards a harmonized water quality and pollution risk management" (LLIV-303 „HOTRISK" project) is to revise and analyze the existing river typologies that have been previously provided in order to prepare the Venta River Basin district management plans (RBDMP) in 2009. The revised typology is important for elaboration in 2015 in both countries of harmonized Venta RBDMP, what should include the settlement of mixing zones on rivers of concern.
In this project on typology issue it is consequently necessary to use exact type-dependent threshold values for concentrations of elements of concern for calculation and modelling the mixing zones. Hydrological approach is used as the anchor for the rivers types' classification system. Nowadays there are 61 river water body in the Venta River Basin district of Latvia and 104 river water bodies in the Venta River Basin district of Lithuania. Each of those 61 river body in the Venta River Basin district of Latvia has been reviewed and analyzed by the developed in this project methodology.

Types of rivers in Latvia are specified, using System B of the European Community and focusing on the catchment's area (km^2) and mean water surface slope (m/km). The mean water surface slope is the main parameter in identifying the types of rivers, depending on such hydrological regime changes as water flow regulations (dams, weirs, and sluices) and morphological alterations as straightening and canalization. Whereas for Lithuanian rivers A system of typology is used, where the obligatory descriptors such as an absolute altitude, size of catchment's area and geology are included; an average water surface slope is used as additional factor from B system. At this stage there are 5 river types (of total 6) found in the Venta River Basin district of Latvia. These types are the following: large potamal (6^{th} type), large ritral (5^{th} type), medium potamal (4^{th} type), medium ritral (3^{rd} type) and small ritral (1^{st} type) rivers (water bodies).

Data of the catchment's area and mean water surface slope were calculated, using: 1) „Hydrographic Descriptions of Rivers – Surface Water resources" (LEGMC, 1972); 2) „Regionalization of Small Rivers" (A. Pastors, 1987); 3) Geographic Information System (GIS) and Cartographic materials. The latest topographic maps (1:10 000 and/or 1:50 000) used in ArcGis ArcMap 9.2 software are the most important instruments in delineation of the catchment's area and a calculation of the mean water surface slope in cases when a river is considered as two or more water bodies.

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bringing neighbours closer

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Exploring the spatial temporal variability of precipitation and streamflow changes in Xiangjiang River Basin, southern China using multiple methods

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Precipitation and streamflow are principal elements of the hydrological cycle. Quantification of the trends and changing patterns in streamflows and investigation of the influencing factors are vital for sustainable water resource planning and management for a basin and a region. The main objective of the study is to use an integrated approach to quantify the spatial-temporal variability of daily and seasonal streamflow and precipitation in Xiangjiang River basin, southern China for the period 1960–2005. This research goal is achieved through the following steps. First, the annual precipitation and streamflow trends were analysed using the Mann-Kendall test and the linear regression method. Then, wavelet transforms, which determine the spatial-temporal differences and trends in the annual and monthly records, were used to analyse the main frequency components in the time series to detect the dominant oscillations and to extract additional information. At last, annual and seasonal maximum daily precipitation and streamflow time series were analysed to examine storm and flood frequency from a regional perspective. This study is expected to contribute to exploring the complex spatial-temporal patterns of precipitation and streamflow as well as the extreme hydrological events in Xiangjiang River basin in order to reveal the underlying linkages between precipitation and streamflow from a broad geographical perspective.

Key words: Xiangjiang River basin, Mann-Kendall test, Linear regression, wavelet transforms, extreme event.

The water quality of oxbow lake under an agricultural water use restructuring project in Ishikari River Basin, northern part of Japan

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Land improvement projects with restructuring of irrigation and drainage system are operated in the Lake Chashinainuma watershed in Bibai, Hokkaido, northern part of Japan. In this watershed, irrigation water was pumped from the lake until 2010, but the water is now drawn from a distant river. These projects incur changes of land use and water management, and hence, influence water quality and the hydrological environment. The objective of this study is to evaluate the impacts of the agricultural water use restructuring project on the physical and chemical water properties of the oxbow lake "Chashinainuma" in terms of; (1) Changes of nitrogen concentration in the lake and inflow water, (2) Impact of the abolishment of pumping station on water balance and water quality in the lake and (3) Evaluation of water balance and total nitrogen load balance of the lake.

Surveys were performed at Lake Chashinainuma between 2007 and 2013; To measure the water quality, water was drawn from outflow drainage and inflow drainage sampling points in the lake. From April 2007 to October 2013 water sampling was conducted about twice a month during irrigation periods and once per month during non-irrigation periods. From 2009 to 2012 water sampling was performed twice a day during the paddling period (May) and once per day during normal irrigation periods (June–August) using an automatic water sampler from 2009 to 2012. These samples were analysed in accordance with Japanese Industrial Standards (JIS). Observed water level data was obtained in the lake and each drainage channel. Total nitrogen (TN) content in the bottom sediment and reed grass growing in the lake was measured.

We predicted that decreased water removal after the pumping station was abolished would increase TN concentrations in the lake water. Though removal of water by pumping tends to take pollution from the lake, TN concentrations fell after pumping station was abolished. The cause of decreased TN concentration was mainly decreased organic nitrogen concentration. Moreover, the TN load balance changed from an outflow type to a storage type in 2011 and 2013 despite decreased input load into the lake.

We suggest that this reduction in TN concentration after 2011 reflects the decreased organic nitrogen concentration due to biological purification effects. This is because increasing retention time caused load removal from the lake (K. Nakamura and K. Amano, 2007), and the water retention time also increased significantly in this lake. Extension of retention time may cause (1) sedimentation of particulate matter, (2) nitrogen fixation by phytoplankton or aquatic plants, and (3) organic matter decomposition due to microbes. However, nitrogen contents in the bottom sediment and reed grass were too small than the TN input load to consider as a direct factor of the decreased nitrogen concentration. Thus, this decrease in total nitrogen concentration is attributed to increasing of organic matter decomposition and denitrification in this lake.

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Characteristics of extreme precipitation based on the Generalized Pareto Distribution model for the Beas basin in Himalayan region, India

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Changes in precipitation extremes are of great importance to the welfare of human beings as well as the entire ecosystem. Considerable attention should be paid to the statistical modelling of extreme precipitation, which can help prevent flooding hazards, and help formulate the regional development strategies for water resources management.

The hydrology of Himalayan basins is not well understood due to the complexities in the climatic and geographic conditions, and the scarcity of data. The Beas River, one of the Western Himalayan rivers in India, is one of the main branches of the Indus River system. However, the characteristics of extreme precipitation in this river basin have rarely been explored yet.

In this paper, the daily rainfall data from 1982 to 2010 were used to model the extreme precipitation based on Generalized Pareto Distribution (GPD) model for seven stations in the Beas River basin. Firstly, stationarity was detected by using autocorrelation test, Mann-Kendall test, and wavelet analysis method. Secondly, GPD model was used to model the extreme precipitation in the study area. In order to select a suitable threshold value, mean residual life plots and threshold ranges method were used. Maximum likelihood method was used to estimate the parameters. Diagnostic plots of residual probability and quantile plots confirmed the suitability of GPD model. Thirdly, extreme rainfall of different return periods and the 95% confidence interval were estimated by the best fitted model. Fourthly, the influences of sea surface temperature (SST) on the extreme precipitation were investigated by using Nino3.4 SST as a covariate in the GPD parameters. The methods and findings will be beneficial in the planning, design, and management of water resources projects in the study the area.

Keywords: extreme precipitation; Generalized Pareto Distribution model; Beas River; statistical modelling

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Relationships Between Individual Small Tree Canopy Structure And Rainfall Interception

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Among the layers of a plant community, the canopy has the most important hydrological function in water circulation. Understanding the canopy's inner structure and its relationship to water transport is fundamental for the functional mechanisms of the vegetation canopy. Using an artificial rainfall simulator to supply three levels of rainfall intensity, the interception of rainfall by the canopy was measured to study the characteristics of individual trees using different rainfall conditions and structural parameters. The study was done for four small native tree species: Platycladus orientalis, Pinus tabulaeformis, Quercus variabilis and Acer elegantulum. The resulting variations in the process of canopy interception could be divided into periods of increasing, slightly decreasing in some species, and stable levels of interception. In addition, duration of the initial period of increasing interception shortened as rainfall intensity increased. When rainfall was less intense, the percentage of gross rainfall intercepted by P. orientalis, P. tabulaeformis and A. elegantulum canopy layers was in the order mid > upper > lower canopy, while for Q. variabilis the sequence was upper > mid > lower canopy. These sequences indicate that canopy superstructure was more important than canopy substructure regarding the ability of the canopy to intercept precipitation and thus prevent soil erosion. Furthermore, it was found that exponential and logarithmic functions could be used to describe the relationship between interception of coniferous and deciduous species, respectively, and their own canopy body types. This study provided preliminary criteria for determining the optimal crown type for rainfall interception.

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