Abstract Volume
9th Swiss Geoscience Meeting

Zurich, 11th – 13th November 2011

8. Hydrology and Sustainable Water Resources Management in View of Global Changes

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Geosciences
Platform of the Swiss Academy of Sciences

ETH
Eidgenössische Technische Hochschule Zürich
Swiss Federal Institute of Technology Zurich

8. Hydrology and Sustainable Water Resources Management in View of Global Changes

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Swiss Hydrological Commission (CHy)
Swiss Society for Hydrology and Limnology (SGHL / SSHL)
Steering Committee NRP 61

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8.1

Respiration and microbial dynamics as indicators of floodplain heterogeneity: the alpine Urbach valley, Switzerland

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Natural floodplains can be considered as a heterogeneous mosaic of aquatic, semi-aquatic and terrestrial habitats, ranging from aquatic channels to terrestrial floodplain forests (Langhans et al. 2006). As such, they can serve as ideal model ecosystems to study the effects of environmental heterogeneity through different habitat properties on ecosystem processes (Tockner et al. 2010). The present study was conducted to improve the understanding of such linkages within floodplains. We investigated a 4-km long and up to 600-m wide alpine floodplain (800 m asl; Urbachtal (Büchi 1980), Innertkirchen, CH), which is characterized by a high hydrologic variability encompassing expansion and contraction as well as downwelling and upwelling dynamics. The focus of the study was two-fold: 1) Ecosystem respiration, an important process integrating the energy flow through biotic elements of aquatic and terrestrial ecosystems (Doering 2007), and 2) enzyme activities, which are responsible for the modification and remineralization of organic matter, thereby influencing its amount and composition (Sinsabaugh et al. 1991). We combined spatio-temporal assessment of habitat properties (temperature, organic matter content, grain size distribution and water content), aquatic (O_2 consumption in Plexiglas tubes) and terrestrial respiration measures (CO_2 production, IRGA) with microbial techniques (bacterial abundance by flow cytometry and enzyme bioassay) to (1) examine functional heterogeneity within the floodplain, (2) determine the main environmental drivers of respiration, and (3) find linkages between floodplain structure and function using respiration, bacterial abundance and enzyme activity data. Overall, we found high functional heterogeneity in measured habitat properties, respiration activities, bacterial abundance and enzyme activities. Lowest respiration and enzyme activities were generally measured in the harshest habitats including the river channel and exposed gravel, whereas activities were highest in more stable habitats such as alluvial forest and meadows. The main drivers of respiration were determined to be temperature and organic matter content. The results underline a tight and sensitive linkage between habitat heterogeneity and ecosystem functioning in this alpine floodplain which can serve as a framework to assess and monitor changes in floodplain ecosystems in terms of sustainable resource management or increasing environmental pressures such as from climate change or hydropower production.

REFERENCES

Büchi, E. 1980: Geologie der autochthonen Sedimentbedeckung des Aar – Massivs im Urbachtal bei Innertkirchen. University of Bern.

Doering, M. 2007: Environmental heterogeneity and respiration in a dynamic river corridor: Structural properties and functional performance. Diss. ETH no. 17046.

Langhans, S.D., Tiegs, S.D., Uehlinger, U. & Tockner, K. 2006: Environmental heterogeneity controls organic-matter dynamics in river-floodplain ecosystems. Pol. J. Ecol. 54, 675-680.

Sinsabaugh, R.L., Antibus, R.K. & Linkins, A.E. 1991: An enzymatic approach to the analysis of microbial activity during plant litter decomposition. Agric. Ecosyst. Environ. 34, 43-54.

Tockner, K., Lorang, M.S. & Stanford, J.A. 2010: River flood plains are model ecosystems to test general hydrogeomorphic and ecological concepts. River Res. Appl. 26, 76-86.

8.2

Implications of simplifying heterogeneous streambeds in models simulating surface water groundwater interactions

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A common approach in modeling surface water-groundwater interaction is to represent the streambed as a homogeneous geological structure with hydraulic properties obtained by means of model calibration. In reality, streambeds are among the most heterogeneous geological structures. Currently, no systematic analysis to quantify the implications of this modeling strategy exists. We aim to close this gap and estimate the errors associated with the simplification of the complexity of streambeds. The work builds on previous papers on the physics and the modeling of surface water groundwater interaction (Brunner et al 2009a, Brunner et al 2009b, Brunner et al 2010, Brunner et al 2011).

Using a fully coupled, physically based numerical model (HydroGeoSphere), synthetic observations of infiltration flux from a river to an aquifer were generated using heterogeneous streambeds. The streambeds themselves were constructed using geostatistical methods. These observations of infiltration flux were used to calibrate homogeneous substitute streambeds that reproduced the observation data. The calibrated models were subsequently used for predicting infiltration fluxes between the stream and the aquifer under different hydrological conditions.

An in-depth analysis of the errors revealed that two important factors determine the error in flux: In streambeds that allow for a simultaneous occurrence of both saturated and unsaturated flow the largest errors can be expected. Whether such unsaturated zones can occur in a stream-aquifer system is related to the spatial distribution of the hydraulic properties in the streambed. The second factor is related to the state of connection the observation was obtained from (e.g. connected, transitional or disconnected flow regime), and if the calibrated model is used to simulate a rising or a falling water table. Finally, we show that the maximum error in flux can often be easily estimated, even without a numerical model.

REFERENCES

Brunner, P., P. G. Cook, and C. T. Simmons (2009a), Hydrogeologic controls on disconnection between surface water and groundwater, *Water Resour. Res.*, *45*(1), W01422.

Brunner, P., C. T. Simmons, and P. G. Cook (2009b), Spatial and temporal aspects of the transition from connection to disconnection between rivers, lakes and groundwater, *Journal of Hydrology*, *376*(1-2), 159-169.

Brunner, P., C. T. Simmons, P. G. Cook, and R. Therrien (2010), Modeling Surface Water-Groundwater Interaction with MODFLOW: Some Considerations, *Ground Water*, *48*(2), 174-180.

Brunner, P., P. G. Cook, and C. T. Simmons (2011), Disconnected Surface Water and Groundwater: From Theory to Practice, *Ground Water*, *49*(4), 460-467.

8.3

Water management and allocation in semi-arid areas: lessons from Hyderabad water supply, India

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Sustainable water management rests upon delicate fine tuning and orchestration of disparate fields of research and action, and is a process often frayed with latent or actual conflicts. A symbolic example is water allocation among water uses and users in water-scarce areas, that is, where water demand drifts critically close to what can be possibly supplied.

Drawing from research conducted on Hyderabad water supply (Celio et al., 2010), this contribution specifically explores the dynamics and implications of water allocation between the urban and the agricultural sectors. The city of Hyderabad, located in south peninsular India, has experienced a vibrant population growth over the last decades, and counts today a population of approximately 4 million. It is thus exemplar of the urban growth phenomenon observed in many other parts of the world, which poses tremendous challenges to municipal authorities and constantly redefines and strains rural-urban tradeoffs (on this particular aspect, see e.g. the seminal work by Swyngedouw, 2004)

From the city foundation in the late 1500s up to date, the response to Hyderabad growing water requirements fits within a generally observed pattern of urban water appropriation (see e.g. Molle & Berkoff, 2006): when local supply through withdrawals from shallow dugwells and artificially impounded water becomes insufficient to meet the growing demand, cities begin catching nearby sources and convey water via canals. Then, as demand growth outpaces supply, far located sources are tapped and/or water previously impounded and used for agricultural production is appropriated – water reallocation from agriculture to cities ensues.

The backdrop against which Hyderabad water supply has expanded and impinged upon water use in agriculture is a legal framework entirely handling over surface water (allocation) rights to the state government (Celio, 2010). While this supremacy of rights has eased the massive development of water resources during the so-called green revolution, it has actually had the opposite effect on Hyderabad. The historical reconstruction of the development of the city water supply clearly shows that the government representatives have been adverse to make any decisions regarding taking water from agriculture to meet Hyderabad needs, as such a move would have been politically risky as unpopular among farmers who make up the bulk of the electors. Thus, the increase of Hyderabad water supply was characterized by fears of negative impacts on agriculture, conflicts, party politics, and constant delays.

A research question triggered by the assumption that reallocation is harmful to farmers is: “to what extent agriculture, respectively farmers’ households, are *actually* affected by reallocations to Hyderabad”? While the mechanisms and actual development of water reallocation were studied by deciphering party politics, by retracing historical facts, and by reading through legal provisions and understanding how they translate in water rights, assessing actual impact requires a different approach and method.

First of all, a water balance was calculated for a water source shared by Hyderabad and an irrigation project (called “Nizamsagar”), so as to determine what variations in water supply to Nizamsagar could be specifically attributed to urban water supply. These variations were then translated into corresponding variations in agricultural output, notably using empirical data as crops water use, cropping patters, and conjunctive use of groundwater in Nizamsagar command area. The study has yielded two main findings: firstly, that existing institutional arrangements – or rules – governing the daily sharing of water between Hyderabad and Nizamsagar have partially attenuated the potential negative impact on agriculture; secondly, that groundwater use in agriculture significantly compensates for the urban transfer.

The second component of the research question asked above still needs to be addressed: what does water transfer to Hyderabad entail for *farmers’ households*? Primary data collected through questionnaires interviews in Nizamsagar irrigation project show that water shortages, either brought about by withdrawals for urban supply or resulting from precipitations below average, tend to impact more heavily poor farmers located towards the tail end areas of the irrigation project. Besides being more exposed to drought as being situated the farthest from the water reservoir, these farmers are also unable to afford to pay for a borewell and thereby accessing groundwater, and only seldom rely on coping strategies as diversification of cropping patterns or shifting cropping calendars.

The plain simplicity of water pipelines easing their way through the landscape and supplying water to Hyderabad today tends to reassert engineering as being the challenge to overcome and the solution to water problems. The unfolding of Hyderabad water supply though, from its origins up to seemingly unrelated concerns as water provision to agriculture, clearly demonstrates the multi-faceted complexity of water resources management and thereof the need to address the challenge through multidisciplinary research approach and action.

REFERENCES
Celio, M., Scott, C. & Giordano M. 2010: Urban-agricultural water appropriation: the Hyderabad, India case. Geographical Journal 176(1), 39-57.
Celio, M. 2010: More drops for Hyderabad city, less crops for farmers: water institutions and reallocation in Andhra Pradesh. In Cullet, P., Gowlland-Gualtieri, A. et al. (Eds.). Water governance in motion – towards socially and environmentally sustainable water laws. Cambridge University Press, New Delhi.
Molle, F., Berkoff, J. 2006: Cities versus agriculture: revisiting intersectoral water transfers, potential gains and conflicts. International Water Management Institute, Colombo.
Swyngedouw E. 2004: Social power and the urbanization of water. Flows of power. Oxford University Press, New York.

8.4

IDENTIFICATION OF GLACIER MELT ROUTING PATH WAYS IN A KARSTIC ENVIRONMENT: A CASE STUDY OF THE GLACIER DE LA PLAINE MORTE

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Glaciers all over the world are expected to continue to retreat due to the global warming throughout the 21st century. Subsequently, future water management strategies will strongly be affected by changes in glacial melt runoff, as future water availability might become scarce once glacier area has declined below a certain threshold. Particular attention should be paid to glaciers sitting on top of the main water divide, thus providing melt water to two different mountain valleys. Predictions of such systems become even more complex, if the study site is located in a karstic environment, where significant parts of the melt water are drained through a karst system.

A typical study site of such a setting is the Glacier de la Plaine Morte, located at an elevation of 2,750 m asl, in the canton of Berne in Switzerland. The glacier covers about 9 km2, and its thickness reaches up to 200 meters. The particular location of the glacier leads to meltwater runoff to the north, as well as to the south, providing both the canton of Berne and canton Valais with valuable glacial melt water. An accurate quantification of glacier melt water yields is very difficult, as a significant part of the runoff is routed through a karst system. Nevertheless, recent investigations reveal that a projection of future runoff into both valleys may be valuable for water management strategies, as climate change might mitigate vegetation, hydropower activities and subsequently the local economy.

In order to quantify the amount of runoff from Glacier de la Plaine Morte to the two regions, we performed an extensive tracer experiment, injecting three fluorescent dye tracers at three locations on the glacier and observing concentration of the tracer and discharge in major springs and rivers originating from the local karst system or directly from the glacier (Figure 1). On 22 August 2011 we injected 30kg Eosin at a north western location, 40kg Duasyn at a southern location and 12 kg Uranin at a south eastern location of the glacier. Dye tracers concentrations were monitored using automatic sampling devices, fluorimeters and active carbon filters. Altogether, we analyzed tracer concentration in over 1000 water samples at more than 20 locations north and south of the glacier.

Preliminary results indicate that during intense melt periods most of the glacier melt water is rapidly drained towards the north west of the glacier, alimenting the River Simme in the Bernese Simmental (Figure 1). During the first two days of sampling we estimate that the entire amount of Eosin, about 50% of the Uranin and about 20% of the Duasyn was drained to the north east. While this result was expected for the Eosin tracer (injected in the north west), it is surprising that about half of the Uranin (injected in the south east of the glacier) traveled across the glacier to the north western surface runoff. These findings indicate that the rapid drainage system of the glacier follows primarily the thalweg at the bottom of the glacier. We expect to quantify the amount of melt water drained through the karst system by analyzing the remaining water samples. These results provide valuable insights into the structure of the Plaine Morte glacier as well as of the karst system. This is an essential contribution to the hydrological modeling activities within the MontanAqua project (NFP61).

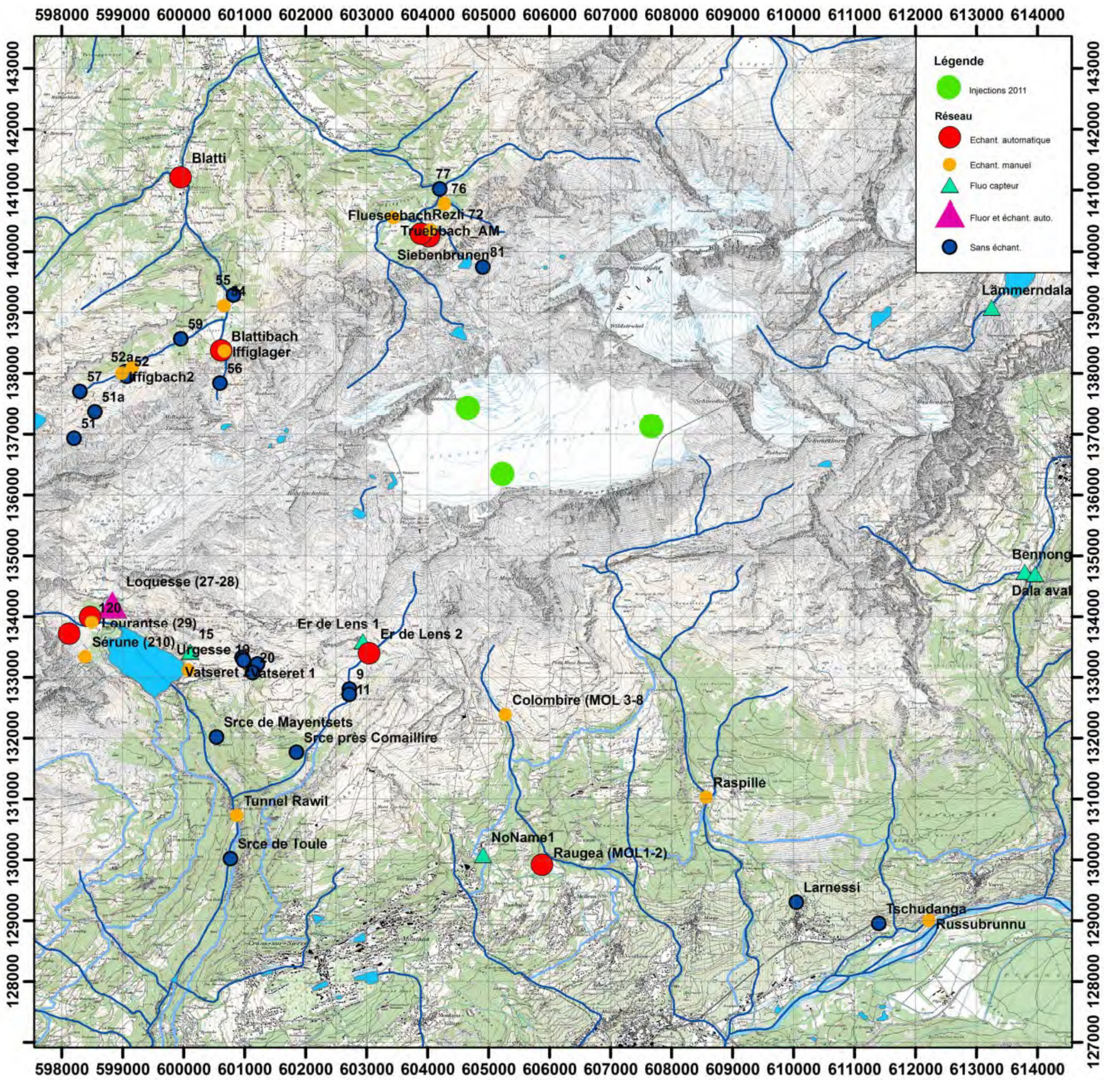

Figure 1: Glacier de la Plaine Morte and the two catchments: in the north the Bernese Simmental and in the south mountain stream in the Crans-Montana region. Symbols on the map locate sampling sites.

8.5

How long can groundwater sustain stream flow during droughts? The influence of stream sinuosity on bank storage in alluvial plains

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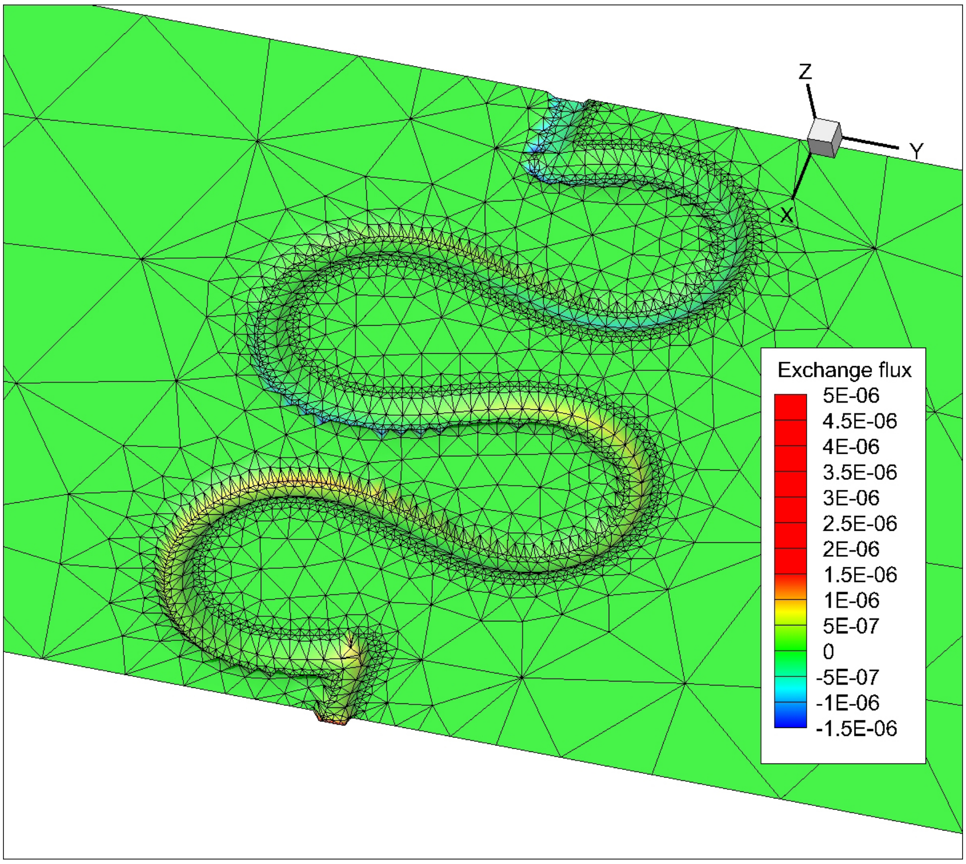
In many regions, the role of groundwater during droughts is critical to sustain minimum stream flows. Among the processes that promote baseflow is the temporary storage of surface water in alluvial aquifers following high flow events. This study aims at understanding the potential significance of such bank storage in subalpine areas, where the narrow valleys imply a small surface area exposed to direct recharge by rain, but a large contact zone between groundwater and streams. This connectivity is partly controlled by the degree of meandering (or sinuosity) of the stream. Yet little is known about the influence of sinuosity on bank storage and its subsequent impact on the tail of stream recession curves. Understanding this geomorphologic control, which can be readily mapped, is likely to help improve low flow predictions.

To investigate the influence of bank storage on a stream hydrograph, we use a three-dimensional model that fully couples subsurface and surface flow (HydroGeoSphere). An idealised conceptualization of the hydrological system is used to evaluate the sensitivity of the hydrograph response to stream sinuosity.

The discussion covers an evaluation of the methodology and the quantitative relationship between sinuosity and bank storage. It addresses the following questions: how long, after peak flow, can bank storage maintain stream flow at least 5% above the steady-state flow? What are the surface and subsurface properties of an alluvial plain that can induce a significant change of a hydrograph recession curve? What is the effect of antecedent conditions, i.e., groundwater levels, on this modification? Is bank storage more sensitive to high flows of short duration (e.g. storms) or moderate flows of longer duration (e.g. snowmelt periods)? And how do these results pertain to the Swiss subalpine hydroscape?



Caption: Figure 1. Model output of a highly sinuous river and its floodplain representing the exchange flux between the stream and the aquifer. Zones of stream water infiltration are coloured in blue, and areas of groundwater discharge in red (ms^{-1}).

8.6

Karst system characterization (KARSYS): a methodology for approaching the hydrogeology of karst systems in Switzerland (Swisskarst Project, NRP61)

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Karst hydrological systems are characterized by a highly heterogeneous structure including quick- and slow flow components (conduit network, phreatic and epikarstic storage). This induces an important hydrodynamic variability and complex flow dynamics. Furthermore, regional characteristics of karsts aquifers in Switzerland are poorly documented and a synthetic overview of karstic resource does not exist yet. This situation is not satisfactory and the management of karst water resources is far from being optimal. In the framework of the SWISSKARST Project, the Swiss Institute of Speleology and Karstology (SISKA) developed a methodology for approaching karst systems in their geometries and behaviours at the scale of Switzerland: This methodology has been called KARSYS for KARst SYStem Characterization. This approach combines several general characteristics of karst media with regional aspects leading to a pragmatic 3D conceptual model of a karst system. This model depicts systems boundaries, catchment areas, the aquifer basement, the location and extension of groundwater bodies and their boundaries in high water stage. Results of this approach are presented as Identification Cards for each main karst system, including hydrogeological karst maps (based on a new mapping methodology), 3D views, a basic data-base and a series of attachments (typically literature). Details on ID cards are presented in a separate paper (Demary *et al.* (2011)). Another part of the SWISSKARST project is dedicated to the development of a pragmatic hydrological modelling tool for the simulation of karst spring discharge from precipitation data. This part is presented in a separate paper (Weber *et al.* (2011)).Application of this applied methodology cover a wide range of water uses and land uses as water supply, management (tunnel, dam,…), renewable energies (evaluation of power production potential or geothermic), natural hazards prediction,...

The present abstract focuses on the KARSYS part of the project. The first step of the KARSYS method consists in identifying all significant karst systems of a region by recognizing major springs through any kind of information such as the spring inventory of cantons, the existing literature, field campaigns or interviews of people knowing concerned region. Then, an iterative approach is applied, aiming at building a geological and hydrogeological conceptual model of karst systems. In this purpose, a 3D-geological model is assembled first, giving the framework for a hydrogeological model. This model describes the geometry of karst aquifer boundaries, of all major springs, and of karst groundwater bodies (assuming that the aquifer is saturated under the spring level). The respective catchment areas can be derived from this model. They usually considerably differ from topographic recharge areas, as they would be delineated in surface hydrology. This model also makes it possible to assess the main underground flowpaths. Data from tracing experiments can also be integrated into the model as a control. It appears frequently that application of KARSYS leads to identify water exchange between adjacent karst systems depending on the water table fluctuations. This methodology is therefore relevant to show the boundaries of systems and their interactions.

KARSYS was applied to the whole Vaud canton (2 822km²) in 2010 and is now extended to the Bern and Fribourg cantons demonstrating that the KARSYS method is applicable and provides much of meaningful information. Results can be viewed on the evolutionary SWISSKARST website: www.swisskarst.ch.

The KARSYS documentation approach of karst systems is an important step for a sustainable management of karst waters and it represents a necessary base for any further step including modelling of water quantity, regime, quality, or the assessment of global change on resources.

REFERENCES

Demary, S., Vouillamoz, J., Eichenberger, U., Weber, E. & Jeannin, P. (2011): Identification Cards of karst systems as tools for a sustainable management of karst systems. , , , .

Weber, E., , Jordan, F., , Jeannin, P. Y., , Vouillamoz, J., , Eichenberger, U., , Malard, A. (2011): Swisskarst project (NRP61): Towards a pragmatic simulation of karst spring discharge with conceptual semi-distributed model. The Flims case study (Eastern Swiss Alps). , , , .

8.7

Using high resolution lysimeter data to quantified current and future recharge rates and evaluating the uncertainty

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Groundwater recharge is the key parameter for sustainable water resources management. However, quantifying its spatial and temporal distribution is difficult, because infiltration is affected by soil types and the presence of vegetation. Different soil types have a profound influence on how precipitation relates to groundwater recharge. The task is further complicated through climate change: The effect of climate change on groundwater recharge is still poorly understood.

Numerical models are an important tool in quantifying groundwater recharge. Typically, water flow and transport is simulated in 1-D models. Unfortunately, these models require a high number of parameters, which are difficult to measure. For example, water retention curves that describe the relation between saturation, matrix potential and hydraulic conductivity are required, yet their measurement in the laboratory is expensive and time-consuming. Pedotransfer fuctions are an alternative to direct measurements, but their reliability is highly questionable. Alternatively, the required parameters are calibrated to fit a set of available observations. However, in many cases only a few observations with low spatial and temporal resolution are available. Therefore, the unknown model parameters cannot be calibrated uniquely, resulting in large uncertainties associated with prediction.

In this project a large amount of high quality data through the lysimeter facility AGROSCOPE in Reckenholz is available to calibrate 1D soil column models. Data from 3 types of soils found in Switzerland are at our disposition. Data measured include deep drainage, evapotranspiration, as well as soil moisture and matrix potential at different depths. For the calibration of unknown parameters we use PEST, a model independent parameter estimation and uncertainty analysis program in combination with the numerical model HydroGeoSphere. Due to the quality and amount of observations, we expect to lower our uncertainty related to predictions significantly.

We use the calibrated models for the different soil types, in order to predict the effects of climate change on groundwater recharge for the main soil types in Switzerland. Additionally, we provide methodological insights into methods to quantify recharge. For instance, the relationship between temporal and spatial availability of observations and predictive uncertainty of the model will be investigated. These results will enable us to provide guidance on the required level of model complexity, amount and type of observation data required for future studies.

8.8

Identifying ecological indicators for the alpine groundwaters in the context of future climate change: the interdisciplinary approach

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Despite the fact that Alps are extremely rich with water, the increase in temperatures and redistribution of precipitations due to climate change together with the human overuse presents the serious threat for the water reserves. Within the EU project Alp-Water-Scarce (Water Management Strategies against Water Scarcity in the Alps, 2008-2011) several concurrent studies across Alpine countries have been carried out to characterize the hydrological systems and develop water management strategies against water scarcity. In the study from Slovenia an attempt was made to ecologically characterize and asses the vulnerability of the alpine aquifers combining hydrogeochemistry and faunistic surveys using springs as an access points to the groundwater. Additionally, we tried to develop simple indicators for the rapid detection of significant decreases in groundwater levels.

Water from 12 springs located in the alpine region in Slovenia (Figure 1) was collected during high and low flows in 2009 and 2010 in order to carry out geochemical analyses (anions, cations, $\delta^{13}C_{DIC}$, $\delta^{13}C_{POC}$, $\delta^{18}O$, δD, tritium). Concurrently, discharge, temperature, oxygen and pH were measured, and invertebrates drifting from the aquifer and inhabiting springs were sampled.

The groundwaters studied represent waters strongly influenced by chemical weathering of Mesozoic limestone. The $\delta^{13}C$ of DIC ranged from -15.8‰ to -1.5‰ and indicated less and more vulnerable aquifers. Isotopic composition of oxygen ($\delta^{18}OH_2O$), and tritium values range from -12.2 to -9.3‰, and from 6.4 to 9.8 TU, indicate recharge from precipitation. The age of spring waters were estimated to be from 2.6 to 5.1 years. The invertebrates collected differed between the hydrogeological units identified by hydrological and geochemical measurements indicating to be a good predictor of aquifers hydrogeological characteristics. Moreover, the number of invertebrate species and their densities were significantly higher in 2009 than in 2010 which was a "dry" year by means of precipitation in comparison to 2010. It seems that lowering of groundwater water table stimulate more intense drifting of groundwater invertebrates. Hence, the monitoring of invertebrate drift from springs can be a useful tool to assess the level of stress in groundwater ecosystems due to decreasing water levels.

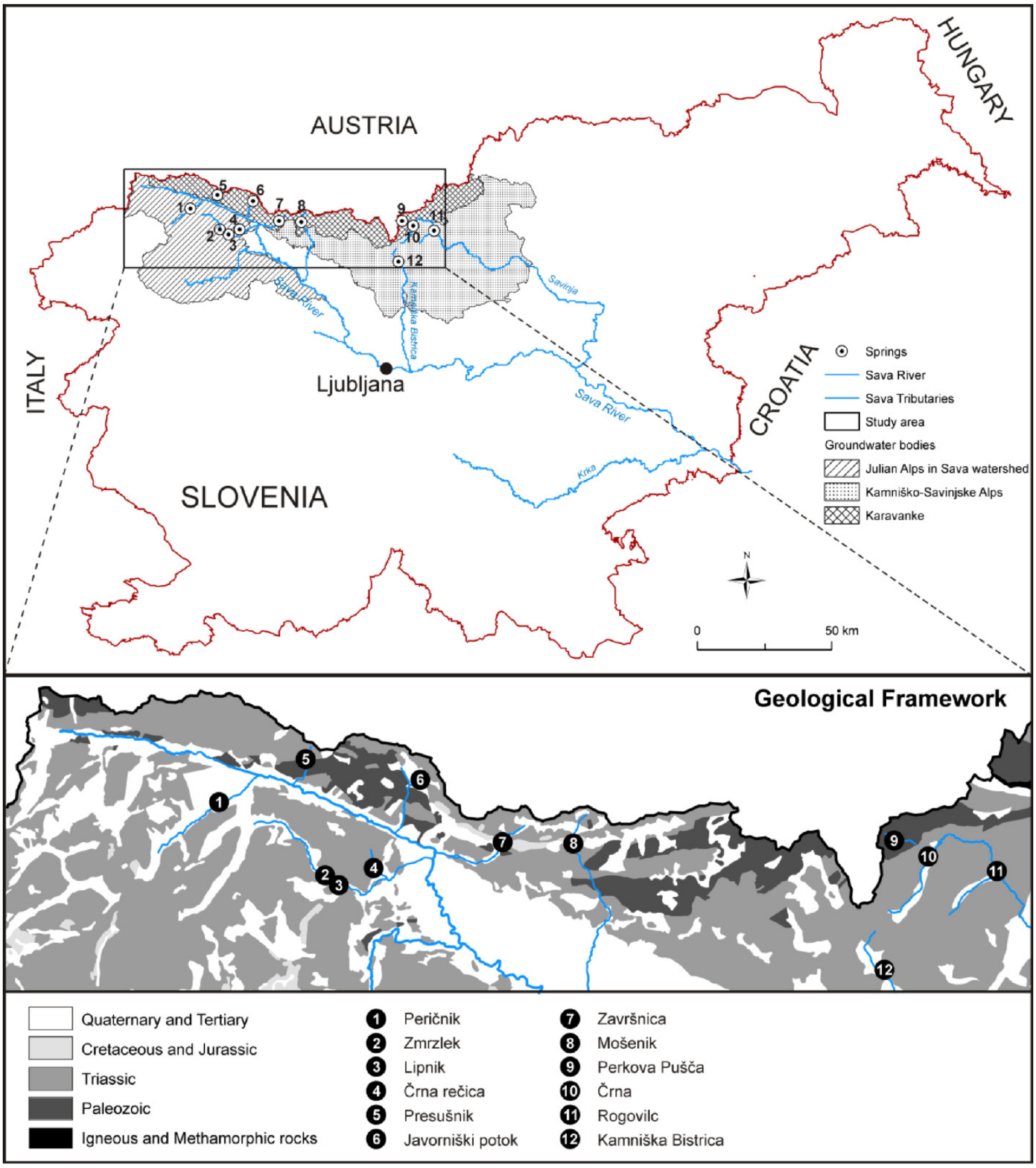

Figure 1. The map of the study area with geological settings and sampling locations.

8.9
A Climate Change Impact Assessment Study on Mountain Soil Moisture with Emphasis on Epistemic Uncertainties

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Mountains are expected to respond sensitive to climate change. Thus, sound climate change impact assessment studies focusing on mountain areas are strongly needed to estimate changes and to develop adaptation strategies. Nowadays, climate change impact assessment studies (CCIAS) are a common approach and many publications on hydrological responses to climate change have been published. Nonetheless, CCIAS focusing on soil moisture are widely missing especially at the catchment scale; even more, as to our knowledge there are only two studies on mountain soil moisture at a coarse scale. The wide neglect of soil moisture in climate change impact assessment studies contrasts the key role of soil moisture in ecosystems. This clearly shows the strong demand for CCIAS on mountain soil moisture. In this study, a commonly used CCIAS approach was used, comprising (1) of a physically based model that was calibrated and validated under recent climate conditions, (2) that was driven by downscaled regional climate models (RCMs) for a reference and a future scenario climate conditions. A major challenge in CCIAS is the propagation of uncertainties that questions the model results. In this study a special focus is set on the structural uncertainties originating from the use of downscaling approaches and climate models. Therefore, an analytic framework was developed based on the both concepts of uncertainty propagation and the uncertainty cascade. The concept comprehensively summarizes all uncertainties occurring in climate change impact assessment studies and illustrates how the uncertainties propagate. We conducted the CCIAS in a mountain catchment (160 km2) in the Swiss Alps at a high spatial resolution (50m). At first, the frequently used, physically based, distributed hydrological model was successfully applied to the catchment for recent years (2001-2007) to provide a sound calibration and validation. The potentials and the limitations of WaSiM-ETH to simulate soil moisture dynamics and patterns were shown by comparing model results with extensive soil moisture measurements at an hourly time step. While WaSiM-ETH was able to reproduce discharge with a high accuracy (R2 = 0.95, ME = 0.8, IoA = 0.95), the simulation of soil moisture for different altitudes and land use types is partly limited, since the model was unable to model the total variability of the soil moisture dynamic, but tended to mean values. An adjusted RMSE of 8.0 Vol-% that takes the intra-plot variability into account was calculated for soil moisture. A necessary prerequisite is the validation of the ability of the downscaled RCM data to drive the hydrological model in such that the hydrological processes are reproduced. A comparative study was conducted based on two common downscaling approaches (statistical downscaling (SD) and direct use (DU)) and two RCMs (CHRM, REMO). Uncertainties were found to be unsteadily distributed, both in terms of variables and time. The "one" model approach that shows least uncertainty for all kinds of hydrological variables like discharge, actual evapotranspiration, and soil moisture was not found. This finding adds considerable value to the scientific discussion, since most previous studies focus on one variable or one downscaling approach alone. In addition, we evaluated the spatial uncertainties of soil moisture and evapotranspiration. We showed that the choice of downscaling approaches is of circumstantial relevance for discharge and water balance, while for all spatial variables, we found SD approaches to perform better than DU approaches. Next, we simulated the impact of climate change on mountain soil moisture by applying three different downscaling approaches and two RCMs. In addition to the SD and DU-models, the very popular delta change approach (Δ) was applied that scales the climate observation by adding the climate signal. Therefore, uncertainty assessment for the Δ-approach was not necessary. The use of multiple downscaling techniques in an ensemble forecast is new for soil moisture impact studies. The study proved the partly superior role of downscaling approaches when focusing on the impact per se under future climate and thereby contrasting findings of recent publications. Moreover, it questions results from studies that are based on one downscaling approach alone. The study provided detailed data on climate change impact on the hydrology of the catchment that are completely in line with previous findings. The high spatio-temporal resolution of the study add value to previous mountain soil moisture studies of Jasper et al. (2004, 2006) by providing site specific data on soil moisture decrease and drought stress potential at the catchment scale. The consensus of six models driven by two threefold downscaled RCM reveals the forested areas below 1800 m a.s.l. to be most affected by climate change in 2070- 2100 (-10 vol-%). The variability of the results from the six ensembles were remarkably high, offering a bandwidth of possibilities from nearly unchanged soil moisture conditions to strong expansion of drought stress in the future. In addition we found uncertainties from the applied hydrological model and downscaling approaches in the magnitude of the predicted changes (+/- 10 vol-%). Therefore, the results have to be interpreted carefully. Probabilistic forecasting with several hundred model runs might confirm the found tendency of soil moisture decrease in future studies.

8.10

Real-time spatiotemporal combination of radar and raingauge measurements in Switzerland

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Merging raingauges and radar measurements to produce high quality rainfall fields has been a central problem in quantitative precipitation estimation. Although it has been attacked before (for instance see [1:10]) there is still demand for increased reliability, faster speed, and higher spatiotemporal resolution naturally motivating additional high-end improvements. Ideally one wants to produce reliable precipitation maps having the same spatial and temporal resolution as the corresponding radar cartesian composite. In the case of Switzerland this resolution is 1km^2 every 5 minutes. This presentation will describe techniques that indeed achieve such resolutions.

This work is part of project within MeteoSwiss which originated in 2009 and expected to be completed in 2012. Although real-time radar-derived precipitation maps have been existed in Switzerland for several years, the main goal of this project is the radar-raingauge adjustment of such maps. The context of this effort can be easily be recognized. Floods are not infrequent natural phenomena. In a real-life scenario it is critical for hydrological and meteorological models to be supplied as soon as possible with high quality, high spatiotemporal resolution precipitation maps.

Our algorithmic design has been constructed with such needs in mind. While most radar-raingauge schemes employ only spatial information, our technique does incorporate both spatial *and* temporal information. Time is introduced through co-krigged variables into a geostatistical scheme, leading to consistent improvements in the produced precipitation maps.

The involved complications in merging techniques are usually as complex as unavoidable: limited information by typically small numbers of real-time raingauges measurements, but also effects like topographic obstructions of the radar beam, common in the alpine regime, come easily to mind: efficient use of any correlated information such as temporal is of importance. Moreover, an operational-mode merging tool owes to be fully automatic ready to treat highly variable meteorological conditions without the need of any human intervention. This requires well-thought decisions in advance of the precipitation event. A continuous and focused effort has also been exercised by our team towards this direction. Our system has already been verified for extensive time-periods and a number of events and presents significant and consistent improvements over the existing maps.

REFERENCES.

Koistinen, J., and T. Puhakka, An improved spatial gauge-radar adjustment technique, in Preprints of the 20th Conference on Radar Meteorology, Boston, MA, Amer. Meteor. Soc., 179-186, 1981.

Krajewski, W.F., Cokriging Radar-Rainfall and Rain Gage Data, Journal of Geophysical research, 92, 9571, 1987.

Creutin, J.D., Delrieu, G., and Lebel, T., Rain measurement by raingage-radar combination: a geostatistical approach, Journal of atmospheric and oceanic technology, 5, 102-114, 1987.

Seo, D., Krajewski, W.F., Bowles, D.S., Stochastic interpolation of rainfall data from rain gages and radar using cokriging. 1. Design of experiments, Water Resources Research, 26, 469-477, 1990.

Gabella M., Joss J., Perona G., Optimizing quantitative precipitation estimates using a non-coherent and a coherent radar operating on the same area, J. of Geophys. Research, 105, 2237-2245, 2000.

Gabella, M., Notarpietro, R., Improving Operational Measurement of Precipitation Using Radar in Mountainous Terrain, IEEE Geoscience and Remote Sensing Letters, 1, 1545, 2004.

Germann U, Galli G, Boscacci M, and M. Bolliger, Radar precipitation measurement in a mountainous region, Q. J. Roy. Meteor. Soc., 132, 1669–1692, 2006.

Salek, M., Novak, P., Experience gained by five years of the utilization of the radar-based quantitative precipitation estimation at the Czech Hydrometeorological Institute, ERAD, 2008.

Velasco-Forero, C.A., Sempere-Torres, D., Cassiraga, E.F., Gomez-Hernandez, J.J., A non-parametric automatic blending methodology to estimate rainfall fields from rain gauge and radar data, Advances in Water Resources, 32, 986-1002, 2009.

Erdin, R., Master Thesis, ETH, Zurich, 2009.

8.11

Modelling of Evaporation in high Alpine Catchments

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In Alpine catchments, evapotranspiration is a small part of the water balance (around 10% of precipitation, Lang, 1981). Accordingly, it is often neglected or very much simplified in glacio-hydrological models used to predict discharge. However, in the context of ongoing climate change, a better understanding of all water fluxes, including namely evaporation, seems essential to make reliable predictions of the future water balance. Indeed, global temperatures are expected to increase in the next century, and because evaporation is linked to temperature and radiation, it will probably increase in future. Furthermore, since glaciers are currently retreating, there is an increase in vegetated area and bare ground, which is likely to result in increasing evapotranspiration. In addition, total discharge of alpine catchments might decrease, which would increase evaporation importance. These changes might affect the water balance of Alpine catchment in a significant way and a more precise modelling of evaporation might become necessary.

In this context, the aim of this Master thesis research is to model evaporation in Alpine catchments and to estimate its real importance in a changing climate. Based on field measurements on Swiss glaciers, we first model ice evaporation and condensation from alpine glaciers and estimate its importance in future climates (Huss et al., 2008). We then use a classical Penman-Monteith approach to calculate potential evaporation from moraines, rocks and vegetation. These results are used in a hydrological simulation of the Rhone catchment (Switzerland) to estimate impacts of evaporation on discharge.

The main results of this study are that evaporation and condensation from glaciers are not likely to have an important impact on alpine dicharge today or in the future. Indeed evaporation and condensation increase in a warmer climate but glacier area decreases. As a result, ice evaporation is higher but on a smaller area. Accordingly it has a similar impact on the total water balance in all climates.

However, impact of evaporation of the total catchment (rock, moraine and vegetation) could be more important than today in a warmer climate as shown in figure 1. The main reasons for this higher importance are discharge reduction, glacier retreat and reduced snow cover in our simulation. Potential evaporation is highly uncertain but has a low impact on the overall result. Transferability of these results to other models or other catchments is not known yet.

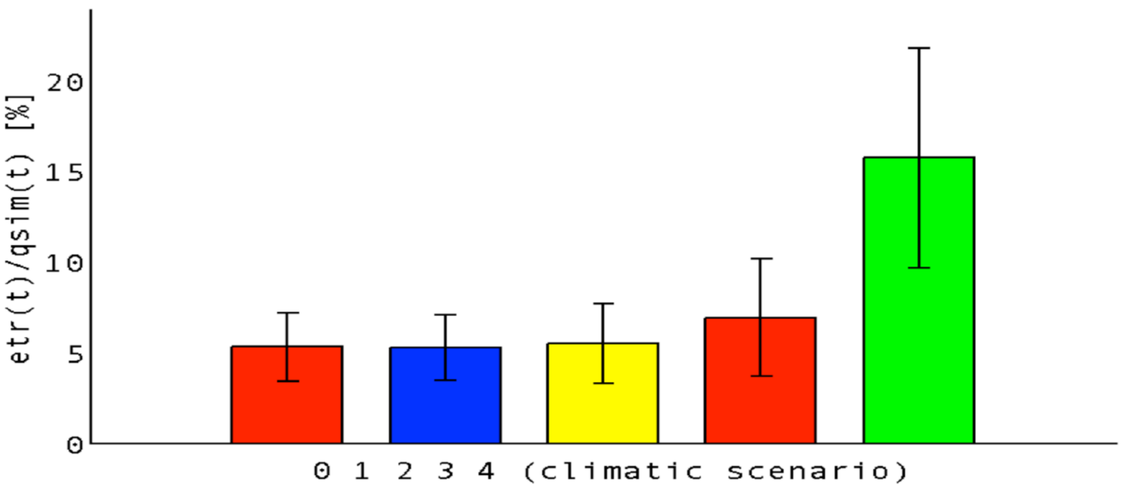

figure 1: evaporation divided by discharge in various climatic scenarios (0: actual climate, 1: wet climate, 2: median climate, 3: warm and dry, 4:small glacier - Huss et al., 2008)

REFERENCES
Barnett T., J.Adam, and D. Lettenmaier, 2005: Potential impacts of a warming climate on water availability in snow-dominated regions. Nature, 438:303– 309
Lang H., 1981:Is evaporation an important component in high alpine hydrology? Nordic Hydrology, 12:217–224.
Oelermans J. and E.J.Klok, 2002. Model study of the spatial distribution of the energy and mass balance of Morteratschgletscher, Switzerland. Journal of
Glaciology, 48
Schaefli B. and M. Huss, 2011: Integrating point glacier mass balance
observations into hydrologic model identification. Hydrology and Earth
System Sciences, 15:1227–1241
Huss M., D. Farinotti, A.Bauder and M.Funk, 2008: Modelling runoff from higly glacierized alpine drainage basins in a changing climate. Hydrological Processes, 22:3888-3902

8.12

Quasi-operational estimation of water resources anomalies during the dry and wet spells of 2011

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During the last few years numerous research initiatives concerning climate impacts on water resources have been going on. Hydrological models have been applied to estimate current and future spatial and temporal availability of water resources in different areas of Switzerland and the European Alps.

In parallel large efforts have been allocated to the development and operational application of hydrological ensemble prediction systems, with focus on floods.

WSL has been active in all these fields and is now testing opportunities of combining the outcomes of climate impacts studies with operational forecasting. The goal is to establish a system for the early detection of anomalies in the temporal and spatial availability of water resources in Switzerland.

To this end the FOEN CCHydro Project water resources climatology for the control period 1980-2009 and probabilistic scenarios (10 members) for two 30-years periods in the future (2021-2050 and 2070-2099) have been created.

From the NRP61 project DROUGHT-CH tools are in preparation for the assimilation of snow water equivalent information for improving the prediction of water resources availability with lead times of up to 1 month. First simulation re-forecast experiments for the basins Thur and Alpine Rhine have been realized. In the presentation we will focus on the forecasts of the summer 2003 drought and the 1999 flood.

Finally, the experience obtained since 2007 with the operational implementation of the hydrological model PREVAH for probabilistic flood forecasts has been transferred to an early prototype focusing on the estimation of water resources anomalies.

A first demonstration period in April to June 2011in the Thur river basin shows that in the first part of April a large deficit with respect to the 1980-2009 period on water availability was mostly caused a deficit in the snow resources. In the following weeks different situations occurred:

- At the begin of May a deficit of about -90 mm with respect to the median of the climatology (that means << 2.5% percentile with respect to the climatology) in the total water resources can be attributed to the deficit in snow (-20 mm), soil moisture (-50 mm) and "groundwater" (-20 mm) storages.
- At the begin of June a deficit of about -50 mm (~10% percentile) in the total water resources can be attributed to the deficit in snow (-10 mm), soil moisture (-35 mm) and "groundwater" (-15 mm) storages.

- At the begin of July the deficit is reduced to -10 mm (~45% percentile) .
- On July 18 a surplus of +30 mm (~75% percentile) is found after longer wet conditions. The surplus is owed to soil moisture (+17 mm) and "groundwater" (+7 mm) storages. Further surplus is split into the interception storage and the storage allocated by the model for generation of surface runoff and interflow.
- After further rainy days on August 8 a surplus of +40 mm is found (>97.5 percentile).

On August 21 2011 (Figure 1) the initial conditions indicate a small surplus of +7 mm in the total water resources in the Thur river basin, as compared to climatology. As compared to August 15, more than 40 mm surplus have been dissipated, mostly by evapotranspiration. Forecasts for the next 5 days indicate high probability of further reduction in the available resources. There is a 50% chance that on August 27 2011 the deficit will be of about -20 mm. Such deficit would result from a surplus of +5 mm in the "groundwater" storage and a deficit of -25 mm in the simulated soil moisture storage. However, the ensemble indicates, that there is also a small chance that five on August 27 the basin would have a surplus of +10 mm.

The presentation will end with some visions on possible further developments of this experimental system and its use for decision making for issues related to early detection of critical anomalies in the availability of water resources in Switzerland.

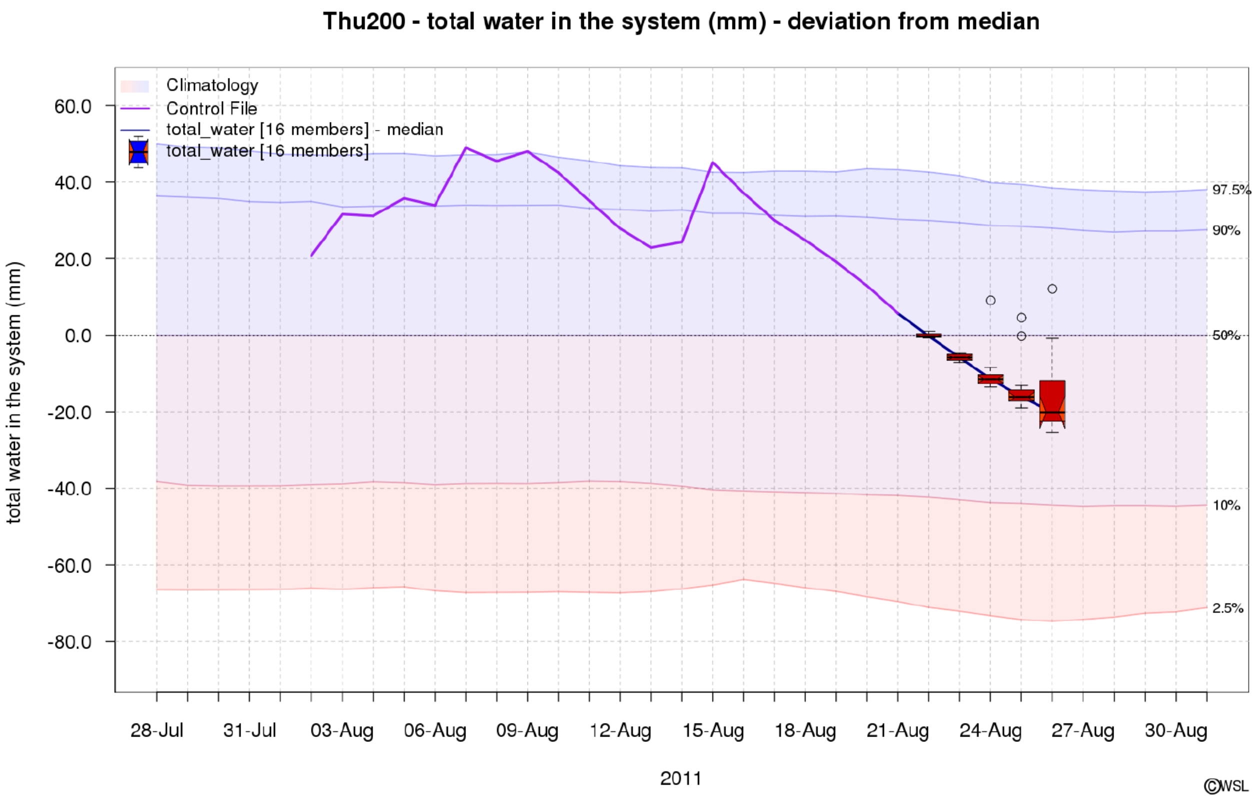

Figure 1. August 21 2011: Climatology (colour areas in the background) and current simulation (pink line and boxplots for COSMO-LEPS based numerical weather forecasts) of total water resources available in the Thur river basin. We plot the current deviation of the simulations from the climatology related to the period 1980-2009. Values above zero are sign of surplus, values below zero represent deficits. Research grants from: **CCHydro** (FOEN) and **Drought-CH** (NRP61).

P 8.1

Effect of climatic forcing on nitrate concentrations in groundwater based on changing recharge rates

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Climate changes can have an impact on the sustainability of groundwater resources not only in terms of groundwater quantity but also groundwater quality. For example after the dry period of 2003–2005 a significant increase of nitrate concentrations was observed at many public pumping wells of Switzerland (OFEV 2009).
In this study we present a simple approach to reproduce recent nitrate concentration trends and recharge rates and to estimate future trends under different climatic conditions. The aquifer of Wohlenschwil (canton of Aargau, Switzerland), where land use change are known since 1997, is taken as a case study site (Figure 1).

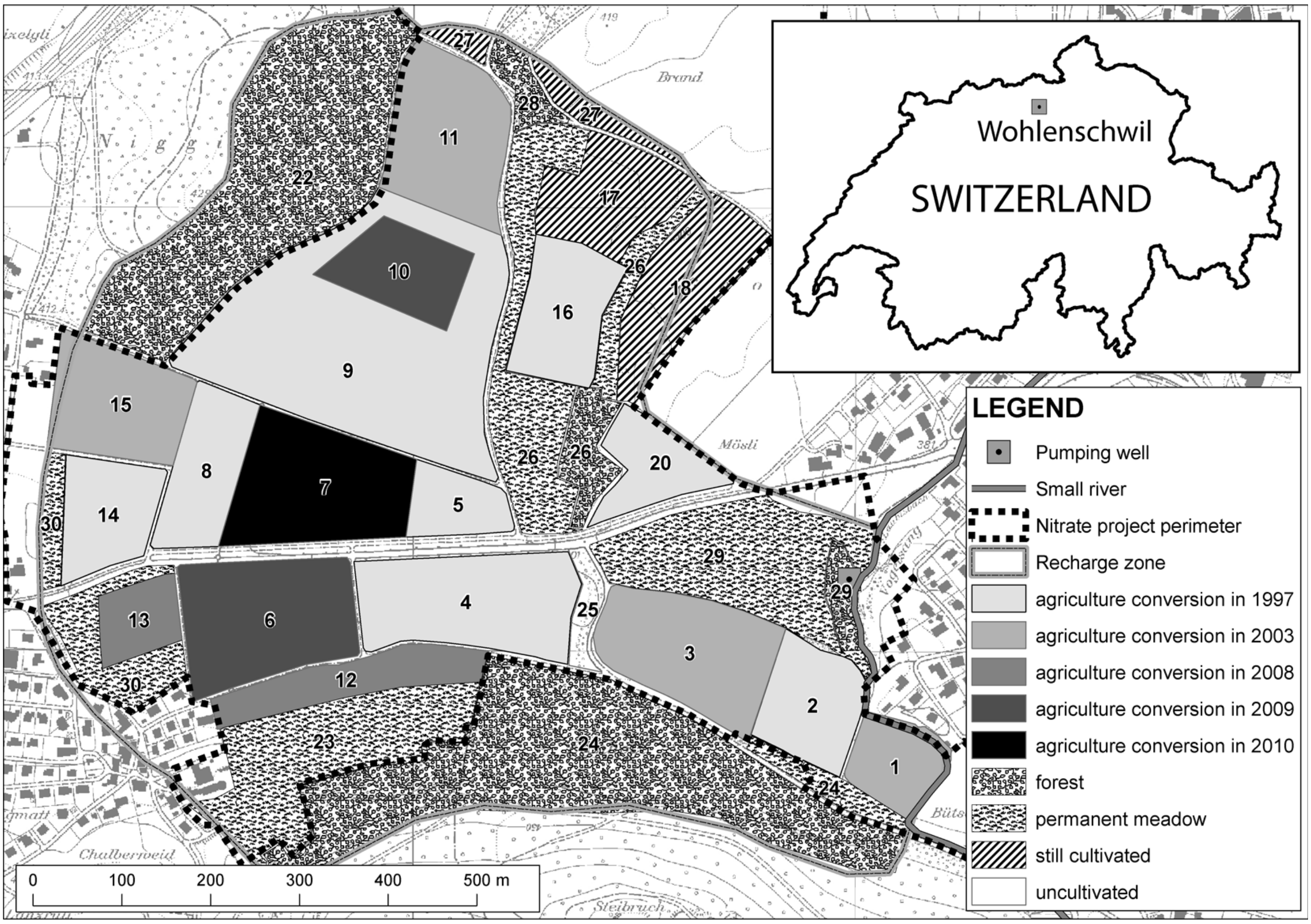

Fig. 1 Catchment area of the Wohlenschwil pumping well and land use changes

In a first step a numerical 1D soil column model estimates the recharge rates based on soil water content observations in different depth. Current recharge rates are compared with results from tracer tests in the unsaturated zone. Then groundwater recharge rates for future climate conditions are quantified using a delta change approach to estimate future temperature and precipitations trends.
In a second step a transfer function approach (Jury & Roth 1990) is applied to estimate the evolution of nitrate concentrations at the pumping well. For each subarea of the catchment with uniform land use (Figure 1), nitrate concentrations in recharge water were estimated based on culture-specific nitrate leaching rates and the estimated annual recharge rate. So far, the proposed approach does not take into account other changes in the nitrate leaching dynamics which could also be influenced by climate change (particularly modification of soil processes and crop productivity) (Stuart & al 2011).

Calculated nitrate concentrations for the period 1997-2010 agree well with the observed concentrations at the pumping well (Figure 2). With this approach it is possible to distinguish the change in nitrate concentration due to variations of recharge rates or due to land use changes. For instance in Wohlenschwil, about 5 mg/L of the nitrate concentration increase during the period 2005–2008 can be attributed to the decrease of recharge in the period 2003–2005 (Figure 2).
The same approach can be used to evaluate the effect of climate change on future groundwater recharge rates and the evolution of the nitrate concentration.

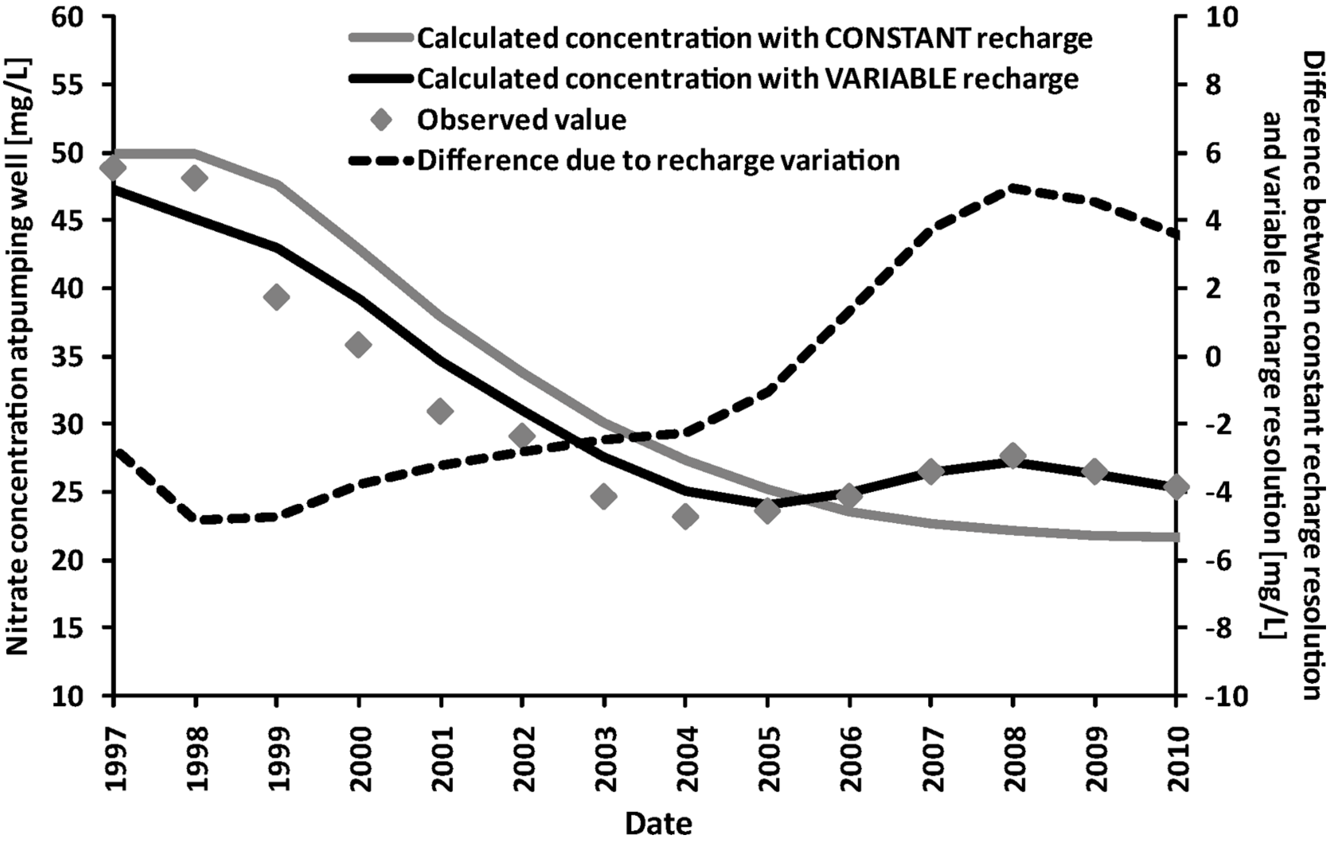

Fig. 2 Observed (grey triangles) and calculated (black line) evolution of the nitrate concentration at the pumping well of the Wohlenschwil aquifer considering annual variations of recharge rates for the period 1997 – 2010. A comparison with results computed with a constant mean annual recharge (grey line) reveals the effect of varying recharge rates on nitrate concentrations (dashed line).

REFERENCES

Jury, W. A. & Roth, K. 1990: Transfer Function and Solute Movement through Soil: Theory and Applications. Birkhäuser Verlag, Basel, 228 p.

OFEV 2009: Résultats de l'observatoire national des eaux souterraines (NAQUA) - Etat et évolution de 2004 à 2006. Etat de l'Environnement, Office Fédérale de l'Environnement, Berne, 144 p.

Stuart, M. E., Gooddy, D. C., Bloomfield, J. P. & Williams, A. T. 2011: A review of the impact of climate change on future nitrate concentrations in groundwater of the UK. Science Of The Total Environment, 409(15), 2859–2873.

P 8.2

Impact of the uncertainty in river water levels on modeled groundwater residence times

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Riverbank filtration is a widely used method to produce drinking water. In Switzerland for instance, it accounts for 25% of the total drinking water supply. The residence time of the bank filtrate in the aquifer plays a key role in the purification process and therefore, modeling the travel times and groundwater flow paths in river-groundwater systems is important. The conceptual representation of the river boundary condition and the assigned river water levels are critical in this process. In past modeling studies, the assignment of river water levels has been accomplished using different methods, for instance by extracting data from a one or two dimensional hydraulic model (Derx et al. 2010; Doppler et al. 2007) or by interpolating measured water levels to the nodes in between measurement points (Lautz & Siegel 2006). These water level data are usually considered to be accurate and the calibrated model is used to extract quantitative information on parameters like residence time. However, there may be a considerable amount of uncertainty in the river water level information. Depending on the method used to derive water level data at specific points and depending on the interpolation approach to each boundary node, a different river water level distribution is likely to result due to the errors and assumptions within each method. This uncertainty would then impact the modeled groundwater flow paths, flow velocities and residence times.

To assess this possible impact we applied three different methods to define the river water levels at each river boundary node of a three dimensional groundwater flow model of a river – groundwater system, using the software FEFLOW (DHI-Wasy GmbH). The study site is located in northeastern Switzerland at the Thur River and has dimensions of 1x0.5 km. The corridor of the Thur River, flowing through the modeling domain, was restored in 2005 and currently has a width of 30-100 m. The first two methods used measured water level data to specify the river boundary condition, but incorporated two different interpolation approaches. The third method extracted river water level data from a two dimensional hydraulic model, which was established and calibrated several months before the data for the first two methods was collected. Each of the three methods was applied to the same steady-state modeling run of the calibrated groundwater flow model. Based on the groundwater flow field, the residence time from the river to several observation wells was calculated using particle backtracking.

The resulting residence times by applying method one and two differed by 15-20%. Compared to the residence times of method three however, the results of the first two methods differed by up to 70%, even if the model fit to groundwater level observations were equally accurate.

We found independent evidence that major flooding events in the period between the development of the different methods changed the riverbed morphology and subsequently the water levels for a given discharge condition. As a consequence, the variation in calculated river water levels may not be entirely due to the selected method.

REFERENCES

Derx, J., Blaschke, A.P. & Blöschl, G., 2010: Three-dimensional flow patterns at the river-aquifer interface -- a case study at the Danube. Advances in Water Resources 33(11), 1375-1387.

Doppler, T., Franssen, H.J.H., Kaiser, H.P., Kuhlman, U. & Stauffer, F., 2007: Field evidence of a dynamic leakage coefficient for modelling river-aquifer interactions. Journal of Hydrology 347(1-2), 177-187.

Lautz, L.K. & Siegel, D.I., 2006: Modeling surface and ground water mixing in the hyporheic zone using MODFLOW and MT3D. Advances in Water Resources 29(11), 1618-1633.

P 8.3

Hydrological changes in glacierized basins of the Swiss Alps: First attempt of a synthesis

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In Switzerland, water resources are often exploited for hydropower production, especially in the mountains. Assessing the impact of the current climate change on the hydrology of Alpine catchments is of both scientific and economic interest. Several stakeholders have invested considerable efforts in addressing this issue and have initiated several studies.
In this contribution we present the results of nine different case studies aiming at quantifying the impact of climate change on the hydrology of glacierized catchments and try to summarize the results in a quantitative but generalized way. The analyses are performed by using the glacio-hydrological model GERM (Huss et al., 2008, Farinotti et al., in press). A large data basis, including ice volume changes, direct mass balance and ice thickness measurements as well as recorded discharge time series, allowed to establish the link between climate and glacier change in the past. The model was then forced with climate scenarios provided by the Center of Climate System Modeling (C2SM) of the ETH Zurich and used to assess the expected future changes. Emphasis was put into quantifying the uncertainties deriving form the unknown climate evolution.

Although a strong glacier retreat is projected for all catchments, the results show a remarkably different evolution for runoff (Fig. 1): while several basins show the characteristic pattern expected for glacierized catchments, with a first phase of increasing runoff and a second one with decreasing annual discharge, the same pattern is not immediately recognizable for others. The reason can be found in the different glacierization, the different ice thickness distribution, and the different contribution of evapotranspiration to the water budget of the different catchments.

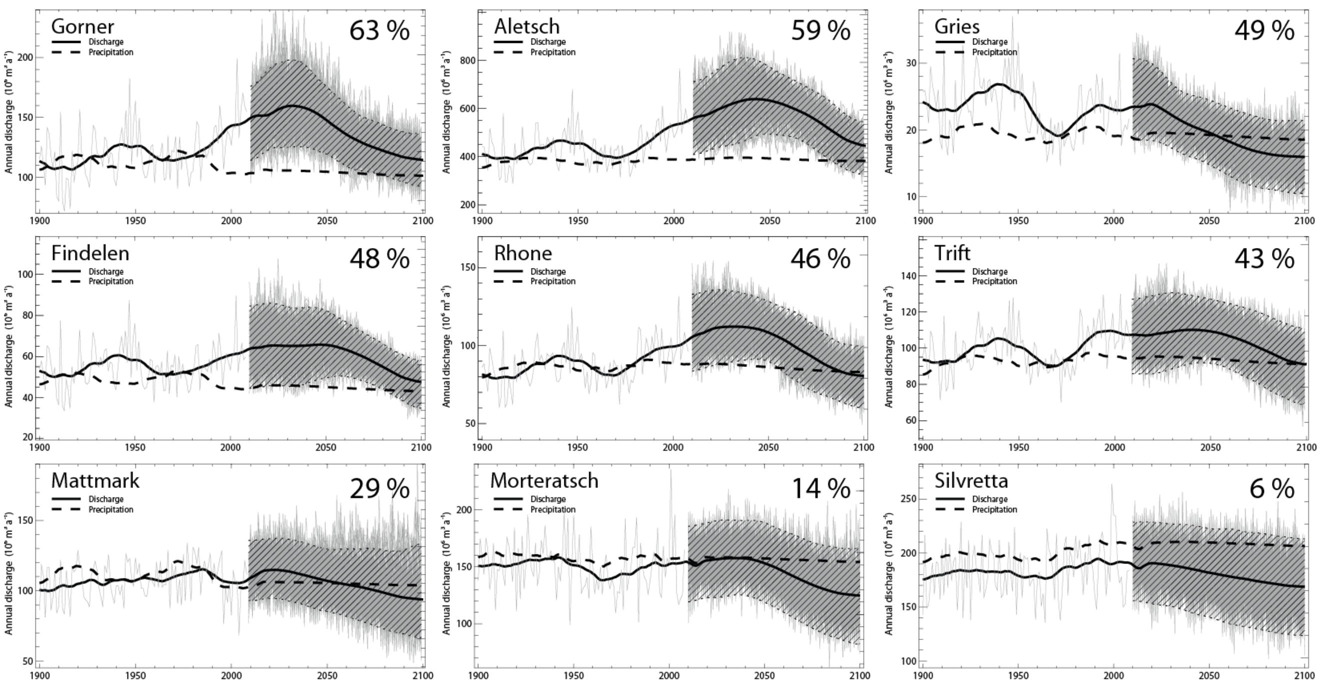

Figure 1. Evolution of annual discharge for the nine analyzed catchments. In the period 2010-2100 the model was forced with 100 different meteorological times series, reflecting the uncertainty in future climate evolution. Accordingly, 100 different time series for annual runoff are generated as well. The tick lines are 30-year running averages for runoff (solid) and precipitation (dashed), the hatched band is an empirical confidence band for runoff including 95% of all model realizations. Catchments are listed according to the present degree of glacierization (percentage shown on the upper right corner).

REFERENCES

Farinotti, D., S. Usselmann, M. Huss, A. Bauder and M. Funk, in press. Runoff evolution in the Swiss Alps: Projections for selected high-alpine catchments based on ENSEMBLES scenarios. Accepted for publication in Hydrological processes. May 2011.

Huss, M., D. Farinotti, A. Bauder and M. Funk, 2008. Modelling runoff from highly glacierized alpine catchment basins in a changing climate. Hydrological Processes, Vol. 22 (19), 3888-3902.

P 8.4

Einfluss der Klimaänderung auf die Stromproduktion der Wasserkraftwerke Löntsch und Prättigau

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An den Fallbeispielen des hydraulischen Speicherkraftwerkes Löntsch und der Wasserkraftwerksgruppe Prättigau wurde der Einfluss der Klimaänderung auf die Stromproduktion untersucht. Dabei wurden verschiedene Klimamodelle mit je einem hydrologischen und einem Betriebsmodell gekoppelt. Für die Berechnungen wurde die aktuelle Stromnachfrage unverändert belassen, sodass die Auswirkungen einer veränderten Zuflussmenge zu den Kraftwerken isoliert betrachtet werden konnten.

Beim Beispiel des Kraftwerkes Löntsch (Klöntalersee) gehen die Klimaprojektionen für die Periode 2021-2050 im Vergleich zur Referenzperiode 1998-2009 von einer Zunahme in den jährlichen Zuflüsse zum Wasserkraftwerk Löntsch aus (Median aller Klimaprojektionen: +2.2%; nicht signifikant). Das Zuflussregime verändert sich signifikant, mit höheren Werten im Winter und Herbst, und tieferen Werten während dem Sommer. Durch eine Anpassung des monatlichen Produktionsprofils kann eine Steigerung der Stromproduktion und des Umsatzes erreicht werden. Die Resultate liefern für hydrologisch ähnliche Gebiete mit gleichem Kraftwerkstyp Hinweise, wie ein sich änderndes Klima den Kraftwerksbetrieb beeinflussen könnte. Durch die Berücksichtigung von klimabedingten Veränderungen in der Stromnachfrage könnten weitere wichtige Hinweise erarbeitet werden.

Unter den gegebenen Klimaprojektionen für die Periode 2021-2050 wird beim Beispiel Prättigau im Vergleich zur Referenzperiode 1976-2004 eine Steigerung der Stromproduktion um 9.3% (Median aller verwendeten Projektionen) simuliert. Die Zunahme resultiert hauptsächlich aus einer Produktionssteigerung während dem Winter, im Sommer bleiben die Produktionsraten unverändert. Die Analyse der Dauerkurven zeigt, dass sich ein Ausbau der Hauptfassung in Klosters nicht lohnt, da die bestehende Fassungskapazität während des Sommers, wenn die grössten Abflussmengen auftreten, in Zukunft nur unwesentlich länger überschritten wird. Die Resultate liefern für hydrologisch ähnliche Gebiete mit gleichem Kraftwerkstyp Hinweise, wie ein sich änderndes Klima den Kraftwerksbetrieb beeinflussen könnte.

P 8.5

Hydrogeological, physical and chemical differences influencing benthic macroinvertebrate communities in alpine springs of Slovenia

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Springs are formed where the water table intersects with the land surface, or groundwater rises to the surface through rock faults, fractures or depressions as a result of geological structure. Springs are important ecotones within the interactions of groundwater, surface water and terrestrial ecosystems. In this paper, environmental variables were measured and benthic macroinvertebrate communities were studied in twelve springs from the alpine region of Slovenia. There are three different alpine components which indicate different hydrogeological characteristics such as limestone, dolomite and clastic rock, influencing physical and chemical characteristics of springs in Slovenia. Canonical Correlation Analysis (CCA), Shannon diversity index and similarity analysis classified different spring types and pointed out that invertebrate assemblages from Gastropoda, Amphipoda, Ephemeroptera, Plecoptera, Trichoptera and Chironomidae were different according to hydrogeological, physical and chemical characteristics of spring types.

P 8.6

Swisskarst project (NRP61): Identification cards as tools for a sustainable management of karst systems.

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SWISSKARST project aims at setting up a specific approach and a series of tools for improving the sustainable management of karst groundwater systems. The KARSYS methodology (Karst system characterization methodology) provides a framework for producing geologically and hydraulically meaningful conceptual models of karst systems (see Malard et al., this volume). The present paper focuses more on the way to present these results in a systematic and applicable way and introduces the idea of ID cards for karst systems.

Identification Cards intend synthetizing the main karst system characteristics. They have to be at once concise and enough complete. They must address questions from cantons, communities, water-supply associations or any further water-user of a karst area. For this reason, some aspects of the ID Cards are being adjusted to the respective demands and priorities of users. Furthermore, ID Cards consider the following potential user conflicts and interactions: drinking water supply, hydropower production, artificial snow, irrigation, geothermic, natural hazard management.

The ID Cards is formed of two parts. The first one consists in a documentation of the main systems characteristics. It documents the following 6 modules: (i) catchment area and recharge, (ii) karst morphology features, (iii) aquifer geology, (iv) groundwater bodies and underground flow paths, (v) related springs characteristics and (vi) resources uses. The second part graphically depicts those characteristics with an original hydrogeological interpreted map showing underground hydrological feature (height of the aquifer base, flow paths and groundwater bodies), surface hydrological behaviour (infiltration characteristics and multiple karst system appurtenances) and interaction between both surface and underground hydrology.ID Cards are placed on a free-access web-site (www.swisskarst.ch) together with 3D hydrogeological model (3Dpdf) to provide a homogenous documentation for further specific research.

REFERENCES

GRETILLAT, P.-A., 1992 : Carte Hydrogéologique de l'Ajoie (Canton du Jura, SUISSE). Eléments pour la gestion et la protection des eaux. 1/25 000

KIRALY, L., 1973 : Notice et carte hydrogéologique du canton de Neuchâtel. Bulletin de la Société Neuchateloise de Sciences Naturelles, 96.

MILANOVIC PT. 2004. Water Resources Engineering in Karst. CRC Presse (Ed.)

STRUCKMEIER, W.-F., MARGAT, J., 1995 : Hydrogeological maps, a guide and a standard legend, International association of hydrogeologists, 17, 177p., Hannover.

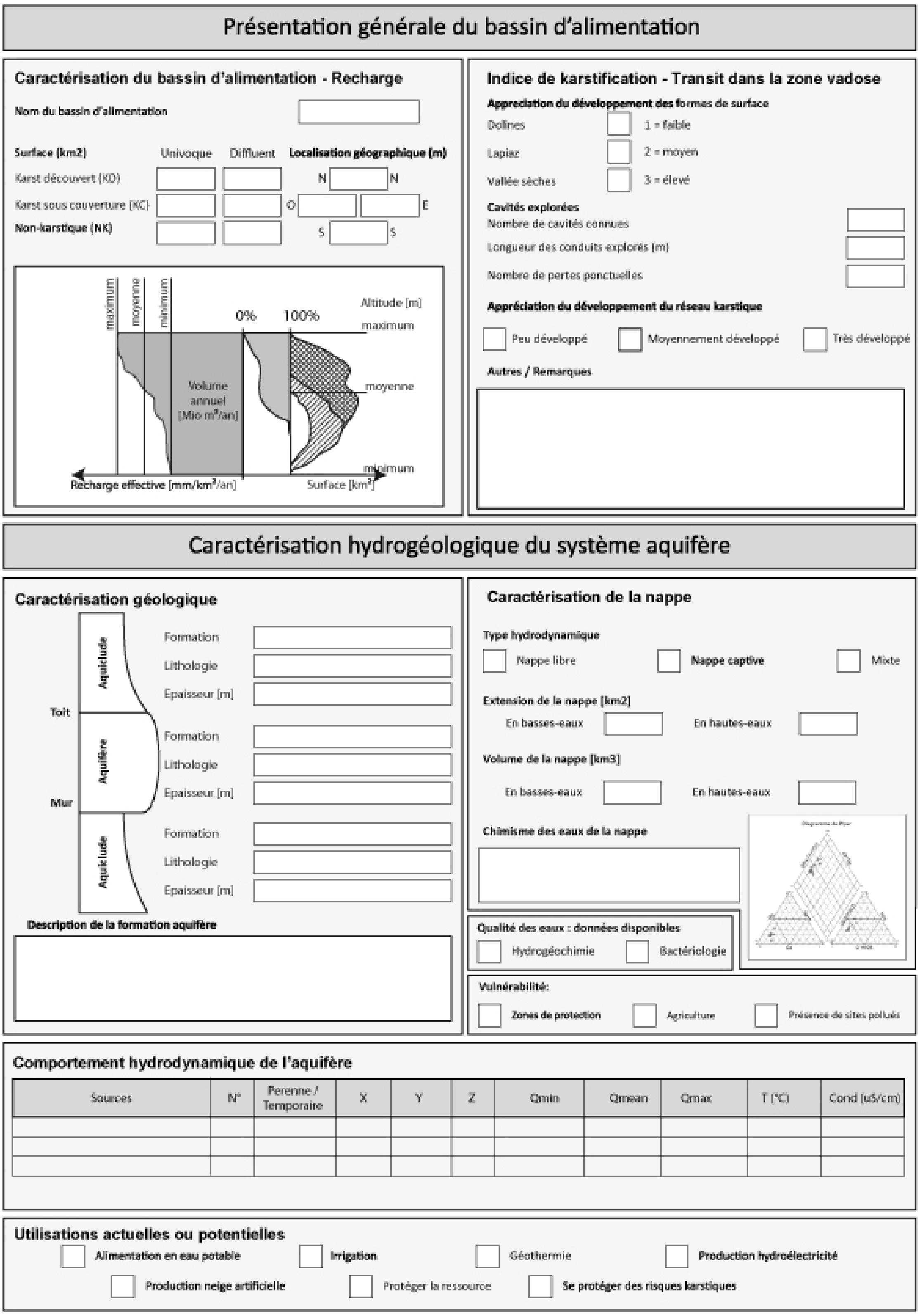

Figure 1 : Example of ID-Cards.

P 8.7

Reconstructing the seasonality of Holocene flood events using varved lake sediments of Lake Ledro (S-Alps, Italy)

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Floods as a result of extreme precipitation events represent a major natural hazard in the Alpine realm, causing enormous financial and social damage. Current climate models predict even an increase in heavy precipitation events in the future as a consequence of global warming (Frei et al. 2006). In particular, extreme summer events are expected to occur more frequently in the future. In order to assess this future flood hazard, knowledge about the natural variability and the climatic forcing factors of heavy precipitation events is required. Lacustrine sediments allow such a reconstruction of flood recurrence rates in the past, reaching beyond the time span covered by instrumental and historic data series. In special cases of annually laminated (i.e. varved) lake sediments, even the season in which the floods occurred can be determined.

Lake Ledro is one of the lakes investigated within the framework of the FloodAlp project aiming to reconstruct the Holocene flood history of the Central Alps. In total, 18 lakes are investigated but only few of them are annually laminated thus offering the possibility to resolve the seasonality of the events. Lake Ledro is located in the Trento Province in Northern Italy and has a surface area of 2.2 km^2 and a maximal water depth of 46 m. The lake is situated in a carbonate catchment built up by Mesozoic sediments, enabling the production of biogeochemical calcite varves. This annual lamination has been preserved for the past 9000 years and is intercalated by flood deposits of various thicknesses (sub-mm to 38 cm). Thus, based on the stratigraphic position of a flood layer within an annual varve cycle, the season, in which the flood occurred, can be determined.

To evaluate the potential of this approach, the past 500 varve-years have been analysed. As a result, a flood pattern dominated by summer and autumn events (78%) was discovered. The flood frequency during the same time period is strongly fluctuating, the highest flood frequencies occur around 1580 AD and between 1850 and 1950. Distinct lows in flood occurrence are observed around 1500 and 1700, corresponding to the Spörer and Maunder sunspot minima. The observed seasonal distribution, as well as the frequency of the events, is in good agreement with the reconstruction of flood frequencies in the Northern Alps since 1500 by Schmocker-Fackel & Naef (2010). The seasonal record of Lake Ledro will be further expanded into the past, offering a unique high-resolution record for tracking the Holocene flood occurrence as well as related climatic forcing mechanisms.

REFERENCES

Frei, C., Schöll, R., Fukutome, S., Schmidli, J. & Vidale, P.L. 2006: Future change of precipitation extrems in Europe: Intercomparison of scenarios from regional climate models. Journal of Geophyscial Research, 111: D06105, doi:10.1029/2005JD005965.

Schmocker-Fackel, P. & Naef, F. 2010: Changes in flood frequencies in Switzerland since 1500. Hydrol. Eart Syst. Sci., 14: 1581-1594.