13 Hydrology, Hydrogeology, and Limnology

Damien Bouffard, Sandra Pool, Michael Döring, Sanja Hosi, Daniel Hunkeler, Christophe Lienert, Peter Molnar, Michael Sinreich, Natacha Tofield-Pasche, Daniel Viviroli

Swiss Hydrological Commission CHy,
Swiss Society for Hydrology and Limnology SGHL,
Swiss Hydrogeological Society SGH

TALKS:

13.1 Astagneau P.C., Bourgin F., Andréassian V., Perrin C., Brunner M.I.: Multi-objective calibration for better simulation of flash floods

13.2 Carratala A.: Proliferation of genus *Planktothrix* drives bacterioplankton community divergence and short-term losses of functional diversity in Lake Geneva

13.3 Currle F., Blanc T., Tomonaga Y., Kipfer R., Hunkeler D., Brunner P., Schilling O.S.: Tracing and quantifying microbes in riverbank filtration sites combining online flow cytometry and noble gas analysis

13.4 Eeckman J., De Grenus B., Miesen F., Fallot J.-M., Peleg N.: Tracking snow melt infiltration over alpine soils : Instrumental approach

13.5 Einzmann T., Lehmann M.F., Bourbonnais A., Zopfi J., Frey C.: Non-canonical denitrification pathways in the anoxic benthic nepheloid layer of a seasonally stratified lake

13.6 Escoffier N., Many G., Mucciolo A., Bedel R., Perga M.-E.: Calcite precipitation in hardwater lakes: new insights into the link with picoplankton dynamics

13.7 Gentile A., Canone D., Ceperley N., Gisolo D., Previati M., Zuecco G., Schaefli B., Ferraris S.: Exploring regional-scale hydrological processes that determine low young water fraction in mountainous catchments

13.8 Heinz M., Schaefli B., Raible C., Holzkämper A.: Modeling irrigation demand under increasing drought extremes

13.9 Janssen D.J., Damanik A., Tournier N., Cahyarini S.Y., Vogel H.: Trace metal and nutrient dynamics in the ferruginous Lake Poso, Indonesia

13.10 Khatun S., Berg J.S., Jézéquel D., Escoffier N., Bouffard D., Schubert C.J., Perga M.: Identifying the origin and distribution pattern of metalimnetic methane dynamics in Lake Geneva

13.11 Lepori F., Lucchini B., Spitzli C., Lehmann M.F.: Zooplankton structure moderates eutrophication effects in a deep perialpine lake (Lake Lugano, Switzerland and Italy)

13.12 Martinetti S., Carminati A., Molnar P. & Floriancic M.: Soil-plant hydraulics and stomatal conductance: When do whole tree water dynamics matter?

13.13 Moeck C., Popp A., Brennwald M.S., Schirmer M., Kipfer R.: Combined use of multiple tracers to idenity groundwater flow and pollutant transport in an urban area

13.14 Müller M.F., McGiven L., Bolster D., Noffsinger M., Reinking C.: Thirsty Earth: a multiplayer online computer game for water resources education and research

13.15 Råman Vinnå L., Epting J., Schilling O.: Projecting future Swiss river temperatures on a National scale while maintaining local features

13.16 Salamin A., Renard P., Christe P., Favre G., Doucerain C.: A model of the evolution of the water resource availability at the Glarey karstic spring in the glaciated Tsanfleuron watershed

13.17 Seibert J., Blanco S., Scheller M., Schwarzenbach F., Goebel R., van Meerveld I.: Citizen-science observations made in Switzerland – Towards new horizons in regional hydrology

13.18 Viviroli D., Sikorska-Senoner A.E., Evin G., Staudinger M., Kauzlaric M., Chardon J., Favre A.-C., Hingray B., Nicolet G., Raynaud D., Seibert J., Weingartner R., Whealton C.: Estimating very rare floods at multiple sites in the Aare River basins with comprehensive hydrometeorological simulations

13.19 Wanner C., Camesi L., Waber H.N., Zimmermann S., Sinreich M.: Natural background concentrations in shallow Swiss aquifers

13.20 Wiersma P., Mariéthoz G.: From flow to snow: streamflow-based snow mass reconstruction using inverse hydrological modeling

POSTERS:

P 13.1 Abhervé R., Roques C., Aquilina L., Brunner P., de Dreuzy J.R., Longuevergne L.: Simulation and calibration of headwater stream intermittency using a groundwater flow model

P 13.2 Acciardo A., Gholizadeh N., Mesimeri M., Scarabello L., Hertrich M., Magnabosco C.: Detection of hydrogen peroxide after hydraulic stimulation of granitic bedrock at the Bedretto Tunnel

P 13.3 Bassani F., Fatichi S., Bonetti S.: Towards a metabolic theory of catchments: scaling of water and carbon fluxes with size

P 13.4 Belloni C., Valley B., Roques C.: Tidal characterization of the Liappey fractured aquifer, Bagnes (VS)

P 13.5 Bouffard D., Amadori M., Brescani M., Giardino C., Odermatt D., Irani Rahaghi A., Runnalls J., Toffolon M., Werther M.: ALPLAKES: Advancing Lake Research and Management through Integrative Remote Sensing and Hydrodynamic

P 13.6 Calvani G., Ruiz-Villanueva V., Schwarz M., Perona P.: On the scaling relationship between grain-size, riverbed slope and catchment area at the reach scale

P 13.7 Dubois E., Marshall M., Boukhreiss F., Cherif S.A., Mariéthoz G., Grossiord C., Perona P.: Tree planting as a nature-based solution for urban flooding in Nouakchott City, Mauritania

P 13.8 Engelhardt M., Hemingway J., De Clippele A., Ludjwera A., Haghipour N., Six J.: Lake archives from tropical Africa: Reconstructing the paleoclimate leading to the African Rainforest Crisis 3000 years ago

P 13.9 Fan X., Peterson T., Henley B., Arora M.: Quantifying the sensitivity of groundwater to climate variations in Australia

P 13.10 Feller K., Calvani G., Caponi F., Perona P.: Evaluating riparian vegetation removal due to morphodynamic processes in the river Thur

P 13.11 Halloran L., Mohammadi N., Figueroa R., Carron A., Gutierrez F., Hunkeler D., Brunner P., Arnoux M., Baumann H.: The RADMOGG Project (2023-2027): Resilience and Dynamics of Mountain Groundwater using Gravimetry

P 13.12 Horton P., Mosimann M., Kaderli S., Martius O., Zischg A.P.: A machine-learning approach to predict overland flow impacts

P 13.13 Humphrey V., Hüsler F., Oesch D., Bircher S., Sturm J., Scapozza C.: The Federal Drought Monitoring and Warning System

P 13.14 Janzing J., Wanders N., Brunner M.I.: The effect of an improved snow and glacier routine of a large-scale hydrological model on Alpine streamflow and extremes

P 13.15 Kayitesi N.M., Guzha A.C., Tonini M., Mariethoz G.: Impacts of Land Use Land Cover and Climate Changes on hydro-morphological processes of the African Great Lakes Regions. Case of Lake Kivu catchment.

P 13.16 Mettra F., Bouffard D., Reiss R.S., Lemmin U., Doda T., Blanckaert K., Barry D.A.: Effects of strong Wind-driven Currents on Winter Cascading in Lake Geneva during a cold Spell

P 13.17 Mhanna S., Brunner P., Halloran L.: Google Earth Engine Applications in Hydrology and Hydrogeology

P 13.18 Mittelbach B., White M., Rhyner T., Haghipour N., Dubois N., Eglinton T.: Radiocarbon Inventories of Switzerland: Insights from a year of sediment trap data in Lake Geneva

P 13.19 Moeck C.: Swiss Groundwater Network – CH-GNet

P 13.20 Müller T., Fischer M., Lane S.N., Schaefli B.: Separating snow and ice melt contributions based on water stable isotopes and a glacio-hydrological model in a highly glacierized catchment

P 13.21 Musy S., Currle F., Nakajima T., Tomonaga Y., Sano Y., Schilling O.S.: The hydrogeology of Mt. Fuji as a model for water resource management in tectonically active volcanic regions

P 13.22 Padoan F., Calvani G., De Cesare G., Perona P.: An improved definition of the Habitat Suitability Index for brown trout including the role of macroroughness

P 13.23 Pastore C., Luetscher M., Doumenc F., Sedaghaktish A., Weber E., Jeannin P.-Y.: Dispersion of artificial tracers in ventilated caves

P 13.24 Pedimina T., von Fumetti S.: Temporal and spatial comparison of springs in three different mountain regions in the Southern Swiss Alps

P 13.25 Pelzmann V., Leis A., Schuerch M., Reszler C.: Regionalization of Oxygen-18 and Deuterium in precipitation in Switzerland as a basis for hydrological and hydrogeological studies

P 13.26 Perego R., Pera S.: Characterization of river/groundwater interactions by signal processing of electrical conductivity time series

P 13.27 Rhyner T.M.Y., Mittelbach B.V.A., White M.E., Broeder L., Raymond O., Haghipour N., Brunmayr A., Storck F.R., Passera L., Schwab M.S., Hilton R., Zobrist J., Eglinton T.I.: Radiocarbon Inventories of Switzerland: What controls the radiocarbon signature of dissolved inorganic carbon in Swiss rivers?

P 13.28 Roques C., Halloran L., Louis C., Abhervé R., Illien L., Andermann C., Hovius N., Oestreicher N., Figueroas R., the CHYN team: Poschiavino Critical Zone Observatory: monitoring impacts of climate change on alpine cryo-hydrological systems

P 13.29 Rotta F., Gallitelli L., Roncoroni M., Capelli C., Leoni B., Marchini A., Lepori F.: Microplastic pollution in rivers: concentrations, environmental drivers and biological risks in Lake Lugano watershed

P 13.30 Sauter G., Bouffard D., Blanckaert K., Kremer K.: Monitoring of river-induced bottom currents in Swiss lacustrine deltas

P 13.31 Simonnot B., Dubois E., Marshall M., Grossiord C., Perona P.: Implementing a 3D groundwater model to simulate tree-planting scenarios against urban flooding in Nouakchott city, Mauritania

P 13.32 Van Hamel A., Brunner M.I.: Extreme water temperatures in mountain rivers

P 13.33 Wenyue Zou, Guanghui Hu, Wiersma P., Shuiqing Yin, Mariethoz G., Peleg N.: Multiple-point geostatistics-based spatial downscaling of heavy rainfall fields

P 13.34 White M.E., Mittelbach B.V.A., Rhyner T., Haghipour N., Wessels M., Dubois N., Eglinton T.I.: Radiocarbon Inventories of Switzerland: Sources and cycling of dissolved organic carbon in Swiss lakes

P 13.35 Zakeri F., Mariethoz G., Girotto M.: Reconstructing High-Resolution Snow Water Equivalent (SWE) Data for Improved Water Resource Management (1950-2100)

13.1
Multi-objective calibration for better simulation of flash floods

Paul C. Astagneau[1,2], François Bourgin[1], Vazken Andréassian[1], Charles Perrin[1], Manuela I. Brunner[2,3,4]

[1] Université Paris-Saclay, INRAE, HYCAR Research Unit, Antony, France (paulastagneau123@yahoo.fr)
[2] WSL Institute for Snow and Avalanche Research SLF, Davos Dorf, Switzerland
[3] Institute for Atmospheric and Climate Science, ETH Zurich, Zurich, Switzerland
[4] Climate Change, Extremes and Natural Hazards in Alpine Regions Research Center CERC, Davos Dorf, Switzerland

River floods characterized by quickly rising water levels, i.e., flash floods, cause large social and economic impacts worldwide. Rainfall-runoff models often have a limited ability to simulate such rapid catchment responses. While the structure of these models may be inadequate to reproduce the processes involved in quick runoff formation, parameter calibration also plays an important role in accurately simulating flash floods. The estimation of model parameters is particularly complex when threshold processes are triggered during flood formation on a small number of time steps. This results in increased uncertainty in model simulations, usually translating into low parameter identifiability and robustness. A single-objective calibration, relying on one standard metric (e.g. Kling-Gupta efficiency; KGE) calculated over the entire streamflow time series only, may limit model accuracy and parameter adequacy in such cases.

This study investigates the use of different objective functions, within a multi-objective calibration framework, for simulating flash floods. It is based on a large-sample dataset of 781 continental French catchments for which 43,019 flood events were selected. A state-of-the-art multi-objective optimiser (Monteil et al., 2020) was used to calibrate the GR5H-RI hourly rainfall-runoff model (Astagneau et al., 2022). Five objective functions placing varying degrees of emphasis on high flows and rapid flood rises were combined within the multi-objective framework resulting in four calibration options. These functions were calculated over the flood event set and vary depending on their emphasis on different periods of the streamflow time series (rising limbs, flash floods…). The four calibration options were compared to a single-objective calibration relying on the KGE criterion. The different calibration options were first evaluated in terms of model performance in simulating floods. Second, the robustness and identifiability of the parameters were assessed using Pareto front theory. Finally, the results were analysed with respect to the number of flood events used to build the objective functions.

Our results show that introducing flood performance criteria (e.g. criteria calculated over flood rise periods only) into the calibration process improves simulation performance for floods, particularly in the case of flash floods. Different trade-offs were found between increasing performance in simulating floods and improving parameter identifiability and robustness. We also find that the use of a classical metric (e.g. KGE calculated over the entire streamflow time series only) as a single objective function is not sufficient to accurately reproduce flood peaks and volumes in many cases. We argue that this shortcoming should be taken into account when calibrating a model for flood forecasting by using a composite single-objective criterion that combines a classical metric and a metric that places more emphasis on flash floods.

REFERENCES

Astagneau, P.C., Bourgin, F., Andréassian, V. & Perrin, C. 2022: Catchment response to intense rainfall: evaluating modeling hypotheses, Hydrological Processes, 36(8), e1467.
Monteil, C., Zaoui, F., Le Moine, N. & Hendrickx, F. 2020: Multi-objective calibration by combination of stochastic and gradient-like parameter generation rules – the caRamel algorithm, Hydrology and Earth System Sciences, 24, 3189–3209.

13.2
Proliferation of genus *Planktothrix* drives bacterioplankton community divergence and short-term losses of functional diversity in Lake Geneva

Anna Carratalà.

Environmental Chemistry Laboratory, EPFL

Planktothrix, a planktonic cyanobacteria genus, often leads to harmful blooms in temperate lakes undergoing recovery from eutrophication. These blooms pose public health challenges due to potential cyanotoxin production. While the effects of cyanotoxins are well-documented, limited knowledge exists about the influence of Planktothrix blooms on lake bacterioplankton communities. In this study, we conducted a 15-month investigation into Planktothrix dynamics and assessed corresponding shifts in bacterioplankton communities using 16S rRNA amplicon sequencing.

The analysis conducted in Lake Geneva revealed prevailing genera, including the CL500-29 marine group, Flavobacterium, Planktothrix NIVA-CYA15, CL500-3, hgcl clade, and Rhodoferax. Notably, Planktothrix NIVA-CYA15 and Flavobacterium emerged as primary drivers of community differentiation, as indicated by multidimensional scaling of Bray Curtis dissimilarities. Moreover, a strong correlation between Planktothrix and the abundance of predicted photosynthesis proteins underscored its importance in the lake's primary production.

Interestingly, an upsurge in Planktothrix reads corresponded with reduced bacterioplankton abundance (quantified via 16S rRNA gene qPCR), alongside diminished taxonomic and functional diversity. Restoration of diversity indices followed the decline in Planktothrix reads. Elevated Planktothrix abundance correlated with specific water column conditions: temperatures of 9-12 °C, pH of 7.8, solar irradiance at 50 W/m2, increased wind speeds, conductivity between 0.2-0.22 μS/cm, low turbidity (0.8 NTU), oxygen saturation of 90-100%, and dissolved oxygen levels of 10-11 mg/l.

In summary, this study enriches our comprehension of spatiotemporal bacterioplankton dynamics and the ecological role of Planktothrix in Lake Geneva. As the largest peri-alpine lake in western Europe, these findings contribute to the broader understanding of how cyanobacteria blooms impact microbial communities in recovering eutrophic ecosystems.

13.3
Tracing and quantifying microbes in riverbank filtration sites combining online flow cytometry and noble gas analysis

Friederike Currle[1], Théo Blanc[2], Yama Tomonaga[1], Rolf Kipfer[3,4,5], Daniel Hunkeler[2], Philip Brunner[2], Oliver S. Schilling[1,3]

[1] *Hydrogeology, Department of Environmental Sciences, University of Basel, Bernoullistrasse 32, CH-4056 Basel (friederike.currle@unibas.ch)*
[2] *Centre for Hydrogeology and Geothermics, University of Neuchâtel, Rue Emile-Argand 11, CH-2000 Neuchâtel*
[3] *Eawag, Swiss Federal Institute of Aquatic Science and Technology, Überlandstrasse 133, CH-8600 Dübendorf*
[4] *Institute of Biogeochemistry and Pollutant Dynamics, ETH Zurich, Universitätstrasse 16, CH-8092 Zurich*
[5] *Institute of Geochemistry and Petrology, ETH Zurich, Clausiusstrasse 25, CH-8092 Zurich*

Understanding microbial transport in surface water – groundwater systems is crucial for drinking water management. Particularly in the context of climate change, the quality of groundwater pumped near streams might be affected by high microbial loads after heavy rain, peak flow and spring snowmelt events. Dissolved noble gases have been shown to be conservative tracers and provide information on pathways and travel times of groundwater. Although it is known that due to size exclusion, microbes appear to travel faster than solutes, most hydrological tracer methods target groundwater movement and solute transport, while specific tracers for microbial transport are not yet considered for protection zone delineation of drinking water supply wells. Recently, online flow cytometry (FCM) has been shown to be a promising tool to track on site, continuously and in near-real time the movement of microbes in riverbank filtration settings (Besmer et al., 2016). Beyond direct cell counting, advanced computational tools enable to extract automatically relevant features from the multivariate FCM data describing the phenotypic diversity of the microbial community.

Aiming to understand microbial transport behavior in surface water – groundwater systems and develop tracer methods to track their movement, we combined online FCM with online (noble) gas analysis at a riverbank filtration site in the Emme valley, Switzerland (Schilling et al., 2022). Dissolved gas concentrations and microbial community patterns (measured using the gas equilibrium-membrane inlet portable mass spectrometer miniRUEDI (Brennwald et al. (2016), Gasometrix GmbH), the electronic radon detector Rad7 (DURRIDGE), and the online flow cytometer BactoSense (bNovate Technologies SA)) were monitored continuously over a period of several months of river restoration activity inside the river, a piezometer next to the river, and nearby riverbank filtration wells. Systematic changes in the microbial and dissolved gas patterns could be observed in reaction to a 2-year peak flow event, river restoration activities, and spring snowmelt events.

In summary, this combination of state-of-the-art analytical techniques allows to track and quantify microbial pathways from surface water into and through an alluvial aquifer. Furthermore, the setup increases understanding of reactive microbial transport compared to the transport of conservative dissolved gases and, highlights the potential of environmental DNA as a hydrological tracer technique.

REFERENCES

Besmer, M. D., Epting, J., Page, R. M., Sigrist, J. A., Huggenberger, P., & Hammes, F. (2016): Online flow cytometry reveals microbial dynamics influenced by concurrent natural and operational events in groundwater used for drinking water treatment. Sci. Rep., 6, Article 38462. https://doi.org/10.1038/srep38462

Brennwald, M. S., Schmidt, M., Oser, J., & Kipfer, R. (2016): A Portable and autonomous mass spectrometric system for on-site environmental gas analysis. Environ. Sci. Technol., 50, 13455-12463. https://doi.org/10.1021/acs.est.6b03669

Schilling, O. S., Partington, D. J., Doherty, J., Kipfer, R., Hunkeler, D., & Brunner, P. (2022): Buried paleo-channel detection with a groundwater model, tracer-based observations, and spatially varying, preferred anisotropy pilot point calibration. Geophys. Res. Lett., 49(14), e2022GL098944. https://doi.org/10.1029/2022GL098944

13.4
Tracking snow melt infiltration over alpine soils : Instrumental approach

Judith Eeckman[1], Brian De Grenus[2], Floreanna Miesen[2], Jean-Michel Fallot[1], Nadav Peleg[2]

[1] Lausanne University, Institute of Geography and Durability, Lausanne, Switzerland (judith.eeckman@unil.ch)
[2] Lausanne University, Institute of Earth Surface Dynamics, Lausanne, Switzerland

Alpine soils, generally poorly consolidated, can induce significant flow delays and significantly influence river flows during low water periods. In particular, the snowmelt flow is particularly conducive to a slow infiltration into soils. A better description of the link between snowmelt and infiltration processes in the soils can then lead to a better understanding of a drought risk induced by a lack of reserves in the soils. The Nant valley (Vaud, Switzerland), instrumented within the framework of various projects within the Faculty of Geosciences of the University of Lausanne, represents a case study for this work. An important instrumental set up has been locally deployed during two consecutives years. Infiltration processes in the soils are estimated through the installation of soil moisture sensors at different depths in areas of alpine meadows. The dynamics of the melt flow is described at one measurement point using a dedicated instrumentation. Infiltrometry tests are performed and soil samples are collected for further granulometry analysis, in order to better describe the infiltration capacity at different points of the catchment. The instrumental device as well as the results deduced from measurements are presented in this work. The results illustrate various possible dynamics of the snowmelt infiltration process. Behaviors at the beginning of winter or in spring are distinguished and the influence of diurnal melting is highlighted.

13.5
Non-canonical denitrification pathways in the anoxic benthic nepheloid layer of a seasonally stratified lake

Teresa Einzmann[1], Moritz F. Lehmann[1], Annie Bourbonnais[2], Jakob Zopfi[1], Claudia Frey[1]

[1] *Department of Environmental Sciences, University of Basel, Basel, Switzerland*
[2] *School of the Earth, Ocean and Environment, University of South Carolina, Columbia, SC, US*

Nitrous oxide (N_2O) is a strong greenhouse gas and ozone-destroying agent, with increasing atmospheric mixing ratios over the last few decades. Lakes play an uncertain role regarding their contribution to global N_2O emissions, in parts due to the lack of a better understanding of the environmental controls on N_2O production and consumption processes.
In this study, through natural-abundance isotope measurements and ^{15}N-label incubations, we investigated N_2O production pathways within the anoxic benthic nepheloid layer (BNL) forming in the South Basin of eutrophic Lake Lugano (Switzerland) during summer stratification. Short-termed accumulation of high N_2O concentrations (up to 800 nmol/L) was observed in near-bottom waters accompanied by a significant decline in $\delta^{15}N$ bulk values, and an increase in the N_2O site preference (SP) to +42 ‰. Incomplete heterotrophic denitrification is usually the main production mechanism for N_2O in low-oxygen environments, but N_2O from nitrate/nitrite reduction is generally characterised by a low SP signature of -5-0 ‰ (Sutka et al., 2006)however, requires a foundation in laboratory experiments in which individual production pathways can be isolated. Here we evaluate the site preferences of N2O produced during hydroxylamine oxidation by ammonia oxidizers and by a methanotroph, ammonia oxidation by a nitrifier, nitrite reduction during nitrifier denitrification, and nitrate and nitrite reduction by denitrifiers. The site preferences produced during hydroxylamine oxidation were 33.5 ± 1.2‰, 32.5 ±0. 6‰, and 35.6 ± 1.4‰ for Nitrosomonas europaea, Nitrosospira multiformis, and Methytosinus trichosporium, respectively, indicating similar site preferences for methane and ammonia oxidizers. The site preference of N2O from ammonia oxidation by N. europaea (31.4 ± 4.2‰, whereas high SP values suggest an oxidative N_2O production mechanism. First incubation experiments with ^{15}N-labelled NH_4^+ (to investigate oxidative N_2O production through nitrification) and ^{15}N-labelled NO_3^- (to investigate reductive N_2O production through denitrification) corroborated reductive N_2O production in the Lake Lugano BNL. Isotope fractionation during partial N_2O reduction can increase N_2O SP, but cannot explain the high values that we observed. Alternative denitrification pathways known to produce N_2O with a high SP, such as fungal denitrification (SP = >30 ‰, Rohe et al. 2014) and chemo-denitrificaiton (SP = 0-27 ‰, Li et al., 2022) were investigated in complementing incubation experiments involving bacterial and fungal inhibitors. These experiments confirmed that bacterial denitrification contributes significantly to N_2O production in the BNL, but also demonstrated the importance of fungal and chemo-denitrification.

REFERENCES

Li, S., Wang, S., Pang, Y., & Ji, G. 2022: Influence of Electron Donors (Fe, C, S) on N 2 O Production during Nitrate Reduction in Lake Sediments: Evidence from Isotopes and Functional Genes , ACS ES&T Water, 2(7), 1254–1264.

Rohe, L., Anderson, T.-H., Braker, G., Flessa, H., Giesemann, A., Lwicka-Szczebak, D., Wrage-Mönnig, N., & Well, R. 2014: Dual isotope and isotopomer signatures of nitrous oxide from fungal denitrification – a pure culture study, Rapid Communiciations in Mass Spectrometry, 28, 1893-1903.

Sutka, R. L., Ostrom, N. E., Ostrom, P. H., Breznak, J. A., Gandhi, H., Pitt, A. J., & Li, F. 2006: Distinguishing nitrous oxide production from nitrification and denitrification on the basis of isotopomer abundances, Applied and Environmental Microbiology, 72(1), 638–644.

13.6
Calcite precipitation in hardwater lakes: new insights into the link with picoplankton dynamics

Nicolas Escoffier[1], Gaël Many[1], Antonio Mucciolo[2], Romain Bedel[3], Marie-Elodie Perga[1]

[1] *Institute of Earth Surface Dynamics, University of Lausanne, CH-1015 Lausanne (nicolas.escoffier@unil.ch)*
[2] *Electron Microscopy Facility, University of Lausanne, CH-1015 Lausanne*
[3] *Flow Cytometry Facility, University of Lausanne, CH-1015 Lausanne*

In hardwater lakes fueled by carbonate weathering from surrounding catchments, calcite precipitation is a major process of the lacustrine carbon cycle by which alkalinity loss is coupled with primary production. While recent studies clarified the magnitude and biogeochemical conditions underlying calcite precipitation at fine scales, the mechanisms supporting the nucleation of calcite are poorly described. In the pelagic realm of deep oligotrophic lakes, calcite nucleation has often been associated with autotrophic picoplankton, however, direct observations remain scarce. Here, we focused on the largest hardwater lake of western Europe, Lake Geneva, and combined depth-resolved high-frequency data with discrete sampling to investigate the link between calcite precipitation and picoplankton dynamics. Calcite precipitation during periods of lake thermal stratification and high primary productivity coincided with increasing abundances of distinct picoplankton populations that were characterized by specific fluorescence signatures using spectral flow cytometry. Phycoerythrin rich picocyanobacteria constituted the dominant population whose maximum abundances in the water column occurred at depths of enhanced stability and alkalinity depletion. Moreover, the sorting of this population combined with imaging by SEM-EDX enabled to confirm that picocyanobacteria acted as nucleation sites for calcite and to analyze the diverse patterns of association between calcite crystals and picoplankton cells. These results provide a refined understanding of calcite nucleation mechanisms and allow inferring the relevance of this biologically mediated process for the lacustrine carbon cycle.

13.7
Exploring regional-scale hydrological processes that determine low young water fraction in mountainous catchments

Alessio Gentile[1], Davide Canone[1], Natalie Ceperley[2,3], Davide Gisolo[1], Maurizio Previati[1], Giulia Zuecco[4,5], Bettina Schaefli[2,3], Stefano Ferraris[1]

[1] *Interuniversity Department of Regional and Urban Studies and Planning (DIST), Politecnico and Università degli Studi di Torino, Viale Mattioli, 29, IT-10125 Torino, (alessio.gentile@polito.it)*
[2] *Institute of Earth Surface Dynamic (IDYST), Faculty of Geosciences and Environment (FGSE), University of Lausanne, CH-1015 Lausanne*
[3] *Institute of Geography (GIUB) and Oeschger Centre for Climate Change Research (OCCR), University of Bern, CH-3012 Bern*
[4] *Department of Land, Environment, Agriculture and Forestry (TESAF), University of Padova, Viale dell'Università 16, IT-35020 Legnaro (PD)*
[5] *Department of Chemical Sciences (DiSC), University of Padova, Via Marzolo 1, IT- 35131 Padova*

Mountains are vital regulators of global water resources, acting as natural water towers that supply freshwater to downstream regions. The age of water, referring to the time elapsed since its entry into the hydrological cycle, has emerged as a critical parameter in understanding the dynamics and the hydrological processes in mountainous catchments.

Natural tracers such as stable water isotopes are commonly used to track the movement of water through catchment. Specifically, the seasonal isotope cycles in precipitation and streamwater allow easy estimation of the portion of runoff younger than roughly 2-3 months, also known as young water fraction (F^*_{yw}). This metric is practical for catchment intercomparison studies, and hydrologists have been intrigued by low F^*_{yw} estimates in high-elevation, mountainous watersheds. Accordingly, such catchments are often assumed to produce a large amount of rapid surface or subsurface runoff due to steep bedrock slopes. This surprising result highlights the limited knowledge of hydrological processes in remote environments, and the challenge to conceptualize these processes.

This study investigates, at a regional scale, the relevance of some key hydrological variables and processes (groundwater storage potential, catchment storage contribution to the stream, low-flow duration, and snowpack ephemerality) that we consider to be the main drivers of F^*_{yw} variation according to elevation, by providing a framework for the interplay of these processes along elevation gradients. We use data from 27 study catchments located across Switzerland and Italy that span a wide range of underlying geology and hydro-climatic regimes.

On one hand, our results reveal that the extension of Quaternary deposits available in geological data sets is not a sufficiently good proxy of groundwater storage potential due to the unknown thickness of such deposits. On the other hand, our results reveal how the interconnection of the other variables/processes investigated in this work explains the F^*_{yw} variations along elevation gradients.

The low-flow periods over the hydrologic year indicate the time windows in which the stored (old) water predominantly contributes to the stream, thus reducing the average annual young water fraction. In mountain catchments, the proportion of low-flow periods over the year is strongly driven by the snowpack duration. At high elevations (> 1500 m a.s.l.), the persistence of winter snowpack causes the lack of a liquid water input to the catchment thus favouring a long (up to six months at the highest elevations) low-flow period dominated by (old) groundwater. The seasonal snowpack melts during the spring/summer seasons preferentially recharging the groundwater storage with old (i.e., > 2-3 months) meltwater and likely pushing out stored water. Conversely, ephemeral snowpacks at low elevations (< 1500 m a.s.l.) can intermittently melt during the winter season, both reducing the length of low-flow periods and providing young water to the stream due to the reduced elapsed time between snowfall and snowmelt and the critical role of soil freezing that inhibits infiltration.
Interestingly, we have also found that the average fraction of baseflow (F_{bf}), estimated by using the Duncan (2019) baseflow filter, roughly indicates the fraction of runoff older than a threshold age between 2 to 3 months (i.e., $F^*_{yw} + F_{bf} \approx 1$), that could be a valuable result for catchments in which stable water isotopes measurements are unavailable.
The framework that emerges from our results is a starting point for the development of hydrological models that want to consider and conceptualize the relevant processes in mountainous alpine catchments.

REFERENCES

Gentile A, Canone D, Ceperley N, Gisolo D, Previati M, Zuecco G, Schaefli B, Ferraris S. 2023: Towards a conceptualization of the hydrological processes behind changes of young water fraction with elevation: a focus on mountainous alpine

catchments. Hydrology and Earth System Sciences, 27 (12), 2301–2323.
Kirchner JW. 2016: Aggregation in environmental systems-Part 1: Seasonal tracer cycles quantify young water fractions, but not mean transit times, in spatially heterogeneous catchments. Hydrology and Earth System Sciences, 20 (1), 279–297.
von Freyberg J, Allen ST, Seeger S, Weiler M, Kirchner JW. 2018: Sensitivity of young water fractions to hydro-climatic forcing and landscape properties across 22 Swiss catchments. Hydrology and Earth System Sciences, 22 (7), 3841–3861.
Hayashi M. 2020: Alpine Hydrogeology: The Critical Role of Groundwater in Sourcing the Headwaters of the World. Ground Water, 58 (4), 498–510.
Duncan HP. 2019: Baseflow separation – A practical approach. Journal of Hydrology, 575, 308–313.

13.8
Modeling irrigation demand under increasing drought extremes

Malve Heinz[1,2,3], Bettina Schaefli[1,3], Christoph Raible[1,4], Annelie Holzkämper[1,2]

[1] *Oeschger Centre for Climate Change Research, University of Bern, Switzerland (malve.heinz@unibe.ch)*
[2] *Water protection and Substance Flows, Agroscope Reckenholz, Switzerland*
[3] *Hydrology, Institute of Geography, University of Bern, Switzerland*
[4] *Climate and Environmental Physics, Physics Institute, University of Bern, Switzerland*

Droughts are the leading cause of agricultural yield losses worldwide and play a significant role in yield variability for European agriculture (Bodner et al. 2015; Joint Research Centre 2023). Farmers may intensify irrigation or extend irrigated areas to prevent these losses and maintain quality. At the same time, water availability for irrigation in the vital summer months is decreasing due to shifted rainfall and streamflow regime patterns. Thus, the potential for water-use conflicts between agriculture, industry, and ecosystems will rise (Klein et al. 2013; Zarrineh et al. 2020; Holzkämper et al. 2020). Since irrigation alone might not be sufficient to mitigate the effects of droughts and heat in the future, solutions to minimize the dependencies are crucial. In this context, a key open question is to which extent management measures could alleviate drought impacts and how these measures impact catchment hydrology. In Switzerland, there is a lack of data on the current irrigation practices to analyze the regional or national irrigation water demand and supply. This data is needed as a basis for planning, both on the field scale regarding agricultural management, as well as on the regional scale regarding larger infrastructural projects like irrigation cooperatives. We are presenting a modeling approach to quantify the irrigation demand on the regional level through a case study in the Broye catchment in Western Switzerland. The region is characterized by intensive agricultural use and increased drought-related irrigation bans in summer (Zarrineh et al. 2020). In the first phase of our project, we quantify irrigation demand for the years 2021 and 2022, both with and without irrigation bans. Our study focuses on potatoes, which account for 50% of irrigation water consumption in the Broye region. For this purpose, we use the SWAP model, a field-scale agro-hydrological model that considers soil-water-atmosphere-plant interactions. SWAP simulates soil water and solute fluxes, as well as crop growth dynamics, by solving equations such as the Richards equations (Kroes et al. 2017). We employ latin hypercube sampling and sobol indices to discern the most influential parameters concerning both yield and irrigation demand. Subsequently, we calibrate the derived subset of parameters by optimizing an objective function linked to the fit with reference data on yield and irrigation demand. This calibration process is facilitated by a genetic algorithm, utilizing the DEoptim package in R. Using land use data, the areas where potato fields can be irrigated within the catchment are identified. We then apply the model for each grid cell containing irrigated potato fields. The irrigated demand is then summed up over all cells. The preliminary results show, that during the summer drought in 2022, only 1/3 of the irrigation demands could be satisfied due to the extensive irrigation bans. In contrast, in the cooler and wetter 2021, irrigation demand was only a fraction of that in 2022 and there were no restrictions on irrigation. Starting from this baseline of demand we now want to explore the potential of field-scale crop and soil management to reduce the reliance on irrigation. Possible measures are the cultivation of different varieties (or even species), reduced tillage, or the application of organic amendments. These measures directly impact plant properties (such as phenology) or soil physical properties that can be represented within the model. In future works, we plan to evaluate the impacts of such measures on runoff generation processes and how they can be represented in a catchment-scale rainfall-streamflow model.

REFERENCES

Holzkämper, A., Cochand, F., Rössler, O., Brunner, P., & Hunkeler, D. (2020). AgriAdapt – Modellgestützte Untersuchung der Einflüsse von Klima- und Landnutzungsänderungen auf Grundwasserressourcen im Berner Seeland, im Auftrag des Bundesamts für Umwelt BAFU

Joint Research Centre (2023). Crop monitoring in Europe - July 2023. JRC MARS Bulletin, European Commission, Joint Research Centre.

Kroes J.G. , v. D. J. C., Bartholomeus , Groenendijk P. , Heinen M., Hendriks R.F.A., Mulder H.M. , Supit I., van Walsum P.E.V. (2017). SWAP version 4. Theory description and user manual. Wageningen University & Research.

Michel, A., Brauchli, T., Lehning, M., Schaefli, B., & Huwald, H. (2020). Stream temperature and discharge evolution in Switzerland over the last 50 years: annual and seasonal behaviour. Hydrology and Earth System Sciences, 24(1), 115-142. https://doi.org/10.5194/hess-24-115-2020

Zarrineh, N., Abbaspour, K. C., & Holzkamper, A. (2020). Integrated assessment of climate change impacts on multiple ecosystem services in Western Switzerland. Sci Total Environ, 708, 135212. https://doi.org/10.1016/j.scitotenv.2019.135212

13.9
Trace metal and nutrient dynamics in the ferruginous Lake Poso, Indonesia

David J Janssen[1], Adrianus Damanik[2,3], Nicolas Tournier[2,3], Sri Yudawati Cahyarini[4], Hendrik Vogel[2,3]

[1] *Eawag – Swiss Federal Institute of Aquatic Science & Technology, Department Surface Waters, 6047 Kastanienbaum Switzerland*
[2] *Oeschger Centre for Climate Change Research, University of Bern, 3012 Bern Switzerland*
[3] *University of Bern, Institute of Geological Sciences, University of Bern, 3012 Bern Switzerland*
[4] *BRIN, Research Centre for Climate and Atmosphere, 40135 Bandung, Indonesia*

The tectonic, ancient Lake Poso is a deep meromictic lake in Central Sulawesi, Indonesia. The lake is near the Malili Lakes of Central Sulawesi, but is hydrologically disconnected (Vaillant et al., 2011), giving it unique potential for biogeochemical and ecological studies over wide temporal scales. While the lake has been studied for the diversity of its endemic species, relatively few geochemical data are available. Here we present data of trace metals and nutrients from the surface to a depth of 350 m from a depth profile collected in the center of the lake. Surface waters are highly depleted in dissolved nutrients, in agreement with recent reports of oligotrophic conditions (Sulawesty et al., 2022; Damanik et al., in rev.), and suggesting little anthropogenic chemical impact on the lake (Damanik et al., in rev.).

The chemical structure of the lake is broadly defined by a redox transition near 90 m, with oxic waters above and anoxic, iron-rich (ferruginous) waters below. Trace metal distributions are largely driven by scavenging onto Fe and Mn oxides near this redox transition as well as redox-driven changes in solubility, both direct and indirect. Scavenging-prone metals show mid-depth minima coinciding with the redox transition and concentrations increase in anoxic deep waters, while sulfide-insoluble metals decrease to near zero at the redox transition, despite only minor apparent SO_4 reduction in the anoxic zone. Given the age of the lake (>1 Ma), relatively low anthropogenic pressure, and the strong geochemical gradients, Lake Poso holds potential for paleoreconstructions and paleoproxy development. In particular, the high concentrations of nutrients in the anoxic zone indicate that deep mixing events could promote major changes in biological productivity, which will likely leave signals in the sediment record associated with enhanced carbon export and changes in O_2 availability in deep waters.

REFERENCES

Damanik, A., Janssen, D.J., Tournier, N., Stelbrink, B., von Rintelen, T., Haffner, G.D., Cohen, A., Cahyarini, S.., Vogel, H. Perspectives from modern hydrology and hydrochemistry on a lacustrine biodiversity hotspot: Ancient Lake Poso, Central Sulawesi, Indonesia. In review at the Journal of Great Lakes Research.

.Sulawesty, F., Triyanto, Haryani, G., Lukman, Samir, O., Ali, F., & Nafisyah, E. (2022). Trophic Status of Waters in Poso Watershed, Central Sulawesi. IOP Conference Series: Earth and Environmental Science, 950(1), 012039. doi: 10.1088/1755-1315/950/1/012039.

Vaillant, J.J., Haffner, G.D. and Cristescu, M.E., 2011. The ancient lakes of Indonesia: towards integrated research on speciation. Integrative and Comparative Biology, 51(4), pp.634-643. doi: 10.1093/icb/icr101.

13.10
Identifying the origin and distribution pattern of metalimnetic methane dynamics in Lake Geneva

Santona Khatun, Jasmine S. Berg, Didier Jézéquel, Nicolas Escoffier, Damien Bouffard, Abolfazl Irani Rahaghi, Carsten J. Schubert, and Marie-Elodie Perga

Although methane (CH_4) is mainly produced in anoxic sediments, a metalimnetic supersaturation of CH_4 has been repeatedly detected in many lakes even in Lake Geneva. Metalimnetic methane accumulation (MMA) has been concomitantly attributed to advective fluxes transporting CH_4 from methanogenic littoral sediments to the lake center, and to oxic methane production through different microbial metabolisms including the phosphonate-pathway by Cyanobacteria. We aimed to address the origin of MMA with an extensive sampling campaign across Lake Geneva in the summer of 2022. Methane advective transport was tracked using CH_4 $\delta^{13}C$ (delta13C) while the potential for aerobic methane production was assessed through molecular analysis. Surprisingly, dissolved CH_4 in Lake Geneva was negatively correlated with blue-green algae (BBE data, to be further confirmed by the targeted amplicon sequencing). Instead, dissolved CH_4 was closely associated with turbidity suggesting that the methane is transported by the interflow of the Rhône River across tens of km during the stratification period which was also confirmed in the isotopic analysis. We used a simple advection model to test the possibility of this hypothesis. In summary, the results suggest that metalimnetic methane peak in Lake Geneva is likely to result from the advection of CH_4 produced in sediments and remobilized by turbulences within the river inflow.

13.11
Zooplankton structure moderates eutrophication effects in a deep perialpine lake (Lake Lugano, Switzerland and Italy)

Fabio Lepori[1], Bianca Lucchini[2], Céline Spitzli[2], Moritz F. Lehmann[2]

[1] *Insitute of Earth Sciences, University of Applied Sciences and Arts of Southern Switzerland, Via Flora Ruchat-Roncati 15, CH – 6850 Mendrisio (fabio.lepori@supsi.ch)*
[2] *Department of Environmental Sciences, University of Basel, Bernoullistrasse 30/32, CH-4056 Basel*

In deep lakes recoverying from eutrophication, chemocline erosion or sporadic mixing after muliple years of stratification can lead to a sudden rise in surface-water phosphorus concentrations (SW-P), decreasing water quality as a result. A major concern is that, due to climate change, periods between mixing events are becoming longer, leading to extended P accumulation in the hypolimnion and, in turn, greater SW-P surges upon mixing. Here we investigated the eutrophication impact of a large SW-P surge in the northern basin of Lake Lugano. After partial recovery from eutrophication in the 1990s, this basin underwent a period of SW-P re-enrichment in the 2000s due to upward mixing of deep waters (Lehmann et al. 2015, Lepori & Roberts 2017). We were particularly interested in comparing two phases: 1984-1988 (Phase I), when SW-P was high (> 30 µg L^{-1}) due to high external P loadings, and 2003-2007 (Phase II), when SW-P was high due to high internal P loadings. Specifically, we assessed if these two phases differed in terms of surface-water nutrient chemistry, water transparency and plankton characteristics.

One important consideration in this study was that, at the end of Phase I (specifically in 1988-1999), the structure of the zooplankton grazer assemblage changed from dominance by small zooplankters (small *Daphnia* and other small cladocerans) to dominance by large zooplankters (large *Daphnia* and calanoid copepods).

We compared several variables between the two phases, including soluble reactive P: SRP, total P: TP, total nitrogen:TN, silicon: Si, Z_{SD}: Secchi depth, CHL: Chlorophyll *a*; PHYTO: phytoplankton biomass, ZOO: zooplankton biomass, and some of their ratios (CHL:TP, ZOO:CHL). We also explored changes in plankton composition using ordination techniques (PCA). Based on classic P-based eutrophication models, we expected that the two phases would cause similar eutrophication symptoms, i.e. similarly high CHL and low Z_{SD}.

Our results indicate that differences in average SW-P concentrations and nutrient ratios (SRP:TP, TN:TP, and Si:TP) between phases were small and usually non-significant. In contrast, the two phases showed different CHL and Z_{SD}, along with other plankton characteristics. During Phase I, CHL was high and Z_{SD} was low, indicating severe eutrophication. During Phase II, CHL remained substantially lower and Z_{SD} reached relatively high values. Differences in the ratios CHL:TP and ZOO:PHYTO were striking. On average, the CHL:TP ratio was approximately two times lower, and the ZOO:PHYTO ratio three times higher during Phase II compared to Phase I (Fig. 1). PCA analyses further indicated that Phase I was characterized by a lower biomass of cladocerans and copepods, a higher biomass of cyanobacteria and a lower biomass of green algae, whereas Phase II showed opposing characteristics.

Our findings demonstrate that the plankton community of the northern basin of Lake Lugano responded in different ways to similar SW-P enrichments, producing severe eutrophication symptoms during the first phase (Phase I) and little signs of eutrophication during the second phase (Phase II). We argue that our results are explained by the change in zooplankton grazer assemblage between phases and support the “consumer-dependent” eutrophication model, which posits that lakes dominated by large grazers are less prone to eutrophication compared to lakes dominated by small grazers (Mazumder & Lean 1994). Two implications in the context of lake management are that: (1) simple P-based models may be inadequate tools for predicting algal biomass, and (2) lake restoration measures that favour large (rather than small) zooplankters (e.g., through biomanipulation) may help reduce eutrophication symptoms alongside classical measures aimed at reducing phosphorus.

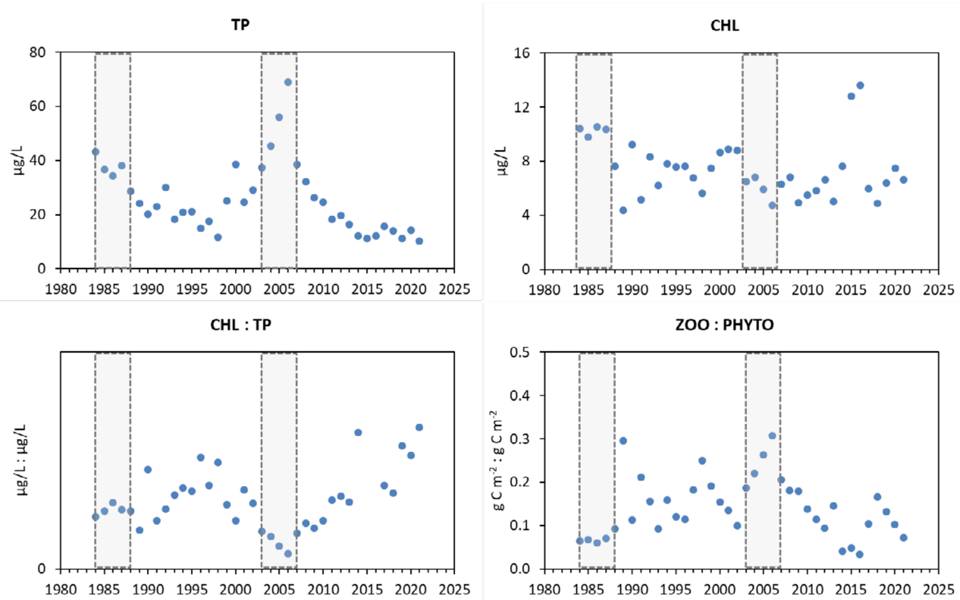

Figure 1. Comparison between P-enrichment phases I and II (indicated by the gray boxes).

REFERENCES

Lehmann, M.F., Simona, M., Wyss, S., Blees, J., Frame, C.H., Niemann, H., Veronesi, M. & Zopfi, J., 2015: Powering up the “biogeochemical engine”: the impact of exceptional ventilation of a deep meromictic lake on the lacustrine redox, nutrient, and methane balances, Frontiers in Earth Science, 3, 45.

Lepori, F. & Roberts, J.J. 2017: Effects of internal phosphorus loadings and food-web structure on the recovery of a deep lake from eutrophication, Journal of Great Lakes Research, 43, 255-264.

Mazumder, A. & Lean, D.R., 1994: Consumer-dependent responses of lake ecosystems to nutrient loading. Journal of Plankton Research, 16, 1567-1580.

13.12
Soil-plant hydraulics and stomatal conductance: When do whole tree water dynamics matter?

Stefano Martinetti[1], Andrea Carminati[2], Peter Molnar[1], and Marius Floriancic[1,2]

[1] *Institute for Environmental Engineering, ETH Zurich, Zurich, Switzerland*
[2] *Institute of Terrestrial Ecosystems, ETH Zurich, Zurich, Switzerland*

When plants transpire they require to take up water from the soil through their roots in order to maintain a sustainable plant water status. During dry periods water can become limiting and cause closure of the stomata, the pores on leaves surface through which water and carbon dioxide diffuse between the atmosphere and the leaves interior. Other than water availability, further known factors that influence stomatal conductance are environmental stimuli such as light exposure and vapor pressure deficit. Also, species-specific hydraulic traits and rooting strategies can modify the magnitude and timing of stomatal closure during drought. The interplay between leaf water potential and stomatal conductance mainly characterizes the hydraulic functioning of different species under dry conditions. However, stem and roots properties influence the pathway of water from the soil to the leaf too. Therefore their hydraulic traits and functioning are likely factors influencing stomatal conductance.

Here we monitored water fluxes and potentials on leaves, stem and deep and shallow roots of beech and spruce, as well as nearby soil, at the “WaldLabor” study site near ETH Hönggerberg. We used the data to calibrate and test a soil-plant hydraulic model and to compare above-ground and below-ground water dynamics of a tree. Our results show the different water use strategies of beech and spruce, with spruce typically closing stomata earlier, i.e. at less negative water potentials than beech, and generally showing a looser link between above-ground transpiration proxies and below-ground root water uptake. Results from the soil-plant hydraulic model were well aligned with measurements for beech and correctly predict the point at which beech close stomata for different states of soil water availability (see Figure 1).

In hydrological modeling the role of stomatal conductance is increasingly gaining importance, given its direct control on the transpiration flux. Species-specific hydraulic traits andx water use strategies need to be considered when modeling stomatal conductance. As such, soil-plant hydraulic models offer a physically-based approach to predict stomatal conductance considering whole tree water dynamics.

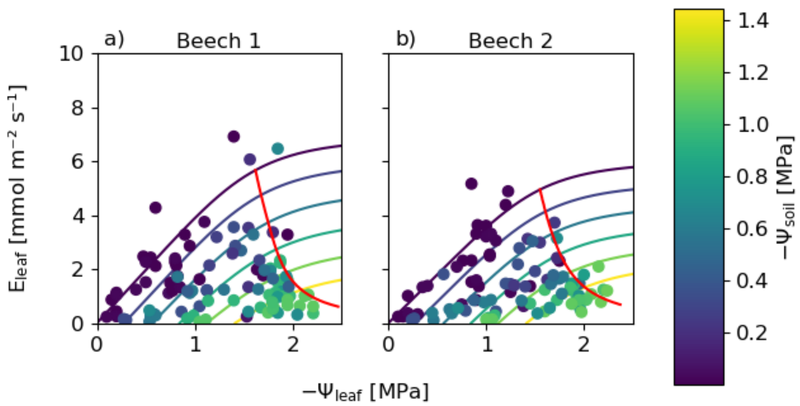

Figure 1. Leaf gas exchanges (y-axis) from stomatal conductance measurements and leaf water potential measurements(x-axis). The color of the dot represents soil water potential at the point of measurement. A soil-plant hydraulic model was calibrated (colored lines) and correctly predicts the point of stomatal closure (red curve) for beech.

REFERENCES

Martinetti, S., Carminati, A., Molnar, P. & Floriancic, M. 2023: Plant hydraulic traits and water use strategies modulate root water uptake and transpiration in beech and spruce, soon to be submitted.

13.13
Combined use of multiple tracers to idenity groundwater flow and pollutant transport in an urban area

Christian Moeck[1],Andrea Popp[1,2],Matthias S. Brennwald[1],Mario Schirmer[1,3,4], Rolf Kipfer[1,2,5]

[1] *Swiss Federal Insitute of Aquatic Science and Technology (Eawag), W+T, Dübendorf (Christian.moeck@eawag.ch)*
[2] *Department of Environmental Systems Science, ETH Zurich, Zurich, Switzerland*
[3] *Centre d'hydrogéology et géothermie (CHYN), University of Neuchâtel, Neuchâtel, Switzerland*
[4] *Département de géologie et de génie géologique, Université Laval, Quebec city, Canada*
[5] *Department of Earth Science, ETH Zurich, Zurich, Switzerland*

For our urban study site in Northern Switzerland, we used stable water isotopes, chlorinated solvents, dissolved gas concentrations, and ^{3}H and tritiogenic ^{3}He concentrations to assess water flow paths and mixing between artificially infiltrated surface water and groundwater. Especially, the recent developments of portable field-operated gas equilibrium membrane inlet mass spectrometer (GE-MIMS) systems provide a unique opportunity to measure dissolved gas concentrations, such as ^{4}He with a high temporal resolution at relatively low costs. Although the GE-MIMS are not capable of providing apparent water ages, ^{4}He accumulation rates are often obtained from $^{3}H/^{3}He$ ages and it has been shown that non-atmospheric ^{4}He concentrations determined in the laboratory (e.g., by static (noble gas) mass spectrometry) and by field-based (GE-MIMS) methods closely agree. This agreement allowed us to establishing an inter-relationship between $^{3}H/^{3}He$ apparent water ages and the non-atmospheric ^{4}He excess (e.g., calibrating the ^{4}He excess in terms of residence time).
We demonstrate that the ^{4}He excess concentrations derived from the GE-MIMS system serve as an adequate proxy for the experimentally demanding laboratory-based analyses. We combined the obtained water ages with hydrochemical data, water isotopes ($\delta^{18}O$ and $\delta^{2}H$), and PCE concentrations to understand water flow dynamics. Moreover, we explain the origin and spatial distribution of PCE contamination found at our study site with our multi-tracer approach.

13.14
Thirsty Earth: a multiplayer computer game for water resources education and research

Marc F. Müller[1,2], Lauren McGiven[2], Diogo Bolster[2], Matthew Noffsinger[3], Caleb Reinking[3]

[1] *Department of Systems Analysis, Integrated Assessment and Modelling, Eawag, Ueberlandstr 133, CH-8600 Dübendorf (marc.mueller@eawag.ch*
[2] *Department of Civil and Environmental Engineering and Earth Science, University of Notre Dame, Notre Dame, IN 46556, USA*
[3] *Center for Research Computing, University of Notre Dame, Notre Dame, IN 46556, USA*

The sustainable and management of water resources requires cooperative institutions whose development are rarely included in already overloaded engineering and earth sciences curricula. The resilience of such institutions in the context of climatic and demographic change is also poorly understood. We propose an open access online multiplayer simulation game to help address both of these education and research gaps. The game -- Thirsty Earth – assigns players to the roles of farmers within rural communities making annual decisions on the type of crop to plant and water sources to use to maximize their agricultural profits given random climate inputs. In doing so they experience key tradeoffs linked to climate variability, cooperative infrastructure management and sustainable water use that are at the heart of many of today's water management challenges.To address these challenges, players can purchase and share reliable information bits on the status and use of water resources, which can then be used to regulate behavior through collective action. In the talk or poster, we will (i) demonstrate the game, (ii) report on its integration as an experiential learning module within a University-level water resources engineering class and (iii) describe plans to use the game within an experimental research design. We will deploy the game massively online via the Mechanical Turk platform, where observing player's behavior will help understand the resilience of water management institutions to changing climate inputs.

13.15
Projecting future Swiss river temperatures on a National scale while maintaining local features

Love Råman Vinnå[1], Jannis Epting[1], Oliver Schilling[1,2]

[1] *Applied and Environmental Geology, Hydrogeology, Department of Environmental Sciences, University of Basel, Basel*
[2] *Department Water Resources and Drinking Water, Eawag–Swiss Federal Institute of Aquatic Science and Technology, Dübendorf*
Corresponding author: ramanvinna@unibas.ch

A key water quality indicator for both ecosystem and human water needs is river temperature, which is expected to change as climate warms. River temperatures are strongly controlled on regional to local scale by hydrological and atmospherical processes upstream. Therefore, when studying influencing factors on river temperatures it is desirable to use local-scale atmospheric data. Yet, climate change is a global phenomenon, usually studied with Global Circulation Models (GCMs), which sometimes are coupled to Regional Climate Models (RCMs), through the use of Representative Concentration Pathway (RCP) climate scenarios. This coupling produces climatic projections on a relatively coarse spatial scale. However, local biases are a huge problem for the use of thes projections in local-scale, especially in mountainous regions. For Switzerland, most biases have been removed by downscaling GCM-RCM coupled models to the local scale in the CH2018 project (2018). Switzerland's use and management of water resources is already impacted by a changing climate. As temperatures increase, glaciers recede and snow is present for fewer days each year, affecting both temperature and discharge of streams and rivers (FOEN (ed.), 2021). One important consideration for riverine temperature management is the tolerance threshold for aquatic life. The Swiss Water Protection Ordenance stipulates that river water may not be thermaly used once the temperature exceeds 25 °C, which is the critical temperature for the survival of the Brown Trout (FOEN (ed.), 2021).

To simulate river temperatures, one important process to include is river flow. Yet, the coupling of advanced discharge models with water temperature models and the consideration of a sufficient number of climate change projections is often unfeasible on the regional scale due to computational constraints. Here, we present a physically based, semi-empirical modelling approach with two surface water temperature models (air2stream and air2water) to provide regional projections of future river temperatures in Switzerland. Our method was first applied in Basel and has since been expanded to project future river temperature at all river stations where the Federal Office of the Environment monitores water temperature. Our approach simplifies the computation of river temperatures while maintaining local robustness by including the most important factors affecting river water temperature (i.e., air temperature, discharge variations, seasonality and river depth). We project river water temperatures based on locally downscaled climate forcings from 9 GCM, 8 RCM, 3 RCP scenarios and future river flows from 4 discharge models. Our results beeing presented spann a wide variety of river thermal types including alpine, regulated, groundwater springs, plateau, and downstream lake types.

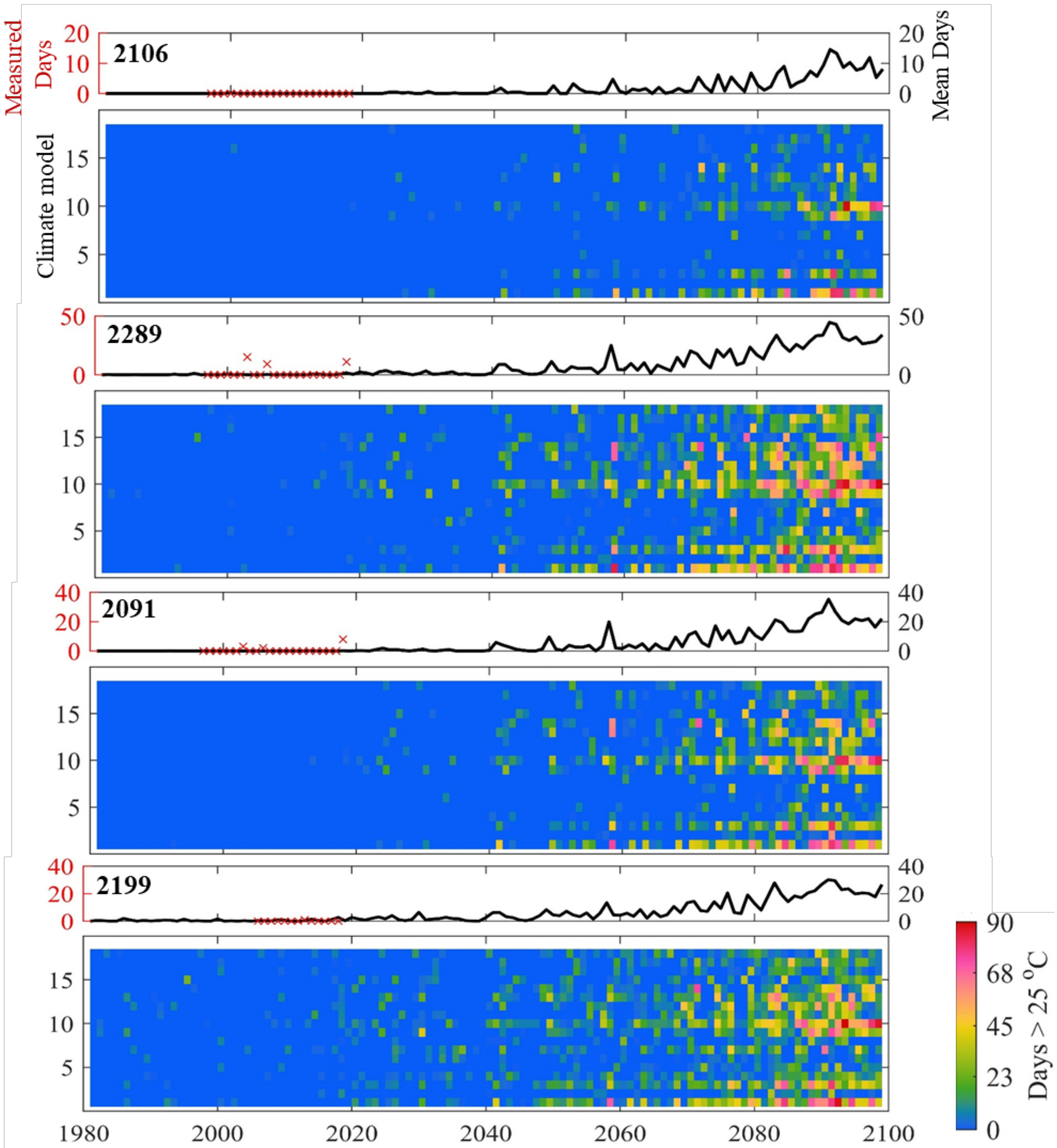

Figure 1. The total number of days per year during which river water temperatures exceed 25 °C at stations 2106 (Birs), 2289 (Rhein), 2091 (Rheinfelden) and 2199 (Wiese) for RCP8.5. Top figures: Mean threshold values from all climate models combined (black line) and from measurements (red crosses). Bottom figures: Simulation results from individual climate models (Epting et al., 2023).

REFERENCES

CH2018. 2018. CH2018 – Climate Scenarios for Switzerland, Technical Report, National Centre for Climate Services, Zurich, 271 pp. ISBN: 978-3-9525031-4-0.

Epting, J., Råman Vinnå, L., Annette, A., Stefan, S., & Schilling, O. S. 2023. Climate change adaptation and mitigation measures for alluvial aquifers - Solution approaches based on the thermal exploitation of managed aquifer (MAR) and surface water recharge (MSWR). Water Research, 238, 119988. https://doi.org/10.1016/j.watres.2023.119988

FOEN (ed.). 2021. Effects of climate change on Swiss water bodies. Hydrology, water ecology and water management. Federal Office for the Environment FOEN, Bern. Environmental Studies No. 2101: 125 p.

13.16
A model of the evolution of the water resource availability at the Glarey karstic spring in the glaciated Tsanfleuron watershed

Anthony Salamin[1,2], Philippe Renard[1], Pierre Christe[3], Gérald Favre[4], Carole Doucerain[1,5]

[1] Centre for Hydrogeology and Geothermics (CHYN), University of Neuchâtel, Rue Emile-Argand 11, 2000 Neuchâtel (philippe.renard@unine.ch)
[2] BEG - Géologie & Environnement SA, Route de la Printse, 1994 Aproz (anthony.salamin@unine.ch)
[3] Groundwater Group. Department of the Environment (SEN), Canton of Valais, Avenue de la Gare 25, 1950 Sion (pierre.christe@admin.vs.ch)
[4] Geologos SA, rte de Crassier 16, 1277 Borex (geologos@bluewin.ch)
[5] Laboratory of the ecology of natural and anthropised hydrosystems (LEHNA), Université Claude Bernard, 43 Boulevard du 11 novembre 1918, 69622 Villeurbanne Cedex (carole.doucerain@ens.psl.eu)

The Glarey spring is one of the main outlets of the Diablerets massif. The commune of Conthey in Valais taps it for its drinking water supply. This spring drains most of the Tsanfleuron lapiaz located at altitudes ranging from 2,000 to almost 3,000 meters. The upper part of the catchment is covered by a glacier that contributes to the flow of the spring. The region is subject to heavy precipitations, which can bring an annual equivalent water level of over three meters in the upper reaches of the basin. Much of this precipitation falls in the form of snow, causing high spring flow when the snowpack melts. However, this substantial snowfall cannot compensate the inexorable melting of the Tsanfleuron glacier. Its inevitable disappearance threatens to upset the hydrological and hydrogeological regime within the watershed. The objective of this work is therefore to evaluate the possible evolution of the water resources at the Glarey spring.

The research approach involves the collection of novel field data and the construction of a model able to forecast the impact of climate change scenarios. The model includes two main components (Figure 1). The hydrological component models the evolution of the Tsanfleuron glacier based on mass balance computations as a function of altitude. It uses the precipitation and temperature records measured in Sion. The hydrological model provides watershed-wide chronicles of liquid precipitation, snowmelt, and glacier melt. These chronicles are the input of the hydrogeological model that estimates the discharge rate at the Glarey spring. This component of the model includes a production function, representing the infiltration through the epikarst while taking into account the effects of evapotranspiration, and transfer function representing the hydraulic behavior of the endokarst with fast and slow flows. The model was calibrated using actual measurements and was then used to forecast future discharge using a broad range of Swiss CH18 climate scenarios. This allowed to obtain a range of possible evolutions from 2020 to 2090.

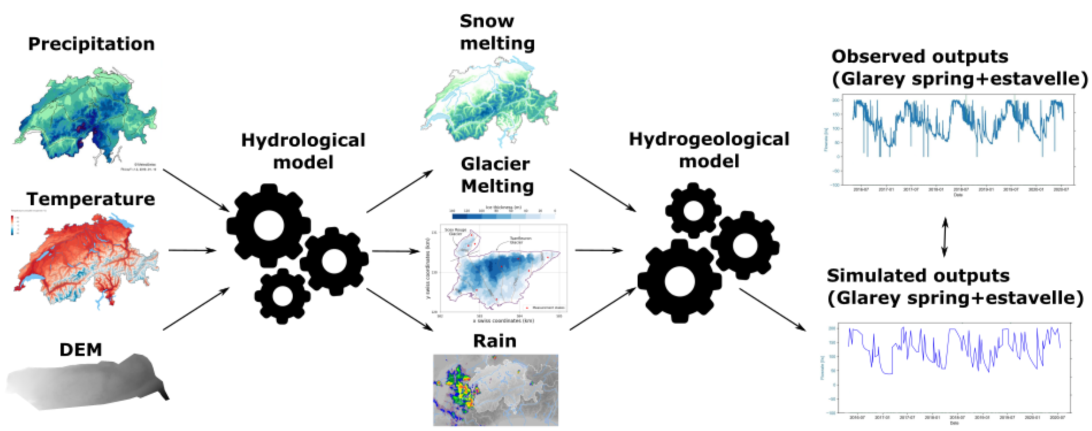

Figure 1. Illustration of hydrological and hydrogeological models used to simulate the evolution of the Glarey spring discharge.

The results show a large variability and uncertainty in the long term forecasts depending on the climate scenarios. All the models predict the complete melt of Tsanfleuron glacier. But the impact on the discharge rate at the Glarey spring is less drastic, most of the models indicate a change in the temporal distribution of the discharge:

- A reduction in summer induced by the disappearance of the glacier and the reduction of the amount of snow accumulated at high altitude.
- An increase in winter and spring due to more rain and earlier snowmelt.

But depending on the climate scenario, some models show a global reduction of the water availability while others show even an increase in water availabilty. Figure 2 shows one example of such results for the RCP8.5 scenario plotted with the MASH (Moving Average Shifted Horizon) technique.

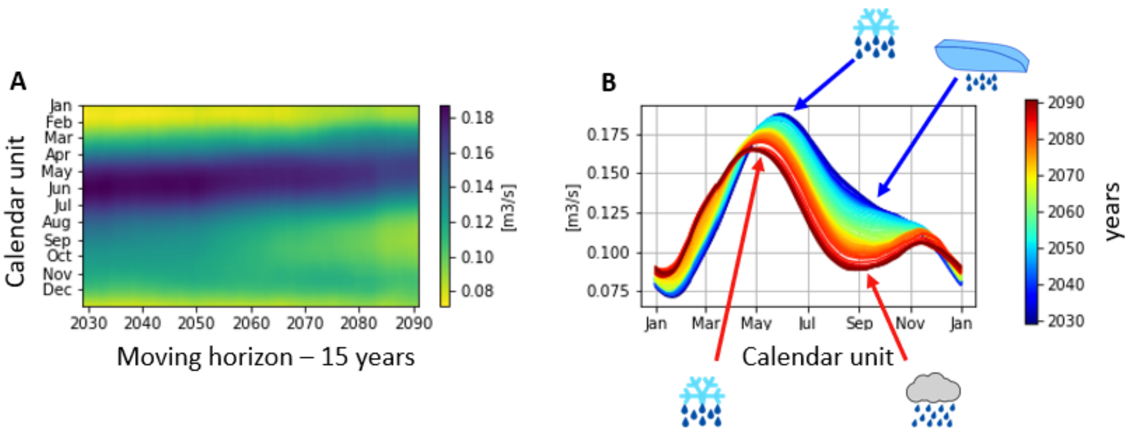

Figure 2. Example of predicted evolution of the Glarey spring discharge based on the average of the RCP8.5 scenarios. The graph B clearly shows an evolution from a nivo-glacial to a pluvio-nival groundwater regime.

13.17
Citizen-science observations made in Switzerland – Towards new horizons in regional hydrology

Jan Seibert, Sara Blanco, Mirjam Scheller, Franziska Schwarzenbach, Rieke Goebel, Ilja van Meerveld

Department of Geography, University of Zurich, Switzerland, jan.seibert@geo.uzh.ch

CrowdWater is a citizen science project in which we investigate how the public can be involved in collecting hydrological data, such as stream water levels, soil moisture conditions and the presence of water in temporary streams. Even in data-rich countries like Switzerland, these observations by the public can provide an important addition to the existing data. In CrowdWater, we also study the value of the collected data for hydrological modeling. Therefore, in several studies, we have evaluated the potential value of citizen science observations, which might be uncertain and spotty in time. The project's long-term goal is to collect many observations and thus improve the prediction of hydrological events, such as drought or flooding, by using data collected by the public in hydrological model calibration. Here, we present experiences from the CrowdWater project with regard to app-based data collection and evaluation of these data. We also highlight methods to ensure data quality, including a gamified approach and machine learning for analyzing the photos submitted through the app. Additionally, we will give an update on new activities in the CrowdWater project.

13.18
Estimating very rare floods at multiple sites in the Aare River basins with comprehensive hydrometeorological simulations

Daniel Viviroli[1], Anna E. Sikorska-Senoner[1,2], Guillaume Evin[3], Maria Staudinger[1], Martina Kauzlaric[4,5], Jérémy Chardon[6], Anne-Catherine Favre[6], Benoit Hingray[6], Gilles Nicolet[6], Damien Raynaud[6], Jan Seibert[1,7], Rolf Weingartner[4,5], Calvin Whealton[8]

[1] *Department of Geography, University of Zürich, Zürich, Switzerland*
[2] *now at: MeteoSwiss, Zürich, Switzerland & Center for Climate Systems Modeling ETH Zürich, Zürich, Switzerland*
[3] *Université Grenoble Alpes, INRAE, CNRS, IRD, Grenoble INP, IGE, Grenoble, France*
[4] *Mobiliar Lab for Natural Risks, University of Bern, Bern, Switzerland*
[5] *Oeschger Centre for Climate Change Research, University of Bern, Bern, Switzerland*
[6] *Université Grenoble Alpes, CNRS, IRD, Grenoble INP, IGE, Grenoble, France*
[7] *Department of Aquatic Sciences and Assessment, Swedish University of Agricultural Sciences, Uppsala, Sweden*
[8] *Paul Scherrer Institute, Villigen, Switzerland*

Rare to very rare floods (associated to return periods of 1000–100 000 years) can result in extensive human and economic damage. However, their estimation is limited by the comparatively short streamflow records available. Some of the limitations of commonly used estimation methods can be avoided by employing continuous simulation (CS), which considers many simulated meteorological configurations and a conceptual representation of hydrological processes. CS also avoids assumptions about antecedent conditions and their spatial patterns.

In this study, we implemented CS to estimate rare and very rare floods at 19 locations in the Aare River basin, covering an area of 17 700 km². To achieve this, we utilized exceedingly long simulations from a hydrometeorological model chain (Viviroli et al., 2022). The model chain consisted of three components: First, the multi-site stochastic weather generator GWEX produced 30 meteorological scenarios (precipitation and temperature) spanning 10 000 years each. Second, these weather generator simulations served as input for the bucket-type hydrological model HBV, run at an hourly time step for 80 catchments covering the entire Aare River basin. Third, runoff simulations from the individual catchments were routed for a representation of the entire Aare River system using the routing system model RS Minerve, including a simplified representation of main river channels, major lakes and relevant floodplains. The final simulation outputs spanned about 300 000 years at an hourly resolution, encompassing the Aare River outlet, critical points further upstream as well as the outlets of the catchments simulated with HBV. These simulation results were subsequently used to asses flood hazard and flood risk for critical infrastructure within the EXAR (Extreme flood events on the River Aare) project (Andres et al., 2021).

The comprehensive evaluation conducted over different temporal and spatial scales demonstrated that the main features of the meteorological and hydrological observations were well represented, enabling meaningful insights into low probability floods. While uncertainties were still considerable, the explicit consideration of important flood generating processes (snow accumulation, snowmelt, soil moisture storage) and routing (bank overflow, lake regulation, lake and floodplain retention) provided a substantial advantage compared to common extrapolation of streamflow records.

The suggested approach enables a comprehensive exploration of possible but unobserved spatial and temporal patterns of hydrometeorological behaviour (Figure 1). This is particularly valuable in a large river basin where the complex interaction of flows from individual tributaries and lake regulations are typically not well represented in the streamflow records. The framework is also suitable for estimating more common, i.e., more frequently occurring floods.

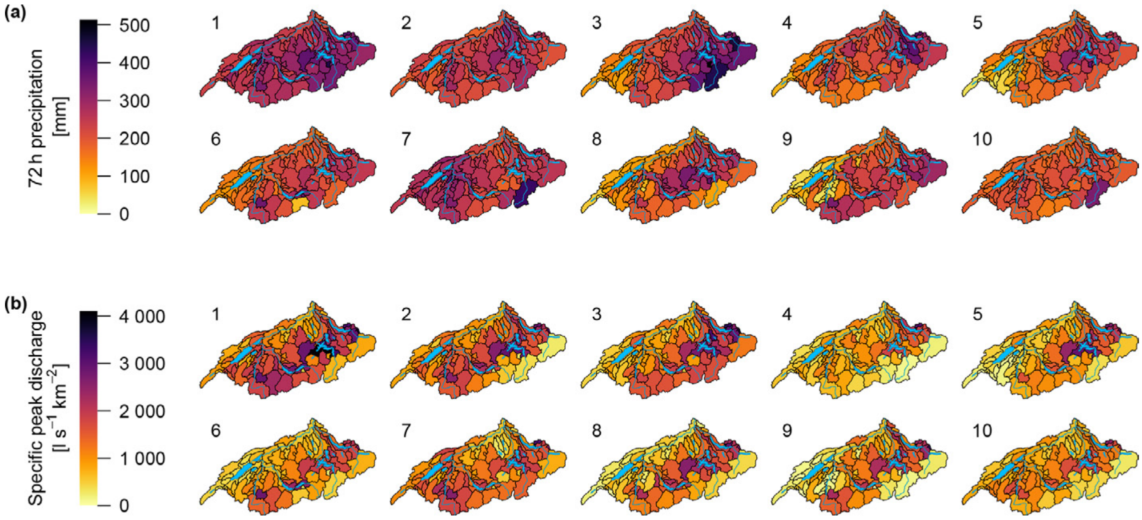

Figure 1. Patterns of cumulative precipitation (maximum 72 h sum) (a) and specific peak discharge (b) for the 10 largest peak flow events simulated at the outlet of the Aare River basin.

REFERENCES

Andres, N., Steeb, N., Badoux, A. & Hegg, C., 2021. Extremhochwasser an der Aare. Hauptbericht Projekt EXAR, Methodik und Resultate. WSL Berichte, 104. WSL, Birmensdorf. https://www.wsl.ch/de/projekte/exar-1.html

Viviroli, D., Sikorska-Senoner, A.E., Evin, G., Staudinger, M., Kauzlaric, M., Chardon, J., Favre, A.-C., Hingray, B., Nicolet, G., Raynaud, D., Seibert, J., Weingartner, R. & Whealton, C., 2022. Comprehensive space-time hydrometeorological simulations for estimating very rare floods at multiple sites in a large river basin. Natural Hazards and Earth System Sciences, 22(9), 2891–2920. https://doi.org/10.5194/nhess-22-2891-2022

13.19
Natural background concentrations in shallow Swiss aquifers

Christoph Wanner[1], Lola Camesi[1], H. Niklaus Waber[2], Stephanie Zimmermann[3], Michael Sinreich[3]

[1] Rock-Water Interaction Group, Institute for Geological Sciences, University of Bern, Baltzerstrasse 3, CH-3012 Bern (christoph.wanner@unibe.ch)
[2] WaterGeoChem Consulting, CH-3013 Bern
[3] Federal Office for the Environment FOEN, Division Hydrology, Section Hydrogeological Basis, CH-3003 Bern

The determination of geogenic background concentrations of dissolved constituents in groundwater is an important prerequisite to identify anthropogenic influences on the groundwater composition. In Switzerland, this is for instance accounted for by the water protection ordinance (GSchV). This ordinance defines exceptions for the numerical requirements for groundwater to be used as drinking water resource if the corresponding solutes (e.g. Cl, SO_4) originate from natural sources. Until recently, however, no systematic determination of background concentrations in shallow groundwater of Swiss aquifers has been carried out. Accordingly, in case of natural sources, the requirements for groundwater for use as drinking water could not be fully quantified.

In this contribution, we present the first nationwide determination of background concentrations for 32 inorganic parameters in shallow groundwater. The determination is based on groundwater collected in 2018 and 2019 at about 550 monitoring sites of the Swiss National Groundwater Monitoring (NAQUA), which is operated jointly by the Federal Office for the Environment (FOEN) and cantonal authorities. In a first step, the area of Switzerland was divided into 18 classes based on geographical, geological, hydrogeological and hydrogeochemical criteria. In a second step, background concentrations were determined individually for each of the 18 classes and for each of the 32 parameters using a statistical approach based on probability plots (Walter et al., 2012).

In most cases, the determined background concentrations probably correspond to the geogenic background concentrations. Exceptions include classes with a limited number of sampling locations. This is the case for the greater Geneva area, the upper Rhone and Rhine Valley, the western Jura, the main valleys in Ticino, and the crystalline parts of the Alps. For all these regions, no conclusive statement can be made about the representativeness of the determined background concentrations due to the low number of sampling locations. Furthermore, in the Swiss Molasse Basin characterized by a high population density and intensive agricultural activity, the determined background concentrations of Na, Cl, K, B, Cr, Cu, Pb, and Zn are overprinted by anthropogenic sources that cannot be separated from the geogenic background using the applied statistical method.

Despite the identified limitations, the determined background concentrations reflect the local geology very well. Since calcite occurs in all hydrogeochemical classes at least as trace mineral, Ca^{2+} and HCO_3^- are the dominating ions in almost all shallow groundwater. Depending on the mineralogical composition, however, large differences in the total mineralization and trace element concentrations occur in the different classes. NAQUA thus reflects well the chemical composition of shallow groundwater.

The determined background values are generally low and meet the requirements for groundwater to be used as drinking water resource in almost all aquifers. This also applies for the classes where an anthropogenic contribution to the background concentrations of Na, Cl, K, B, Cr, Cu, Pb, and Zn was identified. However, two potentially critical parameters remain. In aquifers of the crystalline parts of the Alps, the background concentration of arsenic locally exceeds the Swiss drinking water limit of 10 mg/L due to the natural occurrence of As-bearing minerals such as arsenopyrite. In addition, in consolidated sandstone aquifers in the western part of the molasse basin, the background concentration of Cr is locally close to the Swiss drinking water limit of 20 mg/L due to naturally occurring Cr-spinels. It follows that in these two regions, groundwater to be used as drinking water supply needs to by systematically analysed for arsenic or chromium.

To improve the representativeness of the determined background concentrations in the future, more data from the cantons and municipalities should be taken into account in addition to the data from NAQUA. Using more data from more sampling locations will also help to better separate between anthropogenic and geogenic contributions to the determined background concentrations. In any case, repeating the determination of background concentrations in the future is crucial to identify potential adverse effects of inorganic anthropogenic sources on the quality of Swiss shallow groundwater.

REFERENCE

Walter, T., Beer, A., Brose, D., Budziak, D., Clos, P., Dreher, T., Fritsche, H. G., Hübschmann, M., Marczinke, S., Peters, A., Poeser, H., Schuster, H., Wagner, B., Wagner, F., Wirsig, G., & Wolter R. 2012: Determining natural background values with probability plots. In: Groundwater Quality Sustainability Edition: IAH Selected Papers on Hydrogeology Chapter: Chapter 26. CRC Press. DOI: 10.1201/b12715-32.

13.20
From flow to snow: streamflow-based snow mass reconstruction using inverse hydrological modeling

Pau Wiersma[1], Grégoire Mariéthoz[1]

[1] *University of Lausanne, Faculty of Geosciences and Environment, Institute of Earth Surface Dynamics, Switzerland*

With climate change, rivers will contain more rainwater and less snow melt. This affects flood and drought risk, as well as the management of water resources. To quantify these changes in detail over the past decades, we need both runoff observations and daily estimates of snow melt, which in turn require spatial snow water equivalent (SWE) reconstructions. Methods to reconstruct SWE exist, but they depend on either remote sensing data or abundant in-situ observations, which limits their applicability in time (recent satellite timespans) and space (Global North) respectively. In addition, existing methods are often not assisted by or evaluated against streamflow observations, which contain valuable indirect information on the catchment-wide SWE. Without assessing whether the reconstructed SWE matches the streamflow after melting out there is limited guarantee that it respects the catchment›s mass balance.

In this study, we propose an inverse streamflow-based SWE reconstruction framework that can operate without remote sensing data or in-situ snow observations, allowing it to be applied far back in time and across different mountainous areas. As a basis, we use a distributed hydrological model with a temperature-index snow model at 1km resolution. On a year by year and catchment by catchment basis, we calibrate the inputs and parameters controlling the spatial SWE evolution (precipitation, temperature, spatially distributed melt rate) using streamflow observations. The calibration is done using the Robust Parameter Estimation (ROPE) algorithm, which narrows the parameter space across several stages of Latin Hypercube sampling and produces an ensemble of parameter sets with nearly equal likelihood rather than a single global optimum. This finally produces an ensemble of SWE scenarios that match the streamflow after melting out and therefore respect the water balance of the catchment as best as possible. As a proof of concept, we apply the framework on 5 Swiss catchments over the years 2000-2020 and evaluate it using in situ snow observations, MODIS snow cover and upstream streamflow observations. We expect the method to potentially be less efficient in simulating fine-scale variations but to be able to capture the SWE evolution well on the catchment scale at 1km resolution.

P 13.1
Simulation and calibration of headwater stream intermittency using a groundwater flow model

Ronan Abhervé[1], Clément Roques[1], Luc Aquilina[2], Philip Brunner[1], Jean-Raynald de Dreuzy[1], Laurent Longuevergne[1]

[1] *Centre for Hydrology and Geothermics (CHYN), Université de Neuchâtel, Neuchâtel, Switzerland (ronan.abherve@unine.ch)*
[2] *Univ Rennes, CNRS, Geosciences Rennes - UMR 6118, 35000 Rennes, France*

Recent research has highlighted the crucial role for ecological communities (1) and the significant prevalence of temporary streams: over 50% of the world›s rivers are temporary (2). However, the main parameters and processes involved in the stream intermittency remain poorly understood (3). The literature identifies several controlling factors, including meteorology, geology and land cover (4), but a major challenge remains: understanding the role of the subsurface, i.e. the effect of the aquifer›s hydraulic properties (5).

In line with the new definition of an intermittent river (6), "*a non-perennial river or stream with a considerable connection to the groundwater table, having variable cycles of wetting and flow cessation, and with flow that is sustained longer than a single storm event*", we use a 3D process-based groundwater flow model at the catchment-scale to simulate stream flow and the spatio-temporal extension/contraction of the hydrographic network. Focusing on two crystalline catchments in Brittany (northwest France), with a similar temperate climate, we explore the combined effect of hydraulic conductivity K (transmission capacity) and porosity θ (storage capacity). We propose a calibration approach with performance criteria based solely on surface information: 1) stream flow measured at the catchment outlet and 2) mapping of the observed hydrographic network (7) (for the low-water period: perennial streams and for the high-water period: perennial + intermittent streams).

The calibration results show that the methodology leads to an optimal aquifer model for the 2 catchments (Canut: $K = 4.5 \times 10^{-5}$ m/s, θ = 0.1% and Nancon:
$K = 1.5 \times 10^{-5}$ m/s, θ = 2.2%). For both catchments, the comparison of simulated versus observed stream flow, focusing on low flows, achieves an excellent $NSE_{log}>0.86$. At the same time, the model reproduces very well the hydrographic network observed during both high and low water periods (Figure 1), resulting in a very good success criterion. Finally, the models are validated using data from discrete visual monitoring of stream hydrological conditions (national ONDE network).

Based on these modelling results, we then discuss hydrogeological controls such as the role of aquifer storage capacity on headwater stream intermittency. We believe that the use of stream intermittency mapping, benefiting from innovations in crowdsourcing and remote sensing, will address the need for hydrological models and predictions for ungauged basins.

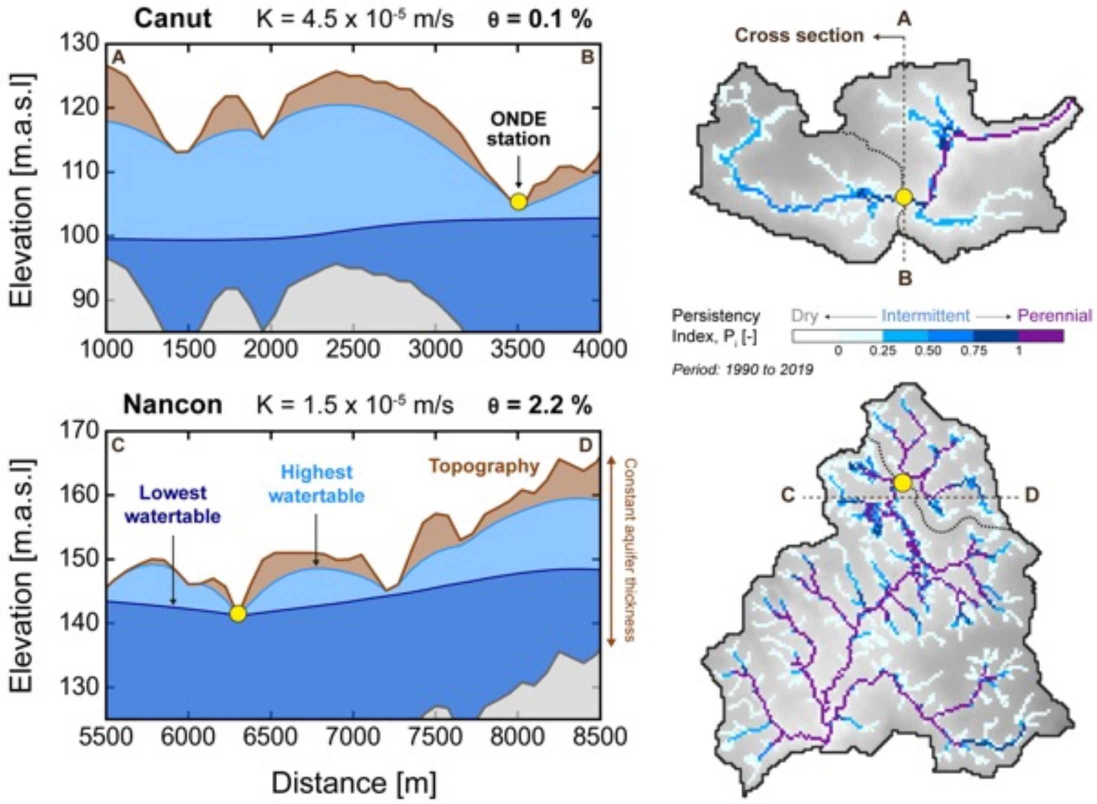

Figure 1. Simulation results for the calibrated model for the two catchments studied, the Canut and the Nancon. Left panels: cross-section of simulated maximum (high water) and minimum (low water) groundwater levels. Right panels: persistency index map (probability of water occurrence) calculated from simulation results between 1960 and 2019.

REFERENCES

1. Datry T, Larned ST, Tockner K. Intermittent rivers: A challenge for freshwater ecology. Bioscience. 2014;64(3):229–35.
2. Messager ML, Lehner B, Cockburn C, Lamouroux N, Pella H, Snelder T, et al. Global prevalence of non-perennial rivers and streams. Nature. 2021 Jun 17;594(7863):391–7.
3. Fovet O, Belemtougri A, Boithias L, Braud I, Charlier JB, Cottet M, et al. Intermittent rivers and ephemeral streams: Perspectives for critical zone science and research on socio-ecosystems. Wiley Interdiscip Rev Water. 2021;8(4):1–33.
4. Costigan KH, Jaeger KL, Goss CW, Fritz KM, Goebel PC. Understanding controls on flow permanence in intermittent rivers to aid ecological research: integrating meteorology, geology and land cover. Ecohydrology. 2016;9(7):1141–53.
5. Shanafield M, Bourke SA, Zimmer MA, Costigan KH. An overview of the hydrology of non-perennial rivers and streams. Wiley Interdiscip Rev Water. 2021;8(2):1–25.
6. Busch MH, Costigan KH, Fritz KM, Datry T, Krabbenhoft CA, Hammond JC, et al. What's in a Name? Patterns, Trends, and Suggestions for Defining Non-Perennial Rivers and Streams. Water. 2020;1–19.
7. Abhervé R, Gauvain A, Roques C, Longuevergne L, Louaisil S, Aquilina L, et al. Calibration of groundwater seepage on the spatial distribution of the stream network to assess catchment-scale hydraulic conductivity. Hydrol Earth Syst Sci Discuss. 2022;(Preprint):1–26.

P 13.2
Detection of hydrogen peroxide after hydraulic stimulation of granitic bedrock at the Bedretto Tunnel

Andrew Acciardo[1], Nima Gholizadeh[1], Maria Mesimeri[1], Luca Scarabello[1], Marian Hertrich[1], Cara Magnabosco[1]

[1] Department of Earth Sciences, ETH Zurich, Sonneggstrasse 5, CH-8092 Zurich (andrew.acciardo@erdw.ethz.ch)

Earthquakes and other seismicity-inducing events grind up and crush rocks in the subsurface. In the presence of water, this process can initiate a mechanoradical reaction that results in the formation of reactive oxygen species (ROS), including hydrogen peroxide. For the anaerobic microorganisms that live in the subsurface, exposure to these oxidants presents a potential threat to their existence, as ROS can cause cell damage that may eventually lead to cell death. Laboratory based experiments have demonstrated that H_2O_2 can be derived from this water-rock reaction, but field evidence is lacking. To evaluate whether cataclastic H_2O_2 production is observable in a deep groundwater reservoir, can be measured following induced seismicity, a hydraulic stimulation experiment was performed in the Bedretto Lab Deep Life Observatory (Ticino, Switzerland). In this experiment, 5.25m^3 of water was injected into a packer-isolated interval of a borehole, which led to measurable deformation in the surrounding reservoir and over 3,000 seismic events (maximum Magnitude -3.0) within a total volume of 26,000,000m^3. Fluorometric analysis of water samples taken from the flow-back of the interval indicate an increase in H_2O_2 concentrations relative to both baseline levels and levels after a less intense hydraulic stimulation experiment that produced an order of magnitude less seismic events. Peak H_2O_2 concentrations in flow-back fluids reached approximately 1.7μM during the stimulation. These experiments demonstrate that seismicity-related increases in H_2O_2 are able to be measured in-situ. Whether the observed change in H_2O_2 can be attributed directly to water-rock interactions will be verified with additional laboratory-scale experiments, which will also enable a more precise quantitative understanding of the amount of H_2O_2 produced during fracturing. The abiotic production of H_2O_2 in the deep subsurface, along with other molecules including H_2 and O_2, may have played an important role in the origin of life as well as in the ability of microorganisms to exist in such an energy-poor environment. These studies will help illuminate the influence of mechanoradical ROS production for life on Earth as well as potential life on planets and moons in our solar system and beyond.

P 13.3
Towards a metabolic theory of catchments: scaling of water and carbon fluxes with size

Francesca Bassani[1], Simone Fatichi[2], Sara Bonetti[1]

[1] *Laboratory of Catchment Hydrology and Geomorphology, EPFL Valais Wallis, Route des Ronquos 86, CH-1951 Sion, Switzerland (francesca.bassani@epfl.ch)*
[2] *Department of Civil and Environmental Engineering, National University of Singapore Institut, 1 Engineering Drive 2 Block, E1A #07-03, Singapore*

Catchments are heterogeneous ecosystems involving several abiotic and biotic processes, where the mutual interactions among water, vegetation, and biogeochemical fluxes take place at different scales.

Many biological processes in nature are characterized by allometric scaling relationships (Brown, 2004), which postulate that a biological variable B (e.g., the metabolic rate of an organism) scales with its mass M to the power of a scaling exponent ranging between 3/4 and 2/3 (West, 1997; da Silva, 2006).

Few studies adopted scaling laws to describe the metabolism of ecosystems including forests (Enquist, 2017) and river basins (Rodriguez-Iturbe, 2011), although at the catchment and regional scales these dynamics remain largely unexplored.

Our analysis goes towards this direction, with the aim of finding a feasible reduced-order framework relating key water and carbon fluxes to the catchment's physical and geometrical properties. Supported by hyper-resolution ecohydrological simulations covering the whole European Alps (Mastrotheodoros, 2020) and remote sensing data, we identify allometric scaling relationships linking water and carbon dynamics (e.g., transpiration, gross primary productivity, carbon use efficiency) to topographic catchment properties (e.g., contributing area), respectively acting as proxies for the catchment metabolic rate B and mass M.

These results reveal that drainage basins can be seen as complex biological systems whose dynamics follow similar scaling relations.

REFERENCES
Brown, J. H. (2004). Toward a metabolic theory of ecology. *Ecology*, 1771-1789.
da Silva, J. K. (2006). Allometric scaling laws of metabolism. *Physics of Life Reviews*, 229-261.
Enquist, B. J.-R. (2017). Assessing trait-based scaling theory in tropical forests spanning a broad temperature gradient. *Global Ecology and Biogeography*, 1357--1373.
Mastrotheodoros, T. a. (2020). More green and less blue water in the Alps during warmer summers. *Nature Climate Change*, 155-161.
Rodriguez-Iturbe, I. a. (2011). Metabolic principles of river basin organization. *Proceedings of the National Academy of Sciences*, 11751-11755.
West, G. B. (1997). A general model for the origin of allometric scaling laws in biology. *Science*, 122-126.

P 13.4
Tidal characterization of the Liappey fractured aquifer, Bagnes (VS)

Céleste Belloni[1], Benoît Valley[1], Clément Roques[1]

[1] *Centre for Hydrogeology and Geothermics, University of Neuchâtel, Rue Emile Argand 11, CH-2000 Neuchâtel (celbelloni@gmail.com)*

Solid Earth tides have had an increased use in hydrogeology to characterize aquifers and wells. The Liappey fractured aquifer has shown a strong response to tides through the CHA-1 well. The Earth tides strain cyclically closes and opens up the fractures, increasing and decreasing pore pressure. The increase in pore pressure causes higher discharge at the well.

The aquifer, a fractured ante-Permian gneiss, was the object of geothermal investigations by the Bagnes commune, and the artesian CHA-1 bore was drilled. This work's main focus is the use of tidal analysis to infer aquifer properties, fracture orientation and understand the flow dynamics. The goal is to explore different models and methods in tidal analysis and verify their use for the CHA-1 well. To this end, the discharge of the flowing well was continuously monitored for a 6-month duration (in addition to discharge data from 2017), and logging (optical and flow log) was performed in the well.

The logging exhibits a well with importantly damaged walls, as well as large collapses; and a general SE dip direction of the fracturation, with principally subvertical fractures. The tidal analysis reveals that there is a large discrepancy between the discharge response to tides in 2017 against 2023, including the phase shift going from negative to positive. In the end, the analysis leads to the interpretation that the flow in the Liappey well-aquifer system has evolved from a horizontally dominated permeability to a bi-directional permeability, with a sharp increase in vertical flow, probably associated with degradation of the cementing around the well, resulting in an increase in vertical exchanges between the waters of the Quaternary sediments and those of the fractured aquifer.

Moreover, the use of tidal analysis permitted the estimation of the orientation of the average hydraulic transmission in the aquifer, yielding results congruent with the fracturation analysis from the logging, demonstrating that this passive method is promising for fracture orientation estimation.

P 13.5
ALPLAKES: Advancing Lake Research and Management through Integrative Remote Sensing and Hydrodynamic

Damien Bouffard[1,2] , Marina Amadori[3], Mariano Brescani[3], Claudia Giardino[3], Daniel Odermatt[1], Abolfazl Irani Rahaghi[1,4] , James Runnalls[1], Marco Toffolon[5] , Mortimer Werther[1]

[1] *Eawag, Swiss Federal Institute of Aquatic Science & Technology, Surface Waters – Research and Management, Kastanienbaum, Switzerland*
[2] *Faculty of Geosciences and Environment, Institute of Earth Surface Dynamics, University of Lausanne, Lausanne, Switzerland*
[3] *Institute for Electromagnetic Sensing of the Environment (IREA), National Research Council of Italy (CNR), 20133 Milan, Italy*
[4] *Department of Geography, University of Zurich, 8057 Zurich, Switzerland*
[5] *Department of Civil, Environmental and Mechanical Engineering, University of Trento, Italy*

The ALPLAKES initiative aims at advancing in lake research and management, building upon the achievements of the previous Meteolakes (ESA SEOM S2-4Sci Land and Water, http://meteolakes.ch/) project. Meteolakes pioneered the integration of satellite Earth observation and hydrodynamic modeling, exemplified by the web-centric platform Meteolakes, which has engaged over 600,000 users since 2016. ALPLAKES progresses this approach, expanding from the foundational Meteolakes platform to encompass twelve Alpine lakes spanning altitudes from 60 to 1800 meters above sea level. Utilizing Sentinel-2 products, ALPLAKES combines remote sensing data with hydrodynamic models, enhancing the predictive capabilities of the models. Light penetration maps from Sentinel-2 play a crucial role in inputting solar radiation distribution on the hydrodynamic model and thereby impacting lake thermal evolution. Maps of total suspended matter (another Sentinel-2 product) provide visible space-borne patterns, which are incorporated into hydrodynamic models using particle tracking techniques. This method, initially developed for Sentinel-2’s total suspended matter product, holds potential for various other products such as chlorophyll, oil spills, or RGB composites, provided constituent proliferation rates are negligible within the chosen timeframe. The outcomes are openly accessible through the new web-based platform (release date oct. 2023).

P 13.6
On the scaling relationship between grain-size, riverbed slope and catchment area at the reach scale

Giulio Calvani[1], Virginia Ruiz-Villanueva[2], Massimiliano Schwarz[3], Paolo Perona[1]

[1] *Platform of Hydraulic Constructions PL-LCH (IIC-ENAC), Ècole Polytechnique Fédérale de Lausanne, Lausanne, Switzerland (giulio.calvani@epfl.ch)*
[2] *Institute of Earth Surface Dynamics, University of Lausanne, Switzerland*
[3] *Forestry Department, Bern University of Applied Sciences, Zollikofen, Switzerland*

Since the 1950s, several authors have attempted to model the scaling relationships among geometrical and hydro-morphological characteristics of fluvial streams at different spatial scales (i.e., section, reach or catchment). For instance, flow discharge, water depth, river width, and channel slope have been related each other for gravel-bed (Parker et al., 2007) and sand-bed (Wilkerson & Parker, 2011) rivers in bankfull condition, based on a dimensionless approach at the cross-sectional scale. At a much larger scale (i.e., the catchment scale), relationships between drainage area, bed slope and mean grain size diameter have been proposed by several authors (e.g., Hack, 1957). However, the literature lacks proper explanation for such empirical formulations. In this work, we derived an equation relating catchment area, mean grain size and channel bed slope, based on physically-based formulations available in the literature and a flow discharge-catchment area relationship valid in bankfull conditions. As a result, the proposed model mathematically explains the existing link between geomorphological characteristics and hydrological quantities observable in mountain streams at equilibrium conditions. For the sake of comparison, we successfully tested the derived relationship against the dataset of river measurements of Hack (1957) and an additional dataset for different rivers (e.g., Wohl & Wilcox, 2005). The proposed relationship may be applied to infer catchment-scale characteristics based on local (reach-scale) measurements.

REFERENCES

Hack, J. T. (1957). Studies of longitudinal stream profiles in Virginia and Maryland (Vol. 294). US Government Printing Office.

Parker, G., Wilcock, P. R., Paola, C., Dietrich, W. E., & Pitlick, J. (2007). Physical basis for quasi-universal relations describing bankfull hydraulic geometry of single-thread gravel bed rivers. Journal of Geophysical Research: Earth Surface, 112(F4).

Wilkerson, G. V., & Parker, G. (2011). Physical basis for quasi-universal relationships describing bankfull hydraulic geometry of sand-bed rivers. Journal of Hydraulic Engineering, 137(7), 739-753.

Wohl, E. E., & Wilcox, A. (2005). Channel geometry of mountain streams in New Zealand. *Journal of hydrology*, *300*(1-4), 252-266.

P 13.7
Tree planting as a nature-based solution for urban flooding in Nouakchott City, Mauritania

Emmanuel Dubois[1], Montana Marshall[1], Fatimatou Boukhreiss[2], Saleck Ahmed Cherif[2], Grégoire Mariéthoz[3], Charlotte Grossiord[4], Paolo Perona[1]

[1] *Platform of Hydraulic Constructions (PL-LCH), Civil Engineering Department, Ecole Polytechnique Fédérale de Lausanne (EPFL), Station 18, 1015 Lausanne, Switzerland (emmanuel.dubois@epfl.ch)*
[2] *Région de Nouakchott, avenue Bacar Ould Soueid'Ahmed, B.P. 5203, Nouakchott, Mauritania*
[3] *Institute of Earth Surface Dynamics (IDYST), University of Lausanne, UNIL-Mouline, Geopolis, 1015 Lausanne, Switzerland*
[4] *Plant Ecology Research Laboratory (PERL), Civil Engineering Department, Ecole Polytechnique Fédérale de Lausanne (EPFL), Station 2, 1015 Lausanne, Switzerland*

Nouakchott City has been facing constant flooding for more than a decade, making part of the city inhabitable and posing long-term health threats. Within the city, a shallow groundwater table had relatively constant groundwater levels due to sea intrusion. However, the infiltration of most of Nouakchott's used water since the establishment of a new domestic water supply in 2010 has acted as artificial aquifer recharge, resulting in a rise of groundwater levels that reached the topographic surface in the low-lying parts of the city. This surge in groundwater, coupled with a decrease in already limited soil water storage, causes the city's flooded area to double during the rainy season spanning July to September. The goal of this project is to assess how tree planting could increase Nouakchott's resilience against urban flooding by lowering the water table level. This nature-based solution would be advantageously oriented toward sustainable development as it would be a low-cost and multi-benefit solution. An integrated tree planting strategy could enhance the provision of services for the people, the economy, and biodiversity (e.g., shade in the streets, potential fruit harvesting, livestock food production, green habitats...). Consequently, this work presents a joined interdisciplinary ecohydrology and plant physiology approach for monitoring and modelling the transpiration and dewatering capacity of diverse local tree species. Given the exceptionally challenging conditions for vegetation, characterized by a hot desert climate and an available shallow water table with brackish water, the annual dynamics of trees and transpiration remain highly uncertain. In order to quantify and simulate the impact of tree planting scenarios, five tree species found in Nouakchott were identified as salt-tolerant and selected as potential candidates for this nature-based solution. Since February 2023, the transpiration rates of the selected tree species have been monitored using sap flow meters. Furthermore, as knowledge regarding groundwater dynamics was limited, five observation wells have been equipped with automatic water depth sensors to facilitate long-term data collection and a spatio-temporal time series of the city's flooded areas was reconstructed using an innovative methodology based on remote sensing data. Based on these preliminary results, the proposed tree planting solution is being analyzed through a SWOT approach (strengths, weaknesses, opportunities, and threats). This holistic approach ensures comprehensive consideration of all transdisciplinary aspects associated with the endeavour, which we present and discuss in this work.

P 13.8
Lake archives from tropical Africa: Reconstructing the paleoclimate leading to the African Rainforest Crisis 3000 years ago

Michelle Engelhardt[1], Jordon Hemingway[1], Antoine de Clippele[2], Alfred Ludjwera[3], Negar Haghipour[1,4], Johan Six[2]

[1] Geological Institute, ETH Zürich, Sonneggstrasse 5, 8092 Zurich, Switzerland (mengelhardt@erdw.ethz.ch)
[2] Department of Environmental Systems Science, ETH Zürich, Universitätsstrasse 2, 8092 Zurich, Switzerland
[3] Institut Supérieur des Techniques Appliqués (ISTA), 3930 Aérodrome, Kinshasa/N'dolo, Democratic Republic of Congo
[4] Ion beam Physics, ETH Zürich, Otto-Stern-Weg 5, 8093 Zurich, Switzerland

The second largest rainforest biome on Earth lies in the Congo Basin in central Africa. However, due to slash-and-burn farming practices as well as climate change, the rainforest is quickly contracting. Interestingly, former studies have found evidence for a similar so-called "African Rainforest Crisis" taking place in the late Holocene around 3000 years ago (Brncic et al. 2009; Garcin et al. 2018). There are indicators assigning this crisis to the expansion of the Bantu people, who are believed to have migrated to this area to pursue extensive farming at this time. Pollen records, on the contrary, speak for a shift towards a drier climate as the primary mechanism inducing the crisis. Since data from this area are scarce, more information is needed to resolve the exact causes of the African Rainforest Crisis, especially as it is a likely analog for ongoing and future rainforest contraction.

To provide such information, we collected about 30 m of core from in sum 13 lakes along the rainforest-savannah boundary in the Kasaï Basin, Democratic Republic of Congo, which constitutes the southwest portion of the Congo Basin. We use bulk radiocarbon measurements to develop age models of the sediment records. Additionally, XRF data will offer insights on the underlying mineralogy. By using the mineralogy as an indicator of the weathering degree, we expect to draw conclusions on the hydrology and temperature throughout the late Holocene. To further constrain the paleoclimate reconstructions, XRD, pollen and triple-oxygen isotope analysis on the clay-size fraction are planned. A holistic interpretation will aim to reveal the role of climate change as a trigger of the African Rainforest Crisis.

This work is part of a larger project which is the first to study the erosion dynamics from source to sink in the Kasaï region. The ultimate goal is to combine data from the uplands, floodplains, rivers, and lakes to further constrain estimates of this ecosystem's net carbon balance through time and to better predict how the Congo rainforest will respond to today's land use- and climate-triggered challenges.

REFERENCES

Brncic, T. M., Willis, K. J., Harris, D. J., Telfer, M. W., & Bailey, R. M. 2009: Fire and climate change impacts on lowland forest composition in northern Congo during the last 2580 years from palaeoecological analyses of a seasonally flooded swamp, The Holocene, 19(1), 79–89.

Garcin, Y., Deschamps, P., Ménot, G., de Saulieu, G., Schefuß, E., Sebag, D., Dupont, L. M., Oslisly, R., Brademann, B., Mbusnum, K. G., Onana, J.-M., Ako, A. A., Epp, L. S., Tjallingii, R., Strecker, M. R., Brauer, A., & Sachse, D. 2018: Early anthropogenic impact on Western Central African rainforests 2,600 y ago, Proceedings of the National Academy of Sciences, 115(13), 3261–3266.

P 13.9
Quantifying the sensitivity of groundwater to climate variations in Australia

Xinyang Fan[1,6,7,8], Tim Peterson[2,1], Benjamin Henley[3,4,5,1], Meenakshi Arora[1]

[1] *Department of Infrastructure Engineering, University of Melbourne, 700 Swanston St, VIC 3053, Melbourne, Australia*
[2] *Department of Civil Engineering, Monash University, Wellington Rd, VIC 3800, Melbourne, Australia*
[3] *School of Earth, Atmosphere and Life Sciences, University of Wollongong, Northfields Ave, NSW 2522, Wollongong, Australia*
[4] *Securing Antarctica's Environmental Future, Monash University, Wellington Rd, VIC 3800, Melbourne, Australia*
[5] *ARC Centre of Excellence of Climate Extremes, Monash University, Wellington Rd, VIC 3800, Melbourne, Australia*
[6] *Institute of Applied Geosciences, Karlsruhe Institute of Technology, Adenauerring 20b, 76131, Karlsruhe, Germany*
[7] *now at Institute of Geography, University of Bern, Hochschulstrasse 6, 3012, Bern, Switzerland*
[8] *now at Faculty of Civil, Geo and Environmental Engineering, Technical University of Munich, Arcisstraße 21, 80333, Munich, Germany (xinyang.fan@tum.de)*

Climate change is projected to impact groundwater availability in many regions globally but the projections are highly uncertain. Quantifying the historic impact contributes to an improved understanding of the climate change impact but has been rarely studied, primarily because of limited groundwater records and influences of multiple drivers, such as pumping for agricultural irrigation and land use changes. This study aims to understand the risks to groundwater by estimating the sensitivity of groundwater level and recharge to climate variations across Australia. More than 4000 groundwater sites in the country were first modelled with a time-series groundwater modeling toolbox *HydroSight* to identify the sites, where >80% of the groundwater level fluctuations have been driven by climate variations alone. A multiple linear regression approach was then applied to quantify the groundwater level and recharge sensitivity to precipitation and potential evapotranspiration at the identified climate-dominated sites. Results show that groundwater level and recharge are around 8 times more sensitive to precipitation than to evapotranspiration variations. The head sensitivity shows to be higher at the sites located in the arid climates and porous media than those in the tropical climates and fractured media, and contrarily for the recharge sensitivity. Land use however shows a modest impact on the sensitivity. These findings allow for an essential first-order estimate of climate change impact on groundwater and understanding the governing factors of groundwater response.

P 13.10
Evaluating riparian vegetation removal due to morphodynamic processes in the river Thur

Kilian Feller[1,2], Giulio Calvani[1], Francesco Caponi[2], Paolo Perona[1]

[1] *Platform of Hydraulic Constructions PL-LCH (IIC-ENAC), Ècole Polytechnique Fédérale de Lausanne, Lausanne, Switzerland (kilian.feller@epfl.ch)*
[2] *Laboratory of Hydraulics, Hydrology and Glaciology, ETH Zurich, Zurich, Switzerland*

The dynamics of riparian vegetation in a fluvial environment are characterized by numerous both positive and negative feedbacks with the hydrology of the river. Vegetation influences the flow field, the sediment transport, and the morphodynamics, whereas the hydrology of the river has an influence on the vegetation growth and can cause flood-induced mortality due to either burial or uprooting. In this work, the applicability of the physically based stochastic uprooting model for riparian vegetation by Perona and Crouzy (2018) is discussed. The results of the uprooting model are compared to field studies performed in 2009 and 2010 by Pasquale et al. (2014) on a gravel island of the river Thur restored corridor. For this field study, willow cuttings were planted all across the island, and their evolution was systematically monitored over the growing season. We perform 2D morphodynamic simulations (with BASEMENT v2.8.2) of the seasonal floods occurring in the study reach, and use model's results to produce a comparison of the empirical statistics against the theoretical one predicted by Perona and Crouzy (2018). This model considers plant uprooting by flow occurring as a result of the stochasticity affecting the erosion process and the plant rooting depth. The uprooting model depends, aside from the erosion, on two input parameters that were not directly measured in the field study, the critical erosion depth and the variance of the erosion. The critical erosion depth had to be approximated from literature formulae, and the variance of the erosion was calibrated. The results of the morphodynamic simulation are sufficiently accurate for 2009, whereas substantial differences between the simulated and the measured bed level changes exist for 2010. This discrepancy between the simulation and the measurements is explained by the high number of floods that had to be simulated in 2010. The comparison of the uprooting model with the data from the field study shows a high model performance ($R^2 = 0.68$) for 2009, where the erosion input data is accurate, but almost no predictive power in 2010 with the inaccurate erosion input data ($R^2 = 0.06$). To this regard, the uprooting model by Perona and Crouzy (2018) is then compared to the performance of two additional simplified models (e.g., one purely deterministic and one conceptual). We show that the model by Perona and Crouzy (2018) still outperforms the simplified models for the accurate input data but displays predictive power in the same range as the simplified models in the case of the inaccurate morphodynamic simulation in 2010.

REFERENCES

Pasquale, N., Perona, P., Francis, R., & Burlando, P. (2014). Above-ground and below-ground Salix dynamics in response to river processes. Hydrological Processes, 28 (20), 5189–5203.

Perona, P., & Crouzy, B. (2018). Resilience of riverbed vegetation to uprooting by flow. Proceedings of the Royal Society A: Mathematical, Physical and Engineering Sciences, 474 (2211), 20170547.

P 13.11
The RADMOGG Project (2023-2027): Resilience and Dynamics of Mountain Groundwater using Gravimetry

Landon J.S. Halloran[1,*], Nazanin Mohammadi[1], Ronny Figueroa[1], Antoine Carron[1], Fernando Gutierrez[1], Daniel Hunkeler[1], Philip Brunner[1], Marie Arnoux[2] & Henri Baumann[3]

[1] *Centre d'hydrogéologie et de géothermie (CHYN), Université de Neuchâtel, Neuchâtel (NE).*
[2] *Centre de recherche sur l'environnement alpin (CREALP), Sion (VS).*
[3] *Federal Institute of Metrology (METAS), Bern-Wabern (BE).*
[*] *landon.halloran@unine.ch*

RADMOGG is a new SNSF-funded project that will strengthen the use of hydro-gravimetric methods in hydrogeology and will deepen our comprehension of hydrogeological processes in mountain catchments. Alpine catchments are increasing in importance for water supply, yet are also critically impacted by climate change. Groundwater in alpine catchments will progressively play a more critical role in ensuring perennial streamflow down-gradient, yet these catchments remain under-monitored. Furthermore, the data value of direct, single-point piezometric measurements is especially low in these catchments due to their inherent heterogeneity and extreme seasonal changes.

To address this knowledge and monitoring gap, RADMOGG will develop a numerical method for the assimilation of time-lapse gravimetry (TLG) data into groundwater models. Correspondingly, it will quantitatively evaluate the value of gravimetric data in reducing uncertainty in hydro(geo)logical models. Based on these methodological developments, it will quantify, in a spatially-resolved way, groundwater export from mountain catchments. Finally, it will use numerical methods to evaluate the role and limits of groundwater in ensuring hydrological resilience in the face of climatic stress.

RADMOGG is both a numerical- and field-focused project. It involves two field sites: *Tsalet* (VS), an alpine headwater catchment with hydrogeological heterogeneity where groundwater plays a crucial role in streamflow dynamics, and *Röthenbach* (BE), a subalpine basin characterised by substantial temporal variability in subsurface water storage within its alluvial aquifer. The outcomes of this project will provide quantitative insights that will inform future water management strategies in mountainous regions in the face of climate change.

P 13.12
A machine-learning approach to predict overland flow impacts

Pascal Horton[1], Markus Mosimann[1], Severin Kaderli[1], Olivia Martius[1], Andreas Paul Zischg[1]

[1] *Mobiliar Lab for Natural Risks, Oeschger Centre for Climate Change Research (OCCR), Institute of Geography, University of Bern, Hallerstrasse 12, CH-3012 Bern (pascal.horton@unibe.ch)*

While overland flow events are responsible for frequent and costly damages, they only recently became a focus for research and a target for insurance companies. Here, as a follow-up of the work of Bernet et al. (2019), we focus on an impact-based approach, using aggregated damage claims related to surface water floods recorded by the Mobiliar insurance company. Based on data-driven approaches, we aim to predict the probability of occurrence of such damages using precipitation data and features characterizing local conditions.

The CombiPrecip precipitation dataset, which is a combination of radar and gauges data at an hourly time step and with a 1 km^2 resolution, has been used to build a catalog of precipitation events for each of its pixels and over the period 2013-2022. Events were defined by a precipitation total above 10 mm separated by a period of at least 8 hours without precipitation (> 0.1 mm/h). The damage data were aggregated to the same resolution. In addition, static terrain properties were derived for each pixel and consist of the slope, aspect, plan, profile, and total curvature, flow accumulation, land cover (percentage of 12 land cover classes), and the percentage of the pixel covered by the national overland flow map. The terrain and flow accumulation features were computed at different resolutions (10, 25, 100, and 250 m) and aggregated to the 1 km^2 cells by computing the mean, median, minimum, maximum, and standard deviation of the values.

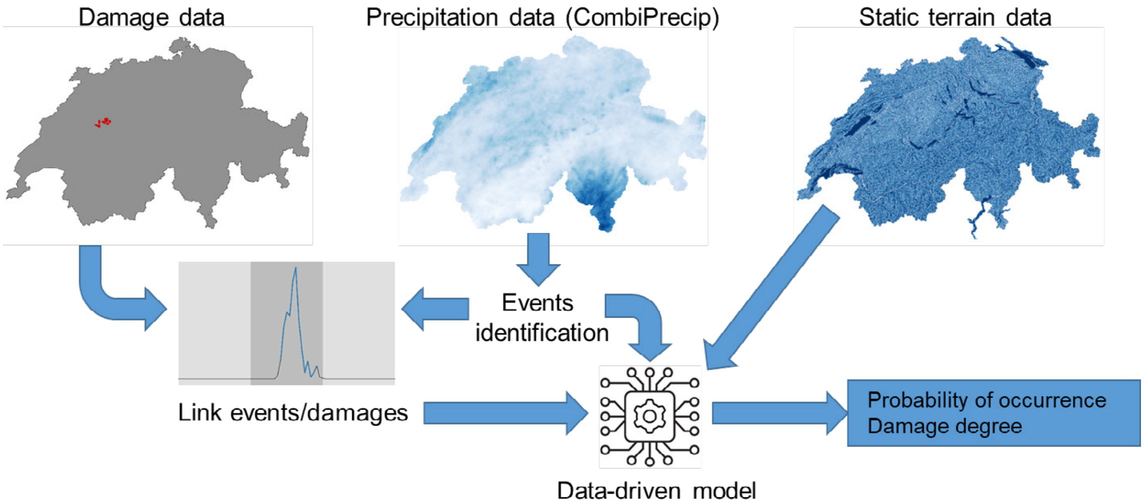

Figure 1. Illustration of the different components of the data-driven model for the prediction of damages related to overland flow.

A random forest model has been trained using these terrain features in addition to the event characteristics (mean and maximum intensity, precipitation sum, antecedent precipitation index, and three temporal properties). The most important features identified by the random forest model are related to the event properties, the number of contracts per cell, the urban land cover type, and to a minor extent some terrain properties. Although the random forest improves on previous work that was done in a similar context, we feel that we are limited by the tabular-type approach and are heading toward a model that better accounts for spatio-temporal patterns, such as a convolutional neural network (CNN).

REFERENCES

Bernet, D. B., Trefalt, S., Martius, O., Weingartner, R., Mosimann, M., Röthlisberger, V., & Zischg, A. P. 2019: Characterizing precipitation events leading to surface water flood damage over large regions of complex terrain. Environmental Research Letters, 14(6), 64010. https://doi.org/10.1088/1748-9326/ab127c

P 13.13
The Federal Drought Monitoring and Warning System

V. Humphrey[1], F. Hüsler[2], D. Oesch[3], S. Bircher[1], J. Sturm[3], C. Scapozza[2]

[1] *Federal Office of Meteorology and Climatology MeteoSwiss*
[2] *Federal Office for the Environment*
[3] *Federal Office of Topography swisstopo*

In May 2022, the Swiss Federal Council mandated the Federal Office for the Environment (FOEN), MeteoSwiss and swisstopo to jointly develop a national monitoring, early detection, and warning system for drought. This new platform is scheduled to first go into operation on January 1, 2025 and aims at providing comprehensive information on historical, current, and forecasted drought conditions in Switzerland. Within this project, a new web portal will be established integrating the “drought.ch” platform from the Swiss Federal Institute for Forest, Snow and Landscape Research (WSL). It will primarily support decision-making by cantonal and regional authorities, and provide relevant information to critically impacted economic sectors. The platform will be further developed and improved over the coming decades, in collaboration with the user community and Swiss research institutions. In this contribution, we provide an overview of the project organization and ongoing activities, including some of the envisaged new climatological and hydrological products, as well as satellite-based data streams, that are also expected to benefit research applications. FOEN is leading the program and coordinates efforts to establish the web platform and implement warnings. Furthermore, FOEN will be responsible for the hydrological monitoring and modeling, and the impacts on forestry. MeteoSwiss will develop a national soil moisture monitoring network, new climatological products to support drought monitoring, as well as extended-range meteorological forecasts required for hydrological modelling. Finally, swisstopo will provide a repository accessible via download and webservices of analysis-ready and postprocessed satellite imagery and vegetation indices from high-resolution satellites like Sentinel-2.

P 13.14
The effect of an improved snow and glacier routine of a large-scale hydrological model on Alpine streamflow and extremes

Joren Janzing[1,2,3], Niko Wanders[4] and Manuela Brunner[1,2,3]

[1] WSL Institute for Snow and Avalanche Research SLF, Davos Dorf, Switzerland. (joren.janzing@slf.ch)
[2] Climate Change, Extremes and Natural Hazards in Alpine Regions Research Center CERC, Davos Dorf, Switzerland.
[3] Institute for Atmospheric and Climate Science, ETH Zurich, Zurich, Switzerland.
[4] Department of Physical Geography, Utrecht University, Utrecht, The Netherlands.

To accurately study spatial patterns in streamflow and upstream-downstream relationships in Alpine regions, large-scale hydrological models are needed that exceed national boundaries. These large-scale models have increasingly higher resolutions, which are required to capture the complex topography of mountain regions. Therefore, process representations at smaller spatial scales become relevant. However, large-scale hydrological models do not always capture cryospheric processes well (Hou et al. 2023), which can affect simulations of discharge in Alpine regions through errors in timing, quantity and spatial patterns of snow and glacier melt. Here, we propose an improved snow and glacier routine for the PCR-GLOBWB 2.0 global hydrological model (Sutanudjaja et al. 2018; Hoch et al. 2023) and study their effects on simulations of discharge and hydrological extremes over the Alps.

We set up the PCR-GLOBWB 2.0 model over the Alps at a resolution of 30 arcsec (~1km). The existing model uses a simple constant degree-day factor to simulate snowmelt and does not explicitly represent glaciers. First, we implemented, tested, and compared different extensions of the existing temperature index model including a degree-day factor that varies seasonally or one that is dependent on snow albedo effects. Second, we added a new dynamic glacier component to the model. We calibrated the model against datasets of snow cover, glacier mass balances and discharge over Switzerland.

Our preliminary results show a limited improvement of discharge simulations through the new snowmelt routine. The glacier routine leads to strong increases in performance for glacierized catchments. Furthermore, the new snow and glacier modules address the issue of unrealistic snow accumulation across multiple seasons in PCR-GLOBWB 2.0. Our future work will specifically focus on the effect of cryospheric processes on historical floods and droughts by running the model over the larger Alpine domain including the headwater catchments of the Rhine, Rhone, Danube and Po rivers.

REFERENCES

Hoch, J. M., Sutanudjaja, E. H., Wanders, N., Van Beek, R. L., & Bierkens, M. F. 2023: Hyper-resolution PCR-GLOBWB: opportunities and challenges from refining model spatial resolution to 1 km over the European continent, Hydrology and Earth System Sciences, 27(6), 1383-1401.

Hou, Y., Guo, H., Yang, Y., & Liu, W. 2023. Global evaluation of runoff simulation from climate, hydrological and land surface models, Water Resources Research, 59(1), e2021WR031817.

Sutanudjaja, E. H., Van Beek, R., Wanders, N., Wada, Y., Bosmans, J. H., Drost, N., ... & Bierkens, M. F. 2018. PCR-GLOBWB 2: a 5 arcmin global hydrological and water resources model, Geoscientific Model Development, 11(6), 2429-2453.

P 13.15
Impacts of Land Use Land Cover and Climate Changes on hydro-morphological processes of the African Great Lakes Regions. Case of Lake Kivu catchment.

Kayitesi N.M., Guzha A.C., Tonini M., Mariethoz G.

Lake Kivu (LKV), bordering Rwanda, and Democratic Republic of Congo is one of the African Great Lakes, which are a series of Rift Valley lakes in and around the East African Rift. LKV catchment is highly susceptible to natural disasters, including floods, landslides, mass movement and soil erosion. This is a result of the catchment geologic formation, steep topography, and the loss of forest cover on fragile soils, coupled with the increased prevalence of extreme rainfall events. Over recent decades, the LKV catchment has undergone substantial Land Use Land Cover Changes (LULC), driven by a complex interplay of political, economic, and socio-demographic factors. Furthermore, climate change is intensifying these changes due to global warming and increased frequency of extreme events. These changes manifest in catchment hydro-morphological processes, such as alteration of rainfall- runoff patterns, and changes in the water balance. The LKV catchment represents a case of rapid landscape degradation, and prompt efforts are being made to implement reforestation schemes. However, there is a lack of detailed spatio-temporal analysis to understand the landscape changes, and their subsequent impacts on the hydro-morphological dynamics of the catchment.

This study aims at analyzing the LULC and Climate changes that occurred in the LKV catchment from 1980s, and subsequently forecast future scenarios, using remote sensing data and a predictive LULC model. The resultant changes in LULC and climate are then related to associated changes in catchment hydro-morphology. Preliminary findings indicate that during the 1980s and 1990s, the catchment encountered a forest decline of about 10% of the catchment area (340 km^2), with a 13% expansion in agricultural land. This trend reversed after the 2000s, marked by extensive reforestation that expanded total land cover by 8%, primarily driven by changes in bare land, grass land and intensified agricultural areas. Furthermore, the study applies a hydrological model to analyze the catchment responses to these landscape changes. It provides a foundation for prioritizing and implementing strategic measures to restore and maintain the integrity of LKV catchment.

P 13.16
Effects of strong Wind-driven Currents on Winter Cascading in Lake Geneva during a cold Spell

François Mettra[1], Damien Bouffard[2], Rafael Sebastian Reiss[1], Ulrich Lemmin[1], Tomy Doda[2], Koen Blanckaert[3], David Andrew Barry[1]

[1] *ECOL-IIE-ENAC, Ecole Polytechnique Fédérale de Lausanne (EPFL), 1015 Lausanne, Switzerland (current e-mail address: francois@meteomettra.ch)*
[2] *Eawag, Swiss Federal Institute of Aquatic Science and Technology, Surface Waters – Research and Management, 6047 Kastanienbaum, Switzerland*
[3] *Institute of Hydraulic Engineering and Water Resources Management, TU Wien, A-1040 Vienna, Austria*

Cooling-driven density currents, also known as winter cascading or thermal syphon, are important for horizontal littoral-pelagic exchange of heat and dissolved gases. They contribute to the erosion of the thermocline, deep mixing and sediment focusing. In the literature, they have been studied only in the case of weakly to moderate wind conditions (e.g., Doda et al., 2022; Ramón et al., 2022). Earlier studies in Lake Geneva related the dynamics of those cold density currents to the shelf width and the cooling intensity, and determined that they represent an important volume flushed from the shelf (Fer et al., 2001, 2002). Recently, it has been found by numerical simulation that they also significantly contributed to deep water renewal during the last bottom re-oxygenation in 2012 (Peng et al., submitted), which was caused by an extremely cold spell, accompanied by strong winds.

In this field study, we investigated winter cascading on the north-western shore of Lake Geneva during a strong and cold *Bise* (wind from North-East) event in February 2018 based on nearshore mooring data from two sites which are spaced 2-km in the alongshore direction. The wind direction was alongshore and favored coastal downwelling (Fer et al., 2002). One site, characterized by a wide shelf, is upwind of the second site, characterized by a narrow shelf.

During this cold wind event, strong differential cooling, with colder water in the shallow littoral zone (than in the pelagic zone), was observed, especially at the upwind site (as expected for a wide shelf). However, the upwind site did not show winter cascading during the strongest winds. Interestingly, the downslope flow was stronger at the narrow shelf than at the wide upwind shelf, whereas, during weaker winds, winter cascading was stronger at the wide shelf, as expected from the existing literature. The downslope velocity scale of winter cascading, ~5-10 cm s^{-1} (Fer et al., 2002), became occasionally smaller than the alongshore velocity scale (up to 20 cm s^{-1}). This means that alongshore advection dominated and that the cold water formed on the wide shelf caused winter cascading further downstream along the shore. In both situations, Ekman transport due to the coastal downwelling was significantly weaker than the observed downslope transport. This confirms that the main driving mechanism of this downslope transport is differential cooling, even during strong winds, although Ekman transport also contributes to the downslope flow.

In summary, we show that winter cascading occurs on both wide and narrow shelves, depending on background currents (resulting from wind) and cooling intensity. Differential cooling is always stronger on wide shelves, but due to the long initiation and propagation time scales of the subsequent cooling-driven flow (compared to background alongshore currents), winter cascading is generated downstream of the wide shelf. Overall, it points to the important effects of the wind direction (relative to the shore direction) and the nearshore bathymetry on the generation of winter cascading.

REFERENCES
Doda, T., Ramón, C. L., Ulloa, H. N., Wüest, A., & Bouffard, D. 2022: Seasonality of density currents induced by differential cooling. Hydrology and Earth System Sciences, 26(2), 331–353.
Fer, I., Lemmin, U., & Thorpe, S. A. 2001: Cascading of water down the sloping sides of a deep lake in winter. Geophysical Research Letters, 28(10), 2093-2096.
Fer, I., Lemmin, U., & Thorpe, S. A. 2002: Winter cascading of cold water in Lake Geneva. Journal of Geophysical Research: Oceans, 107(C6), 13-1.
Peng, N., Lemmin, U., Reiss, R. S., Mettra, F., & Barry, D. A. Heat Budget Decomposition: A Novel Approach to Identify and Quantify Density-Driven Deepwater Renewal Processes during Winter Cooling in a Large, Deep Lake (Lake Geneva), submitted to Water Resources Research.
Ramón, C. L., Ulloa, H. N., Doda, T. & Bouffard, D. 2022: Flushing the Lake Littoral Region: The Interaction of Differential Cooling and Mild Winds. Water Resourses Research, 58(3), e2021WR030943.

P 13.17
Google Earth Engine Applications in Hydrology and Hydrogeology

Saeed Mhanna[1*], Landon Halloran[1], Philip Brunner[1]

[1] *Center of Hydrogeology and Geothermics, Université de Neuchâtel *(saeed.mhanna@unine.ch)*

With the advancement of remote sensing and computing technology, cloud-based platforms, such as Google Earth Engine (GEE), have emerged as necessary tools for storing and processing large volumes of data. While it is well-known that remote sensing products can offer valuable insight into planetary processes, many in the hydrology and hydrogeological community are unaware of the power and relative simpilicy of open-access, cloud-based tools. Hydrological and hydrogeological studies that seek to monitor and understanding complex processes can often benefit by integrating extensive RS datasets. GEE enables access to a wealth of Earth observation data sources, providing opportunities for researchers to examine changes in total water storage, land cover, surface water availability, soil moisture, precipitation patterns, vegetation dynamics, and much more. In this presentation, we present an overview of current and future applications of GEE for the hydrology and hydrogeology community. We also demonstrate multiple practical examples showing how this tool can be used to rapidly provide valuable insight on a variety of hydrology research themes and discuss the caveats of the approaches.

P 13.18
Radiocarbon Inventories of Switzerland: Insights from a year of sediment trap data in Lake Geneva

Benedict V.A. Mittelbach[1], Margot E. White[1], Timo M.Y. Rhyner[1], Negar Haghipour[1,2], Nathalie Dubois[1,3], and Timothy I. Eglinton[1]

[1] Department of Earth Sciences, ETH Zürich, Switzerland (benedict.mittelbach@erdw.ethz.ch)
[2] Laboratory for Ion Beam Physics, ETH Zürich, Switzerland
[3] Department of Surface Waters Research & Management, EAWAG, Dübendorf, Switzerland

This study investigates the allochthonous and autochthonous contributions of organic and inorganic carbon to burial fluxes in Lake Geneva. By understanding these contributions, we aim to shed light on the broader implications for carbon sequestration in freshwater systems.

From July 2022 to July 2023, monthly samples were retrieved from sediment traps at two strategically selected sites: near the Rhone delta (river-proximal) and the deepest part of the lake (river-distal). These locations differed in their expected ability to capture river-derived (allochthonous) and lake-derived (autochthonous) sediment contributions. Initial findings indicate substantial temporal variations in sedimentation rates throughout the year. External inputs, evident from heightened levels of clastic sediment, were especially dominant at the river-proximal site. Further, autochthonous biogenic material, which can be linked to internal lake processes, displayed distinct seasonal patterns.

Subsequent analyses focussed on the carbon dynamics recorded by these sediment traps. Different carbon sources, such as atmospheric vs. rock-derived, can be distinguished by their isotopic composition. We thus used radiocarbon and stable carbon analyses as means of source identification of the different carbon pools entering the sedimentary reservoir in Lake Geneva. Future analyses will aim to understand and quantify the mechanisms of carbon deposition. This includes the transformation of dissolved inorganic carbon to organic carbon through in-situ primary production and to particulate inorganic carbon through calcite precipitation.

This exceptionally well-monitored lake and river system offers the ideal site for our in-depth analyses. When coupled with existing sediment and carbon budgets of the lake, this research provides a comprehensive perspective on the carbon dynamics of Lake Geneva and other hardwater lakes globally.

P 13.19
Swiss Groundwater Network – CH-GNet

Christian Moeck[1]

[1] *Swiss Groundwater Network, CH-8600 Dübendorf (christian.moeck@eawag.ch)*

The primary objective of CH-GNet is to raise awareness of existing research in the field of groundwater and related disciplines and to create a forum for exchange, information and networking.
More specifically, we make developed tools and gained information from science visible, promote practice-oriented research, compile scientific facts and identify groundwater-relevant problems as well as possible (voluntary) solutions. We are seeking to promote a smooth exchange between different organisations and provide advice and arrange contacts with research institutions. We are bundling practice-relevant research results and making them visible, through organized workshops and conferences and the development of documents, help promoting continuous competence building. CH-GNet wants to support the cooperation of various interest groups. In the present poster examples of the CH-GNet activities are shown.

Figure 1. Swiss Groundwater Network. More Information can be found on our webpage www.swissgroundwaternetwork.ch

P 13.20
Separating snow and ice melt contributions based on water stable isotopes and a glacio-hydrological model in a highly glacierized catchment

Tom Müller[1,2], Mauro Fischer[2,3], Stuart N. Lane[1], Bettina Schaefli[2,3]

[1] *Institute of Earth Surface Dynamics (IDYST), University of Lausanne, UNIL Mouline, CH-1015 Lausanne (tom.muller.1@unil.ch)*
[2] *Institute of Geography, University of Bern, Hallerstrasse 12, CH-3012 Bern*
[3] *Oeschger Centre for Climate Change Research, University of Bern, Hochschulstrasse 4, CH-3012 Bern*

Highly glacierized catchments are rapidly evolving with climate warming. Changes in annual glacier runoff leads to significant impacts on downstream ecosystems and water availability for human uses. Glacio-hydrological models have been developed to assess current or future changes in runoff but predictions are mainly based on statistical models using past or present observations which may simplify the physical processes responsible for runoff generation. In addition, detailed in-situ mass balance observations are sparse and uncertainties remain in the spatio-temporal interpolation of point mass balance measurements. Water stable isotopes are widely used in catchment hydrology to assess the main sources of water but application in snow dominated catchments remains challenging. In highly glacierized catchments, studies using water stable isotopes are still sparse.

Here, we develop a semi-distributed glacio-hydrological model and implement a simple, parsimonious isotope routine allowing to simulate the contribution and corresponding discharge signature of snow and ice melt isotopes. We compare our modelling results with two years of discharge and isotope measurements directly at the glacier portal of the Otemma glacier in southwestern Switzerland. We find a satisfying potential of the model to reproduce stream observations, but show that the use of isotopes to separate between snow and ice contributions appears very challenging. In particular, we show that the spatio-temporal variability of snow isotopes may lead to large uncertainties in the contribution of different water sources and thus challenges the use of mixing models using only isotopes for temperate mid-altitude glaciers. Although further research is needed, we provide guidelines and discuss the potential of combining isotopes within a glacio-hydrological modelling framework.

P 13.21
The hydrogeology of Mt. Fuji as a model for water resource management in tectonically active volcanic regions

Stéphanie Musy[1], Friederike Currle[1], Teresa Nakajima[2], Yama Tomonaga[1,3], Yuji Sano[2], Oliver S. Schilling[1,4]

[1] *Hydrogeology, Department of Environmental Sciences, University of Basel, Bernoullistrasse 32, CH-4056 Basel (stephanie.musy@unibas.ch)*
[2] *Center for Advanced Marine Core Research, Kochi University, Japan*
[3] *Entracers GmbH, Dübendorf, Switzerland*
[4] *Department Water Resources and Drinking Water, Eawag–Swiss Federal Institute of Aquatic Science and Technology, Dübendorf, Switzerland*

Mt. Fuji is the iconic centerpiece of a large, tectonically active volcanic watershed (100 km^2) which plays a vital role in supplying safe drinking water to millions of people through groundwater and numerous freshwater springs. Situated at the top of the sole known continental triple-trench junction, the Fuji watershed is characterized by a complex geology and significant tectonic instability.

Recently, the long-standing understanding of Mt. Fuji catchment being a conceptually simple, laminar groundwater flow system with three isolated aquifers was challenged. The combined use of noble gases, vanadium, and microbial eDNA as measured in different waters around Fuji revealed the presence of substantial deep groundwater water upwelling along Japan's tectonically most active fault system, the Fujikawa Kako Fault Zone[1].

These findings call for deeper investigations of the hydrogeology and the mixing dynamics within large-scale volcanic watersheds, which are typically characterized by complex geologies and extensive networks of fractures and faults. In our study, we approach these questions by integrating existing and emerging methodologies, such as continuous, high-resolution monitoring of dissolved gases (GE-MIMS;[2]) and microbes[3]we implemented a custom-built continuous staining device in combination with real-time flow cytometry (RT-FCM, eDNA, trace elements, and integrated 3-D hydrogeological modeling[4]the information content of the tracers can potentially be fully explored through the explicit simulation of an advection-dispersion transport equation, for example using integrated surface-subsurface hydrological models (ISSHMs.

The collected tracer time series, along with hydraulic and seismic observations, are used to develop an integrated SW-GW flow model of the Mt. Fuji watershed. Climate change projections will further inform predictive modeling and facilitate the design of resilient and sustainable water resource management strategies in tectonically active volcanic regions.

REFERENCES
[1] Schilling, O.S. et al., Revisiting Mt Fuji's groundwater origins with helium, vanadium and environmental DNA tracers, Nat. Water **1** 1 (2023) 60.
[2] Brennwald, M.S., Schmidt, M., Oser, J., Kipfer, R., A Portable and Autonomous Mass Spectrometric System for On-Site Environmental Gas Analysis, Environ. Sci. Technol. **50** 24 (2016) 13455.
[3] Props, R. Et al., Detection of microbial disturbances in a drinking water microbial community through continuous acquisition and advanced analysis of flow cytometry data, Water Res. **145** (2018) 73.
[4] Delottier H. et al., Explicit simulation of environmental gas tracers with integrated surface and subsurface hydrological models, Front. Water **4** (2022).

P 13.22
An improved definition of the Habitat Suitability Index for brown trout including the role of macroroughness

Francesca Padoan[1], Giulio Calvani[1], Giovanni De Cesare[1], Paolo Perona[1]

[1] *Platform of Hydraulic Constructions PL-LCH (IIC-ENAC), Ècole Polytechnique Fédérale de Lausanne, Lausanne, Switzerland (francesca.padoan@epfl.ch)*

The Habitat Suitability Index (HSI) is a quantitative measure that has been developed to help aquatic ecologists, river scientists and engineers identifying preferred habitats for a particular species (Raleigh et al., 1984; Shim et al., 2020, among others). To this aim, the quantification of the HSI usually considers several parameters, identifying food availability and environmental characteristics, and combines them in a comprehensive indicator. For the specific case of mountain river habitats and the brown trout (Salmo trutta L.), the HSI considers environmental variables such as water temperature, flow velocity, water depth, and substrate type (e.g., Raleigh et al., 1984). However, in mountain streams, the interaction between large bed materials (e.g., cobbles and boulders) and the flow field is responsible for the formation of local wake zones in the river reaches that fish can use as shelters to rest or feed, and its inclusion in the quantification of the HSI via manual surveys can be very time consuming. In this work, we build on a recent literature work to correct actual HSI in the low-flow range where the presence of macroroughness is particularly evident when the flow stage is in the order of the grain size of such large boulders (i.e., macroroughness regime). This technique is based on the derived distribution approach and is particularly useful to take the spatial distribution of large stones/obstacles into accounts (Niayifar et al., 2018). As a result, we provide the HSI as a function of the flow magnitude and show that the correction due to the role of macroroughness can generate an additional peak at low discharges thus making the HSI function bimodal. This more detailed definition of the HSI is particularly useful to refine hydrodynamic models and their use to better assess new habitat formation following renaturation measures.

REFERENCES

Niayifar, A., Oldroyd, H. J., Lane, S. N., & Perona, P. (2018). Modeling macroroughness contribution to fish habitat suitability curves. Water Resources Research, 54(11), 9306-9320.

Raleigh, R. F., Zuckerman, L. D., & Nelson, P. C. (1984). Habitat suitability index models and instream flow suitability curves: brown trout. Western Energy and Land Use Team, Division of Biological Services, Research and Development, Fish and Wildlife Service, US Department of the Interior.

Shim, T., Kim, Z., Seo, D., Kim, Y. O., Hwang, S. J., & Jung, J. (2020). Integrating hydraulic and physiologic factors to develop an ecological habitat suitability model. Environmental Modelling & Software, 131, 104760.

P 13.23
Dispersion of artificial tracers in ventilated caves

Claudio Pastore[1,2], Marc Luetscher[1], Amir Sedaghaktish[1,2], Frédéric Doumenc[3,4], Eric Weber[1], Pierre-Yves Jeannin[1]

[1] *Swiss Institute for Speleology and Karst Studies (SISKA), Rue de la Serre 68, 2300 La Chaux-de-Fonds, Switzerland, (claudio.pastore@isska.ch)*
[2.] *Université de Neuchâtel, Avenue du 1er-Mars 26, 2000 Neuchâtel, Suisse*
[3] *Université Paris-Saclay, CNRS, FAST, 91405, Orsay, France*
[4] *Sorbonne Université, UFR 919, 4 place Jussieu, F-75252 Paris Cedex 05, France*

The high permeability characterizing the karst vadose zone favours significant air circulation. Together with water fluxes, airflows are recognised to drive the transport of bacteria, fungi, pollens and airborne matter, but also hazardous gases and aerosols in general, into the deeper part of the network.

Therefore, ventilation is an efficient mode of transport for aerosols in caves, and there is a strong relationship between cave air motion, aerosol/gas transport, and subsequent deposition and spatial distribution in cave systems.
Modelling this airborne transport requires geometrical and physical parameters, including the conduit cross-section areas, the airflow, and more specifically the average air speed as well as the longitudinal dispersion coefficient () related to the advective fluxes. Longitudinal dispersion can be described as the spreading of a solute along the longitudinal axis of the flow.

Using punctual injection of artificial CO_2 in different cave and mine settings, we demonstrate that it is possible to infer reliable geometric information (average cross-sections) when compared to topographic survey, and a more accurate estimate of average air velocity (peak tracer velocity) otherwise difficult to estimate along conduits with complex geometries. Moreover, we estimate the longitudinal dispersion , fundamental to solving the 1-D advection-diffusion equation, using Chatwin's method (Chatwin, 1971)it is argued, has certain advantages over more usual methods. It is shown that Fischer's observations in an open channel were not made at a sufficient distance downstream from the point of injection for Taylor's theory to apply but that they are consistent with a description of the early stages of the dispersion process due to Sullivan (1968. This method is commonly used in hydrogeology to estimate the retardation of the tracer related to the tailing.

In caves, where conduits are far from smooth, the ratio (where d is the conduit diameter and U* is the friction velocity) is much higher than that predicted by Taylor's theory. According to Taylor's (1954) experiments, in smooth pipes, the ratio is constant and equal to 5.05. During our experiments, this ratio was three or more times higher.

We suggest also that the method could be used with opportune adjustments to similar breakthrough curves carried out for any aerosols moving along a ventilated pipe.

REFERENCES

Chatwin, P.C., 1971: On the interpretation of some longitudinal dispersion experiments. J. Fluid Mech. 48, 689–702. https://doi.org/10.1017/S0022112071001800
Taylor, G., 1954: The dispersion of matter in turbulent flow through a pipe. Proc. R. Soc. Lond. A 223, 446–468. https://doi.org/10.1098/rspa.1954.0130

P 13.24
Temporal and spatial comparison of springs in three different mountain regions in the Southern Swiss Alps

Tania Pedimina[1] & Stefanie von Fumetti[1]

[1] *Department of Environmental Sciences, Geoecology, University of Basel, Klingelbergstrasse 27, CH-4056 Basel (tania.pedimina@unibas.ch)*

Springs in the Alps are environmentally stable and biodiverse habitats, which are threatened by anthropogenic impacts. Due to their environmental stability they may function as refugia for species endangered by climatic changes. In this study springs in three distinct regions within the southern Alps of Switzerland were analyzed to gain a better understanding of how these sensitive habitats are being preserved or affected by environmental changes. Specifically, the study focuses on the springs of Monte Generoso, Monte Tamaro, and Monte Bar in the Canton Ticino. The aim was to conducted a) a spatial comparison of the three mountain summits and b) a temporal comparison of springs at the Monte Generoso, which have been sampled in 2012 for the first time (Bonta, 2012). The sampling of the springs took place in May 2023. Subsequently, an analysis of the ecological conditions (i.e. macroinvertebrate assemblages, ecomorphology, and physiochemistry) of the springs was carried out. The sampling followed standardized protocols set by the FOEN (Lubini et al., 2014). The chosen regions exhibit similar characteristics in terms of valley shape and altitude, but they differ in exposure and geology. Despite their geological dissimilarities, all three selected regions share comparable environmental conditions besides electrical conductivity, which is considerably higher in the Monte Generoso springs (Fig. 1).

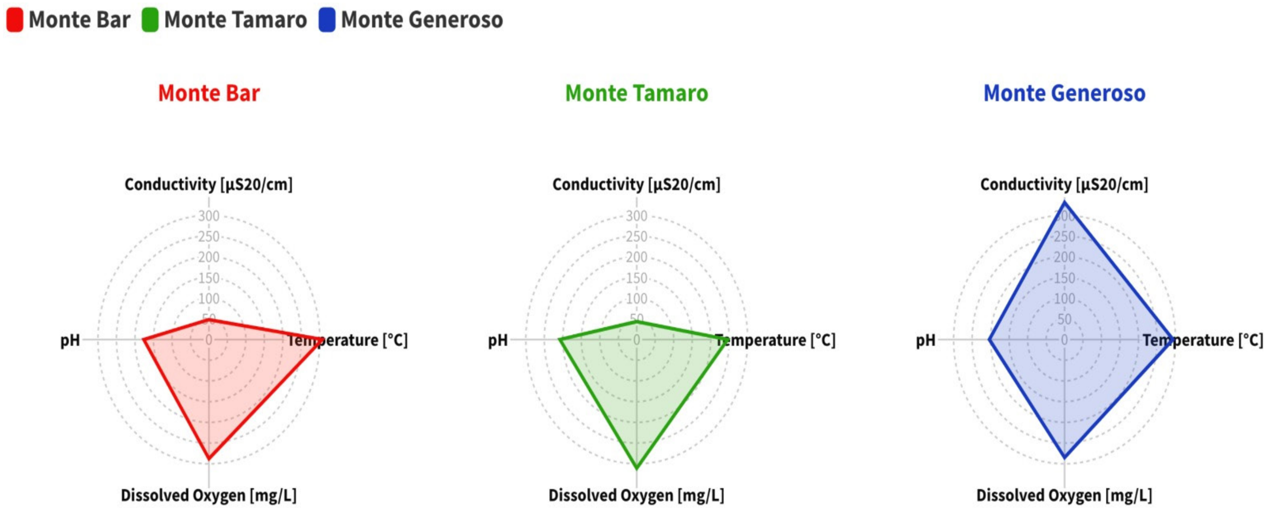

Figure 1: Schematic representation of average measurements (2023) for the 19 springs from Monte Bar (red), Monte Tamaro (green), and Monte Generoso (blue), depicting abiotic factors such as temperature (°C), pH, dissolved oxygen (mg/L), and conductivity (µS20/cm).

While the springs of Monte Bar and Monte Tamaro remain primarily in their natural states, the springs of Monte Generoso show a higher degree of human influence. Initial disparities are observed, particularly in the springs of Monte Generoso: they exhibit minimal presence of Ephemeroptera, Plecoptera and Trichoptera (EPT-Taxa). Other taxa such as Diptera, specifically Chironomidae, as well as Annelida and diverse Crustacea, were consistently abundant across all observed regions. The relatively low number of bioindicators such as EPT-Taxa in Monte Generoso could indicate the potential occurrence of significant eutrophication during these years. This is supported by the observation of numerous cows and signs of intensive pasturing near the sampled springs, particularly in the most impacted areas. The assumed degradation of the springs at Monte Generoso is further supported by the decrease in the number of EPT-Taxa from 2012 to 2023.

Conversely, Monte Bar and Monte Tamaro appear to host more diverse macroinvertebrate assemblages. Both areas seem to be better preserved or less affected by human impacts. As a result, they exhibit a lower number of individuals but a higher diversity. These differences in faunal composition might be due to various factors such as distinct exposures or varying geological characteristics of the regions as well as a different degree of anthropogenic influence. Another possible factor could be the exceptionally dry winter of 2022, during which snowfall was significantly reduced, potentially affecting the microclimate (Zhao et al., 2022) of the springs' soil. This, in turn, could have influenced the macroinvertebrate communities.

REFERENCES

Bonta, S. (2012): Natural characterization of springs and their Biocoenosis in the Canton Ticino (Southern Swiss Alps). MSc Thesis, University of Basel, 79 pp.

Lubini-Ferlin V., Stucki P., Vicentini H., Küry D. (2014): Ökologische Bewertung von Quell-Lebensräumen in der Schweiz. Entwurf für ein strukturelles und faunistisches Verfahren. Bericht im Auftrag des Bundesamtes für Umwelt (BAFU), 33 pp.

Zhao, Z., De Frenne, P., Peñuelas, J., Van Meerbeek, K., Fornara, D.A., Peng, Y., Wu, Q., Ni, X., Wu, F., Yue, K. (2022): Effects of snow cover-induced microclimate warming on soil physicochemical and biotic properties. Geoderma, Volume 423, 115983, ISSN 0016-7061. https://doi.org/10.1016/j.geoderma.2022.115983

P 13.25
Regionalization of Oxygen-18 and Deuterium in precipitation in Switzerland as a basis for hydrological and hydrogeological studies

Valentina Pelzmann[1], Albrecht Leis[1], Marc Schuerch[2], Christian Reszler[1]

[1] *JR-AquaConSol GmbH, Steyrergasse 21, 8010 Graz (valentina.pelzmann@jr-aquaconsol.at)*
[2] *Swiss Federal Office for the Environment (FOEN), Hydrology Division, Hydrogeological Basis Section, 3003 Bern, Switzerland*

The stable isotopes of the water molecule, oxygen-18 and deuterium, are conservative tracers and therefore widely used in hydrology and hydrogeology. The applications comprise, e.g, the determination of the catchment location and water travel times of springs, groundwater wells and surface waters, in the frame of water resources management and protection studies. Long-term data also allow insights into the effects of climate change on the atmospheric conditions (air moisture sources, temperature, evaporation). Crucial part of these studies is the knowledge of the “input” function for the particular catchment or point of interest. This presentation shows the developement and test of a method regionalizing, i.e. interpolating, stable isotope data in precipitation on a monthly basis. Data of the isotope observation network in Switzerland (ISOT), a module of the NAQUA National Groundwater Monitoring, are used as well as data of nearby stations in neighbouring countries. The main influencing variables (e.g., topographical and climate variables) are tested in a multi-regression framework, and the residuals are interpolated by the use of ordinary kriging. The tests are performed by cross-validation, also to provide information about regional differences of the interpolation quality. Monthly maps of oxygen-18 and deuterium, so-called “Isoscapes”, in a 500 m raster has been generated for selected years. As an example, the Isoscape of oxygen-18 in January 2013 is shown in Figure 1. The figure illustrates the high spatial variability in this month due to the topography (e.g., differences between the Plateau and the Alps) as well as the different climate zones (e.g., higher values in the south).

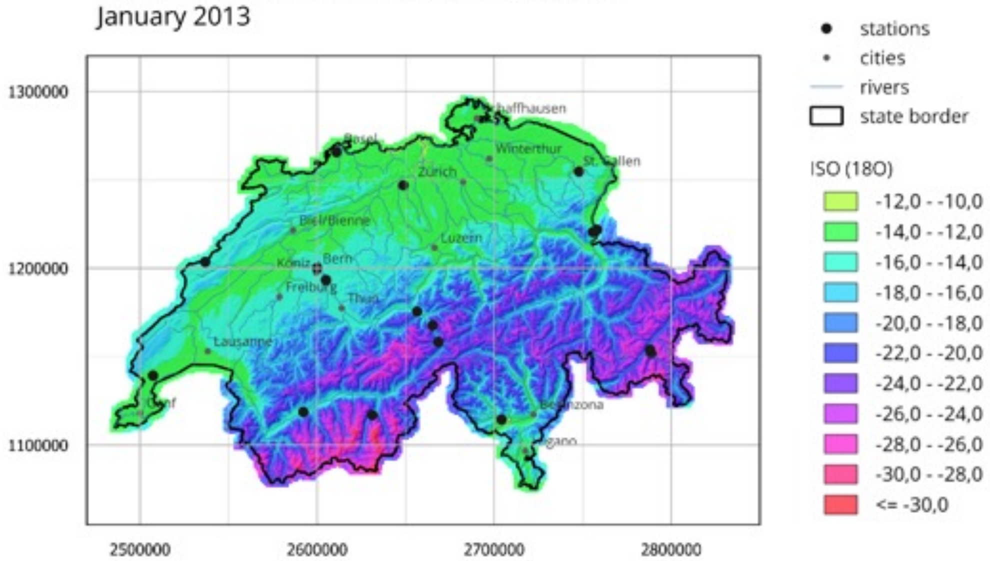

Figure 1. Calculated pattern of oxygen-18 in precipitation in January 2013 for Switzerland in a 500m raster (Swiss reference system: CH1903+ (LV95)).

As a further validation of the method, for particular monitoring sites of groundwater and surface water with known catchments, the “input” function is determined and compared to the measurements. Doing this, existing hydrological and hydrogeological information for the corresponding site could be improved. For example, in Figure 2, precipitation-weighted regional means of oxygen-18 extracted from the Isoscapes are compared to the measured oxygen-18 in groundwater stations, both averaged over seven years. The scatter plot shows that, for most of the catchments the regionalized data fit well to the measurements. Larger deviations are marked with red and blue colour. The red-marked samples/catchments represent an overestimation by the regionlized values. This indicates, that the real catchment of the sample point is located at higher elevation than the catchment polygon that was used to extract the data from the Isoscapes. This is plausible at the corresponding sample points, because they are groundwater wells influenced by a nearby large river with a catchment, that reaches very high altitudes and is dominated by snow and glacier meltwater (e.g., Rhone). At the blue-marked samples the measured data are underestimated by the regionalized data. This indicates larger uncertainties in the Isoscapes. The corresponding sample points are mainly located in the south and at the borders of different topography and climate zones.

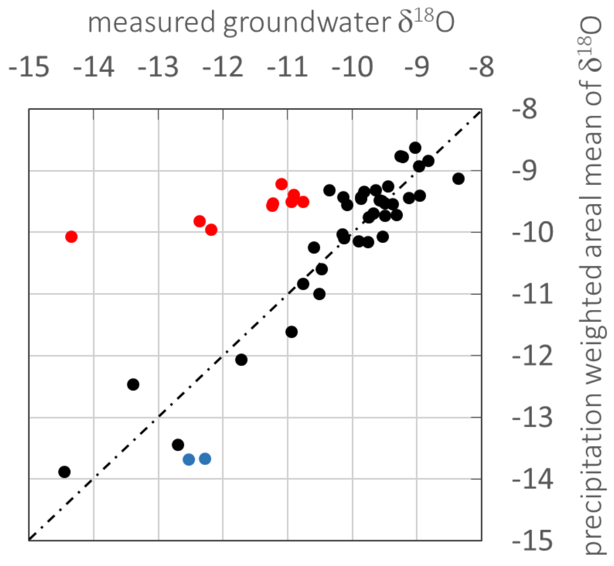

Figure 2. Precipitation-weighted regional mean of oxygen-18 against measured groundwater oxygen-18, both averaged over the period 2007-2013. Red: groundwater stations influenced by a river from the Alps; blue: stations in the south.

Monthly time series for every location can be extracted from the Isoscapes to be used as input in hydrological data analyses and modelling. Therby the data offer new possibilities in water movement and quality research by allowing spatially distinguished insights into the corresponding atmospheric and hydrological processes. By the well tested and validated method, monthly patterns of isotope data in precipitation (Isoscapes) are available at the Swiss Federal Office for the Environment (FOEN) for selected years (2013, and 2020).

P 13.26
Characterization of river/groundwater interactions by signal processing of electrical conductivity time series

Rodolfo Perego[1], Sebastian Pera[1]

[1] *Institute of Earth Sciences, University of Applied Sciences and Arts of southern Switzerland SUPSI - Campus Mendrisio, Via Flora Ruchat-Roncati 15 CH – 6850 Mendrisio (rodolfo.perego@supsi.ch)*

In the framework of climate change that leads to increased frequence of extreme events and to more frequent floodings, river restoration has become a fundamental nature-based solution to reduce the likelihood of flooding events and mitigate their damage on human structures and population.

Canton Ticino, southern Switzerland, currently hosts very important river restoration projects such as the one designed for river Vedeggio, which final part crosses the Vedeggio aquifer before flowing into lake Lugano. Vedeggio aquifer also hosts the two largest drinking water wells of the Canton in terms of pumping rate, Manno and Bioggio, which can provide up to 60 m^3/min of drinking water to the city of Lugano and are strategical to the Cantonal water supply framework. Due to their proximity to the river, it can be assumed that a significant fraction of water pumped by wells is exfiltrated river water.

Both the effectiveness of river restoration and the amount of river water exfiltrating in the aquifer can be studied in detail by designing and operating a high-frequency surface water/groundwater monitoring network.

This work proposes a time-series analysis of electrical conductivity signals, a natural tracer that is already present in the water, propagates fast and is subject to less smoothing than temperature, in order to better understand the correlations between surface water and groundwater. Electrical conductivity signals were treated (detrended, outliers removal) and different signal analysis techniques were applied (simple cross-correlation, optimized cross-correlation and non-parametric deconvolution). The methods converged in the estimate of the lag times between river and groundwater signals, allowing to understand the mutual interactions between surface water and groundwater and estimating the amount of river water flowing into the different piezometers and wells.

This has a double value: from one hand to assess the modifications induced by river restoration projects and from the other hand to improve the management of drinking water wells, understanding their connections to the river channel. The proposed method can be useful for similar cases where river exfiltrates into the aquifer and there is the need to assess how river restoration modifies the interactions between surface and groundwater.

REFERENCES

Vogt, T., Hoehn, E., Schneider, P., Freund, A., Schirmer, M., and Cirpka, O.A. 2010 Fluctuations of electrical conductivity as a natural tracer for bank filtration in a losing stream, Advances in Water Resources (33), pp. 1296-1308.

P 13.27
Radiocarbon Inventories of Switzerland: What controls the radiocarbon signature of dissolved inorganic carbon in Swiss rivers?

Timo M. Y. Rhyner[1*], Benedict V. A. Mittelbach[1], Margot E. White[1], Lisa Broeder[1], Olivier Raymond[1], Negar Haghipour[2], Alexander Brunmayr[3], Florian R. Storck[4], Lucas Passera[4], Melissa S. Schwab[5], Robert Hilton[6], Jürg Zobrist[7], Timothy I. Eglinton[1]

[1] Geologisches Institut, ETH Zürich, Sonneggstrasse 5, 8092 Zürich, Switzerland (timo.rhyner@erdw.ethz.ch)
[2] Department of Physics, Laboratory of Ion Beam Physics, Zürich, Switzerland
[3] Department of Physics, Imperial College London, London, UK
[4] Hydrology Division, Federal Office for the Environment FOEN, Bern, Switzerland
[5] Jet Propulsion Laboratory, California Institute of Technology, United States
[6] Department of Earth Sciences, University of Oxford, Oxford, United Kingdom
[7] Senior Eawag Emeritus, Herracherweg 103, Uster, Switzerland

Carbon transport through rivers represents a fundamental connection linking different reservoirs of the global carbon cycle. Yet the influence of natural and human-induced controls on sources and cycling of riverine carbon remains poorly understood and disentangling the relative importance of their drivers is challenging. Dissolved inorganic carbon (DIC), which typically represents the dominant carbon phase in rivers, derives from a complex array of physicochemical and biological processes. We explore radiocarbon (^{14}C) signatures of DIC carried by Swiss rivers from spatial, longitudinal, and temporal perspectives to assess different source contributions, delivery pathways and dynamics. A total of twenty-one rivers were explored, originating from the five distinct Swiss ecoregions: Jura, Swiss Plateau, Northern Alps, Central Alps, and Southern Alps. The sharp spatial contrasts in elevation, geomorphology, lithology, climatic controls, hydrological and cryospheric characteristics, as well as anthropogenic influences (Botter et al., 2019; Nussbaum et al., 2014) in their corresponding drainage basins allow for the assessment of regional-scale controls on DIC isotopic signatures. We observed marked variability in riverine $\Delta^{14}C$ of DIC with values ranging from -301‰ (2840 ^{14}C yr) to -41‰ (450 ^{14}C yr), indicating a large diversity in sources and processes contributing to fluvial DIC loads. In general, mean basin elevation correlated negatively with $\Delta^{14}C$ of DIC (i.e., older ages at higher elevation), however additional factors such as lithology and seasonal controls also exert a strong influence. The influence of the latter factors is exemplified by a closer look into the longitudinal variations along the Engadin Valley. Here, weathering processes in the upper and lower Engadin manifest themselves into differences in magnitude of longitudinal variability of fluvial radiocarbon signals, with seasonal modulation of $\Delta^{14}C$ values. To test whether this observation of the characteristic dependency of DIC on rock-weathering processes persists, we extend this longitudinal view onto the Upper Rhone Valley in Switzerland. This longitudinal perspective is complemented by a monthly time-series of the Sihl River, providing a temporal perspective and further insights into the complexity of seasonally changing source contributions to the DIC pool. We apply mass balance calculations using radiocarbon and supporting data to constrain petrogenic, biospheric, cryospheric and atmospheric sources of DIC in Swiss rivers. Our ultimate goal is to explore how carbon export from different drainage basins and ecoregions may evolve in the face of on-going regional climate and environmental change.

REFERENCES

Botter, M., Burlando, P., & Fatichi, S. (2019). Anthropogenic and catchment characteristic signatures in the water quality of Swiss rivers: A quantitative assessment. Hydrology and Earth System Sciences, 23(4), 1885–1904. https://doi.org/10.5194/hess-23-1885-2019

Nussbaum, M., Papritz, A., Baltensweiler, A., & Walthert, L. (2014). Estimating soil organic carbon stocks of Swiss forest soils by robust external-drift kriging. Geoscientific Model Development, 7(3), 1197–1210. https://doi.org/10.5194/gmd-7-1197-2014

P 13.28
Poschiavino Critical Zone Observatory: monitoring impacts of climate change on alpine cryo-hydrological systems

Clément Roques[1], Landon Halloran[1], Cyprien Louis[1], Ronan Abhervé[1], Luc Illien[2], Christoff Andermann[2,3], Niels Hovius[2], Nicolas Oestreicher[4], Ronny Figueroas[1], and the CHYN team[1]

[1] *Centre for Hydrology and Geothermics (CHYN), Université de Neuchâtel, Neuchâtel, Switzerland.*
[2] *GFZ, German Research Centre for Geosciences, Potsdam, Germany*
[3] *Univ Rennes, CNRS, Geosciences Rennes, UMR 6118, 35000 Rennes, France*
[4] *Department of Earth Sciences, Institute of Geology, ETH Zürich, Zürich, Switzerland*

Mountains are the "water towers" of the hydrological cycle, storing water as snow, ice, and groundwater which is progressively delivered to the valleys. The cryosphere is a key component of alpine hydrology, controlling groundwater storage and stream runoff dynamics. Recent observations have revealed long-term modifications in stream discharge and water quality which have been attributed to increasing degradation of the cryosphere due to climate change. Considering that the degradation of the cryosphere is likely to have an important impact on interdependent natural- and socio-ecosystem services, there is an urgent need to provide reliable predictions of future water availability in a changing climate perspective. However, quantifying and predicting the impact of cryosphere degradation on water resources availability remain major challenges for the Critical Zone community. This is a direct consequence of the difficulties in gathering relevant data at high elevations and a lack of fundamental understanding of the processes that need to be integrated in numerical tools at relevant spatiotemporal scales.

The University of Neuchâtel is currently developing a Critical Zone Observatory dedicated to the monitoring of cryo-hydrological systems. The catchment is located in the Swiss Alps, in the Bernina range of Canton Grisons (Figure 1). It is a unique infrastructure with 18 boreholes previously drilled for a hydroelectricity project (Lago Bianco Pump storage project, RePower). The boreholes are about 200 meters deep, and located at elevations ranging from 1'000 to 2'400 masl. Boreholes have been cored and logged with optical televiewer for lithological and fracture mapping, and tests have been performed to infer hydraulic properties of the bedrock. Variations in pore pressures have been recorded in all boreholes from 2010 to 2018. Since 2018, the monitoring setup has been maintained on eight selected boreholes. In addition, river gauge stations owned by the Swiss Federal Office of Environment, located on the Poschiavino river and one on the Val d'Ursé river, were installed in 2017. The sub-catchment of Val d'Ursé is the focus of active research, with a higher density of environmental sensors (Figure 1c). This catchment hosts a major rock glacier located on its north-east facing slope, which strongly contributes to spring and stream discharge dynamics through freezing/thawing cycles. Several perennial and non-perennial springs are currently monitored for water temperature and conductivity to quantify mixing. The catchment is also equipped with two passive seismic stations that were also deployed by the GFZ in 2022 to record ambient seismic noise.

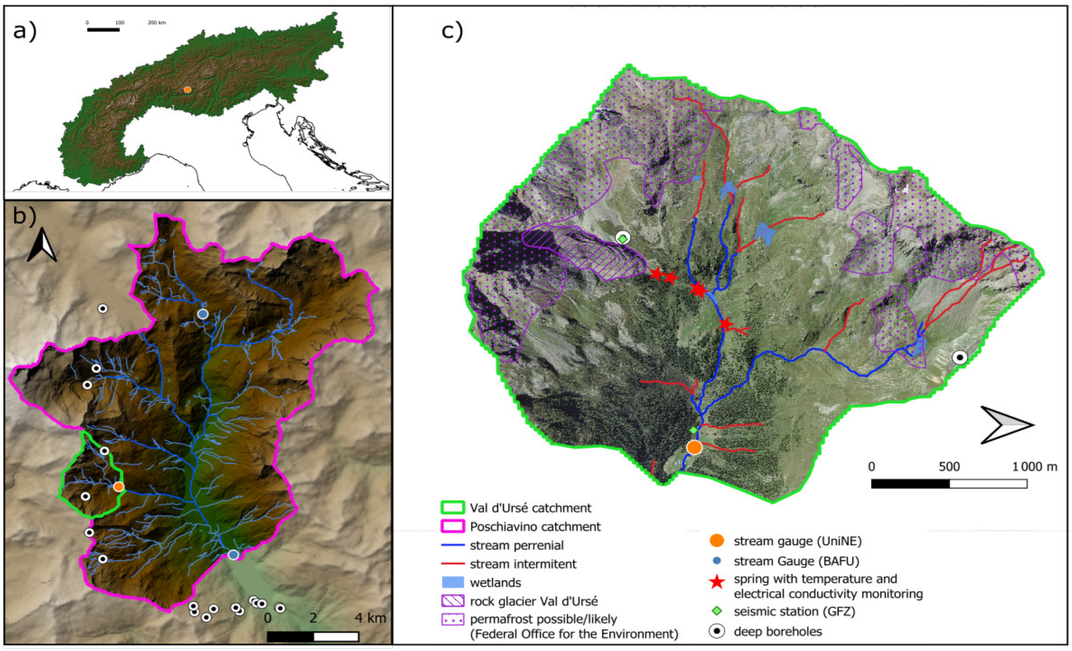

Figure 1. Location and monitoring setup of the Poschiavino Observatory (a-b) and overview of the Val d'Ursé sub-catchment and its monitoring settup (c).

The amount and quality of data provided by the Poschiavino CZO is rare for a high Alpine setting. In our presentation, we will provide an overview of: 1) the data that are currently available, 2) the current knowledge on the hydrological functioning of the site, 3) the hypotheses driving our work, and, 4) the perspectives for future multi-disciplinary collaboration.

P 13.29
Microplastic pollution in rivers: concentrations, environmental drivers and biological risks in Lake Lugano watershed

Federica Rotta[1,2], Luca Gallitelli[3], Matteo Roncoroni[1], Camilla Capelli[1], Barbara Leoni[4], Agnese Marchini[2], Fabio Lepori[1]

[1] *Institute of Earth Sciences, Department of Environment Constructions and Design, University of Applied Sciences and Arts of Southern Switzerland, Via Flora Ruchat-Roncati 15, CH-6850 Mendrisio, Switzerland (federica.rotta@supsi.ch)*
[2] *Department of Earth and Environmental Sciences, University of Pavia, Italy*
[3] *Department of Sciences, University Roma Tre, Italy*
[4] *Department of Earth and Environmental Sciences, University of Milano-Bicocca, Italy*

Since the Industrial Revolution, tons of plastic waste have been dispersed into the environment, of which approximately 10% have ended up in rivers, lakes and oceans (Mora-Teddy & Matthaei, 2020). Long exposure to environmental factors (e.g. UV radiation, wind and wave action) eventually weathers and breaks up of large plastics into particles below 5 mm, known as microplastics (MPs). Because of the large volumes involved, MPs have become one of the most widespread pollutants of the 21st century.

Rivers are an important component in the MP pathway, carrying approximately 70 - 80% of all plastic waste entering the marine environment (De Carvalho et al., 2021). In addition, recent research indicates that riverbeds retain high amounts of MPs and that riverine biota (e.g. macroinvertebrates and fish) frequently ingest MPs, potentially causing ecological impacts. However, research on the distribution and behavior of MPs within river ecosystems is still limited.

We present preliminary results from an ongoing study promoted and funded by the International Commission for the Protection of Italian-Swiss Waters (CIPAIS), which aims to assess MP pollution in small rivers located in Lake Lugano's catchment. Recent research has reported high concentration of MPs in the surface waters of this lake compared to other lakes in Switzerland and abroad (Nava et al., 2023). In contrast, no other studies have addressed the contamination of the rivers in the catchment, which comprise eight tributaries and the lake's outlet.

In this study, environmental samples of MPs were collected using nets (mesh: 0.25 mm) and a sediment sampler to (1) measure the abundance of MPs in the water column and sediments, further divided into coarse sediments and fine sediments; and (2) identify, through data analysis, the main environmental factors influencing MP pollution in rivers (e.g. water velocity, presence/absence of wastewater treatment plants upstream, percentage of urbanized land in the upstream catchment). In addition, the MPs in the gut of benthic macroinvertebrates (plastic burden) were analyzed with the objective to (3) examine ingestion levels by riverine biota.

MPs were found in all the studied rivers (mean: water column 8.4 MP m^{-3}, sediments 33.7 MP kg^{-3} dry weight), in concentrations comparable to those found in the water column and sediments of large urban rivers around the world (D'Avignon et al., 2022). Moreover, MP particles (< 50 μm) were found in approximately 80% of individual macroinvertebrates at all sites. The variability in MP concentration among rivers was not explained by any of the environmental factors considered, suggesting that MP pollution reflected unmeasured local point sources rather than large-scale catchment characteristics. In addition, the MP burden of macroinvertebrates was unrelated to the MP environmental concentration (cf. Windsor et al., 2019).

Our results support the idea that small rivers are both important pathways for MP transport and sites of high MP accumulation. In addition, the high MP burden observed in benthic macroinvertebrates indicates that plastic particles enter into riverine food webs, posing a risk to these organisms and, potentially, organisms at higher trophic levels.

This study, along with other ongoing research on MP in Lake Lugano's catchment, will provide a comprehensive basis to understand the spatial and temporal variability of MPs and reveal the complex dynamics that drive MP pollution in fresh-water ecosystems.

REFERENCES

D'Avignon, G., Gregory-Eaves, I., Ricciardi, A., 2022: Microplastics in lakes and rivers: an issue of emerging significance to limnology. Environmental Review 30, 228-244.

De Carvalho, A.R., Garcia, F., Riem-Galliano, L., Tudesque, L., Albignac, M., ter Halle, A., Cucherousset, J. 2021: Urbanization and hydrological conditions driven the spatial and temporal variability of microplastic pollution in the Garonne River. Science of the Total Environment 769, 144479.

Mora-Teddy, A.K. & Matthaei, C.D. 2020: Microplastic pollution in urban streams across New Zealand: concentrations, composition and implications. New Zealand Journal of Marine and Freshwater Research 54:2, 233-250.

Nava et al., 2023: Plastic debris in lakes and reservoirs. Nature 619, 317-322.

Windsor, F.M., Tilley, R.M., Tyler, C.R., Ormerod, S.J. 2019: Microplastic ingestion by riverine macroinvertebrates. Science of the Total Environment 646, 68-74.

P 13.30
Monitoring of river-induced bottom currents in Swiss lacustrine deltas

Gaétan Sauter[1], Damien Bouffard[2,3], Koen Blanckaert[4] Katrina Kremer[1,5]

[1] *Institute of Geological Sciences and Oeschger Centre for Climate Change Research, Baltzerstrasse 1+3, CH-3012 Bern, Switzerland*
[2] *Swiss Federal Institute of Aquatic Science and Technology (EAWAG), Department Surface Waters – Research and Management, Kastanienbaum, Switzerland.*
[3] *Faculty of Geoscience and Environment, University of Lausanne, Lausanne, Switzerland*
[4] *TU WIEN Research Unit Hydraulic Engineering and Environmental Hydromechanics*
[5] *Swiss Seismological Service, ETH Zurich, Sonneggstrasse 5, CH-8092 Zurich, Switzerland*

Slopes failures in deltas have the potential to induce underwater mass movements that can be tsunamogenic as shown in historical records. For instance, in 1687 AD, the spontaneous Muota Delta failure caused a 4-meter wave height (Hilbe and Anselmetti, 2015), while in 1996 AD, the triggered Aare Delta failure generated a 50-centimeter wave (Girardclos et al., 2007). The processes responsible for such delta failures remain unclear and notably the dynamic of erosion and deposition pattern of sediments in sublacustrine deltas. We propose to combine moored Acoustic Doppler Current Profilers (ADCPs) and repeated bathymetric mapping to advance in this research gap.

Here, we focus on two ADCPs measurement campaigns in the Aare delta in Lake Brienz in 2022 and the Muota Delta in Lake Lucerne in 2023. In both cases, two moorings with downward-looking ADCPs were deployed for a period of three months. Measured bottom currents are subsequently compared with other parameters, including river parameters from the Federal Office of Environment FOEN (discharge, temperature, turbidity), meteorological data from Meteoswiss (wind speed, wind directions, rainfall).

Our analysis highlights the large variability in bottom lake currents in submerged channels near river mouths and especially their linkage with wind and river discharge. The next steps will be to (i) fully characterize the triggers responsible for such currents in the deltaic area and (ii) to combine such hydrodynamic observations with repeated bathymetry mapping and finally better asses the origin and distribution of sediments related to these bottom currents.

REFERENCES

Girardclos S, Schmidt OT, Sturm M, Ariztegui D, Pugin A, Anselmetti FS (2007) The 1996 AD delta collapse and large turbidite in Lake Brienz. Marine Geology 241 (1-4):137-154

Hilbe M, Anselmetti FS (2015) Mass Movement-Induced Tsunami Hazard on Perialpine Lake Lucerne (Switzerland): Scenarios and Numerical Experiments. Pure and Applied Geophysics 172 (2):545-568. doi:10.1007/s00024-014-0907-7

P 13.31
Implementing a 3D groundwater model to simulate tree-planting scenarios against urban flooding in Nouakchott city, Mauritania

Barthelemy Simonnot[1], Emmanuel Dubois[1], Montana Marshall[1], Charlotte Grossiord[2], Paolo Perona[1]

[1] Platform of Hydraulic Constructions (PL-LCH), Civil Engineering Department, Ecole Polytechnique Federale de Lausanne (EPFL), Station 18, 1015 Lausanne, Switzerland
[2] Plant Ecology Research Laboratory (PERL), Civil Engineering Department, Ecole Polytechnique Federale de Lausanne (EPFL), Station 2, 1015 Lausanne, Switzerland

Despite its hot desert climate, parts of Nouakchott City, the capital of Mauritania, experience persistent flooding due to combined soil saturation excess and surface runoff, which causes damage to urban infrastructure and health issues. An investigation into the potential of tree planting as a solution to mitigate flooding is underway in Nouakchott. The city is located by the Atlantic Ocean that acts as a hydraulic boundary condition and contributes to the shallow aquifer that outcrops in the low-lying areas of the city. Another source of groundwater recharge lies in the infiltration of wastewater in the city. In the absence of a wastewater network, individual septic systems in households act as a diffuse artificial groundwater recharge system throughout the city.

By utilizing information provided by local stakeholders regarding the distribution system for domestic water (domestic water network and kart delivery), a conceptual map of artificial groundwater recharge was created, estimating recharge volumes for each neighborhood. As well, groundwater levels have been intermittently measured since 2015 across a network of 13 observation wells, while five automatic sensors have been sampling water depths since February 2023. Along with these measured data, a time series of the flooded areas in Nouakchott was reconstructed for the 2017-2023 period based on remote sensing data.

The goal of this project is to quantify the impacts of tree planting scenarios on lowering the groundwater table and potentially reducing the risk of flooding in the city.

Using the available geological and hydrogeological data, a 3D groundwater model was established using the FREEWAT software (Rosetto et al., 2018), which is built upon the MODFLOW code. The model was calibrated using groundwater level observations and the reconstructed time series of flooded areas. Additionally, five tree species were identified as suitable for such a long-term solution and are being monitored with sap flow meters since February 2023 to measure their transpiration. Based on the measured transpiration rates, a groundwater level-vegetation feedback routine is being implemented in order to formulate effective tree planting scenarios.

These scenarios aim to optimize the trees' impact on the water table while respecting local layout conditions, considering that trees are not yet abundant in public spaces and available space can be constrained.

REFERENCES

Rossetto, R., De Filippis, G., Borsi, I., Foglia, L., Cannata, M., Criollo, R., & Vázquez-Suñe, E. (2018). Integrating free and open source tools and distributed modelling codes in GIS environment for data-based groundwater management. Environmental Modelling & Software, 107, 210–230. https://doi.org/10.1016/j.envsoft.2018.06.007

P 13.32
Extreme water temperatures in mountain rivers

Amber van Hamel[1,2,3*], Manuela Brunner[1,2,3]

[1] WSL Institute for Snow and Avalanche Research SLF, Davos Dorf, Switzerland
[2] Institute for Atmospheric and Climate Science, ETH Zurich, Zurich, Switzerland
[3] Climate Change, Extremes and Natural Hazards in Alpine Regions Research Center CERC, Davos Dorf, Switzerland
**amber.vanhamel@slf.ch*

Human-induced warming, accompanied by more frequent extreme weather phenomena such as heat waves and prolonged drought, can result in extreme river water temperatures. Since water temperature is one of the main variables regulating physical, chemical and biological processes in streams, extreme water temperatures potentially result in severe impacts on both human resources and the survival of aquatic ecosystems. Despite the importance of extreme water temperatures, current research has mainly focussed on changes in mean water temperature. As there is little research on water temperature extremes, this project aims to improve our understanding of the spatial and temporal processes influencing the occurrence of current and future water temperature extremes in mountain rivers in Europe.

In this study, we analyze both temporal changes and spatial variability in the occurrences of water temperature extremes in mountain regions. First, to gain insights into the temporal variability of these extremes, we compare 30-year data series of water temperature in 18 catchments in the Alps. We apply trend analyses to extract information about the seasonality and long-term trends of these extremes. Second, to understand the frequency, severity and variability of extreme water temperature at a regional scale, we also compare 170 catchments spread over four different mountain regions in Europe. We use random forests to get insight into the importance of different contributing processes and the potential variations of water temperature extremes in both time and space.

Preliminary results of the trend analysis in the Alps show that extreme water temperatures, i.e. water temperature exceeding a locally varying threshold, have increased faster over the summer period 1991-2021 than mean water temperatures. Although the most severe extreme events can be mainly found at low elevations, the number of extreme events has increased over time at all elevations, with the strongest increase for catchments at high elevations. These first insights into the behaviour of water temperature extremes are already valuable for predicting future changes in extremes and the aquatic state of mountain rivers. Additional results on the spatial variation of extreme water temperature and the importance of different contributiong processes are expected soon.

P 13.33
Multiple-point geostatistics-based spatial downscaling of heavy rainfall fields

Wenyue Zou[1*], Guanghui Hu[1,3], Pau Wiersma[1], Shuiqing Yin[2], Grégoire Mariethoz[1], Nadav Peleg[1]

[1] *Institute of Earth Surface Dynamics, University of Lausanne, Lausanne, Switzerland (* wenyue.zou@unil.ch)*
[2] *State Key Laboratory of Earth Surface Processes and Resource Ecology, Faculty of Geographical Science, Beijing Normal University, Beijing 100875, China*
[3] *School of Geography, Nanjing Normal University, Nanjing, 210023, China*

High-resolution gridded rainfall products at sub-daily and 10^0 km scales are required for hydrological applications in mountainous and urban catchments. As most catchments are ungauged, gridded rainfall data are often obtained through remote sensing. However, their spatial resolution is often too coarse (at 10^1 km) and requires to be downscaled to a finer resolution. The challenge is not only to downscale the rainfall intensity to a finer scale by considering areal reduction factors, but also the spatial structure of the storm, as both elements are equally important to the assessment of the surface hydrological response. As a result of the lack of training data, the latter is difficult to obtain. Further development of the stochastic multiple-point geostatistics (MPS) [1] framework is presented to downscale long-term satellite-derived gridded rainfall series using only a few years of high-resolution rainfall observations. We demonstrate how the MPS framework can be used to downscale the satellite-derived CMORPH rainfall from 8 to 1 km resolution for 1998-2019, taking the city of Beijing as a case study, with a specific focus on extreme rainfall events. The high-resolution multisource-merged CMPAS dataset (1 km, hourly), available for 2015-2020, is used as the source of the training images. We show that the downscaling framework preserves the observed mean areal rainfall (with a bias of 2%), reproduces the spatial coefficient of variance (with a similar bias), and also retains extreme rainfall at the 99th percentile (with a bias of 6%). Furthermore, it adequately reproduces the rainfall spatial structure, preserving the variograms of the rainfall fields. Similarities were also observed comparing the 2- to 30-year return period maps of the downscaled rainfall extreme with ground observations, with half of the stations (10 out of 19) agreeing on the location and intensity of the extreme rainfall for all return periods**.** The results indicate that our framework downscales rainfall intensities and preserves the spatial structure well, especially for heavy rainfall, even if limited data is available. The proposed approach can be applied to other rainfall datasets and regions.

REFERENCES

[1] Gravey, M., Mariethoz, G., 2020. QuickSampling v1.0: a robust and simplified pixel-based multiple-point simulation approach. Geosci. Model Dev. 13, 2611–2630. https://doi.org/10.5194/gmd-13-2611-2020

P 13.34
Radiocarbon Inventories of Switzerland: Sources and cycling of dissolved organic carbon in Swiss lakes

Margot E. White[1], Benedict V.A. Mittelbach[1], Timo Rhyner[1], Negar Haghipour[1,2], Martin Wessels[3], Nathalie Dubois[1,4], and Timothy I. Eglinton[1]

[1] *Department of Earth Sciences, ETH Zürich, Switzerland (margot.white@erdw.ethz.ch)*
[2] *Laboratory for Ion Beam Physics, ETH Zürich, Switzerland*
[3] *Institut für Seenforschung der LUBW, Langenargen, Germany*
[4] *Department Surface Waters Research & Management, EAWAG, Dübendorf, Switzerland*

The Radiocarbon Inventories of Switzerland project (RICH) aims to establish a first-of-its-kind national inventory of radiocarbon for the country of Switzerland, emphasizing the role of aquatic systems as transporters, integrators, and processors of carbon. Delineating how environmental changes impact the carbon cycle requires a thorough understanding of reservoirs, fluxes, and processes - a task for which natural abundance radiocarbon is uniquely suited. Here, we focus on dissolved organic carbon (DOC) in Swiss lakes. DOC plays a crucial role in both nutrient transport and food web dynamics in aquatic ecosystems. By widely applying ^{14}C measurement of lake water DOC for the first time in ~15 lakes across Switzerland, we gain new insight into the sources and cycling of this important carbon pool. The ^{14}C signature of DOC produced by *in situ* primary productivity is constrained by concurrent measurements of dissolved inorganic carbon (DIC). In addition to radiocarbon and stable carbon isotope measurements, we use fluorescence and absorbance properties of dissolved organic matter to disentangle sources and understand the composition of lake water DOM. We find a range in the contributions of allochthonous DOC across lakes with different watershed characteristics and trophic states. Monthly measurements from Lake Constance and Lake Geneva further help to constrain seasonal changes in primary productivity and river influence, which impact the composition of DOC within these large oligotrophic lakes.

P 13.35
Reconstructing High-Resolution Snow Water Equivalent (SWE) Data for Improved Water Resource Management (1950-2100)

Fatemeh Zakeri [a,b] , Gregoire Mariethoz [a], Manuela Girotto [b]

[a] *Institute of Earth Surface Dynamics, Faculty of Geosciences and Environment, University of Lausanne, Lausanne, Switzerland*
[b] *Department of Environmental Science, University of California Berkeley, Policy, and Management, Berkeley, CA, USA*

Accurate knowledge of Snow Water Equivalent (SWE) is essential for water resource management, climate change insights, and hydrological studies. However, obtaining precise SWE data at high resolution remains challenging due to limitations in satellite, climate, and in-situ information. This research introduces an innovative method to derive daily SWE data spanning from 1950 to 2100 at a 500 m resolution. Utilizing the WUS–UCLA dataset, which offers daily 500 m SWE details for the years 1985–2021, this study seeks to bridge both the temporal and spatial resolution gaps.

Our methodology builds on recurring snow patterns and incorporates meteorological predictors from the low-resolution CMIP version 6 simulations with a 100 km resolution. We utilize the K-nearest neighbor algorithm paired with a specialized similarity metric to estimate SWE values. The approach selects days with available SWE data whose meteorological conditions match those of a query day lacking SWE, and then it estimates the SWE for that day.

To evaluate the effectiveness of our technique, we employed a leave-out cross-validation method and compared our results with the 1 km SWE Daymet and 4 km SWE datasets from the University of Arizona. In this validation, 80% of the days from the WUS–UCLA dataset were used as the learning set, while the remaining 20% were for validation. Our results reveal a strong alignment between our estimated SWE and actual observations, indicating this methodology’s promise for enhancing water resource management and climate research.