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ZHydro is a celebration of current hydrological research in Zürich. It is an annual day-long meeting in November of hydrologists working at the various departments and institutes in the Zürich area – mostly groups at ETH Zürich, University of Zürich, EAWAG and WSL. It is aimed mainly at PhD students and Postdocs, and in particular at new incoming scientists, who present their current research and network with peers. ZHydro is organized on a rotational basis by one of the participating chairs. In case of questions, please contact one of the organizers.

WHEN: 27 November 2024 (Wednesday) from 8:30-16:30

WHERE: ETH Zentrum, MM C 78.1 (Alumni Pavillon) next to top station of Polybahn

FORM: 12 talks (10 & 20 mins), 4 posters

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(orange)	10+5 mins
(green)	20+5 mins

Time	Oral contributions	Presenter
08:30-09:00	**Healthy breakfast**	
09:00	**Welcome address**	**Fabrizio Fenicia** (Eawag)
	Session 1	
09:05	Anna Leuteritz, Victor Gauthier: **Overland Flow and Topsoil Interflow during natural and artificial rainfall events in a pre-Alpine Catchment**	**Anna Leuteritz, Victor Gauthier** (UZH)
09:30	Jovan Blagojevic, Nadav Peleg, Athanasios Paschalis, Francesco Marra, Peter Molnar: **Estimating Present and Future IDF Curves Using Global Precipitation and Climate Projection Data**	**Jovan Blagojevic** (ETH)
09:45	Yann Yasser Haddad**,** Lukas Gudmundsson, Jonas Savelsberg, Jared Garrison, Elena Raycheva Tobias Wechsler, Massimiliano Zappa, Gabriela Hug, and Sonia I. Seneviratne: **Vary me a river: impacts of climate variability on run-of-river hydropower and electricity** systems planning in Switzerland	**Yann Yasser Haddad** (ETH)
10:00	**Poster Headlines**	**VA**
10:15	**Coffee break (Posters)**	
	Session 2	
11:10	Marit van Tiel, Matthias Huss, Walter Immerzeel, Bettina Schaefli and Daniel Farinotti: **Linking observed glacier mass loss to worldwide streamflow trends**	**Marit van Tiel** (ETH, WSL)
11:35	Basil Kraft**,** Michael Schirmer, William H. Aeberhard, Massimiliano Zappa, Sonia I. Seneviratne, Lukas Gudmundsson: **Towards deep learning-based river flow modelling for Switzerland**	**Basil Kraft** (ETH)
11:50	Christian Moeck, Carl Love Raman Vinna, Jannis Epting, Joaquin Jimenez-Martinez, Mario Schirmer, John Molson ,Raoul Collenteur: **Modelling Climate Change Impacts on Future Groundwater Recharge and Temperature Trends: Insights from a Lysimeter Data** Simulation	**Christian Moeck** (Eawag)
12:05	Paul C. Astagneau, Jonas Peters, and Manuela I. Brunner: Causal invariance for robust estimation of hydrological parameters	**Paul C. Astagneau** (WSL, ETH, CERC)
12:20-13:30	**Lunch break (poter viewing possible), independent**	
	Session 3	
13:30	Peter Lehmann and Andrea Carminati: **Meaning and use of soil hydraulic properties at increasing spatial scales: from cm to km**	**Andrea Carminati, Peter Lehmann** (ETH)
13:55	Julie Faure, Marc Muller, Leonardo Bertassello, Elizabeth Dolan, Ellis Adams, Rahman Sulaimanov, Diane Desierto, Portia Chigbu, and Jonathan Pabillore: **Mapping Water Security and Governance to Human Rights in Water-Intensive Industries**	**Julie Faure** (Eawag)
14:10	Joren Janzing, Niko Wanders, Marit van Tiel, and Manuela I. Brunner: **High and dry: understanding the spatiotemporal evolution of streamflow droughts in the larger Alpine region**	**Joren Janzing** (WSL, CERC, ETH)
14:25	Stefano Martinetti, Julian Schoch, Andrea Carminati, Marius G. Floriancic, Peter Molnar: **The effect of plant-hydraulic traits and soil drying on transpiration dynamics of beech and spruce**	**Stefano Martinetti** (ETH)
14:40	Thiago Nascimento, Julia Rudlang, Marvin Hoege, Jan Seiber, Markus Hrachowitz and Fabrizio Fenicia: **Recent advances in the development of integrated datasets of streamflow, water quality, hydro-climatic, and landscape variables for Europe**	**Thiago Nascimento** (Eawag)
14:55-15:05	**Short break**	
	Session 4: Farewell honors	
15:10	**OUTLOOK 2025 and closing of the general presentations**	**Fabrizio Fenicia** (Eawag)
15:20-15:30	**Farewell Paolo Burlando**	**Manfred Stähli** (WSL)
15:30-16:30	**Apero**	

Poster contributions	Presenter
Andrés Velásquez-Parra and the ARTS Scientific Team: **Towards the energy transition: understanding aquifer reaction to underground energy storage**	**Andrés Velásquez-Parra** (Eawag, ETH)
Christian Moeck, Joaquin Jimenez-Martinez, M. Schirmer, R.A. Collenteur: **Diving into data: The Swiss Groundwater Database 1.0**	**Christian Moeck** (Eawag)
Pauline Seubert, Stephan Thober, Dominik L. Schumacher, Sonia I. Seneviratne, Lukas Gudmundsson: **250-years of global river flow from routed CMIP6 runoff: Dataset validation and future projections**	**Pauline Seubert** (ETH)
Amber van Hamel, Peter Molnar, and Manuela I. Brunner*:* **Suspended sediment concentrations in Alpine rivers: from annual cycles to sub-daily extreme events**	**Amber van Hamel** (WSL, ETH, CERC)

Oral Contributions Abstracts

Overland Flow and Topsoil Interflow during natural and artificial rainfall events in a pre-Alpine Catchment

Anna Leuteritz and Victor Gauthier
University of Zurich, Department of Geography, Hydrology and Climate group

Near-surface flow pathways, such as overland flow (OF) and topsoil interflow (TIF), play a critical role in the hydrological response of headwater catchments, especially those underlain by low permeability soils. To better understand these processes and their interactions, we installed 14 small trenched runoff plots (3 m²) at various topographic positions across the Studibach catchment in the Alptal (Canton Schwyz). We measured the flow rates of OF and TIF together with soil moisture for 27 events and took samples from OF and TIF for 12 events. Additionally, we conducted artificial rainfall experiments on two large (>80 m²) trenched plots: one in a natural clearing in the mixed forest and the other in a pasture. We applied streamwater to the surface of the plots using sprinklers and added tracers to the surface (Uranine, NaCl, deuterium enriched water) and the subsurface (NaBr) once steady-state flow rates were reached. We determined the particle velocity from the break-through curves for OF and TIF. We also added blue dye to the surface to determine the flow path length for OF. Finally, we determined the celerity for OF and TIF by temporarily increasing the rainfall rate at different distances (2, 4 and 6 m) from the trench.

Data collected during the natural rainfall events highlighted the frequent occurrence of OF and TIF (14 to 86% of the events), as well as their high spatial variability. Runoff ratios increased with increasing soil moisture storage and precipitation and were generally higher for sites with a higher Topographic Wetness Index. The hydrograph separation results highlighted the importance of mixing of precipitation with soil water for both OF and TIF, and the frequent occurrence of return flow. The median event water fractions in OF and TIF were 0.68 ± 0.29(SD) and 0.51 ± 0.31, respectively.

The tracer experiments highlighted the rapid transport of water and solutes, as well as the interaction between OF and TIF. Particle velocities for OF and TIF were high for both plots. They were highest for the clearing in the open forest, indicating the importance of preferential flow pathways through macropores and soil pipes.

Overall, these results did not only highlight the importance of near-surface flow pathways for runoff generation in pre-Alpine catchments underlain by Gleysols, but also the high spatial and temporal variability in the occurrence of OF and TIF.

Estimating Present and Future IDF Curves Using Global Precipitation and Climate Projection Data

Jovan Blagojevic[1], Nadav Peleg[2], Athanasios Paschalis[3], Francesco Marra[4], Peter Molnar[1]
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[4]Department of Geosciences, University of Padova, Italy

In this study we present a new methodology for obtaining present and future Intensity-Duration-Frequency (IDF) curves from global precipitation and climate datasets by combining stochastic rainfall modelling and climate projection based adjustments of the rainfall frequency-intensity relations.

With a warming climate, large regions of the world are projected to experience an intensification of extreme rainfall events. This phenomenon is particularly pronounced in the tropical belt, where temperature-rainfall scaling rates have been observed to deviate from the commonly referenced Clausius-Clapeyron (CC) relationship of approximately 7% rainfall intensification per degree Celsius increase. In some cases, scaling rates have reached 2 to 3 times the CC value, while in other instances, no scaling has been observed. At the same time, these tropical regions are expected to experience significant population growth and urbanization in the near future, highlighting the need for a deeper understanding of rainfall intensity-frequency relationships and their projected changes to address rainfall-related hazards.

Global precipitation datasets (eg. CMORPH, GSMaP or MERRA2), often derived from satellite observations and/or coarse-scale climate modelling, provide an accessible means for rainfall-hazard risk related studies in data-scarce regions. However, these datasets tend to missrepresent the short-duration, high-intensity rainfall events, especially those lasting one hour or less, and which belong to the tails of the distributions (i.e., return levels higher than 30-year).

We introduce a methodology for estimating present IDF curves using openly available global datasets and then fitting a joint distribution rainfall-magnitude-temperature model to make predictions for the future IDF curves, based on projected dew point temperature changes from climate models. In the first step, we use high temporal resolution satellite remote sensing rainfall data (GSMaP) to train a stochastic rainfall generator model - the point process Bartlet-Lewis model. The ensemble data generated using the rainfall simulator is used to develop more accurate present climate IDF curves. In the next step, using the dew point temperature as a covariate for modelling the rainfall intensity and adapting the TENAX model procedure, we fit a temperature-dependent rainfall intensity magnitude model to the present climate IDF distribution. The fitting procedure is conducted based on the present climate dew point temperature distribution and the observed rainfall-temperature scaling. Using this fitted model, we then use future-climate dew point temperature distributions, combined with the projected number of rainy days, to construct future climate IDF curves.

Our findings demonstrate that the proposed methodology produces IDF curves with greater accuracy compared to those derived directly from raw global rainfall datasets. Furthermore, future rainfall intensification appears to be highly spatially variable in the tropics, highlighting the importance of site-specific modeling and local measurements and predictions.

Vary me a river: impacts of climate variability on run-of-river hydropower and electricity systems planning in Switzerland

Yann Yasser Haddad[1], Lukas Gudmundsson[1], Jonas Savelsberg[2], Jared Garrison[3], Elena Raycheva[2,4], Tobias Wechsler[5], Massimiliano Zappa[5], Gabriela Hug[5], and Sonia I. Seneviratne[1]
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Clean and renewable energy systems play a pivotal role in climate change mitigation strategies. Nevertheless, climate change constitutes a threat to current and future supply of clean energy.

In this study, we investigate how climate variability affects run-of-river (RoR) hydropower production and electricity systems planning in Switzerland. As the “water tower of Europe”, Switzerland encompasses a wide range of hydro-climatological conditions and showcases a high share of hydropower in its energy mix, making it a relevant case study.

Focusing on all run-of-river hydropower plants with a capacity > 300 kW, we used daily runoff simulations from the PREVAH model, at 500 m resolution spanning 1991-2022, to estimate water availability and hydropower production for each power plant. Our method provides an accurate estimation of national RoR hydropower generation and its variations. Notably, it showcases a slight decreasing trend over the investigated time frame when considering the current RoR infrastructure. Our analysis extends earlier efforts by providing a national assessment at a power plant level and on a continuous historical period.

We then examine the impacts of such variability on the outputs of Nexus-e, an integrated electricity systems modeling framework. Specifically, we run simulations with our different hydropower timeseries under two policy scenarios: “Reference” and “Extreme”. The integration of climate-informed inputs into Nexus-e strongly affects investments in renewables, electricity prices, and imports/exports. We disentangle the climate and policy effects and highlight an exacerbation of the climate effect on electricity prices in the “Extreme” case. Moreover, the two policy scenarios present different strategies to compensate for the variability of RoR hydropower: either through additional imports or further investments in wind power.

The findings raise important questions regarding the implementation of a resilient energy system for Switzerland, in light of increasing changes in the climate system and mounting pressure on ecosystems and biodiversity.

Linking observed glacier mass loss to worldwide streamflow trends

Marit van Tiel[1,2], Matthias Huss[1,2], Walter Immerzeel[3], Bettina Schaefli[4] and Daniel Farinotti[1,2]
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Glacier retreat is causing significant water resource loss in mountainous regions, affecting downstream areas by altering seasonal runoff patterns, summer water availability, and low flow conditions. Many previous studies have focused on specific mountain regions, often using future climate scenarios, to study these impacts. Combining new large-scale remote sensing data of glacier losses with streamflow observations of glacier-fed rivers worldwide offers a better understanding of the observed rate of changes in these high mountain hydrological systems globally. Here we assess how glacier loss has influenced water balances from 2000-2019. The analyses reveal spatial differences in glacier retreat and how this impacts streamflow trends.

Towards deep learning-based river flow modelling for Switzerland

Basil Kraft[1], Michael Schirmer[2], William H. Aeberhard[3], Massimiliano Zappa[2], Sonia I. Seneviratne[1], Lukas Gudmundsson[1]
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Runoff reconstruction supports long-term environmental monitoring, informs water resource management and flood risk assessments, and aids in the evaluation of climate change impacts on hydrological systems.

This study reconstructs daily runoff across Switzerland from 1962 to 2023 using deep learning models that learn runoff processes directly from observations. By inputting temperature and precipitation data available since the 1960s, we create a contiguous spatiotemporal runoff simulation, validated against a widely used hydrological model. Despite the reduced data requirements for achieving a longer reconstruction, our model demonstrates competitive and often improved performance in replicating daily runoff, capturing annual variability, and identifying long-term trends.

The long-term reconstruction highlights a growing number of dry years and a negative decadal trend, especially in summer, offering key insights for managing water resources amid climate change. The model's efficiency and reduced data dependence enable rapid simulation of diverse scenarios, advancing climate attribution studies. The runoff data is available online.

Modelling Climate Change Impacts on Future Groundwater Recharge and Temperature Trends: Insights from a Lysimeter Data Simulation

Christian Moeck[1*], Carl Love Raman Vinna[2], Jannis Epting[2], Joaquin Jimenez-Martinez[1,5], Mario Schirmer[1,4,6], John Molson[4] ,Raoul Collenteur[1,3]
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The climate is undergoing transformations, leading to shifts in precipitation, air temperature, and the frequency and intensity of extreme weather events. These alterations in climatic conditions have far-reaching consequences on hydrological processes such as groundwater

recharge and temperature. Especially in shallow groundwater systems, changes in recharge volume, timing, and temperature are decisive for groundwater quality and quantity. However, a systematic assessment and prediction of the changes are difficult because direct measurements of recharge and soil temperature are typically not available, which reduces our process understanding and makes predictions uncertain.

In this study, we overcome this problem by using seepage and temperature measurements from a lysimeter in Switzerland to facilitate the construction of a robust physically-based 1D model used to assess the impacts of climate change on groundwater systems. The calibrated model is the basis for predicting future recharge and temperature variations based on 46 different GCM-RCM model chains and three different greenhouse gas scenarios for transient daily time series from 1981 to 2099.

Although a significant uncertainty exists due to climate forecasts, the results suggest that the seasonal distribution of recharge will be more irregular with longer periods of lower or no recharge in summer and fall. These periods will be partially offset by higher recharge in winter. For temperature, we note a lag time between air and groundwater temperatures of a few months, paired with an increase and prolongation of warmer groundwater for future periods. This study provides insights into the consequences for shallow groundwater resources and the broader implications for water management by unraveling the complex dynamics at the nexus of climate, groundwater recharge and temperature changes.

Causal invariance for robust estimation of hydrological parameters

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Hydrological models require some form of parameter estimation to efficiently simulate streamflow observations at the outlet of a catchment. Hydrologists typically calibrate these parameters based on one or several objective functions that quantify the efficiency of the simulations in matching the observations. The calibration process then consists in selecting the parameter set that has the highest efficiency, assuming that this set corresponds to the dominant system response. However, when we perform such calibration for two independent climatic sub-periods (i.e. periods characterised by different precipitation and temperature inputs), we often obtain very different parameter sets, which means that the optimal parameters depend on the climate inputs and are therefore not robust. Consequently, if the climate inputs change, the accuracy of the hydrological model will also change, which is a problem for climate-impact studies. There have been several attempts to solve this problem, for example by performing differential split-sample tests, but too often modellers consider different sets of parameters for different climatic sub-periods. While this may be a valid assumption if we observe actual changes in the physical properties of a catchment, in the absence of such changes (or information about these changes), the parameters should not vary between periods if we consider them to be “dominant”. In this work, we propose a new way to find dominant hydrological model parameters by using causal inference methods that test the variability of residuals over time. We investigate whether and how combining a causal inference method with a calibration algorithm can improve the robustness of hydrological model parameters. To do so, we calibrate a hydrological model for 208 catchments in

Germany using a multi-objective framework algorithm that searches for an optimal parameter set based on (1) an invariance criterion derived from the causal inference method and (2) a streamflow efficiency criterion. The invariance criterion tests whether the distribution of residuals associated with a given parameter set vary over time. For each catchment, if at least one parameter set passed the invariance test, we then selected the parameter set that both passed the invariance test and had the highest efficiency. We evaluated the efficiency and robustness of our approach, linking it to catchment characteristics and the model's underlying assumptions about hydrological processes (i.e. its structure). We found that the calibration of the hydrological model passes the invariance test for 73% of the catchments, but sometimes at a high cost in terms of streamflow efficiency. The efficiency compromise needed to find invariance depends on the streamflow transformations used during calibration, the structure of the hydrological model, and the catchment type. Our new approach has the potential to improve the robustness of hydrological models for climate-impact studies.

Meaning and use of soil hydraulic properties at increasing spatial scales: from cm to km

Peter Lehmann and Andrea Carminati

Land surface models simulate the soil water distribution at large scale to quantify the fluxes across the soil-plant-atmosphere continuum and their effects on weather, climate, water and carbon cycle. For that purpose, the same rules and parameters that have been developed for the characterization of processes in the soil matrix at sub-meter scale are applied without critical discussion. For instance, they are extended from soil columns of a few centimeters size to a quasi-2D domain having a width of about one kilometer and a few meters thickness. This is a width-to-thickness ratio of about 1000:1, making the soil looking like a soil-sheet.

The simulation of 1D water flow in such 'soil sheets', neglecting smaller scale structures and lateral flow, raises several questions: Should we represent the 3D flow in a huge area by a simple 1D description? Is it correct to apply rules designed for small scale processes and determined in lab experiments at the large scale? Is our research on processes at the pore scale in the root-soil interface relevant for better predictions in land surface model?

To answer these questions, we present two examples discussing the validity and challenges of using lab-measured soil hydraulic properties to model processes at the large scale: 1) groundwater recharge and 2) evapotranspiration.

Groundwater recharge: We compare drainage simulations of wet soils based on the 1D column simplification with the full 2D-and 3D geometry using the correct sheet-like size ratio. The spatial heterogeneity of soil hydraulic properties is deduced from soil textural maps, using transfer functions that were trained on lab samples. In another series of simulations, we show the effect of new rules to compute soil hydraulic properties that were trained to reproduce field conditions. Finally, we quantify the effect of structures that result in different flow processes compared to the rather slow flow in the soil matrix.

Evapotranspiration: Ecosystems switch between being energy to water limited below a critical soil moisture threshold. The accurate prediction of these thresholds is the basis to estimate fluxes to the atmosphere. The thresholds could be either imposed as parameters in empirical models or predicted based on process based hydraulic models, which require information on the hydraulic conductivities of soils and plants. However, the question whether soil hydraulic conductivities measured in the laboratory could be used in ecosystem scale models is unclear. Here, combining a physical based model with large scale observations of gas-exchange, we show that soil hydraulic conductivity curves (as estimated from lab-based methods) can be used to successfully predict and explain observed soil moisture thresholds of evapotranspiration at the ecosystem scale.

Mapping Water Security and Governance to Human Rights in Water-Intensive Industries

Julie Faure[1], Marc Muller[1], Leonardo Bertassello[2], Elizabeth Dolan[2], Ellis Adams[2], Rahman Sulaimanov[2], Diane Desierto[2], Portia Chigbu[2], and Jonathan Pabillore[2]
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There is an urgent need for a standardized approach to human rights assessments of extractive industries that accounts for the multiple dimensions of the right to water. However, the local context of water issues in affected communities makes it difficult to align them with universal human rights norms in a way that is both objective and transferable. Our framework addresses this challenge by systematically classifying water security (e.g., green, blue, and economic water scarcity) and governance issues (e.g., power asymmetry, threats to hydrosocial relations) in water-intensive industries and mapping them to key elements of the human right to water, as defined by recent international jurisprudence. We apply this framework to 15 cases of water-intensive operations across various industries (e.g., mining, textile, agriculture, beverage), using content analysis and clustering techniques to offer new insights into the relationship between the human right to water and its underlying water security and governance drivers.

High and dry: understanding the spatiotemporal evolution of streamflow droughts in the larger Alpine region

Joren Janzing[1,2,3], Niko Wanders[4], Marit van Tiel[5,6], and Manuela I. Brunner[1,2,3]

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Severe droughts ravaged Europe in the first decades of the 21st century, for example in the summers of 2003, 2015 and 2018. These drought events affected different aspects of the hydrological cycle and led among other impacts to widespread streamflow deficits. Streamflow droughts generally affect a larger continuous region that can cross water divides and national borders. Still, the scope of many studies on streamflow drought is limited to individual river basins or countries and these studies often use a limited set of streamflow gauges. Therefore, we know relatively little about the spatio-temporal dynamics of individual

drought events. To study the true spatiotemporal evolution of streamflow droughts, spatially continuous data on discharge and its driving processes over a larger region are needed. Here, we use a large-scale hydrological model and set it up to simulate streamflow and other hydrological variables over the larger Alpine region. Then, we identify streamflow drought events and apply a clustering algorithm to track their evolution over time.

We find that the evolution of streamflow droughts has distinct characteristics: they often merge or fall apart into smaller clusters and can undergo phases of growth and shrinking. Furthermore, the spatio-temporal evolution of streamflow droughts is affected by topographical and climatic characteristics. For example, rivers within the Alps often show distinctly different drought behaviour than rivers in the surrounding regions. These differences in drought behaviour can be attributed to the characteristic flow regimes and driving processes between these regions, which can influence the growth of streamflow droughts. Our results suggest that climate change and the associated shifts in hydrological regimes in mountain regions could affect the extent to which mountain regions can act as a buffer against future drought events.

The effect of plant-hydraulic traits and soil drying on transpiration dynamics of beech and spruce

Stefano Martinetti[1], Julian Schoch[2], Andrea Carminati[2] Marius G. Floriancic[1,3], Peter Molnar[1]
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The role of stomatal conductance is continuously gaining more importance in hydrological modeling, given its direct control on transpiration fluxes. Plants control stomatal conductace depending on environmental stimuli, such as light exposure or vapor pressure deficit, but are also constrained by water availability in the soil. However, plant response to limited water availability differs among species. Such species-specific hydraulic traits, i.e., xylem hydraulic conductance or hydraulic capacitance, affect plant water potentials, which are constrained by stomatal conductance. However, we still lack a comprehensive mechanistic understanding of the links between plant water storage, capacitance, and stomatal regulation.

At the WaldLab forest experimental site on Zürich Hönggerberg we have been measuring water fluxes and potentials in soils, roots, stems and stomata of beech and spruce trees for the past four growing seasons, including periods of limited water availability. These measurements yield insights into species-specific water use strategies and build the foundation for sensitivity analyses with a parsimonious soil-plant hydraulic model that simulates water fluxes across the soil-plant system utilizing well-constrained concepts of water flow in porous media. The model was extended to include plant water storage and capacitance in the different tree compartments, in order to explore the effects of species-specific hydraulic traits on transpiration. Our results shown the different stomatal behaviour and shifts in depth of root water uptake during soil drying in beech and spruce trees, and observed and simulated effects of plant water storage and capacitance on transpiration dynamics across the two species.

Recent advances in the development of integrated datasets of streamflow, water quality, hydro-climatic, and landscape variables for Europe

Thiago Nascimento, Julia Rudlang, Marvin Hoege, Jan Seiber, Markus Hrachowitz and Fabrizio Fenicia

In recent years, large-sample hydrology (LSH) datasets have become increasingly available, contributing to significant advancements in hydrological research by facilitating studies across diverse catchments globally. In Europe, however, only a few such datasets have been published, capturing just a fraction of the wealth of information available from national data providers in terms of spatial density and temporal scope. Here, we present two key datasets that mark significant progress in European LSH: "EStreams" and "CAMELS_CH_Chem."

EStreams is an extensive dataset of hydro-climatic variables, landscape descriptors, and a catalogue of openly available stream records for 17,130 European catchments. Spanning up to 120 years, it includes streamflow indices, catchment-aggregated hydro-climatic signatures, and landscape attributes (topography, soils, geology, vegetation, and landcover). The dataset's catalogue provides detailed metadata, enabling users to directly access streamflow data sources while addressing challenges related to data redistribution policies, language differences, and varied data portal structures. Additionally, EStreams offers Python scripts for data retrieval, aggregation, and processing, making it a dynamic alternative to static datasets.

Complementing EStreams, we introduce CAMELS_CH_Chem that will be released in 2025. This dataset expands the CAMELS_CH (Catchment Attributes and Meteorology for Large-sample Studies in Switzerland) dataset to include stream water parameters, atmospheric chemistry, and isotope data for 117 Swiss stations, adding new parameters essential for water quality studies.

Together, these datasets represent recent advancements in integrated data resources for Europe, bridging gaps across streamflow, water quality, hydro-climatic, and landscape data. They enable more detailed and spatially comprehensive research, promoting a deeper understanding of the environmental drivers influencing European catchments and supporting informed water management strategies across diverse landscapes.

Poster Contributions Abstracts

Towards the energy transition: understanding aquifer reaction to underground energy storage

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Underground energy storage is one of the most promising alternatives for the efficient use of energy with regards to the energy transition. High-Temperature Borehole Thermal Energy Storage (HT-BTES) systems use the subsoil as a heat-exchanger to both store and recover heat depending on the season, using the ground as a thermal battery. They allow storing the excess of energy, e.g., from solar energy during the summer months, deep in the subsurface, which then remains available for extraction in the winter months, reducing the dependency on non-renewable energy sources for heating purposes. This is achieved by using water as a heat carrier, which interacts thermically with the subsoil by flowing through a closed loop of pipes hosted inside a cluster of boreholes. The larger both the number of boreholes and their depth, the larger the underground temperature changes induced by the operation of the facility, which can reach up to 90 ℃. However, the implications of such a large temperature change on the aquifer's behavior remains an open question. In the ARTS project (Aquifer's Reaction to Thermal Storage), we investigate the impact of using the subsoil as a thermal battery on the underlying aquifer, with particular emphasis on the changes in water chemistry, microbial activity, and microbial community composition derived from the cyclic heating and cooling of the subsoil. This is approached through an extensive field work campaign, spanning over the course of three years. It consists of both continuous on-site monitoring and additional periodic sampling and post-analysis at three measurement stations installed in the vicinity of a HT-BTES facility finished recently at the Empa/Eawag campus. The outputs from this campaign will be employed for the generation and calibration of a numerical model, i.e., digital twin, that will allow a close representation of the hydro-bio-geo-chemical processes in the aquifer. It will be employed for subsequent long-term prediction of the aquifer's behavior to future operational conditions of the facility, thus contributing to optimizing its operation. With this project, we plan to contribute to the development of greener and more sustainable energy sources by understanding the effects of underground energy storage on the environment, and in that way, to suggest better strategies for its implementation.

Diving into data: The Swiss Groundwater Database 1.0:

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Readily available open hydrological data is at the core of numerous scientific discoveries and advancements. An increasing number of hydrological investigations rely on extensive

datasets to enhance our comprehension of hydrogeological phenomena and systems. Consequently, there is a growing trend towards the development of larger, more accessible, and openly available hydrological datasets. Groundwater level data, in particular, offers invaluable insights into subsurface conditions and the underlying forces and environmental factors that contribute to water level fluctuations and groundwater interactions with surface water or the atmosphere. Unfortunately, large datasets of groundwater variables are challenges to obtain, as they often exhibit heterogeneous data structures and lack systematic compilation for different regions.

The aim of this project is to develop an open-source accessible database of groundwater data and metadata adhering to the principles of FAIR (Findable, Accessible, Interoperable, and Reusable). This initiative seeks to facilitate extensive groundwater research not only within Switzerland but also on an international scale. By centralizing data resources, it aims to streamline the efforts of practitioners and prevent redundant research endeavors. For this purpose, we are collecting in the initial phase hydraulic head time series and metadata from as many locations as possible in Switzerland. Along with the groundwater data, when available, metadata of various kinds will be provided, such as climatological and environmental descriptors (e.g., soil texture, altitude, etc.). Additionally, a wide array of groundwater signatures will be calculated for each head time series. All the scripts used for the data generation will be publicly available alongside the dataset. Subsequent versions of the database will incorporate additional types of groundwater data such as temperature and electrical conductivity, further enriching its utility and scope.

250-years of global river flow from routed CMIP6 runoff: Dataset validation and future projections

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River flow extremes such as fluvial floods and hydrological droughts can have devastating impacts and are expected to change in the future due to anthropogenic global climate change. But projecting future river flow on a global scale is challenging since global climate models (GCMs) like those contributing to the CMIP6 effort typically only provide runoff at the grid cell level rather than routed river flow. This disconnect has previously been addressed by combining GCMs with global hydrology models (GHMs) which are designed to close the terrestrial water balance. However, only a limited number of GCM projections can be considered with this approach and hence uncertainties associated with GCMs and effects of internal climate variability may be underestimated.

To bridge this gap, we route 250 years of daily runoff from the full CMIP6 archive along the global river network at a horizontal resolution of 0.1 degrees. Specifically, CMIP6 models that provide simulated daily runoff for both the historical radiative forcing and the most extreme future scenario, the Shared Socioeconomic Pathway 5-8.5 (SSP5-8.5), is routed to create a new and comprehensive dataset of simulated river flow spanning the years 1850 to 2100. For the routing step we use the multiscale routing model mRM which can flexibly be adapted to a wide range of spatial scales. Internally, mRM solves a kinematic wave equation to route gridded runoff along a river network derived from upscaling high-resolution morphological data. We carefully evaluate the new river flow dataset by comparing simulated seasonal cycle climatologies and river flow distributions to observations from GRDC-Caravan gauge stations. Moreover, we project future changes in global mean, high, and low river flow. Leveraging the large number of GCM projections available in the new river flow dataset, we further explore the robustness and range of future streamflow projections resulting from the CMIP6 model spread.

Suspended sediment concentrations in Alpine rivers: from annual cycles to sub-daily extreme events

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Suspended sediment is a natural component of rivers, but extreme concentrations can have substantial impacts on water quality, aquatic ecosystems, flood impacts, and hydropower production. In alpine basins, sediment transport and availability are modified by a changing climate through changes in erosive precipitation, snow cover and glacier retreat. As it is well known that the majority of suspended sediment is transported during a few extreme events, it is essential to better understand the spatial and temporal dynamics of the suspended sediment concentration (SSC) and its extreme events, now and in the future. To date, many studies have attempted to predict SSC dynamics based on catchment characteristics and hydroclimatic factors, however, mostly for individual catchments or specific events, which limits our understanding at larger spatial scales. This research aims to identify the main factors that influence the spatio-temporal variability of SSC and the occurrence of SSC extremes in the Alps.

We use 10 years of observed subdaily SSC data from 38 gauging stations in Switzerland and Austria to study the variation of SSC behavior in space and time. We assume that spatial variations between the annual SSC regimes are mainly explained by static climatic and catchment characteristics, while internal short-term variations and the occurrence of extremes at individual stations can be explained by non-static climatic and catchment characteristics. First, we examine spatial patterns in the annual median SSC cycle using hierarchical clustering based on regime differences in magnitude, timing, and shape of the annual SSC cycle. We reconstruct and explain the clusters by linking them to a large set of potential static hydroclimatic and catchment-related indicators. This approach results in three main types of annual SSC cycles, where the timing of the annual maximum SSC is strongly dependent on catchment elevation and the presence of glaciers. Second, we move from the annual scale to the event scale at a subdaily time step by identifying extreme events. We describe different types of events based on their dominant transport processes and examine their temporal and spatial variability. Although the events with the highest SSC were caused by high-intensity summer rainfall, on average glacier melt events lead to higher SSC and have the largest specific suspended sediment yield. These insights into the large-scale and catchment-specific variations in SSC and their extremes are valuable for improving our understanding of the complex hydrology-sediment system response.