2025/2026

Water-Earth Systems

PhD School Conference

Friday, February 13th, 2026

9:30-16:00

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Thank you for attending and contributing to the 2025/2026 Water-Earth Systems (WES) PhD Conference!

Our WES PhD School is a collaboration among academic institutions across Switzerland, established to elevate the standards of PhD training in groundwater studies and related geoscientific research fields. Its mission is to provide PhD students working on groundwater issues and related disciplines with a national platform for training and networking opportunities.

As of the end of 2025, the WES PhD School has 62 registered students. Over the past year, we organized 6 short courses, resulting in approximately 160 student-days of participation.

In 2026, we will continue to offer new courses covering a diverse range of topics. Many exciting ideas are in development, and you will receive updates via email whenever registration opens.

If you have any suggestions or questions, please don’t hesitate to reach out at school.earth-water@unine.ch.

We hope you enjoy today’s opportunity to learn about your peers’ work and to forge new connections.

Wish you all the best for 2026!

Dr. Qi Tang (Coordinator)

Prof. Benoît Valley (Director)

Schedule

9:30	***Registration and morning coffee***			
10:00	***Welcome address by Benoît Valley***			
10:10	Gaëlle	Toussaint	UNINE	A numerical framework to investigate coupled processes and induced seismicity in Enhanced Geothermal Systems (EGS)
10:30	Friederike	Curle	UNIBAS	Impacts of hydrological events and river restoration on microbial dynamics in riverbank filtration systems
10:50	Rony	Figueroa	UNINE	Stress-Dependent Fracture Aperture and Directional Hydraulic Conductivity in Mountain Environments
11:10	Alex Naoki	Asato Kobayashi	UNINE	Advancing agricultural soil gas flux monitoring: low-cost approaches with uncertainty quantification
11:30	Paul	Southard	UNIBAS	Integrated Hydrologic Modeling of Hydrotechnical Natural Small Water Retention Measures: Quantifying Impacts and Influencing Factors
12:00	***Lunch & posters (preceded by a group photo)***			
14:00	Francesco	Scattolini	UNINE	Vertical stratification and enrichment of PFAS in the surface microlayer of an artificial pond
14:20	Nina	Egli	UNINE	DeltAs project: Geological and hydrogeological modelling of the Red River Delta
14:40	Robin	Voland	UNINE	Project Nappes 70: What can be expect in the future for the Roussillon aquifer?
15:00	***Posters/Apéro***			

Posters

Neomi	Widmer	UNINE	Optimizing SOC stability in drained organic soils - a two-scale approach
Joshua	Richards	UNIBE	Evidence for variable sources of Na–Cl in groundwaters of the northern Basel-Landschaft area
Maha	Sheikh	UNIBE	River Morphological Adjustment to Repeated Experimental Floods in a Partially Regulated Alpine System
Domitille	Dufour	UNINE	Karst network geometry and groundwater flow in the Aulp du Seuil catchement (Chartreuse, France)
Odile	de La Rue du Can	UNINE	Cryosphere-Groundwater interaction processes: How to measure and model critical processes in remote areas?
Angela	Welham	UNIBAS/ EAWAG	Characterising Cryosphere–Groundwater Interactions and Water Availability in Alpine Spaces: Tracer-Based Approaches and Geo-/Hydrological Models of The Upper Engadine - Conceptual Framework

Presentation abstract

A numerical framework to investigate coupled processes and induced seismicity in Enhanced Geothermal Systems (EGS)

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Enhanced Geothermal Systems (EGS) aim to provide sustainable energy by increasing the permeability of deep, low-productivity reservoirs through hydraulic stimulation. While micro-seismicity is an expected outcome of stimulation, larger induced earthquakes such as those recorded in Basel (2006) and Pohang (2017) remain a major challenge for the safe deployment of deep geothermal projects. This highlights the need for physics-based models capable of resolving the coupled processes and fault behavior that control induced seismicity, and of assessing how reservoir properties and stimulation strategies influence seismicity rates and maximum magnitudes.

We present a numerical framework designed to investigate how coupled thermo-hydro-mechanical (THM) processes govern fault reactivation and induced seismicity in EGS. The model explicitly couples fluid flow, heat transfer, and stress evolution, and incorporates stress-dependent deformation, fault reactivation, and a built-in earthquake detection algorithm based on deviatoric strain rate. This approach enables consistent identification of induced events within simulations and quantification of their magnitudes, providing a process-based framework to explore the spatio-temporal evolution of seismicity. To resolve fault complexity and process coupling at high spatial and temporal resolution, the model is implemented using high-performance computing tools, enabling efficient exploration of a wide range of scenarios.

Preliminary simulations of the 2006 Basel project reproduce key seismic characteristics, including b-values and maximum magnitudes consistent with observations. Early tests on different fracture networks indicate that fracture size strongly influences the resulting seismicity. Ongoing work systematically investigates the roles of fracture size, fracture criticality, and stress ratio in controlling induced seismic behavior. Overall, this modelling framework provides a flexible tool to explore the physical mechanisms driving induced seismicity in EGS and to support the development of safer stimulation strategies.

Impacts of hydrological events and river restoration on microbial dynamics in riverbank filtration systems

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Riverbank filtration (RBF) is an important drinking water supply method by which infiltrated river water is naturally filtered during its passage through alluvial sediments. This process efficiently removes microbial contaminants under average hydraulic conditions. Extreme hydrological events such as high discharge, intense precipitation, and snowmelt, as well as anthropogenic disturbances like river restoration, alter the natural system and potentially reduce filtration efficiency, increasing the risk of microbial contamination.

To investigate microbial dynamics and hygienic risks under such extreme conditions, we combined online flow-cytometric monitoring of microbial communities with noble gas analyses at two contrasting RBF sites in Switzerland. Microbial concentrations increased at both sites following discharge events, indicating enhanced microbial transport from the river into the aquifer. Local mobilization of microorganisms from the topsoil was observed after snowmelt and precipitation, while only intense precipitation posed a potential risk for drinking water quality. River restoration activities caused transient microbial responses comparable to those observed during discharge events, but natural sedimentation processes rehabilitated the filtration efficiency of the riverbed sediments within a month.

Overall, extreme natural and anthropogenic forcings led to short-term perturbations of groundwater microbial communities. Our results thus emphasize the importance of continuous online monitoring and drinking water protection zones to ensure the hygienic safety of drinking water produced at RBF sites that are subject to dynamic hydrological conditions or anthropogenic perturbations.

Stress-Dependent Fracture Aperture and Directional Hydraulic Conductivity in Mountain Environments

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Fractured crystalline rocks are highly heterogeneous subsurface systems in which flow is governed by the connectivity and aperture of fracture networks. These fractures can be affected by in-situ stress fields that, in the shallow crust, result from the combined influence of regional tectonic loading, gravity, and topographic relief. While stress-dependent fracture behavior is well documented at the fracture scale, the impact of spatially variable stress tensors on hydraulic conductivity at the catchment scale remains insufficiently understood.

In this study, we examine how topographic and tectonic stresses interact with fracture network geometry to generate heterogeneity and anisotropy in hydraulic conductivity within a high-mountain catchment. A three-dimensional geomechanical model is used to compute spatially variable stress tensors for both synthetic and real topographies. These tensors are extracted on a cell-by-cell basis and applied to discrete fracture networks with different orientation statistics. For each fracture, the normal stress is calculated and used to derive stress-dependent hydraulic apertures through an exponential closure law, followed by the computation of fracture transmissivities using the cubic law. Directional hydraulic conductivities are then obtained from numerical flow simulations in the principal directions (Kx,Ky,Kz).

The results reveal strong spatial heterogeneity and directional dependence of hydraulic conductivity across the catchment. At first order, anisotropy is governed by fracture geometry, with low conductivities occurring in directions poorly aligned with dominant fracture sets (e.g., low Kx for NS oriented vertical fractures or low Kz for horizontal fractures). In addition to this geometric control, the relative orientation between fractures and the local stress tensor exerts a strong mechanical influence: fractures perpendicular to the principal compressive stress experience increased closure and reduced conductivity. Local topography induces stress variations further create zones of relatively higher hydraulic conductivity. Together, these effects produce pronounced anisotropy and zones of preferential flow, underscoring the importance of accounting for spatially variable stress fields in models of fractured catchments.

Advancing agricultural soil gas flux monitoring: low-cost approaches with uncertainty quantification

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Monitoring soil gas flux is essential for understanding greenhouse gas (GHGs) interactions at the soil-atmosphere boundary. Chamber-based methods provide localized measurements, but commercial systems can be expensive, particularly when multiple units are required. As affordable alternatives become more popular, assessing their effectiveness across different conditions is vital. Additionally, both commercial and low-cost systems rely heavily on the flux calculation schema (FCS) used. Arbitrary choices, such as measurement time or model selection, can significantly impact flux estimates, often resulting in underestimation.

In an agricultural context, water or soil management can generate soil gas flux events that affect the total carbon budget. These transient phenomena are difficult to quantify accurately due to measurement timing and pose a significant challenge for modelling without an appropriate measurement setup.

This study investigates low-cost soil gas flux systems combined with advanced flux calculation schemas that account for uncertainty, aiming for a scalable and accurate approach to measure greenhouse gas emissions in agricultural soils. We focus on implementing a flux calculation schema (FCS) that minimizes user-related uncertainties and includes sensor precision to improve flux estimates. Conducted in Switzerland’s Seeland region, the research examines how natural, anthropogenic, and management-related events influence soil gas flux emissions. By integrating affordable sensors with uncertainty quantification, our findings seek to enhance soil greenhouse gas monitoring to support sustainable agriculture and climate change mitigation.

Integrated Hydrologic Modeling of Hydrotechnical Natural Small Water Retention Measures: Quantifying Impacts and Influencing Factors

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Climate change in Switzerland is expected to cause increases in the frequency and intensity of droughts as well as extreme precipitation events, leading to problems related to runoff, erosion and agricultural drought in agricultural watersheds. Natural Small Water Retention Measures (NSWRM) comprise a wide range of farm-scale adaptation strategies that intend to mitigate climate change impacts by conserving farm water resources and harvesting rainwater. There are, however, a limited number of scientific studies providing quantitative evidence for the effectiveness of such measures, and many are one-off field or modelling studies studying small amounts of measures in a small amount of conditions. Farmers and agricultural resource managers currently lack broadly-applicable, science-based tools to help guide the process of a successful NSWRM implementation design. To address this knowledge gap, we are undertaking the first synthetic modelling experiment that we know of that utilizes physically-based Integrated Surface-Subsurface Hydrologic Modeling and high-performance computing resources to study hydrologic impacts of several hydrotechnical NSWRM types and designs across thousands of catchment conditions scenarios. The modelling study enables wide-ranging measure design and type scenario testing as well as testing of catchment conditions scenarios and their impact on measure effectiveness. Results show that measures can have a significant impact on hydrologic variables like runoff, soil moisture, and infiltration, but that impact magnitudes are highly dependent on catchment conditions like soil type and bedrock transmissivity as well as on measure design. This research highlights that there is a need for more quantitative information in the NSWRM implementation design process to ensure the success of implementations, and in the future will be combined with results from Slow Water project NSWRM implementation field studies to produce universal, accessible and straightforward tools and findings about cost-effective NSWRM implementation selection.

Vertical stratification and enrichment of PFAS in the surface microlayer of an artificial pond

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The surface microlayer (SML) is the thin boundary layer between surface water and the atmosphere, with a thickness of less than 1 mm. Despite its minimal thickness, the SML plays a crucial role in various earth system processes, including the enrichment of biogenic molecules that influence carbon cycling, aerosol formation, and pollutant accumulation. PFAS, a group of toxic and persistent pollutants, accumulate at the air-water interface, directly impacting wildlife that interact with this zone.

While PFAS accumulation in the SML is well-documented, most studies focus on oceanic environments. Artificial ponds, despite their localized geographic impact, offer a unique opportunity to investigate SML enrichment and determine the partition coefficient (Kd) under site-specific conditions, thereby improving assessments of PFAS transport and retardation factors.

In this study, we sampled water at multiple depths, including the SML, in an artificial pond. Our results revealed vertical stratification due to a secondary, potentially PFAS-free groundwater input, which diluted PFAS concentrations at the pond's bottom. The average enrichment factor (EF) in the SML was 7.5, with PFAS-specific EFs indicating higher enrichment for sulfonic acids compared to carboxylic acids of similar or longer chain lengths. These findings underscore the importance of accounting for air-water interface accumulation in both the design of sampling strategies and environmental risk assessments.

DeltAs project: Geological and hydrogeological modelling of the Red River Delta

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Arsenic contamination of groundwater is observed throughout South and Southeast Asia, affecting the low, flat floodplains of rivers draining the Himalayas. This geogenic contamination exposes over 100 million people to arsenic through their drinking water, posing a major health hazard [1].

Two such affected areas are the Red River and Mekong deltas in Vietnam, where growing population and climate change combine with natural arsenic occurrence to form highly unpredictable spatial and temporal patterns of groundwater contamination [2]. Moreover, the sedimentological context of the area leads to highly heterogeneous deposits which increase the difficulty in identifying these patterns.

In the context of the DeltAs project, which aims to quantify the temporal and spatial variability of arsenic in deltaic environments, we develop a detailed 3D geological ensemble of models of the Red River delta, which then serves to characterize the properties of the subsurface for an ensemble of groundwater flow models.

We present here the latest developments of these geological and groundwater models of the Red River delta. They are developed using ArchPy [3], an automated, hierarchical method for stochastic geological modelling, and MODFLOW 6, the latest version of a widely-used groundwater flow simulation program.

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Project Nappes 70 : What can be expect in the future for the Roussillon aquifer?

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The Roussillon region of southern France recently experienced long dry periods that caused a water shortage for public and agricultural use. Groundwater has been the region's only remaining water source and is being over pumped. Given that we are already seeing the consequences of climate change in this Mediterranean region, we wonder what to expect in the future. Should the region improve its water use by preventing losses during distribution or by changing crop types to plants better suited to dry climates? To investigate the impact of climate change, we calibrated a steady-state MODFLOW 6 groundwater model using current water heads. Then, we exported this model into four climatic scenarios using climate model projections for the year 2070. Precipitation predictions are notoriously uncertain, some models predict an increase in the yearly total of rainfall, while others predict a decrease. All of the models predict an increase of temperature and precipitation seasonality. To represent future possibilities, we used four scenarios across the full range of possible future precipitation. I will present the conclusions drawn from this study. There will be a stronger impact in the upstream regions of the Roussillon plain. Meanwhile, an increase in water head in the coastal area due to rising sea levels will be accompanied by an increased risk of saline intrusion.

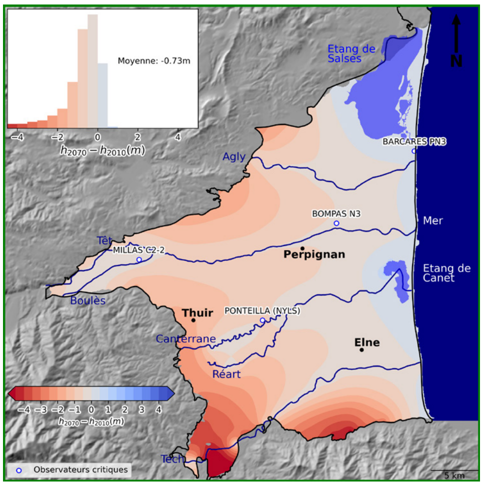

Figure 1: Change in water head from 2010 to 2070 in the green scenario

Optimizing SOC stability in drained organic soils – a two-scale approach

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Drained organic soils are among the most productive agricultural soils but are also major sources of soil organic carbon (SOC) loss and greenhouse gas (GHG) emissions. In the Swiss Seeland region, extensive drainage has enabled intensive horticulture but caused soil subsidence of up to 2.4 m over the past century. To counteract soil loss, farmers increasingly mix mineral soil into the degraded organic topsoil. While this practice improves soil structure and bearing capacity, its potential to stabilize the remaining SOC is poorly constrained.

Rewetting is widely recommended to reduce SOC loss and GHG emissions by limiting oxygen availability, yet full rewetting implies a transition to wetland-adapted agricultural practices and substantial economic trade-offs. Partial rewetting may offer a compromise, but SOC responses depend strongly on water table position and redox dynamics.

This project investigates how combining mineral soil mixing with targeted groundwater management can enhance SOC stabilization in drained organic soils. Repeated wetting and drying cycles, corresponding to repeated oxic-anoxic transitions can induce the cycling of Fe and associated co-precipitation, sorption and aggregation processes. Using a two-scale approach, a long-term field experiment is complemented by laboratory mesocosm studies to disentangle the individual and combined effects of mineral amendment and water table dynamics. Carbon balances are linked to underlying biogeochemical and hydrological processes, including redox cycling, organo-mineral associations, and aggregate formation.

We hypothesize that mineral soil addition increases sorption and physical protection of SOC, while elevated groundwater levels suppress aerobic decomposition. Targeted groundwater level management may further enhance SOC stability by promoting redox cycling and microaggregation. Together these mechanisms may act synergistically to reduce SOC loss and support more sustainable management of drained organic soils.

Evidence for variable sources of Na–Cl in groundwaters of the northern Basel-Landschaft area

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Elevated salinity in the Schinznach Formation aquifer (Muschelkalk aquifer) has been measured in the Muttenz-Pratteln area. This salinity must originate from deeper formations and may derive from evaporite subrosion within the Zeglingen Formation, from solution mining operations in the area, or from the upflow of basement-derived fluids.
Several coupled processes are thought to enhance saline water migration in this setting, including fault-controlled basement upflow, more than 150 years of solution mining, and large-scale pumping that promotes mixing with deeper brines (Spottke et al., 2005; Zechner et al., 2011). Differentiating and quantifying basement upflow is critical for understanding regional flow systems and disentangling natural from anthropogenic drivers. However, in this context, any basement derived waters migrating upward through the Zeglingen Formation may acquire a partial evaporitic signature, complicating source attribution.
While Br/Cl ratios confirm halite dissolution in the evaporites, they cannot by themselves distinguish between shallow driven subrosion and evaporite-modified basement upflow. Elevated Li and He concentrations occur almost exclusively in groundwaters originating from the basement and therefore can be used as diagnostics for such a contribution.
Analysis of historical Li, Br, and He groundwater chemistry data (Zechner, 2019), reveals geochemical signatures indicative of a basement-derived component in wells within the Muschelkalk Aquifer. Such a basement signature is consistent with data from the Riehen geothermal well on the edge of the Upper Rhine Graben, suggesting fault-controlled upflow as a plausible mechanism in the study area.
Targeted measurements of Li, Br, and He provide a method to differentiate between natural versus anthropogenic drivers of salinisation in the Muttenz-Pratteln area and thus help to assess risks to groundwater resources.

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River Morphological Adjustment to Repeated Experimental Floods in a Partially Regulated Alpine System

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Floods are key drivers of river evolution, reshaping channel morphology, influencing sediment dynamics, and altering patterns of erosion and deposition. These morphological adjustments can pose risks to infrastructure and ecosystems. However, predicting river responses to floods remains challenging due to complex interactions between flow and sediment transport. By investigating post-flood morphological changes in a partially regulated river subjected to repeated floods, this study aims to improve understanding of these processes and their implications for flood risk management.

The research focuses on the lower Spöl River in Switzerland, where experimental floods are released annually from the Punt dal Gall and Ova Spin dams as part of a long-term river restoration program. The study reach is influenced by an unregulated tributary that supplies substantial sediment, resulting in highly dynamic geomorphological conditions. Geomorphic changes associated with a sequence of experimental floods were quantified using high-resolution digital surface models (DSMs) derived from drone-based Structure-from-Motion photogrammetry and analyzed with the Geomorphic Change Detection (GCD) 7.5.0 Standalone software.

Four experimental floods between 2019 and 2023 were examined. The upstream section of the study reach, located immediately downstream of the tributary confluence, consistently exhibited pronounced erosion, whereas downstream responses varied among floods. The first flood in 2019 and the 2021 flood were predominantly erosion-dominated, while the second flood in 2019 and the 2023 flood were characterized by net deposition. These contrasting responses are likely related to differences in antecedent morphological conditions prior to each flood. Despite this variability, a general trend of aggradation was observed over the 2019–2023 period, indicating that sediment supply exceeded the transport capacity generated by the experimental floods. This finding suggests that sediment availability should be more explicitly considered in experimental flood design.

Future research will focus on developing predictive models of flood-induced morphological change. Overall, the results demonstrate that sediment supply strongly constrains the effectiveness of experimental floods and must be considered in river restoration planning.

Karst network geometry and groundwater flow: a case study

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Groundwater flow in karstic aquifers is highly dependent on the geometry of the conduit network. Not integrating the geometry explicitly leads to inaccurate predictions of the aquifer's behavior under both high and low flow conditions.

At the same time, discharge time series at the spring contain information about the internal network organization. Hence, we study how hydrological properties can be related to the statistical metrics developed to characterize network geometry and topology.

One possible way to answer this question is to compare the results of flow simulations in an ensemble of karst networks. We propose using pyKasso, a pseudo-genetic karst network simulator, to obtain a large number of karst networks constrained by the same geological and hydrological settings. We then run flow simulations with openKARST, a flow simulator that handles turbulent and laminar flow in complex karst networks.

Here we present our study case: the Aulp du Seuil catchment in the Chartreuse Mountains (France). The small (~10 km^2) karstic catchment was chosen due to its 16-year record of discharge measures at the outlet (Fig.1), and the 25 kilometers of conduits explored and mapped by speleologists.

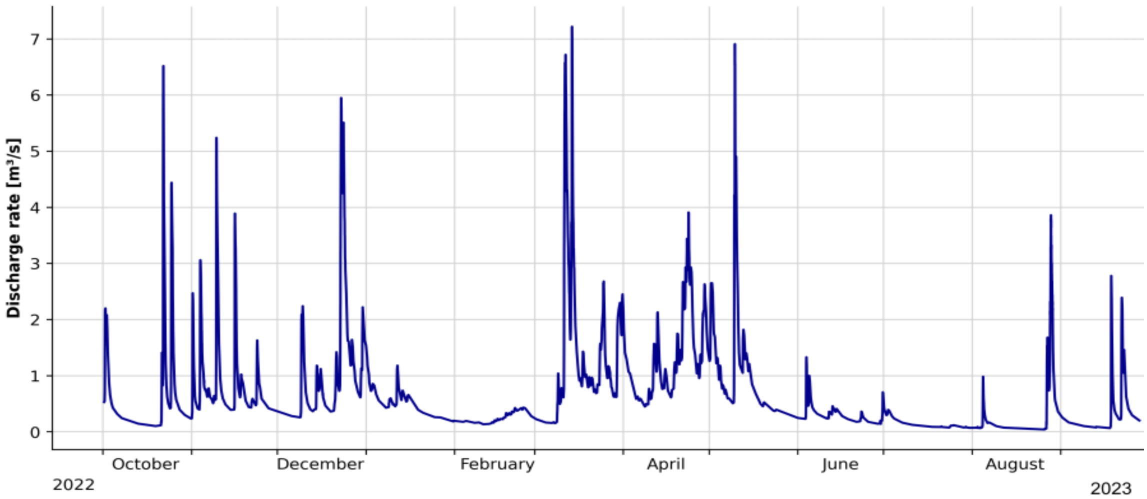

Figure 1: DISCHARGE RATE AT THE OUTLET OF THE KARST NETWORK 2022-2023

Cryosphere-Groundwater interaction processes: How to measure and model critical processes in remote areas?

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Groundwater plays a pivotal role in the mountain water cycle. It sustains river base flow, thereby supporting downstream ecosystems and human societies during dry periods. However, our understanding of the interaction between groundwater and the cryosphere is limited. The scarcity of hydrogeological data in high-altitude environments poses a significant challenge to improving our understanding of these interactions.

Common methods to investigate groundwater processes include deconvolution and hydrograph separation techniques. These methods use integrated signals from discharge and tracer time series to estimate groundwater contribution, storage, and flow paths at the catchment scale. Over the past decades, various flow- and tracer-based hydrograph separation methods have been developed to characterize catchments and their subsurface.

Flow-based approaches describe catchment response to hydrological forcing and include recession curve analysis and frequency-domain analysis. Transport-based approaches rely on solute or tracer signals, such as electrical conductivity, to infer transit times, mixing processes, and flow-path activation. Together, these approaches aim to resolve both response timescales (from flow signals) and residence timescales (from transport signals), providing a useful framework for diagnosing groundwater behaviour when subsurface data are limited.

My PhD research applies hydrograph analysis and numerical modeling to alpine headwaters to improve our understanding of these interactions. By combining these tools with numerical modeling, we can test hypotheses, identify key processes, and parameterize models to reproduce observed signals. This approach allows us to explore how these systems might respond to a changing climate.

Characterising Cryosphere–Groundwater Interactions and Water Availability in Alpine Spaces: Tracer-Based Approaches and Geo-/Hydrological Models of The Upper Engadine - Conceptual Framework

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Climate-driven disruption of mountain cryosphere dynamics is increasingly altering groundwater recharge and water availability in Alpine regions. The Upper Engadine, one of the driest Inner-Alpine valleys in Switzerland, has experienced sustained glacier retreat since the mid-19th century (GLAMOS, 2025) and represents a highly climate-sensitive hydrological system. In addition to its climatic vulnerability, the region exhibits an unusually complex hydrogeology, including snowmelt-fed and mineralised springs, CO_2-rich thermal groundwater, arsenic-enriched lakes, and an extensive fluvio-glacial Quaternary aquifer. This study aims to quantify cryosphere-controlled groundwater recharge processes and subsurface flow pathways in the Upper Engadine catchment (470 km^2; 1520 - 3980 m.a.s.l) by integrating multi-tracer observations with three-dimensional geological and hydrological modelling. The isotope compositions of water ($\delta^{18}O$, δ^2H, ^3H), major ions, trace elements, dissolved gases, and microbial indicators are measured in springs, streams, lakes, and shallow and deep groundwater by various water representatives and during seasonal field campaigns. This is complemented by continuous dissolved gas monitoring and high-resolution isotope sampling of snow, rainwater and river waters. Two sub-catchments with contrasting glacier coverage - the Rosegbach (15% cover, 66.5 km^2) and the Beverin (0.01% cover, 59.6 km^2) - serve as natural end-members to isolate cryospheric controls on recharge (GLAMOS, 1881-2023). Tracer interpretations are constrained by a high-resolution three-dimensional geological model defining hydrostratigraphic units and subsurface flow properties. The combined tracer-model framework will identify dominant recharge mechanisms, groundwater residence times, and flow pathways under contrasting cryospheric conditions, and evaluate how hydrological model structure influences the simulation of Alpine water sources. Overall, this work establishes a transferable, groundwater-focused framework to improve hydrological predictions in climate-sensitive Alpine catchments.

Figure 1: Val Roseg Glacial Catchment, Proglacial Lake, Upper Engadine
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Reference
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