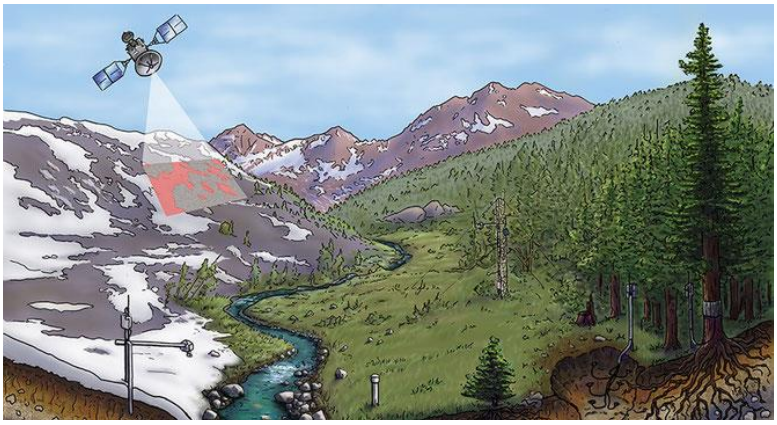
Zhydro 2022



An illustration of a critical zone observatory

www.zhydro.ch

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: 23 November 2022 (Wednesday) from 8:30-17:00

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

FORM: 15 talks (10 & 20 mins), 10 posters (with 1 min pitches)

PLEASE REGISTER HERE

ZHydro Contact Persons

Organization 2022
Institute of Environmental Engineering, ETH Zürich, and EAWAG
Joaquin Jimenez-Martinez, joaquin.jimenez@eawag.ch, jimenez@ethz.ch
Peter Molnar, peter.molnar@ifu.baug.ethz.ch

ZHydro Secretary
Peter Lehmann, peter.lehmann@env.ethz.ch
Physics of Soil and Terrestrial Ecosystems, ETH Zürich

WEBPAGE: www.zhydro.ch

ZHydro 2022 SCHEDULE
23 November 2022, Alumni Pavillon, ETH Zürich

10+5 mins
20+10 mins

	Introduction	
08:30	Welcome address	Molnar, Jimenez-Martinez
08:35	**POSTER HEADLINES (1-min pitches)**	Lehmann
	Models "old and new"	
08:45	Long continuous simulations: the role of antecedent conditions in the generation of large floods	Staudinger (UZH)
09:15	How to build a distributed perceptual model at the regional scale?	Fenicia (EAWAG)
09:30	Transit time distributions of reactive contaminants: The role of sorption and degradation investigated with a distributed hydrochemical model	Sui (ETH-IfU)
09:45	Neural ODEs in Hydrology: Fusing Conceptual Models with Deep Learning	Höge (EAWAG)
10:00-10:30	**Coffee break (Posters)**	
10:30	Moving deep learning models underground – simulating groundwater heads with a Long Short-Term Memory Network	Frank (EAWAG)
	Soil "the hidden half of hydrology"	
11:00	Subsurface processes in hydrology: A micro-scale view	Velasquez-Parra, Stoll (EAWAG, ETH-IfU)
11:15	Ecosystem scale critical soil moisture thresholds of transpiration and their global variability are explained by soil hydraulic conductivity	Carminati (ETH-ITES)
	Land-Atmosphere interactions	
11:45	Attributing the 2022 soil drought to human–induced global warming	Schumacher (ETH-IAC)
12:15-13:30	**Lunch break (Poster viewing possible), *independent***	
13:30	A high-performance algorithm to compute terrain parameters relevant for modelling surface radiation in hydrological and atmospheric models	Steger (ETH-IAC)
14:00	Spatio-temporal variability of drought generation processes over Europe	Brunner (ETH-IAC)
14:15	Rapid drought-flood transitions: When and where do they occur?	Götte (ETH-IAC)
14:30	Potential for significant precipitation cycling by forest-floor litter and deadwood	Floriancic (ETH-ITES)
15:00-15:30	**Coffee break (Posters)**	
	A "potpourri" of hydrological impacts	
15:30	Trout parr's thermoregulation in transient temperature contrasts – An imaging-based tracking approach	Naudascher (ETH-IfU)
16:00	Future glacier evolution and their impacts on hydrology	Compagno (WSL, ETH-VAW)
16:30	Climate sensitivity and changes in water productivity across agricultural landscapes of Ethiopia	Wakjira (ETH-IfU)
16:45-17:00	**OUTLOOK 2023**	**Molnar, Jimenez-Martinez**

ETH GROUPS:
ETH-IAC Schär, Seneviratne/Gudmundsson, Brunner
ETH-IfU Burlando/Molnar, Stocker/Jimenez-Martinez
ETH-ITES Kirchner, Carminati/Lehmann
ETH-VAW Farinotti

ZHydro 2022 POSTERS

1	Brunner, Manuela (ETH-IAC Brunner)	An introduction to the HYCLIMM group
2	Duddek, Patrick (ETH-ITES Carminati)	The role of root hairs in root water uptake - insights from an image-based 3D model
3	Collenteur, Raoul (EAWAG Schirmer)	Pastas: an open-source python package to analyse groundwater data
4	Cramer, Andreas (ETH-ITES Carminati)	Microplastic interaction with soil water dynamics
5	Droujko, Jessica (ETH-IfU Molnar)	Sediment source and pathway identification using Sentinel-2 imagery and (kayak-based) lagrangian river profiles on the Vjosa river
6	La Cecilia, Daniele (EAWAG Schirmer)	Microplastics transport during managed aquifer recharge – A potential cause of groundwater contamination?
7	Moeck, Christian (EAWAG Schirmer)	CH-GNet – Swiss Groundwater Network
8	Schoch, Julian (ETH-ITES Carminati)	New pedotransfer function for soil hydraulic properties of Swiss forest soils to quantify transpiration during droughts
9	Sinclair, Scott (ETH-IfU Burlando)	GoNEXUS - Integrated solutions for water, energy, food and ecosystems
10	Bernhard, Fabian (WSL Biogeochemistry)	Disentangling forest ecosystem water fluxes with stable water isotopes

ABSTRACTS IN ALPHABETICAL ORDER BY FIRST AUTHOR (only oral presentations)

Spatio-temporal variability of drought generation processes over Europe

Manuela Brunner (manuela.brunner@env.ethz.ch)

Institute for Atmospheric and Climate Science, ETH Zürich, 8092 Zürich, Switzerland

Hydrological extreme events are generated by different sequences of hydro-meteorological drivers, the importance of which may vary within the sample of drought events and in space and time. Here, we investigate how the importance of different hydro-meteorological driver sequences varies by event magnitude, in space, and in time using a large sample of catchments in Europe and the Alps. To do so, we develop an automated classification scheme for streamflow drought events, which assigns events to one of eight drought event types - each characterized by a set of single or compounding drivers. The objective event classification reveals how drought drivers vary in space, by season, and by event magnitude. In addition, it highlights that drought generation processes have changed over time.

Future glacier evolution and their impacts on hydrology

Loris Compagno (loris.compagno@wsl.ch)

Mountain Hydrology and Mass Movements, WSL, 8903 Birmensdorf, Switzerland

As a direct consequence of climate change, glaciers worldwide are rapidly losing mass. This trend is projected to continue in the future, with consequences for sea level, natural hazards and water availability. Quantifying the future evolution of glaciers under different climate scenarios by using process-based glacier evolution models is the key to anticipate glacier-related impacts, to undertake appropriate and prompt mitigation measures, and to anticipate future adaptations. We analyze the effect that limiting the increase in global average temperatures to 1.0, 1.5, or 2.0°C compared to pre-industrial levels has on the future glacier evolution, highlighting the consequences from a water resources perspective. This exercise sheds light on the urgency of limiting anthropogenic climate change from a glaciological perspective, and highlights the consequences from a water resources perspective.

Moreover, we analyze the water storage and hydropower potential of mountain areas projected to become ice-free during the course of the 21st century. Thus, we perform a first-order suitability assessment of constructing a dam in front of each glacier on Earth, taking into account environmental, technical and economic factors. These results indicate that deglaciating basins could provide an important contribution to national energy supplies in a number of countries. Finally, we focus on the future evolution of potential ice-dammed and supraglacial lakes. Such lakes are responsible of glacier lake outburst floods, regularly causing fatalities and economic damage. We find a strong correlation between large modelled lakes and historical outburst floods.

How to build a distributed perceptual model at the regional scale?

Fabrizio Fenicia (fabrizio.fenicia@eawag.ch)

Eawag, Swiss Federal Institute of Aquatic Science and Technology, Department Systems Analysis, Integrated Assessment and Modelling, 8600 Dübendorf, Switzerland

Perceptual models are the starting point of the modelling cycle, but limited guideline is available to their development. This is particularly true for models that are intended to work at the regional scale, where the scale of fieldwork observations is order of magnitudes smaller than the scale of the modelled processes. This study addresses the problem of building a perceptual model for a regional nested catchment, where the

available landscape data consists of maps of common attributes such as topography, vegetation, geology and soil. The case study is represented by the Moselle basin, which extends over an area of 27,100 km^2, and includes streamflow measurements at 26 sub-catchments. We break down the problem of building a regional scale perceptual model into understanding (i) which fingerprints best characterize streamflow spatial variability, (ii) which landscape properties affect these differences, and (iii) which dominant processes are involved. This process combines simple data analyses with basic hydrological knowledge. Our Moselle perceptual model highlights the role of precipitation, geology and topography on average flow rates, base runoff and delay time respectively. Soil and vegetation, on the other hand, were not found to be dominant causes of hydrographs spatial variability, which might seem surprising, considering that soil properties are one of the key ingredients of distributed models. In this case, the perceptual model served as a basis for the development of a distributed model, it could serve other purposes such as catchment classification. The process undertaken in this study may be useful in developing perceptual models in other basins on a regional scale, and in mapping the variety of dominant hydrological processes where available data allow.

Potential for significant precipitation cycling by forest-floor litter and deadwood

Marius G. Floriancic[1,2] (floriancic@ifu.baug.ethz.ch)
Scott T. Allen[3]
Raphael Meier[1]
Lucas Truniger[1]
James W. Kirchner[2,4]
Peter Molnar[1]

1 Dept. of Civil, Environmental and Geomatic Engineering ETH Zürich, 8093 Zürich, Switzerland
2 Dept. of Environmental Systems Science, ETH Zürich, 8092 Zürich, Switzerland
3 Dept. of Natural Resources & Environmental Science - University of Nevada, Reno, USA
4 Swiss Federal Research Institute WSL, 8903 Birmensdorf, Switzerland

The forest-floor litter layer can retain substantial volumes of water, thus affecting evaporation and soil-moisture dynamics. However, litter layer wetting/drying dynamics are often overlooked when estimating forest water budgets. Here we present field and laboratory experiments characterizing water cycling in the forest-floor litter layer, and outline its implications for subcanopy microclimatic conditions and for estimates of transpiration and recharge. Storage capacities of spruce needle litter and beech broadleaf litter averaged 3.1 mm and 1.9 mm respectively, with drainage/evaporation timescales exceeding 2 days. Litter-removal experiments showed that litter reduced soil water recharge, reduced soil evaporation rates, and insulated against ground heat fluxes that impacted snowmelt. Deadwood stored ~0.7 mm of water, increasing with more advanced states of decomposition, and retained water for >7 days. Observed daily cycles in deadwood weight revealed decreasing water storage during daytime as evaporation progressed and increasing storage at night from condensation or absorption. Water evaporating from the forest-floor litter layer modulates the subcanopy microclimate by increasing humidity, decreasing temperature and reducing VPD. Despite the relatively small litter storage capacity (<3.1 mm in comparison to ~10 2 mm for typical forest soil rooting zones) the litter layer alone retained and cycled 18% of annual precipitation, or 1/3 of annual evapotranspiration. These results suggest that overlooking litter interception may lead to substantial overestimates of recharge and transpiration in many forest ecosystems.

Moving deep learning models underground – simulating groundwater heads with a Long Short-Term Memory Network

Corinna Frank (corinna.frank@eawag.ch)
Raoul Collenteur
Christian Moeck

Eawag, Swiss Federal Institute of Aquatic Science and Technology, Department Water Resources and Drinking Water, Group Hydrogeology, 8600 Dübendorf, Switzerland

The use of data-driven deep learning (DL) models in surface hydrology is now well established. Particularly Long Short-Term Memory networks (LSTM) have shown to outperform more traditional rainfall-runoff models in terms of predictive power. The use of DL models can further simplify and shorten the calibration procedure,

allow for a flexible set of descriptor variables, and potentially increase simulation accuracy. For the analysis of hydraulic groundwater head time series, applications of DL models are still rather uncommon. The question how DL models compare to more established methods to simulate hydraulic head fluctuations remains open. In this study, we assess the suitability of LSTM networks for simulating hydraulic groundwater heads. The model is applied on 29 head time series, observed in selected monitoring wells across Switzerland ranging from high altitude alpine aquifers to pre-alpine aquifer systems on the Swiss plateau. The LSTM is calibrated separately for each monitoring well using meteorological forcings and nearby river stage as input features. The optimal model size (in terms of hidden units) determined through hyperparameter tuning was found to be small compared to typical values in surface hydrology indicating a lower complexity of the modelled systems or insufficient amount of data. Simulation performance, with a median Kling-Gupta efficiency of 0.76 and a median root-mean-square error of 32 cm is comparable to a lumped-parameter model previously applied to the same data set. In future research, we will explore generalizing the LSTM and build one model for the use on all stations, which replaces tedious recalibration for each well and leverages the power of deep learning models through a joint, larger dataset.

Rapid drought-flood transitions: When and where do they occur?

Jonas Götte (jonas.goette@env.ethz.ch)

Institute for Atmospheric and Climate Science, ETH Zürich, 8092 Zürich, Switzerland

Drought-flood transitions greatly challenge water management and the development of adaption measures to extreme events. These transitions can occur rapidly but may also take many months or years and are often studied using climate instead of streamflow data – neglecting the role of surface processes. In this study, we analyse how drought-flood transition times vary across different hydro-climates in the contiguous United States. We analyse the durations of drought-to-flood transitions and the streamflow development during transition periods. Then, we link the seasonal transition properties to catchment and climate characteristics such as snow dominance.

Neural ODEs in Hydrology: Fusing Conceptual Models with Deep Learning

Marvin Höge (marvin.hoege@eawag.ch)

Eawag, Swiss Federal Institute of Aquatic Science and Technology, Department Systems Analysis, Integrated Assessment and Modelling, 8600 Dübendorf, Switzerland

Deep learning methods have repeatedly outperformed conceptual hydrologic models in specific tasks of rainfall-runoff modelling. Although attempts of investigating the internals of such deep learning models are being made, traceability of model states and processes and their interrelations to model input and output is not fully given, yet. Direct interpretability of mechanistic processes has always been considered as asset of conceptual models that helps to gain system understanding aside of predictability. We introduce hydrologic Neural ODE models that perform as well as state-of-the-art deep learning methods in rainfall-runoff prediction while maintaining the ease of interpretability of conceptual hydrologic models. In Neural ODEs, internal processes that are part of differential equations of the model are substituted by one or several neural networks. Therefore, Neural ODE models offer a way to fuse deep learning with mechanistic modelling. We demonstrate the predictive capabilities for several hundred catchments of the continental US (CAMELS dataset). Further, we shed light on what the neural networks within the Neural ODE models have learned about the internal model processes making model behavior and predictions more traceable and explainable.

Trout parr's thermoregulation in transient temperature contrasts – An imaging-based tracking approach

Robert Naudascher[1,2] (naudascher@ifu.baug.ethz.ch)
Stefano Brizzolara[1,3]
Jukka Jokela[4]
Robert Boes[2]
Markus Holzner[1,3]
Luiz da Silva[1]
Roman Stocker[1]

1 Institute of Environmental Engineering, ETH Zürich, 8093 Zürich, Switzerland
2 Laboratory of Hydraulics, Hydrology and Glaciology (VAW), ETH Zürich, 8093 Zürich, Switzerland
3 Swiss Federal Institute of Forest, Snow and Landscape Research WSL, 8903 Birmensdorf, Switzerland
4 Department of Environmental Systems Science, ETH Zürich, 8092 Zürich, Switzerland

Anthropogenic activities such as the operation of storage hydropower plants alter the thermal regime of rivers at a large variety of temporal scales. As thermal plumes travel downstream, riverine biota deploy navigational strategies that allow them to avoid unfavorable temperatures. As ectotherms, fish thereby rely on behavioral thermoregulation meaning that their behavioral output is biased by experienced environmental temperatures. To shed light on this navigational task and thermal avoidance behaviour of brown trout parr, we evaluated thermal contrasts within the physical range of 4°C to 20°C in a laboratory setup. Combining gravity currents with imaging-based fish-tracking techniques allowed us to derive fine-scale movement behavior in relation to a thermal gradient.

While cold water avoidance became more pronounced for colder treatments, warm water did not trigger avoidance behavior, but led to increased swimming activity. We analyzed each cold-water encounter (cold-plunge) and found that stronger thermal contrasts lead to shorter and shallower plunges. This work aims to provide a mechanistic understanding of how ectotherm fish negotiate sharp thermal contrasts and thereby inform mitigation efforts of anthropogenic thermal pollution.

Long continuous simulations: the role of antecedent conditions in the generation of large floods

Maria Staudinger (maria.staudinger@geo.uzh.ch)
Daniel Viviroli

Hydrology and Climate, Department of Geography, University of Zürich, 8057 Zürich, Switzerland

Continuous simulation has proven to be a promising base for flood frequency analysis since it avoids some of the shortcomings of other methods, such as assumptions about antecedent conditions or omission of relevant processes. In the EXAR (hazard information for extreme flood events on the rivers Aare and Rhine) project, we have elaborated long continuous simulations of streamflow using a hydrometeorological modeling chain. This chain consists of a stochastic weather generator that provides precipitation and temperature series to a hydrological model, whose outputs are finally processed with a hydrological routing system. As a result, distinctively long (several 100'000 years) continuous simulations are available at hourly resolution. Since the long continuous simulations provide not only streamflow but also other model internal fluxes and states, we can analyze and characterize the antecedent conditions of extreme floods. Here we look at the translation of precipitation into extreme floods from two angles, namely starting from floods with a specific return, and starting from precipitation events with a specific return. We then examine how antecedent conditions influence this translation and study their role in the generation of large floods.

A high-performance algorithm to compute terrain parameters relevant for modelling surface radiation in hydrological and atmospheric models

Christian R. Steger[1] (christian.steger@env.ethz.ch)
Benjamin Steger[2]
Christoph Schär[1]

1 Institute for Atmospheric and Climate Science, ETH Zürich, 8092 Zürich, Switzerland
2 ESRI Research & Development Center Zürich, Zürich, Switzerland

Hydrological and atmospheric models require a representation of grid and subgrid-scale topographic effects on atmospheric surface radiation. In complex terrain, incoming short- and longwave surface fluxes are strongly influenced by local and surrounding topography. Direct shortwave radiation depends both on local slope as well as on neighbouring terrain, which can induce topographic shading. Incoming diffuse shortwave radiation can be enhanced by terrain reflection – particularly under snow covered conditions, which feature a relatively high surface albedo. Finally, incoming longwave radiation can also be modulated by radiative exchange between facing slopes.

An accurate representation of the above processes is required in a broad range of numerical models like spatially distributed hydrological and glacier models as well as weather and climate models. Additionally, such processes are also relevant for the generation or downscaling of precise radiation data sets. Parameterisations to account for these effects typically require the terrain parameters horizon and sky view factor (SVF). The derivation of these parameters is computationally expensive because large quantities of non-local digital elevation model (DEM) data have to be processed. The costs are particularly large for high-resolution DEM (grid spacing of $\lesssim$30 m), which become increasingly available.

We thus developed a new algorithm, called HORAYZON, which allows the computation of terrain horizon and SVF both in a very efficient and accurate way. HORAYZON is based on a high-performance ray tracing library (Intel Embree) and is provided as a Python package for simple workflow integration. The package also allows to directly generate shadow maps and factors to adjust direct incoming shortwave radiation for terrain effects for arbitrary geographical locations and times. Ongoing work focus on the improvement of the radiation parameterisation itself. Processes that are of particular interest are the effects of sub-grid topography on surface radiation and terrain-reflected shortwave radiation, which is typically represented with an extremely simplified approach.

Attributing the 2022 soil drought to human–induced global warming

Dominik L. Schumacher (dominik.schumacher@env.ethz.ch)
et al.

Institute of Atmospheric and Climate Science, ETH Zürich, 8092 Zürich, Switzerland

Europe experienced an unusually warm summer in 2022 with widespread precipitation deficits. West–Central Europe, ravaged by several heatwaves from mid–June, was particularly affected, with far-reaching impacts across different sectors such as human health, agriculture, energy and municipal water supply. But not only most of Europe suffered from heat and dryness; parts of China experienced the hottest and driest summer on record, and severe droughts occurred in the southern United States. The simultaneous occurrence of drought conditions across the extratropical Northern Hemisphere could be indicative of a human fingerprint, but most existing attribution studies either focus on hot extremes or on heavy precipitation. For such events, the link to human–induced climate change already emerges clearly. Droughts, on the other hand, are generally more difficult to attribute, and their assessments are usually restricted to precipitation. In West–Central Europe, 2022 summertime precipitation was below–average but not close to a record low, yet the drought signal manifested in the driest soils since at least 1950, with far-reaching effects on agriculture and ecology.

Therefore, under the umbrella of the World Weather Attribution, a group of scientists performing rapid attribution analyses of extreme weather and climate events using peer-reviewed approaches, the human contribution to the exceptional 2022 summer soil drought was investigated (Schumacher et al., 2022). The analysis was performed for both surface and root-zone soil moisture in West–Central Europe and the northern extratropics, relying on state-of-the-art observation-driven land surface models and Earth System Models. For

West–Central Europe, a root-zone soil moisture drought in the warm season such as witnessed in 2022 has become about 3 to 4 times more likely. The 2022 root-zone drought conditions in the northern extratropics are estimated to occur about once every 20 years as compared to once in 400 years or more in pre–industrial times, that is with 1.2 °C less global warming. In a climate warmed by a total of 2 °C, as pledged under the Paris agreement, the probability of summer droughts is further increased, with dry soils in the northern extratropics expected to occur nearly every year with similar or even higher intensity as in 2022.

More info: Schumacher, D. L. et al. (2022): High temperatures exacerbated by climate change made 2022 Northern Hemisphere droughts more likely, World Weather Attribution.

Transit time distributions of reactive contaminants: The role of sorption and degradation investigated with a distributed hydrochemical model

Chunming Sui[1,2] (chunming.sui@istp.ethz.ch)
Simone Fatichi[3]
Paolo Burlando[1]

1 Institute of Environmental Engineering, ETH Zürich, 8093 Zürich, Switzerland
2 Institute of Science, Technology, and Policy (ISTP), ETH Zürich, 8092 Zürich, Switzerland
3 Department of Civil and Environmental Engineering, National University of Singapore, Singapore

Studying the transport process of reactive contaminants is crucial for catchment pollution control. In this context, it is important to systematically understand how processes, i.e., sorption and degradation influence solute transport. Here, we introduced a new solute tracking module in the distributed hydrological model TOPKAPI-ETH, which is able to explicitly compute the age and transport dynamics of both conservative and reactive tracers from local to catchment scale. We use the model to track the environmental fate of conservative solute Cl- and reactive solute Na+ that entered the Hafren catchment (UK) through rainfall over two years. Two reactive tracer mixing methods were proposed and their rationales and realism in simulating the transit time distribution of Na+ were discussed. Numerical experiments were run to quantify the role of sorption and degradation on modifying solute forward and backward transit time distributions and to evaluate the importance of the initial adsorption/desorption state. The analysis illustrates that in general the sorption process leads to older solute stored in the soil matrix, which results in a high age variability and old solute fractions in the discharge and evapotranspiration. Oppositely, the degradation process decreases the old solute fraction in the storage compartment, therefore resulting in a younger solute in discharge and evapotranspiration.

Subsurface processes in hydrology: A micro-scale view

Andres Velasquez-Parra[1,2] (andres.velasquez@eawag.ch)
Ishaan Markale[1,2]
Maximilian Stoll[1,2] (maximilian.stoll@eawag.ch)
Joaquin Jimenez-Martinez[1,2]

1 Eawag, Swiss Federal Institute of Aquatic Science and Technology, Subsurface Environmental Processes Group, 8600 Dübendorf, Switzerland
2 Institute of Environmental Engineering, ETH Zürich, 8093 Zürich, Switzerland

Soil and aquifers are porous and topologically complex environments. The flow field is a heterogeneous mosaic of high and low velocities, rheological properties, and partially miscible or immiscible phases (e.g., air and contaminants). Each of these elements controls chemical mixing and reactions occurring in these highly structurally complex environments. The biochemical activities of microbes also play a major role in controlling both the local fluid dynamics (by clogging and re-routing of flow due to biofilm formation) and the cycling of nutrients, trace elements, and contaminants in these environments. First, we study the control of the physical complexity of porous media on fluid mixing, focusing in particular on the impact of an immiscible phase such as air. Secondly, we focus on the consequences of fluid mixing on the kinetics of fluid-fluid and fluid-solid reactions. And finally, we show the control that hydrodynamics and chemical heterogeneity exert on microbial behavior.

Climate sensitivity and changes in water productivity across agricultural landscapes of Ethiopia

Mosisa Tujuba Wakjira[1] (wakjira@ifu.baug.ethz.ch)
Nadav Peleg[2]
Peter Molnar[1]

1 Institute of Environmental Engineering, ETH Zurich, 8093 Zürich, Switzerland
2 Institute of Earth Surface Dynamics, University of Lausanne, 1015 Lausanne, Switzerland

In this study, we examined the spatio-temporal changes in water productivity (WP) and its sensitivity to the changes in precipitation and temperature in various climatic zones across the rainfed agriculture (RFA) regions of Ethiopia. To do this, we (i) downscaled the future precipitation, air temperature, and shortwave radiation to a 5 km grid resolution considering multiple GCM projections under three shared socioeconomic pathways (SSPs) namely, SSP1-2.6, SSP2-4.5, and SSP5-8.5 for three future periods: 2020-2049, 2045-2074, and 2070-2099 using the present climate (1981-2010) as a reference; (ii) computed the reference evapotranspiration using the FAO Penman-Monteith, and simulated the actual evapotranspiration using a daily bucket soil water balance model; (iii) determined the main growing season (May-September) Evaporative Stress Indexes (ESI) as a proxy for WP, and (iv) analyzed the sensitivity of WP to changes in precipitation and temperature based on the one-at-a-time (OAT) approach. The results show that the median rainfall WP (percent of the potential WP) during the growing season under the present climate ranges from 45% in semi-arid climates to 90% in humid climates. The projected WP shows an increase in the sub-humid and humid zones (by up to 8%) as well as in the semi-arid zones (up to 16%) under the three SSPs already in the next few decades. However, in the mid of the century, WP is likely to decrease by up to 4% in significant parts of the sub-humid and humid zones under the three SSPs, and this change tends to spatially expand by the end of the century. The observed changes are the combined effects of the somewhat consistent (but spatially variable) increase in precipitation (for example up to 30% under SSP5-8.5 in the 2080s) and rising temperature (up to 5°C under SSP5-8.5 in the 2080s) over the RFA region. The OAT sensitivity analysis results reveal that WP is more sensitive to changes in temperature than to changes in precipitation.

Ecosystem Scale Critical Soil Moisture Thresholds of Transpiration and their Global Variability are Explained by Soil Hydraulic Conductivity

Fabian Wankmüller[1*], **Louis Delval**[2*] (*authors with equal contribution)
Andrea Cerere[2]
Peter Lehmann[1]
Mathieu Javaux[2,3]
Andrea Carminati[1] (andrea.carminati@usys.ethz.ch)

1 Physics of Soils and Terrestrial Ecosystems, D-USYS, ETH Zürich, 8092 Zürich, Switzerland
2 Earth and Life Institute, UC Louvain, Belgium
3 Agrosphere, Forschungszentrum Jülich, Germany

Predicting and understanding the critical soil moisture thresholds (θ_c) at which plants start to downregulate transpiration and photosynthesis is crucial to evaluate drought impacts on ecosystems and represent water stress in earth system models. Thanks to the existing monitoring networks of terrestrial fluxes and soil moisture, θ_c can now be estimated across biomes and climates. However, the underlying mechanisms explaining critical soil moistures thresholds remain elusive. Here, we used a parsimonious soil-plant hydraulic model in which stomatal closure (downregulating transpiration) is triggered by a loss in the hydraulic conductance of the soil-plant continuum to predict observed θ_c by varying the soil hydraulic properties to match the soil textures of the corresponding observation sites. The good agreement between observed and modelled θ_c proved that mean soil moisture thresholds and their variability are controlled by soil hydraulic properties. We further found that the critical soil matric potential thresholds (h_c) are not unique (varying over two orders of magnitude) and are inversely related to the slope of the soil hydraulic conductivity. This implies that the loss in soil hydraulic conductivity is the trigger of stomatal closure and marks the onset of water-limited ecosystem fluxes. It follows that the effect of plant adaptation and plant traits on soil moisture thresholds is soil texture dependent, with greater sensitivity in fine textured soils. Similarly, the effect of climate change on θ_c will be larger in fine textured soils.