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ZHydro Seminar 2018

Seminar in Hydrology

Program and teasers for the presentations

October 31, 2018
ETH Zürich, GEP-Pavilion (MM C 78.1)

Organisation: Hydrology and Climate; Department of Geography; University of Zurich
Info: jan.seibert@geo.uzh.ch, ilja.vanmeerveld@geo.uzh.ch

Registration (for sandwich lunch, until 19 Oct) https://doodle.com/poll/tmgy8vkt9qh6p9se

Registration of poster or pop-up: https://docs.google.com/spreadsheets/d/1IU3QkVwMSoWykjRJLxaTUEj3X-6-7iXoO71FZBRVnto/edit?usp=sharing

ZHydro 2018, Schedule

Time	Speaker	Title
8:45		Arrival
9:00		Welcome
9:15	Robin Tecon (ETH, Soil and Terrestrial Environ. Physics)	Hydration conditions affect bacterial interactions on soil surfaces
9:30	Qinghua Lei (ETH, Engineering Geology)	Impact of geomechanical processes on hydrogeological behaviour of fractured media
9:45	Dorothee Kurz (ETH/EAWAG, Subsurface Environmental Processes)	Microbial life in porous media: a microfluidic approach
10:00		Poster appetizers and other pop-ups
10:15		Coffee break / Posters
10:45	Max Ramgraber (Eawag, Hydrogeology)	Data Assimilation and Online Parameter Optimization in Groundwater Modeling using Nested Particle Filters
11:15	Saskia Gindraux (WSL, Mountain Hydrology and Mass Movements)	The potential of UAV photogrammetry for hydro-glaciological forecasts
11:45	Daphne Freudiger (UZH, Hydrology & Climate)	Future contributions of snow and ice to streamflow in the River Rhine
12:00		Poster appetizers and other pop-ups
12:15		Lunch & Posters
13:15	Marius Floriancic (ETH, Hydrology and Water Resources Management)	Low-flow seasonality across Switzerland – Climatic drivers and the influence of landscape
13:45	Andrea Ruecker (ETH, Physics of Environmental Systems)	Tracing streamflow generation during rain-on-snow events using stable isotopes
14:00	Simon Etter / Barbara Strobl	Citizen science in hydrology (CrowdWater)
14:15	Vincent Humphrey (ETH, Land-Climate Dynamics)	Sensitivity of atmospheric CO2 growth rate to observed changes in terrestrial water storage
14:30		Coffee break & posters
15:00	Peter Lehmann (ETH, Soil and Terrestrial Environ. Physics)	Physically constrained pedotransfer functions for land surface models - incorporating soil structural effects
15:15	Scott Allen (ETH, Physics of Environmental Systems)	The seasonal origins of soil water used by trees
15:30	Heewon Moon (ETH, Land-Climate Dynamics)	Soil moisture effects on afternoon precipitation in global climate models
15:45	Nikolina Ban (ETH, Climate and Water Cycle)	Intensification of heavy precipitation events in continental-scale climate-change simulations with kilometer-scale resolution
16:15		Final notes, planning of ZHydro 2019, etc
16:45		End of ZHydro 2018

Hydration conditions affect bacterial interactions on soil surfaces

R. Tecon, A. Ebrahimi, H. Kleyer, S. Erev Levi and D. Or

Soil & Terrestrial Environmental Physics, ETH Zürich, 8092 Zürich, Switzerland.

Bacterial cell-to-cell interactions drive many evolutionary and ecological processes in soil environments. Interactions are controlled by factors such as bacterial density, distribution, growth, motility, and dispersal. Importantly, biophysical constraints to cell-to-cell contact are different in terrestrial habitats (e.g. unsaturated soils) compared to aquatic habitats: soil bacteria inhabit pore spaces where the aqueous phase is often fragmented and limited to thin films that may trap cells in close proximity for prolonged periods or limit access to neighbors. Improved mechanistic understanding of factors that control cell-to-cell interactions is key to quantitative modeling and predictions of microbial community functioning in soil. We hypothesized that bacterial cell level interactions are affected by soil properties and hydration status both shaping the microscale conditions experienced by cells. We have used bacterial conjugation (i.e. the transfer of a plasmid that necessitates physical contact between a donor and a recipient cell) as a measure of cell interactions within a population of the soil bacterium *Pseudomonas putida*. A tagging system with fluorescent proteins allowed us to visually discriminate donors and transconjugants, while the frequency of transfer events was quantified by plating on selective media. Using hydration-controlled sand microcosms, we demonstrated that the frequency of cell-to-cell contacts during 20 hours under constant conditions slightly but significantly increased when water matric potential values were lowered from -1.2 kPa to -6.5 kPa. In addition, we have developed a mechanistic and spatially-explicit individual-based model that linked the macroscopic matric potential to microscopic distribution of liquid phase and bacteria in porous media. Results of the model simulations were in good agreement with experimental data, and they permitted us to systematically investigate the link between water potential, aqueous fragmentation and cell-to-cell contact, as well as the effects of cell density. These results demonstrate how mathematical modeling and experiments in artificial porous media help us tease out basic principles of bacterial organization and activity in soil, and highlight the role of biophysical processes in unsaturated environments.

Impact of geomechanical processes on hydrogeological behaviour of fractured media

Qinghua Lei

Chair of Engineering Geology, Department of Earth Sciences, ETH Zürich, Switzerland

The understanding of geomechanical effects on fluid flow in fractured geological media is a challenging issue, which is relevant to various engineering applications, such as civil construction, hydrocarbon recovery, geothermal energy, groundwater remediation and geological disposal of radioactive waste. In the seminar, I will first discuss the complexities of natural fractures in rock with respect to their length distribution, spatial organisation and scale dependence. Then, I will describe the computational framework of a finite-discrete element method that can be used to simulate important geomechanical processes in fractured rocks such as matrix deformation, stress variability, fracture displacement and crack propagation. The impact of these geomechanical responses on hydrogeological properties such as equivalent permeability, flow pattern and

mass transport will be further elucidated based on fluid flow simulation. The presentation will be finalised with a discussion of outstanding issues and future plans.

Microbial life in porous media: a microfluidic approach

Authors: Dorothee Luise Kurz[1,2], Eleonora Secchi[1], Vicente Fernandez[1], Roman Stocker[1] and Joaquin Jimenez-Martinez[1,2]

[1]Department of Civil, Environmental and Geomatic Engineering, Institute for Environmental Engineering, ETH Zurich; [2]Department Water Resources and Drinking Water, Swiss Federal Institute of Aquatic Science and Technology, EAWAG, Dübendorf, Switzerland

The subsurface is a complex environment in which the presence of several phases creates numerous interfaces (solid-liquid, liquid-gas and solid-gas). In the field of bioremediation and ecology, it has been of growing importance to understand the interplay between hydrodynamics and biogeochemical processes such as nutrient cycling. In natural subsurface environments, microorganisms are found in large numbers in the pore space, where a mosaic of regions with low and high water velocity exists. This variety of conditions permits microorganisms to live in the free-swimming phase and to form surface attached communities known as biofilms.

The structure of a growing biofilm influences pore geometries by clogging pores and therefore altering local hydrodynamics. This affects the biofilm development and mass transport. To obtain a mechanistic understanding of the effect on different flowrates and pore sizes on biofilms and vice versa at the pore scale, a soil-born microorganism, *Bacillus subtilis*, is studied in microfluidic devices. Carefully designed channel geometries coupled with automated video microscopy allowed us a zoomed-in view on specific interactions and a study of the biofilm forming behavior. Varied biofilm growth is observed caused by the influence of varied hydraulic and geometric parameters.

The potential of UAV photogrammetry for hydro-glaciological forecasts

Saskia Gindraux [1], Ruedi Bösch [1], Guillaume Jouvet [2] Umberto Morra di Cella [3], Daniel Farinotti [2,1]

[1] Swiss Federal Institute for Forest, Snow and Landscape Research WSL, Birmensdorf, Switzerland

[2] Laboratory of Hydraulics, Hydrology and Glaciology (VAW), ETH, Zürich, Switzerland

[3] Environmental Protection Agency of Valle d'Aosta, Saint-Christophe, Italy

Under ongoing and future climate changes, glaciers are retreating rapidly, leading to a diminution in water availability for agriculture, energy production and river transportation for instance. The evolution of glacierized catchments and prediction of future glacier runoff are usually forecasted with glacio-hydrological models. Although numerous studies predict a similar general trend in future runoff, their predictions suffer from several uncertainties. These sources of errors arise in the input meteorological/climate forecasts and in the glacier-related input data. This project (i) investigates how the quality in the meteorological forecasts propagates in the quality of the runoff forecast, as well as (ii) explores the potential of UAV photogrammetry to derive glacier-related information. Complementary information about these two points can be found below.

(i) The first study shows how the skill (i.e. the quality) of temperature and precipitation forecasts are transferred to the runoff predictions in glacierized catchments. Synthetic meteorological forecasts with different skills were produced with a weather generator and fed into two different hydrological models. The results show that for catchments with high glacierization (>50%), the runoff forecast skill is more dependent on the skill of the temperature forecasts than the one for precipitation. The influence of the temperature forecast skill diminishes with decreasing glacierization, while the opposite is true for precipitation. Precipitation starts to dominate the runoff skill when the catchment's glacierization drops below 30%, or when the total contribution of ice and snow melt is less than about 60%.

(ii) In the second study, the accuracy of the UAV products is quantified on snow and ice. In particular, the influence of the number and disposition of Ground Control Points on the accuracy of Digital Surface Models (DSMs) is investigated. It shows that the accuracy increases asymptotically with the increasing number of GCPs until a certain density is reached. In addition, this study shows that as long as the glacier's surface is not fresh snow, DSMs and ortho-images can be generated on glacier, with a vertical (horizontal) accuracy ranging between 0.10 and 0.25m. (0.03 and 0.09m). The third study shows how ortho-images and/or DSMs can be used to derive glacier surface velocities. A python toolbox is presented, which applied several filters and matching functions to the input datasets, generating many different velocity fields. All displacement vectors are then combined to create a more complete and robust result, along with an error estimation. The results show velocity fields obtained from different types of glaciers.

Future contributions of snow and ice to streamflow in the River Rhine

Daphné Freudiger

Alpine snow and ice covers are highly sensitive to changes in temperature. In a warming climate, there is considerable interest in understanding and predicting the changing hydrological processes in high mountain headwater catchments. The aim of this study is, therefore, to estimate the contributions of snow, glacier melt, and rainfall to streamflow in Swiss alpine catchments for past, present, and future climate conditions with the HBV-model. Thereby, the focus is not to identify the origin of single water particles, but rather to quantify how streamflow reacts on a given day to the inputs of snow, ice melt, and rainfall. Processes in high alpine areas are highly variable and, at the same time, data is scarce. We show the challenges and benefits of combining multiple regional data sources to constrain hydrological modeling in the headwater catchments. The model results analysis will help improve the understanding of climate sensitivity in high mountain environments with a special focus on low flow events.

Marius Floriancic (ETH, IfU – Hydrology): **Low-flow seasonality across Switzerland – Climatic drivers and the influence of landscape**

We identified and quantified the regional patterns of low-flow seasonality for 380 gauges across Switzerland. Seasonal and regional variation in low-flow magnitudes and occurrence were traced back to interactions of climatic driving mechanisms (e.g. lack of precipitation, high evapotranspiration) and physical landscape properties (e.g. topography, morphology, geology, soils) that are revealed in our study.

Citizen science in hydrology (CrowdWater)

Barbara Strobl[1], Simon Etter[1], Jan Seibert[1], H.J. (Ilja) van Meerveld[1]

[1] Department of Geography, University of Zurich, Zurich, Switzerland

Hydrological observations are crucial for decision making for a wide range of water resource challenges. Citizen science is a potentially useful approach to complement existing observation networks to obtain this data. Previous projects have demonstrated that it is possible to engage the public in contributing hydrological observations. An initial study has shown that streamflow estimates are very difficult for citizens and that these estimates are not informative for hydrological model calibration. However, water levels are easier to estimate and can still be used for model calibration. While it may be relatively easy to install a staff gauge at a few river sites, the need for a physical installation makes it difficult to scale this type of citizen science approach to a larger number of sites because these gauges cannot be installed everywhere or by everyone. Here, we present a smartphone app that allows collection of stream level information at any place without any physical installation as an alternative approach. The first experiences with the use of the app by citizen scientists were largely encouraging.

www.crowdwater.ch

Physically constrained pedotransfer functions for land surface models - incorporating soil structural effects

Peter Lehmann, Sara Bonetti, Samuel Bickel and Dani Or

Soil and Terrestrial Environmental Physics, ETH Zurich

Soil ecological and hydrological functioning is critically dependent on maintenance of favorable soil structure; a fragile assembly of biopores and aggregates. Soil structure affects the partitioning of rainfall into infiltration and runoff and thus recharge and surface energy balance relative to soils lacking structure. Such flux partitioning in hydrologic and climate models relies on input soil hydraulic parameters often derived from auxiliary soil properties, such as soil textural type, using statistically-based pedotransfer functions (PTF). Present day PTF's correlate soil texture, bulk density, and organic matter to a subset of sample scale soil hydraulic parameters that rarely consider soil structure. Cursory tests of PTF's show that in many cases the resulting parameter combinations may violate physical constraints. We present an overview of the limitations of present PTF's and propose strategies to consider soil structure and land cover to improve parameterization of land surface models.

Seasonal origins of the precipitation used by trees

Scott T. Allen[1,2*], James W. Kirchner[1,3,4], Sabine Braun[5], Rolf T.W. Siegwolf[2], Gregory R. Goldsmith[2,6]

[1]ETH Zurich, Physics of Environmental Systems Group, Department of Environmental Systems Science, Zurich, Switzerland.
[2]Paul Scherrer Institute, Ecosystem Fluxes Group, Laboratory for Atmospheric Chemistry, Villigen, Switzerland.
[3]Swiss Federal Research Institute WSL, Birmensdorf, Switzerland
[4]Department of Earth and Planetary Science, University of California, Berkeley, California, USA
[5]Institute for Applied Plant Biology, Witterswil, Switzerland
[6]Schmid College of Science and Technology, Chapman University, Orange CA, USA
[*]corresponding author: scott.allen@usys.ethz.ch

The seasonal origins of water used by plants have not been systematically explored. In 182 Swiss forests sites, we characterized the seasonal origins of waters in soils and trees by comparing their mid-summer isotopic compositions to seasonal isotopic cycles in precipitation (using a new seasonal origin index). The xylem water isotopes show that growing-season precipitation was not the predominant water source for mid-summer transpiration in any of three sampled tree species. Two broadleaf species mostly used winter precipitation, whereas one conifer used water with more varied seasonal origins. Even when paired in the same plots, the broadleaf trees consistently used less summer precipitation than the conifer trees, demonstrating differences in rhizosphere soil-water niches across a wide range of soils and climates. Regardless of species differences, in only the wettest regions did trees mostly use summer rainfall, suggesting that those trees may be most vulnerable to summer precipitation shortages. The widespread prevalence of winter precipitation in tree xylem suggests that the turnover of water (and thus flushing of solutes) in these trees' rooting zones must be remarkably small in summer.

Soil Moisture Effects on Afternoon Precipitation in Global Climate Models

Heewon Moon[1], Benoit P. Guillod[1,2], Lukas Gudmundsson[1], Sonia I. Seneviratne[1]

[1]Institute for Atmospheric and Climate Science, ETH Zurich

[2]Institute for Environmental Decisions, ETH Zurich

Soil moisture can influence precipitation at various spatial and temporal scales by partitioning the incoming radiative fluxes, which in turn may affect cloud development and precipitation. Despite substantial uncertainties in the phenomena, there have recently been several consentient studies on the sign and strength of soil-moisture-precipitation-feedback based on observations. In this study, we are aiming to evaluate the state-of-the-art climate models from the 5th phase of Coupled Model Intercomparison Project (CMIP5) on their capability to capture both temporal and spatial soil moisture impact on afternoon rainfall at subdaily time scale. We adopt a set of three metrics introduced in previous studies, which estimate the soil moisture impact on afternoon rainfall by sampling spatial and temporal conditions of pre-rainfall morning soil moisture from morning soil moisture conditions on the days without morning precipitation. Each metric respectively assesses spatial, temporal and heterogeneity soil moisture conditions preferred by afternoon rainfall. We confirm previous results highlighting a dominantly positive spatial feedback, indicating that the afternoon rainfall prefers wetter patch than surroundings, in the models as opposed to observations. On average, models tend to agree better with observations for temporal and heterogeneity feedback characteristics that are generally positive, although inter-model variability is largest for these metrics. The collective influence of the three feedbacks suggests that they may bring more localized dry or wet persistence in the models than those can be supported through observations.

Intensification of heavy precipitation events in continental-scale climate-change simulations with kilometer-scale resolution

Nikolina Ban[1],

Nico Kröner[1], David Leutwyler[1], Daniel Lüthi[1], and Christoph Schär[1]

[1]Institute for Atmospheric and Climate Science, ETH Zürich

Advances in computational power and recent developments in atmospheric modeling have enabled the use of climate models at kilometer-scale horizontal resolutions. At this resolution, the parametrization of convection, known as one of the major sources of uncertainties in climate models, is switched off, and convection (thunderstorms and rain showers, including vertical redistribution of heat, moisture, and momentum) is thus explicitly resolved by the atmospheric dynamics.

Here we present decade-long convection-resolving climate change simulations at horizontal resolution of 2.2 km on a computational domain with 1536x1536x60 grid points over Europe. Such computationally demanding simulations have become feasible with a COSMO (Consortium for Small-Scale Modeling) model version that runs entirely on Graphics Processing Units. We compare a present-day simulation driven by ERA-Interim reanalysis with the corresponding Pseudo-Global Warming (PGW) simulation to project climate change. The PGW simulation is driven by ERA-Interim reanalysis perturbed with the mean annual cycle of climate changes derived from a CMIP5 model. With this approach, resulting changes are due to large-scale warming of the atmosphere and due to slow-varying circulation and stratification changes.

In this presentation, we will address the performance of different modeling approaches (convection-resolving versus convection-parameterizing), and discuss the thermodynamic effects on changes in water cycle. We will show that heavy precipitation and water fluxes intensify with a warmer climate, but the rate of intensification depends on the region investigated.