Euromediterranean Network of Experimental and Representative Basins

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Book of Abstracts

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ERB MEDAL AWARD

Learning and contributing to hydrological knowledge: a 34-year journey within research basins.

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Abstract

I obtained my degree on Geological Sciences in 1974 and my Ph.D. about detailed Geomorphological Mapping in 1980. After my doctorate my interest turned to the study of erosion processes, particularly in badlands, using field observations and low-cost equipment. It was in 1988 when we obtained two projects for establishing a network of small research basins, funded by the late ICONA (Spanish Government) as a contribution to the UNCCD (United Nations Convention to Combat Desertification). The main purpose was land conservation rather than hydrology. Two areas were selected near Vallcebre, in the headwaters of the Llobregat River: the Cal Rodó basin, selected to study the behaviour of badland areas and supervised by Núria Clotet, and a smaller Cal Parisa basin, I selected to analyse the behaviour of abandoned terraced agricultural fields. Sadly, Núria Clotet suffered a fatal car accident in 1990 and I was appealed to manage the entire network.

Since these early times, we succeeded to renew research questions and obtain funding from diverse sources, so we continued our activity developing a long series of research projects and Ph.D. studies, even if we have no permanent sources for continuing observations. Some of the subjects that we early learned have conducted our research thereafter: i) even in a Mediterranean environment, soil saturation is more important than rainfall excess in runoff generation, ii) agricultural terraces modify the spatial pattern of soil saturation areas, iii) soils are habitually drier under forest cover than under grass, iv) badland activity is the result of an annual cycle that turns from frost weathering in winter, regolith erosion in summer to sediment exportation in autumn, and v) the main environmental consequence of mountain land abandonment is the decrease of water resources due to increased evapotranspiration by the spontaneous encroachment of tree cover.

From my experience, there are two main aspects that are in the core of the ERB basins that make them necessary for the development of hydrological sciences: Hydrological models rarely give the good answers for the right reasons; internal “orthogonal” observations allow us to discern if the model adequately simulates the hydrological processes and may provide ways to improve the imitation. Particularly in small catchments and Mediterranean environments, short periods of high flow may convey the main part of sediments, solutes or environmental tracers; intensive sampling during these periods may help to identify sampling biases obtained by regular, operational samplings made in network basins.

Keywords: Runoff generation, badlands, eco-hydrology, land abandonment, model development.

SESSION 1:
HYDROLOGICAL AND ECOYDROLOGICAL MONITORING TECHNIQUES

Water stress index analysis using infrared thermography and computer vision to perennial crops in a small basin in the Brazilian semiarid

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Abstract

Perennial crops play an important role on ecohydrological processes, mainly in semiarid catchments. Nevertheless, climate change has been affecting the water resources' availability, promoting an increase in air temperature, increasing crop water demands, and thus interferring on the water budget. On this context, studies show the beneficial effect of adopting conservation practices on sustainable land use and agricultural production. Additionally, monitor the plant water status contributes to the understanding of hydrological processes and soil moisture dynamics. One of the main parameters adopted for water stress analysis in plants is the leaves temperature, which is a result of metabolism and local climatic conditions. A non-destructive technique to assess leaves temperature is based on thermography. Thus, the objective of the present research is to present an inovative algorithm to process thermographic images of the Neem canopy, extracting temperature data from the leaves, in order to quantify and map plant water stress under different soil cover conditions, through stochastic geostatistical techniques and computer vision. The study was carried out in a small experimental basin in the Brazilian semiarid region, where hydrological and climatic information are recorded. The thermal images of the leaves were obtained from a portable thermographic camera, for March, and September 2017 (dry season), and May 2017 (rainy season), for bare soil condition and mulch cover. For thermal image processing, Python language and OpenCV database were used, in the PyCharm software. The average leaves temperature data obtained from thermal imaging were combinate with air temperature to calculate the daily water stress index (DWSI). Descriptive and geostatistical techniques were applied to identify patterns of spatio-temporal variability and spatial dependence of DWSI, aiming at mapping the stress index, and evaluating the density probability function. The sequential gaussian simulation (SGS) was used to generate conditional scenarios of temperature and to assess the degree of uncertainty in the kriging maps. The highest levels of water stress were recorded for the month of March due to a spatial distribution of high temperature in the canopy, due to high rates of evapotranspiration, and low antecedent rainfall (0 mm). Water Crop Indices in May were associated to the lowest rate of plant stress (28.4 mm), followed by the assesment in September. Even under extreme water scarcity conditions, mulching attenuated the Neem physiological water stress in relation to the environment, promoting higher plant comfort, associated to a higher soil moisture content.

Keywords: mulching; semiarid; machine learning; plant status; Neem

Spatio-temporal dynamics of the vegetation index related to basin scale rainfall in the Brazilian semiarid region

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Abstract
Climate change is expected to affect the rainfall regime in semi-arid regions. Such changes systematically impact the spatial and temporal dynamics of the vegetation cover of the Caatinga Biome, which is a deciduous Brazilian ecosystem, strongly controlled by the rainfall regime. Therefore, spatiotemporal monitoring of the vegetation cover in those areas is crucial for hydrological processes assessments and water resources planning. Therefore, remote sensing provides essential reflectance information regarding the vegetation cover, and its heterogeneities at different scales. Thus, the objective of this work is to evaluate the spatial and temporal variability of precipitation and its correlation with land use conditions in a small basin in the semiarid region of Brazil. The study was carried out in the Alto Ipanema watershed located in the municipality of Pesqueira, in the Pernambuco State, Brazil, which presents a long and narrow alluvial valley at the basin outlet. Information from seven rainfall and agrometeorological Campbell Scientific stations, distributed at different land use conditions, between 2015 and 2017, was used. For the same period, Landsat 8/ OLI images were used to determine the Normalized Difference Vegetation Index (NDVI). To verify the spatial and temporal correlation of the NDVI with precipitation, three combinations were adopted: 1 - central pixel; 2 - pixels on the two diagonals, and 3 - center pixel and pixels on its boundary. It was found that the lowest and highest point of the basin received an average of 500.7 and 662.1 mm year-1, respectively, with the highest precipitation depths occurring between February and June, with a maximum of 56.2, 74.8, and 56.7 mm day-1 and accumulated values of 404.5, 489.9 and 633.1 mm, while annual evapotranspiration were 1257.4, 1280.1 and 1067.0 mm, with maximum values of 5.4, 7.3 and 5.6 mm day-1, in 2015, 2016, and 2017, respectively. It can be identified the predominance of open Caatinga, with large areas of bare soil in the region of the alluvial valley, despite the shallow water table. Responses of vegetative growth due to precipitation throughout the year are strongly correlated to 90-days antecedent precipitation that precede the imaging data. The adoption of nine pixels in a regular mesh arrangement, with a station at the central image pixel, increases the correlation coefficient. It is verified that the NDVI presents a high correlation with the 90-days antecedent precipitation. Additionally, the arrangement adopting jointly nine pixels improves the precision of the estimates.

Keywords: Brazilian semiarid; climate change; remote sensing.

Use of Copernicus Sentinel-2 data for monitoring rice irrigation: applications in the Central region of Portugal

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Abstract

Rice irrigation by continuous flooding is often identified as contributing largely to low water use efficiency in rice agricultural areas, an issue of growing importance due to the increasing competition for fresh water, water scarcity and demand for food security. Related problems and challenges involve water users and managers and the scientific and technical communities.

In recent years remote sensing has been allowing new insights in agriculture, particularly because it is capable of providing timely and reliable information related to agricultural systems, in particular, hydrologic assessment and modelling (e.g., water use and productivity, and crop yield monitoring). However, satellite data resolutions are still too coarse to address plot scale conditions, which is important for precision agriculture. For surveying relatively small areas (tens of hectares), the use of lightweight Unmanned Aerial Systems (UAS) can be a good alternative, especially due to the data's finer resolution and versatility, and lower economic cost than other remote sensing techniques. The remote sensing data allow to calculate Vegetation Indices (e.g., Normalized Difference Vegetation Index – NDVI) using several spectral bands that are sensitive to plant biomass and vigour, thus, to water requirements and availability. Multi-temporal spectral data acquired during rice cropping seasons can provide information about the crop response to adopted agronomic and water-saving irrigation practices, but further studies and applications are needed for achieving full understanding of the potential of remote sensing tools for specific local conditions.

Rice cultivation has a long tradition in Portugal and is of great importance to local economies. Portugal produces annually about 180 million kilograms of rice in the main dedicated downstream rice cultivation areas of the Tagus, Sado and Mondego River basins, but rice is cultivated also in other areas (e.g., Lis basin). Climate change scenarios for these geographies anticipate that fresh water scarcity will be aggravated in the future. It is thus important to improve the sustainable use of water in the regional rice agro-ecosystems. This study focuses on the Lower Mondego and Lis Valleys, in the Central region of Portugal, and on the increased understanding of the usefulness of remote sensing tools for rice agriculture. Main targets are: 1) to contribute to improve the estimation of rice water consumption using remote sensing-based products including satellite Sentinel-2 and UAS images; and 2) to better understand the relation between the Sentinel-2 and UAS signals.

Keywords: Precision Agriculture, Rice Farming, Sentinel-2, Vegetation Indices, Water management.

Introducing FALCON array of artificial catchment for large scale ecosystem manipulation

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Abstract
Understanding how natural processes arise from complex interactions between specific processes at small spatiotemporal scales and how these processes in turn form patterns at large spatiotemporal scales is one of the most important questions in environmental science. One of the major obstacles is that landscape-scale processes are difficult to manipulate and, in many cases, even measure. Moreover, the problem is multidisciplinary. In many cases, the most important processes are studied by researchers from different disciplines, such as ecology, soil science, or hydrology. In particular, subsurface processes are in many cases overlooked or at least not sufficiently studied.
Here we briefly describe a methodological solution to address this problem, describing artificial catchments developed for experimental manipulations at the scale of a landscape, called FALCON. This array consists of two treatments: one mimics a site that was rehabilitated with alder plantation, and the other was left to unmined primary succession. FALCON is part of the LTER site Sokolov Post Mining Ecosystems (LTER_EU_CZ_026), which consists of 8 well-instrumented sites representing two chronosequences, the first comprising rehabilitated and the second unrehabilitated post mining sites ranging in age from 10 to 65 years. The LTER sites have been studied since 1992 and good background information is available on soil and ecosystem development at these sites. Two treatments from FALCON mimic the situation at the remediated and non-remediated sites that were part of the long-term chronosequences studied above.
For each treatment, there were two replicates in four similar watersheds. Each catchment is hydrologically isolated from the environment and equipped with instruments so that all the main processes and all the significant flows of materials and energy in the ecosystem can be monitored, including the cycling of water, nutrients and gas between the ecosystem and the atmosphere. In addition, there are a number of lysimeters in each catchment that allow the study of small-scale processes and their extrapolation to the catchment scale. Also, in addition to the catchments, there are two lysimetric fields for monitoring the effects of the experimental manipulations.

Keywords: artificial catchment, multidisciplinary, ecosystem manipulation

Estimating Recharge to the Groundwater in Transient Ecosystem by Integrating Multi-Sensors Observations

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Abstract
Regulatory agencies are often required to allocate groundwater extraction licenses in aquifers that are fully allocated and will be further stressed by predicted drier future climate. Agencies use numerical models to assist in the licensing decisions; for these models, recharge is a key flux that can be highly uncertain and is often not entirely understood. From a quantitative perspective, recharge fluxes are largely driven by climatic inputs. However, recharge also depends on factor such as land use, soil type and the depth to water table. Understanding how transient changes in climate affect recharge fluxes, subject to these mediating factors, provides valuable information to constrain the numerical models used for groundwater allocation. We designed a strategic field program to estimate recharge to groundwater across key land use/soil combinations over the Mediterranean area around Perth in Australia. The monitoring campaign relies on multiple observation packages to derive variables used, independently or in combination, to understand recharge dynamics and to estimate recharge fluxes. Five locations have been instrumented with soil sensing devices varying from permanent electromagnetic sensors for soil water content and soil water potential sensors, to manually operated neutron moisture probe and electrical resistivity tomography transects. High-quality soil cores (by sonic drilling) were collected at these locations. By combining the observations at these installation sites with laboratory analyses of the extracted cores, we aim to increase understanding of local recharge mechanisms and to evaluate the suitability of different recharge estimation methods under the changing climate. The design of the installed observation system, combined with satellite remote sensing observations, will help upscale recharge estimates to the plot and field scale.

Keywords*:* Recharge; Groundwater; Field work; Transient climate

Plot, slope and catchment scale electrical resistivity tomography of the Weierbach catchment (Luxembourg) for mapping regolith's structures and inferring hydrostratigraphic units

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Abstract
Within the Critical Zone, the architecture and properties of the regolith and its patterns across the landscape play a key role in how rainfall is collected, stored and finally released to generate and shape streamflow. Factors such as depth and composition of the soil cover and rock weathering determine water pathways, residence times in the subsurface and subsequent interactions with surface water bodies. While conventional invasive investigation techniques (e.g., soil pits and drillings) of the subsurface provide direct information about hydrological functions of the regolith, their spatial representativeness is limited. Geophysical prospection techniques have received increasing attention in recent years within the hydrological community, thanks to their non-destructive character and ability to provide information on subsurface features over large areas. They are now recognized as being essential for complementing traditional methods and fill in gaps between the sparse direct measurements. In this study we used electrical resistivity tomography (ERT) to better understand the hydrological functioning of the Weierbach headwater catchment (Luxembourg; 0.45 km²). Since the electrical resistivity of the subsurface is a weighted average of the electrical properties of its mineral grains, liquid and air, ERT has the potential to provide subsurface images that can be related to variations in lithological and hydrological properties (e.g., soil texture, rock type, weathering, porosity, hydraulic conductivity or water content). The Weierbach catchment is a slate forested area representative of the Ardennes massif (northern Luxembourg), and whose regolith highly controls runoff generation. Our study illustrates how we used a multi-scale ERT survey in combination with direct intrusive measurements for subdividing the regolith in units with similar hydrological properties. The delineation of these units at catchment scale will strengthen future modelling exercises by allowing the definition of a more realistic headwater catchment hydrostratigraphic structure.

Keywords: electrical resistivity tomography; regolith mapping; the Weierbach experimental catchment.

Innovative observations to monitor ephemeral streams in a Mediterranean headwater catchment

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Abstract
Understanding runoff formation in ephemeral and intermittent streams is fundamental for the comprehension of natural systems; however, monitoring such watercourses remains a major challenge in hydrology. Direct field observations are best to detect spatial patterns of flow persistence but they are time and labour intensive and may be impractical in difficult-to-access environments. Moreover, instrumentation deployed in the riverbed can provide information about the streamflow state, nevertheless these methods lack in streamflow quantification. Inspired by latest advancements in digital cameras and computer vision, we propose the development and application of a stage-camera setup to monitor the water level in an ungauged headwater stream. This system encompasses a camera with near infrared (NIR) night vision capabilities and a white pole that serves as reference object in the collected images. To evaluate the efficacy of this system in the detection of river dynamics, a set of 21 stage-camera stations is installed along the entire river network of the 4 km^2 Montecalvello catchment, near Viterbo (VT, Italy). Time-lapse imagery is processed through a computationally inexpensive algorithm featuring image quantization and binarization and water level time series are filtered thought a simple statistical scheme. The feasibility of this approach is demonstrated through a set of benchmark water level estimations obtained from a supervised procedure. Preliminary evaluations are encouraging and support the usability of this approach in monitoring ephemeral and intermittent stream dynamics.

Keywords*:* headwaters, intermittent/ephemeral drainage network, water level, stage-camera.

Toward the long-term monitoring of water availability to trees: preliminary validation of the Weierbach Experimental Catchment soil moisture database.

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Abstract

Tree nutrition capacity and related health is highly affected by water availability in the soil and the subsoil. The drought events experienced over the last four years in Luxembourg clearly showed the limit of certain regoliths for sustaining given tree species on the long-term in non-stationary climate conditions. Soil moisture sensors were installed in 2012 in the Weierbach Experimental Catchment in Luxembourg. We can now assess soil moisture dynamics during 10 successive vegetative periods. This information could therefore allow one to quantify the resilience of the water resource stored in soil when trees transpired and to observe inter-species differences in the evolution of water stocks at different soil depths.

The Weierbach Experimental Catchment (0.45 km^2) is the most instrumented and studied sub-catchment of the Alzette River basin in Luxembourg. Within the last decade, it has matured towards an internationally recognized Critical Zone Observatory focusing on a better understanding of hydrological and eco-hydrological processes. The Weierbach regolith is composed of Devonian slates, overlaid by Pleistocene slope deposits and entirely covered by forest with 70% deciduous (European beech + oak) and 30% coniferous trees (Norway spruce + Douglas-fir). Since 2009, the Weierbach has been extensively equipped for continuously monitoring water fluxes and physico-chemical parameters within different compartments of the Critical Zone. This ongoing monitoring and sampling programme is used for answering pressing questions related to fundamental catchment functions of water infiltration, storage, mixing and release in forest ecosystems. A recently started complementary research line aims at investigating interactions between forest eco-hydrosystems and the atmosphere and understanding how tree growth will respond to a non-stationary climate.

We present here a first analysis of the soil volumetric water content time-series that were recorded from September 2012 to December 2021 at seven stations, installed in sites with various topography and vegetation types that are representative of the catchment physiographic conditions. This monitoring system allows us to record at each station soil volumetric water content every 30 minutes along two profiles of sensors installed at 10, 20, 40 and 60 cm depths. The preliminary results enable us to investigate the volumetric water content intra- and inter-site variability in relation to the different sites' specific topographic and vegetation characteristics. We especially relate the regolith structure and tree species with the dynamics of the water content in soils between the different monitoring locations.

Keywords: Critical zone; soil water content; catchment scale, tree species, topography

Preferential flow occurrence in a small mountain catchment inferred from continual soil moisture measurements

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Abstract
Preferential flow is a well known and often occurring phenomenon. However, the conditions under which and where it occurs are still not well understood. In the last decade, continuous soil moisture measurements have been used as one of the possible methods of identifying preferential water flow in the soil. In addition to indicator methods, they can contribute to a better understanding of water dynamics in the soil.
Preferential flow occurrence in the top layer of two different stony soils located at altitudes, representing different climate areas, of the Jalovecký Creek Catchment in Slovakia, was quantified. The soil moisture was analysed from 10-minutes time interval measurements during the vegetation period of years 2013 – 2015. The measurements were carried out by the FDR type soil moisture sensors. Overall 74, and 106 rainfall events were analysed at the foothill and at the high mountain site of the catchment, respectively. The methodology was based on the comparison of different wetting front velocities, sequential and non-sequential soil moisture responses, and saturated and unsaturated hydraulic conductivities of the studied soils. The aim was to quantify the occurrence of preferential flow and the conditions for its occurrence. Different wetting front velocities and water dynamics were identified at the threshold rainfall intensities. At low rainfall intensities (smaller than 0.9 mm / 10 min), the soil moisture at the foothill site Ondrašová responded on average after 130 minutes in the uppermost soil layer and the lag times at the depths 10 and 20 cm were 180 – 270 minutes. At the high mountain site Červenec, the soil moisture response was about 70 minutes in the uppermost soil layer, followed by the lag of 120 – 200 minutes at the depths 10 cm and 20 cm. At large rainfall intensities (greater than 4 mm / 10 min), a rapid increase of the soil moisture was identified at both sites. The lag times were 30 – 50 minutes at the Ondrašová, and 20 – 30 minutes at the Červenec site, respectively. At large rainfall intensities preferential flow was always identified. Quantification of different water dynamics during different rainfall intensities may serve for better soil water flow model parameterization in the studied catchment.

Keywords: rainfall intensity, wetting front velocity, hydraulic conductivity.

Towards harmonization in the use of rainfall simulators – On the pursuit of better and more comparable experimental results

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Abstract

Rainfall simulators are an important experimental tool in hydrology and geomorphology studies. Rainfall simulators of different spatial scales have been widely used both in the laboratory and in the field for a wide range of research objectives and purposes. Furthermore, rainfall simulators can be developed and adapted to address more specific research demands. This flexibility and adaptability, which is usually seen as a major advantage, can also have some drawbacks, such as the significant diversity in the type, sizing, form, operation, and methodologies that can be found in rainfall simulators. The literature presents more than 250 different rainfall simulator setups. As such, this leads to numerous difficulties when comparing the results and outputs obtained from different rainfall simulator studies. Standardisation of rainfall simulation is one way of ensuring that key design and experimental methodologies (*i.e.,* design criteria, working procedures and data collection) are aligned. However, standardisation reduces the adaptability of rainfall simulators to answer specific research needs. Thus, 'harmonization' (*i.e.,* aligning rainfall simulation within a series of best practices but appreciating that variation in design characteristics should exist to allow rainfall simulators to be best suited for different research purposes) would deeply enhance the characterization and comparability of rainfall simulators. Harmonization will thus add value to simulated rainfall-based research as synergies can arise by establishing comparisons between different studies when this was not possible before. Rainfall simulators should be in harmony, rather than working in unison.

Having this in mind, it was found important to promote further the discussion on this issue. This poster aims to call upon researchers working with rainfall simulators, or with data obtained from simulated rainfall, to set a platform to pursue harmonization of rainfall simulator based experimental research. Moreover, this poster also aims to call the international research community attention to a future international meeting dealing with this theme, to be held in the spring or summer of 2023 in Coimbra, Portugal.

Keywords: Rainfall simulation; Harmonization; Hydrology; Experimental.

Assessing and measuring Subsurface Storm Flow (SSF) by Artificial Rainfall Simulation (ARS)

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Abstract
The use of artificial rainfall simulation (ARS) is a common method to study the interaction of soil and water (Strauss et al. 2000). Traditionally, precipitation simulation has been used as a tool to assess and determine the importance of surface runoff, usually with reference to soil erosion. Large-scale experiments are generally rare, although they are an efficient way to obtain directional soil hydraulic properties that functionally average local heterogeneities. Flow processes in the subsurface are usually measured indirectly. Such non-destructive methods for measuring subsurface flow processes often rely on soil moisture measurements or other indirect geophysical measurements (ERT, EMI, GPR,...) often accompanied by isotope or tracer analyses.
Direct measurement of subsurface rainfall runoff involves considerable effort and cost, and in some cases, it is even impossible e.g., when it is not possible to dig a drainage ditch. At BFW - Department of Natural Hazards, about 150 representative plots in the Eastern Alps have been irrigated over the last 30 years using portable sprinkler systems for large plots (50 to 400 m²). In total, more than 350 rain simulation trials have been conducted. Specifically, this BFW rainfall simulation database contains data from 11 plots and 21 experiments where subsurface storm runoff was directly quantified.
The results derived from these eleven test plots basically confirm the often-observed bimodal nature of subsurface flow, consisting of preferential/macropore flow and flow through the soil matrix (e.g., Weiler et al. 2005, Dasgupta et al. 2006, …). Preferential flow paths are mostly attributable to heterogeneities in the soil. Preferential macropore flow can be differentiated by means of such various types of heterogeneities. Four specific categories may be distinguished: phytogenic macropores (e.g. cavities left by decomposing roots); zoogenic macropores e.g. mole burrows, mouse holes); geogenic heterogeneities (e.g. periglacial cover beds, bedrock fissures and cracks) and anthropogenic heterogeneities (e.g. drainage systems, tillage pans). Each of these four categories is covered by at least one experiment in the BFW data record.
The observed subsurface hydrographs provide insight into the process-dependent differences in precipitation-infiltration-subsurface runoff response. In a research group currently applied for at the DFG (SSF Research Unit), new and novel irrigation experiments for the measurement of subsurface stormflow will be carried out in four test areas and the existing ones from the BFW database will be reanalyzed and modeled.

Keywords: infiltration, subsurface stormflow SSF, artificial rainfall simulation ARS

Analysis of the hydrometeorological conditions based on 10-year forest biometeorological monitoring in the region of Central Slovakia

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Abstract
The phenomenon of a substantial increasing in air temperature along with a simultaneous precipitation reduction during the growing seasons in Central Europe will bring the periods of long and intensive summer droughts which may have severe consequences on vegetation in forest ecosystems. The forest response to climate change is manifested in the frame of long-term horizons. Even if precipitation prediction for central European measures increase slightly the conditions become drier because the temperature increasing will lead to potential evapotranspiration and vapour pressure deficit increasing.
The aim of this paper is evaluation the development of climate conditions in sub-montane and montane regions of Zvolen valley and its surrounding (Central Slovakia) in wide altitudinal gradient from 350 m a.s.l. to 1264 m a.s.l which represent different forest vegetation zones. The forest vegetation zones represent the basic regional frames of climatic conditions for the growth of forest tree species. We have developed the functional and sustainable web applications for the forest biometeorological monitoring (http://www.forestweather.sk/). The applications allow to evaluate operatively a range of climate related risks (droughts, fires, floods and pest outbreaks) in forests to inform the foresters and broader public as well as the using in the educational system. At the same time extensive forestry and climatological databases will be evaluated to identify the adverse effects of recent climate variability (particularly of droughts and heats) on forest growth and yield.
The paper is focused on dynamic temperature analysis, dry and wet conditions in the period of 2011–2020 with focus on the vegetation period. From measured meteorological data were calculated climatic characteristics (totals, extremes) and compared with long-term mean climate values of the years 1961–1990. The chosen climatic characteristics were evaluated i.e. (precipitation distribution, frequency of rainless periods) and meteorological drought indices. Observations during the last decade have showed a higher frequency of extreme weather situations in the region of Central Slovakia, in accordance with predictions and scenarios. Although the analysis of combination the precipitation and evaporation conditions as well as precipitation and air temperature show that Zvolen valley and its surrounding are not still attacked by a years of severe and intensive drought nevertheless it indicates the gradual drying of sites at all altitudes.

Keywords: climate change, forest vegetation zone, climatic water balance, drought indices

Field measurements on the experimental catchment of Magyaregregy

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Abstract
In order to improve the forecasting of the water flow of small watersheds, even under extreme hydrological conditions, it is necessary to carry out a detailed exploration and continuous monitoring of the basins. In Hungary the mountain and hilly catchments are ungauged, and it would be an impossible task to explore them completely. This is why we need an experimental area which, through a detailed exploration of their hydrological and hydraulic processes and their extension, can even reduce the data deficit of ungauged catchments. The research programme on mountain and hilly watersheds at the Faculty of Water Sciences of the University of Public Service (Hungary) is based on the experimental catchment in the upper reach of the Völgységi creek (under Magyaregregy settlement). This experimental catchment is located in southwestern Hungary at the Mecsek hills. During the practical training of engineers (since 1970s), teams of students and lecturers have been carrying out expeditionary measurements to monitor and measure the catchment's water network and infiltration conditions. Since 2019, when we established the experimental catchment these kinds of exploration measurements are multiplied and supplemented. We did flood measurements, infiltration measurements with experimental irrigation field and soil exploration in the area of experimental catchment. On these poster we would like to show the process, and the results of the measurements.

Keywords: infiltration measurements, flood measurements, soil exploration

WaldLab: Measuring and modelling the soil-plant-atmosphere continuum

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Abstract
Forest water cycle processes like interception, infiltration, and transpiration greatly impact the redistribution of water between the atmosphere and the subsurface. In order to better understand the origin and magnitude of water redistributed among the different compartments of the forest water cycle we established a “hillslope laboratory” in the forest of Hoenggerberg (Zurich) at a SW facing slope at 515 m asl. Since 2020 we monitor water fluxes and isotopic composition across the soil-plant-atmosphere continuum, i.e., the main meteorological drivers, stomatal conductance, leaf water potential, sapflux, stem diameter changes and xylem isotopes at spruce and beech trees, soil moisture in various depths, groundwater, and streamflow magnitude and composition. The proximity of the site to the ETH campus allows to conduct high-frequent and labor-intensive data collections and experiments, and to contribute to student education.
The collected data allow us to address a great number of open research questions. For example, we observe the dynamics of plant water uptake and transpiration of beech and spruce trees, to understand the underlying physiological processes. We can demonstrate how both species adapt their water use through stomatal regulation during times of dry soil (i.e. low water availability) or dry atmosphere (i.e. high water demand). The responses of beech and spruce trees during those conditions differed, where beech species usually kept their stomata open for longer periods. These transpiration regulations could even be observed during short and low-intensity dry spells. We found that beech and spruce trees access different water pools (i.e., soil water depths) for transpiration limited by rooting strategies and controlled by stomatal opening. The water pools that the different tree species access depend on catchment wetness and water availability, nevertheless both species predominantly transpire waters with an isotopic winter signature (also throughout the summer season, after recent precipitation events). Xylem water signatures in both tree species were similar to the bulk soil water signatures and rather different from the mobile soil water signatures. Our dense measurement and sampling setup is complemented by sensitivity simulations with a fully mechanistical ecohydrological model (T&C), where in the future we intend to better incorporate the transpiration regulation processes during times of limited water availability, high water demand, as well as the various soil water uptake depths. The combination of a detailed, high-frequency sampling strategy and the use of state-of-the-art models will allow us to validate the T&C simulations and suggest ways to incorporate plant specific regulation strategies in other ecohydrological models.

Keywords: forest water cycle, water fluxes, isotopes, tree water uptake, drought

Natural and artificial runoff and irrigation experiments in an alpine torrential catchment –building the basis to improve hydrological modelling

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Abstract

Nature-Based Solutions (NBS) can be effective measures to respond to land degradation processes and consequently reduce intensities of flood events. In frame of the EU project RECONECT benefits of NBS are evaluate with regard to their direct impacts on flood reduction as well as to co-benefits supporting biological and social indicators as well. Here we present first hydrological investigations made in the torrential catchment Geroldsbach-Götzens (Tyrol, Austria) being used as a lead catchment. It is a typical alpine/torrential catchment with interacting urban and torrential features. A continuous afforestation realized since the early 1950ies is the main NBS given. Besides forest parts, the runoff and infiltration behavior of grassland parts and open soil parts is investigated using continuous measurements of soil moisture probes installed at different locations.

Core part within the field installations are four experimental plots established on grassland at the Götznerberg, located in the lower part of the catchment. Focus is on the continuous measurement of surface runoff generated during natural rainfall events, including aspects of varying initial conditions and vegetation cover changes. Surface runoff is collected at a lower trench and continuously measured with a connected gauge/weir system. Further the site is equipped with an automatic weather station and the estimated infiltration rates are verified using a dense network of soil moisture and temperature sensors. To capture the spatial variation in the infiltration process, over 200 soil moisture sensors are installed at varying depths. Besides the continuous observation of natural rainfall runoff behavior, the site is designed to run artificial rainfall simulations as well. In the irrigation experiments up to 180 mm/h rainfall can be applied onto each 5/16 m plot, allowing spatial and temporal variation of intensities. Additionally, inflow introduced at the plot's upper end (runon) allows to virtually extended the plots. Goal is the better understanding of the interaction of infiltration/runoff on plot and consequently on catchment scale.

In the wider scope of the RECONECT project, the plot scale results will be used for improved modelling of the catchment behavior allowing e.g. NBS scenario building (past/future states of afforestation) including seasonal aspects of NBS under todays' and future boundary conditions.

he results illustrate the potential use of upland land management for ameliorating local-scale flood generation but emphasise the need for long-term monitoring to more clearly separate the effects of land management from those of climatic
variability.

Keywords: Alpine catchments; Artificial rainfall simulations; Nature-Based Solutions; Runoff generation

Spring recharge patterns in flysch aquifer in the Carpathian Mountains

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Abstract
Flysch-type aquifers in the Eastern Carpathians usually feed periodic and low-discharge springs. However, in some areas, such as in the upper part of the Połonina Wetlińska Massif (the Bieszczady Mountains, Poland), perennial springs with a relatively high discharge were identified. Therefore, the aim of this study was to identify recharge and groundwater flow patterns of three high-discharge springs based on 1) defining the response of spring discharge to rainfall, 2) determining the relationship between specific electrical conductivity (SEC) of water and spring discharge, 3) geological mapping, and 4) mapping the shallow subsurface using electrical resistivity tomography (ERT).
Generally, cumulative rainfall over a period from 10 days to 3 months is most strongly correlated with discharge; however, the response time varies between springs and throughout the year. A small range of SEC combined with the varying discharge of two springs suggest that dilution of groundwater by rainwater does not play a significant role. The third spring discharge, characterized by the shortest response time, is clearly negatively correlated with SEC. Therefore, the groundwater flow pattern of the studied springs may be described by a model consisting of two crucial systems: 1) a relatively deep, fissure-pore flow system with a long response time to precipitation and 2) a shallow, fissure-dominated system with a short response time to precipitation, which is superimposed on the longer response.
It would appear that the differences in spring recharge patterns across such a small area as the Połonina Wetlińska Massif are determined by the local bedrock and regolith structures, which role has been underestimated thus far. First, the occurrence of joints and faults of different origin promotes the enlargement of groundwater storage capacity, which is higher than in many other flysch areas of the Carpathians. Secondly, the steep dip of the Otryt sandstone facies within the Połonina Wetlińska syncline facilitates the extension of the drainage area due to an inflow of infiltrating water from the opposite site of the ridge. Thirdly, gravitational slope deformations modify the conditions of subsurface water flow on the slope and may locally increase the retention capacity and the thickness of the active zone, with a particular increase in infiltration in the area of occurrence of landslides and ridge-top trenches.

Keywords: spring response time; groundwater flow; geological mapping; electrical resistivity tomography; sedimentary rocks

Four years of stream discharge and rainfall continuous monitoring in wildfire-affected watersheds: Instrumentation network structure and preliminary results from the continuous monitoring

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Abstract
Wildfires are important ecological disturbances that influence watershed hydrology, inducing extensive land cover changes that have important implications for streamflow generation.
In September 2018, February 2019 about 1,400 ha of mountainous forests and farmlands got burnt by two large wildfires in the Pisano Mount area (municipalities of Calci and Vicopisano, Tuscany Italy). The area is mainly formed of a hilly landscape, with extensive forest cover and peculiar geomorphological features. Moreover, in August 2021 a smaller wildfire burnt a smaller basin of mixed pine tree forest and olive grove near the village of Vicopisano.
A continuous monitoring network for stream stage was rapidly implemented to monitor the effects of these large wildfires on the watershed's hydrological processes and their temporal evolution. Both burnt and unburnt basins were selected to obtain perturbated and reference streamflow regimes.
At the present date, around four years of data have been acquired, at less than 5 minutes time resolution.
We present our experiences with different stream water level monitoring instrumentation in high and fast responsive mountainous watersheds to rainfall inputs. Also, an open-source design for a low-cost water level sensor and logger will be presented.
The database structure utilized to handle datasets composed of millions of acquisitions will be illustrated.
Preliminary/some results on the monitoring period will also be presented.

Keywords: wildfire, small catchment, streamflow, continuous monitoring.

Impacts of a large wildfire on hydrologic behaviour and water resources quality in the Pisano Mount area (northwestern Tuscany): preliminary results

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Abstract

Wildfires are recognized as one of the most effecting ecological agents, altering geomorphological processes, hydrologic cycles, and water quality (Shakesby, 2011; Smith et al., 2011; Moody et al., 2013). On average from 50,000 to 65,000 fires occur in Europe every year, burning approximately 500,000 ha of forested areas (Turco et al., 2014).

Between September 2018 and February 2019 two large wildfires burned about 1,400 ha of forest and farmlands in the Pisano Mount area, mainly in the municipalities of Calci and Vicopisano (northwestern Tuscany) (Salbitano et al., 2020). The area is mainly formed of a hilly landscape, with extensive forest cover and peculiar geomorphological features. The main outcropping rocks are composed of quartzite, arenite, phyllite and quartz metaconglomerate. The burned area is of primary importance in the hydrologic recharge processes of the groundwater resources hosted in the alluvial fan of the Zambra stream and in the multi-layer aquifer of the Pisa plain (Del Tredici, 2019).

The presented study is concerned with a characterization of the hydrological cycle and water resources quality in the burned area of the Pisano Mount.

The recent wildfire impact on hydrological behaviour and water quality and quantity is being evaluated by the comparison between burned and unburned areas, selecting two major catchments in the former and two sub-catchments in the latter. The catchments were selected as similar as possible by evaluating morphometry, geology and pre-fire vegetation features.

A network of meteorological stations was already present and was implemented.

Five hydraulic sections of the main streams draining the area are currently monitored for hydraulic level and physico-chemical parameters. All the sections are equipped for monitoring water level, electrical conductivity, and temperature, whereas two probes register also pH, turbidity and oxidation-reduction potential.

Monthly samples are collected for stream water and groundwater. In addition, four plate lysimeters will be installed to sample water infiltrated through the soils to evaluate the chemical exchanges between soil and rainwater. Samples are analysed for major anions and cations, total suspended solids, trace elements, water isotopes and organic compounds, to search chemical perturbation potentially arising by the wildfire.

Finally, a survey of measurement of the hydraulic properties, permeability and sorptivity, is also scheduled, aiming to address changes of these properties induced by wildfires.

The main knowledge about wildfire perturbation and the experimental design will be illustrated including the preliminary results of the work.

Keywords: wildfire, small catchment, groundwater, monitoring, hydrologic cycle.

Water runoff from small experimental basins under various anthropogenic influences

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Abstract
In the Šumava Mts. (Bohemian Forest) in the south of the Czech Republic, water flow and substance transport have been monitored in three experimental river basins since mid-1997. Thus, for a period of almost 25 years, information is available on land cover, geological and soil conditions, temperature conditions, precipitation, runoff, water chemistry, etc. from experimental basins of about 2 km^2. These basins are in close proximity and have comparable climatic and geological conditions, altitude ranges from 780 to 1035 m, average annual air temperature 5 - 6 °C and yearly precipitation total 1000 - 1100 mm, but differ in the way of landuse. The Bukový river basin is practically entirely forested, the Mlýnský river basin is used mainly as pastures and meadows, it was drained in the 1980s, and the Horský river basin is a landscape mosaic of commercial and natural forest, wetland habitats and meadows. Different management of river basins use does not change throughout the monitoring period.
The results of long-term monitoring show differences in the runoff and the quality of the water. The long-term runoff coefficient is based on the Mlýnský (drained pasture) 0.6, Horský (mosaic of forests, wetlands and meadows) 0.4 and Bukový (mature forest) 0.35. The average electrical conductivity of the water reflecting the amount of dissolved substances is for Mlýnský 82, Horský 44 and Bukový 40 µS.cm-1, and NO_3^- content 6.6 , 2.2 and 2.0 mg.l^{-1} respectively. From the evaluation of deposition and matter losses, it is clear that a higher amount of NO3- leaves from the drained river basin (Mlýnský) than it comes in precipitation, while in other river basins the opposite is true. There are also significant differences in the matter losses from river basins in the case of carbon, calcium or magnesium. During precipitation-runoff episodes, there is also a higher fluctuation of water flow in the drained river basin compared to others. From the evaluation of the temperature of the landscape cover by means of satellite data, on clear sunny days there are on average higher values in the drained catchment area (Mlýnský) compared to the catchments with forest and landscape mosaic. Higher heating of the landscape surface may affect other hydrochemical processes in the basin. From the long-term monitoring, the influence of the way of land use on the integral parameters of landscape assessment, such as runoff characteristics, outflowing water quality and land cover temperature, is obvious.

Keywords: experimental basin, Bohemian Forest, water flow, water chemistry, land use

Ecosystem ET dependent on a leaf scale energy management; The Yatir forest case at the desert edge.

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Abstract
A fundamental research question is how forests manage their water availability and withstand long, hot, and dry seasons. We study these questions in the Yatir Allepo Pinus forest, located at the edge of the Negev desert, growing under an aridity index of 0.18, receiving on average 285 mm annually, without available groundwater supply, but with radiation load similar to that of the Sahara desert, and with high atmospheric water demand (VPD; of up 6 KPa in summer). An irrigation manipulation experiment in the forest was used to partition the trees' sensitivity to soil moisture stress vs. atmosphere drynesses.
At the peak of the hot and dry summer season, transpiration rates (T) in the irrigated trees (high VPD but no soil moisture stress) were up to 20 times higher than in the control leaves (both soil drought and high VPD). In contrast to expectations, the leaf temperatures were similar in the two treatments. Furthermore, even in the irrigated trees, the ratio of the energy invested in T (as latent heat) to the total available radiation energy was <0.5. Such ratios were, in fact, also estimated from data across all evergreen-needle forests in the global eddy flux observation networks (FLUXNET). These results indicate that most of the energy absorbed by leaves in evergreen-needle forests is dissipated via sensible heat flux (H), and not via evapotranspiration (ET), which is usually considered the main leaf cooling process. This has important implications because relying on H for cooling helps suppress the trees' ET, saving water, more efficiently managing photosynthetic activity, and increasing water use efficiency. Models that predict ecosystem response to warming and drying climate should consider such effects and their consequences on local carbon and water balance.

Keywords: evapotranspiration, sensible heat, drought, leaf temperature, water use efficiency.

Influence of selected hydrometeorological elements on the moisture content of forest litter in relation to the fire danger level

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Abstract

Forest fires are the dominant disturbance in most forests and are strongly influenced by hydrometeorological conditions. Recently, emerging climate change has also caused changes in the fire regime in Central and Northern Europe, which has experienced extreme wildfire seasons and fire frequency increases in forests. The main factor influencing the occurrence and development of a forest fire is the availability and condition (primarily moisture) of combustible forest materials, which are always available in sufficient quantities in the forests. Hydrometeorological conditions (precipitation, air humidity, temperature, wind speed and direction, cloud cover, etc.), terrain relief, the nature of vegetation placement and other natural and climatic factors influence their readiness to ignition and burning activity, the rate of spread and the nature of the fire.

The aim of the present paper is to demonstrate the influence of selected hydrometeorological elements on the moisture content of forest fallout in relation to the fire danger level. Field measurements were carried out in the area of the Zvolen basin (350 m a.s.l.) for stands of Scots pine (*Pinus sylvestris* L.), European beech (*Fagus sylvatica* L.) and Norway spruce (*Picea abies* (L.) H. Karst.). The measurements were carried out in the interior of the forest stand as well as at the stand edge. In the period from 1 April to 30 September 2020 we monitored and analysed the development of air temperature, precipitation, potential evapotranspiration and relative humidity. We calculated four fire weather indices (Angstrom, Baumgartner, Nesterov and MK - meteorological forest fire risk index). Correlation analysis of the dependence of forest litter moisture showed its statistical high significance ($\alpha < 0.001$) to mainly relative humidity, air temperature and the index according to Angstrom, at the stand edge. For the interior of pine, beech and spruce forest stands, these correlation relationships were less significant ($0.1< \alpha < 0.05$ and $0.05< \alpha < 0.01$, respectively).

This pilot study showed that the different microclimates of the stand edge and stand interior, as well as the different microclimatic conditions in spruce, pine and beech stands, create the conditions for the emergence of different degrees of fire hazard in these stands.

Keywords: wildfires; forest litter moisture content; hydrometeorological elements; fire weather; forest fire indices; European beech; Scots pine; Norway spruce; forest edge and interior microclimate.

Throughfall spatio-temporal dynamics at the hillslope scale

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Abstract

Spatio-temporal variability of throughfall in forested catchments depends on climatic forcing, forest stand parameters, and rainfall characteristics. Despite several studies were conducted in different forest environments, very little is known about the role of hillslope topography and the associated tree population characteristics in shaping throughfall spatio-temporal variability. Therefore, this work aimed at better understanding the dominant factors on throughfall spatial variability and on the temporal persistence of throughfall spatial patterns at the hillslope scale.

The experimental activities were carried out in the lower part of the Lecciona catchment (0.3 km2), Tuscany Apennines, Central Italy. The hillslope has a mean slope of 22° and a north aspect. The forest stand is dominated by European beech trees, with the tree diameter that decreases frm the bottom to the hillslope top. The experimental plot consists of 126 throughfall collectors divided in three sub-plots: two square plots of 49 samplers at the bottom and the top of the hillslope, and a transect of 28 collectors from the bottom to the top of the hillslope. Throughfall was manually measured from the collectors approximately monthly from June 2020 to May 2022 and compared with gross precipitation measured by a rain gauge placed outside the vegetation cover. Leaf Area Index (LAI) was manually measured above each sampler in dormant and growing season.

Preliminary results from 31 manual measurements highlighted a large temporal variability of throughfall (mean: 63%, standard deviation: ±24%), reflecting the variable seasonal precipitation pattern of Mediterranean areas and the phenological stage of trees. Throughfall variability decreased with gross rainfall amount in both phenological seasons. Despite the bottom plot is characterized by lower tree density and larger tree size compared to the top plot, we found no statistical correlation between throughfall and basal area ($P>0.5$). However, a significant correlation between throughfall and LAI in the growing season was found: The bottom plot showed higher values of LAI than the other sub-plots and lower values of throughfall compared to the others sub-plots. The temporal stability analysis, carried out considering the entire experimental plot and the three sub-plots separately, allowed us to identify the most representative throughfall sampling locations.

Future work will make use of the high-resolution measurements of five automatic gauges recently installed to improve the temporal resolution of throughfall monitoring Moreover, throughfall and LAI values will be compared with soil moisture dynamics along the hillslope to better understand the role of canopy cover on the hydrology of this catchment.

Keywords: Throughfall; Spatial-variability; Temporal-stability; European Beech; Experimental hillslope.

European beaver colonization patterns in low-mountains in Magura National Park (Southern Poland)

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Abstract
The spread of the European beaver population is a phenomenon that is currently observed on a large scale, both in Poland and, more broadly, in many European countries. The growing activity of this animal entails the creation of many structures that have a significant impact on the water cycle in the catchment area. The aims of our research were:
to determine the preferred directions of beaver colonization of new areas in the conditions of low mountains, where abandonment of agricultural land by humans is observed,
to describe the basic hydrological and geomorphological parameters of the catchment area in which the European beaver assumes its positions,
to characterise the beaver positions existing at the time of the research in terms of the number of water damming structures and the size of the transformed areas.
The research was conducted in the area of the Magura National Park, where the European beaver was reintroduced in the number of several families in the 1980s and has now reached a population of over 60 individuals. The obtained data on the distribution of active beaver sites came from field work carried out in 1996, 2010 and 2021, for which appropriate information on the land cover was obtained from remote sensed data.
The obtained results indicate the displacement of the beaver population in 1996-2021 period from the bottoms of the main river valleys, towards the source areas of small streams. At the same time, the number of damming structures constructed by beavers within one site (and thus, thecreated ponds) has significantly increased, as has the size of the area transformed by beaver activity.
In the context of land cover, it was found that, as far as possible, the beaver left the areas located in the immediate vicinity of humans, moving towards the catchment areas that were more forested and characterised by a considerable higher distance from roads and buildings. However, it was not specified what was the main factor in choosing the direction of beaver migration - whether anthropogenic or natural conditions
The main conclusion is that in the study area within 20-30 years there was a complete penetration by beavers and changes in hydrological conditions also in the upper parts of the catchments.

Keywords: European beaver; colonization; directions, mountains, land cover

SESSION 2:
HYDROLOGICAL AND ECOYDROLOGICAL MODELLING

Assessing the impact of climate change on coastal catchment (Bruna – Italy) using SWAT+gwflow

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Abstract
Surface and groundwater model coupling is a challenging task due to the cumbersome code modification and high computation time. However, the interaction between the surface and groundwater bodies is also a crucial element to investigate. Recently, the spatially distributed and simplified version of the SWAT+MODFLOW model is developed and is called as SWAT+gwflow. This module has advantages that hydrological modelers can leverage from and this is tested for Bruna catchment in the Tuscany region. The model is calibrated based on two approaches; one using only streamflow data and the other using both streamflow and groundwater head data. Furthermore, the ground and surface water interaction, recharge, groundwater-soil fluxes, etc. are investigated under different climate change scenarios.
The results suggested that the new module has performed superior where the NSE is 0.94 for calibration and 0.7 for validation periods. In addition, the impact of climate change is expected to reduce the available freshwater in both the ground and surface water bodies. Furthermore, the impact can be substantial as the area is known for irrigation and recharge is expected to decrease according to the climate scenarios that are analyzed. Further investigation is required to assess salt water intrusion toward the irrigation schemes from the adjoining sea under several climate change scenarios.

Keywords: surface and groundwater model coupling; SWAT+; SWAT+gwflow; climate change; Bruna

Assessing the ability of the GEOframe modeling system for water budget analysis of a challenging carbonate basin in the Apennines chains, Central Italy.

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Abstract
Placed at the center of the Mediterranean, the Apennines chains provide a critical water supply for people living in the Italian Peninsula. Yet, the quantification of water resources in this region is challenging given that the different components of the water cycles (i.e., snowmelt, evapotranspiration, and subsurface water recharge) are highly variable in space and time due to the specificity of the climate, the reforestation trend, and the complex landscapes and geology. In this study, we investigated the challenging hydrological river regime of a complex carbonate basin with significant external (and partially karst) groundwater contribution - the Upper Nera basin - affected by recent important seismic sequences.
When dealing with such types of basins, the generic approach to delineate the basin boundaries based on the geomorphology of the area can lead to questionable results potentially yielding significant water budget imbalances. Therefore, both (hydro) geological and hydrological features have to be considered for understanding the challenging hydrological behavior of these basins.
Here we proposed a specific analysis of precipitation-runoff time series corroborated with a hydro-geological survey to obtain information on basin response time and the true contribution area of the basin. We applied the extreme versatility of the GEOframe-NewAge modeling system to simulate the significant fraction of external groundwater contribution by embodying hydrogeological information of the area obtained by surveys and the hydrological analysis in a conceptual reservoir approach. We validated the model against in situ discharge observations and with remote sensing information of evapotranspiration and snow.
We show that the model (tested with several hydrological signatures and a new conceptual evaluation based on an empirical probability function) performs relatively well in reproducing the different water balance components and that the upper river basin is significantly impacted by carbonate rock river discharge (i.e., up to 85% in proportion to the total discharge for some stations) coming from outside the geomorphological boundary of the basin. Yet, the groundwater recharge effects on the river, gradually attenuates at the outlet of the basin (Visso station).

Keywords: Fissured and Karst basin; GEoframe-Newage modeling system; Spatial Snow Cover Variation; Actual Evapotranspiration; Correlation Analysis; Empirical error score.

Critical processes in burned areas. A comparison between an event based and a continuous model under post-fire conditions.

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Abstract
Wildfires are a source of instability for the normal water cycle in hydrologic basins, endangering the quantity and quality of water reaching downstream water bodies. The impacts of forest fires on water bodies are most evident following post-fire rainfall events when increased runoff transports high loads of ash and sediment particles. Implementing event-scale simulations can help understand these impacts since the short time step of event-based modelling can be an advantage when addressing this subject because it prevents the smoothing effect from daily and monthly modelling approaches. However, there are several difficulties in using modelling tools to assess post-fire impacts, being one of the most challenging that most models have been developed to address undisturbed conditions.
This study aims to compare the ability of two hydrological models to simulate quickflow and sediment transport during the first year after a fire to ultimately understand which one would best serve as a postfire hydrological assessment at event scale. To address this goal, OpenLisem event-based hydrologic and erosion model, already applied to burned areas, was used as the base model for calibration and validation of the input parameters. Subsequently, simulations with MohidLand, a continuous model with variable timestep, were performed using the same input structure. This was the first test for this model for postfire conditions.
The study was conducted in a small watershed located in the central region of Portugal, affected by a fire in August 2016. A total of twelve events were analysed, of which seven were used for calibration and five for validation. To consider the effects of wildfires, hydrological parameters were calibrated to different fire severities and boundary conditions before each specific event. Although the flow prediction during the calibration phase of both models was satisfactory, OpenLisem validation results presented lower performance than MohidLand's. However, the plot scale analysis revealed additional limitations in the simulation of surface runoff, allegedly due to the 2D domain utilized for overland flow. Regarding the model performance in predicting sediment export, OpenLisem simulated better sediment transport and obtained peaks and sediment yields closer to observed data, probably due to the use of a physically-based model for erosion.
The results obtained do not provide a clear answer as to which model to use since neither model excels over the other. Therefore, the choice of the model should be based on the type of information needed for the hydrological assessment, without relying on their overall performance.

Keywords: wildfires; event-based; hydrological model; sediments

Reproducing streamflow diel fluctuations in a small agricultural catchment with an integrated surface-subsurface hydrological model

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Abstract
During dry periods, diel fluctuations can attain up to 10% of discharge in small streams, which account for the majority of rivers' network length. Although intensive research efforts have been put in observing and interpreting diel fluctuations of stream discharge across a wide range of environmental and climate conditions, the capability of state-of-the-art physics-based hydrological models to reproduce such processes has rarely been tested. Here, we use CATHY (CATchment HYdrology), an integrated surface-subsurface hydrological model, to simulate and explain diel fluctuations as observed in the stream discharge of a small agricultural catchment in Switzerland. The model is able to reproduce the measured stream discharge with a Kling-Gupta efficiency index of 0.8. Despite the simplifying assumption of homogeneous soil properties, model simulations highlight the significant interplay of vegetation and topography in driving the occurrence of sub-daily fluxes from groundwater to surface water. A series of hypotheses-testing modelling scenarios with changing vegetation and soil properties reveal that the fluctuations are predominantly controlled by the presence of vegetation and not influenced by changes in saturated hydraulic conductivity driven by diel temperature fluctuations in the soil. The model capability to simulate dynamic spatial patterns of evapotranspiration fluxes, soil moisture and groundwater flows enhance our understanding of the role of these hydrological processes in small catchments during dry periods.

Keywords: numerical modelling; headwater stream; low flows; groundwater; evapotranspiration.

A new look into vegetation: GEOSPACE 1D for modelling the soil-plant-atmosphere continuum

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Abstract
Measuring and modelling the water and solute transport along the soil-plant-atmosphere continuum is fundamental to predict transpiration fluxes. This contribution illustrates the GEOframe Soil Plant Atmosphere Continuum Estimator (GEOSPACE), the ecohydrological model of the GEOframe system that simulates the soil-plant-atmosphere interactions to study and analyze the complex processes that occur in the Earth Critical Zone (CZ).
GEOSPACE is a coupled model in which there are three major components: WHETGEO, GEO-ET and BrokerGEO. WHETGEO, Water Heat and Transport in GEOframe, (Tubini N. and Rigon R., 2021), solves the conservative form of Richardson-Richards equation using the Newton-Casulli-Zanolli algorithm (Casulli V. and Zanolli P., 2010) that guarantees the convergence at any time step, and the proper transition from unsaturated condition to saturated one. WHETGEO also implements the numerical solution shown in Casulli and Zanolli (2005) to solve the advection-dispersion equation and simulate the solute transport. GEO-ET, EvapoTranspiration in GEOframe, computes evapotranspiration according to three different formulations, the Priestley-Taylor model, Penman FAO model and GEOframe-Prospero model (Bottazzi, 2020), by considering Jarvis model (Macfarlane et al., 2004) to compute environmental and water stress factors. BrokerGEO is the coupler component that allow the exchange of data between the other two components in memory and considers the root water uptake for the computation of the actual evapotranspiration.
The GEOSPACE model was tested with the lysimeter of the "Spike II" experiment (Nehemy et al., 2019; Benettin et al., 2021) of the Ecole Polytechnic Federal de Lausanne. The analysis we carried out with GEOSPACE concern the flux partitioning of precipitation and irrigation water into evaporation, transpiration and groundwater storage. we analyzed the transport of water stable isotopes through the soil and in the transpired water. In this research we present them and show how GEOSPACE can be used to model the water and solute transport along the soil-plant-atmosphere continuum
GEOSPACE is developed in Java using the Object-Oriented programming paradigm and it provodes a ready to use open access numerical model for the estimation of water fluxes in the soil-plant-atmosphere continuum system, available on the GEOframe GitHub website. The code organization and its functionalities besides solving the hydrological issues are designed according to principle of open science to be inspectable and verified by third parties.

Keywords: soil-plant-atmosphere continuum; ecohydrological modelling; solute transport.

Modelling flow regimes of a temporary river with limited data availability

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Abstract
The flow regime plays an important role in the river ecosystem influencing water chemistry, morphological and physical factors, and ecological functioning. Flow regime characterization is a fundamental stage for river type classification and river basin management. The reference condition (un-impacted or least impacted) used as the baseline for the ecological status assessment varies across the river types, therefore, a wrong river type classification may lead to an unreliable assessment of the ecological status of the river and to inadequate management operations.
In this work, a procedure to characterise the flow regimes of non-perennial rivers in regions with limited data availability was defined. The specific aims were to adapt the Soil and Water Assessment Tool (SWAT) for simulating time series of daily streamflow in a basin with a temporary river network (Nil wadi, Algeria) and to characterise the flow regime in a number of the river reaches. An inexpensive streamflow monitoring program was implemented to collect a basic dataset to calibrate the hydrological model. Regional databases, surveys, and images from Google Earth were used to integrate the available data to set up the model. The flow regime was characterised by using a number of indicators describing the aquatic phases (AS) (flow, pool, and dry permanence). The metrics were computed on the basis of long-term time series of modeled daily streamflow.
The Nil Wadi resulted characterised by perennial and temporary flow regimes. The analysed river reaches were classified as “intermittent-pool” and “intermittent-dry”, they showed “alternate-fluent” (AF) aquatic phase upstream and in the middle course, and a gradient from AF to “fluent-stagnant” phases downstream. The AS “oligorheic” (low flow or pools connected) and “arheic” (pools disconnected) mainly occurred from May to October. “Dry” conditions mainly occurred in summer. This study provides a contribution to the unsolved question of the management of temporary rivers under the Mediterranean climate.

Keywords: Temporary river; flow regime; data scarcity; SWAT model; river classification.

Near Surface flow pathways in a pre-Alpine catchment

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Abstract
In catchments with low permeability soils, surface and subsurface flow can contribute significantly to streamflow during rainfall events. However, these processes remain poorly understood because most studies in temperate climates have focused on hillslopes with permeable soils. Furthermore, these processes are characterized by a high spatial and temporal variability. Therefore, the TopFlow project aims to investigate surface and shallow subsurface flow generation and their connectivity. We installed 14 plots on vegetated hillslopes in the Swiss pre-Alpine Studibach catchment that is underlain by poorly drained gleysols and Flysch bedrock. We measure overland flow and shallow subsurface flow at small (3 m wide) trenches, as well as groundwater levels near each plot, and streamflow at multiple locations in the catchment. In addition, we describe and analyze the environmental factors (topography, vegetation, soil, etc.) that may influence these near-surface flow pathways, and study how runoff generation depends on event characteristics (antecedent soil moisture, event size, etc.). In this poster, we will present the TopFlow project and measurement methods, as well as some first preliminary results.

Keywords: overland flow; subsurface flow; pre-Alpine catchment; low permeability.

Event-based runoff simulations show forest roads enhancing floods

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Abstract
Forest road networks influence runoff (generation) processes of a catchment, mainly through the reduction of infiltration capacities due to compacted surfaces, the conversion of interflow into surface runoff and generation of additional flow paths, e.g. through culverts. However, the magnitude of the influence highly depends on the characteristics of a catchment and a quantification of the changes in runoff behaviour and especially on flood runoff due to the forest road network is still not well understood. Evidence during heavy rainfall events in the Rosalia forest research catchment in southern Lower Austria shows intense surface runoff on roads and skid trails.
This study therefore aims at quantifying the influence of the forest road network on runoff processes in the Rosalia headwater catchment, covering an area of 2.23 km². A reconstructed historical terrain model without anthropogenic influences such as forest roads or built-up areas was created and compared with the current catchment, thereby analysing the surface runoff paths, the drainage area and differences in time-area diagrams. The influence of the forest road network on the runoff behaviour was further quantified using the physically based rainfall-runoff model RoGeR for three selected flood events.
The results show that the catchment area has increased by around 10% in the current state and that it drained more slowly in the historical condition. Independent of uncertainties in rainfall estimation methods, model parameters and antecedent moisture conditions, it is shown that runoff depths of the single events increased by 47 to 128% and the peak discharge values increased by 46 to 104% in the current catchment, compared to the historical state. Although the different interpolation methods of areal precipitation (Inverse Distance Weighting, Thiessen Polygons, Lapse rate model, average rainfall) generated the largest uncertainties, the influences on the percent changes were small.
The research is based on a small headwater basin and further studies are necessary to evaluate the effects of forest roads on floods of larger catchment areas. The study nevertheless clearly illustrates the influence of forest roads on flood generation processes and flood magnitudes, which can influence flood hazard and flood risk conditions in river catchments.

Keywords: rainfall-runoff model, forest roads, flood discharge, anthropogenic influence, Rosalia catchment

How to improve hydrological model forecast using precipitation data from small experimental basin

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Abstract
The Hydrological Forecasting Service (HFS) of Slovak Hydrometeorological Institute (SHMU) produces hydrological forecasts for gauging station Liptovská Ondrašová at the Jalovský creek (the Jalovecký Creek). The river basin is situated in the Western Tatra Mountains, northern Slovakia and is characterized by high elevation range, from 570 to 2178 m a.s.l, in a relatively small area (45 km^2). It is a typical high mountain basin of central Europe. In the upper part of the river basin is located the experimental basin of the Institute of Hydrology Slovak Academy of Sciences (IH SAS).
The forecasting service operates the conceptual rainfall-runoff model HBV. The combined radar – rain gauge information in hourly time step is used as the precipitation input to the model. From the HFS point of view it is necessary to train (calibrate) model for different climatic conditions (wet/dry periods). Hydroclimatic conditions of calibration period should be similar to those expected in the forecast period. After process of model recalibration covering period from August 2016 to December 2019, it turned out that the model was not able to simulate some significant flood waves with required accuracy. A more detailed analysis showed that for a certain type of weather patterns the precipitation input data derived by the radar are underestimated. The skill to simulate extreme runoff phases strongly influences the model ability to set up the initial states in future process of hydrological forecasting. In forecast mode, HBV model calibrated using historical data and simulating runoff with actual meteorological forcing is run forward in time with the input data provided by meteorological forecast.
The rain gauge network of SHMU covers lower altitudes, so there is a lack of point information from high mountain areas that could be used to correct the radar estimate. The precipitation data from the experimental basin of the IH SAS, specifically from the measuring point at Červenec, were used to precise precipitation input to the model. Rainfall data were provided within the project “Connectivity and flood runoff dynamics in headwater catchments of Slovakia”.
Our study focuses on improving the model ability to simulate extreme rainfall-runoff events by considering the revision of precipitation input to force the model to match observed runoff.

Keywords: precipitation; flood; rainfall-runoff model.

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Introduction of experimental catchment of Magyaregregy

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Abstract
Völgységi creek can be found in the southwestern part of Hungary in the northern part of Mecsek hills, where it collects waters from the eastern part of the so-called Völgység region (völgység mean valley). The creek is not regulated on its upper reach. On the upper reach of Völgységi-creek, over Magyaregregy settlement (where is the experimental catchment) there is a characteristic erosion area, the small creeks flow in rocky beds. We can observe that the creek reacts very quickly to rainfall and can produce high floodwaves.
On the upper catchment take place the Lászlóffy Woldemár Hydrometric Camp of the Faculty of Water Sciences of the University of Public Service.
Scientific research and continuous development in the catchment had stoped decades ago. The research work and related monitoring activities resumed in 2017. At that time, we made plans for the development of catchment monitoring. After the preparatory works for the monitoring, in 2019 the installation of the first equipment started. We installed hydrometerologogical monitoring systems, stream gauge stations, soil moisture monitoring network on the area (32 km2). Field measurements are carried out in parallel with data collection. Due to this, we can measure the a charactereistics of environmental parameters of runoff process. The aim is to use these data to estimate a number of model parameters for modelling with HECHMS and Mike She.

Keywords: catchment exploration, experimental catchment, hydro-meteorological monitoring, monitoring systems, rainfall-runoff process

Assessing hydrological connectivity of a small agricultural catchment by process-based modelling

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Abstract
Hydrological connectivity represents the spatial patterns of properties or state variables that facilitate flow and transport within a catchment. Also, understanding spatial variations in soil moisture and runoff generation is useful for assessing hydrological connectivity within a catchment. Thus, we have applied numerical modelling approaches to investigate the spatial patterns of soil moisture and runoff generation at the Nučice experimental catchment (0.53 km^2), the Czech Republic.
The Nučice catchment was established in 2011 to observe the rainfall-runoff processes, soil erosion and water balance in the agricultural landscape. The catchment consists of three fields covering over 95 % of the area. Even though the soil management and soil properties in the fields of Nučice seem to be nearly homogeneous, we have observed spatial variability in the topsoil moisture. In the numerical simulation, a 3D spatially-distributed model MIKE-SHE has been used to simulate the water movement within the catchments. The MIKE-SHE simulation has been mainly calibrated with rainfall-runoff observations and soil moisture sensors at point-scale. Within the simulation, we have obtained the spatial patterns of soil moisture and surface runoff for both dry and wet antecedent conditions. The hydrological connectivity has been assessed based on the spatial patterns from the simulation with the topographic indexes (e.g. elevation, slope, and TWI) and topsoil moisture patterns from field surveys. Future research will further investigate the spatial patterns of soil moisture and runoff generation at the catchment with other datasets (e.g. remote sensing, cosmic-rays neutron sensing, isotope data).
This study has been supported by the Grant Agency of the Czech Technical University in Prague, grant No. SGS20/156/OHK1/3T/11 and the Project SHui which is co-funded by the European Union Project: 773903 and the Chinese MOST.

Keywords: soil moisture; hydrological connectivity; agricultural catchment; hydrological modelling

Modelling of snow interception in the spruce forest in the Ptaci Brook basin, Sumava Mts., Czechia

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Abstract
Snow interception is one of the most important processes of the catchment hydrological balance. Direct measurement of snow interception is a very complex and often invasive activity. Therefore, models are frequently used to calculate snow interception from the vegetation structure and measured meteorological variables. Field research has been carried out at the selected research site in Czechia with a considerable seasonal snow storages to describe the canopy structure of the spruce forest using hemispherical images taken in the winter season 2020/21. The vegetation characteristics were essential for modelling of the snow interception. The mean Leaf area index calculated from the hemispherical images at the study plot reached 2.34 with the respective canopy closure equal to 86.16%. However, values ranged from 2.03 to 2.72 and from 83.6% to 90.2% for the canopy closure, respectively. These values were further used as state variables for the calculation of seasonal cumulative snow interception at the study plot for the winter season 2020/21. A more complex model was evaluated with two, less complex equations employing measured data of snow storages under the forest canopy. Consequently, the complex model was applied to four consecutive winter seasons 2017-2021. The efficiency of the snow interception (a proportion of the intercepted snow to total snowfall water equivalent) ranged from 36.9% to 45.8% and it varied between individual study seasons. The snow interception efficiency was considerably higher in the last winter season compared to other winter seasons, which could reflect the weather conditions during this season and overall lower extremity of snowfall events. The correlation analysis between the efficiency of snow interception and daily snowfall amount showed the mean coefficient of determination $r^2 = 0.64$ and it confirms that interception efficiency decreases with extremity of the individual snowfall events. Overall, the results of this study showed that the complex model produced satisfactory results which might be further used to improve the conceptual hydrological models in forested catchments.

Keywords: snow interception, modeling of snow interception, spruce forest, hemispherical images of the canopy, Leaf Area Index

Trends in seasonal snowpack and their relation to climate variables in mountain catchments in Czechia

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Abstract
Seasonal snowpack is an important part of the water cycle and it has a large impact on runoff regime in mountain catchments of Central Europe. We investigated trends in snowpack for the period 1965–2014 in 40 catchments located in five mountain regions in Czechia. Daily time series of air temperature, precipitation, and snow water equivalent (SWE) were analysed. Since availability of time series of water content in snowpack is limited, conceptual semi-distributed hydrological model HBV-light was used for simulating time series of daily SWE. The Mann-Kendall test showed strong increasing trends in air temperature at all elevations, mostly at the end of the cold season. This increase caused a decrease in snowfall fraction and SWE. Maximum SWE decreased mainly in western parts of Czechia (by up to −45 mm/decade). The length of the snow-covered period decreased by up to −6.8 days/decade, mainly due to earlier melt-out. No significant trends were found for date of snow cover onset. Snowpack was more sensitive to changes in air temperature at elevations below 900 m a.s.l., while precipitation had a larger impact on snowpack at elevations above 1200 m a.s.l. The relative importance of air temperature for snow variability increased at all elevations in the last few decades.

Keywords: snow cover trends; snowpack variability; snow water equivalent; snow cover duration; snow modelling

Probabilistic delineation of *Preferential Groundwater Networks*: a novel energy-based groundwater approach

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Abstract
We assess the possibility of characterizing the main patterns of subsurface flow preferential pathways by considering it as a slope-driven phenomenon, only relying on aquifer bottom data we gathered from borehole data. We consider synthetically generated realizations of aquifer bottom topography, collected within a Monte Carlo framework (MC), to define subsurface preferential paths under uncertainty, which we term *Preferential Groundwater Networks* (PGNs). We prove the novelty and the relevance of this viewpoint in subsurface hydrological features identification, such as interactions between surface water bodies or surface-subsurface ones, and its consistency and coherence with hydrogeological information and available piezometric reconstructions. Furthermore, the study of *Preferential Groundwater Networks* statistics at the threshold change can improve the degree of knowledge of subsurface flow patterns in a study-area, since the deep correlation between network spatial coverage and its energetic patterns.

Keywords: groundwater, Monte Carlo simulations, Preferential Groundwater Networks, energy minimization, probabilistic approach, geostatistics.

The role of different sources of uncertainty on the probabilistic quantification of subsurface discharges in heterogeneous alluvial aquifers

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Abstract
The quantification of subsurface discharges may significantly be affected by multiple sources of uncertainty, especially in highly heterogeneous aquifers. In this work, subsurface discharges within alluvial aquifers located in the province of Lecco (Lombardy, Northern Italy) are quantified under geological and conditioning data uncertainty sources, relying upon a Monte Carlo (MC) framework. Different geological conceptual models return facies spatial distributions, simulated via *Sequential Indicator Simulations* methodology (SISIM), being conditioned with different data constrains. Stochastic subsurface discharge fluxes are quantified upon literature-based porosity values, assigned to facies, leading to a saturated hydraulic conductivity field for each MC realization and to a subsurface discharge one, considered under steady hydraulic conditions. Generalized Extreme Values (GEV) approach is then employed to interpret peak-over-thresholds (POTs) discharges spatial distribution, and to study the role geological and data uncertainty sources on their quantification. As case-studies, stochastic discharges across a hydrogeological section and through a lake's perimeter are presented. These uncertainty-based analysis show that subsurface discharges clearly convey in correspondence of main alluvial aquifers such as within preferential pathways. Discharges POTs empirical probability spatial distributions highlights that the geological uncertainty plays as a primary uncertainty source rather the conditioning data one.

Keywords: subsurface discharge, geostatistics, Monte Carlo, geological uncertainty, data uncertainty.

Influence of vegetation type and soil properties on soil water dynamics in the Šumava Mountains (Southern Bohemia)

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Abstract
This study focuses on the description of soil water dynamics at four sites with different land cover types, namely beech forest, conifer forest, meadow and clipped grass. The analysis was based on soil tensiometer measurements from five consecutive vegetation seasons (comprising both wet and dry years). We investigated both column average pressure heads and also their vertical distribution. The soil water balance was studied by the HYDRUS-1D model. The highest pressure heads were observed at the grassland site, followed by the meadow site. The forested sites were generally reaching lower pressure head values, which was a result of higher evapotranspiration and different soil properties. The differences between the spruce forest (Picea abies (L.)) and beech forest (Fagus sylvatica L.) were evident namely in dry periods, when the beech site was experiencing lower pressure heads. Contrarily, the spruce site was drier (with recorded lower pressure heads) in wet periods and at the beginning of each season. Compared to the conifer forest, lower pressure heads were observed in beech forest, namely at the bottom of the inspected soil column (down to 100 cm). The inspection of the soil water balance revealed different rates of evapotranspiration and drainage at all sites. The evapotranspiration was highest in the beech canopy followed by spruce and both grass covered sites. The differences between spruce and beech forest were based namely on the water consumption efficiency and differences in interception rates, vertical distribution of the roots, and soil hydraulic properties.

Keywords: soil moisture; spatial variability; HYDRUS-1D; land cover; forest hydrology

Dynamics of runoff generation in a small mountain catchment

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Abstract
The theory of runoff generation from variable source areas is already generally accepted among hydrologists. Runoff generation from rainfall events is a complex process that is controlled by catchment's surface and subsurface connectivity. Hydrological connectivity in this sense describes the physical linkages of different elements within a landscape that control the formation of runoff. It is one of the keys to understanding hydrological response of a catchment.
The study investigates the relationship between runoff generation and hydrological connectivity in a mountain catchments. The goal is to evaluate which parts of the catchment contribute to runoff during the big rainfall-runoff. We will present results of the runoff response modelling in an hourly time step during four summer rainfall-runoff events, for which we also have data on soil moisture and spatial distribution of precipitation. The study is conducted in a well-instrumented mountain catchment of the Jalovecký Creek in Slovakia (area 22,2 km^2, elevations 820-2178 m a.s.l., mean elevation 1500 m, mean slope 30°). The catchment is representative for the highest part of the Carpathian Mountains and hydrological monitoring and research are conducted there since 1986. Two spatially distributed hydrological models (WaSiM, Mike SHE) and hourly data during the largest summer rainfall-runoff events in years 2014, 2015, 2017 and 2018 are employed in the study.
The preliminary results indicate that the simulated saturated areas (also considered as source areas of runoff formation) are mainly concentrated near the river network. During the runoff event, greater catchment area becomes gradually involved, and the saturated areas increase. Based on the simulations obtained by both hydrological models, a better agreement between the measured and simulated runoff is achieved for the largest runoff event than for several consecutive smaller ones.

Keywords: hydrological connectivity; saturated source areas; hydrological modelling; mountain catchment

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Modelling processes leading to diurnal discharge fluctuations in forested microwatersheds

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Abstract
At the hydrological research watershed Rosalia (Austria) pronounced diurnal discharge fluctuations are observed during precipitation-free days from spring until autumn. Soil water content shows a similar but less pronounced diurnal pattern. The daily amplitudes of both variables show a distinct seasonal signal with peaks in July and August. Daily discharge amplitudes can be about 30 % of the mean daily discharge. Interrelations between air temperature, soil water content and discharge on a daily and seasonal scale implicate evapotranspiration, with transpiration as the dominant driver, as the primary linking process causing fluctuations in diurnal discharge. Considering a transpiration rate of 1 mm/h for an area of 27 ha (sub-catchment Rosalia) would result in a flux of 75 l/s. This would be a multiple of the observed amplitudes which are around 0.1 l/s for this watershed. Therefore, we conclude that not the whole subcatchment, but only direct root water uptake in the vicinity of the creeks generate these fluctuations.
This contribution investigates the processes causing this phenomenon in forested micro-watershed in detail and identifies the riparian area contributing to such discharge fluctuations. The basis for the study was a detailed time-series analysis of hydro-meteorological observations. To be able to analyze and interpret the underlying processes, a HYDRUS 2D model was set up for a characteristic hillslope. The soil transect represented in the model is located next to the gauge, which defines a subcatchment of 27 ha of the Rosalia. Soil hydraulic properties were considered based on multiple analyzed soil samples collected in the field. The vegetation at the selected site is dominated by beech trees.
In this context, the root water uptake by the riparian vegetation obviously plays a crucial role. To analyze its impact, different root distribution scenarios were simulated by stepwise removing the roots along the creek. Thus, it could be shown that the riparian vegetation within a distance of 8 m from the creek was influencing the discharge. The boundary flux between the stream and soil matrix only showed diurnal fluctuations if roots were assigned to the soil matrix within 2 m distance from the creek. Diurnal fluctuations in the boundary flux decreased with each scenario, where roots assigned at increasing distance. This indicates that only roots very close to the creek directly induced diurnal discharge fluctuations. In summary, the results show that root water uptake of the riparian vegetation in the immediate vicinity and the corresponding transpiration is the most important process causing the diurnal discharge fluctuations.

Keywords: diurnal discharge fluctuations, forested micro-watershed, riparian vegetation

SESSION 3:
ENVIRONMENTAL TRACERS IN HYDROLOGICAL AND ECOHYDROLOGICAL STUDIES

WATZON: the Italian network of small experimental catchments for the investigation of the critical zone

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Abstract
The Italian initiative WATZON (WATer mixing in the critical ZONe) is a network of instrumented catchments and sites, that brings together eight research observatories monitoring the different compartments of the critical zone (the zone between "the rock and the sky"). These observatories cover a gradient of different climatic and physiographic settings over Italy. The project poses specific scientific questions, monitoring strategies, databases, and modeling activities. The diversity of the WATZON catchments and sites is well representative of the heterogeneity of the critical zone, and of the scientific communities studying it. Despite this diversity, all WATZON sites share three main objectives:
1) describing water mixing processes across the critical zone with integrated high-resolution isotopic, geophysical and hydrometeorological measurements from point to catchment scale, under different physiographic conditions and climate forcing;
2) understanding water exchange mechanisms between subsurface reservoirs and vegetation, and assessing ecohydrological dynamics in different environments by coupling the high-

resolution data from different study sites of the project consortium with advanced ecohydrological models at multiple spatial scales;
3) developing a process-based conceptual framework of ecohydrological processes in the critical zone to translate scientific knowledge into evidence to support policy and management decisions concerning water and land use in forested and agricultural ecosystems.

Keywords: critical zone; ecohydrology; stable isotopes; geophysical measurements; ecohydrological models

Permafrost distribution and effects on spring water physical characteristics in Val di Sole (Eastern Italian Alps)

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Abstract

Knowing the spatial distribution of permafrost in alpine catchments is highly relevant because it is an important water resource, and because it is involved in several geomorphological, hydrological and ecohydrological processes. Permafrost distribution is often modelled based, for example, on geomorphological evidence (e.g. rock glaciers) combined with the spatial variability of topographic factors such as elevation, aspect and/or clear-sky radiation. Information on permafrost distribution can be gathered also investigating the tracer characteristics of spring water, a method that is still little used.

The aim of this work was to study the spatial distribution of alpine permafrost in a 600-km^2 alpine catchment (Val di Sole, northern Italy), by analysing the physico-chemical, geomorphological and topographic characteristics of spring water. A total of 138 springs have been measured, most of which are fed by rock glaciers. Measurements of water temperature, electrical conductivity and spring flow were made in late summer in 2018, 2019 and 2020, also installing temperature dataloggers in a subset of springs. Spring catchments were delimited in a GIS environment, and in the buffer zones immediately upstream of the springs, solar radiation and mean elevation were calculated. The collected data were statistically analysed to identify which variables significantly influenced the water temperature of the springs.

Analyses revealed that water temperature was mostly influenced by the presence of open-work deposits and rock glaciers upstream of the springs. In particular, water temperature was lower for springs emerging at the front of intact rock glaciers. However, some relict rock glaciers were also found to have cold springs, with time series of water temperature that were very similar to those of intact rock glaciers. This suggests that ice and/or permafrost may persist at least in some rock glaciers classified as relict, confirming evidences from the recent literature.

The spatial distribution of permafrost was mapped over the whole study area by means of a multiple linear regression model between the spring water temperature, the mean solar radiation and the mean elevation over the buffer zones upstream of the springs. The obtained map improved existing permafrost maps including relict rock glaciers that have characteristics favourable for permafrost/ground ice preservation.

Keywords: alpine permafrost, permafrost hydrology, spring water, ecohydrological processes

Impact of a summer flood on ecological status of a temperate, lowland river

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Abstract
Naturally occurring extreme hydrological events, such as floods, have the potential to affect stream habitats and biota at multiple extents. To assess ecological status in rivers, benthic macroinvertebrates (BM) are commonly used, but their resistance and resilience to floods in temperate, lowland rivers in Europe have not been sufficiently explored. This study described the effect of a moderate (5-year return period) yet long-lasting and unpredictable flood that occurred in summer 2020 on the BM community of the upper Jeziorka River and its catchment (382 km^2) in central Poland. In order to gain a better understanding of the mechanisms by which the studied flood affected the BM community, the dynamics of hydrological, hydraulic, channel morphology, and water quality conditions across the studied 1300 m long reach were also evaluated. Continuous water level monitoring, stream depth surveying, and discharge measurements, as well, in-situ and lab-based water quality measurements were carried out between March and August 2020. BM communities were sampled three times at eight sites along the reach, once before and twice after the flood. High flow velocities during the flood resulted in stream bed instability leading to sand substrate movement that caused streambed aggradation by up to 0.2 m. Dissolved oxygen and ammonium-nitrogen were major drivers of BM community structure. Taxa richness, abundance, and the BMWP-PL index reduced significantly, whereas Shannon evenness and Simpson diversity indices showed no significant change in the first post-flood sampling, as evidenced by Kruskal–Wallis and Tukey tests. Non-metric multidimensional scaling (NMDS) analysis showed that community composition was also significantly affected by the flood. Seven weeks following the flood peak (August 2020 sampling), BM communities had fully recovered from the disturbance. The results indicate a first approximation of the resistance and resilience of BM communities for relevant applications in other medium-sized, low-gradient, temperate rivers.

Keywords: moderate flood; flow-ecology relationships; macroinvertebrate communities; ecosystem resilience; channel bed

Contrasting tree water use strategies along hillslopes in forested catchments in Luxembourg and Italy

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Abstract
Topography plays a major role in mediating subsurface water redistribution and ultimately water availability for tree transpiration. Trees located in valley bottoms commonly benefit from greater accessibility to groundwater and wetter soil from lateral redistribution of water compared to trees growing upslopes. However, water availability and movement in the subsurface may differ according to subsurface properties (permeability, soil texture, geology) and climatic regimes. So far, the understanding of how hydrological processes occurring at the hillslope scale affect tree water use is still limited, rising the need of measurements at hillslope-level to allow deeper comprehension of forest dynamic and survival.
Here, we set up a comparative study on a gentle and very steep forested hillslope located in the Weierbach catchment (Luxembourg) and the Re della Pietra catchment (Italy), respectively. We aimed at testing if different climatic and hydrological conditions, i.e., meteorological forcing, groundwater depth, soil moisture, and water redistribution affect water use patterns of beech trees (*Fagus sylvatica* L.) along hillslopes. We carried out biweekly field campaigns during the growing season 2019 and 2020 in Weierbach catchment and throughout 2021 in Re della Pietra catchment to sample xylem water, soil water at different depths, groundwater, stream water, and precipitation.
Trees in the Weierbach catchment rely on water stored in the unsaturated zone regardless of the hillslope position and the hydrologic conditions of the season. On the contrary, preliminary results from Re della Pietra suggest position-specific water use strategy. Trees located at the footslope experienced longer vegetative period compared to plants located at the midslope and hilltop locations due do larger soil moisture content recorded at the footslope. Additionally, xylem water of footslope trees displayed lighter isotopic composition compared to other trees, suggesting the use of a less fractionated water sources. We argue that contrary to the Weierbach catchment where subsurface hillslope structure promotes vertical water flux over lateral redistribution in the vadose zone, the steep hillslope on the Re della Pietra catchment experiences shallow lateral downslope water redistribution which results in substantial differences in vadose zone water supply between hillslope positions.

Keywords: isotopes, topography, sap velocity, hillslope

Hydrological functioning of a high-elevation grassland and a forested catchment in northwestern Italy inferred from isotopic tracers

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Abstract
The age and the seasonal origin of water are topics of great interest, and thanks to the analyses of stable water isotopes, giant steps forward have been made.
The average young water fraction *(F_{yw})*, i.e., the fraction of water in a stream with transit times of less than roughly 0.2 years, can be estimated as the ratio between the amplitudes of the seasonal isotope cycles of streamwater and precipitation, respectively. Also, the Seasonal Origin Index (*SOI*) is a useful metric for understanding the contribution of summer and winter precipitation to streamflow using such very informative tracer cycles.
Here, we present data and results for three small experimental catchments instrumented by the DIST department of Polytechnic and University of Torino in which both isotopic and eddy-covariance measurements are available. Two of them are high-elevation mountain catchments located in the Valle d'Aosta Region, Italy, within the Gran Paradiso National Park territory. The third is a forested mountain catchment located in the Piemonte Region, Italy, partially within the Orsiera Rocciavrè Natural Park.
We wonder about the hydrological functioning of such different landscapes through key insight achieved from isotopic tracers.

Keywords: Young water fraction; Seasonal Origin index; snow-dominated catchment; forested catchment; Eddy-Covariance

Overland flow in a changing forest

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Abstract
Visible deforestation at larger areas appeared in the previously densely forested highest mountains of Slovakia in the last decade. Forest changes occur also in the Jalovecký Creek catchment that is studied since the end of the 1980' as representative for the hydrological cycle of the highest mountains of Western Carpathians. As part of the protected area (the Tatra National Park), catchment forests have been little affected by human activities in that period. Forests dominated by spruce (Picea abies) used to cover 44% of the catchment and additional 31% of the catchment was covered by the dwarf pine (Pinus mugo). Although past human activities decreased the natural forest line almost in the entire catchment, most of the forest was recently classified as natural. However, its largest area was covered by the forest 121 to 140 years old. Therefore, forest breakdown and regeneration were expected dure to forest age. It seems that these processes already started or were intensified by several windfalls and bark beetle outbreaks that occured after 2010.
We will present results of the overland flow measurements in live and dead forest in summer 2021 (June to September) at a site where the forest dieback started in 2012. Isotopic composition ($\delta^{18}O$, $\delta^{2}H$) of precipitation and soil water sampled once per week will be presented as well. The overland flow from seven runoff plots (area 1 m^2) and precipitation measured at four sites along with the soil moisture data were used to examine the overland flow formation during the rainfall-runoff events. Seasonal overland flow represented on average about 4% to 8% of the open area rainfall. The highest average value was measured in the live forest with little forest floor vegetation. Overland flow during individual rainfall events represented from <1% to 17% of the open area rain. The open area rainfall had almost always slightly lower concentrations of heavy isotopes than the forest rainfall (both live and dead). Rainfall in the live forest was in most weeks isotopically heavier than in the dead forest (by 0.1‰ to 2‰ for $\delta^{18}O$). Soil water, sampled by the suction cups was recorded regularly over the season only at one site in the dead forest, but its isotopic composition was very different (isotopically lighter) from precipitation until the mid-July. Much fewer soil water samples were obtained at other two sites (in the dead and live forest), but they resembled the isotopic composition of precipitation more.

Keywords: forest dieback, rainfall-runoff events, stable isotopes of oxygen and hydrogen

Fine-scale variability in clay soil-water isotopic composition driven by recharge mechanism and *in-situ* fractionation

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Abstract
Isotopic composition of soil waters depends on both hydrologic processes controlling the water budget and biogeochemical fractionations of water within the soil. Both of these dimensions of soil-water isotope hydrology are more complicated in fine-grained soils because of the large role played by surface chemistry. Our laboratory experiments and field observations in vertic clay soils have revealed state-dependent relationships between soil moisture recharge mechanisms (by rain, groundwater, or floodwater) and isotopic composition. The resulting fine-scale spatial variability of soil-water isotopic composition varies by season and is hysteretic by soil moisture state. *In-situ* fractionation in vertic clay soils includes the expected evaporative enrichment, but also unexpected fractionation that suggests there are important vapor pathways of soil water flux. The fractionating effects of Van der Waals forces affiliated with solutes and surface interactions are more pronounced in clay soils, which can confound interpretation of some experimental results and creates spatial variability that can be interpreted in hydrologic terms.

Precipitation fate and transport in a Mediterranean catchment through models calibrated on plant and stream water isotope data

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Abstract

To predict hydrologic responses to inputs and perturbations, it is important to understand how precipitation is stored in catchments, released back to the atmosphere via evapotranspiration (ET), or transported to aquifers and streams. We investigated this partitioning of precipitation using stable isotopes of water (^{2}H and ^{18}O) at the Can Vila catchment in the Spanish Pyrenees mountains. The isotope data covered four years of measurements, comprising >550 rainfall and >980 stream water samples, capturing intra-event variations. They were complemented by fortnightly plant-water-isotope data sampled over eight months. The isotope data were used to quantify how long it takes for water to become evapotranspiration or discharged as streamflow, using StorAge Selection (SAS) functions. We calibrated the SAS functions using a conventional approach, fitting the model solely to stream water isotope data, as well as a multi-objective calibration approach, in which the model was simultaneously fitted to tree-xylem-water isotope data.

Our results showed that the conventional model-fitting approach was not able to constrain model parameters that represented the age of water supplying ET. Consequently, the ET isotope ratios simulated by the conventionally calibrated model failed to adequately simulate the observed xylem isotope ratios. However, the SAS model was capable of adequately simulating both observed streamwater and xylem water isotope ratios, if those xylem water isotope observations were used in calibration (i.e., the multi-objective approach). The multi-objective-calibration approach led to a more constrained parameter space, facilitating parameter value identification. The model was tested on a segment of data reserved for validation, showing a Kling-Gupta Efficiency of 0.72, compared to the 0.83 observed during in the calibration period.

The water age dynamics inferred from the model calibrated using the conventional approach differed substantially from those inferred from the multi-objective-calibration model. The latter suggested that the water supplying evapotranspiration is much older (median age 150-300 days) than what was suggested by the former (median age 50-200 days). Regardless, the modeling results support recent findings in ecohydrological field studies that highlighted both subsurface heterogeneity of water storage and fluxes and the use of relatively old water by trees. We contextualized the SAS-derived water ages by also using young-water-fraction and endmember-splitting approaches, which respectively also showed the contribution of young

water to streamflow was variable but sensitive to runoff rates, and that ET was largely sourced by winter precipitation, that must have resided in the subsurface across seasons.

Keywords: Precipitation fate, stable isotopes of water (^{2}H and ^{18}O), StorAge Selection (SAS) functions, multi-objective-calibration, Mediterranean catchment

Gradual ^{18}O and ^{2}H enrichment in xylem water in the pathway from roots to branches in Fagus sylvatica L.: potential impacts in ecohydrology

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Abstract
Understanding water dynamics in the Critical Zone (CZ) is crucial to provide better water management strategies. This is especially true in a period during which the concern for climate change and water scarcity is spreading around the globe. Of particular interest is the large amount of water exchanged between regolith and trees in forest ecosystems.
For example, drought seems to become more and more frequent during vegetative periods and a lack of understanding of how and where trees take the water in the regolith becomes a critical economic and social issue even in temperate ecosystems. Stable isotopes of water (O and H) have been largely used as tracers in eco-hydrology, contributing enormously to the development of various types of hypotheses and interpretations regarding the trees' water uptaken and evapotranspiration fluxes. However, many issues arise when using O-H stable isotopes to trace the origin of the water uptaken by trees. Indeed, the lack of standard protocols for sampling and analysis and the lack of understanding of the effect that tree physiology and biochemistry have on the extracted water represents a limitation when studying these tracers in the regolith-tree continuum.
In this framework, we hypothesized that sap extracted from roots with an *in-situ* vacuum extraction (*IS*VE) would be more reliable, in terms of understanding the potential water source, when compared to other methods (cryogenic extraction – CE) or sample types (e.g. branch sap, stem sap) since the roots are the first organs of the tree that comes in contact with the source water and in which we expect the lesser isotopic fractionation due to the reduced exposure to the tree metabolism. This latter, indeed, would determine a modification in the isotopic signatures of the waters extracted from the different tree compartments and such a modification would be proportional to the distance travelled by the water inside the tree: the longer the sap will be exposed to the metabolic processes, the stronger will be the modification of its isotopic signature.
To verify our hypotheses, we applied *IS*VE method to collect water from roots, stems and branches of European beech trees (Fagus sylvatica L.), and CE method to extract the water from roots and stem cores. The O-H isotopic signatures of the samples obtained with the two techniques were then compared to observe differences attributable to the techniques and/or to the tree metabolism. The isotopic signatures of the tree waters were also compared with the ones of the potentially available water sources to identify the origin.

Keywords: water tracing; tree water uptake, O-H stable isotopes, forest ecosystems, isotopic fractionation, Weierbach Experimental Catchment

Unexpected changes in ionic composition of stream water in a small headwater catchment after partial deforestation

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Abstract
Deforestation and reforestation may contribute significantly to the chemistry of surface water as forest plays an important role in the weathering processes and element cycling in the ecosystem. Therefore, the aim of our study was to determine changes in the ionic composition of stream water caused by partial deforestation of the Wüstebach experimental catchment in the Eifel mountains. The experimental catchment (including the main catchment – 38.5 ha and control catchment – 11.4 ha) is part of the Terrestrial Environmental Observatories in Germany (www.tereno.net). The complex monitoring of hydrological, climatological, and soil characteristics is carried out in the study area since 2008. In 2013, about 22% of the main catchment area (covered with the spruce forest) was deforested to promote the regeneration of near-natural beech forest. A comparison of two catchments, one treated and the other fully forested, allowed us to identify changes in stream water chemistry caused by deforestation.
The results of our study showed that the effect of partial deforestation was more pronounced on the chemical properties of stream water than on the runoff. Some chemical characteristics differed significantly from the pre-deforestation period, and these changes persisted until the end of the study period (7 years after deforestation), i.e. stream water electrical conductivity significantly decreased in the post-deforestation period which was connected with a significant decrease in the concentration of base cations (Ca^{2+}, Mg^{2+}, Na^{+}), Mn^{2+} and Cl^{-}. The percentage of NO_3^- and HCO_3^- increased significantly, causing a shift in the sequence of the average proportion of water ions. This is in contrast to other experimental catchments where deforestation has been carried out (e.g. in the USA) and where an increase in most of the ion concentrations was observed in the stream water. This difference is probably related to the cut-to-length logging method used in the study area and securing the skidding alleys with branches which caused little disturbances to soil cover. Therefore, our results are likely to better reflect the effect of the natural extinction of spruce forests associated with the droughts in the Eifel region on the surface water chemistry.

Keywords: clear-cut; environmental monitoring; ion concentrations; spruce forest

Freshwater mussels as a proxy for assessing catchment resilience to interdecadal climate variability

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Abstract
With the intensification of the hydrological cycle, the identification and assessment of factors controlling catchment climate resilience are key. Stable isotopes of O and H in streams and precipitation are cardinal tools for investigating questions related to water source, flowpaths and transit times. However, their spatial and temporal variability remain largely unknown – essentially due to the limited availability of long historical time series of O-H isotope signatures in stream water, as opposed to the multi-decadal records in precipitation.
Recently, we have explored the potential for freshwater mussels to serve as natural archives of long-term fluctuations in stream water isotope signatures. Our seminal work has shown that $\delta^{18}O$ values extracted from their shells closely mirror the variance of the measured stream water $\delta^{18}O$ – both showing a strong damping of the precipitation signal. In our follow-up study, we leverage prior work by Schöne et al. (2020) on potential links between the NAO index, precipitation isotope signatures and subsequent interdecadal variabilities in reconstructed stream water $\delta^{18}O$ signals for three catchments located in Sweden. Using freshwater bivalve shell $\delta^{18}O$ as a proxy of stream water $\delta^{18}O$ signatures, we hypothesize that interdecadal shifts in atmospheric circulation patterns translate into modifications of $\delta^{18}O$ isotope signatures in precipitation and subsequent stream water $\delta^{18}O$ signals – the latter eventually revealing changes in young stream water fractions related to fast flow paths.
For testing our hypothesis, we have designed a comprehensive set of laboratory and field experiments – investigating further (i) the potential for freshwater mussel shells to serve as proxies of stream water temperature and $\delta^{18}O$ signatures, (ii) the links between atmospheric circulation patterns, precipitations totals and $\delta^{18}O$ signals, and (iii) the translation of precipitation $\delta^{18}O$ signals into stream water $\delta^{18}O$ signals.
Here we focus on preliminary findings gained from a unique dataset of 5 years-worth of sub-daily precipitation O-H isotope data from the Belvaux (L) meteorological station – leveraged for investigating the links between water vapour sources, atmospheric circulation patterns, rain amount and precipitation isotope signatures. Our preliminary results show (i) a strong temperature-induced seasonality of the isotopic signal, characteristic for semi-continental sites, (ii) an intra-seasonal variability attributed to the joint influence of temperature and atmospheric circulation patterns, (iii) a high variability of the O-H isotope signal at the event-scale – matching the magnitude of the seasonal signal – indicating the influence of complex frontal systems and moisture recycling.

Keywords: Atmospheric circulation patterns, stream water $\delta^{18}O$, precipitation isotope signature, freshwater mussel, stream water stable isotope reconstruction

Studying the seasonal variance of end-members in the Critical Zone: the Weierbach Experimental Catchment.

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Abstract
End member mixing analysis has been a frequently used tool to attempt to link the hydrological and biogeochemical functioning of the Critical Zone to concentration-discharge patterns observed at catchment scale. The technique suffers however from the uncertainty of identifying end-members, and accounting for the spatiotemporal variation of end-members composition. Several studies have proposed a distributed model approach to deal with these uncertainties. G-EMMA, for instance, is based on the generalized likelihood uncertainty estimation but one of the main problems that still needs to be solved is how to combine the use of hydrological tracers that have high reactivity inside CZ. To briefly contextualize this problem, one must consider the difficulty of linking biogeochemical transformation to travel time. The reaction rates depend on the contact time of water with reactive materials, furthermore kinetic theory delineates the dependence on intrinsic rock properties, which is highly variable spatially. In terms of hydrological controls it was also shown in a recent study that vertical connectivity was a first order control of mean transit time (MTT) in hillslope catchments, regulating the hydro-geochemical functioning of the system. Briefly considering the scope of the problem, it is clear why precisely identifying end-members and also accounting for its spatiotemporal variation can be so complex.
We propose to identify end-members by delineating redox zones in combination with the most-likely flow paths approach and we hypothesised that the dynamics of distinct redox zones can be related to the chemical evolution of solutes along flow paths in the catchment. To test this hypothesis a one-year field campaign was designed to monitor at weekly scale electrical conductivity, pH, dissolved O_2 and redox potential) at 9 groundwater wells along a catena from the plateau to the outlet of the Weierbach Experimental Catchment (Luxembourg).
The proposed approach leverage the behaviour of ecological succession of electron acceptors (O_2> NO_3-> Mn(IV) > Fe(III) > SO_4^{2-} > CO_2). A consequence of this sequence is that redox processes tend to segregate into zones that are dominated by a single electron-accepting process. These distinct zones also have distinct reaction products. With this approach some of the technical problems with reactive tracers may be circumvented. Chemical parameters associated with the redox processes of interest was used in conjunction with calcium to observe seasonal variation of end members. The study has given further insight into processes driving chemical changes along flow paths linking distinct end-members and related ages of water.

Keywords: Critical zone; EMMA; catchment scale, Mean Transit Time

Using a fluorescent quinine tracer to estimate overland flow velocities: laboratory and field experiments

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Abstract
In this study a tracer technique based on the fluorescent properties of quinine was used to help on the visualization of shallow flows and allow to estimate rill and overland flow velocities. The experimental tests were conducted both in the laboratory and in the field, for different light conditions. Rill flow and overland flow velocities were estimated on bare, eroded, mulched, and vegetated soil, as well as on urban paved surfaces. In these experiments dye and thermal tracer techniques were used as a benchmark for assessing the performance of the quinine tracer. The tracers were injected into a very shallow flow and the trajectory of the tracers' plumes were recorded with optical and infrared cameras. The videos of the experiments were then processed to estimate the leading-edge tracer velocities. By tracking the leading-edge of the tracer plumes and calculating the travel distance of the tracers' leading edge over a certain time lapse, the surface velocity (V_{tr}) of the flow was estimated. The results show that the flow velocity estimates obtained using the quinine tracer technique are similar to those obtained using dye and thermal tracers. Thus, the quinine tracer can be used to estimate rill flow and overland flow velocities for a wide range of soil and urban surfaces (e.g. bare, eroded, mulched, vegetated soil, paved surface). Limitations of this fluorescent tracer are e.g. the invisibility of the tracer for bright light conditions or heavy mulched/vegetated soil, but this last limitation is shared by all tested tracers. However, the main advantage of using the quinine tracer is that it surpasses other flow velocity tracers in low/dimmed light conditions due to the fluorescent properties of the injected tracer when excited by UVA spectrum. Thus, this technique can be particularly useful in experimental work carried out at e.g. night, twilight, or shielded environments.

Keywords: fluorescent tracers; shallow flows; leading-edge velocities; night experiments.

Which water sources are used by beech and chestnut trees? An application of stable isotopes in a small catchment in the Italian pre-Alps

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Abstract
Stable isotopes are tracers used for the investigation of water flow paths, the quantification of the relative contribution of water sources to stream runoff, as well as to determine the origin of water exploited by plants for transpiration. However, the presence of different water pools in a catchment and soil water allocation hamper the understanding of water cycling and the interactions between soil and plants.
In this work, we used isotopic data from a small forested catchment in the Italian pre-Alps to i) investigate the spatial and temporal variability of the isotopic composition of the sampled water sources, and ii) determine which waters, and their seasonal origin, are used by beech and chestnut trees for transpiration.
The ecohydrological monitoring took place in the 2.4-ha Ressi catchment. Elevations are comprised between 598 and 721 m a.s.l., and the climate is temperate humid. The catchment is covered by a deciduous forest, with beech, chestnut, hazel and maple as the main tree species.
Water samples for isotopic analysis were taken monthly from bulk precipitation, approximately bi-weekly from stream water, groundwater and soil water by two suction lysimeter cups in the riparian zone. Xylem water and bulk soil water samples were extracted by cryogenic vacuum distillation bi-weekly during summer. All water samples were analysed by laser spectroscopy, except xylem water that was analysed by mass spectrometry.
Preliminary results show that stream water, groundwater and soil water extracted by suction lysimeters were isotopically similar to precipitation. Bulk soil water obtained by cryogenic vacuum distillation showed an evaporation signature, particularly on the hillslope sites where soil moisture was lower. At greater depths, bulk soil water extracted by cryogenic vacuum distillation was slightly less evaporated and less enriched in heavy isotopes compared to soil water extracted from shallow layers. Xylem water was more similar to soil water extracted by cryogenic vacuum distillation, suggesting that in the study area trees likely use more bulk soil water than the mobile soil water, groundwater and stream water. Specifically, hillslope trees tended to take up more deep bulk soil water, whereas riparian trees exploited more shallow bulk soil water, likely due to the different rooting depth of the vegetation in the hillslope and the riparian zone.

Keywords: stable isotopes; xylem water; soil water; forested catchment; cryogenic vacuum distillation.

SESSION 4:
EVAPOTRANSPIRATION AND DROUGHT

Nature-based solutions for drought resilient forests

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Abstract
Climatic extremes are the new normal for large parts of the world. Also temperate places, such as northern Bavaria, have experienced an abundance of extreme weather with significant impacts on the local ecology. Heavy torrential rainstorms are observed more often, while simultaneously, the precipitation required for a healthy ecology does not occur for increasing periods of time. These droughts, in combination with anthropogenic influences, have severely weakened the vitality of vast stretches of forest in northern Bavaria. In consequence, secondary pests were able to cause wide spread tree mortality. This indicates the need for innovative water management strategies to increase the resilience of forest ecosystems with regard to an increased occurrence of droughts.
This study is aimed at investigating the potential of storing additional water in the unsaturated soil-water (vadose) zone as a nature-based solution for increased drought-resilience of forest ecosystems. On the one hand, methods aimed at increasing the infiltration into the vadose zone are explored and on the other hand, the flows and retention potential of water in the vadose zone for use during drought periods are investigated. Following approaches were conceived to retain water in a forest catchment and increase the infiltration:

- Reduce discharge via ditches
- Adjust path construction, adding lateral drains
- Construct small-scale to micro-scale retention basins, e.g. by using dead wood

To be able to understand and quantify the relevant processes a small, highly monitored study site of five acres was set up on a forested slope with 51 soil moisture measurements at 13 sites. These measurements are augmented with numerous climatic measurements. Furthermore, state-of-the-art drone LiDAR measurements were used to produce a high-resolution (10 cm resolution) Digital Elevation Model.
By setting up micro-scale retention basins in the study site, the extensive monitoring system will enable us to explore the impact of this measure in detail. Furthermore, the high-density data in addition to soil investigations, was used to set up a high resolution (<1m^2) physically based hydrological model of the study site. The model chosen for this task is Hydrogeosphere (HGS), which amongst many other features, simulates the water flow in the vadose zone 3-dimensionally and can therefore give insights into retention potential of water in the soil. In addition to improving the modeling of water flow in the vadose zone, an in-depth investigation of the efficiency of the conceived measures is possible. Scenarios show the impact of various measures on the soil-water content.

Keywords: Drought; Forest ecosystem; Hydrogeosphere; LiDAR

Effect of geology on seasonal changes of stream water chemistry in a small catchment in the Western Tatras in southern Poland

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Abstract
The purpose of the study was to examine the effects of geology on seasonal changes in water chemistry in the Bystra catchment (13 km^2) – located in the Western Tatra Mountains in Poland. The southern, crystalline portion of the catchment is formed of poorly soluble granite and granodiorite. The middle part is formed of limestone undergoing karstification and dolomite (sedimentary, karst, part of the catchment). The northern part is mostly formed of dolomite and marl-type dolomite (the sedimentary, not karst, part).
The research was conducted in the years 2018-2019 and encompassed 3 karst-type springs, 3 regular springs, and 2 streams. Discharge (Q) was measured in the field every two weeks, along with specific electrical conductivity (SEC). In addition, water samples were collected for chemical analysis – main ions, biogenic ions. Air temperature data (T_a) were acquired from the weather station on Kasprowy Wierch Mountain (elevation: 1,987 m). Principle Component Analysis (PCA) was performed for the available data as well as correlation coefficients were calculated for discharge versus physical and chemical parameters of the studied waters.
The most important determinant of water chemistry for all the studied springs and streams is stream discharge and air temperature. This factor explains from 40% to 70% of variances in water chemistry in the studied area. The strongest calculated correlation between water chemistry and discharge was noted for streams draining the crystalline part of the Tatras, and for the Goryczkowe Wywierzysko karst spring (karst part of the catchment) whose recharge area is largely located in the crystalline part of the Tatras. The weakest correlation between water chemistry and discharge was noted for the Bystre Dolne karst spring in the karst part of the studied catchment, and for spring no. 3 in the sedimentary (not karst) part of the catchment. This suggests a complex hydrogeology of the recharge area. For most of the studied springs and streams the strongest negative correlation between water chemistry and discharge is noted for SEC, Ca^{2+}, Mg^{2+}, Na^+, HCO_3^-, and SO_4^{2-}, which points to their geogenic origin. At low discharge in the winter season the values of these parameters are high, while at higher summer discharge they are low. In all the investigated springs and streams a weak negative correlation between Cl^- and discharge was observed. The correlation between biogenic ions (K^+, NO_3^-) and discharge was weak or statistically insignificant due to the complex circulation patterns of these ions in the environment.

Keywords: stream water chemistry; high mountain areas; karst springs; geology; the Tatra Mountains

On the spatiotemporal variability of the transpiration-to-evapotranspiration ratio

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Abstract
Reported observations of the ratio of transpiration to total evapotranspiration (T:ET) spans from 35 to 90% globally with values centered around 60-65%, when averaged across different biomes. Large scale Earth system models simulate considerably lower (41%) values of T:ET, particularly in dry areas. Concurrently, previous results suggest that T:ET does not depend on mean precipitation and has a positive correlation with Leaf Area Index (LAI). Here, we used the mechanistic ecohydrological model, T&C, with a refined process-based description of the soil evaporation together with a detailed representation of canopy biophysics and physiology, to investigate the spatiotemporal variability of T:ET across multiple biomes. Numerical simulations highlight a more constrained range of mean T:ET (70 ± 9%) when compared to observation-based estimates and a much higher value when compared with other models. T:ET is lower than 55% only in a few sites that often correspond to specific biomes (e.g., boreal tundra). The constrained range of T:ET is the result of systematic covariation between local vegetation characteristics and climate in undisturbed ecosystems that prevent ground evaporation or evaporation from interception to become dominant. Because of this, modifications in the T:ET in a changing climate are likely to be considerably constrained as well. Overall, our analysis confirms that T:ET is independent from mean annual precipitation and only weakly correlated to wetness index, while LAI dependence is found seasonally but not across biomes.

Keywords: Evapotranspiration; Ecohydrology; Modeling; Transpiration; Climate Change

Seasonal streamflow response in a Mediterranean catchment with abandoned agricultural terraces

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Abstract
Agricultural terraces have been built in mountain regions worldwide in order to provide a larger surface for cultivation, improve water availability and reduce soil erosion, as they favour infiltration and reduce runoff. Their construction substantially alters the dynamics of the hillslope hydrology. In the Mediterranean region, many valleys were occupied by terrace cultivation; however, during the XXth century, rural population declined resulted in the abandonment of agricultural practices and the maintenance of the terraced fields. The aim of this study is to analyze the seasonality of the hydrological response of an environment characterized by abandoned agricultural terraces. For this purpose, a small catchment (1.9 km^2) was monitored in 2012 in the north-western Iberian ranges (Spain), largely occupied by abandoned terraces, which are currently covered with sparse grass and shrubs. Annual rainfall in the area is 450±150 mm, with two clear rainy seasons, autumn and spring. The equipment installed in the catchment registers continuously meteorological data and streamflow discharge at the outlet of the catchment. Here we present the results of the hydrological response at the flood event scale of 7 hydrological years (from 2012-13 to 2018-19). Event runoff coefficient (RC) was moderate (mean RC<0.10), with higher values occuring in winter and spring, which occasionally could reach >0.30. These two seasons registered the larger number of floods. Floods were rarely recorded in autumn and summer. However, autumn could registered high RC associated to large rainfall events. Summer rainfall events with high intendity were not able to produce high RC nor high peakflows. Higher peakflows were mainly registered in winter and spring and were mostly related to rainfall amount. Catchment response was on average relatively slow (mean time response >8h) and flood events presented long duration (mean duration > 2 days), except in summer when they lasted on average < 15h and response time was shorter (mean < 5h).

Keywords: streamflow response; seasonality; land abandonment, agricultural terraces, Mediterranean mountains

Development of drought, low flow and water scarcity over past and future in a German low mountain range basin - a long-term analysis

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Abstract
The lack of precipitation, increased temperatures and resulting water scarcity can have far-reaching effects on the environment, society and the economy. In recent years, the issue of drought has gained major presence and importance in Germany and Europe, as the effects of a changing climate are becoming evident. The sensitivity to drought and the resulting water scarcity manifests itself differently depending on the region. Catchment characteristics play an important role in basin-scale analyses. The study, which was conducted at the Chair of Engineering Hydrology and Water Management of the Technical University of Darmstadt, deals with the long-term development of drought in a low mountain range catchment characterized by forest and agriculture. The Gersprenz catchment, located in south Hesse, covers about 500 km² and is part of the Rhine River basin district.
An initial study addressed past trends in low flow and drought on the basis of measurement data (1980-2018). With the help of drought- and low flow indices the interconnectedness of drought- and low flow events was observed and the role of catchment characteristics was discussed. In order to assess the future development of drought, projected climate data was employed. Using two emission scenarios RCP8.5 and RCP2.6, it was thus possible to investigate the development of the climate and dryness for a high- and a low-emission scenario for the period 2011-2100. The climate projections used for this purpose are part of the bias-adjusted core ensemble of the German Weather Service (DWD).
The results of the study indicate that both the magnitude and duration of low flow and drought periods have increased in the past and will increase in the future. The results of the study underscore the importance of watershed characteristics to low flow processes. It was also shown that water scarcity will be a prevailing topic of the future, under both emission scenarios. Nevertheless, the extreme hydrometeorological developments in the RCP8.5 scenario were noticeably mitigated under the RCP2.6 scenario.

Keywords: drought, climate change, water scarcity, low flow, hydrological extremes

Hydrological drought as a result of the interactions between water and carbon cycles within the critical zone: the experimental site of Ussita in the Sibillini National Park

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Abstract

Mediterranean mountainous basins provide critical water supply and ecosystem services, yet these environments are increasingly at risk due to anthropogenic stressors and competition for water across urban, agricultural and environmental demands.

In spite of the recent progress in land surface monitoring, current drought estimation in widely used operational products still largely relies on poorly parameterized potential evapotranspiration, in combination with simple hydrological bucket models (e.g., drought indices) which have shown to lead to questionable results.

As hydrological systems are intrinsically intertwined with climatological and ecological systems, the propagation of meteorological droughts through them is modulated by a variety of mechanisms which are linked to carbon and water cycle interactions and specifically to how different plant species i) access subsurface water storages and ii) respond to water stress, high CO_2 and high evaporative demand. Ignoring the parameterization of these mechanisms is often the norm in state-of-the-art land surface and hydrological models and impacts water balance closure via incorrect representation of transpiration leading to uncertainties in hydrological drought prediction.

Here we present the experimental setup of the of the Ussita catchment (8 km^2) tributary of the Nera River located in the Apennines chain in the Monti Sibillini National Park and part of the critical zone observatory that we aim at building within the two recently funded projects (WATERSTEM and WAFER) which trying to unravel the interactions between WATER and carbon cycles during drought in the forest and grassland ecosystems of the Mediterranean region. The site is characterized by complex interactions between surface and groundwater fluxes and has been experimented with multiple pressure transducers for the measurement of river and groundwater levels, electrical conductivity meters, soil moisture probes, instrument for the collection of throughfall, tree talkers, an eddy covariance station and a weather station. The experimental site will be used to answer the following research questions:

1. What are the feedback mechanisms between plant strategies to survive water stress and water allocation in the different (eco)hydrologic compartments?
2. To which extent do these mechanisms modulate runoff deficit during droughts?
3. What is the impact of these feedback mechanisms on the depletion of water resources and degradation of forest and grassland ecosystems (e.g., tree mortality, reduced ability to sequester CO_2) in a warming climate?
4. Does a more detailed integration of these feedback mechanisms into ecohydrological models improve the accuracy of water supply modelling and thus support drought mitigation strategies?

Keywords: drought; carbon cycle; water cycle

Differences in streamflow after farmland abandonment –a comparative study in four small mountain catchments

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Abstract

Farmland abandonment usually leads to vegetation expansion with important environmental consequences. In this study, we assess the streamflow response at the flood event scale in five long-term monitored small headwater catchments in northern Spain. Three of them are representative of different post farmland abandonment scenarios: natural revegetation dominated by shrubs (Arnás), afforestation (Araguás_afforestation) and abandoned terraced fields (Munilla). Two more cathments, covered by dense natural forest (San Salvador) and badlands (Araguás), were used as reference for undisturbed and degraded environments, respectively.

The five catchments registered a larger number of flood events in late autumn and spring, showing the influence of the Mediterranean climate. While the badlands, shrubs and afforested catchments generated events over the entire year, the terraced and forested catchments showed very limited response during the summer. Furthermore, the badlands, shrubs and afforested catchments recorded more than twice floods per year than the other two catchments. At the flood event, the mean runoff coefficient was higher in the badlands and shrubs catchments. However, under wet conditions, both the forested and afforested catchments could registered high hydrological reponses, with similar runoff coefficients than those recorded in the badlands and shrubs. The terraced cathment showed the lowest runoff coefficients. The highest peakflows were observed in the badlands catchment, charcaterized by sharp flood hydrographs, suggesting the dominance of overland flow processes. The flood hydrographs of the abandoned catchments differed significantly, suggesting the influence of both vegetation cover and soil properties inherited from past agricultural activities. In the shrub catchment, peakflows were always greater; however, under very wet conditions and/or intense rainfalls, the afforested catchment recorded high peaks, comparable to that of the shrub catchment. The response time in both catchments were fast and recession limbs were short, suggesting the occurrence of ovelrand flow processes, probably over localized degraded areas. This greatly differed from the hydrographs of the terraced and forested catchments, characterized by gentler hydrographs, with long response times and recessions, indicating subsurface flow processes associated with thick and well developed soils. Differences in the land use legacy, which affects vegetation cover but also soil properties, may explain the differences in the hydrographs characteristics, suggesting contrasting dominant runoff generation processes in each catchment. These results highlight the need to consider these differences to reduce future uncertainties in forecasting water resources and soil conservation in areas affected by farmland abandonment.

Keywords: streamflow; flood hydrograph; farmland abandonment; headwater catchment; Mediterranean mountain

Unravelling hydrological processes in Mediterranean headwater catchments by means of water stable isotopes

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Abstract
Ensuring an adequate supply of good quality water is one of the major challenges of the future. Within this general context, the Mediterranean basin has been identified as one of the areas that will experience increasing pressure on freshwater resources. The best way to improve predictions of the hydrological consequences of global change in Mediterranean headwater catchments, is to significantly improve our understanding of water fluxes in the critical zone. Even if stable isotopes of water (^{2}H and ^{18}O) are an essential tool for investigating hydrological processes, particularly at the small catchment scale, and they have been used as hydrological tracers for more than five decades, recent advances have revealed problems related to some of the simplifying assumptions that underlie past investigations. The main objective of this work is to tackle some of the simplifying assumptions related with hydrological isotope-based studies in Mediterranean headwater catchments. To achieve it, we are focusing on three specific research objectives that require additional scientific knowledge to better understand hydrological processes dynamics and to quantify the contribution of different sources to streamflow at different catchment scales. First, we want to investigate how rainfall amount and isotopic composition vary spatially and temporally at the small catchment scale. Then, we want to examine how shallow groundwater level and groundwater isotopic composition vary temporally (especially during floods) at the small catchment scale. Finally, we want to investigate possible spatial heterogeneities in streamwater isotopic composition variations during floods. Our work, conducted in the Vallcebre research catchments (NE Spain), is based on a twofold approach grounded on intensive hydrometric measurements and on the use of water stable isotopes as hydrological tracers. These two approaches are being developed at different temporal frequencies (weekly, daily, subhourly time steps) and at different catchment scales with a special emphasis on the spatio-temporal variability observed in water compartments and fluxes. Here we present our monitoring design, the type of new data we are gathering and the first results obtained after 6 months of intensive monitoring and sampling in the catchments.

Keywords: stable isotopes of water (2H and 18O); rainfall; groundwater; streamflow; Mediterranean headwater catchments

Trends of baseflow in midsize Carpathian catchments in 1970-2019

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Abstract
Climate change associated with global warming is increasingly often reflected in the water cycle at a catchment scale. Increases in air temperature affect groundwater recharge conditions. Since the last few decades this phenomena in the Carpathian has been emphasized by a changing role of snowmelt recharge in winter and spring. However, there is no evident tendency in the yearly precipitation sums in this area. The overall water circulation patterns are slowly changing which includes groundwater recharge conditions.
The aim of the study was to assess baseflow trends in the Western Carpathians in the period 1970-2019. The baseflow was calculated for 20 medium-sized (100–500 km^2) catchments in Poland and Slovakia using a recursive digital filter proposed by Eckhardt (2005). The parametrization of the filter was made on a base of recession analyses of daily discharge during recessions and runoff below $<Q_{25\%}$ (Collischonn and Fan 2013). The trends analyses were performed with a non-parametric method including the Mann-Kendall test, the Theil-Sen slope estimator and the trend-free pre-whitening procedure (Yue et al., 2002) separately for series representing baseflow throughout a whole year as well as series representing particular seasons of the years.
In the study period several substantial changes in baseflow of Carpathian rivers were noted, with a prevalence of declining trends. The most evident changes were noted for low baseflow in summer and autumn, especially in western foothill catchments. Statistically significant decreases in low daily baseflow ranged from -9% to -66% per 10 years for summer, and from -12 to -82% mm per 10 years for autumn. In winter and spring trends in low baseflow were not significant, except high mountain catchments where 14% increases in low baseflow were noted in winter and spring.
Significant decreases in annual and summer median daily baseflow values were observed only for foothills and middle mountains in the western part of the study area. Annually and in the summer, the strongest decreasing trends in relation to median daily baseflow were noted for foothill catchments. Spring and autumn seasons lacked significant changes in median baseflow.
The results indicate a changing role of snowmelt recharge in the Carpathians and increasing problem of the groundwater depletion in summer and autumn mainly in foothill areas. The results reflect trends noted for the total river runoff which is in general declining in summer, and in some catchments also in autumn and generally throughout the entire year.

Keywords: baseflow; the Carpathians; climate change; groundwater recharge.

Precipitation in the winter season in higher altitudes of the Bohemian Forest under a changing environment conditions: evaluation and use of new techniques

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Abstract
Higher mountainous areas in the Czech Republic generally have lower fluctuations in precipitation during the year than in the lowlands. In addition to the altitude, this is mainly due to the oceanic character of precipitation, especially in Bohemia, where there is an increase in precipitation before and during winter. In the past, the higher locations of the Bohemian Forest were significantly reduced by precipitation measurements. This has been gradually improved by restoring measurements at both extinct and new sites. The results of the measurements show a very significant proportion of winter precipitation.
The main objectives of the present article are to: (i) describe the snow cover characteristics (snow depth – SD and snow water equivalent – SWE) concerning the mid-latitude forested catchment; (ii) use the snow cover evaluation in the Bohemian Forest as an indicator of climatic and related changes; and (iii) introduce new techniques for a monitoring both snow depth and snow water equivalent.
The influence of the forest canopy (*Picea abies* and *Fagus sylvatica*) and altitude (ranging from 835 m a.s.l. to 1118 m a.s.l.) was investigated for the time period from 2002 to 2021. Preliminary results proved that forest cover have a significant influence on the snow cover accumulation, reducing SWE by 50 % on average, compared to open sites. The elevation gradient concerning SWE ranged from 30 to 40 mm and from 5 to 20 mm per 100 m in open and forested sites, respectively. Its magnitude was found to be temporarily variable and positively related to the total seasonal snowfall amount.
The hydrological effects related to changes in the snowmelt regime were studied. The attention was paid to the streamflow generation during spring snowmelt, which is a dominant hydrological event in many seasonally snow-covered regions. The changes in snow cover amount and its variability at two mountainous stations in the Bohemian Forest (Churanov 1118 m n. m., 1962 - 2021 and Breznik 1137 m n. m., 1987 - 2021) were used as indicators of going along climate transition in the area. It was proved that the streamflow originating from the snowmelt starts earlier compare to the end of the 20th century.

Keywords: winter precipitation, snow cover, hydro-ecological monitoring, time lapse camera system, climate change

Hydrological trends for three headwater catchments in the Alptal valley, Switzerland

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Abstract
Hydrological research in the steep forested headwater catchments of the Alptal valley in central Switzerland started in the late 1960s. It has mainly focused on the runoff mechanisms that lead to the very quick streamflow responses, the relation between forest management and floods, biogeochemistry and nutrient cycling, and sediment transport. Current research in the Alptal also includes the assessment of the impacts of climate change on low flows and peak flows. In this poster, we will describe the research catchments and present the results of trend analyses for three headwater catchments. The hydro-meteorological measurements over the last 50 years indicate that there is considerable inter-annual variability in rainfall, snow cover, and streamflow. The approximately 2°C increase in mean annual air temperature has led to a shorter period with snow cover and an earlier snowmelt, a decrease in streamflow in May, and an increase in streamflow in January and March. The number of dry summers is still small (2003, 2015 and 2018) but they have all occurred in the last 20 years. The coefficient of variation of streamflow and the Richard-Baker flashiness index suggest that both the day to day and overall variability in streamflow is increasing, which motivates us to continue our studies on runoff generation and storage dynamics in the study catchments.

Keywords: hydrological trends, climate change, catchment change, hydrological regime

Predicted changes in precipitation greatly underestimated the impact on water yield and water availability

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Abstract
Decreasing precipitation (P) and increasing vapor pressure deficit (VPD) in many regions will impose substantial pressure on the water supply for ecosystem functioning and human consumption, which are key to sustainability. Much effort is invested in monitoring and predicting changes in P, but it is "Ecosystem Water Yield" (the residual of P and ecosystem evapotranspiration, ET: WYe=P-ET) that is the critical factor for sustainability. Plant ecosystems are conservative water users, and as long as P>ET, ET tends to remain within a limited range. We show that as a result, climate-driven changes in WYe are greatly amplified compared with changes in P itself. We demonstrate the enhanced sensitivity of WYe to changes in precipitation based on the global observation of ET, P, and net radiation from 158 sites, providing a total of 771 data years with a sufficient amount of P and ET data for the calculation of annual WYe. We demonstrate two key aspects: 1) That above a certain threshold, changes in rainfall have little impact on the rates of evapotranspiration, in contrast to some model predictions. 2) Evapotranspiration (and, therefore, 'water yield') can be greatly influenced by changes in the land cover and the vegetation type. As forests are known to have greater evapotranspiration than grassland, we show in our research site in Israel that a decrease of about 20% in precipitation (predicted by the end of the century) will lead to zero 'water yield' and an unsustainable forest ecosystem, but will leave WYe significantly above zero in grassland or shrubland areas. Our results demonstrate that shifting our focus from changes in rainfall to those in 'water yield' is critical since it is the 'water yield' that is directly linked to sustainability. These aspects of the interactions of ET, land cover on the hydrological balance, water availability, and sustainability, are poorly investigated and quantified.

Keywords: water-yield; evapotranspiration; precipitation; climate change; land-cover-change

SESSION 5:
EROSION AND SEDIMENT TRANSPORT

Continuous monitoring of bedload transport in a glacierized Alpine basin

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Abstract
In mountain basins, long-term observations of water and sediment fluxes are crucial for understanding the dynamics of sediment transport processes at multiple temporal scales. Here we analyze 7 years of data gathered at a bedload monitoring station located in the glacier-fed Sulden/Solda River (South Tyrol, Italy). The Sulden basin (drainage area 130 km^2) ranges in elevation between 1,110 and 3,905 m a.s.l. and features a glacier area of about 18 km^2. The monitoring station is equipped with 8 geophone plates that continuously measure the vibration induced by the impact of moving particles with a sampling frequency of 5 kHz. Continuous seismic data are analyzed to calculate the bedload flux at 1 minute scale by means of calibration equations derived from 65 direct bedload sampling conducted from 2014 to 2020. The signal power is proposed as a more effective metric for calculating bedload mass than threshold-based impulses. Results show: (i) a remarkable variability - from 0.02 to 200 kg/m/min - of bedload rate for the same value of mean flow discharge of 10 m^3/s; (ii) the joint effect of storm-driven flood events and seasonal changes in sediment supply on bedload rates; and (iii) the strong impact of climatic factors (i.e., temperature and snow cover) on bedload fluxes. Moderate bedload rates occurring in late spring/early summer are likely related to the mobilization of riverbed sediments, while higher bedload peak rates observed in July-August are associated with the activation of glacial and proglacial sediment sources. The dataset shows a complex climatic control on bedload transport at the basin scale, where precipitation, air temperature and snow cover determine flow and glacier melting dynamics. These findings suggest how the effects of the ongoing climatic change (e.g., higher frequency of intense rainfall events and prolonged heat waves) can result in a marked increase in bedload transport in glacier-fed rivers of the Alps.

Keywords: bedload transport; monitoring; geophone plates; glacierized basins.

Impact of small woody debris jams on local groundwater and surface water flow; case study in the Noor Brook, The Netherlands

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Abstract

The Noor Brook is a small headwater in the southeast of the Netherlands. Over the last decades the brook incised deeply into its own Holocene sediments, at most places >3m below surface level. The adjacent Natura 2000 area the Noorbeemden is highly dependent on the chalk-rich seepage conditions. The incision might result in an increase of seepage towards the brook and a decrease of seepage to the Noorbeemden. Some small woody debris jams were inserted in the brook to decrease erosion and increase sedimentation in the brook bed. Over the course of 3 years (2016 – 2019) detailed measurements were done on the erosion and sedimentation in the stream bed and flanks, on the groundwater levels and on the chemical composition of the groundwater (unsaturated zone as well as saturated zone) and surface water. In order to predict future developments in the brook bed, a model was constructed in HEC-RAS and local groundwater flow was modelled in MODFLOW.

It was found that the stream flow was effectively reduced by installing woody debris jams. However, the patchy character of such a jam causes heterogeneous flow and therefore possibly even higher flow velocities underneath some parts of the dam. This can result in even deeper erosion gullies than without the jams. A gravel bed in between the soft silty clay loam of the stream bed and the debris jam can reduce this effect or even create more sedimentation. Suppletion of some extra gravel upstream of the debris jam is a useful tool to refill deeper erosion gullies when they might develop over time.

A significant groundwater level decline was measured, but this was mainly due to the very dry years 2018 and 2019. The MODFLOW groundwater model showed that when the brook would incise another 10 into its own sediments, the groundwater level close to the brook would drop about 8 cm and at 50m distance only 2 cm. The scenario with an incision of 40 cm into the current bed, the groundwater level decline would be ~ 30 cm (close to brook) and 7 cm (at 50m), respectively. The HEC-RAS model showed that in the coming 6 years due to the woody debris jams no further erosion is expected and that on average 5 cm sedimentation can occur.

Keywords: woody debris jams; MODFLOW; HEC-RAS; streambed erosion.

The effect of surface heterogeneity of erosion and other transport processes and their potential implication for ecosystem functioning

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Abstract
This study combines results from a series of artificial catchments FALCON and two chronosequences of rehabilitated and unrehabilitated post-mining landscapes near Sokolov (Czech Republic). All study sites were formed by the deposition of post-mining overburden consisting of Miocene clays impregnated with carbonates and fossil organic matter (kerogen). Each chronosequence consists of four sites and covers the first 65 years of ecosystem development. FALCON was established in 2019 and allows the first stages of ecosystem development to be studied in detail. It consists of four parallel catchments (0.25 ha each) that are completely isolated hydrologically. Two catchments are rehabilitated and two are not, as is common in the region, copying the approaches used at the sites of the rehabilitated and unrehabilitated chronosequences. The remediated areas were leveled and planted with alders, while no action was taken in the non-remediated areas where the longitudinal undulations created by the fill remain. In the remediated areas, alders formed a closed canopy in the 10-15 year old areas. In unrehabilitated areas, sheath willow, birch, and aspen are the predominant trees colonizing the areas and forming a closed canopy in the 15-25 year old areas.
Detailed surface change studies using erosion pins and 3D terrain models created using drones show that the surface area in the undulating areas is decreasing more than in the apartment areas, while sediment loss measurements show no difference between the apartment and undulating areas. In wavy areas, there is a great heterogeneity in the erosion process. The upper part of the undulations is heavily eroded, while the eroded material accumulates in the depression. The depressions contain more silt and clay material, have higher water retention and lower infiltration rates, while the opposite is true for the elevated wave tops. Studies along the chronosequence also show that the elevated portion of the waves retain portions of the original mudstone that are more resistant to weathering, such as pelocarbonates. These stone-like parts of the mudstone provide the safe spaces for woody vegetation to colonize. In contrast, the vegetation in the depressions between the waves is dominated by grasses. The study shows that vegetation establishment depends on the formation of microsites with specific soil conditions created by surface processes in the initial phase of ecosystem development.

Keywords: erosion, sedimentation, infiltration, retention, artificial catchment.

Assessing soil erosion by monitoring hilly lakes silting

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Abstract
Soil erosion continues to be a threat to soil quality, impacts crop production and the ecosystem services delivery. The quantitative assessment of soil erosion, both by water and by wind, is generally carried out through modeling the phenomenon via remote sensing approaches. Several empirical and process-based physical models are worldwide used for erosion estimation, like USLE (or RUSLE), MMF, WEPP, PESERA, SWAT, etc. Furthermore, the sediment produced by erosion phenomena is the result of direct measurements carried out in experimental sites. Data collection for this purpose is very complex and expensive, in fact we have few cases of measures distributed at the basin scale to monitor this phenomenon. With this work, we propose a methodology based on an expeditious way to monitor the volume of hilly lakes with GPS, sonar sensor and aquatic drone. The volume is obtained by means of an automatic GIS procedure based on the measurements of lake depth and surface area. Hilly lakes can be considered as sediment containers. Time-lapse measurements make it possible to estimate silting rate of the lake. The volume of 12 hilly lakes in Tuscany was measured in 2010 and 2018, and the results in terms of silting rate were compared with the estimates of soil loss obtained by RUSLE and MMF. The relationships found are significant and promising for a distributed application of the methodology, which allows rapid estimation of erosion phenomena. The proposed approach allows for a monitoring of basin-scale erosion, which can be extended to larger domains, which have hilly lakes, as for example the Tuscany region, where there are more than 10,000 lakes.

Keywords: Sediment monitoring, remote sensing, lakes, water capacity, sonar, aquatic drone

Estimating pre- and post-fire soil erosion in the temperate Andes by adjusting the C-factor within the revised universal soil loss equation (RUSLE).

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Abstract
Wildfires are a major global concern influencing vegetation development, its composition, soil erosion processes and sediment. Burned vegetation impacts the erosion behavior of river basins and watersheds, affecting adjacent habitants. To get an overview of the amount of erosion at basins the Revised Universal Soil Loss Equation (RUSLE) can be used, as it is easily applicable globally. It delivers an assumed annual erosion value (A) based on the product of various input parameters: rainfall erosivity (R), soil erodibility (K), topography expressed by slope length and steepness (LS), (plant-)cover management factor (C), as well as support practices (P). When investigating wildfire areas at a real scale, one frequent problem is missing reliable data before the fire event and therefore a comparison of the pre- and postfire conditions is not always possible. With the increasing use of open access Sentinel 2 (S2) images, NDVI time series can contribute to a differentiation between the pre-fire and the post-fire estimation of the C-factor and therefore a different estimation of the soil erosion with intact, as well as burnt vegetation. To demonstrate the changing pre- and post-fire erosion estimation, the basin of El Saco in the southern Andes was selected as study site. It was affected by a wildfire in September 2019 and its landcover consists mainly of grassland and pasture. The pre- and post-fire C-factors were calculated according to van der Knijff et al.[1], using the means of eight pre-fire, as well as eight post-fire NDVIs respectively. As a result, the pre-fire soil erosion estimation of basin El Saco was 227 $t/ha^{-1}/yr^{-1}$ and the post-fire estimation 255 $t/ha^{-1}/yr^{-1}$, what leads to an estimated post-fire erosion increase of 28 $t/ha^{-1}/yr^{-1}$. These values match with studies at similar areas in southern Ecuador. Challenges with this method could appear in areas with high precipitation over a certain time, as the selected S2 scenes should be free from clouds over the area in question to get exact NDVI values. Depending on the extent of the wildfire, large scale analysis of various basins could therefore be problematic regarding the accuracy of the erosion estimation value if no cloud mask is used. Nevertheless, the easy application and the global popularity of RUSLE can help to further understand post-fire erosion behavior of basins and watersheds. This study showed that the adjustment of the C-factor can contribute to understand the pre- and post-fire erosion. Further, short- and long-term effects of wildfires on a basin´s soil loss could be investigated with this method.

Keywords: Pre- and post-fire erosion, RUSLE, Cover management factor (C), NDVI, Sentinel 2

Automated Determination of Support Practice P-Factor Using Line Detection on Open Remote Sensing Data

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Abstract
The practice of tilling and planting crops parallel to the contour of the terrain has proven effective in reducing soil erosion caused by rainfall and surface runoff. In Germany, this risk of erosion from water is typically determined using the *'Allgemeine Bodenabtragsgleichung'* (ABAG), derived from the Universal Soil Loss Equation (USLE), in order to estimate the average annual soil loss. Many studies dealing with the USLE or its revised/modified versions often not consider the P-factor. It is mostly neglected due to insufficient data, although it considers erosion-preventing measures such as contouring, strip-cropping and terrace systems. Contouring is a recommended and simple but effective measure to prevent soil erosion on arable land with a mean slope less than 15% and for rainfall events with low or moderate intensity.
In this study, we determine the P-factor within a part of the hydrological research basin Gersprenz located in the southeast of Hesse, Germany. The part of the basin in the low mountain range is 169 km² in size and is characterized by 47.4% of arable land and grassland. With a focus on arable land, we used polygon data of agricultural land parcels from the German Land Parcel Information System to account for the different characteristics of each parcel, as intended in the original USLE publication. To verify where the P-factor is applicable, we calculated the mean slope, erosion-effective slope length and, in addition, the main gradient direction from a digital elevation model. In order to obtain information about contouring, we automatically derived the tramlines within the parcels from remote sensing data with high resolution from Google Earth™ mapping service using a line detection algorithm of OpenCV. Afterwards we defined a main direction of tillage and planting for each land parcel from the detected lines. Comparing the main gradient direction with the main direction of tillage, we were able to determine the rate of contouring and calculated individual P-factors for each agricultural parcel depending on slope and slope length.
With this study, we provide a method to automatically derive information about contouring on agricultural land parcels and quantify support practice within the P-factor considering slope length and slope steepness. The developed method and the results could make an important contribution to the reduction of soil erosion and the input of particles into rivers if applied according to the local conditions in the catchment.

Keywords: soil erosion; USLE; support practice factor; contouring; remote sensing

Dynamics of soil water potential in the territory affected by deep brown coal mining in the Upper Nitra coal basin (Slovakia).

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Abstract
Anthropogenic disturbance of geological structures has recorded a considerable extent in Slovakia in recent decades. The reason was the need for mining sources for the national economy. One of the essential was also brown coal, which was mined in the Upper Nitra coal basin area in the district of Prievidza (Slovakia). Brown coal was mined around the town of Handlová, the village of Koš, and the villages of Cígeľ and Sebedražie. Cígeľ coal mine (near the village of Cígeľ and Sebedražie) caused several geological defects, which have the character of large cracks and local landslides, which disrupt the hydrogeological conditions, resulting in significant impacts on soil water regime stability of forest ecosystems growing in such a damaged area. This paper aims to point out the variability and dynamics of soil water potential in the mining-damaged locality (Račkov laz) and intact reference area (Čertove chodníky) during the vegetation periods 2020 and 2021. The results showed that mining activity probably significantly impacts the soil water regime and thus the ecological stability of forest ecosystems.

Keywords: soil water potential, anthropogenic disturbance, forest ecosystems, water regime, undermining

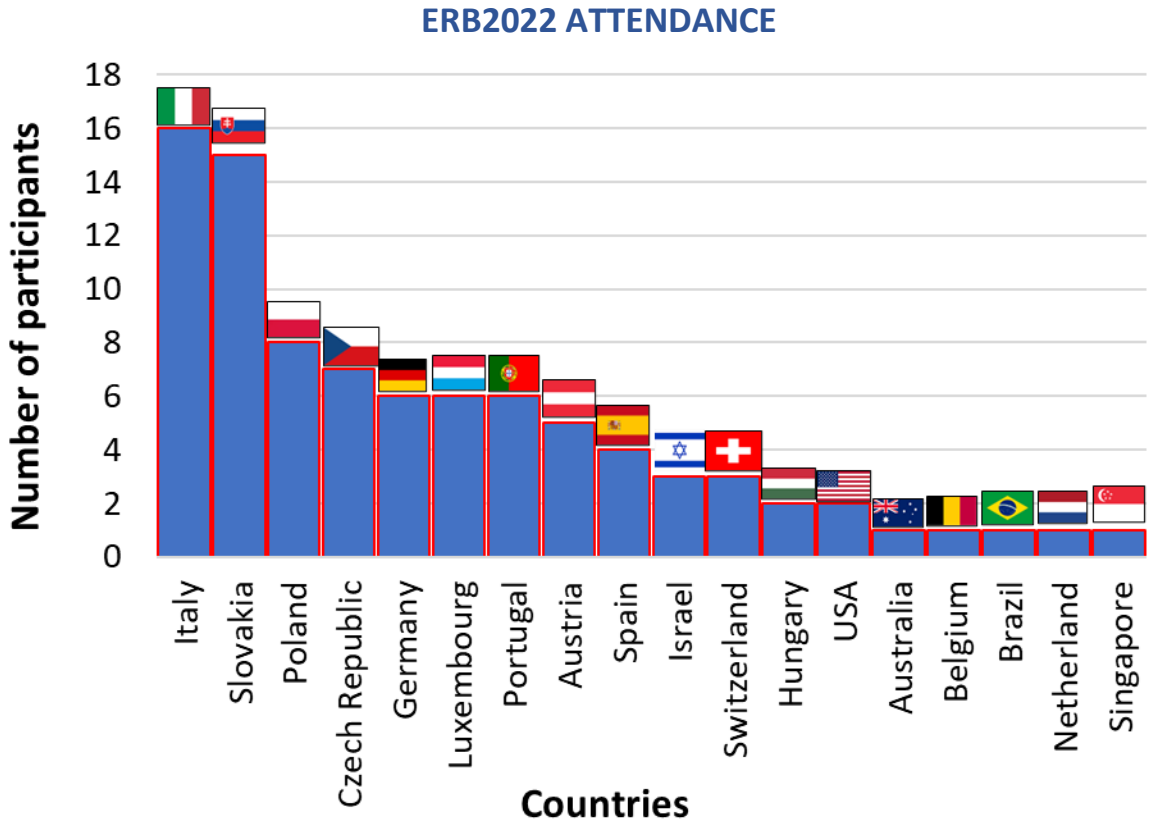

Figure 1 ERB 2022 Number of participants for each country

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