



SMT100 Academic References & Acknowledgement

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Effective Calibration of Low-Cost Soil Water Content Sensors

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Abstract

Soil water content is a key variable for understanding and modelling ecohydrological processes. Low-cost electromagnetic sensors are increasingly being used to characterize the spatio-temporal dynamics of soil water content, despite the reduced accuracy of such sensors as compared to reference electromagnetic soil water content sensing methods such as time domain reflectometry.

Here, we present an effective calibration method to improve the measurement accuracy of low-cost soil water content sensors taking the recently developed SMT100 sensor (Truebner GmbH, Neustadt, Germany) as an example. We calibrated the sensor output of more than 700 SMT100 sensors to permittivity using a standard procedure based on five reference media with a known apparent dielectric permittivity ($1 < K_a < 34.8$).

Our results showed that a sensor-specific calibration improved the accuracy of the calibration compared to a single “universal” calibration. The associated additional effort in calibrating each sensor individually is relaxed by a dedicated calibration setup that enables the calibration of large numbers of sensors in limited time while minimizing errors in the calibration process.

(70 pcs of SMT100 soil moisture sensors were used in the study)

A soil moisture monitoring network to characterize karstic recharge and evapotranspiration at five representative sites across the globe

Berthelin, R., Rinderer, M., Andreo, B., Baker, A., Kilian, D., Leonhardt, G., Lotz, A., Lichtenwoehrer, K., Mudarra, M., Padilla, I. Y., Pantoja Agreda, F., Rosolem, R., Vale, A., and Hartmann, A.: A soil moisture monitoring network to characterize karstic recharge and evapotranspiration at five representative sites across the globe, *Geosci. Instrum. Method. Data Syst.*, 9, 11–23, <https://doi.org/10.5194/gi-9-11-2020>, 2020.

EGU - Geoscientific Instrumentation, Methods and Data Systems

Abstract

Karst systems are characterized by a high subsurface heterogeneity, and their complex recharge processes are difficult to characterize. Experimental methods to study karst systems mostly focus on analyzing the entire aquifer. Despite their important role in recharging processes, the soil and epikarst receive limited attention, and the few available studies were performed at sites of similar latitudes. In this paper, we describe a new monitoring network that allows for the improvement of the understanding of soil and epikarst processes by including different karst systems with different land-cover types in different climate regions.

Here, we present preliminary data from the network and elaborate on their potential to answer research questions about the role of soil and epikarst on karstic water flow and storage. The network measures soil moisture at multiple points and depths to understand the partitioning of rainfall into infiltration, evapotranspiration, and groundwater recharge processes.

We installed soil moisture probes at five different climate regions: Puerto Rico (tropical), Spain (Mediterranean), the United Kingdom (humid oceanic), Germany (humid mountainous), and Australia (dry semi-arid).

At each of the five sites, we defined two 20 m×20 m plots with different land-use types (forest and grassland). At each plot, 15 soil moisture profiles were randomly selected, and probes at different depths from the topsoil to the epikarst (in total over 400 soil moisture probes) were installed. Covering the spatio-temporal variability of flow processes through a large number of profiles, our monitoring network will allow researchers to develop a new conceptual understanding of evapotranspiration and groundwater recharge processes in karst regions across different climate regions and land-use types, and this will provide the base for quantitative assessment with physically based modelling approaches in the future.

(400 pcs of SMT100 soil moisture sensors were used in the study)

A distributed soil moisture, temperature and infiltrometer dataset for permeable pavements and green spaces

Schaffitel, A., Schuetz, T., and Weiler, M.: A distributed soil moisture, temperature and infiltrometer dataset for permeable pavements and green spaces, *Earth Syst. Sci. Data*, 12, 501–517, <https://doi.org/10.5194/essd-12-501-2020>, 2020.

Earth System Science Data

Abstract

Knowledge of water and energy fluxes is key for urban planning and design. Nevertheless, hydrological data from urban environments are sparse, and, as a result, many processes are still poorly understood and thus inadequately represented within models.

We contribute to reducing this shortfall by providing a dataset that includes time series of soil moisture and soil temperature measured underneath 18 different permeable pavements (PPs) and 4 urban green spaces located within the city of Freiburg (Germany).

Time series were recorded with a high temporal resolution of 10 min using a total of 65 individual soil moisture sensors and covering a measurement period of 2 years (November 2016–October 2018).

The recorded time series contains valuable information on the soil hydrological behavior of PPs and demonstrates the effect of surface properties and surrounding urban structures on soil temperatures. In addition, we performed double-ring infiltration experiments, which in combination with the soil moisture measurements yielded soil hydrological parameters for the PPs, including porosity, field capacity, and infiltration capacity.

We present this unique dataset, which is a valuable source of information for studying urban water and energy cycles. We encourage its usage in various ways, for model calibration and validation purposes, study of thermal regimes of cities, and derivation of urban water and energy fluxes.

The dataset is freely available from the FreiDok plus data repository at <https://freidok.uni-freiburg.de/data/151573> and <https://doi.org/10.6094/UNIFR/151573> (Schaffitel et al., 2019).

(65 pcs of SMT100 soil moisture sensors were used in the study)

Using water stable isotopes to understand evaporation, moisture stress, and re-wetting in catchment forest and grassland soils of the summer drought of 2018

Kleine, L., Tetzlaff, D., Smith, A., Wang, H., and Soulsby, C.: Using water stable isotopes to understand evaporation, moisture stress, and re-wetting in catchment forest and grassland soils of the summer drought of 2018, *Hydrol. Earth Syst. Sci.*, 24, 3737–3752, <https://doi.org/10.5194/hess-24-3737-2020>, 2020.

EGU – Hydrology and Earth System Sciences

Abstract

In drought-sensitive lowland catchments, ecohydrological feedback to climatic anomalies can give valuable insights into ecosystem functioning in the context of alarming climate change projections.

However, the dynamic influences of vegetation on spatio-temporal processes in water cycling in the critical zone of catchments are not yet fully understood.

We used water stable isotopes to investigate the impacts of the 2018 drought on dominant soil–vegetation units of the mixed land use Demnitz Millcreek (DMC, north-eastern Germany) catchment (66 km²).

The isotope sampling was carried out in conjunction with hydroclimatic, soil, groundwater, and vegetation monitoring.

Drying soils, falling groundwater levels, cessation of streamflow, and reduced crop yields demonstrated the failure of catchment water storage to support “blue” (groundwater recharge and stream discharge) and “green” (evapotranspiration) water fluxes.

We further conducted monthly bulk soil water isotope sampling to assess the spatio-temporal dynamics of water soil storage under forest and grassland vegetation.

Forest soils were drier than grassland, mainly due to higher interception and transpiration losses. However, the forest soils also had more freely draining shallow layers and were dominated by rapid young (age <2 months) water fluxes after rainfall events.

The grassland soils were more retentive and dominated by older water (age >2 months), though the lack of deep percolation produced water ages >1 year under forest.

We found the displacement of any “drought signal” within the soil profile limited to the isotopic signatures and no displacement or “memory effect” in d-excess over the monthly time step, indicating rapid mixing of new rainfall.

Our findings suggest that contrasting soil–vegetation communities have distinct impacts on ecohydrological partitioning and water ages in the sub-surface.

Such insights will be invaluable for developing sustainable land management strategies appropriate to water availability and building resilience to climate change.

(72 pcs of SMT100 soil moisture sensors were used in the study)

A dense network of cosmic-ray neutron sensors for soil moisture observation in a highly instrumented pre-Alpine headwater catchment in Germany

Fersch, B., Francke, T., Heistermann, M., Schrön, M., Döpfer, V., Jakobi, J., Baroni, G., Blume, T., Bogena, H., Budach, C., Gränzig, T., Förster, M., Güntner, A., Hendricks Franssen, H.-J., Kasner, M., Köhli, M., Kleinschmit, B., Kunstmann, H., Patil, A., Rasche, D., Scheiffele, L., Schmidt, U., Szulc-Seyfried, S., Weimar, J., Zacharias, S., Zreda, M., Heber, B., Kiese, R., Mares, V., Mollenhauer, H., Völksch, I., and Oswald, S.: A dense network of cosmic-ray neutron sensors for soil moisture observation in a highly instrumented pre-Alpine headwater catchment in Germany, *Earth Syst. Sci. Data*, 12, 2289–2309, <https://doi.org/10.5194/essd-12-2289-2020>, 2020.

Earth System Science Data

Abstract

Monitoring soil moisture is still a challenge: it varies strongly in space and time and at various scales while conventional sensors typically suffer from small spatial support.

With a sensor footprint up to several hectares, cosmic-ray neutron sensing (CRNS) is a modern technology to address that challenge.

So far, the CRNS method has typically been applied with single sensors or in sparse national-scale networks. This study presents, for the first time, a dense network of 24 CRNS stations that covered, from May to July 2019, an area of just 1 km²: the pre-Alpine Rott headwater catchment in Southern Germany, which is characterized by strong soil moisture gradients in a heterogeneous landscape with forests and grasslands.

With substantially overlapping sensor footprints, this network was designed to study root-zone soil moisture dynamics at the catchment scale. The observations of the dense CRNS network were complemented by extensive measurements that allow users to study soil moisture variability at various spatial scales: roving (mobile) CRNS units, remotely sensed thermal images from unmanned aerial systems (UASs), permanent and temporary wireless sensor networks, profile probes, and comprehensive manual soil sampling.

Since neutron counts are also affected by hydrogen pools other than soil moisture, vegetation biomass was monitored in forest and grassland patches, as well as meteorological variables; discharge and groundwater tables were recorded to support hydrological modeling experiments.

As a result, we provide a unique and comprehensive data set to several research communities: to those who investigate the retrieval of soil moisture from cosmic-ray neutron sensing, to

those who study the variability of soil moisture at different spatiotemporal scales, and to those who intend to better understand the role of root-zone soil moisture dynamics in the context of catchment and groundwater hydrology, as well as land–atmosphere exchange processes.

The data set is available through the EUDAT Collaborative Data Infrastructure and is split into two subsets: <https://doi.org/10.23728/b2share.282675586fb94f44ab2fd09da0856883> (Fersch et al., 2020a) and <https://doi.org/10.23728/b2share.bd89f066c26a4507ad654e994153358b> (Fersch et al., 2020b).

(165 pcs of SMT100 soil moisture sensors were used in the study)

Does afforestation increase soil water buffering? A demonstrator study on soil moisture variability in the Alpine Geroldsbach catchment, Austria

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Journal of Hydrology

Abstract

This study employed an operational monitoring network to measure soil moisture and runoff behavior continuously in the Alpine catchment Geroldsbach-Götzens, Austria.

We hypothesize that afforestation can have a positive impact on soil water buffering.

To analyze the impact of soil properties and vegetation cover changes on soil water dynamics, four experimental plots were established on grassland and monitoring stations were installed in the forest. The rainfall test site is equipped with an automatic weather station to obtain meteorological observations, and weirs to measure surface runoff of natural occurring precipitation events and artificial rainfall simulations.

In the plots, 200 soil moisture sensors were installed at five different depths, aimed at tracking and visualizing infiltration and subsurface flow processes. Another twenty sensors monitored soil moisture at different afforestation stages in the forested part of the catchment.

The measurements show that soils covered with young and old-growth forests have a higher and more stable soil moisture content than grassland and soils with a lack of vegetation throughout the seasons.

We observed large spatial differences at plot scale, where the spatial variability of soil moisture increases with depth and is highest during convective precipitation. The initial conditions and rainfall characteristics play an important role in infiltration processes and soil water storage.

Our rainfall test site demonstrated the challenges of innovative monitoring techniques and that it offers opportunities for more experiments to gather evidence-based data as input for flood models.

Overall findings confirm the sponge effect of forest soils and indicate that afforestation as Nature-Based Solution reduces the temporal soil moisture variability, buffering soil water during precipitation events, which can be beneficial for runoff reduction in Alpine catchments.

(195 pcs of SMT100 soil moisture sensors were used in the study)