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Assessing the heterogeneity of soil hydraulic properties in stony soils by long term irrigation experiments performed on a highly instrumented lysimeter

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Stony vadose zones are notoriously underrepresented in respect to flow investigations and simulation studies in part due to their lack of suitability for agricultural purposes and the inherent difficulties for observations of water flow in such materials. Therefore, the effect of stones on vadose zone water flow, their influence on the governing processes and the resulting soil hydraulic heterogeneity remain largely unknown in the vadose zone and hydrological community.
We present the first results of investigations performed on an undisturbed stony lysimeter, approximately the estimated size of the required representative elementary volume. In a novel experimental setup the water flow within the lysimeter was observed by 6 one-dimensional observation arrays consisting of 4 tensiometers and 4 water content probes each. Seepage water fluxes are collected in a segmented bottom plate, which allows the quantification of the seepage fluxes underneath the individual arrays. Thus, water flow and the main driving processes in the $1m^3$ lysimeter were observed by 6 replicated one-dimensional observations of the state variables through the 1m deep soil profile and the according bottom flux.
Our results show, that a detailed observations of soil water pressure heads as well as water contents are necessary to understand water flow in stony soils. While soil water pressure heads shows a state depend degree of heterogeneity, heterogeneity of the measured soil water contents is even more expressed and independent of the system state. These high degrees of spatial heterogeneity in stony soils have a strong influence on the water flow behavior. Water flow within the lysimeter occurs mainly preferential and strongly channeled, which could only be revealed by the replicated measurements of the seepage fluxes. Moreover, the extend of the spatial heterogeneity in the seepage fluxes is more expressed than the heterogeneity of the state variables. Furthermore, the results show that the soil hydraulic behavior changes with time, which manifests in variant retention curves and water flow paths. Detailed analysis of the observations, reveal the complex water flow behavior in stony soils, which is affected by a combination of multiple processes, such as preferential flow, hysteresis and non-equilibrium. Thus, specialized measurement setups are required to resolve water flow in stony soils, allow further insights into the extend of soil hydraulic heterogeneity and its implication on the resulting water flow.