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Quantification of hydraulic non-equilibrium during infiltration

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Classical continuum models can be applied to describe infiltration processes in soils. However, these approaches loose their validity under rapidly changing conditions (e.g. heavy rain on relatively dry soil), when water content and water potential are not in equilibrium anymore. In the classical description of hydraulic functions water potential is a time-independent function of water content. In the case of hydraulic non-equilibrium, the water phase reorganizes itself from an unstable conformation to a stable one which is accompanied by the relaxation of the water potential.

In addition to multistep outflow experiments we use multi-flux-step experiments to explore non-equilibrium processes during infiltration and drainage. A soil core is irrigated under gravity-flow conditions with different but fixed fluxes following a controlled protocol. Soil matric potential is monitored at different positions in the sample during the experiment as well as the total water content of the sample.

The experiments showed strong, abrupt changes in water potential after the irrigation rate was lowered (increased) followed by a slow decrease (increase) of water potential until the steady-state condition was reached. This phenomenon showed a strong hysteresis within increasing and decreasing fluxes.

The current work presents an improved experimental setup where the trajectory of the system within the state space of water potential and water content during hydraulic non-equilibrium can be evaluated. This is possible over a large range of water contents. It gives a direct measurement of the unsaturated hydraulic conductivities, not only in equilibrium but also for the dynamic transition including hysteresis.