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Complementary development of geophysical and hydrological observation and modelling techniques advancing understanding of soil water processes in structured soils

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Non-uniform flow in soils is an imprint of non-equilibrium conditions and is known for a long time. In most cases, dye tracer experiments are used to exhibit the respective flow paths. However, the method does not resolve the processes leading to the observed stained pattern. Moreover, excavating and therefore destroying the site prohibits hypothesis testing under different states and forcing, thus preventing to study system evolution. Unfortunately, strategies based on monitoring soil moisture dynamics (e.g., point based soil moisture measurements) also fail to resolve such processes beyond the Darcy-scale.

While performing a series of irrigation experiments, we developed a time-lapse 3D ground-penetrating radar (GPR) monitoring approach to image soil water dynamics. Providing sufficient spatial and temporal resolution, GPR helps to observe non-uniform flow in-situ in a non-invasive manner. Although first approaches for quantifying soil dynamics show promising results the detailed interpretation of such GPR data remains a challenging task.

Moreover, we developed a Lagrangian model for event scale soil water dynamics. Through the treatment of water as particles two core innovations were possible: First, the interplay of advection in macropores and diffusive redistribution in the soil matrix was formulated in a thermodynamic and self-controlled manner based on film flow and soil water retention properties. Second, the pore water space was re-defined as an explicit distribution of capillaries avoiding the implicit assumption of well-mixed states.

We will present a numerical study combining both GPR and Lagrangian modelling. By calculating representative time-lapse GPR data based on non-uniform soil water distributions, we test and develop novel GPR interpretation approaches before applying them to field data. Complementary, the improved observation technique allows for advancing our understanding of the dynamics and controls of advective and diffusive soil water redistribution in structured and evolving soil systems.