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Infiltration and drainage in the unsaturated zone: comparison of numerical simulations to a monitored field experiment

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The unsaturated zone has a prominent role for groundwater resources, as it controls through flow and transport any mass exchange between atmosphere and groundwater. However, providing reliable predictions for the unsaturated zone is very demanding, as it is dominated by complex two-phase flow processes that produce high uncertainty with respect to the hydraulic properties. When modeling unsaturated flow, the typically unknown spatial distribution of hydraulic properties in the soil constitutes a primary source of uncertainty. Even if information on the exact distribution is known, additional uncertainty may stem from the non-uniqueness of the hydraulic properties, most profoundly expressed through hysteresis in the capillary pressure-saturation relationship, also known as water retention curve.

In this work, we present modeling considerations for predicting an infiltration and drainage event in the unsaturated zone during a field experiment. The experiment was performed by infiltrating brilliant-blue solution while monitoring the plume movement with ERT. After the completion of infiltration (and the consequent drainage), the upper 1 meter of the soil was excavated in slices to obtain the 3D distribution of water saturation and pressure. Numerical simulations are carried out with a two-phase flow model. The results illustrate possibilities and limitations of predicting such flow processes based on the experimental information available. We demonstrate the influence and significance of hysteresis by comparing experimental findings with model runs that explicitly consider wetting and drying conditions in the experiment.

Our approach allows us to identify key processes that have to be accounted for. In a feedback loop with the design of future experiments we aim at improving input specifications necessary for reliable predictive modeling of unsaturated flow.