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Laboratory experiments on solute transport in bimodal porous media under cyclic precipitation-evaporation boundary conditions

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Flow and solute transport in the shallow subsurface is strongly governed by atmospheric boundary conditions. Erratically varying infiltration and evaporation cycles lead to alternating upward and downward flow, as well as spatially and temporally varying water contents and associated hydraulic conductivity of the prevailing materials. Thus presenting a highly complicated, dynamic system.
Knowledge of subsurface solute transport processes is vital to assess e.g. the entry of, potentially hazardous, solutes to the groundwater and nutrient uptake by plant roots and can be gained in many ways. Besides field measurements and numerical simulations, physical laboratory experiments represent a way to establish process understanding and furthermore validate numerical schemes.

With the aim to gain a better understanding and to quantify solute transport in the unsaturated shallow subsurface under natural precipitation conditions in heterogeneous media, we conduct physical laboratory experiments in a 22 cm x 8 cm x 1 cm flow cell that is filled with two types of sand and apply cyclic infiltration-evaporation phases at the soil surface. Pressure at the bottom of the domain is kept constant. Following recent studies (Lehmann and Or, 2009; Bechtold et al., 2011a), heterogeneity is introduced by a sharp vertical interface between coarse and fine sand. Fluorescent tracers are used to i) qualitatively visualize transport paths within the domain and ii) quantify solute leaching at the bottom of the domain. Temporal and spatial variations in water content during the experiment are derived from x-ray radiographic images.
Monitored water contents between infiltration and evaporation considerably changed in the coarse sand while the fine sand remained saturated throughout the experiments. Lateral solute transport through the interface in both directions at different depths of the investigated soil columns were observed. This depended on the flow rate applied at the soil surface and significantly influenced solute leaching. Dynamic boundary conditions generally resulted in faster initial breakthrough and stronger tailing.

References:

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