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Enhanced preferential solute transport near the soil surface due to transient flow conditions

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To estimate mass inflow of, for example, pesticides into aquifers, a good understanding of the transport times through the unsaturated zone is crucial. The uppermost part, or the root zone, is the most important, as attenuation often happens mostly there. Flow and transport in soils often happens along preferential paths, which leads to fast transport of solutes downwards. Such preferential flow and transport processes are often modeled with double domain approaches. Breakthrough curves typically show an early breakthrough and a long tailing.

The influence of soil structure on the transport properties for transport with preferential flow have been discussed a lot. The flow field is usually assumed to be static according to net infiltration into the domain. Flow in the uppermost part of the soil, however, changes in reality with time due to changing conditions in the atmosphere (infiltration and evapotranspiration). Flow direction and flow paths can vary with time.

Based on numerical simulations we show that, depending on the dynamics of the rainfall and evapotranspiration patterns and the hydraulic properties of the soils, the transient flow conditions can lead to a strong increase of tailing of breakthrough curves. A criterion to quantify the onset of such behavior is discussed. We also discuss a suitable parameterization of a double domain transport model that is based on a static flow field with net infiltration rate and that takes the effects of the (not directly modelled) influence of the dynamic flow conditions into account. The enhanced tailing is due to redistribution of solutes between the two domains caused by the changing flow paths. We show the occurrence of such redistribution processes and the resulting enhanced tailing in a set of laboratory experiments carried out in artificial sand packings.