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Estimating soil hydraulic properties from soil moisture time series by inversion of a dual-permeability model

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Dual-permeability type models are widely used to simulate water fluxes and solute transport in structured soils. These models contain two spatially overlapping flow domains with different parameterizations or even entirely different conceptual descriptions of flow processes. They are usually able to capture preferential flow phenomena, but a large set of parameters is needed, which are very laborious to obtain or cannot be measured at all. Therefore, model inversions are often used to derive the necessary parameters. Although these require sufficient input data themselves, they can use measurements of state variables instead, which are often easier to obtain and can be monitored by automated measurement systems.

In this work we show a method to estimate soil hydraulic parameters from high frequency soil moisture time series data gathered at two different measurement depths by inversion of a simple one dimensional dual-permeability model. The model uses an advection equation based on the kinematic wave theory to describe the flow in the fracture domain and a Richards equation for the flow in the matrix domain. The soil moisture time series data were measured in mesocosms during sprinkling experiments.

The inversion consists of three consecutive steps: First, the parameters of the water retention function were assessed using vertical soil moisture profiles in hydraulic equilibrium. This was done using two different exponential retention functions and the Campbell function. Second, the soil sorptivity and diffusivity functions were estimated from Boltzmann-transformed soil moisture data, which allowed the calculation of the hydraulic conductivity function. Third, the parameters governing flow in the fracture domain were determined using the whole soil moisture time series.

The resulting retention functions were within the range of values predicted by pedotransfer functions apart from very dry conditions, where all retention functions predicted lower matrix potentials. The diffusivity function predicted values of a similar range as shown in other studies. Overall, the model was able to emulate soil moisture time series for low measurement depths, but deviated increasingly at larger depths. This indicates that some of the model parameters are not constant throughout the profile. However, overall seepage fluxes were still predicted correctly.

In the near future we will apply the inversion method to lower frequency soil moisture data from different sites to evaluate the model's ability to predict preferential flow seepage fluxes at the field scale.