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Beyond classical infiltration - using Stokes flow in a diverse landscape

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Preferential flow significantly affects the distribution of water and solutes in soil and many studies showed its relevance worldwide. Soil structure and biopores are central features causing preferential flow but in many infiltration and flow models these features are neglected. Dual porosity or permeability models try to overcome that by accounting for a fast flow domain but suffer from a lack of data. Additionally, interpretation of inversely obtained parameters of these models is questionable due to equifinality issues. We therefore explored the potential of a simple 1D Stokes flow infiltration model that simulates water flow as a dynamic water content wave. In this model gravity is the only dominant force that drives water flow against the viscous momentum dissipation, without assuming any pressure gradient. Because of the simulated film flow process, the two parameters of the model are related to the soil structure, but they also integrate over the matrix portion of flow.

We used a soil moisture dataset from the mesoscale Attert catchment in Luxembourg as a test case. The 4 years of time series stem from 126 soil profiles with different soil types, textures and land-use (forest and grassland). The soil moisture probes were installed in 10, 30 and 50 cm depth and measured at 5-minute temporal resolution. Nearly 7000 infiltration events could be extracted and were used to determine the parameters of the Stokes model by inverse calibration. Every infiltration event was treated separately to examine the capability of the model to capture the different infiltration conditions (season, dry-wet, etc.). Moreover, the parameters were analyzed with respect to measurable attributes such as texture, precipitation characteristics, initial soil water content and land-use. Furthermore, the obtained parameter sets were compared against measured patterns of preferential flow to estimate their relative importance for indicating the occurrence of preferential flow.