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# Determination of hydraulic properties of model soil column using combined magnetic resonance imaging and multi-step-outflow experiments

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Knowledge of the hydraulic properties is essential for all simulation studies and the prediction of water and solute flow in the vadose zone. In general, there is a wide range of measurement techniques available for the estimation of soil hydraulic parameters. Unfortunately, all known setups do not count for the heterogeneity which might be included in the observation sample. Soils contain large heterogeneities in terms of refilled earth worm borrows, root channels, and/or inclusions of different material.
In this study, we aim to accurately and reliably determine soil hydraulic properties of a strongly heterogeneous soil sample by combining a classical multi-step-outflow (MSO) experiment with magnetic resonance imaging (MRI). A laboratory MSO experiments was performed on a model coaxial sample filled with sand and sand-clay mixture. MRI images at 4.7T (200 MHz) were recorded during each pressure step, to provide information about the soil water distribution at specific locations within the soil sample, using a pure phase-encoding MRI sequence which ensured the desired linearity between signal amplitude and water content at different pressures, e.g. various water saturations. The recorded cumulative outflow and water content data were used as input parameters in the inversion. For the inversion the hydrological model HYDRUS-2D was coupled with a global-optimization algorithm, namely the shuffled complex evolution (SCE-UA) algorithm.
The results show conclusively that the combination of the two MRI and MSO methods leads to a unique estimation of the retention and hydraulic conductivity functions of two materials simultaneously. These results could have applications in understanding the hydraulic behavior of heterogeneous agricultural soils, clay or lignite imbedded soils, and forest-reclaimed mine soils.