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Combining ERT, NMR and matric potential measurements for characterizing the vadose zone

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We introduce a two-step approach for identifying layers in the vadose zone of soils and for characterizing their two-phase fluid transport properties in situ. For the first step, we apply borehole to surface Electrical Resistivity Tomography (b2s ERT) measurements to image the near surface range (up to two meters) with high resolution. In a second step, we carry out Nuclear Magnetic Resonance (NMR) and matric potential measurements in each layer identified in the first step. We jointly invert matric potential and NMR measurements at different waters saturations for pore size distribution. Subsequently, we utilize the latter for estimating the water retention curve as well as the effective water permeability.

The b2s ERT array has very small electrode spacings to achieve the required high resolution. For small-scale ERT, sensitivities and geometric factors are influenced by the size of the closely spaced electrodes, which we represent with the Complete Electrode Model (CEM). We explore the effect of the electrodes on sensitivity and resolution for a surface array and apply our findings to the b2s array. We show that small-scale b2s arrays outperform pure surface arrays by far in terms of model recovery of a layered subsurface. However, this requires 3D simulations and the consideration of the electrodes with their real geometry.

Based on the characterization of the layering with ERT we define target depths for NMR and matric potential measurements. We infer the pore size distribution of each layer by a joint inversion of NMR data at different saturations. The joint inversion approach is verified in a laboratory setup and we adapt the procedure for field measurements using a NMR slim-line borehole logging tool.