Upscaling soil hydraulic functions based on connectivity in heterogeneous porous media

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Abstract. Natural soils contain heterogeneities that are manifested at all scales of measurement of hydraulic properties. Soil samples are typically collected at a limited number of discrete locations within the field. The measured properties at these small scales are then used for averaging or upscaling to obtain effective properties in larger application scales. How different soils with varying characteristics are connected in space affects water flow and solute transport. Connectivity of different soil materials at small scale is critical to influence flow and transport properties at larger scale. This is especially very important for heterogeneous unsaturated soils where fine materials contain inclusion of coarser materials or vice versa, which may dramatically change effective hydraulic properties and time scale of drainage and wetting at the large scale system. We present a new methodology that uses individual soil water retention characteristics and connectivity to estimate the effective behavior of soil hydraulic functions in heterogeneous soils. Estimated effective water retention and relative permeability functions are used for numerical solution of two phase/single phase flow in upscaled soil. The new upscaling approach was validated with the previous experimental data collected during drainage of a simple heterogeneous soil that contains a block of coarse sand embedded in fine sand. We also tested the new approach with the numerical simulations conducted in more heterogeneous soils with hypothetical deterministic and random structures. The upscaled model successfully matched the results from both the laboratory and the numerical experiments in heterogeneous soils.

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