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Inverse modeling of dynamic non-equilibrium in water flow with an effective dual continuum approach

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The soil water retention curve is fundamental for characterizing and modeling water flow in the unsaturated zone. It is common practice to measure the water retention curve under equilibrium or steady-state flow conditions and then to use the estimated function to model processes at larger scales. However, evidence obtained from drainage experiments using dynamic methods suggests that more water is withheld in soil at a given pressure head than is the case in a static experiment corresponding to similar pressure heads. Several reasons to explain the observed discrepancies between retention curves estimated from transient and static experiments are proposed in the literature, e.g., entrapment of water, pore water blockage, entrapment of air, air-entry-value effects and dynamic contact angle effects. A simple non-equilibrium model is presented which considers two continua at the macroscopic scale: one continuum is described by the Richards equation and the second, associated with non-equilibrium water flow, is described by an extended Richards equation using the Ross and Smettem non-equilibrium approach. We can show that our observations can be described by neither of these models alone. Thus, we propose a superposition of these models with no water exchange between the domains. Effective pressure heads are obtained as weighed mean of the two independent pressure heads, whereas total water contens and fluxes are just the sum of the respective properties in the two domains. The proposed model is tested with experimental data obtained from multitep-outflow experiments by means of inverse modeling using flexible parameterizations which minimize parameterization error in the constitutive relationships. The analysis is performed for two different soils. The results show that the proposed model describes well dynamic non-equilibrium effects occurring in multistep-outflow experiments.