Unbiased simultaneous estimation of soil hydraulic properties and dynamic nonequilibrium parameters from transient outflow experiments

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Simulation of variably saturated water flow in soils requires accurate knowledge of soil hydraulic properties. Transient flow experiments like the multistep outflow and evaporation methods are now routinely applied to determine soil hydraulic parameters by inverse modelling. Recent experimental evidence suggests that the water content dynamics during such flow experiments is subject to dynamic non-equilibrium. The extent to which this affects the accuracy of determining the equilibrium soil hydraulic properties is still unknown. Conversely, any bias in the equilibrium soil hydraulic properties caused by an inappropriate parameterization must be expected to lead to biased estimates of the parameters describing the hydraulic non-equilibrium. We coupled a dual porosity non-equilibrium model which combines the Richards equation and the Ross and Smettem approach for non-equilibrium with a free-form inversion algorithm. The free-form method has been shown before to guarantee an unbiased estimation of soil hydraulic properties. The freeform non-equilibrium estimation method was applied to data from various multistep outflow experiments. The results confirm that errors in the parameterization of the soil hydraulic properties cause biased estimates of non-equilibrium parameters. Such bias can be minimized or even eliminated with the free-form approach.