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Determination of soil hydraulic properties by coupled inversion of laboratory nuclear magnetic resonance.

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Simulation of unsaturated flow and transport by solving Richards' equation requires information defining water content with respect to pressure head. The soil moisture retention curve is approximated by relations like the van Genuchten equation. However, laboratory measurements required to estimate the parameters for retention curve equations are time consuming, tedious, and expensive. Nuclear magnetic resonance, NMR, has been demonstrated as an alternative for quick and reliable measurements of pore size distribution.
In NMR, the hydrogen atoms are energized and the relaxation to their initial energy level is measured. For an individual pore this relaxation is exponential, defined by a decay constant, T. In a soil sample the cumulative response is a weighted sum, based on the pore size distribution, of the response of the individual pores. The pore size distribution is estimated from NMR data by solving a poorly constrained inverse problem that requires regularization to make it tractable. Estimation of the pore size distribution can be sensitive to the choice of the regularization parameter. Combined with the Young-Laplace equation for capillary rise in a cylindrical tube, the NMR derived pore size distribution provides an estimate of the retention curve. Retention curve equation parameters are then estimated by fitting these data to the retention curve model.
Here we present an alternative approach to estimating the parameters in the soil moisture retention curve from NMR measurements using coupled hydrogeophysical inversion. In this approach the soil physics model (soil moisture retention curve to pore size distribution) is coupled with a forward model of the NMR relaxation to enable a prediction of NMR signal from the soil moisture release curve. This coupled forward model is used with DREAM, an MCMC parameter estimation algorithm, to estimate retention curve parameters and the associated certainty in the parameter estimates. Using the coupled approach removes the necessity of regularization in the independent inversion for relaxation decay constant distribution since the distribution of the relaxation decay constant is now controlled by the possible shapes of the soil moisture release curve rather than by regularization. Using both synthetic and laboratory data, we compare the results achieved using both approaches to estimating the parameters in the soil moisture retention curve model.