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Model Structure Identification through Joint Inversion of Hydrological and Geophysical Data

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Subsurface flow and contaminant transport processes are critically affected by the structure and heterogeneity of the subsurface as well as the related distribution of soil moisture. While geophysical methods (such as GPR) may provide high-resolution images of the subsurface, the relation between these images and parameters affecting flow and transport remains ambiguous. On the other hand, while hydrological data contain information about properties relevant to flow and transport, their spatial coverage and resolution are usually insufficient. To combine the strengths of both characterization methods, a joint geophysical-hydrological inversion approach was developed by coupling (a) an unsaturated flow simulator, (b) a forward model for calculating GPR travel times, and (c) a geostatistical simulation package, and linking them with nonlinear optimization methods. The approach is examined for a ponded infiltration test, in which time-lapse multiple-offset cross-borehole GPR travel times and hydrological data (flow rates and water content measurements) are used to estimate (a) soil hydraulic parameters that govern unsaturated flow, (b) petrophyscial parameters that relate the dielectric constant to water content, and (c) geostatistical parameters that characterize the soil structure. Focusing on the estimation of geostatistical measures (such as correlation length, anisotropy, and its orientation), we examine viable parameterizations of the highly variable (but structured) subsurface, evaluate model bias as well as estimation and prediction uncertainties, and discuss the advantages and limitations of joint inversion techniques for the characterization of soil properties and fluid distribution in the vadose zone. This work was supported in part by the U.S. Dept. of Energy under Contract No. DE-AC03-76SF00098.