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Estimating field-scale soil hydraulic properties and petrophysical models through joint GPR/hydrological measurement inversion

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As ground-penetrating radar (GPR) travel times are highly sensitive to transient and non-uniform water distributions, they are potentially quite useful for inferring soil hydraulic parameters. In this research, multiple-offset cross-borehole GPR travel times are used jointly with additional hydrological measurements to estimate field-scale soil hydraulic parameters through inversion. Our approach allows for estimation of 1) the soil hydraulic parameters, 2) the parameters describing the petrophysical model (the constitutive model relating the dielectric constant to the porosity and water saturation), and 3) spatial correlation model parameters of the permeability field. A synthetic example involving the point injection of water and the simultaneous collection of nearby borehole neutron probe and GPR measurements is first considered to examine the impact of inaccurate petrophysical models on the estimation of soil hydraulic parameters. Errors can be introduced when applying a petrophysical model to a situation with conditions different from those for which the model was derived (e.g., when non-site-specific or laboratory-scale petrophysical models are applied to field-scale measurements). Our synthetic study suggests that small errors in the petrophysical model parameters cause substantial errors in the soil hydraulic parameter estimates. However, we show that these errors may be overcome through joint estimation of the petrophysical model parameters and the soil hydraulic parameters. Finally, the approach is applied to a GPR-neutron probe data set collected at the Hanford DOE site in Washington, allowing us to draw conclusions regarding the strengths and weaknesses of the approach in a real-world, 3-D setting. This work was supported in part by the U.S. Dept. of Energy under Contract No. DE-AC03-76SF00098.