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Combining full-wave surface GPR Green's function inversion with hydrodynamic modeling to monitor the shallow water dynamics and estimate the soil hydraulic properties: possibilities and limitations.

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Knowledge of the spatial distribution and dynamics of the shallow subsurface water content and hydraulic properties at a scale being relevant for the understanding and management of the soil-plant-atmosphere system is essential in many agricultural and environmental engineering applications. In that respect, ground penetrating radar (GPR) constitutes a tool with great potential. Recently, Lambot et al. proposed a new promising approach for identifying the soil hydrogeophysical properties using GPR. Relying on a conceptual GPR model, the method is based on full-wave inversion of the GPR signal in the frequency domain for an off-ground monostatic antenna configuration. The approach has been successfully validated in laboratory conditions for identifying both the dielectric permittivity and electric conductivity of a two-layered sandy soil subject to a range of water contents, to identify a continuous water content profile in controlled outdoor conditions using hydrostatic concepts, to monitor the dynamics of water in a sand column and subsequently derive the soil hydraulic properties using hydrodynamic inverse modeling, to investigate the frequency dependence of the soil dielectric permittivity and electric conductivity, and to map surface soil moisture.

In this study, we investigate the theoretical and practical possibilities and limitations of combining electromagnetic and hydrodynamic inverse modeling to monitor the shallow water dynamics and estimate the soil hydraulic properties using off-ground GPR. The hydraulic properties are obtained by minimizing the difference between the measured and modeled GPR Green's function. The synthetic electromagnetic profiles are generated using soil specific petrophysical relationships and the hydrodynamic model

subject to a set of hydraulic parameters. Numerical experiments were performed to investigate the uniqueness of the inverse solution and the related optimization issues. Then a laboratory infiltration experiment was conducted in a sand box in order to examine the stability of the inverse solution with respect to radar modeling errors, the uncertainty in the petrophysical relationships, the inherent variability of the soil hydraulic properties, and the uncertainty on the initial and boundary conditions in the hydrodynamic model.