Geophysical Research Abstracts,
Vol. 11, EGU2009-2677, 2009
EGU General Assembly 2009

Unsaturated soil hydraulic characterization using Full-Waveform Hydrogeophysical Inversion of Time-Lapse, GPR Data

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Geophysical methods are increasingly being used to provide quantitative information of subsurface distributions and hydrological properties. Traditionally, the geophysical data are inverted first, and the obtained information is subsequently used to calibrate the hydrological model. This ill-posed sequential inversion ignores the potential constraints that are provided by available hydrological information (e.g., mass balance, shape of wetting front, etc.). Additionally, artifacts of the geophysical data inversion (e.g., due to lack of sensitivity, high measurement and modeling errors, etc.) will be directly translated in errors of the hydrological model calibration.

In this study, we explore an alternative method by resorting to integrated hydrogeophysical inversion of time-lapse, proximal ground penetrating radar (GPR) data to remotely estimate unsaturated soil hydraulic properties of a laboratory sand during four infiltration events. Hydrodynamic modeling was based on a one-dimensional solution of Richard's equation and was solved numerically using HYDRUS-1D code. The radar model involves a full-waveform solution of Maxwell's equations for wave propagation in three-dimensional multilayered media. Petrophysical relationships have been used to link radar and hydrological state variables. In total, 16 GPR observations were made with uneven time steps, to catch most of the observed water dynamics. Results were compared with TDR measurements and ground truth measurements. GPR-based predictions capture major features of TDR and better agree with visual observations. Finally, we tested the approach in real field conditions for a single profile and traditional reference methods were used for comparison. The results suggest that the proposed method is promising for characterizing the shallow subsurface hydraulic properties at the field scale with a high spatial resolution.