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Determination of unsaturated soil hydraulic properties through integrated hydrogeophysical inversion of time-lapse proximal GPR data

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Measurement of the soil hydraulic properties at the field scale remains a challenge in different research and engineering areas such as precision agriculture, near surface hydrology or remediation. In our study, we investigated the applicability of integrated electromagnetic and hydrodynamic inversion of time-lapse proximal ground penetrating radar (GPR) data to determine the soil hydraulic properties at the field. The one-dimensional (1-D) Richard's equation is used to physically constrain full-waveform radar data inversion and reconstruct continuous vertical water content profiles. As a result, the solution space is reduced and inherent non-uniqueness issues may be completely or partially resolved in the inverse problem. The uniqueness of the inverse solution is analyzed using numerical experiments for different textured soils and infiltration events. The stability of the inverse solution with respect to errors in fixed key hydraulic and petrophysical parameters is quantified. Finally, the approach is tested in controlled laboratory conditions for a transient infiltration event in a homogeneous sandy soil. The proposed approach appears to be promising for characterizing the shallow subsurface hydraulic properties at the field scale with a high spatial resolution.