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Monitoring infiltration with time-lapse relative gravity: An option for non-invasive determination of soil hydraulic parameters?

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Various hydrogeophysical methods have been proposed to monitor infiltration and determine soil hydraulic parameters using coupled hydrogeophysical inversion. Methods include electrical resistivity tomography (ERT), ground penetrating radar (GPR, both surface and cross-hole) as well as passive microwave radiometry. Depending on the measurement set-up, both ERT and GPR can provide high-resolution images of soil water content. However, soil water content monitoring with both ERT and GPR depends on the validity and accuracy of empirical relationships linking soil water content to electrical resistivity (ERT) and dielectric permittivity (GPR). This has emerged as one of the main limitations for the performance of soil water monitoring with both GPR and ERT.

As an alternative, ground-based time-lapse relative gravity (TLRG) is proposed for infiltration monitoring. The method is based on the fact that water content changes in the subsurface constitute changes in subsurface density and can be monitored as changes in the gravitational field. The advantage of TLRG over GPR and ERT is that TLRG directly senses mass changes. Thus, no empirical relationship is required to link water content changes to changes in a geophysical property. This study evaluates the performance of TLRG for infiltration monitoring and hydrogeophysical inversion of soil hydraulic parameters. Results include both synthetic infiltration experiments and a real-world infiltration experiment monitored with TLRG. In the synthetic experiments, soil water content profiles are generated using analytical infiltration solutions. Soil water content profiles are translated into gravity signals and are corrupted with random noise to produce synthetic data. The synthetic data is subsequently used in a hydrogeophysical inversion of soil hydraulic parameters. Fitted parameter confidence intervals and covariances are evaluated. The same inversion procedure is used on the real-world data.

The results show that TLRG data contains information that constrains soil hydraulic parameters. However, useful signal-to-noise ratios require large amounts of infiltration. TLRG sensing of infiltration is thus limited to deep soil profiles and long-duration infiltration events.