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Comparison of soil hydraulic parameters estimated from time-lapse GPR data under natural loading and forced infiltration conditions

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Geophysical methods can provide valuable information on vadose zone hydrological properties and reduce uncertainties in the estimation of the van Genuchten-Mualem (VGM) parameters, which provide a comprehensive description of the soil water retention characteristics. In particular, time lapse crosshole GPR measurements allow for the monitoring of water content changes in the subsurface during infiltration, which can be used to effectively estimate the pertinent hydraulic parameters when combined with a process-based model. Infiltration can be monitored under natural or forced loading conditions. Under natural loading, a number of studies have found the estimation of the VGM parameters to be difficult because changes in moisture content over time can be quite small. Specifically, multiple measurements over time have been found to provide only limited additional constraints on the estimated hydraulic parameters. A forced infiltration test can help to overcome this issue by producing large variations in subsurface water content. However, this type of experiment may disturb the original medium and hence may result in errors related to the forced, artificial conditions. Here, our goal is to compare the results of inverting time-lapse GPR data collected under natural loading conditions with those collected during a forced infiltration experiment. Recent research has shown that stochastic inverse methods can be an effective means of accounting for the inherent non-linearity and non-uniqueness in coupled hydrogeophysical parameter estimation problems. Therefore, we perform our inversion within a Bayesian framework and use a Markov chain Monte Carlo (McMC) strategy to estimate the posterior distributions of model parameters. With this methodology, parameter uncertainties can be obtained and parameter distributions can be compared between the two experiment types. Using a synthetic example, we first examine a five-layer case and invert for the VGM parameters for each layer. We then apply our inversion approach to data from a field experiment conducted near Arrenaes in eastern Denmark. Our initial results, which are largely based on evidence from the synthetic study, indicate that the saturated hydraulic conductivity tends to be better resolved under forced infiltration than under natural loading conditions.