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Retrieving water content dynamics and complex subsurface structures from multi-offset GPR measurements

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We present a new approach for analyzing GPR data that is intermediate between ray tracing and full-waveform inversion. It relies on the accurate numerical (forward) simulation of the radar measurements using a regularized model of the subsurface. There, layer interfaces and the dielectric permittivity are represented by interpolating splines. By automatic detection of the groundwave and of reflections in the measured and modeled data, travel-time and amplitude information is retrieved. This information is used to inversely estimate the parameters which are the optimal interpolation values of the splines.
We demonstrate our approach by analyzing two multi-offset surface GPR datasets, a single line in a multi-layer soil (Oftersheim, Germany) and time-series of a dune-deposit soil (Fengqiu, China).
The first dataset was recorded at a sandy soil site with two horizontal interfaces which are diagonally crossed by a third one originating from ancient dunes. The analysis retrieves the position of these interfaces as well as the water content distribution in-between.
The second dataset consists of a multi-offset time-series. One prominent reflection was used to determine the position of the corresponding interface and the water content distribution above. All points in time were analyzed in a combined inversion assuming a static interface position but a dynamic water content distribution.