Geophysical Research Abstracts, Vol. 8, 04314, 2006
SRef-ID: 1607-7962/gra/EGU06-A-04314

Taking correlated data errors into account during inversion of cross-borehole GPR data

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Cross-borehole GPR data are used in integrated geophysical-hydrogeological studies of the water content of the upper ˜10 m of the unsaturated zone in sandy environments in the Danish area. Tomographic algorithms are used for estimating the radar wave velocities between the boreholes. The boreholes used for the tomographic analysis are typically placed 3.5-4 m apart, and they are ˜10 m deep. During data collection a transmitter antenna is lowered into one borehole while a receiver antenna is lowered into the other borehole. The cross section between the boreholes is covered by crossing ray paths of the GPR signals determined by the selected source-receiver geometries. In our studies we have selected transmitter and receiver position intervals of 0.25 m down the boreholes. From each transmitter position GPR signals are radiated to all receiver positions. The tomographic algorithm we use for inverting the picked first arrival travel times relies on a standard straight-ray approximation. Numerous sources of correlated data errors exist: 1) Incorrect positioning of the receiver and/or the transmitter antenna during data acquisition; 2) unknown cavities around the borehole walls; 3) unknown anomalies close to the borehole walls; 4) unknown time jumps due to mis-calibration of the transmitted pulse; 5) accidental picking of undesired refracted arrivals which have not followed the straight ray path between the source and the receiver. If not accounted for, such data errors may give rise to significant artefacts in the tomographic velocity image obtained during the inversion process. We analyse and quantify selected correlated errors likely to contaminate typical cross-borehole GPR data sets. The correlated data errors are accounted for by specification of data error covariance matrices which are included in the inverse operator used for obtaining the velocity distribution from the picked travel times. We show that accounting for the correlated data errors results in more optimal inverse estimates and more realistic model resolution estimates.