Geophysical Research Abstracts,
Vol. 10, EGU2008-A-01370, 2008
SRef-ID: 1607-7962/gra/EGU2008-A-01370
EGU General Assembly 2008

Influence of correlated data errors on the resolution of ground penetration radar cross-borehole tomograms

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Ground penetrating radar (GPR) cross-borehole data are increasingly being used to obtain tomographic images of the moisture content of the unsaturated zone. The images are achieved by inverting the first arrival travel-times of the transmitted radar signals. In this way a radar signal velocity distribution of the subsurface is obtained, which is subsequently transformed into moisture content using empirical relationships. GPR cross-borehole data are contaminated by several sources of data errors which highly influence the quality of the inverse estimates. Previous studies have shown that many of these data errors are likely to be spatially correlated. We demonstrate that small-scale anomalies near the antennae positions constitute likely sources of correlated data errors.

The resolution matrix reveals to what extent the inverse estimate recovers the true subsurface. Traditionally, the inverse estimates are obtained by assuming that only uncorrelated data errors are present in the data. Increasing the amplitude of the expected uncorrelated data errors decreases the resolution of the inverse estimates and, consequently, the tomographic images become smeared.

We demonstrate that the resolution is only negligibly decreased if the magnitude of correlated data errors is increased. Furthermore, we demonstrate how: 1) artefacts are introduced in the inverse estimate when the correlated data errors are not accounted for

during the inversion; 2) both the adverse effects and the subsurface features of interest are smeared when the correlated data errors are assumed to be uncorrelated; 3) when the correlated data errors are taken into account the resolution is improved and, at the same time, the adverse effects are effectively suppressed; 4) an overestimation of the amplitude of the correlated data errors does not have a negative influence on the inverse estimate; and 5) the inverse estimate is basically not affected by taking correlated data errors into account when these are not present in the data.

We demonstrate the significance of our findings by taking correlated data errors into account and investigating model resolution properties using a field dataset.