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Time-lapse inversion of ERT monitoring data using variogram-based regularization

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Hydrogeophysics has become a major field of research in the past two decades and time-lapse electrical resistivity tomography (ERT) is one of the most popular techniques to monitor passive and active processes in subsurface reservoirs. Time-lapse inversion schemes have been developed to refine inversion results; but, in contrast with static inversion, they mostly still rely on the spatial regularization procedure based on the standard smoothness constraint. In this contribution, we propose to apply a variogram-based regularization operator in the time-lapse ERT inverse problem, using the model difference covariance matrix to replace the standard smoothing operator. The variogram of resistivity variations can be computed through independent borehole data, such as electromagnetic logs or hydrogeological monitoring, which is often available during monitoring experiments.

We first illustrate the method for surface ERT with a synthetic case and compare the results with the standard smoothness constraint solution. This example shows that the variogram-based constraint images better the assumed anomaly both in terms of shape and amplitude. The improvement is largely higher than the one obtained with more classical anisotropic smoothness constraint. This synthetic example also shows that an error made in the range of the variogram has a limited impact on the resulting image, which still remains better than the smoothness constraint result. Anomalies located in various part of the tomograms were tested. Although more crucial in low-sensitivity zones, improvements are observed everywhere in the tomograms.

The method is then applied to cross-borehole ERT field data from a heat tracing experiment, where the comparison with direct temperature measurements shows a strong improvement of the breakthrough curves retrieved from ERT. Using the variogram-based regularization, it is possible to reduce the smoothing of resistivity variations in low sensitivity zones and therefore to avoid overestimation of temperatures. The proposed method could be extended to the time dimension which would allow the use of variogram-based constraints in 4D inversion schemes.