Inversion of multi-temporal geoelectrical field data sets: insights on noise characterization and regularization

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Inversion of geoelectrical time-lapse data sets is increasingly growing as monitoring systems are being used in more applications such as seawater intrusion, landslides, remediation of contaminated sites, landfill operation, shallow geothermal systems, or management of water resources. To date, several inversion strategies exist for taking into account the temporal dimension of the data. The most used nowadays are the independent inversion of multi-temporal data sets, the difference inversion, the temporally-constrained inversion, and the more recent process-based inversion. However, difference inversion schemes generally assume that part of the noise contained in the data cancels out when working with temporal data differences. Temporally-constrained inversion on the other hand assumes that the changes are localized and minor. Process-based inversion requires a more advanced knowledge of the system prior the inversion.

In this study we demonstrate that the resolution of the time-lapse inversion scheme is mostly dependent on the quantification of the temporal behavior of the data error, on the resolution of the model-dependent pattern of the survey, and not on the regularization strategy. Our study is based on the imaging results of different data sets with different time and spatial scales, and with different degrees of geological complexity and resistivity contrast, The considered sites are a shallow sandy aquifer and a fractured hard rock aquifer where tracer experiments were performed and monitored using surface arrays. The two studied transport processes are advection, with velocities on the order of 10 m/hour and slower advection/diffusion processes. The strongest improvements were brought by using the data difference and a quantitative estimation of the data error. We found in particular a dependence of the time-lapse data error to the measured resistance (i.e., signal-to-noise-ratio), permitting to formulate an error model to describe the data error present in time-lapse data sets. We used minimum gradient support regularization to invert for model changes with enhanced contrast and found this technique more suited to time-lapse studies than for static images. Noise characterization and error models appear therefore as essential and the most impacting for a successful inversion both for static and time-lapse data whereas different spatio-temporal regularization techniques allowed to decrease artefacts but needs to be coherent with the process.