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Regularized focusing inversion of time-lapse electrical resistivity data: an approach to parametrize the minimum gradient support functional

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Inversion of time-lapse resistivity data allows obtaining ‘snapshots’ of changes occurring in monitored systems for applications such as aquifer storage, geothermal heat exchange, site remediation or tracer tests. Based on these snapshots, one can infer qualitative information on the location and morphology of changes occurring in the subsurface but also quantitative estimates on the degree of changes in certain property such as temperature or total dissolved solid content. Analysis of these changes can provide direct insight into flow and transport and associated processes and controlling parameters. However, the reliability of the analysis is dependent on survey geometry, measurement schemes, data error, and regularization. Survey design parameters may be optimized prior to the monitoring survey. Regularization, on the other hand, may be chosen depending on available information collected during the monitoring. Common approaches consider smoothing model changes both in space and time but it is often needed to obtain a sharp temporal anomaly, for example in fractured aquifers.

We here propose to use the alternative regularization approach based on minimum gradient support (MGS) (Zhdanov, 2002) for time-lapse surveys which will focus the changes in tomograms snapshots. MGS will limit the occurrences of changes in electrical resistivity but will also restrict the variations of these changes inside the different zones. A commonly encountered difficulty by practitioners in this type of regularization is the choice of an additional parameter, the so-called β, required to define the MGS functional. To the best of our knowledge, there is no commonly accepted or standard methodology to optimize the MGS parameter β. The inversion algorithm used in this study is CRTomo (Kemna 2000). It uses a Gauss-Newton scheme to iteratively minimize an objective function which consists of a data misfit functional and a model constraint functional. A univariate line search is performed at each Gauss-Newton iteration step to find the optimum value of the regularization parameter λ which minimizes the data misfit as a function of λ while the data misfit is above the desired value and yields the desired target misfit (root-mean square value of error-weighted data misfit equal to 1) at the last iterations for a maximum value of λ. We propose here to optimize the β of the MGS functional by considering a univariate line search at the first iteration to find the β that minimizes the data misfit. The parameter is then kept constant during the Gauss-Newton iterative scheme. In this contribution, we validate our approach on a numerical benchmark and apply it successfully on a case study in the context of salt tracers in fractured aquifers.

Zhdanov M.S. 2002. Geophysical Inverse Theory and Regularization Problems. Elsevier, Amsterdam, 628 p.

Kemna A. 2000. Tomographic Inversion of Complex Resistivity - Theory and Application. PhD Thesis, Ruhr University Bochum.