Use of a priori Regularization in Tomographic Inversion and its implications

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Abstract

Tomographic inversion remains a vital technique for estimating velocity models in the seismic imaging process. However, due to the ill-posed nature of the problem, obtaining a unique and stable solution for parameter estimation can be challenging. In this study, we employed a tomographic algorithm with regularization to estimate velocity models using a two-dimensional synthetic experiment with deep sources received on a surface. Several rank deficiency problems were tested, and the forward modeling was performed using the Eikonal Equation to estimate the travel times. The inversion was performed using an iterative updating algorithm with Least Squares and Single Value Decomposition (SVD) solutions. We employed various regularization methods to obtain the final velocity model, including Levenberg-Marquadt, SVD with zeroth-order regularization, and different orders of a priori model-based regularization. We conducted test analyses, interchanging the initial and a priori models, to compute different solutions and facilitate a robust comparison. We estimated the covariance and resolution model matrices for each test and utilized them to evaluate the final solution. Preliminary results demonstrated a strong sensitivity to the choice of the initial model and the selected regularization approach. When the initial model significantly deviated from the expected geometrical velocity, the solutions yielded numerous errors. However, aligning the initial model with a feasible geological velocity framework helped achieve improved solutions. The regularization methods produced similar results across different tests when referencing the a priori model as the initial model, although they did lead to some enhancements in outcomes. Furthermore, incorporating the original model as a priori information suggested improvements in the final solution. Nevertheless, it is essential to note that selecting a high value for the regularization parameter may reduce the significance of data fitting. Based on the conducted tests, the findings thus far are promising, indicating that incorporating additional geological knowledge as prior information through regularization can enhance the coherence and accuracy of the inversion estimation.