On preconditioning multiparameter FWI imaging for simultaneous velocity and reflectivity estimation

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Abstract

FWI imaging aims to produce high-resolution images and accurate velocity models of the subsurface. One straightforward approach involves deriving a reflectivity image as the normal derivative of the high-resolution velocity model obtained from FWI and scaling it with a density proxy to approximate subsurface reflectivity. More sophisticated approaches use formulations based on reparameterized wave equations, performing a multiparameter inversion for velocity and reflectivity. At least two formulations for this problem, one using velocity and the normalized rate of impedance change and the other using velocity and the logarithm of mass density, have shown impressive results when applied to field data. We show through numerical experiments that propagation velocity and the logarithm of mass density are particularly robust for implementing FWI imaging. However, as a multiparameter inversion, a critical aspect of its successful implementation is preconditioning the gradient of the objective function relative to the model parameters. Preconditioning accelerates convergence, reduces crosstalk among parameters, and compensates for the decline of inversion results with depth. We investigate the performance of FWI imaging using synthetic data computed with the Marmousi2 model for velocity and density. This model is challenging for FWI imaging, and existing approaches often struggle to achieve convergence and to recover vector-reflectivity that is well correlated structurally with the correct model. To address these challenges, we propose new preconditioners for the simultaneous inversion of velocity and vector reflectivity, which improves the convergence of L-BFGS iterations and provides a better reconstruction of velocity and vector-reflectivity models.