Robust time-domain full waveform inversion

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Abstract

Full waveform inversion (FWI) is a method capable of estimating subsurface physical property models with high resolution. The classical formulation of this method consists of a least-squares problem that is iteratively solved using local optimization algorithms. However, the success of FWI is highly dependent on the quality of the initial velocity model and the presence of low-frequency content in the data. In addition, the use of the least-squares misfit function makes the inversion highly sensitive to amplitude discrepancies between the observed and calculated data, which represents a difficulty when implementing the method on real seismic data. Given these limitations, this work aims to investigate strategies that can improve the robustness of acoustic full-waveform inversion. We investigated the use of second-order optimization algorithms, which accounts for the Hessian within the inversion. Additionally, we investigated the adaptive waveform inversion (AWI) method. This approach uses Wiener filters as a misfit measure between data, unlike the conventional least-squares criterion. Our study shows that second-order algorithms are capable of estimating models with higher accuracy, compared to the other two algorithms tested that only require gradient calculation, namely, steepest descent and L-BFGS. Regarding AWI, we presented a broad discussion on its implementation aspects, including using the regularization by model reparameterization. The results demonstrated the robustness of AWI in relation to inaccurate initial models and the absence of frequency components below 3 Hz. Finally, we propose a robust inversion workflow that sequentially combines adaptive waveform inversion and least-squares inversion. The results obtained demonstrated the effectiveness of this sequential strategy and its superior performance compared to the individual use of AWI.