Random objective surface-wave waveform inversion

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The full-waveform inversion (FWI) of surface waves, including both Rayleigh and Love waves, is becoming increasingly popular for near-surface characterizations. Due to the high nonlinearity of the objective function and a huge amount of data, FWI may converge towards a local minimum and is usually computationally expensive. To overcome these problems, we reformulate FWI under a multi-objective framework and propose a random objective waveform inversion (ROWI) method for surface-wave characterization. We use three objective functions: the classical least-squares ($l_2$) waveform difference, the envelope difference, and the difference in the FK spectra. At each iteration, we randomly choose one shot and randomly assign one of the three objective functions to this shot. We only update the model with one iteration using a preconditioned steepest descent algorithm to optimize the currently assigned objective function. Therefore, ROWI has high freedom in exploring the model and objective spaces.

We use a synthetic example to compare the performance of ROWI with conventional FWI approaches. ROWI converges to better result compared to the conventional FWI approaches, while some of the conventional FWI approaches are trapped at local minima and fail to reconstruct reasonable results. We also apply ROWI to a field data acquired in Rheinstetten, Germany. The main geological feature, a refilled trench, is successfully reconstructed in the ROWI result. The reliability of the ROWI result is also proven by a migrated GPR profile. Overall, both synthetic and field-data examples show that ROWI is computationally more efficient, less dependent on the initial model, and more robust compared to conventional FWI approaches.