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Automatic Velocity Model Building Using Waveform Inversion and Least Squares Reverse Time Migration

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ABSTRACT

Full waveform inversion (FWI) is a promising technique for estimating earth parameters such as velocity and impedance by using an optimization method. In spite of considerable improvements to objective functions and preconditioning methods in FWI, there remains the critical limitation that the lack of low frequency components in most seismic data hinder FWI from being used without a good starting model. Therefore, generating a good macro (long-wavelength) velocity model is essential to successfully employ FWI. Least Squares Reverse Time Migration (LSRTM) is a technique used for obtaining high resolution broadband seismic images and so provides a significant uplift in quantitative seismic interpretation. In addition, the LSRTM can be used to update the velocity model during iterations because the velocity perturbation is the function of the reflectivity model. Therefore, to overcome the starting model limitation in FWI, we propose a three-step velocity building procedure by using seismic envelope inversion, FWI with a global correlation norm and LSRTM. Seismic inversion using envelopes of seismograms is chosen to build the long-wavelength structure of the velocity model because envelopes of seismic traces minimize the issue of cycle skipping when matching computed versus observed waveforms. We compute the envelopes of signals by using a Hilbert transform of the data to emphasize the low frequency information in the event moveouts. Another advantage of using envelopes in seismic inversion is that it is less sensitive to white Gaussian noise and seismic interference. To construct the mid-wavelength velocity model, we perform FWI with the model obtained from the seismic envelope inversion as a starting model. We use a global correlation norm as an objective function instead of a more conventional L2-norm. Many papers have demonstrated that using global correlation leads to better inversion results than conventional approaches because the correlation norm tends to make the solution converge to the global minimum. Finally, we update the velocity model by using the reflectivity model obtained from a scaled LSRTM image. Updating velocities via LSRTM usually shows higher fidelity structures, especially in steeply dipping fault zones, than the conventional FWI inverted model. We test the validity of our proposed procedure on 2D synthetic and real marine seismic datasets.