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Full waveform inversion for subsurface exploration using vertical cable seismic data
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Subsurface exploration for natural resources is mainly conducted by surface seismic experiments which use receiver arrays on the surface to record the propagated energy from seismic sources and produce an image of the earth after processing. Sources and receivers could be placed on the ground, i.e. land acquisition, or towed in the sea by a vessel, i.e. marine acquisition, in order to cover the desired area of the imaging. This requires appropriate data acquisition geometry and optimized data processing flows for reliable subsurface images. However, when the target is a small area in the marine environment with certain obstacles like platforms or buoys, in the deep sea conditions, or in the geologically complex areas the surface seismic exploration fails to deliver a high resolution image either because of the restrictions in the data acquisition or inefficiency of the data processing algorithms. Instead, a Vertical Cable Seismic (VCS) experiment provides a high resolution image for the investigation of the natural resources below sea floor. In the VCS configuration vertical arrays of hydrophones are deployed near the sea floor and are kept in the vertical situation by using an anchor in the bottom and a buoy at the top of the cable. Seismic source is towed by the vessel and the data is recorded for every shot point, then processing and Pre-Stack Depth Migration (PSDM) of the data yields an image of the structures. However, a good PSDM section is achieved only if accurate wave velocity model is available for the migration. Full Waveform Inversion (FWI) of the seismic data is a reliable tool to reconstruct the subsurface properties by using pre-stack recorded data. We use full waveform inversion of the acoustic data recorded by a VCS simulated experiment to develop P wave velocity model.

In the FWI workflow acoustic wave equation is solved using 2D finite difference method to produce waveforms using an initial model. Then, misfit between recorded and simulated waveforms is minimized via a local optimization algorithm, e.g. preconditioned conjugate gradient, to update the model. This process is iterated until a convergence criteria is satisfied or the maximum number of FWI iterations is reached. Because of the nonlinearity of the problem, a good initial model which is close enough to the exact solution is necessary. For the simulated experiment, we considered a marine environment with water depth of 900 m and lateral extension of 5000 m. We used four vertical cables located near the sea floor in the middle of the model area. Each vertical cable has 8 hydrophones spaced every 10 m and the deepest hydrophone is 10 m above the sea floor. Seismic sources are located 10 m beneath sea level and 500 shots at every 10 m are used for the VCS experiment. VCS experiment showed reliable results to prove that it is very useful for high resolution imaging of a small area in the subsurface, which is not practically resolvable by using surface seismic experiments.

キーワード: full waveform inversion, vertical cable seismic, acoustic
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