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Imaging the shallow subsurface with surface waves: dispersion curve analysis versus full waveform inversion

Carlos Andrés Pérez Solano (1), Daniela Donno (1), Claudio Strobbia (2), and Hervé Chauris (1)
(1) MINES ParisTech, France, (2) Total, France

Seismic surface wave analysis is a standard tool in geotechnical engineering for imaging the shallow subsurface. Most current surface wave analysis methods assume a horizontally layered medium, and estimate the near-surface shear velocity profile from dispersion curves, which are picked on frequency-wavenumber (f-k) gathers and then inverted using 1D modelling approaches. Media containing high velocity contrasts and irregular lateral variations might be difficult to be handled with the local 1D approximation.

For 2D model estimation, full waveform inversion (FWI) is an alternative and can estimate high resolution models. The classical FWI objective function consists of the least-squares misfit between observed and modelled shot gathers (Tarantola, 1986). Classical FWI needs an accurate initial model for achieving convergence. Data sets containing surface waves could be inverted, without falling into secondary minima, if the data contains sufficiently low frequencies and large offsets such that multi-scale and time windowing approaches can be applied.

We propose to invert surface waves with an alternative FWI-based approach that uses a modified objective function. It is based on the least-squares misfit between the absolute value of the f-k transform of windowed shot gathers. We refer to this approach as the windowed-Amplitude Waveform Inversion (w-AWI). Some secondary minima problems are mitigated: the choice of an initial model is easier in w-AWI than in FWI. The alternative objective function is intermediary between the one used in the 1D inversion approach (dispersion curves) and classical FWI. As most of the phase information is neglected in w-AWI, we use it as a first step before classical FWI. This sequential inversion approach using w-AWI followed by classical FWI aims at estimating a high-resolution near-surface velocity model, by explaining the complete elastic wavefield, even when the initial velocity model is far from the exact one.

The proposed approach is tested on a synthetic model with high velocity contrasts. Comparison with classical 1D inversion methods is also provided. In the observed data, late arrivals are associated to back-scattered waves, which have been shown to be useful information for near-surface imaging (Campman and Riyanti, 2007). We define an inversion strategy tailored to better exploit the information of scattered surface waves. We invert first the more energetic direct arrivals, and then the complete dataset. By using this approach, we can assess the contribution of scattered waves to the estimation of a highly contrasted velocity model.