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3-D Surface-wave estimation and separation using an iterative closed-loop approach

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ABSTRACT

Surface waves in seismic data are often dominant and mask primaries in land or shallow-water environments. Separating them from the primaries is of great importance either for removing them as noise for reservoir imaging and characterization, or for considering them as signal for near-surface characterization. However, their complex properties, such as dispersion, multi-modality and spatial variability, make the surface-wave separation significantly challenging in processing. To address the challenges, we introduced a method of 3-D surface-wave estimation and separation using an iterative closed-loop approach.

The closed loop contains a relatively simple forward model of surface waves and adaptive subtraction of the forward- modelled surface waves from the observed surface waves, making it possible to evaluate the residual between them. In this approach, the surface-wave model is parameterized by the frequency-dependent slowness and source properties for each surface-wave mode. The optimal model parameters are estimated in an iterative way such that the residual is minimized and, consequently, the approach solves the inverse problem.

We applied this method to several data sets to demonstrate its virtues, such as real 3D geophone/hydrophone seismic data onshore/offshore Abu Dhabi where ground-roll/mud-roll is significantly dominant in land/shallow-water environments. Through the examples, we observed that the method successfully estimates and separates out the surface waves from the seismic data to consequently obtain the subsurface signals. The method provides a better result than a conventional slowness/velocity-based filtering method which cannot handle both surface waves and subsurface signals overlapping each other. We also observed its wide range of applicability to under-sampled, asymmetrically sampled, irregularly sampled and blended seismic data. This suggests the possibility of relaxing requirements for seismic survey parameters in terms of surface-wave separation and, therefore, offers flexibility as well as potential effort reduction with respect to seismic surveys. It should be noted that recent advances in acquisition, such as point receivers and a large amount of stations, make the method more effective because of the improved spatial sampling of surface waves without negative array effects.