Near Surface Characterization of Middle East Land Data by Elastic Full-Waveform Inversion of Surface Waves

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Abstract

Introduction and motivations
Seismic imaging is particularly difficult in the Middle East where lateral and vertical near surface heterogeneities generate complex wave propagation phenomena. Accurately characterizing the near surface is crucial in this region. Unlike the traditional approach that treats the surface-wave train as coherent noise to be removed, we propose to use it for creating a detailed shear-wave velocity (Vs) model of the shallow subsurface by inverting it with elastic full-waveform inversion (FWI).

Elastic FWI of surface waves: the methodology
Conventional methods for characterizing the near surface, such as surface wave inversion, rely on picking of dispersion curves, which can be cumbersome and lack lateral resolution. Elastic FWI offers several advantages over these conventional methods, such as the full-wavefield modeling and no requirement for picking. Moreover, since the surface wave propagation depends almost exclusively on Vs, it provides a favorable context for elastic FWI, which is often hampered by the coupling between elastic parameters.

As the penetration depth of surface waves depends upon the shear-wave wavelength, the inversion of surface waves from active data typically limits Vs model updates to a few hundred meters only. We employ virtual ultra- low frequency surface waves obtained by interferometry using continuous recording (Le Meur et al., 2020). It permits to start elastic FWI at 0.5 Hz and to capture the background Vs velocity model down to a few kilometers' depth.

Application to real data and results
The proposed method is applied on a survey from the south of the Sultanate of Oman, where strong surface waves mask the body waves usually used for velocity model building. Our approach involves starting the elastic FWI workflow with a very smooth initial Vs velocity model and inverting virtual data from 0.5 to 2 Hz. The updated model provides the background velocity down to 2 km and serves as input for elastic FWI of active surface waves. Elastic FWI up to 7 Hz helps to improve the lateral and vertical resolution of the shallow part of the Vs model. The final Vs model correlates well with amplitude variations visible on migrated data and matches with near-surface geological features.

Furthermore, we have integrated the first 500 m of the inverted Vs model into a conventional Vp velocity model building workflow for the near surface characterization. The migrated images reveal that the shallow velocity variations retrieved by elastic FWI help flatten the shallow reflections and simplify the geological structures.

Conclusions

Elastic FWI of the surface waves enables a detailed shallow Vs model without relying on dispersion-curve picking. The very energetic surface waves observed in the region require minimal pre-processing, allowing the model building flow to start shortly after deblending. Our approach benefits from the ultra-low frequencies recovered by interferometry to get a deeper update. We demonstrate the effectiveness of this workflow to enhance the imaging of the shallow subsurface. The inverted Vs model could be used for shallow hazard and geotechnical studies or as starting point for subsequent Vp update by elastic FWI.

Acknowledgements: We are grateful to Shell and the Ministry of Energy and Minerals of the Sultanate of Oman for permission to publish this work.