WS6-C02

Near-surface Modelling from Surface and Guided Waves and Its Applications

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SUMMARY

Surface and guided waves are effective sources of information for near-surface characterization. They constitute a large part of the recorded energy and, with proper acquisition, analysis, and inversion, can be used to model the near surface with surprisingly high resolution. In this role, they can be used for correcting short- to long-wavelength perturbations, building velocity models, and optimizing coherent noise-filtering workflows.

Introduction

In the context of seismic exploration, the near-surface is often considered the shallow part of the subsurface whose properties can distort or degrade the observed response of deeper targets. It can be generally described as a layered waveguide in which the upper boundary is the free surface and the lower boundary is the bottom of the weathering layer. A large part of the wavefield recorded in surface seismic consists of energy trapped in this waveguide, which manifests itself in the form of surface and guided waves.

Method

Surface and guided waves found in land data and shallow marine environments, whether recorded by ocean-bottom cable (OBC), ocean-bottom nodes (OBN), or towed streamers, consist of several modes of Rayleigh waves (Scholte waves in shallow-water environments), Lamb waves (when strong velocity inversions are present), Love waves (on horizontal components when properly excited), Stoneley waves (which typically propagate along a solid-fluid interface, and, more rarely, a solid-solid interface), and guided P- and S-waves. In many cases, some of these modes may be simultaneously present and are superimposed on each other. All of these dispersive modes can be analysed together to build a reliable near-surface velocity model according to the following workflow:

- obtaining a high-resolution spatial distribution of the modes' properties
- modelling the near surface from the propagation properties of different type of surface and guided waves.

Surface waves methods are widely used for building near-surface velocity models and are under continuous and rapid evolution for exploration seismology applications (Strobbia *et al.* 2011); however, using guided waves is not yet considered common practice. The presence of guided waves with significant P-wave sensitivity can be exploited for a complete elastic characterization using a multimode surface-wave inversion (Boiero *et al*., 2013a).

Examples

In Figure 1a, an S-wave velocity section (28–35-m depth) is shown. This has been obtained inverting a superposition of different ground-roll modes (Rayleigh, Lamb, and S-guided). In this specific case, the S-wave velocity model has been calibrated using up-hole information about the P-wave velocity and subsequently used for computing static corrections (Boiero et al, 2013b). Figure 1b shows an example of velocity model obtained from shallow towed-streamer data. The depth slice illustrates the use of guided P-waves to characterize lateral variations in the shallow sediments.

Discussion

The inferred high-resolution P- and S-wave near-surface velocity models can be used in seismic exploration for different applications. The first one concerns the calculation of short- to long-wavelength perturbation corrections (Zarkhidze *et al.*, 2013). Surface-wave inversion is of particular interest in the presence of complex near-surface conditions such as velocity inversions (Boiero *et al.*, 2013b). In these cases, refraction methods fail, and up-holes, while providing point-wise measurements, are difficult to collect and are expensive, especially in presence of karst, which can cause circulation loss. Additionally, surface- and guided-wave inversion has the ability to enhance conventional shallow velocity model building (Ernst, 2013), depth imaging, and full-waveform inversion (FWI) efficiency and results. The assumptions that typically underpin current acoustic FWI methods are generally not justified in the elastic near-surface environment, and surface-wave inversion may provide shallow velocity models that can be incorporated into the FWI initial model.

Near-surface properties can also be used to design and optimize the coherent noise-filtering workflow and can be used for local adaptive filters (Strobbia *et al.*, 2011). Model-based direct and scattered noise generation can be used to predict the coherent noise, even beyond aliasing (Yanchak *et al.*, 2013). Finally, interpreting the inversion results can provide a robust geological, structural, and lithological model of the near surface (Zarkhidze *et al.*, 2013) from which geotechnical parameters and drilling hazards may be identified.

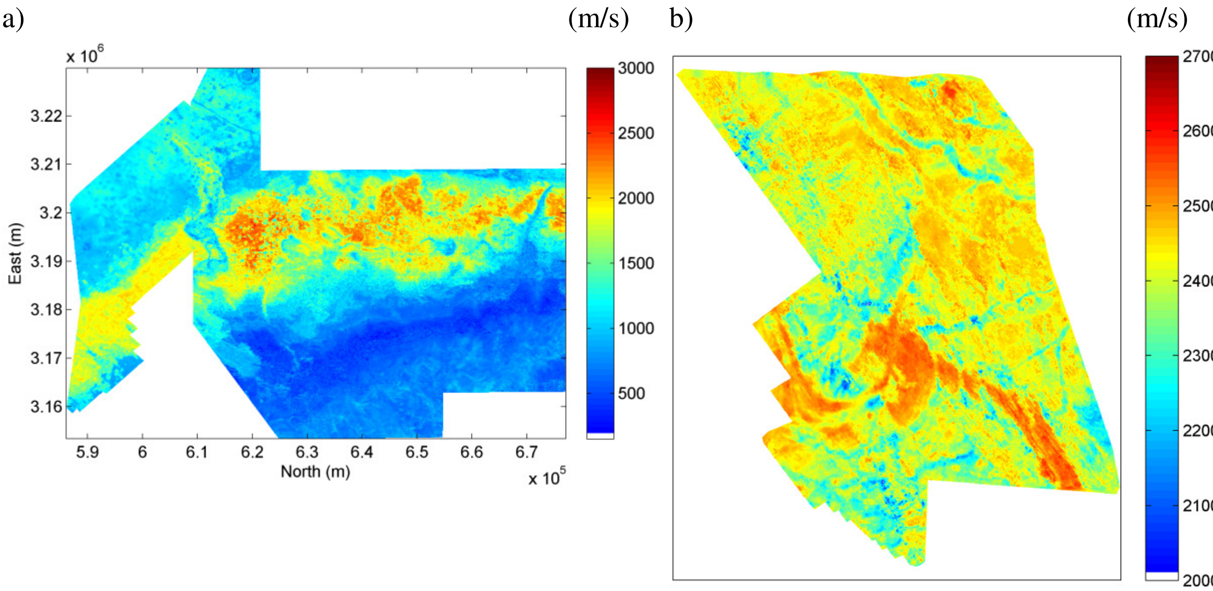

Figure 1 *a) S-wave velocity at 28–35 m of depth (Boiero* et al.*, 2013b); b) P-wave velocity at 40 m of depth below seabed.*

Acknowledgments

The authors would like to thank Schlumberger for permission to publish this work.

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