Wireless nodal seismic for high-resolution subsurface characterization using FWI

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ABSTRACT

High-resolution 3D seismic surveys present one of the best opportunities for investigating the near surface. High-resolution and low-cost 3D seismic acquisition is enabled by single-sensor nodal technology that utilizes wireless communication. Single-sensor land seismic applications, however, are difficult because of signal distortions introduced by the weathering layer and the low signal-to-noise (S/N) of the single sensor data. Such characteristics of single sensor seismic require special software development.

INTRODUCTION

The newly developed platform, called iNeS (intelligent near surface) is able to automatically correct the near surface distortions and enhance the data by generating high S/N signal beams through digital group forming. The resulting seismic gathers are called "virtual super gathers" (VSG). iNeS technology accelerates the operations of data analysis and interpretation via inversion.

Seismic data acquisition was performed with wireless nodes using a nitrogen-powered hammer source. The developed seismic workflow for geohazard analysis relies on a dense sampling of the propagated seismic wavefield as obtained from narrow-spaced seismic nodes and shot points (SP). A carpet layout is adopted in which the whole area of interest is occupied by equally spaced nodes by interleaved and staggered SP positions. Each receiver of the mesh is active 24 hours during the acquisition, so active source signal and passive noise recordings are obtained for the same survey. SP configurations follow a similar pattern with a spacing of 2.5 x 5m. The carpet acquisition layout proves to be more efficient compared to a roll-along configuration that uses fewer nodes.

METHODS

We describe the main characteristics of the developed approach (Colombo et al., 2021). The method consists of a transmission-based surface-consistent data preconditioning scheme, that is applied to individual traces, a S/N enhancement step through the definition of VSGs, and of a 1.5D Laplace-Fourier FWI in the acoustic approximation that takes advantage of the enhanced S/N provided by the CMP-reconstructed VSG. The 1.5D FWI scheme is designed to obtain a fast, accurate and robust velocity modeling of the near surface for direct application to depth imaging processes or as a robust starting model for successive 3D and multiparameter FWI.

RESULTS and CONCLUSIONS

LF-FWI was performed through a multiscale approach progressing from lower to higher frequencies and damping parameters. The following frequencies were used: 10 Hz 5 s-1, 15 Hz 5 s-1, 20 Hz 5 s-1, 25 Hz 10 s-1, 30 Hz 10 s-1, in an offset range from 100 m to 300 m. The nodal dataset does not contain lower frequencies and this made the application of FWI challenging. Nevertheless, the multiscale approach through increasing frequencies and the use of damping from the first arrival times enabled to invert up to 30 Hz frequency (Figure 1). This represents an industry first for the ultra-dense nodal acquisition and for the model depth scale resolution.

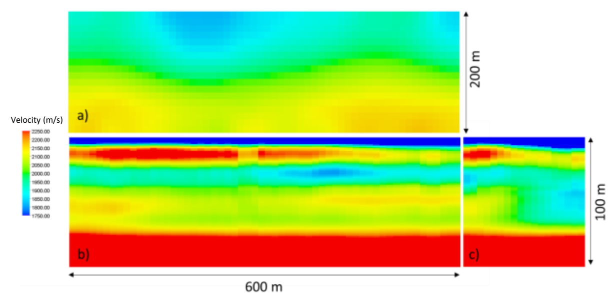

Figure 1. FWI inversion velocity model: a) 50m depth section, b) W-E central cross section, and c) S-N central cross section