Geophysical Research Abstracts
Vol. 14, EGU2012-2707, 2012
EGU General Assembly 2012

Three-dimensional seismic full waveform inversion of ocean bottom cable data from the Valhall oil field

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In the past few years, the ability to reconstruct accurate 3D velocity models by full waveform inversion (FWI) has been shown by the academic research and the oil industry. In this study, we present a massively parallel algorithm for 3D seismic FWI together with an application to the ocean bottom cable (OBC) data from the Valhall oil field (North Sea).

To achieve a computational efficiency and a flexible algorithm, we design a process, which can combine various forward modelling engines (such as finite-difference or finite-element methods) in time or frequency domains and an inversion core formulated in the frequency domain. Our algorithm relies on two key features: (1) the parametrizations of the subsurface for the seismic modeling and the inversion are uncoupled, that allows to interface different modeling engines with the inversion, and to consider target-oriented imaging. (2) Two nested levels of parallelism, by source distribution and domain decomposition, are implemented for the optimization of the performances of the scheme with respect to the computational platform, the dimensions of the model and the acquisition geometry.

We present an application of our algorithm to OBC data recorded in the Valhall oil field. A total of 49 954 air-gun sources and 2 302 receivers located at the sea-floor (70 m depth) are used in this seismic experiment. The dimensions of the inverted target are 9.6 x 16.6 x 4.8 km. For the forward modelling, we adopt a finite-difference method in time to solve the acoustic wave equation, and monochromatic solutions are extracted from time signals. For the inversion, three overlapping groups of frequencies, [3.5 – 4], [4 – 5] and [5 - 7] Hz, respectively, are inverted successively to build a P-wave velocity model from the hydrophone component. The algorithm is performed on a IBM Blue Gene computer, by combining source distribution and domain decomposition over several hundreds of processors. The final FWI model exhibits remarkable structures, which are consistent with previous studies: paleo-channels below the sea-floor, low velocity and fractured zones in depths, probably related to accumulation of gas, and deep reflectors below the reservoir level. Comparison between the inverted model and a well log of vertical velocity possibly reveals the footprint of the anisotropy.