Exploring the Differences between Parallel and Joint Inversions in 4D FWI and 4D LSRTM

André Bulcão*, Angelo Correa Almeida, Bruno Pereira Dias, Cristhian Alberto Celestino Cortez, Djalma Manoel Soares Filho, Filipe Augusto de Souto Borges, Gustavo Catão Alves, Pablo Machado Barros, Roberto de Melo Dias, Tiago Illipronti Girardi, Petrobras

Abstract

Seismic reservoir monitoring is an essential tool during the life span of an oil reserve. The introduction of 4D seismic technologies were a technological leap ahead of classic 3D seismic surveys, as it incorporated changes over time in the processing workflow. In 4D seismic, changes in the subsurface are tracked over time between different seismic acquisitions, base and monitor, with the aim of monitoring alterations resulting mainly from production activities. This results in improvements in the economic value of reservoirs through the optimization of production costs and reservoir management. In addition, 4D seismic can reveal property changes within oil reservoirs and surrounding areas, generate property volumes that vary over time, assist in the identification of faults, fractures and/or regions of greater permeability of reservoirs, and even monitor Water Alternating Gas (WAG) injection to improve the recovery factor.

Several schemes have been developed over the years to tackle 4D seismic inversion. Among the inversion methodologies for 4D seismic, parallel inversion schemes are those in which inversion is applied independently to base and monitor surveys, while joint inversion schemes are those in which a single inversion process involves seismic datasets from both surveys, base and monitor, and uses a single objective function. In both cases, after the end of the inversion process, warping is performed between inverted models (base and monitor), followed by the calculation of the actual 4D difference.

In this work, we compare the traditional parallel approach with joint inversion schemes, in which a single objective function considers seismic data from base and monitor surveys, in addition to the inclusion of regularization terms for each of the data sets, and an extra regularization term that considers the coupling between inverted property models. We highlight the advantages of the joint approach, which enable better focusing of 4D anomalies in regions of interest.

We compare 4D inversions based on the linear inversion method called Least Squares Reverse Time Migration (LSRTM), where the inversion parameters are the reflectivity models for each survey, as well as the traditional Full Waveform Inversion (FWI), a non-linear inversion scheme aimed at recovering the compression velocity (P velocity). Synthetical examples are presented in a simple property model called Camembert, based on Peter Mora`s work (1986), followed by another 2D synthetic model based on Mero field geological features.