Research project

4D imaging using time-domain full waveform inversion application to Valhall 4C OBC and Sleipner field data


Frame: The SEISCOPE consortium (https://seiscope2.osug.fr/) aims at developing and applying high resolution seismic inversion technique relying on the full waveform. For the past few years, high resolution estimations of primary (P-wave velocity) and secondary (density, attenuation) subsurface mechanical parameters have been reconstructed from 4C OBC (4 components Ocean Bottom Cables) data acquired in the North Sea on the Valhall field (Operto et al., 2015; Operto and Miniussi, 2018; Kamath et al., 2018, 2019a,b), aside other application scales from the near-surface to regional scales.

In 2017, AKER BP, one of the sponsors of the SEISCOPE project, has made available to us two releases of data acquired using the same 4C OBC system and similar acquisition campaigns, the first in 2003, the second in 2011. This makes possible to investigate time-lapse FWI on 3D field data, capitalizing on earlier methodological developments performed in the frame of SEISCOPE during a former PhD project, focused entirely on 2D data (Asnaashari, 2013; Asnaashari et al., 2015).

In parallel, a research collaboration is being built with SINTEF in Norway, in order to work on 4D monitoring of the SLEIPNER field, a CO2 storage site, for which data will be made available to us.

Project:
The PhD project will be related to the application of our 3D time-domain FWI code TOYxCDAC_TIME in this 4D context, using these two field datasets. Several questions will first need to be addressed.

- Most importantly, the determination of the best 4D strategy for real data including noise repeatability: double difference (Asnaashari et al., 2015) or model difference (Maharramov et al., 2016). This will be the starting point of the project. This will be assessed first on 2D synthetic models.

- Stability of multi-parameter reconstructions: P-wave velocity, density, attenuation. How preconditioning and second-order optimization strategies can help to mitigate potential trade-offs in this frame (Métivier et al., 2017; Kamath et al., 2018)? This question will also be assessed first on 2D synthetic examples.

- Efficient implementation using source decimation via random selection or encoding: the number of sources, even after applying reciprocity, reaches more than 2000 on the Valhall data, which implies significant computational cost. It is thus mandatory to reduce this cost through either encoding or decimation to consider application on the 3D field data. The best strategy will need to be assessed.
Based on these three questions, the application on the 3D field data will be conducted. Exchanges with AKER BP, which exploits the Valhall field, and SINTEF, which has strong experience on 4D monitoring on Sleipner data with more conventional techniques, will make possible to control the quality of the result, on top of standard data-based quality controls and potentially image-based quality controls.

Additional topics could be investigated, depending on the PhD progress:

- Extraction of 4D attributes in the data thanks to the optimal transport based techniques.
- Importance of the inversion of the 4C data to stabilize the 4D reconstruction: what brings 4C data compared to inverting only for hydrophone data?
- Uncertainty quantification based on Ensemble Kalman filter strategies or Hessian probing: we have developed tools to quantify the uncertainty in the frame of FWI based on Ensemble Kalman Filter (Thurin et al., 2019). Applications on 2D synthetic examples in the frame of 4D FWI could be considered.
- Toward downscaling strategies to recover micro-scale parameters 4D changes: the multi-parameter reconstruction can be seen as a first step toward recovering micro-scale parameters such as the porosity of the reservoir. Linking the 4D changes of the macro-parameters to the micro scale parameters could be very interesting.

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Collaborations: This PhD project will be performed in strong collaboration with different actors of the SEISCOPE project (R. Brossier, L. Mérivier, A. Görszczyk, J. Cao, A. Pladys, P. Yong), as well as researchers in Aker BP and SINTEF working on these datasets.

Competences: Computational seismology: wave propagation modeling and inversion. Good mathematical and geophysical background. Willingness to be involved in numerical developments and high performance computing usage.
References


