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Feasibility of crustal-scale imaging from 3D OBS data by Full Waveform Inversion. Phase I: building a 3D synthetic model of a subduction zone and wavefield modelling

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In order to improve our understanding of the geodynamical processes that shape the crust in various environments there is an urgent need to improve our ability to build 3D seismic models of the deep crust with a spatial resolution close to the wavelength with a leading-edge seismic acquisition and imaging techniques. However, designing 3D OBS surveys for high-resolution crustal-scale velocity model-building is not so common due to the costs of acquisition. In academia, coarse 3D OBS surveys are conducted to perform traveltime tomography, while only 2D acquisitions are increasingly designed for high-resolution velocity model building utilizing FWI. Therefore, this work is a part of the project which aims to fill this gap, through the development of the new generation of 3D OBS surveys suitable for FWI.

The first question we need to answer is related to the OBS spacing that is acceptable to perform reliable FWI up to a maximum frequency ranging between 8Hz and 15Hz considering that the number of available instruments will be necessarily limited. The second question is related to the computational cost of the FWI when performed at the crustal scale. We need to assess the feasibility of 3D FWI of OBS data to image crustal targets with a maximum depth about 30km and which cover a surface of the order of few thousands of kilometers. The underlying problems are: Which computational resources do we need? Which numerical strategies in terms of parallelism, I/O, data management should be implemented to minimize the computational resources? Which wave physics can be considered?

To answer these questions, the first step is to build a 3D realistic marine crustal model amenable to benchmark different acquisition geometries and imaging techniques suitable for deep crustal imaging. Here we present such a model that has been inspired by the geology of the Nankai subduction zone, as well as the previous results of geophysical investigations of this area. The model contains different geological settings from variations of bathymetry and complex folds in accretionary prism, through the alternations of sediments, low velocity zones, oceanic ridges, faults and thrusts, layered oceanic crust and heterogeneous mantle. The size of the 3D cube is 30km x 150km x 100km with 25m grid size. We demonstrate the procedure that has been used to cast 2D section consisting of 39 geological units, into 3D structure. We use dependencies and relationships between velocity, attenuation and density parameters to derive multi-parameter model amenable for visco-elastic wavefield modeling and inversion. Additionally we include stochastic components in the structural units such that they produce realistic wave propagation.

We perform preliminary acoustic and elastic modelling in a 120km x 20km x 25km target of the crustal model to investigate the anatomy of the wavefield and, what is more important, to estimate the computational resources necessary to generate visco-acoustic and visco-elastic multi-component datasets amenable to assessment of different imaging techniques such as traveltime and slope tomography, FWI and migration.