Application of full-waveform inversion to crustal-scale velocity model building in complex subduction zone setting: Eastern Nankai Trough, Japan

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Since decades wide-angle reflection/refraction (WARR) surveys and ray-based methods remain typical tools for crustal-scale velocity model building. However they ability to resolve complex structures is limited by factors such as receiver spacing, width of the Fresnel zone or interpreter's ability to distinguish and associate the crustal phases with the crustal interfaces. With the developments both in terms of modelling/inversion methodology represented by full-waveform inversion (FWI), as well as the ability to deploy dense arrays of receivers on land or availability of sufficient number of ocean-bottom seismometer (OBS) nodes, it is now possible to automate the process of high-resolution crustal-scale velocity model building.

Here we demonstrate how to build such a model using FWI applied to a 2D OBS dataset from the Eastern Nankai Through involving 100 OBS uniformly deployed along a 100-km long profile recording air-gun shots extended along 140-km long profile with a 100 m spacing. We develop practical workflow including: (i) preprocessing focused on the improvement of the coherency and boost of the low frequencies; (ii) thorough and early-stage QC starting from the analysis of the traveltime error in the initial model; (iii) final model validation procedures using source estimation, evaluation of the data fitting with Dynamic Image Warping, correlation with PSDM image and the interpretation of crustal phases by the ray-tracing. As a result we obtain velocity model of the complex subduction zone with clearly delineated shallow and deep structures. In particular in the Backstop we observe large-scale stacked thrust sheets of Shimanto Wedge covered by sediments of Forearc Basin. These structures spatially extend to the area of Miocene Wedge in Accretionary Prism forming Kodaiba and Tokai Thrusts. Further into seaward direction we can point sequence of smaller thrusts delineating Active Wedge covered by Slope Basins and the thick layers of sediments in the trench. We observe local thickening of the oceanic crust corresponding to the subducting oceanic ridges as well as a sharp LVZ atop the oceanic crust which represent a damage fault zone created by one of these ridges colliding with the Backstop. The top of LVZ correspond to a splay fault along which the co-seismic slip can occur during the next large earthquake in the area. Our study indicates great potential of the FWI as a semi-automatic method for better imaging of complex crustal targets being beyond the reach of the conventional WARR or towed-streamer surveys.