Target oriented seismic tomography: Toward higher-resolution images of subduction zones

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From the classic ray-based traveltime tomography to the state-of-the-art full waveform inversion, because of the ill-posedness of the inverse problem, regularization techniques are always used to get stable but approximated solutions. If the data sampling or the starting model is not good enough, regularization schemes can migrate anomalies of our interests partially away from their correct places and also suppress their amplitudes.
In Japan islands, earthquakes mainly occurred in the upper crust and the subduction zone, and seismic stations are all very close to the surface, resulting that the recorded seismic data do not have a full spherical coverage over the interested subsurface structures. Meanwhile, the crust is sampled by much more regional data than the subduction zone is. The regularized algorithm may "ignore" the less sampled subduction zone. Many experiences tell that the expected high-velocity subducting slabs sometimes do not show up if the starting model is not close enough to the "real" model. It is not surprising that subduction zone images are manly obtained by using teleseismic data. However, low frequency teleseismic data have relatively low resolving ability. To get high-resolution images, we still need to rely on regional data. As discussed, the spatial distribution of regional seismic data requires us to carefully design seismic tomography algorithms.
In this study we propose a target oriented seismic tomography algorithm for imaging subduction zones. The new seismic tomography scheme consists of three main steps. We first construct a large-scale average background model of the whole crust and upper mantle structure of the study area. To avoid being trapped by local minimums, a multi-grid model parameterization is used to decompose the scale of the inverse problem. The second step is a localized tomographic inversion. We only use seismic data generated by earthquakes in the subduction zone. Considering that the first step is likely to yield an accurate average velocity model of the crust, we only perturb the upper mantle model at the second step. The third step is to invert the differential traveltime residual of two neighboring subduction zone earthquakes at the same station. This approach can further refine the subduction zone structures.
We will test this target oriented method in the framework of ray-based traveltime inversion using our newly developed eikonal-based traveltime tomography software package tomoQuake. Real application results in the Japan subduction zone will be demonstrated.

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