Synthetic tests for evaluating the precision of the centroid depth estimation of offshore earthquakes using onshore and offshore seismic networks

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In our previous study, we showed that the use of offshore seismograms in addition to inland seismograms significantly improved the estimation of the horizontal location and focal mechanism of centroid moment tensor (CMT) for offshore earthquakes than the use of only onshore seismograms (Kubota et al., 2017). Recently, the new offshore seismic network called S-net (Seafloor observation network for earthquakes and tsunamis along the Japan Trench) (Uehira et al., 2012) was constructed in Tohoku-Oki region, which will provide better constraints of the CMT solutions for offshore earthquakes. However, the subsurface structure in offshore region is substantially different from that in onshore. Furthermore, it is important to take seawater and shallow low-velocity sediments into account when calculating the seismic wave propagation through offshore region (e.g., Noguchi et al. 2017; Takemura et al. 2018). Therefore, we should consider such offshore structures for calculating offshore Green’ s functions in order to obtain more precise CMT solutions. In this study, using the synthetic seismograms at the inland and offshore seismic networks, we investigated the effects of offshore structures on the CMT estimation for offshore earthquakes, especially focusing on the centroid depth.

We assumed the reverse-faulting point source in Tohoku-Oki region at plate boundary depth (~18 km) and numerically evaluated the synthetic seismograms at inland and offshore networks, using finite-difference simulation of seismic wave propagation (e.g., Takemura et al., 2017). In the calculation, we used the 3D structure model, “JIVSM” (Koketsu et al., 2012). The model covered the region of 960×960×240 km^3, which was discretized by grid intervals of $\Delta x = \Delta y = 0.4$ km and $\Delta z = 0.15$ km and time step interval of $\Delta t = 0.005$ s. We then analyzed the synthetic seismograms for the periods of 20–100 s to estimate centroid depths and the moment tensors. We used three velocity models for the CMT estimation: one is the average velocity structure model of the inland Japan, which is used for the F-net CMT analysis (Kubo et al. 2002) (inland 1D model). This 1D model does not include the seawater and shallow low-velocity layers. The second one is the 1D structure including seawater and shallow low-velocity layers (offshore 1D model). The last one is the JIVSM 3D velocity structure model (3D model). Green’ s functions in 1D models were calculated by wavenumber integration method (Herrmann, 2013).

When we used the inland 1D model, the optimal depth of the CMT analysis was ~17 km, which was consistent with the input source. However, the depth resolution of the solution, which was evaluated via fitness of target seismograms, was relatively low: the estimated centroid depth ranged from 5 to 30 km depth. By using the 3D model, the optimal solution was also located at the depth of the input source. The vertical resolution of the solutions was improved slightly: the estimated centroid depth ranged from 15 to 25 km. The analysis using the offshore 1D model also showed the similar results as those obtained using the 3D model.

These synthetic tests showed that the shallow low-velocity layers are modestly helpful to constrain the depth range for the estimated CMT solutions. However, it is difficult to obtain higher resolution even if we use the 3D structure. This is probably because the Green’ s functions for the centroid depths of 15 –25 km were quite similar in the low-frequency rage (20-100 s).

Keywords: Centroid moment tensor, Synthetic test, Offshore earthquakes, Onshore and offshore seismic network