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The 2011 Tohoku-oki Earthquake related to a large velocity gradient within the Pacific plate

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We conduct seismic tomography using arrival time data picked by the high sensitivity seismograph network (Hi-net) operated by National Research Institute for Earth Science and Disaster Prevention (NIED). We used earthquakes off the coast outside the seismic network around the source region of the 2011 Tohoku-oki Earthquake with the centroid depth estimated from moment tensor inversion by NIED F-net (broadband seismograph network) as well as earthquakes within the seismic network determined by Hi-net.

The target region, 20-48N and 120-148E, covers the Japanese Islands from Hokkaido to Okinawa. A total of manually picked 4,622,346 P-wave and 3,062,846 S-wave arrival times for 100,733 earthquakes recorded at 1,212 stations from October 2000 to August 2009 is available for use in the tomographic method. In the final iteration, we estimate the P-wave slowness at 458,234 nodes and the S-wave slowness at 347,037 nodes. The inversion reduces the root mean square of the P-wave traveltime residual from 0.455 s to 0.187 s and that of the S-wave data from 0.692 s to 0.228 s after eight iterations (Matsubara and Obara, 2011).

Centroid depths are determined using a Green's function approach (Okada et al., 2004) such as in NIED F-net. For the events distant from the seismic network, the centroid depth is more reliable than that determined by NIED Hi-net, since there are no stations above the hypocenter.

We determine the upper boundary of the Pacific plate based on the velocity structure and earthquake hypocentral distribution. The upper boundary of the low-velocity (low-V) oceanic crust corresponds to the plate boundary where thrust earthquakes are expected to occur. Where we do not observe low-V oceanic crust, we determine the upper boundary of the upper layer of the double seismic zone within high-V Pacific plate. We assume the depth at the Japan Trench as 7 km.

We can investigate the velocity structure within the Pacific plate such as 10 km beneath the plate boundary since the rays from the hypocenter around the coseismic region of the Tohoku-oki earthquake take off downward and pass through the Pacific plate. The landward low-V zone with a large anomaly corresponds to the western edge of the coseismic slip zone of the 2011 Tohoku-oki earthquake. The initial break point (hypocenter) is associated with the edge of a slightly low-V and low-Vp/Vs zone corresponding to the boundary of the low- and high-V zone. The trenchward low-V and low-Vp/Vs zone extending southwestward from the hypocenter may indicate the existence of a subducted seamount. The high-V zone and low-Vp/Vs zone might have accumulated the strain and resulted in the huge coseismic slip zone of the 2011 Tohoku earthquake. The low-V and low-Vp/Vs zone is a slight fluctuation within the high-V zone and might have acted as the initial break point of the 2011 Tohoku earthquake.

Reference

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