Seismic imaging of the Tohoku megathrust zone using S-net and Hi-net data

*Dapeng Zhao[1], Yuanyuan Hua[1], Genti Toyokuni[1]

1. Department of Geophysics, Tohoku University

The great 2011 Tohoku-oki earthquake (Mw 9.0) was one of the greatest earthquakes recorded by modern instruments, which occurred in a megathrust zone formed by the subducting Pacific plate and the overriding Okhotsk plate. It produced a huge tsunami and caused great damage to the local society and infrastructure in NE Japan. The occurrence of this great megathrust earthquake has updated our knowledge about megathrust ruptures, especially due to the large coseismic slip at shallow depth near the Japan trench and high-frequency radiations from small-slip areas. However, the mechanism and rupture process of the great 2011 Tohoku-oki earthquake are still a matter of some controversy due to the lack of permanent near-field observations. In this work we used high-quality P-wave arrival-time data of local earthquakes from June 2002 to December 2018 recorded at 480 permanent stations of the Japanese Kiban seismic network on land and 120 OBS (ocean bottom seismometer) stations of the S-net. We selected 2446 local earthquakes that occurred beneath the Kiban seismic network and 1281 events that were recorded by the S-net. From the high-quality vertical-component seismograms recorded by the S-net, we picked P-wave arrival times generated by the 1281 events. The picking accuracy of the arrival times is estimated to be 0.05-0.15 s. As a result, our data set contains a total of 100,662 P-wave arrival times from 3727 local earthquakes. Only arrival times of the events with well-located hypocenters (uncertainty < 3 km) are used in the tomographic inversion. The tomographic method of Zhao et al. (1992, 2011) is used to determine a detailed 3-D Vp model of the Tohoku subduction zone. The well-determined geometries of the Conrad and Moho discontinuities and the upper boundary of the subducting Pacific slab (UBP) are considered in the velocity model. The general pattern of the obtained tomographic model is similar to that of previous models (e.g., Zhao et al., 2011; Liu and Zhao, 2018), but our present model shows that a low-velocity anomaly exists near the Japan trench off Miyagi and Sanriku. The mainshock hypocenter of the great 2011 Tohoku-oki earthquake is located at a boundary between a down-dip high-velocity anomaly and the up-dip low-velocity anomaly. The slow anomaly at shallow depths near the Japan trench may reflect low-rigidity materials that are close to the free surface, resulting in large slip and weak high-frequency radiation. Our new tomographic model can account for not only large slip near the trench but also weak high-frequency radiation from the shallow rupture areas.

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Keywords: the 2011 Tohoku-oki earthquake, seismic tomography, suboceanic seismic network S-net

