Japan Geoscience Union Meeting 2011
(May 22-27 2011 at Makuhari, Chiba, Japan)
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SSS027-19 Room:105 Time:May 22 17:15-17:30

The mechanism of anomalous seismic wave propagating along trench revealed by FDM simulation

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During shallow earthquake occurring near the trench (outer-rise earthquake), an anomalous later phase is observed occasionally at stations distant from the epicenter (around 1000 km). From the late arrival of the phase (hundreds of seconds after S-wave), the propagation speed of the phase is estimated as 1~1.5 km/s. The phase has the particle motion like Rayleigh wave, the dominant period of around 12~20 s and the large amplitude. About such phase, the report by Nakanishi et al. (1992) would be the initial, which was about the observation at a station in Hokkaido during the earthquake near the Kuril Trench. Following this, Yomogida et al. (2002) discussed that these phases could be Rayleigh wave trapped along the trench by means of ray tracing. After the installation of broadband network (F-net), a number of such phases were obtained. For example, it appeared at Izu Islands during 2005 off-Sanriku outer-rise earthquake (Mw 7.0) (Noguchi et al., 2010; 2011). It also found at stations in Hokkaido during the aftershocks of 2007 Kuril outer-rise earthquake (Mw 8.1) and at stations in Kanto region during December 2010 Bonin Islands outer-rise earthquake, etc. They appear at limited stations whose propagation path is along the trench. They will not appear during the earthquakes nearer to land. From such relative positions of the epicenters and stations, there is no doubt on that the anomalous phases are generated on the long way along the trench. Because the phases appear around the kink of trench, off-Tokachi junction or off-Chiba triple junction, such particular structures with thicker seawater and sediments also could play a role on the generation of the phase. To investigate the mechanism of the phase, we conduct the 2D- and 3D- finite difference method (FDM) simulations using various model structures.

First, we conduct 2D-FDM simulation considering the case of F-net AOGF during 2005 off-Sanriku outer-rise earthquake using model structure along Japan Trench which is made from the seafloor topography by J-EGG500, subsurface structure by J-SHIS and subducting plate structure by Special Project for Earthquake Disaster Mitigation in Urban Areas. To take the interaction between the seawater and seafloor into account properly, we introduced the calculation method for solid-fluid boundary proposed by Okamoto and Takenaka (2005). As a result, the mechanism of the anomalous phase is clearly shown; the ocean acoustic wave coupled with the seismic wave propagating along the seafloor (boundary wave) is excited and propagates slowly (around 1 km/s), then be converted to Rayleigh wave at the seafloor slope to the land and observed as an anomalous phase. It represents that the slow propagation of boundary wave in deep sea area along trench and the conversion at seafloor slope are important for the generation of the phase.

Then we investigated the roles of seawater, sediment and seafloor topography using the various cases of simplified 2D models. It is shown that the depth of seawater affects on the travel time and the dominant period of the phase. The travel time also depends on the thickness of sediment. The angle of seafloor slope controls the ratio of conversion and reflection of boundary wave and affect on the amplitude of the phase.

Finally, we conduct the 3D-FDM simulation to investigate the role of 3D structure containing trench and its junction on the phase. As the result, it is shown that the boundary waves are trapped along the trench because of low velocity zone due to thick seawater. Then a part of them are converted at the seafloor slope which faces the kink of trench, and reach on the land as a Rayleigh wave. From the results, the mechanism in the case of off-Sanriku outer-rise earthquake can be explained as below; the boundary wave trapped along Japan Trench is converted into Rayleigh wave at off-Chiba triple junction, then be observed as anomalous later phase at AOGF.

We used the continuous seismic data recorded by F-net, NIED.

Keywords: ocean acoustic wave, trench trapped wave, Rayleigh wave, FDM simulation, outer-rise earthquake