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The mechanism of anomalous wave propagating along trench shown by 3D-FDM simulation considering topography and seawater

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To clarify the mechanism of anomalous later phase which appears during shallow earthquake near a trench, we investigate the effect of heterogeneous structures around a trench on generation and conversion of seismic waves by means of numerical simulation using 3D finite difference method (FDM).

During shallow earthquake occurring near a trench (outer-rise earthquake), an anomalous later phase is observed occasionally at stations distant from the epicenter (~1000 km). From the late arrival of the phase, 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 10~20 s and the large amplitude. The initial report for the observation of such anomalous phase would be given by Nakanishi et al. (1992), which was about the observation at a station in Hokkaido during the earthquake near the Kuril Trench. After the installation of broadband network F-net, a number of such phases were observed. For example, it appeared at the F-net station AOGF in Izu Islands during 2005 off-Sanriku outer-rise earthquake (Mw 7.0) (Noguchi et al., 2011). It was also found at stations in Kanto region during 2010 Bonin Islands outer-rise earthquake (Mw 7.4). They appear at limited stations located around the junction of trenches. Also, the propagation path for these observations are along the trench. So that the anomalous phase should be attributed to particular propagation path around the trench. For the mechanism of such phenomena, Yomogida et al. (2002) discussed that these phases could be Rayleigh wave trapped along the trench by means of ray tracing. In Noguchi et al. (2011), based on 2D-FDM simulation, we showed that the slow (~1.1 km/s) solid-liquid boundary wave propagates along the deep seafloor, then converted into Rayleigh wave at the seafloor slope and finally observed as an anomalous later phase. In this result, the role of 3D structure around a trench which could trap and convert the boundary wave was not clear.

Based on the result, we conduct the 3D-FDM simulation for the case of AOGF during 2005 off-Sanriku outer-rise earthquake considering the seawater layer, realistic topography and 3D heterogeneous structure. We simulate the seismic wave propagation with the period of longer than 10 s in the area of 900 km x 360km around Japan Trench. We construct 3D structure model using data of the seafloor topography by J-EGG500, subsurface structure by J-SHIS and 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 introduce the calculation method for solid-fluid boundary proposed by Okamoto and Takenaka (2005). As a result, it is clearly simulated that the boundary wave propagating along the seafloor travels a long distance trapped along the Japan Trench axis. It is due to the low velocity zone for the boundary wave caused by the thick seawater along the trench. The boundary wave then escapes the trench at the triple junction at off-Chiba, converted into Rayleigh wave at the seafloor slope, and finally observed as an anomalous phase at AOGF. The result supports the mechanism revealed by 2D simulation, yet it becomes very clear newly that the boundary wave is trapped along trench axis and converted at the trench junction. It is also shown that the relative amplitude of anomalous phase compared to S or Rayleigh phase depends on the hypocentral depth or the relative position of epicenter to the trench. Similar to the other simulations considering water layer (e.g. Maeda et al., 2011), totally, the amplitude and duration of later phase observed onshore become bigger and longer compared to the case without water layer. It would be due to the slow boundary wave trapped in sea area widely for a long time. It indicates that it is necessary to consider the seawater layer when we estimate the ground motion due to the earthquake occurring in sea area.

Keywords: Ocean acoustic wave, Trench trapped wave, FDM simulation, Outer-rise Earthquake, Long period ground motion simulation