Evaluation of the generation and propagation mechanism of T-phase based on wave propagation simulation

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1. Introduction
The T-phase is the tertiary wave observed after P and S waves, which is acoustic wave propagating in the oceanic layer at speed of 1.5 km/s. T-phases are generated by P and S waves radiated from the earthquake below the ocean floor and transmitted into seawater directly and by S-to-P conversion at the solid-liquid interfaces of sea bottom, and then captured within the seawater by wide-angle reflections of P waves. In the presence of a sloping ocean floor above hypocenter, it is getting easier to make large-angle P reflections, and it is expected to enhance the excitation of T-phase. On the other hand, there is still question why T-phase is also generated on almost flat ocean floor (Okal 2008). For efficient propagation of T-phases, it is also explained that T-phases are trapped in the so-called SOFAR channel (SOund Fixing And Ranging) of minimum sound velocity. Also the T-phase reflected at large variation of topography such as seamounts (Obara and Maeda, 2009). In order to answer these questions and to understand the generation and propagation process of T-phases, we analyzed T-phase observed in ocean-bottom seismometer (OBS) and the conduct in 2D finite-difference method (FDM) simulation of seismic wave propagation.
2. T-phase data observed by OBS
We inspected the seismograms for T-phases in the broadband OBS station (WPAC) placed on North Pacific for 18 events occurred around Kuril and Aleutians in depth range 14-62 km and in distances range 788-1899 km. A band-pass filter of 2-8 Hz was applied to remove surface wave. To compensate the magnitude we examined relative amplitudes of T-phases normalized by P or S waves. We confirmed that T-phases propagated to far-field had a spindle shape of long duration properties. It is also confirmed that T-phase amplitudes were greater when slopes of seabottom above hypocenter is larger and longer. In addition, T-phase amplitudes were usually larger for shallow events. Also T-phase amplitudes attenuated drastically when propagation paths crossed seamounts.
3. Wave propagation simulation
For reappearance of such strong T-phases observed by OBS, we investigated the influence of submarine topography and underground structure by 2D FDM simulation of seismic wave propagation. For analyzing the relation between the generation of T-phases and seabottom topography, we computed the wave propagation using a flat topography model and a linearly sloping topography model. The crust and the mantle structural model was followed by Sereno and Orcutt (1985), and P waves velocity in oceanic layer were set to 1.5 km/s. In a reverse fault earthquake in 33 km depth, ground motion in maximum frequency of 8 Hz was calculated. As a result, in the sloping topography model, T-phases appeared after S waves, but T-phases did not generated in the flat topography model. When heterogeneous topography was added in the sloping model, T-phase amplitudes became somewhat weaker, and waveforms of T-phases became the spindle sphapes. Moreover, in the crust and the mantle model containing horizontally-elongated small-scale heterogeneous structure (Kennett and Furumura, 2014), waveforms had much longer duration of P and S waves (Po and So waves), but waveforms of T-phases were almost the same. Therefore, the generation of T-phase with the spindle shape relates strongly to sloping and roughly subsurface topography. Additionally, we could show that T-phase amplitudes became larger in the case of the shallow focal depth. Also, we could confirm that the attenuation of T-phase energy was weaker by being trapped in the SOFAR channel, and T-phases could propagate to longer distance easily.

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