Dominance of mode-conversion seismic wave scattering in small-scale randomly heterogeneous media having anisomeric characteristic scales

*Takuto Maeda[1], Nozomi Kanaya[1]

1. Earthquake Research Institute, the University of Tokyo

Recent studies based on large-scale numerical simulations revealed that small-scale velocity heterogeneity with non-isotropic characteristic scales, called anisomeric media, significantly affects the complicated seismic wave observations. However, the behavior of seismic waves in such an anisomeric medium has been interpreted mostly from the results of numerical simulations with scattering theories for the random media having isotropic characteristic scales. In this study, we applied the first-order Born approximation for the scattering problem of seismic waves in an anisomeric medium and found that the mode-conversion scatterings between P and S waves play particularly essential roles in strongly anisomeric media such as subducting plates.

Let us consider a fluctuation of medium velocities and density in the equations of motion of elastic medium. Under the assumption of the small first-order fluctuation, the scattered waves obey the same equations of motion having the equivalent body force term related to the incidence of the seismic waves into the fluctuations, which is known as the Born approximation. We here assume that the medium is characterized statistically by the power spectral density function (PSDF) of the velocity fluctuation. The scattering coefficient - an index of the average strength of the scattering - is proportional to the fourth power of the wavenumber, the basic scattering pattern which is an essential non-isotropic radiation pattern determined by the wave type, and the PSDF of the velocity fluctuation. Notice that the PSDF takes the exchange wavenumber, the difference between wavenumber vectors of scattered and incident waves, as its arguments.

We consider an anisomeric medium with a shorter characteristic scale along an axis relative to other two axes, which mimics the anisomeric structure of the subducting plates. In this medium, scattering coefficients depend on the direction of the incident waves, in addition to the scattering angles. Scattering coefficients and its angular dependence have been investigated as a function of incident angles and the aspect ratio between longer and shorter characteristic scales.

We found that there are two situations that conversion scatterings between P- and S-waves play significant roles. One is the P-to-S scattering occurred when P-wave propagates along a long axis. In this case, the along-long-axis component of the exchange wavenumber can be zero at a specific scattering angle determined by the P-to-S wave velocity ratio, which leads strong conversion scattering at around a particular angle. The another is S-to-P scattering mode. This scattering dominates when the S wave propagates nearly along the short axis of the heterogeneity. In this case, S-to-P scattering dominates at a narrow band of scattering angle at around 30 degrees from the incident angle. The scattering coefficient increases as increasing aspect ratio of the small-scale heterogeneity, but it reaches the peak at around aspect ratio of 20. Significant precursors of S-wave observed at Kanto, Japan, region for deep-focus earthquake (Kanaya et al., 2017 AGU) can partly be explained by this effect.

