High-frequency shear wave propagation across the Honshu slab subducting beneath NE Japan

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We studied the nature of propagation of high-frequency S-waves and their relative excitations to P-waves from sources at different depths and discuss its relation to slab morphology and phase changes at major discontinuities in the upper mantle beneath the Honshu slab subducting beneath NE Japan. We analyzed deep focus (>350 km) earthquakes of moderate magnitudes (M4.5-7) recorded at fore-arc broad-band F-net stations. The waveforms are deconvolved from instrument response, band-pass filtered (0.2-10 Hz), noise removed, coda-normalized three-component mean square (MS) envelopes. The energy envelopes are normalized by average coda energy in a time window of 10 sec duration starting from about two times S-wave arrival time to minimize the influence of source and site effects. The events from tight cluster of events are analyzed to interpret the gross behavior of P and S-wave propagation through different source-receiver paths (Figure 1) around the Izu-Japan arc-arc collision zone.

Previous studies of subduction zone structure in the region are mainly based on seismic tomography data (Miller et al., 2006; Obayashi et al., 2009); however, a few studies interpreted the high-frequency waveform attributes to constrain the plate geometry (Furumura & Kennett, 2005; Kennett & Furumura 2010) around the northern part of the Honshu slab. Furumura & Kennett (2005) shows the presence of a low-frequency (f < 0.25 Hz) precursor followed by high-frequency (f > 2 Hz) arrival with long coda due to multiply scattered seismic waves in the stochastic waveguide of the Pacific slab.

Recent analysis from this study shows that for some specific source-receiver paths, the waveforms exhibit (i) inefficient S-wave arrivals with amplitudes less than that of P-waves, and (ii) impulsive P-waves with a rapid decay of its high-frequency coda energy for certain source and receiver pairs for deep earthquakes occurring in the Pacific plate. Figure 1 shows the gross behavior of the nature of S-wave arrivals, where the grey and black color paths represent paths with efficient and inefficient S-wave propagation, respectively. The S-waves are more depleted of high-frequency energy for stations on southern part (HRO, YMZ and HRO) than that on northern part (IYG, TYS and KSN) of the study area. These features are also correlated with rapid decay of energy in P-wave coda. Because we observe this feature of S-arrival for specific source receiver pairs, the effect of pure source and site effects are least likely. However, we did not observe similar and systematic pattern from analysis of intermediate depth earthquakes (< 300 km) occurred almost in the same region. Such complexities in the observed waveforms, which are difficult to explain by anomalous propagation of seismic waves in the existing plate model, provide evidence of lateral variations in plate structure.

In order to explain these observations, we use a large-scale finite difference modeling of the 2D structure of the subducted plate in order to provide constraints on the thickness, velocity and geometry of the deep slab structure in this region. The model consists of 8000 x 6000 grid points with a uniform grid spacing of 0.15 km. Random heterogeneity is introduced into the plate model through an anisotropic form stochastic distribution described by a von Karman correlation function with elongated structures with a correlation length of 10 km in horizontal direction and much shorter correlation length of 0.5 km in depth and standard deviation from background velocities of 5%.

The results of simulation for thin plate model show that high-frequency energy escapes the slab near the thinning portion of the slab and consequently trapped energy is not clearly observed at the fore-arc stations compared to that for flat plate model. We infer that the multiply-scattered high-frequency energy decouples from the waveguide where the slab is deformed or thin. Thus, the structural complexity of the plate with distorted plate geometry interrupts the guiding high-frequency S-energy through the slab. The modeling results show that the energy is easily defocussed from the slab with thinned lower slab boundary and for sources close to the upper plate boundary. The results of this study, along with the evidence from seismic tomography, suggest thinning of the Pacific slab at deeper level (> 350 km). As an extension to this study, we are trying to incorporate the effect of Olivine to Spinel phase transition around the 410 and 660 km discontinuities in the model to explain any wave guiding behavior from still deeper events in the Pacific plate, as a scope of future study.

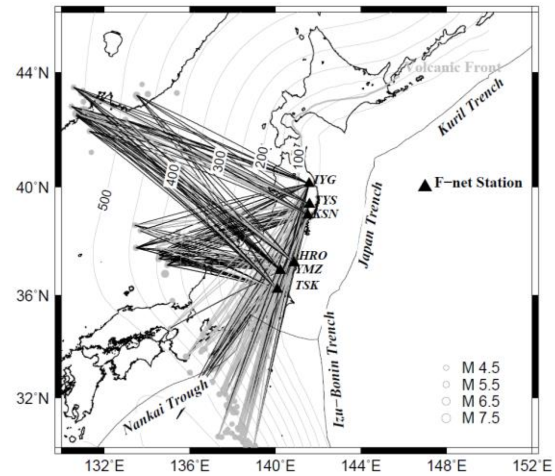

Figure 1: Figure showing the nature of S-arrivals. Grey and black color paths denote the efficient and inefficient propagation of S-arrivals, respectively.