Seismic velocity discontinuities inferred from multiple frequency band analyses of receiver functions

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Receiver functions are time series, deconvolved ground motion of horizontal (radial) component by vertical component. From this process, we can extract phases of converted P-wave to S-wave at any seismic discontinuity beneath each station. Positive and negative amplitudes of receiver functions indicate velocity increase and decrease downward, respectively. In general, we think that peak times of receiver function are consistent with the velocity discontinuities. However the location of peak times on the receiver function profile are different with frequency bands of the low-pass filter on the depth converted images. It makes miss-location of the discontinuities. For example, a peak depth of positive amplitude, which corresponded with the Moho discontinuity of the subducting Philippine Sea plate, became shallow at higher frequencies in the Boso Peninsula, central Japan.

In this study, we make synthetic receiver function traces and investigate the shift of peaks with different frequency bands. Synthetic receiver function traces are calculated using the reflectivity algorithm. Multiple reflected phases are considered for this calculation. We used a squared cosine-taper function low-pass filter with cut-off frequencies (fc) of 1 Hz and 3 Hz. The frequencies of the filter are suitable to detect the boundaries in crust and mantle, because the dominant frequencies of their filtering are about 0.4 Hz and 1.0 Hz, respectively.

We put a low velocity layer in the model, and assumed that a velocity of the underlying layer is higher than that of the overlying layer. In the first model, we assume that the low velocity layer is homogeneous. In this case, the peak amplitudes completely separate without frequency dependence if the thickness of the low velocity layer is larger than about 10 km with fc=1 Hz and about 4 km with fc=3 Hz. The locations of the peak amplitudes also agree with the depths of both velocity discontinuities. However, the positive and negative peaks interfere in case of the thickness of the low velocity layer is smaller than those values. If the low velocity layer is extremely thin, the amplitude of low velocity discontinuity disappears.

Next, we used low velocity layer that the negative velocity jump is given at the top of the low-velocity layer and the velocity is gradually increase in the low-velocity layer. The velocity of the underlying layer is constant. Therefore the velocity will increase gradually as the layer becomes thick. In this case, the shape of the trace depends on both the layer thickness and frequency band. The amplitude increase as rapidly as high frequencies. However, we can not distinguish easily the peak position of positive amplitude, because it becomes almost constant in the depth ranges with a positive velocity gradient. Moreover, the peak position of negative amplitude also changes.

From tomographic studies, it is reported that subducting oceanic crust and slab are characterized by the overlying low-velocity layers, which associated with the existence of hydrous material and/or pore water, and high-velocity layers, respectively. On the other hand, oceanic crust is also characterized as a layer with a steep velocity gradient.

Amplitude traces estimated from multiple frequency band analyses of receiver function become important information for interpreting the structure with velocity gradient. We should be more careful when we discuss the velocity discontinuities with complex amplitude change.