

Crustal structure beneath the Japanese Islands inferred from grid search analysis of receiver functions

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Information on seismic velocity and seismic velocity discontinuities is important to clarify the characteristics of the seismogenic zone. Recent seismic tomography analyses elucidate 3D velocity structures in the whole area of Japan. However, very few studies have paid attention to velocity discontinuities. A receiver function (RF) analysis can extract velocity discontinuities at any depth. In this study, we applied the grid search analysis of RFs to estimate seismic velocity structures in the crust and depths of the uppermost mantle beneath the Japanese Islands. We used seismic stations operated by NIED, JMA and ERI in the period from August 2002 to December 2008. The earthquakes are selected from the PDE catalogues by the USGS with M5.5 or greater and epicentral distances of 30-90 degrees. The total number of events is 1502. We searched for the best-correlated model between observed RF and synthetic RF for 10 seconds from the direct P arrival. Synthetic RFs were calculated by the reflectivity algorithm from many 1-D horizontal layered structure models which consist of a sediment layer and two velocity discontinuities from the ground surface to the depths of 60 km. We considered only the positive velocity step. RFs after low-pass filtering by a squared cosine-taper with a cutoff frequency at 1 Hz were stacked without considering backazimuth or epicentral distance. Average 1-D structure estimated from results of each station showed the very slow Vs less than 3.0 km/s to 2 km deep. On the other hand, Vs is higher than the JMA2001 model in the range 5-20 km deep and 30-40 km deep. Their high-Vs are consistent with the results of Nishida et al. [2008], which estimated by the tomography analysis using ambient noises. From average Vs from the ground surface to 5 km deep, we imaged thick sediment layers in several plains and basins. There are relatively high-Vs zones in western Japan and the non-volcanic mountain district in eastern Japan. In particular, Vs around the Median Tectonic Line (MTL) has very high. These characteristics are consistent to the result of basement depths by Earthquake Research Committee. In the upper crust, our results show low Vs corresponding to the volcanoes in eastern Japan and Kyushu, or the accretional belts in the Pacific coastline from Kanto to Shikoku. In the lower crust, we imaged low Vs bands in the Niigata-Kobe Tectonic Zone (NKTZ) and the MTL. Around the crust-mantle boundaries, there are clear low-Vs zones beneath NKTZ, active volcanoes, and the occurrence regions of the non-volcanic low-frequency tremors in Tokai to Shikoku. These resultant crustal Vs pattern are consistent to previous Tomographic studies. Furthermore, our results show the Itoigawa-Shizuoka Tectonic Line (ISTL) is the boundary of the velocity structure of the upper crust in the Japanese Islands. The western side is covered in the relatively stable high-Vs zone. On the other hand, the eastern side has heterogeneities of velocity perturbations. The crust along the ISTL shows relatively low-Vs in shallower part and high-Vs in deeper part compared to the neighborhood areas. We think that the spatial resolution of RF analysis is higher than that of previous studies. The average depth of the uppermost mantle is 35.8 km. The depths exceed 40 km in the mountain districts and become shallow toward the surrounding seas in most part. This depth pattern is similar to Zhao et al. [1992] in Tohoku and Chubu. However, our results have some undulations locally. The depths also exceed 40 km in some areas near the Pacific coastline. These discontinuities are corresponding to the depths of the uppermost mantle in the subducting plates.

This result suggests that Vs discontinuities of the subducting plates are larger than that of the overriding plate in most areas. These differences maybe suggest the heterogeneity around the crust-mantle boundary beneath the Japanese Islands.

Keywords: Receiver function analysis, Crustal structure, the Japanese Islands