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Characteristics of the crustal structure in the occurrence areas of crustal earthquakes

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The 2011 off the Pacific coast of Tohoku earthquake occurred on 11 March 2011 in the subducting Pacific plate boundary in northeast Japan. This earthquake caused many induced earthquakes in land areas. The strain accumulation process due to interplate coupling should have a large effect on inland shallow earthquakes that occur in the overriding plate. Investigation on the crustal structure is the key to understanding the stress concentration and strain accumulation process. In this study, we estimated the seismic velocity structures of the crust beneath the Japanese Islands by using receiver function analysis, and compared them with seismic activities in land areas.

We searched for the best-correlated velocity structure model between an observed receiver function at each station and synthetic ones by using a grid search method. Synthetic receiver functions were calculated from many assumed one-dimensional velocity structures that consist of four layers with positive velocity steps. Observed receiver functions were stacked without considering backazimuth or epicentral distance. Telemetric seismographic network data covered on the Japanese Islands and several temporal dense seismographic stations are used. We selected events with magnitudes greater or equal to 5.0 and epicentral distances between 30 and 90 degrees based on USGS catalogues. Data analysis was performed separately before and after the 2011 mainshock occurred.

As a result, we clarified spatial distributions of the crustal S-wave velocities. Average one-dimensional S-wave velocity structure estimated from analyzed stations is approximately equal to the JMA2001 structural model although the velocity from the ground surface to 5 km in depth is slow. The low velocity distributions correspond to thick sediment layers in several plain and basin areas. The velocity perturbations in the crust are consistent with existing tomography models. There are low-velocity zones corresponding to volcanoes in the upper crust to the crust-mantle boundary. In contrast, non-volcanic mountain foothills are relatively high velocity zones.

Many crustal earthquakes have occurred around the edge of the high or low velocity region; Earthquakes which occurred before the 2011 mainshock were located mainly around low velocity zones whereas earthquakes induced by the 2011 mainshock tend to occur around high velocity areas. This suggests that there is a correspondence between the structure to generate earthquakes and stress state in the crust. Furthermore, a comparison of the upper crustal structure before and after the 2011 mainshock suggests that the forearc side and backarc side of northeastern Japan arc changed to higher and lower velocities in some areas, respectively. However, this kind of velocity changes might be due to other effects such as the difference of used seismic waveforms and/or changes of velocity polarizations. We will clarify the cause of changes in the estimated velocity structure in the further studies.

Keywords: Receiver function analysis, Crustal structure, Crustal earthquake, the 2011 off the Pacific coast of Tohoku earthquake