The cause of long-time-duration long-period ground motion observed in Hokkaido during off-Tohoku earthquakes

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We found a development of anomalously large and long-time-lasting long-period ground motions in the area around Ishikari, Hokkaido Japan, during off-Tohoku earthquakes. In order to clarify the generation mechanism of this anomalous wave, we conducted a set of numerical simulations of seismic wave propagation in realistic 3D heterogeneous subsurface structures by means of a finite difference method (FDM).

The anomalous long-period wave spreads Ishikari Basin and Teshio Basin, Hokkaido, was clearly observed for shallow earthquakes occurred off-Tohoku. The dense broadband records of Hi-net short-period seismographs after correcting the instrumental response showed that a large long-period ground motion (T=14~18 s) lasting more than 200 s appears in the region in Hokkaido. This long-period ground motion dominates in both horizontal and vertical components indicating dominance of surface waves propagating northward. Such anomalous wave did not appear obviously during the earthquakes away from the off-Tohoku region.

Based on the geophysical reflection and refraction experiments and analysis of the gravity data, it is known that deep (~10 km) tectonic basins extends from northern Hokkaido to the sea of southern Hokkaido toward the direction to off-Tohoku through the west of Hidaka Mountains. Thus, it is expected that such deep basin structure causes strong effect on the development of the anomalous long-period ground motions mentioned above.

To investigate the cause of the observed long-time-lasting long-period ground motions with interaction to the heterogeneous subsurface structure below Hokkaido in detail, we conducted a FDM simulation of seismic wave propagation using the OpenSWPC (Maeda et al., 2017). We used a realistic 3D subsurface structure model including topography, seawater, sediments and subducting Pacific plate. The result of the simulation demonstrated the development of the long-period ground motion in the area around Ishikari Basin and Teshio Basin which qualitatively reproduces the observed feature, however the duration of the simulated long-period ground motion was not long enough compared with the observation. By modifying the sedimentary structure where the P- and S-wavespeed of the sedimentary layers were replaced with much smaller values, we succeeded in obtaining much longer-time lasting long-period ground motions similar to the observation. The results of the simulation with snapshots of seismic wavefield at each time step and movies demonstrating clearly the process in which the surface waves generated above the epicenter were trapped and amplified in deep sediments at south off Hokkaido, and radiated the long-period motion to northward for a long time to develop a large and long-time-lasting long-period ground motion.

Keywords: Long-period ground motion, Numerical simulation, Surface wave, Long-time duration, Deep basin

