Effects of the heterogeneous crustal structure on the amplitude fluctuation of high-frequency seismic waves

*Kazuo Yoshimoto[1], Shunsuke Takemura[2]

1. Graduate School of Nanobioscience, Yokohama City University, 2. National Research Institute for Earth Science and Disaster Resilience

It is considered in the seismic scattering analyses that crustal heterogeneity may be modeled by combining deterministic heterogeneity and stochastic heterogeneity. A simple technique of this modeling adopts a uniform averaged structure model (background structure model) for deterministic heterogeneity and a uniform random heterogeneity model for stochastic heterogeneity. Although this technique may be adequate for the seismic scattering analysis with a small target area, the simplification might lead erroneous results if the target area of the analysis becomes large. In this study, we investigated the effect of the deterministic crustal heterogeneity on the amplitude fluctuation of high-frequency (0.5-4 Hz) seismic waves on the basis of finite-difference method (FDM) simulations.
We conducted FDM simulations of shallow moderate earthquakes, including a target earthquake occurred on 25 November 2011 at a depth of 14 km beneath the Chugoku region, western Japan. Our simulation model covered a volume of 256×256×80 km^3, which was discretized by a uniform grid spacing of 0.05 km. Technical details are the same as those of Takemura et al. (2017). The background velocity structure was referred from the Japan Integrated Velocity Structure Model (JIVSM; Koketsu et al., 2012). Small-scale random velocity heterogeneity (Takemura et al., 2017) was superposed on the crust of the JIVSM. We adopted a double-couple point source with a focal mechanism reported by the F-net MT catalog. This model setting well reproduced observed high-frequency seismograms at the Hi-net borehole stations (Takemura et al., 2017). Because we employed a finer FDM grid compared to previous simulations (Takemura et al., 2017), our FDM simulation can evaluate seismic wave propagation for higher (~ 8 Hz) frequencies. To investigate fluctuation of seismic amplitudes, we evaluated peak ground velocity (PGV) from filtered synthetic seismograms.
Simulation results of a strike-slip source model showed that the cross-shaped (four-lobed) large PGV distribution in the epicentral area becomes unclear in the surrounding area as the hypocentral distance increases. Theoretical and empirical models of high-frequency seismic amplitudes also predicted a similar characteristic of apparent radiation pattern (Yoshimoto et al., 2015; Takemura et al., 2016). Although this phenomenon, which is mainly caused by the seismic scattering due to random heterogeneity, showed azimuthal symmetry, the symmetry was found to be broken for a certain focal depth condition. Our additional simulations using different properties of background structure model indicated that, at least in our target region, the reflection due to a small velocity contrast of the Conrad discontinuity (about 10% in JIVSM) may cause the large amplitude fluctuation of high-frequency seismic waves in the surrounding area of the epicenter (distance > 40 km).

Keywords: High-frequency seismic ground motion, Amplitude fluctuation, Random crustal heterogeneity, Conrad discontinuity, Seismic ground motion simulation

