A numerical study on P-wave travel time fluctuation and amplitude fluctuation in the short-wavelength inhomogeneous crustal structure

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It is considered that short-wavelength crustal inhomogeneity causes travel time fluctuation and amplitude fluctuation [e.g., Yoshimoto *et al*. (2015)] of high-frequency (> 1 Hz) seismic waves of local earthquakes. However, the characteristics of these phenomena have not yet been fully studied compared to those of teleseismic P-waves [e.g., Butler (1989)]. Thus, we conducted a numerical study on P-wave travel time fluctuation and amplitude fluctuation in the inhomogeneous crustal structure based on 3D FDM simulations.
We conducted 3D FDM simulations for P-wave propagation in different random inhomogeneous media constructed by assuming Birch's law and exponential-type randomness with the correlation distance of 1, 3, and 5 km and the fractional fluctuation of 0.01, 0.02, 0.03, 0.04, and 0.05. Uniform background seismic velocities were assumed to be 6.0 km/s and 3.5 km/s for P wave and S wave, respectively. The medium volume of 204.8×204.8×204.8 km^3 was discretized by a uniform grid spacing of 0.05 km. A double-couple point source of pure strike-slip with an asymmetric cosine source-time function [Ji *et al*. (2003)] with t_s=0.1 s and t_e=0.4 s was set at the center of the model volume. Other technical details are the same as those of Takemura *et al*. (2017). Synthetic velocity seismograms were calculated for stations that were uniformly distributed in the source depth at a grid interval of 2 km. Using simulated seismograms at hypocentral distances less than 60 km, we picked P-wave arrival times (travel times) using an automatic phase-time picker [Maeda (1985)], and measured the maximum amplitudes of filtered seismograms in the passbands of 1-2, 2-4, and 4-8 Hz using a 1 s time window from the P-wave onset.
Simulation results show that the travel time fluctuation of P waves increases as the correlation distance and the fractional fluctuation of inhomogeneous media increase. As for the parameter range in our simulations, observed dependency was much more clear for the variation of correlation distance. In the case of our simulation using an inhomogeneous crustal structure model of southwestern Japan [Kobayashi *et al*. (2015); (correlation distance, fractional fluctuation) = (1 km, 0.03)], simulation results showed that travel time fluctuation is about 0.1 s at a hypocentral distance of 50 km. This result implies that the travel time fluctuation due to random inhomogeneity may decrease the accuracy of hypocentral determination of local earthquakes.
Our analysis showed that the travel time fluctuation and the amplitude fluctuation have positive correlation. This indicates that the amplitude of P-waves tends to be small for faster arrival and oppositely to be large for later arrival. This tendency was much clearly observed at low frequencies, and observed for the P-wave propagation in the random inhomogeneous media with large correlation distance and fractional fluctuation. The aforementioned our results imply that velocity perturbation on and around the wave propagation path from the source to receiver affects travel time and also causes focusing and defocusing effects which alter the amplitude of observed P waves.

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