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Effect of seismic wave scattering due to the heterogeneous topography on the high-frequency seismic wavefield

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Introduction

High-frequency seismic wavefield would be significantly affected by the seismic wave scattering due to small-scale heterogeneity in the lithosphere and heterogeneous surface topography. In order to reproduce and understand the characteristics of the high-frequency wavefield, the detail distributions of small-scale heterogeneity are required [e.g. Takahashi et al., 2009]. In previous our works, we conduct FDM simulation and compare these results with observed feature derived from dense seismic array [e.g. Takemura et al., 2009; Takemura and Furumura, 2010 SSJ]. In this study, we conduct FDM simulation for seismic wave propagation including surface topography. We compare the both effects of seismic wave scattering due to topography and small-scale heterogeneity using each simulation result.

FDM Simulation including heterogeneous topography

Our simulation model covers a zone 128 km by 128 km by 64 km, which has been descretized with grid size 0.1 km in horizontal direction and 0.05 km in vertical direction. In order to conduct such large scale simulations, we use a parallel staggered-grid FDM simulation technique. We assume the heterogeneous surface topography using the 50 m mesh topography data provided by the Geospatial Information Authority of Japan. In order to include the effect of seismic wave scattering due to small-scale heterogeneity, we also assume the stochastic random heterogeneity characterized by exponential auto-correlation function with correlation distance a = 5km and rms value e = 0.05.

We put the explosion (P-wave) source at the center of model, depth h = 10 km. In the case of homogeneous media, P-wave amplitude can be observed in the radial and vertical components only. However, in the case of heterogeneous media, P-wave amplitude would be observed in transverse (T) component due to seismic wave scattering and diffraction. Therefore some researchers have estimated the structure of small-scale heterogeneity using the P-wave amplitude of T component [e.g. Kubanza et al., 2007; Takemura and Furumura, 2010 SSJ]. In this study, using simulated three component waveforms, we examine the P-wave Energy Partition (EP), which is evaluated as the ratio mean P-wave energy of T component to sum of all components. We compare P-wave EP value as a function of distance for each simulation result.

Simulation results

We conduct FDM simulation for seismic wave propagation in the three models, 1) flat surface model with stochastic random structure, 2) uniform velocity structure model with surface topography and 3) uniform back ground velocity model with both heterogeneities. In the model 1, P-wave EP increases with increasing distance, at 50 km, P-wave EP is 005. On the other hand, in the model 2, P-wave EP value is 0.02 on overall distance. In the model 3, the P-wave EP value increases by the effect of both heterogeneities and at 50 km it is 0.07. This values is corresponding to the observed EP value at Chugoku Shikoku region.

In the FDM simulation for the high-frequency seismic wavefield, we should include the surface topography effect on the seismic wavefield.

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Keywords: Seismic wave propagation, body wave, seismic wave scattering, numerical simulation, surface topography