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Effect of complex surface topography on the distortion of the apparent S-wave radiation pattern

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Introduction

In the high frequency (f > 1 Hz), the observed maximum amplitude pattern don't show clear four-lobe pattern expected from a double-couple source [e.g. Liu and Helmberger, 1985; Takemura et al., 2009]. By analyzing a large number waveform data, Takemura et al. (2009) concluded that the main reason of such distortion is the seismic wave scattering due to small-scale velocity fluctuation in the medium. However, the resent studies revealed that the scattering due to irregular topography is also important for the propagation of high-frequency seismic waves. In order to clarify the effect of irregular surface topography on the distortion of the apparent S-wave radiation pattern, we conduct FDM simulations of seismic wave propagation in the model including topography.

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 model provided by Geospatial Information Authority of Japan. In order to achieve precise simulation of high-frequency wave propagation, we employ the suitable boundary condition at the free surface [e.g. Okamoto and Takenaka, 2005; Maeda and Furumura, 2011].

We also assume the stochastic random heterogeneity characterized by exponential auto-correlation function with correlation distance a = 5km and rms value e = 0.05 and compare scattering properties of both heterogeneities. We assume a pure-strike slip at the center of model, depth h = 5 km, and so expected apparent S-wave radiation pattern at the free surface is a four-lobe shape

Simulation results

We conduct FDM simulation of seismic wave propagation in the three models, 1) uniform velocity structure model with surface topography, 2) flat surface model with stochastic random velocity fluctuation and 3) uniform back ground velocity model with both heterogeneities. We examine the maximum amplitude pattern of mean square envelopes for the sum of three components in frequency band of 2-4 Hz.

In the model 1, the amplitude pattern shows the four-lobe pattern maintains a four-lobe pattern, although the amplifications due to topography occur at the mountain regions. On the other hand, in the model 2, the effects of diffraction and scattering due to velocity fluctuation are accumulated during propagation and at larger distance (D> 30 km) the amplitude pattern is clearly collapsed from four-lobe pattern. In the model 3, the distortion become 11% stronger compared with the model 2 which is including velocity fluctuation alone.

Takemura et al. (2009) estimated the parameters of velocity fluctuation in the southwestern Japan by comparison of observation and simulation including velocity fluctuation alone. Therefore the estimation of velocity heterogeneities may be overestimated by the effect of irregular topography. We may be able to estimate the velocity fluctuation more precisely by considering the effects of irregular topography.

Acknowledgement

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Keywords: Seismic wave propagation, Seismic wave scattering, Small-scale heterogeneity, topography, numerical simulation