Japan Geoscience Union Meeting 2010
(May 23-28 2010 at Makuhari, Chiba, Japan)

SSS018-08 Room: IC Time: May 25 14:00-14:15

Characteristics of the high-frequency P-wave propagation thorough the heterogeneous crust and upper mantle

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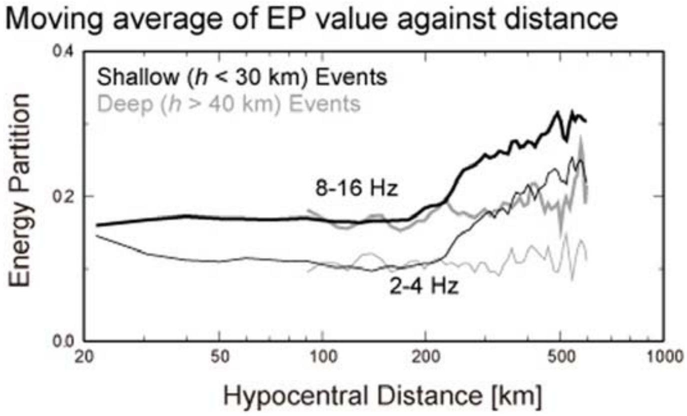

Introduction

High-frequency seismic wavefield is significantly different from low-frequency wavefield due to seismic wave scattering caused by small-scale heterogeneities in the curst and mantle. For example, Nishimura et al. (2002) and Kubanza et al. (2007) reported that, in high frequencies, P-waves amplitudes are observed in transverse (T) component and this feature reflects the inhomogeneity in the media.
In order to construct the heterogeneous model of the crust and upper mantle, we analyze frequency- and distance-change properties of P-wave amplitudes in T component using large number records observed around Japan.

Data and Method

We use the Hi-net velocity waveform data derived from shallow (h < 30 km) crustal earthquakes with M_{JMA}2-5.3 occurred around Japan. Analytical methods are following; we apply band-pass filter into each waveform with 1-2, 2-4, 4-8, 8-16, 16-32 Hz and synthesize envelope of each component by using Hilbert transform. Mean P-wave energies of each component are calculated for 3 sec window from 1sec prior to P-wave onset and then energy partition (EP) is evaluated as the ratio mean energy of transverse component to sum of all components. In this study, we analyze 53220 waveform data from 310 small earthquakes. In addition, to compare the results from shallow events with deep events, we also analyze 3957 waveform data from 14 deeper (h > 40 km) events.

Result

Figure shows the moving average of EP values against distance. At hypocentral distance 50-150 km, EP values increase with increasing frequency and are independent of hypocentral distance. However, at hypocentral distance over 150 km, EP value is not only dependent on frequency but also hypocentral distance. In high frequencies (8-16 Hz), especially, EP values at over 300 km asymptotically reach from 0.2 to 0.33, i.e. equi-partition of P-wave energy into three components at large distance.
Using data from events located at deeper than Moho depth, EP values increase with increasing frequency and are independent of distance (gray lines in figure). Therefore, we suggest that in the case of shallow events, distant change properties of EP value at distance over 150 km is caused by propagation features of Pn-phase. In addition, cause of frequency change property of EP values would be seismic wave scattering due to samll-scale heterogeneity in the crust and upper mantle.

FDM Simulation

In order to construct the heterogeneous structure model which can reproduce observed features, we conduct 3-D FDM simulations using stochastic random media. The 3-D model covers a zone 409.6 km by 102.4 km by 64.0 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 [Furumura and Chen, 2004]. The heterogeneous models of small-scale heterogeneity in the crust and upper mantle are constructed by velocity fluctuation g(x) from average velocity V_0. The fluctuation g(x) is statistically characterized by the correlation length a and the rms value e. Here, we employ exponential-type auto-correlation function (ACF) to characterize the property of g(x).

We conduct FDM simulations of shallow earthquake using IASP 91 [Kennett and Engdahl, 1991] with a = 5km, e = 0.07 in the crust and a = 10 km, e = 0.04 in the upper mantle. The simulation results can reproduce frequency- and distant-change properties of EP value derived from shallow events. It indicates that distant change property of EP values is mainly caused by difference of scattering properties between direct-P and Pn-phases. However, EP values from our simulations are smaller than observed EP values and so we should conduct simulations using other heterogeneous models which include complex topography and more realistic background velocity structures.

Keywords: body wave, seismic wave scattering, seismic wave diffraction, crust, upper mantle, computer simulation