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Spatial distribution of random inhomogeneities revealed from the inversion of peak delay time of S-wave in northeastern Japan

Tsutomu Takahashi[1]; Haruo Sato[1]; Takeshi Nishimura[1]; Kazushige Obara[2]

[1] Geophysics, Science, Tohoku University; [2] NIED

High-frequency seismic wave envelopes (higher than 1Hz) propagating through inhomogeneous media are broadened as travel distance increases. Previous studies of envelope broadening in northeastern (NE) Japan [Obara and Sato (1995), Saito et al. (2001)] reported that S-wave envelopes are broadened more significantly for higher frequency especially in the back-arc side of the volcanic front. Recently, from the detailed classification of S-wave envelopes in NE Japan, we found that the envelope broadening indicates a clear path-dependence along the volcanic front. We simulate the propagation of spherical waves impulsively radiated from a point source in spatially non-uniform random media, and analyze the peak delay time which is measured from the S-wave onset to the maximum amplitude arrival to reveal the spatial distribution of power spectral density function (PSDF) of random inhomogeneities. We here report the inversion results and the relation between the random inhomogeneities and other seismological observations such as velocity structure, apparent attenuation and seismicity.

The peak delay times in 4-8Hz, 8-16Hz and 16-32Hz bands generally increase with travel distance and frequency increasing. In NE Japan, the peak delay times for earthquakes occurred around subducting Pacific plate indicate the following path-dependence; (1) in the fore-arc side, peak delay times are generally small and indicate little frequency dependence, (2) in the back-arc side, larger values are observed in higher frequencies if waves propagate beneath Quaternary volcanoes, on the other hand, waves propagating through only non-volcanic area show small peak delay times for all of the frequency bands, (3) the waves propagating around western Hidaka, Hokkaido show large peak delay times for all of the frequency bands. We constructed an inversion of peak delay time assuming von Karman type PSDF. From this inversion, we can estimate the spatial distribution of the spectral decay at large wavenumber and the PSDF level at lower wavenumber. If the decay rate of PSDF is small, the peak delay time strongly depends on frequency. At the depth of 20-40km beneath Quaternary volcanoes, PSDFs in large wavenumber are significantly larger than those of their surrounding regions, and their spectral decay are also significantly small. Beneath western Hidaka region, PSDF in large wavenumber is quite larger than those in its surrounding areas even though the spectral decay doesn't show significant difference. At the depth of 40-60km, PSDFs in large wavenumber are large in the following regions; Hakkouda-Iwate, Zao-Bandai and Nikko.

The regions having large PSDFs beneath Quaternary volcanoes show good correlation with high-Vp/Vs regions revealed by travel time tomography [Nakajima et al. (2001)]. These high-Vp/Vs regions beneath Quaternary volcanoes imply the existence of partially molten material or fluid [Hasegawa and Nakajima (2004)]. These molten materials and fluid may generate large velocity inhomogeneities. At the depth of 20-40km, apparent attenuation [Sekine et al. (2004)] is strong in the most parts of the back-arc side. On the other hand, large PSDF regions appear only beneath the Quaternary volcanoes on the volcanic front. Even though we need to consider frequency dependence of apparent attenuation, this significant difference with our result implies that intrinsic attenuation may be large in the most of the back-arc side and strong scattering attenuation occurs beneath Quaternary volcanoes. Most of the western Hidaka region which shows large PSDF at 20-40km depth corresponds to high seismicity region. This relation implies that cracks made by earthquakes generate the spatial fluctuation of effective elastic modulus which may cause strong scattering.