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Scattering and intrinsic attenuation in Kyushu

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Attenuation of seismic wave energy is caused by two factors: scattering and intrinsic absorption. The former is the scattering of seismic wave energy due to random heterogeneities in seismic wave velocity and the density of the medium, while the latter is the conversion from seismic wave energy to heat energy by internal friction due to anelasticity of the medium. Quantifying scattering and intrinsic attenuation is important to understanding the structure of the lithosphere in terms of seismotectonic features.

We separately estimate scattering and intrinsic attenuation by applying the multiple lapse time window analysis (MLTWA) technique [Hoshiba et al., 1991]. This technique is based on a comparison between observed and calculated seismic wave energy density obtained using radiative transfer theory in several successive lapse time windows. In the present study, we measure the integrated seismic wave energy as a function of distance and frequency for three consecutive time windows with a length of 15 s following the S-wave onset. The window length is chosen in such a way that the first window contains a significant contribution of the direct S-wave energy and the last two windows mainly contain the contribution of the scattered energy. The observed energy is calculated in three steps. First, we filter the waveforms using a third-order Butterworth band-pass filter at the following frequency bands: 1-2, 2-4, 4-8, 8-16, and 16-32 Hz. Second, we obtain the envelopes by taking the sum of squares sum of the three-component amplitudes of filtered waveforms. Third, we integrate the root mean square amplitude of the envelopes in the three time windows. By comparing the observed and calculated energy distributions in terms of the misfit function, we obtain the best pair of scattering and intrinsic attenuation. We use the Lavenberg?Marquard algorithm, a non-linear least squares fitting procedure, to find the minimum of the misfit function.

We estimate the scattering and intrinsic attenuation in Kyushu, which is the site of active volcanoes and seismic activity within the Beppu-Shimabara rift valley and elsewhere. We collect waveform data from the Hi-net network operated by NIED. During the period from 2004 to 2014, we choose 180 earthquakes with magnitudes (Mjma) of 0.5-3.5 and with depths of $<$20 km. We select event station pairs with epicentral distances of $<$100 km recorded at 78 Hi-net stations.

In all the studied area, intrinsic absorption dominates over scattering loss at low frequencies (1-2 Hz), whereas scattering loss predominates at high frequencies (16-32 Hz). The results show strong spatial variations in scattering and intrinsic attenuation that depend mainly on the tectonic setting. For frequencies of 1-2 Hz, areas with strong scattering loss correspond mainly to the locations of the volcanoes, while areas with strong intrinsic absorption correspond to the locations of volcanoes and active faults, which are marked by low-velocity anomalies.

Keywords: crust, scattering attenuation, intrinsic attenuation