Isotropic radiation of *S* waves at volcanoes revealed by numerical simulations of high-frequency scattered wavefields

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Volcanoes have highly heterogeneous structures, which produce scattered seismic wavefields in seismic wave propagation. At many volcanoes, the amplitude source location (ASL) method has been used to locate volcano-seismic events and tremor. The ASL method uses high-frequency seismic amplitudes under the assumption of isotropic radiation of *S* waves. This assumption has been interpreted to be valid in a high-frequency band because of the path effect caused by the scattering of seismic waves. *Kumagai et al*. [JGR, 2011] simulated seismic waveforms in heterogeneous medium with topography to investigate the validity of this assumption. However, they could not reproduce isotropic radiation and suggested that strong short-scale structural heterogeneity is required to achieve isotropic radiation. To validate the isotropic radiation assumption and to investigate the characteristics of scattered seismic wavefields at volcanoes, we performed numerical simulations of high-frequency seismic waveforms with stronger heterogeneous media. We synthesized seismic waveforms with a 3-D finite-difference method at Taal volcano, Philippines. We used topography of this volcano and heterogeneous structural models characterized by von Karman-type power spectral density function (PSDF). We used the correlation distance (a) in a range between 50 and 1000 m and the root-mean-square amplitude of velocity fluctuation (ε) between 0.05 and 0.2, in which a constant value of 0.5 for $\kappa$was used. To test isotropic *S* wave radiation, we used synthetic seismograms at actual station locations to determine the source location using the ASL method in various frequency bands (0.2-2, 1-6, 3-8 and 5-10 Hz). We found that the source location was determined near the input location when using a = 50 m and ε= 0.2 in a frequency band of 5-10 Hz. In this condition, ka is around 1 and the mean free path is about 1500 m, where k is wavenumber. This mean free path is similar to those estimated at volcanoes, which are around 1000 m [e.g., Yamamoto and Sato, JGR, 2010]. Our study strongly supports that isotropic *S* wave radiation is achieved by the path effect caused by seismic scattering in heterogeneous media similar to actual volcanoes.

Keywords: Scattering, Volcano, Isotropic radiation of S waves, Amplitude source location method, Finite-difference method

