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Mode conversion and energy partitioning of elastic waves in a heterogeneous half-space

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Small-scale inhomogeneity beneath active volcanoes is closely related to the existence of volcanic fluids and fractures, and the quantification of such inhomogeneity may provide us important information on the various volcanic processes. So far, we have been studying mode conversion and multiple scattering of seismic energies at shallow volcanic structure of Asama volcano and Aso volcano using observed spatio-temporal distributions of propagating energy from artificial sources and quantifying the scattering parameters (e.g., Yamamoto and Sato, 2010). However, in these studies, we assumed multiple isotropic scattering and mode conversion in an infinite space, and used an analytic solution derived from the radiative transfer theory. So, the effects of the free surface and non-isotropic scattering remain as issues to be addressed.
In this study, we examine the effects of the free surface and non-isotropic scattering through the modeling of multiple scattering and mode conversion in a half space using the finite difference and Mote Carlo methods. Based on the results of numerical modeling, we also examine the temporal change of P/S energy ratio observed by an array observation at Sakurajima volcano. In the numerical modeling, we consider 2D and 3D random media having relatively strong inhomogeneity relevant to volcanic environment, and assume the media is statistically characterized by the Gaussian auto-correlation function. For the finite difference modeling, we use a parallel time domain finite difference code we implemented, and compute MS envelopes by averaging envelopes obtained with different realizations of media. For the Monte Carlo simulation, we follow the method of Margerin et al. (2000), and assume that each scattering process has a radiation pattern derived from Born approximation. We also use the transmission coefficient of plain incident energy at the free surface.
Temporal changes in the ratio of P and S energies obtained by these two numerical modeling indicate that the rate of energy ratio change and time duration needed to establish local equipartition strongly depend on the non-isotropy of the scattering process, although overall characteristics of energy partitioning is similar to that of multiple isotropic scattering case. This result may reflect the fact that local equilibration process depends on the amount of energy flux from the vicinity of source where S energy is strongly trapped due to the multiple scattering, and thus the difference in forward scattering strength mainly control the equilibration time. The characteristics of numerical results seem to be consistent with the observation at Sakurajima that energy ratio changes more rapidly than that expected from the multiple isotropic scattering at early stage of transition, and indicates the contribution of non-isotropic scattering.
These results suggest that observation of mode conversion as well as spatio-temporal distribution of energy is a useful method to understand small-scale heterogeneity like existence of volcanic fluids and fractures in volcanic environments.

Keywords: Seismic wave propagation, Seismic wave scattering, Volcano structure