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Radiative Transfer Theory for a Random Distribution of Low-Velocity Spheres

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Short-period seismograms of earthquakes are complex because of scattering caused by distributed heterogeneities; however, their smooth amplitude variation makes the radiative transfer theory (RTT) useful. Especially beneath volcanoes, we know scattering of seismic waves is very strong and we may expect the presence of fluid bodies, in which the velocity is much lower than that of surrounding rocks. Low velocity bodies function as strong resonant scatterers for seismic waves, and they can trap and release wave energy with a time lag. If the mean free time is short, we cannot ignore such a time delay effect; however, the conventional RTT is applicable to the instantaneous scattering only. Here, we focus on resonant scattering of scalar waves by low velocity spheres of the same size, where scattering is isotropic at low frequencies. In order to describe the time delay effect, we calculate the deconvolution of the MS amplitude of scattered wavelet by the MS amplitude of an incident plane wavelet, and define it as the time derivative of the total scattering cross section. Thus, we write the scattering process as a convolution in time. For the incidence of a band-limited delta function plane wavelet, the convolution kernel is an exponential decay function. We further calculate convolution kernels for scattering processes of higher orders. Next, we build up the propagator for the MS amplitude by using causality, a geometrical spreading factor and the scattering loss calculated from the time integral of the convolution kernel for each order of scattering. Then, using those propagators with convolution kernels, we formulate the RTT for a spherical source radiation in a random and uniform distribution of many low velocity spheres of the same size. Synthesized MS amplitude has a delayed peak after the direct arrival in the time domain. Synthesized MS amplitude shows a swelling near the source region in space, and it becomes a bell shape a like a diffusion solution at large lapse times. Our model is limited to isotropic resonant scattering of scalar waves so far; however, it could be a base for studying nonisotropic resonant scattering process of elastic waves. Those approaches will contribute to the physical understanding of the medium characteristics.