Scattering attenuation of elastic waves due to weak discrete inhomogeneities

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There are two major theoretical approaches for predicting seismic scattering attenuation due to the lithospheric random inhomogeneity. In one approach, inhomogeneous media are modeled by materials with randomly and weakly (usually, continuously) perturbed elastic wave velocity and density (termed random media), and the single-scattered energy due to the perturbations are evaluated on the basis of the Born approximation (Chernov 1960). Note that the perturbation is described using the autocorrelation function. In the other, the mean wave formalism is adopted for treating wave propagation within a disperse system of discrete inhomogeneities, such as inclusions and cracks. The first-order approximated solution for this problem was first obtained by Foldy (1945).

A continuous random medium appears quite differently from a disperse systems of discrete inhomogeneities. Nevertheless, one can formally describe the disperse system in terms of the autocorrelation function, and thus estimate scattering attenuation using the Born approximation. If the distribution were very sparse as well as the material contrasts between the inhomogeneities and the surrounding matrix were sufficiently low, such an approach would give a result equivalent to the Foldy-approximated solution. In our previous study (JGU Meeting 2006, S206-P005), we evaluated respectively the Born- and Foldy-approximated solutions for SH-wave scattering attenuation due to 2-D circular inclusions, and verified their coincidence under low-contrast and long-wave conditions (Rayleigh-Gans scattering regime). In this study, we make similar verification on realistic 3-D elastic wave scattering. Here we do not consider the traveltime correction as before.

We treat here randomly distributed spherical inclusions with the same size. For the spatially averaged P-wave velocity of the composite medium to be equal to the matrix P-wave velocity V_{P0}, we assume that half of the inclusions have the P-wave velocity of V_{P0} + dV_P and the rest does that of V_{P0} - dV_P, with dV_P being a small positive value. Following Sato (1984), we assume that the fractional perturbations of P-wave velocity, S-wave velocity, and density are proportional to each other. We also assume the distribution to be sufficiently sparse so as to make the Foldy approximation reliable. The computation of the scattering cross section of a spherical inclusion, necessary for evaluating the Foldy-approximated solution, is based on the formulas of Korneev & Johnson (1993). The Born-approximated counterpart is evaluated on the basis of Sato's (1984) theory, in which the autocorrelation function for spheres are taken from Stoyan et al. (1995). The two solutions are calculated for P-wave scattering attenuation, and it is shown that they highly coincide within the Rayleigh-Gans scattering regime, as was in the previous study. This coincidence is also seen respectively for P-P and P-S scattering terms in the attenuation factor, implying that the equivalence of the two solutions for weak discrete inhomogeneities is general.

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