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Simulating the whole envelope of scalar-waves in 2-D random media having power-law spectra of velocity perturbation

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During propagation through random media, impulsive waves radiated from a point source decrease in amplitude and increase their duration with increasing travel distance. The excitation of coda waves is prominent at long lapse time in media with short-wavelength heterogeneity. We compare numerical simulations of wave propagation in random media described by von Karmen autocorrelation functions of order k with those obtained from modeling techniques based on the Markov approximation and the radiative transfer theory. We develop a hybrid method for modeling regional waveforms in media with strong short-wavelength heterogeneity. Numerically simulating wave propagation of a 2Hz Ricker wavelet in an ensemble of random media (RMS fractional velocity fluctuation e = 0.05, spatial scale of inhomogeneity a = 5km and average wave velocity V = 4km/s), we got the mean square envelope from the ensemble average of squared waveforms for propagation distances out to 200 km. We examined the validity of the Markov approximation modeling method and the multiple isotropic scattering model by using the envelopes of the finite difference ensemble average envelopes as references. For smooth random media of k = 1.0, the Markov approximation method predicts excellent envelopes for all propagation distances. For rough random media of k = 0.1, the Markov approximation method cannot explain large coda-excitation, although the method well predicts the early part of the envelopes at all distances examined. The discrepancy in the coda portion is due to the disregard of wide-angle scattering in the Markov approximation. For the coda portion, mean square envelopes decrease in proportion to the inverse of the lapse time, as seen in the finite difference simulations. This feature can be predicted by the radiative transfer theory, which includes multiple isotropic scattering. The coda excitation is quantitatively well explained by using the momentum transfer scattering coefficient as the effective isotropic scattering coefficient. The multiple isotropic scattering model, however, cannot explain envelopes around the direct arrivals because of the isotropic scattering assumption. Combining the merits of the Markov approximation and the radiative transfer approach, and considering energy conservation, we propose a hybrid method for synthesizing the entire envelope, where envelopes around the direct arrivals caused by multiple forward scattering are simulated by the Markov approximation method and the coda part composed of wide angle scattering is given by the multiple isotropic scattering model with the momentum transfer scattering coefficient. The hybrid method quantitatively well explains the entire envelopes from the onset to coda for k = 0.1. For k = 0.5, smoother than k = 0.1 and rougher than k = 1.0, however, the radiative transfer theory with the momentum transfer scattering coefficient predicts more coda excitation than that of the finite difference simulations. Even in such a case, the hybrid method can explain entire envelopes by using the effective isotropic scattering coefficient estimated from coda-excitation.