THE GLOBAL SHORT-PERIOD WAVEFIELD MODELED WITH A MONTE CARLO SEISMIC PHONON METHOD

Peter Shearer, Paul Earle

At high frequencies (~1 Hz), much of the seismic energy arriving at teleseismic distances is not found in the main phases (e.g., P, PP, S, etc.) but is contained in the extended coda that follows these arrivals. This coda results from scattering off small-scale velocity and density perturbations within the crust and mantle and contains valuable information regarding the depth dependence and strength of this heterogeneity as well as the relative importance of intrinsic versus scattering attenuation. Most analyses of seismic coda to date have concentrated on S-wave coda generated from lithospheric scattering for events recorded at local and regional distances. Here we examine the globally averaged vertical-component, 1-Hz wavefield (>10 degree range) for earthquakes recorded in the IRIS FARM archive from 1990 to 1999. We apply an envelope-function stacking technique to image the average time-distance behavior of the wavefield for both shallow (<50 km) and deep (>500 km) earthquakes. Unlike regional records, our images are dominated by P and P-coda owing to the large effect of attenuation on PP and S at high frequencies. Modeling our results is complicated by the need to include a variety of ray paths, the likely contributions of multiple scattering, and the possible importance of P-to-S and S-to-P scattering. We adopt a stochastic, particle-based approach in which millions of seismic “phonons” are randomly sprayed from the source and tracked through the Earth. Each phonon represents an energy packet that travels along the appropriate ray path until it is affected by a discontinuity or a scatterer. Discontinuities are modeled by treating the energy normalized reflection and transmission coefficients as probabilities. Scattering probabilities and scattering angles are computed in a similar fashion, assuming random velocity and density perturbations characterized by an exponential autocorrelation function. Intrinsic attenuation is included by reducing the energy contained in each particle as an appropriate function of travel time. We find that most scattering occurs in the lithosphere and upper mantle, as previous results have indicated, but that some lower mantle scattering is likely also required. A model with 3% to 4% RMS velocity heterogeneity at 4-km scale length in the upper mantle and 0.5% RMS heterogeneity at 8-km scale length in the lower mantle (with intrinsic attenuation of Q\(\alpha\) = 450 above 200 km depth and Q\(\alpha\) = 2500 below 200 km) provides a reasonable fit to both the shallow and deep earthquake observations, although many tradeoffs exist between the scale length, depth extent and strength of the heterogeneity.