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The Influence of Crustal Heterogeneity on Translational and Rotational Motions using Data from Local and Teleseismic Events

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In this study we use Monte Carlo (MC) solutions to the Radiative Transfer Equations (RTE) to model translational and rotational motion seismogram envelopes in random elastic media with deterministic background structure. The observation and modeling of the three additional components of rotational motions can provide independent information about wave propagation in the Earth's structure. Rotational motions around the vertical axis observed in the P-wave coda are of particular interest as they can only be excited by horizontally polarized shear waves and therefore indicate the conversion from P to SH energy by multiple scattering of the high-frequency seismic wave field at 3D heterogeneities.
Radiative Transfer Theory (RTT) is used to model the propagation of seismic energy in a deterministic structure described by macroscopic medium properties with statistically distributed small scale heterogeneities. It describes the spatial and temporal distribution of seismic energy emitted from a seismic source. The central quantity of the RTT, the specific intensity $I(n, r, t)$, is modeled by a number density of particles $N(n, r, t)$ located at position r and moving into direction n at time t. Particles can experience scattering processes at medium heterogeneities that are described by the Born scattering coefficients. This processes include mode conversion and a change of propagation direction. When no scattering events occur particles move through the medium according to ray theory including the interaction with interfaces (reflection, transmission, mode conversions). Using projections of $I(n, r, t)$ onto specific directions we can simulate the three rotational components of the wave-field in a random elastic medium additional to the translational components.
The MC-RTT simulation results are verified by comparisons with 3D finite difference simulations. Six-component envelopes from the two approaches are compared and a reasonable agreement for translational and rotational energy is obtained.
To investigate crustal scattering and attenuation parameters in South-East Germany beneath the Gräfenberg array, multi component seismogram envelopes from Monte Carlo Radiative Transfer Theory simulations are compared to reference traces from seismic data of local swarm-earthquakes and of deep teleseismic events. In the local case a nonlinear genetic inversion process is used to estimate scattering and attenuation parameters at high frequencies (4-8Hz) that result in energy density traces that fit the measured local reference seismogram envelopes. Our preferred model includes crustal heterogeneities with velocity fluctuations ϵ in the range of 3%, autocorrelation lengths a in the order of a few hundred meters and an intrinsic quality factor for S-waves $_sQ_i$ of 625. In a second step simulations using this estimated set of scattering and attenuation parameters are compared to envelopes of P-wave Coda from deep teleseismic events. Results from the local and teleseismic simulations with consistent parameters both show a good agreement with data.
We therefore conclude that scattering in this region also the scattering that generates the teleseismic P-wave coda is mainly confined to the crustal part of the lithosphere beneath the sensor. Our observations do not require scattering in the upper mantle, but weak scattering in the lithospheric mantle cannot be ruled out.