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The Radiative Transfer Approach to Rotational Motions – Estimation of Crustal Scattering Parameters

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Monte Carlo solutions to the Radiative Transfer Equations are used to model translational and rotational motion seismogram envelopes in random elastic media. Crustal attenuation and scattering parameters are estimated in a nonlinear inversion process.

High amounts of rotational energy can be measured in the seismic wave-field excited by earthquakes or even by ambient seismic noise sources. The observation of these three additional components of rotational motions can provide independent information about wave propagation in the Earth's structure. In particular the rotational motions around the vertical axis recorded in the P-wave coda carry interesting information as they can only be excited by multiple scattering of seismic waves at 3D heterogeneities. As rotational motions in the bulk can only be excited by shear waves, they clearly indicate the conversion scattering from P to S energy in the high-frequency seismic wave-field.

In this study Radiative Transfer Theory (RTT) is used to model the propagation of seismic energy in a deterministic structure described by macroscopic medium properties. Additionally the structure contains statistically distributed small scale heterogeneities. RTT describes the spatial and temporal distribution of seismic energy emitted from a seismic source. The central quantity of the RTT, the specific intensity $I(r,t)$, is modeled by a number density of particles $N(n,r)$ moving into direction n and located at position r. Particles can experience scattering processes at medium heterogeneities that are described in the Born approximation. 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. This includes the interaction with interfaces (reflection, transmission, mode conversions). This way seismogram envelopes for the three translational and the three rotational components of the wave-field in a random elastic medium are simulated.

The results of the MC-RTT simulations are verified by comparisons with 3D finite difference simulations. Six-component seismogram envelopes from the two different approaches are compared and a reasonable agreement for both translational and rotational energy is obtained.

In a real data application regional swarm-earthquakes will be used to calculate reference seismogram envelopes for different epicentral distances. A nonlinear inversion process will be used to estimate attenuation and scattering parameters that result in energy density traces that fit the measured reference seismogram envelopes.

In conclusion, the RTT allows to model six-component seismogram envelopes of the high frequency wave-field from the initial P-wave onset to the later parts of the S-wave coda in random elastic media.