Geophysical Research Abstracts,
Vol. 10, EGU2008-A-11167, 2008
SRef-ID: 1607-7962/gra/EGU2008-A-11167
EGU General Assembly 2008
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Modelling of seismic waves scattered at small-scale structures using the Born approximation

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Scattered seismic waves in the coda after direct seismic body or surface waves allow inferences on small-scale perturbations in the propagation medium. Such inferences are of interest in technical applications like underground excavation and mining but also in exploration seismics and seismology. We have developed a flexible, parallelized algorithm based on the Born approximation that allows the modelling of seismic waves scattered at local small-scale structures. It can be applied to scattering problems on spatial scales from meters to hundreds of kilometers. In addition, scattering calculations can be performed in cartesian or spherical coordinates.

The scattering structures are implemented as localized perturbations of the elastic parameters of a suitable background model. Both the exciting waves travelling from the seismic source to the scatterer and the scattered waves propagating from the scatterer to the receiver are calculated using an exact Green's tensor for the background model. Different shapes of scattering volumes can be realized by a tessellation of the volume. For the application of the Born scattering approach in spherical coordinates a transformation to a global cartesian coordinate system and a subsequent backtransformation to spherical coordinates is performed. The total wavefield is the sum of the direct wavefield in the background model and the scattered wavefield. We currently work with 1D-background media and use a method derived from the GEMINI code to calculate 1D-Green's tensors (Friederich \& Dalkolmo, 1995). However, the Born scattering algorithm has been designed to be independent of the particular Green's tensor used and thus also allows for numerically calculated Green's tensors for 3D-background media.

To test the accuracy of the Born approach we used a parallel elastic 2-D/3-D finite-difference code (Bohlen, 2002) to model wave propagation in 2-D and 3-D coal seam models containing different small-scale perturbations (Essen et al., 2007). Comparison with seismograms calculated with our Born approximation algorithm shows a good agreement if an appropriate grid spacing is chosen for the tessellation. The Born seismograms show a clear convergence as the size of the tetrahedra is decreased. We found a grid spacing of about 1/8-th of the dominant wavelength sufficient to achieve a satisfactory accuracy.

We also present scattering calculations performed in a spherical background medium with perturbations on the 10 km scale. We intend to use these calculations to search for small-scale structures in the Hellenic subduction zone with focus on the vicinity of the plate contact and the mantle wedge below the volcanic arc. An inversion algorithm is to be developed, that allows to localize small-scale structures and to determine perturbations of the elastic material properties.