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Modularized seismic full waveform inversion based on waveform sensitivity kernels - The software package ASKI

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We present a seismic full waveform inversion concept for applications ranging from seismological to enineering contexts, based on sensitivity kernels for full waveforms. The kernels are derived from Born scattering theory as the Fréchet derivatives of linearized frequency-domain full waveform data functionals, quantifying the influence of elastic earth model parameters and density on the data values. For a specific source-receiver combination, the kernel is computed from the displacement and strain field spectrum originating from the source evaluated throughout the inversion domain, as well as the Green function spectrum and its strains originating from the receiver. By storing the wavefield spectra of specific sources/receivers, they can be re-used for kernel computation for different specific source-receiver combinations, optimizing the total number of required forward simulations.

In the iterative inversion procedure, the solution of the forward problem, the computation of sensitivity kernels and the derivation of a model update is held completely separate. In particular, the model description for the forward problem and the description of the inverted model update are kept independent. Hence, the resolution of the inverted model as well as the complexity of solving the forward problem can be iteratively increased (with increasing frequency content of the inverted data subset). This may regularize the overall inverse problem and optimizes the computational effort of both, solving the forward problem and computing the model update. The required interconnection of arbitrary unstructured volume and point grids is realized by generalized high-order integration rules and 3D-unstructured interpolation methods. The model update is inferred solving a minimization problem in a least-squares sense, resulting in Gauss-Newton convergence of the overall inversion process.

The inversion method was implemented in the modularized software package ASKI (Analysis of Sensitivity and Kernel Inversion), which provides a generalized interface to arbitrary external forward modelling codes. So far, the 3D spectral-element code SPECFEM3D (Tromp, Komatitsch and Liu, 2008) and the 1D semi-analytical code GEMINI (Friederich and Dalkolmo, 1995) in both, Cartesian and spherical framework are supported. The creation of interfaces to further forward codes is planned in the near future. ASKI is freely available under the terms of the GPL at www.rub.de/aski . Since the independent modules of ASKI must communicate via file output/input, large storage capacities need to be accessible conveniently. Storing the complete sensitivity matrix to file, however, permits the scientist full manual control over each step in a customized procedure of sensitivity/resolution analysis and full waveform inversion.

In the presentation, we will show some aspects of the theory behind the full waveform inversion method and its practical realization by the software package ASKI, as well as synthetic and real-data applications from different scales and geometries.