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Simultaneous inversion for anisotropic and structural crustal properties by stacking of radial and transverse receiver functions

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The well-known H-κ-stacking method of Zhu and Kanamori (2000) has developed into a standard tool to infer the thickness of the crust, H, and the average P to S-wave velocity ratio, κ. The stacking approach allows for the largely automated analysis of teleseismic waveforms recorded in the distance range between 30° and 95°. Here, we present an extension of the method to include the inversion for anisotropic crustal properties. For a single anisotropic crustal layer, this involves the computation of delay times and amplitudes for 20 P-to-S converted phases and their crustal reverberations, instead of (up to) five phases in the isotropic case (Kaviani and Rümpker, 2015). The delay times and amplitudes exhibit a complex dependency on slowness and backazimuth. They can be calculated semi-analytically from the eigenvalues and eigenvectors of the system matrix, as defined by Woodhouse (1974). A comparison of the calculated delay times and amplitudes with those obtained by similar methods (Frederiksen and Bostock, 2000) shows a very good agreement between the results.

In our approach, the crust exhibits hexagonal anisotropy with a horizontal symmetry axis, such that the anisotropic properties are defined by two parameters: the orientation of the symmetry axis w.r.t. North, ϕ, and the percentage of anisotropy, a. The inversion, thus, involves a grid search in a 4-dimensional parameter space (H, κ, ϕ, a) and the stacking of both radial and transverse receiver functions. Known input parameters are the average P-wave velocity of the crust, and the slowness vector (as given by the event-receiver configuration and a global 1D-velocity model). The computations are performed by the new software package AnStack which is based on MATLAB.

Synthetic test show that the extended anisotropic stacking has advantages compared to the conventional H-κ stacking as it may allow for inversions at even higher noise levels. We further test for the effect of the azimuthal distribution of events on the results. It turns out, that the orientation of the symmetry axis is most sensitive to limitations and gaps in the azimuthal distribution. The extended stacking method provides an average model of the anisotropic crust below a station. Therefore, internal (vertical) variations cannot be resolved. Complex structures, which differ from the assumed single-layer model, will also affect the results. For example, an inclination of the layer boundary may cause an apparent anisotropic effect. We will also show examples for the application of the method to recently obtained data sets.