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# Observation and modelling of P-wave polarization for teleseismic events

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P-wave polarization may yield valuable information on lateral heterogeneity and anisotropy of the crust and uppermost mantle. Using 20 years of the Gräfenberg (GRF) array data we show that stable measurements of P-wave polarization attributes - azimuthal deviation and incidence angle - may be obtained by automated data processing. The P-wave polarization at the GRF array is frequency dependent and a function of backazimuth. By applying harmonic analysis, properties of the 180° and 360° periodicities of azimuthal deviation and incidence angle as a function of backazimuth are quantified. The observations point to the presence of azimuthal anisotropy and lateral heterogenetiy in the crust and uppermost mantle in the vicinity of the stations. The fast propagation direction of P-waves and lateral velocity gradients of P-wave velocity may be estimated based on results of the harmonic analysis. For the GRF array the fast direction of P-wave propagation is found to be about 20° in the frequency range from 0.03 to 0.1Hz that is mainly sensitive to the lower crust and the uppermost mantle. At higher frequencies from 0.1 to 0.5 Hz, mainly related to the upper crust, the variability is larger with a predominant direction of fast P-wave propagation of about 100°.

In order to investigate the sensitivity of P-wave polarization to azimuthal anisotropy quantitatively, full waveform forward modellings are performed using 3D Elastic Ray-Born Modelling.
Ray and ray-Born techniques have proven their importance in seismology as all travel time tomography is based on ray tracing and all finite frequency travel time and amplitude kernels are based on ray-Born theory. Moreover ray and ray-Born methods are relatively fast and specifically valid at high frequencies. Thus these methods complement the finite-difference and spectral-element full waveform modelling methods .

The actual implementation is done using an isotropic background medium with an anisotropic medium perturbation characterized by the 3 Thomsen parameters (which were originally developed for use in hydrocarbon exploration). The ray tracing through the background model is done using 4th order Runge-Kutta and the background model maybe 1D or 3D. Kinematic ray tracing is used for the computation of the travel times and dynamic ray tracing is used for the computation of the amplitudes.

In our numerical examples we use a velocity model with a horizontal size 2000 km and depth 1000 km. The background model is a smoothed version of PREM. The 3D anisotropic perturbation has a Gaussian shape and is placed 30 km below the receiver. The modelling is done for earthquakes located within an annulus around the receiver. The inner radius of the annulus is 1400 km and its outer radius is 1900 km. All three components of the seismograms have been computed and are shown. These seismograms are used to perform a synthetic polarization analysis of the P-phase. The effects of the strength, depth and horizontal location of the anisotropic perturbation are investigated. Finally, we compute and show sensitivity attributes for the polarization parameters.