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Illuminating heterogeneous anisotropic upper mantle: testing new anisotropic teleseismic body wave tomography code - part I: Forward mode

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Considering only isotropic wave propagation in teleseismic tomography studies and neglecting anisotropy is a simplification obviously incongruent with current understanding of the mantle-lithosphere plate dynamics. Furthermore, in solely isotropic high-resolution tomography results, potentially significant artefacts (i.e. amplitude and/or geometry distortions of 3D velocity heterogeneities) may result from such neglect. We have undertaken to develop an anisotropic version of frequently used isotropic teleseismic tomography code (TELINV), which will allow us to invert simultaneously for coupled isotropic-anisotropic P-wave velocity models. In the first step, we test the forward mode of the new code by calculating travel times of teleseismic body waves propagating through an anisotropic heterogeneous model of the upper mantle. The forward mode itself shows how specific heterogeneous anisotropic structure projects into P-wave travel times, particularly into directional variations of travel time residuals, which are presented by P-residual spheres showing the directional terms of relative residuals. This step further allows to investigate the trade-off between effects of P-wave anisotropy and isotropic heterogeneities.

We present plots of synthetic P-residual spheres calculated for P waves propagating through several synthetic models of the upper mantle. The models are designed to represent schematically different structures of the upper mantle. We approximate the mantle lithosphere and asthenosphere by cells with various values of isotropic velocities as well as of strength and orientation of anisotropy in 3D, which is defined by azimuths and inclinations of symmetry axes of the hexagonal approximations of the media. We compare the synthetic P-residual spheres with observation examples from tectonically different regions which were subjected to anisotropy studies earlier. Modelling the P-residual spheres confirms that anisotropy is a significant source of directional variations of P-wave travel-time residuals in most of the models tested. Anisotropy is responsible for often observed clear bipolar pattern of the P spheres, which remains unchanged over areas as large as several hundreds of kilometres. Areas with a consistent pattern of P-residual spheres thus mark the lateral extent of the upper mantle domains characterized by similar anisotropy. On the other hand, influence of heterogeneities on directional terms of travel time residuals needs to be considered and tested as well, though it is less prominent in the P-residual spheres, from which the static terms of the relative residuals are eliminated. The amplitudes of P-sphere patterns due to an isotropic heterogeneity decrease with increasing lateral distance. Successful application of both the inversion and the forward modes of the new code strongly depends on amount of input data and ray geometry within the volume analyzed. Therefore, we test the forward mode of the new code also for real teleseismic ray geometry in different regions of the upper mantle.