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Novel anisotropic teleseismic body-wave tomography code AniTomo to illuminate heterogeneous anisotropic upper mantle: Theory, inversion tuning and application

Helena Žlebčíková (1), Jaroslava Plomerová (1), Eduard Kissling (2), Luděk Vecsey (1), and Vladislav Babuška (1)

(1) Institute of Geophysics, The Czech Academy of Sciences, Seismology, Prague, Czech Republic (helena@ig.cas.cz), (2) Institute of Geophysics, Department of Earth Sciences, ETH Zürich, Switzerland

Teleseismic body waves recorded during passive seismic experiments allow us to investigate isotropic velocities of the Earth's upper mantle in a great detail, on scales of tens of kilometres, by means of the standard high-resolution travel-time tomography. Nowadays, the quality of data enables exploration of anisotropic properties of the mantle by the means of travel-time tomography as well. Nevertheless, most of the tomography studies neglect the body-wave anisotropy completely or they are limited to either azimuthal or radial anisotropy.

Therefore, we have developed a code called AniTomo for coupled anisotropic-isotropic travel-time tomography of the upper mantle (Munzarová et al., Geophys. J. Int. 2018 – Part I). The novel code allows inversion of relative travel-time residuals of teleseismic P waves simultaneously for 3D distribution of P-wave isotropic-velocity perturbations and anisotropy of the upper mantle. We assume weak anisotropy of hexagonal symmetry with either the 'high-velocity' axis or the 'low-velocity' axis that is oriented generally in 3D. Such an approach of searching for orientation of the symmetry axes freely in any direction is unique and more general in comparison with the published methods that usually assume only horizontal or vertical orientation of the high-velocity symmetry axis. The code represents a step further from modelling homogeneously anisotropic blocks of the mantle lithosphere (e.g., Vecsey et al., Tectonophysics 2007; Plomerová et al., Solid Earth 2011) towards modelling anisotropy arbitrarily varying in 3D.

We tested the new code thoroughly, involving simple methodological tests to find out basic characteristics of the method and tests mimicking real tomographic inversions as to the target structures and the station-event distribution. Regarding the well-known trade-off between P-wave anisotropy and isotropic heterogeneities, the inversion with code AniTomo can successfully distinguish the isotropic and the anisotropic components of the velocity, depending, of course, on data quality.

For a first application of the novel code (Munzarová et al., Geophys. J. Int. 2018 – Part II), we opted for data from international passive seismic experiment LAPNET (2007 – 2009) deployed in a tectonically stable region of northern Fennoscandia. The resulting tomographic model shows that the strongest anisotropy and the largest isotropic-velocity perturbations concentrate at the mantle-lithospheric depths while in the deeper parts their amplitudes decrease significantly. It is possible to delimit regions of laterally and vertically consistent anisotropy in the mantle-lithospheric part of the model. These regions are compatible with domains inferred from a joint interpretation of directional variations of P-wave travel-time residuals and SKS-wave splitting parameters. We associate the domain-like anisotropy with fossil fabrics of blocks of the Archean mantle lithosphere, preserved probably from the time of the lithosphere origin.