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Role of seismic anisotropy in isotropic tomographic models of the upper mantle

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Standard teleseismic regional tomography of the upper mantle results in velocity perturbations relative to a reference radial model of the Earth with isotropic velocities. However, the observed upper mantle anisotropy affects resulting velocity perturbations, particularly because of distribution of earthquake foci relative to a station array is not uniform as to back azimuths and incidence angles. The isotropic tomography returns velocity perturbations in a volume approximated by a system of blocks or nodes. However, blocks with similar average velocities, but with different fabrics, i.e. different anisotropy and/or orientation of symmetry axes, are not resolved as regions with different structures (Plomerova et al., 2001). Splitting of core-mantle refracted shear waves (SKS) is usually considered as a proof of their propagation through an anisotropic medium and used to model upper mantle structures. However, often a large portion of null split measurements is evaluated (up to about 50%, Salimbeni et al., 2008) and such finding can be misinterpreted as a sign of an isotropic upper mantle. But detecting the null splitting, particularly if evaluated for shear phases from only a few events, does not mean the medium is always isotropic. Besides a propagation within an isotropic medium, the null splitting occurs, e.g., if (1) the incoming ray parallels a symmetry axis, i.e. the 'fast′ and 'slow′ shear waves propagate within such anisotropic medium with the same velocities, (2) polarization of incoming wave coincides with polarization of the fast/slow wave, i.e. energy on the slow/fast wave is close to zero. Moreover, models with weak anisotropy can also provide nulls, or very close to null splitting delay times, in fans up to 30° around the symmetry axis. On top of that, presence of noise in real data can increase number of null measurements, even if small delay times (up to 0.3s) between the slow and fast waves would be evaluated in noise free signal. Anisotropic structures of the upper mantle affect propagation of both P and S waves. Because of a natural lack of the 3D ray coverage, which would allow to invert jointly for isotropic and anisotropic velocity perturbations, we propose to correct the input travel times for anisotropic contributions derived from independent analyses and then to perform standard isotropic inversions. Joint inversion of body-wave anisotropic parameters retrieved by combining independent data sets (P-wave residual spheres and shear-wave splitting) results in 3D self-consistent anisotropic models of the mantle lithosphere domains with inclined symmetry axes. Such models can be used to correct the data for isotropic tomography. An example of regional tomography of the upper mantle beneath the Baltic Shield (Eken et al., GJI in review) shows that general features of velocity perturbation images calculated from the original data and the data corrected for anisotropy are similar. Amplitudes of the velocity perturbations decrease below ∼200 km depth in the latter. The observed large-scale anisotropy related to the olivine fabrics in the mantle lithosphere of the Baltic Shield can contaminate tomographic images in some parts of models and, therefore, should not be ignored.