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Documenting the importance of coupled isotropic-anisotropic seismic tomography of the upper mantle beneath Northern Apennines subduction zone

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The upper mantle velocity anisotropy together with the velocity heterogeneities affect significantly propagation of seismic waves. Velocity perturbations both due to isotropic heterogeneities and due to anisotropy are probably comparable in their amplitudes. Standard methods of imaging velocity perturbations in the upper mantle consider only isotropic propagations, in spite of the fact that seismic anisotropy has been undoubtedly proven within the whole of upper mantle. Neglecting anisotropy can cause significant artefacts in isotropic tomography results (e.g., wrong amplitudes of the heterogeneities, and/or, seriously distorted or false heterogeneities altogether). In addition, anisotropy yields unparalleled information on subsurface fabric and thus strongly enhances tectonic interpretation capabilities.

The region of Northern Apennines (Italy) can serve as an example of an upper mantle volume where both a strong isotropic velocity heterogeneity and significant seismic anisotropy are present. The distinct velocity heterogeneity is represented by the subducting Adriatic slab. Strength and orientation of seismic anisotropy, both fossil one in the mantle lithosphere and anisotropy in the sub-lithospheric mantle flow, are evaluated from teleseismic P-wave travel times and shear-wave splitting (Plomerova et al., EPSL 2006). Anisotropic models of the upper mantle fabrics beneath the Northern Apennines were derived by joint analysis of anisotropic parameters evaluated from two independent body-wave data sets recorded during the RETREAT experiment (2003-2006; Munzarova et al., G-Cubed 2012, submitted).

To evaluate effects of the well-known trade-off between anisotropy and heterogeneity, we calculated synthetic P travel time residual spheres, showing azimuth and incidence-angle dependent parts of the P-wave relative residuals, for the most recent tomographic model of isotropic velocity perturbations in the upper mantle beneath the Northern Apennines (Benoit et al., G-Cubed 2011) and compared them with P spheres from the observed data. The synthetic P spheres differ significantly from the observed ones. From this testing it is evident that the observed spheres cannot be explained solely by heterogeneities but have to be associated with anisotropic wave-propagation as well. As a consequence, we undertake to develop an anisotropic version of a teleseismic tomography code, which will allow us to invert simultaneously for the coupled isotropic-anisotropic velocity model problem.