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The effects of seismic anisotropy on S-wave travel time-tomography: the problem of apparent anomalies and possible solutions

Francesco Rappisi, Brandon Paul Vanderbeek, and Manuele Faccenda

Università degli studi di Padova, Geoscienze, Italy (francesco.rappisi@phd.unipd.it)

Teleseismic travel-time tomography remains one of the most popular methods for obtaining images of Earth's upper mantle. While teleseismic shear phases, most notably SKS, are commonly used to infer the anisotropic properties of the upper mantle, anisotropic structure is often ignored in the construction of body wave shear velocity models. Numerous researchers have demonstrated that neglecting anisotropy in P-wave tomography can introduce significant imaging artefacts that could lead to spurious interpretations. Less attention has been given to the effect of anisotropy on S-wave tomography partly because, unlike P-waves, there is not a ray-based methodology for modelling S-wave travel-times through anisotropic media. Here we evaluate the effect that the isotropic approximation has on tomographic images of the subsurface when shear waves are affected by realistic mantle anisotropy patterns. We use SPECFEM to model the teleseismic shear wavefield through a geodynamic model of subduction that includes elastic anisotropy predicted from micromechanical models of polymineralic aggregates advected through the simulated flow field. We explore how the chosen coordinates system in which S-wave arrival times are measured (e.g., radial versus transverse) affects the imaging results. In all cases, the isotropic imaging assumption leads to numerous artefacts in the recovered velocity models that could result in misguided inferences regarding mantle dynamics. We find that when S-wave travel-times are measured in the direction of polarisation, the apparent anisotropic shear velocity can be approximated using sinusoidal functions of period π and 2π . This observation allows us to use ray-based methods to predict S-wave travel-times through anisotropic models. We show that this parameterisation can be used to invert S-wave travel-times for the orientation and strength of anisotropy in a manner similar to anisotropic P-wave travel-time tomography. In doing so, the magnitude of imaging artefacts in the shear velocity models is greatly reduced.