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Separating intrinsic and apparent seismic anisotropy

Jeannot Trampert (1), Andreas Fichtner (1), and Brian Kennett (2)

(1) University of Utrecht, Dept. of Earth Sciences, Utrecht, Netherlands (jeannot@geo.uu.nl), (2) Autralian National University, Researh School of Earth Sciences

Seismic anisotropy plays a key role in studies of the Earth's rheology and deformation because of its relation to flow-induced lattice-preferred orientation (LPO) of intrinsically anisotropic minerals. In addition to LPO, small-scale heterogeneity produces apparent anisotropy that need not be related to deformation in the same way as intrinsic anisotropy. Quantitative interpretations of observed anisotropy therefore require the separation of its intrinsic and apparent components.

We analyse the possibility of separating intrinsic and apparent anisotropy in media with hexagonal symmetry – typically used in surface wave tomography and SKS splitting studies. Our analysis is on the level of the wave equation, which makes it general and independent of specific data types.

We find that commonly observed anisotropy can always be explained by a purely isotropic laminated medium unless all anisotropic parameters are known with unrealistic accuracy. Most importantly, minute changes in the poorly constrained P wave anisotropy and the parameter eta can switch between the existence or not of a laminated isotropic equivalent.

Important implications of our study are: (1) Intrinsic anisotropy over tomographically resolved length scales is never strictly required when reasonable error bars for anisotropic parameters are taken into account. (2) Currently available seismic observables do not provide adequate constraints on the relative contributions of intrinsic and apparent anisotropy. (3) Therefore, seismic observables alone do not provide compelling constraints on the magnitude of mantle flow. (4) Quantitative interpretations of anisotropy in terms of mantle flow require a combined seismic/geodynamic inversion that properly accounts for the formation of both LPO and small-scale heterogeneity.