High-Resolution 3D Anisotropic Structure of the North American Upper Mantle from Inversion of Body and Surface Waveform Data

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Seismic anisotropy provides insight into paleo and recent deformation processes and therefore mantle dynamics. To date, our knowledge of the North American anisotropic structure arises mainly from global tomographic models or SKS splitting studies which lack horizontal and vertical resolution, respectively, and are limited to either radial or azimuthal anisotropy. Our goal is a high-resolution model for the North American upper mantle incorporating both radial and azimuthal anisotropy. We hope to achieve unprecedented lateral and depth resolution by improving both current methodology and data coverage. In a first step, we inverted long period waveform data simultaneously for perturbations in the isotropic S-velocity structure, the anisotropic parameter $\xi = V_{SH}^2 / V_{SV}^2$ and the depth to the Moho, in the framework of normal mode asymptotic theory (NACT) (Li and Romanowicz, 1995). The resulting 2D broad-band sensitivity kernels allow us to exploit the information contained in long-period seismograms for body, fundamental and higher-mode surface waves at the same time. This approach has previously only been applied at the global scale, with a lateral parametrization in terms of spherical harmonics. We have adapted the NACT algorithm for the regional case by implementing a lateral parametrization in terms of spherical splines on an inhomogeneous triangular grid of nodes, with the finest mesh for North America. The inverted dataset consists of more than 100,000 high quality 3-component body, fundamental and overtone surface waveforms, recorded at broad-band seismic stations in North America from teleseismic events and provides a fairly homogeneous path and azimuthal coverage. Our 3D radial anisotropic model shares the large scale features of previous regional studies for North America. We confirm the pronounced difference in the isotropic velocity structure between the western active tectonic region and the central/eastern stable shield, as well as the presence of subducted material (Juan de Fuca and Farallon plate) at transition zone depths. Concerning the anisotropic signature, we observe a positive $\xi$ anomaly in correspondence of the cratonic areas, within the lithosphere, while a negative $\xi$ anomaly beneath the Basin and Range province suggests possible mantle upwelling. In the future, we expect to further improve the data coverage, in particular by taking advantage of the broad-band dataset that will be collected under the USAArray effort within EarthScope. The combination of this exceptional set of data with our methodology will allow us to invert for a more complete model of anisotropy that will also include azimuthal information. Hence we will be able to gain 3D detailed insight into mantle dynamics and address unresolved geophysical questions such as the nature and strength of lithosphere/asthenosphere coupling, the depth extent of continental sub-regions and the relation of imaged seismic anisotropy to present-day asthenospheric flow and/or past tectonic events recorded in the lithosphere.

Horizontal slices at different depths through our 3D radial anisotropic model. Anomalies are relative to PREM, (a) Perturbations in the isotropic S-velocity structure, (b) Perturbations in the anisotropic parameter $\xi$.

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