

Constraining Global Transition Zone Anisotropy With Overtone Surface Waves and Free Oscillation Coupling

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Seismic anisotropy can be generated by large-scale deformation, and can therefore provide us with important constraints on mantle dynamics. However, because its detection below ~200-300 km depth remains challenging, it is unclear whether and what kind of seismic anisotropy is present in the deep upper mantle and transition zone. Here, we address the problem of global azimuthal anisotropy in the upper mantle and transition zone with two different types of data: global overtone surface wave phase velocity maps and coupled free oscillation splitting measurements.

The azimuthally anisotropic phase velocity maps obtained by Visser et al. (2008), however, constitute a unique dataset with high sensitivity to structure down to depths of ~1000 km. These maps obtained for 149 fundamental mode and overtone Love and Rayleigh waves, up to the sixth overtone for Rayleigh and up to the fifth for Love waves, will enable us to assess the presence of azimuthal anisotropy in the deep upper mantle and transition zone. A first important step in determining whether azimuthal anisotropy is present at these depths lies in the analysis of the effect of crustal structure. Lateral changes in crustal structure and Moho depth can affect the local partial derivatives that relate the depth-dependent elastic parameters to the phase velocity of fundamental mode and first overtone surface waves (Marone and Romanowicz, 2007). Here, we examine the effect of the crust on the sensitivity kernels of higher mode surface waves, and how it affects models of deep azimuthal anisotropy.

Earth's free oscillations coupled modes constitute another promising tool to constrain large-scale seismic anisotropy in the transition zone. We show that several coupled modes of oscillations are sensitive to radial and azimuthal anisotropy throughout the mantle. In particular, modes of the type ${}_0S_{l-0}T_{l+1}$ have high sensitivity to shear-wave radial anisotropy and to six elastic parameters describing azimuthal anisotropy in the 200 km-1000 km depth range. We attempted to fit degree two splitting measurements of ${}_0S_{l-0}T_{l+1}$ coupled modes using existing isotropic and transversely isotropic mantle models, but we could not explain the signal. We then explored the model space with a forward modeling approach and determined that, after correction for the effect of the crust and mantle radial anisotropy, the remaining signal could be explained by the presence of azimuthal anisotropy in the upper mantle. While the depth extent and distribution of the anisotropy are not well constrained due to parameter tradeoffs and a limited coupled mode data set, it is clear that mode coupling measurements constitute a promising tool to study deep mantle anisotropy. In addition, because some of the elastic parameters that can lead to mode coupling do not affect surface wave phase velocities, coupled free oscillations complement surface wave data, and have the potential to provide new and unique constraints on other elastic parameters. In the future this could help us discriminate between different compositional models of the mantle.