Mantle flows in the lowermost mantle beneath the Northern Pacific inferred by 3-D waveform inversion for radially anisotropic structure

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The lowermost several hundred km of the Earth's mantle immediately above the core-mantle boundary (CMB), commonly called the D" region, is the thermal boundary layer (TBL) of mantle convection and plays a major role in governing the modality of convection in the mantle. The D" region, especially beneath the subduction zones, provides clues for understanding the dynamics of the Earth's mantle, because thermally and chemically distinct slab materials can perturb the temperature and mantle flow.

The D" region beneath the northern Pacific is of particular geodynamical interest, because the paleo-Izanagi and present Pacific plates have been subducting beneath the northwestern margin of Laurentia since ~250 million years ago (Young et al. 2019), which implies that paleoslabs could have reached the lowermost mantle. Suzuki et al. (2016) inferred the detailed 3-D isotropic S-velocity structure in the lowermost 400 km of the mantle beneath the northern Pacific and found a sheet-like lateral high-velocity which they interpreted as paleoslabs and a prominent low-velocity anomaly adjacent to the high-velocity anomaly interpreted as a passive plume induced by slab sinking. In order to verify the above interpretation and also infer flow direction, it is required to infer the 3-D anisotropic S-velocity structure beneath the northern Pacific.

We conduct waveform inversion to infer the 3-D variation of the TI (transverse isotropy) elastic parameters such as the effective isotropic V_S and anisotropic parameter ξ straightforwardly in the lowermost mantle. We use the full USArray data which provide dense coverage of the D" region beneath the Northern Pacific. We used deep- and intermediate-focus events recorded at epicentral distances $70<\Delta<100$. The use of relatively short-period (20–200 s) radial and transverse components data for the S/ScS time window which is sensitive to the D" structure makes it possible to image smaller-scale structure than previous global tomography studies. We also conduct several tests to confirm the robustness of the inversion results.

The inferred anisotropic structure is considered as due to deformation-induced alignment of crystal caused by mantle flow for either Mg-perovskite, Mg-post-perovskite, ferro-periclase or a combination thereof because of the high-stress condition in the thermal boundary layer of the mantle convection. When we assume the dominant glide system of each mineral under the lowermost mantle conditions according to previous experimental results, the observed anisotropy can be interpreted as horizontal and vertical flow related to the subducted paleo-Izanagi plate and the upwelling flow of hot material, respectively.

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