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Radial anisotropy of the upper mantle

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The enigmatic radial anisotropy of the upper mantle remains difficult to resolve. Recent global models show strong disagreements and suggest different inferences on mantle dynamics and evolution. Here, we present a new radially and azimuthally anisotropic shear-wave velocity model of the upper mantle, LLCS-2026, and validate its key patterns using independent seismic and thermodynamic phase-velocity inversions for tectonic-type-average 1D profiles. LLCS-2026 is computed using waveform fits of 1,630,432 seismograms (1,252,717 vertical; 377,715 transverse components). Automated multimode waveform inversion is used to extract structural information from surface and S waveforms in very broad period ranges, from 11 to 450 s, with most data sampling in the 20–350 s period range. The vertical and transverse component waveforms are jointly inverted for the isotropic average shear-wave velocities, their pi-periodic and pi/2-periodic azimuthal anisotropy, and radial anisotropy. Statistical and manual outlier analysis yields a final dataset of 1,009,038 seismograms (765,302 vertical, 243,736 transverse components) that constrains the final model, which captures complex patterns of seismic isotropic and anisotropic structure within the Earth. In agreement with previously published models, prominent low-velocity anomalies indicative of thin lithosphere and partial melting are observed at 20-150 km depth beneath mid-ocean ridges. At 300-400 km, however, high isotropic-average velocities are present in the vicinity of some of the ridges in the Indian and Atlantic oceans. They suggest drips of cold, lithospheric mantle material, probably related to rapid lithospheric cooling in the complex 3D context of triple junctions and ridge-hotspot systems. Radial anisotropy is positive (Vsh > Vsv) at 100-150 km depth everywhere in the mantle, with cratons showing smaller anisotropy compared to other units. Below 200-250 km depth, radial anisotropy is negative (Vsv > Vsh) nearly everywhere. The depth at which the anisotropy sign changes varies with tectonic region. The anisotropy sign flips at the shallowest depth (~200 km) beneath young oceans and continents and at the greatest depth (~250 km, on average) beneath cratons. Radial anisotropy is also negative in the top 50 km of the oceanic lithosphere. Together with azimuthal anisotropy observations, this indicates a complex pattern of crystallographic preferred orientations created by mantle flow beneath mid-ocean ridges, with an interplay between the alignment of crystals due to the vertical flow below the ridge and the lateral flow away from it. Independent seismic (Civiero et al. 2024) and thermodynamic (Lebedev et al. 2024; Xu et al. 2025) inversions of phase-velocity data confirm

and validate the anisotropy-sign-flip observations and inferences.

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