Lower mantle dynamics

Modelling Shear Wave Seismic Anisotropy from Crust to the Lowermost Mantle

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In Short

- Elucidate fundamental geodynamic processes shaping thermochemical mantle plumes, dynamics of large low shear velocity provinces and shear wave seismic anisotropy
- Integrate seismological observations into high-performance thermo-mechanical forward modelling
- Bridge spatial and temporal scales of deformation in LLSVPs, lower mantle flow pattern and entrainment of deep mantle material to surface.

1 | Motivation. The dynamics of Earth's deep mantle, including the evolution of Large Low Shear Velocity Provinces (LLSVPs) at the Core-Mantle-Boundary (CMB), play a fundamental role in driving present-day plate tectonics [1], analyzed through seismic anisotropy [2] and numerical geodynamic modeling [3], offering insights into mantle deformation, mantle plume generation [4], and the rheology of the lower mantle. Here we study three different perspectives of lower mantle dynamics.

The evolution of Large Low Shear Velocity Provinces (LLSVPs) at the Core-Mantle-Boundary (CMB) significantly influences the dynamics of Earth's deep mantle. These dynamics are pivotal for the formation of convective mantle cells, which are crucial drivers of Earth's present-day plate tectonics.

Seismic anisotropy analysis, particularly at the margins of LLSVPs, provides insights into mantle deformation and flow patterns [5]. We employ numerical geodynamic modeling techniques to investigate the generation of mantle plumes from LLSVP boundaries and the flow behavior of the lower mantle.

By comparing simulated seismic anisotropy with observed data, we aim to refine our understanding of the rheology and dynamics of the lower mantle.

2 | Methods. We use the open-source massively-parallel finite-element code ASPECT [7], which is designed to solve the equations for thermally and chemically driven convection and long-term tectonic deformation. ASPECT employs fully adaptive meshes, which enable us to resolve small local objects in the flow field such as faults without refining the mesh for the whole model. We recently developed one way coupling of ASPECT to a mantle fabric generation code ECOMAN [8] to incorporate the effect of deformation of LLSVPs in generating the shear wave radial anisotropy.

3 | Goals. In this proposal, we delineate our strategy to utilize cutting-edge computational techniques for modeling radial anisotropy of shear waves throughout the entire mantle, with particular emphasis on the lowermost portion. Through the integration of seismic tomography data, constraints from mineral physics, and advanced numerical methodologies, our objective is to enhance our comprehension of the factors dictating anisotropic characteristics in the lowermost mantle and their ramifications for mantle dynamics and Earth's geophysical phenomena. Our investigation aims to bridge the disparity between observational limitations and theoretical frameworks, thereby facilitating a more profound insight into Earth's interior and its dynamic evolution through geological time.

WWW

https://www.gfz-potsdam.de/en/section/geodynamic-modeling/overview/

More Information

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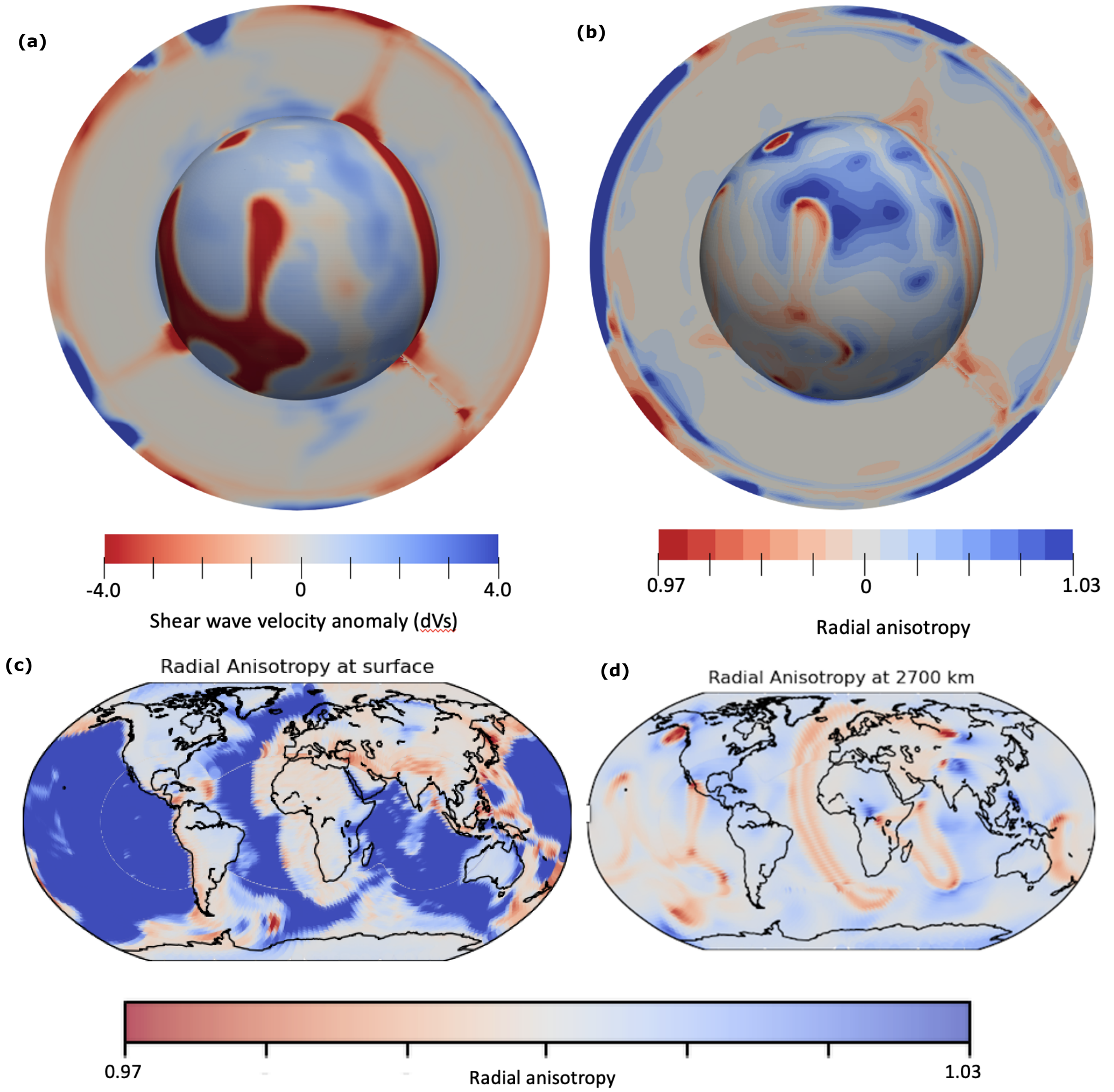

Figure 1: *The generation of shear wave velocity anomalies and radial anisotropy based on the geodynamic model. (a) Shear wave velocity anomaly shows higher than average velocity in the cold subduction and lower than average velocity in the plumes and LLSVPs, (b) Radial anisotropy shows Vsv > Vsh at the edges of LLSVPs and inside plume conduits, whereas at the surface where plumes flatten out the signature is opposite. (c) The map view of radial anisotropy at the surface, showing Vsv > Vsh near the subduction regions and other places show opposite signature. (d) Same property as (c) at 2700 km depth, showing Vsv > Vsh at the LLSVPs' edges. Image from Roy et al. (2024, In prep.)[6], based on models run within the context of this project.*

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