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Implications for mantle dynamics based on isotropic and anisotropic velocity variations above the core-mantle boundary

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LLSVPs (Large Low Shear Velocity Provinces) are approximately antipodal regions, 1000s of kilometers across on the core-mantle boundary, that are characterized by low rigidity, Vs reductions of several percent, and bounded by strong lateral velocity gradients. Only two LLSVPs exist: one situated beneath the Pacific and the other beneath Africa and the Atlantic. The exact morphology, composition, and origin of LLSVPs remains mysterious.

We have applied 3D clustering analysis across the lower mantle and across eight different recent tomographic models, assuming the lower mantle is dominated by three different types of material: 1. LLSVPs 2. Subducted slabs 3. Ambient mantle. The suggested boundaries of the LLSVPs traced out by cluster analysis agree well with local waveform studies. Their boundary morphology shows the two provinces consist of different cone-shaped sub-piles whose topographic slopes range from shallow-dipping, to steep, and even overhanging. This suggests that either the provinces have internal compositional variations or that interaction with surrounding convection controls the boundary shape.

Outside the two LLSVPs, clustering analysis suggests the existence of multiple slow velocity meso-scale features approximately 1000 km across, beneath Perm (Russia), South Pacific, Kamchatka, and Iceland. Lekic et al. (2012) modeled seismic waveforms to confirm the existence of the Perm anomaly, and show that it has sharp boundaries and a velocity reduction similar to LLSVPs. Here we present evidence of new meso-scale features (e.g. South Pacific anomaly), documenting that they represent a third type of lowermost mantle structure, intermediate in scale between the LLSVPs and ultra-low velocity zones (ULVZs). The existence and aspect ratio of such meso-scale regions further constrains the nature of these anomalies.
Additionally, the clustering analysis suggests a fourth class: these are slow meso-scale features, which appear several hundreds of kilometers above the core-mantle boundary. It is still unclear if these represent anomalies that float, sink, or rise.

Recent studies of anisotropy in the lowermost mantle seem to correlate with anisotropy being present in the anomalously fast regions, this can give an additional constraining on the dynamics and/or composition in these regions.