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The Importance of Asthenospheric Temperature Anomalies in Maintaining Observed Dynamic Topography

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A new compilation of observed oceanic residual depth anomalies show that $\sim \pm 1$ km of dynamic topography occurs at wavelengths of 10^3–10^4 km. At the same time, seismic studies provide strong evidence for the existence of a substantial and widespread low-viscosity channel beneath the oceanic basins. In light of these observations, we investigate whether the shorter wavelength ($<$ 4,000 km) signal in the global residual depth database can be linked to temperature variations within this sub-plate channel. We calculate upper mantle temperature structure using an experimentally-derived anelasticity model that is calibrated against shear wave velocity and attenuation constraints. Residual depth anomalies are predicted for a range of channel thicknesses and tomographic models by converting upper mantle temperature anomalies to density anomalies and calculating the isostatic response. We find that thermal anomalies of ± 150 °C within a 100–175 km thick channel yield a better match to residual depth anomalies than many predictive geodynamic models. Oceanic viscosity profiles calculated using the above parameterisation suggest that the average viscosity is two orders of magnitude lower within the channel than in the underlying upper mantle, confirming the validity of an isostatic calculation at shorter wavelengths. Spectral cross-correlation shows that an isostatic approximation yields poorer results at wavelengths $>$ 7,000 km, consistent with sensitivity kernel considerations. These results suggest that observed dynamic topography in the oceanic realm can be primarily attributed to temperature-induced buoyancy variations within an asthenospheric channel with more minor contributions from the deeper mantle. Our work indicates that incorporation of better resolved surface wave tomography of the upper mantle combined with an improved treatment of the lithosphere-asthenosphere system in geodynamic models may hold the key to reconciling observed and predicted dynamic topography.