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Global Mantle Dynamic Topography Renormalised Using Residual Topography Measurements for "Normal" Oceanic Crust

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We produce a global map of mantle dynamic topography by renormalising the predicted dynamic topography of Steinberger et al. (2017). Dynamic topography renormalisation, consisting of its rescaling and shifting, is determined by comparing predicted dynamic topography with observed residual topography for "normal" oceanic crust where observations are less prone to errors than for continents, margins and oceanic plateaus. Renormalisation is then applied globally to generate an improved map of dynamic topography for the continents, other remaining oceanic areas, and the Antarctic and Arctic polar regions.

We use global mapping of crustal basement thickness using gravity anomaly inversion to identify oceanic crust of 10 km thickness or less to select measured residual topography for comparison with predicted mantle dynamic topography. Measurements of residual topography, calculated by removing the isostatic effects of crustal thickness variation, bathymetry, sediments, ice and lithosphere thermal anomalies, from the observed topography, are inaccurate for continents and oceanic plateaus due to uncertainties in determining their crustal thickness and density. As a consequence, residual topography measurements for these non-oceanic regions are unsuitable for testing mantle dynamic topography predictions. For oceanic regions with crust less than 10 km thick, we compare mantle dynamic topography and residual topography using amplitude histogram matching and grid searches, and compute the amplitude rescaling and shift which needs to be applied to predicted mantle dynamic topography to fit the observed residual topography.

We examine three global compilations which use different approaches to determine mantle dynamic topography: (i) Steinberger (2007), which uses seismic topography deeper than 220 km to determine mantle density; (ii) Flament et al. (2013), which uses plate velocity and subduction history; and (iii) Steinberger et al. (2017), which uses seismic tomography, including that above 220 km, to determine shallow upper mantle densities.

Our analysis shows that for the Steinberger (2007) and Flament et al. (2013) compilations, the predicted mantle dynamic topography for oceanic regions requires a rescaling of approximately $\times 0.5$ and a negative shift of approximately -500 m to match the observed residual topography. In contrast Steinberger et al. (2017), which includes shallow upper mantle densities above 220 km, requires only a small shift (+50m) but a greater scaling of $\times 0.375$. Maps of renormalised mantle dynamic topography for Steinberger et al. (2017) show a close resemblance to measured residual topography.

The need for renormalisation most probably arises from uncertainties in the conversion of seismic velocity anomalies from mantle tomography into density anomalies and uncertainties in upper and lower mantle viscosity structure, both of which are required to compute predicted dynamic topography. An important caveat is that the renormalisation can only be calibrated for oceanic regions, and we assume that the same rescaling of predicted mantle dynamic topography can be applied to the continents.