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Relation between flow in the Earth's mantle, phase boundary topography and dynamic topography at the Earth's surface

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The prediction of surface uplift and subsidence over time on a large scale is one of the most important outcomes of mantle flow models. Dynamic topography influences which regions are below sea level, and at what depth, and therefore where sediments and related natural resources may form. Before attempting to compute uplift and subsidence in the geologic past, we must first understand present-day dynamic topography.

Here we present a quantitative comparison between computed dynamic topography due to density heterogeneities and flow in the mantle and "residual topography" computed by subtracting topography due to ocean floor cooling and topography isostatically compensated in the crust from actual topography. Mantle density heterogeneities are inferred from tomography models. We find that (1) Dynamic topography is about a factor 2 larger than residual topography (2) Correlation between residual and dynamic topography models is typically about 0.5 or less (3) Absorption and release of latent heat may displace phase boundaries in the direction of flow. This additional phase boundary topography reduces dynamic surface topography, but with realistic parameters, reduction is only about 5 %. (4) Using seismically "observed" instead of computed phase boundary topography does not improve the dynamic topography fit. (5) Only in some regions (e.g. the North Atlantic) we find good agreement between dynamic and residual topography. We conclude that an improved understanding of present-day dynamic topography requires a multi-disciplinary approach including, but not limited to the following aspects (a) Improving both seismic and geodynamic models of phase boundary topography: In particular, can other mechanisms cause phase boundary displacements leading to improved dynamic topography predictions? (b)

Improving mantle density models: In particular, which seismic velocity anomalies in the lithosphere are due to temperature, and which due to compositional variations? (c) Including more realistic and laterally variable rheology, in particular within the lithosphere. (d) Doing regional computations, focusing first on those regions where residual topography is better known and where no large compositional anomalies in the mantle are expected, before moving on to "more complicated" regions.

Reliable computations of uplift and subsidence in the more distance past will require further improvement of computational methods, as past mantle structure cannot be fully recovered by simple backward-advection. A global mantle reference frame through geologic times is required to related computed uplift and subsidence to geological observations.