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Isostasy Revisited: A Novel Approach to an Age-Old Theory

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While the isostatic compensation of crustal thickness and density heterogeneity provides the dominant contribution to Earth's observed topography, a significant difference persists between these two fields, known as 'residual topography'. This discrepancy arises from dynamic processes within the mantle, primarily driven by time-dependent vertical surface stresses from mantle convection. These mantle convection dynamics also lead to disparities between the observed geoid and the isostatic geoid resulting from crustal heterogeneity, known as the 'residual geoid.'The combined consideration of both residual geoid and topography provides unique and fundamental global constraints on the amplitude and spatial distribution of density anomalies in the convecting mantle.

Although isostasy plays a crucial role in residual geoid and topography determination, the precision of constraints is strongly dependent on isostasy calculation quality. The first-order treatment of hydrostatic equilibrium used by classic isostasy theory is insufficient to accurately calculate isostatic geoid anomalies on a compressible, self-gravitating mantle. Thus, using dynamic kernels computed employing a viscous flow model that includes a fully compressible mantle and core (based on the PREM reference model) with self-gravitation, we provide a geodynamically consistent method based on the surface loading response.

Another important consideration is the accuracy of global crustal heterogeneity models. Our analysis shows significant variations in the predicted residual geoid and topographic fields utilizing CRUST1.0 and the most recent ECM1 crustal heterogeneity models. We shed light on the importance and implications of these distinctions for achieving the most precise constraints on density anomalies in the convecting mantle.

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