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Constraints on the mantle and lithosphere dynamics from the observed geoid with the effect of visco-elasto-plastic rheology in the upper 300 km

Anthony Osei Tutu (1), Bernhard Steinberger (1), Irina Rogozhina (2), and Stephan Sobolev (1)
(1) Geodynamic Modelling, GFZ - Potsdam, (2) Earth System Modelling, GFZ - Potsdam

Over the past decades rheological properties of the Earth's mantle and lithosphere have been extensively studied using numerical models calibrated versus a range of surface observations (e.g., free-air-gravity anomaly/geoid, dynamic topography, plate velocity, etc.).The quality of model predictions however strongly depends on the simplifying assumptions, spatial resolution and parameterizations adopted by numerical models.

The geoid is largely (Hager & Richards, 1989) determined by both the density anomalies driving the mantle flow and the dynamic topography at the Earth surface and the core-mantle boundary. This is the effect of the convective processes within the Earth's mantle. The remainder is mostly due to strong heterogeneities in the lithospheric mantle and the crust, which also need to be taken into account. The surface topography caused by density anomalies both in the sub-lithospheric mantle and within the lithosphere also depends on the lithosphere rheology. Here we investigate the effects of complex lithosphere rheology on the modelled dynamic topography, geoid and plate motion using a spectral mantle flow code (Hager & O'Connell, 1981) considering radial viscosity distribution and a fully coupled code of the lithosphere and mantle accounting for strong heterogeneities in the upper mantle rheology in the 300 km depths (Popov & Sobolev, 2008).

This study is the first step towards linking global mantle dynamics with lithosphere dynamics using the observed geoid as a major constraint. Here we present the results from both codes and compare them with the observed geoid, dynamic topography and plate velocities from GPS measurements. This method allows us to evaluate the effects of plate rheology (e.g., strong plate interiors and weak plate margins) and stiff subducted lithosphere on these observables (i.e. geoid, topography, plate boundary stresses) as well as on plate motion. This effort will also serve as a benchmark of the two existing numerical methods used.

Finally, given significant dispersion of geodynamic predictions from different seismic tomography models currently available, we further look for seismic models that provide predictions closest to observations at both regional and global scales.

References

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