Geophysical Research Abstracts
Vol. 15, EGU2013-8976, 2013
EGU General Assembly 2013

Predicting dynamic topography from mantle circulation models

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Dynamic topography is anomalous vertical motions of Earth's surface associated with viscous flow in the mantle. Deformable boundaries, such as the surface, CMB and phase transition boundaries, within a fluid (Earth's mantle) are deflected by viscous flow. Denser than average, sinking mantle creates inward deflections of Earth's surface. Equally, upwelling flow creates bulges in the surface; large plumes are commonly thought to produce superswells, such as the anomalously high elevation of Southern Africa. Dynamic topography appears to operate on a number of length scales. Mantle density anomalies estimated from seismic tomography indicate long wavelength dynamic topography at present day of around 2 km amplitude (e.g. Conrand & Husson, 2009) whilst continental scale studies suggest vertical motions of a few hundred metres. Furthermore, time scales must be an important factor to consider when assessing dynamic topography. Stable, dense lower mantle 'piles' may contribute to dynamic surface topography; as they appear stable over reasonably long time scales, long wavelength dynamic topography may be a fairly constant feature over the recent geological past. Shorter wavelength, smaller amplitude dynamic topography may be due to more transient features of mantle convection. Studies on a continental scale reveal shorter term changes in dynamic topography of the order of a few hundred metres (e.g. Roberts & White, 2010; Heine et al., 2010). Understanding dynamic topography is complicated by the fact it is difficult to observe as the signal is often masked by isostatic effects.

We use forward mantle convection models with 300 million years of recent plate motion history as the surface boundary condition to generate a present day distribution of density anomalies associated with subducted lithosphere. From the modelled temperature and density fields we calculate the normal stress at or near the surface of the model. As the models generally have a free slip surface where no vertical motion is allowed, an excess or deficit of stress exists near the surface. A pointwise force balance between this stress excess and the weight of rock above is used to calculate the anomalous elevation associated with the stress. Here we present some of the results obtained from mantle circulation models. We look at different ways of predicting dynamic topography, including the depth at which the stress field is calculated and by removing lithospheric density anomalies from the calculation. We also assess the impact of crustal thickness and isostasy on the predictions of dynamic topography.