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Coupling between mantle and surface processes: Insights from analogue modelling

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Thermal or density anomalies located beneath the lithosphere are thought to generate dynamic topography. Such a topographic signal compensates the viscous stresses originating from the anomaly driven mantle flow. It has been demonstrated that the erosion modulates the dynamic signal of topography changing the uplift rate by unload. The characteristic time for adjustments of dynamic topography due to surface erosion is likely similar to post-glacial rebound time (10000 – 50000 years).

Here we present preliminary results of a new set of analogue models realized to study and quantify the contribution given by erosion to dynamic topography, during a process specifically driven by a positively buoyant deep anomaly.

The adopted set up consists of a Plexiglas box (40x40x50 cm3) filled with glucose syrup as analogue upper mantle. A silicon plate positioned on the top of the syrup simulates the lithosphere. On the silicone plate is placed a thin layer of a high viscous glucose syrup which reproduces the upper, erodible layer of the crust. To simulate the positively buoyant anomaly we used an elastic, undeformable silicon ball free to rise by buoyancy in the syrup until the floating silicone plate is hit.

The changes in topography have been monitored by using a 3D laser scan, while a side-view camera recorded the position of the rising ball in time.

Data have been post-processed with image analysis techniques (e.g., Particle Image Velocimetry) in order to obtain the evolution of topography, uplift rate, erosion patterns of the top layer, bulge width and mantle circulation during the experiment.

We ran experiments with and without the shallow, erodible crustal layer in order to quantify the effect of erosion on dynamic topography.

Preliminary results showed that both the maximum topography and uplift rate are inversely proportional to the lithospheric thickness. The maximum uplift rate and the deformation of the lithospheric plate occurred just before the arrival of the rising ball at the bottom of the plate. Additionally, the presence of the thin erodible layer did not modify significantly the overall evolution of the dynamic topography despite for giving a second minor pick in the uplift rate (i.e. 30% of the maximum -dynamic- uplift) after the sphere interacted with the lithosphere.

This research represents a novel attempt to study the interaction of deep mantle and surface processes by analogue modeling. Our results demonstrate how surface dynamics may perturbate the evolution of lithospheric bulging driven by a positively buoyant anomaly. Indeed further analogue and numerical models are needed to better understand the link between these mechanisms.