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Investigating feedbacks between surface processes and tectonics in rift settings using numerical models

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The Earth's landscape is a product of complex feedbacks between tectonics, driven by plate motion, and climate, which control the erosional processes. Interactions between erosion, tectonics and climate form, modify or destroy geomorphic features while the transfer of mass resulting from erosion and sedimentation affects isostasy and the mechanical behaviour of the lithosphere. Evolution of extensional basins and rifted continental margins creates significant topography, which in turn can change precipitation and erosion patterns. Transfer of sediments from the margins into the basin may change the stress pattern in the crust and thus affect the geometry of the rift.

Modelling the complexity of such a system requires an integrated approach looking at interactions between tectonics and surface processes on a range of spatial and temporal scales. We use high-resolution numerical experiments coupling a 2D upper-mantle-scale thermo-mechanical model with a plan-form 2D surface processes model (SPM) to investigate the factors controlling the style of deformation. The experiments consist in simple extension models involving lithosphere with variable thickness (normal-like lithosphere to thick cratonic-like lithosphere) and explore the effects of rheological and compositional variability of the layer components of the crust and the lithosphere. We also explore different values of erosion efficiency together with different pattern of precipitation, including orographic effects. Tomography and geochemistry evidences suggest compositional stratification of the lithosphere. We also explore the effect of a depleted lower lithosphere (compositionally less dense than sublithospheric mantle) on the rift geometry and the effect of the isostatic responses in terms of uplift or subsidence on the surrounding topography.

The models provide a basis to discuss the type of interactions between erosion and tectonics in rift settings. Preliminary results show that if erosion does play a role, sediment load and deposition evolution plays a much bigger role on controlling the activity of fractures and rift geometry. We discuss the implications in our understanding of the coupling between mantle dynamics, lithosphere and atmosphere.