Slab detachment dynamics: Insights from 0D to 3D numerical experiments

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Slab detachment is a process that has been invoked to explain rapid uplift, deep seismicity, and magmatic activity in several active orogens (e.g., Alps, Himalaya). However, it is not yet clear to which extent slab detachment is the primary cause of these phenomena. Thus, deciphering the physical processes controlling detachment is important to understand its impact on the post-collisional evolution of orogens.

Here we employ numerical models to investigate the nonlinear coupling between mantle flow and slab detachment. Due to the three-dimensional nature of slab detachment and the variety of involved processes, it is daunting to pinpoint the first order controls on the time scale of this process. We therefore investigated this issue by first developing a simplified 0D necking model that describes the temporal evolution of the thickness of a detaching slab.

Our 0D numerical experiments highlight the importance of slab temperature and activation volume of the slab and upper mantle. The combination of these two parameters can delay the detachment process and yield different transient surface and stress signals. These results have been confirmed with 2D numerical experiments The same insights have been furtherly validate with 3D numerical experiments, allowing us to focus our attention on the radius of curvature of the subduction zone and on the lateral heterogeneities. Based on these findings, we then used 2D and 3D numerical models to further determine higher dimensional geometrical effects on slab detachment. For more complex slab geometries, higher dimensional results deviate from the 0D predictions. Nevertheless, the combination of 0D and 2D/3D numerical models allows to determine first order controls on slab detachment.

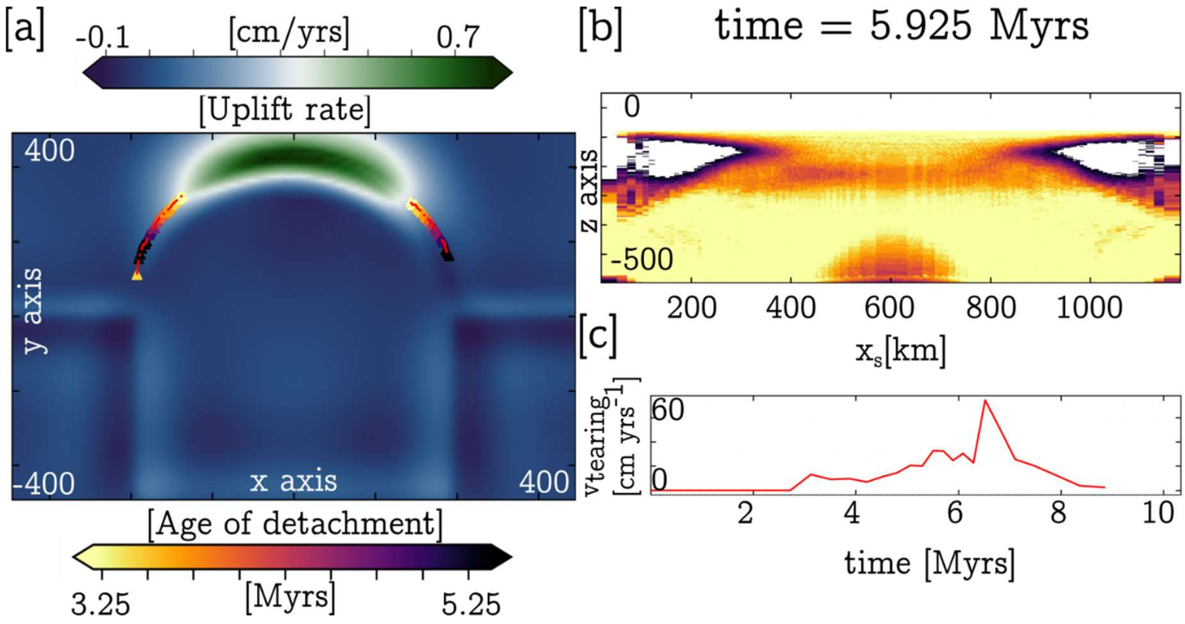

Figure 1: a) This map displays a 3D numerical simulation featuring a slab with an average temperature of 900°C and a curvature of 0.0026 km^{-1}. The colored triangles depict the propagation of tearing and are shaded based on the age at which tearing occurs at specific coordinates. **b) Thickness of the slab:** This figure represents the actual slab below the surface, and how the tearing propagates along the slab. **c) Tearing velocity vs time**