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Effect of rheological approximations on slab detachment in 3D numerical simulations of continental collision

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It is commonly accepted that slab detachment results from the development of extensional stresses within the subducting slab. Subduction slowdown due to arrival of buoyant continental material at the trench is considered to cause such stress build up in the slab. Following slab detachment, slab pull partially or completely loses its strength and hot asthenosphere may flow through the slab window, which can have major consequences for continental collision.

The dynamics of slab detachment has been extensively studied in 2D (i.e. analytical and numerical), but 3D models of slab detachment during continental collision remain largely unexplored. Some of the previous 3D models have investigated the role of an asymmetric margin on the propagation of slab detachment (van Hunen and Allen, 2011), the impact of slab detachment on the curvature of orogenic belts (Capitanio and Replumaz, 2013), the role of the collision rate on slab detachment depth (Li et al., 2013) or the effect of along-trench variations on slab detachment (Duretz et al., 2014).

However, rheology of mantle and lithosphere is known to have a major influence on the dynamics of subduction. Here, we explore a range of different rheological approximations to understand their sensitivity on the possible scenarios. We employ the code LaMEM (Kaus et al., 2016) to perform 3D simulations of subduction/continental collision in an integrated lithospheric and upper-mantle scale model.

The models exhibit a wide range of behaviours depending on the rheological law employed: from linear, to temperature-dependent visco-elasto-plastic rheology that takes into account both diffusion and dislocation creep. For example, we find that slab dynamics varies drastically between end member models: in viscous approximations, slab detachment is slow, dominated by viscous thinning, while for a non-linear visco-elasto-plastic rheology, slab detachment is relatively fast, dominated by plastic breaking and inducing strong mantle flow in the slab window. Moreover, in models of viscous approximation, slab break-off starts in the slab interior due tot the nature of slab necking, while in models of non-linear visco-elasto-plastic rheology, slab tear will first occur at the edges of the continental collision.