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Sinking of spherical slablets through a non-Newtonian mantle

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The dominant driving force for plate tectonics is slab pull, in which sinking slabs pull the trailing plate. Forward plate velocities are typically similar in magnitude (7 cm/yr) as estimates for sinking velocities of slabs through the upper mantle. However, these estimates are based on data for slabs that are coherent into the transition zone as well as models that considered the upper mantle to be entirely Newtonian. Dislocation creep in the upper mantle can strongly influence mantle flow, and is likely activated for flow around vertically sinking slabs in the uppermost mantle. Thus, it is possible that in some scenarios, a non-Newtonian mantle will have an influence on plate motions but it is unclear to what degree. To address this question, we investigate how the non-Newtonian rheology modifies the sinking velocities of slablets (spherical, negatively buoyant and highly viscous blobs).

The model set-up is similar to a Stokes sphere sinking, but is in 2-D cartesian with temperature-and stress-dependent rheology. For these numerical models, we use the Stag-YY code (e.g., Tackley 2008) and apply a pseudo-free surface using the 'sticky-air' approach (Matsumoto and Tomoda 1983; Schmeling et al, 2008, Crameri et al., 2012). The sinking blob is both highly viscous and compositionally dense, but is the same temperature as the background fluid which eliminates thermal diffusion and associated variations in thermal buoyancy. The model domain is 2x1 or 4x1 and allows enough distance to the sidewalls so that sinking velocities are not influenced by the boundary conditions. We compare our results with those previously obtained for salt diapirs rising through a power-law rheology mantle/crust (Weinberg, 1993; Weinberg and Podladchikov, 1994), which provided both numerical and analytic results. Previous results indicate a speed-up of an order of magnitude is possible. Finally, we then extend the models and analysis to mantle convection systems that include for single-sided subduction.

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