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A discussion of numerical subduction initiation

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In nature, subduction can initiate in various ways: Shortening can localise at oceanic transform faults, extinct spreading centres, or inherited passive margin faults; or, alternatively, subduction can be triggered from existing subduction systems by along-strike trench propagation, polarity reversals, or trench jumps. Numerical studies that specifically address subduction initiation have highlighted the roles of sediment loading, rheological strength contrasts, strain softening, and continental topographic gradients, among others. Usually, however, numerical models that aim to investigate subduction dynamics prefer to bypass the subduction initiation phase and its complexities, and focus instead on the stages during which the slab is descending into the mantle. However, even in these models, subduction still needs to begin.

It is disturbingly easy to define initial model geometries that do not result in subduction. The specific combination of initial model geometries and values for rheological parameters that successfully initiates subduction has even been referred to as 'the sweet spot' in model space. One cause of subduction initiation failure is when the subducting and overriding plates lock, resulting in either indentation or severe dragging downwards of the overriding plate. This may point to a difficulty in maintaining a weak subduction interface during model evolution. A second factor that may cause difficulties is that initial model geometry and stresses need to balance, as otherwise the first model stages may show spurious deformation associated with reaching equilibrium. A third requirement that may cause problems is that the surface needs to have sufficient displacement freedom to allow the overriding plate to overthrust the subducting plate. That also implies an exclusion of sharp corners in the subduction interface near the surface.

It is the interplay of subduction interface geometry, interface strength and subducting plate rheology that determines if subduction can numerically initiate. However, once a setup has been found that successfully initiates subduction, a small change in either rheology or geometry can again lead to subduction initiation failure. We will discuss subduction setups that have been known to fail and how to avoid them, thus potentially leading to successful recipes for numerical subduction initiation.

A further point we will discuss is how the geometry of weak zones and pre-existing slabs that are used to initiate a subduction model can impact subsequent subduction style and velocity. For example, using simple linear viscous subduction models we find that initiation along shallow initial pre-existing weak zones and/or pre-existing slabs results in shallow, forward dipping slabs, whereas steep initial dip angles lead to steep slab dips and an overturned slab.