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The role of the initiation phase in numerical subduction models

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Subduction initiates by localisation of contraction, but it is still not well understood how this process occurs in nature. For this reason, numerical models of subduction dynamics often bypass the subduction initiation phase. However, subduction in these models still needs to be started and different approaches exist to do so. Many models use a short slab that represents an initial phase of subduction which is not explicitly modelled. The geometry of such a pre-existing slab may vary in dip angle, initial depth of the slab tip, and the radius of curvature near the trench. The slab starts to subduct because it has a higher density than its surroundings and/or because its rheological and geometrical contrast with the surrounding mantle helps to localise contraction caused by applied velocity boundary conditions. Alternatively, subduction may start at inherited shear zones or discrete faults between the subducting and overriding plate or at so-called weak 'seeds', thought to represent remnants of earlier deformation phases. There is clearly no unique approach to start a numerical model of subduction. As published models of subduction not only differ in their initial setup, but also in their material properties and boundary conditions, their results cannot be used to evaluate the potential impact of the initial thermal and mechanical structure on the subsequent evolution of a numerical model. We therefore use one numerical model to show how different choices for starting a subduction model could propagate into later stages of model evolution. We use SULEC, our thermo-mechanical finite-element (ALE) code, which is tailored to modelling large deformation processes at crustal to upper-mantle scales with a true free surface. We show how the geometry of subducting slabs in the upper mantle may vary in dip angle and curvature depending on the initial dip angle of weak lithosphere shear zones or pre-existing short slabs. Initiation along shallow weak zones or pre-existing slabs leads to non-vertical slab dip angles and a slab that drapes on the base of the upper mantle in a forward manner, whereas steep initiation can cause the slab to bend over backwards. A pre-existing slab leads to a fast subduction start and may influence slab geometries for low dip angles, but its role becomes less important for increasing initial dip angle. Our results show that as long as there is no general agreement on how subduction initiates, we should be careful how we start subduction in our models.