Auxiliary material for

Parameters Controlling Dynamically Self-Consistent Plate Tectonics and Single-Sided Subduction in Global Models of Mantle Convection

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S1 Figure: Numerical Resolution Test

A resolution test is carried out with the numerical experiments of mantle convection in 2-D geometry of 2:1 aspect ratio with resolutions ($nx \times ny$) ranging from 128×64 up to 1024×512. The overall dynamics of mantle convection is similar for resolutions higher than 128×64 (see Figure S1.1). However, the temporal evolution of plate tectonics is quite different between differently resolved models: Lower resolved models tend to favour shutting down the mobile lid style of plate tectonics early, whereas higher resolved models ($dz < 15$ km throughout the lithosphere) show ongoing subduction for a longer time period. The slabs are harder to break off in high-resolution cases because of two reasons: (a) the remaining strength in the core of the down-going plate during subduction and (b) the remaining weakness of narrow shear zones, two key ingredients for single-sided subduction. A strong core and narrow shear zones can be lost if they are not resolved properly.

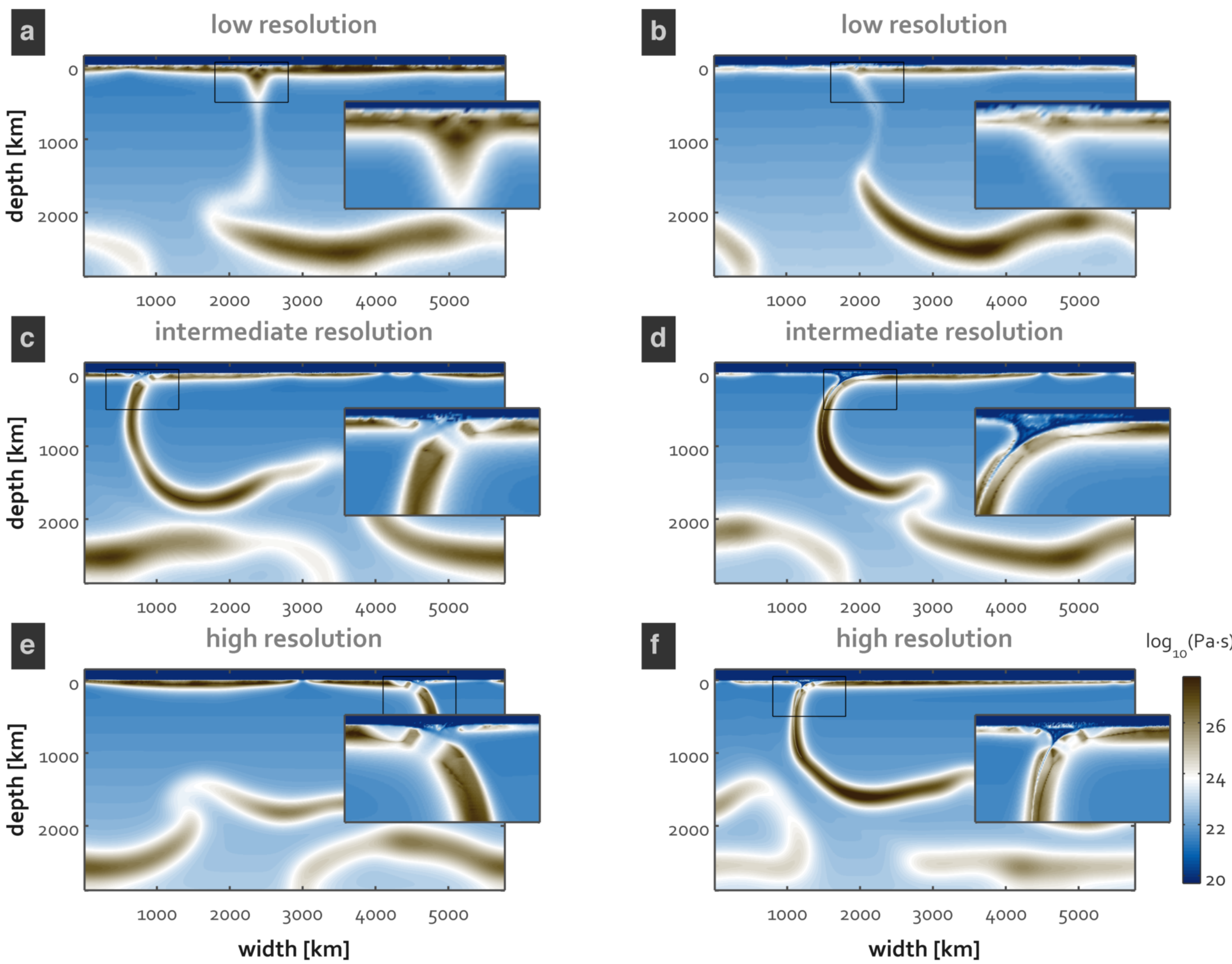

Figure S1.1: Resolution test for 2-D experiments of mantle convection with a mobile lid for (a,c,e) a model with free surface without a weak crustal layer ('$topBC2'$) and (b,d,f) a model with free surface plus a weak crustal layer ('$topBC3'$). Shown are ($nx \times ny$) grid resolutions of (a,b) 256×128, (c,d) 512×256 and (e,f) 1024×512.

S2 Figures: Initial Condition Test - Slab Depth

The initial slab depth (d_{slab}) is varied from a non-dimensional depth of $d_{slab} = 0.1$ down to $d_{slab} = 0.7$ while keeping the plate thickness constant (Figure S2.1). The negative pressure exerted by the negative buoyancy of the slab measured at the top of the slab (just at the bottom of the surface boundary layer) steadily increases with increasing slab depth as presented by a separate experiment without plasticity (Figure S2.2). The stress exerted there solely by the hanging slab is described by $\sigma_{slab} = \Delta\rho \cdot g \cdot d_{slab}$, where $\Delta\rho$ is the density difference between the slab and the surrounding mantle and g is the gravitational acceleration. If the stress exerted by a very shallow reaching slab is too low to overcome the strength of the plate, subduction cannot be initiated as is the case for $d_{slab} = 0.1$ (see Figure S2.1a). In order to also give strong plates a chance to initiate subduction, an initial slab depth of $d_{slab} = 0.5$ is chosen for subsequent experiments.

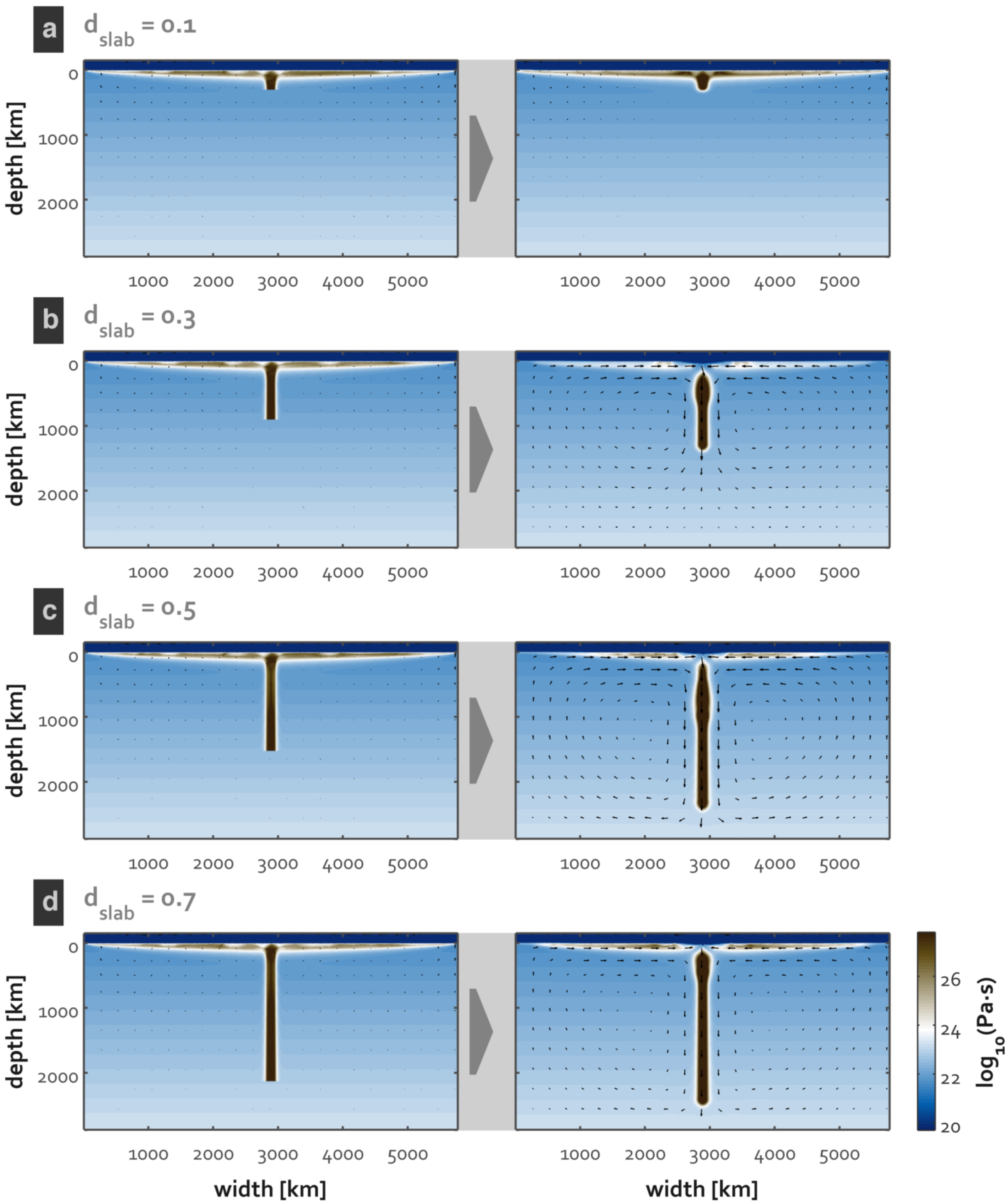

Figure S2.1: Time evolution (from left to right) of different initial setups showing a selection of initial slab depth ranging from (a) $d_{slab} = 0.1$ to (d) $d_{slab} = 0.7$. An initial slab depth of $d_{slab} \leq 0.1$ does not initiate subduction. Snapshots are taken at 0 (left hand side) and 19 Ma (right hand side).

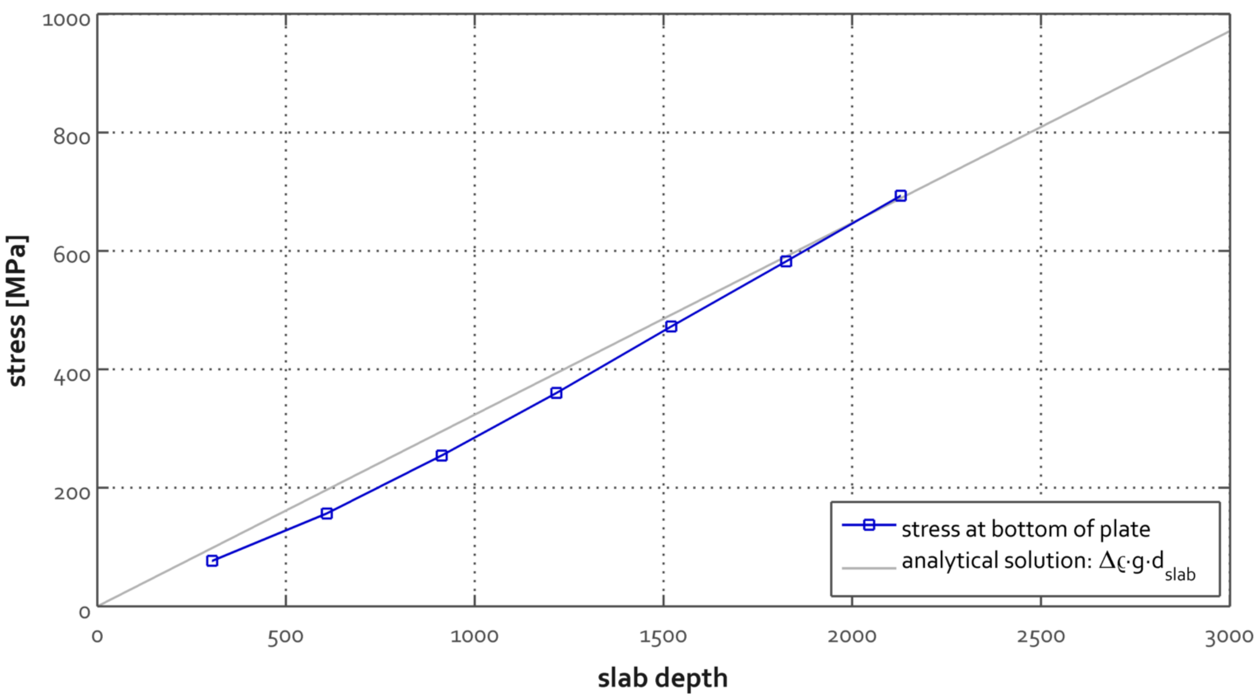

Figure S2.2: Stress magnitude at the bottom of the plate just above the initial slab for the different initial setups ranging between an initial slab depth of $d_{slab} = 0.1$ and $d_{slab} = 0.7$ compared to the analytical solution of $\sigma(h) = \Delta\rho \cdot g \cdot h$. This is derived from an experiment that is run without plasticity, in order to not influence stress distribution and initial tendency of slab sinking.

S3 Figure: Initial Condition 2 - Explanation

Figure S3.1 explains the second initial condition for on-going subduction used in this study.

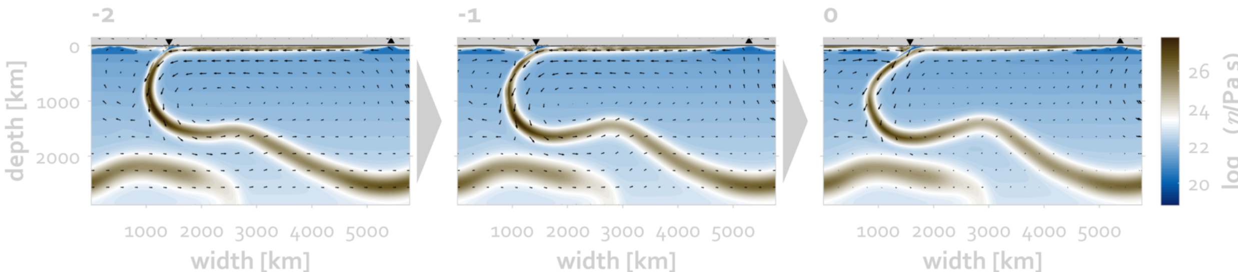

Figure S3.1: The time evolution of the model '*standard*1' shortly before ($t = -2$ and $t = -1$) and at the time snapshot ($t = 0$) that is chosen as a second initial condition. The model stage at $t = 0$ provides a possibility to compare parameters during already well developed, on-going subduction.

S4 Movie: Mobile-Lid Evolution

The movie shows a typical mobile-lid evolution of the case '*comp*1' for horizontal plate velocity (top left), viscosity (top right), the second invariant of the stress tensor (bottom left) and the second invariant of the strain rate (bottom right): Asymmetric double-sided subduction evolves into single-sided subduction after a weak part of the overriding plate collides with the subduction trench. Single-sided subduction operates until a subduction-polarity reversal occurs. Finally mobile lid is terminated by slab break-off due to a ridge-trench collision.

See separate movie file: ms01.mov