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Transient subduction following upper plate acceleration/slow down

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Plate reorganization associated with mantle convection leads to changes in plate absolute velocity over geological time scales. At the global scale, these accelerations/slow down can reach values up to $2.5\text{x}10^{-23}$ m.s^{-2}, i.e changes of up to 5 cm/yr over a 2 m.y. period (after Zahirovic et al., 2015). In this study, we aim at understanding how such changes in the kinematics of the upper plate can influence subduction dynamics and slab geometry. Are changes in the overriding plate tectonic regime and in the slab geometry synchronous or delayed with respect to modifications of plate kinematics? For this, we use an approach combining three-dimensional analogue models and two-dimensional numerical models of subduction (ADELI code).

In analogue models, we impose instantaneous changes of the upper plate velocity during subduction and observe how the subduction system turns back to equilibrium with the new boundary conditions. The adjustment times appear independent of the imposed upper plate velocity and of the changes of upper plate velocity. Scaling of our models show that this transient stage lasts $\sim$ 11±4 m.y. for the shallow ($\sim$125 km deep) dip of the slab, $\sim$16±2 m.y. for the deeper ($\sim$330 km deep) part of the slab, and $\sim$4±2 m.y. for bulk upper plate deformation. Using 2-D numerical models, we explore the effect of different internal parameters (thickness and viscosity of the slab, viscosity of the mantle) as well as external parameters (instantaneous vs. progressive acceleration slow/down of the upper plate) on the duration of the transient stage.

We also compare our modeling results with present-day subduction zones and their evolution through the last 20 m.y. Data analysis suggests an adjustment time of $\sim$15 m.y. for shallow slab dip and $\sim$20 m.y. for deep slab dip in Nature. Since only 1% and 9% of the 260 studied subduction transects exhibit a constant upper plate velocity over the last 20 m.y. and 15 m.y., respectively, most of subduction zones must be in a transient stage at present-day. It may explain why the correlation observed in present-day subduction zones between upper plate velocity on the one hand, slab geometry and upper plate deformation on the other hand, is not as good in Nature as expected from simple subduction models in which applied boundary are constant with time.