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Influence of overriding plate velocity changes on slab dip and deformation: insights from laboratory models

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Over geological times, plate reorganization associated with mantle convection led to changes in absolute plate velocities, which may in turn have impacted the geometry of the subducting plate as well as the overriding plate regime of deformation. Indeed, previous studies have shown a very good correlation between the absolute motion of the overriding plate on one hand and slab dip and overriding plate deformation on the other hand: extension and steep slab are associated with an overriding plate moving away from the trench while shortening and shallow slab occur if the upper plate goes the other way. However, these correlations are established when subduction has reached a steady-state regime and for a constant motion of the overriding plate over the subducting plate, which may not always be the case on Earth. The response of the subduction system to changes in absolute overriding plate velocity still remain an open question.

In this study, we conducted a set of 3-D mantle-scale laboratory models of subduction in which we incrementally changed the velocity of the overriding plate to reproduce changes of velocities that may arise from variations of far-field boundary conditions in Nature. We first show that strain rates in the overriding plate are correlated with overriding plate absolute velocity but also that the regime of deformation adjusts rapidly to changes of velocity. This may explain for instance why despite the subduction has been continuous beneath South America since at least the middle Jurassic, shortening along its active margin is only recorded episodically, the main phases of Andean orogeny roughly corresponding to periods of South American plate westward acceleration. We also show that slab dip adjusts to changes of overriding plate velocity but it requires several Myr before it stabilizes. It may explain why the correlation between absolute overriding plate motion and slab dip from the analysis of present-day subduction zones is only moderate, part of the subduction zones possibly not being at steady-state at present-day.