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Intrinsic and Extrinsic Factors in Subduction Dynamics

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Since the realization that tectonic plates sink into the mantle, in a process we now call subduction, our understanding of this process has improved dramatically through the combined application of observations, theory and modeling. During that time independent research groups focusing on different aspects of subduction have identified factors with a significant impact on subduction, such as three-dimensionality, slab rollback, rheology of the slab and mantle and magnitude of phase changes. However, as each group makes progress we often wonder how these different factors interact as we all strive to understand the real world subduction system. These factors can be divided in two groups: intrinsic factors, including the age of the slab, its thermal structure, composition, and rheology, and extrinsic factors including others forces on plates, overall mantle flow, structure of the overriding plate, rheology of the mantle and phase changes. In addition, while modeling has been a powerful tool for understanding subduction, all models make important (but often necessary) approximations, such as using two dimensions, imposed boundary conditions, and approximations of the conservation equations and material properties. Here we present results of a study in which the “training wheels” are systematically removed from 2D models of subduction to build a more realistic model of subduction and to better understand how combined effects of intrinsic and extrinsic factors contribute to the dynamics. We find that a change from the Boussinesq to the extended Boussinesq form of the conservation equations has a dramatic effect on slab evolution in particular when phase changes are included. Allowing for free (dynamically-driven) subduction and trench motion is numerically challenging, but also an important factor that allows for more direct comparison to observations of plate kinematics. Finally, compositional layering of the slab and compositionally-controlled phase changes also have a strong effect on the rate of subduction and small-scale buckling and folding of the slab. These studies suggest that the evolution of slabs can differ significantly from more simplified models, and therefore a better understanding of the underlying physical controls on slab dynamics requires more realistic models.