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Numerically modelling along-strike rheologic variations in 3D subduction zones

Derek Neuharth[1], Whitney Behr[1], and Adam Holt[2]
[1]Geological instituite, ETH Zurich, Zurich, Switzerland
[2]Rosenstiel School of Marine, Atmospheric, and Earth Science, University of Miami, Miami, USA

Because subduction zones can extend thousands of kilometers along-strike, many previous studies have used 2D subduction models which inherently assume homogeneity along-strike. However, in nature we see that subduction zones are often heterogeneous along-strike and can exhibit significant variations in the subducting plate age, thickness, and viscosity, trench location, as well as in the geometry of the overriding plate. While 2D models can test large system-wide changes to these parameters by assuming homogeneity along-strike, how variabilities in the geometry and rheology interact with each other in a three-dimensional setting is poorly understood.

To understand how along-strike variations affect an evolving subduction zone, we developed self-consistent 3D subduction models using the finite element code ASPECT. The models include a thermally-defined subducting plate and overriding plate, and a constant-viscosity crust/interface. We vary two primary parameters along-strike: 1) the viscosity of the interface shear zone and 2) the thickness of the overriding plate, which affects the interface shear zone length. We explore how varying each of these parameters affects the subduction, convergence, and trench rollback velocities, slab morphology, and the stress distribution and topography formation within the overriding plate.

We find that along-strike variations to the interface viscosity or overriding plate thickness has only minor effects on the slab morphology and convergence velocities, but largely affects the surface stress distribution. While variations in the overriding plate thickness or interface viscosity do not affect the convergence velocity along-strike, having a thicker overriding plate or stronger interface leads to a reduction in the system-wide convergence velocity. Despite the similar velocities along-strike, slab morphology changes along-strike, with lower dips seen in regions with a greater overriding plate thickness or weaker interface viscosity. Most importantly, along-strike changes to either parameter results in significant differences in the surface stress distribution. Higher stresses build within the side that has a thicker overriding plate or stronger interface. This increase in stresses results in greater topography, with a maximum variation along-strike of up to ~1.2 km.