Arcuate subduction – a fragile structure

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Present-day curved subduction zones range from recently deformed trenches (e.g. Marianas, Melanesia) to old and well established subduction zones (e.g. Scotia, Caribbean). Seismic tomography in the Marianas has imaged the subducting slab to have torn horizontally, which has also been suggested for the Melanesia subduction zone. The slab tears in the subducting lithosphere are most likely to result from varying rollback velocities during initial phases of curvature. They segment the lithosphere and allow for continuous subduction along the arcuate trench. The trench shape for older arcuate subduction zones has been reconstructed to have been increasing its curvature continuously. Underlying processes might include buoyant features on the subducting plate, toroidal flows around the slab edges or other dynamic adjustment due to slab curvature.

In this study, we develop 3-D numerical models to investigate a lifetime of arcuate subduction zones, with a special focus on plate deformation and slab tearing. The models suggest that a horizontal slab tear during the initial phase of curvature is a common feature for subduction in this geometry. We also expect the curved slab to tear periodically until it reaches its preferred subduction orientation, namely, trench-perpendicular. During the restructuring of subduction dynamics, both subducting and overriding plates are deformed as well as neighbouring plates rotating inwards towards the trench. Main parameters governing the dynamics of arcuate subduction zones have been identified as the slab's strength, thickness and width, as well properties of the overriding plate such as its mobility. Finally, we also compare the model results to the observed examples.