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Numerical modeling of subduction beneath non-uniform overriding plates: Time-dependent evolution of slab geometry and trench-parallel flow

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Seismic anisotropy measurements show that the fast spreading direction below the slab is aligned parallel to the trench in the central region and perpendicular near the edges. Above the slab it has a complex pattern, often showing abrupt transitions between trench-parallel and trench-perpendicular directions and sharp changes in intensity.

The origin of this complex pattern is poorly understood, however, previous models have shown that variations in slab geometry can cause trench-parallel flow above the slab. In turn, overriding plate thermal state influences the slab dip, which suggests a causal link between overriding plate structure, slab geometry and mantle flow in subduction zones.

We study the effect of along-strike variations in thermal thickness of the overriding plate on the evolution of slab geometry and induced mantle flow. To perform the study we implement generic 3D time dependent thermo mechanical numerical models of buoyancy driven subduction using CitcomS. We find that increased hydrodynamic suction beneath the colder portion of the overriding plate causes shallower slab dip. The variation in slab geometry drives strong trench-parallel flow beneath the slab and a complex flow pattern above the slab. The mantle flow pattern responds to the changing geometry of the slab, which makes the process strongly time-dependent. The location and strength of trench-parallel flow vary throughout the simulations, which suggests that the global variability in seismic anisotropy in present-day observations is in part due to the non-steady-state behavior of subduction systems. This new mechanism for driving trench-parallel flow provides a good explanation for seismic anisotropy observations from the Middle and South America subduction zones, where both slab dip and overriding plate thermal state are strongly variable and correlated.