EGU21-7344
https://doi.org/10.5194/egusphere-egu21-7344
EGU General Assembly 2021

Presence and significance of backstops in the overriding plate during the megathrust earthquake cycle

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Seismological and geodetic observations indicate that similar physical processes are active at different subduction margins and provide information about the deformation at the different stages of the earthquake cycle. We analyze geodetic observations along sections of the South American subduction zone during the inter-seismic stage. Results show that overriding plates shorten from the trench to a “backstop”, where horizontal inter-seismic velocities become close to zero. In most, but not all regions, the backstop location from trench-perpendicular GPS velocities agrees with that from trench-parallel velocities. The distance of the backstop from the trench varies along the western South America margin. Backstop locations shows some correlation with gradients in the effective elastic thickness of the overriding plate. An apparently conflicting observation is that co-seismic and early post-seismic GPS-displacements during the 2010 Maule earthquake extended well beyond the backstop into eastern South America. Similarly conflicting observations were made in the overriding plate of the 2004 Sumatra earthquake and the 2011 Tohoku earthquake.

We use cyclic 3D numerical models with dynamically driven co-seismic and afterslip to test the hypothesis that lateral contrasts in the thickness and/or elasticity of the overriding plate explain the observations. The model setup allows us to explore the sensitivity of geodetically observable surface motion to the mechanical structure of the subduction system during all parts of the earthquake cycle. We conclude that the observations can be explained by a lateral contrast. Such contrast restricts inter-seismic horizontal velocities in the region between the trench and the backstop, controlling their gradient, while allowing deformation due to coseismic slip and afterslip to reach well into the far field. One particularly interesting finding from our models is that stress accumulation in the overriding plate is controlled by the distance to the backstop.