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The signature of the earthquake cycle at subduction zones: comparing geodetic observations with long-term models for Mw>8 events

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Some of the convergent margins are now densely instrumented on the overriding plate side. As a result, recent megathrusts events in Tohoku, Maule and Sumatra were well recorded. Regional models of the earthquake cycle have become increasingly sophisticated tools to understand the geodetic signals. They capture critical physical processes like (partial) locking of the plate interface, the detailed co-seismic slip, poro-elastic and mantle relaxation and afterslip. Emerging from the observations and the models is that similar physical processes are active at different margins, and that part of the observed complexity is controlled by them being in different stages of the earthquake cycle. We present results of geodynamic models aimed at isolating the geodetic signature of these physical processes after many earthquake cycles. This setup allows us to incorporate earthquake history and make long-term predictions of geological observables. Different time scales enter the problem: the loading time scale is defined by the recurrence time of the largest earthquake in the catalogue, the relaxation time scale by viscoelastic material properties. The results show that the ratio of the loading and relaxation time scales exerts a critical control. For Tohoku and Sumatra, this ratio is relatively large. These margins therefore undergo a protracted post-seismic relaxation period, including a slow migration away from the trench of the (convergence) point where horizontal velocities change from trench- to continent ward. The time ratio is much smaller in Chile, resulting in a short post-seismic relaxation period. After post-seismic relaxation, simple horizontal shortening of the elastic surface layer dominates. Formal inversion of the synthetic geodetic velocities reproduces the imposed 100% locking of the seismogenic fault during this stage. Vertical velocities on the overriding plate are largely controlled by the geometry of the seismogenic fault, and by the horizontal distance between the trench and the back-stop. Application of our model results to pre-, co- and post-seismic geodetic observations suggests that our models capture the main aspects of earthquake cycle that are shared by different convergent margins.