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Studying the along fault variability of slow earthquake characteristic by modeling a combined viscoelastic and damage rheology

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The seismo-tectonic cycle in the subduction zones is largely controlled by the level of coupling between the sliding oceanic and continental plates that strongly varies with depth. Close to the surface, at depths of a few tens of kilometers, the plate interface remains most of time locked and is occasionally broken by large earthquakes. On the other hand, the oceanic lithosphere slips into the mantle continually at large depths. Between these two zones of locked and stable slip, the transient zone is characterized by "slow earthquakes" that are mainly manifested by episodes of silent slip and tectonic tremor that are to some degree correlated in time.

Along-fault changes of the degree of inter-plate coupling are controlled by variations of the fault-zone rheology, which in turn is related by depth-dependent thermo-mechanical conditions and composition of rocks. The brittle-ductile transition and the slow earthquake cycle are often modeled with using the rate-and-state interface rheology. This empirical formulation represents the transition segment by assimilating brittle and frictional processes to the problem of a material interface friction. To this aim, a parametric model is obtained based on experimental studies of the frictional behavior of various materials at the laboratory scale. Although this framework reproduces the transition between a stick-slip cycle and the stable sliding behaviors it cannot represent steady-state relaxation processes and presents a limit to which it can be enriched to include the chemical, mineralogical and hydro-mechanical processes within faults.

To overcome these limitations, we are using a modeling approach based on a continuum volumetric rheology that allow us to model physically-based variations of parameters with depth. Namely, we use a combination of viscoelastic Maxwell and damage rheologies. The resulting model is capable to take into account the localized deformations associated with quasi-brittle processes on short time scales as well as the diffuse deformations associated with the stress relaxation in the bulk of the geophysical system over long time scales. The problem is studied in two dimensions with associated boundary conditions. Along fault variations of the important controlling parameters such as the viscosity, the cohesion coefficients, and the damage recovery time are investigated in order to understand their respective contribution in the slow earthquake cycle.

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