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The long-term seismic cycle in geodynamic, numerical simulations of a subduction zone

Ylona van Dinther (1), Taras V. Gerya (1), Luis A. Dalguer (1), P. Martin Mai (2), and Gabriele Morra (3)

(1) Institute of Geophysics, ETH Zurich, Zurich, Switzerland (ylona.vandinther@tomo.ig.erdw.ethz.ch), (2) Division of Physical Sciences & Engineering, KAUST, Thuwal, Saudi Arabia, (3) School of Geosciences, University of Sydney, Sydney, Australia

Earthquakes occur over different spatial and temporal scales. While abundant data are available to gain understanding of short-term behavior of earthquakes, the long-term evolution of subduction zone seismicity remains elusive due to the limited observational time span. Additional complexities of subduction zone seismicity arise from its inaccessibility, complex setting, and the uncertainty about the nature of the thrust fault interface. Realistic numerical modeling of subduction zone physics can help to improve our understanding of the long-term seismic cycle. By means of quantification of macroscopic parameters comparable to seismic observations and periodicity through time we aim to increase our comprehension of this long-term cycle and the physics governing it. The main challenge will be to unravel the source of this periodicity, and see how different friction laws operating on the thrust fault affect it.

We use a plane-strain, coupled petrological and thermo-mechanical finite-difference scheme with marker-in-cell technique to solve the conservation of momentum, mass, and energy for a visco-elasto-plastic rheology (I2ELVIS). In a 1500x200 km^2 model a generic oceanic plate subducts below a continental overriding plate, spontaneously generating localizations of plastic strain when the second invariant of the deviatoric stress tensor exceeds the Drucker-Prager yield stress.

The fluid-dynamic continuum models show several spontaneously formed clusters of plastic strain localizations whose activity is coupled through the thrust interface. The link, in terms of type and degree of correlation, between these clusters and their periodicity varies with different subduction regimes, which are most likely distinguished by thrust coupling. We observe long-term periodicities varying between either 20.000 and 40.000, and 100.000 years. Within the localization zones, we observe sudden drops in stress simultaneously with strong increases in strain rate, i.e. a rapid spatial increase in acceleration, that we use to define slipping events. Preliminary results from an event detection algorithm show a heterogeneous distribution of slip within the weakest basaltic crustal layer, where the high slip patches, i.e. asperities, are located at its thinnest, most coupled section. Also the main seismogenic zone is located at the most coupled portion of the interface, where events occasionally extend upward to below the accretionary wedge reaching slip lengths up to 45 km. The seismogenic zone is roughly bounded by the 200 and 450 degrees Celsius isotherms. Preliminary we observe that a distribution of events over a period of 200.000 years follows a power law, partially with a slope of 1. In order to be able to draw conclusions on these patterns, we need to identify the source of the periodicities and patterns observed and understand the physics behind it.