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

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Earthquakes occur over different spatial and temporal scales. Due to a lack of direct observations, a full understanding of the long-term evolution of seismicity within subduction zones remains elusive. Without this information, it is difficult to quantify the recurrence interval of large earthquakes based on observations over our current, limited time period. Realistic numerical modeling of subduction zone physics can help to improve our understanding of the long-term seismic cycle. In this study, we aim at understanding the physics driving this cycle. By quantitatively balancing energy sources and sinks we try to estimate the types of mechanisms that are potentially driving seismic energy release. At the same time, we try to determine the causes of and space-time relationships for the activity within different clusters, where special attention is given to the potential presence of compressional events within the bending area.

We use a plane-strain finite-difference scheme with marker-in-cell technique to solve the conservation of momentum, mass, and energy for a visco-elasto-plastic rheology (code I2ELVIS). In our 4000×200 km^2 numerical model of ocean-continent convergence, a generic oceanic plate subducts below a continental overriding plate. In a petrologically realistic setting, localizations of plastic strain are spontaneously formed when the second invariant of the deviatoric stress tensor exceeds the Drucker-Prager yield stress. This leads to a correction of stresses to the yield stress at each marker, accompanied by a decrease in overall viscosity to mimic local weakening.

Preliminary results show the existence of spontaneous clusters of plastic strain localizations, within the thrust, outer-rise bending, and back-arc areas. Within these localizations, we observe periods of rapid deformation that are accompanied by an immediate stress drop. The activity of the clusters is closely linked to the most energetic events at the thrust interface that have a periodicity of 25-30.000 years. In periods of reduced coupling, the thrust slips more rapidly, and promotes extension within both the bending and back-arc areas. This coupling suggests that pressure unloading drives faulting within these areas. Tentatively, the main thrust event is preceded by activity within the bending area. Increasing time resolution and comparison with observational evidence, should tell us whether this could provide a numerical tool to help forecast major earthquakes.