Geophysical Research Abstracts
Vol. 12, EGU2010-8193, 2010
EGU General Assembly 2010

Subduction thrust seismicity in geodynamic numerical simulations compared to observations

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Subduction thrust earthquakes occur over different spatial and temporal scales. In this study, the long-term earthquake cycle is investigated in a 4000x200 km ocean-continent subduction setting. Events or periods of rapid deformation, present within spontaneously formed localizations of plastic strain, are collected and quantified for comparison to observations and scaling to nature. The resulting database gives insight into the cyclic nature and timing of large earthquakes.

The characteristics of the subduction zone seismic cycle also differ for different convergent margins. Subduction zones that are weakly coupled and receive a lot of sediment are likely to produce large mega-thrust earthquakes, while more and smaller earthquakes are observed next to compressive overriding plates, where the coupled fault receives less sediment. This distinction is tested in our model by producing different databases with events for different overriding plate tectonic regimes, different inter-plate frictions and different amounts of sediments.

To model the long-term seismic cycle in a subduction zone 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 a generic, petrologically complex continent-ocean subduction zone, localizations of plastic strain are formed when the second invariant of the deviatoric stress tensor exceeds the Drucker-Prager yield criterion, leading to a correction to the pressure-dependent yield stress by decreasing a viscosity-like parameter.

We assume a seismic event occurs when a sudden considerable stress drop occurs simultaneously with an immediate strong increase in strain rate. For these events we collect estimates of depth, stress drop, and slip area, assuming equi-dimensional slip areas, and thereby acquire a very rough indication of earthquake size.

Previous results have shown the existence of several clusters of plastic strain localizations, at the thrust interface, bending outer-rise, back-arc, and accretionary wedge, whose cycle is related to the by far most energetic events at the thrust interface. These thrust events spread over depths of about 15 km and occur about every 10.000 years within a seismogenic zone extending from about 20 to 35 km depth. They also showed the presence of a long-term cycle in dissipated strain energy rate of the order of 30.000 years.