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Earthquake and slow-slip nucleation investigated with a micro-physics based seismic cycle simulator

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Laboratory experiments grant essential insights into the frictional behaviour of faults over a wide range of conditions. However, these experiments are limited in the size of the test subject (the rock sample) and in their duration, which hinders the extrapolation of lab results to the scales of natural faults. Seismic cycle numerical modelling provides the means to bridge this spatial and temporal gap between laboratory experiments and nature. Modelling of the evolution of fault rock friction, leading to earthquake nucleation, and rupture propagation is commonly performed based on rate-and-state friction (RSF). While the governing equations are convenient for implementation into numerical codes, they are empirical in nature, and the absence of a physical basis for extrapolation of laboratory-derived parameters complicates the interpretation of results that are derived from such models. By contrast, analytical models based on micro-physical principles allow for an interpretation of their predictions in terms of well-defined material properties and thermodynamic quantities, but are often restricted to highly simplified geometries and boundary conditions.

In this work, we present a numerical implementation of the micro-physical model proposed by Chen & Spiers (2016), which describes the interplay between granular flow and ductile creep of fault gouges, into an earthquake cycle simulator, QDYN (Luo & Ampuero, 2011). This physics-based approach offers an alternative to the rate-and-state friction laws for more detailed investigation of earthquake source mechanics. With this implementation, characteristic features typically ascribed to rate-and-state friction laws emerge spontaneously from the model, and can be related to physical properties of the material of study under the appropriate pressure and temperature conditions. We investigate the nucleation behaviour of frictional instabilities, with focus on the transition from stable creep to slow-slip and to dynamic rupture. The outcomes are subsequently compared with predictions of classical rate-and-state friction models.

References:

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