EGU21-16502
https://doi.org/10.5194/egusphere-egu21-16502
EGU General Assembly 2021

State evolution laws and earthquake nucleation

Robert Viesca

In models of faults as elastic continua with a frictional interface, earthquake nucleation is the initiation of a propagating dynamic fault rupture nucleated by a localized slip instability. A mechanism capturing both the weakening process leading to nucleation as well as fault healing between events, is a slip rate- and state-dependent friction, with so-called direct effect and evolution effects [Dieterich, JGR 1979; Ruina, JGR 1983]. While the constitutive representation of the direct effect is theoretically supported [e.g., Nakatani, JGR 2001; Rice et al., JMPS 2001], that of the evolution effect remains empirical and a number of state-evolution laws have been proposed to fit lab rock friction data [Ruina, JGR 1983; Kato and Tullis, GRL 2001; Bar-Sinai et al., GRL 2012; Nagata et al., JGR 2012]. These laws may share a common linearization about steady-state, such that a linear stability analysis of steady, uniform sliding yields a single critical wavelength for unstable growth of perturbations [Rice and Ruina, JAM 1983]. However, the laws' differences are apparent at later, non-linear stages of instability development.

Previously, we showed that instability development under aging-law state evolution could be understood in terms of dynamical systems [Viesca, PR-E 2016, PRS-A 2016]: the non-linear acceleration of slip occurs as the attraction of a fault's slip rate to a fixed point, corresponding to slip rate diverging with a fixed spatial distribution and rate of acceleration. Here we show that this framework can also be applied to understand slip instability development under all commonly used evolution laws, including the so-called slip and Nagata laws. To do so, we develop an intermediate state evolution law that transitions between the slip and aging laws with the adjustment of a single parameter. We show that, to within a variable transformation, the intermediate law is equivalent to the Nagata law and that fixed-point blow-up solutions exist for any value of the transition parameter. We assess these fixed-points' stability via a linear stability analysis and provide an explanation for previously observed behavior in numerical solutions for slip rate and state evolution under various evolution laws [Ampuero and Rubin, JGR 2008; Kame et al., 2013; Bar-Sinai et al., PR-E 2013; Bhattacharya and Rubin, JGR 2014].