CONDITIONS FOR SLOW-TO-FAST SLIP IN A SINGLE-ASPERITY STRIKE-SLIP FAULT

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Numerical models are typically invoked to predict if and where slow (aseismic) or fast (seismic) slip occurs on a fault over geological time scales. However, results are problem-dependent: predictions cannot be obtained without prior numerical simulations. Here, we provide a mechanistic approach that allows to predict a-priori and accurately whether a finite fault governed by rate-and-state friction and loaded by steady creep at its extremities is expected to give rise to seismic slip, aseismic transients, or simply steady creep. We focus on a vertical strike-slip fault with a rate-weakening asperity embedded within an otherwise stable, rate-strengthening surface. We leverage linear and non-linear stability analyses of slip to define semi-analytically the critical asperity size that could lead to an earthquake or simply a transient acceleration of creep, as a function of governing dimensionless parameters.

Our results, supported by elasto-dynamic numerical simulations, show that, for a given rate-strengthening condition surrounding the asperity, its critical size above which slip rate becomes linearly unstable to tiny perturbations decreases non-linearly with decreasing values of a/b (< 1) characterizing the asperity, with b and a being the phenomenological parameters of rate-and-state friction. Also, when this size is much smaller compared to the total fault length, we show its value agrees well with the calculated critical size of a single asperity within an infinitely long fault, whose value is shown to increase logarithmically the less pronounced rate-strengthening condition is around the asperity. Finally, when the asperity size is large enough for slip rate to be both linearly and non-linearly unstable, seismic events nucleate, and inertia is mobilized.