

## Numerical friction experiments on macroscopic friction law of a heterogeneous fault element

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The friction law of a fault is one of the main ingredients of modeling of fault behaviors including a large earthquake and its recurrence. It is usually studied in laboratory experiments for cm-scale specimens, and one of the prominent problems is its direct applicability to large-scale behaviors. Small repeating earthquakes (repeaters) may be a realization of heterogeneous frictional property on faults, which were modeled by rate-weakening patches embedded in a rate-strengthening fault [e.g., Chen and Lapusta, 2009]. After the 2011 Tohoku-oki earthquake, so many repeaters were found in the Tohoku subduction zone [e.g., Kato and Igarashi, 2012]. But it is quite difficult to numerically resolve all of them in a large-scale simulation of the whole subduction zone, which is demanded for potential disaster mitigation. Therefore, it is important to investigate a spatiotemporally coarse-grained friction law of a fault region including unstable inclusions. We hypothesized that each point on a fault obeys the cm-scale friction law (the rate-state friction law in the aging law formulation) with sub-mm state evolution distance  $L$ , and assumed a rate-weakening circular patch (80 m diameter) which generates repeating events. We set 256 m periodicity along the fault, and conducted dynamic earthquake sequence simulations [e.g., Liu and Lapusta, 2009] by driving the system by far field stress  $\tau_0$  and observing averaged slip on the fault. Those simulations can be seen as numerical friction experiments with controlling the shear stress and observing the slip rate.

The macroscopic steady-state can be explained by a logarithmic law, with the frictional resistance slightly smaller and the rate-dependency slightly more rate-strengthening than the spatial average of the friction law assumed for each point on the fault. The transient behavior on a positive step in  $\tau_0$  can be explained by the aging law with significantly longer  $L$  and smaller  $a$ - and  $b$ -values. The optimum parameters and estimation errors do not intersect for different amount of the stress step, indicating that the macroscopic friction law takes a different form from the aging law.

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