Quantitative relationship between aseismic migration speed and frictional properties

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Motivated by recent observations of the migration of slow slip transients such as slow earthquakes, the propagation of tremors and very low-frequency earthquakes, postseismic slip and the expansion of aftershock areas, we develop a new analytical relationship between the migration speed of aseismic slip transients and frictional properties of the fault, modeled by a rate- and state-dependent friction law. The relationship explains the migration speed of slow slip in 3-D numerical model simulations to first order (Figure 1), except near the earth's surface.

Based on this relationship, we identify systematic dependencies of slow slip migration speed on effective normal stress σ and frictional properties. Lower values of the parameter $A=a\sigma$ cause faster propagation in areas where the passage of the postseismic slip front induces large shear stress changes $\Delta\tau$ compared to A. Reducing the values of a-b and σ is more effective at accelerating slow slip propagation in areas where $\Delta\tau/A$ is small. The migration speed is inversely proportional to d_c.

The relationship developed here should be useful to constrain the frictional properties of faults based on observed migration speeds, independently of rock laboratory experiments, which can then be used in predictive numerical simulations of aseismic slip phenomena.

By applying our theory to slow slip propagation observed in the Tohoku region, we suggest that an apparent propagation speed increase about two weeks before the 2011 Tohoku earthquake may be explained by a temporal increase of background slip rate due to partial decoupling of the locked region around the mainshock or by an increase of fault fluid pore pressure.

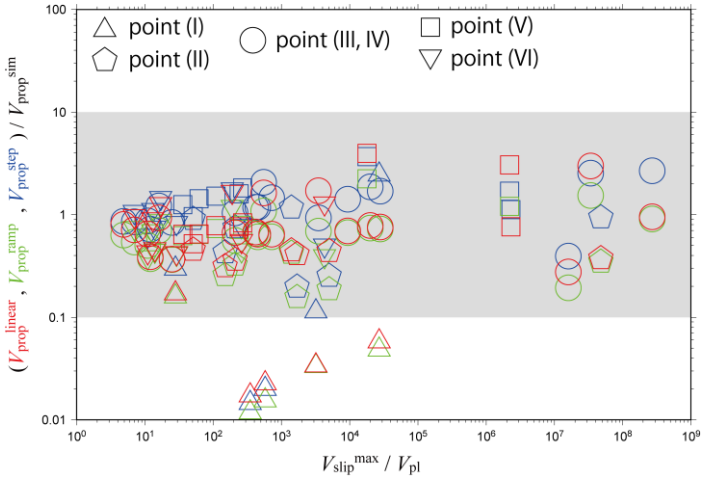

Figure 1. Comparison of between analyzed (V_{prop}^{linear}: red, V_{prop}^{ramp}: green, V_{prop}^{step}: blue) and simulated (V_{prop}^{sim}) postseismic slip propagation speed as a function of maximum slip velocity (V_{slip}^{max}) normalized by plate convergence rate (V_{pl}). Gray colored band indicates the range of values for which the analyzed propagation speed is predicted within one order of magnitude.