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Stick-slip as a monitor of rates, states and frictional properties along thrusts in sand wedges

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We developed a sandbox setup which allows monitoring the push of the moving backwall indenting a layer of sand. Depending on the ratio between indenter compliancy versus strain weakening of the granular material, wedge deformation shows unstable slip marked by force drops of various sizes and at multiple temporal scales. Basically we observe long-period slip instabilities related to strain localization during the formation of new thrusts, intermediate-period slip instabilities related to reactivation of existing thrusts and short-period slip instabilities related to the stick-slip mechanism of slip accumulation along "seismic" faults.

Observed stick-slip is characterized by highly correlated size and frequency ("regular stick-slip") and is sensitive to integrated normal load, slip rate and frictional properties along the active thrust(s). By independently constraining the frictional properties using a ring-shear tester, we infer the integrated normal loads on the active faults from the stick-slip events and benchmark the results against a model calculating the normal loads from the wedge geometry. This way we are able to monitor rates, states and frictional properties along thrusts in sand wedges at unprecedented detail.

As an example of application, a kinematic analysis of the stick slip events in the sandbox demonstrates how slip rates along thrusts vary systematically within accretion cycles although the kinematic boundary condition is stationary. Accordingly transient fault slip rates may accelerate up to twice the long-term convergence rate during formation of new thrusts and decelerate in the post-thrust formation stage in a non-linear way. Applied to nature this suggests that fault slip rate variations at the thousand-year time scale might be attributable to the elasticity of plates and material weakening rather than changes in plate velocities.