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Mesoscopic scale analysis of deformation patterns for dynamically triggered slip in sheared granular layers: insights into the granular mechanics of dynamic earthquake triggering via Discrete Element Method numerical simulations

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Seismologists have accumulated, in the last 20 years, increasing evidence that many earthquakes are induced or influenced by the seismic waves produced by other distant earthquakes.
This seismological phenomenon goes under the name of "dynamic earthquake triggering" and the underlying physics of triggering is still not understood. Experiments with laboratory scale model faults have shown that elastic waves can induce slip events when the model fault is filled in by a granular layer, which corresponds to wear rock materials, called "fault gouge", in actual mature Earth crust faults. The granular mechanics of dynamic earthquake triggering may be related with dynamic triggering of the solid-to-fluid transition in sheared granular layers undergoing stick-slip dynamics.
Discrete Element Method (DEM) numerical simulations of sheared granular layers are of paramount importance in investigating the granular mechanics origins of dynamic earthquake triggering because they allow monitoring particle-scale variables during their temporal evolution as well as tracking down and characterizing the granular spatial-temporal patterns.
In this talk, we present results of Discrete Element Method (DEM) simulations of a granular layer confined between and sheared by two deformable, thick blocks. In the simulations, the layer undergoes stick-slip motion.
We have performed simulations both in the absence and in the presence of a vibration displacement imposed at the boundaries of one of the blocks. The aim of these simulations is to investigate the granular mechanics of the layer during the stick-slip dynamics and how it is affected by vibration.
We present results of detailed analysis about the spatial-temporal evolution of the mesoscopic scale affine and non-affine deformation fields that develop during the stick-slip cycle, both in the absence and in the presence of externally applied vibration. We also show how energy is dissipated during spontaneous and dynamically triggered slip events.
The results show that slip in general is accompanied by the appearance of localized regions with high values of both affine and non-affine deformations. These regions are correlated in time and space and mainly located within a shear zone. We found that the energy released during slip is also mainly localized in the shear zone during the initial stage of slip. Dynamic triggering is found to initiate immediate or delayed slip when vibration is applied once the shear stress has reached 75% or more of the shear strength for the corresponding non-vibrated stick phase. Vibration is found to introduce affine and non-affine strains in the granular layer, which then trigger slip at lower shear stress.