The source scaling of swarm-genic slow slip events

Luigi Passarelli¹, Eleonora Rivalta², Paul Antony Selvadurai³, and Sigurjón Jónsson¹
¹King Abdullah University of Science and Technology (KAUST), Physical Sciences and Engineering Division (PSE), Thuwal, 23955-6900, Saudi Arabia
²GFZ German Research Centre for Geosciences, Telegrafenberg, 14473 Potsdam, Germany
³Swiss Seismological Service, ETH Zürich, Zürich, Switzerland

Slow slip events (SSEs) are slow fault ruptures that do not excite detectable seismic waves although they are often accompanied by some forms of seismic strain release, e.g., clusters of low- and very-low frequency earthquakes, and/or episodic or continuous non-volcanic tremor (i.e. tremor-genic SSEs) and earthquake swarms (swarm-genic SSEs). At subduction zones, increasing evidence indicates that aseismic slip and seismic strain release in the form of non-volcanic tremor represent the evolution of slow fracturing. In addition, aseismic slip rate modulates the release of seismic slip during tremor-genic SSEs. No general agreement has been reached, however, on whether source duration-moment scaling of SSEs is linear or follows that of ordinary earthquakes (cubic). To date, investigations on the source scaling has been based on global compilations of tremor-genic SSEs while no studies have looked into the source scaling of swarm-genic SSEs.

We present the first compilation of source parameters of swarm-genic slow slip events occurring in subduction zones as well as in extensional, transform and volcanic environments. We find for swarm-genic SSEs a power-law scaling of aseismic to seismic moment release during episodes of slow slip that is independent of the tectonic setting. The earthquake productivity, i.e., the ratio of seismic to aseismic moment released, of shallow SSEs is on average higher than that of deeper ones and scales inversely with rupture velocity. The inferred source scaling indicates a strong interplay between the evolution of aseismic slip and the associated seismic response of the host medium and that swarm-genic SSEs and tremor-genic SSEs arise from similar fracturing mechanisms. Depth dependent rheological conditions modulated by fluid pore pressure, temperature and density of asperities appear to be the main controls on the scaling. Large SSEs have systematically high earthquake productivity suggesting static stress transfer as an additional factor in triggering swarms of ordinary earthquakes. Our data suggest that during the slow slip evolution the proportion of seismic strain release is always smaller than the aseismic part although transient changes in stress and fault rheology imparted by swarm-genic SSEs can lead to delayed triggering of major and devastating earthquakes like in the Tohoku, Iquique and L’Aquila cases. The evidence of source scaling reported here will help constraining theoretical models of SSEs rupture propagation and seismic hazard assessments that should take into account the new scaling between aseismic and seismic moment release.