Towards a better understanding of the impact of erosion on fault slip and seismicity

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Tectonics, climate and surface processes dictate the evolution of Earth's surface topography. Topographic change in turn influences lithospheric deformation, but the temporal and spatial scales at which this feedback can be effective remains an open issue. Here, we make a synthesis of recent developments investigating how erosion impacts the stress-loading of faults and potentially induces some earthquakes. We first show, using an elastic model for the lithosphere, that erosion rates of ca. 0.1–20\,mm\,yr\textsuperscript{-1}, as documented in active compressional orogens, can raise the Coulomb stress by ca. 0.1–10 bar on the nearby thrust faults over an earthquake cycle, by changing both the normal and tangential stress. This model also suggests that short-lived but intense erosional events can represent a prominent mechanism for inter-seismic stress loading of faults near the surface. Indeed, we demonstrate that typhoon Morakot in 2009, which triggered numerous landslides, was followed by a step increase in the shallow (< 15 km depth) earthquake frequency and in the $b$-value, lasting at least 2.5 years. These observations suggest that the progressive removal of landslide debris by rivers from southern Taiwan has increased the crustal stress rate and earthquake activity. Last, we use QDYN, a quasi-dynamic numerical model of earthquake cycles to investigate the effect of a large erosional event, such as typhoon Morakot, on seismicity. We show that erosional events with a duration shorter than the duration of an earthquake cycle can significantly increase the seismicity rate, even for small stress changes. Consistent with the increase in the $b$-value observed after typhoon Morakot, our results also show that large erosional events with a period similar to the earthquake nucleation timescale can change earthquake size distribution by triggering more small events. Overall, these modelling
results and observations highlight that short-lived but intense erosional events can lead to perceptible changes in shallow seismicity, affecting both earthquake frequency and size-distributions.