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Transient responses of surface properties to large earthquakes: what do we learn from coupling geomorphological and geophysical data?

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Some studies have suggested that the shaking and deformation associated with earthquake would result in a temporary increase in hillslope erodibility. However very few data have been able to clarify what causes this transient and what controls it temporal evolution.

We present integrated geomorphic data constraining an elevated landslide susceptibility to rainfall following 5 continental shallow earthquakes, the Mw 6.9 Finisterre (1993), the Mw 7.6 ChiChi (1999), the Mw 6.6 Niigata (2004), the Mw 6.8 Iwate-Miyagi (2008) and the Mw 7.9 Gorkha (2015) earthquakes. We constrained the magnitude (5 to 20 fold) and the recovery time (1 to 4 years) of this susceptibility change and associated it with subsurface damage caused by the strong shaking. The landslide data suggest that this ground strength weakening is not limited to the soil cover but also affect the shallow bedrock. Coseismic rock damage is supported by observations of shallow (0 to $\sim$100m) seismic velocity drops constrained with ambient noise waveform correlations within the epicentral area of four of those earthquakes. For most stations we observe a subsequent exponential velocity recovery with an e-folding time in fair agreement with the one estimated based on landslide observation. This recovery dynamics is also consistent with post-seismic processes, namely GPS post-seismic displacement and aftershocks decay. We analyzed strain time series in Japan and Taiwan and it appears inconsistent with the recovery of landslide susceptibility and shallow seismic velocities. In contrast, surface dynamic strain associated with ground shaking caused by aftershocks display similar relaxation time and may control the subsurface property recovery.

However, two end-member models remain plausible at this stage. one in which repeated shaking cause additional damages that delay internal rock healing similar to the one observed in the laboratory. The other, in which repeated vibration allows progressive compaction and strengthening of the regolith, similar to dynamics observed in granular materials. Further data currently acquired in the Gorkha earthquake epicentral area may allow to favor clarify the role of aftershocks.

In any case, our data suggests that in tectonically active areas, deep processes may be significant drivers of the subsurface material properties and thus important to understand and forecast a variety of surface processes.