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Typhoon-driven landsliding induces earthquakes: example of the 2009 Morakot typhoon

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Extreme rainfall events can trigger numerous landslides in mountainous areas and a prolonged increase of river sediment load. The resulting mass transfer at the Earth surface in turn induces stress changes at depth, which could be sufficient to trigger shallow earthquakes. The 2009 Morakot typhoon represents a good case study as it delivered 3 m of precipitation in 3 days and caused some of the most intense erosion ever recorded. Analysis of seismicity time-series before and after the Morakot typhoon reveals a systematic increase of shallow (i.e. 0-15 km of depth) earthquake frequency in the vicinity of the areas displaying a high spatial density of landslides. This step-like increase in frequency lasts for at least 2-3 years and does not follow an Omori-type aftershock sequence. Rather, it is associated to a step change of the Gutenberg-Richter b-value of the earthquake catalog. Both changes occurred in mountainous areas of southwest Taiwan, where typhoon Morakot caused extensive landsliding. These spatial and temporal correlations strongly suggest a causal relationship between the Morakot-triggered landslides and the increase of earthquake frequency and their associated b-value. We propose that the progressive removal of landslide materials from the steep mountain landscape by river sediment transport acts as an approximately constant increase of the stress rate with respect to pre-typhoon conditions, and that this in turn causes a step-wise increase in earthquake frequency. To test this hypothesis, we investigate the response of a rate-and-state fault to stress changes using a 2-D continuum elasto-dynamic model. Consistent with the results of Ader et al. (2013), our preliminary results show a step-like increase of earthquake frequency in response to a step-like decrease of the fault normal stress. We also investigate the sensitivity of the amplitude and time-scale of the earthquake frequency increase to the amplitude of the normal stress change and to rheological parameters. Our study offers new insights on the potential influence of extreme erosional events on the short-time scale dynamics of faults and earthquakes.