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Spatial Patterns of Storm-Induced Landslides and Their Relation to Past Extreme Rainfall

Odin Marc[1,2], Marielle Gosset[3], Hitoshi Saito[4], Taro Uchida[5], and Jean-Philippe Malet[6]
[1]CNRS, Geosciences Environnement Toulouse, France
[2]ETH-Zurich, Earth Surface Dynamics, Zurich, Switzerland (odin.marc@erdw.ethz.ch)
[3]IRD, Geosciences Environnement Toulouse, France
[4]Kanto Gakuin University, College of Economics, Kanagawa, Japan
[5]Graduate School of Life and Environmental Sciences, University of Tsukuba, Tsukuba, Japan
[6]IPGS, CNRS, University of Strasbourg, France

Storm-induced landslides are a common hazard, but the link between their spatial pattern and rainfall properties is poorly understood, mostly because hillslope stability is modulated by under-constrained, spatially variable topographic, hydrological and mechanical properties.

Here, we use a 26 years long, high spatial resolution rainfall dataset from the Japanese radar network, to analyze the landslide pattern (1900 landslides within ~5000 km2) caused by Typhoon Talas (>1500 mm in 3 days) in 2011 in the Kii Peninsula. We show that it poorly correlates with the rainfall amount accumulated during the event over short to long timescales (1-72h), but agrees well with the rainfall anomaly (i.e., the event rainfall amount over the rainfall amount expected for a 10-year return period rainfall). Normalizing the event rainfall by mean annual or seasonal rainfall does not match as well the landslide pattern. This suggests that the variability in hillslope properties has co-evolved with the recent climate, where slopes exposed to stronger extreme rainfall have experienced higher landslide rates until their properties (e.g., regolith thickness, strength and permeability) have reached an equilibrium. In this framework, the 10-year return rainfall amount would be a proxy for hillslope properties, and we show that it allows an improved prediction of the landslide pattern when coupled with rainfall amount and slope. Finding ways to constrain the spatial variability of these parameters to test this hypothesis is an exciting challenge.

Last we note that rock-types seem to respond to rainfall anomalies at various timescales, favoring specific landslide geometries, and suggesting various hydrological properties in these zones. Specifically, a coastal area underlain by highly weathered volcanic rocks yielded a high landslide density with a high proportion of debris flow, correlating with the 2h anomaly while the rest of the landslides matches best the 48h anomaly.

Although such influence of lithology on hydrological behavior remains hard to predict, we propose the computation of rainfall anomalies for multiple timescales to pave the way towards operational landslide forecasts in case of large storms. More generally, regional landslide susceptibility maps may also be significantly enhanced by considering maps of past extreme rainfall.