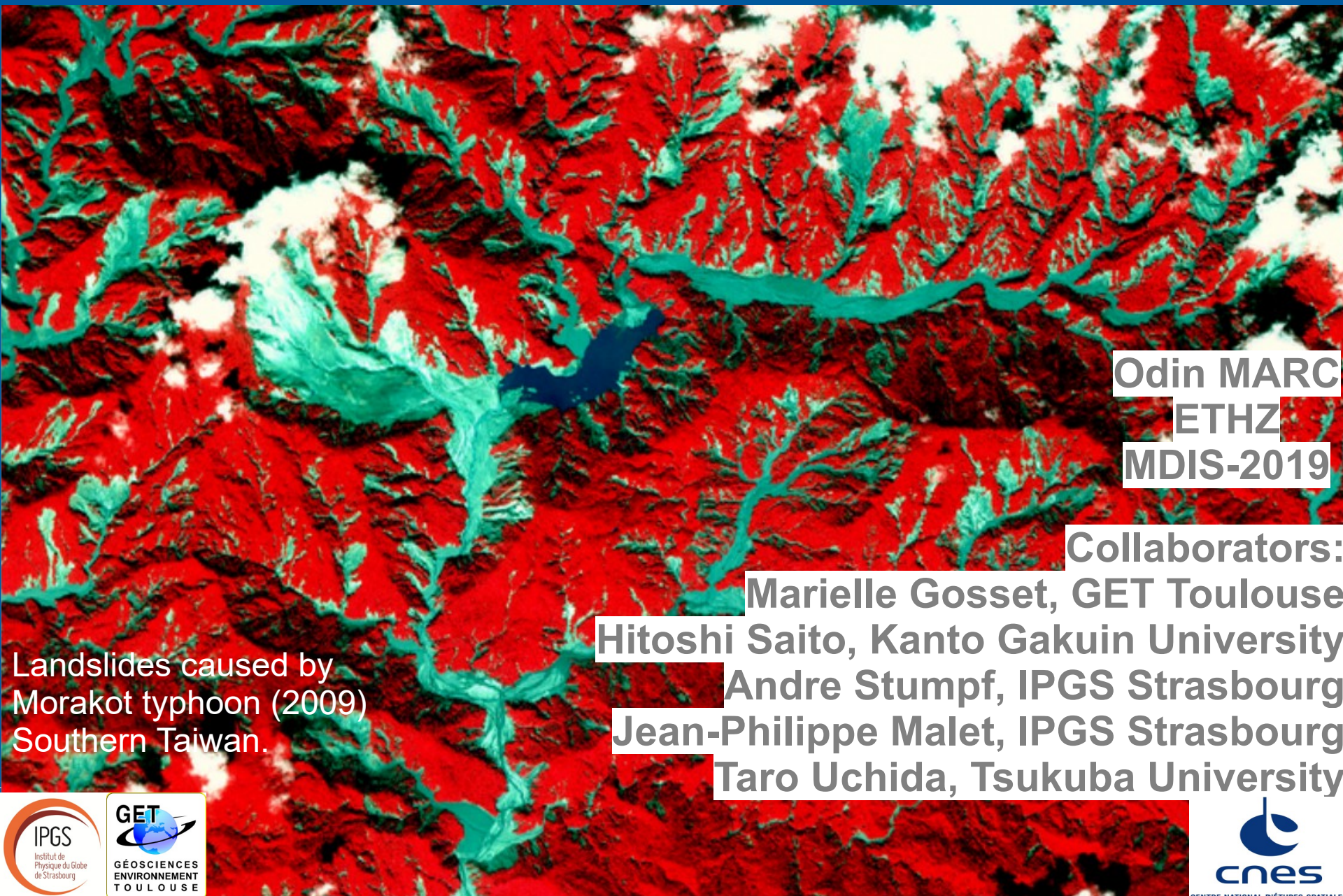
What do we learn from storm-induced landslide inventories ?

The role of total rainfall, landscape steepness and extreme climatology.



Odin MARC
ETHZ
MDIS-2019

Collaborators:
Marielle Gosset, GET Toulouse
Hitoshi Saito, Kanto Gakuin University
Andre Stumpf, IPGS Strasbourg
Jean-Philippe Malet, IPGS Strasbourg
Taro Uchida, Tsukuba University

Landslides caused by
Morakot typhoon (2009)
Southern Taiwan.

IPGS Institut de Physique du Globe de Strasbourg

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Outline

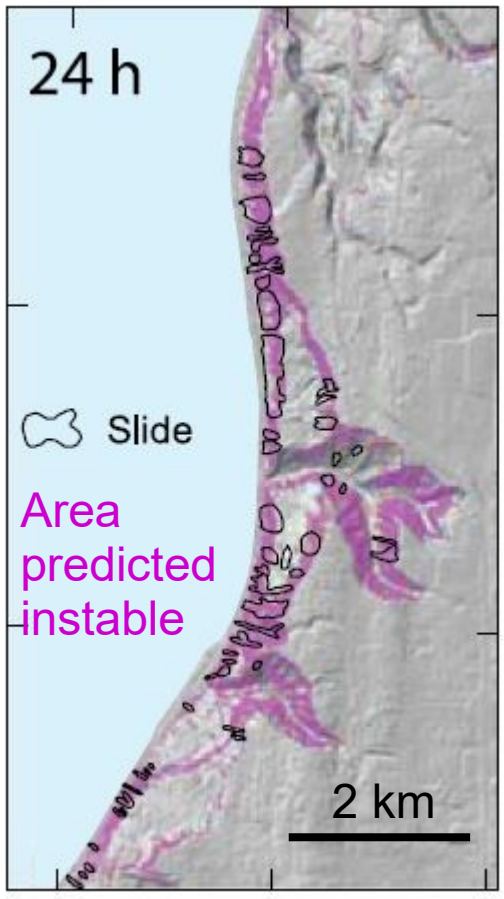
1/ Motivation and approach

2/ Sites and data processing

3/ Developing Landslide-Rainfall scaling relationships ?

Conclusions

Mechanistic models are underconstrained



Baum et al., 2010

Slope stability models require fine scale constraints on:

→ Topography,

→ Materials properties (friction, cohesion)

→ Subsurface hydrology (porosity, thickness and permeability of different layers)

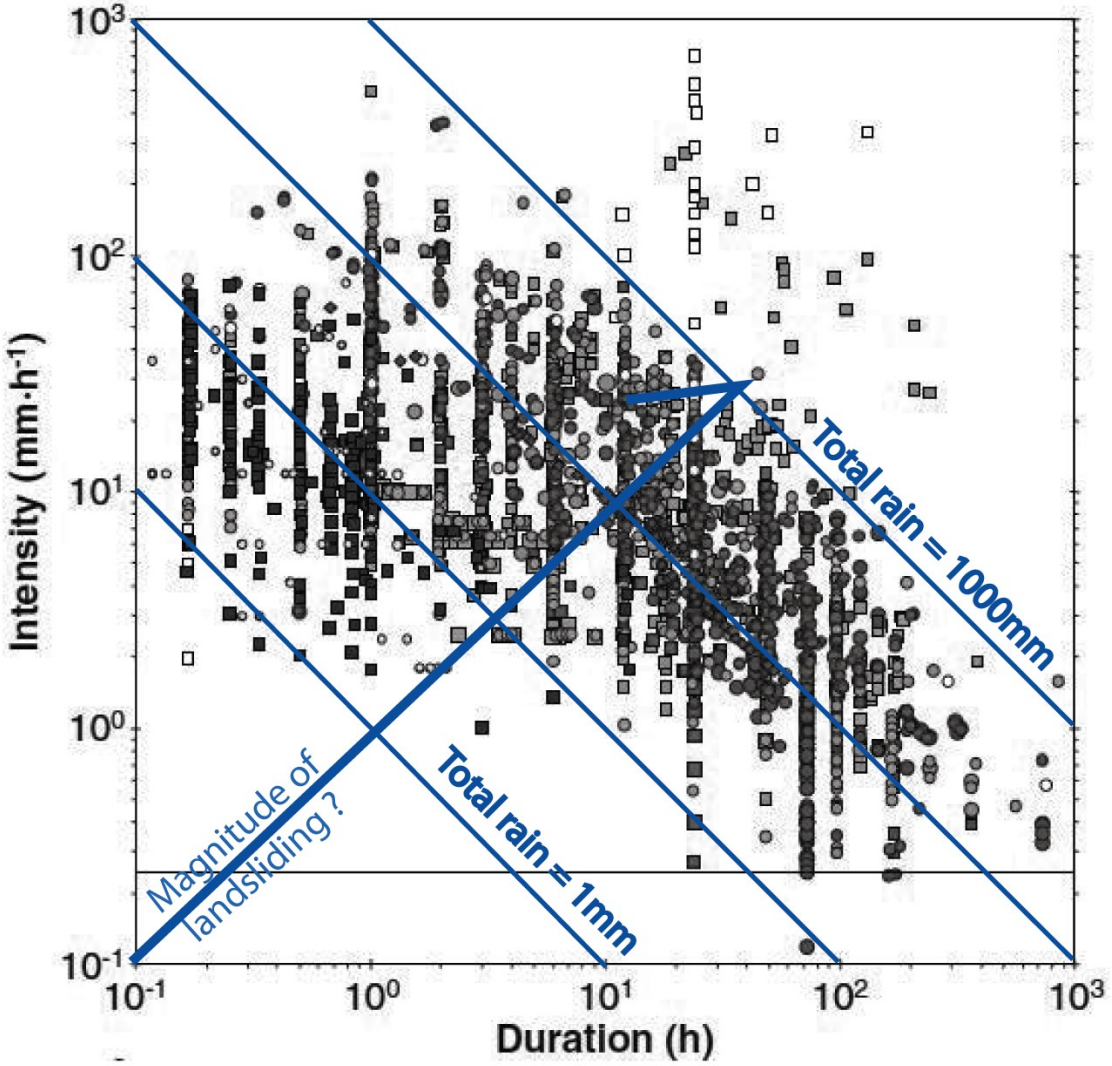
→ History of rainfall intensity.

Hardly applicable at regional scales.

→ Statistical approach based on large inventories, and meso-scale (10km) averaging.

Empirical approach: Rainfall threshold

Conventional approach : relate the occurence of a given landslide to nearby meteorological information. Almost no info on landslides.

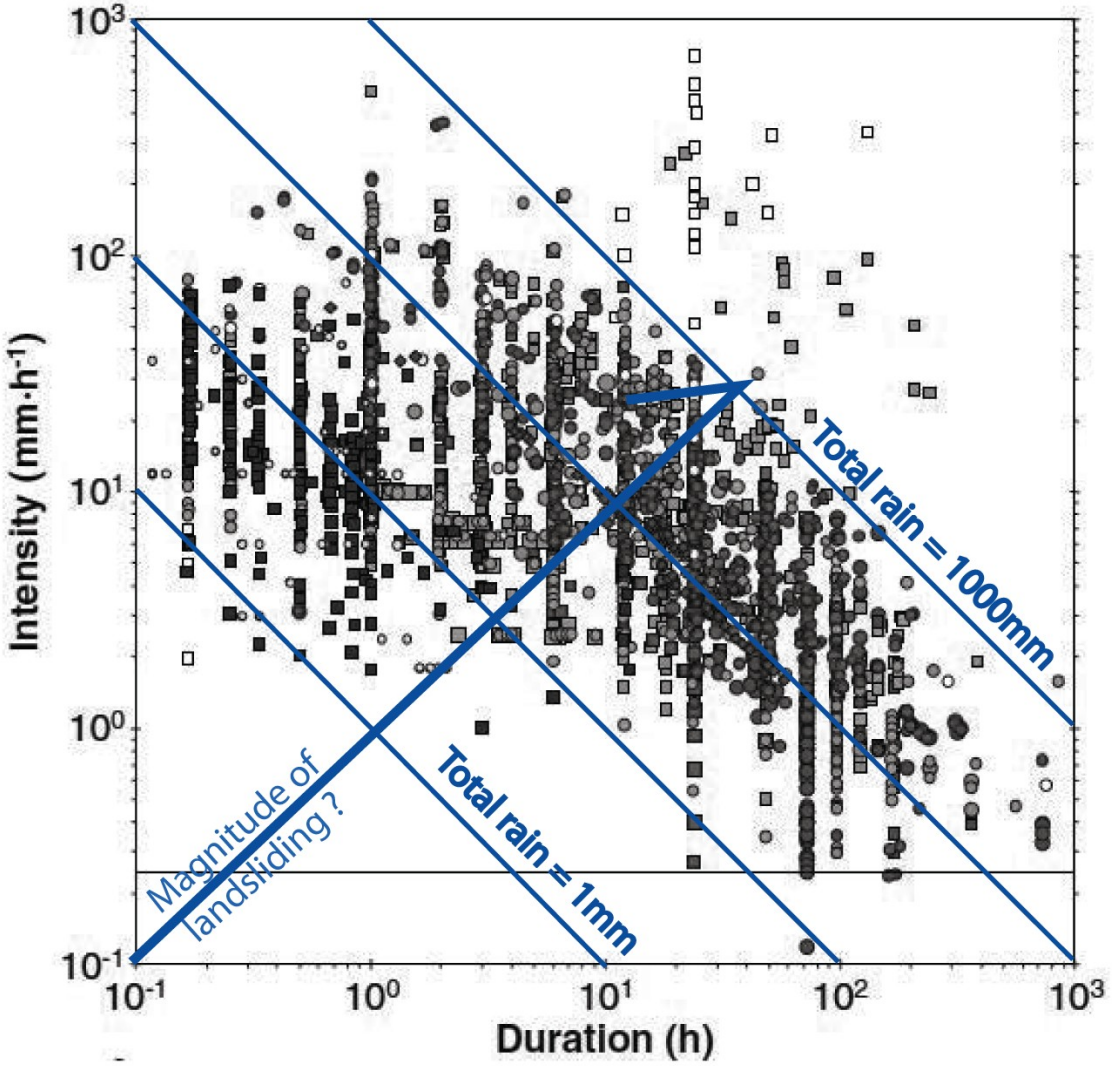


Guzzetti, et al., 2008

Empirical approach: Rainfall threshold

→ **How does rainfall drive landsliding beyond the threshold ?**

→ **What type of rainfall data do we need to understand landsliding ?**



Guzzetti, et al., 2008

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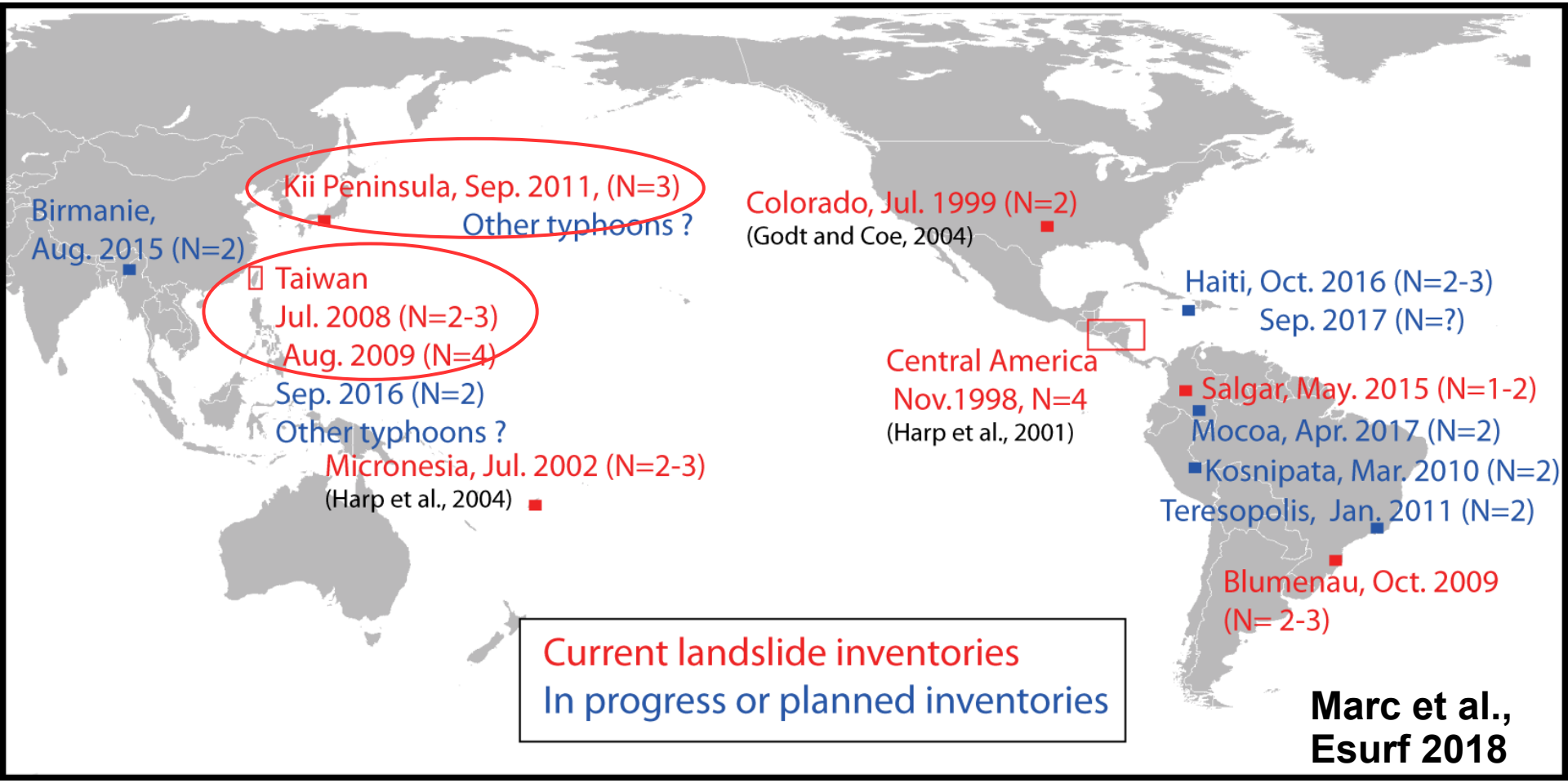
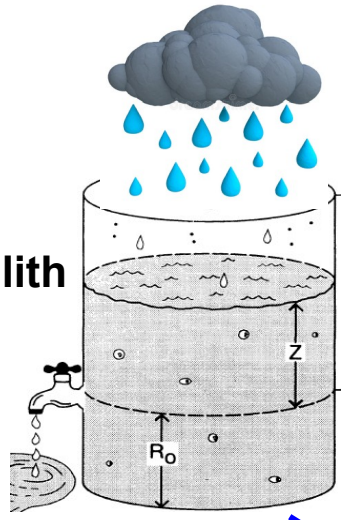
Site of interest

Focus on Japan and Taiwan, because landslding occurred over wide areas and within an extensive raingage network.



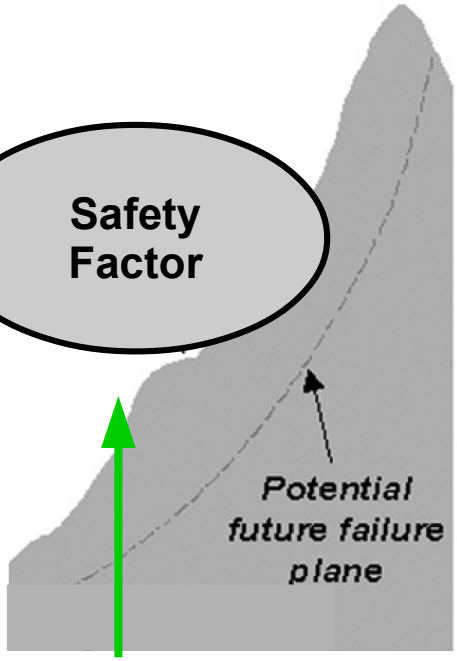
Controls on landsliding



Pore-Pressure

Total rainfall, intensity, Duration,...

Safety Factor



Internal Parameters

Cohesion, friction, slope gradient, permeability...

Available constraints:

→ Rainfall pattern;

→ Slope distribution (DEM)

Approach

1) Average landsliding and constraints over ~10 km radius.

2) Fit a rainfall – landslide relationship

3) Predict landslide pattern.

Outline

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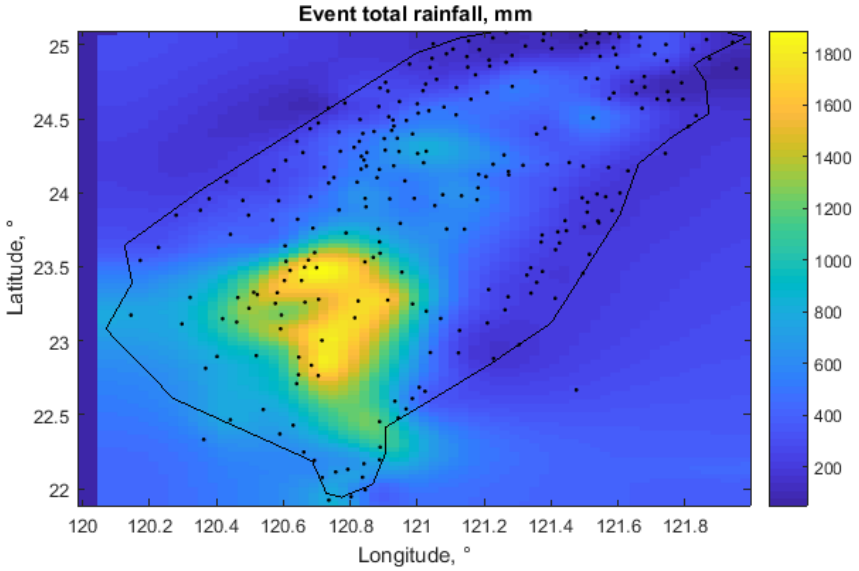
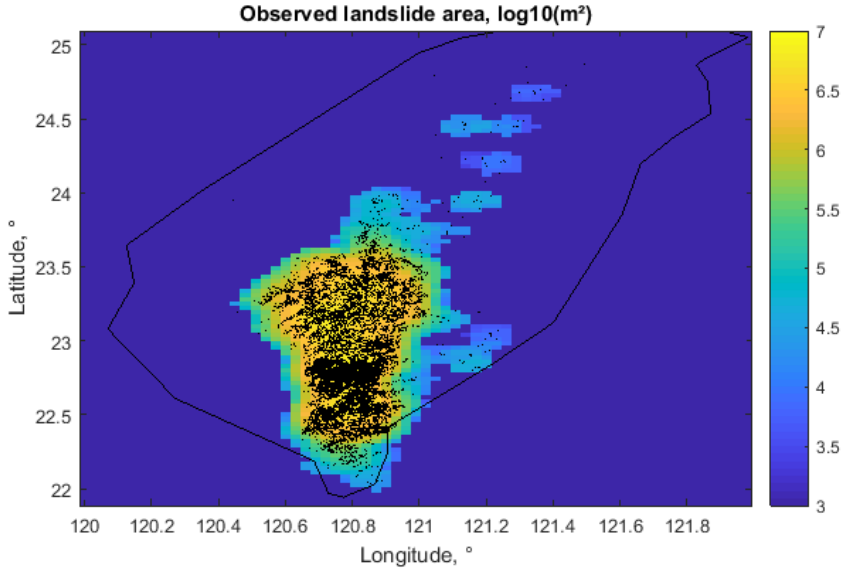
Landslide pattern:Taiwan 2009

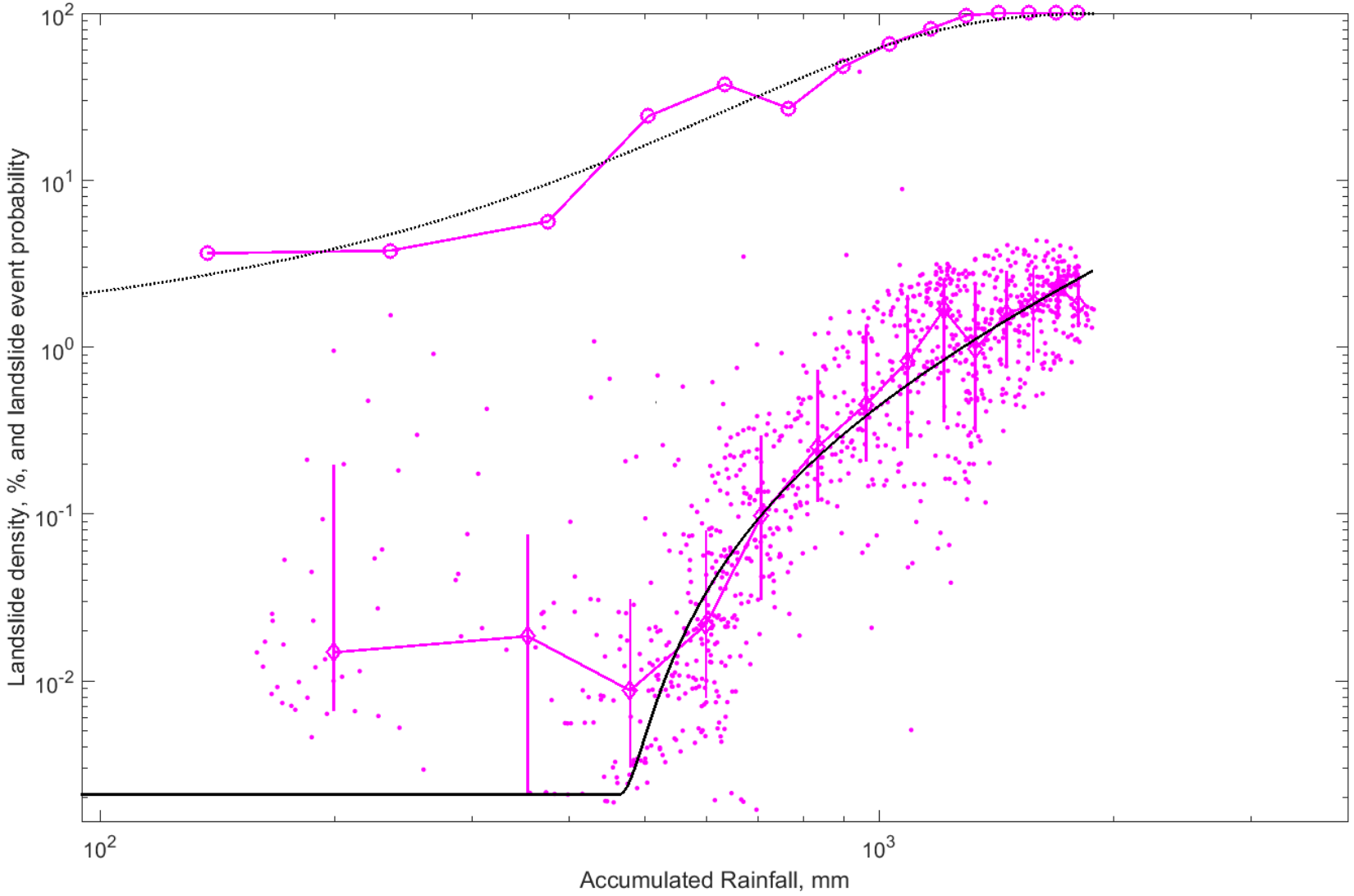




Landslide rainfall scaling: Taiwan 2009

Landslide probability: P (Rain=X & $\mathbf{L_d}$ >0) / P (Rain =X)

Landslide Density : total landslide area / area with Slope>15°



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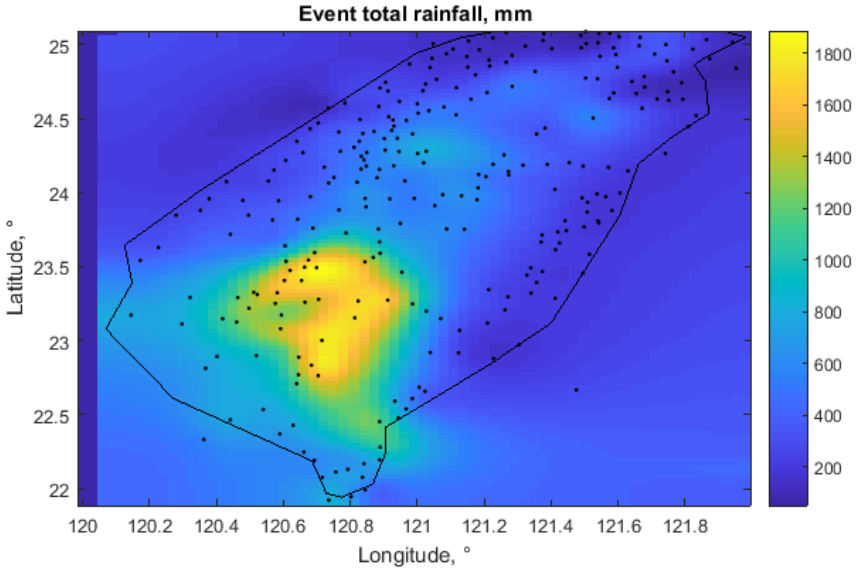
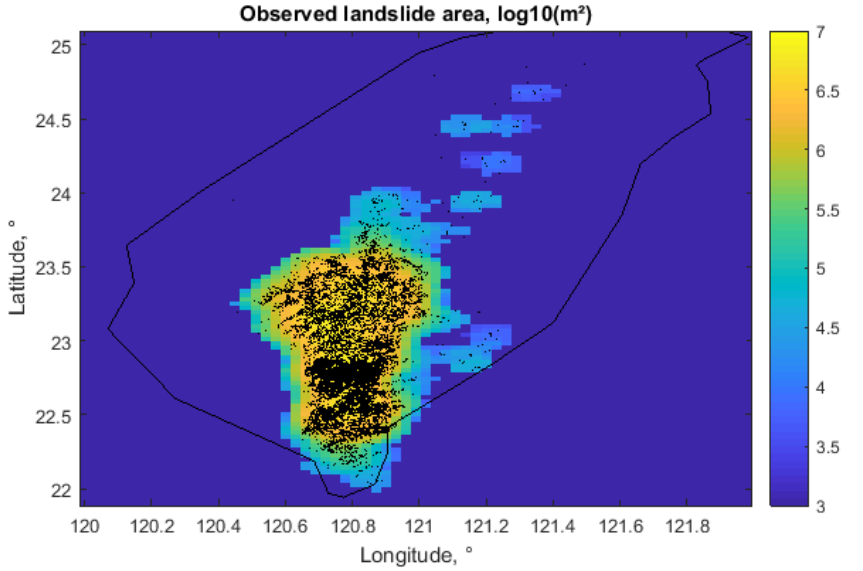
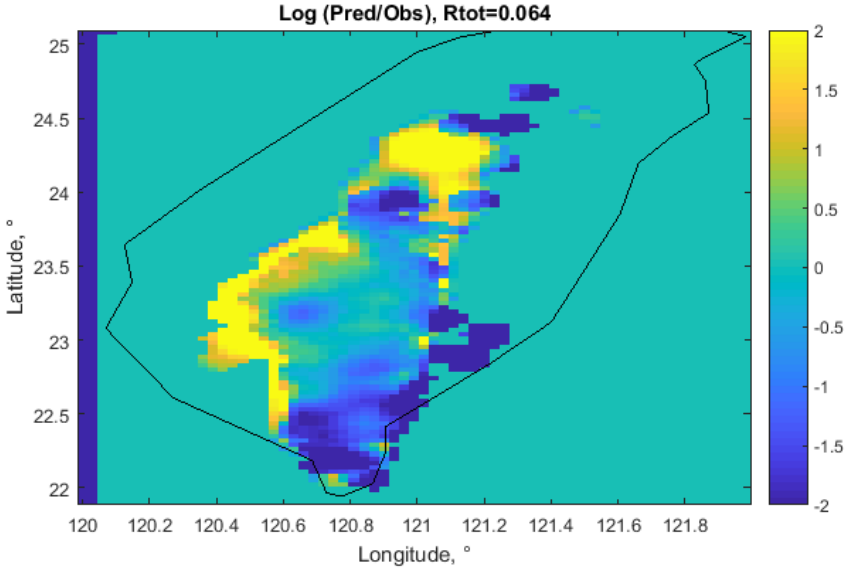
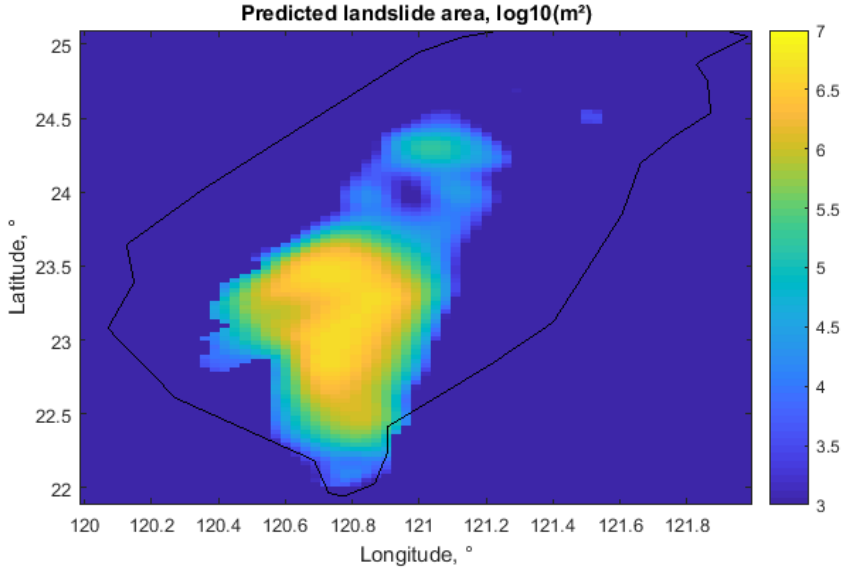
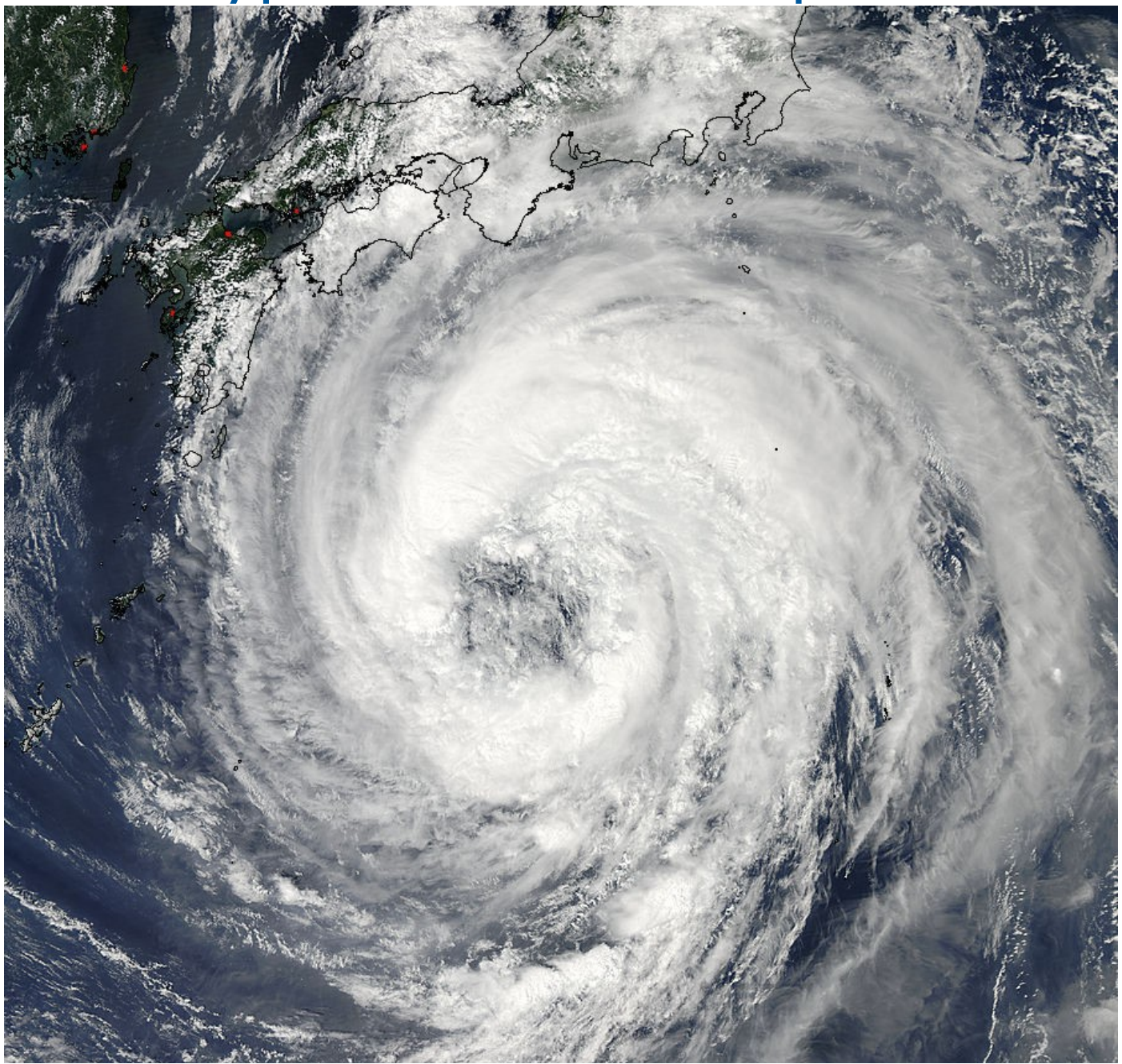




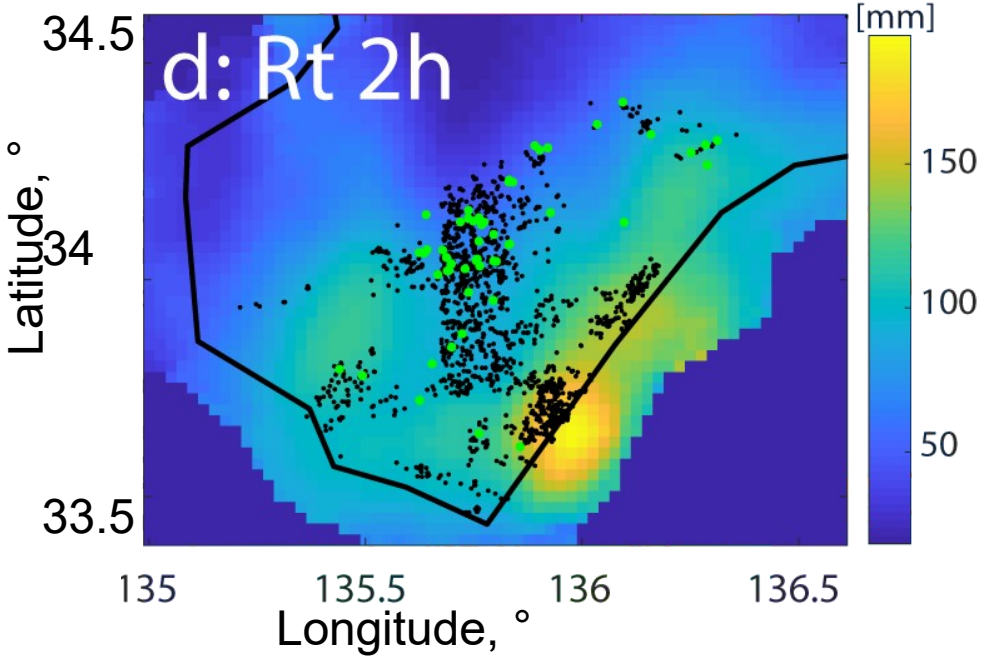




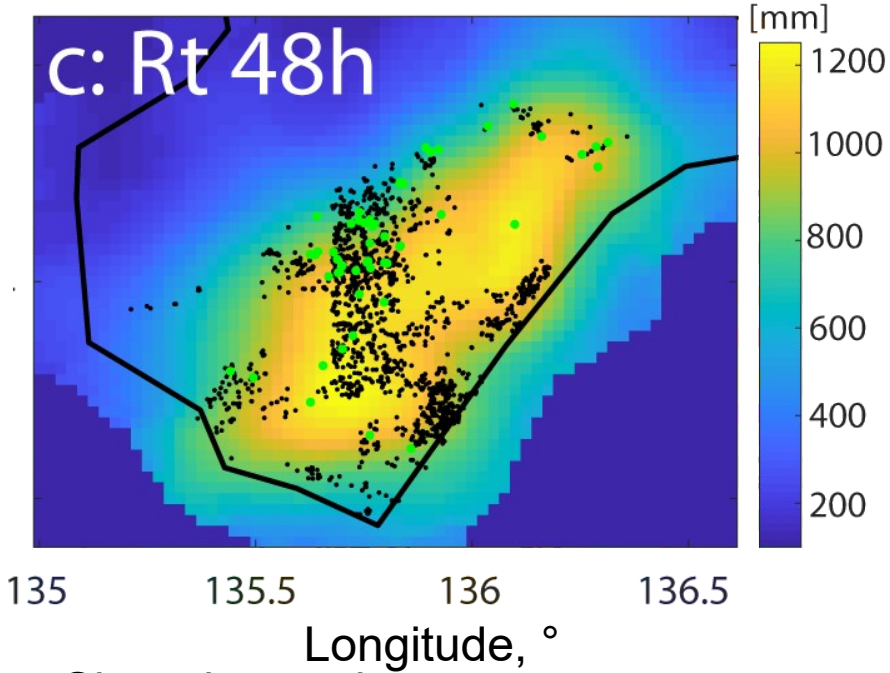
Typhoon Talas in Japan



Landslide pattern: Rainfall ?



Long timescales:
heavy rainfall inland on the topography.



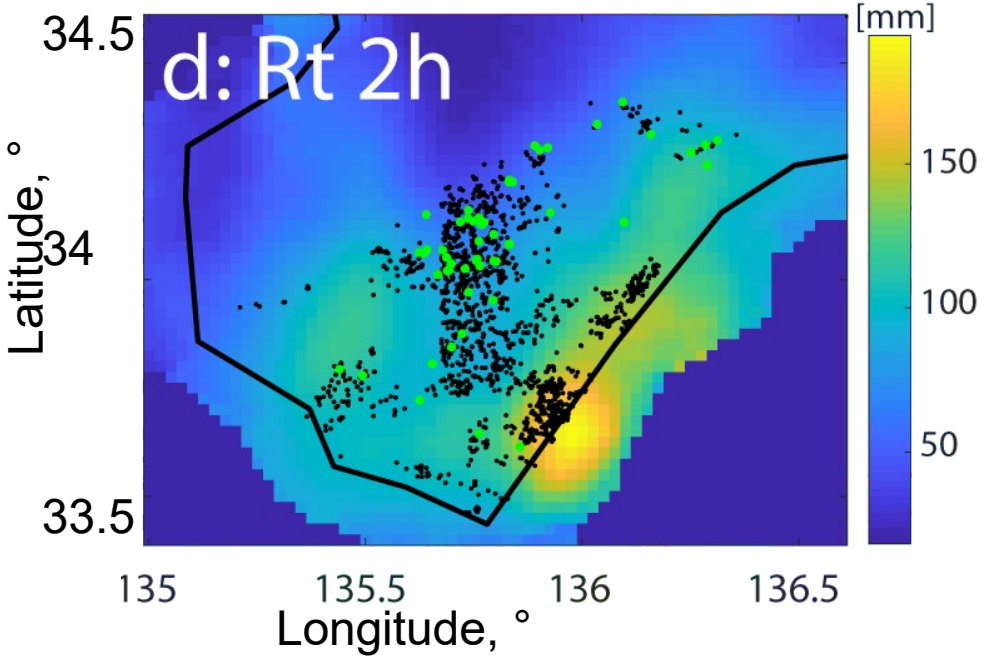
Short timescales:
heavy rainfall on the coast.

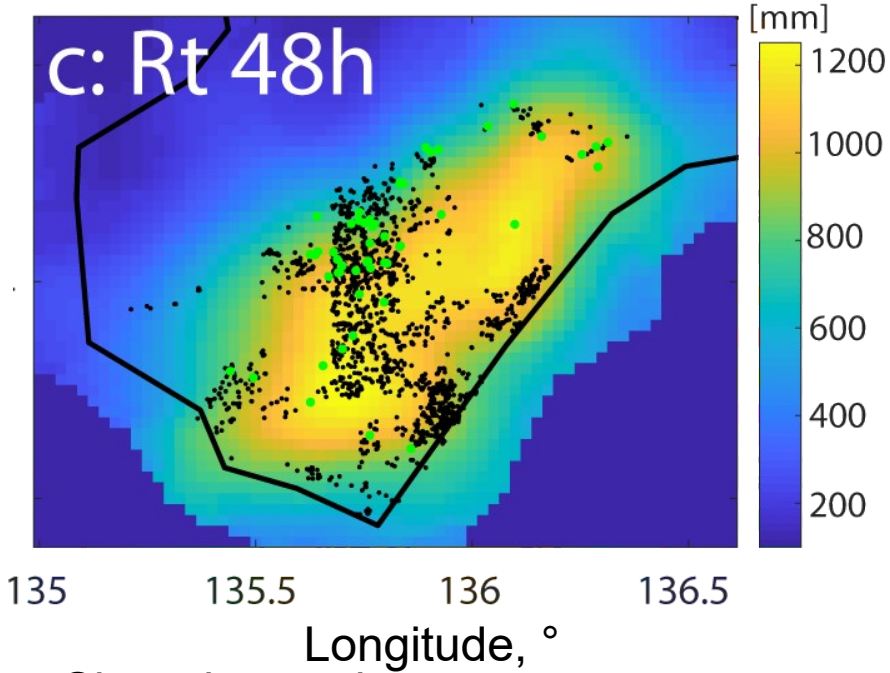
Marc et al., GRL, 2019

Landslide pattern: Rainfall ?

Poor relation with rainfall. Why ?

→ Regional variations in slope gradient ? → DEM
→ Regional variations in regolith strength or hydrological properties ?
→ Almost impossible to measure !!
Potential proxy: Lithological map ? Extreme climatology ?





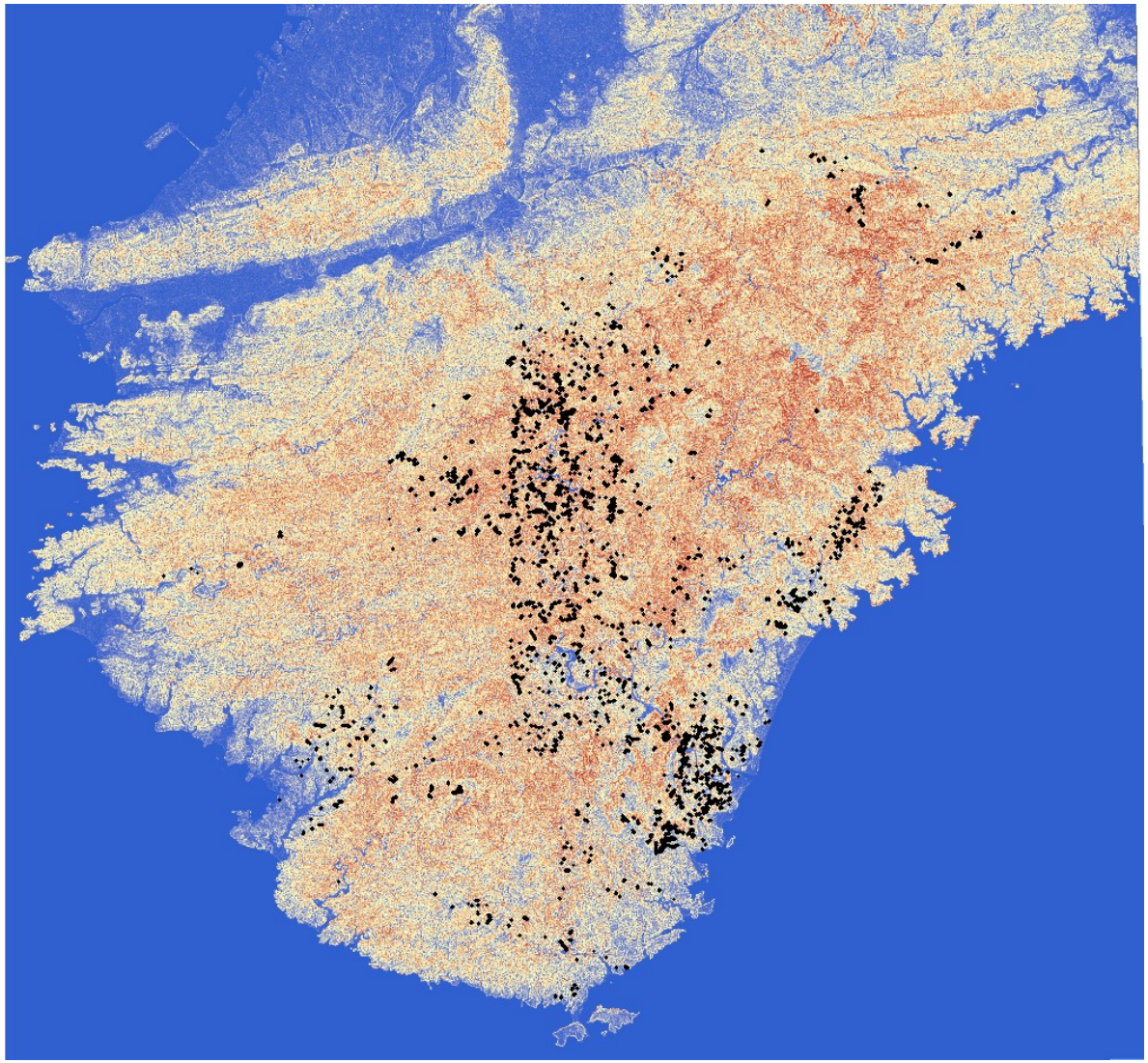
Long timescales:
heavy rainfall inland on the topography.

Short timescales:
heavy rainfall on the coast.

Marc et al., GRL, 2019

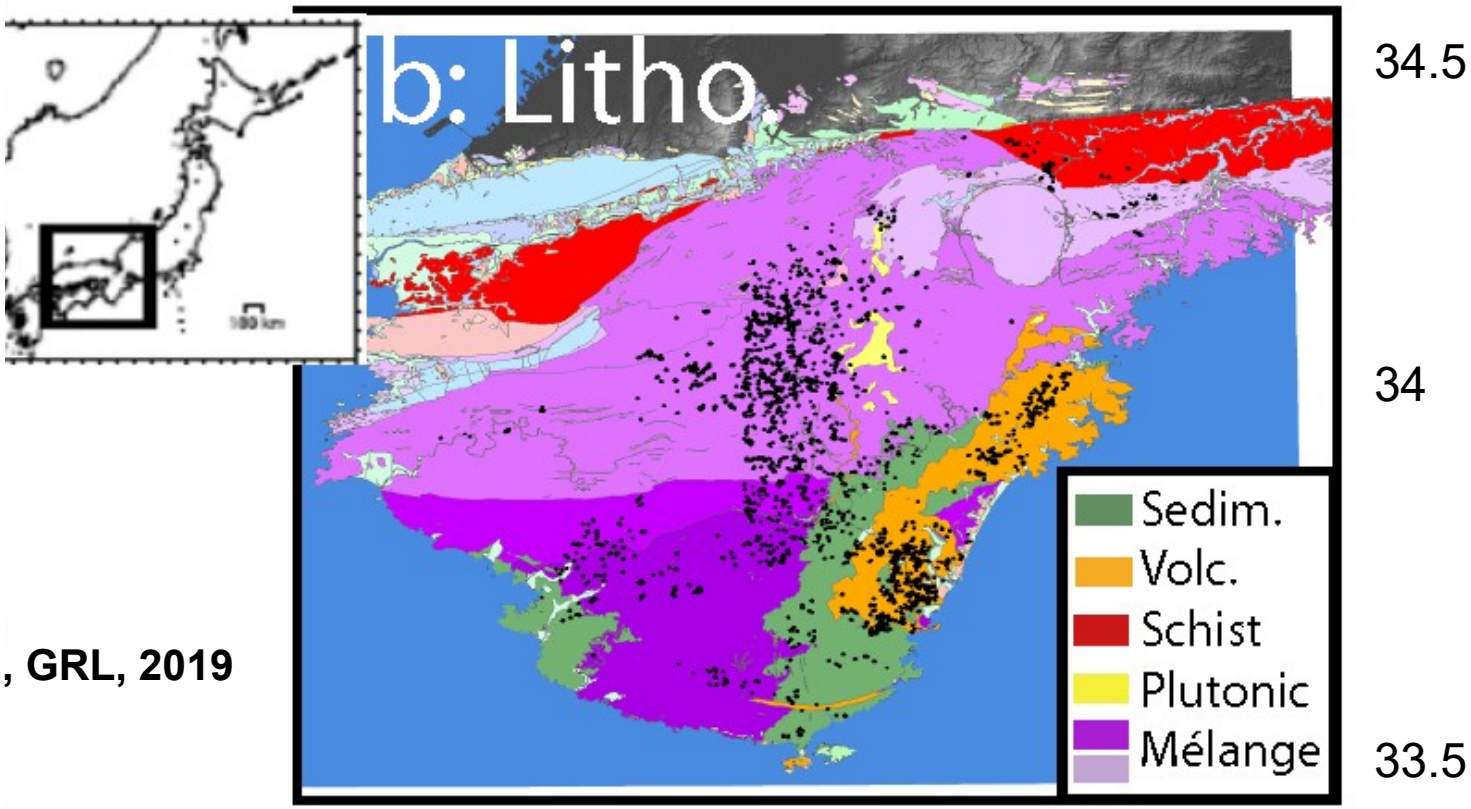
Landslide pattern: Topography ?

No major difference in slope angle throughout the peninsula.



Landslide pattern: Lithology ?

Sharp boundaries of the landslide pattern inland are not lithological.



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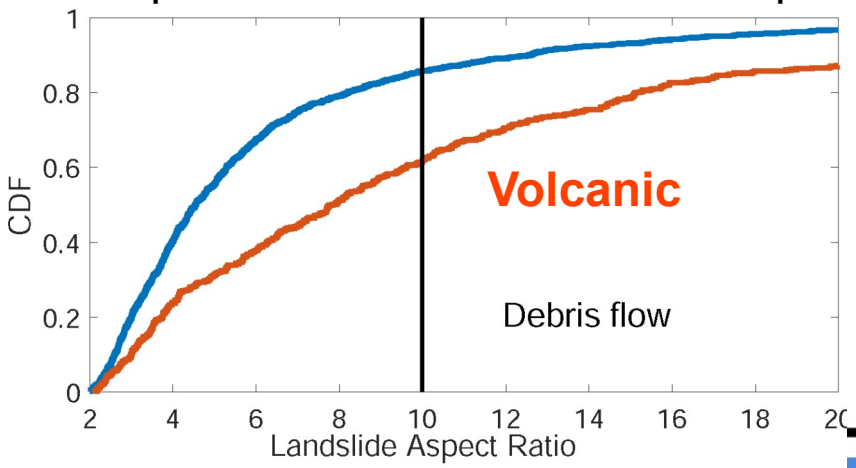
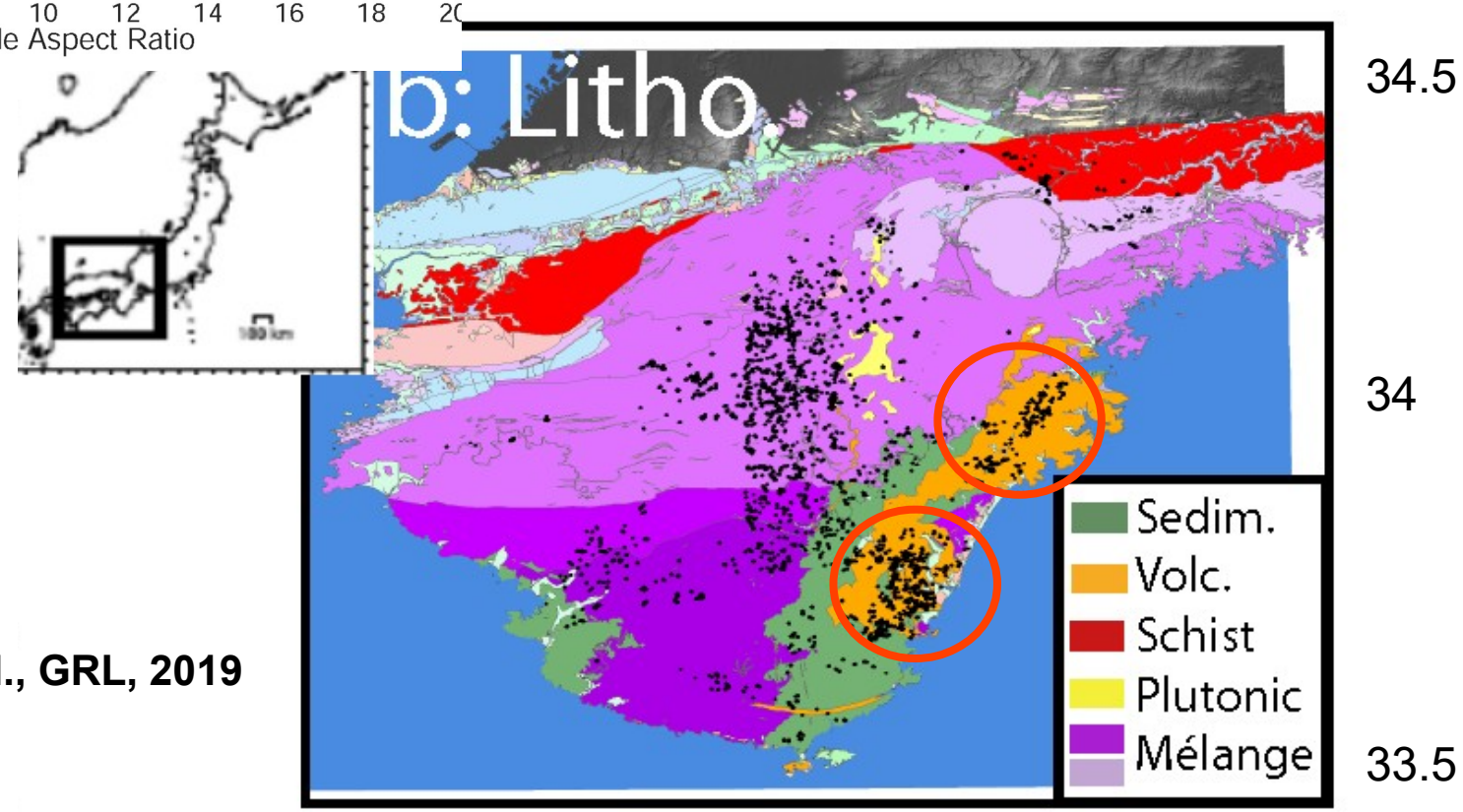


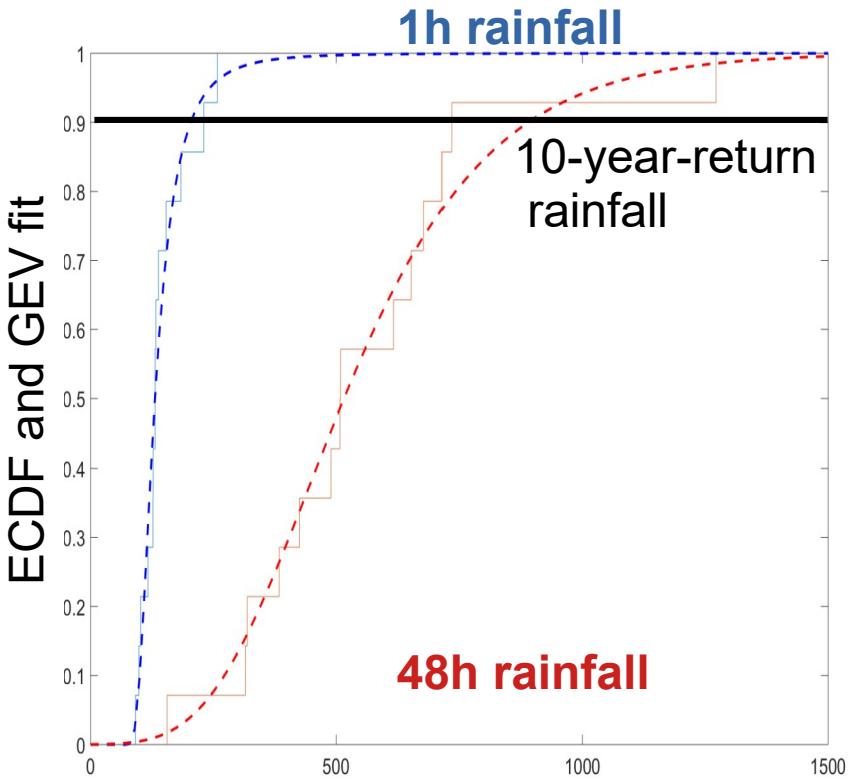
However, coastal landslide clusters may relate to the volcanic rock formation.

As supported by ther exceptional proportion of debris flow.



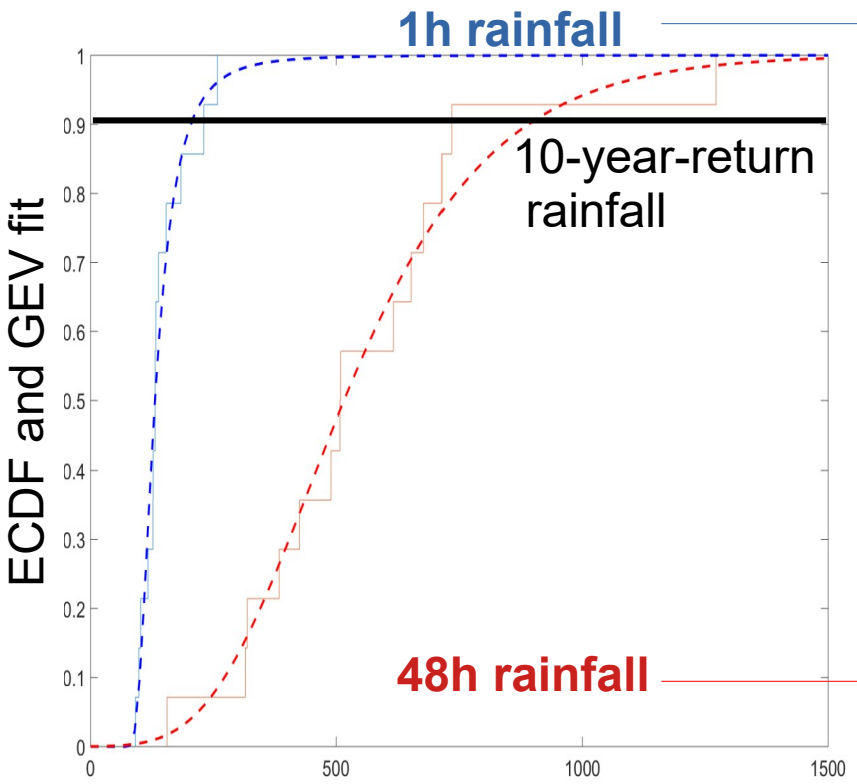
Marc et al., GRL, 2019

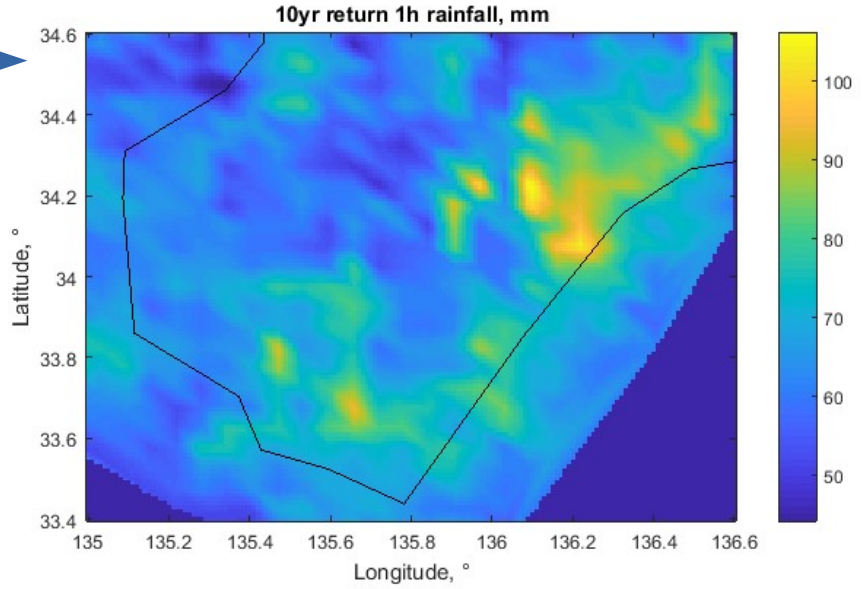
Past extreme rainfall

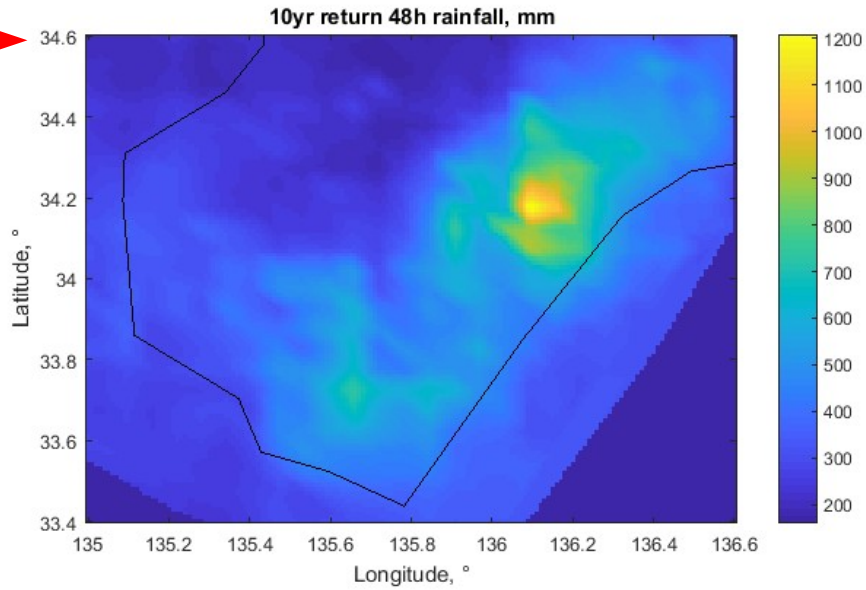


26 years (1988-2013) of radar data in Japan.

Past extreme rainfall

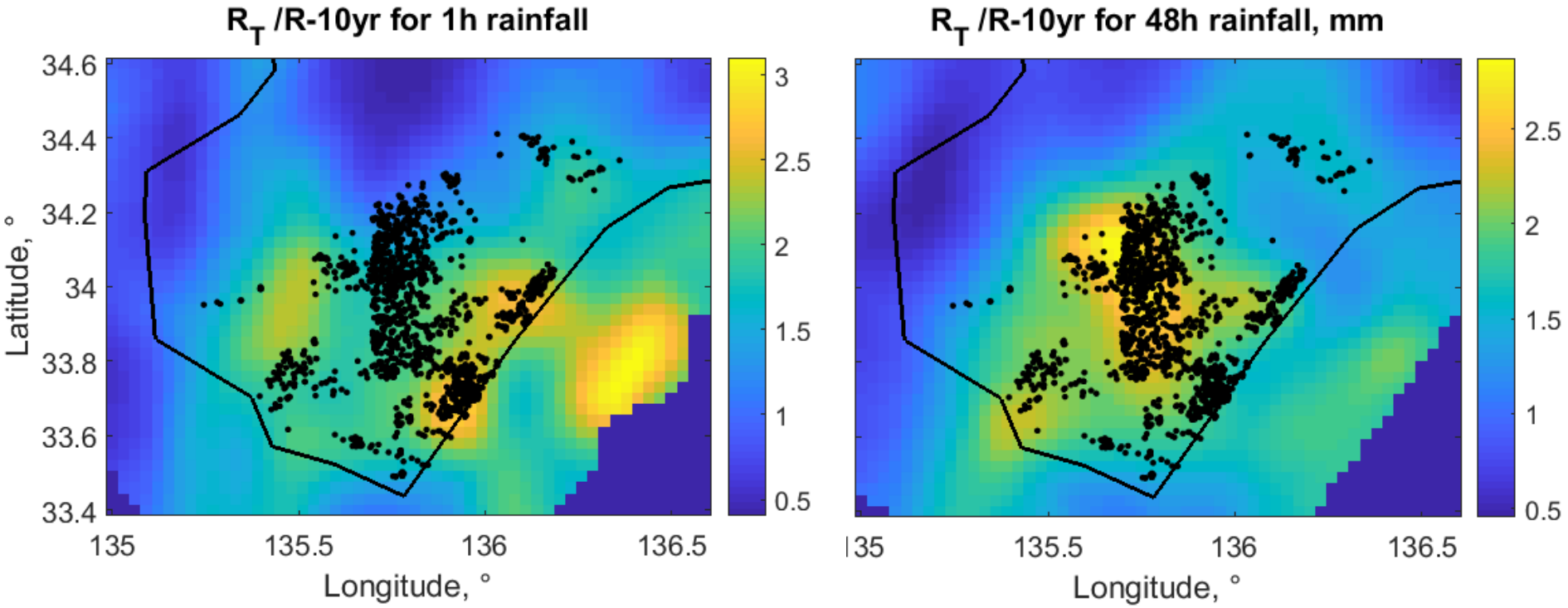






At both timescales, extremes are much larger in the northeastern part of the peninsula than in its center.

Landslide pattern matches Rainfall anomaly !



Marc et al., GRL, 2019

Empirical model

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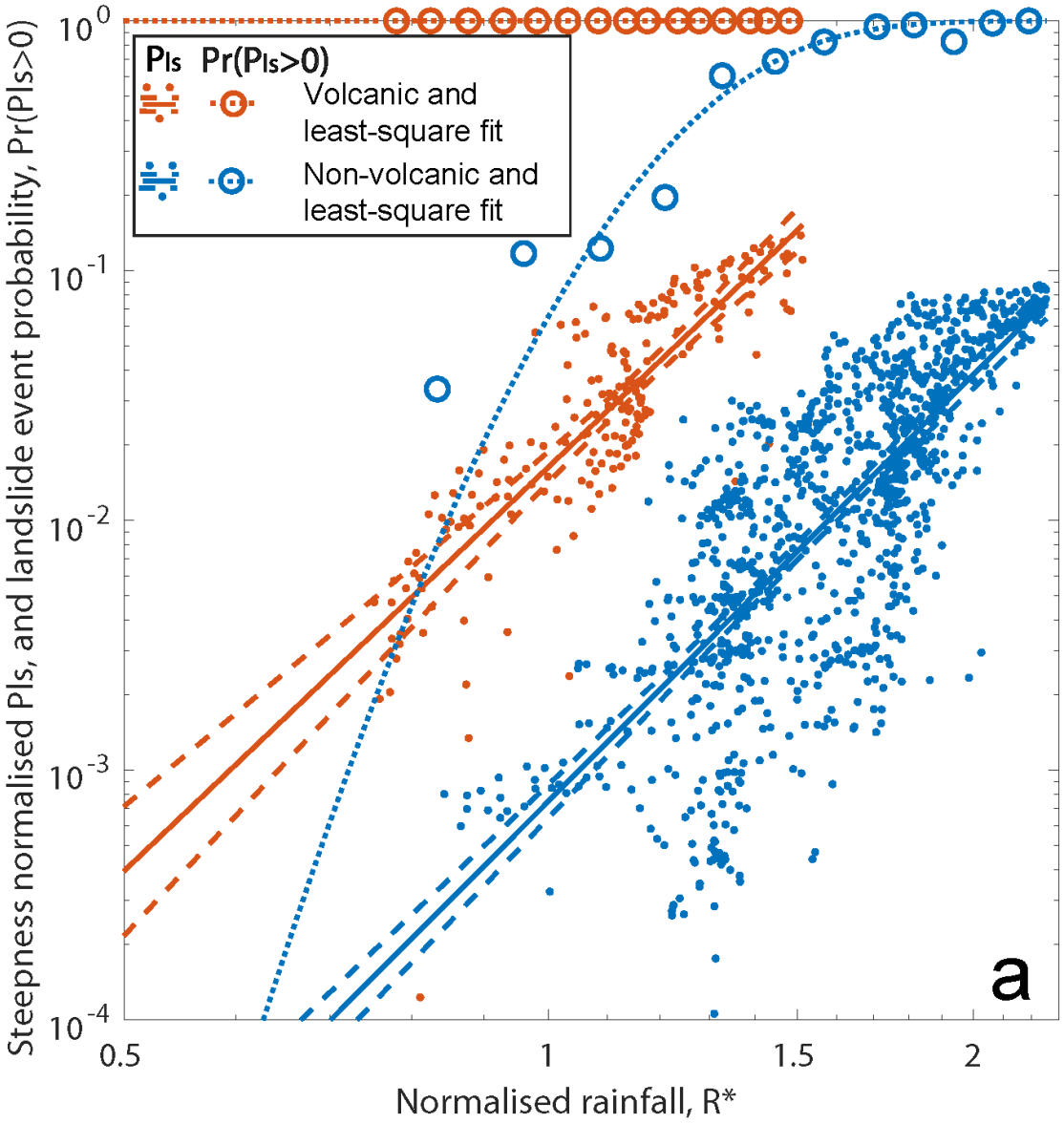
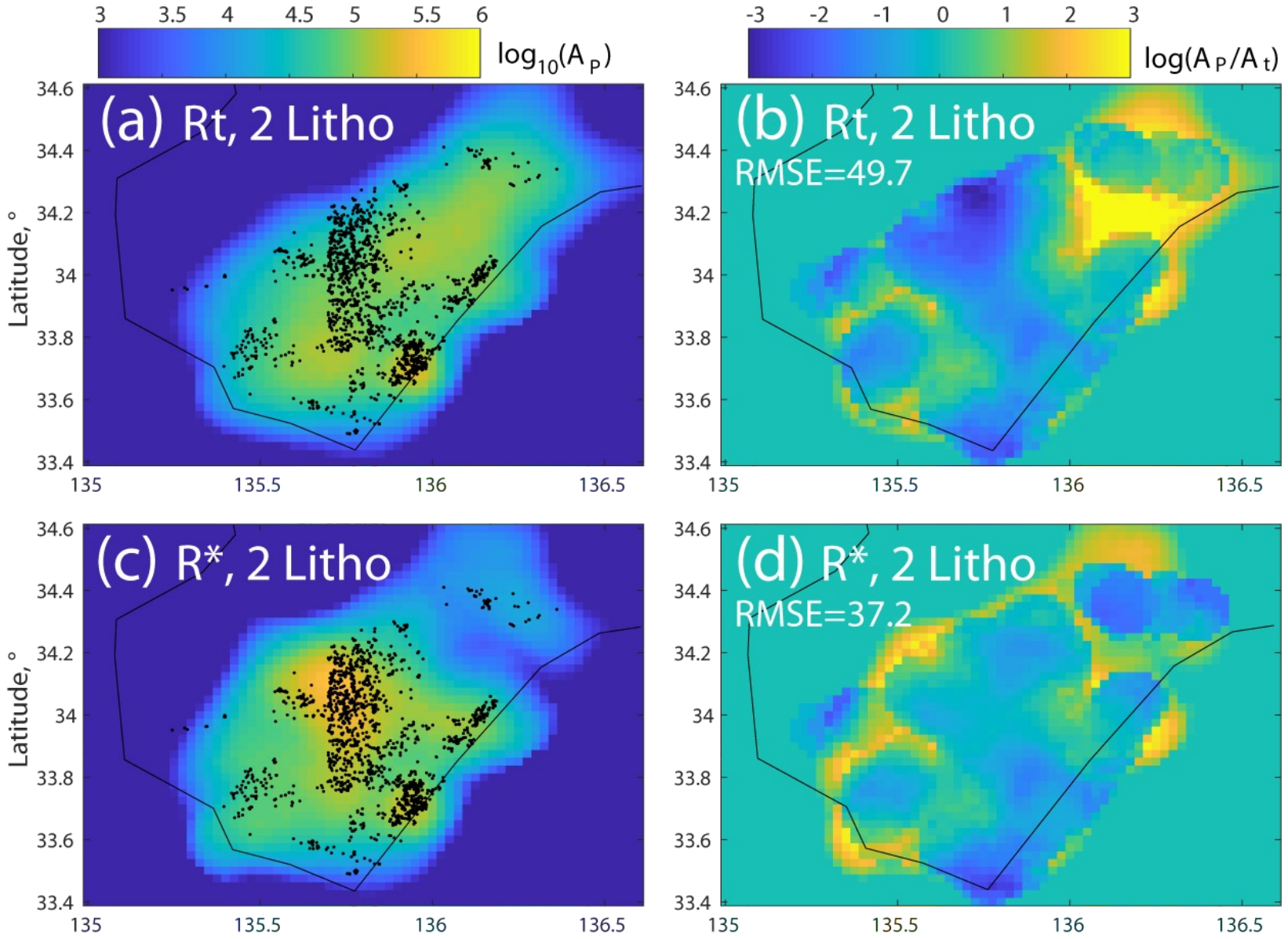
Landslide Density : total landslide area / area with Slope>15°



Marc et al., GRL, 2019

Landslide pattern prediction



Marc et al., GRL, 2019

CONCLUSIONS

We are assembling a database or rainfall induced landslide inventories associated with an identified rainfall triggers.

During large storm, landslide density and probability appear to scale with the total rainfall over various timescales.

However, where extreme rainfalls vary over a region, as in Japan, the event rainfall must be normalized for past extreme to correlate with landsliding.

Hypothesis: in steep landscapes, extreme climatology correlates with hydromechanical properties of the regolith, because of landscape co-evolution.

In Japan, lithological difference may control the timescales relevant for landsliding as well as landslide runout.

Landscape steepness modulate landslide density to a minor extent.

Challenges and future work:
– Spatialized recurrence time for extreme rainfall.
– Can rainfall product estimated by satellite retrieve landslide pattern.
– Compare extreme rainfall to independent proxy of regolith properties