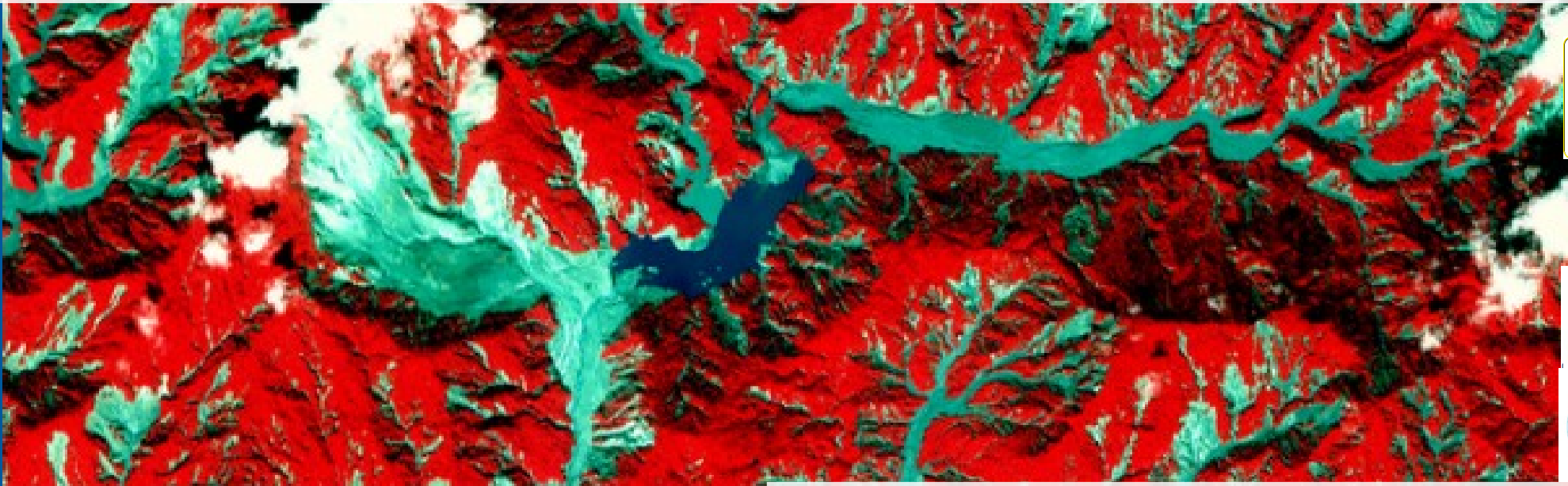
Global assessment of the skills of satellite precipitation products to retrieve extreme rainfall events causing landsliding

Odin MARC, CNRS/GET

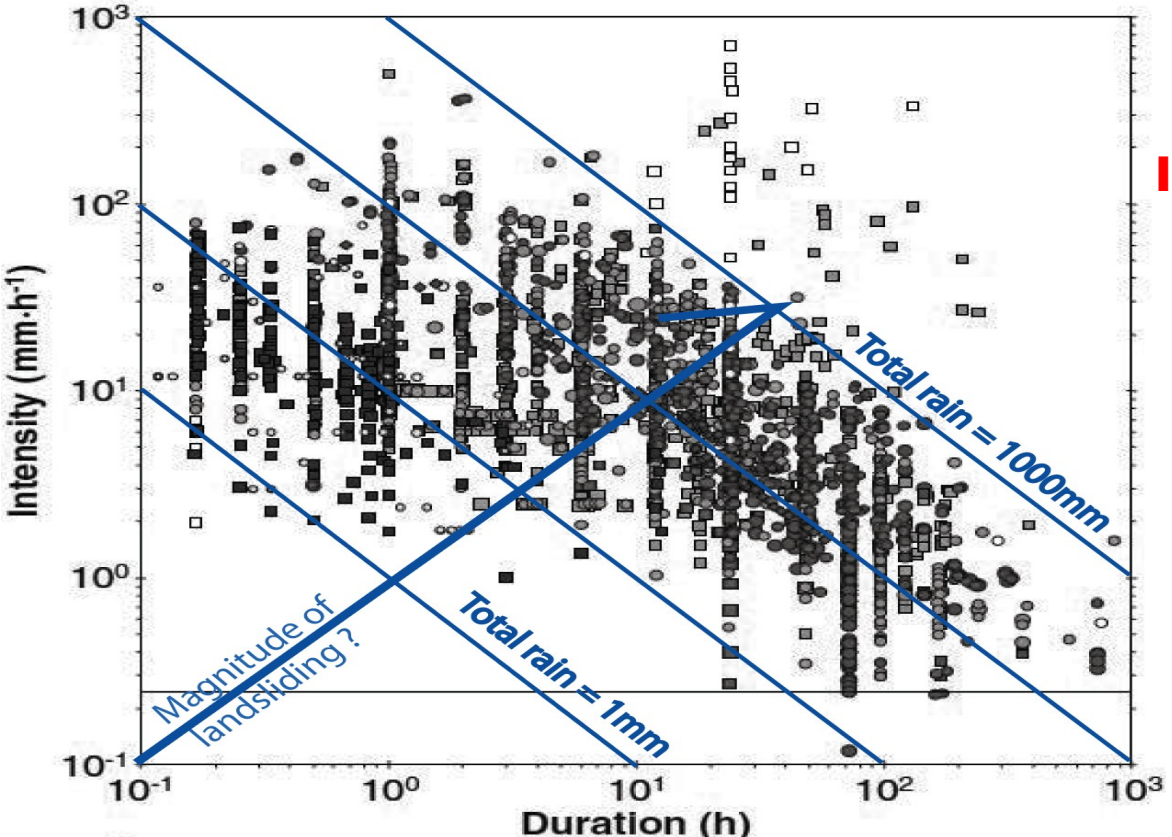


Landslides caused by Morakot typhoon (2009) Southern Taiwan.

Collaborators:
Marielle Gosset, Romulo Oliveira, GET Toulouse
Robert Emberson, NASA Goddard space center
Jean-Philippe Malet, ITES Strasbourg

Empirical approach: Rainfall threshold

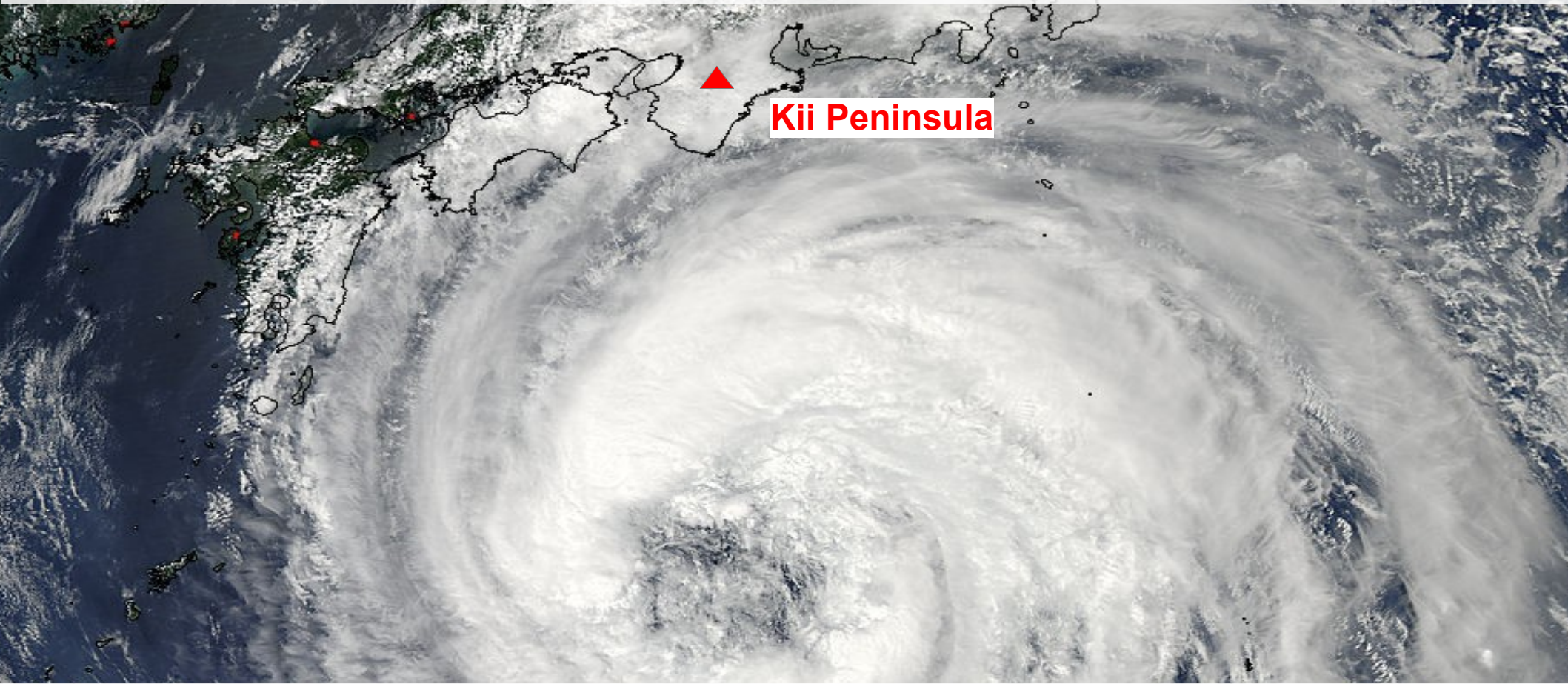
Is it enough to know that landsliding is likely, but not where it will occur and how widespread it will be?



→ **How rainfall drives landslide beyond the threshold ?**

Guzzetti, et al., 2008

What do we learn from detailed rainfall measurements ?

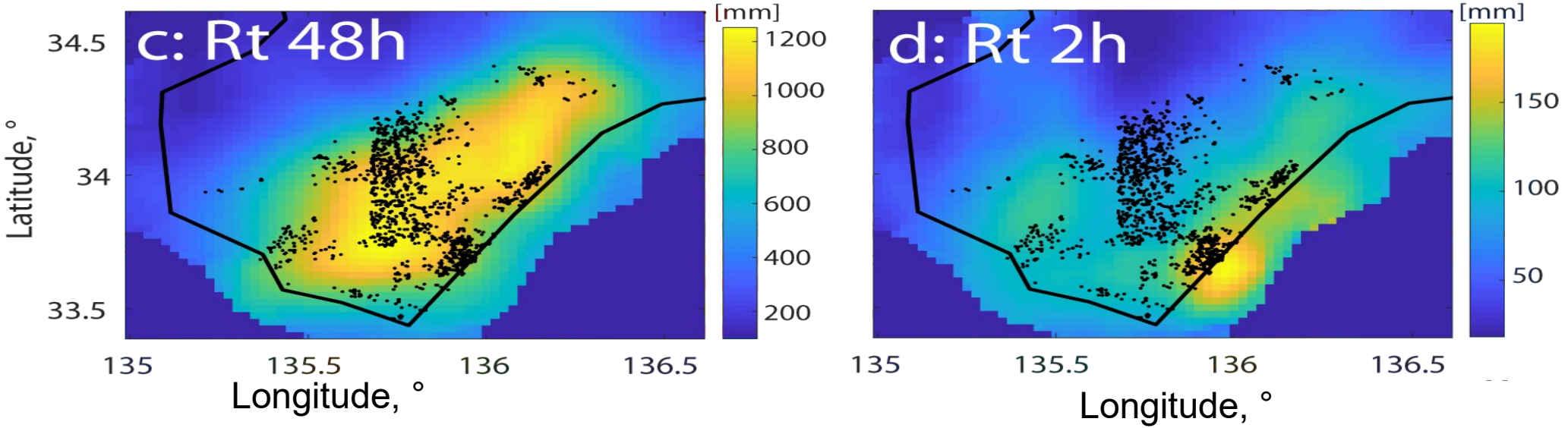


Typhoon Talas in Japan (2011)

Landslide pattern poorly relating to rainfall ?

What could cause disagreement between rainfall and landsliding ?

→ Regional variations in slope gradient ? → not seen in local DEM
→ Regional variations in regolith strength or hydrological properties ?
→ Almost impossible to measure !!
Lithological map cannot explain the sharp landslide boundaries...



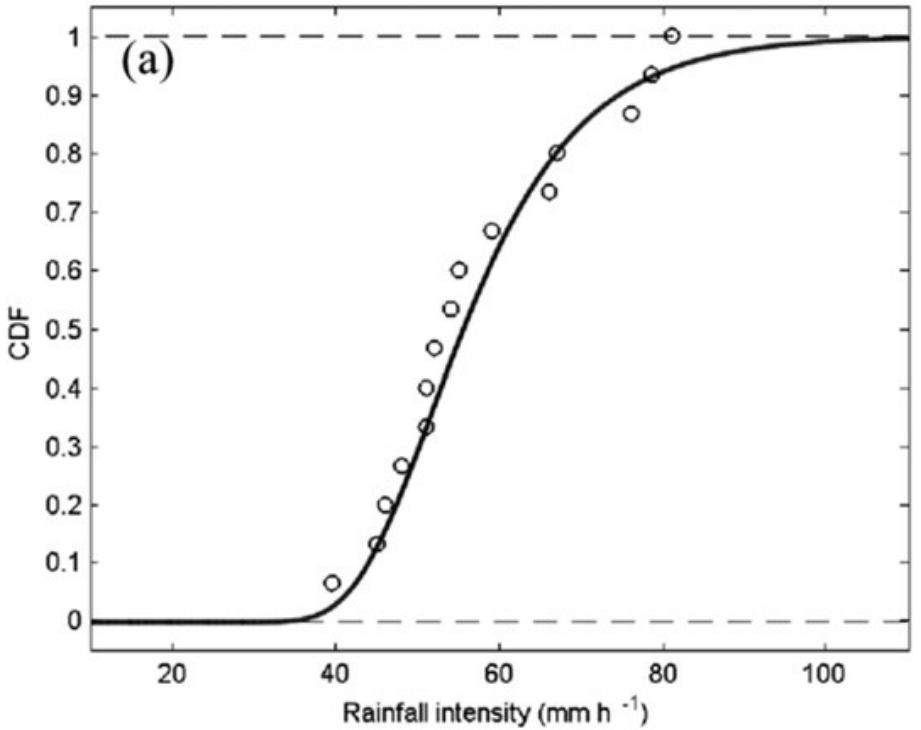
Rainfall maps (from JMA radars network) during the event with individual landslides in black.
Only landslide attributable to the typhoon, based on pre and post imagery.

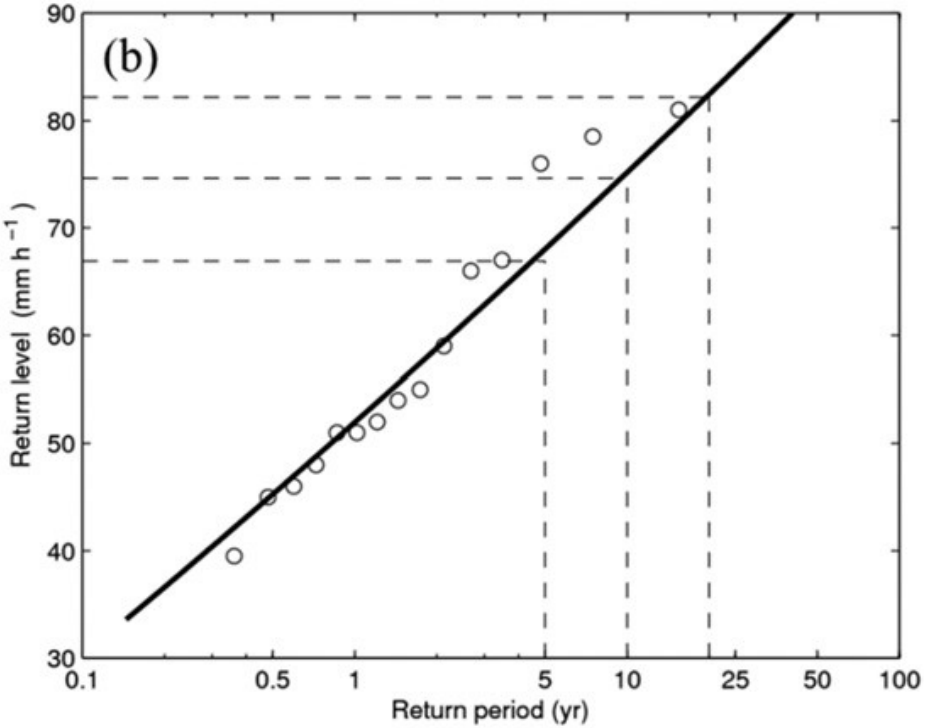
Marc et al., GRL, 2019

Extreme climatology and landscape co-evolution ?

Can we use a regional map of extreme rainfall as a proxy of regolith susceptibility to landsliding ? (as suggested by geomorphological modeling)

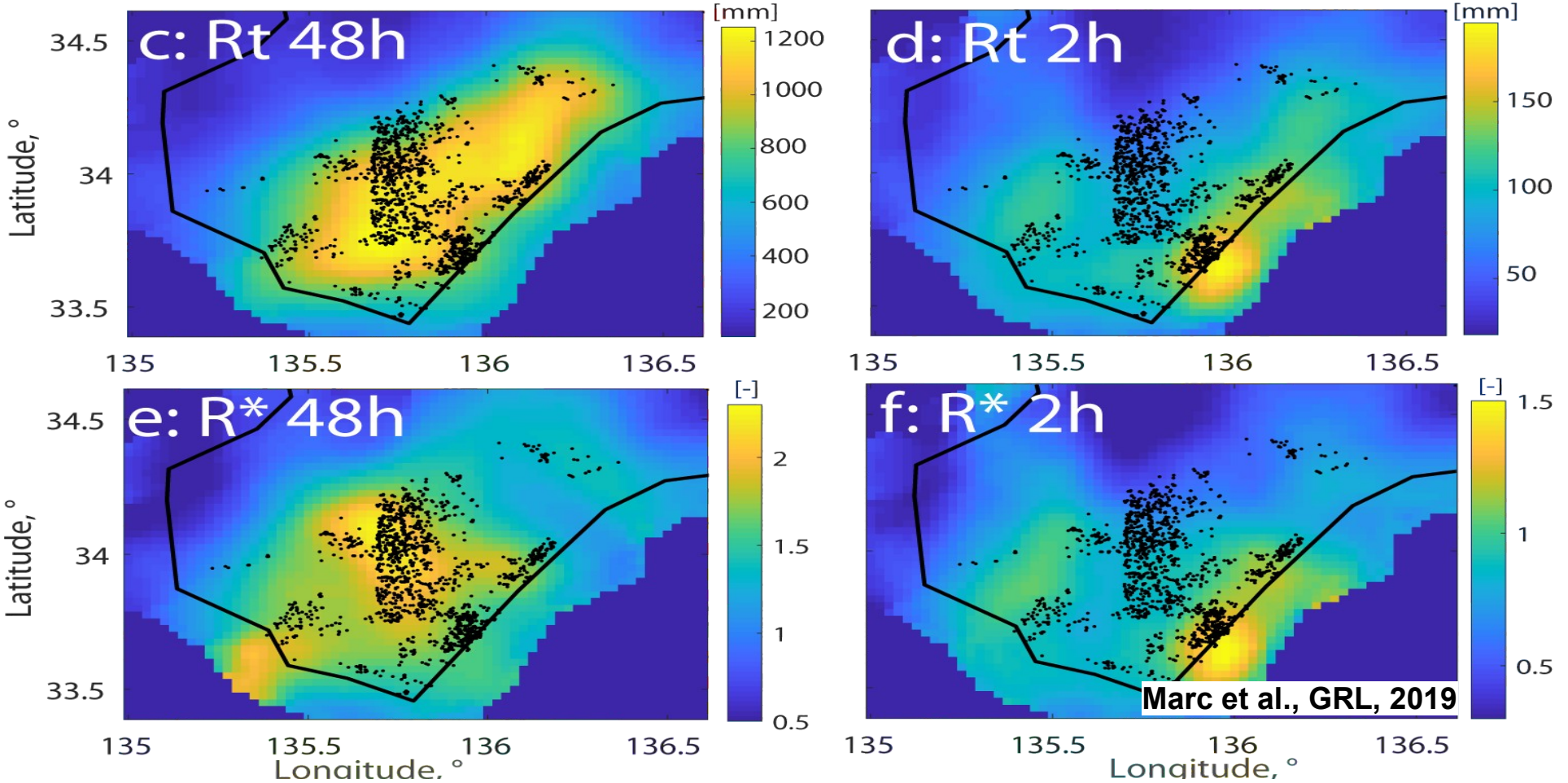
We accessed 26-years of radar data, unlocking across the study area:
The maximum annual rainfall over any timescale.
The total rainfall of a 10-yr return-rainfall, R10, over any timescale.



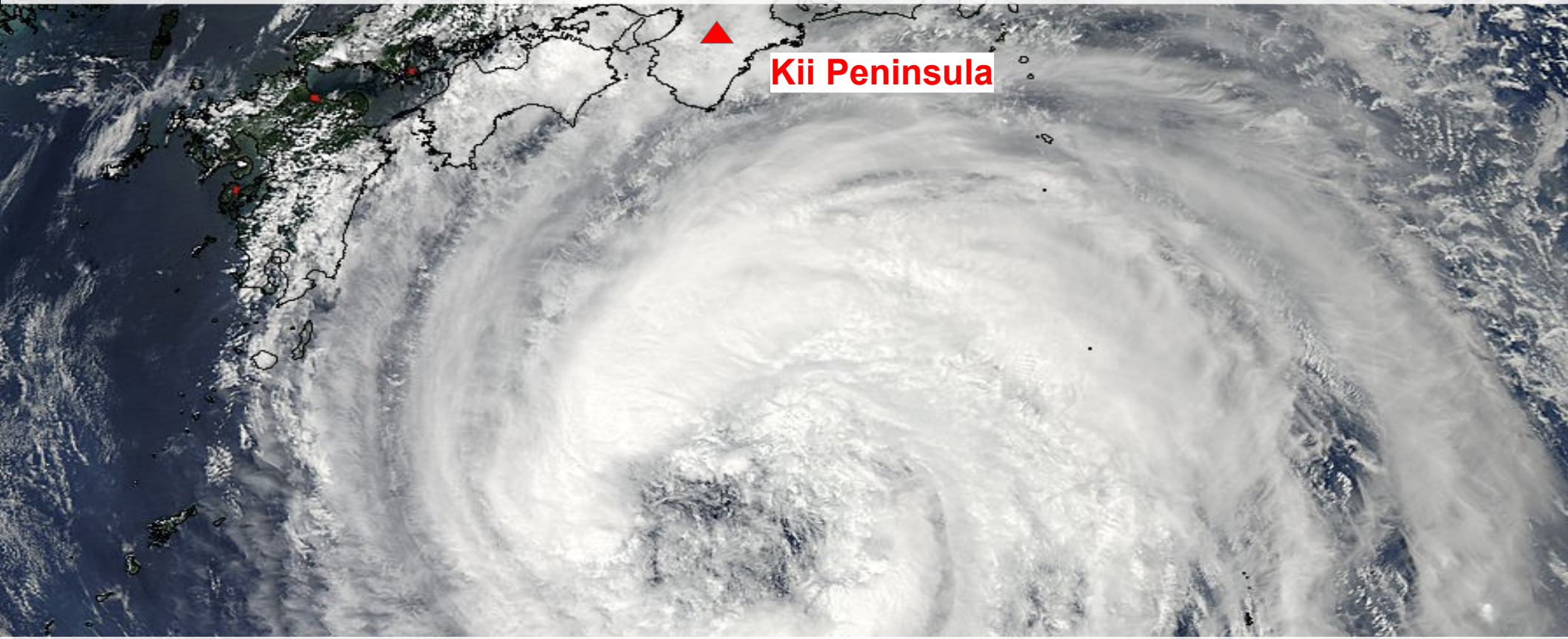


Landsliding matches rainfall anomaly: $R^*=Rt/R_{10}$

→ Landslide density (in %) quantitatively scales with the rainfall anomaly !



Could we estimate R* from satellite measurements only?
How would that compare to landslide spatial pattern?



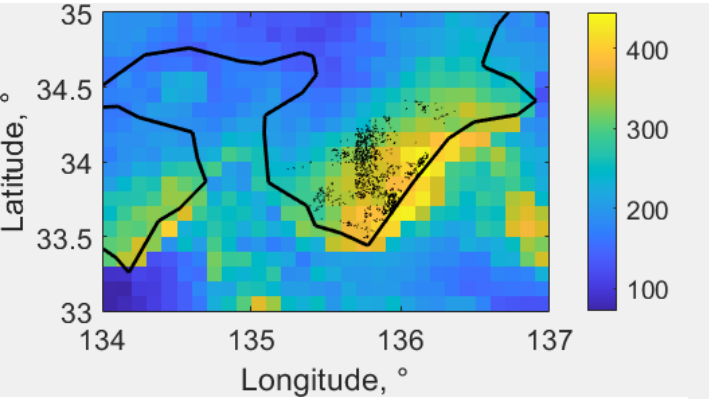
Typhoon Talas in Japan (2011)

Computing R* from satellite records

→ **GsMAP / IMERG / MSWEP : 3h, 0.1°, global coverage from 2001 to present.**

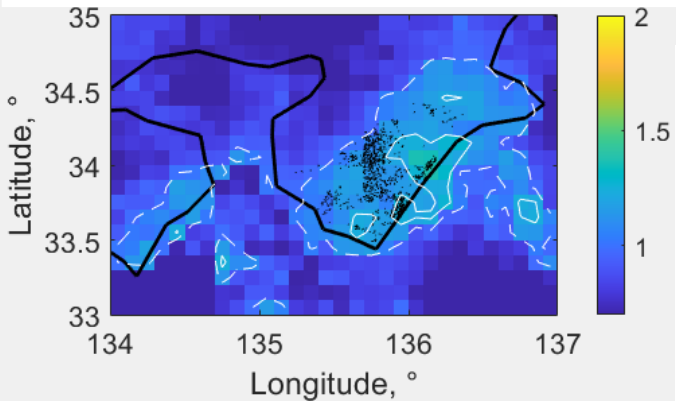
Event rainfall Rt estimated at a given timescale, here 48h.

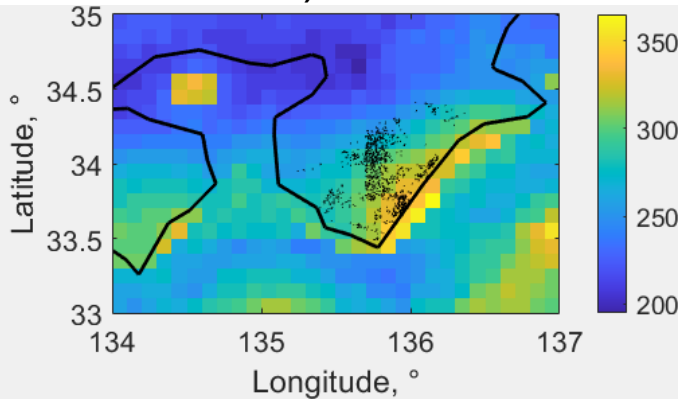
Then the 20 years of data are resampled to the same timescales and used to estimate R10 from Metastatistical Extreme Value theorv (Zorzetto et al., 2015).



Rt (48h)

R*=Rt/R10

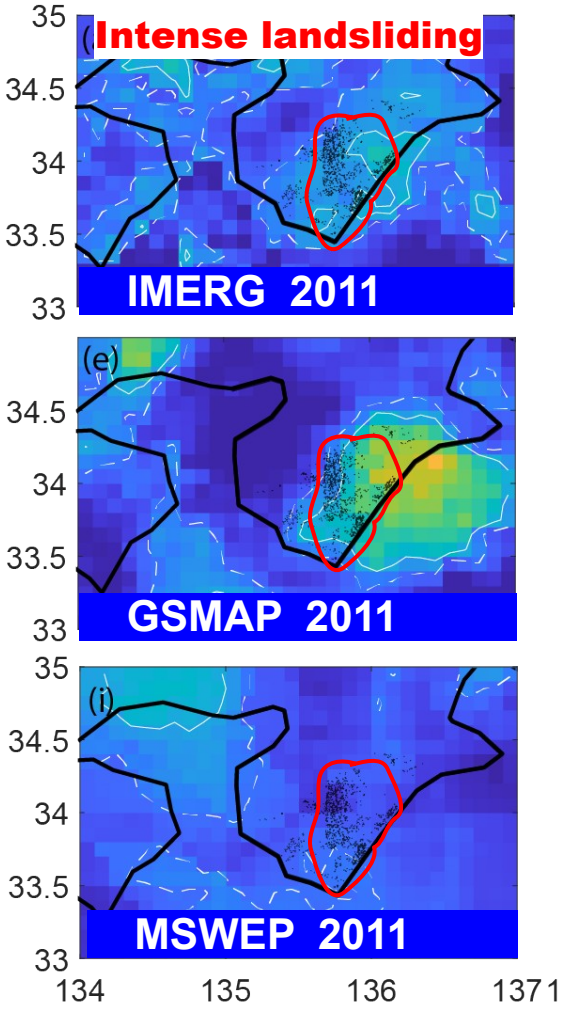




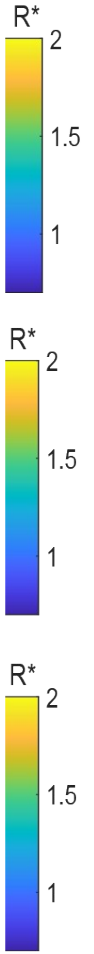
R10 (48h)

Marc et al., Earth Interactions, 2022 (Accepted)

Satellite skills vary in space...

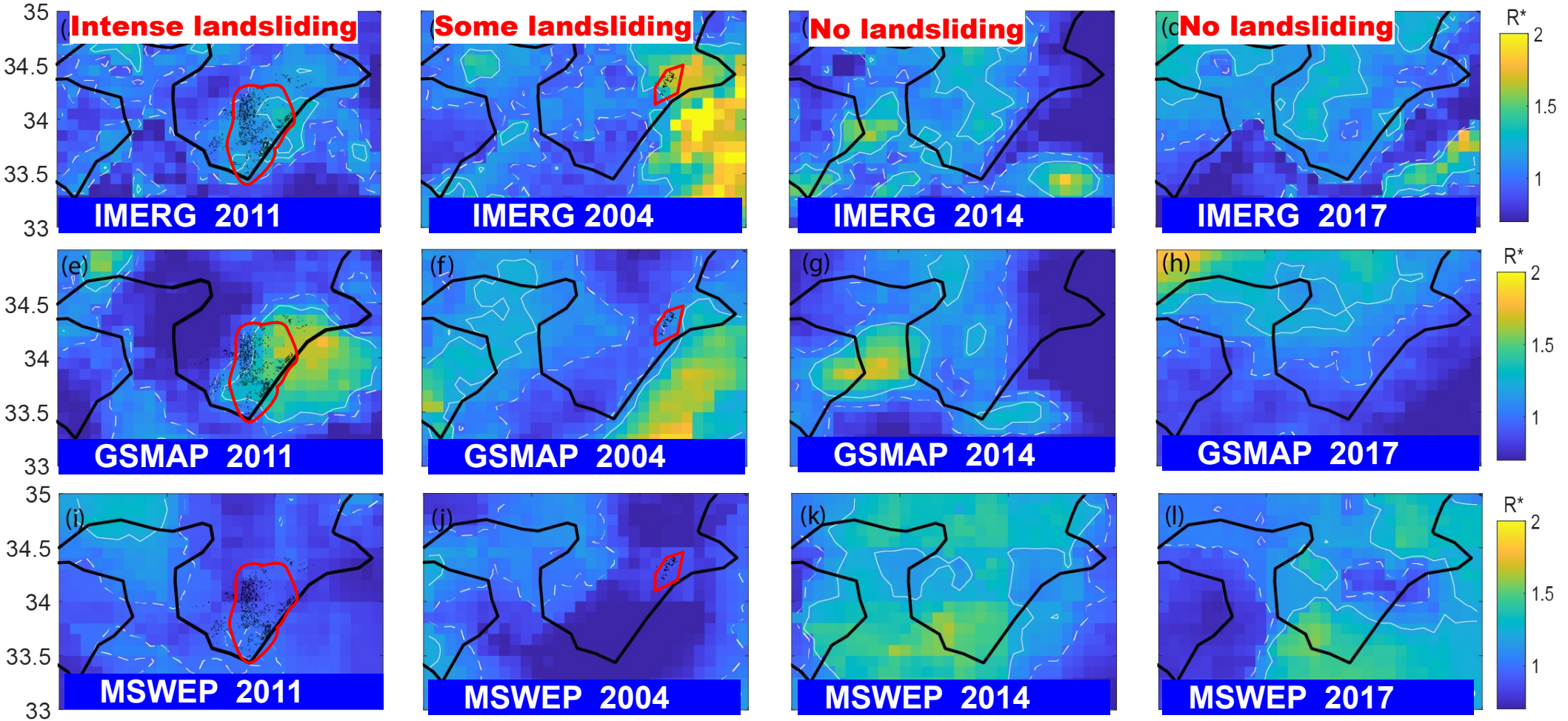


R* 48h in 4 different years over the Kii peninsula



Marc et al., Earth Interactions, 2022 (Accepted)

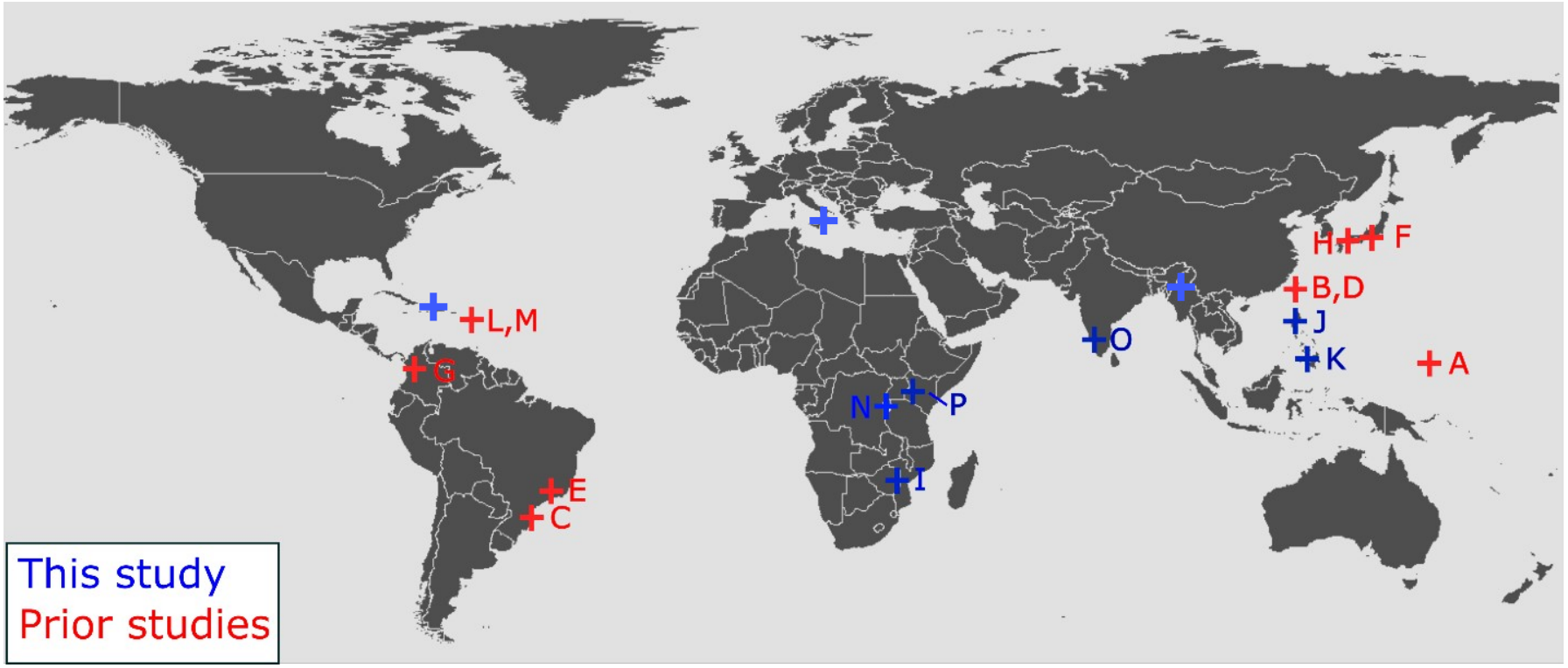
Satellite skills vary in space… and time



Marc et al., Earth Interactions, 2022 (Accepted)

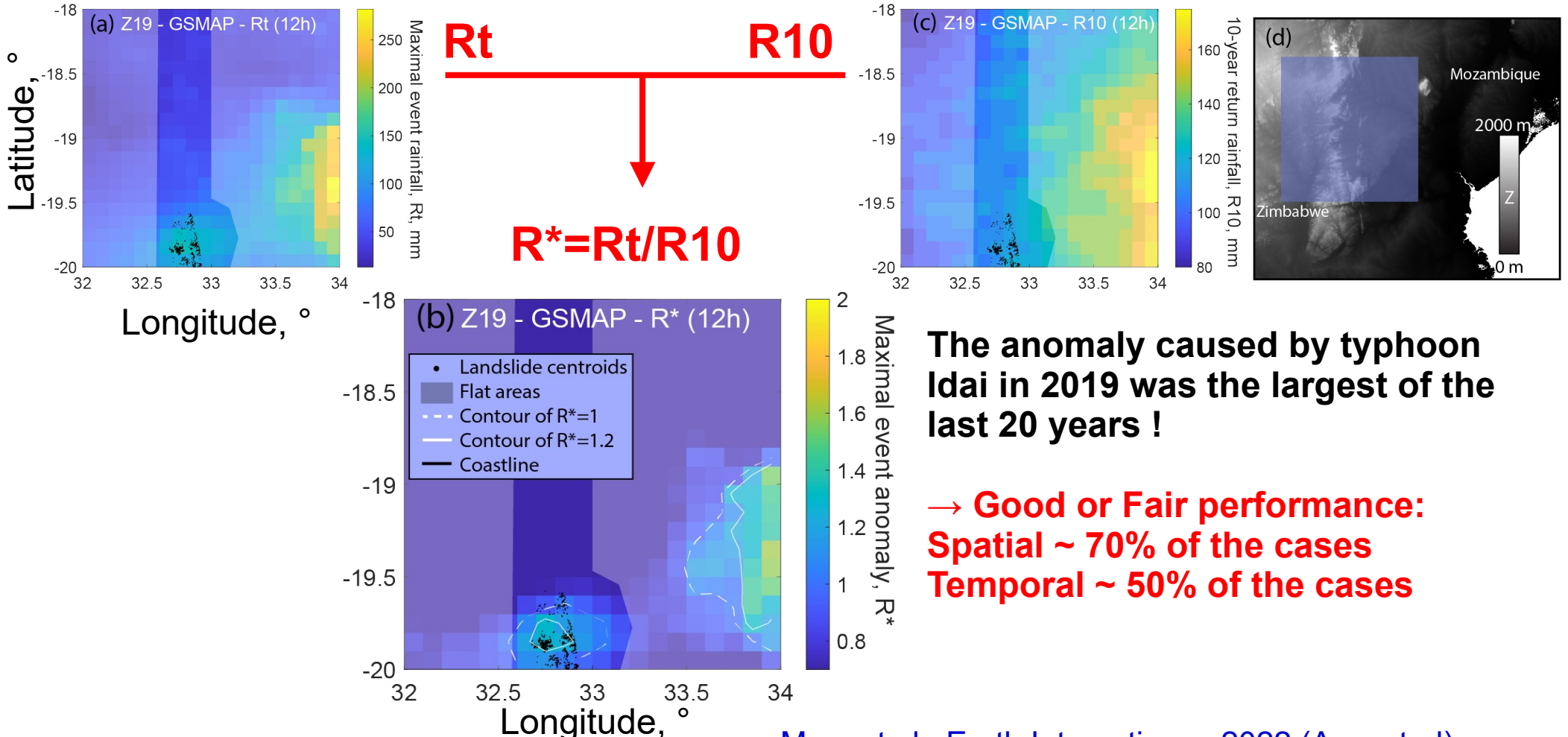
Test for 20 landslide events across the globe

Inventories for rainfall induced landslides triggered during a single storm event collected from Marc et al., 2018, Emberson et al., 2022 and Literature...



Emberson et al., ***NHESS,*** 2022

An example of good performance across products



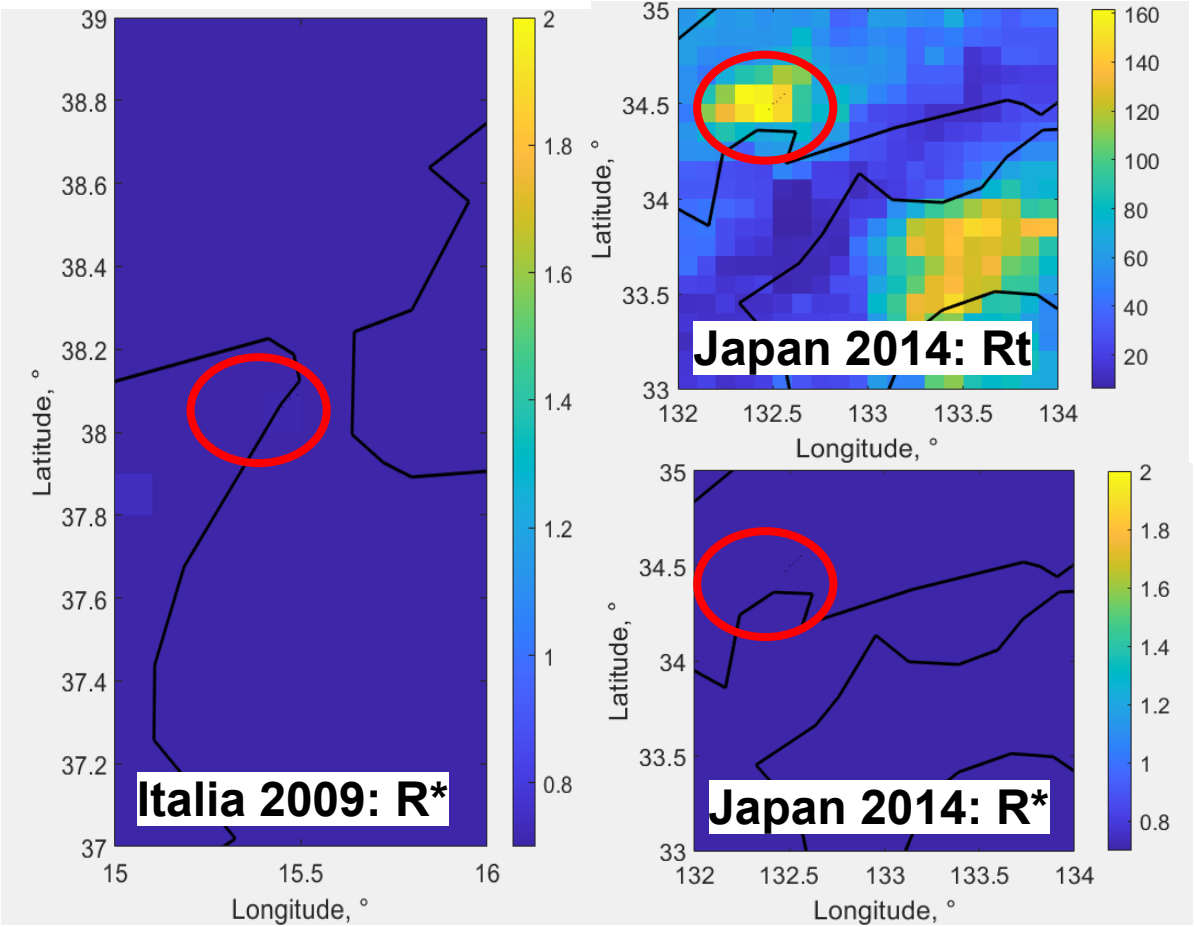
The anomaly caused by typhoon Idai in 2019 was the largest of the last 20 years !

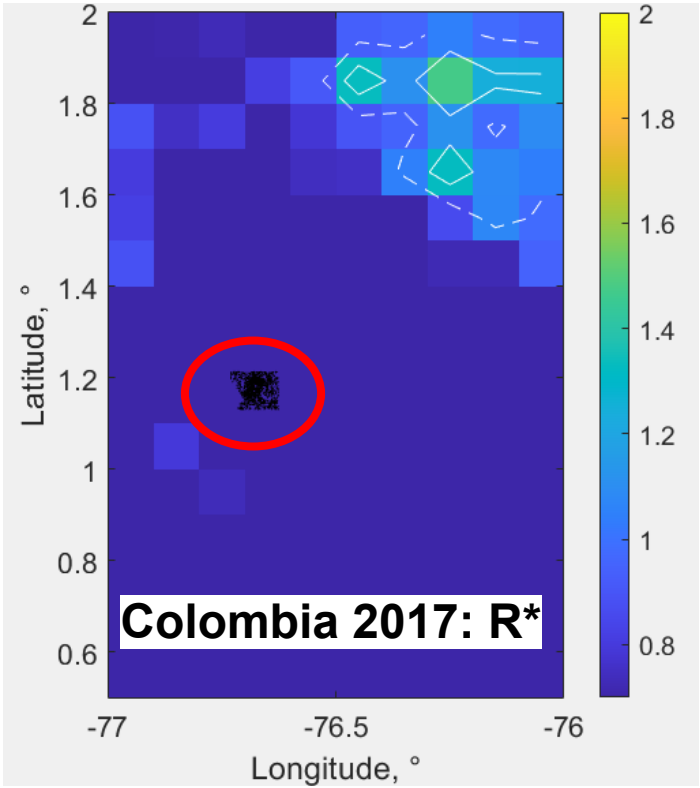
→ Good or Fair performance:
Spatial ~ 70% of the cases
Temporal ~ 50% of the cases

Marc et al., Earth Interactions, 2022 (Accepted)

Poor performance is frequent for short, localized storms

3 out of 4 events which were shorter than 8h are mostly undetected.





Marc et al., Earth Interactions, 2022 (Accepted)

Conclusions*

We built on the Hypothesis presented in Marc et al., 2019, GRL:
That landsliding better correlates with rainfall anomaly than absolute rainfall
(Possibly because landscape and climate have co-evolved to an equilibrium, implying that extreme climatology correlates with hydromechanical properties of the regolith.)

Thus we have derived rainfall anomaly from 3 satellite products for 20 landslide events induced by rainfall across the globe.

Computing anomaly remove large variations in absolute rainfall, and allows to compare products.

Most events caused by large hurricane/typhoons display R*>1 during the landslide event, but the various products still often disagree in the details.

Short, **localized events were mostly (3 out of 4) undetected** (e.g., in Italy and Colombia).

Substantial **chance of false alarms** remains (i.e., anomalies (R*>1) without landsliding).

Future Research:
- **Improvements of satellite rainfall retrieval algorithms ? Including new data (GOES) ?**
- **Assess the potential of Nowcast products ? Includes R* in hazard awareness products?**
- **Impact of hydrology and landscape properties on the relevant timescale and threshold for R* ?**

*** Check the extra slides online if you want to see more details !**

Quantitative precipitation estimate from space

1) Active radar retrieve rainfall rate vertical profile and also retrieve passive microwave brightness
2) Used to calibration a constellation of satellite with passive microwave
3) Geostationary infrared in between microwave overpass

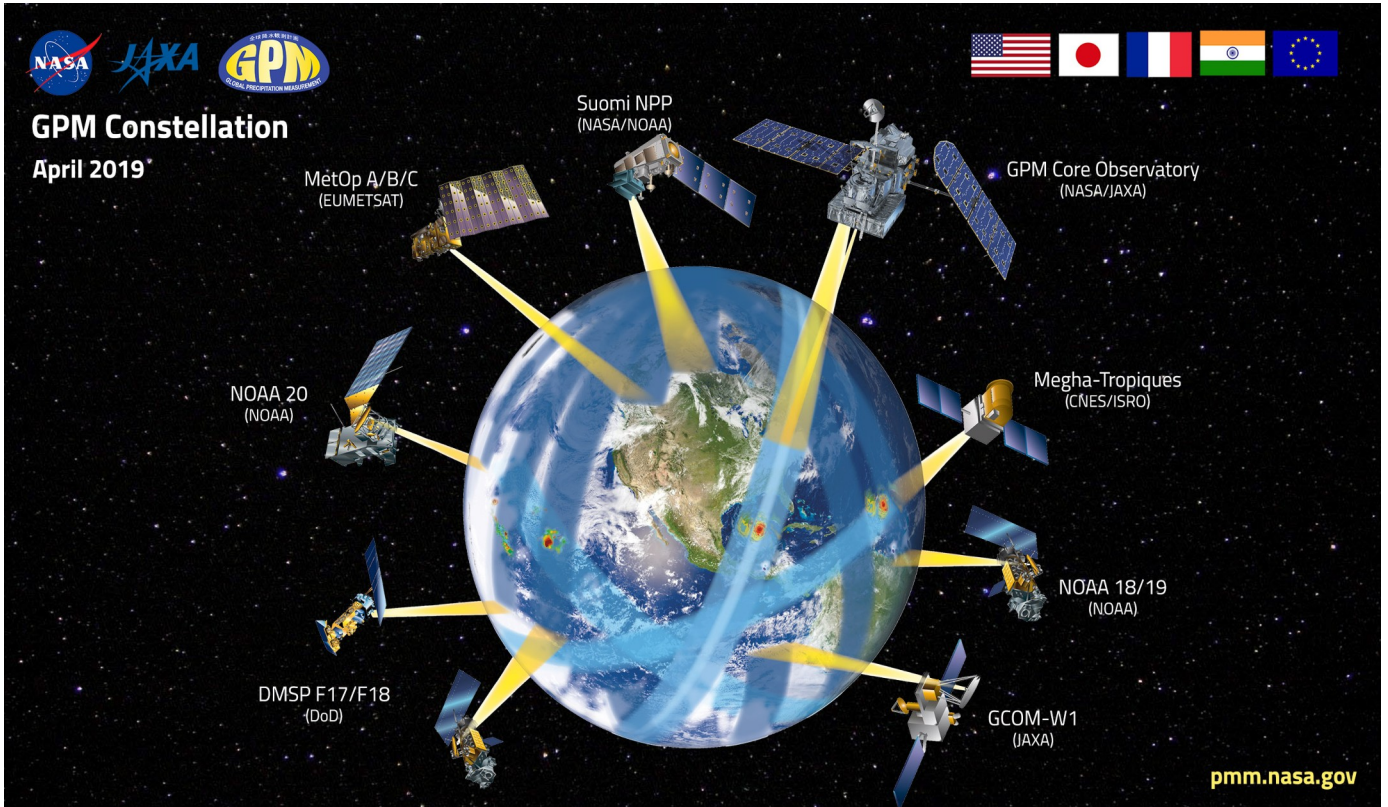
Here, we consider 3 long-term **(2000 to present)**, high-resolution **(0.1°)** products:

GSMAP-v7

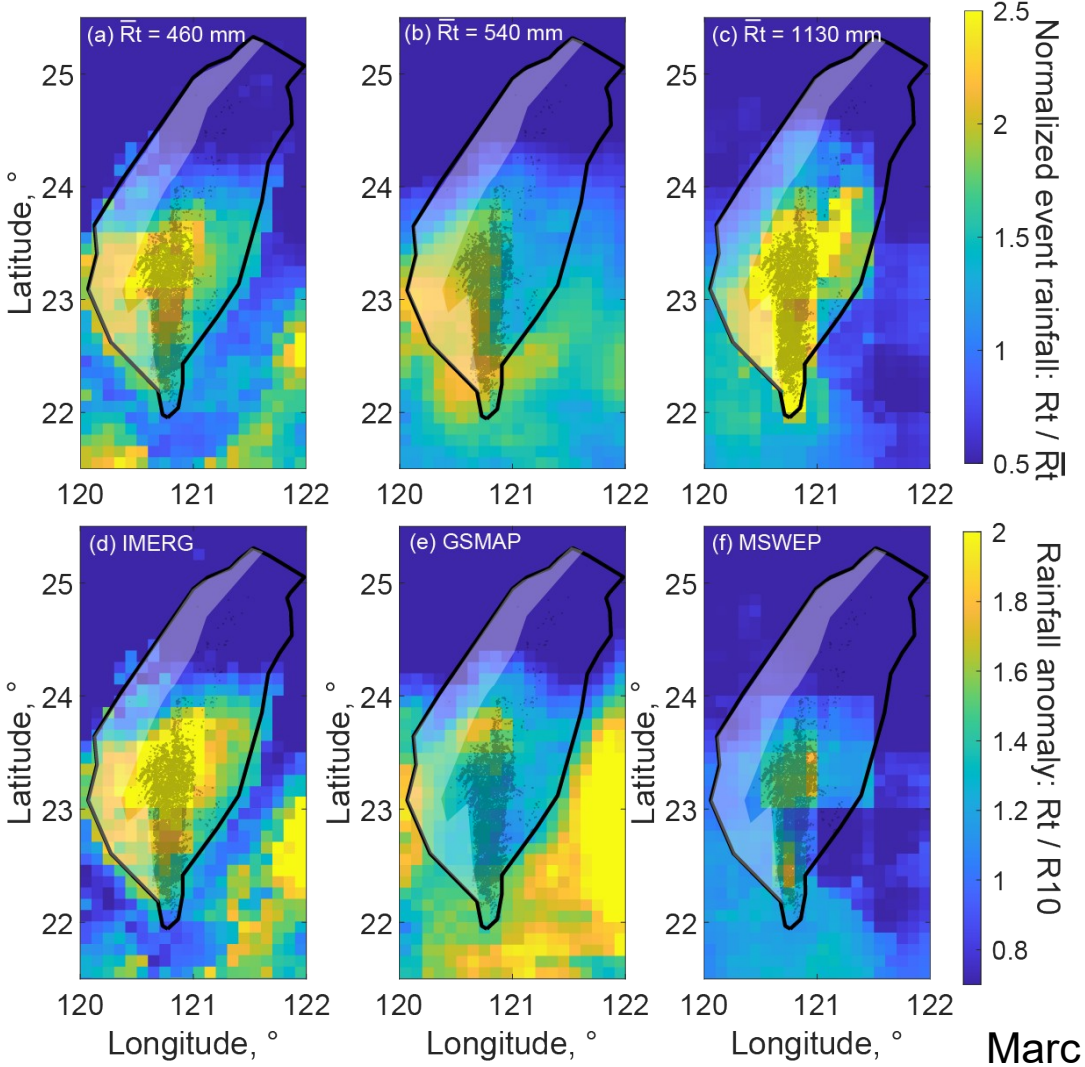
IMERG-v6

MSWEP-v2

Note they have similar raw data but different processing algorithms.



Another advantage of using rainfall anomaly

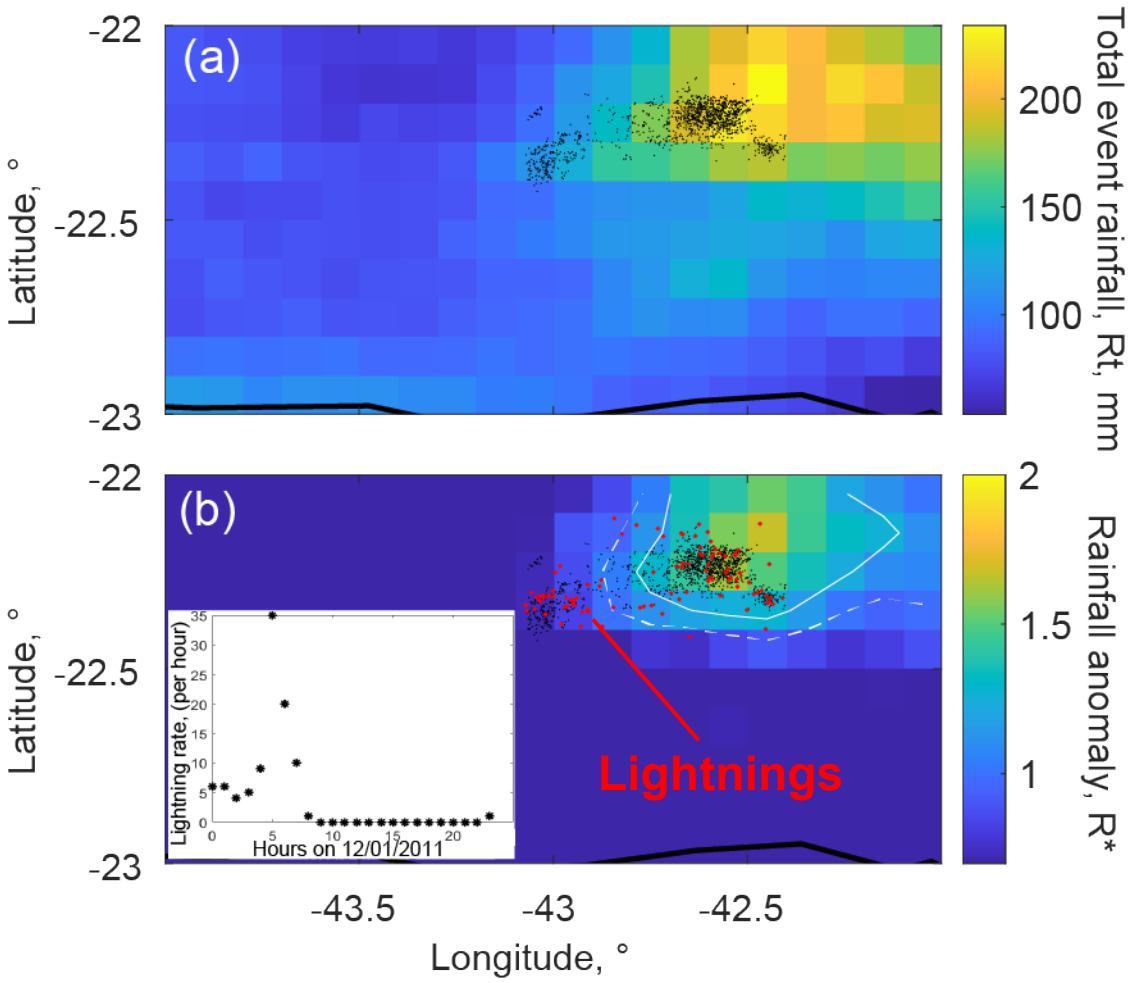


At least using R* remove bias in absolute rainfall (note the larger variability in the upper panels and different mean absolute rainfall)

But if all products detect a significant anomaly (R*>1.2) across the island in 2009, the detailed pattern varies a lot

Marc et al., ***Earth Interactions,*** 2022 (Accepted)

Example of potential ways forward



Include orographic effects in IMERG (Improve them in GSMAP).

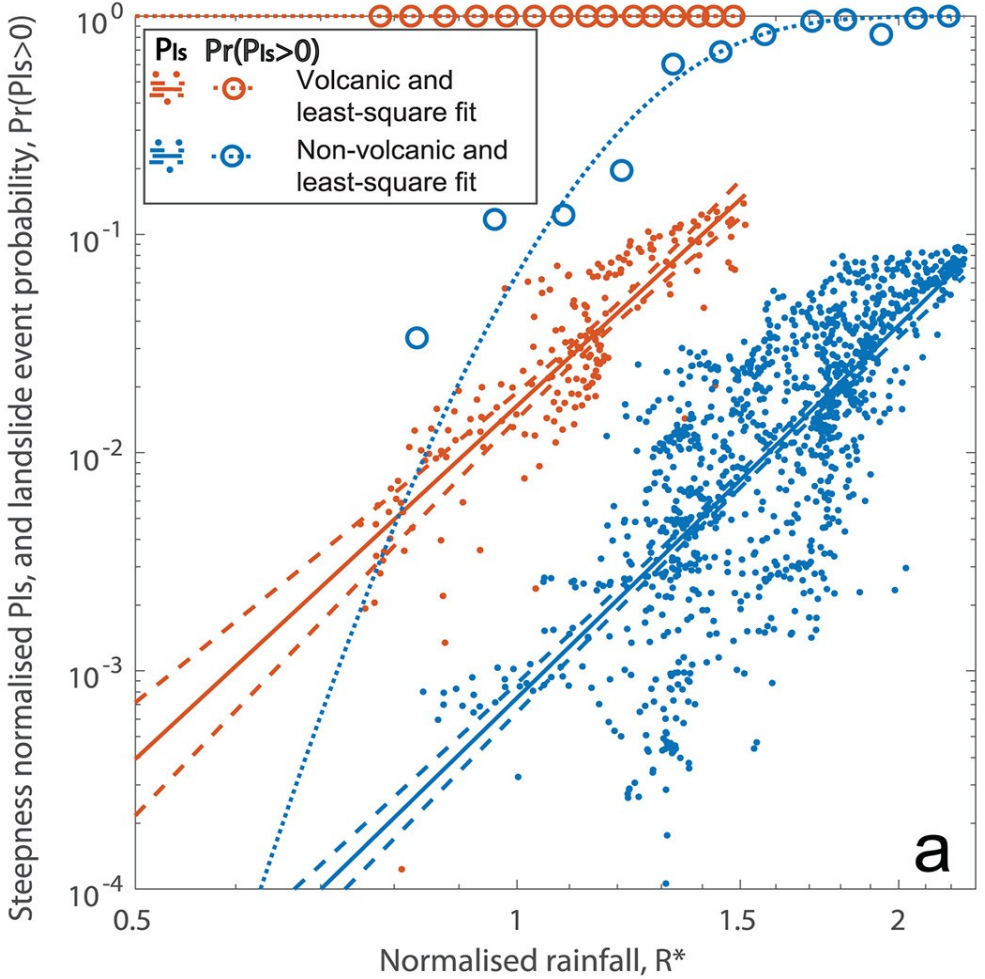
Potentially use information from lightning retrieval obtained by GOES satellites. This could both sharpen the pattern and improve its location.

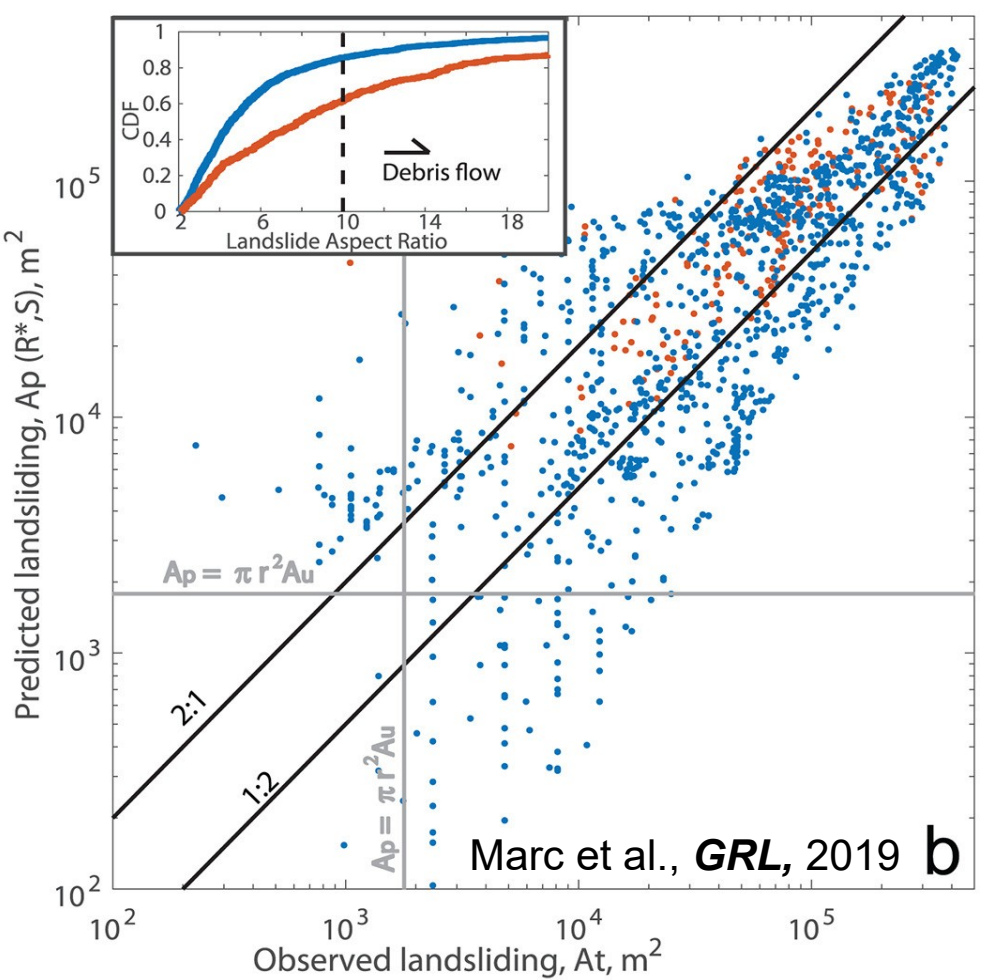
Combine results from various products ?

Marc et al., ***Earth Interactions,*** 2022 (Accepted)

Quantitative scaling with rainfall anomaly

Empirical fits based on slope and rainfall anomaly only, within 2 lithological units.

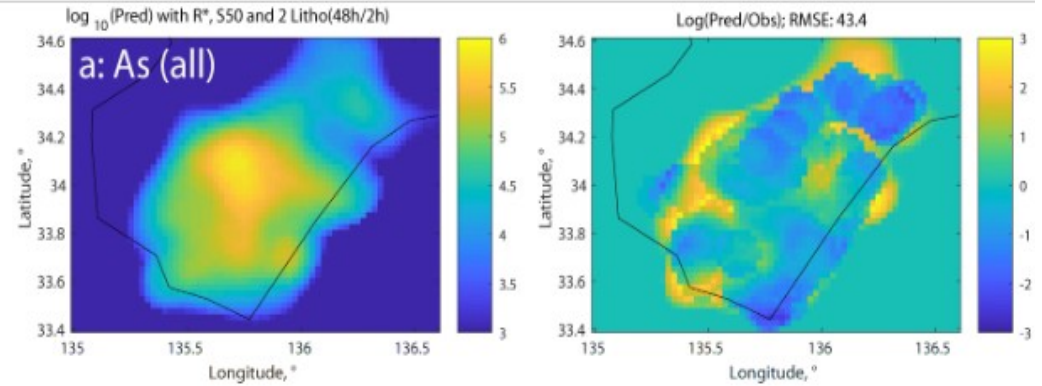


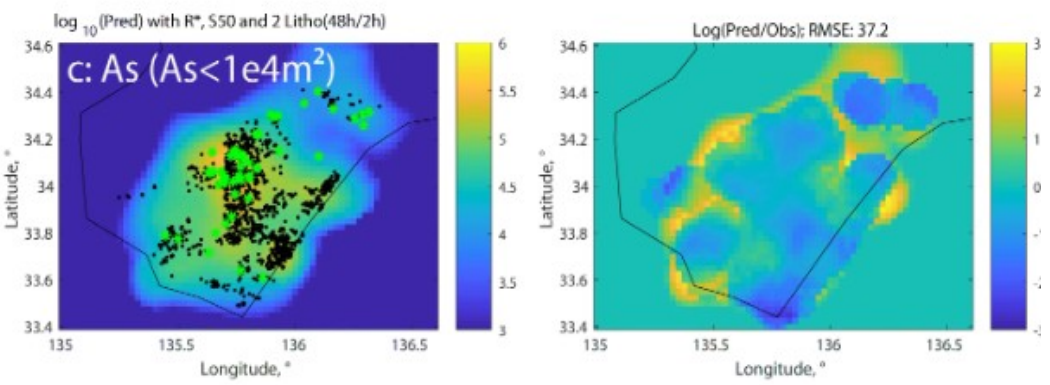


Including large landslides degrade the results

Predictions and residuals: with or without landslides with scar area > 10^4 m² .

Large landslides (in green) are not strongly related to the rainfall anomaly...





Marc et al., ***GRL,*** 2019

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Zorzetto, E., Botter, G., and Marani, M., 2016, **On the emergence of rainfall extremes from ordinary events**, 43, 8076–8082, https://doi.org/10.1002/2016GL069445.