EGU General Assembly 2022

EGU GENERAL ASSEMBLY 2022
23-27 MAY 2022

VIENNA, AUSTRIA AND ONLINE

Climate anomalies and geomorphic hazards in high-mountain regions in the Alps: new perspectives from the integrated use of observations and satellite-based products

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Session GM10.2

Thursday, 26 May 2022, 11:12–11:19, Room G2

ISAC

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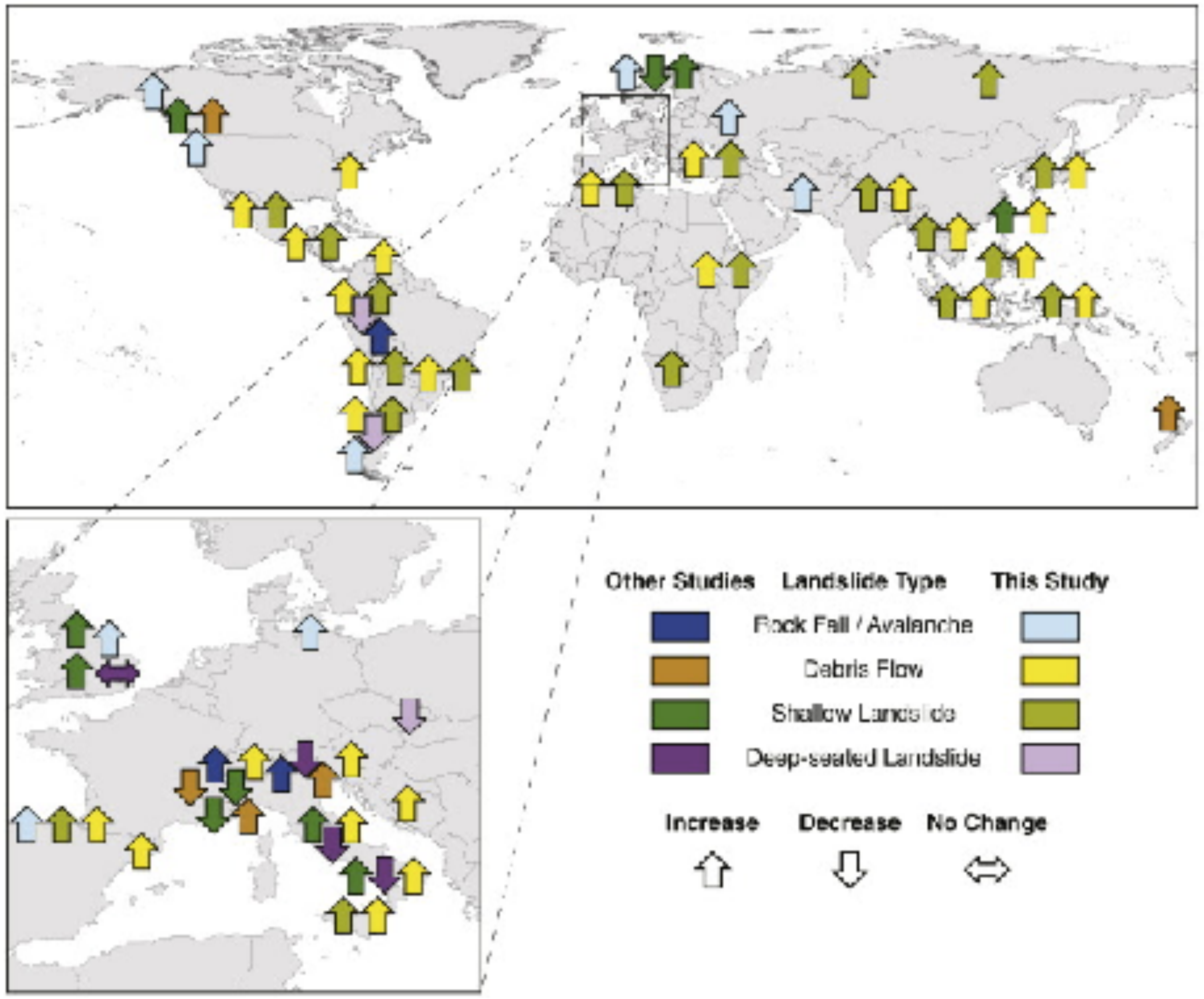
Rationale

Climate anomalies responsible for slope failure occurrence

Integration of observation and satellite based-products

Conclusions and Further developments



Map of expected variations in the abundance or activity of four landslide types, driven by the projected climate change. Gariano and Guzzetti, 2016

State of art

- Studies on glacier retreat and permafrost degradation in a context of global warming
- Rainfall induced-landslides (Guzzetti et al., 2008)
- Focus on specific processes and parameters (Allen and Huggel, 2013; Saez et al., 2013)

Lack

- Studies on the effect of temperature in combination with precipitation on landslides and rockfall initiation at high elevation sites
- Statistical-based and systematic approach aimed to quantify the presence of climate anomalies (Paranunzio et al., 2015)

→ **Statistical-based and bottom up approach as a tool to catch a possible climatic signal at different timescales, which could be possibly related to landslide occurrence**

Paranunzio R, Laio F, Nigrelli G, Chiarle M (2015) A method to reveal climatic variables triggering slope failures at high elevation. Nat Hazards 76:1039–1061. https://doi.org/10.1007/s11069-014-1532-6

Method

Selecting variables

Temperature T

Temperature variation ΔT

Precipitation R

Snow depth Sd

Freezing-Thaw cycles FT

Aggregation scale

T, R: daily, weekly, monthly. quarterly

ΔT: one, three, six days

Sd: one, three, six days

FT: weekly, monthly, quarterly

Selecting weather stations

Data availability

Spatial proximity to failure site

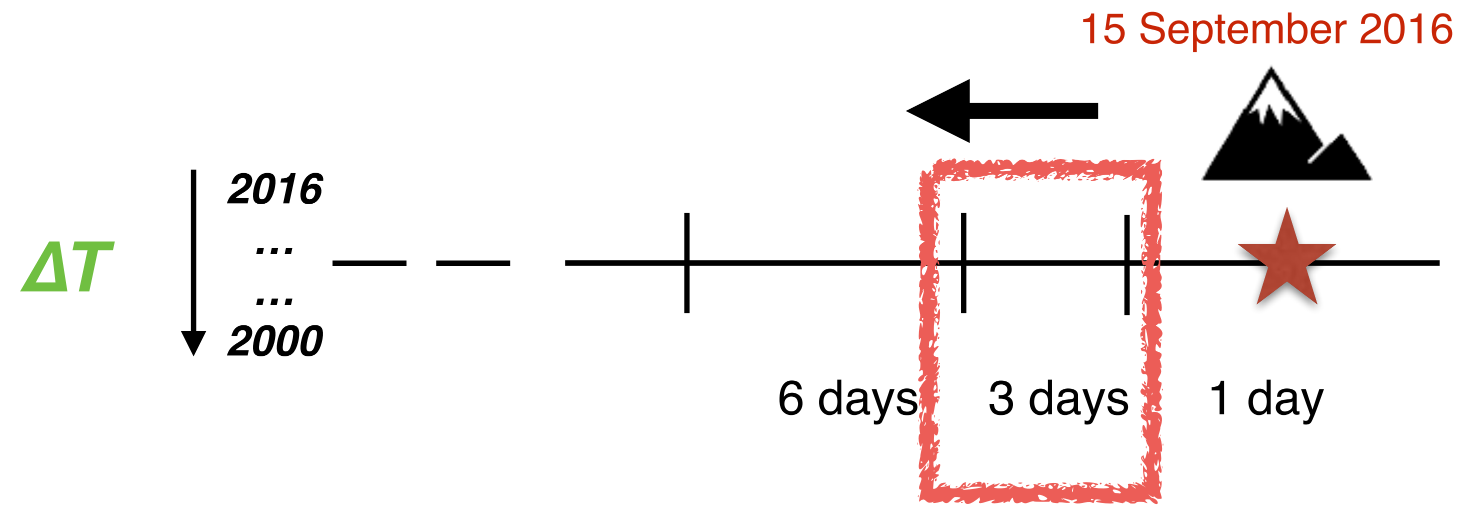
Reference sample

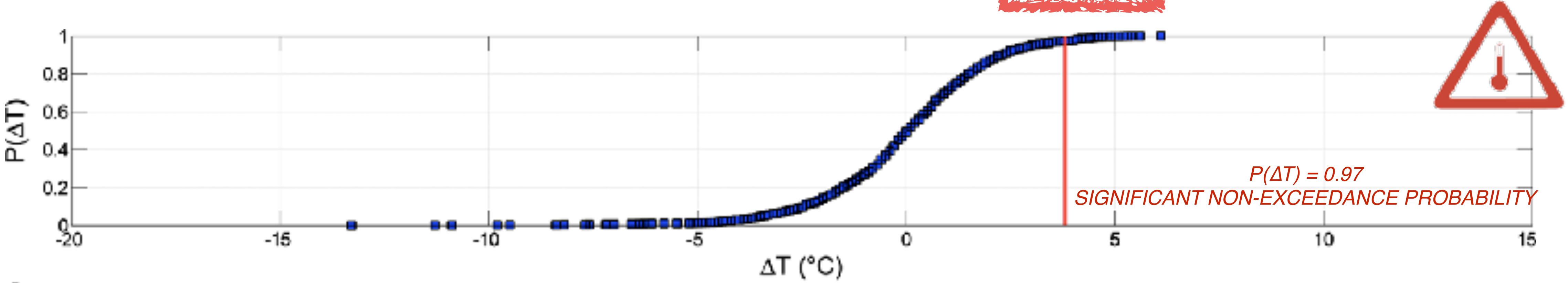
based on variable seasonality

Detecting climate anomalies

$P(V) \leq \alpha/2$ or $P(V) \geq 1-\alpha/2$

$\alpha=0.2$





Paranunzio, R., Chiarle, M., Laio, F., Nigrelli, G., Turconi, L., & Luino, F. (2019). New insights in the relation between climate and slope failures at high-elevation sites. *Theoretical and Applied Climatology*, *137*(3), 1765-1784.

Challenges

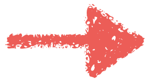
Climate data retrieval

- Lack and inconsistency of climate data (different climate data providers across Italy)
- Length oh the historical series
- Fragmentation of the data into multiple regional and national datasets

Location of the weather stations

- Sometimes records are not fully representative of the local weather and climate conditions of the detachment area
- Precipitation are affected by a large spatial variability in high-mountain areas (Marra et al. 2016)

The availability of new products based on a merging and/or combination of gridded data and in situ climate records could be a way to partially overcome the shortcoming related to lack and inconsistency of climate data, finding a compromise between data availability and spatiotemporal resolution of remotely sensed records



Extending Landslides' Dataset

New knowledge on geohazards triggered by convective rainfall and subdaily processes at high elevation sites

Marra, F., Nikolopoulos, E. I., Creutin, J. D., & Borga, M. (2016). Space–time organization of debris flows-triggering rainfall and its effect on the identification of the rainfall threshold relationship. *Journal of Hydrology*, *541*, 246-255.

Data Integration

Selecting variables
Temperature *T*
Temperature variation *ΔT*
Precipitation *R*
Snow depth *Sd*
Freezing-Thaw cycles *FT*

→

Aggregation scale
T, R: daily, weekly, monthly. quarterly
ΔT: one, three, six days
Sd: one, three, six days
FT: weekly, monthly, quarterly

→

Selecting weather stations
Data availability
Spatial proximity to failure site

↓

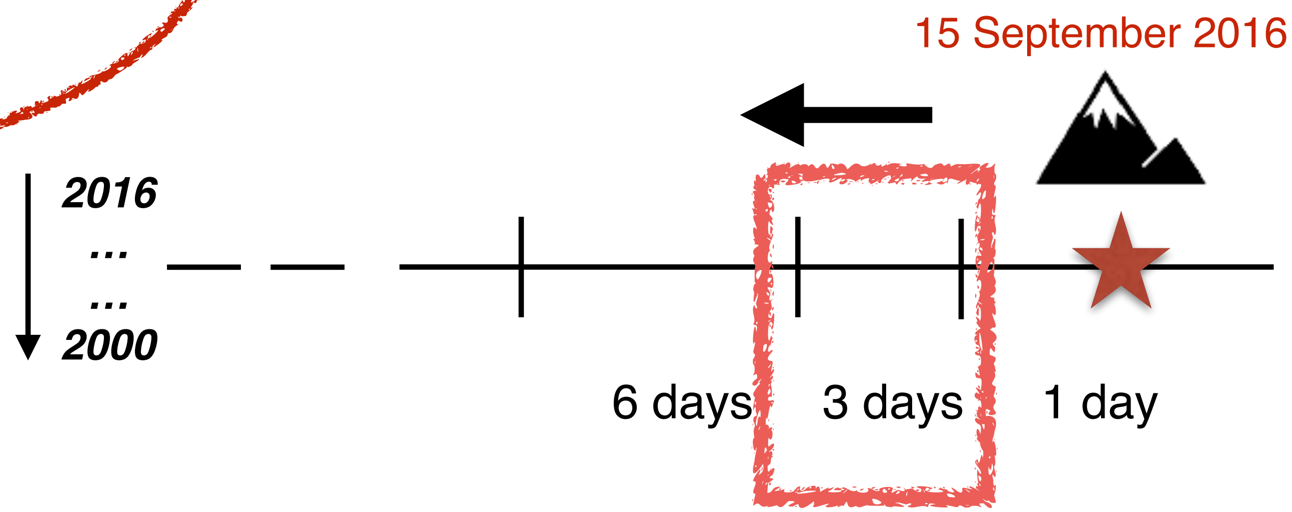
Reference sample
based on variable seasonality

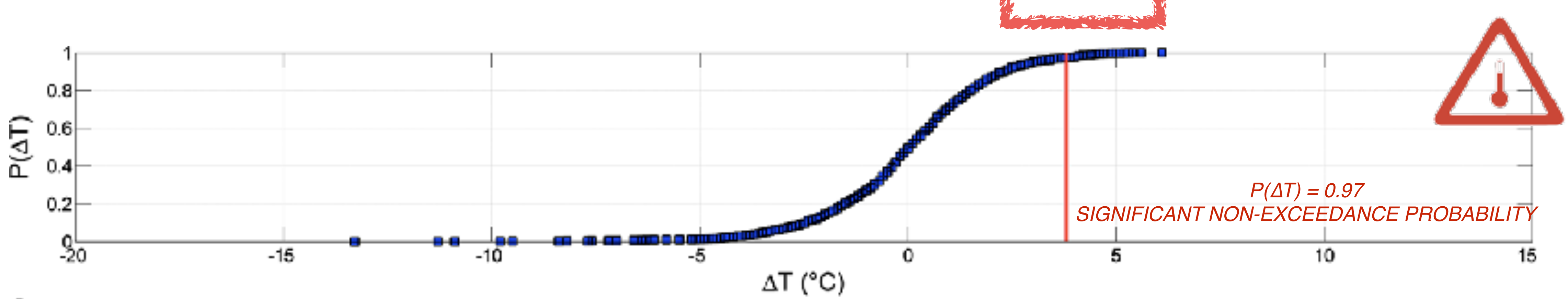
←

Detecting climate anomalies
P(V) ≤ α/2 or P(V) ≥ 1-α/2
α=0.2

Integration of obs and satellite-based products
In-situ obs
GLP (IMERG)
E-OBS
CMC

ΔT





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Climate Data

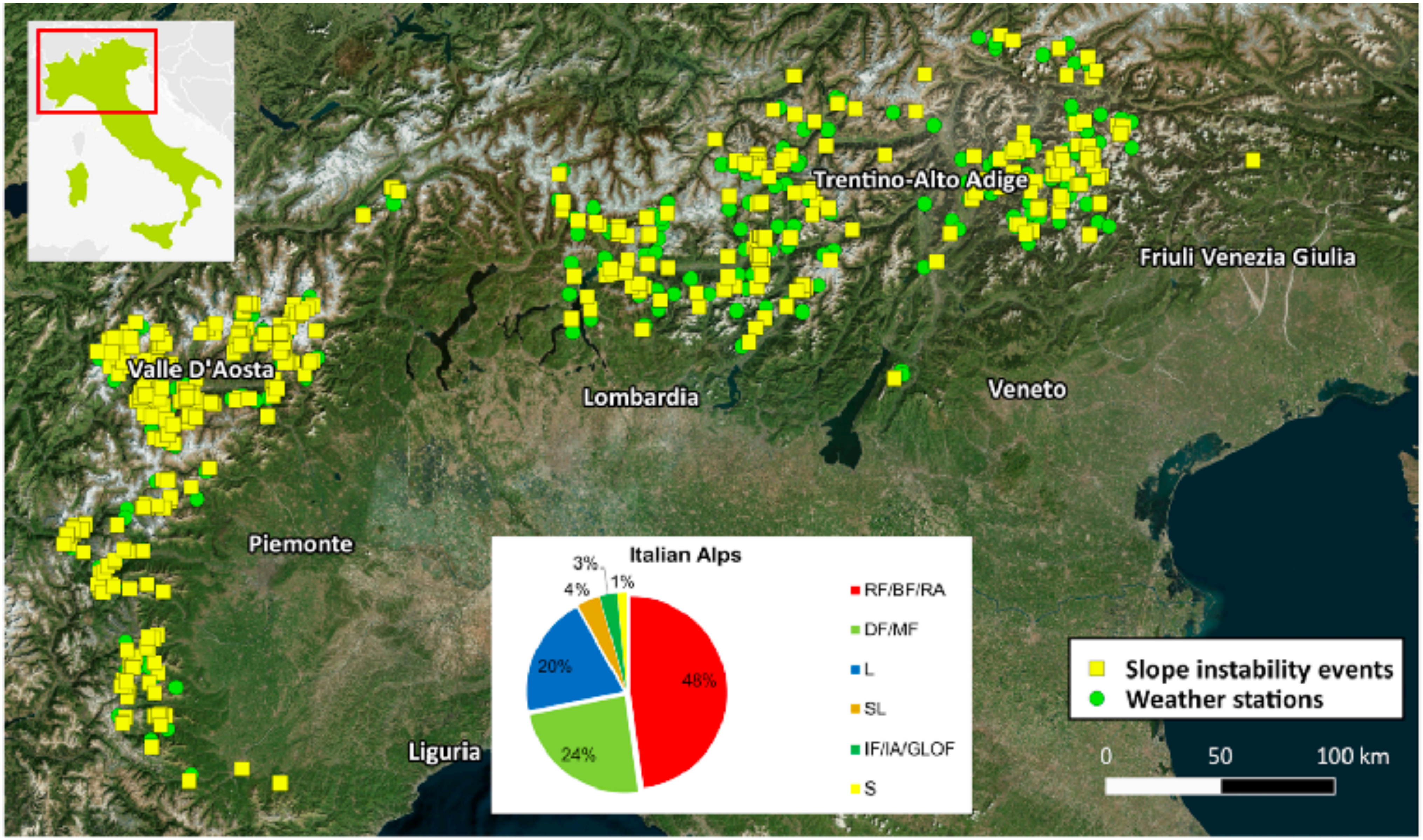
- **In-situ information from around 130 daily weather stations (Regional Agencies)**
  Temporal resolution: Day
  Spatial resolution: point
  Temporal Coverage: variable (1990 or before - on)
  Data format: Multiple

+

- **High-resolution precipitation estimates from the Integrated Multi-Satellite Retrievals from GPM (IMERG)**
  Temporal resolution: 30-min
  Spatial resolution: 0.1° x 0.1°
  Temporal Coverage: 2000 - 2020
  Data format:

- **Daily gridded temperature observations from ENSEMBLES OBServation (E-OBS)**
  Temporal resolution: Day
  Spatial resolution: 0.1° x 0.1°
  Temporal coverage: January 1950 to present
  Data format: NetCDF-4

- **Canadian Meteorological Centre (CMC) Daily Snow Depth analysis Data, Version 1**
  Temporal resolution: Day
  Spatial resolution: 24 x 24 km
  Temporal coverage: August 1998 - December 2020
  Data format: GeoTIFF - ASCII



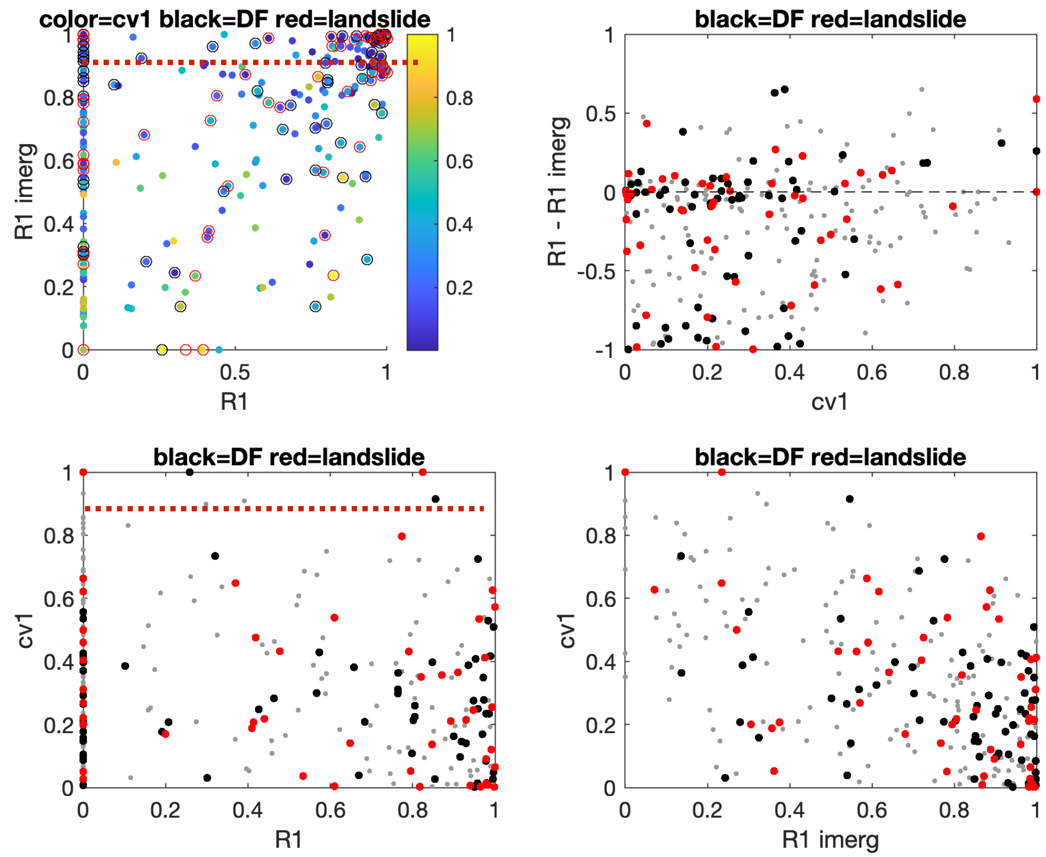
Location of the 358 geomorphic hazards occurred across the Italian Alps in the period 2000-2016, including landslides, rockfalls and debris-mud flows over 1500 m a.s.l. (Paranunzio et al., 2019)

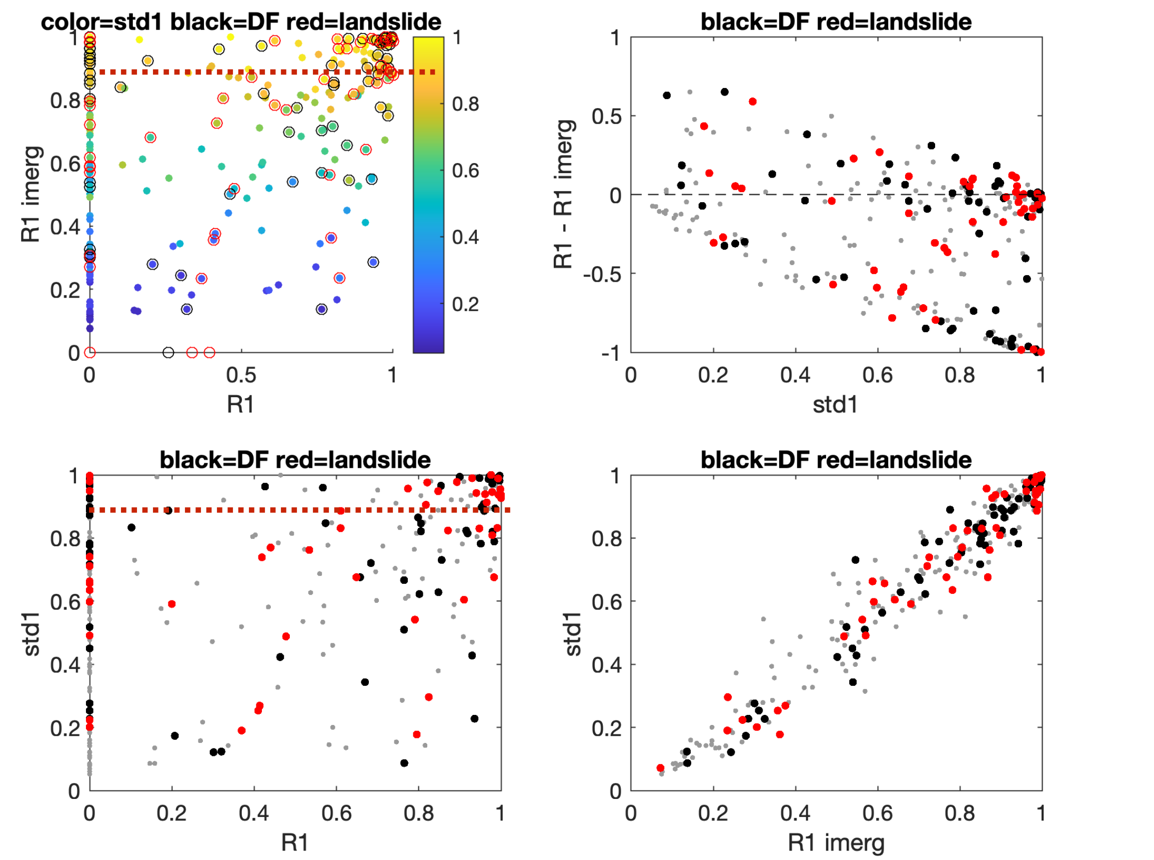
To be extended with new 2016-2020 data (Guerini et al. 2021)

Guerini M., Giardino M., Paranunzio R., Nigrelli G., Turconi L., Luino F., Chiarle M. (2021) – Slope failures at high elevation in the Italian Alps in the period 2000-2020. Pangaea Data Publisher for Earth & Environmental Science;

Analysis of sub-daily rainfall processes

Daily rainfall (R1-R1 imerg) variability in terms of Percentiles of Coefficient of Variation (cv1) and Standard Deviation (std1) at 30 minutes



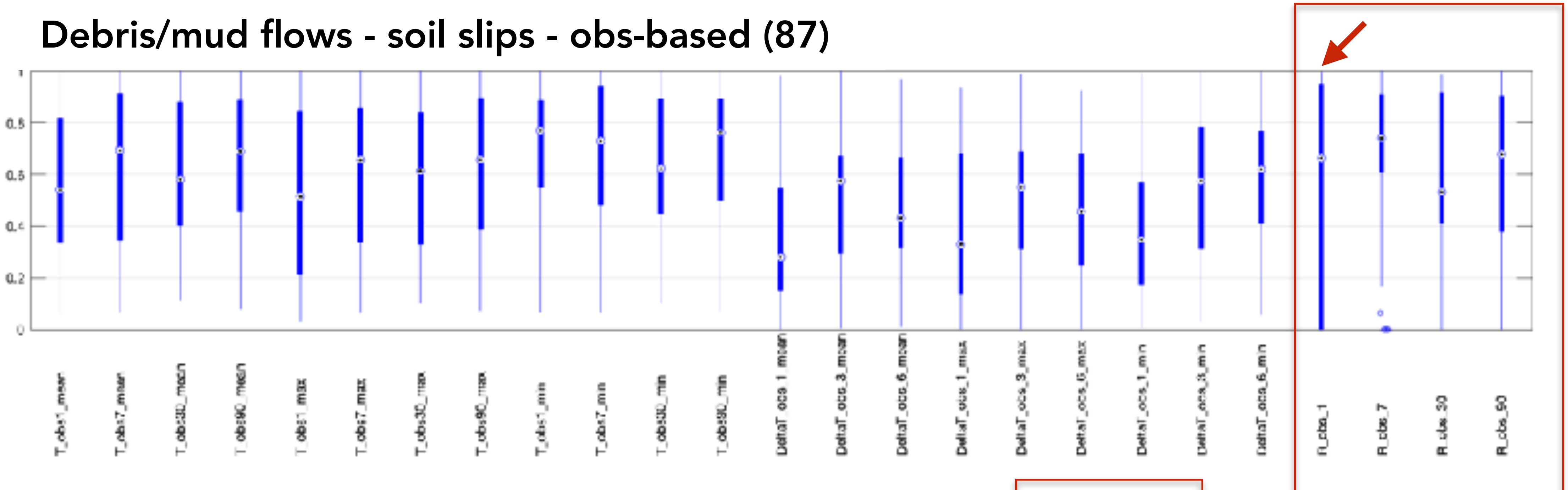


IMERG allows to detect precipitation in numerous cases (~60%) for which in-situ data showed no precipitation; in ~19% of these, climatic anomalies (exceedance of the 90th percentile) are detected.

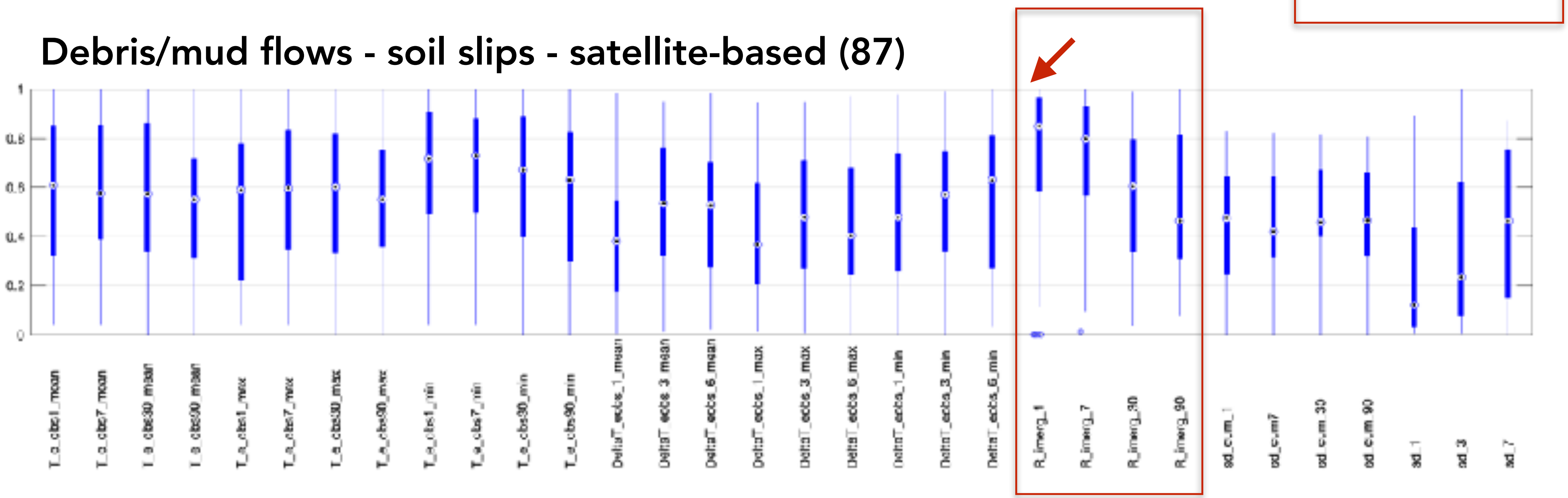
Analysis of sub-daily rainfall processes

Especially in the case of rainfall-induced processes, IMERG data reveal significant rainfall anomalies at daily scale which have not been detected by the mere use of in-situ measurements

Debris/mud flows - soil slips - obs-based (87)



Debris/mud flows - soil slips - satellite-based (87)



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Analysis of sub-daily rainfall processes

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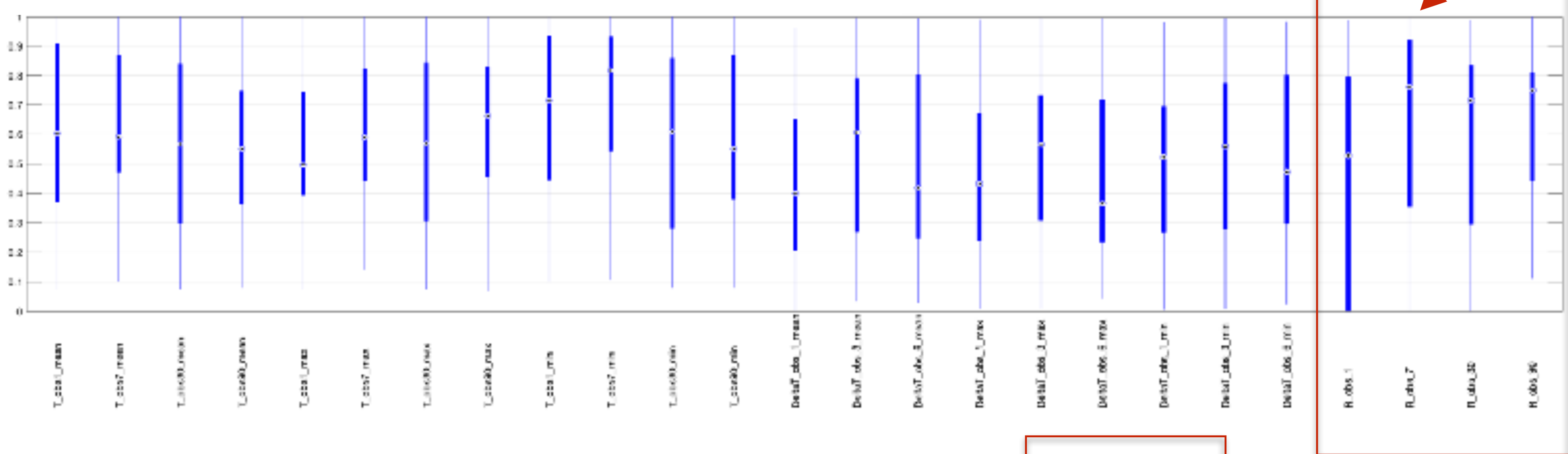
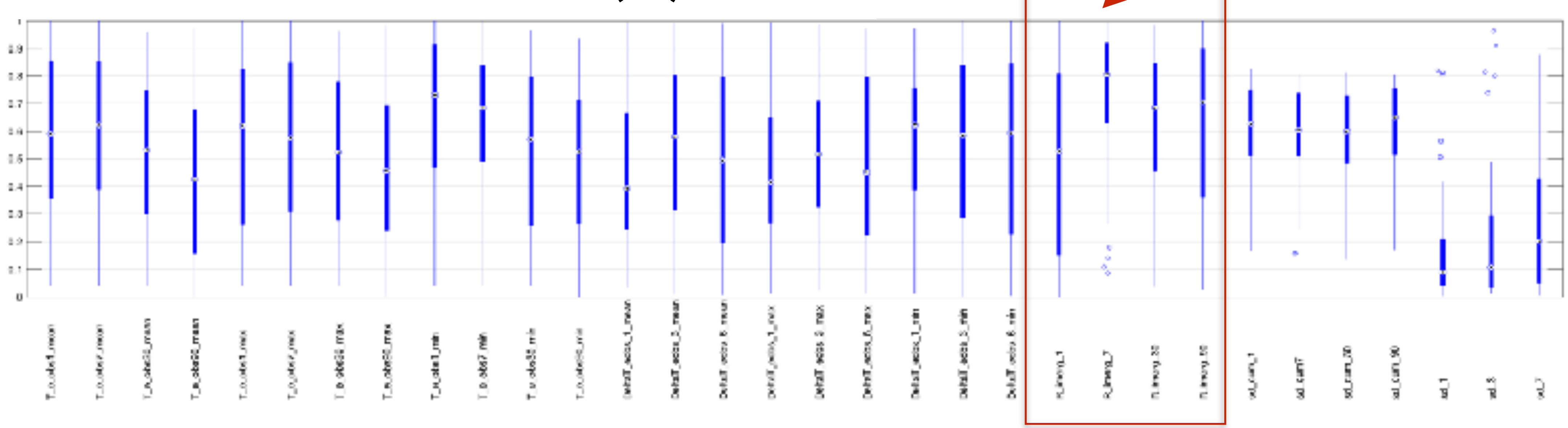
Blockfall - obs-based (50)



Blockfall - satellite-based (50)



IMERG allows to detect precipitation in numerous cases (~60%) for which in-situ data showed no precipitation; in ~19% of these, climatic anomalies (exceedance of the 90th percentile) are detected.

Conclusions and Further Developments

- Preliminary findings indicate that IMERG could significantly improve precipitation information by providing estimates directly on the initiation zones, which is particularly relevant in case of hazards triggered by small-scale convective storms. This advantage is evident and in particular for the case of debris-mud flows.

- Satellite-based products allow to investigate the role of climate triggers in landslides' initiation phase also when in-situ records are not available, making a further extension of the analysed dataset easier

Further developments

- Extending the landslides' catalogue size (new data from 2016 on will be soon analysed)
- Improving the method by adding further variables (e.g., freeze-thaw cycles, snow depth) and flexible temporal aggregation scales, to investigate further their role in the initiation and in particular in the preparation phase
- Sub-daily temporal scale analyses needed, in particular for rainfall induced processes
- Analysis of the inter-correlation and dependency between climate variables (e.g. multivariate cumulative distribution functions)

Rocca la Meja, 2831 m a.s.l., Piedmont, Italy - View from the top
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