Updating annual rainfall maxima statistics in a data-scarce region

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MOTIVATION

The growing number of extreme hydrological events observed (*Fischer and Knutti*, 2016; *Papalexiou and Montanari*, 2019) has raised the level of attention toward the **impact of climate change** on **rainfall process**, which is difficult to quantify given its strong spatial and temporal heterogeneity. Therefore, the impact of the climate cannot be determined on the individual hydrological time-series but must be assessed on a regional scale. This work aims at identifying the **trends and dynamics of extreme sub-daily rainfall** in southern Italy in the period 1970-2020.

CASE STUDY AND RAINFALL DATA

The area under investigation is the **southern Italy**, a large portion of the Italian peninsula (about 20% of the whole territory). It is located within the **Mediterranean basin** and is characterized by a **complex orography**.

The database of **rainfall annual maxima for sub-daily durations** (1, 3, 6, 12, and 24 hours) was assembled using all available rainfall data (provided by the National Hydrographic and Mareographic Service - SIMN, and the Regional Department of Civil Protection through the network of the Functional Centres). The database is made up of around 910 rain gauges, for a total of 17000 years of observations, representing the 36.8% of the total number of possible data.

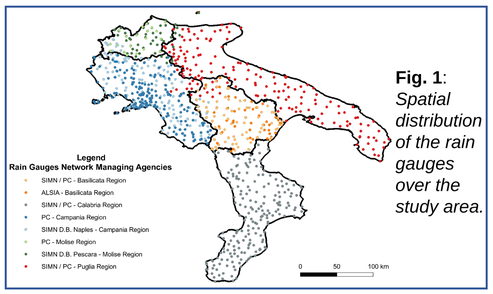

Fig. 1: *Spatial distribution of the rain gauges over the study area.*

RECONSTRUCTION OF THE RAINFALL DATABASE

Due to the numerous changes (location, type of sensor, managing agencies) experienced by the national monitoring network, the time-series were found to be **extremely uneven and fragmented**.

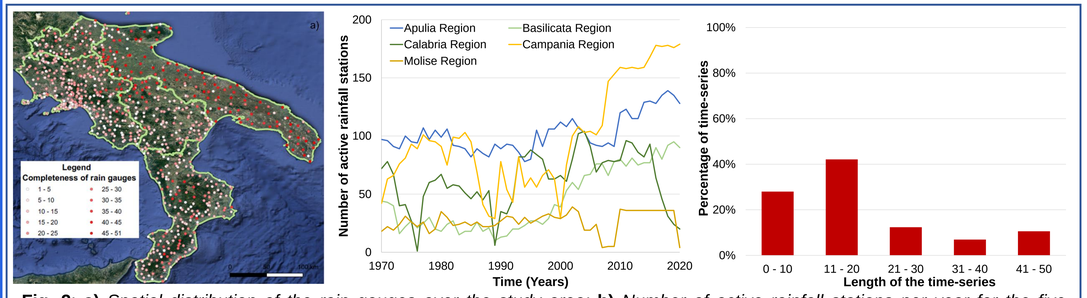

Fig. 2: **a)** *Spatial distribution of the rain gauges over the study area;* **b)** *Number of active rainfall stations per year for the five considered regions*; **c)** *Percentage of series per length class in the recorded database at the southern Italy scale.*

Therefore, we tried to estimate missing rainfall data by means of gap-filling procedures, in particular the **spatially-constrained Ordinary Kriging (SC-OK) approach** (*Avino et al.*, 2021). It is a **mixed procedure** that adopts the **OK equations** coupled with the same **spatial constraints as the IDW**. The SC-OK will reconstruct only the missing data in the same locations identified by the IDW parameters.

The impact of the reconstruction procedure on the rainfall database is detailed in the following figure.

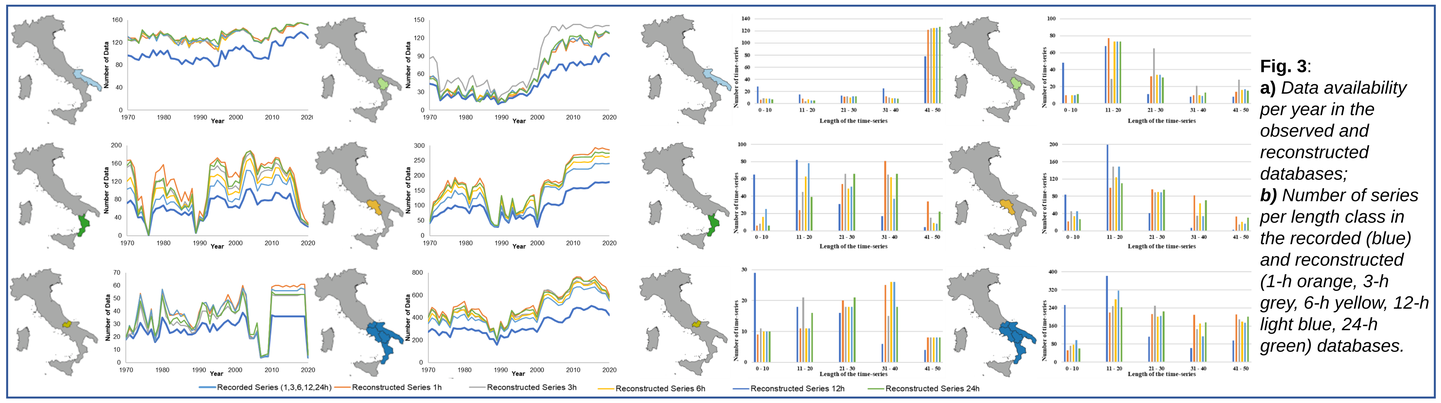

Fig. 3: **a)** *Data availability per year in the observed and reconstructed databases;* ***b)*** *Number of series per length class in the recorded (blue) and reconstructed (1-h orange, 3-h grey, 6-h yellow, 12-h light blue, 24-h green) databases.*

The reconstruction percentage is in the range 10-20% for the five regional databases, with an **average percentage increase of 17%**. The reconstruction error, at the southern Italy scale, in terms of **RMSE ranges from 10 to 20 mm** as the duration increases, while in terms of **MAPE passes from 23% at 1 hour to 20% at 24 hours**.

TREND ANALYSIS

▶ Graphical evaluation of possible changes in the rainfall regime

Graphical comparison of the average values of annual maxima for two different time periods (1970-1994 and 1995-2020) given by:

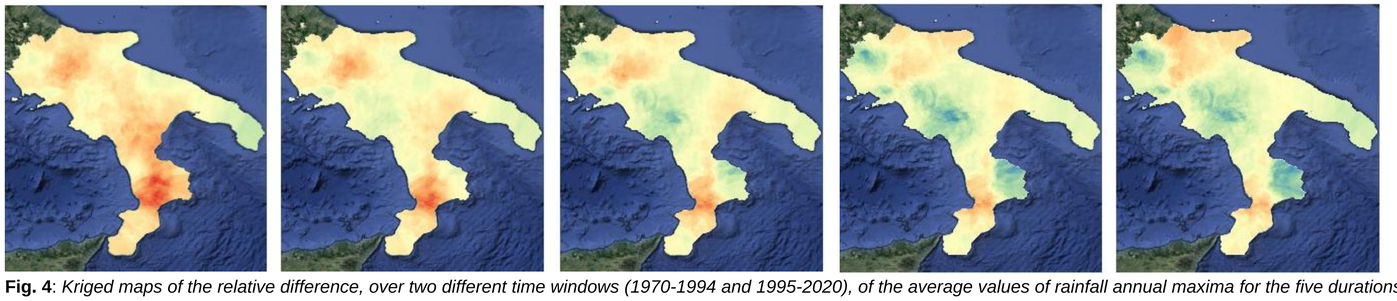

Fig. 4: *Kriged maps of the relative difference, over two different time windows (1970-1994 and 1995-2020), of the average values of rainfall annual maxima for the five durations.*

$$H = \frac{\bar{h}_{1995-2020} - \bar{h}_{1970-1994}}{\bar{h}_{1970-1994}} \cdot 100$$

Legend
-20% 0% 40%
-15% 10% 50%
-10% 20% 60%
-5% 30%

▶ At-site Mann-Kendall (MK) trend test

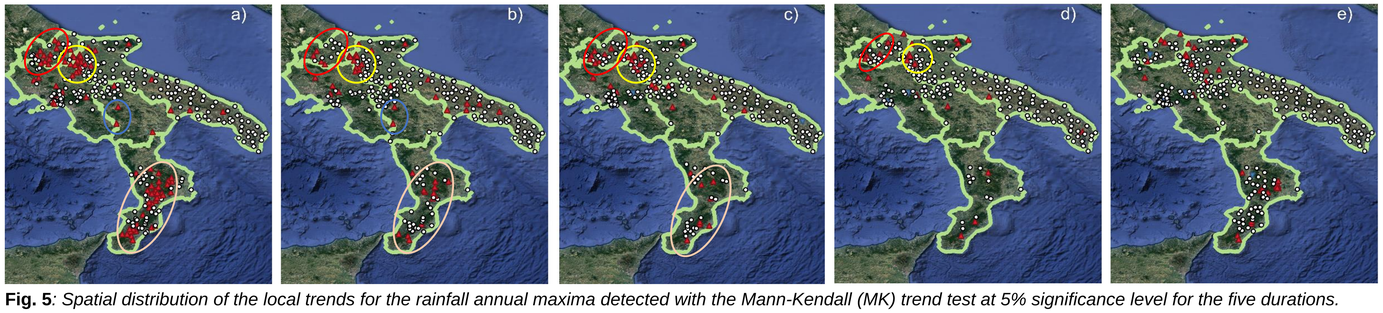

Fig. 5: *Spatial distribution of the local trends for the rainfall annual maxima detected with the Mann-Kendall (MK) trend test at 5% significance level for the five durations.*

Central highlands of Molise and the Matese Regional Park, on the border between Campania and Molise

The Campano Apennines, on the border between Apulia, Campania, and Molise

The Lucanian Apennines, on the border between Basilicata and Campania

The Calabrian Apennines, from the Sila plateau to Aspromonte

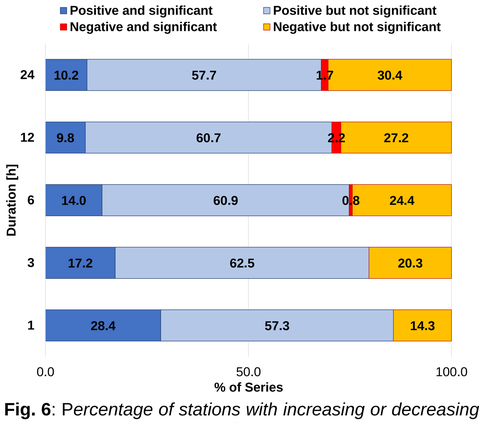

Fig. 6: *Percentage of stations with increasing or decreasing trends, significant or not at 95% confidence level.*

CONCLUSIONS

- ▶ Most extreme rainfall series display no trend for the longer durations (12 and 24 hours), while clusters of change emerge at the shorter durations and in small areas with homogeneous climatic and morphological characteristics;
- ▶ Significant trends cannot be detected at the Southern Italy scale, but, on the contrary, homogeneous behaviours appear within the regional borders: increasing trends have been detected in Calabria, Molise, and Apulia for all durations and in Campania and Basilicata for short durations;
- ▶ Construction of a database of sub-daily (1-h, 3-h, 6-h, 12-h, 24-h) rainfall annual maxima, homogeneous and continuous over time.

REFERENCES

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Fischer and Knutti (2016): *Observed heavy precipitation increase confirms theory and early models,* Nature Climate Change.

Papalexiou and Montanari (2019). *Global and regional increase of precipitation extremes under global warming*, Water Resources Research.

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