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Analyzing trends in ordinary and extraordinary rainfall extremes by using fragmented records

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Understanding trends in rainfall extremes is essential for managing hydrological risks and designing climate-resilient infrastructure. Among the European countries, Italy presents a complex case study for such analyses due to its diverse topography, ranging from sea-level plains to alpine peaks, and its fragmented hydrological datasets.

This study investigates trends in short-duration rainfall extremes (1 to 24 hours) across Italy using annual maximum rainfall depths measured by rain gauges, coming from the Improved Italian - Rainfall Extreme Dataset (I^2-RED), a collection of more than 5000 time series spanning the period 1916–2022.

Two complementary methodologies were employed. The Mann-Kendall test was initially applied together with the evaluation of the Sen's slope to assess trend significance and magnitude. This approach, however, suffered the presence of highly-fragmented time series, covering different periods. Then, to address data fragmentation, a distributed quantile regression approach was used, pooling data within defined radii around grid cells. This latter approach ensured consistency across regions with different spatial and temporal densities while maintaining sensitivity to local variations and allowed for a robust analysis of trends in the median (0.5 quantile) and higher quantiles (0.95 and 0.99), enabling the identification of spatially coherent clusters of positive and negative trends.

The results reveal substantial variability across regions, with higher quantiles showing more pronounced changes than the median, indicating faster changes in extreme events compared to more ordinary rainfall. The median values of the 1h annual maxima show an increase all over the country. For the 24h duration, opposite tendencies can emerge even at close distances. The findings emphasize the spatial heterogeneity of rainfall trends in Italy and their implications for hydrological design.