Investigating temporal changes in ordinary and extraordinary precipitation extremes over Italy

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Understanding how rainfall extremes are evolving over time is essential for infrastructure design, hydrological risk assessment, and climate adaptation strategies. However, detecting trends at a national scale in a complex country like Italy, with its varied topography and meteorological influences, poses significant challenges.

This study aims to evaluate temporal changes in short-duration (1 to 24 hours) rainfall extremes across Italy by analyzing the most extensive and recent dataset of annual maximum rainfall depths, sourced from I^2-RED, the Improved Italian - Rainfall Extreme Dataset. The dataset includes over 5500 time series spanning from 1916 to 2022. Unlike studies relying on reanalysis data or climate model outputs, which may introduce uncertainty due to the model's ability to reproduce extremes and coarse spatial resolution, our analysis is based solely on direct rain gauge observations.

Two complementary methods were used: (i) the non-parametric Mann-Kendall test complemented by Sen's slope estimator to detect trends at individual sites, and (ii) a distributed quantile regression analysis for a gridded investigation. The latter employs a moving window approach, pooling data from nearby rain gauges to enhance the robustness of the estimates.

Our results reveal that changes in rainfall extremes across Italy are highly variable, and regional patterns are present. Notably, the quantile regression method highlighted stronger trends in higher quantiles compared to ordinary rainfall extremes: while median rainfall (50th percentile) showed only slight changes over time, extreme events (95th and 99th percentiles) displayed more pronounced variations. This suggests that the most intense precipitation events are becoming more extreme in certain regions, while ordinary extreme rainfall remains relatively stable.

These findings have important implications for hydrological design and flood risk assessment, emphasizing the need to account not only for mean changes in precipitation but also for shifts in extreme events. The increasing trends in extreme rainfall point to the necessity of updating intensity-duration-frequency (IDF) curves, particularly in regions where significant increases in extreme precipitation have been detected. Conversely, negative trends in some areas may suggest reduced design rainfall values, though caution is necessary in making such adjustments due to the uncertainties surrounding future rainfall variations.