Mapping Temporal Changes in Ordinary and Extraordinary Rainfall Extremes in Italy

Paola Mazzoglio [a], Alberto Viglione [a], Daniele Ganora [a] & Pierluigi Claps [a]

[a] Department of Environment, Land and Infrastructure Engineering (DIATI), Politecnico di Torino, Torino, Italy

E-mail: paola.mazzoglio@polito.it

Understanding how rainfall extremes are evolving is essential for infrastructure planning, hydrological risk assessment, and climate adaptation strategies. However, detecting trends at the national scale is particularly challenging in a country like Italy, where complex topography and diverse meteorological influences create strong spatial variability.

This study provides a comprehensive assessment of temporal changes in short-duration (1 to 24 hours) rainfall extremes across Italy, using the most extensive and up-to-date dataset of annual maximum rainfall depths available (I^2-RED, the Improved Italian - Rainfall Extreme Dataset; Mazzoglio et al., 2020). Unlike studies based on reanalysis or climate model outputs, which can introduce uncertainties due to model resolution and limitations in reproducing rainfall extremes, our analysis relies exclusively on direct rain gauge observations of more than 5,500 time series spanning the period from 1916 to 2022.

A distributed quantile regression was applied for a spatially continuous analysis (Mazzoglio et al., 2025). This approach pools data from nearby gauges within a specified radius to enhance the robustness of the estimates. Our findings reveal that changes in rainfall extremes across Italy are highly heterogeneous, showing only modest spatial coherence. Although no widespread national-scale trend emerges, distinct regional patterns are evident. One of the most notable results is the stronger magnitude of trends observed in higher quantiles compared to ordinary extremes. While median rainfall intensities (50^{th} percentile) display only limited temporal changes, the most extreme events (95^{th} and 99^{th} percentiles) exhibit more pronounced variations. This indicates that the most intense precipitation events are becoming even more extreme in certain regions, whereas moderate rainfall remains relatively stable. These results carry important implications for hydrological design. They emphasize the need to account not only for changes in average precipitation but also for shifts in the tails of the distribution. The observed increases in extraordinary extremes highlight the necessity of updating depth–duration–frequency curves to reflect these evolving patterns, particularly in areas showing significant upward trends. Conversely, while negative trends in some regions could suggest a potential reduction in design rainfall values, such adjustments should be made cautiously, given the uncertainty surrounding future precipitation variability.

Keywords: rainfall, extremes, climate change, territory

References:

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