



## Exploring the seasonality of extreme precipitation in Italy: the SEASONEX project

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### Abstract

Extreme precipitation events are among the most critical hydro-meteorological hazards in Italy, causing flash floods, landslides, and severe infrastructure damage. In 2023 alone, the extreme rainfall event that triggered floods and landslides in Emilia-Romagna caused 17 fatalities and 8.5 billion euros in damages (SNPA, 2024). While most studies generally focus on how the intensity of precipitation extremes is changing, the shift in their seasonality remains largely unexplored, such as the connection that can exist between these two characteristics. Indeed, extreme precipitation events are generally modulated by localized or large-scale weather conditions that can have a strong seasonal concentration. Moreover, the same precipitation amount can lead to markedly different consequences depending on when it occurs, due to different antecedent conditions (e.g., soil moisture, snowpack, etc.), making timing as important as intensity for risk assessment.

Italy's complex morphology and climatic variability, from Alpine regions to Mediterranean coasts, lead to diverse seasonal patterns of precipitation extremes driven by atmospheric circulation, orography, and land–sea interactions (Mazzoglio et al., 2025). To the best of our knowledge, no systematic, nation-wide investigation across multiple sub-daily durations using historical rain gauge observations has been conducted to assess potential changes in the seasonality of extreme precipitation, also using intensity-related information.

The SEASONEX (*a data-based investigation of the SEASONality of EXtreme rainfall in Italy*) project aims to bridge this gap, delivering the first national characterization of the seasonality of extreme precipitation in Italy for durations ranging from 1 to 24 hours. The project is creating an extensive dataset of annual maxima dates by digitizing historical hydrological yearbooks and integrating recent observations from regional agencies, which are combined with magnitude information from the I<sup>2</sup>-RED database (Mazzoglio et al., 2020). This approach enables a multi-scale characterization of precipitation extremes, identifying predominant or multimodal seasonal concentration across the Italian territory. Beyond descriptive characterization, SEASONEX also investigates the spatial and temporal variability of seasonality. Innovative trend tests based on circular statistics are applied to detect non-stationarity and climate-driven shifts in seasonality, offering insights into how changing atmospheric conditions alter the timing of high-impact events. Finally, to advance risk understanding, the project employs circular–linear copulas to jointly model

precipitation magnitude and timing (Treppiedi et al., 2025), enabling an assessment of out-of-season event probabilities.

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### **References**

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