Geographically-based approaches to the statistical analysis of rainfall extremes

Abstract

Extreme rainfall is one of the most critical hazards worldwide, and Italy makes no exception: the vulnerability is particularly high due to a high population density associated with complex topography, extended coastlines, and high climate variability. The statistical investigation of short-duration rainfall extremes is thus a challenging and evolving topic.

In this work, the first national-scale quality-controlled dataset of rainfall extremes is presented, together with simple but effective methods for the detection of errors and inconsistencies. The so-called Improved Italian - Rainfall Extreme Dataset (I^2-RED) is a collection of short-duration (1, 3, 6, 12 and 24 hours) annual maximum rainfall depths measured by more than 5200 rain gauges from 1916 to the present. An exploratory statistical analysis carried out to identify extremes that could be considered "critical" in relation to the local climatology is here reported. This work highlighted that particularly intense rainfall events (in relation to the mean annual rainfall depth) are generally concentrated near the coastline. However, the work also shows a uniform spatial distribution of time series that contains a maximum value twice as large as the second highest one, suggesting that these “Super-Extremes” can be recorded almost everywhere. The analysis was then further expanded by investigating the possible presence of temporal trends in the time series. The results confirmed that rainfall extremes of different durations are not increasing uniformly over Italy and that separate tendencies emerge in different sectors, even at close distances.

A second dataset was thus created: it represents a collection of daily maxima recorded over a domain that coincides with the Po river basin and Liguria region. This second dataset was used to compute the Hershfield factor, that is a coefficient used to retrieved 24 h sliding maxima starting from fixed daily maxima, allowing to take advantage of the relevant amount of information included in historical records of daily extremes.

The investigation of the influence of elevation and other geomorphological and climatological parameters on the index rainfall (computed using the data of I^2-RED) was also performed. The results of the national-scale regression analysis did not confirm the assumption of elevation being the sole driver of the variability of the index rainfall. However, when comparing the results of the best multivariate regression models with univariate regressions applied to small areas, it clearly emerged that “local” rainfall–topography relationships outperform the country-wide multiple regressions, offer a uniform error spatial distribution and allow the effect of morphology on rainfall extremes to be better reproduced.

Finally, a sequential application of interpolation to the annual maxima (patched kriging) is performed to provide reconstructed time series that are consistent with the measured values. Different configurations of the patched kriging incorporating the main results achieved in the overall work are applied and discussed. A first application over an area (Piedmont, Aosta Valley and Liguria) that is both bigger and more complex than the one used in the original methodology (Piedmont) is here presented and an improved methodology that handles the local-scale influence of elevation on the extremes is proposed. The application serves also to highlight the possible influence of a record-breaking event in the rainfall frequency analysis. Then, a comparison with other established approaches is performed over Sardinia and Thessaly (Greece).

The results summarized in this dissertation provide quantitative information for improving the rainfall frequency analysis for a future provision of maps of design rainfall for different return periods at the national scale, with potential impacts also in the flood risk assessment and reduction field.