A regional model for estimating the design storm in Northern-Central Italy

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ABSTRACT

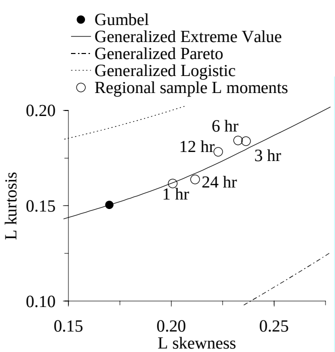
Several hydrological analyses need to be founded on the design storm, which is the expected rainfall depth corresponding to a given duration and probability of occurrence, usually expressed in terms of return period. The annual series of precipitation maxima for storm durations ranging from 15 minutes to 1 day are obtained for a dense network of raingages sited in Northern-Central Italy and are statistically analyzed using an approach based on L-moments. The study investigates the statistical properties of rainfall extremes and identifies important relations between these statistics and the mean annual precipitation (MAP) [e.g. Alila, JGR, 1999]. The study develops a regional model for estimating the rainfall depth for a given storm duration and recurrence interval in any location of the study region. The reliability of the regional model is assessed through Monte Carlo simulations. The results of the study point out that the design storms estimated by the proposed approach are significantly accurate.

Statistical Analysis

The regional model is founded on the generalized extreme value (GEV) distribution.

The parameters are estimated through the L moments method (Hosking, 1990).

The diagram of L moment ratios (Hosking and Wallis, 1993) shows that the theoretical relationship between L skewness and L kurtosis for the GEV distribution is very close to the regional L skewness and L kurtosis values for the storm durations of interest.



The GEV distribution is written as:

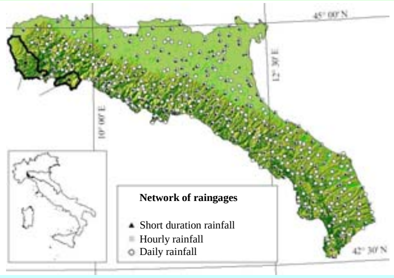
$$F_X(x) = \exp\left\{-\left[1-\frac{k(x-\xi)}{\alpha}\right]^{1/k}\right\} \quad \text{and} \quad (1)$$

$$F_X(x) = \exp\left\{-\exp\left[-\frac{(x-\xi)}{\alpha}\right]\right\} \quad \text{for } k=0 \quad (2)$$

where α, ξ, and k are the distribution parameters. When $k = 0$ the GEV distribution is equal to the Gumbel distribution.

Study Area

The study region includes the administrative regions of Emilia-Romagna and Marche, in northern central Italy. The area is bounded by the Po River to the north, the Adriatic Sea to the east, and the divide of the Apennines to the southwest. The northeastern portion of the study area is pre-dominantly flat, while the southwestern and coastal parts are mainly hilly and mountainous.

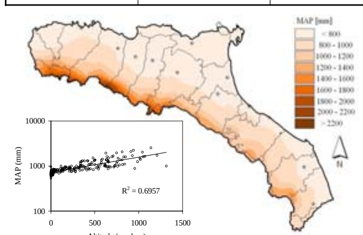


The available extreme rainfall data consists of annual series of precipitation maxima with duration from 15 minutes to 1 day that were obtained for a rather dense network of recording raingages from the National Hydrographic Service of Italy.

The mean annual precipitation (MAP) varies on the study region from about 500 to 2500 mm. Altitude is the factor that most affects the MAP, which exceeds 1500 mm starting from altitudes higher than 400 m above sea level and exhibits the highest values along the divide of the Apennines

ANNUAL MAXIMUM RAINFALL DATA

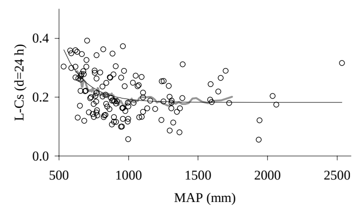
duration	*Number of stations*	*Number of data*
daily	394	20557
hourly	125	5945
30 min	186	3430
15 min	152	1810

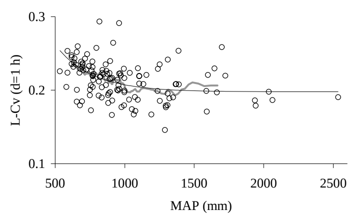


Local Regime of Rainfall Extremes

Several regional frequency analyses of rainfall extremes were performed over the study area. These studies proposed subdivisions of the region into homogeneous climatic regions, within which the statistics of rainfall extremes for a given duration are assumed to be constant (Brath and Castellarin, 2001). This assumption contrasts with the findings of other studies, which demonstrated that the statistics of rainfall extremes vary systematically with location (Schaefer, 1990; Alila, 1999). These studies also identified statistically significant relationships between these statistics and the MAP, which was used as a surrogate of geographical location. Schaefer (1990) and Alila (1999) showed that the coefficients of variation and skewness of rainfall extremes tend to decrease as the local value of MAP increases.

The figures below show 2 examples of this relation in our study based on L-moments (L-Cv and L-Cs).





Regional Model

The study identified statistically significant relationships between the MAP and the L statistical properties of rainfall extremes. The above relation is described by:

$$L\text{-}Cx(MAP) = a + (b-a)\cdot\exp(-c\cdot MAP) \quad (3)$$

where the value of a, b and c are in the below table 1 (L-Cv) and table 2 (L-Cs).

TABLE 1

duration	*a*	*b*	*c*
15 min ≤ d ≤1 h	0.1999	0.1999	0
3 h ≤ d ≤ 6 h	0.2318	0.2318	0
12 h ≤ d ≤ 24 h, d=1 day	0.1824	4.7240	0.0061

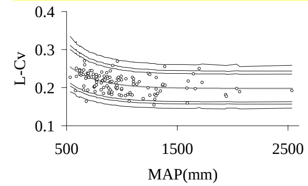
TABLE 2

duration	*a*	*b*	*c*
15 min	0.1539	0.1539	0
30 min	0.1893	0.1893	0
1 h	0.1978	0.6255	0.0038
3 h	0.1856	0.8352	0.0042
6 h	0.1741	0.8436	0.0042
12 h ≤ d ≤ 24 h, d=1 dAY	0.1706	0.7694	0.0040

The model reliability was assessed through Monte Carlo simulations developed in the following steps:

- For any station and for each duration, the *L-Cv* and the *L-Cs* were calculated using the MAP value trough the model (3).
- Whit these L-statistical properties we identified the GEV probabilistic model, used to generate synthetic series of the same historical series length.
- For these synthetic series the L-Cv and the L-Cs were calculated.

We repeated these steps 10000 time, obtaining 10000 L-moment values finally used to derivate the confidence intervals to test the model. The figure below shows, for the L-Cv of duration d=1 hour, 90%, 95% and 99% confidence intervals.



Results of Montecarlo test: percentage of L-moments values out of confidence interval

Confidence intervals	*L-Cs*	*L-Cv*
90%	8.2%	9.8%
95%	4.2%	4.8%
99%	0.5%	1.1%

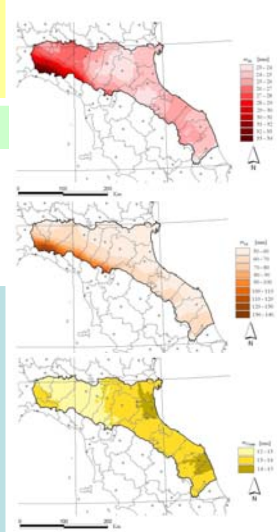
The paper propose a new hierarchical regional model for estimating design storms at any site in study area. For each storm duration the approach consists of the following steps:

1. Compute the mean annual precipitation (MAP) using the observed records.
2. Compute the value of the L-Cs from the relationship (3) and the a, b, c value in table 1
3. Compute the value of the L-Cv from the relationship (3) and the a, b, c value in table 2
4. Compute the parameters of the GEV distribution using the estimated regional L-Cs and L-Cv
5. Compute the mean annual rainfall maxima (m_d) using observed records.
6. Compute the design storms for required return periods using the quantile function of the GEV distribution

Kriging interpolation

When it is not possible to calculate the mean annual precipitation (MAP) or the mean of annual rainfall maxima (m_d) using observed records we can use the kriging interpolation.

The figures show some kriging interpolation examples. The reliability of the kriging is assessed through Jack-knife procedure.



References

Alila Y., A hierarchical approach for the regionalization of precipitation annual maxima in Canada, Journal of Geophysical Research, Vol. 104, 31645-31655, 1999.

Brath A., Castellarin A., Montanari A., Assessing the reliability of regional depth-duration-frequency equations for gaged and ungaged sites, Water Resour. Res., Vol. 39(12), 1367-1379, 2003.

Burn D.H. Evaluation of regional flood frequency analysis with a region of influence approach, Wat. Resour. Res., Vol. 26(10), 2257-2265, 1990.

Castellarin A., Brath A., Tecniche di perfezionamento delle stime regionali del rischio pluviometrico, Atti del XXVIII Convegno di Idraulica e Costruzioni Idrauliche, Potenza 16-19 settembre 2002, Vol. I, 225-236, Ed. BIOS, Cosenza, 2002.

Hosking J.R.M., Wallis J.R., Some statistics useful in regional frequency analysis, Water Resour. Res., Vol. 29(2), 271-281, 1993.

Schaefer M.G., Regional analyses of precipitation annual maxima in Washington State, Water Resour. Res., Vol. 26(1), 119-131, 1990.