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Statistical characterization of rainfall climate along the future high-speed rail track in Portugal.

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Abstract

The regionalized characterization of rainfall extremes is an important step for the evaluation of the hydrologic risk exposure of geographically extended systems. Our specific focus is the region interested by the newly proposed high-speed rail system in Portugal. Rainfall can induce major accidents, for example through the activation of landslides, and affects operations by causing slowdowns and delays. We present an exploratory analysis of a vast array of point rainfall data, distributed over an area of approximately 30 km by 460 km around the high-speed rail line. Key rainfall statistics are investigated to characterize the spatial variability of the rainfall climate in the region.

Objectives

A key step in hydrologic risk assessment is the evaluation of the Intensity Duration Frequency (IDF) Curves. In a regionalized approach, at-site IDF estimates can be improved by pooling information from nearby stations with similar hydroclimatic characteristics. Regionalization is clearly necessary for IDF estimation at non-instrumented sites. The classical approach to regional rainfall frequency analysis involves three steps: the identification of the form of the annual-maximum distribution, the delineation of "homogenous regions" where one or more characteristics of the rainfall process (for example the kurtosis or the skewness of the annual maximum distribution) are considered constant, and the estimation of the distribution parameters. An alternative approach to regionalization is to recognize that precipitation statistics are influenced by factors such as proximity to the sea, altitude, slope and other physiographic characteristics. These influences are then captured by using regression models. In the area analysed here there is a general lack of long high-resolution rainfall series [except for 4 long datasets, the average at-site record duration is around 5yr]. This makes it impossible the use standard methodologies based on annual maxima series. Rather, we use newly developed methods based on marginal distributions [1].

Acknowledgements

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The long series data (Porto S. Pilar, Coimbra Geofisico, Lisboa Geofisico and Evora) were made available by M.F.E.S. Coelho – Institute of Meteorology, Lisbon.

References

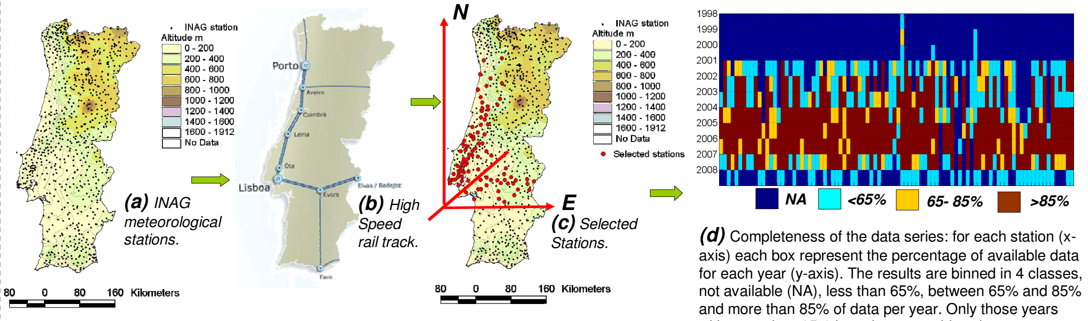
[1] Veneziano, D., C. Lepore, A. Langousis, and P. Furcolo (2007), Marginal methods of intensity-duration-frequency estimation in scaling and nonscaling rainfall, *Water Resour. Res.*, **43**, W10418

Database

The database in the area interested by the high-speed rail (**Fig. 1b**) comprises:

- 92 short-duration records from the INAG website (www.snirh.pt)
- 4 long records (Porto, Coimbra, Lisbon, Evora) from the Institute of Meteorology, Lisbon

Of the 92 short-duration records, see red dots in **Fig. 1c** and completeness chart in **Fig. 1d**, 74 have been used after excluding stations with less than 3 yrs of data. Given the particular "L-shape" of the corridor, some analyses are performed using as *geographical location* the distance in km from an arbitrary point, diagonal line in **Fig. 1c**, which divides the stations along the coast (N direction) from those orthogonal to the coast (E direction), **Fig 1c**.



(*d*) Completeness of the data series: for each station (x-axis) each box represent the percentage of available data for each year (y-axis). The results are binned in 4 classes, not available (NA), less than 65%, between 65% and 85% and more than 85% of data per year. Only those years with more than 65% have been considered.

Fig 1: available dataset

Characteristics of rainfall climate

First we examine the spatial variation of three rainfall characteristics:

- The Mean Annual Precipitation, MAP
- The Mean positive intensity, $I^+(d)$
- The Rainy fraction, P_1

These variables are contour-plotted in **Figs. 2-4**.

To understand the factors that control the local rainfall climate and identify possible regression models for the area, we have analyzed dependence of the variables on geographical location and orientation (N and E direction – as described in ***Database***), distance from the ocean, and elevation. Here we show results only for the geographical location as it gives a clearer description of the spatial variability of the values; the local estimates are smoothed through a simple weighted moving average shown as the red solid line (boxes below in **Figs. 2-4**);.

There is a clear spatial gradient in the rainfall climate:

- The northern part is the wettest, with MAP up to 1200 mm,, whereas in the south-eastern part it goes down to 400 mm;
- The mean positive intensity for duration d = 1hr is high in both the north and the south-east. However the same is not evident for d = 24hr, suggesting a dominance in the inland area of sub-diurnal storms that, when averaged to 24 hr, no longer produce high intensity values. In the north, the mean positive intensity is high for both durations.
- The rainy fraction, with very high values in the north and much lower values in the south-east, are consistent with previous observations.

MAP

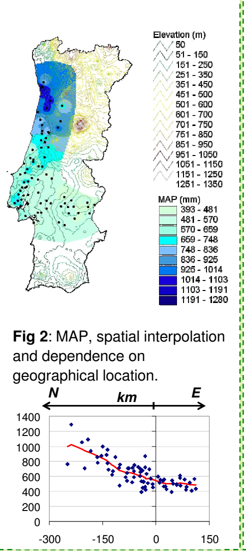


Fig 2: MAP, spatial interpolation and dependence on geographical location.

Mean Positive Intensities

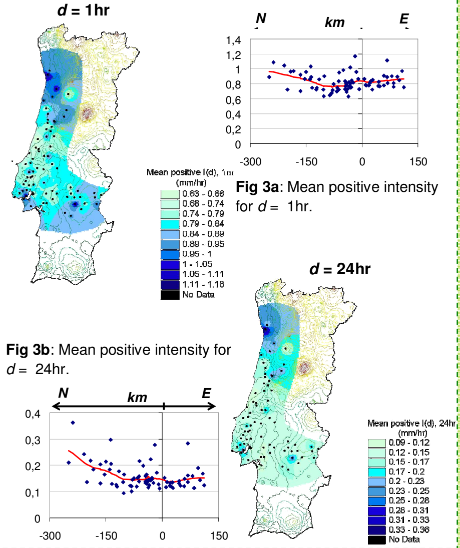


Fig 3a: Mean positive intensity for d = 1hr.

Fig 3b: Mean positive intensity for d = 24hr.

Rainy Fraction

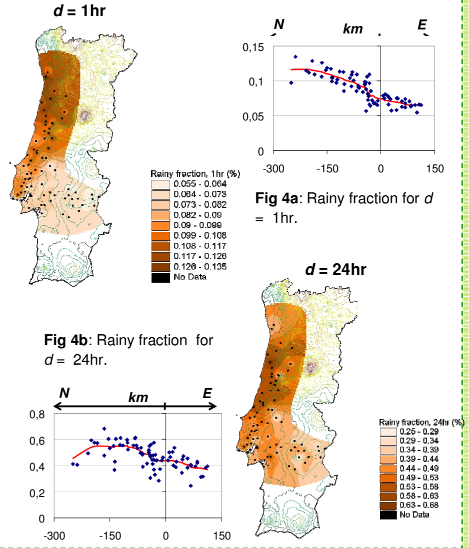


Fig 4a: Rainy fraction for d = 1hr.

Fig 4b: Rainy fraction for d = 24hr.

Preliminary analysis on rainfall extremes

To estimate IDF values using also the short-duration records, we use the marginal distribution method of [1]. The marginal distribution of rainfall intensity in an interval of duration d, $I(d)$, is assumed to have a probability mass P_0 at zero and positive lognormal distribution with log-mean μ and log-standard-deviation σ. Following [1], we fit the three parameters of this distribution to reproduce the first three empirical moments (the moments of order 1, 2 and 3).

$$F_{I_d}(i) = P_0 + (1-P_0)\cdot N\left(\frac{\ln i-\mu}{\sigma}\right) \longrightarrow F_{I_{max}(d)}(i) = F_{I_d}(i)^{1/d} \qquad (1)$$

Figs. 5-8 show how the marginal distribution parameters $\{P_0, \mu, \sigma\}$ vary with geographic location (N-E in **Fig. 1c**). The local estimates are then smoothed through a simple weighted moving average and shown by the superimposed red line. when the smoothed parameters are used to infer annual-maximum values, for two return periods T = 10 and 25 years, the results obtained are those shown as continuous line in **Fig. 8**.

The inferred parameters show in **Figs. 5 & 6** similar pattern to the empirical ones; the latter (**Fig 3 & 4**) and the fitted parameters are not directly comparable though, as the fitted ones represent a LN distribution which best fits only the upper tail of the process ignoring the lower intensity values which is instead included in the estimation of the empirical parameters.

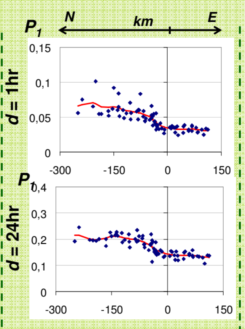


Fig 5: Rainy fraction, $1 - P_0$.

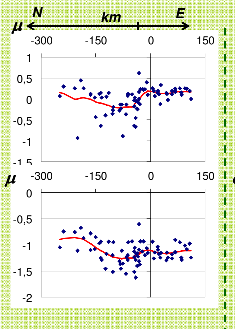


Fig 6: μ , mean of the log of the intensities.

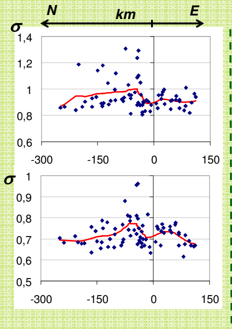


Fig 7: σ, standard deviation of the log of the intensities.

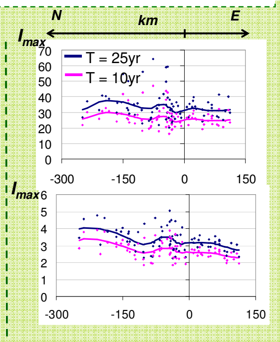


Fig 8: I_{max} values for T = 10, 25yr. The smoothed lines are obtained using smoothed parameters, Fig. 5- 7.

These are just preliminary results. A continuation of the study will include physiographic effects and the generation of rainfall-extreme maps for different durations and return periods. Comparisons with alternative IDF curve estimation methods will also be made.