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THE INTENSITY OF RAINFALL IN MEDITERRANEAN ENVIRONMENTS. EXTREME VALUES ACCORDING TO THE SCALE OF OBSERVATION

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I. INTRODUCTION

Mediterranean environments are dominated by episodes of torrential rain, whereby the critical parameter is not so much the amount of rain these episodes accumulate, but rather the intensity they can reach. The heavy intensities that extreme events can achieve are critical in the dynamics of soil erosion; those related to triggering of debris-flow and above all in hydrology, as they affect rainfall-runoff conversion processes, runoff and coefficient thresholds and flash floods generation.

Despite the importance of the rainfall intensity parameter, it is not easy to identify reference thresholds because the structure of rainfall differs according to the timescale used for observation. Moreover, even though the intensity analysis should start from observation time intervals on a minute scale, in most Mediterranean countries rainfall data is normally daily recorded. In this paper, we undertook an empirical study of maximum rainfall intensities at different observation timescales, ranging from 5 minutes to 24 hours, over a large area on the Mediterranean side of the Iberian Peninsula (River Júcar Water Authority, 43,000 km^2) during a period of 14 years (1994-2007).

On one hand, this paper analyses the rain structure for each timescale and on the other, it studies the effect of specific geographical factors – altitude and distance to the sea – for each observation interval. The study also looks into the effect of general exposure based on two criteria: the coastal-inland dichotomy and the compartmentalisation of the territory according to its large relief structure.

Preliminary studies showed that the behaviour of extreme Mediterranean rainfall is heavily dependent on the observation timescale. However, new questions need to be answered: what are the most representative observation scales?, what is the structure of the extreme values for intensity at different observation timescales?, which geographical factors condition the extreme values?, does the role these factors play differ from one observation scale to another.

II. METHOD

In order to find the preliminary behaviour of rainfall intensity for each observation timescale, the rainfall data, originally recorded every 5 minutes, was filtered and rescaled using moving averages for intervals of 15 minutes, 30 minutes, 1 hour, 2 hours, 3 hours, 4 hours, 6 hours, 12 hours and 24 hours. The maximum intensity values were calculated in mm/h for each rain gauge at each time interval. Then, the average of the maximums (to acquire a solid measure of maximum values) and the absolute maximums (to find the extremes reached) were obtained. The trend curves obtained for both, absolute maximum values and the average maximum intensities, show r^2 determination coefficient adjustments greater than 0.9, which means that rainfall data is heavily dependent on the observation interval.

To test the feasibility of this hypothesis, maximum intensity spatial distribution analyses were carried out for selected time intervals and were subsequently contrasted using mean comparison tests (Kolmogorov-Smirnov test for normal distributions and Wilcoxon for no normal distributions). Finally, the analysis of the spatial distribution of intensities was tackled by mapping the intensity values, grouped by quartiles for each observation interval.

With respect to the relationship between the maximum intensities for different observation intervals and geographical factors, a multivariate analysis was carried out, which consisted of a multiple regression analysis between maximum intensities and the independent variables – altitude and distance to the sea – and on the other hand, a cluster analysis of these variables. We are aware of just how important it is to study the atmospheric conditions to analyse torrential rainfall events. In this paper, however, we focused our analysis on the influence of the geographical factors – topography and distance to the sea – as we are not working on specific episodes, but on the maximum intensities recorded in each time interval, regardless of the event that they belong to. These geographical factors have a permanent influence on rainfall processes. In some cases they would only act as modifiers and in others cases (especially for short time scale intervales, bellow than 1 hour) as trigger.

The aim of the multiple regression analysis was not to build a rain prediction model, but rather to explore which variables were most significant and what type of relationship best fitted the rainfall intensity for each time interval. The objective of the cluster analysis was to detect whether there were different rainfall behaviour patterns with regard to these geographical factors at these time intervals.

The relationship between geographical factors and maximum intensities, which can be applied in general terms to the entire study area, may be tempered by the configuration of the territory. In order to verify whether the overall exposure of the territory affected the relationship between geographical factors and maximum intensities, we proceeded to divide the study into different scenarios according two criteria: a) the coastal-inland dichotomy, and b) the direction of large relief structures.

In the first case, two scenarios were identified: 1) coastal zones and 2) inland zones. In the second case, four scenarios were identified: 1) zones that follow the NW-SE direction of the Iberian mountains, 2) zones that make up the continental plateau and the coastal plain of the easterly mid-lower valley of the River Júcar; 3) the zone that follows the direction of the Betic mountains which is exposed to NE winds and 4) the zone that follows the directiont of the Betic mountains which is exposed to SE winds. A multiple regression analysis was carried out for each of these exposure areas between the maximum intensities for each observation timescale and the independent variables (distance to the sea and altitude).

III. RESULTS

In response to the questions about the most representative observation timescales and their structure, the answers are 5 minutes, 1 hour, 6 hours, and 24 hours. The results obtained in this work show how a reduction in the observation interval increases the values for intensity. In this general trend there are two important turning points at 1 hour and 6 hours. The maximum intensities between 5 minutes and 1 hour show normal, symmetrical and mesokurtic distributions, while between 6 hours and 24 hours distributions are not normal, and show leptokurtic and positive asymmetry.

This could be related to the structure of rainfall intensity fields described by Waymire and Gupta (1981) and Waymire et al. (1984). According to this model, the characteristics shown by the distributions of the maximum intensities recorded from 5 minutes to 1 hour mainly reflect the action of powerful convective cells, which precipitate large amounts of water in a very short period of time and over a very small area. In this sense, the behaviour of the cells is quite similar and thus the distributions are normal and about average. From 6 hours onwards, the behaviour is mixed, and therefore a more differentiated, asymmetric intensity distribution appears which collects rainfall within the *large mesoscale precipitation areas* (LMSA) and *Synoptic Areas*, as well as some less intense convective cells. The intensities recorded in the intermediate timescale, between 1 hour and 6 hours, respond to the so-called s*mall mesoscale precipitation areas* (SMSA).

These spatial rainfall structures, and particularly the convective cells, are affected by the distance to the sea and the relief. On one hand, proximity to the sea implies the availability of a continuous supply of humidity and, on the other, the increase in elevation provokes a «mechanical trigger» forcing the unstable air masses upwards and favouring precipitation. Different behaviour patterns are also reflected in the type of influence these geographical factors have on maximum intensities according to the observation timescale. Thus, in general, distance to the sea is significant for all observation timescales (except for 5 minutes which is subject to very local factors), although it begins to be important as an explanatory factor after 6 hours, in that its proximity to the source of the air humidity supply is essential to achieve maximum intensities, especially for a duration of 24 hours. Altitude, in turn, is only significant between 30 minutes and 6 hours, because the mechanical effect exerted by the relief promotes condensation as a result of a decrease in air temperature, but does not increase the partial pressure of water vapour.

The type of relationship established between the variables, which is linear for intervals between 5 minutes and 1 hour and semi-logarithmic from 6 hours onwards, is also important. This could be related to the complexity of precipitation processes. Up to 1 hour, the effect of geographical factors is much more direct, because it acts primarily on very unstable convective cells that normally come in from the sea, while after six hours altitude is no longer significant and distance to the sea and the characteristics of the rain fields at larger scales (SMSA, LMSA and synoptic areas) gain in importance, thus adding complexity to precipitation processes.

A consequence of this is the result of the cluster analysis which shows two distinct patterns of rainfall intensity which affects all observation timescales. The first pattern, which is linked to the orographic trigger effect exerted by the first mountain ranges close to the sea, relates maximum intensities to altitude ranges between 200 and 400 metres and proximity to the sea (20-30 km). The second pattern associates less intense rainfall at higher altitudes (900-1000 metres) and distances to the sea (90-100 km) with widespread rainfall (LMSA and synoptic areas). Furthermore, between 5-minute and 1-hour time intervals the orographic trigger fronts of the maximum intensities are below 200 metres, while from 1 hour onwards, they are located between 200 and 400 metres.

As regards the effect that different exposures of the territory have over the influence of geographical factors on maximum intensities, we worked on a criterion that distinguished between coastal-inland exposure scenarios, and on another criterion that differentiated configuration scenarios of the territory according to large relief structures. The analyses conducted in the two established scenarios according to the first criterion (coastal-inland) did not add information to the general analysis. The second criterion, however, presents four scenarios (Iberian mountain range – NW-SE direction; mid-lower valley of the River Júcar – E direction, Betic mountains – NE exposure, and Betic mountains – SE exposure), some of which represent a significant increase in the r^2 determination coefficient of the geographical variables as an explanatory factor of the maximum intensities. In this sense, the easterly exposure scenarios (mid-lower valley of the River Júcar – E exposure and the Betic mountains – NE exposure), in which the distance to the sea is crucial, stand out and especially for time intervals over 6 hours which account for over 70% of cases. The altitude variable is only significant (although with a very low r^2, around 0.3) in the Iberian mountain range (NW-SE) scenario from 30 minutes to 1 hour.

These findings reinforce the aforementioned idea of the importance of the proximity of the sea as a source of moisture to maintain maximum intensities in periods over 6 hours and the effect of altitude on intervals of less than 6 hours. For the exposure scenario associated with the Betic mountains – SE exposure, no variable is significant at any timescale. This confirms the importance of windward or leeward exposure of the territory to the prevailing humid winds from the northeast when generating maximum intensities, especially in longer time intervals of around 24 hours.

We are aware that this paper is only an initial approach to the behaviour of rain according to different observation timescales and that more detailed studies are needed to differentiate between maximum intensities according to the type of weather situation that has caused them. However, we believe that the interest of this paper lies in its empirical character as it has used real data which has recorded maximum intensities at different observation intervals in a geographically diverse and heterogeneous environment and under Mediterranean climate conditions.