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The effect of observation timescales on the characterisation of extreme Mediterranean precipitation

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Abstract. This paper analyses the behaviour of five rainfall indicators (maximum intensity, cumulative rainfall, irregularity, probability of rain and persistence of rain) over different observation timescales ranging from 5 min to 24 h. It covers a large area on the Mediterranean side of the Iberian Peninsula (River Júcar Water Authority, 43 000 km^2) on a continuous basis over a period of 14 years (1994–2007). The results show that the behaviour of extreme Mediterranean rainfall is heavily dependent on the observation timescale. There are a number of turning points in the indicator trends which occur on different timescales (1 and 6 h in the case of rain intensity and irregularity, 6 h for cumulative rainfall and between 15 and 30 min for the persistence of rain) and may be relevant for the determination of thresholds used in water management.

1 Introduction

Mediterranean storms are characterised by high values for rainfall intensity and great irregularity in their space-time distribution (Romero et al, 1999; Llasat, 2001; Peñarrocha et al., 2002; Beguería et al., 2009). In the Spanish Mediterranean region, storms frequently exceed 100 mm/h at their greatest intensity, and can on occasion reach intensities of more than 375 mm/h (Camarasa, 1994). Average annual rainfall has often been doubled or even tripled in a single storm (Gil Olcina, 1989). These magnitudes are critical in hydrology as they affect rainfall-runoff conversion processes due to their impact on initial soil infiltration capacity and runoff and coefficients thresholds (Yair and Lavee, 1985; Camarasa and Segura, 2001; Cammeraat, 2004), thus making flash floods more likely. Furthermore, there are large numbers of ephemeral streams in Mediterranean environments where runoff production is highly dependent on rainfall (Bull et al., 1999; Camarasa and Tilford, 2002; Kokknen et al., 2004; Cudennec et. al, 2007).

It is well known that the structure of rainfall differs according to the timescale used for observation (Waymire and Gupta, 1981; Valdés et al., 1985; Jebari et al., 2007; Dunkerley, 2008) so that a reduction in the observation interval increases the values for intensity and irregularity. Nonetheless, it is by no means clear what the most appropriate time interval for measuring rainfall intensity is. In terms of resource and risk management, it is imperative to have an observation scale that is appropriate both for the type of phenomenon being dealt with and also for the specific objectives concerned. Thus, further studies are required to describe the behaviour of maximum rainfall intensities in different observation intervals.

This paper analyses the behaviour of five rainfall indicators (maximum intensity, cumulative rainfall, irregularity, probability of rain and persistence of rain) over different observation periods ranging from 5 min to 24 h. The study was carried out using a database covering fourteen years (1994–2007) in a large area on the Mediterranean side of the Iberian Peninsula.

2 Study area and data

The study area (Fig. 1) covers the geographical territory of the River Júcar Water Authority (43,000 km^2) in Spain. It is a geographical area of contrasts - it has a topographic height difference of more than 2000 m, is open to the Mediterranean Sea and is exposed to humid winds from the east, which are responsible for the most intense rain events.

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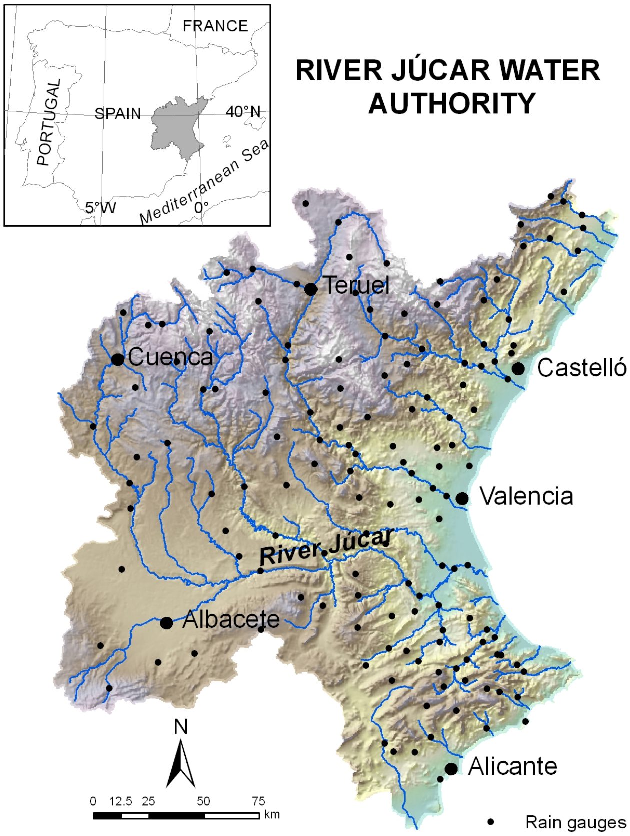

Fig. 1. Study area.

Rainfall data was collected by the SAIH network (Automatic Hydrological Information System) every five minutes from 147 rain gauges. The study period covers fourteen uninterrupted years (1994–2007).

3 Methodology

The rainfall data, originally recorded every 5 min, was filtered and rescaled using moving averages to intervals of fifteen minutes, thirty minutes, one hour, two hours, three hours, four hours, six hours, twelve hours and twenty-four hours.

The following indicators were calculated for each rain gauge and each time interval:

a) Maximum intensity in mm/h.

b) Cumulative rainfall in mm

c) Irregularity. The irregularity estimation was based on the Concentration Index of Precipitation calculation put forward by Martín-Vide (2004) using the Gini Coefficient. Using this methodology, the statistical structure of rainfall intensity can be analysed using concentration curves that relate the cumulative rainfall percentages with the cumulative interval percentages in which the rainfall occurred. The Concentration Index ranges from 0 (minimum irregularity) to 1 (maximum irregularity) and enables data from different observatories for different observation timescales to be compared.

d) Probability of rain. The probability that a rain interval will occur.

e) Persistence of rain. The probability that it will rain in two consecutive observation intervals, in other words the probability of rain after it has rained.

Next, the maximum values of each indicator were selected for each observation interval from each rain gauge. Based on these values, the average of the maximums for each indicator by interval (in order to have a solid measure of maximum values) and absolute maximums (to find out the extremes reached) were obtained. Based on the values obtained in the various observation intervals, trend curves were then estimated which make it possible to analyse each indicator's behaviour model as per these time intervals.

4 Results and conclusions

Figure 2 shows the trend curves obtained for each statistic in terms of both absolute maximum values and the average of the maximums. In all cases the adjustments show r^2 determination coefficients greater than 0.9, which means that data is heavily dependent on the observation interval.

The maximum intensity indicator shows a downward potential trend. Two critical observation interval have been identified at 1 and 6 h. Thus, for observation scales from 5 min to 1 h very high absolute maximums have been recorded (274 mm/h and 101 mm/h respectively); for observation scales of 6 h, an absolute maximum of 56 mm/h was registered; and finally, lower maximums have been recorded for higher observation scales with 19 mm/h at 24 h.

The cumulative rainfall indicator has an upward logarithmic trend with a single turning point at 6 h, which makes it possible to differentiate between two behaviour patterns: a) one from 5 min (with a maximum of 22 mm) to 6 h (with a maximum of 337.6 mm/h), and another, b), from 6 h to 24 h with a maximum of 461 mm.

The irregularity index follows a downward potential trend, with a pattern similar to rainfall intensity. Its highest irregularity values are between 5 min (0.5) and one hour (0.3) followed by a second section between 1 h and 6 h (0.15). After 6 h the rain becomes much more regular, reaching a value of 0.05 at 24 h.

The probability of rain indicator follows an upward potential trend and has no significant turning points.

As for the persistence of rain, it presents a downward potential trend. The behaviour of this indicator can be better tracked using the "average of the maximums" variable, where it can be seen that the time intervals which have a higher persistence of rain are 15 and 30 min, in relation to the average duration of convective cells, and can become

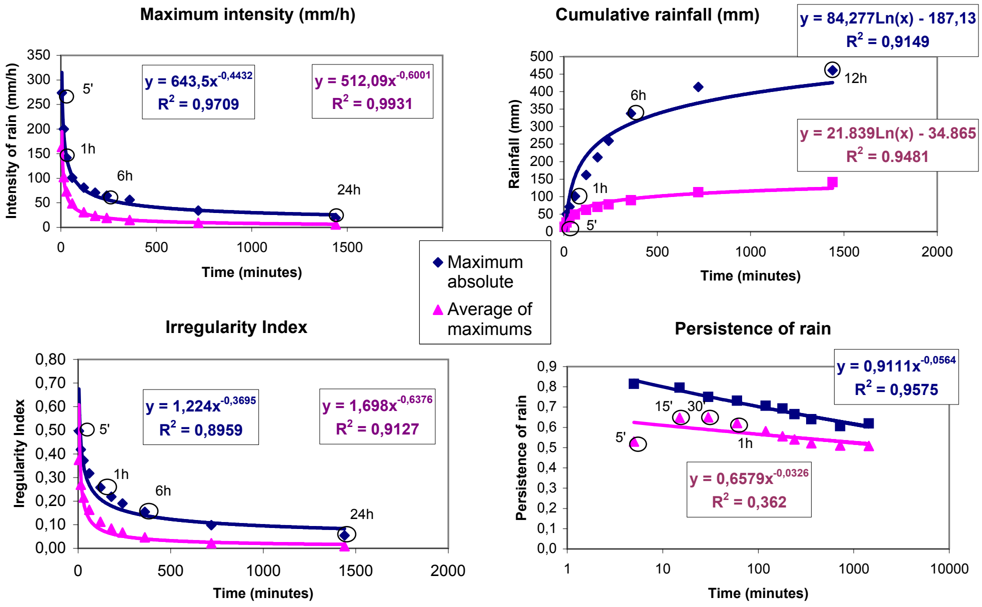

Fig. 2. Rainfall indicators of Maximum Intensity, Cumulative Rainfall, Irregularity and Persistence of Rain.

prolonged up to 1 h. After three hours, the persistence of rain values decrease by less than expected.

This paper has made it possible to confirm the strong dependence of rainfall data on the measurement interval and to develop empirical trend curves for the 5 parameters studied using the data recorded at 147 automatic rain gauges that record data every 5 min. The curves obtained are widely applicable as they present both the absolute maximum values and the average values recorded during the series of years available and can be used as a reference for the determination of rainfall thresholds applied to water management tasks. However, because of the extension and variability of the study area, rainfall characteristics varies also spatially. Therefore it would be convenient to define homogeneous areas from the point of view of rainfall behaviour and to calculate specific curves for every of them.

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