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ORIGINAL PAPER

Influence of regional and seasonal rainfall patterns on the ratio between fixed and unrestricted measured intervals of rainfall amounts

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Abstract

Historically, most precipitation data have been measured by collecting rainfall, usually at intervals of 24 h, with a fixed starting time. Nonetheless, it is known that the use of fixed time intervals to measure rainfall quantities could lead to an underestimation of the true maximum precipitation amounts for the considered duration, so a single multiplicative correction factor is commonly applied, generally without taking into account the rainfall pattern of the place, nor regional or seasonal considerations. In the present work, hourly measurements from 120 stations of Catalonia (northeast of the Iberian Peninsula) have been used to analyse how the ratio between rainfall amounts measured by fixed and unrestricted intervals, i.e. the correction factor, depends on the considered duration and on the specific starting time of the fixed interval (local 00:00, 08:00, 12:00 or 16:00), as well as the influence of geographical location and seasonality and actual rainfall duration. For fixed sampling intervals starting at 16:00, the mean correction factor has been found to be higher (1.137) than at the usual 08:00 starting time (1.129). Some geographical patterns of the correction factor over Catalonia arose which, moreover, depend on the season, with a mean value of 1.161 in spring and a value of 1.093 in summer. Also, the value of the correction has been found to increase with the actual duration of the maximum rainfall events used in the analysis. Some of these extreme events had actual mesoscale durations between 6 and 9 h, linked to highly convective mesoscale organisations acting mainly in summer and the beginning of autumn. Other maxima episodes, with more advective rainfall lasting more than 12 h registered in the northern area of the territory, presented the highest values of the correction factor, especially in spring.

Keywords Correction factor · True-interval rainfall · Fixed-interval rainfall · Maximum rainfall · Rainfall pattern · Catalonia

1 Introduction

In maximum rainfall studies, systematically recorded data of accumulated precipitation is commonly used, typically over a 24-h period. However, daily measurements are usually taken using a fixed starting point (e.g. local 08:00) as a beginning of the daily period and this is known to condition the measurement of true maxima values (Hershfield 1961). In order to correct the maximum precipitation obtained from measurements taken at fixed times as if it had been obtained from a sliding window of the considered duration, it is recommended to carry out a correction which is usually applied through a multiplicative factor. One of the first studies to deal with this topic was performed by Hershfield (1961) using data from the USA, proposing an empirical factor of 1.13 to correct fixed maxima obtained from daily measurements as if a sliding 1440-min window had been used, as well as correcting fixed

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hourly measurements as if a sliding 60-min window had been used. This correction factor was also derived theoretically by Weiss (1964), who proposed a model based on simple assumptions which yielded different correction values depending on the sampling discretisation. Later studies were, among others, performed by Huff and Angel (1992), who applied an empirical factor to develop a rainfall frequency atlas for the Midwest of the USA; Dwyer and Reed (1995), who studied rainfall records from the UK and Australia at a sampling resolution of 1 h to determine empirical correction factors ranging from 1.15 to 1.17; Van Montfort (1997), who used monthly maxima of daily rainfall from a Chinese dataset and found a dependence with location, autocorrelation and the fraction of wet days; Asquith (1998), who determined an empirical value of 1.13 for the state of Texas; and Young and McEnroe (2003), who used high-temporal resolution automatic rain gauges to derive the empirical correction factor for Kansas city. An extensive overview of the matter was presented by Papalexiou et al. (2016) in their analysis of the behaviour of the correction factor at different time scales using hourly records from 7127 automatic gauges across the USA, shedding light on the probabilistic characteristics of fixed and sliding maxima. Other recent studies were carried out by Yoo et al. (2015), investigating how significantly rainfall temporal distribution affects the correction factor value, and Morbidelli et al. (2017, 2018), who studied the error involved in the estimation of annual maxima due to the use of a coarse temporal aggregation.

As commented by Yoo et al. (2015), it is not clear whether some rainfall characteristics such as temporal distribution and duration, or regional and seasonal features, affect the value of the correction factor. Thus, the objective of the present study is to analyse the possible dependence of the ratio between sliding maxima and fixed-interval maxima on the characteristic rainfall pattern of the specific location being studied. Several factors which might influence the value of this ratio have been considered:

- The ratio could be influenced by the starting time of the fixed interval. Some maxima can be caused by events centred on a time of day that is conditioned by the effect of the diurnal cycle, in the case of rainfall arising from land heating. In the region of study, the diurnal cycle especially affects summer storms, which appear mainly in the afternoon. If rainfall episodes occur with this kind of influence, the correction needed would depend on the time at which daily measurements were taken.
- Season is another condition that generates different rainfall patterns; therefore, its influence on the correction factor has been studied. The climatological definition of season has been considered, with spring comprising the months from March to May, summer June to August, autumn September to November and winter December to February.
- The possible influence of geographical location on the value of the ratio has been analysed by performing a spatial distribution of the empirical factors over the studied territory.
- The dependence of the ratio on the actual duration of the rainfall events and, thus, on the physics behind rainfall generation has been also explored.

2 Data and methods

The present study has been carried out on Catalonia (Spain), a region in the northeast of the Iberian Peninsula (Fig. 1), using a selection of 120 automatic weather stations (AWS) from the network managed by the Meteorological Service of Catalonia (SMC). Almost all the rain gauges of this selection are tipping-bucket type with a resolution of 0.1 mm, manufactured by the German companies Lambrecht and Thies. The few exceptions are four totalizer gauges located at high altitudes, over 1500 m, where snow is recurrent. These gauges accumulate rain or snow and weight it every 30 min, using special liquids to avoid freezing and evaporation, and incorporate a shield to reduce the effect of wind on the measurement of precipitation in the form of snow. In places where snowfall is only sporadic, rain gauges have electrical resistances to heat and melt snow in an optimal way. All gauges have a catchment area of 200 cm^2, which is the standard of the World Meteorological Organization.

Measured data at any temporal resolution, and in particular hourly data used in the present study, are subject to quality controls (Llabrés-Brustenga et al. 2019), which consist of several semiautomatic verification processes, always under the supervision of technical personnel. Every day, the reliability of generated data is verified according to consistency with other weather variables, nearby observations and estimated precipitation from the radar network. In case erroneous precipitation values are detected, either by excess, by absence, by default or by incoherent temporal distribution, they are initially invalidated. Subsequently, missing and suspect data is reconstructed when possible, using all the available information. Wind corrections in the case of snow are taken into consideration during the quality control and posterior reconstruction.

The temporal period of study ranges from 1988 to 2016 and the selected hourly series have a minimum of 15 years of data, the average length being 19.6 years. In Fig. 1, the selected stations are displayed according to their series length.

Empirical correction factors have been obtained from the ratio of rainfall amounts measured at unrestricted against fixed intervals in the following way:

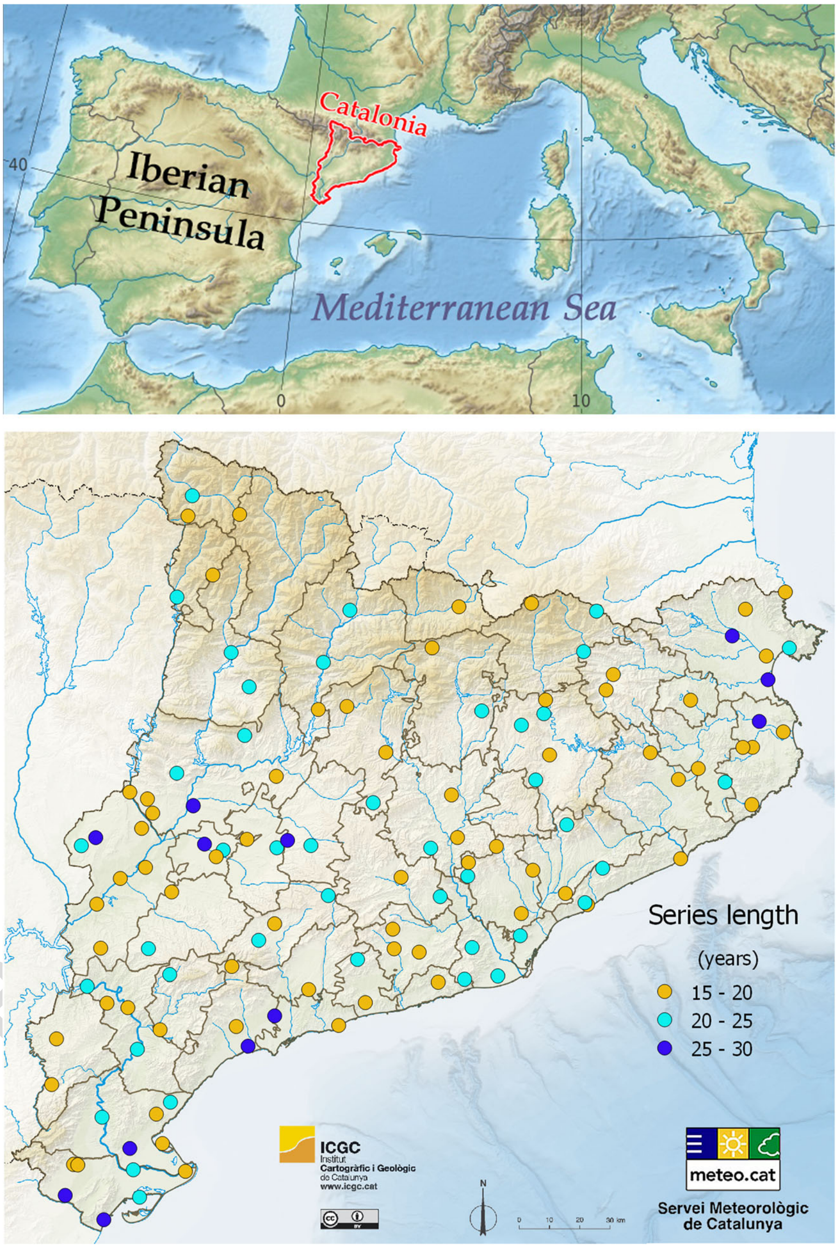

Fig. 1 Map of Catalonia (Iberian Peninsula) displaying the weather stations selected for the study and their record length

- The annual maximum daily rainfall calculated using a 24-h fixed time interval has been found for every AWS and every year with rainfall data.
- The maximum rainfall for unrestricted intervals of 24 h has been found using a sliding window of 1 h on every episode detected in the previous step, with the condition of having at least 1 h inside the considered fixed time interval.
- The maximum value obtained using the sliding window has been divided by the value for the fixed time interval, thus, yielding a ratio for each AWS for each year in which there is available data.
- Since a 3-month resolution is needed in order to analyse the ratio seasonality, the former three steps have been followed also using the monthly maximum daily rainfall for every AWS and every month with rainfall data. An averaged value has then been calculated for the 3 months of the particular season.

This process has been repeated for different fixed starting times as well as for durations other than 24 h. Specifically, four different starting times throughout the day have been considered in order to explore the influence of the diurnal cycle on the ratio: local 00:00, 08:00, 12:00 and 16:00. As for durations, it is known that increasing the number of fixed time intervals in which each duration has been discretized leads to a decrease in the correction factor (Weiss 1964). To investigate this dependence, the ratio between amounts measured using fixed and sliding intervals has also been calculated for durations higher than 1 day, from 2 days up to 12 days.

The global averaged value obtained at each AWS has been interpolated using the simple kriging methodology in order to display a spatial distribution of the correction factor over Catalonia and compare it with the mean annual and seasonal rainfall maps.

The actual duration of the episodes with maximum daily rainfall registered at every AWS has been measured with the aim of exploring dependence of the ratio on meteorological time scales, and thus, on the physics behind rainfall generation.

3 Results and discussion

3.1 Comparison with previous factors

Empirical results obtained by the methodology described in the previous section agree with correction factors previously obtained by several authors. In this study, the value of the global averaged correction factor for a duration of 24 h for the whole studied region, calculated as the mean value obtained from the annual daily maxima registered at the 120 considered AWS, resulted 1.125, almost corresponding with the Hershfield (1961) factor and other studies listed in Table 1 (Huff and Angel 1992; Young and McEnroe 2003). The Weiss (1964) factor for 1-day duration had a slightly higher value (1.143). The difference between the empirical factors and the one proposed by Weiss might be explained by the fact that Weiss derived the factor theoretically, assuming an unrealistic rainfall behaviour as a uniform rainfall intensity. Comments on the significant overestimation of the correction factor obtained from the calculation carried out by Weiss can be found (Dwyer and Reed 1995; Young and McEnroe 2003), and it was also pointed out by Asquith (1998) that Weiss's assumption that the probability of a rainfall event is equal throughout any time interval cannot be applied to some locations.

Table 1 Comparison between correction factors for fixed temporal intervals of rainfall measurement obtained by several authors

Duration (in days)	Hershfield (1961)	Weiss (1964)	Huff-Angel (1992)	Young-McEnroe (2003)	Present study
1	1.13	1.143	1.13	1.13	1.125
2		1.067	1.05	1.05	1.053
3		1.044	1.02	1.03	1.032
4		1.032			1.021
5		1.026	1.01		1.018
6		1.022		1.01	1.015
10		1.013	1.01		1.011
12		1.011		1	1.011

Table 1 also shows the correction factor calculated by several authors for durations higher than 1 day. As commented before, durations of 2 days and more were considered in order to explore how the correction factor decreases along with the increase of the number of fixed time intervals N in which each duration has been discretized. In the present work, this calculation has been done by considering accumulated rainfall over several N days measured using a 1-day fixed time interval and then comparing measurements using a sliding 1-day interval. Weiss (1964) formulated the dependence of the correction factor F with the number of intervals N as Eq. 1, whereas Young and McEnroe (2003) used Eq. 2. Among other statistics, Papalexiou et al. (2016) compared the mean and standard deviation of the annual maxima sample measured using fixed intervals and using sliding intervals, obtaining an empirical function for the mean which is formulated in terms of the ratio F, seen in Eq. 3.

$$F = N/(N-0.125) \tag{1}$$

$$F = 1 + 0.13\, N^{-1.5} \tag{2}$$

$$F = 1 + 0.135 \exp\left[-\left(\frac{N-1}{1.078}\right)^{0.408}\right] \tag{3}$$

Regarding the results obtained for those durations, the empirical correction factor obtained is lower than the theoretical factors proposed by Weiss (1964) for durations shorter than 10 days, but correspondence improves for accumulations longer than 10 days. This result is caused by the fact that the more fixed intervals are accumulated, the less important the problems caused by Weiss's unrealistic assumptions.

In order to test if the correction factor depends on the probability of occurrence of the rainy episodes from which it has been calculated or not (Weiss 1964; Dwyer and Reed 1995), its value has been calculated by averaging annual maxima and monthly maxima. The value of the global averaged correction factor from annual daily maxima resulted in 1.125 ± 0.039, while the mean value calculated from monthly daily maxima lead to a smaller confidence interval, 1.129 ± 0.014. As expected, the use of longer period lengths leads to greater sample variability due to the lesser number of periods available to estimate ratios. Since both results are almost the same, we can conclude that, as found by Dwyer and Reed (1995), the correction factor value is not dependent on the extremity of the events.

The type of scaling equation proposed by Young and McEnroe (2003) has been used to fit the values of the correction factor obtained for durations between 1 and 10 days, forcing the function to equal 1.129 for a sampling ratio of one (Eq. 4), resulting in a scaling exponent of −1.2.

$$F = 1 + 0.129\, N^{-1.2} \tag{4}$$

Figure 2 shows the comparison between the empirical factors obtained in the present study and curves given by Eqs. 1, 2, 3 and 4.

3.2 Dependence on the fixed starting time

Traditionally, rainfall is most commonly measured daily at a fixed time in the morning. Nonetheless, as a part of the present study, the difference in the empirical correction factor depending on the sampling time has been analysed. Specifically, we have taken into consideration how the ratio between amounts measured with fixed and sliding intervals varies if fixed intervals start at four different times throughout the day: at 00:00, 08:00, 12:00 and 16:00.

In order to graphically compare the correction factors derived from this calculation at each of the 120 AWS and, moreover, to show which fixed starting time causes a worst result compared with what sliding intervals would produce, a specific system of axes has been used (Fig. 3). Whereas the *y*-axis represents the empirical correction factor, the *x*-axis represents the fraction of daily rainfall collected in 1 h around the time of the fixed interval considered. The fraction of daily rainfall has been calculated for every AWS as the amount collected in 1 h at the fixed measuring time (on every day with available data) and averaged over the total amount of daily rainfall collected by the AWS. The vertical line at 0.0417 represents the fraction of daily rainfall that would be collected during 1 h if the rain were uniform over time (i.e. 1/24). The horizontal line at 1.129 indicates the global averaged empirical correction factor for measurements at 08:00 obtained in this study. Low values of the fraction of daily rainfall indicate that at the time the measurement was taken at the particular station it was rarely raining, and on the contrary, high values of this fraction indicate that at that particular time, it was frequently raining and therefore might not be the most appropriate starting time for accumulated rainfall measurements, because rainy episodes would frequently be split into two parts.

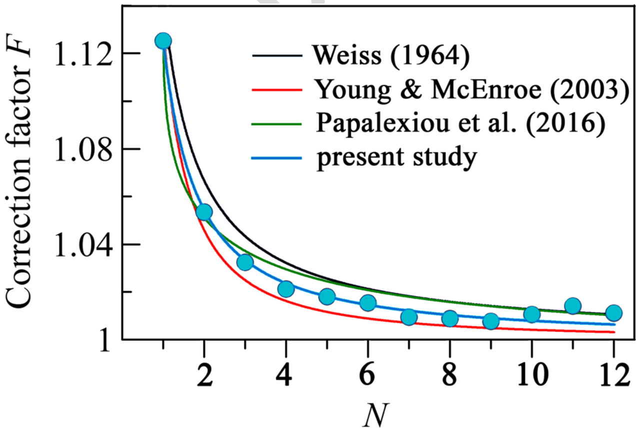

Fig. 2 Graphical comparison between the correction factors for fixed temporal intervals of measurement obtained in the present study (dots) and those yielded by Weiss (1964), Young-McEnroe (2003) and Papalexiou et al. (2016), where N is the number of fixed intervals in which each duration has been discretized

In Fig. 3, the empirical factors obtained for each of the 120 AWS have been represented against the fraction of daily rainfall registered in each station at the starting time considered: local 00:00, 08:00, 12:00 and 16:00. Comparing the four representations, it is shown that at almost every location considered, it often rains less in the morning than what would be collected by a constant rain, whereas at 16:00, most locations present a higher fraction of daily rainfall at the moment the measurement is taken. In the same way, empirical correction factors indicate a need for a higher correction in the case of measurements taken in the afternoon in favour of those taken in the morning. In particular, Fig. 3 demonstrates that daily amounts would have been slightly more precise (lower correction factors and lower fraction of daily rainfall) if they had been taken at 00:00 instead of at 08:00, which is the most common starting time to measure daily rainfall in the area of study. Regardless, 08:00 seems to be a good starting time. Correction factors for daily amounts measured at fixed time intervals starting at 08:00 yielded a mean value of 1.129, lower than the mean value of 1.137 corresponding to factors obtained for amounts measured at fixed time intervals starting at 16:00, proving that rainfall events would more often be split if measurements were taken in the afternoon. Most locations in mountainous areas of Catalonia present a very high fraction of daily rainfall in the afternoon. As an example, Fig. 4 compares this fraction for every hour of the day for two different locations: First, Núria station, located in the Pyrenees at 1971 m altitude, presents very high values of the fraction of daily rainfall after midday, linked to solar heating of mountains slopes, whereas there are low values for the rest of the day. Second, the city of Barcelona, which is on the coast, shows a fraction almost uniform in comparison, around the value 1/24.

3.3 Seasonality and spatial distribution

Due to several geographical and aerological factors, rainfall in Catalonia is highly diverse from one area to another, with some mountainous areas where the mean annual precipitation exceeds the value of 1200 mm in contrast to other areas, mainly in the centre of the region, where the mean value is lower than 400 mm. Regarding seasonality, pluviometric maxima are observed in Catalonia especially in autumn and in spring, depending on the area. Thus, 48% of the annual maxima considered in this work occurred in autumn, 22% in spring, 16% in summer and 14% in winter.

The mean empirical correction factors at each AWS represented in Fig. 3 were obtained after averaging the ratio values calculated for every monthly maximum amount recorded. With the aim of showing the monthly variations of the

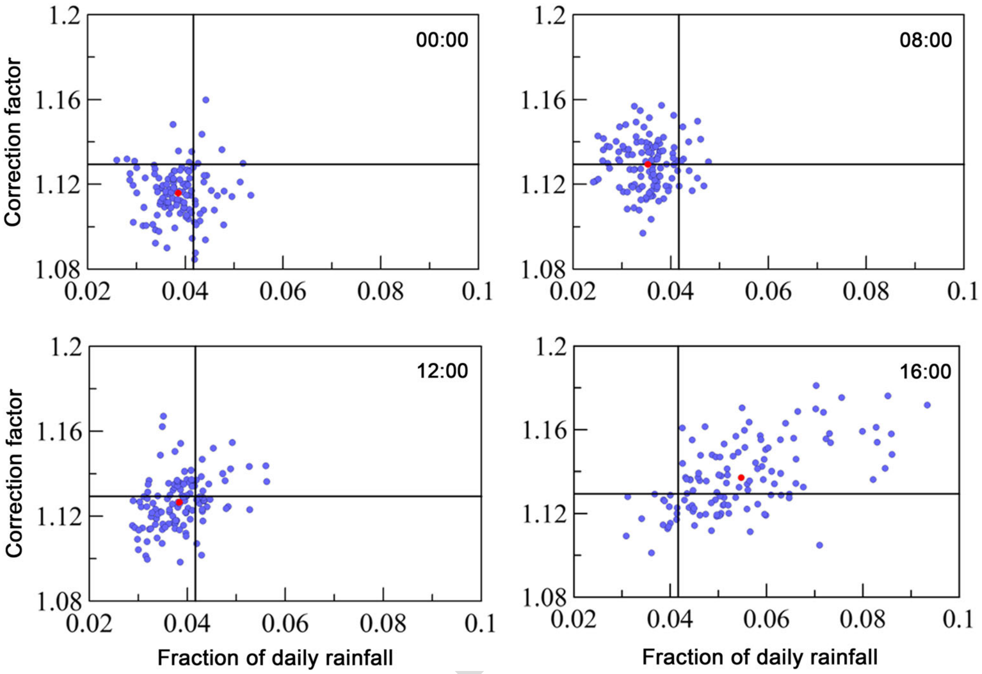

Fig. 3 Empirical correction factors for fixed temporal intervals of measurement starting at 00:00, 08:00, 12:00 and 16:00, represented against the fraction of daily rainfall at the given starting time. Red dots are the sample centroids

frequency factors against the fraction of daily rainfall, as well as seasonality, Fig. 5 represents every month, the averaged ratios calculated from monthly maxima at every station, with all measurements being taken at 08:00 local time. In Fig. 6, these points have been averaged by season, with spring comprising the months from March to May, summer June to August, autumn September to November and winter December to February.

Figures 5 and 6 show that summer is the season for which lower factor corrections would be needed because a very low fraction of the daily rainfall is registered at 08:00. This is an expected result since rainfall maxima recorded in summer in Catalonia are often produced by local storms taking place after midday, due to a clear diurnal surface warming effect in their convective development, as well as mesoscale formations also triggered in the afternoon (Casas et al. 2004; Pérez-Zanón et al. 2016). The same result is shown in Fig. 7, where empirical correction factors have been averaged by month. Figure 7 also shows that factors for the climatological spring (March, April and May) are high, all of which are over the value of 1.14.

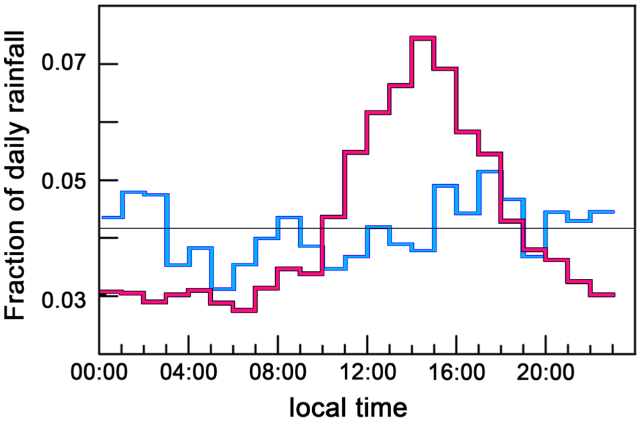

Fig. 4 Fraction of daily rainfall registered every hour of the day in Núria Station (Pyrenees, at 1971 m of altitude, in red) and in the coastal city of Barcelona (in blue)

Regarding the influence of seasons, empirical factors are found to have a mean seasonal global value in Catalonia of 1.161 in spring, 1.093 in summer, 1.124 in autumn and 1.139 in winter. The fact that correction factors are found to be highest in spring means that it is when rain episodes are more often split when measurements are taken at 08:00; hence, a higher ratio is obtained between rainfall at unrestricted intervals and rainfall at fixed time intervals. On the contrary, as commented, episodes in summer need the lowest correction; indeed, summer episodes in the study area are often raised by the influence of the diurnal cycle and the 24-h maxima are not usually split by a measurement taken in the morning.

A spatial distribution of the correction factor in Catalonia has been obtained using a simple kriging methodology for which the global averaged value at each AWS has been interpolated. Figure 8 shows this spatial distribution for the four climatological seasons. The general pattern of the spatial distribution resembles the mean annual and mean seasonal rainfall patterns in Catalonia, with a need for lower correction in drier regions. However, it must be noted that this spatial pattern is highly variable depending on season, up to the point of having a region (in central Catalonia and slightly to the west) which clearly needs high correction factors in winter while the same region presents low correction factors in autumn (see Fig. 8).

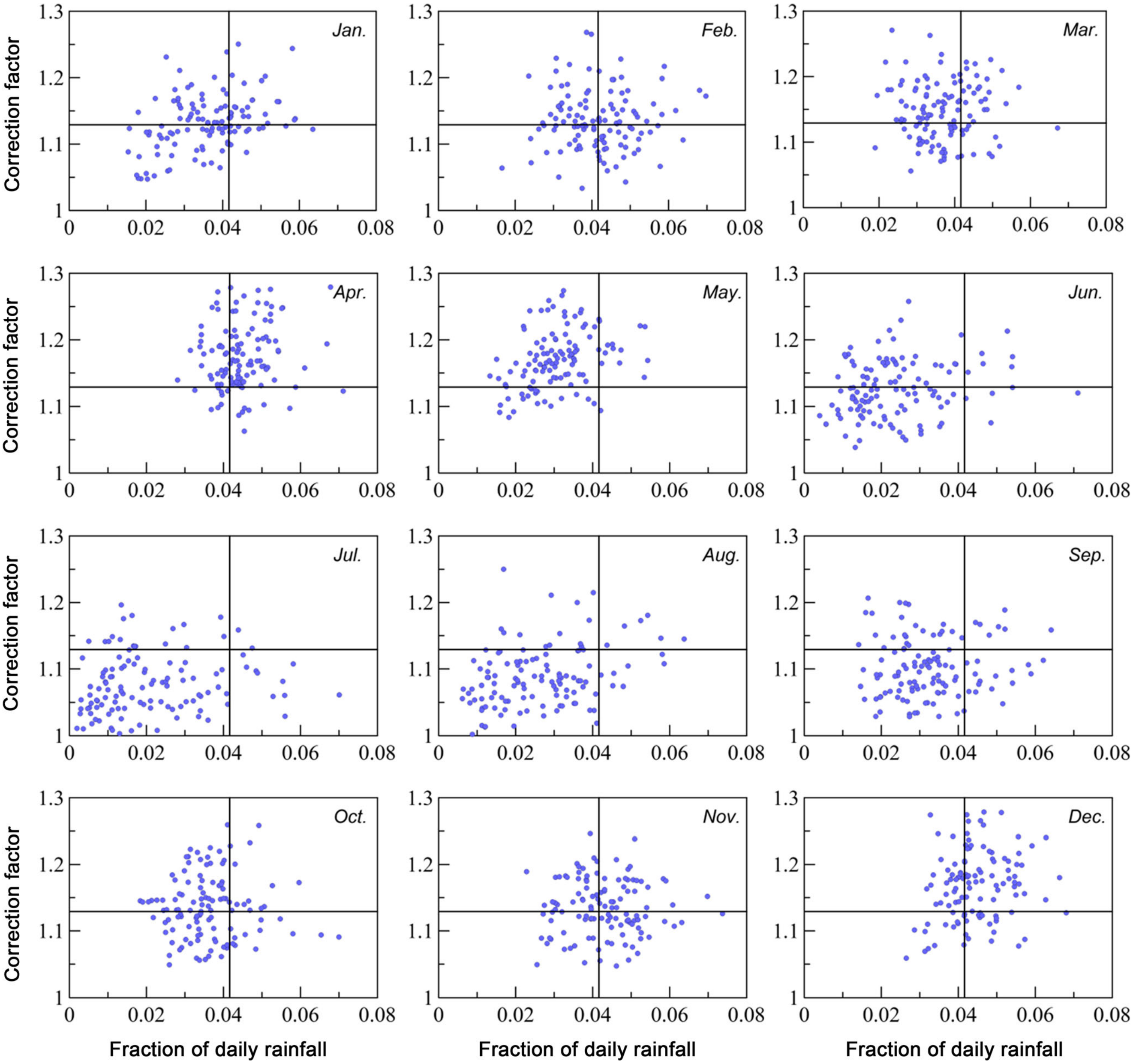

Fig. 5 Empirical correction factors for fixed temporal intervals of measurement against the fraction of daily rainfall at the starting time 08:00 by month

Both spring and summer distributions present a low spatial variability and the mean ratio yields the highest and lowest seasonal correction factor respectively. Autumn distribution presents a high spatial variability of empirical ratios, with the lowest correction coinciding with the driest regions. Winter presents a high spatial variability as well, but the relation to the mean rainfall distribution is not so clear. It should be noted that winter was the season with the smallest percentage of annual maxima registered.

3.4 Actual rainfall duration

In many areas of Catalonia, the meteorological situations producing abundant rainfall amounts highly contributing to monthly and annual totals are not always the same as those involved in daily maxima (Casas et al. 2008). Thus, while synoptic-scale situations have a greater influence on the annual mean rainfall, daily maxima are usually related to smaller organisations for which local and mesoscale factors are decisive. These factors can include orography, distance from the sea, temperature and humidity advections at low levels and between sea and land. With the aim of investigating the possible influence of meteorological scales on the ratio between fixed and sliding intervals and, thus, on the correction factor, the actual duration of rainfall episodes which produced monthly maxima at every AWS has been taken into account. Figure 9 shows that the mean value of the actual duration of the monthly maxima events averaged by year is mostly

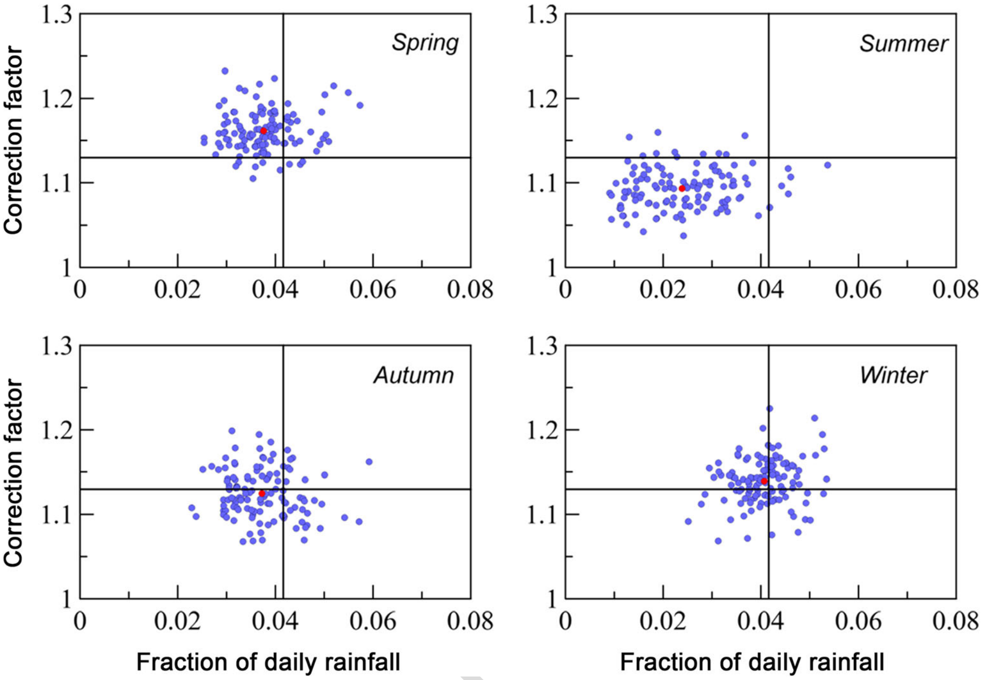

Fig. 6 Empirical correction factors for fixed temporal intervals of measurement against the fraction of daily rainfall at the starting time 08:00 by season. Red dots are the sample centroids

between 8 and 12 h. Anyway, different durations are contributing to these mean values depending on the season. In Fig. 9, the actual duration averaged by month has also been displayed, showing that the monthly maxima in summer months, as well as in the first month of autumn (September), were the shortest events: between 6 and 9 h according to their primary relationship to highly convective mesoscale organisations. For the rest of the year, especially spring, with high correction factors and durations above 12 h, synoptic-scale situations, sometimes with smaller mesoscale systems inside, seem to have more influence on the rainfall pattern. Both graphics in Fig. 9 show a certain increasing dependence between the correction factor and actual duration. Due to the expected relationship between the mean annual rainfall and the mean actual duration of the monthly maxima (Fig. 10), an increasing dependence between the correction factor and the mean annual rainfall can also been observed.

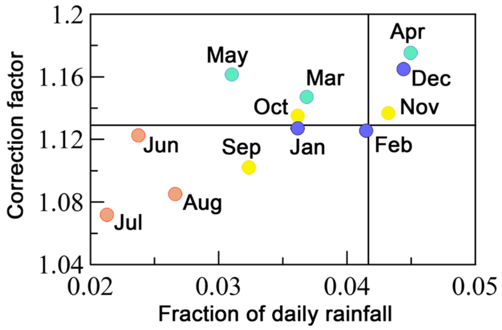

Fig. 7 Empirical correction factors for fixed temporal intervals of measurement averaged by month. Colours indicate the climatological seasons

Figure 11 shows latitude at every AWS along with the mean actual duration of their monthly maxima, to prove that stations located in the north of Catalonia register the longest episodes, mostly in spring, leading to generally high correction factors. In the most northern zone, due to its distance from the coast and the blockage effect of the high Pyrenees mountains, climate is less influenced by the Mediterranean Sea. The north-western corner of the territory, often affected by Atlantic fronts, has some of the Atlantic climate characteristics, such as a high amount of advective and long-lasting rain registered in a regular way throughout the year (Casas-Castillo et al. 2018; Pérez-Zanón et al. 2018).

4 Conclusions

The analysis of empirical correction factors in Catalonia, obtained as the averaged ratio of rainfall amounts measured using fixed time intervals and rainfall amounts measured using unrestricted (sliding) intervals of the same duration, has been performed. The well-known decreasing dependence of this correction factor (F) with the number of time intervals (N) in which every duration has been discretized has been found, leading to a scaling equation similar to others found in related literature: $F = 1 + 0.129\,N^{-1.2}$.

The value of the correction factor was found to be almost the same whether averaging annual maxima or monthly maxima, providing evidence of no dependence of this value on the probability of occurrence of the events used in the calculation. As expected, the use of longer period lengths leads to greater sample variability due to the lesser number of periods

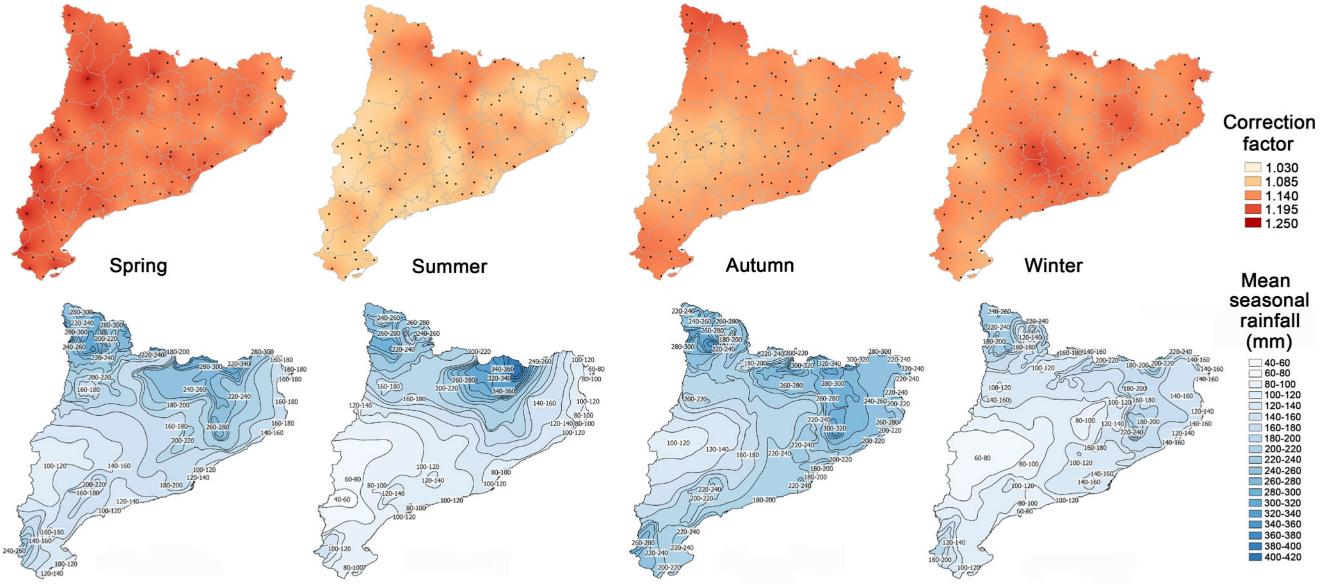

Fig. 8 Spatial distribution of empirical correction factors for fixed temporal intervals of measurement (up) compared with mean seasonal rainfall distributions (down, SMC (2008))

available to estimate ratios. Therefore, while the value of the global averaged correction factor from annual daily maxima resulted in 1.125 ± 0.039, the mean value calculated from monthly daily maxima leads to a smaller confidence interval, 1.129 ± 0.014.

The study has also shown the influence of the fixed starting time on the needed correction factors, 08:00 being a suitable time to take daily measurements since a small fraction of daily rainfall is expected to occur around this time. A lower fraction of daily rainfall has been registered at 00:00 local time, which suggests this time would be even better than the most common used in the area, 08:00, to measure accumulated daily rainfall. The mean correction factor obtained for the whole region for daily amounts taken at 08:00 from monthly maxima was 1.129, whereas a higher correction (1.137) would be needed if measurements were taken in the afternoon at 16:00.

The empirical correction factors have also been analysed taking into account seasonality and geographical location. In general, the correction factor has been found to be lower in the driest regions of Catalonia, but a high spatial variability has been obtained, which depends also on the season. Rainfall maxima recorded in summer in Catalonia are often produced by local and mesoscale formations with remarkable diurnal cycles for which the diurnal heating surface effect is decisive in their convective development. Due to this fact, summer requires the lowest correction factors because of the very low fraction of the daily rainfall registered at the usual time, 08:00.

The correction factor has been found to increase with the actual duration of the maximum rainfall events used in the analysis. Some of these extreme events had actual mesoscale durations between 6 and 9 h, linked to highly convective

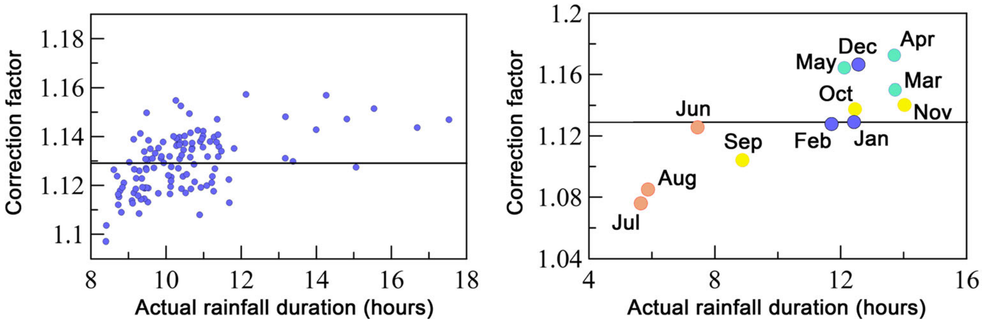

Fig. 9 At the left, empirical correction factors for fixed temporal intervals of measurement against the mean actual duration of the monthly maximum daily events at each AWS averaged by year. Linear regression has been calculated for mean actual durations shorter than 12 h. At the right, correction factors and mean actual durations averaged by month

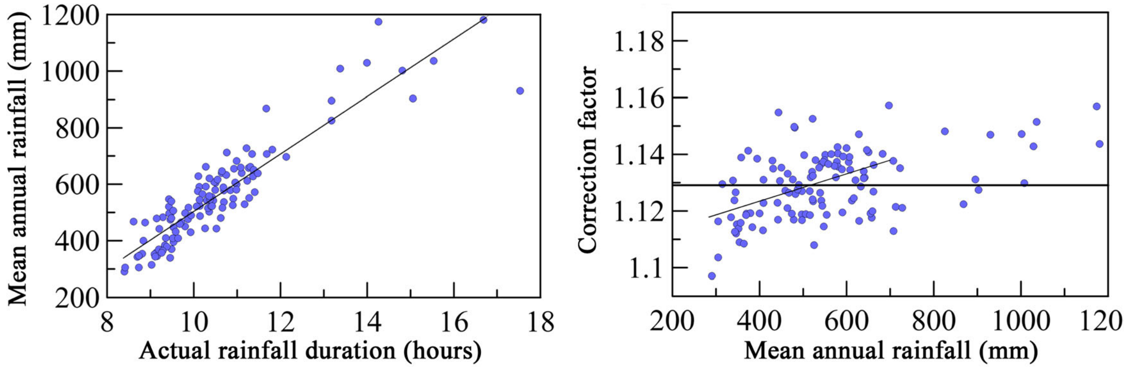

Fig. 10 Relationship between mean annual rainfall at every AWS and the mean actual duration of the monthly maxima (left), as well as with correction factors for fixed temporal intervals of measurement (right)

mesoscale organisations acting mainly in summer and the beginning of autumn. It is in summer when the shortest monthly maxima have been registered, leading to the lowest correction factors. In the northern area of the region, other maxima episodes with more advective rainfall were recorded, lasting more than 12 h and presenting the highest values of the correction factor, especially in spring. Mean annual rainfall is proportional to actual duration of the monthly maxima; therefore, some dependence between the correction factors and this magnitude has also been found. In order not to underestimate the measurements of true maxima, the use of the correction factor is more necessary in rainy locations and during seasons with higher rainfall.

In view of the results obtained, the recommended correction factor for Catalonia might be a nuanced factor based on the season, which would be valid for daily amounts and a fixed starting time at 08:00. Autumn presents a high spatial variability of empirical ratios over the studied territory, with the lowest correction coinciding with the driest regions and yielding a mean correction factor of 1.124. Winter presents a high spatial variability as well, with no clear relationship to the mean rainfall distribution, and a mean correction factor of 1.139. Both spring and summer present a low spatial variability and the mean ratio yields the highest (1.161) and lowest (1.093) seasonal correction factor respectively.

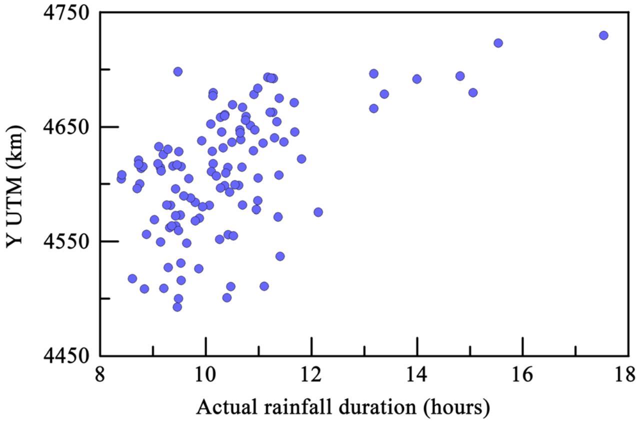

Fig. 11 Latitude and mean actual duration of monthly maxima events at every AWS

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Compliance with ethical standards

Conflict of interest The authors declare that they have no conflict of interest.

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