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Intra-annual rainfall variability in the Spanish hydrographic basins

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ABSTRACT: Understanding the intra-annual distribution of rainfall is an important element for climatic classification and serves as a basis for natural resources management. The present study analyses multi-annual irregularities of the rainfall distribution throughout the year in the period 1941 to 2010, in the hydrographic basins of the Iberian Peninsula. In order to analyse its variation, the rainfall centralisation and dispersion parameters throughout the annual cycle were previously defined and calculated for each year. Inter-annual series of both parameters were generated, which allowed detecting their temporal behaviour in each of the basins and relating differentiated geographic areas. Independent of the total annual rainfall, greater temporal simultaneity is observed in the fluctuations of the intra-annual parameter "centralisation" in the Atlantic basins and wider inter-annual oscillations in the Mediterranean basins. Around the year 1970, there was a displacement in the predominance of autumn rains, although the process is inverted in the last decades. Also from the decade of 1970 there is a general increase in the inter-annual variability of the "dispersion" parameter, especially in the basins that drain toward the Atlantic Ocean. The "dispersion" parameter allows detecting latitudinal (Cantabrian vs Guadalquivir)

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and longitudinal (Atlantic vs Mediterranean) patterns of intra-annual rainfall distribution irregularity in the Iberian Peninsula. The results obtained are also associated to atmospheric general circulation patterns of the North Atlantic Oscillation and the Western Mediterranean Oscillation. The monthly winter values of the North Atlantic Oscillation present a marked influence on dispersion, especially in the basins that discharge into the Atlantic Ocean, which show a double gradient: decreasing longitudinally from the Atlantic coast to the Mediterranean coast and latitudinally from north to south.

KEY WORDS: Intra-annual rainfall, basins, temporal irregularity, centralisation parameter, dispersion parameter, Iberian Peninsula, NAO, WeMO.

1. Introduction

Hydrographic basins constitute territorial units of management where the climatic characteristics are directly related to the hydrological and environmental effects, as a consequence of rainfall (González-Hidalgo *et al.*, 2010; García-Barrón *et al.,* 2015). Due to its complex topography, the Iberian Peninsula is divided into hydrographic basins that show geographic areas with different meteorological traits (Martin-Vide and Olcina, 2001). Thus, characterisation by basins provides objective criteria in the making and application of scientific and technical decisions, which have wide-reaching natural and social results (Krysanova *et al.,* 2010; Cabello *et al.*, 2015). Except for the mountain range located in the north, the Iberian Peninsula is included in the Mediterranean climate domain (De Castro *et al.,* 2005; Martin-Vide, 2011). Thereby, the rainfall in the hydrographic basins, with its particularities, shows the general characteristics of a Mediterranean climate: inter-annual irregularity (García-Barrón *et al*., 2011) with marked fluctuations that include relatively rainy years next to periods of drought and intra-annual irregularity (García-Barrón *et al*., 2013) and with high rain concentrations for only a few days and minimum values of rainfall during the summer months.

The existence of rainy periods in certain months, the duration of such periods and the intensity that they reach are the most relevant elements for the characterisation of intra-annual rainfall. In turn, understanding these elements provides a criterion of climatic classification and constitutes a component used for the detection of the variation of the regional climate. In each hydrographic basin, the rainfall distribution throughout the year is represented by a characteristic profile. A large number of environmental, social, economic or landscape processes are closely related to the intra-annual rainfall distribution (Nunes *et al*., 2016). Thus, the rainfall concentration after a summer period, with poorly developed vegetation, results in greater rainfall erosivity. Several studies have proved how periods of high rainfall irregularity induce clogging processes in the lagoons (Sousa *et al*., 2013) and streams in the southwest of Spain (Sousa *et al*., 2015) and Portugal (Devereux, 1982). Alternation of dry and rainy periods, sometimes with the overlapping of human activity that alters the use of soil, has generated periods of greater dynamism in the activity of the layers of quaternary sands of the southwest of Spain (Sousa *et al*., 2003, 2010), particularly accentuated at the end of the Little Ice Age in western and central Mediterranean areas (Diodato *et al*., 2011).

In the Iberian Peninsula there are many studies showing the spatiotemporal variation of rainfall and the availability of water resources (García-Barrón *et al*., 2010; Sánchez *et al*., 2011; Estrela *et al*., 2012; Guerreiro *et al*., 2014; Aguilar-Alba, 2016). Other studies have analysed the rainfall variation at daily time scales (Martin-Vide, 2004; Rodrigo and Trigo, 2007; Acero *et al*., 2011; Gallego *et al*., 2011; Ramis *et al*., 2013), or at monthly or seasonal time scales (García *et al*., 2007; Ninyerola *et al*., 2009). Thus, De Luis *et al.* (2010) showed that, from 1946 to 2005, there was a rainfall decrease in the Iberian Peninsula during the winter and spring months and an increase in the autumn. These results confirm the ones previously obtained in the south of Spain (Aguilar-Alba, 2007). In general, these studies highlight the multi-annual tendency or variability of the total rainfall volume recorded in the selected periods.

A method used to analyse the rainfall distribution within each year is the Annual Precipitation Concentration Index or *PCI* (Oliver, 1980), which determines the level of seasonal grouping. De Luis *et al*., (2011) showed that the annual values of *PCI* in Spain follow a general NW-SE spatial pattern during the wet months due to the Atlantic storm track. The multi-decade analysis also shows significant changes from 1970 onwards in the *PCI* detected by several studies, showing important spatial and seasonal differences suggesting for most of the Iberian Peninsula greater intra-annual dispersion with shifts of the rainfall periods to autumn and/or spring. In Portugal, Nunes and Lourenço (2015) observed *PCI* changes which revealed that even though the annual trend for the amount of precipitation was negative overall, most of the stations registered a more marked seasonality for precipitation during the period 1960–2011; the highest values were found in the south. Also, García Barrón *et al.* (2015) used *PCI* to analyse the aggressiveness of rainfall in the Spanish hydrographic basins (1940-2010).

However, there are fewer studies that analyse the intra-annual rainfall variability and even fewer that do so in a comparative manner between different hydrographic basins. The present paper tackles this complementary approach with the aim of studying the variation of the intra-annual rainfall distribution in the period between 1941 and 2010 in the hydrographic basins of the Iberian Peninsula. Although there is substantial research about rainfall and its impact on some of the Spanish hydrographic basins, there are very few studies that consider all of the hydrographic basins of the Iberian Peninsula. González-Hidalgo *et al*. (2010) detected a negative tendency of rainfall during spring in all the Iberian basins and a positive tendency in October, especially in the northwestern basins. Estrela *et al*. (2012) used the precipitation data as a basic variable to calculate the flows and storage of water in the hydrographic basins.

The main purpose of the present study is to establish the intra-annual regime of rainfall to determine analogies and differences between hydrographic basins of the Spanish peninsular territory. Thus, it is intended to determine, for each basin, the stability of intra-annual rainfall distribution and to verify if, throughout multi-annual periods, there are displacements of rainy periods. We consider that the proposal is new regarding the procedure and the geographic scope of implementation. Obviously, this procedure requires us to previously define parameters that allow identifying the rainfall distribution for each year in a precise manner.

Furthermore, in order to explain the rainfall regime in the Iberian Peninsula, previous researchers related the annual, seasonal or monthly volume to synoptic situations linked to patterns of atmospheric circulation and weather types (Muñoz-Diaz and Rodrigo, 2006; López-Bustins *et al.*, 2008; Casado *et al.,* 2010; Hidalgo-Muñoz *et al.*, 2011; Cortesi *et al.*, 2014; Ríos-Cornejo *et al.*, 2015) or to the temperature of the sea surface (Gámiz-Fortis *et al.*, 2010). The connection with the North Atlantic Oscillation (NAO) presents particular interest. Generally, different studies (Gallego *et al.*, 2005; Queralt *et al.,* 2009; Rodríguez-Puebla and Nieto, 2010; Castro *et al.*, 2011) agree in highlighting the strong correlation between the NAO and the monthly rainfall values from December to March in the entire Iberian Peninsula, with lower impact on the Mediterranean and Cantabrian areas. In fact, during these months, the NAO effect is more intense and, therefore, its influence on precipitation is greater. Recent studies have improved the understanding of precipitation behaviour in the Iberian Peninsula, like the one by Sousa *et al.* (2016), who demonstrated increases in the rainfall associated with Euro-Atlantic blocking situation patterns.

Some authors even chose the Spanish hydrographic basins as the territorial basis on which to analyse the effects of atmospheric circulation. Trigo *et al.* (2004) relate the impact of the NAO on the winter river flows of Atlantic basin to the potential production of hydroelectricity. Lorenzo-Lacruz *et al.* (2011) analysed the influence of the NAO on the streamflow in basins of the Iberian Peninsula and demonstrated the impact of the NAO on the streamflow of Iberian rivers during winter, and in the Atlantic watershed during autumn.

The teleconnection index of the Mediterranean Oscillation (MO), with a dipole in the eastern and western Mediterranean areas, shows a very low correlation with the meteorological variables in Eastern Spain and its influence on precipitation is not significant (Criado-Aldeanueva and Soto-Navarro, 2013). In the last decade, a new index has been proposed with effects on precipitation in the Iberian Peninsula: the Western Mediterranean Oscillation (WeMO), with dipoles in the areas of Gibraltar and the Gulf of Genoa-Liguria (Martin-Vide and Lopez-Bustins, 2006; Martin-Vide, 2016).

The scientific literature directly relates, with different approaches, the values of monthly or seasonal rainfall to the teleconnection patterns. However, the authors of the present study consider, as a complementary approach, relating the Atlantic and Mediterranean atmospheric circulation systems to intra-annual rainfall distribution irregularities. In order to achieve this, the NAO and the WeMO were selected as the main indices that may affect the intra-annual rainfall distribution in the Spanish hydrographic basins.

According to the aforementioned, for each of the major hydrographic basins that constitute the Iberian Peninsula, it is intended to:

- Quantify, through markers of centralisation and dispersion, the rainfall distribution throughout the annual cycle.
- Establish the variation of the intra-annual rainfall distribution for the period of 1941 to 2010.
- Characterise the spatiotemporal relationships of the intra-annual rainfall distribution in the Iberian Peninsula between the different hydrographic basins.

- Relate the situations of atmospheric circulation to the intra-annual distribution of precipitation in the different basins using the NAO and WeMO values.

2. Study area and data

The study area covers the Spanish hydrographic basins of the Iberian Peninsula during the period from September 1941 to August 2010. This region is located in the southwestern end of Europe, next to North Africa and is framed by the Mediterranean Sea in the east and the Atlantic Ocean in the west. Moreover, due to its situation of transition between the middle and subtropical latitudes and its complex orography, its climatic characteristics are different from those of other European latitudes. The Iberian Peninsula includes three different watersheds: Cantabrian, Atlantic and Mediterranean (Figure 1). The watershed toward the Cantabrian Sea is composed of short rivers that flow northward from the Cantabrian mountain range. The Atlantic watershed includes rivers that flow to the west toward the Atlantic Ocean: including the basins of Galicia, the basins of the Plateau (Douro, Tagus, Guadiana) and the Guadalquivir river. The basins in the southeast of the Spanish peninsular territory in the Mediterranean watershed are the Jucar, Ebro and Catalonian basins, which flow toward the Mediterranean Sea.

Fig. 1 around here

The basins of the rivers that cover a greater surface (Ebro, Tagus, Douro, Guadiana and Jucar) are considered separately in this study. On the other hand, the basins that cover a smaller surface (Cantabrian, inner Basque Country, Miño-Sil, Galician Coast, Southern Atlantic, Segura, Andalusian Mediterranean and inner Catalonian) were grouped in order to facilitate a complete comparative study of the whole of the Spanish peninsular territory. The monthly rainfall results obtained from the SIMPA model for the basins included in the study area can be consulted in Tables S1 and S2 of Supporting Information. This grouping was performed according to geographic proximity and similar climatic characteristics. This criterion allows grouping all the basins into ten groups. Table 1 shows the resulting ten basins, their total area and the relative proportion of the surface of each of the integral basins with respect to the basin in which they are included. The rainfall assigned to each of these ten basins was calculated from the monthly rainfall of each of the small basins that compose them, weighted according to the respective surface.

Table 1 around here

The Integrated System of Water Information (SIA in Spanish: "Sistema Integrado de Información del Agua") is the official system of the Ministry of Agriculture, Food and Environment of Spain, dedicated to the management of water resources. For this purpose, the SIMPA model (which in Spanish stands for "Integrated System for Rainfall-Runoff Modelling") was developed in the Centre for Hydrographic Studies (CEDEX, Spain) (Estrela and Quintas 1996; Álvarez *et al.,* 2005). The system was implemented using GRASS as the GIS spatial database. In order to determine the rainfall values, the model uses the interpolation procedure through the inverse square of the distance, with data from over 5,000 meteorological stations of the Spanish network (MAPAMA, 2013). Through this interpolation, double regression and white noise, the incomplete series were filled without altering the natural variation of the records. In addition, specific procedures were used to estimate the rainfall in areas of higher altitude in the sources of the basins where there is lower density of meteorological stations (Estrela *et al.*, 1999; Belmar *et al.*, 2011). Therefore, the rainfall information in each basin results from a top quality method of allocation. These series are homogenous and do not present gaps.

The SIMPA model was used in Spain for the official evaluation of water resources published in the *White Paper of Water*, which includes the location of the meteorological stations used (MAPAMA, 2000). The SIMPA model was used to elaborate the National Water Plan and its subsequent modifications (MAPAMA, 2001). The SIMPA model is frequently used for the development of many technical and hydrographic management projects by public administrations. It has also served as a basis in studies about hydrological regimes (Sánchez *et al*., 2011; Chavez-Jimenez *et al*., 2013). Vargas-Amelin and Pindado (2014) used the SIMPA data to analyse the impact of climate change in Spain and García-Barrón *et al.* (2015) used them to calculate the rainfall variation aggressiveness in the basins of the Iberian Peninsula.

The advantage of the information offered by SIMPA is that it assigns an estimated value of monthly rainfall to each hydrographic basin, based on the records of multiple meteorological stations. The combining capacity that this poses allows characterising each basin by a single representative temporal series of rainfall. Thus, it is possible to conduct a direct spatio-temporal analysis of the rainfall patterns of the major natural geographic areas of the Iberian Peninsula and observe their compared variation throughout long multi-annual periods.

The NAO and the WeMO were selected to study the influence of teleconnection patterns on the intra-annual rainfall distribution, since these have a greater influence on the rainfall regime of the Iberian Peninsula. The NAO index was attained from NOAA (National Oceanic and Atmospheric Administration, USA) and the WeMO index was obtained at the website http://www.ub.edu/gc/English/wemo.htm.

The NAO is determined from the difference in the standardised values of pressure between the subarctic latitude of the Atlantic Ocean (low pressure of Iceland) and the subtropical latitude (anticyclone of the Azores). The values of the southern region of the NAO´s barometric dipole are frequently measured in the continental meteorological stations (Lisbon *38°44'N, 9°09'W* or San Fernando *36°28'N, 6°12'W*), located in the Iberian Peninsula.

The WeMO, a regional teleconnection pattern complementary to the NAO, was used to explain rainfall behaviour in the east of the Iberian Peninsula. It is elaborated from the barometric dipole formed between the Gulf of Cadiz (San Fernando, *36°28'N, 6°12'W*) and the Gulf of Genoa-Liguria (Padua, *45º24'N, -11º52' E*), which is an area under the influence of Central Europe barometric conditions (Martin-Vide and Lopez-Bustins, 2006). The axis of this teleconnection is, therefore, in line with the Mediterranean facade of the Iberian Peninsula.

3. Methodology

The method used to establish the variation of the intra-annual rainfall distribution was based on the annual calculation of the centralisation (C_n) and dispersion (D_n) parameters. For each year, n, both parameters characterise the intra-annual distribution (García-Barrón *et al.,* 2013). In turn, the obtained annual results generate the temporal series of both parameters, in each hydrographic basin, throughout the complete period of N years of observations (1941–2010). Subsequently, it is possible to compare the variation of the intra-annual distribution in time among basins. Then, the behaviour of each basin throughout the study period is related to the teleconnection indices.

3.1. Characterisation of the intra-annual distribution

For each year, the centralisation parameter C_n corresponds to the date when the temporal moments of first order with respect to the origin of the rainfall recorded throughout year n, are equivalent to that obtained if the whole annual rainfall is produced on that single date.

$$C_n = \Sigma(x_i\, p_i) \,/\, \Sigma(p_i);\ (i = 1, 2, \ldots .12) \qquad (1)$$

In this equation, p_i represents the rainfall of month i and x_i is the order of the day, estimated by interpolation in the respective month, from the annual origin selected. For the sake of symmetric optimisation, the annual origin was chosen to be August 1st, which marks the minimum rainfall values in the Iberian Peninsula.

The value of C_n is not sufficient to interpret the intra-annual distribution: the centre of a unimodal profile with its maximum in January may coincide with that of a bimodal profile with maximum values in October and May. Thereby, it is necessary to introduce the parameter D_n as a measure of rainfall dispersion around the central value. The intra-annual dispersion was calculated by adding the second-order temporal moments of the rainfall of each month, with respect to the previously calculated centre C_n. Thus, the intra-annual dispersion parameter is defined as:

$$D_n = [\Sigma(d_i^2\, p_i) \,/\, \Sigma(p_i)]^{1/2}\ ;\ d_i = \left| x_i - C_n \right| \qquad (2)$$

If the rainfall was concentrated in the months around the date C_n, low values of D_n were obtained; conversely, if the rainfall was distributed throughout the annual cycle and, particularly, over the early months of autumn and late spring, high values of D_n were obtained.

Regardless of the total rainfall, if two different years, n and n', had the same monthly distribution (i.e., their rainfall records for the corresponding months were proportional

$p_i = kp_i'$, k being a constant) then, the same value was obtained for the dispersion parameter $D_n = D_n'$.

In an analogous manner, for each of the years, the values C_N and D_N were obtained for each basin. In this case, the intra-annual distribution was calculated from the average monthly rainfall values of the whole period of N years. Thus, for each basin, these serve as a reference that allows comparison with the particular value of the respective parameters, obtained in each of the n years. This D_n presents greater information capacity than *PCI* since, in addition to establishing the seasonality, it shows the range and localisation of the rainy periods throughout the year. This allows to detect inter-annual displacements, and thus it complements the results obtained only with *PCI*.

3.2. Analysis of the inter-annual irregularity

Two complementary methods were used to analyse the annual irregularities of centralisation and dispersion: cumulative deviations and long-term variations.

Let us consider a_j as the value for the year j of the time series generated for parameter C_n or D_n. Based on these inter-annual series, the cumulative deviations were calculated by adding all the deviations to the mean annual value of all the years preceding the current one:

$$A_n = \sum (a_j - \mu_N); \quad (j = 1, 2, \ldots n; \ n \leq N) \qquad (3)$$

where μ_N is the mean value of the full series. The cumulative deviation detects the net trend of multi-annual sequences.

In order to account for the changes of long-term variability, an 11-year running variation coefficient was calculated and a new series was created. The running variation coefficient is defined as the quotient of the standard deviation σ over the corresponding mean μ of a given sub-series.

$$V_{(11)j} = \sigma_{(j\,,\,j-10)} / \mu_{(j\,,\,j-10)} \qquad (4)$$

Selecting a period of 11 years allows smoothing the extreme values and makes it easier to detect the behaviour of variability in time. This period coincides with the period of sun activity, as an objective reference of the temporal fluctuation of energy input into the world climatic system (Dima *et al.*, 2005; Rodrigo and Trigo 2007; García-Barrón *et al.*, 2011). Obviously, the first term of the moving average series results from the first ten terms of the original series. Likewise, the variation coefficient of the complete series is $V_N = \sigma_N / \mu_N$, where σ_N is the standard deviation and μ_N is the mean value.

The general disparity index I_D is calculated from the deviations between consecutive years, expanded to the entire series obtained for each parameter. Thus, if a_j is a value calculated from a parameter of year j and a_{j+1} is that of the following year and if μ_A is the mean value of the complete series obtained, then:

$$I_D = (\{\Sigma[(a_{j+1} - a_j)^2] / N\text{-}1\}^{1/2}) / \mu_A \qquad (5)$$

The specific disparity index of year j, I_{dj}, is only calculated with the elements $\{a_{j-1}, a_j, a_{j+1}\}$ of the chronological series, with μ_j being the mean value of three consecutive centred elements in j.

$$I_{dj} = (\{[(a_j - a_{j-1})^2 + (a_{j+1} - a_j)^2] / 2\}^{1/2}) / \mu_j \qquad (6)$$

3.3. Relationship between teleconnection patterns and the intra-annual distribution

The present study introduces an innovative and complementary aspect: the analysis of the influence of teleconnection patterns on the intra-annual rainfall distribution. For this purpose, the values of the monthly indices of the NAO and WeMO were related to the annual parameter of intra-annual dispersion in each hydrological basin. The Pearson´s correlation coefficient was used between each of the monthly series of the mentioned indices and the annual series of D_n for the entire period of observation (1941–2010). This relationship implies that parameter D_n is a single value for each year, although it is obtained from the intra-annual rainfall distribution of the corresponding months. Therefore, it is appropriate to analyse the influence of the monthly values of the NAO (and WeMO) indices of each year with the intra-annual rainfall distribution. Thereby, for each index, the analysis offers twelve correlation results, which allows interpretation of the relationship of both types of variables.

4. Results and discussion

For each hydrographic basin, the annual series of rainfall centralisation and intra-annual dispersion were calculated for the period from 1941 to 2010. Section 4.1 shows the general characterisation of the intra-annual rainfall. Section 4.2 includes the analysis of centralisation C_n and its variation in time. Then, in section 4.3 a similar analysis is conducted for intra-annual dispersion D_n. Finally, section 4.4 is dedicated to relating the values of the monthly indices of NAO and WeMO to the annual dispersion in each hydrologic basin.

4.1. General characterisation of the intra-annual distribution

Before showing the analysis of the temporal variability in the following sections, the rainfall characteristics of each basin are presented. Table 2 shows the values and theoretical dates of reference: annual rainfall P_N (mm), centralisation C_N (days) and dispersion D_N (days). These values were obtained from the mean value of the monthly series of rainfall for the study period.

Table 2 around here

A graphic representation of the regimes of intra-annual rainfall in the Spanish basins, calculated for the period 1941 to 2010, is provided in Figure 2. This figure provides combined information of all the characteristics of the intra-annual regime of each basin. Thus, separated from the annual total value, the profile of every basin is represented, with polynomial smoothing of the relative intra-annual distribution. This intra-annual rainfall is determined by the quotient between the mean values of the monthly and annual rainfall, throughout the months of the year. The position of the vertical line indicates the date of centralisation C_N. The length of the double horizontal arrow, centred in C_N, indicates the degree of dispersion D_N and corresponds to the theoretical duration of the dispersion period included in Table 2. It is important to highlight the asymmetric unimodal profile with maximum values at the beginning of winter (December), predominantly in the Atlantic region (Cantabrian, Galicia, Douro, Tagus, Guadiana and Guadalquivir) and the bimodal profile with maximum values in autumn (October) and spring (May), predominantly in the Mediterranean region (South East, Jucar, Ebro and Catalonian).

Fig.2 around here

It is possible to observe, for instance, that the unimodel profile of the Guadalquivir basin is associated with the highest intra-annual concentration (lower dispersion) of all the Spanish basins (D_N =70). This coincides with the lower length of the horizontal segment that indicates $D_{N.}$ In the Atlantic basins, the rainfall proportion of the driest months (July and August) does not reach 3% of the annual rainfall. Also, the basins of the Plateau of the Iberian Peninsula (Douro, Tagus and Guadiana) have similar profiles and close centralisation dates, although with decreasing dispersion from north to south. Moreover, these Spanish basins show softened winter maximum values with respect to other Atlantic basins (Guadalquivir and Galicia). This is considered by the authors of the present study to be due to the effect of continentality, as a result of the blocking of Atlantic fronts by adjacent Portuguese territories (García-Barrón *et al.,* 2010).

The Jucar and southeastern basins show a bimodal profile, with very close centralisation dates, although the Jucar basin presents a greater dispersion of the intra-annual rainfall. The Catalonian basin has an earlier start in autumn compared to the Ebro basin, with a more accentuated deficit of winter rainfall, which involves a great intra-annual dispersion.

4.2. Variability of centralisation

The temporal series of centralisation C_n of each of the Spanish basins was calculated for the period of 1941 to 2010. Table 3 shows the coefficient of the trend line and its corresponding coefficient of determination R^2, the coefficient of variation V_N and the index of general disparity I_D.

Table 3 around here

With the exception of the Cantabrian basin, the linear coefficient of the trend line of centralisation C_n is negative in all the Spanish basins, with a greater descending slope in the Atlantic basins compared to the Mediterranean basins. This would indicate that, during the study period, there was a generalised displacement of the rainy periods toward autumn. However, the R^2 values show that the variance explained by the trend line for the period 1941 to 2010 is below 5% in all the basins (R^2<0.05). Thereby, it is not a useful indicator of temporal forecast (Table 3). The inter-annual irregularity of centralisation was also calculated throughout the analysed period for each basin, through its variability V_N and disparity I_D. The V_N and I_D values are higher in the Mediterranean basins (SE, Jucar and Catalonian). This indicates greater amplitude of the inter-annual oscillations of the annual centralisation date and that, frequently, greater oscillations occur in successive years. Likewise, it is shown that throughout the studied period the highest stability of the centralisation date takes place in the Cantabrian and Galicia basins for the Atlantic region and in the Ebro basin for the Mediterranean area.

The relative cumulative deviations A_n report on the existence of multi-annual sequences of centralisation. In Figure 3, the descending phases (sawtooth) indicate the higher frequency of early annual C_n deviations with respect to the C_N characteristic of the complete period of the corresponding basin; conversely, the ascending phases indicate delay. There is a similar temporal behaviour among the basins of the Iberian Plateau and also among the basins that drain toward the Mediterranean Sea. Without the behaviour being uniform it is possible to detect that, initially, an oscillating or descending phase occurs with a predominance of C_n values below the reference date C_N of each basin. Later on, around 1970, a phase change occurs in all the basins and an ascending interval begins, of variable length, which indicates a displacement of the rainy periods toward spring (C_n>C_N). In a general manner, for the last two decades a new descending phase takes place, which indicates the beginning of a predominant displacement of the rainfall toward autumn (C_n<C_N) in all of the Iberian Peninsula. This finding is in line with those obtained for the seasonal rainfall variability in the south of the Peninsula (Aguilar-Alba, 2007; De Luis *et al.,* 2010; González-Hidalgo *et al.* 2010). The lines of the temporal profile show considerable similarity between bordering basins.

Fig. 3 around here

Moreover, in order to quantify the simultaneity of the inter-annual variability of centralisation C_n among the different basins (Figure 3), Pearson's correlation coefficient was used (Table 4). T-test for correlation significance was also performed for the analysis of the inter-annual simultaneity of the dispersion parameter between the different basins. Correlations bellow 0.2 were not statistically significant and bellow 0.3 they were significant for α=0.05 but not for 0.01.

In addition to the statistical significance, we want to highlight the climatic relevance of the simultaneity between basins when the correlation values are very high (*Pearson's r* > 0.8). The highest simultaneity between the temporal displacements of the annual centralisation date occurs in the Atlantic region, particularly between the basins of the Iberian Plateau (Douro, Tagus and Guadiana) and between these and the bordering basins. This suggests that the seasonal variations of the rainy periods in these basins are the result of analogous synoptic situations. However, the higher stability of C_n in the Cantabrian basin throughout the analysed period does not coincide with the rainy period variability of the rest of the Iberian Peninsula. This allows delimitation of differentiated climatic fields.

Table 4 around here

The high simultaneity of C_n between the Atlantic basin of Guadalquivir and the Mediterranean SE basin may be due, besides their geographic proximity, to the effect of the humid Atlantic winds over areas east of the Strait of Gibraltar. Thus, the largest range of annual rainfall average in Spain takes place in the Andalusian Mediterranean sub-basin (the most western basin of the southwest Iberian Peninsula). In fact, a latitudinal distance of 200 km includes the mountain ranges of Ronda and Grazalema (*36º 46'N, 5º 22'W*), with an annual rainfall above 1800 mm and Tabernas (*37º 04´N, 2º 21´E*), with an annual rainfall below 200 mm.

4.3. Intra-annual dispersion variability

In a similar way to that of the previous section, the characteristics for the dispersion parameter D_n were established for the complete period of 1941 to 2010 in each basin (Table 5). It is observed that the respective temporal series have not a relevant predicting behaviour. The inter-annual irregularity of D_n, calculated from its variability V_N and disparity I_D, for the complete analysed period, shows different characteristics among the different basins. The higher values in the Atlantic basins ($V_N > 0.10$ and $I_D > 0.15$) indicate that intra-annual dispersion is unstable throughout the study period. Furthermore, the north–south ascending latitudinal gradient stands out, both in the basins that drain toward the Atlantic Ocean and in those of the Mediterranean region. The higher values of V_N and I_D in the south of each watershed indicate greater inter-annual oscillations, with years of intra-annual rainfall highly concentrated around the centralisation date, compared to other years with a very disperse distribution. Sometimes, this also occurs with alternation between consecutive years.

Table 5 around here

These D_n values are consistent with those obtained by García Barrón *et al.* (2015), when analysing the *PCI* average in the Spanish hydrographic basins for the same period. These authors state that the south–north gradient of *PCI* is observed in both the Atlantic and the Mediterranean watersheds. The highest frequencies of years with high intra-annual concentration values and marked seasonality are found in the southern areas of the Iberian Peninsula. However, the northern areas show the highest frequency of years with high dispersion throughout the year. There is also a parallelism between both indicators, *PCI* and D_n, when analysing the variability (V_N) and disparity (I_D) in both the Atlantic and Mediterranean basins.

The previous results allow detailed analysis of the temporal irregularities of dispersion D_n in each basin throughout the study period. For this purpose, firstly, the coefficient of variation by periods of 11 years was calculated $V_{(11)}$, the results of which are shown in Figure 4. It is possible to detect the different behaviour of the northern half of the Peninsula (Galicia, Cantabrian, Douro and Tagus) with respect to the southern half, since in the former there is a marked increase in the intra-annual dispersion variability in the last three decades. More specifically, in Galicia (Atlantic watershed) there is a sharp increase of $V_{(11)}$ in 1979, from values around 0.07 to 0.12; a similar behaviour is observed in the Douro and Tagus basins. However, the dispersion variability of the Guadiana basin in the south, throughout the entire analysed period, fluctuates around 0.12. The Guadalquivir basin shows a particular behaviour of large fluctuations of $V_{(11)}$, with values around 0.12 in the 1970s and 0.16 in the 1980s.

Fig. 4 around here

The bimodal profile of the rainfall distribution (concentrated in autumn and spring) in the Mediterranean basins is considered to have an influence on the greater inter-annual stability of the D_n values through the seasonal compensation of the intra-annual displacements. The Mediterranean basins located in the north of the Iberian Peninsula show a positive increase of $V_{(11)}$ in 1979, both in the Ebro basin (0.05 to 0.08) and the Catalonian basin, where from 1980, after reaching a short period of maximum values, $V_{(11)}$ shows a sharp decrease to minimum values at the end of the century. On the other hand, in the more southern Mediterranean basins that discharge (Jucar and SE), $V_{(11)}$ does not show this sharp increase but it rather evolves to a greater uniformity of dispersion, with a decrease throughout the study period.

The analysis of the inter-annual simultaneity of dispersion between different basins reinforces the previous results (Table 6). As in section 4.2, the Student´s T-test was used to determine the significance of the correlation between basins, from which the same criteria derived (*Pearson's* $r > 0.2$, significant $\alpha = 0.05$). Therefore, there is a positive relationship between all the basins, although with different intensity. There is a high correlation (Pearson´s $r > 0.8$) between the Atlantic basins in Portugal (Douro, Tagus and Guadiana), between the bordering basins in the north (Douro and Galicia) and between those in the south (Guadiana and Guadalquivir) of the Iberian Peninsula. This shows that the years of great intra-annual dispersion (or great intra-annual concentration) coincide in time between these basins, which seems to indicate a similar influence on the synoptic situation and the teleconnections of this parameter. In general, the correlation is lower between the basins that drain toward the Mediterranean Sea and the basins that discharge into the Cantabrian Sea. The Cantabrian and Catalonian basins show the lowest simultaneity of intra-annual dispersion compared to the rest of the basins of the Iberian Peninsula, which could indicate a different effect of the synoptic situation due to their geographic location.

Table 6 around here

Finally, the specific disparity index I_{di} was used to expand the analysis of the inter-annual irregularity of dispersion. This provided information about the stability of D_n values in consecutive years for each basin. In order to compare the latitudinal behaviour, two basins were selected, which had similar length (Figure 1) and opposite latitudinal locations (i.e., at the north and south of the Iberian Peninsula: Cantabrian vs Guadalquivir). The Cantabrian basin shows I_{di} values around 0.15 and oscillations of standard deviation $\sigma = 0.07$; on the other hand, the Guadalquivir basin has I_{di} values around 0.25 and oscillations of σ = 0.13. Separately, two basins with opposite longitudinal locations but with comparable latitude were analysed: the Ebro basin, which drains toward the Mediterranean Sea in Spain and the Tagus basin, which discharges into the Atlantic Ocean in Portugal. The Ebro basin shows I_{di} values around 0.11 and oscillations of σ = 0.06; in the Tagus basin it is possible to distinguish a temporal disruption: before 1970 I_{di} values are around 0.16 and oscillations are σ = 0.07 and after 1970 I_{di} values are around 0.25 and oscillations are σ = 0.13. However, between the Ebro and Tagus basins there are analogies of the inter-annual profile, with extreme values coinciding in time. Figure 5 shows the temporal variation of the specific disparity index I_{di} in the basins selected.

Fig. 5 around here

4.4. Relationship with atmospheric circulation patterns

The negative phases of the NAO (from now on: NAO-) are associated with rainy periods due to the entering of hot and humid air masses from the west-southwest into the Iberian Peninsula (Lopez-Bustins *et al.,* 2008; Rodríguez-Puebla and Nieto, 2010; Castro *et al.*, 2011). Therefore, if this happens during the winter months, it intensifies the unimodal character of the intra-annual distribution, which involves a greater rainfall concentration. This leads to low values of dispersion and thus the correlation between the winter NAO- and D_n, is positive. Conversely, if the NAO- takes place at the beginning of autumn or at the end of spring, it produces rains that soften the intra-annual distribution profile and generates high values of dispersion. In such cases the correlation between the variables NAO- of autumn/spring and D_n is negative. The positive phase of the NAO (from now on: NAO+), associated with anticyclone weather in the Atlantic coasts of the Iberian Peninsula, prevents the arrival of low pressure air from the west; this phenomenon is the opposite of that previously described. Table 7 shows the comparison of the correlations between the monthly values of the NAO and the WeMO with the dispersion parameter D_n for each of the basins throughout the study period.

Table 7 around here

The significance of the correlation between dispersion and the monthly values of the NAO and WeMO was also tested by using the T-test (values above 0.23 were considered significant for $\alpha = 0.05$). The results obtained (Table 7) show that the NAO values of December have a positive correlation with dispersion in all the basins of the Iberian Peninsula. The positive correlation of the values of January and February indicate that the NAO affects the intra-annual distribution, mainly that of the Atlantic watershed and the southern Mediterranean region, by delivering rainfall, which consequently reduces dispersion. Therefore, the intensity of the NAO effect on the inter-annual distribution is accentuated during the winter months and is greater in the Atlantic region, although also with relevant levels in the Mediterranean area. It is observed that the NAO influence is weakened longitudinally due to continentality caused by the natural barriers generated by the relief, which restrict the air masses as they cross the Iberian Plateau from the west to the east on their way the Mediterranean basins. The negative correlation values in October in the Atlantic basins mean that dispersion increases, due to the rainfall produced if NAO- occurs during such dates. Given the scarce rainfall during the summer months in a large part of the Iberian Peninsula, the respective values of the correlation coefficient are unimportant.

The NAO has a weak influence on the intra-annual distribution of the Cantabrian watershed. This is due to the barrier effect of the Cantabrian mountain range, which spreads from west to east, preventing the west-southwest winds from discharging rains over the basins of the rivers of this watershed. The rainfall in this area is mainly due to rainy fronts from the north-northwest. The results confirm that the Cantabrian watershed constitutes a climatic field differentiated from the rest of the Iberian Peninsula. In Galicia, the west and north flows have a shared influence that buffers the NAO effect with respect to dispersion. The interpretation of the results obtained is consistent with the conclusions of other studies (Rodríguez-Puebla and Nieto, 2010; Castro *et al.*, 2011; Lorenzo-Lacruz *et al.*, 2011) regarding the influence of the NAO on the total monthly rainfall in the Iberian Peninsula.

Likewise, the WeMO does not exert a great influence on dispersion in the Mediterranean basins (Table 7). The positive WeMO phase (WeMO+) strengthens anticyclones in the southwest of the Peninsula and carries humid west winds from the sea toward the east coast of the Peninsula (Martin-Vide and Lopez-Bustins, 2006). However, the long mountain range parallel to the coast limits its effect on the coastal strip and thus, these flows do not enter the inner areas of the basins. The behaviour of the rainfall mechanisms associated with the Mediterranean dynamics is usually convective and has a greater influence at the local scale. Therefore, when considering the whole of the basin as a geographic unit, the WeMO+ effect is attenuated. The negative WeMO phase (WeMO-), accentuated high pressure at the north of Italy shows the effect that the flows from the northwest have on the Cantabrian area, which significantly affect the intra-annual distribution. Moreover, the negative correlation of the WeMO- values in April with some Atlantic basins suggests that the high pressures in the northern dipole are linked to the easy entrance of low-pressure air masses in the spring from the northwest of the Iberian Peninsula, which increases the intra-annual dispersion.

The results that these teleconnection patterns have on the intra-annual rainfall distribution in the Spanish basins are in line with those obtained via other methods, by the authors previously mentioned in the Introduction section, regarding the rainfall in the Iberian Peninsula.

5. Conclusions

The procedure applied in this article allowed for the precise quantification of the intra-annual rainfall distribution for each year using centralisation C_n and dispersion D_n parameters. This made it possible to generate a temporal series for each basin and detect variability throughout the period observed (1941–2010). Furthermore, spatial relationships were established after comparing the behaviour of both parameters among the hydrographic basins.

There is a remarkable unique feature that takes place in the year 1970, at the centralisation date of all the basins. Around this year, there is a shift in the predominance of autumnal rains ($C_n < C_N$) toward a greater frequency of spring rains ($C_n > C_N$). In the last few decades, after periods of different length in each basin, the process switches.

From the 1970s, there is also a general increase in the inter-annual dispersion D_n variability, which is more accentuated in the Atlantic basins. Moreover, these basins show high inter-annual simultaneity in the inter-annual fluctuation of D_n. Generally speaking, the inter-annual dispersion D_n irregularity also presents a double gradient: longitudinally (Atlantic/Mediterranean) and latitudinally (Cantabrian/Guadalquivir). In the future, it would be interesting to further analyse the internal variability in each basin based on geographic variables (altitude, distance from the sea, latitude and orientation), with the aim of finding a pattern for the spatial behaviour of rainfall by basins in each watershed. However, the same methodology can be applied in those basins of regions or countries where more detailed spatial-temporal databases are available with even more accurate results.

The lack of spatial and temporal evenness in the behaviour of the intra-annual rainfall distribution leads us to associate the results obtained with changes in the patterns of teleconnections and atmospheric circulation. The monthly winter values of the NAO show a marked influence on dispersion, especially in the Atlantic basins. A double gradient is also detected here: decreasing longitudinally from the Atlantic coasts to the Mediterranean coasts and latitudinally from north to south. The intra-annual distribution in the Cantabrian basin is not influenced by the NAO. When considering the entire basin, due to its orography, it is observed that the WeMO values exert little influence on the intra-annual rainfall distribution, even in the basins that drain toward the Mediterranean Sea.

Therefore, the authors of the present study consider that the methodology used is scientifically founded and that it is suitable for determining the variation of the irregularities of intra-annual rainfall distribution. Its application allowed detecting spatial and temporal similarities and differences in the Spanish hydrographic basins.

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Supporting Information

The following supporting information is available as part of the online article:

Table S1. Groups of basins that occupy smaller surface within the great basins of the Iberian Peninsula.

Table S2. Data of average monthly rainfall (mm) from SIMPA for all the basins of the Iberian Peninsula studied during the period (1940-2010).

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Table legends

Table 1. Characteristics of the ten hydrographic basins studied, including their total surface area and the constituent percentages of smaller basins.

Table 2. Characteristic values and dates throughout the period of 1941–2010: annual rainfall (mm), centralisation parameter C_N (days), dispersion parameter D_N (days).

Table 3. Linear trend (Trend), coefficient of linear determination R^2, variation coefficient V_N and general disparity index I_D of the centralisation parameter in the Spanish basins throughout the study period of 1941–2010.

Table 4. Pearson's correlation coefficient of the centralisation parameter C_n among the hydrographic basins throughout the period of 1941–2010.

Table 5. Characterisation of the intra-annual dispersion parameter D_n in the Spanish hydrographic basins throughout the study period of 1941–2010.

Table 6. Pearson´s correlation coefficient of the dispersion parameter D_n among the Spanish hydrographic basins throughout the period of 1941–2010.

Table 7. Pearson´s correlation coefficient between the monthly NAO or WeMO values and the dispersion D_n values for each of the hydrographic basins of the Iberian Peninsula throughout the study period of 1941–2010.

Figure legends

Figure 1. Locations of the ten hydrographic basins into which the study area was divided.

Figure 2. Characterisation of the intra-annual rainfall distribution with centralisation C_N (vertical line) and dispersion D_N (horizontal line) represented.

Figure 3. Cumulative deviations of rainfall centralisation C_n in the Spanish hydrographic basins.

Figure 4. Variation coefficient by periods of 11 years $V_{(11)}$, of rainfall dispersion D_n in the Spanish hydrographic basins.

Figure 5. Comparison of the specific disparity (I_{di}) of dispersion D_n in the hydrographic basins indicated.

Intra-annual rainfall variability in the Spanish hydrographic basins

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The procedure applied in this article allowed for the precise quantification of the intra-annual rainfall distribution for each year using centralisation C_n and dispersion D_n parameters. This made it possible to generate a temporal series for each basin and detect variability throughout the period observed (1941–2010). Furthermore, spatial relationships were established after comparing the behaviour of both parameters among the hydrographic basins.

Table 1

Basin	**Surface area (km^2)**	**Percentage of the constituting basins (%)**	
Cantabrian	25343	Cantabrian	89
		Inner Basque Country	11
Galicia	34056	Miño-Sil	52
		Galician Coast	48
Douro	78859	Douro	100
Tagus	55764	Tagus	100
Guadiana	55468	Guadiana	100
Guadalquivir	69140	Guadalquivir	84
		South Atlantic	16
SE	40128	Andalusian Mediterranean	50
		Segura	50
Jucar	45117	Jucar	100
Ebro	85939	Ebro	100
Catalonian	18047	Inner Catalonian	100

Table 2

	Cantabrian	**Galicia**	**Douro**	**Tagus**	**Guadiana**	**Guadalquivir**	**SE**	**Jucar**	**Ebro**	**Catalonian**
Rainfall	1285	1364	614	636	525	605	439	514	646	708
C_N	174	170	180	176	176	171	170	174	180	171
C_N date	21-I	17-I	27-I	23-I	23-I	18-I	17-I	21-I	27-I	18-I
D_N	88	80	87	81	77	70	77	94	99	103
D_N start date	25-X	29-X	I-XI	3-XI	7-XI	9-XI	1-XI	19-X	20-X	7-X
D_N end date	19-IV	7-IV	24-IV	14-IV	10-IV	29-III	4-IV	24-IV	5-V	2-V

Table 3

	Cantabrian	**Galicia**	**Douro**	**Tagus**	**Guadiana**	**Guadalquivir**	**SE**	**Jucar**	**Ebro**	**Catalonian**
Trend	0.07	-0.05	-0.14	-0.11	-0.12	-0.12	-0.05	-0.00	-0.01	-0.03
R^2	0.02	0.01	0.04	0.02	0.02	0.03	0.00	0.00	0.00	0.00
V_N	0.07	0.07	0.08	0.08	0.09	0.09	0.10	0.10	0.08	0.10
I_D	0.08	0.09	0.10	0.12	0.13	0.12	0.15	0.15	0.11	0.15

Table 4

	Cantabrian	**Galicia**	**Douro**	**Tagus**	**Guadiana**	**Guadalquivir**	**SE**	**Jucar**	**Ebro**
Galicia	0,31								
Douro	0,48	**0,80**							
Tagus	0,42	**0,80**	**0,97**						
Guadiana	0,38	0,74	**0,93**	**0,95**					
Guadalquivir	0,27	0,74	**0,89**	**0,92**	**0,97**				
SE	0,33	0,63	0,74	0,78	**0,88**	**0,90**			
Jucar	0,58	0,32	0,54	0,59	0,56	0,56	0,63		
Ebro	0,47	0,50	0,63	0,63	0,45	0,48	0,34	0,70	
Catalonian	0,40	0,56	0,72	0,73	0,60	0,64	0,55	0,75	**0,88**

Table 5

	Cantabrian	**Galicia**	**Douro**	**Tagus**	**Guadiana**	**Guadalquivir**	**SE**	**Jucar**	**Ebro**	**Catalonian**
Trend	-0.01	0.03	0.02	0.00	0.03	0.04	0.06	-0.04	-0.05	-0.03
R^2	0.00	0.01	0.00	0.00	0.01	0.00	0.03	0.01	0.02	0.01
V_N	0.08	0.11	0.11	0.12	0.13	0.14	0.10	0.08	0.07	0.07
I_D	0.11	0.15	0.15	0.17	0.18	0.19	0.14	0.11	0.09	0.10

Table 6

	Cantabrian	**Galicia**	**Douro**	**Tagus**	**Guadiana**	**Guadalquivir**	**SE**	**Jucar**	**Ebro**
Galicia	0.57								
Douro	0.61	**0.81**							
Tagus	0.47	0.76	**0.90**						
Guadiana	0.38	0.68	0.80	**0.89**					
Guadalquivir	0.35	0.60	0.69	0.80	**0.93**				
SE	0.26	0.18	0.37	0.45	0.56	0.65			
Jucar	0.37	0.29	0.49	0.54	0.53	0.46	0.56		
Ebro	0.64	0.60	0.75	0.68	0.58	0.50	0.27	0.60	
Catalonian	0.33	0.18	0.36	0.35	0.34	0.29	0.30	0.50	0.58

Table 7

Basin	**NAO**											
	Sep	**Oct**	**Nov**	**Dec**	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**
Cantabrian	-0.10	-0.06	-0.04	-0.06	-0.01	0.18	-0.01	0.15	-0.06	-0.22	0.00	0.03
Galicia	-0.23	**-0.27**	0.17	**0.30**	**0.23**	**0.34**	0.02	0.18	0.12	-0.23	-0.24	0.16
Douro	**-0.21**	**-0.24**	**0.26**	**0.38**	**0.27**	**0.47**	0.14	0.18	0.01	-0.14	-0.12	0.22
Tagus	-0.16	-0.19	**0.27**	**0.50**	**0.28**	**0.42**	0.20	0.18	0.11	-0.07	-0.16	0.09
Guadiana	-0.16	-0.17	**0.21**	**0.49**	**0.35**	**0.38**	0.16	0.13	0.04	-0.03	-0.35	-0.02
Guadalquivir	-0.08	-0.20	0.14	**0.50**	**0.38**	**0.39**	0.18	0.12	0.05	0.03	-0.35	0.02
SE	-0.11	0.05	0.01	**0.35**	**0.28**	**0.37**	**0.28**	-0.05	-0.06	-0.03	-0.10	-0.09
Jucar	0.02	0.12	-0.02	**0.23**	**0.25**	0.14	0.04	-0.12	-0.07	0.05	-0.09	-0.07
Ebro	-0.02	-0.01	0.09	**0.25**	0.16	0.22	-0.06	**0.27**	-0.02	-0.10	0.04	0.01
Catalonian	0.10	0.12	0.02	**0.33**	0.01	0.05	-0.02	0.04	-0.08	-0.08	-0.03	-0.02
Basin	**WeMO**											
	Sep	**Oct**	**Nov**	**Dec**	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**
Cantabrian	0.08	0.10	0.24	-0.19	**-0.33**	0.04	-0.06	-0.08	-0.22	0.24	0.09	-0.05
Galicia	-0.06	0.15	0.14	-0.13	-0.06	-0.01	-0.17	**-0.26**	-0.18	0.03	0.10	-0.23
Douro	-0.09	0.16	0.08	-0.12	-0.04	0.06	-0.06	**-0.21**	**-0.24**	-0.09	0.03	-0.24
Tagus	-0.09	0.01	0.09	-0.02	-0.03	0.07	0.04	**-0.21**	-0.17	-0.11	0.04	-0.10
Guadiana	-0.20	-0.12	0.09	-0.02	-0.02	0.10	0.12	-0.14	-0.18	-0.15	0.06	-0.11
Guadalquivir	**-0.25**	-0.18	0.09	0.02	0.02	0.07	0.17	-0.16	-0.21	-0.10	-0.02	-0.08
SE	-0.17	-0.16	**0.21**	0.07	-0.04	-0.01	**0.35**	-0.09	-0.25	-0.04	0.02	0.06
Jucar	-0.11	0.06	0.21	-0.02	0.10	0.06	-0.04	-0.13	-0.10	-0.16	0.17	0.07
Ebro	-0.04	0.18	0.11	-0.14	-0.19	0.18	-0.16	-0.10	-0.09	0.05	0.11	-0.09
Catalonian	0.09	0.13	0.11	-0.03	0.01	0.18	-0.01	0.02	0.05	0.03	0.20	-0.10

Figure 1 (colour)

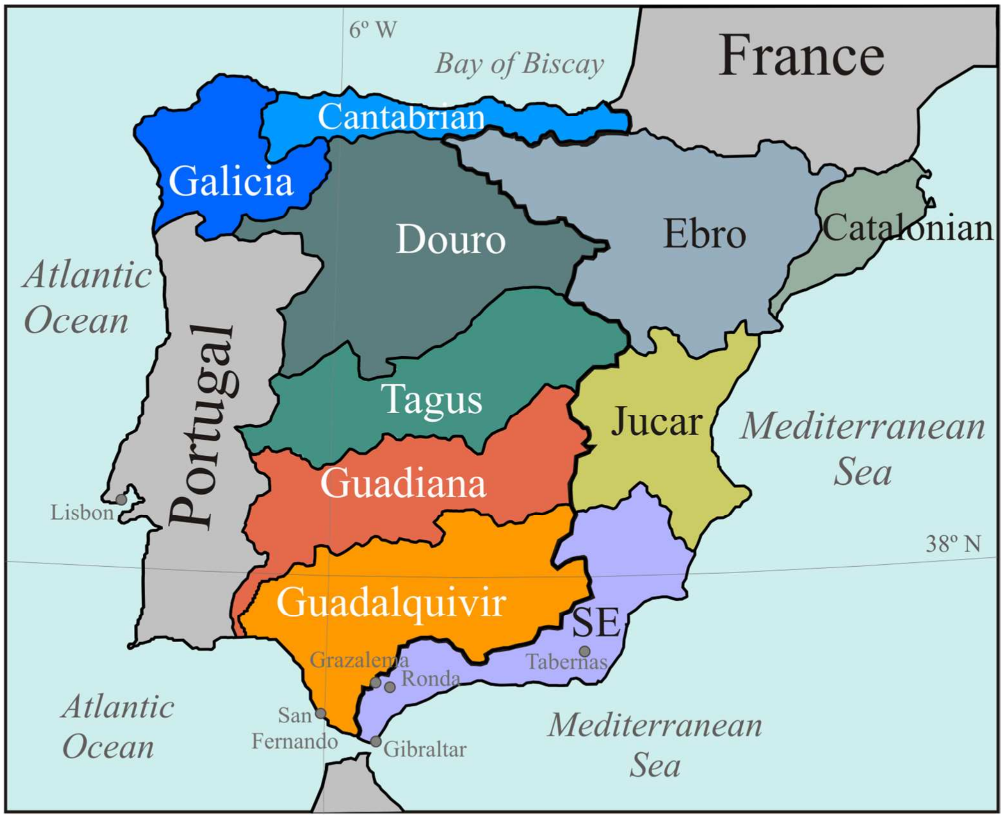

Figure 1. Locations of the ten hydrographic basins into which the study area was divided.

Figure 2

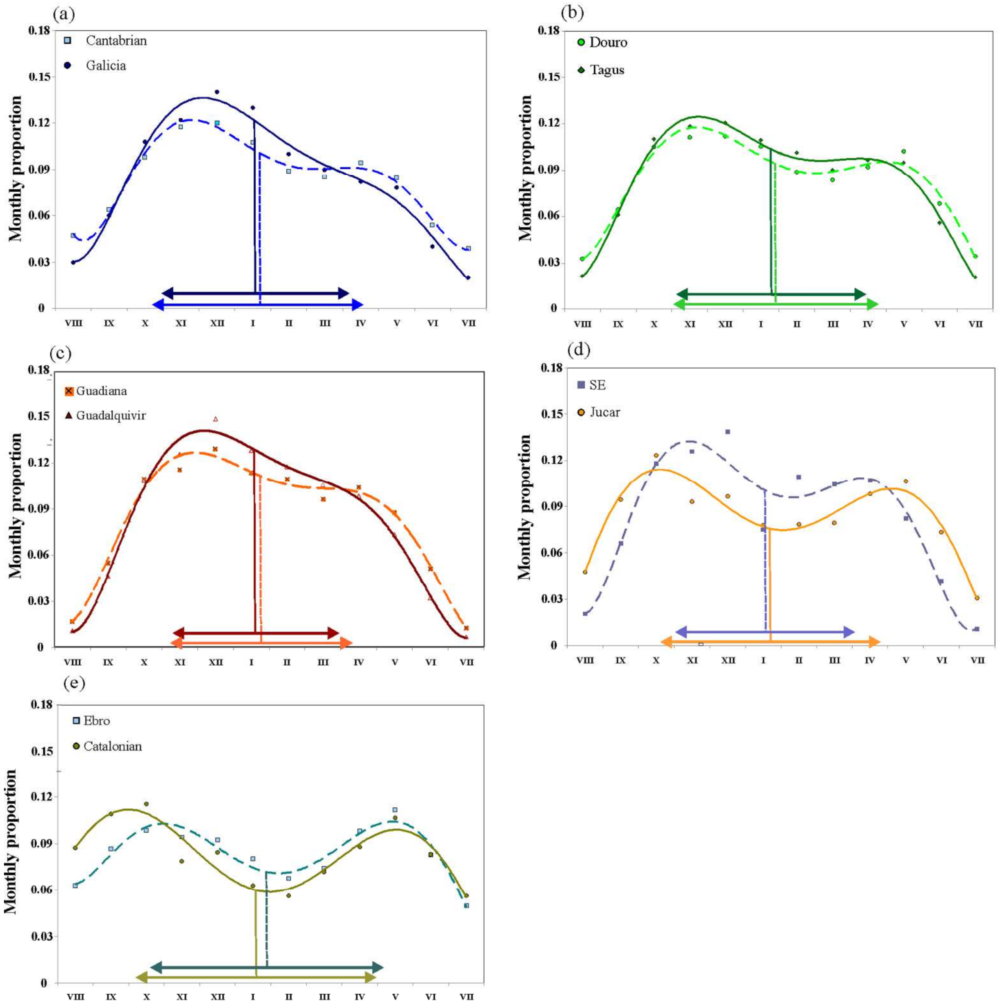

Figure 2. Characterisation of the intra-annual rainfall distribution with centralisation CN (vertical line) and dispersion DN (horizontal line) represented.

Figure 3

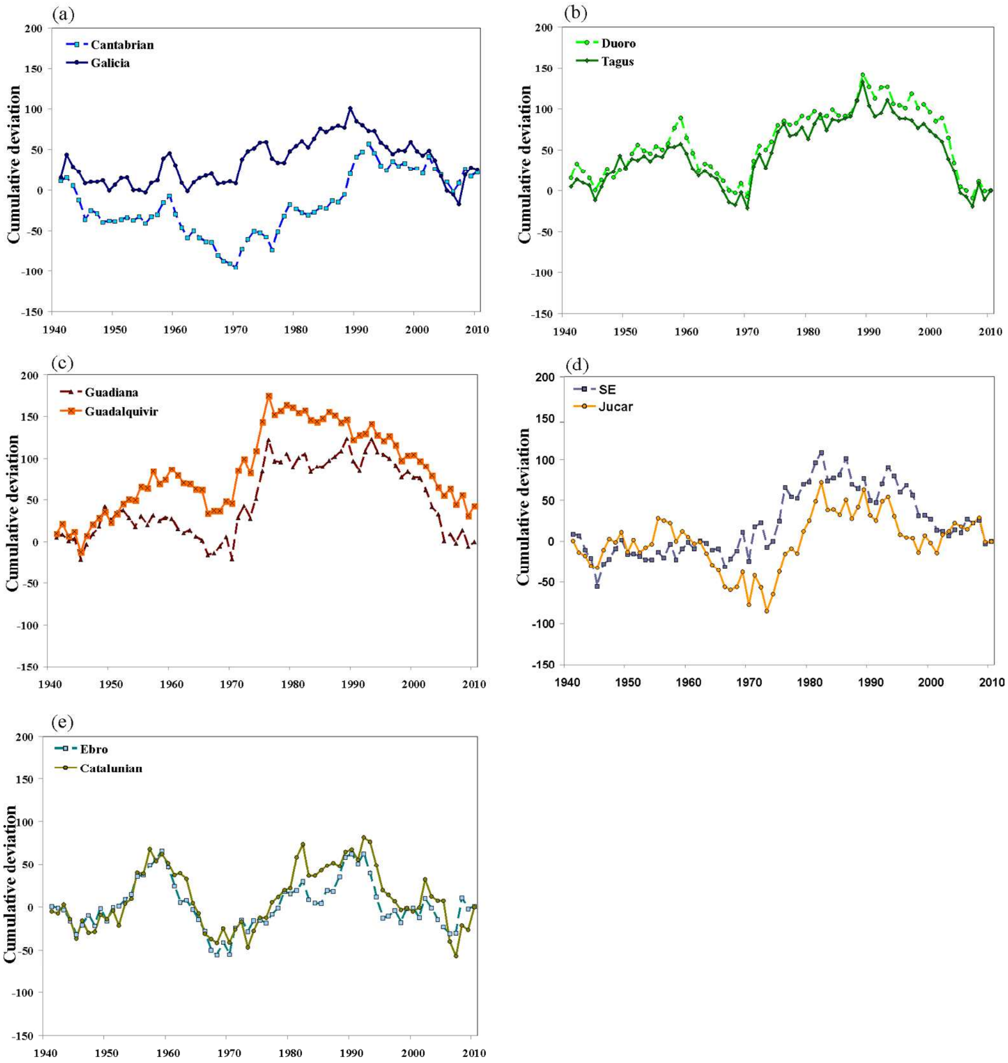

Figure 3. Cumulative deviations of rainfall centralisation Cn in the Spanish hydrographic basins.

Figure 4

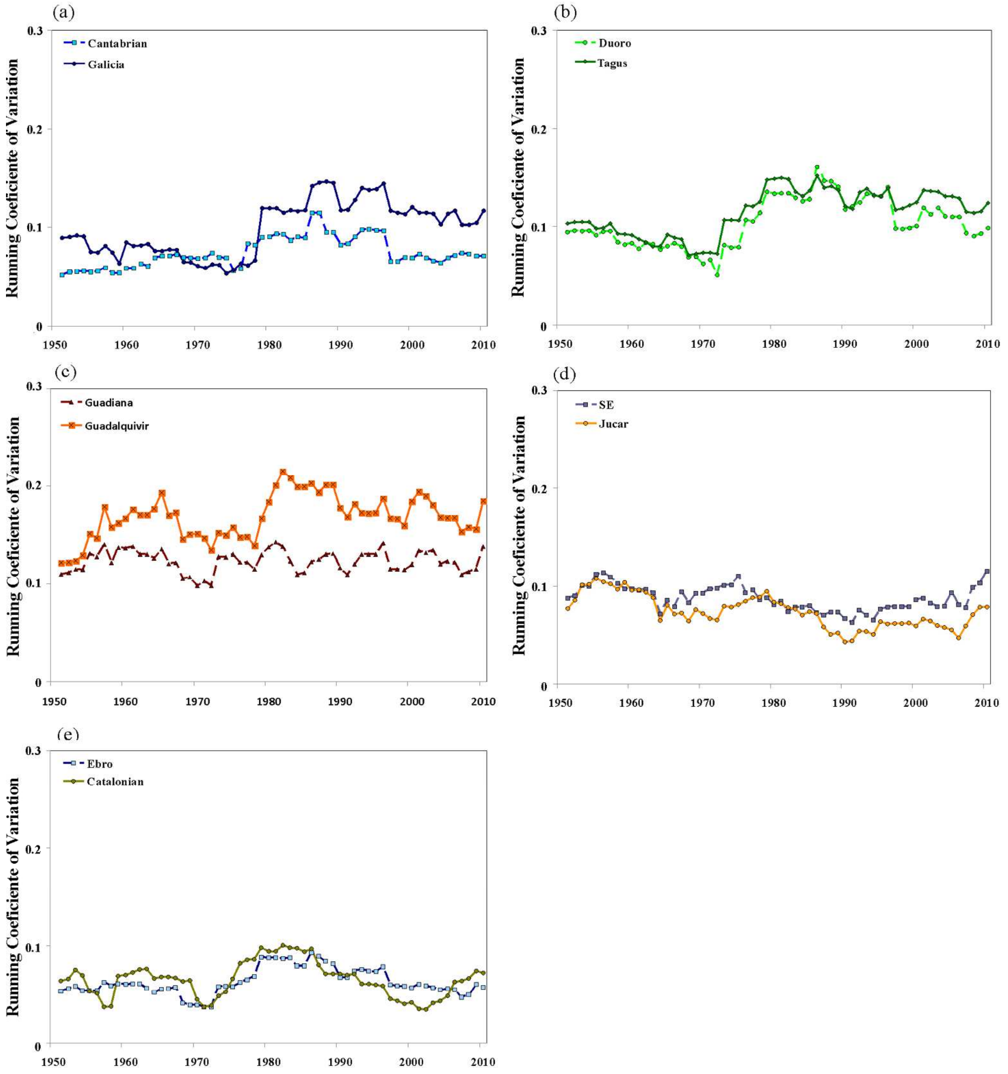

Figure 4. Variation coefficient by periods of 11 years V(11), of rainfall dispersion Dn in the Spanish hydrographic basins.

Figure 5

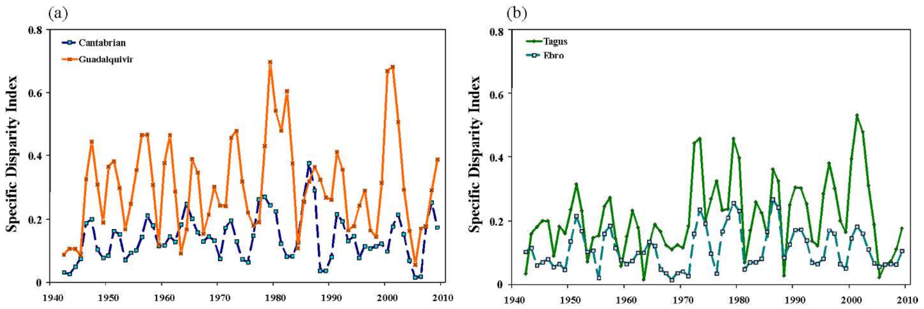

Figure 5. Comparison of the specific disparity (Idi) of dispersion Dn in the hydrographic basins indicated.