Evolution of annual rainfall irregularity in the Southwest of the Iberian Peninsula

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Abstract:

The areas of the Iberian Peninsula with Mediterranean climate are characterized by rainfall irregularity. Standard statistical estimation methods provide a limited insight of all the dimensions of such irregularity. Based on different techniques to describe the inter-annual irregularity of rainfall, the authors develop a new method: the disparity indices. These indices are then applied to several historical rainfall series (dating from the end of the 19th century up to the present) from the Southwest of the Iberian Peninsula. Similar rainfall irregularity pattern are found in all weather stations in the studied area confirming their belonging to the same climatic region. The results indicate a relative stability during the first third of the XXth century coinciding with a period of low precipitation and a progressive increase during the last three decades. The use of a new index named Specific Disparity Index has proved be useful in highlighting the irregularity within the rainfall series at each meteorological station. This new index could contribute to monitor future changes in precipitation within the general framework of research on climate change. Although Mediterranean ecosystems are

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adapted to important fluctuations in the rainfall regime, this increase in irregularity may affect rivers, wetlands and the hygrophytic vegetation.

KEY WORDS Precipitation; rainfall irregularity; variability; disparity index; mediterranean ecosystems; Iberian Peninsula.

1. INTRODUCTION

One of the main characteristics of the rainfall regime in extensive areas of the Iberian Peninsula is the great inter-annual irregularity: years with rainfall far below the mean value contrast with others, sometimes following in consecutive years, with high precipitation values. Additionally, intra-annual variability also exists (García-Barrón 2007): frequently the rainfall of just a few days represents a significant percentage of the total monthly and annual rainfall values (Peñarrocha et al. 2002). The study of this rainfall variability requires a new approach for very detailed description of variability through a considerable number of alternative spread measurements.

Irregularity refers to any changes in the stationarity of climatic phenomena. It has therefore, a broader meaning than variability: whereas variability only measures changes or lack of stability of the variance of a series, irregularity describes any change in the habitual patterns of the meteorological series. Thus, variability is the opposite of homoscedasticity. When analysing meteorological series, irregularity refers to significant changes in the internal organization or evolution pattern (trend, variability or frequency distribution) when considering subsets in a series. A wide range between extreme values and the unusual frequency or persistence of anomalous values in any of the subset series are also indications of irregularity.

To a great extent, the analysis of rainfall irregularity has been linked with a search for signs of climate change. The extensive literature addressing the issue of climatic irregularity in the South of Iberian Peninsula has focused on the analysis of trends, on the annual, seasonal or monthly variability patterns (Pita et al. 1997; Santos et al. 2005; Norrant and Douguédroit 2006; Aguilar 2007) or on the occurrence of extreme events (Manrique and Fernández-Cancio 2000; Rodrigo 2002; Haylock and Goodess 2004;

García et al. 2007; Costa et al. 2008). Other authors have analysed variability related with atmospheric circulation modes (Hurrell 1995; Jones et al. 1997; Rodríguez-Puebla et al. 1998; Rodrigo et al. 2000; Rodrigo and Trigo 2007; Vicente-Serrano and Cuadrat 2007) interpreting the atmospheric mechanisms causing such irregularity (Win-Nielse 2002; De la Torre 2003; Dünkeloh and Jacobeit 2003; Trigo et al. 2004).

Numerous studies have addressed climatic variability (Peterson et al. 2001; González Hidalgo et al. 2003; Vicente-Serrano and Cuadrat-Prats 2007) but very few have pursued the analysis of disparity (Martínez et al. 2007), that we define as the degree of contrast between the rainfall values of consecutive years. The study of disparity is an indicator of inter-annual rainfall irregularity, for which there is a rising interest within the field of climatology both its implications for water resources management and from the perspective of climate change and the consequent increase in the occurrence of extreme events. Although these measurements are not strictly predictive, they can conducive towards the improvement of water management practices along with other climatic information.

Previous research of the authors of this article in the Southwest of the Iberian Peninsula has focused on the analysis of rainfall annual and seasonal trends, highlighting a clear and statistically significant downward trend in springtime precipitation, which amounted to a 30 % reduction in the course of the 20^{th} century (García-Barrón 2002a), especially during the month of March (Aguilar et al. 2006; Aguilar 2007), and may have been the cause of important environmental impacts (Sousa et al. 2006).

Irregularity is also a key factor in decision making and planning, both in agriculture and urban water supply management, introducing risk and uncertainty in forecasting and water assessment. Long term socio-economic planning should be based on the knowledge of climatic time series for extended periods. So far, most of the studies concerning rainfall irregularity in the Mediterranean have been devoted to the analysis of extreme events due to the social and economic impacts of floods and droughts (Pita 1995; García-Barrón 2002b; Vicente-Serrano 2006; Cuadrat et al. 2007). However, only few studies have related rainfall irregularity with its implications for water management and planning (Giansante et al. 2002). Water management and planning require that consideration is given to the pluri-annual periods in rainfall behaviour as the basis for predicting water availability in reservoirs. The goal of this article is to contribute to a better knowledge of such behaviour.

Based on previous research on the identification of trends in precipitation, the overall purpose of this study is to further develop the in-depth analysis of rainfall variability and its temporal evolution for some historical rainfall series from the Southwest of the Iberian Peninsula. For this purpose, the article discusses and applies standard statistical techniques for the description of the temporal evolution of variability and proposes two new indexes that indicate the relative strength of variability in a given lag of time.

Although all the sections in the text are obviously linked together, the results obtained in each of them are consistent separetely when analyzing the precipitation series. For this reason, the results obtained are described and discussed for each of the sections.

Section 2 describes the study area and the meteorological station from which data have been registered. The environmental characteristics of this area are also described enphasizing the possible impacts caused by an increase in rainfall irregularity.

Section 3 provides a statistical description of data and methods used to study the evolution of irregularity, including the definition of two new indices (subsections 3.3 and 3.4). Section 4 the cumulative deviation to the mean is used to define predominantly dry or wet periods and a moving variation coefficient is calculated. In Section 5 a *general disparity index* is introduced and calculated to describe the annual rainfall series through a single value. A particular disparity index to measure the degree of change in the variability over time is obtained (Section 6).

2. STUDY AREA AND DATA

The study area is in the Southwest of the Iberian Peninsula. Only the Iberian Southwestern meteorological stations under Atlantic influence with rainfall data series of over a century were selected for study (Figure 1 and Table1). The records analysed cover the 1882-2005 periods, except for the station in Cordova, whose records started in 1894, and Sao Bras de Alportel in 1901. Therefore, the time scale exceeds one century and the surface cell is approximately 400 x 400 km.

Fig.1 around here

Table 1 around here

The region in which the study area is located is particularly interesting from a climatic point of view for a number of reasons: (1) its transitional position between the mid-latitude and subtropical climates; (2) its position between two continents and two water bodies (the Atlantic Ocean and the Mediterranean Sea) and (3) the complex and diverse topography of the Iberian Peninsula relief, which increases the overall irregularity of the climatic variables. Given the high degree of correlation between the precipitation values of the different observatories of the area, the region can be represented by a single precipitation series. Such series will hereafter be referred to as the Southwestern Series.

The northern part of the Iberian Peninsula was chosen in order to compare the irregularity pattern of the Southwest zone with another climatic area with different rainfall regimes. In the Cantabric area (Bay of Biscay) was four meteorological stations were selected (see Figure 1): Gijon (Asturias), Santander (Cantabria), Bilbao (Vizcaya) and San Sebastian (Guipuzcoa). This group of stations will be called "*North-Atlantic*" and the Southwest observatories "*South-Atlantic*".

2.1. Hydrological systems and natural vegetation

The main ecosystems in this region are highly adapted to irregular precipitation conditions, as it is the case of the most widespread forest trees in the Iberian Peninsula's are mainly evergreen oaks (*Quercus rotundifolia*) and cork oaks (*Quercus suber*) *sensu* Galiano (1987). However, due to the existence all along the SW coast of the Iberian Peninsula of continental wetlands, which are highly sensitive to the rainfall regime, the impacts of climate variability upon these valuable natural systems is of particular interest (Sousa et al. 2009, 2010).

Assessing the environmental effects that could arise as a result of an increase of rainfall irregularity in the SW of the Iberian Peninsula is extremely complex due to the fact that Mediterranean ecosystems are adapted to high annual and seasonal rainfall variability. Within the hydrological system, river courses —that do only exceptionally have large-volume water flows— show a great drainage capacity with a wide but deep talweg. Many wetlands in the area under study are recharge in a rather *epigeal* manner (depending directly on the infiltration of rainfall, runoff water or subsurface water). Less frequent are *hypogeal* water inputs in ponds (depending on water table level) or peat-bogs that infrequently appear in Mediterranean environments. This explains why, in response to past climatic changes (such as the end of the Little Ice Age), each type of wetland in the SW of the Iberian Peninsula has evolved diffently (Sousa and García-Murillo 2003).

On the other hand, during the last few centuries, the number and the length of short seasonal streams on the Spanish Atlantic coast have decreased radically. This process has intensified from the end of the XIXth century caused by rainfall changes and an increase in the erosion processes that has lead to the clogging of these beds (Sousa and García-Murillo 2001). The intensification of rainfall irregularity increases the risk of this phenomenon (even if other climatic factors are exerting their influence simultaneously). It is especially relevant that a similar process is detected in the creeks of the Portuguese Algarve region (Devereux 1982), indicating that this similar process may be affecting, at least, the whole Southwestern European coast.

Vegetation species that predominate in the SW of the Iberian Peninsula, bordering the north of Africa, are those adapted to the conditions of the Mediterranean summer. As pointed out by Rivas-Martínez (1988), in spite of its closeness to the Atlantic Ocean, the Western Andalusian rainfall is markedly Mediterranean, even more so than in the Spanish territories on the Mediterranean Sea coast. To a certain extend, the natural adaptation capacity Mediterranean natural ecosystems prepare them for changes in rainfall irregularity. However, the long-term vegetation show important changes related to water availability indicating that further analysis is required in relation to rainfall and water balance changes.

Woods and shrublands in the Southwest of the Iberian Peninsula, such as cork oak or dense juniper trees have a xerophytic character and, therefore, are adapted to the deficient water balances and to the absence of rainfall during the summer season. However, an increase in irregularity may well affect the natural renovation, regeneration and reproduction processes of these plant communities. Thus, an increase in rainfall irregularity together with global warming may intensify the mobilisation of the sandy layers and, thus, affecting the regeneration of tree species of the European Southwestern coast, such as the cork oak (*Quercus suber*), the savin (*Juniperus phoenicea* subsp. *turbinata*) or the juniper (*Juniperus oxycedrus* subsp. *macrocarpa*). This process has clearly been detected in ancient climatic periods in the same area although at the present time it could be masked by the impact of human activity (Sousa and García-Murillo 2003; Sousa et al. 2006).

2.2. Water resources and demand

Annual renewable (or natural) water resources can be defined as the long-term average freshwater volume supplied naturally by the hydrological cycle, which is the result of total run-off (surface and underground) minus evapotranspiration. To compensate for inter-annual irregularity natural ecosystems accumulate water in the subsoil. However annual renewal rates are also subject to variability. Spatial and temporal variability in rainfall imply that only a portion of these natural resources is actually available at the time and place where it is required. These annual available resources are obviously affected by technological constrains, as well as by socio-economic and institutional considerations. In regions with high climatic variability water management requires the regulation of water flows through a network of reservoirs that store excess resources for their later use and laminate floods. The remarkable variability has historically had important implications for the institutions that must try to manage the irregularity and deal with the risk of water scarcity.

The study area is included within two water basins: the Guadalquivir river Basin *sensu lato* (Cordova, Riotinto San Fernando and Seville) and the Spanish-Portuguese Guadiana river basin (Badajoz). The most important factor in the water resources use and planning of these basins is the prime importance of irrigation agriculture. Although the urban sector demands less water than the irrigation sector, its needs are also critical to planners because they require a guaranteed supply of high quality throughout the year (Giansante et al. 2002). On the coast [San Fernando and Sao Bras] the importance of tourism increases water demand. The Sierra Morena Mountain ranges [Riotinto], is the rainiest area with impermeable soils making it ideal for water storage. This is why this area supplies water to the main cities like Seville and Huelva, and the coast.

2.3. Quality control and homogeneity

Historical rainfall series with less than 5 % of missing values (low number of missing values with respect to the length of the series) were selected (see Table 1). Annual series are obtained starting in the month of September to be associated with the natural progression of the hydrologic seasons. Quality control was performed on monthly data using neighbouring stations before producing the annual series. Data errors and outliers were detected and turned into missing values. Graphical evaluation of the series was also performed to check the coherence of rainfall values in the selected meteorological stations included within this geographical unit.

The gaps in the original series were filled through regression analysis of meteorological stations with the highest correlation and subsequently checked through homogeneity tests.

Absolute and relative homogenity test were then applied to the anual series using the AnClim and Proclim climatic software (Stepanek 2007; Stepanek 2008). The absolute test applied were the Cumulative Deviations test, T-test (Buishand 1982) and Standart Normalized Homogeneity test (SNHT) for single series (Alexandersson 1986). The SNHT relative homogenety test was also applied creating referece series with the neighboring stations. As a result of this process two observatories presented homogeneity problems due to changes in location. On the one hand Badajoz station moved its location in 1985 and was homogenized using the nearby Talavera observatory. The second station with homogeneity problems was Cordova, presenting a single shift inhomogenety when tests for single series was performed. The changing date given by the three tests applied on this series was documented with metadata corresponding to the year 1959 when the meteorological station was moved from the city centre to the airport (Almarza et al. 1996). This series was, thus, adjusted and homogenized following the SNHT procedure. These results were consistent with previous homogeneity analysis performed on the same series (Almarza et al. 1996).

As mentioned before, given the high degree of correlation between the precipitation values of the different observatories of the area, the region can be represented by a single precipitation series referred to as the Southwestern series that was calculated as the mean value of the different observatories. The graphs of only a few series were used as an example to illustrate the results of all the series with a similar pattern.

3. METHODS

Four complementary methods are used to analyse rainfall irregularity. Each of them shows different aspects of this phenomenon and suppose progressive stages in the study of annual precipitation series. Results should not be contradictory as they try to analyze the same feature of rainfall evolution.

3.1. Cumulative rainfall deviations

As the main objective of this study is the characterization of irregularity it is necessary to undertake a temporal analysis. Based on the annual rainfall series the cumulative deviations were calculated adding all the deviations to the mean annual rainfall value of all the years preceding the current one.

$$A_j = \Sigma l_i \ (i = 1, 2, ..., j) \text{ siendo } l_j = (p_j - \mu); \quad (1)$$

Lets l_j be the deviation to the mean of year j; it is then calculated the cumulative deviation Aj from the first year to year j by adding the deviations from the previous years to j.

Standardised values were used to compare the rainfall series, from our working meteorological stations and to generate a mean regional series (Southwestern series) representing the whole area under study.

3.2. Long-term variability

The simplest and most frequently method used to smooth out time series aimed at the identification of long-term fluctuations is to create a new set of data by calculating the running mean of the original values (Burroughs, 1992). Therefore, in order to account for the evolution 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 annual rainfall standard deviation σ over the corresponding mean μ of a given sub-series.

$$C_i = \sigma_{(i\,,\,i\text{-}10)} / \mu_{(i\,,\,i\text{-}10)} \quad (2)$$

The 11-year choice is a reasonable compromise between achieving the desired level of smoothing and providing an effective insight into how the variability behaves, but with the benefit of arithmetic simplicity. The 11-year running variation coefficient series were produced for both the annual rainfall series of each meteorological station and the Southwestern series**.** Obviously the resulting is reduced in the first ten terms.

The selection of the 11-year period to derive the running variation coefficient series has been based on the solar activity period like other authors had done. Although meteorological variability is globally determined by the climatic system interactions, the fluctuation of the incoming energy due to solar activity is an objective relevant factor (Dima et al. 2005; Rodrigo et al. 2007). Furthermore, when analyzing long-term rainfall series, the 11-year period smoothes the annual extreme values allowing the detection of time patterns.

3.3. The measurement of disparity in rainfall. The general disparity index

Two indexes are proposed to assess the inter-annual disparity: the *General Disparity Index* (in this section) measures the disparity between all the elements of the series series, whereas the *Specific Disparity Index* considers each element related to the previous and following ones in the time series. The latter method is described in Subsection 3.4.

In order to calculate the general disparity index, based on a rainfall series of n years, a new series of deviations d_i (i = 1, 2, ..., n-1) of two consecutive years is generated. The General Disparity Index (I_D) is defined as the square root of the addition of the squares of such deviations over the number of years in the series minus one, in turn divided by the mean value of the original rainfall series. As a result, a single value is obtained for each time series. The formula is as follows, where p_i is the rainfall value corresponding to year *"i"* and p_{i+1} is the rainfall value corresponding to the next year:

$$I_D =(\{ \Sigma(p_{i+1} - p_i)^2 / n-1\}^{1/2}) /\mu_p \qquad (3)$$

The index so defined fullfils the following properties for any time series with n elements and different orders (although in climatology the only relevant time series are chronologically ordered):

If the values of the series are constant, the disparity index is null:

$$p_i = p_{i+1} \;, \forall\; i = 1, 2, ..., n-1 \;=>\; I_D = 0 \qquad (4)$$

If the series increases (or decreases) at a constant rate, the disparity index is directly proportional to the increment h between two consecutive years and the proportionality coefficient is inverse to the mean rainfall value of the series.

$$p_{i+1} = p_i + h \;;\; h = \text{const}, \; \forall\, i = 1, 2, ..., n-1 \;\;=>\;\; I_D = h/\mu_p \tag{5}$$

For any given order of a set of elements, if each term p_i differs from p_{i+1} by a random value ε_i (either positive or negative), I_D is lowest when the order of such elements generates an increasing series ($\varepsilon_i \geq 0$) [or to a monotous decreasing series ($\varepsilon_i \leq 0$)].

$$p_{i+1} = p_i + \varepsilon_i \;;\; p_{i+1} \geq p_i \,, \;\; \forall\, i = 1, 2, ..., n-1 \;\;=>\; I_D \equiv I_{Dmin} \tag{6}$$

For any given order of a set of elements, if each term differs from the following one in an random value ε_i (either positive or negative), the disparity index I_D is highest when the order of the elements is such that the sum of the absolute differences between two consecutive years is the highest.

$$p_{i+1} = p_i + \varepsilon_i \;;\; \Sigma_i \left(\left| p_{i+1} - p_i \right| \right)_{max} ; \;\; \forall\, i = 1, 2, ..., n-1 \;\;=>\; I_D \equiv I_{Dmax} \tag{7}$$

The disparity index I_D does not change if the order of the elements is completely changed by moving the first element to the end and vice versa. This is why third property applies both to increasing and decreasing series.

The value of the I_D index is the same for a set of values that follow a "jigsaw pattern" with distances h between the peaks of the curve and a set of values in an increasing or decreasing series with a constant increase h, provided that the mean μ_p is the same.

If the series were truly random, the correlation coefficient between the general disparity index and the variation coefficient of the whole series would reach one. Unlike the general disparity index, the variation coefficient for the entire series, calculated based on the deviation from the mean, does not depend on the chronological order. It should be noticed that General Disparity Index provides information about the series in the real chronological order. If the order is changed the index values are different. Nevertheless, the Coefficient of Variation for the complete series is the same for any chronological order of the precipitation values. As a result, the disparity index characterises the series better than the variation coefficient.

The results obtained from this new General Disparity Index will be compared with other Disparity Index described in literature (Lana and Burgueño 2000; Martín-Vide et al. 2001), to substanciate the difference and contributions of this index.

The approach of other studies cited is to obtain a single value that characterizes rainfall irregularity in each meteorological station for a given period. The aim is to show the spatial distribution of each index. On the contrary, the present study tries to analyze the evolution of rainfall irregularity through time within a region. Therefore, the General Disparity Index does not provide this information so further development is required to achieve this purpose. This is the reason why the Specific Disparity Index is proposed.

3.4. The measurement of disparity in rainfall. Specific disparity index

To improve the accuracy of the General Disparity Index and given the lack of indexes providing information of the temporal evolution of rainfall irregularity, a new index (I_{di}) is proposed – The Specific Disparity Index - to relate the disparity of each element of series with the neighbouring elements. A new series is generated in which each element is the specific disparity index (I_{di}), only referred to the $\{p_{i-1}, p_i, p_{i+1}\}$ element of the series, for $1 < i < n$.

$$D_{di} = \{[\,(p_i - p_{i-1})^2 + (p_{i+1} - p_i)^2\,]\ /2\}^{1/2}\ ;\quad I_{di} = D_{di}\ /\mu_i \qquad (8)$$

where μ_i is the average of the three consecutive elements around i. Hence

$$I_{di} = (\{[(p_i - p_{i-1})^2 + (p_{i+1} - p_i)^2] / 2\}^{1/2}) / \mu_i \quad (9)$$

The Specific Disparity Index has the same properties as previously assigned to the General Disparity Index. It should be noted that when disparity is obtained through the squares of the deviations between consecutive elements, so the deviation sign is irrelevant.

In each meteorological station the Specific Disparity Index is calculated for each year *i* (I_d) generating a new time series of disparity.

4. CUMULATIVE RAINFALL DEVIATIONS

Table 2 show a descriptive summary of the annual rainfall series with the average values and variation coefficient for each meteorological station in the study area.

Table 2 around here

One of the main features of the Mediterranean climate is a marked variability in precipitation patterns. Temporal irregularity has two components: seasonal/intra-annual variability and inter-annual variability. The seasonal variability implies the alternation of a dry season of five to six months, when evaporation exceeds precipitation, and a rainy winter season, which accounts for most of the annual rainfall. The range, persistence and extreme values of inter-annual variability are also extremely high. Torrential precipitation can be extremely intense in most of the area being sometimes over 150-200 mm in twenty-four hours, which represents one-third of the total annual rainfall values (Giansante et al. 2002).

The average annual precipitation values are scarce – generally below 600 mm - for most of the meteorological stations. Only the Riotinto and Sao Bras mean value is higher (Table 2) due to the fact that this stations is located on the Southern hillside of Sierra Morena (Sao Bras is closer to the sea). The orientation of these mountains produces a barrier effect against the humid winds entering the Southwest of the Iberian Peninsula from the Atlantic Ocean. In order to assess the overall variability for each one of the meteorological stations, the variation coefficient was used as a statistical measure of the deviation of a variable from its mean.

In the Iberian Peninsula annual coefficients below 0.2 only occur in the so-called "Green Spain" in the Northern and North-Western part of the Iberian Peninsula under Atlantic influence. Coefficients below 0.3 appear in the Central Plateau and the Douro, Tagus and Ebro river basins whereas values above 0.3 are characteristic of the Mediterranean domain. These geographical differences are consistent with the spatial pattern of daily precipitation described by Martín-Vide (2004) despite the different time scale of analysis.

4.1. Analysis of the cumulative rainfall deviations

Using Equation 2 the cumulative deviation for the Southwestern series is obtained. Figure 2 represents this series from 1885 to 2005. Downward segments between following years indicate that annual rainfall is below the mean. The increase in the number of these segments within an interval identifies dry periods. Rainfall evolution in the Southwest area of the Iberian Peninsula can be described as follows. After the wet period at the end of the XIXth century the beginning of the XXth is dominated by dry years (1898-1934). The second period (1934-1957) begins with low precipitation values reaching a pick in the early 40s. The last period starts with a steep increase in the precipitation values reaching a maximum value in 1970 followed by a gradual decrease until the end available data.

Fig.2 around here

No attempt is being made to identify drought periods or their intensity. Therefore, this is a less stringent method than those used to elaborate the most frequently used drought indexes (Pita, 1995).

If individual rainfall series were analysed a similar pattern would be identify despite the lack of a complete coincidence among the meteorological stations under analysis. The definition of these periods coincides with those described by Aguilar and Pita (1996) for the Spanish Southwest.

4.2. Analysis of the long-term variability

Each year is assigned with a variability number obtained with the Coefficient of Variation calculated with the ten previous values. Figure 3A and B shows the evolution of 11-year running coefficient of variation for (A) San Fernando and Seville and (B) Sao Bras and Riotinto, and their corresponding long-term variability obtained by a polynomial fitting line. Long-term variability values were high at the end of the 19^{th} century and decreased later between 1900 and 1930. Since then the curve has been increasing sharply up to 1950 and more smoothly since the mid 70s. The general pattern described above applies to all the rainfall series and throughout the period, although some difference can be detected. Overall the most interesting feature is the clear increase in variability in the last three decades of the 20^{th} century in all meteorological stations.

Fig.3 around here

Figure 4 shows the results obtained from the six meteorological stations studied together (Badajoz, Cordova, San Fernando, Sao Bras de Alportel, Seville and Riotinto). Thus, the overall variability of the SW area of the Iberian Peninsula can be appreciated by smoothing the extreme anomalies of each station when constructing a single serie.

Fig.4 around here

5. THE DISPARITY IN RAINFALL. THE GENERAL DISPARITY INDEX

The General Disparity Index provides a single value (Equation 3) for each annual rainfall series in each meteorological station. Values of this index are shown in Table 3. A positive association takes place between the values of the variation coefficients in the complete series, as shown in Section 4, and the corresponding general disparity indexes. It should be noted that the variation coefficient is not dependent on the temporal order. It only depends on the deviations of elements from the average. On the other hand, two sets of data with the same elements show different disparities as a result of their relative positions, i.e. as a function of the chronological order of the series. The General Disparity Index is larger than the variation coefficient to the mean minimizes the procedure when the distribution approaches randomness.

Table 3 around here

The annual rainfall irregularity in the Iberian Peninsula has been characterized by several authors. Lana and Burgueño (2000) have elaborated non-dimensional indexes based directly on the addition of the absolute differences between consecutive years of the series, divided by the mean rainfall average and the number of years. A drawback of this method is that different series with the same mean value and the same addition of absolute differences will generate the same value. The general disparity index overcomes this problem by amplifying the effect of irregularity due to the "2nd-level differences". For the same sum of absolute values of the difference between the central element and the lateral ones, d_{ab} and d_{bc}, the disparity index is higher when the difference $|d_{ab} - d_{bc}|$ is higher.

Instead of using the differences of the absolute values of consecutive elements divided by the number of years, Martín-Vide et al. (2001) used the logarithm of the absolute value of the ratios. Nevertheless, this method does not take into account that it assigns equal values to non-comparable transitions like decreasing from 600 mm to 300 mm (half), and increasing from 600 mm to 1200 mm (double). Another indirect method is proposed to asses irregularity based on fractal dimension, the *rescaled range analysis*, associated to the internal dependence of the series. Warning about its generalised application is given as the result is affected by the sample size used in the procedure (Martín-Vide et al. 2001).

There should not be differences between disparity indexes measuring the same phenomenon. A high degree of correspondence (with a correlation coefficient greater than 0,95) is observed between the three indexes, when considering syncronous precipitation series of more than 30 years and from observatories belonging to the same geographical unit. Any of these indexes can be used to compare the irregularity between the different observatories. Although the absolute values of these indexes may not be the same, the spatial distribution of disparity within the same geographical unit is similar no matter which method is used.

As mentioned before, these methods provide a single value for each meteorological station and therefore they are focused on the spatial distribution of rainfall irregularity. Specific Disparity Index is presented in the next section to achieve the main goal of this study: rainfall irregularity evolution.

6. THE DISPARITY IN RAINFALL. SPECIFIC DISPARITY INDEX

The Specific Disparity Index is calculated for each year of the rainfall series in each meteorological station using Equation 9 presented in subsection 3.4. Figure 5 show the evolution of the Specific Disparity Index in Seville-Sao Bras and in Badajoz-Cordova areas. When compared with other variables, the most outstanding characteristic in the graphs is jigsaw evolution of the index and the wide range of variation during short periods of time. However, in the course of a century, an outstanding stability of the mean can be observed. A similar behaviour of the index is also observed within each region. If the XXth century is subdivided into four quarters, the first quarter can be visualised as one with plenty of low-disparity years; the second quarter has plenty of high disparity years; the third has low values again and finally, in the last quarter of the century, both the maximum and minimum increase.

Fig.5 around here

Figure 6A show the disparity index values during the last decades of the XXth century calculated for the series of Seville highlighting a linear growth trend. Unlike the previous decades, a marked growing trend and persistence is observed (continuous line). Figure 6B represents the Southwestern series of annual average values of the index, which is similar to the one from Seville station. It is noteworthy that there is a upward trend in the set of maximum values (dotted line); this justifies 65 % of the internal variance. From this data we can inferred that this permanent growth in irregularity is a characteristic of the rainfall evolution in the South Atlantic area of the Iberian Peninsula, and has not previously been observed with such intensity and duration.

Fig.6 around here

Table 4 shows a summary of the average values and standard deviation of the I_{di} series. For each of the meteorological stations, the average value of the Specific Disparity Index is lower than the corresponding value of the General Disparity Index, although a good association level is maintained. The variation coefficient values in these disparity series are far higher than those in the original rainfall series indicating that the method highlights rainfall irregularity and is suitable for its analysis.

Table 4 around here

The Table 5 showing the correlation coefficients among the series of disparity indexes, that range from 0.5 to 0.7 (relatively low thus indicating that the temporal evolution of the meteorological stations of Southwestern are not fully uniform).

Table 5 around here

In order to compare rainfall irregularity evolution in the Southwest of the Iberian with another climatic zone a group of meteorological stations have been selected from the North of the Iberian Peninsula. A regional "*North-Atlantic*" series was calculated for the period 1975 to 2005 being each year value the mean from the stations rainfall records (Gijon, Santander, Bilbao, San Sebastian). Table 6 and Figure 7 show the differences between the two climatic groups of stations in the Iberian Peninsula (*South-Atlantic* and *North-Atlantic*) in terms of their mean values and Disparity Indices calculated with different procedures from 1950 to 2005.

Table 6 around here

The Specific Disparity Index evolution (Figure 7A) and the 11-year Moving Coefficient of Variation (Figure 7b) are presented for both groups of meteorological stations, "*South-Atlantic*" and "*North-Atlantic*". This Figure 7 clearly shows the higher variability of the Southwest observatories ("*South-Atlantic*") from the North stations of the Iberian Peninsula ("*North-Atlantic*"). Both areas also differ in their temporal evolution, something that had never been concluded in other publications. Figures 7A and 7B show the different values of the Specific Disparity Index and the Coefficient of Variation in the Cantabric area (Bay of Biscay). Figure 7A does not show an increase in irregularity in the last decades, something that is outstanding for the meteorological stations of the Southwest area ("*South-Atlantic*").

Fig.7 around here

7. CONCLUSIONS

This article characterises the rainfall evolution throughout the XXth century in the South Atlantic area of the Iberian Peninsula. The annual rainfall series has been submitted to three methods during the analysis: deviations to the mean, variability and disparity. For each case, new temporal series were generated. The proposed indexes are mutually complementary and should be viewed as consecutive steps in the study of precipitation irregularity. The precipitation cumulative deviation graph is a first easy approach to the analysis of pluviometric disparity, though the main purpose of this technique is to show the temporal distribution of dry and wet spells in the series. The cumulative deviations discriminates changes between dry and wet periods of the annual rainfall series.

The evolution of irregularity was studied by means of the running variation coefficient, calculated for an eleven-year period. The results indicate a relative stability during the first third of the XXth century and a progressive increase during the last three decades. During the first third of the century, the low variability coincides with a period of low precipitation. The most outstanding feature is the increase of the inter-annual rainfall variability in the Southwest of the Iberian Peninsula during the last third of the XX century up to the present.

In order to characterise the irregularity of a series, better results are obtained with the general disparity index calculated with the consecutive terms of the series rather than with the variation coefficient based on the deviations from the mean. Other disparity index proposed by other authors shows high correlation when applied to long series.

These indexes can be used to analyse the spatial distribution of disparity. To this respect, the general disparity index gives insights into the aspects of rainfall irregularity, but is not suited for a diachronic analysis.

The specific disparity index gives more accurate information on the temporal evolution of irregularity in precipitation series and allows making comparisons between different periods of the series. Therefore, the specific disparity index is more suited to dynamic studies. As a result, the general and specific disparity indexes complement each other in temporal and spatial distribution analysis of pluviometric irregularity.

The use of the Specific Disparity Index has proved useful in highlighting the irregularity within the rainfall series at each meteorological station. Disparity is higher between 1925 and 1950, with a continued growth during the last quarter of the XXth century. It therefore seems that the Southwest of the Iberian Peninsula has experienced a progressive increase of rainfall irregularity in terms of its variability and disparity.

Although Mediterranean ecosystems are adapted to important fluctuations in the rainfall regime of these areas, this increase in irregularity may affect rivers, wetlands and the vegetation (in particular hygrophytic vegetation, as well as the regeneration of some xerophytic woody communities). In fact, an important reduction has been detected in the number and length of the seasonal streams of the European Southwest area (Sousa and García-Murillo 2001).

Both the numerical analysis and the observation of the graphs from each one of the meteorological stations confirm this positive trend in rainfall irregularity. If this trend goes on in the future, it is likely that the frequency and length of both wet and dry spells will increase. In conclusion, the new index improves the existing procedures for the analysis of precipitation irregularity and could contribute to monitor future changes in precipitation within the general framework of research on climate change.

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REFERENCES

Aguilar M (2007) Cambios y tendencias recientes en las precipitaciones de Andalucía. In: Sousa A, García-Barrón L, Jurado V (eds) Climate Change in Andalusia: trends and environmental consequences. Consejería de Medio Ambiente de la Junta de Andalucía, Seville, pp 99-116 [Online]. Available: http://www.juntadeandalucia.es/medioambiente/web/Bloques_Tematicos/Educacion_Y_Participacion_Ambiental/Educacion_Ambiental/el_cambio_climatico_en_andalucia/capitulo5.pdf

Aguilar M, Pita MF (1996) Evolución de la variabilidad pluviométrica en Andalucía: su repercusión en la gestión de recursos hídricos. In: Marzol MV, Valladares P (eds) Clima y agua: la gestión de un recurso climático. Tabapress, Madrid, pp. 299-310

Aguilar M, Sánchez E, Pita MF (2006) Tendencia de las precipitaciones en marzo en el sur de la Península Ibérica. In:. Cuadrat JM et al (eds) Publicaciones de la Asociación Española de Climatología (AEC) Serie A 5, Zaragoza, pp 41-51. [Online] Available: http://www.aeclim.org/images/stories/articulos_pdf/Vcongreso/ponencia_cambio_climatico/aguilar%20alba.pdf

Alexandersson H (1986) A homogeneity test applied to precipitation data. J Climatol 6:661-675

Almarza C, López A, Flores C (1996) Homogeneidad y variabilidad de los registros históricos de precipitación en España. Instituto Nacional de Meteorología, Madrid

Buishand. TA (1982) Some methods for testing the homogeneity of rainfall records. J Hydrol 58:11-27

Burroughs WJ (1992) Weather cycles real or imaginary?. Cambridge University Press, Cambridge

Costa AC, Durão R, Pereira MJ, Soares A (2008) Using stochastic space-time models to map extreme precipitation in Southern Portugal. Nat Hazards Earth Syst Sci 8:763-773

Cuadrat JM, Saz M, Vicente-Serrano SM, González-Hidalgo JC (2007) Water resources and precipitation trends in Aragon (Spain). Int J Water Resour Dev 23:107-124

De la Torre L, Gimeno L, Ribera P, Gallego D, García R, Hernández E (2003) Interannual variability of relative angular momentum in the Northern Hemisphere and its relationship with the North Atlantic Oscillation and the Arctic Oscillation. Atmosfera 16:149-156

Devereux CM (1982) Climatic speeds erosion of the Algarve's Valleys. Geographical Magazine 54:10-17

Dima M, Lohmann G, Dima I (2005) Solar-induced and internal climate variability at decadal time scales. Int J Climatol 25:713-733

Dünkeloh A, Jacobeit J (2003) Circulation dynamics of Mediterranean precipitation variability 1948-98. Int J Climatol 23:1843-1866

Galiano EF (1987) Familia Fagaceae. In: Valdés B, Talavera S, Fernández-Galiano E (eds) Flora Vascular de Andalucía Occidental. Ketres, Barcelona, pp. 159-163

García JA, Gallego MC, Serrano A. and Vaquero JM (2007) Trends in Block-Seasonal Extreme Rainfall over the Iberian Peninsula in the Second Half of the Twentieth Century. J Climate 20:113–130

García-Barrón L (2002a) Evolución de las precipitaciones estacionales en el suroeste español; posibles efectos ambientales. In: Guijarro J, Grimalt M, Laita M, Alonso S (eds) Publicaciones de la Asociación Española de Climatología (AEC) Serie A 3, Mallorca, pp 209-218 [Online]. Available: http://www.aeclim.org/images/stories/articulos_pdf/IIIcongreso/ponencia_agua_atmosfera/garcia%20barrn.pdf

García-Barrón L (2002b) Un modèle pour l'analyse de la sécheresse dans les climats mediterranéens. Publication de l'Association Internationale de Climatologie 14:67-73

García-Barrón L (2007) La evolución climática del Suroeste de la Península Ibérica basada en registros instrumentales. In: Sousa A, García-Barrón L, Jurado V (eds) Climate Change in Andalusia: trends and environmental consequences. Consejería de Medio Ambiente de la Junta de Andalucía, Seville, pp 81-95 [Online]. Available: http://www.juntadeandalucia.es/medioambiente/web/Bloques_Tematicos/Educacion_Y_Participacion_Ambiental/Educacion_Ambiental/el_cambio_climatico_en_andalucia/capitulo4.pdf

Giansante C, Aguilar M, Babiano L, Garrido A, Gómez A, Iglesias E, Lise W, Moral L, Pedregal B (2002) Institutional adaptation to changing risk of water scarcity in the Lower Guadalquivir Basin. Nat Resour J 42:521-563

González Hidalgo JC, De Luís M, Raventós J, Sánchez JR (2003) Daily rainfall trend in the Valencia Region of Spain. Theor Appl Climatol 75:117-130

Haylock MR, Goodess CM (2004) Interannual variability of European extreme winter rainfall and links with mean large-scale circulation. Int J Climatol 24:759-776

Hurrel JW (1995) Decadal trends in the North Atlantic Oscillation: regional temperatures and precipitation. Science 269:676-679

Jones PD, Jonsson T, Wheeler D (1997) Extension to the North Atlantic oscillation using early instrumental pressure observations from Gibraltar and south-west Iceland. Int J Climatol 17:1433-1450

Lana X, Burgueño A (2000) Some statistical characteristics of monthly and annual pluviometric irregularity for the Spanish Mediterannean Coast. Theor Appl Climatol 65:79-97

Manrique E, Fernández-Cancio A (2000) Extreme climatic events in dendroclimatic reconstructions from Spain. Clim Change 44:123-138

Martínez MD, Lana X, Burgueño A, Serra C (2007) Spatial and temporal daily rainfall regime in Catalonia (NE Spain) derived from four precipitation indices, years 1950-2000. Int J Climatol 27:123-138

Martín-Vide J (2004) Spatial distribution of a daily precipitation concentration index in peninsular Spain. Int J Climatol 24:959-971

Martín-Vide J, Prom M, Bohigas M, Peña JC, Esteban P, Montserrat D (2001) Índices de irregularidad temporal y dimensión fractal de la precipitación anual en España. In: Pérez-Cueva A, López-Baeza E, Tamayo J (eds) Publicaciones de la Asociación Española de Climatología (AEC) Serie A 2, Valencia, pp 157-166. [Online] Available: http://www.aeclim.org/images/stories/articulos_pdf/IIcongreso/martinvide.pdf

Norrant C, Douguédroit A (2006) Monthly and daily precipitation trends in the Mediterranean (1950–2000). Theor Appl Climatol 83:89-106

Peñarrocha D, Estrela MJ, Millán M (2002) Classification of daily rainfall patterns in a Mediterranean area with extreme intensity levels: the Valencia region. Int J Climatol 22:677-695

Peterson TC, Folland C, Gruza G, Hogg W, Mokssit A, Plummer N (2001) Report on the activities of the Working Group on Climate Change Detection and Related Rapporteurs 1998–2001. WMO, Rep. Geneva

Pita MF (1995) Las sequías: análisis y tratamiento. Consejería de Medio Ambiente de la Junta de Andalucía, Sevilla

Pita MF, Camarillo JM, Aguilar M (1997) L´evolution de la variabilité pluviometrique en Andalousie (Espagne). Publication de l'Association Internationale de Climatologie 10:313-321

Rivas-Martínez S (1988). Bioclimatología, biogeografía y series de vegetación de Andalucía Occidental. Lagascalia 15:91-119

Rodrigo FS (2002) Changes in climate variability and seasonal rainfall extremes: a case study from San Fernando (Spain) 1821-2000. Theor Appl Climatol 72:193-207

Rodrigo FS, Esteban-Parra MJ, Pozo-Vázquez D, Castro-Díez Y (2000) Rainfall variability in Southern Spain on decadal to centennial time scales. Int J Climatol 20:721-732

Rodrigo FS, Trigo RM (2007) Trends in daily rainfall in the Iberian Peninsula from 1951 to 2002. Int J Climatol 27:513-529

Rodríguez-Puebla C, Encinas AH, Nieto S, Garmendia J (1998) Spatial and temporal patterns of annual precipitation variability over the Iberian Peninsula. Int J Climatol 18:299-316

Santos JA, Corte-Real J, Leite SM (2005) Weather regimes and their connection to the winter rainfall in Portugal. Int J Climatol 25:33–50

Sousa A, García-Barrón L, Morales J, García-Murillo P (2006) Post-Little Ice Age warming and desiccation of the continental wetlands of the Aeolian sheet in the Huelva region (SW Spain). Limnetica 25:57-70

Sousa A, García-Murillo P (2001) Can place names be used as indicators of landscape changes? Application to the Doñana Natural Park (Spain). Landscape Ecol 16:391-406

Sousa A, García-Murillo P (2003) Changes in the Wetlands of Andalusia (Doñana Natural Park, SW Spain) at the End of the Little Ice Age. Clim Change 58:193-217

Sousa A, García-Murillo P, Morales J, García-Barrón L (2009) Anthropogenic and natural effects on the coastal lagoons in the southwest of Spain (Doñana National Park). ICES J Mar Sci 66:1508-1514

Sousa A, García-Murillo P, Sahin S, Morales J, García-Barrón L (2010) Wetland place names as indicators of manifestations of recent climate change in SW Spain (Doñana Natural Park). Clim Change. DOI 10.1007/s10584-009-9794-9

Stepanek P (2007) AnClim - software for time series analysis (for Windows). Dept. of Geography, Fac. of Natural Sciences, Masaryk University, Brno. 1.47 MB

Stepanek P (2008) ProClimDB - software for processing climatological datasets. CHMI, regional office Brno

Trigo R, Pozo-Vázquez D, Timothy J, Osborn TJ, Castro-Díez Y, Gámiz-Fortis M, Esteban-Parra MJ (2004) North Atlantic oscillation influence on precipitation, river flow and water resources in the Iberian Peninsula. Int J Climatol 24:925-944

Vicente-Serrano SM (2006) Spatial and temporal analysis of droughts in the Iberian Peninsula (1910–2000). Hydrolog Sci J 51:83-97

Vicente-Serrano SM and Cuadrat-Prats JM (2007) Trends in drought intensity and variability in the middle Ebro valley (NE of the Iberian peninsula) during the second half of the twentieth century. Theor Appl Climatol 88:247-258

Vicente-Serrano SM, Cuadrat J (2007) North Atlantic Oscillation control of droughts in Northeast of Spain: evaluation since A.D. 1600. Clim Change 4:176-191

Win-Nielse A (2002) A note on nonlinear aspect of large-scale atmospheric instabilities. Atmosfera 14:53-68

Legend of the figures

Fig. 1 Map with the location of the meteorological stations used in the study area

Fig. 2 Cumulative deviations of annual rainfall of the Southwestern series

Fig. 3 Evolution of 11-year running coefficient of variation for (A) San Fernando and Seville and (B) Sao Bras and Riotinto, and their corresponding long-term variability obtained by a polynomial fitting line

Fig. 4 Evolution of 11-year running coefficient of variation for Southwestern series obtained by polynomial fitting line method.

Fig. 5 Specific Disparity Index in (a) Seville and Sao Bras and (b) in Badajoz and Cordova areas

Fig. 6 Specific Disparity Index values during the last decades of the XXth century calculated for the series of Seville (a) and the Southwestern series (b). Linear fitting model to the series (continous line), relative maximum values and explained variance.

Fig 7. Rainfall irregularity evolution comparison between the SW area (*South-Atlantic*) and the North area (*North-Atlantic*) of the Iberian Peninsula (A) Moving Variation Coefficient and polynomial fitting (B) Specific Disparity Index and polynomial fitting.

Figure 1

Figure 2

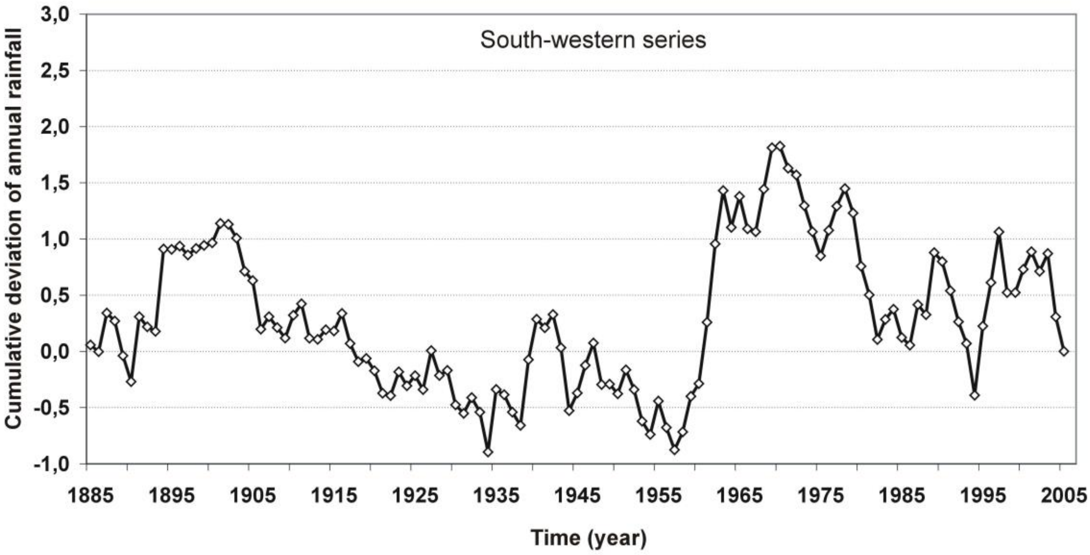


Figure 3

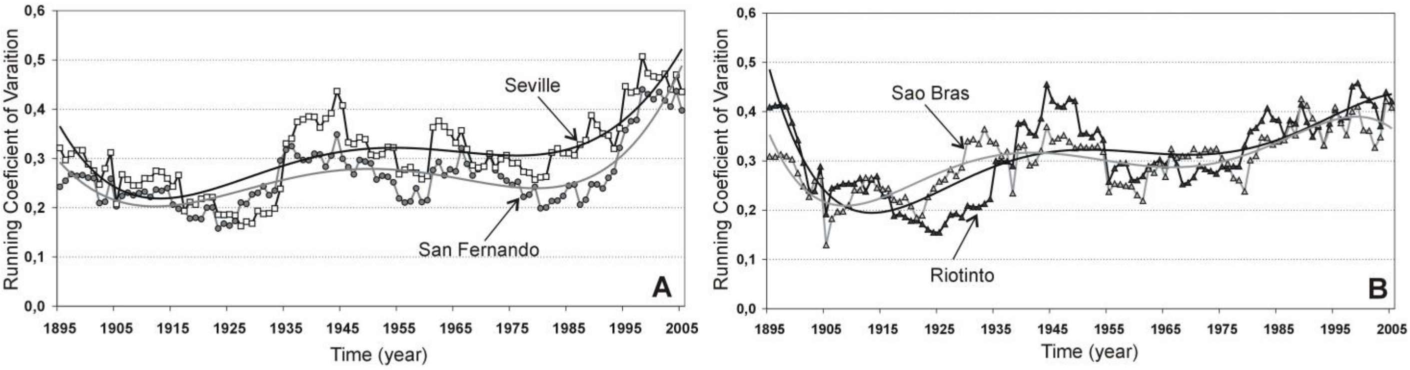


Figure 4

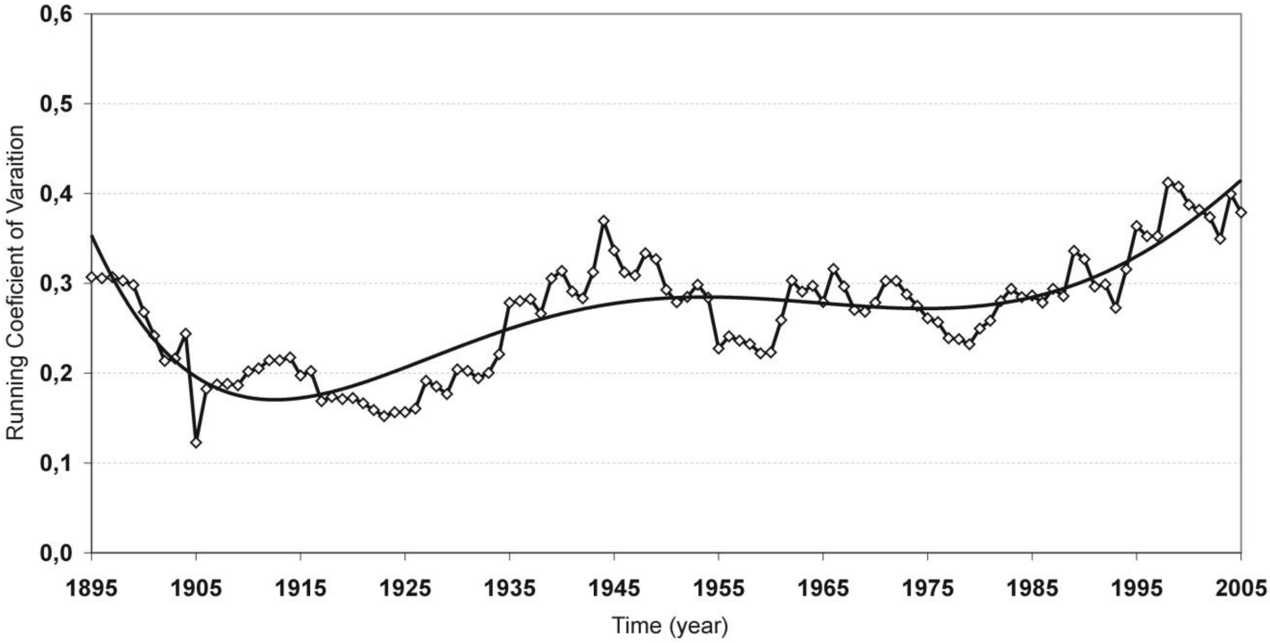


Figure 5

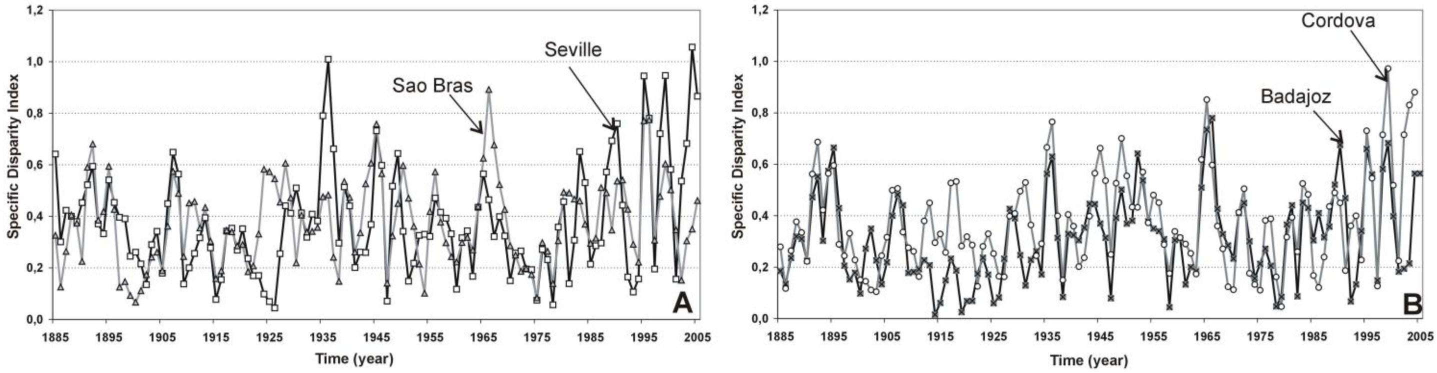


Figure 6

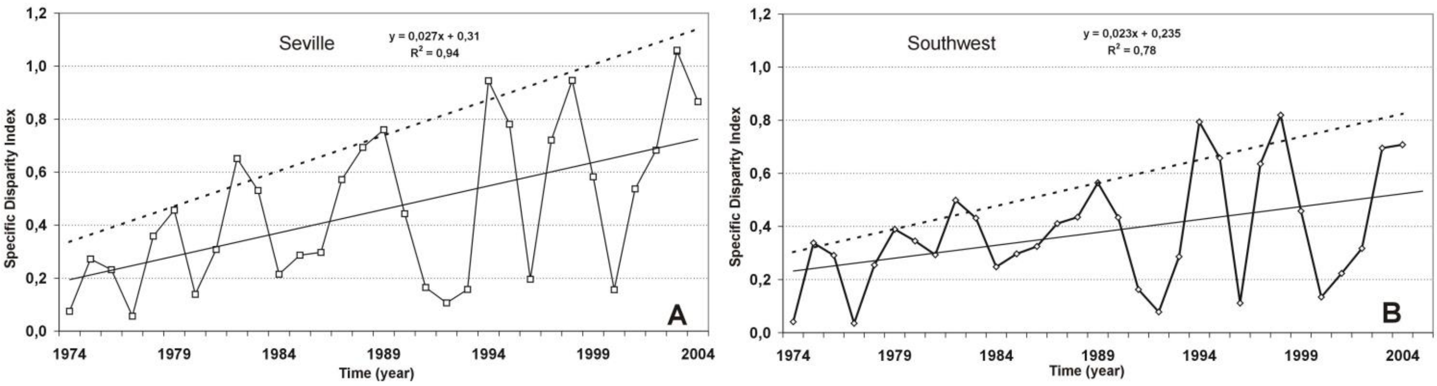
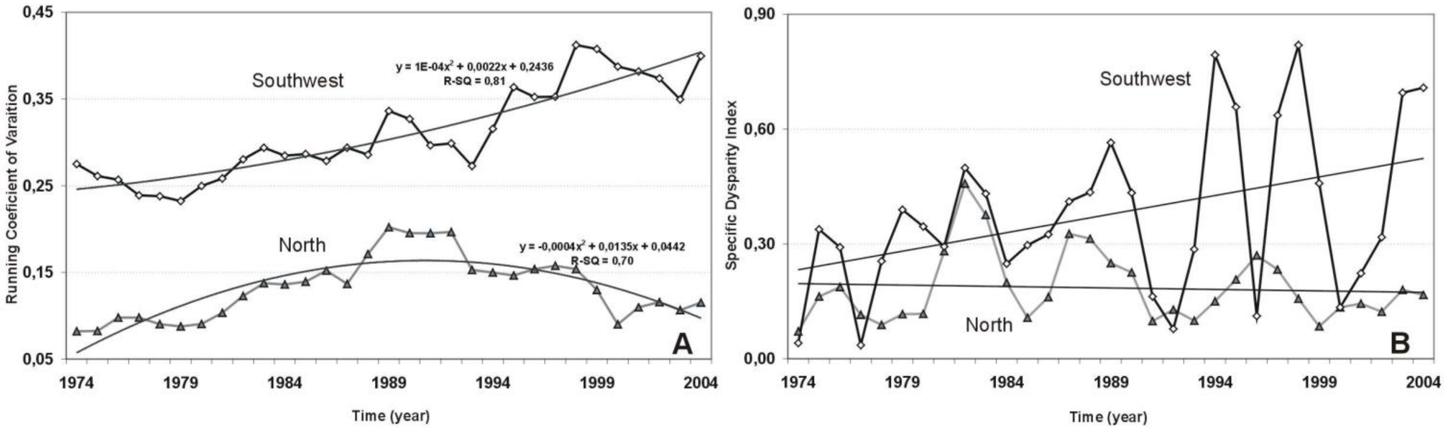


Figure 7



Legend of the tables

Table 1 Geographical coordinates, province, time period and institution responsible of data

Table 2 Mean values (mm) and Variation Coefficient of the annual rainfall series of the Southwest observatories of the Iberian Peninsula

Table 3 General Disparity Index (I_D), index from Lana and Burgueño (2000) and Martín-Vide et al. (2001) of the annual rainfall series of the Southwest observatories of the Iberian Peninsula

Table 4 Statistical characteristics of the annual Specific Disparity Index of the Southwest observatories of the Iberian Peninsula

Table 5 Correlation coefficients among the series of Specific Disparity Indexes of the Southwest observatories of the Iberian Peninsula

Table 6 Rainfall series and General disparity Index comparison between the SW area (*South-Atlantic*) and the North area (*North-Atlantic*) of the Iberian Peninsula (1950-2005)

Table 1

Station	Time period	Province	Longitude	Latitude	Institution	Porcentage of missing values
Southwest of the Iberian Peninsula ("*South-Atlantic*")						
Badajoz	1882-2005	Badajoz	6º 49'45" W	38º 43' 02" N	Spanish National Agency of Meteorology	1.2
Cordova	1894-2005	Cordova	4º 51' 02" W	37º 50' 40" N	Spanish National Agency of Meteorology	0.2
Riotinto	1882-2005	Huelva	6º 36' 17" W	37º 42' 00" N	Riotinto Mining Company	0.0
San Fernando	1882-2005	Cadiz	6º 12' 20" W	36º 27' 56" N	Spanish Navy	2.9
Sao Bras de Alportel	1901-2005	Algarbe	7º 52' 12" W	37º 08' 59"N	Portuguese Institute of Meteorology	4.5
Seville	1882-2005	Seville	6º 00' 30" W	37º 21' 55" N	Spanish National Agency of Meteorology	0.7
North of the Iberian Peninsula ("*North-Atlantic*")						
Bilbao	1950-2005	Vizcaya	2º 54' 21" W	43º 17' 52" N	Spanish National Agency of Meteorology	<1.0
Gijon	1950-2005	Asturias	5º 18' 31" W	43º 32' 18" N	Spanish National Agency of Meteorology	<1.0
San Sebastian	1950-2005	Guipuzcoa	2º 02' 22" W	43º 18' 27" N	Spanish National Agency of Meteorology	<1.0
Santander	1950-2005	Cantabria	3º 49' 10" W	43º 25' 48" N	Spanish National Agency of Meteorology	<1.0

Table 2

	Badajoz	**Cordova**	**Riotinto**	**San Fernando**	**Sao Bras Alportel**	**Seville**
Mean	471.7	640.8	750.6	565.6	820.3	574.4
Variation Coefficient	0.27	0.34	0.32	0.28	0.31	0.32

Table 3

	Badajoz	**Cordova**	**Riotinto**	**San Fernando**	**Sao Bras Alportel**	**Seville**
I_D	0.36	0.42	0.45	0.38	0.42	0.44
Lana and Burgueño (2000) index	0.28	0.33	0.35	0.30	0.34	0.35
Martín-Vide et al. (2001) index	0.28	0.35	0.37	0.32	0.35	0.36

Table 4

	Badajoz	Cordova	Riotinto	San Fernando	Sao Bras Alportel	Seville
Mean	0.31	0.37	0.39	0.33	0.37	0.38
Standard Deviation	0.17	0.19	0.21	0.18	0.17	0.21

Table 5

	Riotinto	San Fernando	Seville	Cordova	Sao Bras Alportel
Badajoz	0.65	0.56	0.58	0.65	0.58
Riotinto	1	0.56	0.61	0.55	0.66
San Fernando	-	1	0.64	0.51	0.59
Seville	-	-	1	0.67	0.50
Cordova	-	-	-	1	0.50

Table 6

	"South-Atlantic"	***"North-Atlantic"***
Mean anual rainfall (mm)	615	1210
Standard Deviation	170	195
Lana and Burgueño (2000) index	0.31	0.16
Martín-Vide et al. (2001) index	0.33	0.16
$\mathbf{I_D}$	0.39	0.19