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A monthly precipitation database for Spain (1851–2008): reconstruction, homogeneity and trends

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Abstract. The compilation and reconstruction of a dataset integrated by 66 long monthly precipitation series, covering mainland Spain and the Balearic Islands, is presented. The reconstruction is based on the hypothesis that the cessation of data recording at one observatory is followed by the establishment of a new observatory very close to the closed one. In order to detect and adjust for possible multiple change points or shifts that could exist in the precipitation series, the R-package CLIMATOL V2.0 is used. This method enables to take advantage of the whole historical Spanish precipitation network in the detection and correction of inhomogeneities. The analysis of annual precipitation trends indicate a high temporal variability. Negative trends dominate for the period 1951–2008 but not for all observatories. On the other hand, positive trends can be detected in the northern Spain for 1902–2008.

1 Introduction

Global warming will likely to cause changes in the hydrological cycle and, hence, in the precipitation. Even if the total amount of precipitation does not change, rainy days frequency and precipitation rates will likely to change (IPCC, 2007). According to model predictions, the precipitation in the Mediterranean region will decrease in response to anthropogenic global warming because of the northward migration of the Hadley cell. In addition, the global climate simulations predict a precipitation reduction for the 21st century. However, a general decrease in precipitation has not been detected in Spain during the 20th century: the large natural interannual variability and the short length of instrumental records impede the detection of possible trends (CLIVAR España, 2011).

There is a clear necessity of a set of long time precipitation series for Spain that extend over the whole 20th century. A statistically robust analysis needs historical precipitation series that can include temporal periods with negligible anthropogenic forcing. The purpose of this study is to extend, revise, improve and update the Spanish monthly/annual centenarian precipitation series in an earlier work at the Spanish Meteorological Agency by Almarza et al. (1996). Historical precipitation series is aimed to obtain in order to achieve more consistent variability and trend analyses. In this paper, a dataset integrated by 66 long monthly precipitation series covering mainland Spain and the Balearic Islands is compiled to allow the research community to use it as a reference for climatic studies, and a preliminary analysis of their trends is performed.

2 Data and reconstruction process

The data used have been extracted from the historical data base of the Spanish Meteorological Agency (AEMET: **A**gencia **E**statal de **MET**erología). The precipitation series stored in the historical data base of AEMET are very irregular, differing in length, missing data amount, beginning and end dates, etc, and therefore they are difficult of analyze in its original form. Nevertheless, they contain enough information to have the possibility of creating a reconstructed database. A single long time series is constructed from a number of shorter series belonging to nearby observatories. The reconstruction is based on the hypothesis that the cessation of data recording at one observatory is followed by the establishment of a new observatory very close to the closed one. If the observatories are very close, the differences in monthly precipitation amounts are usually very small. The reconstructed series is attributed to the last observatory that

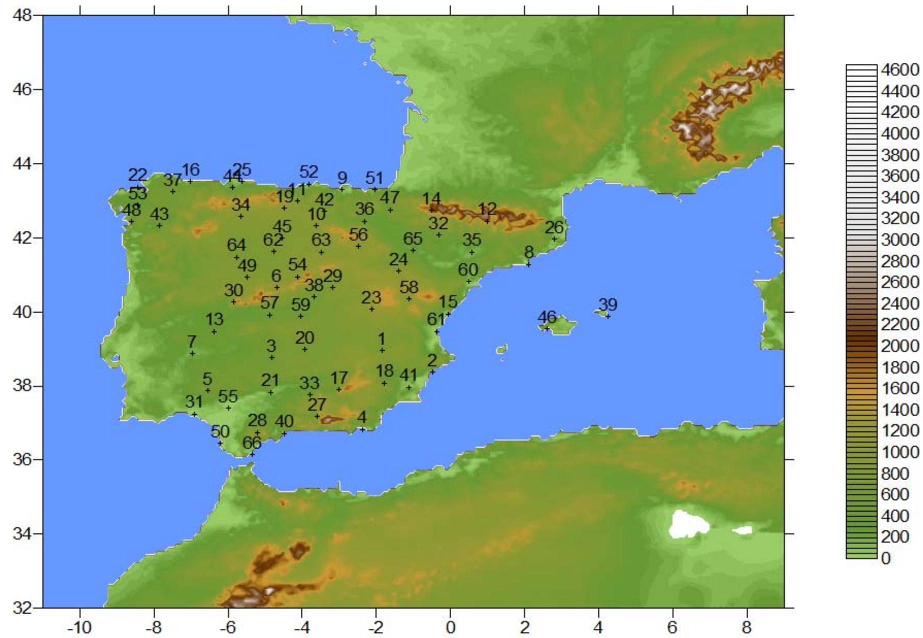

Figure 1. Geographical distribution of the 66 precipitation series in Spain. The orography is displayed.

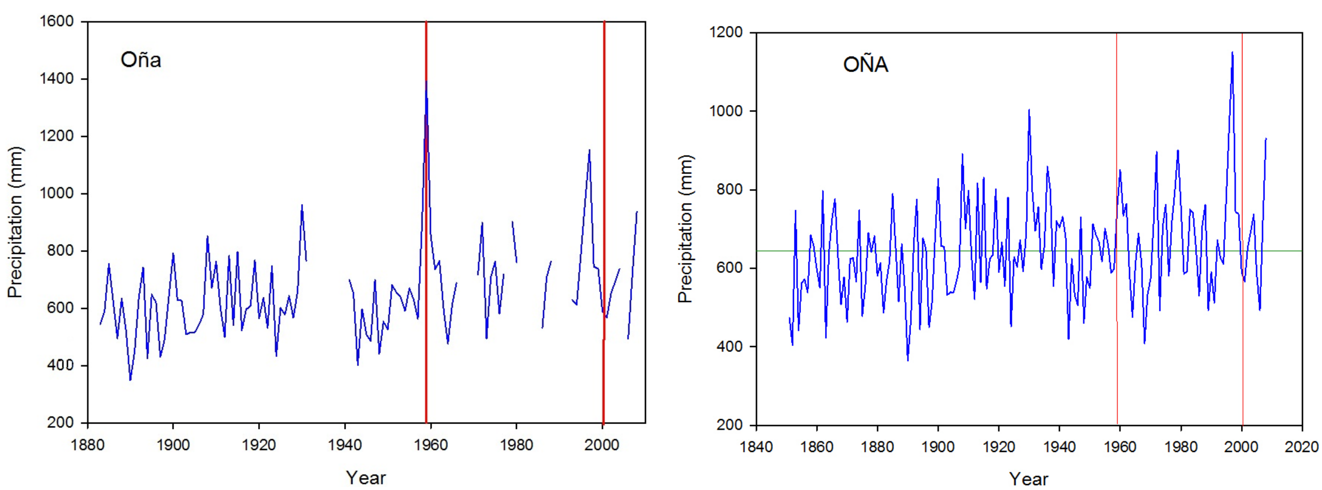

Figure 2. Example of the homogenisation and reconstruction process for Oña observatory (no 42 in Fig. 1). **(a)** Recorded data and the breaks detected in 1959 and 2000. **(b)** Reconstructed time series.

is nowadays working and will be probably working in the future. In this way, 65 series have been reconstructed distributed around the mainland Spain and the Balearic Islands. These time series have records greater than 90 yr and the number of missing values is less than 10 %, most of them during the Spanish civil war. A metadata archive that contains the information about relocations and other technical changes is generated. Figure 1 displays the spatial distribution of the precipitation series and the topography of the studied area, covering peninsular Spain and the Balearic Islands. In this figure, it can be observed that Spain is located between two very different water bodies, the Atlantic Ocean and the Mediterranean Sea, and the mountain ranges are oriented mainly W-E in the western peninsular area and N-S near the eastern coast, making the spatial precipitation patterns highly variable. In this geographical environment, three pluviometric areas have been identified: one in the north-eastern part, another covering the south-western and central area and finally, the area covering the Mediterranean coast and the south-eastern (Morata el al., 2006).

Table 1. Inhomogeneities detected by CLIMATOL package.

NAME	NO BREAKS	DATE 1	DATE 2	DATE 3
OÑA-IBERDUERO	3	2000	1959	1958
PAMPLONA OBSERVATORIO	2	1941	1933	
CIUDAD REAL (ESCUELA DE MAGISTERIO)	2	1880	1872	
GRANADA (BASE AEREA)	2	1939	1938	
BUSTAMANTE PANTANO	2	1994	1989	
LEON (VIRGEN DEL CAMINO)	2	1920	1906	
SAN SEBASTIAN (IGUELDO)	2	1921	1925	
A CORUÑA (ESTACION COMPLETA)	2	1942	1935	
CACERES (CARRETERA TRUJILLO)	2	1914	1910	
OURENSE (GRANXA DEPUTACION)	1	1969		
LINARES DEL ARROYO	1	1962		
AVILA (OBSERVATORIO)	1	1907		
LUGO (COLEXIO FINGOI)	1	1985		
SEGOVIA (OBSERVATORIO)	1	1919		
SEVILLA (AEROPUERTO)	1	1875		
GERRI DE LA SAL	1	1995		
HUELVA (RONDA ESTE)	1	1936		
SALAMANCA (MATACAN)	1	1911		
SANTIAGO COMPOSTELA (LABACOLLA)	1	1929		
ALICANTE (CIUDAD JARDIN)	1	1857		

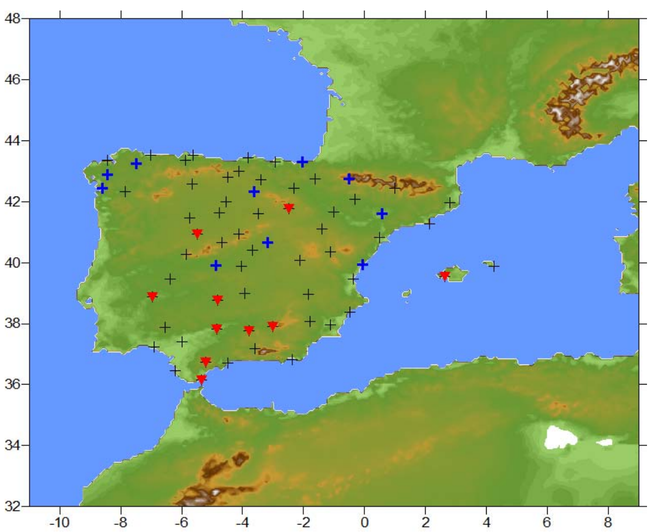

Figure 3. Significative trends for the 1902–2008 period: red triangles (blue crosses) indicate negative (positive) trends.

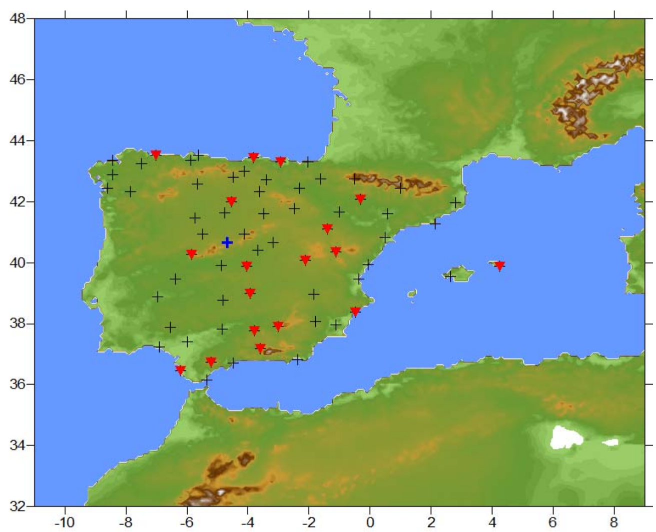

Figure 4. Significative trends for the 1951–2008 period: red triangles (blue crosses) indicate negative (positive) trends.

Data from Gibraltar observatory are included in order to use the information contained in a series that began in the 19th century. The Gibraltar data were obtained from The Global Historical Climatology Network (GHCN-Monthly) database of the Climate Services and Monitoring Division (NOAA).

3 Homogenisation process

Logically, the resulting combined series can exhibit inhomogeneities which must be identified and removed before any further analyses. In order to detect and adjust for possible multiple change points or shifts that could exist in the precipitation series, the R-package CLIMATOL 2.0 (Guijarro, 2011) has been used. This method enables to take advantage of the whole Spanish precipitation network in the detection and correction of inhomogeneities. The homogeneity tests are applied on a difference series between the problem station and a reference series constructed as a weighted average of series from nearby stations. The selection of these stations is only based on proximity in order to use the nearest stations even when no or too short common period of observations compromise the computation of correlation coefficients. This homogenisation methodology involves three steeps: a type II regression (Sokal and Rohlf, 1969), missing data estimation and outlier and break detection and correction (Guijarro, 2011).

The results of the homogenisation process are displayed in Table 1. Only 20 of 66, the 30 %, series have been found inhomogeneous and 9 of them present two breaks. In Oña observatory (in the north of the peninsular area) CLIMATOL detects two very close breaks, maybe due to the missing data. The time series for Oña is displayed in Fig. 2 before and after the reconstruction process as an example.

4 Trend analysis results

The statistical significance of the trends has been obtained for all observatories by the Mann-Kendall statistical test for two different periods: 1902–2008 and 1951–2008. The first temporal period encompasses the whole 20th century and the second one is elected in order to compare the results with similar analysis from different authors. In general, it can be seen in Figs. 3 and 4 that the trend is significant in some sites, but not everywhere. For the 20th century (Fig. 3), there are significant positive trends in the north of the peninsular area and negative ones in the south and the Balearics. These results are in agreement with precipitation variability studies compiled and described in Cuadrat and Martín-Vide (2007). The negative trend detected in Gibraltar, one of the longest records, has been detected by other authors (CLIVAR España, 2011). However, for the second half of the 20th century (Fig. 4), the observed significant trends are negative, except for Avila observatory. This observatory is situated at 1130 m of altitude in the north slope of a mountain chain (Sistema Central) and the positive value could be due to orographic effects. Only 17 of the 66 observatories show significant negative trends. In both time periods, the spatial distribution of the negative or positive trends does not correspond to any Spanish pluviometric area described in Morata el al. (2006).

5 Conclusions

A historical monthly precipitation data base has been constructed by means of CLIMATOL package that provides a useful tool for homogenization and missing value estimation taking into account the whole climatic information available in the historical Spanish climatic database. There is no overall valid significant trend in the historical precipitation series in Spain: it depends on the analysed period.

There is a clear negative trend for the period 1951–2008 consistent with other authors. The 60's and 70's decades were exceptionally rainy and the following dry decades contributed to this negative trend that is not reproducible if centenarian series are analyzed. The historical precipitation dataset created in this work does not exhibit a significant reduction in precipitation amounts. The anthropogenic precipitation signal in this region predicted by climate models (CLIVAR España, 2011) is not detectable in the analysis of this instrumental database.

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