Physics and Chemistry of the Earth 94 (2016) 146–154

Contents lists available at ScienceDirect

Physics and Chemistry of the Earth

journal homepage: www.elsevier.com/locate/pce

Regionalisation of precipitation for the Iberian Peninsula and climate change

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ARTICLE INFO

Article history:
Received 28 February 2015
Received in revised form
4 May 2015
Accepted 22 July 2015
Available online 26 July 2015

Keywords:
Precipitation
Cluster Analysis
Regionalisation
Iberian Peninsula

ABSTRACT

Temporal variability of precipitation over the Iberian Peninsula (IP) has high spatial gradients. Therefore, statistics of the temporal behaviour of precipitation and derived quantities over the IP must be estimated taking into account these spatial gradients. Some statistics can be displayed over a map. However there are statistics, such as Probability Density Functions at each location of the IP, that are impossible to display in a map. Because of this, it is mandatory to reduce the number of degrees of freedom which, in this case, consists of a reduction of the time series representative of the IP domain. In this work, we present a spatial partition of the IP region into areas of similar precipitation. For that, an observed dataset of daily-total precipitation for the years between 1951 and 2003 was used. The land-only high resolution data was obtained on a regular grid with 0.2° resolution in the IP domain. This data was subjected to a k-means Cluster Analysis in order to divide the IP into K regions. The clustering was performed using the squared Euclidean distance. Four clusters of IP grid points, defining 4 IP regions, were identified. The grid points in each region share the same time-varying behaviour which is different from region to region. The annual precipitation discriminates the following regions: (1) north Iberia, (2) a large region extending from the centre to the Mediterranean shores of the IP, (3) a large region ranging from the centre to the western and southwestern shores of the Iberia, and (4) northwest Iberia. The regions obtained for the four seasons of the year are similar. These results are consistent with the thermodynamic characteristics described in the available literature. These Iberian regions were used to assess climate change of seasonal precipitation from the multi-model ensemble of the fifteen simulations provided by the European project ENSEMBLES. Probability Density Functions of annual- and seasonal-total precipitation, consecutive dry days, and total precipitation above the 95th percentile, averaged in each region were estimated for a reference climate (1961–1960), a near-future climate (2021–2050), and a distant-future climate (2069–2098). Climate change projections are based on comparisons of these functions between each future climate and the reference climate.

Finally, we emphasize that: (i) the methodology used here, based on Cluster Analysis, can be used to regionalise other areas of the world, and (ii) the identified regions of the IP can be used to represent the Iberian precipitation by four time series that can be subjected to further analysis, whose results can be presented in a concise manner.

1. Introduction

Precipitation is a key variable in climate studies, with changes in its amount and spatial and temporal distributions having an important impact on both human activities (such as agriculture and drinking water resources), and natural hazards (such as droughts and floods). However, climate changes in precipitation world-wide are not yet well understood, due to their complexity and regional variability (López-Moreno et al., 2009).

This is also true for the Iberian Peninsula (IP), where precipitation has a strong spatial gradient (with several small humid zones generally coinciding with mountainous headwaters (López-Moreno et al., 2008) amid larger dry areas) and a strong seasonal character (Garrido and García, 1992; Serrano et al., 1999). Whereas for autumn, winter and spring, precipitation is mostly due baroclinic synoptic perturbations, moving eastward from Atlantic Ocean; for summer, the precipitation is mostly associated with convective storms due to ground heating, high moisture content,

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http://dx.doi.org/10.1016/j.pce.2015.07.004
1474-7065/

and upper instability (Serrano et al., 1999). This uneven distribution of precipitation over the IP region and throughout the year makes it important to monitor, not only the trends in mean precipitation, but also the trends in extreme precipitation events.

Rodrigo and Trigo (2007) found a general decrease in the daily intensity of rainfall in the IP, without a pronounced change in the number of wet days, from 1951 to 2002. They concluded that there was a decreasing trend in the amount of rainfall during the rainy days. Furthermore, they did not find a significant trend in the extreme precipitation indices, with the exception of a decrease in the 95th percentile in a few of the stations at study. On the other hand, Garcia et al. (2007) focused on the trends in extreme rainfall for 1958–1997 for 35 stations over the IP. The results showed mostly negative trends in winter in all regions except along the southeastern Mediterranean coast. Negative trends were also generally found for spring, with positive trends over the northeast of the IP only. For autumn, positive trends were found over the southwest and negative trends over the northeast. Generally, a tendency toward decreasing seasonal extreme precipitation was found. A study of the changes in the seasonal precipitation over Spain from 1946 to 2005 by De Luis et al. (2009) also found a reduction of rainfall amounts from summer to winter, coupled with an increase in rainfall for autumn. Tapiador et al. (2007) used eight Regional Climate Models (RCM) over Europe, and found that for the future climate (2070–2100), the Iberian Peninsula becomes a drier region, with lower high precipitation monthly amounts. However, Rodríguez-Puebla and Nieto (2010) found that 20th century simulations underestimated precipitation trends (when compared to observations) due to an underestimation of the North Atlantic Oscillation (NAO). They also found a positive trend in the NAO regimes for the 21st century which would lead to a decrease in the winter precipitation over the IP (especially the southern regions) under a warmer climate.

In general, there is still considerable uncertainty when it comes to the impact of climate change on precipitation in the IP. Some statistics (such as Probability Density Functions) that could be used in the study of extreme precipitation events cannot be displayed over a map. In order to overcome this, a reduction of the number of time series representative of the IP domain is necessary. This could be achieved through the definition of regions with similar precipitation.

Several attempts at regionalising the precipitation over the Iberian Peninsula have been recorded in literature, with varying results. In general, three distinct regions have been suggested: northern coastal region (Cantabian coastline), eastern coastal region (Mediterranean coastline) and central-south region, with mountainous areas as boundaries (Fernandez-Mills, 1995; Esteban-Parra et al., 1998; Rodríguez-Puebla et al., 1998; Serrano et al., 1999; Garcia et al., 2002; Muñoz-Díaz and Rodrigo, 2004; Morata et al., 2006; Queralt et al., 2009). The regionalisation can be performed using different techniques, such as cluster and principal component analysis. Muñoz-Díaz and Rodrigo (2004) compared the use of both these techniques in the regionalisation of rainfall over Spain for the period 1912–2000. They concluded that cluster analysis is suitable in establishing spatio-temporal patterns of seasonal rainfall distribution over the region at study.

In this work, a partition of the IP region into areas of similar precipitation is proposed, using cluster analysis. The data set used as well as the clustering method applied in this work are explained in the next section (Section 2), followed by a section presenting and discussing the results obtained (Section 3) and, finally, a section exposing the conclusions reached (Section 4).

2. Data set and methods

2.1. Observed data

Observational data for model validation was obtained for Spain and Portugal at a spatial resolution of 0.2°. The Portuguese dataset (PT02, Belo-Pereira et al., 2011) was created by the Portuguese Institute of Meteorology, and the Spanish dataset (Spain02, Herrera et al. (2012)) was developed by the University of Cantabria, The

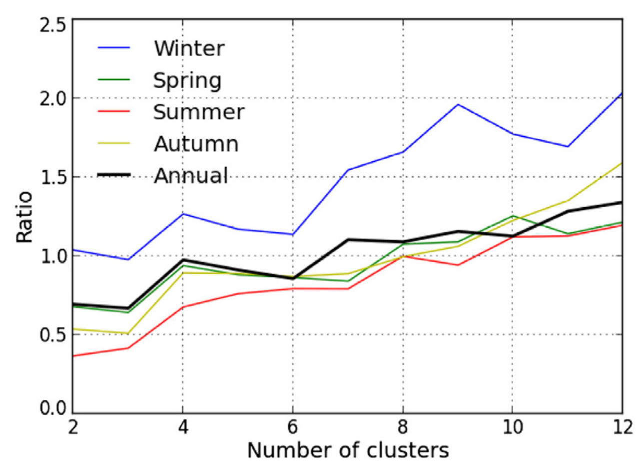

Fig. 1. Pseudo *F*-statistic (ratio) of Calínsky and Harabasz determined from *k*-means cluster analysis of observed daily-total precipitation data, from 1950 to 2003, over the Iberian Peninsula.

Table 1
Simulations, produced by ENSEMBLES' modelling groups, analysed in this work.

Institution	RCM	GCM
C4I	RCA3 (Jones et al., 2004)	HadCM3-Q16 (Gordon et al., 2000)
CNRM	RM5.1 (Radu et al., 2008)	ARPEGE (Gibelin and Déqué, 2003)
DMI	HIRHAM5 (Christensen et al., 1996)	ARPEGE (Gibelin and Déqué, 2003)
		BCM (Furevik et al., 2004)
		ECHAM5-r3 (Roeckner et al., 2003)
ETHZ	CLM (Böhm et al., 2006)	HadCM3-Q0 (Gordon et al., 2000)
ICTP	REGCM3 (Giorgi and Mearns, 1999)	ECHAM5-r3 (Roeckner et al., 2003)
KNMI	RACMO2 (van Meijgaard et al., 2008)	ECHAM5-r3 (Roeckner et al., 2003)
METO-HC	HadRM3-Q0 (Collins et al., 2006)	HadCM3-Q0 (Gordon et al., 2000)
	HadRM3-Q3 (Collins et al., 2006)	HadCM3-Q3 (Gordon et al., 2000)
	HadRM3-Q16 (Collins et al., 2006)	HadCM3-Q16 (Gordon et al., 2000)
MPI-M	REMO (Jacob, 2001)	ECHAM5-r3 (Roeckner et al., 2003)
SMHI	RCA (Kjellström et al., 2005)	BCM (Furevik et al., 2004)
		ECHAM5-r3 (Roeckner et al., 2003)
		HadCM3-Q3 (Gordon et al., 2000)