Atmospheric Research 178–179 (2016) 217–230

Contents lists available at ScienceDirect

Atmospheric Research

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

The influence of weather types on the monthly average maximum and minimum temperatures in the Iberian Peninsula

D. Peña-Angulo [a,b,*], R.M. Trigo [c], N. Cortesi [d], J.C. González-Hidalgo [a,b]

[a] Department of Geography, University of Zaragoza, Zaragoza, Spain
[b] Institute University of Research in Sciences Environmental (IUCA), University of Zaragoza, Zaragoza, Spain
[c] Institute of Geophysics do Infante D. Luiz, University of Lisbon, Portugal
[d] Earth Science Department, Barcelona Supercomputing Center (BSC), Barcelona, Spain

ARTICLE INFO

Article history:
Received 14 December 2015
Received in revised form 17 March 2016
Accepted 21 March 2016
Available online 5 April 2016

Keywords:
Weather types
Lamb's classification
Monthly maximum and minimum temperatures
Iberian Peninsula
Stepwise regression model
Adiabatic process

ABSTRACT

The climate of the Iberian Peninsula is highly variable due to geographic and atmospheric factors. To better understand and characterize this variability in this work a stepwise regression procedure is used to model the relationship between the atmospheric circulation patterns (expressed by weather types) and the monthly mean value of maximum and minimum temperatures in the Iberian Peninsula (1950–2010). The study uses a temperature database with high spatial resolution that allows the estimation of the type and strength of the relationship between weather types and temperatures, and also the definition of spatial areas with specific behaviors for each month. The results show that estimations are better for Tmin than Tmax, during winter months than summer ones, and in coastal areas than inland. The analyses of directional weather types and temperature show a generalized adiabatic processes across Iberian Peninsula affecting Tmax, not detected in Tmin.

Contents

* Corresponding author.
E-mail addresses: dhaispa@gmail.com (D. Peña-Angulo), rmtrigo@fc.ul.pt (R.M. Trigo), nicolacortesi@ymail.com (N. Cortesi), jcgh@unizar.es (J.C. González-Hidalgo).

http://dx.doi.org/10.1016/j.atmosres.2016.03.022

1. Introduction

The use of atmospheric circulation patterns, commonly named Weather Types (WTs), has become standard procedure in the last decades for different purposes because of its advantages to resume the spatial distribution of the continuum of the atmospheric pressure fields into a set of specific patterns. Following this argument, WTs have been associated with numerous processes such as soil erosion (Nadal-Romero et al., 2014), forest fires (Montserrat, 2000), rainfall and floods droughts (Vicente-Serrano and López-Moreno, 2006), extreme temperatures (García-Herrera et al., 2005; Fernández-Montes et al., 2013), and pollution affecting human health (Santurtún et al., 2015), among others. In addition, considering the generalized consensus regarding the reliability with which climate models are able to capture the distribution of pressure fields, studying the relation between WTs and climatic elements (i.e., temperature, rainfall, etc.) can provide relevant information in downscaling processes and in the analysis of the climate change (Ramos et al., 2014).

The classifying processes to obtain the Weather Types (WTs) can be of two types (Philipp et al., 2010): subjective classifications are based on expert's opinions (e.g. Lamb, 1972), while the objective ones are based on techniques such as Principal Component Analysis and clustering strategies (Romero et al., 1999; Esteban et al., 2006), Synoptic Processes Objectives (PSO), iterative algorithms (Fernández et al., 2003), or atmospheric circulation indices. Sometimes, the difference between classification approaches is less obvious, e.g. the subjective classification proposed by Lamb (1972) was adapted to an objective algorithm by Jenkinson and Collison (1977) and improved later by Jones et al. (1993) is of special relevance for its direct physical interpretation and has been widely used in Iberia (Trigo and DaCamara, 2000; Cortesi et al., 2013a; Ramos et al., 2014).

Several previous studies have analyzed the relationships between WTs and the Iberian Peninsula (IP) climate, but most of them have dealt with rainfall data (Azorín Molina and López Bustins, 2004; Paredes et al., 2006; Casado et al., 2010; Garau and Garau, 2012; Fernández-González et al., 2012; Ramos et al., 2014), while studies on temperature data are less frequent (Prieto et al., 2004; Bermejo and Ancell, 2009; Fernández-Montes et al., 2012, 2013). However, these studies have used datasets with low spatial density. Those works that employed higher density datasets have focused at a regional level and with different methodologies, such as studies in the eastern Mediterranean coast (Romero et al., 1999; Miró et al., 2015), in Catalonia (Albentosa Sánchez, 1973), in the Northern Plateau (Calonge Cano, 1984), in the Iberian System (Ortega, 1992), or in the central Pyrenees (Creus Novau, 1983). Up to now, no study has provided a detailed and spatially precise description of the interactions between WTs and temperatures for the IP as a whole using high-density datasets.

This study analyzes the relationship between WTs and monthly average maximum (Tmax) and minimum (Tmin) temperatures in the IP for the period 1951–2010. Using a stepwise regression model, the WTs that best explain the behavior of Tmax and Tmin are selected. In addition, this study analysis as the spatial behavior of temperatures (i.e., how they increase or decrease in different regions of the IP) is influenced by the different WTs. The study was performed using a high-resolution grid (10 $*$ 10 km) of monthly averages of Tmax and Tmin obtained from the MOTEDAS database (González-Hidalgo et al., 2015), which provides an unprecedented high spatial detail for temperatures in the IP.

2. Databases and methods

2.1. Study area

The climate in the IP is influenced by its position in the area of subtropical transition in the European western facade (Lionello, 2012). IP's climate is also affected by its position between the Atlantic Ocean and the Mediterranean Sea, with contrasting characteristics, and by the distribution its main mountain systems, with east–west orientations, dividing the space into three major climatic areas: i) the north coast; ii) the mid-west regions spanning down to the south coast; and iii) the Mediterranean coast (Font Tullot, 1983; Martín and Olcina, 2001) The large interior space is divided into two large units (the North and South Plateaus) with high elevations (values above 600 m over the sea level in the Northern Plateau and around 400 m over the sea level in the Southern Plateau). The relief distribution is a critical element determining the distribution of climate elements, such as rainfalls and its different gradients, as well as spatial differences along the year according as pressure systems evolve with the solar zenith.

Studies of synoptic climatology in the IP indicate that, throughout the year, a sequence of different types of air masses is observed, implying different WTs (Martín and Olcina, 2001). These WTs impact on the temperature distribution, so that the temperature climatology typically exhibits variations in the directions north–south, inland-coast and altitude effects caused by: (1) the north–south distance (circa 1000 km), (2) the position between two contrasting masses of water, and (3) the altitude and distribution of the most relevant mountain ranges. On the other hand, it has been generally accepted that the spatial temperature distribution is less variable than rainfall, although recent studies have shown that the spatial variability can be very high even at distances less than 100 km as has been suggested by Peña-Angulo et al. (2015) and Miró et al. (2015) using different approaches, decorrelation distance decay function (CDD) and statistical downscaling of high spatial resolution respectively.

2.2. Databases

This study uses the high-resolution grid version (10 × 10 km) of the MOTEDAS database published recently (González-Hidalgo et al., 2015). MOTEDAS has been developed after exhaustive quality control and homogenization procedure of the c. 4000 original stations stored at Meteorological Agency from Spain (AEMet) archives. All 4000 series went through a reconstruction step to fill in the gaps and missing data. This process required the use of reference series calculated from selected neighbors not far than 50 km and highly correlated, and finally weighted by inverse distance. From the total amount of reconstructed series, a set of 1358 stations were chosen favoring those with higher percentage of original data and reconstructed by distances was selected to perform a high resolution grid (10 km × 10 km). Then, MOTEDAS grid version consists of 5236 pixels of complete monthly Tmax and Tmin series from 1951 to 201 (Fig. 1a). The grid was complemented with data from 28 stations from the IPMA (Portuguese Institute of Sea and Atmosphere) to which we applied the same quality control process and reconstruction. Given the lower density of information in the Portuguese territory, this data is used in its original location (coordinates of observatories) without including it in the Spanish grid, and it is used to test the spatial coherence between the results in the two countries.

Here, WTs are analyzed using the daily database of surface pressures from NCAR/NCEP, with a spatial resolution of 2° (Kistler et al., 2001). It was chosen because it provides information from 1948 onwards (unlike other reanalyzes datasets often used, but that start later in time, such as ERA-Interim, ERA-40, or MERRA).

The authors are aware that using monthly data instead of daily data presents both advantages and disadvantages. Beyond the first and more intuitive advantage of the higher density available with the monthly precipitation networks, monthly data also reduces the existing uncertainties of the temperature records, given the difficulty of having reliable and homogeneous daily temperature datasets. In our case, each monthly series is complete during all the study period, so station density is constant in time, and homogeneously distributed all over the IP, while for daily series this is often a problematic issue. However, using monthly data has the important disadvantage of masking the