Atmospheric Research 138 (2014) 41–58

Contents lists available at ScienceDirect

Atmospheric Research

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

Circulation types and extreme precipitation days in the Iberian Peninsula in the transition seasons: Spatial links and temporal changes

S. Fernández-Montes [a,*], S. Seubert [b], F.S. Rodrigo [a], D.F. Rasilla Álvarez [c], E. Hertig [b], P. Esteban [d], A. Philipp [b]

[a] Department of Applied Physics, University of Almería, Spain
[b] Institute of Geography, University of Augsburg, Germany
[c] University of Cantabria, Santander, Spain
[d] Snow and Mountain Research Centre, Andorran Research Institute, Principality of Andorra

A R T I C L E   I N F O

Article history:
Received 1 August 2013
Received in revised form 14 October 2013
Accepted 23 October 2013

Keywords:
Iberian Peninsula
Circulation types
Daily extreme precipitation
Within-type changes
Transition seasons
Moisture sources

A B S T R A C T

In the Iberian Peninsula a great amount of precipitation concentrates in relatively few days, primarily conditioned by the atmospheric circulation and the moisture content. This paper investigates the relationship between synoptic circulation types (CTs) and the frequency of precipitation extremes (>90th percentile) in spring and autumn at 44 stations. From 1950 to 2003, in spring, extreme precipitation days diminished in the West and South mainly due to a decreasing frequency of cyclonic Southwest flow. In contrast, in autumn most patterns conducive to extreme precipitation (mainly NW flow) become more frequent, contributing to more extremes at the central and North-western stations. The observed inter-annual variability of extreme precipitation days appears well related with changes in the frequency of the CTs for westernmost Iberia and high altitude stations. In addition, low-frequency changes within the CTs are analysed throughout the 20th Century: they demonstrate that a remaining part of the variability in the frequency of extreme precipitation must be explained by other long-term factors, such as changes in air temperature, in the upper troposphere circulation, and ocean–atmosphere and land–atmosphere processes. In general, the within-type frequency of extreme daily precipitation seems to decrease (increase) in warmer (cooler) periods, except for western and central parts of Iberia under certain CTs. The identification of changes in precipitation extremes, both due to CTs frequency and to other factors, takes advantage of the seasonal basis and the regional responses.

1. Introduction

In the Iberian Peninsula (IP), high precipitation variability and a complex topography yield distinct precipitation and water storage regimes. Different regions are characterised by multiple variants of wet-oceanic, mountainous and semi-arid climates. The greatest hydrological impacts are usually related to droughts, affecting most southern, central and eastern areas (Rodríguez-Puebla et al., 1998; Sousa et al., 2011). In turn, the spatially and temporally irregular rain, together with frequent dry spells, enhances the hazards of heavy rainfalls, such as floods (Olcina Cantos, 1994) or landslides (Trigo et al., 2005). Heavy precipitation events may occur anywhere in Iberia and at any time of the year, but daily intensity and percentiles are higher in winter and autumn, particularly in coastal regions (Acero et al., 2011; Rodrigo, 2010). In the IP, a high fraction of total precipitation falls in relatively extreme days (such us above 90th or 95th percentile, Rodrigo and Trigo, 2007), especially in the transition

* Corresponding author at: Department of Physics and Quemistry - University of Almeria, Carretera de Sacramento s/n. La Cañada de San Urbano, 04120 Almeria, Spain.
E-mail address: soniafm@ual.es (S. Fernández-Montes).

0169-8095/$ – see front matter © 2013 Elsevier B.V. All rights reserved.
http://dx.doi.org/10.1016/j.atmosres.2013.10.018

seasons. Focussing on intense or extreme precipitation days from mid-20th Century, some positive trends have been detected in autumn in SW and NW Iberia and negative in spring, mainly in the South (Rodrigo and Trigo, 2007; López-Moreno et al., 2010; Gallego et al., 2011; Hidalgo-Muñoz et al., 2011; Santos and Fragoso, 2013). For very extreme precipitation events (20-year return values), Acero et al. (2011) obtained positive trends in the East and South, especially in autumn.

Although winter is on average the wettest season in western and central regions of the IP (e.g., De Luis et al., 2010; De Lima et al., 2013), spring and autumn accumulate the bulk of annual precipitation in other areas, e.g., regions to the NE (Ramos, 2001; De Luis et al., 2010; López-Moreno et al., 2010). These transition seasons are essential for the annual water balance. In Spain, De Luis et al. (2010) highlighted a change towards a greater contribution of autumn and lesser of spring and winter to total precipitation in 1975–2004 compared with 1946–74. A reduction of precipitation in spring has important impacts, such as on vegetation and agriculture losses. Besides, drier soil conditions in spring and summer may enhance extreme temperatures (e.g., Fernández-Montes et al., 2013) and the vulnerability to subsequent heavy rainfalls. In addition, precipitation in autumn brings forward the start of the growing season, being crucial in vegetation production in Mediterranean semiarid regions right after summer drought (Cabello et al., 2012).

Despite the marked spatial and temporal variability of precipitation in the IP, it appears largely related to the atmospheric circulation (e.g., Goddess and Jones, 2002; Trigo and DaCamara, 2000; Rodriguez-Puebla et al., 1998; Dünkeloh and Jacobeit, 2003; Corte Real et al., 1998; Muñoz-Díaz and Rodrigo, 2006; Paredes et al., 2006; Hidalgo-Muñoz et al., 2011; Cortesi et al., 2013). Most works linking surface circulation and precipitation focussed in winter (e.g., Goodess and Jones, 2002; Trigo and DaCamara, 2000; Vicent-Serrano and López-Moreno, 2006; Toreti et al., 2010; Fernández-Montes et al., 2012), when mid-latitude atmospheric dynamics is most strengthened. However, also in the transition seasons precipitation totals (Dunkeloh and Jacobeit, 2003; Cortesi et al., 2013) and even precipitation extremes (Seubert et al., 2013) in the IP are largely linked to sea level pressure patterns. Both the Atlantic Ocean and the Mediterranean Sea are main sources of water vapour and cyclone development (Lionello et al., 2006; Gimeno et al., 2010). The mountain chains along Iberia (Fig. 1a) allow orographic ascension of the air, condensation upwind and rain-shadow effect downslope (e.g., Romero et al., 1999; Costa et al., 2010). Therefore, precipitation in western Iberia, open to the prevailing westerly winds and fronts, usually exhibits a closer relationship with atmospheric circulation than the low-lands in the interior, Ebro Valley and Mediterranean coastal regions (e.g., Cortesi et al., 2013), which are less exposed to this Atlantic influence. Besides circulation patterns and orography, thermodynamic conditions (e.g., air–sea temperature gradient, convective processes) are also usually essential for intense precipitation in the transition seasons. Sometimes the trigger factor is found in the mid to high troposphere, such as cut-off lows (COLs) (Nieto et al., 2007a,b) which may reinforce convective instability. Nevertheless, since water vapour concentrates in the low atmosphere, extreme events in east Iberia are also primarily induced by surface pressure anomalies (Romero et al., 1999; Goodess and Jones, 2002; Estrela et al., 2002; Millán et al., 2005a,b; Hidalgo-Muñoz et al., 2011), such as Atlantic depressions entering through the strait of Gibraltar and Alboran Sea, humid easterly flow perpendicular to the orographic slopes, or Mediterranean cyclogenesis itself.

Circulation type (CT) classifications are widely used in climate studies as a tool to simplify daily atmospheric circulation patterns into manageable discrete classes (see, e.g., reviews by Huth et al., 2008; Philipp et al., 2010). Although they are not real atmospheric patterns themselves, CTs are suitable, and therefore are widely applied, to explain precipitation variability in the IP, from seasonal (e.g., Goodess and Jones, 2002, Vicente-Serrano and López-Moreno, 2006, Casado et al., 2010) to monthly (Corte-Real et al., 1998; Trigo and DaCamara, 2000; Cortesi et al., 2013) and daily timescales (Corte-Real et al., 1999; Esteban et al., 2005; Lorenzo et al., 2008). CT classifications are also useful for analysing other meteorological phenomena in the IP, e.g., thunderstorms (Ramos et al., 2011; Pineda et al., 2010). Although a detailed dynamical characterisation of extreme local precipitation can be obtained by classifying circulation fields for just rainy (Romero et al., 1999) or extreme days (Toreti et al., 2010; Hidalgo-Muñoz et al., 2011), that approach needs a small and homogeneous region to define the criteria for extreme days (e.g., one or a few stations exceeding a threshold), which is not the case for the whole IP. To our knowledge, CTs classifications have been applied to extreme precipitation in the IP only for one station (e.g., Lorenzo et al., 2008) or region (Hidalgo-Muñoz et al., 2011), or for winter extreme days (Fernández-Montes et al., 2012). Recently, Hertig et al. (2012) evaluated statistical and dynamical models for the Mediterranean area and concluded that the frequency of extreme precipitation events is better modelled by statistical downscaling whereas the intensity is better captured by the regional model. Therefore, a classification of daily CTs seems more suitable for the frequency than the intensity of extreme precipitation.

Cluster analysis (CA) is probably the most common method to derive classes of circulation (Huth et al., 2008). Clusters of Sea Level pressure (SLP) grids as averages of individual daily patterns should reflect well short-term phenomena, like heavy precipitation (Jacobeit, 2010). In the framework of COST Action 733, comparing different classification methods for modelling precipitation variability across Spain, Casado et al. (2010) showed that SANDRA CA (Philipp et al., 2007) performs as one of the best methods. In this paper we consider CTs for the IP derived by a SANDRA CA applied to SLP fields for all autumn days in 1850–2003 (longest available period), assessing also changes in the period 1950–2003 (shared by precipitation stations). Spring classification is used here from Fernández-Montes et al. (2013), therein studied in relation to extreme temperatures. First we aim to identify those CTs most conducive to extreme local precipitation. Subsequently low-frequency within-type variations (Beck et al., 2007) for each region, season and CT, are studied to quantify the contribution of the CTs to extremes over time, to check the stability of the relationship CTs-precipitation extremes and to discover other physical factors influencing in the long-term. Finally, we check the capability of such simplified synoptic classifications to reproduce the observed inter-annual frequency of extreme precipitation days in 1950–2003.