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Regionalization and susceptibility assessment to daily precipitation extremes in mainland Portugal

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ABSTRACT

The present study aims to identify regions of extreme precipitation in mainland Portugal and to create a single index of extreme precipitation susceptibility (EPSI). For this purpose, twelve extreme precipitation indices were selected from the Expert Team on Climate Change Detection and Indices between 1950 and 2003. By considering only six extreme precipitation indices: R×1day, R×5day, SDII, R20, CWD and R95PTOT for the 10-year return period, between 1950 and 2003, the EPSI was developed to both annual data and meteorological season. The regionalization of extreme precipitation in Portugal were determined using a principal component analysis in T-mode. The results, show three spatial regions obtained from PCA. The three regions were analyzed separate. In the annual EPSI, the highest susceptibility areas are the mountainous regions in northern (e.g. Gerês, Peneda, Alvão, Marão and Montesinho) and central Portugal (e.g. Serra da Estrela), as well as in the Algarve (southern Portugal). Conversely, the lower susceptibility classes are in municipalities of the northeast, Alentejo and along the central-western coast. The results of EPSI show similar results in autumn and winter. In spring, however, the high susceptibility class increases in the Lisbon region and in the Sado Basin. In summer, there is an increase in susceptibility in the northeast, while susceptibility is low over much of Alentejo and Algarve, where precipitation is neglectful. This work presents a first attempt to implement this type of index for mainland Portugal. The first results are very promising, showing a consistent representation of the overall spatial distribution of extreme precipitation susceptibility. The combination of this information by municipalities can be of foremost relevance to civil protection and risk management.

Contents

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1. Introduction

Precipitation extremes may have great impacts on the frequency, intensity and duration of natural hazards, such as droughts, floods or landslides, and may seriously compromise human life, economy, natural ecosystems and agriculture (Song et al., 2015; Sun et al., 2016; Zwiers et al., 2013). The average global temperature increased by approximately 0.85 °C between 1880 and 2012, while mid-latitude land areas of the Northern Hemisphere have showed an overall increase in precipitation (IPCC, 2013; Liu et al., 2017). Klein Tank et al. (2006) showed that precipitation events are projected to be more extreme in the future. Therefore, studies on climate extremes are essential in vulnerability assessments and impact research under future climate change scenarios.

Many recent studies have been conducted in order to detect extreme precipitation trends in different regions of the world (e.g. Bennett & Walsh, 2015; Burić, Luković, Bajat, Kilibarda, & Živković, 2015; Khomsi, Mahe, Tramblay, Sinan, & Snoussi, 2016; Merino et al., 2016; Stephenson et al., 2014; van den Besselaar, Klein Tank, & Buishand, 2013; Westra, Alexander, & Zwiers, 2012; Zhou, Xu, Wu, Dong, & Shi, 2016; Zollo, Rillo, Bucchignani, Montesarchio, & Mercogliano, 2016). In the Iberian Peninsula, several studies on observed precipitation changes were carried out, mainly concentrated on the Mediterranean region (Santos, Corte-Real, Ulbrich, & Palutikof, 2007; Sáez de Cámara, Gangoiti, Alonso, & Iza, 2015). These works showed a reduction in precipitation totals accompanied by a concentration of precipitation in fewer days (e.g. Gonzalez-Hidalgo, Lopez-Bustins, Štepánek, Martin-Vide, & de Luis, 2009; González Hidalgo, De Luís, Raventós, & Sánchez, 2003; Hidalgo-Muñoz, Argüeso, Gámiz-Fortis, Esteban-Parra, & Castro-Díez, 2011; Martin-Vide, 2004; Martínez, Lana, Burgueño, & Serra, 2007; Millán, Estrela, & Miró, 2005; Vicente-Serrano & Beguería-Portugués, 2003). For Portugal and for the 1941–2007 period, Lima, Santo, Ramos, and Trigo (2015) reported predominant downward trends in the extreme precipitation indices, but in most of them no statistically significant trends are identified. Nevertheless, several episodes of heavy precipitation have triggered floods and landslides and caused severe damages (Fragoso et al., 2015; Zêzere et al., 2014).

In Portugal, between 1865 and 2010, floods caused 1.012 deaths, 478 injured, 13.372 displaced and 40.283 homeless people. Examples of remarkable disasters occurred on 25 November 1967 in the Lisbon region, when 522 people were killed (Pereira, Zêzere, Quaresma, Santos, & Santos, 2016; Trigo et al., 2016) or on the second half of December 1909, when an exceptional rainfall period was responsible for 35 death people in the north and central Portugal (Pereira, Ramos, Zêzere, Trigo, & Vaquero, 2016).

In addition, Melo-Gonçalves, Rocha, and Santos (2016) evaluated the climate change projections of the Iberian daily-total precipitation for near-future (2021–2050) and distant-future (2069–2098) climates, with respect to a recent past climate (1961–1990). This work showed a decrease in annual precipitation over the entire peninsula, particularly in the north and northwest, where it can decrease to 400 mm by the mid-21st century, except in winter. The number of consecutive dry days (CDD) are projected to increase, in the summer and spring, until the mid-21st century throughout the peninsula, reaching more than three weeks in the southwest. For the maximum 5-day consecutive precipitation (R×5day), a decrease is projected to occur during spring and autumn over most of the peninsula, and during summer in northern Iberia. The very wet days (R95) should decrease around 20% in summer over northern Iberia, and around 15% in autumn over the south-southwest. The combined effect of these projections will potentially aggravate the constraints of water resources management in Portugal, because of the decrease in the river flows and extraction of ground water during a more extended dry season.

In the context of the environmental and societal implications of the above-identified projections and trends, it is critical to regionalize the territory in terms of precipitation extremes. In this study, we apply a multivariate statistical technique aiming at creating a single index to regionalize precipitation extremes in Portugal, as there are no previous studies with such a purpose. This approach allows defining spatially similar areas for climate change research or for providing guidelines to civil protection systems. Hence, our purposes are three: 1) to identify regions of extreme precipitation in mainland Portugal; 2) to create a single index of extreme precipitation susceptibility (EPSI) and 3) to analyze the relationship between the EPSI regionalization and the spatial distribution of disastrous hydro-geomorphological events (floods and landslides) in mainland Portugal (Zêzere et al., 2014).

2. Materials

2.1. Study area

Mainland Portugal is located in the transitional region between the sub-tropical anticyclonic and the sub-polar cyclonic belts, among the latitudes of 36° 56′ and 42° 09′ N and the longitudes of 6° 10′ and 9° 34′ W. The area North of Portugal is much more mountainous than its southern half (Fig. 1). The main relief systems are roughly parallel to the coastline, forming an efficient orographic barrier against the moist Atlantic winds (Santos & Fragoso, 2013). As such, the spatial variability of precipitation largely reflects the irregular distribution of orography. Others factors influence the spatial and temporal precipitation variability, such as the effect of the Atlantic Ocean proximity, the latitudinal location (between subtropical and mid-latitudes) and diverse weather types (Goodess & Jones, 2002; Melo-Gonçalves et al., 2016; Santos, Belo-Pereira, Fraga, & Pinto, 2016; Santos, Corte-Real, & Leite, 2005; Santos, Santos, & Fragoso, 2015). The mean annual precipitation in mainland Portugal is around 900 mm for the 1961–1990 baseline (Espírito Santo, Ramos, de Lima, & Trigo, 2014), but precipitation exhibits large north–south and east–west variability. In fact, the mean annual precipitation varies from over 2000 mm in the northwest to roughly 500 mm in the inner Douro River valley and over the south-eastern part of the country. Furthermore, the precipitation regime is characterized by a strong annual cycle and, on average, about 40% of the annual precipitation occurs in winter (December to February) (Lima et al., 2015). In summer (June to August), precipitation amounts are of only ca. 6% of the annual amounts. April, May, September and October are transitional months into and out of the rainy season (Trigo & DaCamara, 2000). These months are still relatively rainy in the northwest, while they tend to be dry in the south.