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The role of the stratosphere in Iberian Peninsula rainfall: A preliminary approach in February

Joan-Albert Lopez-Bustins[a,*], Pere Esteban[a], Karin Labitzke[b], Ulrike Langematz[b]

[a] *Group of Climatology, University of Barcelona, Montalegre 6, 08001 Barcelona, Catalonia, Spain*
[b] *Institute für Meteorologie, Freie Universtät Berlin, Carl-Heinrich Becker Weg 6-10, 12165 Berlin, Germany*

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Abstract

This paper attempts to establish a connection between stratospheric anomalies in the North Pole and rainfall on the Iberian Peninsula through the occurrence of major midwinter warmings (MMWs) and cold events (CEs), taking February as a preliminary approach. We define the MMWs as the warmings which break down the polar vortex, whereas the CEs are the episodes in which the polar vortex remains cold and undisturbed. Both anomalies lead to a wind anomaly around the north polar stratosphere, which is connected with a shortly lagged tropospheric anomaly through a stratosphere–troposphere coupling in winter. A T-mode principal component analysis (PCA) was used as an objective pattern classification method for identifying the main daily surface-level pressure (SLP) patterns for February for the 1961–1990 reference period. Subsequently, those February months with an MMW or a CE influence in the troposphere are identified in the whole study period (1958–2000) by means of the Arctic Oscillation Index (AOI). Thus, performing the same analysis for the selected February months, new principal patterns for detecting changes in surface circulation structure and morphology are obtained. The results show a significant decrease in the westerlies and a southward shift of the storm tracks in Western Europe some weeks after an MMW occurrence, leading to an increase in precipitation in western Iberia and a slight decrease on the eastern Mediterranean fringe. The results are quite the opposite under a CE influence: the westerlies are strengthened and shifted northwards due to the displacement of the Atlantic anticyclone towards Central Europe; dry conditions are established throughout Iberia, except for the Mediterranean fringe, where precipitation shows a considerable increase due to the greater frequency of the northeasterly winds. Finally, an 11-year sunspot cycle–quasi-biennial oscillation (QBO) modulation might be demonstrated in Iberian rainfall in February through the occurrence of these stratospheric anomalies.

Keywords: Arctic Oscillation Index; Circulation patterns; Iberian rainfall; Major midwinter warming; Principal component analysis; Stratosphere–troposphere coupling

1. Introduction

Very early studies have already shown that extreme anomalies in the stratosphere can occasionally be propagated downwards to the surface level (Julian and Labitzke, 1965; Quiroz, 1977). Some studies are currently confirming those previous

*Corresponding author. Tel.: +34 93 403 78 97; fax: +34 93 403 78 82.
E-mail address: jlopezbustins@ub.edu (J.A. Lopez-Bustins).

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studies in which the stratosphere is considered as a good predictor of tropospheric weather (Christiansen, 2006; Thompson et al., 2006). Camara et al. (2007) suggested stratospheric variations in the development of tropospheric seasonal forecasting models. Some studies even attempt to establish certain levels in the stratosphere in order to predict weather in the troposphere, as Siegmund (2006) did at level 50 hPa over the North Pole. Researchers therefore question the hypothesis that states that the stratosphere is a better predictor of the troposphere than the troposphere itself. The stratosphere–troposphere coupling has now been appropriately studied, but there are still some uncertainties with regard to its temporal and spatial irregularity (Baldwin and Dunkerton, 2005). The mechanism involved in the way extreme circulation in lower stratosphere circulation affects the troposphere is not yet fully understood, but it is likely that synoptic-scale baroclinic waves are taking part (Wittman et al., 2004). Nevertheless, research into dynamic couplings between the troposphere and the stratosphere, during the evolution of extreme anomalies in the stratospheric northern annular mode (NAM), has been currently improved with the use of some general circulation models (GCMs) (Omrani et al., 2006).

The present study attempts to follow the work done by Baldwin and Dunkerton (2001) as they detected different circulation patterns in the northern extratropical troposphere following the occurrence of stratospheric anomalies, major midwinter warmings (MMWs) or cold events (CE), through the stratosphere–troposphere coupling which takes place in winter. An earlier forecast of the stratospheric state would be very useful for determining the winter season on the Iberian Peninsula and throughout Europe. Baldwin et al. (2003) detected the strongest modulation at surface level of the NAM at 150 hPa in February, which partly explains why we present an initial approach taking only February into account. We focus on the study of morphological and structural changes in circulation patterns and their effects on precipitation on the Iberian Peninsula in February following the occurrence of a stratospheric anomaly. In Section 2, we define the stratospheric anomalies and detect those February months with a potential influence of the stratospheric anomaly at surface level by means of the Arctic Oscillation Index (AOI). In the following section, we present the results of the application of a principal component analysis (PCA) to a daily sea-level pressure (SLP) grid over Europe in order to establish the main circulation patterns in February over the 1961–1990 reference period. The same analysis was subsequently conducted for those February days with a potential stratospheric anomaly influence in order to make a comparison. Finally, in Section 4, we attempt to demonstrate the existence of a possible solar cycle–quasi-biennial oscillation (QBO) modulation influencing Iberian rainfall through the occurrence of these stratospheric anomalies, which is also most likely to be detected in February (Labitzke, 2005), which further justifies the selection of the month of February as an initial approach.

2. Methods and data

2.1. The MMWs and the CEs

For this analysis, the 1958–2000 period was considered, as daily NCEP/NCAR reanalysis grid data (Kalnay et al., 1996) are only available since 1958 on the Climatic Research Unit (CRU) website. Furthermore, our monthly rainfall database on the Iberian Peninsula ends in 2000; consequently, 43 winters were considered. In 16 of these, there is an MMW (Labitzke and Collaborators, 2002) (Table 1). MMWs are selected due to their influence on wind, temperature and pressure anomalies in the stratosphere. Thus, MMWs are circulation anomalies in the middle to low stratosphere which disturb the polar vortex and replace it with an anticyclone circulation over the North Pole, and they are usually preceded by significantly important fluxes from the troposphere (Quiroz et al., 1975). The break-down in the polar vortex takes place when the latter is entered by planetary-scale Rossby waves (Quiroz, 1977; Baldwin et al., 2001). These waves are usually created in the troposphere, transporting westward angular momentum upwards to interact with the lower stratosphere circulation. Hence, our main criteria for detecting an MMW are both at 10 hPa, an easterly flow over 60°N and a positive temperature difference between 90°N and 60°N. In Table 1, those temperatures ($T_{30\,\mathrm{hPa\ N\ Pole}}$) that in January are much higher than $-72\,^{\circ}$C or those that in February are much higher than $-67\,^{\circ}$C are related to a weak and warm polar vortex. Other warmings in the stratosphere, minor warmings or Canadian warmings, do not succeed in strongly increasing pressure in the middle to low stratosphere or in establishing easterlies, i.e., to split up or