DYNAMICAL CHARACTERIZATION OF THUNDERSTORM DAYS IN PORTUGAL

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I. INTRODUCTION

Thunderstorms in the atmosphere are produced in large convection cells (*Cumulonimbus*) under conditions of strong atmospheric instability. Their electrical discharges (flashes) may represent a serious threat to the electric power networks, may trigger forest fires and cause injuries and losses of human lives. In Portugal, since 2002, the Meteorological Institute maintains four detection sensors in order to effectively cover the national territory. Although this database is still very recent, the RAIDEN project (Lightning activity in Portugal: variability patterns and socioeconomic Impacts) intends to systematize all the available data so as to characterize its spatial and temporal variability and to assess the main dynamical mechanisms underlying the occurrence and development of thunderstorms in Portugal. Nevertheless, it should also be emphasized that the actual local atmospheric conditions, orography and local/regional thermodynamic and dynamical mechanisms also play a key role in triggering lightning activity. Some results concerning the temporal scaling of the lightning activity for the same dataset were already presented in previous studies (Fragoso *et al*., 2010; Leite *et al*., 2011 and Santos *et al*., 2011).

II. PRESENTATION OF RESEARCH

In the present study, the dataset of the atmospheric electric discharges, collected by the four lightning sensors of the Portuguese Meteorological Institute, in the period between 2003 and 2009 (7 years) is analyzed. Further, in order to assess the dynamical features of the thunderstorm days in Portugal, several atmospheric fields from the NCEP-NCAR (*National Centers for Environmental Prediction / National Center for Atmospheric Research*) reanalysis data are considered on a daily basis (daily means), namely mean sea level pressure (MSLP), 500 hPa geopotential height, 500 hPa temperature, and 10 m zonal and meridional wind components (for streamlines computation). These fields are defined over a 2.5º x 2.5º latitude-longitude grid an only the geographical sector (30ºW-20ºE, 20-70ºN) is selected. In future work, higher-resolution reanalyzes will also be taken into account (e.g., Japanese reanalysis - JRA).

The study started with the analysis of the daily discharges totals, i.e., the time series of the sum of observed (cloud-to-ground and cloud-to-cloud) flashes over Continental Portugal on a given day.

Aiming to dynamically characterize the thunderstorm events in Portugal, only days with discharges above the 50th percentile (P50 or median) are herein considered. This threshold corresponds to 25 daily discharges over Portugal and a total of 376 days fulfill this criterion. This reasonably high value warrants that the prevailing large-scale atmospheric conditions are mostly favorable to lightning activity in important areas of the country. Lower thresholds imply the inclusion of small-scale events that are generally driven by local mechanisms and are not reflected in the large-scale atmospheric flow. On the other hand, using a higher threshold would lead to a relatively small sample of thunderstorm days, with obvious limitations in terms of the statistical significance of the results.

The composites (average patterns) of the atmospheric fields for days with a number of discharges over 25 reveal little dynamical coherence amongst the different days (not shown); no well-defined systems are apparent. Therefore, a K-means clustering is directly applied to the reanalyzed mean sea level pressure (MSLP) for days with a number of discharges over P50 (376 days) and two different regimes of atmospheric circulation are clearly identified. The choice of two regimes is supported by a previous study (Santos et al., 2005), where the weather regimes relevant to Portuguese precipitation were presented. The Remote regime (REM; Fig. 1a) is verified in 104 days, while the Regional regime (REG; Fig. 1b) occurs in 272 days. Their designations, as explained below, are related to the location of the low-pressure systems linked to thunderstorm occurrences in Portugal.

As can be observed in Fig. 1a, the REM regime is characterized by a low pressure center northwards of the British Islands (remote location), but with a strong trough extending towards Portugal. For the REG regime (Fig. 1b), a blocking anticyclone, extending from the Azores towards the British Islands, and a weak low pressure / inverse trough located over Portugal (regional location) can be observed.

Both troughs are clearly favorable to unsettled weather conditions over Portugal. The resulting instability may potentially lead to the development of convective cells, thunderstorms and lightning activity throughout the country. Although local effects also play a central role in controlling lightning activity (both temporally and spatially), these large-scale patterns of the atmospheric flow are still quite informative. In fact, they provide a clear differentiation between two dynamically contrasting situations, both with important lightning activity.

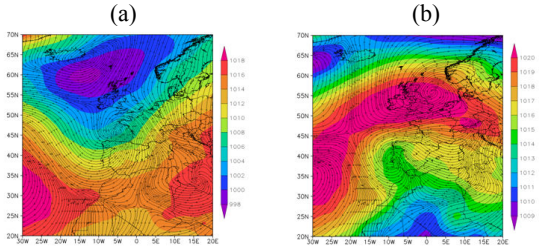

FIG. 1: Composites of the MSLP and respective streamlines only for days with a number of discharges over 25 and for the: (a) REM regime; (b) REG regime.

Since the general atmospheric dynamics during the

winter and summer halves are different, the winter (W; October-March) and summer (S; April-September) periods are considered separately. Hence, the two regimes are analyzed for W and S., i.e., REM_W with 70 days, REM_S with 34 days, REG_W with 76 days and REG_S with 196 days. Their corresponding patterns are depicted in Fig. 2.

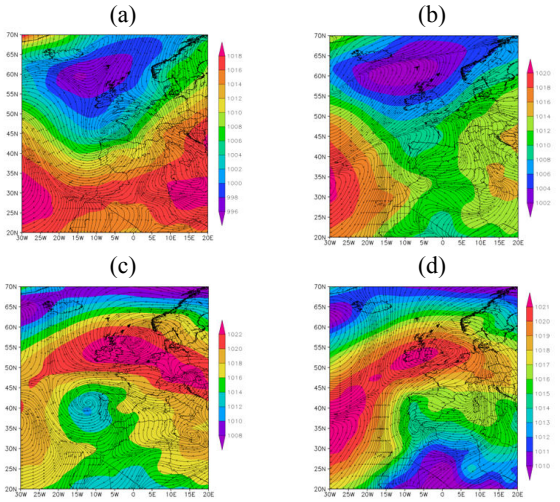

FIG. 2: As in FIG. 1, but for the winter (W) and summer (S) halves of the year: (a) REM_W; (b) REM_S; (c) REG_W; (d) REG_S.

This seasonal subdivision highlights that the discharges occur predominantly during the REG regime. Furthermore, while in the REG regime the discharges are more frequent in summer, they are more frequent in winter during the REM regime, being relatively rare in summer (only 34 days).

Some differences in detail can be found between the W and S patterns for each regime, though most of them are only a manifestation of seasonality. The composites of the 500 hPa geopotential height and 500 hPa air temperature of these regimes are shown in Fig. 3. These patterns are in clear agreement with the patterns in Fig. 2.

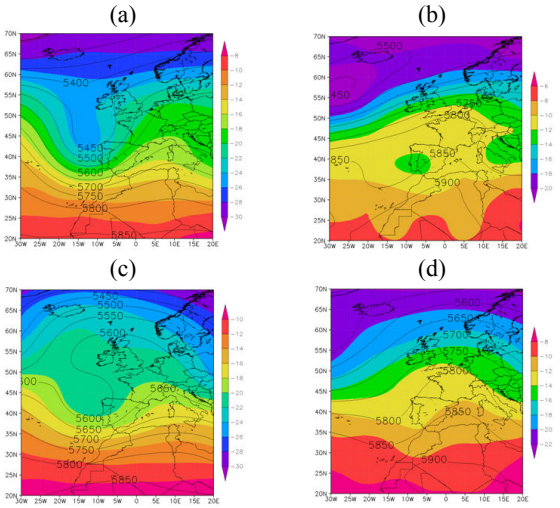

FIG. 3: Composites of the 500 hPa geopotential height and air temperature only for days with over than 25 discharges and for the: (a) REM_W; (b) REM_S; (c) REG_W; (d) REG_S.

III. RESULTS AND CONCLUSIONS

This study identifies the regimes of the large-scale atmospheric circulation associated with the occurrence of severe thunderstorms in Portugal. Two regimes relevant to the occurrence of discharges over Portugal are identified. Moreover, the results show that the REM regime is dominant in the coldest period (between October and March), whereas the REG regime is more prevalent in the warmest period (between April and September).

It is shown that the most common regime is the REG_S (Regional-summer) regime, with 196 days of a total of 376 days, i.e., 52% of the occurrences of a number of discharges above P50. This regime is characterized by an inverted trough extending from northwestern Africa towards Portugal. This system is commonly enhanced by the high temperatures that are typically observed at this time of the year (‘thermal low pressure’). Discharges are much less frequent during the REM_S regime, with only 9% of the total occurrences. This can be mainly attributed to the northward displacement of the low pressure systems over the North Atlantic during summer. This not only makes the REM regime less frequent, but also generally weaker, with relatively low potential for the development of strong convective cells and significant lightning activity over Portugal.

The analysis of other atmospheric fields allows an ample characterization of these regimes and suggests these two regimes are physically meaningful. The present study not only highlights the distinct dynamical features of each regime, but also suggests some dynamical predictors for the occurrence of thunderstorms in Portugal. The results indeed suggest that some of these large-scale variables might be valuable predictors for modeling the discharge occurrences in Portugal. This is expected to have great applicability not only to weather forecasting, but also to the development of downscaling strategies applied to climate model data (including future scenarios and transient simulations). In future work this modeling will be undertaken.

IV. ACKNOWLEDGMENTS

The current research was developed under the project “*Lightning Activity in Portugal: Variability Patterns and Socio-economic Impacts* (RAIDEN)”, with contract number FCT: PTDC/CTE-ATM/101931/2008.

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