

CLOUD-TO-GROUND LIGHTNING ACTIVITY IN PORTUGAL: OVERALL CHARACTERIZATION, SPATIAL AND TEMPORAL PATTERNS OF ASSOCIATED THUNDERSTORMS OVER THE 2003-2009 PERIOD.

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I. INTRODUCTION

This study aims to achieve two main objectives. First an overall characterization of the geographic incidence and temporal rhythms of lightning activity in mainland Portugal territory over the 2003-2009 period will be presented and discussed. This summary characterization will focus on the cloud-to-ground (CG) lightning activity, analysing parameters like the total number of flashes, the frequency of negative and positive flashes. The second objective is devoted to the identification of the spatial and temporal patterns of thunderstorm events, based on the associated clusters of CG flashes. Taking into account the large number of days with CG lightning in Portugal over the studied period (754 days, with maximum daily count of 4951 CG flashes), only CG lightning days whose strikes number exceeded the 50 percentile (376 days) were selected for this study.

II. PRESENTATION OF RESEARCH

Since June 2002, the Portuguese Institute of Meteorology has been operating a lightning network that comprises 4 sensors (Braga, Castelo-Branco, Alverca and Olhão). Taking into account that 2002 is incomplete, only data for 2003-2009 is considered in this study. The research on lightning activity on the Iberian Peninsula started some years ago with relation to the Spanish regions of Iberian Peninsula (Rivas Soriano et al, 2005), but the first steps with regard the Portuguese territory are very recent (Rodrigues et al., 2008; Fragoso et al, 2010; Leite et al, 2010; Ramos et al, 2011; Santos et al, 2011; Ramos et al, 2011). The total densities of CG flashes in mainland Portugal (2003-2009, including negative and positive flashes) are shown in FIG. 1. This pattern clearly highlights that the lightning activity is relatively strong in the interior areas of the country, whereas in littoral areas it is generally much lower. The absolute maxima of CG lightning activity occurred over the southern interior areas of Portugal (Alentejo). With regard the seasonal rhythm, the temporal distribution of CG lightning activity exhibit a maximum in late summer (September) and a minimum in winter.

The main goal of this study is to identify and characterize the temporal and spatial patterns of thunderstorms in Portugal mainland territory, based on CG lightning data. The research period analysed under the RAIDEN project comprises seven years (2003-2009), however only preliminary results over 52 thunderstorm events occurring in September - the month of the year with higher CG lightning activity - are presented in this study.

Moreover, as we are specially interested into analyse situations with stronger thunderstorm activity, the sample of events was selected from a subset of daily CG lightning data, extracting the daily cases exceeding the 50th percentile of total frequency of CG flashes over the Portugal mainland territory, an amount equivalent to 25 flashes/day.

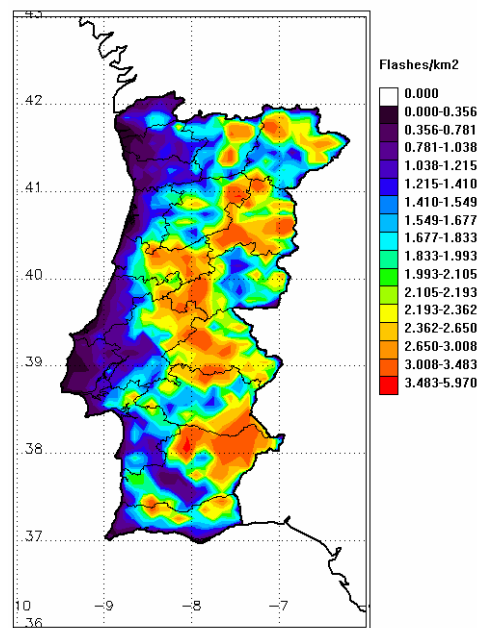


FIG. 1: Total density distribution of CG flashes (2003-2009) over a 0.1°x0.1° regular grid.

The applied methodology followed the overall procedures conducted by Murphy and Konrad III (2005), in their study concerning the temporal and spatial patterns of thunderstorms in the interior SE United States. Therefore, the methodology involved a sequence of two main phases of classification: (a) the temporal clustering of CG flashes into separated lightning events; and (b) the analysis of the corresponding flashes distribution in space, classifying the associated spatial pattern of the thunderstorm events. The procedures are summarized as follows:

a) An algorithm developed with IDL programming software allowed the identification of the temporal events, applying the same criteria considered by Murphy and Konrad III (2005), which means that events were initiated by the first occurrence of a CG lightning flashes (begin phase) and terminated when one or more hours elapsed without a single lightning strike (end phase). The mature phase of the event was identified as the hour period in which the greatest

number of CG flashes was observed. Additionally, a set of parameters and maps was obtained to characterize the features of the temporal clusters, e.g. starting time, ending time, total duration, date and hour of mature phase, number of flashes per event and during the mature phase and hourly maps of spatial distribution of CG flashes.

b) The classification of the spatial patterns of CG flashes was defined for the mature phase of each selected event. Using appropriate GIS software (ArcGis 9.3), two metrics were computed in order to permit an objectively based classification: 1) the size of the region containing the flashes and 2) the spatial pattern of the flashes within the region of flash activity (RFA), estimated by a parameter of shape (*D ratio*), measuring the thickness ratio of the polygon that delimits the RFA. With these measurements, several criteria were assumed, resulting in four possible categories of thunderstorms patterns (FIG. 2):

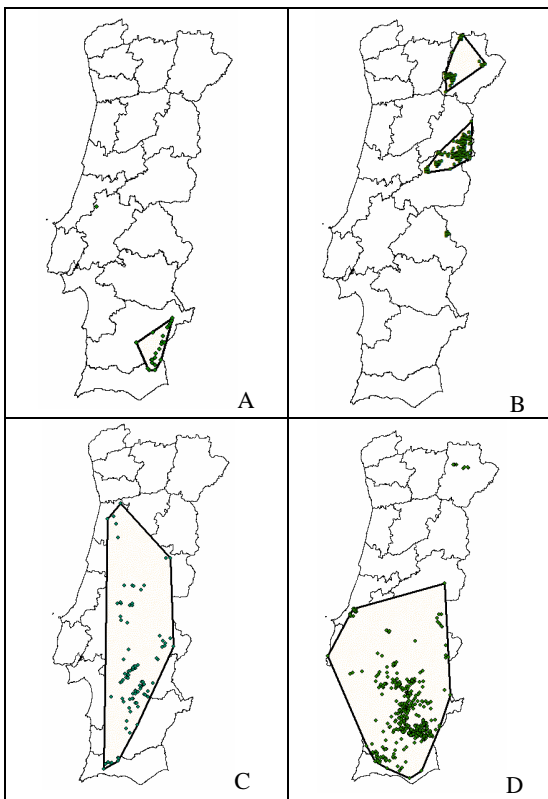


FIG. 2: Spatial patterns of thunderstorm events: A: Local; B: Multi-local; C: Regional/Linear; D: Regional/Elliptical.

- Local – CG flashes confined to a small area of the study region (in any case $< 1/6$ of the mainland Portuguese territory) and grouped as a single cluster, suggested by the short distances (< 50 km) between more peripheral flashes and the core of the cluster;
- Multi-local – Two or more clusters of local events occurring simultaneously, which means different RFA's (away each other more than 50 km), and possibly related with separated mesoscale convective systems.
- Regional – Events with CG flashes distributed over a much wider area, covering at least $1/6$ of the mainland Portuguese territory. Moreover, if the RFA polygon is similar to a narrow band ($D \text{ ratio} < 0.7$), the regional thunderstorm event is also classified as *linear*.

Conversely, if the polygon is similar to a more circular area ($D \text{ ratio} > 0.7$), the regional thunderstorm event is also classified as *elliptical*. Examples of each type of considered patterns are shown in FIG. 2.

III. RESULTS AND CONCLUSIONS

An overall characterization of the classification of the temporal and spatial patterns of these preliminary results, regarding 52 September events, is briefly synthesized on the statistical description presented in Tables I and II.

Type	Frequency	N°CG Flashes
Local	24 (46%)	5575 (14%)
Multilocal	16 (31%)	10611 (26%)
Regional	12 (23%)	24576 (60%)

TABLE I: Frequency (absolute/relative) and number of CG flashes by event type.

Type	Duration (h)	Area (km ²)
Local	5	3.900
Multilocal	8	1.945
Regional	10	22.327

TABLE II: Duration and mean affected area (mature phase hour) by event type.

Local thunderstorms events were the most frequent type among the three main categories (local/multi-local/regional), being identified in 46% of the cases. In general, they affected relatively small areas, with an average size of 3900 km². Their associated flash frequency was the lowest among the three main categories, producing only 14% of the total number of CG flashes, corresponding to an average of 232 flashes per event. Local events were also characterized by its relatively short duration (5 hours, on the average).

Multi-local events were the second most frequent observed type (31% of the cases). They produced a larger number of CG flashes than the local events, being responsible for 26% of the total number of flashes (average of 663 flashes per event). Since this type is characterized by the occurrence of simultaneous clusters of lightning activity, the typical size of a single RFA is small, not reaching 2000 km². The mean duration of multi-local events (8 hours) was considerably higher than the observed in local events.

The most part of the total CG flashes (60%) were associated with regional thunderstorm events, in spite of their lowest frequency, with only 12 cases (23% of the total), corresponding 10 of them to elliptical patterns and 2 to linear. On average, each Regional event produced 2048 CG flashes. Regional events were very different from all other classified cases, affecting larger areas of the mainland Portugal territory, with a mean size of RFA equivalent to 22 327 km². The longer duration of this type of events was another distinctive feature, being 10 hours the typical (mean) duration of the regional pattern thunderstorm events.

In conclusion, preliminary results of a classification of temporal and spatial patterns of thunderstorm events with regard the mainland Portuguese territory was shown in these study, focusing on September events, the month with highest lightning activity in this region (over the 2003-2009 period). The results suggest that the tested classification separates very distinguishable thunderstorm events, regarding different features, as the associated duration, the number of CG flashes produced and the size of affected areas. Further analysis based on a larger sample of thunderstorm events will, possibly, improve the consistency of this classification.

IV. ACKNOWLEDGMENTS

The current research was developed within the project “*Lightning Activity in Portugal: Variability Patterns and Socio-economic Impacts* (RAIDEN)”, funded by the Portuguese Science and Technology Agency (FCT) with the reference PTDC/CTE-ATM/101931/2008. Lightning data, after validation procedures, was provided to RAIDEN Project by the Portuguese Institute of Meteorology, accordingly to a cooperation protocol.

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