# A SEVEN-YEAR STUDY ABOUT CLOUD-TO-GROUND LIGHTNING CHARACTERISTICS IN PORTUGAL

João A. Santos[1], Solange Leite[1], Margarida Reis[1], João Sousa[2], Sandra Correia[3], Marcelo Fragoso[3]

[1]UTAD, CITAB, Physics Department, Vila Real, Portugal, jsantos@utad.pt
[2]Meteorological Institute, Lisbon, Portugal,
[3]Centre for Geographical Studies, Institute of Geography and Social Planning, University of Lisbon, Portugal

## I. INTRODUCTION

A seven-year study of cloud-to-ground (CG) lightning characteristics in Portugal is presented. The study is based on approximately 180 thousand discharges recorded by a lightning detection network from January 2003 to December 2009, which is the longest available dataset over Portugal. It provides a unique opportunity to study the long-term annual, seasonal, monthly, and daily time distributions of the number, density, intensity (peak current), polarity and multiplicity of CG discharges in Portugal, as well as the spatial variability of these parameters. As there is strong inter-annual variability in this dataset, our study also examines fundamental statistics, such as mean, median, standard deviation, 10th and 90th percentiles of the number, density, intensity, polarity and multiplicity of CG discharges. For the sake of succinctness, only the most relevant results are shown herein.

## II. PRESENTATION OF RESEARCH

The lightning network of the Portuguese Meteorological Institute comprises 4 sensors located at Braga, Castelo-Branco, Alverca and Olhão, as shown in Fig. 1, with the recording period starting in June 2002. Since 2002 is incomplete, only data for 2003-2009 is considered herein.

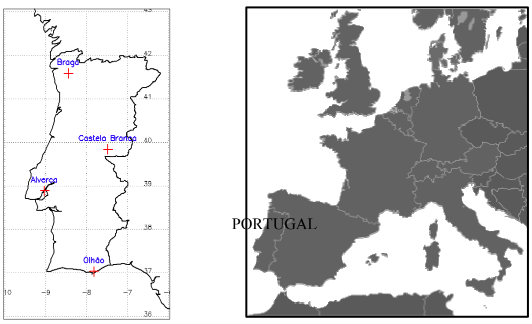


**FIG. 1:** *On the left*: Map showing the locations of the lightning sensors in Portugal. *On the right*: geographical situation of Portugal in Europe.

Portugal geographical limits are roughly: 37°N to 42°N in latitude and 10ºE to 7ºW in longitude. The analyzed temporal period is 2003-2009 and annual, seasonal, monthly and daily time scales are considered. Furthermore, in order to analyze the spatial variability of the variables, data is also considered over a 0.10º latitude x 0.10º longitude regular grid. In this approach, each grid box contains information about all the detected discharges within its boundaries.

Some results concerning the temporal scaling of the lightning activity for the same dataset were already presented in a previous study (Fragoso *et al*., 2010; Leite *et al*., 2011 and Santos *et al*., 2011). As such, only new results for spatial variability are presented in the present study.

In Fig. 2 the average distribution of CG discharges for the entire period is displayed. Low values in some grid boxes along the Spanish border occur because most of their area is already over Spain (only discharges over Portugal are accounted). 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 weak.

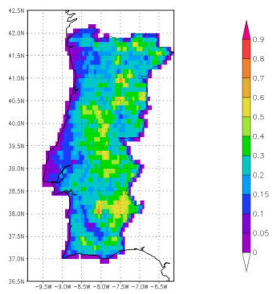

**FIG. 2:** Spatial distribution of the average CG lightning activity (number of discharges per day) in 2003-2009.

Fig. 3 depicts the mean number of negative CG discharges over the period 2003-2009. This pattern is indeed very similar to Fig. 2, supporting the large dominance of negative over positive CG discharges. The pattern of positive discharges confirms the much lower occurrences compared to the negative ones (not shown). Fig. 4 shows the mean duration of CG discharges in 2003-2009. Higher durations occur over northwestern Portugal, the most exposed region to the frontal systems coming from the North Atlantic. This fact is likely to be related to the longer durations in this area, but further analysis is required in order to test this hypothesis.

Fig. 5 shows the geographical distribution of the average number of occurrences of CG discharges with respect to the seasonal scale for the entire period (2003-2009). During summer maxima occur over northeastern Portugal, while in autumn maxima tend to occur in southern Portugal. In fact, the southward displacement of the area of maximum lighting activity from summer to autumn is in clear agreement with the relatively rapid cooling of northeastern Portugal during autumn, leading to more stable thermal conditions. However, diurnal temperatures in southern Portugal remain relatively high during most of the autumn, explaining the strong lightning activity.

Fig. 6 shows the 10th and 90th percentiles of the annual CG discharges in 2003-2009. These two patterns reveal a strong inter-annual variability in the number of CG discharges (e.g., high activity was recorded for 2007 and rather low activity was verified in 2005).

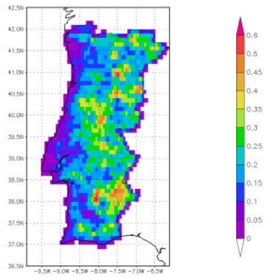

**FIG. 3:** Spatial distribution of the average number of CG negative discharges (per day) in 2003-2009.

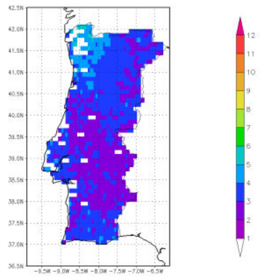

**FIG. 4:** Spatial distribution of the average duration (in $10^{-6}$ seconds) of CG discharges in 2003-2009.

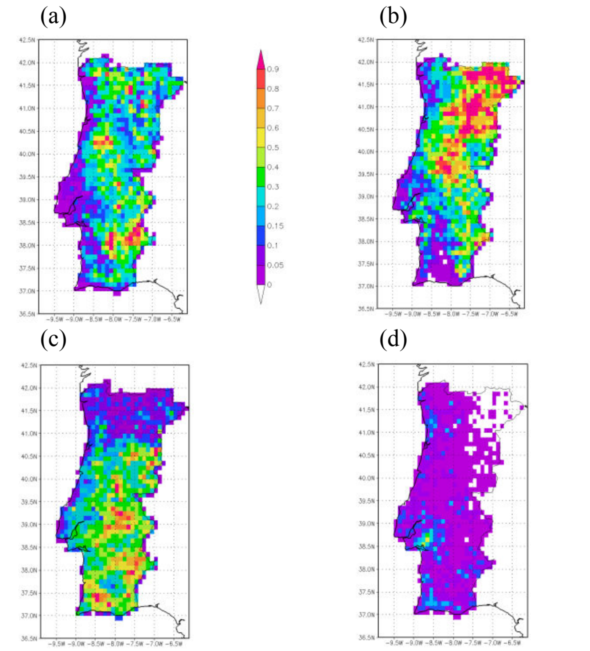


**FIG. 5:** Spatial distribution of CG lightning activity (number of discharges per day) in 2003-2009 for: (a) spring (MAM); (b) summer (JJA); (c) autumn (SON); (d) winter (DJF).

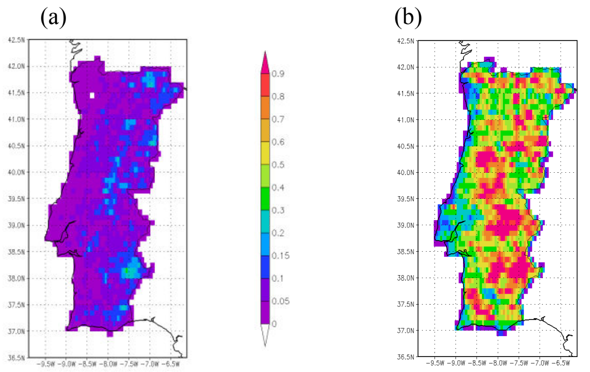


**FIG. 6:** Maps of the (a) 10th and (b) 90th percentiles of the annual CG discharges (number of flashes per day) in 2003-2009.

## III. RESULTS AND CONCLUSIONS

One of the main results of the present study is that the pattern of mean CG discharges clearly divides Portugal into its east-west halves (Fig.2); the eastern half (leeward side) is more continental, with high lightning activity, while the western half (windward side) is exposed to strong maritime influence and generally low lightning activity. In the eastern half, the absolute maximum activity is identified in southern Portugal (over Alentejo). Furthermore, the maps of the negative polarity are more informative than those related to positive polarity and are discussed here. As seen in Fig. 3, the maximum negative polarity is identified over more continental areas of southern Portugal. Similar results are obtained for other lightning parameters, such as the reliability parameter and multiplicity (not shown).

When analyzing the CG discharges on a seasonal scale (Fig. 5), it is found that during summer (June-August) the maxima occur over northeastern Portugal (Fig. 5b), a mountainous region with high summertime temperatures and occasionally strong convective activity. During autumn (September-October), however, northeastern Portugal has almost no electric activity (Fig. 5c), mostly due to the relatively low wintertime temperatures and to snow cover in some areas, whereas central and southern Portugal experience relatively high activity. In spring (March-May), maximum lightning occurrences are observed over the interior areas of southern Portugal (Fig. 5a), while quite low occurrences are identified in winter (December-February) throughout most of the country (Fig. 5d). Moreover, the patterns in Fig. 5 also highlight the variability in the air temperatures throughout the seasonal cycle and also suggest some reflection of the heterogeneity in the soil properties.

On the whole, the results reveal maximum occurrences in autumn and minimum in winter. Spring and autumn correspond to the onset and decay of most of the thermally-driven convective activity over Portugal. Density and intensity of electric activity were also analyzed. The average density and intensity of the CG discharges reach their maxima over southern Portugal (not shown).

Regarding the classical statistical parameters of the lightning activity, the 10th and 90th percentiles are presented here as an illustration (Fig. 6). These parameters provide an important insight into the statistical distributions of the lightning activity over Portugal.

## IV. ACKNOWLEDGMENTS

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## V. REFERENCES

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