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TEN-YEAR LIGHTNING PATTERNS IN CATALONIA USING PRINCIPAL COMPONENT ANALYSIS

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I. INTRODUCTION

It is well known that lightning activity has a great impact on society. Holle et al (2008) presented an analysis of lightning fatalities by country. The fatality rate in Spain, similar to the US., was higher in the middle of the last century but lower in the 90's because of the migration from rural to urban areas. Another problem in the Mediterranean area is wildfire; an average of 750 wildfires occurs in Catalonia every year, 11% of them are caused by lightning (Pineda et al., 2014). In their study, the authors analysed the characteristics of lightning that ignite forest fires.

The aim of the present study is to obtain the regionalisation related to thunderstorm activity in Catalonia (NE of Iberian peninsula, figure 1) through the analysis of ten years of lightning activity. Pineda et al. (2011) did a first approach using hierarchical agglomerative clustering, for the period 2004-2008. They identified regions with different behaviours mainly governed by terrain height and proximity to the Mediterranean Sea. The current study seeks to improve this classification, by using a longer period and applying Principal Component Analysis (PCA) methodology. Afterwards, the synoptic characteristics and the temporal distributions of each of the resulting components are analysed.

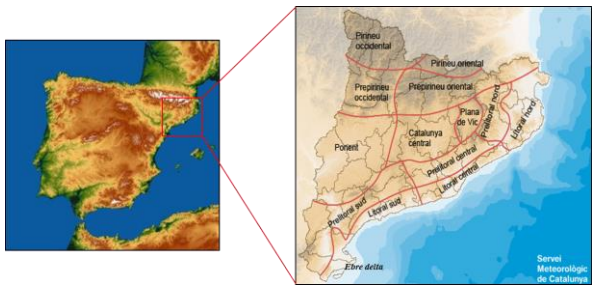

FIG. 1: Left panel: Iberian peninsula and Catalonia location. Right panel: Catalonia and its main orographic regions.

II. DATA AND METHODOLOGY

The Meteorological Service of Catalonia operates a Lightning Location System (SMC-LLS) covering Catalonia with four Vaisala LS-8000 total lightning detectors. Intra-cloud and cloud-to-ground (CG) flashes are detected and processed separately. The analysis of the successive campaigns (Pineda and Montanyà, 2009; Montanyà et al., 2012) establishes a CG-flash detection efficiency for the SMC-LLS around 80-85%. Besides, the estimated median location accuracy for the CG strokes is around 1 km.

The present study relies on the SMC-LLS lightning database for the last ten years (2005-2014). A "thundery event" is defined as a 6-hour period with more than 100 CG strokes registered in Catalonia. A total of 1507 events have been identified throughout these ten years. For each event, a 10-km spatial resolution matrix, covering all the area, has been created.

The PCA method, in S-mode (Aran et al. 2011 and Peña et al. 2011) has been applied to the matrix of events. This method is based on the correlation matrix and the Scree-test criterion. The Orthogonal Equamax procedure is used to rotate the components which minimize the number of variables with high factorial loadings, so the dependence among components is reduced and the orthogonality constraint of the model is maintained. Finally, each event has been classified using the score matrix obtained from the PCA. Only the events with a score higher than 1.0 has been chosen since those with lower score might be considered noise. As a result, the classification is obtained using 351 events (from the total of 1507).

III. RESULTS AND CONCLUSIONS

A total of six components are obtained. The numbers of events related to each pattern are: 89, 83, 80, 56, 21 and 27 for P1, P2, P3, P4, P5 and P6 respectively. These six patterns are characterized by similar synoptic configuration at 500 hPa: a trough, located at western Iberian Peninsula, inducing south-westerly winds over Catalonia. At surface level, slightly differences determine the local convection. Therefore, the description of all of them has been grouped into two subsets according the affected region (figure 2). The first one (P1, P2 and P3) is more related to mountainous precipitation patterns while the other patterns (P4, P5 and P6) are more related to coastal episodes.

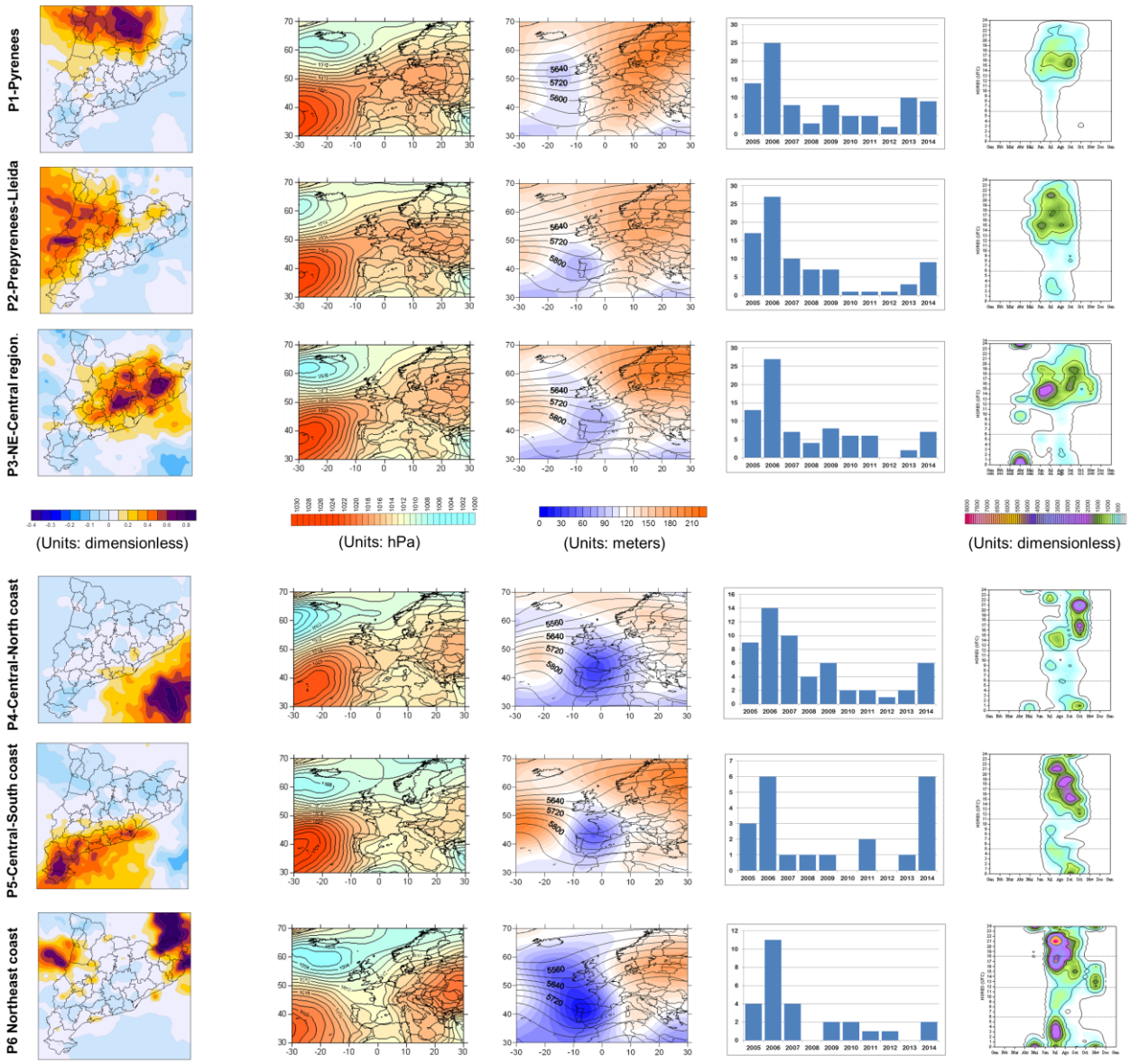

FIG. 2: Patterns characteristics. First column, spatial distribution of scores obtained from PCA. Second column, mean sea level pressure (hPa). Third column, geopotential (lines) and its anomalies (shaded) at 500 hPa (mgp). Fourth column, yearly distribution of the events. Fifth, relative lightning frequency as function of month and hour.

For the first group, orography plays an important role in triggering convection. Figure 2 shows that lightning activity occurs mainly between 12 and 18 UTC on the period from late May to early October (maximum in July). Moreover, solar radiation is another factor to be taken into account for triggering convection in these areas. In early summer, convection is triggered in high mountains (P1). However in spring the mainly convection is triggered in the Prepirineu Occidental and Ponent (P2). The working hypothesis is that the remaining amount of snow covering the summits keeps the surface temperature low. Consequently, convection is mainly triggered at low and mid-altitudes. Finally, in summer, moist supply is important in the NE mountains (P3) being more influenced by sea breezes. On the contrary, in the Pirineu Occidental the lightning activity is lower.

For the second group of patterns, relative low pressures in the Catalan coast were identified. The position of the low determines the area where convection is triggered by local wind convergences. P4 pattern shows a pressure dipole structure that is formed after the pass of a cold front. Northerly winds over the Pyrenees induce easterly wind over the central coast increasing the convergence in this area. In P5 pattern, a low pressure in front of the central coast induces easterly wind in the central and southern of the coast. And finally, in P6 pattern, an anticyclone located in the Eastern Europe induces southerly winds over the northern coast of Catalonia, where the convection is very important. In this second group, lightning activity is more probable between 12 and 18 UTC even though it is also present between 18 and 06 UTC (fig. 2). In this group convection is centred in September, when sea surface temperature is higher. Here, solar radiation seems to have a secondary role.

IV. CONCLUDING REMARKS

The aim of this study was to obtain a regionalization of lightning activity in Catalonia that could help to forecasters to decide, for each season and synoptic situation, which areas are more prone to lightning. To achieve this scope, PCA has been applied in S-mode and the obtained results are significantly better than the preliminary results of Pineda et al. (2011). That is, lightning in the coastal area are discerned in three categories. Furthermore, it is also detected the differences between the Pyrenees and Prepyrenees. Finally, average synoptic maps are built for each pattern.

As a future work, we plan to develop an automatic synoptic classification of lightning events. What is more, the technology applied will be the same we have used for the regionalization, the PCA method, but now applied to upper level fields. However, to obtain an automatic algorithm, that classifies each day into one of the synoptic types discriminant analysis will be used.

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