Ten-year lightning patterns in Catalonia using Principal Component Analysis

Servei Meteorològic de Catalunya

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1. Overview

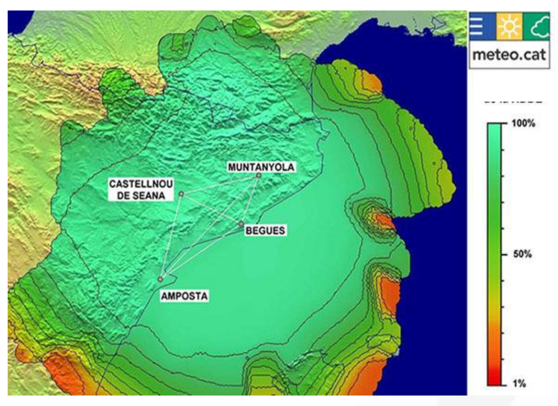


Figure 1. Location of the four detectors and estimated theoretical efficiency of the SMC-LLS.

- The Meteorological Service of Catalonia (SMC) operates a lightning location system (LLS) covering Catalonia (figure 1) with four Vaisala LS-8000 total lightning detectors. Intra-cloud (IC) and cloud-to-ground (CG) flashes are detected and processed separately. On one hand, IC flashes are detected in the very high frequency band (110 to 118 MHz) and located using interferometry (Lojou and Cummins, 2006). On the other hand, CG return strokes are detected by a low frequency sensor and located using a combination of the Time-of-Arrival/Magnetic Direction Finding technique (Cummins et al., 2006). The analysis of the successive campaigns (Pineda and Montanyà, 2009; Montanyà et al., 2012) establishes a CG flash for the SMC-LLS around 80-85%. Regarding the location accuracy, the estimated median location accuracy for the CG strokes is around 1 km.
- A lightning activity regionalization in Catalonia was done for the period 2004-2008 by Pineda et al. (2011). The methodology applied was the hierarchical agglomerative clustering and 5 regions where obtained. Nowadays the SMC is carrying on a new project whose main goal is to reclassify the stormy days applying principal component analysis (PCA) as it was done for hail or strong winds studies (Aran et al. 2011 and Peña et al. 2011).

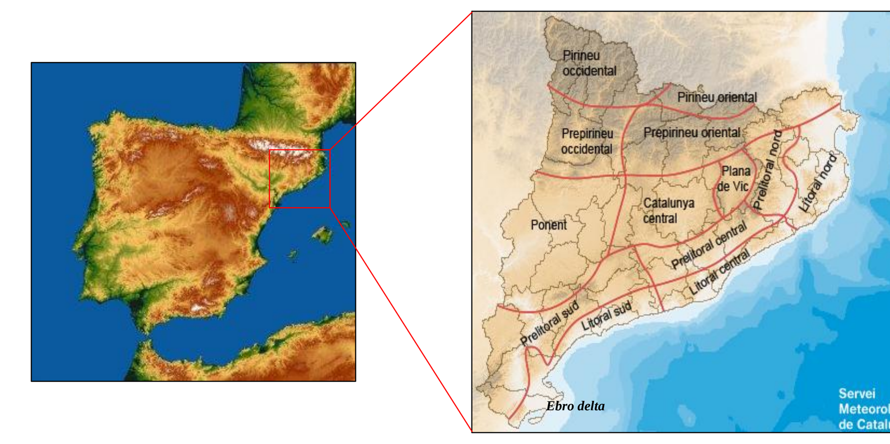


Figure 2. Left panel: Catalonia location. Right panel: Catalonia and its main orographic regions.

2. Objective

The main goal of this study is to update the characterization of the thunderstorm patterns in Catalonia based on ten years of recordings. PCA has been used to regionalize lightning activity in Catalonia (NE Iberian Peninsula). A first approach has been done to characterize synoptically each pattern.

3. Data and methods

Data:

- Lightning data: a grid of 10 km resolution covering Catalonia and time resolution of 6 hours.
- Only the 6-hour periods with more than 100 CG strokes have been used: 1507 periods have been obtained.
- Sea Level Pressure (SLP) and 500 hPa geopotential (Z500) grids are taken from the 20th Century V2 Reanalysis Project.

Methods:

- To achieve a regionalization of Catalonia, a PCA in S-mode is applied. The method relies on the correlation matrix. The Scree-test criterion is used to decide the number of factors.
- The Orthogonal Equamax procedure rotates the components obtained minimizing the number of variables with high factorial loadings; the dependence among components is reduced and retains the orthogonality constraint of the model. Each component is an spatial pattern, as a result the spatial distribution of lightning is represented drawing the correlation coefficients of the loading matrix.
- The 6-hour periods have been classified using the score matrix obtained of the PCA, considering only those days (351) with a score higher than +1.0 (it is considered that the factor is well explained by those days).
- The composites (SLP and Z500) and period distributions (yearly, monthly and hourly) are constructed with the 6-hour periods involved in each component.

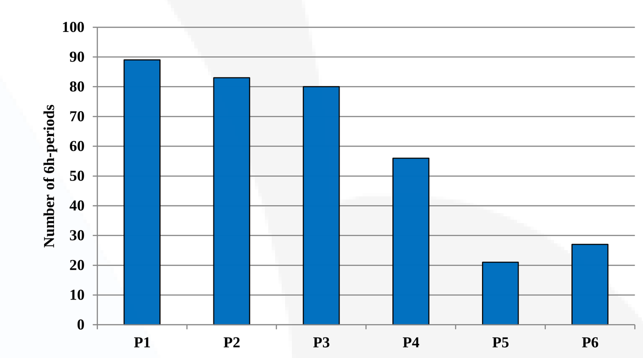


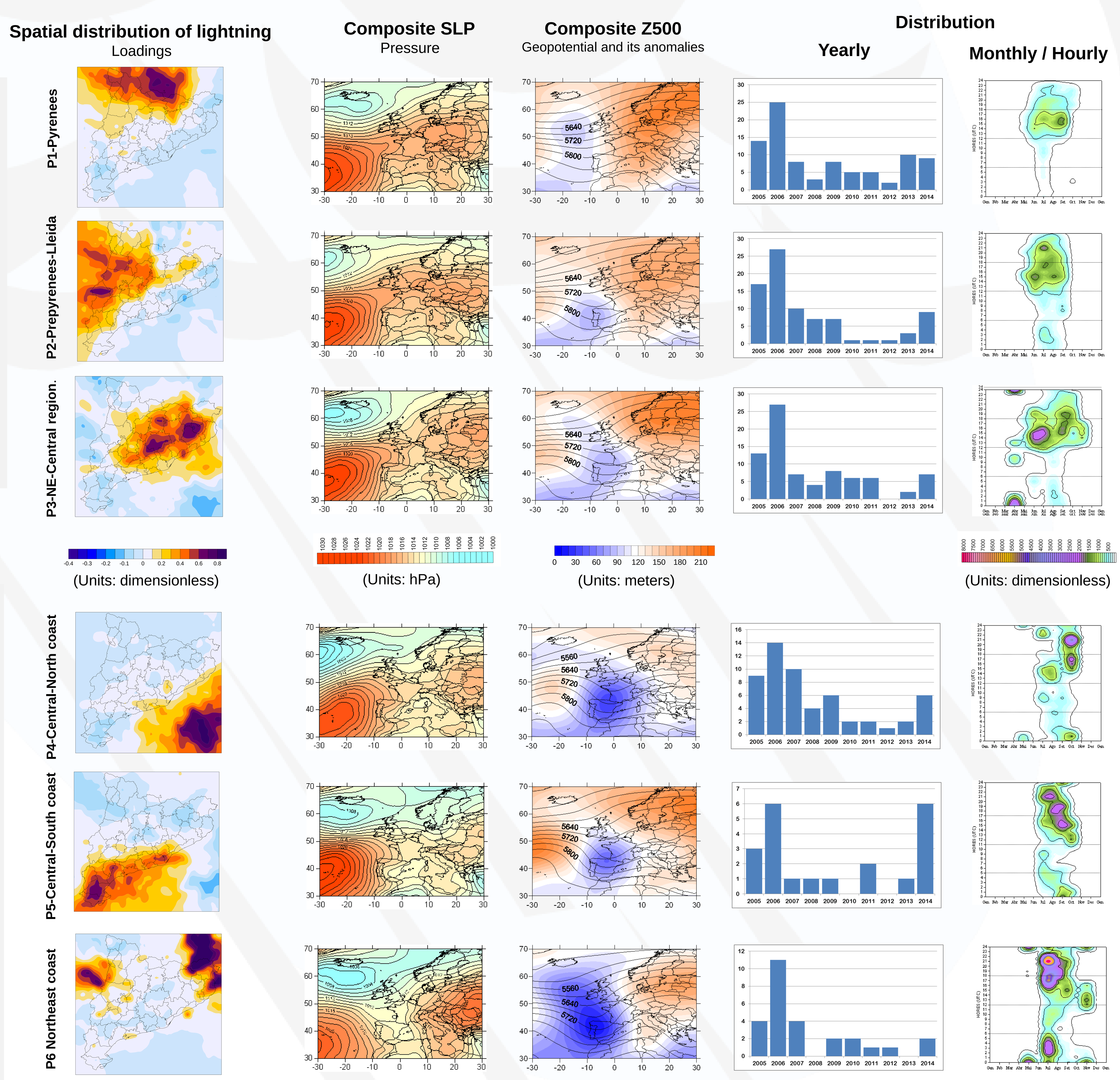
Figure 3. Number of 6h-periods for each pattern

4. Results

A total of six components were obtained, the number of 6-hours periods for each pattern is presented in figure 3. These six patterns are characterized by similar synoptic configuration at 500 hPa but with slight differences at sea level pressure which determines the local convection. So, the description fot all of them has been grouped into two parts, as it follows below.

- A trough located at western Iberian peninsula induces south-westerly winds over Catalonia.
- Orography plays an important role to trigger convection.
- Lightning activity is mainly between 12 and 18 UTC during the period from late May to early October (maximum in July). So, solar radiation is also another factor to take into account for triggering convection.
- In this group, the season of the year plays an important role:
  - Early summer: the convection is triggered in high mountains (**P1**).
  - Spring: the remaining amount of snow cover keeps the surface temperature low. Consequently, convection is mainly in the Prepirineu Occidental and Ponent (**P2**).
  - Summer: moist supply is important in the NE mountains (**P3**) which are more influenced by sea breezes. On the contrary, in the Pirineu Occidental the lightning activity is lower.

- A trough is located over the Iberian Peninsula with cold air at middle levels of the troposphere. The Catalan coast is characterised by the presence of relative low pressures.
- The position of the low determines the area where convection is triggered by local wind convergences:
  - A pressure dipole structure is formed after the pass of a cold front. Northerly winds over the Pyrenees induces easterly wind over the central coast increasing the convergence in this area (**P4**).
  - A low in front central coast induces easterly wind in the central and southern of the coast with a maximum in the mountains close to Ebre delta (**P5**).
  - The anticyclone located in the Eastern Europe induces southerly winds over the northern coast of Catalonia where convection is really important **(P6)**.
- Lightning activity is more probably between 12 and 18 UTC but it is also present between 18 and 06 UTC, not diurnal hours.
- Convection is more important in September, when sea surface temperature is higher. Solar radiation seems to have a secondary role.



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