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Spatial and temporal lightning distribution in Basque Country

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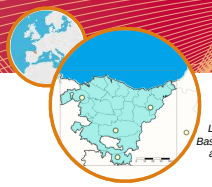
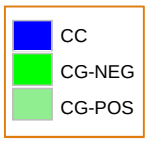


Figure 1: Location of Basque Country and LINET sensors

Abstract

In this work we present the spatial and temporal characteristics of lighting in the Basque Country. For this purpose we use 7-year strokes data (2010-2016) registered in the VLF/LF (very low frequency/low frequency) lightning detection network (LINET) available in the area.

The spatial and temporal distribution of strokes is analyzed, for different spatio-temporal resolution including total strokes (TOT), Cloud to ground (CG), Cloud to cloud (CC), negative (-) and positive (+) polarity, some maps and graphs are presented showing different spatial and temporal patterns .Despite a high year to-year variability, the temporal analysis reveals a clear annual and diurnal cycle and the spatial analysis some orography dependencies and local effects



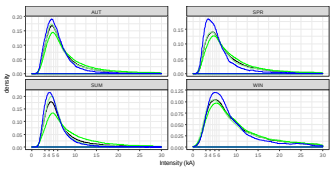


Fig 4. Seasonal (AUT,SPR,SUM,WIN) frequency distribution of absolute amplitudes of TOT (black) ,CG (green) and CC (blue)

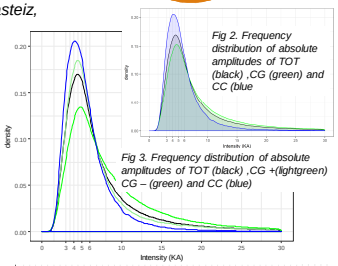


Fig 2. Frequency distribution of absolute amplitudes of TOT (black) ,CG (green) and CC (blue

Fig 3. Frequency distribution of absolute amplitudes of TOT (black) ,CG +(lightgreen) CG – (green) and CC (blue)

Introduction

Since 2009 four LINET sensors are installed by Euskalmet in the Basque Country (Fig 1). Together with the already existing LINET sensors in surrounding area allowed excellent coverage. In fact, due to the relatively short baselines of the 4 sensors and the one in Pamplona the overall data quality is very good.

The network provides data quite homogeneous in efficiency and accuracy over both time and area. The good efficiency of the network can be deduced from the fact that the most probable peak current is around 5 kA. This value allows a high stroke detection efficiency, especially of classical CG return strokes. System report also strokes with even smaller currents; most of these occur within a flash in direct connection with a stronger stroke, but there is some chance that isolated CG strokes have 'untypical' small currents. For each CC event a height is determined which is thought to reflect the central region of the involved channel.

Due to the applied technique and the relatively short baseline the LINET system provides higher sensitivity to weak strokes compared to other lightning detection networks. The detection efficiency does not depend on the type of the stroke but on its amplitude (see Betz et al. 2009 and Nowcast 2017).

Fig 5. Annual distribution of positive and negative CG and CC for years 2010 to 2016.

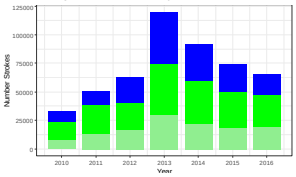


Fig 6. Monthly distribution of positive and negative CG and CC for period 2010-2016.

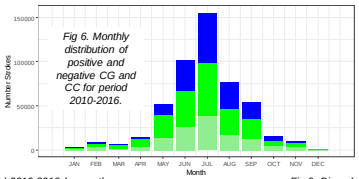
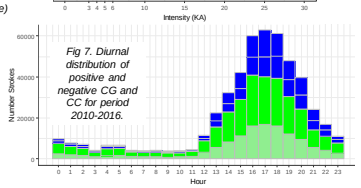


Fig 7. Diurnal distribution of positive and negative CG and CC for period 2010-2016.



Data and Methodology

Data consist of strokes retrieved by the LINET lightning detection network in Basque country from 2010 to 2016 provided off line by Nowcast as txt files with a row for each detected stroke with date, time, lat, lon, height (km), amplitude (A), polarity (+,-) and statistical error (km).

In this study, no grouping of strokes to flashes have been performed, neither mapping into political borders. The analysis was performed for 2010–2016 and includes half million strokes. The analyzed area comprises a 120km x 120km domain including Basque Country. A map of this area including topography and LINET antennas locations is shown in Fig 1 and Fig 13.

We use different R (core team 2014) libraries and scripts in order to analyse temporal and spatial data segmentation and for different calculus and statistics. To study the spatial distribution of lightning occurrence, the strokes have been projected to a 1km x 1km grid. On this grid the number of total lightning strokes, CC, CG, POS and NEG per km2 have been calculated by summing the amount of strokes observed per grid cell and dividing it by the grids' area (1kmx1km).

Fig 8. Diurnal distribution of + and - CG and CC for period 2010-2016 by month.

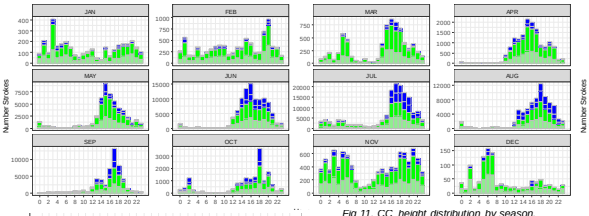


Fig 9. Diurnal distribution of + and - CG and CC for period 2010-2016 by season.

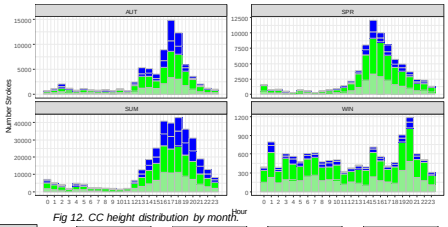


Fig 10. CC height distribution, for period 2010-2016.

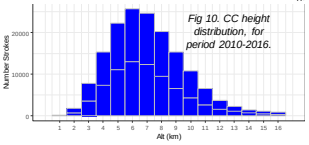


Fig 11. CC height distribution by season.

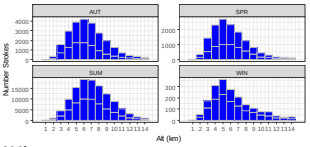
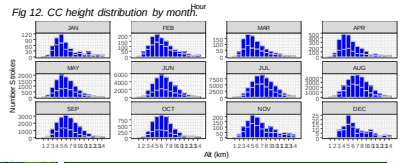


Fig 12. CC height distribution by month.



Results and Discussion

During the study period, 499526 strokes were recorded, 67.4% were CG, 32.6% were CC, 58.8% with negative polarity and 41.2% with positive, the polarity ratio of negative/positive in the CG case is 1.6. In Fig 3 we can see the distribution of CG, CC and total positive and negative strokes counts for 2010-2016 period. in Fig 2 the same for absolute amplitude and in Fig 4 the seasonal distribution. The maximum of the distribution is at 4.5 kA, on average CC are weaker than CG, the distribution of CC strokes is skewed towards lower amplitudes. 51% of all strokes and 33% of all strokes have an absolute amplitude below 5 kA. 9% of all CC strokes and 27% of all CG strokes have an absolute amplitude above 10 kA.

Temporal distribution.

On average 71000 total strokes per year were detected within the analysis domain, 48000 CG and 23000 CC . Despite a high year-to-year variability of lightning rates (see Fig 5), on average a clear **annual** cycle is observed (see Fig 6). The maximum occurs in July (31%), from May to September 87 % of all strokes occurs. In SUM (summer = JJA) 66,6% ,14,8 % during SPR (spring = MAM), 15,9 % in AUT(Autumn SON) and only 2,6 % in WIN (winter =DJF).This lightning seasonal pattern is the consequence of seasonal thunderstorm cycle in Basque Country with a high activity during summer and very low activity during winter.

Furthermore, a **diurnal** cycle with a maximum in the afternoon is present (Fig. 7). From 0 to 6 UTC 8.4% of total lightning occur, 4.9 from 6 to 12 UTC, 46.4 from 12 to 18 UTC and 40,2 from 18 to 24 UTC. 70% of all strokes are detected between 14 and 20 UTC and 30 % between 18 and 24 UTC. The number of strokes is relatively constant from 3 UTC through to 12 UTC. This lightning diurnal pattern is the consequence of the hourly summer thunderstorm cycle in Basque Country with a high activity during the afternoon, related to the solar radiation which is important for triggering convection.

In addition to this well-known annual and diurnal pattern, the analysis shows that the diurnal cycle has an annual cycle, visible in the time of daily maximum which occurs later in the afternoon in summer compared to spring and autumn (Fig 8). During winter no diurnal cycle is present due to wintertime thunderstorms that are related to frontal systems that are not coupled to the diurnal cycle of solar radiation (Fig. 8)

The percentage of CG strokes (67%) is varying annually from around 85% during Jan, Feb, Mar, Apr, Nov and Dec to 65% during Jun, Jul, Aug, Sep and Oct, that is a maximum value during winter and Minimum during summer (the opposite for CC). This reflects the higher proportion of CC during the more active thunderstorm season (Fig 9)

Spatial distribution.

Focusing on the **vertical** distribution of CC in Fig 10 we can appreciate how maximum number of strokes are produced for heights around 6-7 km. These heights present a minimum value around 4-5 km during Winter (Fig 11 and 12). The CC height is related to storm structure, especially the depth of the cloud. That depends on different dynamic and thermodynamic conditions, and to the height of the tropopause, that is higher during summer time.

Focusing on **horizontal** distribution of strokes, the number of total lightning strokes per km2 ,are shown in Fig 14, in Fig 15 we present the same for CC, CG, POS and NEG, and in Fig 16 the seasonal distribution of Total (TOT=CG+CC) and CC.

In the map of total distribution of lightings (Fig 14) we can appreciate areas of relatively high electrical activity at SW and SE of Basque country. Focusing on Basque Country, in general the highest number of lightning strokes occurs in the mountainous interior of Basque Country, particularly in the northwest and mid-south, with the lowest number of light strokes occurring in the west littoral area and in the central area. This distribution is a consequence of different orography effects (barrier, blocking, trigger, etc.) (see Fig 13) and typical summer thunderstorms path from NW to SE generally loosing activity as they approach to the sea. In some density maps (pixels have a resolution of 1kmx1km), the effect of different wind farms, radars and antennas (see Fig 13) are perfectly visible. This is clear in relation to total discharges as a consequence of the CG and NEG discharges, whereas in the POS and CC this effect is not manifested (Fig 15).

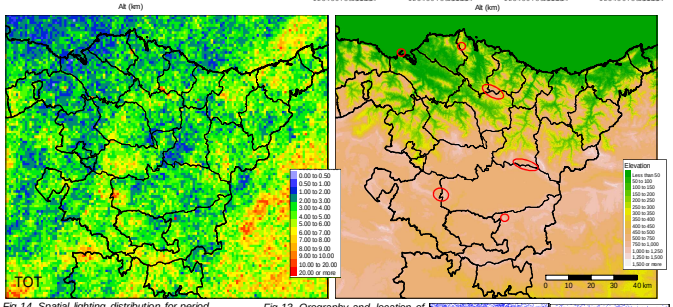


Fig 14. Spatial lighting distribution for period 2010-2016. (number strokes/km2/year).

Fig 13. Orography and location of some high rising structures

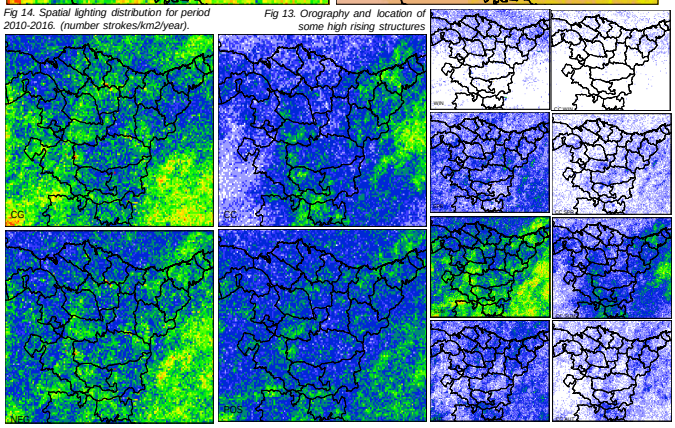


Fig 15. Spatial distribution of CG,CC,POS and NEG for period 2010-2016

Fig 15. Seasonal spatial distribution of TOT and CC for period 2010-2016

Remarks & conclusions

In spite of the seven years of data studied present a high year to-year variability, and are perhaps not sufficient representative, the temporal analysis reveals a clear annual cycle with the highest number of events during summer time (June to August) and a minimum during winter and a diurnal cycle with maximum in the afternoon.

The overall spatial distribution of lighting is consistent with the spatial distribution of parameters favourable for severe weather and orographic aspects that triggers convection in Basque Country. Due to the relatively short period of study and high lightning rate of some thunderstorms, individual events are still visible in this 7-year analysis. The details of lightning occurrence at a resolution of 1 km is very conditioned by the localization of non-natural high-rising structures (wind farms, radar, antennas, TV towers, etc).

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