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ON THE INFLUENCE OF TOPOGRAPHY ON LIGHTNING INCIDENCE IN THE REGION OF PIC DU MIDI

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Abstract – In this paper, we analyze the correlation between altitude and lightning stroke density in the area around Pic du Midi in France. The lightning stroke density was found to increase linearly over the altitude range 600-2700 m in the Pyrenees and remained constant in the plains.
The relation between the lightning stroke amplitude and the altitude was also analyzed. The mean and maximum values of lightning return stroke peak currents observed over the altitude range 0-3000 m were found to remain constant within the area of study.

1 - INTRODUCTION

In general, France is characterized by a relatively low level of lightning activity. There are, however, several spots with high lightning flash density. One of them is the Pic du Midi summit (shown in Fig. 1) in the French Pyrenees where a 104-m tall telecommunication tower is located.
Since 2011, a lightning measurement station [1] is operational at the top of the mountain. Experimental equipment includes a lightning current measuring system, as well as atmospheric electric field and video recordings. Lightning protection systems are studied there by recording lightning impacts to various structures in order to verify experimentally their lightning protection zones.

The objective of this paper is to analyze the influence of the topography on the lightning stroke density distribution measured by Météorage in the region of Pic du Midi. This will allow a more accurate estimation of the downward flash density at elevated sites. Indeed, the estimation of the number of downward flashes from the total number of flashes registered by lightning location systems (LLS) is not a straightforward task [2]. Furthermore, several studies [3]–[5] suggest that the lightning flash density decreases above a certain altitude. Another objective of this paper is to analyze the relation between the peak current of lightning strokes and terrain elevation in the considered region of Pic du Midi.

2 – DESCRIPTION OF THE DATA

Two datasets presenting the spatial distribution of lightning stroke density and topography were used to study the correlation between these parameters. They cover the same geographical area presented in Fig. 1. The area is a circle of 50 km radius centered on the Pic du Midi. The circle is divided into cells of 30″×30″ (30″ ≈ 0.00833º). The differences between the areas of the cells have been disregarded, assuming that they are approximately of 0.6 km^2 each. Details about the data used for this analysis are given in Sections 2.1 and 2.2.

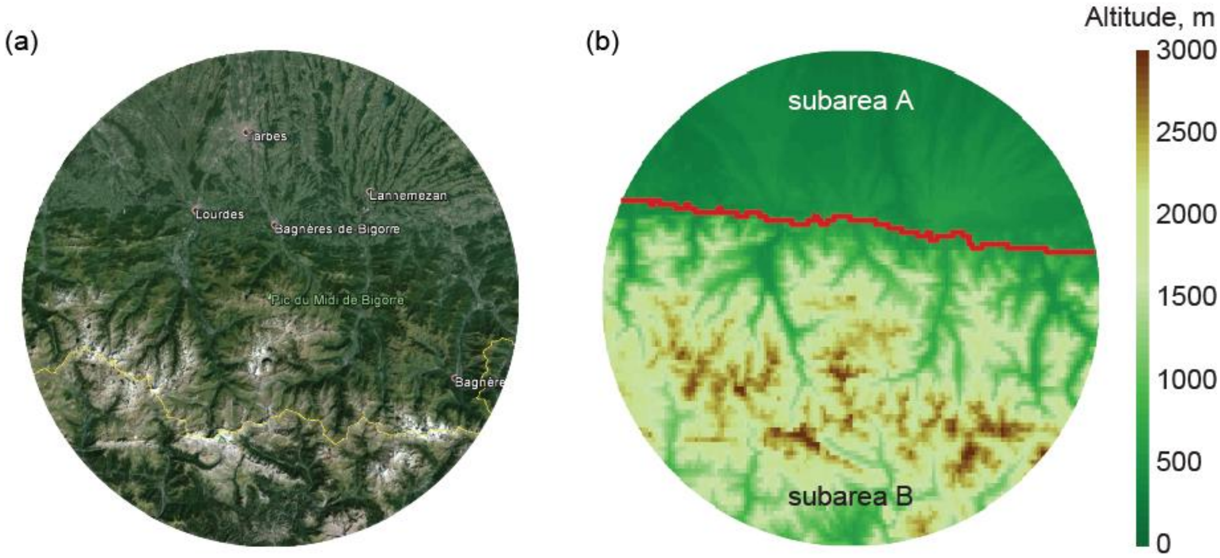

Figure 1 – Area of study: circle of 50 km radius, centered on the Pic du Midi.
(a) – Satellite image, (b) – Topographic map and the border between subareas A and B

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2.1 – TOPOGRAPHIC DATA

The topographic data shown in Fig. 1b were imported from the SRTM30 PLUS database [6]. The data give the average altitude values for the cells of 30″, equal to the size of the cells used in this study.
The altitude of the Pic du Midi is 2877 m. The area of study has two main regions: the plains to the North from Pic du Midi and the Pyrenees to the South. These subareas are defined in Fig. 1b.
There are higher peaks within the area, among them: Vignemale (3298 m), Monte Perdido (3355 m) and Pic de Posets (3369 m). An important notice concerning this study is that a 104-m tall telecommunications tower is installed at the Pic du Midi. Higher summits in the area do not have any tall structures.

2.2 – LIGHTNING DATA

Values of the lightning stroke density for each cell were obtained from the Météorage database. All lightning strokes from the period 2001-2013 were considered for this study. Lightning strokes within the area of study clearly shows two distinctive distributions corresponding to the topographic subareas defined in Fig. 1b: the plains with a lower level of lightning activity and the Pyrenees with a higher lightning activity.

3 – LIGHTNING STROKE DENSITY ANALYSIS

In this paper, we have used two methods of analysis described in [7]: (1) the basic method and (2) the subarea decomposition method. For the first method, all the cells were taken into account, while in the second method only the cells from the respective subareas shown in Fig. 1b were used. The same procedure was then applied to the selected cells, as follows.
Cells selected depending on the chosen method were grouped into 32 intervals based on their altitude: 0-100 m, 100-200 m, … and 3100-3200 m. Some intervals were found to have only very few (less than 100) or none cells and were excluded from the analysis.
The average value of the lightning stroke density was calculated for all the cells within each altitude interval. The results of the application of both methods can be compared in Fig. 2.

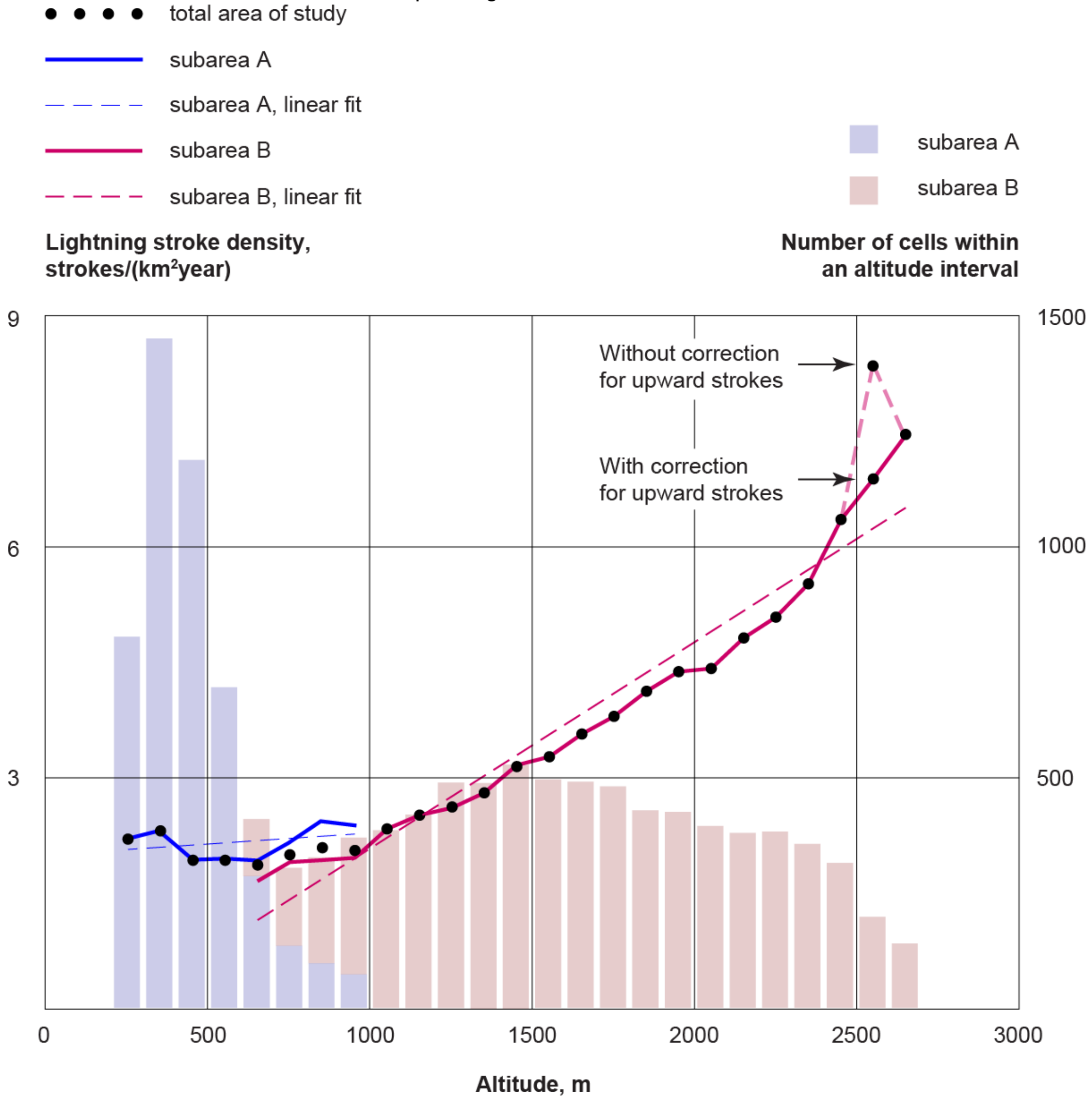

Figure 2 - Distribution of the number of cells within each altitude interval (right abscissa) and average lightning stroke density (left abscissa) as a function of altitude.

The results of the basic method involving the whole area of study are shown with black dots. Note that the lightning stroke density function exhibits an inflexion at around 800 m.

By using the subarea decomposition method and dividing the area of study into two subareas, we can see that the lightning stroke densities (solid blue and red lines in Fig. 2) grow almost linearly in both subareas (see the dashed linear fits) and they intersect at around 1000 m. The blue fit left of the intersection and the red right of it follow the plot function representing the two subareas together. It is clear that, except for the transition altitude intervals, the results of both methods are identical.

Another important part of Fig. 2 concerns the altitude interval 2500-2600 m. Even though the Pic du Midi reaches 2877 m, the cell around it is characterized by an average altitude of 2590 m, thus falling into the specified altitude interval. When the values of lightning stroke density of the Pic du Midi cell together with its neighboring cell are taken into account to find the average value of the respective altitude range, the result is shown in Fig. 2 with a dot marked “Without correction for upward strokes”.

If we now exclude the Pic du Midi cell and its neighboring cell from the calculation of the average value of lightning stroke density for this altitude interval, the result decreases as shown in Fig. 2 with a dot marked “With correction for upward strokes”. Indeed, this decrease can be only explained by the presence of upward strokes in those cells due to the 104-m tall tower and observatory on the Pic du Midi summit. Since we are interested only in the distribution of downward strokes as a function of altitude in the area of study, we have to remove two cells surrounding Pic du Midi, as we cannot distinguish between upward and downward strokes within them.

From these results, we can draw several conclusions. (1) Before searching the best-fit function for the relation between lightning stroke density and altitude, it should be verified that the area of study doesn’t have subareas within it. If this is not the case, the best fit should be applied to the subareas only. (2) A correction is needed for the cells where any objects producing upward strokes are present. Such cells should be ignored when calculating the lightning stroke density average value. (3) The lightning stroke density was found to increase almost linearly within the altitude range 600 – 2700 m in the Central Pyrenees. This result is in agreement with a recent study of the Alps [7]. No decrease of lightning stroke density was observed as reported by other studies [3], [5].

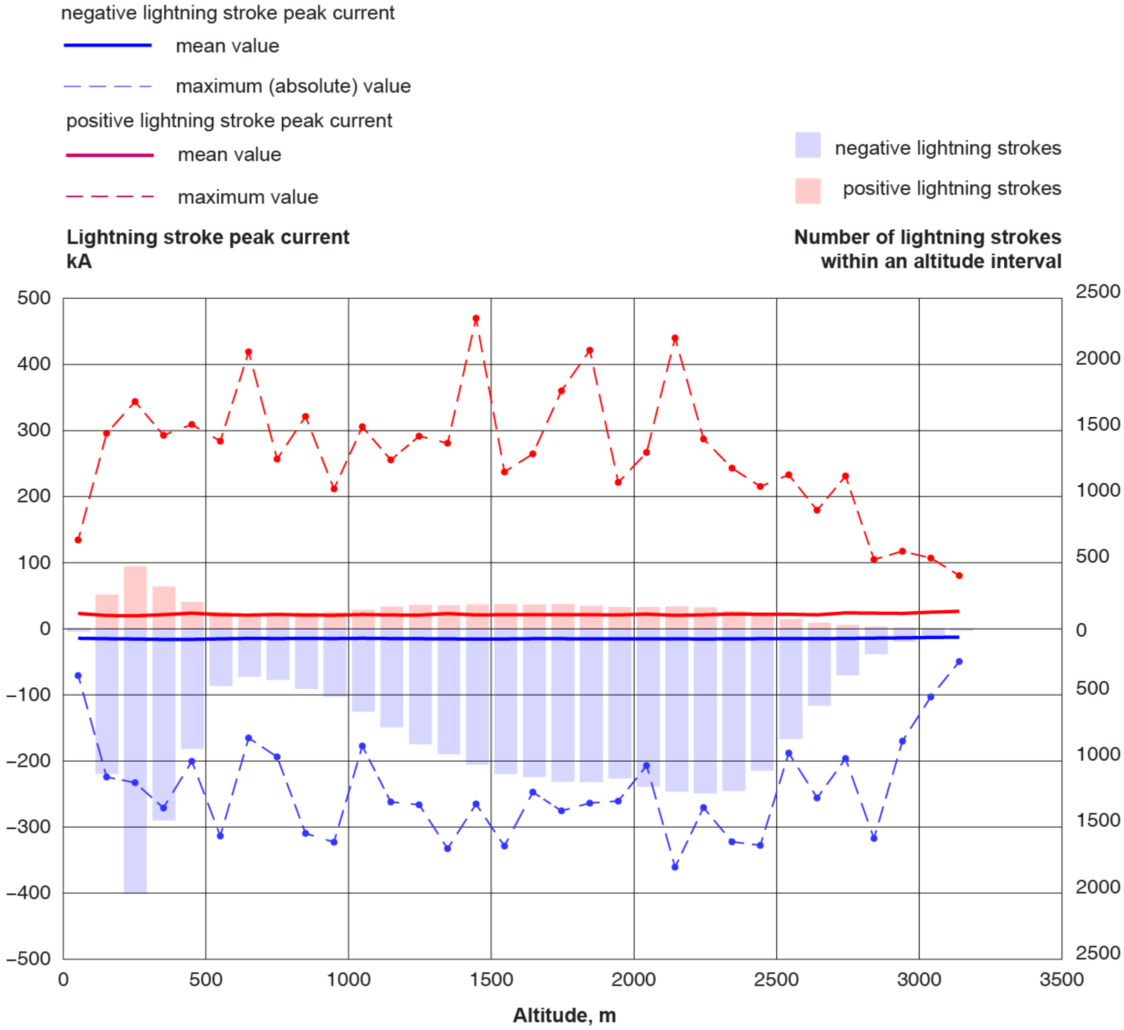

Figure 3 – Distribution of the number of strokes within each altitude interval (right abscissa) and lightning stroke peak current (left abscissa) as a function of altitude

4 – LIGHTNING PEAK CURRENT ANALYSIS

We have also studied the relation between lightning stroke peak current estimated by Météorage and altitude. To perform this analysis, every lightning stroke location from the lightning data presented in Section 2.2 was assigned an altitude value by interpolating the topographic data described in Section 2.1. Lightning strokes were then grouped into 32 intervals based on their altitude: 0-100 m, 100-200 m, … and 3100-3200 m. Mean and maximum values (maximum of absolute peak currents for negative lightning strokes) of peak currents were then calculated for each altitude interval.
The result of this analysis, together with the distribution of the number of lightning strokes within each altitude interval is shown in Figure 3. This plot can be summarized as follows: (1) The significant majority of lightning strokes in this area is of negative polarity. (2) The ratio between the number of positive and negative lightning strokes is about 0.15 for all altitude intervals. (3) The mean peak currents were almost the same for all altitude intervals, the values being -15 kA for the negative lightning strokes and 20 kA for the positive lightning strokes, similar to those reported in [5]. (4) The maximum values of lightning return stroke peak currents show a decrease above the altitude of 2500 m, but this is most probably due to the very small number of lightning strokes within those intervals. A study covering a larger territory is needed to confirm this proposed explanation.

5 – CONCLUSIONS

We have analyzed the relation between the lightning incidence and the altitude in the region of Pic du Midi. We have found that the density of downward lightning strokes increases linearly with terrain elevation within the circle of 50 km radius around Pic du Midi in the Pyrenees area and remains almost constant within the plains in the Northern part of the circle.
Lightning stroke peak currents (both mean and maximum values) were found to be independent of altitude for both polarities of lightning strokes.

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