LIGHTNING AND RAINFALL IN THUNDERSTORMS

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ABSTRACT: The correlations between cloud-to-ground (CG) lightning flash and rain activities have been widely studied during the past ten years. They are usually estimated in terms of location, of rates evolution and of water volume per flash. This work presents some results obtained from this kind of study with data issued from French networks. The CG lightning flash activity is detected by the French network and the rain is estimated from the radar observations. We studied 21 thundercells or systems from 4 days most of them occurring over the French territory. The water volume per flash ranges from 6.2×10^3 to 75×10^3 m^3 with an average value of 26×10^3 m^3. The time lag between the peaks of both activities depends on the detection height of the rain by the radar and the flash maximum precedes by a few minutes the rain detection at low altitude.

INTRODUCTION

The first value of the water volume per flash was proposed by *Battan* [1965], who found, with little sophisticated observation means, 30×10^3 m^3 per CG lightning flash. Then, with the development of the lightning flash location technology, several works have been performed and the values for this volume were close to the first estimation [*Piepgrass et al.*, 1982 ; *Sheridan et al.*, 1997 ; *Tapia et al.*, 1998]. Another important observation has been made by *Piepgrass et al.* [1982] when they noted an advance of a few minutes of the lightning peak rate as compared to that of the rain peak at the ground. So, the CG flash activity can precede the arrival of the heavy rain at the ground [*Williams et al.*, 1989].

DATA DESCRIPTION

We have used data from the French LLP network which detects the spatial and temporal location of the positive and negative CG flashes. This network is composed of 16 magnetic direction-finders. The detection efficiency is better than 90 % over the whole French territory and the localization accuracy is better than 4 km for 50 % of all flashes. We consider in this study the flash density and the flash rate according to the parameter of rain to be compared with.

The rain estimations are issued from the meteorological radars of the French meteorology company. The cm-radars automatically scan at low elevation angle, typically 0.6°, and directly provide the dBZ reflectivity. The rain rate is usually estimated by using the standard Z-R laws, especially that for convective rainfalls proposed by *Austin* [1987] viz. $Z = 400\ R^{1.3}$, where Z is the reflectivity in $mm^6\ m^{-3}$ and R the rain rate in mm h^{-1}.

RESULTS

The results presented in this study concern 11 different cells or systems, according to the ability of separating the activity zones. Thus, the individual cells are not always separated and we call a system when several cells are gathered together. Table 1 shows the synthesis of the calculated parameters for each one of these cases. Two days of activity are considered, one in Southwestern France on August 20, 1994, with 6 cells, one in Northern Spain on August 7, 1996 with only one cell, and one in Paris area on July 11, 1997 with 4 systems.

It namely indicates the CG flash number with the number of positive ones. The maximum CG flash number is 1534 for the cell that occurred in Biescas causing a flash flood in a campground, causing severe casualties. This case studied by *Soula et al.* [1998] presented exceptional duration and stationarity. The number of positive flash is low in each case since its maximum proportion is 7 %. First, the water volume per CG flash has been calculated for each case. It ranges from 6,200 to 75,000 m^3 and the average value is 26,000 m^3. These values are rather common as compared with other results and the variation does not seem to be due to the daily conditions since it appears also within the same day.

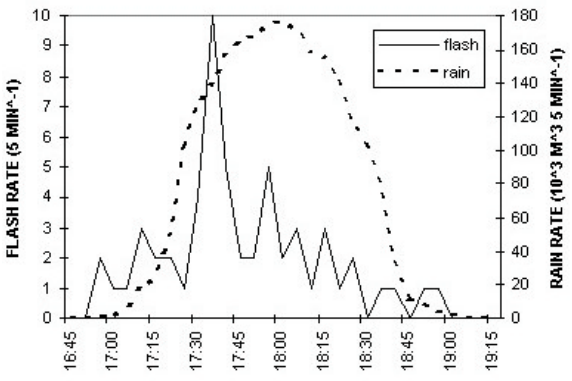

Figure 1. The evolution of rain and CG flash rates for one cell of August 30th, 1994

No correlation appears between this volume and the activity intensity on one hand, and the positive flash proportion on the other hand. In order to compare the evolution of both activities, we calculated the flash rate and the rain rate and we display them in a same graph as it is shown in figure 1. This case of figure 1 corresponds to a cell very close to the radar and therefore, the rain is detected very low, close to 1,000 m. The lightning maximum precedes by 25 minutes in this case.

From the evolution of both rates for each case, we make a quantitative correlation study by curve fitting from the distribution of values pairs of rain and flash rates. In order to take into account the different heights of rain detection, we apply the time lag discussed before to associate both rates. Equation (1) gives the correlation coefficient r between two variables x and y :

$$r = \frac{\overline{x\,y} - \bar{x}\,\bar{y}}{\sigma_x\,\sigma_y} \qquad (1)$$

We try to find a linear relationship between rain rate and flash rate. In Table 1, the results of this fitting are summarized for each case according the following law : V = a L + b, where V and L are respectively the rain volume and the flash rate over 5 minute periods. The values of the constants a and b are indicated in the table as well as the determination coefficient r of the curve fitting. The coefficient r is most of the time clearly larger than 0.5 which indicates a good correlation between both evolutions. The parameter a ranges from 2.34×10^3 to 31.3×10^3 m^3 $flash^{-1}$ and it is close to the water volume per flash when r is high. The parameter a is lower compared to the water volume per flash because the curve fitting do not consider the period with rain and without lightning flash, specially at the end of the thunderstorm lifetime.

Table 1. Characteristics for 11 cases studied

Date and location	a 10^3 m^3 $flash^{-1}$	b 10^3 m^3	r	vol. / flash 10^3 m^3	flash total - positive
Southwestern France August 20th, 1994	9.65	28.17	0.86	16.75	102 - 4
	6.35	18.67	0.92	8.8	235 - 0
	5.47	45.03	0.63	20.6	76 - 0
	8.41	32.24	0.74	11.26	588 - 7
	13.05	30.98	0.93	18.26	224 - 2
	2.34	14.21	0.65	6.2	39 - 0
Biescas	16	41.8	0.57	30	1534 - 40
Paris area July, 11th 1997	13.45	194	0.44	75	99 - 2
	17	141	0.75	36	241 - 2
	31.28	118.26	0.85	41	561 - 7
	10	208	0.69	29	335 - 4

CONCLUSION

The aspects of rain and lightning activities approached in this study show several correlations. For the water volume per flash, our values agree well with previous results. We observe an advance for the CG flash maximum as compared to the heaviest rain at the ground. Both rates of activity seem to be tightly proportional for most of the cases. In the case of storm causing a flash flood, large values of the CG flash rate are detected before large radar reflectivity appear close to the ground. Therefore the CG flashes could be a good indicator of the rainfall. Furthermore the locations of both intense activities correspond very well.

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