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Comparison of radar precipitation fields with lightning observations

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1. Introduction

Lightning activity and convective precipitation are two related characteristics of thunderstorms, and their relationship can be used as a quantitative indicator of the rainfall regime.

The Rainfall-Lightning ratio (RLR) is the usual parameter for the estimation of the convective rainfall volume per cloud-to-ground (CG) lightning flash. Intense storms tend to produce lower RLR values than moderate storms, even if the RLR depends on the thunderstorm type and local climatology.

The objective of this paper is to analyze the relationship between precipitation and lightning in the North Western Mediterranean coastal region (see Fig.1). The present study is a case-by-case study, using daily rainfall accumulations and total lightning information (intra-cloud and cloud-to-ground flashes).

According to the reviewed studies, the RLR in isolated thunderstorms take precipitation values between 38 and 72 103m3 per CG flash.

Figure 1. Coverage of the SMC radar and lightning networks. Radar coverage: lighter area. Radar sites: red dots. Lightning stations: yellow stars. Bottom: pictures of SMC sensors and thunderstorms in the region.

2. Data Sources

2.1 Lightning and Radar Data

Lightning information was collected by the SMC SAFIR lightning detection system (hereafter XDDE). The network is composed by three sensors, covering the region of Catalonia, and its contiguous sea (see Fig.1). The SAFIR stations combine an interferometric sensor to detect intra-cloud (IC) flashes in the VHF with a LF sensor to detect the return strokes of CG flashes. The XDDE spatial accuracy is around 2-3 kilometers, and its efficiency around the 90%.

The weather radar network of the SMC is made up of three C-band Doppler radar systems operating in a highly complex topography environment (see Fig.1). The radar quantitative precipitation estimates (QPE) used in this study were originated from a volumetric short range mode scan updated every six minutes. A composite product was built by selecting the most intense reflectivity (Z) value available for each pixel.

2.2 Selected Days

In the studied region thunderstorms may take place the whole year, but the main lightning activity occurs from June to September. For this study **34 days** were selected. These days contains more of the 75% of the CG flashes registered in 2005 over the study region. The final sample included days of May (3 days), June (8), July (4), August (11), September (5) and October (3).

4. Radar and Lightning Data Processing

Hourly precipitation estimations are obtained through previous conversion of rainfall rate (R) from Z using the standard power-law Marshall and Palmer (1948) Z-R relationship. Daily amounts of precipitation are obtained from the hourly QPE.

The computation of the daily amount of precipitation and lightning activity has been done as follows. Firstly, the region of interest has been divided in cells using a regular mesh of 0.1 degrees, which in the present latitude correspond to approximately 91 km^2 (Fig.2). Then the average of precipitation and the number of IC, total CG and positive CG flashes has been calculated for each cell.

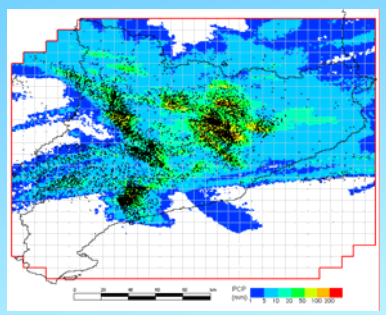


Figure 2. Region of interest (red) with the 0.1 degrees mesh. Example (18/08/2005) of cumulative rainfall and CG flashes (black dots).

Afterwards, different thresholds have been used to consider only the convective cells for each day. A lightning threshold was fixed to a minimum of one CG per cell, while four thresholds of precipitation were used: 1, 2, 5 and 10 mm (hereafter T1,T2,T5 and T10) (see Fig.3).

Regarding lightning data, an 90% efficiency correction has been applied, according to the efficiency estimation for the XDDE (Montanya et al., 2006). Such correction is necessary to facilitate the lightning-precipitation results comparison with prior literature.

Finally, the Rainfall Lightning Ratio was computed on a daily basis, for the 4 threshold situations.

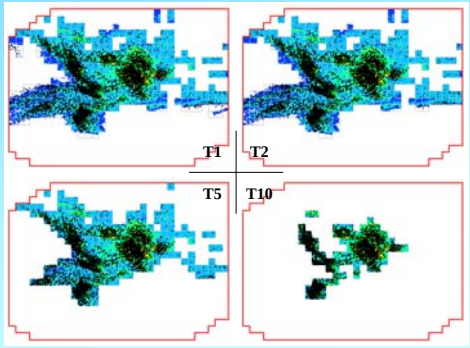


Figure 3. Cells processed according to the four thresholds considered (example: 18/08/2005) T1: Upper left, T2: Upper right, T5: bottom left, T10: bottom right.

5. Results and Discussion

The results found applying the 4 different thresholds for the selection of the convective cells are shown in Table 2. It can be observed that the elimination in the computation of the cells with a daily rainfall average of less than 2 mm reduces the convective cells in a 17%, while the reduction of CG flashes is only of the 6%, and the rainfall volume is only reduced in a 4%. When applying a threshold of 5 mm, convective cells were reduced in more than a half from original ones. However, these cells contains the 70% of the total registered CG flashes. The reduction in rainfall volume is less important compared to lightning, and this difference has the effect of raising the mean daily rainfall volume per CG flash (RLR). This difference in the percents can also indicate that the lightning activity area is not restricted to the highest rainfall areas, but spreads to zones with lower rainfall accumulations. When considering as convective only the cells with a daily rainfall average of more than 10 mm, the total convective area is reduced to only an 18% of the original area. This threshold seems too restrictive in order to account the convective rainfall area.

Table 2. Lightning and precipitation parameters (34 days totals) for the 4 thresholds proposed to identify convective rainfall. Percent under values indicate the convective cells selected (compared to T1) after applying the different thresholds.

Thresh.	Convective Cells	CG flashes	Rainfall Volume (10^9 m^3)	Mean Daily RLR (10^3m^3 CG^{-1})
T1	7010	85451	4095.43	56.2
T2	5849 (83%)	80169 (94%)	3938.43 (96%)	58.9
T5	3294 (47%)	59879 (70%)	3154.55 (77%)	67.0
T10	1250 (18%)	33470 (40%)	1832.25 (45%)	61.8

Table 3. Coefficients of correlation (R^2) for a linear fitting between rainfall volume (with different thresholds) and lightning (intra-cloud, cloud-to-ground, positive CG and total flashes).

Thresh.	IC	CG	CG+	IC+CG
T1	0.666	0.672	0.466	0.673
T2	0.626	0.677	0.466	0.684
T5	0.675	0.699	0.464	0.728
T10	0.781	0.750	0.539	0.779

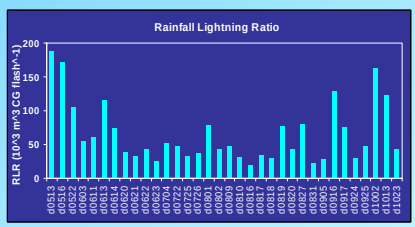


Figure 4. Rainfall Lightning Ratio (10^3m^3 CG flash^{-1}) for the studied days.

The Rainfall Lightning Ratio found in the studied region, (processing 34 days with T2), has a mean value of 58.9 10^3m^3 per flash. The daily range of variation is quite wide, as it goes from 18.2 to 168.8 103m3 per flash (Fig.4). Monthly RLR mean values are the following: 139.7 10^3m^3 per flash for May, 50.0 for June, 38.2 for July, 41.4 for August, 55.5 for September and 99.0 for October.
These results agree in magnitude with other case studies (see summary in Kempf and Krider, 2003). The mean value for the whole studied period is close to the ones found by Soula and Chauzy (2001) and Seity et al., (2001) in France. Meanwhile, if we consider the months of July or August, mean values are more similar to the 43 10^3m^3 found in Florida (Tapia et al., 1998) or the 38 10^3m^3 for the Southeastern United States (Buechler et al, 1990).

The daily rainfall volume has been compared with different types of lightning available. Table 3 summarizes the correlations for a linear fitting between rainfall volume (with different thresholds) and types of lightning. Figure 5 shows, as an example, the daily rain volume versus the daily counts of CG flashes, after processing with T2.

From the overall correlation coefficients presented in Table 3, in most of the cases the R2 is higher as more restrictive is the threshold to select the convective area. Looking to the different types of lightning, the best fitting were obtained with total lightning (IC+CG), followed by the IC flashes.

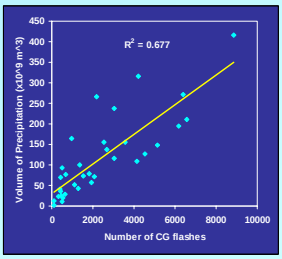


Figure 5. Daily rain volume vs. CG flashes (T2)

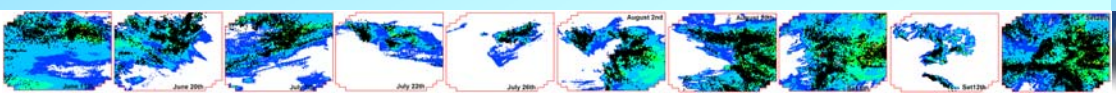
6. Summary and Future Work

This study analyzes the relationship between lightning and precipitation in 34 days of the 2005 thunderstorm season in Catalonia (NE Spain) and its coastal area, in the NW Mediterranean Sea.

The **Rainfall Lightning Ratio** found in the studied region has a mean value of **58.9 10^3m^3** per flash. These results agree in magnitude with other case studies in other regions.

The daily rainfall volume has been compared with different types of lightning available, being the **best fitting with total lightning (IC+CG),** followed by IC flashes, CG flashes and positive CG flashes.

From this analysis, it is clear that lightning data can be useful for estimating the locations and amounts of convective rainfall, when only lightning data is available. Meanwhile, rainwater volume per CG flash can vary much more from one day to another, and the RLR depends on factors like the season of the year, the convective regime, the storm intensity, etc. A good identification of the convective area of the storm will help to reduce such variability. In this sense, rainfall intensities could be calculated in the hourly rainfall estimations, and use such information afterwards to delimitate the convective areas in the daily accumulations, more than using a daily volume threshold, which is mixing convective and stratiform rainfall.



Fourth European Conference on Radar in Meteorology and Hydrology
Barcelona 18 - 22 September 2006
ERAD 2006