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TOTAL LIGHTNING, ELECTROSTATIC FIELD AND METEOROLOGICAL RADAR APPLIED TO LIGHTNING HAZARD WARNING

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1. INTRODUCTION

Several works deal with lightning warning methods developed from cloud-to-ground (CG) lightning locations [i.e. Murphy and Cummins 2000; Murphy et al. 2002a; Holle et al. 2003]. In a few number, the warnings are based on cloud (IC) lightning detections [i.e., Murphy 2002b]. Additionally, other particular works combined total lightning with meteorological radar information in order to improve the efficacy of lightning threat alarms [i.e., Murphy and Holle 2005; Murphy and Holle 2006].

This paper presents the analysis of various combinations of data sets with the purpose of evaluation of lightning warning methods. The data sets include CG flashes, IC sources, radar reflectivity and, for some specific cases, electrostatic field recorded at ground level.

2. DATA

Very High Frequency (VHF) sources associated with the total lightning activity were obtained from the Catalan Lightning Location Network (XDDE) operated by the Meteorological Service of Catalonia (SMC). The XDDE is composed by three VHF interferometers [Richard and Lojou, 1996] that cover the north-eastern region of Spain, corresponding to the studied region. Additionally, the Spanish Lightning Detection Network (SLDN) has provided CG lightning characteristics (time, location, polarity and peak current) for some episodes. The SLDN is composed by fifteen low-frequency (LF) combined magnetic-direction-finding and time-of-arrival (MDF/TOA) sensors over the Iberian Peninsula [Rivas Soriano et al., 2005].

Volumetric reflectivity images were obtained from the three C-band radars operated by the SMC. These radars operate at long (240 km) and short (130 km) ranges performing a series of 14 scans with elevation sweeping of 0.6º every 6 minute.

For several episodes, the electrostatic fields measured at the Eagle Nest tower and at the city of Terrassa (Barcelona) were available.

3. ANALYSIS

The data set for this study is built basically with the summer season storms corresponding to the period comprised from 2004 to 2007.

The warning method is based on the two regions method similar to that was described by Murphy et al. 2002a. The called Area of Concern (AOC) is an area that surrounds the Point of Interest (PI) where lightning warning information is needed. The AOC is surrounded by a second area named Warning Area (WA). An event in the WA is used to trigger the warning at the AOC. Then, an Effective Alarm (EA) is an event that is first detected in the WA previous to a CG flash in the AOC. The time difference between the start of the alarm and a CG flash at the AOC is named as Lead Time (LT). In the case that the first CG flash is produced into the AOC without a previous triggered alarm it corresponds to a Failure to Warn (FTW) case. After an alarm is triggered, a Dwell Time (DT) of 30 minutes is adopted for the alarm extinction. The DT clock is reset with every other alarm trigger event within the WA. Both areas are illustrated in Figure 1.

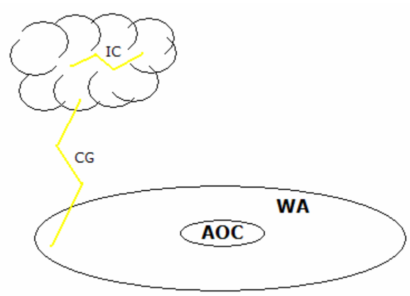

Figure 1. Representation of the warning area (WA) and the area of concern (AOC) according to the two area method for warning.

Four different sources of information are adopted to trigger alarms in the WA. These events are: 1) a CG flash striking the WA; 2) an IC source located within the WA; 3) a 35 dBZ radar reflectivity at 1 km altitude located above the WA; 4) a combination of CG or IC and 35 dBZ within the WA. Three sites in the Northeaster region of Spain were selected for the four-type trigger events at: i) Barcelona's airport (S1) which is very close to the Mediterranean Sea; ii) Tarragona's petrol platform (S2) which is 1.5 km by the sea; and iii) The Eagle Nest Tower (S3) located at a mountain peak (2537 msl). The number of the thunderstorm days analyzed for the site S1 were 18, 31 for the site S2 and 30 for the site S3.

Not for all three sites electrostatic field was available. At the Eagle Nest instrumented tower the electrostatic field is not continuously recorded, so only few storms were analyzed. However, electrostatic fields are permanent recorded at the city of Terrassa.

Figure 2. Geographic locations S1, S2, S3 and Terrassa employed for this analysis.

4. RESULTS AND DISCUSSION

After computation, many different results were obtained. The paper summarizes the most remarkable.

The number of alarms for each type of trigger at S1 (Barcelona's airport) is displayed in figure 3. Strong differences could be observed by employing the four different types of alarm source. The alarms based on CG, IC and radar data present large number of False Alarms (FA) compared to the number of Effective Alarms (EA). The number of alarms from IC detections is much higher than the number of the alarms triggered only by CG. Adopting a 35 dBZ radar reflectivity level, the number of the alarms is reduced, but there is a high proportion of FA/EA. By including radar and total lightning (Combined or type 4) the number of generated warnings is reduced and the ratio EA/FA increases. Very similar results were obtained for locations S2 and S3.

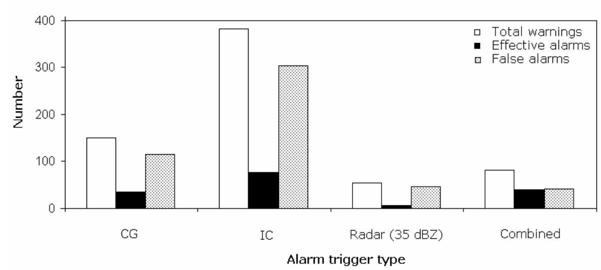

Figure 3. Number of the alarms triggered at Site 1 (Bareclona's Airport) corresponding to the four types of trigger.

The results in figure 3 do not take in to account independently the three AOC sizes (1 km, 5 km and 10 km radius). The relation between the four types of trigger events respect the size of the AOC for S1 location is displayed in figure 4.

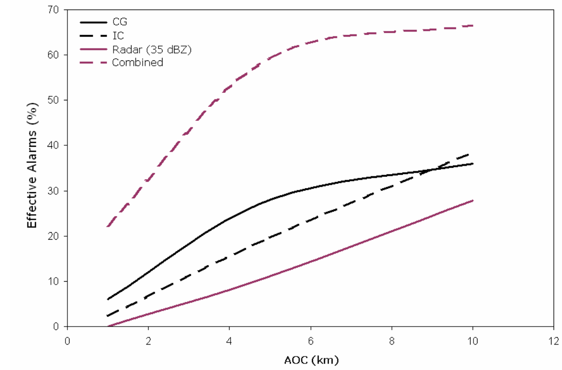

Figure 4. Effective Alarm (%) versus AOC (km) for the four types of alarm source.

The obtained curves clearly show how the Combined trigger source produces an increase of the EA. While the EA increases with the size of the AOC for IC and radar sources, the CG and the Combined sources denotes some saturation. This saturation is confirmed by the analysis of sites S2, S3 and S4. Then, the results suggest that the tested events results more optimal for the medium size of AOC (AOC/WA of 0.25). For smaller AOC (AOC/WA of 0.05) the EA strongly decrease, while for larger AOC (AOC/WA of 0.5) the EA do not increase substantially.

An alarm would be effective if its LT offers enough time to activate preventive actions. Figure 5 displays the average LT obtained at site S1. In this case, statistical results of LT are not too much representative since the number of alarms is not too high. However, it would be logical that bigger AOC would produce lower LT , it is confirmed in all cases except for the CG alarm type. The Radar (35 dBZ) source did not produced any alarm for AOC of 1 km, it could indicate that this reflectivity level was low.

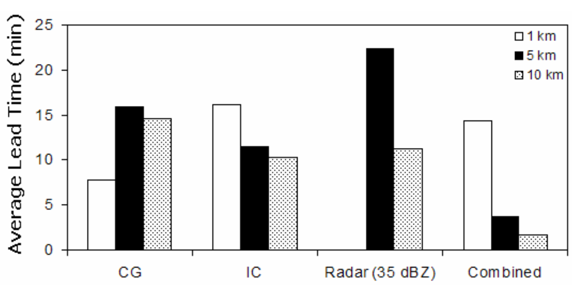

Figure 5. Mean Lead Time corresponding to the alarms of site S1.

The FTW are the cases where a CG struck the AOC before any triggered alarm in the WA. Figure 6 displays the non detected alarms respect the total warnings (TW) for each site. This percentage remains below 2% for an AOC of 5 km and reaches 9 % for AOC of 10 km.

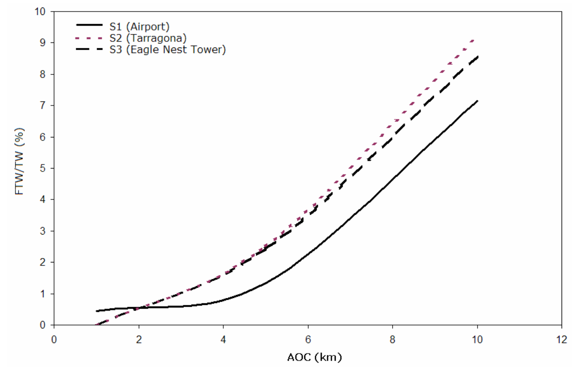

Figure 6. Failure to Warm/Total warnings versus AOC for sites S1, S2 and S3.

At this point we presented the alarm analysis based on the four different sources. In order to reduce understanding difficulties of the electrostatic field evolution in time, we first calculated the 120 s average. We adopted this average in order to smooth the field due to abrupt field changes corresponding to lightning flashes. Then, we analyzed the evolution of this average field with the locations of CG and IC sources. For a 12 s analysis frame step, the nearest IC and CG flash is represented together with the averaged electrostatic field in figure 7

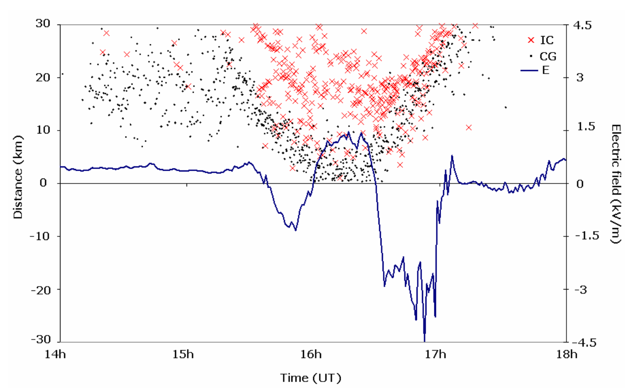

Figure 7 Electric field (in terms of potential gradient), CG and IC activity for a storm in the city of Terrassa.

Figure 7 clearly shows how the electric field (in potential gradient term) reverses from positive to negative when the storm is approaching. For the WA considered in this study, alarms based on lightning location of CG or IC were triggered before 14:30 UT. However, the first CG lightning at the AOC appeared after 16:00 UT. When the storm was approaching, an intensification of the electric field and a polarity reversal were produced after 15:30 UT (aprox.). The polarity changes to negative indicated the presence the negative charge above. But, just after 16:00 UT, when the CG flashes struck the AOC, another polarity change appeared. The polarity became positive for a period of 30 min that was probably caused by the rain. When the storm moved away from the AOC and after some oscillation, the electrostatic field returned to its positive polarity

The electrostatic field could well be combined with alarms based on lightning locations. Considering both information, an alarm could be triggered when a flash is within the WA and the probability of a lightning flash at the site could be evaluated with the electrostatic field and the location of the lightning events.

5. CONCLUSION

Thanks to the facilities available in the Northeaster region of Spain different types of lightning warnings methods have been studied. The paper showed how adopting CG, IC and radar information individually produces different results. Additionally by assuming a simple combined source information for triggering alarms the results are substantially improved.

It is not new that the measurement of the electrostatic field offers some idea of the electrical activity of a storm. However the application to warning is still not too much extended due to the complexity of the electrostatic field behaviour at ground level. In this paper we presented few ideas about how the electrostatic field could be combined with total lightning location information for warning purposes.

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