TOTAL LIGHTNING ANALYSIS OF A TORNADIC SEVERE WEATHER EVENT

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I. INTRODUCTION

This study presents an analysis of total lightning and radar data of a severe weather event that took place in the early morning of 2nd November 2008 in Catalonia (NE Spain). A general overview of the synoptic framework and damage observed, including local flash floods, strong wind gusts and an F2-tornado, is given in a companion study (Bech et al. 2009).

The Meteorological Service of Catalonia operates a total lightning information system based on 4 VHF-LF sensors which provide intracloud (IC) and cloud-to-ground (CG) lightning observations (Pineda and Montanyà, 2009) and a network of 4 C-band Doppler weather radars designed to provide high resolution measurements. Total lightning data may provide very useful severe weather warning information given the higher temporal resolution than radar data.

Severe storms can display more distinct lightning characteristics than ordinary storms, showing what can be considered anomalous lightning activity, whether trough lightning frequencies, CG flash polarity, multiplicity, peak current, etc. Focusing on lightning activity associated to tornadoes, some anomalous activity observed in other studies consists on:

- Predominant CG positive polarity at the time of the tornado (Carey et al., 2003).
- Lightning jumps –abrupt increase in the flash rate in advance of the maximum rate of the storm (Williams et al., 1999) and before the onset of the tornadic activity (Perez et al., 1997).
- Decrease of lightning activity during the tornado lifetime (Williams et al., 1999).
- Low peak currents of positive CG prior to the tornado, strong +CG strokes near the end of the tornado lifetime, and low –CG multiplicity during the tornado lifetime (Dotzek et al., 2005).

II. RESULTS

Two thunderstorm cells affected NE Spain (see area of interest in Fig.1). They originated strong wind gusts and at least a tornado with F2 damage near the Mediterranean coast. The 6-min radar frequency allowed a good monitoring of the lifecycle of the cells.

The main cell (Cell 1 hereafter) had an overall duration of more than 4 hours, it started around 00:06 UTC, travelled north during 3 hours to reach the coastline, and produced a F2-tornado 30 km inland. The second cell formed later (Cell 2), around 01:12 UTC, as a daughter of Cell 1, travelled north-west and produced strong wind gusts in the coastal city of Salou. Table 1 summarizes the cell characteristics. Figure 2 shows a mosaic of radar images that compose the cell's paths. Both cells had a mean velocity of around 43 km/h, to finally merge around 04:06 UTC.

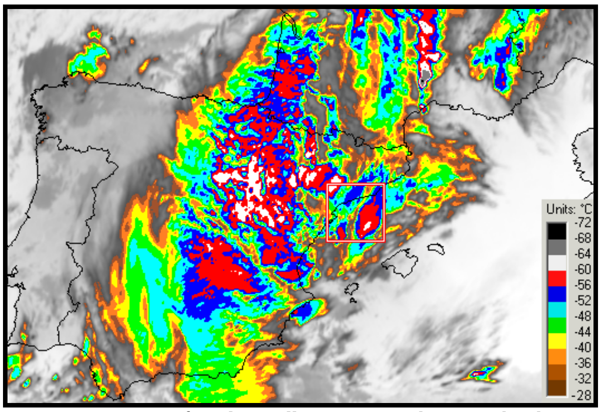

FIG. 1: MSG infrared satellite image showing brightness temperature and the area of interest, marked with a square, in the NE of the Iberian Peninsula.

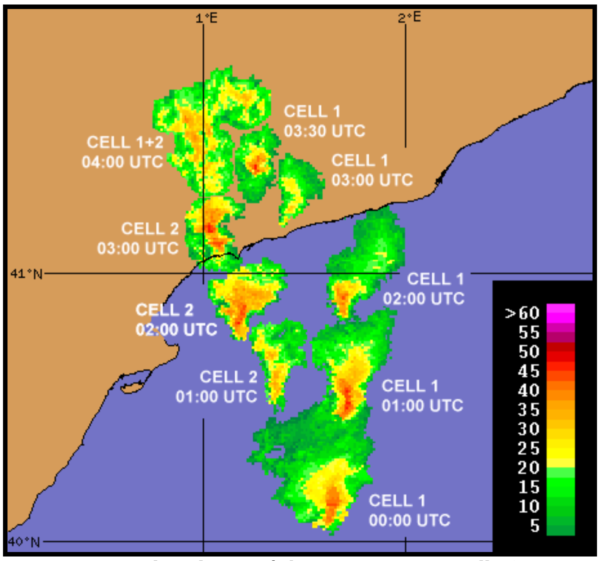

FIG. 2: Temporal evolution of the two convective cells (CELL 1 and CELL 2) examined in this study as seen in a sequence of base-level PPI (0.6º) radar reflectivity images (legend in dBZ).

Cell 1 had two periods of high activity, with a minimum in between. As it can be seen in Fig.3, between 00:36 and 01:42 UTC, maximum reflectivity was above 52 dBZ, TOP-12 above 11 km and a CG flash rate above 4.5 min^{-1}. After 01:42 UTC the cell enters in a decaying stage, with a minimum of activity around 01:54 UTC, after which radar and lightning parameters start to grow gently but constantly.

The cell reached the coastline around 02:42 UTC, and soon after, there was an explosive growth (03:06 to 03:24 UTC), a 18 min period where the IC flash rate changes from 11 to 62 IC flash min^{-1} and the CG flash rate from 1.3 to 10 min^{-1}. Around 03:18 UTC an F2-tornado was reported.

Cell 2 appears at 01:12 UTC and has also a south-north trajectory, while it keeps west from Cell 1. Both cells moved with a similar velocity to the coast, and merged inland after the severe weather, around 04:06 UTC (See Fig 2).

Lightning activity in Cell 2 starts to be considerable at 02:06 UTC, with a CG flash rate of 8.8 min^{-1} (see Fig.4). However, it is not until it reached the coastline that the lightning activity had an important increase, as IC flash rate reached the 100 min-1 at 03:12 UTC (CG flash rate 16 min^{-1}). From that time, all radar and lightning analyzed variables starts to decrease until the cell merges with cell 1.

Characteristic	CELL 1	CELL 2
Cell duration	4h 6 min	2h 54 min
IC flashes	5617	5332
CG flashes	720	970
-CG flashes	41%	57
+CG flashes	59%	43
Average multiplicity	1.47	2.0
Maximum CG flash rate (min-1)	10.0	18.2
Maximum IC flash rate (min-1)	62.0	100.0
Average IC:CG ratio (maximum)	7.7 (14.4)	5.4 (9.2)
Average peak current for -CG kA (median)	-44.3 (-32.8)	-69.9 (-70.5)
Average peak current for +CG kA (median)	26.2 (17.1)	13.4 (9.8)
Average peak current for +CG >10 kA (median)	40.0 (28.3)	28.2 (18.7)

TABLE I: Summary of selected characteristics of the two cells examined in this study.

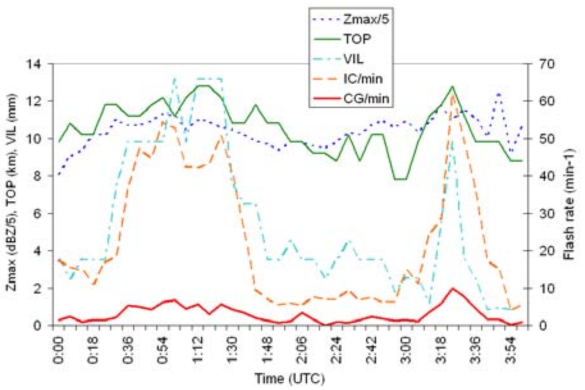

FIG. 3: Radar (Zmax, VIL, TOP-12) and lightning (IC and CG flash rate) evolution during the lifecycle of Cell 1

III. DISCUSSION

In the following, the anomalous lightning activity listed in the introduction is analyzed in the present case study. A lightning activity peak has been observed in both cells (lightning jump), before the onset of the severe weather, especially in the intra-cloud flash rate. About the predominance of positive polarity during the tornado lifetime, in Cell 1 some +CG dominant 6-min periods were observed during the tornado onset.

Patterns described by Dotzek et al. about the peak current behaviours have been observed, as +CG peak currents remain low during the tornado. However, no changes in CG multiplicity were observed.

On the other hand, while in the radar imagery analyzed exhibits some signs of supercell character, no lightning holes were observed.

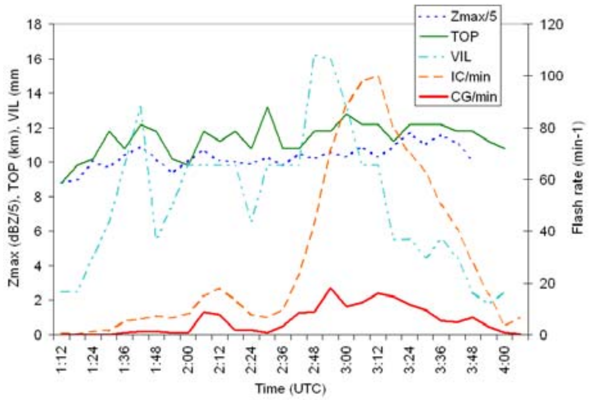

FIG. 4: Radar (Zmax, VIL, TOP-12) and lightning (IC and CG flash rate) evolution during the lifecycle of Cell 2.

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