THE DIFFERENT IMPACT OF A SEVERE HAILSTORM OVER NEARBY POINTS

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I. INTRODUCTION

The present work shows how the effects at surface produced by a supercell can be dramatically different in distances no longer than five kilometres. With this purpose, the data of six hailpads and five weather stations have been compared with the remote sensing data, in order to give possible answers to the question what are the main factors that produce these differences.

The Lleida plain is an agricultural area with about 200.000 ha of crops, covering an area mainly composed by orchards (i.e. apple, pear, peach, almond, and nectarine) and sweet corn fields. This region is placed at the west of Catalonia, at the North East of the Iberian Peninsula (Figure 1). Because of the geographical configuration, the impact of hailstorms in this area is significant. Their impact is also evidenced by the large number of studies done in the area (e.g. Tudurí et al., 2003; Ceperuelo et al., 2006; Aran et al., 2007; Montanyà et al. 2009; Pineda et al.,2009). For this reason, the *Agrupació de Defensa Vegetal de les Terres de Ponent* (Group for the protection of plants in the *Terres de Ponent*, ADV-TP) manages a network of 170 hailpads with an approximate mesh of one hailpad every 4 x 4 km (Palencia et al., 2007; Farnell et al., 2009). In 5th July of 2012, a severe hailstorm affected a great part of the region, producing important damages in the orchards and crops but also in urban areas.

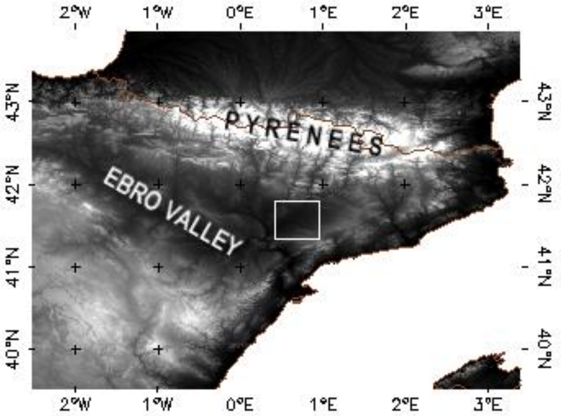

FIG. 1: The Lleida plain in the Ebro valley (white square), North East of the Iberian Peninsula.

In order to study this episode, data from weather observation systems from *Servei Meteorològic de Catalunya* (Meteorological Service of Catalonia, SMC) has been used. The SMC operates two Doppler C-Band weather radars more or less closed to the region: *Creu del Vent* (CDV), located approximately 50 km east of the study area, and *La Miranda* (LMI), placed 65 km at south. Lightning data were registered by the Lightning Location System (LLS) composed of four LS8000 Total Lightning Sensors. The LLS of the SMC has the particularity of detecting cloud-to-cloud flashes (CC) and cloud-to-ground strokes (CG). On the other hand, upper air level data used come from the SMC radiosonde, which is launched in Barcelona (international code 08190). Finally, data from 4 Automatic Weather Stations (AWS), which are part of the 171 AWS SMC network was used.

This data has been complemented with an extensive field work, which includes 20 interviews to people of the area affected by the hailstorm, in order to compile data on the hail size and damages from farmers and other observers.

The work is divided in the following points: firstly, there is presentation of the most important meteorological threats; next follows the description of the field work realized; then the main point of the document is the comparison of the different data types with the aim to detect remarkable features associated to the different affectation at surface; and finally the conclusions are presented.

II. METEOROLOGICAL FEATURES

The synoptic situation was characterised at high levels by a low located at the north-west of France coast, which had moved the previous hours from the British Isles. Around noon the trough axis was situated in the centre of the Iberian Peninsula, showing a North-South orientation. Although the strongest synoptic forcing was in the Bay of Biscay, Catalonia was in the warm sector where there was a remarkable divergence zone over 500 hPa. At the surface level, a relative low developed the previous day in the southeast of the Iberian Peninsula impinged easterly winds on Catalonia. Consequently, the air mass in Catalonia was quite humid and presented potential instability. The radiosounding data of Barcelona showed a CAPE of more than 1936 J/kg at 12 UTC. Another factor that played an important role was the high values of wind shear between 0-6 km (21,2 m/s in Zaragoza) and the veering profile detected. Moreover, the vertical shear in the zone where the storms were initiated was probably modified by the complex orography and by the interaction of another storm.

The preliminary scenario must be situated at 14:30 UTC (Figure 2), when the first thunderstorms had appeared in the Centre and SW of Catalonia. At that time, in addition to intense reflectivity values at low and mid-levels, tilting phenomena in some vertical profiles must be pointed out, as is an indicator of possible severity in the thunderstorm, and that it is associated with strong winds at high levels (that produces intense shear). Other relevant pattern is the hook echo observed in some of the detected structures.

Between 15:30 and 16:00 UTC, the convective cell, responsible afterwards of the hail episode in the area of study, was in an early stage of development. The reflectivity at 9 kilometres ASL presented values that can be considered associated to deep moist convection (Doswell et al., 1996), with values exceeding the 50 dBZ for an area of more or less 50 square kilometres. Having in mind that the mean diameter of a typical thunderstorm is close to 25 kilometres, the analysed thunderstorm presented dimensions clearly associated to a supercell. In fact, it had been growing as a daughter of previous thunderstorms but rapidly acquired a strong identity that made it as the dominant structure into the mesoscalar system. During this stage, the cell moved more or less fast but producing important damages in agricultural areas due to the severe hail and elevated rain rates.

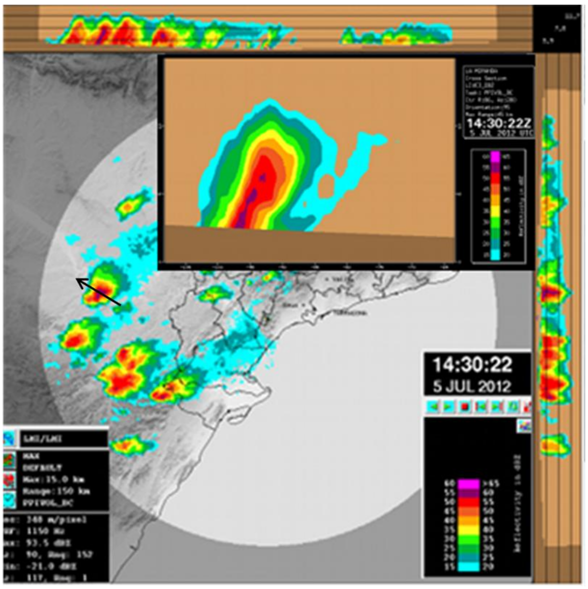

FIG 2: MAX product for the LMI at 14:30 UTC, with the vertical section of a thunderstorm at the top right (the arrow shows the direction of the cut)

Between 16:24 and 16:54 UTC the cell crossed the affected area. At first, the MAX product showed how the region with higher values of reflectivity was placed at mid-levels. However, later on, when the thunderstorm was in the centre of the area, the part with the greater values has gone down, both in altitude and intensity. This pattern is an indicator of the change in the dominant draft inside the thunderstorm: while in the development stage the updraft is clearly the main flow, since that moment the downdraft had started to be more important. It was at this moment when the hail size was probably bigger, and the downburst into the structure more probable. In fact, the wind damages produced by the thunderstorm were probably associated to this last phenomenon, more than to the presence of a tornado. The maximum VIL values are quite similar and hold above 63 mm in practically all the period. However, at the last chart (16:54 UTC), the values had decreased drastically to less than 54 mm. This indicates that the water column collapsed between 16:48 and 16:54 UTC. At the same time, the CG flashes started to decrease since that moment. One of the most interesting aspects is that although the thunderstorm moved quite fast, the effects at surface were really devastating.

After of crossing the affected area, the thunderstorm was moving in the same direction (SW to NE) for more or less one hour (until 18:00 UTC), when it merged with another thunderstorm. This fact produced firstly a brief period of maximum intensity in radar and lightning activity, but rapidly the new structure decreased until its extinction 30 minutes later.

III. FIELDWORK AND HAILPADS

This section analyses the impact of the hailstorm at surface, using two sources of information: data from the hailpads present in the region and the extensive fieldwork that was conducted after the hailstorm. In this sense, 18 hailpads of the ADV-TP network have provided data on the intensity and diameter of the hailstones. Once classified using the Anelfa scale (Dessens et al. 2007) data is represented on a map, giving a picture of the hail distribution along the storm path.

The fieldwork has consisted in an extensive on-site recompilation of information, just after the episode. The damaged areas were visited and interviews were conducted among urban and agricultural population directly affected by the hailstorm. Firstly, the most damaged area was studied. This region is highly populated, which means a lot of observers and observations. The information gathered included not just explanations but also photographs and videos. The next step was visiting the boundary fields of the most damaged sector. People interviewed included farmers, agricultural cooperative technicians, city council members, etc. They helped to define the characteristics of the hailstorm and the severity into the different areas. In this way, the affected zone has been delimited into different categories according to the hail diameter and intensity.

All the gathered information was georeferenced, so as to be mapped as a whole in platforms like Google Earth ™. Besides, data was analysed with GIS in order to mark out the regions with similar hail intensities and diameter. Finally, such fieldwork data has been compared with hailpads data. Figure 3 shows the resume of the both analysis, and it is a graphical demonstration of the narrow linear area where hail size presented diameters over the 5 cm.

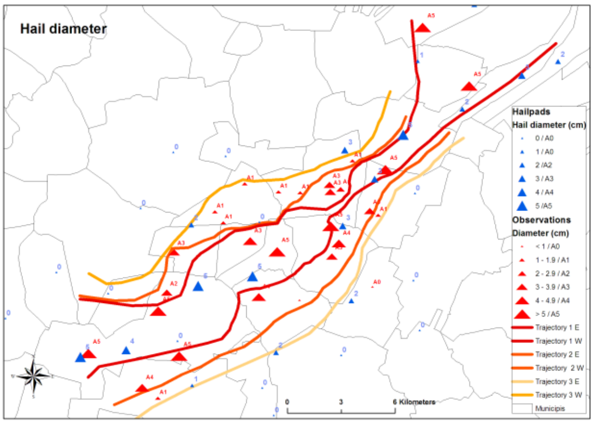

FIG. 3: Results obtained on the fieldwork and the maximum hail diameter recorded in hailpads

IV. RESULTS

In general, analyses of thunderstorms are made from the point of view of the evolution of the convective cloud throughout its life cycle. In the present case, the study has been centred in the observation of the thunderstorm from different points that were more or less affected. In fact, the selected points, corresponding to hailpad locations, presented a large range of hail size and the damages produced were very different. These differences leaded us to study the evolution of different parameters during the passage of the hailstorm. The study has been carried out starting from the observations at surface: fieldwork, hailpads, and automatic weather stations. Some parameters such the hail size, the maximum wind gust, the temperature evolution, or the precipitation have been compared with remote sensing data. In this case, cloud-to-ground (CG) lightning flash observations and different radar magnitudes (reflectivity at surface, maximum reflectivity, TOP30, TOP50 and VIL) have been estimated for each point where ground observations were available (Figure 4).

The comparison of the time evolution of different parameters allowed us to observe some aspects associated with the behaviour of the thunderstorm and its severity. Firstly, a good correlation was observed between the evolutions of all of radar parameters, showing a coincidence in time of the maximum. However, the maximum of reflectivity occurred in advance in comparison to other magnitudes (mainly over the surface reflectivity), being caused by the elevated values associated to the intense updraft (this means that it can be used as a good very short-time forecaster of hail). This fact occurred mainly in those cases where hailpads had detected large hail size. Regarding the lightning activity, this has tended to appear rear the maximum values of the radar parameters, and it was closely related with the intensity of the radar parameters (except for the case of the L8, flashes were detected near the hailpads only in the case where the TOP50 reached the 10 km value). Relating to the last point, the observation of TOP50 values above 10 km indicate the intense vertical development of the thunderstorm, even more if we take into account that when the cloud crossed over the region its life duration had exceeded the 2 hours. Another interesting point is that the rainfall values derived from the rain gauges presented also a delay with the reflectivity at surface. However, in this case the delay is an artefact produced by the time of fusion of hail stones into the rain gauge (Figure 4).

Regarding the effects at surface, the passage of the thunderstorm produced a very significant decreasing of temperature in all points, reaching in some cases the 8 ºC in less than 1 hour. It is also noticeable that the daily maximum was registered few minutes before the thunderstorm arrived. Wind records of the nearby AWS showed gusts up to 21.3 m/s, recorded in Mollerussa. In fact, this AWS has stopped to record wind data just after this maximum, indicating an anemometer failure which was confirmed afterwards on-site. The maximum values of the wind speed after the maximum radar parameters must be associated to the rear front produced by the downdraft generated by the heavy precipitation. Finally, the radar values and the fieldwork helped to observe some problems with hailpad L6, as it must have registered some small size hail (Figure 4).

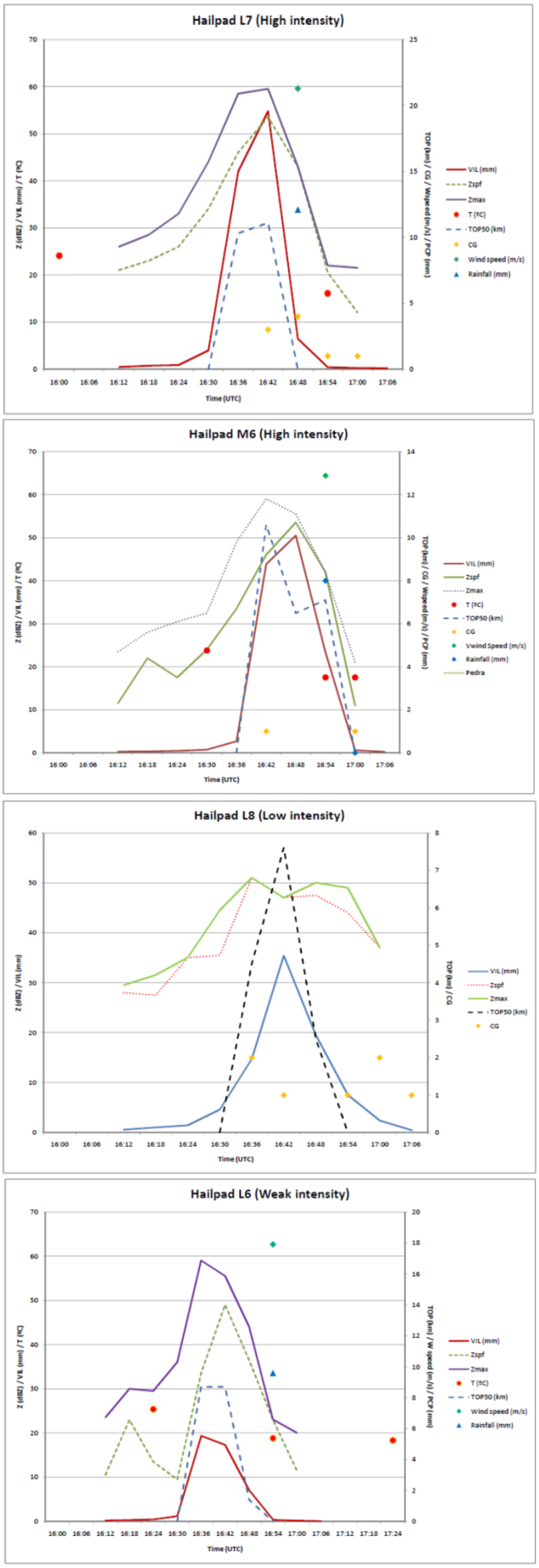

FIG. 4: Time evolution for different radar, electrical and surface variables at the some of the analysed hailpads.

Thanks to the information that has been collected on the field work, the area with the biggest hail size as well as with the heaviest damages has been located. This area coincides with the zone where some radar parameters showed the highest values, for instance, the maximum values of TOP50 radar parameters matches this area (Figure 5). In this sense, there are some parameters that fit better with the observations at surface. These ones are mainly the TOP50, but also VIL, and Zmax (not shown). On the contrary, the TOP30 and the Zsrf do not present a good correlation with hail-size observations.

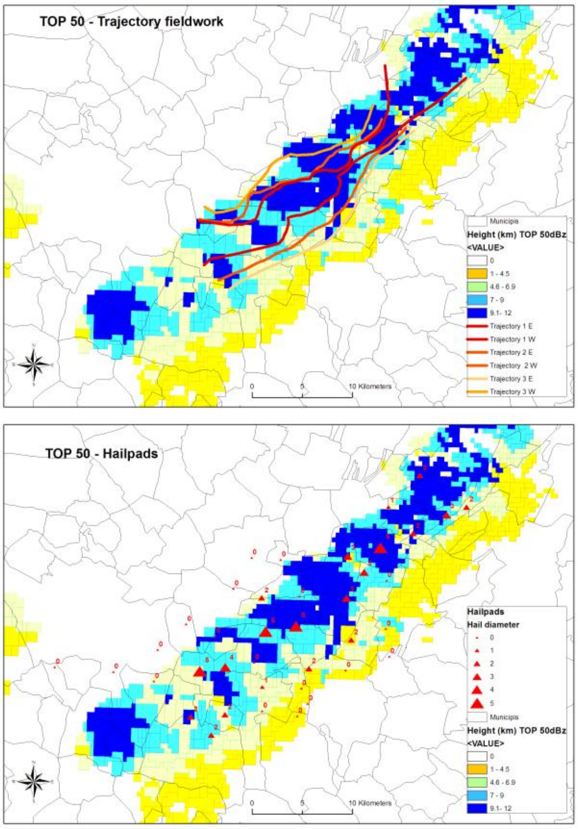

FIG. 5. Upper panel shows and compares the TOP50 radar parameters with data fieldwork. Lower panel shows and compares the TOP50 radar parameters with recorded hail diameter in the hailpads.

IV. FINAL REMARKS

The large amount of data gathered during the fieldwork, along with the hailpad records, has allowed studying a severe hailstorm from a different point of view, emphasizing the ground affectation. Such valuable ground records, not always available, are useful to validate the radar patterns that are used as severe weather indicators. In this way, in one hand there are some parameters that fit better with the observations at surface: mainly the TOP50, but also VIL, and Zmax. On the other hand the maximum of reflectivity occurred in advance in comparison to other magnitudes and this feature should be taken into consideration as a good very short-time forecaster of hail.

IV. ACKNOWLEDGMENTS

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