The Severe Weather Episode of 1-2 August 2014 in Northeastern Spain

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1. Introduction

During 1-2 August 2014, an episode of storms took place in Aragon, the north of Valencia and Catalonia Autonomous Communities, which are located in the north-east of the Iberian Peninsula. These storms were linked to the passage of an Atlantic trough in the upper levels of the atmosphere, with its associated thermal wave and cold front. The storms, accompanied by a high frequency of lightning, also involved, in some cases, abundant large hail and very intense or even torrential downpours, which caused some rivers to overflow and local flash floods. Even if no casualties were reported, there was significant material damage in some regions.

In this study, the synoptic and mesoscale conditions that caused the episode and the most significant events are described:
(1) the hailstorms that affected Zaragoza city and its surroundings, where a probable anticyclonic super-cell and a storm-splitting took place;
(2) the nocturnal mesoscale convective system (MCS) which moved from the north of Huesca province to the Mediterranean coast;
(3) the storms that affected the north of Castellon province causing heavy showers, and (4) the quasi-stationary storm that developed at the north of Tarragona province, with very high intensity showers which led to river overflow and local flash floods.

Even though the synoptic framework was typically favourable for the development of organised deep convection, the phenomenology associated with the storms turned out to be a direct consequence of the pre-existent and developed mesoscale structures, as well as geographical elements such as the topography or the relative proximity to the sea. The main goal of this study is to identify and describe the synoptic and mesoscale structures involved in this episode, so that the forecaster, in a short-range prediction and nowcasting context, may be able to focus on those storms that may be linked to severe episodes similar to the ones analysed here.

2. Synoptic and Mesoscale Framework

The event was characterised by the passage of an Atlantic trough at medium and high levels (visible at 700 hPa and above), coming from Britain, and also by the dynamic forcing associated. This trough had several short-waves embedded that crossed the Iberian Peninsula during Friday 1st and Saturday 2nd August. The temperature at 500 hPa stayed below -12 °C in the northern third of the Peninsula (Fig. 2). A weak cold front, associated with the trough moving from west to east, drove the convective activity to the east throughout the episode.

Figure 1: Location of the most important events of the episode.
At low levels, a large anticyclone centred to the north-west of the Azores Islands spread a wedge over the Vizcaya Gulf by the early hours of Friday 1st August, and a marked thermal ridge at 850 hPa (20-24 °C) extended over the north-east of Spain, progressively moving to the Mediterranean Sea (Fig. 2).

The front approaching the Iberian Peninsula from the north-west generated prefrontal convection during Friday (1st) in the north-east quadrant, marked by a very unstable environment (high CAPE/LI). Relatively low surface pressure established in the north-east of Spain favoured moisture convergence. In turn, a sub-synoptic flux from the south-east was generated and channelled through the Ebro valley (bochorno), combining with the arrival of the sea breeze. The wind and moisture convergence at low levels (up to 850 hPa) as well as the diurnal heating acted as the main convection triggering mechanisms during the event (Fig. 3).

On Saturday morning (2nd), thanks to the diurnal heating and the slow passage of the front, the convection reactivated in Aragon, Catalonia and northern Castellon,

3. Zaragoza storms

During the afternoon of 1 August 2014, many organized convective structures developed in Aragon. The dominating synoptic situation at that moment (SW flux at medium and high levels with diffuence) is the one with highest probability of widespread storm generation in that autonomous region (Álvarez et al., 2011). The more important storms are briefly analysed hereunder:

- Anticyclonic supercell in Zaragoza and Bajo Gallego (origin 13:20 UTC):

  The first storm that affected Zaragoza originated via the wind convergences at all levels between the surface and 850 hPa. The bochorno wind (from the south-east) channelled through the Ebro valley, turning north-easterly towards the south-west of Zaragoza, while another very warm flux from the south-west was coming from the southern Iberian plateau. As the front moved, northerly winds started blowing at the northern edge of the province, contributing to the wind confluence in the region.

  The storm took place in a framework favourable to deep and organized convection, as well as supercell development (TT>50; K=40; LI<1; SBCAPE (surface based CAPE)>200 J/Kg; CIZ6>12 m/s (CIZ6: wind shear computed from the difference between the lowest 6
km mean wind and the lowest 500 m mean wind); SRH3 (storm-relative helicity in the lower three kilometres >200 m$^2$/s$^2$). These indices were not very high, but locally the wind shear and helicity were probably higher at the time the storm was formed. This storm presented some typical supercell patterns:

- Long duration (2-3 hours).
- Anomalous movement (clear deviation to the left of the mean wind (NNE vs. NE) and with respect to the other cells) (Fig. 4. a.).
- Very high vertical maximum reflectivity (ZMAX>60 dBZ) during more than 2 hours. At 14:30 UTC, it reached 67 dBZ over Zaragoza, with a very rapid development during the first 30’. The echotop height (threshold 12 dBZ) at 14:40 UTC reached 15.5 km.
- Probable mesocyclone of lifetime 20 minutes (Fig. 4. b.).
- Severe effects on surface: hail > 2 cm of diameter, wind gusts velocity > 90 km/h.
- Characteristic supercell elements present: flanking line and overshooting top (Fig. 4. c).

• Storm-splitting (origin 15:30 UTC): Simultaneously to the above-mentioned storm, another cell formed 30 km west of Zaragoza city at 15:30 UTC. At 16 UTC, this cell started to split in two symmetric subcells. The occurrence of this storm-splitting phenomenon requires that the vertical wind shear is almost unidirectional. This fact could be appreciated in the high resolution Hirlam forecast sounding (not shown) for a grid-point close to the storm origin.

It was observed that the left cell moved following the mean wind (NE direction) at higher speed (Fig. 5). In turn, the cell to the right moved more slowly and with an anomalous ENE direction, affecting Zaragoza at 17:30 UTC, and with a longer life cycle (several hours). These facts are characteristic of the storm-splitting phenomenon.

Figure 4: a) Image sequence of reflectivity PPI Zaragoza radar product for 1 August 2014 (from 14:30 to 15:10 UTC, every 10 min); b) radial wind from 14:26 to 14:46 UTC; c) MSG-3 HRV channel image at 14:30 UTC where supercell elements such as the overshooting (red circle) and the flanking line (blue circle) can be appreciated.

Figure 5: Image sequence for the PPI reflectivity product from Zaragoza radar (1 August 2014, from 15:50 to 16:30 UTC, every 10 minutes).
4. Nocturnal mesoscale convective system (MCS)

Between the night of Friday 1st and the morning of Saturday 2nd, the biggest, deepest and more persistent convective structure in this episode formed, with a total lifetime of more than 13 hours and travelling across 600 km.

The MCS formed around 20:30 UTC at Cinco Villas region in Zaragoza province, starting from a convective cell which probably originated due to the interaction of gust fronts from previous storms. At the beginning, the MCS had an explosive growth, in such a way that, 20 minutes after its birth, it had reached a great depth (13 km echotop signal) and a ZMAX of 60 dBZ. The maximum vertical development was reached in between 22:00 and 22:15 UTC, with cloud top brightness temperatures of -70 °C. The Meteosat-10 (MSG-3) WV images (6,2 μm channel) allows us to presume that there was a subtropical interaction with a wide dark band extending from Canary Islands to the Pyrenees (Fig. 6).

The storm grew in extension over 4-5 hours (until 01:15 UTC) reaching a maximum coverage of more than 5 000 km². During that initial stage, the structure can be classified as a MCS of circular type and about 1400 cloud-to-ground lightning strikes were registered until 04 UTC as it moved to the ENE. Examining the ZMAX Zaragoza radar images one can distinguish from 21 UTC a bow echo structure and, ahead of it, a stratiform area with lower reflectivity values (Fig. 7). Within the next hours a squall line formed with orientation N-S. It had the more active cells at its southern edge, and also had a stratiform front area, wider than the rear one, and increasingly large (“leading stratiform squall line” typical pattern). The MCS brought some hailstorms along in its way.

5. Castellon storms

On Saturday 2, storms originated at the north of Castellon province, leading to sudden a rise in torrents and ravines which produced flash floods. As a result, 2 people had to be rescued in Benicarlo (Fig. 8). Besides this, large hail and strong wind gusts were registered.

Figure 6: MSG-3 IR channel (10.8 μm) and WV channel (6.2 μm) images on 1 August 2014 at 22 UTC and 21 UTC respectively.

Figure 7: ZMAX images from Zaragoza radar on 1 August 2014 at 23:40 UTC (left) and on 2 August at 01:40 UTC (right).
The first convective cells appeared around 10:30 UTC to the east of Teruel province, also developing subsequently at the interior of Castellon province and the southern end of Tarragona province (Fig. 8). Then, a rapid development of deep convection took place (at 11:10 UTC the main cell already reached a ZMAX of 62 dBZ). During the episode, several cells exceeded 65 dBZ (at 19:10 UTC a cell next to the Castellon coast reached 72 dBZ). The convective cells progressively moved individually as well as propagating as a whole to the ENE. Thus, they affected the pre-littoral and littoral areas of north Castellon and southern Tarragona (these are more vulnerable regions due to their high density of population and infrastructures). The last radar echoes registered in the north of Castellon at 21:30 UTC, so the convective activity lasted in a continuous way for 11 hours, which shows the high instability in the region.

The recurrence of storm formation at the interior of the northern region of Castellon from 13 UTC necessarily indicated a mesoscale convergence zone of humidity flux at low levels. This convergence zone extended from Castellon to northern Catalonia and, combined with the slow passage of the cold front/trough at high levels, may explain the continuous development of storms during that day. Additionally, in that same region a MCS formed between 12 and 13:30 UTC with cloud top brightness temperatures of -56 °C/-60 °C.

Given the extremely high reflectivity signals registered (>65 dBZ in several occasions), strong or very strong precipitation, large hail and strong wind gusts had to be also present quite often in the convective cells of this episode. In a region of 20 km radius around Albocasser (northern interior of Castellon), 1206 lightning strikes were registered between 11 and 19 UTC (907 electrical discharges between 12 and 15 UTC).

6. Llorac and Conesa Flash Floods

This convective episode had an important impact in Catalonia during 2 August 2014 at the north of Conca de Barbera region (Tarragona pre-litoral). There, 164 mm/6h (94 mm/1 h) was recorded in the village of Llorac, and 106 mm in Savalla del Comtat. Sudden rises in torrents and ravines produced serious local flash floods, affecting specially the village of Conesa (200 mm in 2 hours, Fig. 9), where 5 cars and several market stalls were swept away. The large accumulations were due to a superposition of factors in space and time: a high rate of precipitation and the stationarity of the event.

The first convective cells emerged at 10 UTC, reaching the maximum precipitation intensity at 14 UTC. The storm formation took place all along the same long convergence line that originated the storms in northern Castellon. A quasi-stationary multi-cell system appeared between Conesa and Llorac between 12 and 17 UTC (5 hours). The complex relief of the region probably favoured the existence of mesoscale convergence regions. The stationarity of this system was due to the fact that the new cell generation happened in the opposite sense of the propagation direction, since the established wind at surface was from ENE (opposite to the main wind). Thus, several convective cells of strong intensity originated at west/south-west, successively crossing the regions of Conesa and Llorac (a convective train effect).

**Figure 8:** Valencia PPI radar image on 2 August 2014 at 11:40 UTC (left) and a photography of the flooded underpass where two people had to be rescued (right). (Source: Valencia News).

**Figure 9:** Zaragoza radar image on 2 August 2014 at 13:30 UTC (left). Image of Conesa flood (right). (Source: Conesa Bellesa).
7. Conclusions

The passage of an Atlantic trough (in geopotential height and temperature) with its associated cold front during 1-2 August 2014 was able to develop deep convection during that period of the year in a wide area of the north-east of Spain.

The degree of organization of the convection was very varied, with isolated ordinary cells as well as supercells and MCS.

The organized structures gave rise to various severe phenomena on surface: strong or very strong precipitation, large hail and strong wind gusts, as well as a high rate of lightning during the two days. The passage of the trough and the cold front at high levels, combined with mesoscale factors such as the passage of embedded short waves and the existence of convergence zones at low levels, originated deep, even severe, convection. The complex topography of the region, the relative proximity to the sea and the altitude also played an important role in the triggering of the convection at the interior of Castellon and north of Tarragona.

8. Bibliography