P-53

A MEDITERRANEAN DERECHO: CATALONIA (SPAIN), 17 th AUGUST 2003

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Introduction

On the morning of the 17 th August 2003 an episode of damaging winds and heavy rain occurred in the western Mediterranean area, strongly affecting the east coast of the Iberian Peninsula and the southeast coast of France. A squall-line formed over south Catalonia (the north-eastern region of Spain) at 6:00 UTC and moved rapidly north-eastward and crossed Catalonia and the French regions of Languedoc-Roussillon and Provence-Alpes during the next 9 hours. It produced widespread wind gusts and hundreds of trees had branches broken or were uprooted and roads and railroads were blocked by overturned trees.

Fig. 1: Maps and image (NASA) of the north-western Mediterranean, showing orography and regions referenced in the text.

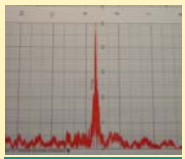

Fig. 2: Wind gust of 51 m/s (181 km/h) at Manresa (8:43 UTC).

Derecho review

A derecho is defined by Johns and Hirt (1987) as a widespread convectively induced windstorm that includes a family of downburst clusters produced by an extratropical mesoscale convective system (MCS). This windstorm is classified as a derecho, a term that has not been used in Spain before, using the definition of Johns and Hirt, who developed four criteria to identify derecho events:

- There must be a concentrated area of reports consisting of convectively induced wind damage and/or convective gusts of more than 26 m/s (94 km/h). This area must have a major axis length of at least 400 km.
- The reports within this area must also exhibit a non-random pattern of occurrence. That is the reports must show a pattern of chronological progression.
- Within the area there must be at least three reports, separated by 64 km or more, of either F1 damage and/or convective gusts of 33 m/s (119 km/h) or greater.
- No more than 3 hours can elapse between successive wind damage (gust) events.

Fig. 3: Several damages: trees uprooted at Taradell (top left), Manresa (top) and France (bottom); roof's, partially ripped up off buildings and industrial warehouse at Centelles and Balenyà; electric tower damaged at Malla (Osona).

Damage incurred (Catalonia)

- No casualties
- The fireman were called out more than 500 times because of the damages by the wind and the floods.
- Two hundred thousand subscribers were left without electric supply.
- Railway transport was suspended for several hours in some areas and some roads were cut off.

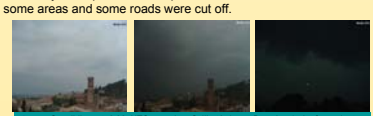

Fig. 4: Squall-line at 9:00 UTC crossing Collbató (near Barcelona). In few minutes, darkness was absolute.

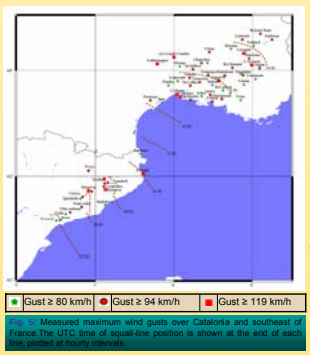

Fig. 5: Measured maximum wind gusts over Catalonia and southeast of France.The UTC time of squall-line position is shown at the end of each line, plotted at hourly intervals.

Observations

Combining the observations of the different networks, we have found an area with 39 observations of maximum wind gusts that reach or overcome 26 m/s (94 km/h) and with a chronological occurrence pattern. The path of strong convective winds was about 550 km in length and 50 to 150 km wide. Inside this area, there are 11 observations that reach or exceed 33 m/s or present evidence of destructions of intensity F2. Six of these observations were separated by, at least, 65 km and they didn't lapse more than three hours among successive episodes of damages by wind. Then, the windstorm that we are examining satisfies the requirements to be considered a derecho.

There are three different types of derechos: progressive, serial and hybrid. This is a progressive pattern, characterized by a short, curved squall-line orientated nearly perpendicular to the mean wind direction. The speed of the convective line increases from 60 km/h, at the beginning, up to 90 km/h in the last phase in French territory (the average speed was 75 km/h). This increase in the speed goes together with an increase in the frequency of the observed gusts and the scale.

Discharge CG

In total, there took place, in the area of the figure, 35.841 discharge cloud-to-ground (CG) in 14 hours that constitutes a record of the network of the National Weather Service of Spain (Instituto Nacional de Meteorología). From the formation of the MCC, the number of discharges CG stayed during the 11 following hours (4:20 to 15:20 UTC), above the 30 CG/min. During the initial period of the convective system (between 5:00 and 6:00 UTC) there was a bigger frequency of discharges CG than before or after, reaching an absolute maximum of 118 CG/min between 5:20 and 5:40 UTC.

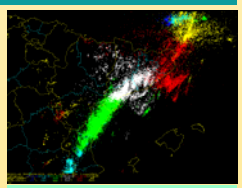

Fig. 6: 17 August, strokes cloud to ground (CG and CG+) from 00 to 14 UTC. (0 to 2:20 UTC, blue; 2:20 to 4:40 UTC cyan; 4:40 to 7 green; 7 to 9:20 UTC, white; 9:20 to 11:40 UTC, red; 11:40 to 14 UTC, yellow.

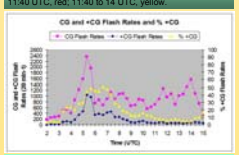

Fig. 7: Temporal distribution of strokes.

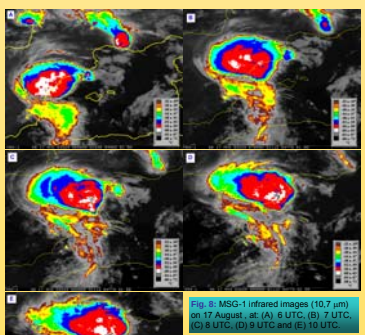

Fig. 8: MSG-1 infrared images (10,7 μm) on 17 August , at: (A) 6 UTC, (B) 7 UTC, (C) 8 UTC, (D) 9 UTC and (E) 10 UTC.

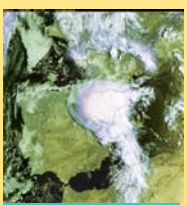

Fig. 9: NOAA-15 satellite visible channel (2) at 07:41 UTC, enhanced with false colour. www.wetter-welt.de

Radar

Radar observations of the evolving squall-line show features often correlated with damaging surface winds, including bow echoes and weak echo channels. The line showed strong low-level reflectivity gradients along the leading edge of the bow and rear inflow notches -RIN- immediately along the rear flank. Doppler radar measured several inbound radial velocity maximums of 24-36 m/s in the RIN area, behind the bow apex. Some isolated cells, developed downwind from the bowing line, eventually merged with the cells of the line, producing an intensification of these.

Catalonia radar (INM)	
Radar altitude	653 m
Power	250 kW
Wave longitude	5,3 cm
Range	240 km (Doppler 120)
Resolution	2x2 km (Doppler 1x1)
Wide	0.92º
Elevation angle	0.5º to 25º every 10 min

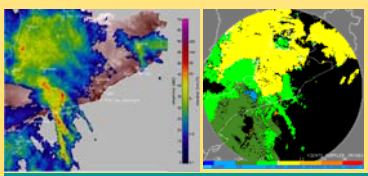

Fig. 10: 0.5º Reflectivity at 07:40 UTC (left) and 0.5º base velocity at 07:44 UTC (right) showing the Tarragona bow echo with a rear inflow jet and weak echo channels.

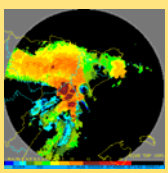

Fig. 11: Echotop at 07:00 UTC

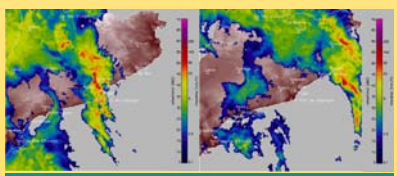

Fig. 12: 0.5º Reflectivity at 09:00 UTC (left) and at 10:20 UTC (right) showing several bow echoes.

Satellite

Examining different surface observations, satellite and radar imagery and cloud-to-ground lightning data, this case shows many similarities to those investigated in the United States. The MCS started, as a cluster of thunderstorms, in Castellón and took linear structure over the delta of the Ebro River at 6 UTC. At this moment, the SCM fulfils the conditions (minimum area of 100.000 km2 with temperature -32 ºC and 50.000 km2, at least, with temperature of -52 ºC or inferior) to be considered a Mesoscale Convective Complex -MCC- (Maddox, 1980).

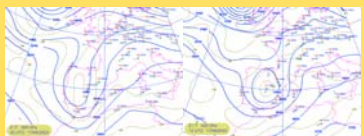

Fig. 14: 17 August, objective analysis (PAMIS) at 00 UTC and 12 UTC at 300 hPa. (Z) Geopotencial height (blue), (T) temperature (brown). Temperatures in ºC, wind in kt.

Fig. 15: 17 August, objective analysis (PAMIS) at 00 UTC and 12 UTC at 500 hPa. (Z) Geopotencial height (blue), (T) temperature (brown). Temperatures in ºC, wind in kt.

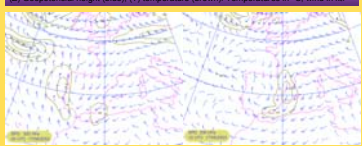

Fig. 16: 17 August, objective analysis (PAMIS) at 00 UTC and 12 UTC at 300 hPa. (SPD) isotach (brown). Wind in kt.

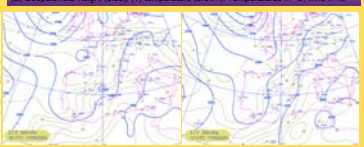

Fig. 17: 17 August, objective analysis (PAMIS) at 00 UTC and 12 UTC at 850 hPa. (Z) Geopotencial height (blue), (T) temperature (brown). Temperatures in ºC, wind in kt.

Synoptic and mesoscalar environment

Synoptic conditions under which the 17th August 2003 event occurred, were typical for the development of warm season derechos associated with weak upper troughs. Analysis displayed a negative-tilted upper-level trough located over the western and central parts of the Iberian Peninsula during the night and morning of 17 August. 250 hPa wind speeds of greater than 40 m/s were observed south of Valencia region as a strong jet rotated around the periphery of the trough. The left-front quadrant (left exit region) of the jet produced upper-level divergence over the coast of Castellón which induced an area of upward vertical motion beginning the deep convection. Analysis showed little warm advection at 850 hPa over the genesis area and cool, dry air was present in the middle troposphere. Surface characteristics include a southwest-northeast orientated front with the highest moisture pooled to the south of the boundary with the maximum located near the River Ebro delta. Surface-based CAPE from the soundings shows values of 3000 J/kg over the genesis area, Downburst CAPE (DCAPE) around 800 J/kg and a lifted index value of -8. A capping inversion was well-established over the zone. There were relatively strong midtropospheric winds (30-40 kt) and unidirectional from the southwest.

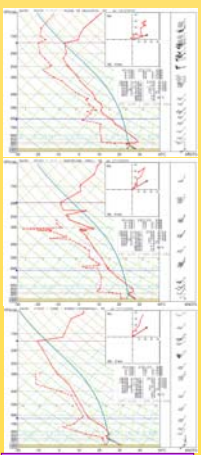

Fig. 18: 17 August, soundings for Palma de Mallorca and Barcelona at 00 UTC and for Nimes at 12 UTC.