Mediterranean Storms
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DIAGNOSIS OF A SEVERE HAIL EVENT OVER NORTHEASTERN SPAIN ON 12 JULY 2002

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ABSTRACT

On 12 July 2002 in the evening a severe hail event occurred over northeastern Spain, particularly affecting the western part of the Lerida province. Hail size attained 5 cm diameter. The event can be considered as one of the most severe events recorded in that area during the last years. Fruit trees were seriously affected and economical damage was substantial.

The meteorological situation was characterized by the presence of a low over the northwest of France (the Brest area) with an associated cold front, which, at the time of the event, was arriving to the Lerida province western border. At the same time, a thermal low was over the Iberian Peninsula favoring the entrance of humid air inland from the Mediterranean. Meteosat pictures show that prefrontal convection developed and moved towards the east, steered by the upper levels winds. The radar located in Zaragoza, to the west of the Lerida province, shows high values of reflectivity from the thunderstorms that developed to the west of Lerida and moved following the same path. The meteorological pattern resembles, in many aspects, previous scenarios associated with summer hail events in the same area. A study of ingredients and factors acting in the development of the convection based on MM5 numerical model simulations indicates the importance of the diurnal heating factor in this event.

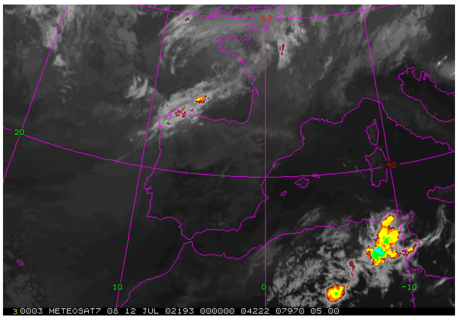
1 INTRODUCTION

In the evening of 12 July 2002, between 16 and 20 UTC, a severe hail event occurred over northeastern Spain affecting the western part of Lerida province. Thunderstorm events are not uncommon in this area. So, they occur with an annual frequency of 10-20 days (*Font*, 1983), most during summer, 5-15 days (*Alonso et al.* 1994). But in this case, the hail size up to 5 cm, requires a more detailed consideration. The event can be considered as one of the most severe events recorded in that area during the last years. About 6.000 ha of fruit trees were seriously affected and economical damage was substantial.

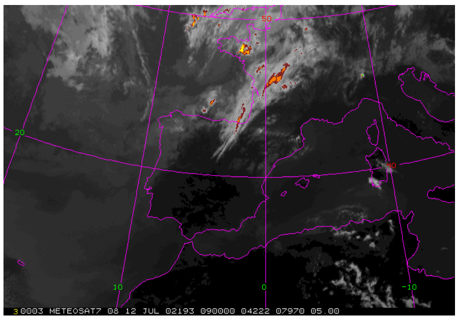
The affected area is situated in the middle of the Ebro valley. This is a terrain depression crossed by the Ebro river and surrounded by the Pyrenees to the north, the Iberic System to the south and partially a coastal range to the east. Because the height of the mountains of Pyrenees and Iberic System, the Ebro valley is blocked to the Atlantic flows and only permit the WNW pass of cold and not very humid air masses towards the ESE. The lower altitude of the coastal range permits the entrance of wet and warm Mediterranean air masses from the Southeast into the valley. Then, there is a clear convergence of these two air masses over the depression. All these ingredients allow us to classify the thunderstorms as thermal (the valley is a closed area subject to a great warming), orographic (presence of mountains) or frontal (presence of two different air masses) or combinations of them (*Pedraza*, 1964).

2 SATELLITE AND RADAR IMAGES

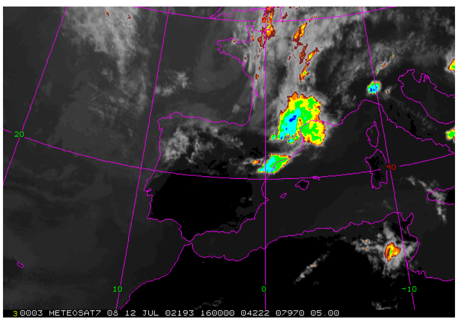
The IR series of Meteosat images every 30 minutes during 12 July 2002 shows a cloud band associated to a cold front moving from Atlantic Ocean over Iberian Peninsula. At 0000 UTC the clouds reaches the western extreme of the Iberian Peninsula and at 0900 the cloud band is located over the western Ebro valley and some localized thunderstorms appear over the Pyrenees. Three hours later, the Pyrenees and southeastern extreme of Ebro valley are covered by prefrontal thunderstorms, which are rapidly developing while the cold front reaches this area. Between 1600 and 1700 the images shows the presence of a new small thunderstorm over Lerida province that grows rapidly with very high tops. This point is situated between two great thunderstorms areas.



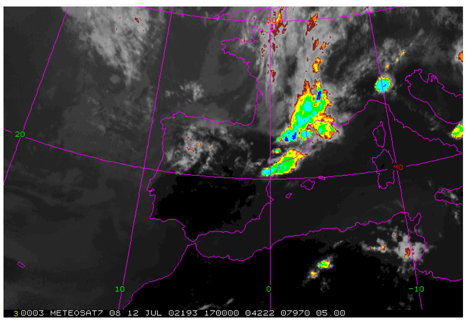
Meteosat IR 0000 UTC



Meteosat IR 0900 UTC

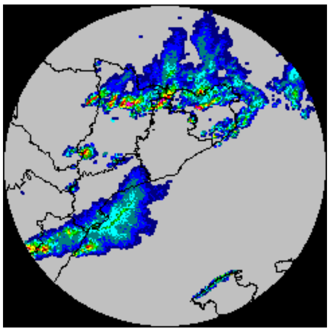


Meteosat IR 1600 UTC

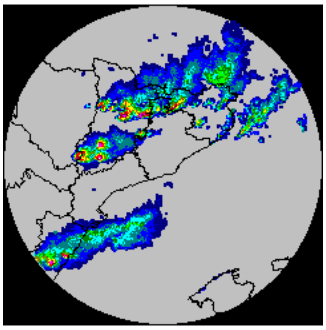


Meteosat IR 1700 UTC

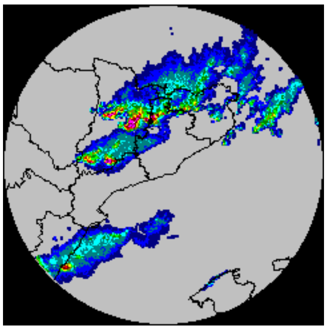
The series of radar images are obtained by the INM Barcelona radar and show us with more detail the onset of intense precipitation over southern Lerida province at 1640 in the Zmax image. This precipitation signal remains stable over the western province while its reflectivity values are increasing in magnitude and area.



1640 UTC Zmax



1730 UTC Zmax

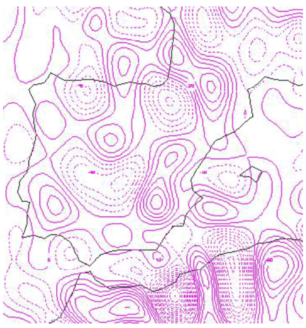


1800 UTC Zmax

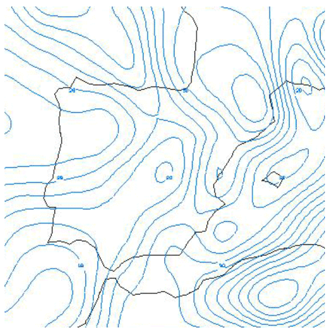
3 DIAGNOSIS

ECMWF analysis on 12 July 2002 at 1200 UTC shows that at low levels there is a cold northwesterly flow from Atlantic Ocean towards Iberian Peninsula. This flow is preceded by a cold front. Over northeastern Spain, there is a weak low and, in front of Mediterranean coast, a slight anticiclonic circulation induces wet and warm air into the Ebro valley. At high levels, a NE-SW trough associated to the front is located to the west of France and induces southwesterly flux over Iberian Peninsula. The evolution of the situation shows the pass of the cold front and the trough over the Iberian Peninsula and particularly over northeastern Spain. The analysis of different variables and convective indices using the ECMWF raw data in the VIS5D show us positive values to aid instability over the region of interest. So, CAPE values of 1.200 J/Kg, K index values up to 50, Total of Totals index up to 52 and significant values of precipitable water are present. The water vapour convergence appears at low levels and there are positive values of vector Q forcing over the same area.

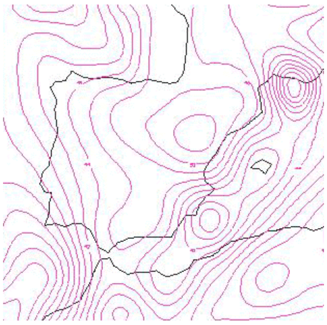
CAPE 1200 UTC



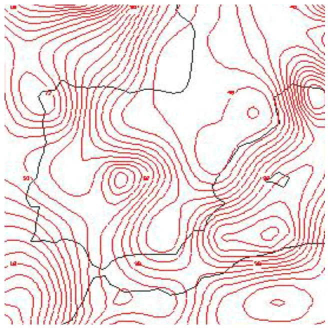
Water vapour convergence 1200 UTC



Vector Q forcing 1200 UTC

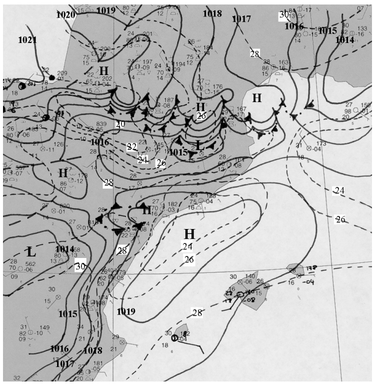


IK 1200 UTC

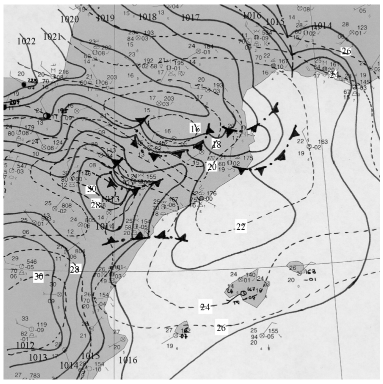


Total of totals 1200 UTC

A detailed analysis of the surface conditions in the Ebro valley has been made with a subjective analysis at 1200 and 1800 UTC using INM stations data. At 1200 UTC, several meso-highs are present in the Pyrenees and on the south of Ebro valley. In association with them, cold areas are present. A light high in front of the Mediterranean coast supplies wet air towards these meso-highs. The northwest flow of the front appears on the NW of the valley. At 1800, the cold meso-highs occupy the eastern extreme of the valley while the western part has been swept by the northwest winds of the front. It seems that in this area there are thunderstorm outflows that generate new convection. All thunderstorms are clearly prefrontal.



Analysis 1200 UTC



Analysis 1800 UTC

4 NUMERICAL SIMULATIONS

In order to complement the information of the previous analysis and provide physical interpretation, several numerical simulations were performed using MM5-v3 model (*Grell et al*., 1994). Three domains of 18, 6 and 2 km horizontal grid resolution and 24 vertical levels were considered. These domains interact with each other with two-way interaction between successive nesting levels. Initial and boundary conditions come from NCEP analyses, and they are updated every 12 hours. These data are interpolated into the model grid points and improved using GTS data (*Benjamin and Seaman*, 1985).

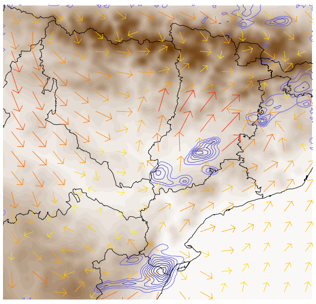
Three experiments have been carried out:

1. Control experiment (CE). Considers a 31 hours simulation (from 12 July at 0000 UTC to 14 July at 0700 UTC), and uses full physics. The Kain-Fritsch scheme (*Kain and Fritsch*, 1990) is considered to parameterise convection for the first domain and no convective scheme is used in the two inner domains.

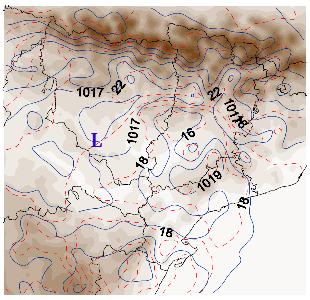
2. No radiation experiment (NRE). This experiment was carried out in similar conditions that CE but without solar component active in the radiation scheme.

3. No orography experiment (NOE). This experiment is similar to CE except that orography was not considered.

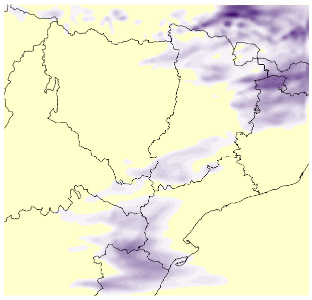
In the CE case, the 900 hPa wind field at 1400 UTC 12 July presents a breeze, which penetrates inland along the Ebro valley. On the other hand, NW winds penetrate from the Golf of Biscay, and its convergence with the breeze is associated with the simulated precipitation systems. Sea level pressure presents a relative low over the Ebro valley, which coincides with a centre of high temperature. It could thus be a thermal low, so the NRE was carried out in order to confirm or dismiss this possibility. Three hours later (1700 UTC, see figures below), other convective systems are developed in lower terrain areas, generated by the outflows of the primary thunderstorms. For the same reason, the thermal mesolow has been moved to the NW. In addition, the simulation reveals that the convective systems are triggered over elevated terrain, where



Wind field at 900 hPa
Precip in the last half hour



Sea level pressure in full lines
Temp. at 900 hPa in dashed lines



Accumulated precipitation

upslope wind systems are induced by diurnal forcing. In order to investigate the role of the orography, experiment NOE was conducted.

For the NRE case, the 900 hPa wind field at the same time as CE shows a flux from NW dominating most of the areas and a very weak flux from the Mediterranean Sea, so there are not marked convergence zones in the centre of the Ebro valley, and consequently precipitation is not generated. The mesolow that appeared in CE over the Ebro valley is not present now, what reasserts the hypothesis of a thermal origin for the low.

In the NOE case, NW winds appear and the breeze is stronger than in CE because owing to the absence of mountains, so the convergence is more important and the precipitation in low terrain areas is more intense. As expected, however, precipitation in the Iberic System and Pyrenees mountains is diminished.

5 CONCLUSIONS

We have analysed a hail event occurred on 12 July 2002 over the Ebro valley (northeastern Spain). The objective of the analysis has been the study of the different mesostructures (lows and highs) present during the event as well as to analyse the atmospheric instability using several indices and parameters. Satellite and radar images show us several prefrontal thunderstorms over the region.

Three numerical experiments have been conducted. The CE simulation reproduces accurately the observed situation. The NRE experiment reveals the thermal origin of the mesolow. And the NOE experiment demonstrates that the position of the precipitation areas is due to the topographic configuration of the Ebro valley, surrounded by the Pyrenees to the north, the Iberic System to the south and partially closed to the Mediterranean Sea by a little coastal range.

This study suggests that the synoptic background flow at upper levels is fundamental in any instability situation over this area. The radiation effect plays an important role by modifying the surface flows due to the generation of thermal mesolows, which permit the incoming of wet air from the Mediterranean Sea. The orography focalizes the low-level wind convergences. The high values of instability have been an important factor in the severity of the hail event.

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