Heavy rain and a tornado outbreak during the pass of a squall line over Catalonia

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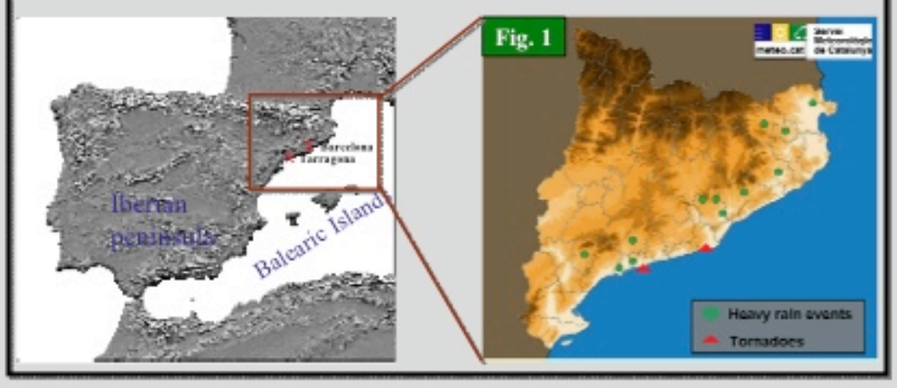
INTRODUCTION

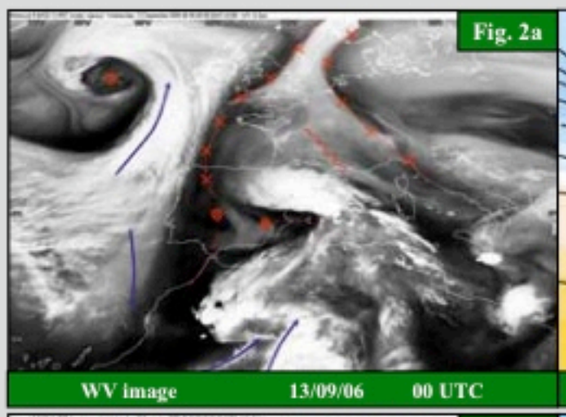
During the 13th of September of 2006 a squall line passed through the coastal regions of Catalonia (NE of Spain) causing heavy rainfalls (more than 20 mm during 30 minutes) and a tornado outbreak in the catalonian coastal region (Fig.1). The aim of the work is to characterize this type of situations and detect local wind convergence lines and their link with tornado events.

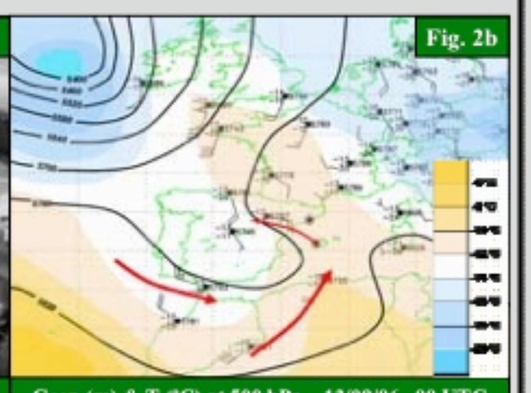


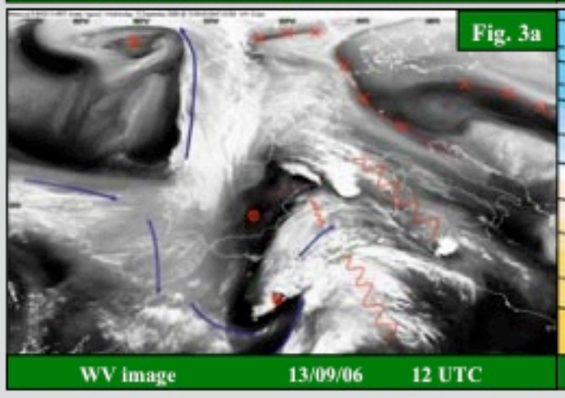
SYNOPTIC ANALYSIS

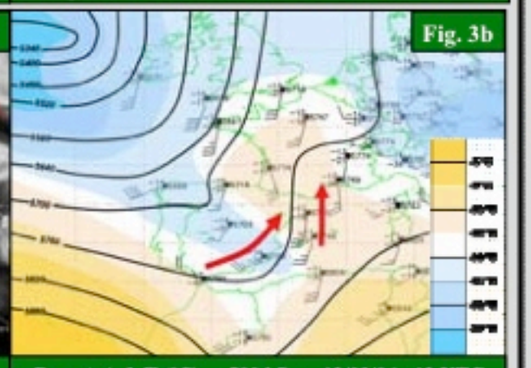
WV images and 300, 500, 700, 850 and 925 hPa levels were analyzed. At 00 UTC a curvature vorticity center was located in the SE of the Iberian Peninsula. A short trough (oriented W to E) was situated in the south of Catalonia (Fig. 2ab). The main flow was from the east at high and middle levels.

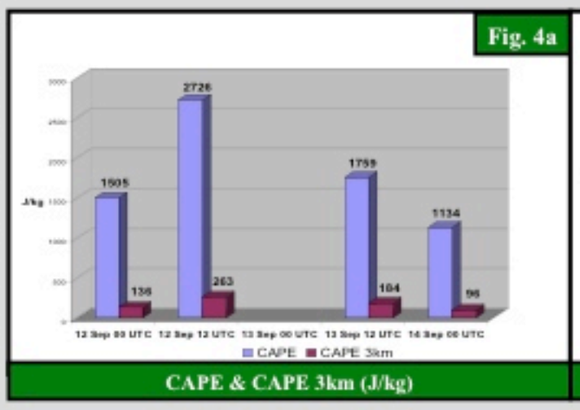
Between 00 UTC and 12 UTC the trough crossed Catalonia from SW to NE and changed its orientation. Wind veered from E to S and SW with a remarkable strengthening of its intensity at high and middle levels. This SW wind led the translation of the squall line. There wasn't thermal advection at these levels.

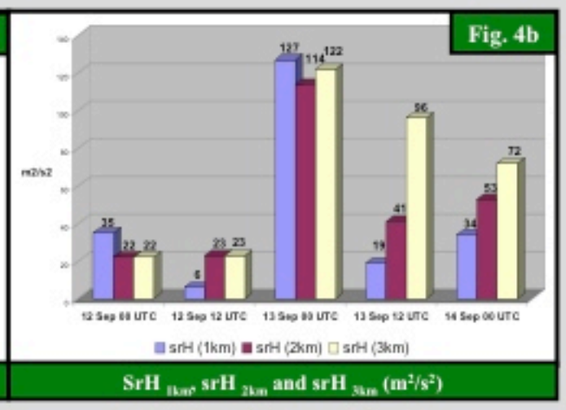












SEVERE WEATHER INDICES ANALYSIS

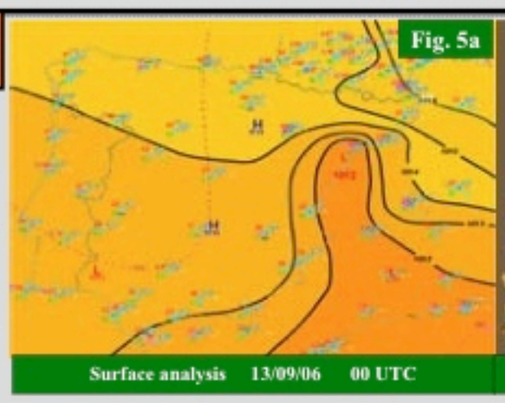
Indices obtained from Barcelona rawinsonde data on the 12th and 13th have been analyzed. Although the tornado outbreak was between 09:00 and 11:00 UTC, rawinsonde data at 00 UTC are more representative to carry out the instability indices analysis. After the pass of the squall line the air mass in Barcelona changed its characteristics.

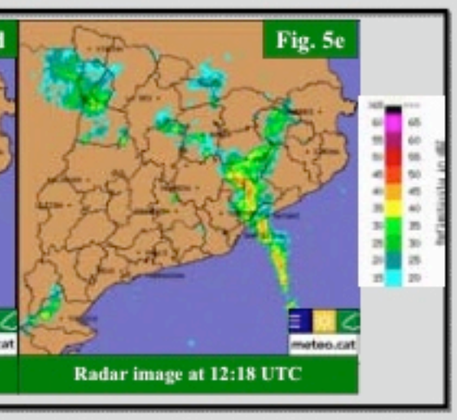
Although **CAPE** values wasn't very high, **CAPE 3 km** reached values around 200 J/Kg (Fig. 4a). These **CAPE 3km** values combined with low **LFC** heights were important in the generation of updrafts in the lowest levels.

Another ingredient to the development of tornadoes is shear at low levels and **SrH** indices were analyzed (Fig. 4b). **SrH** values aren't very high but tornado events were observed in our area with values around 100 m^2/s^2 as other authors pointed out. (Gayà et al. 2001).

EVENT EVOLUTION

At surface level, a low developed in the south coast of Catalonia (Fig. 5a). Due to its position and the peculiar topography of the area, a wind converge line was generated (Fig. 5b). Along this line grew the first convective cells (Fig. 5c) and later moved from SW to NE (Fig. 5d 5e).

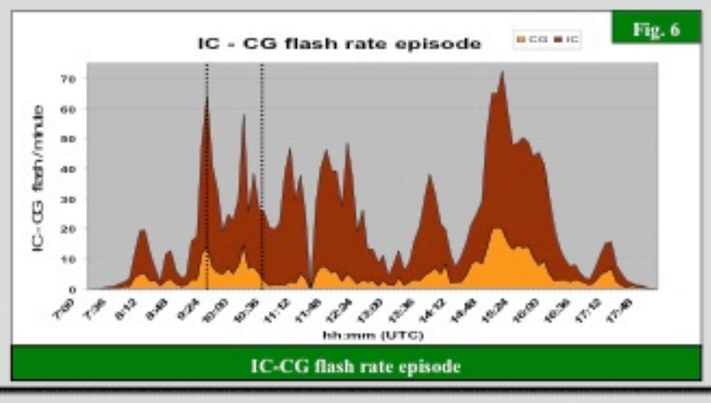




TORNADO EVENTS

During the motion of the squall line some tornadoes were reported. At 09:15 UTC two tornadoes affected Torredembarra and Roda de Barà (about 15 kms NE from Tarragona city). About two hours later the squall line arrived to Llobregat valley and 6 new tornadoes were reported. Tornadoes caused damage to walls, roofs, trees and cars, also two people suffered slight injuries. In the same area (Llobregat valley) a tornado outbreak took place the 7th of September of 2005 (Bech et al. 2006).

IC/CG flash per minute distribution shows two maximums between 09:00 UTC and 11:00 UTC (Fig. 6). First maximum is observed at same hour that two tornadoes affected Torredembarra and Roda de Barà. Second maximum is observed some minutes before the generation of 6 tornadoes in Llobregat valley.



Radar wind doppler data were analyzed and some shear areas were observed (Fig. 7). Horizontal wind shear was observed across the squall line by automatic weather stations of the Catalonian Meteorological Service (Fig. 8), coinciding with the wind profile generated by radar of network of SMC (not showed). South-east winds were observed in the front side of the squall line and west and south-west winds were observed in the rear side.

Classical supercelular structures weren't observed in a preliminary analysis of radar data. Horizontal wind shear was the main factor in the generation of the tornado outbreak combined with high CAPE 3km values and low LFC heights (Caruso et al. 2005).

CONCLUSIONS

- The formation of a low in the south coast of Catalonia, combined with the peculiar topography of the zone, originated the formation of a wind convergence line.

- CAPE 3km values were high and LFC heights were relatively low, consequently the updrafts were important in the lowest levels.

- Vertical wind shear before the arrival of the squall line reached values of srH_{3km}= 122 m^2/s^2.

- Classical supercelular structures weren't observed at radar analysis. Horizontal wind shear was the main factor in the generation of the tornado outbreak.

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