A Quasi-Tropical Cyclone over the Western Mediterranean: Dynamical vs Boundary Factors

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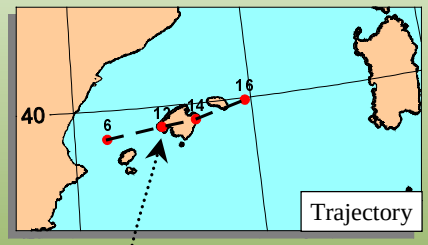
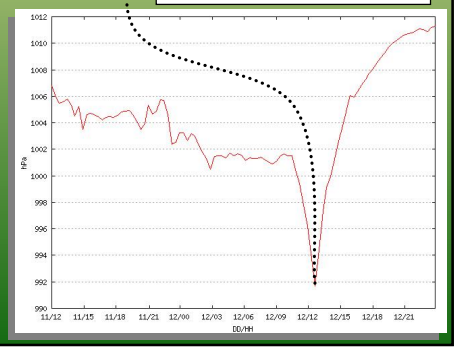
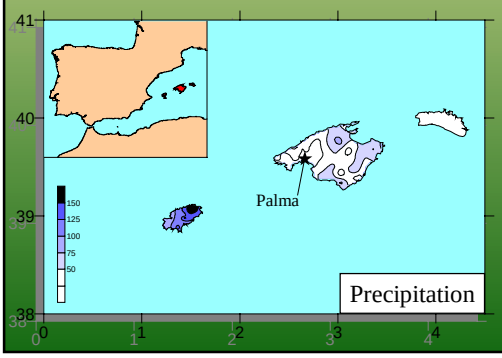
The event. Observations

- A small scale cyclone developed in eastern Spain the morning of 12 September 1996.
- Strong winds and flash floods affected the Balearic Islands.
- Intense convective activity occurred during 11 and 12 September in all the western Mediterranean.
- The cyclone crossed Mallorca and the barograph in Palma registered a sudden decrease of about 9 hPa in 2 h.



Surface pressure in Palma



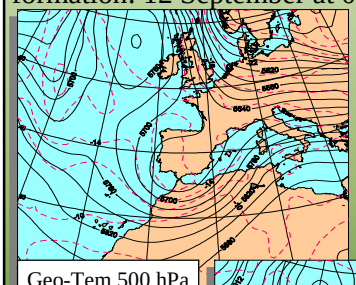


Objectives

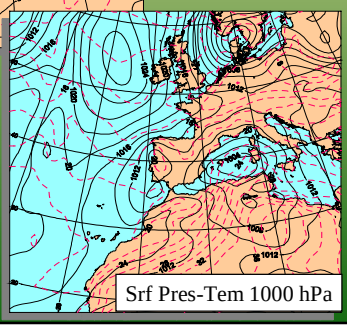
- Numerical study of the synoptic-scale and mesoscale aspects leading to the small quasi-tropical cyclone.
- Analysis of the upper levels influence on hte cyclone formation through the application of the PV inversion procedure.
- Study of the sensitivity of the cyclone development and evolution to the synoptic dynamics, the latent heat release from the convective systems and the orographic forcing.
- Detailed evaluation of the effect of the upper-level dynamics, the evaporation from the Mediterranean, and its interaction on the cyclone development, through the application of the factors separation technique.
- Analysis of the similarities of this event with a polar low development through the theory for tropical cyclones: Air-Sea interaction.

Synoptic Overview

- Presence of a surface low over the Western Mediterranean and a cold cutoff aloft the previous hours to the cyclone formation: 12 September at 0000 UTC

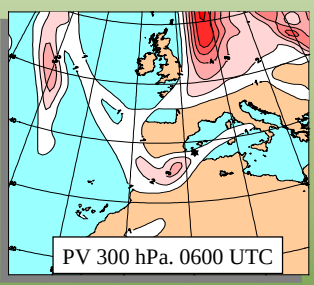


Geo-Tem 500 hPa

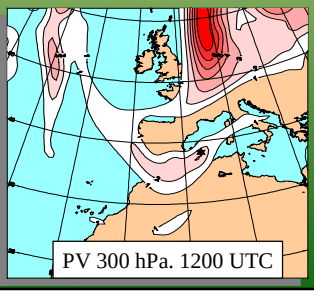


Srf Pres-Tem 1000 hPa

- PV anomaly advancing towards the area at the upper levels



PV 300 hPa. 0600 UTC



PV 300 hPa. 1200 UTC

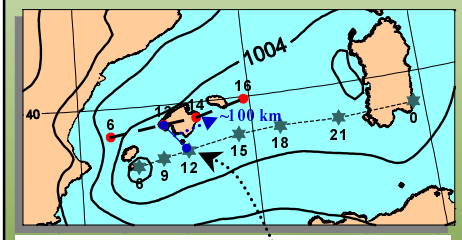
Numerical experiments configuration

- The model MM5v3 has been used to perform the numerical simulations.
- Kain-Fritsch convective parameterization is used.
- Two domains are defined to obtain high resolution over the area of interest while maintaining in the simulation the main synoptic features of the event

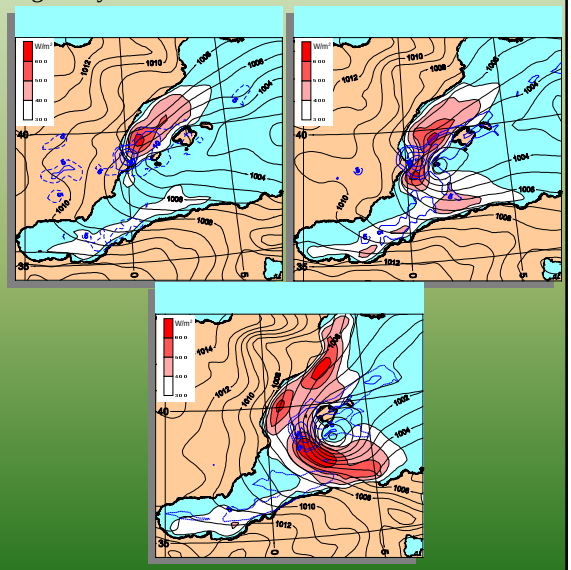
- Simulations start at 1200 UTC 11 September (18 h previous to the cyclone formation) and extend out to 36 h.
- Corrected NCEP global analyses are used as initial and boundary conditions, available at 0000 and 1200 UTC

Control run

- Model run validation. Accurate simulation of the cyclone formation and eastern evolution is obtained. A southern shift of its trajectory of about 100 km is obtained.:

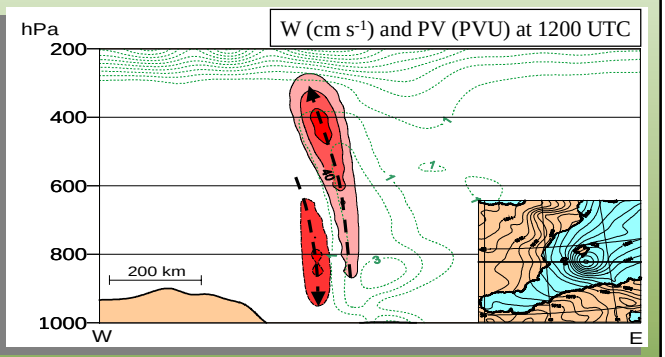


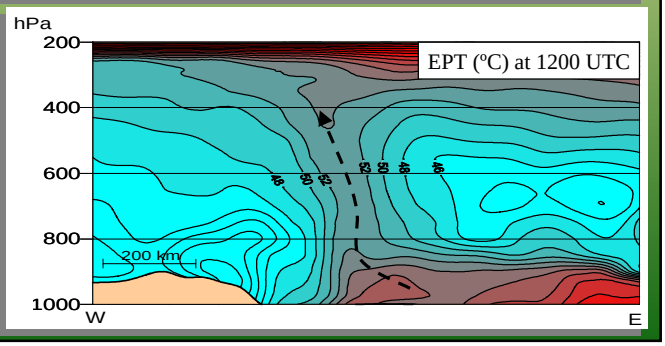
- Surface pressure, rainfall and sea surface evaporation during the cyclone formation:



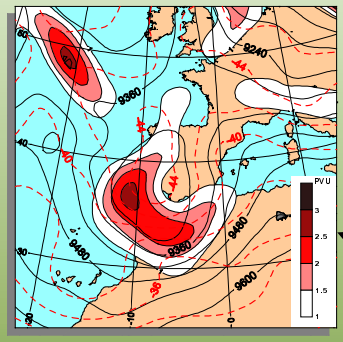
Control Run

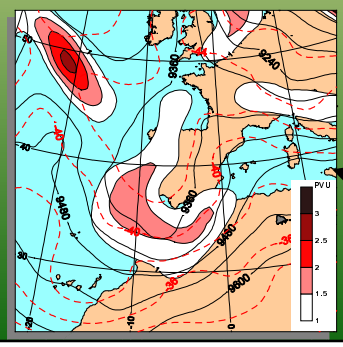
- Strong and deep updrafts are detected close to the cyclone center.
- This reflects the intense convective activity developed in the area.
- A column of high values of PV is identified where most intense latent heat release from convective updrafts exists.
- Convective adjustment is inferred from the EPT cross section through the cyclone.
- Thus, the latent heat release from convective systems emerges as a primary factor in the cyclone genesis and sustain.



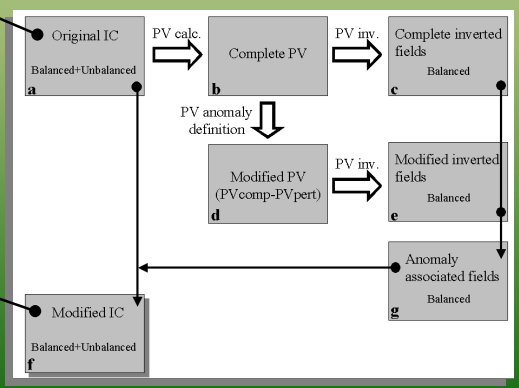


PV inversion



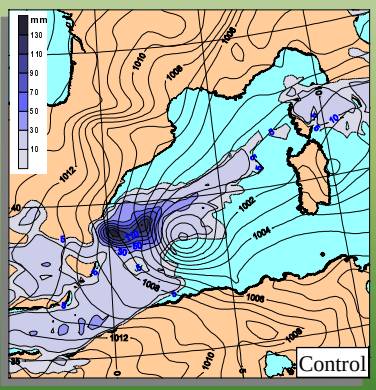


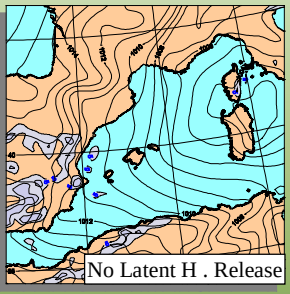
- Sensitivity of the cyclone formation to the effects of the upper-levels cutoff is assessed by weakening its intensity and evaluating the consequences in the model simulation.
- The coherent weakening of the upper levels cutoff is done by means of the PV inversion process applied on the model initial conditions.
- The PV anomaly associated with the cutoff is identified and appropriately modified in the model IC.

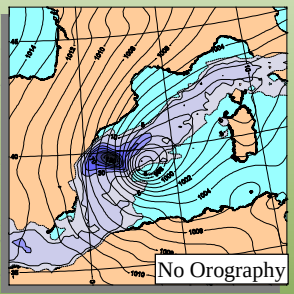


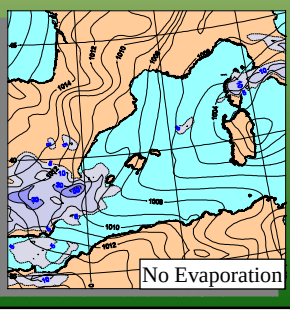
Sensitivity

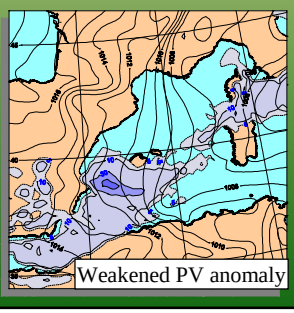
- Results of the sensitivity experiments in terms of surface pressure and accumulated precipitation at 1200 UTC:











Factors separation

- The factors separation technique is used to determine the individual effects of the upper levels PV anomaly and the evaporation from the sea, as well as its interaction.
- The effect of the factors are calculated as:

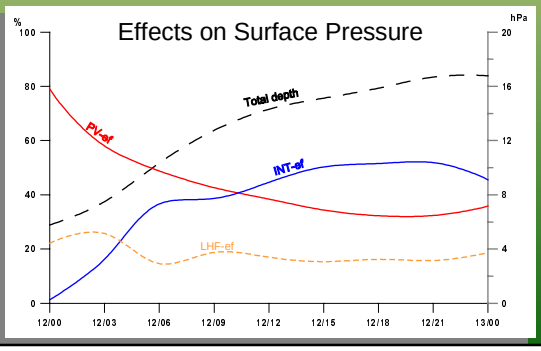
$Eff_{PV}=S_{01}-S_{00}$

$Eff_{ev}=S_{10}-S_{00}$

$Eff_{Inte.}=S_{11}-(S_{10}+S_{01})-S_{00}$

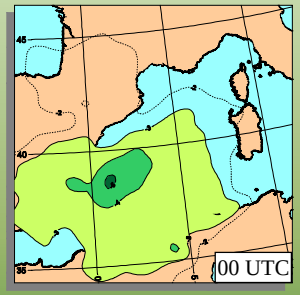
with S_{XY} representing the simulation with the evaporation (X) or the PV anomaly (Y) activated (1) or not (0).

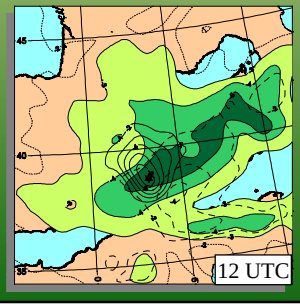
- Evolution of the effects on the central surface pressure: Primary effect of the PV anomaly alone during the first stages of the cyclone genesis. Later, interaction with the evaporation becomes determinant on the cyclone evolution.



- Effects on the surface pressure:

PV ---- Evap. —— Interaction

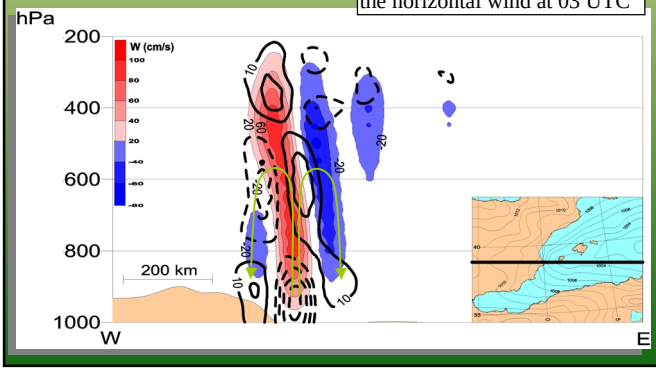




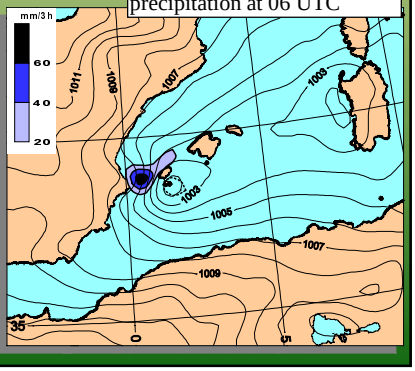
Factors Separation

- The effect of the interaction between the evaporation from the sea and the upper levels PV anomaly emerges as crucial for sustaining the convective developments associated with the cyclone. The latent heat release from convective updrafts is maintaining the cyclonic circulation in a deep and narrow tropospheric column.

Eff_{Int} on W and divergence of the horizontal wind at 03 UTC



Eff_{Int} on the 3h accumulated precipitation at 06 UTC

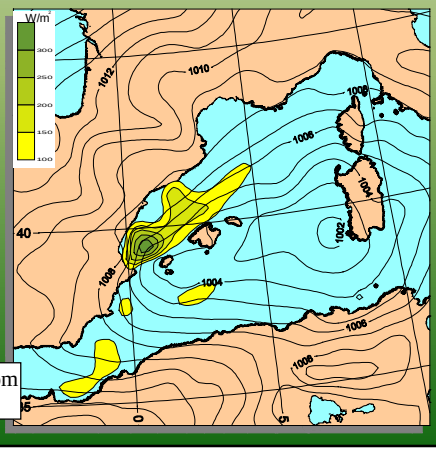


Air-Sea Interaction

- These results suggest that air-sea interaction instability (Emanuel, 1986 JAS) was instrumental in the evolution of the quasi-tropical cyclone.

- Circulation attributed to the PV anomaly aloft is revealed as the triggering agent of the instability by enhancing values of evaporation from the warm sea surface.

- The principal effect of the upper levels PV anomaly was not a direct surface pressure decrease but the generation of surface flow which intensified the evaporation.



Eff_{PV} on the evaporation from the sea at 03 UTC

Conclusions

- A study of the agents contributing to the development of a quasi-tropical cyclone formation over the Western Mediterranean is presented.
- Synoptic settings show a cold cutoff over the Iberian Peninsula and a surface low over the Western Mediterranean.
- Numerical experiments reveal that intense and deep convective activity occurred surrounding the cyclone center.
- Sensitivity experiments show the primary role of the latent heat release on the cyclogenesis, and the negligible role of the orography in this event.
- Detailed analysis of factors leading to the convective developments and its associated diabatic heating points to the crucial effect of the upper levels cutoff and the enhanced evaporation from the sea.
- A factors separation technique shows that the synergism of the circulation at low levels, associated with the upper levels cutoff, and the derived evaporation from the sea was the responsible of the small scale deep cyclogenesis.
- Clear indications appear suggesting that air-sea interaction instability was able to sustain the observed cyclone intensity.