PV approach for the analysis of the 9-12th November 2001 western Mediterranean cyclone

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1 Introduction

From November 9th to 12th of 2001 one of the most severe episode on the western Mediterranean basin in last decades was developed. Heavy rainfalls (200mm /24h) and sustained winds (over 20 m/s) produced 700 deaths in Algiers, 4 victims in Balearic Islands and heavy damages (1 billion trees fell down on Balearic Islands). A sensitive study on the changes in the initial conditions through the use of the PV inversion technique is presented. MM5 primitive equations, nonhydrostatic model is used to perform the simulations related to each modified initial condition. Each modification will be done with different PV anomalies related with different thermodynamical aspects of the flow. Statistical numbers are used to summarize the results in an objective way.

2 Case description

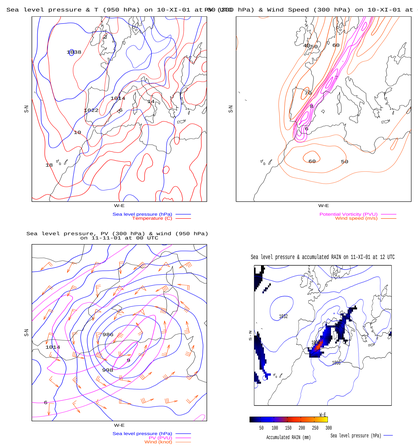

Figure 1: Synoptic overview

Strong baroclinic environment was present on the early stages of the episode (Nov. 10th 2001 at 00 UTC, top left). Warm advection from the North African region and cold advection from European countries occurred over the West Mediterranean basin. A weak cyclone was developed to the South of the Atlas mountains. A significant upper-level trough enhanced the deepening process of the cyclone and drove the cyclone to the Mediterranean basin (top right). The deepest mature state of the cyclone (998 hPa) occurred when the cyclone reached the Mediterranean Sea (Nov. 11th at 00 UTC), meanwhile the strongest winds and heaviest rainfalls were developed (bottom left). On the following 24 hours the cyclone moved to the Corsica Island and diminished (bottom right).

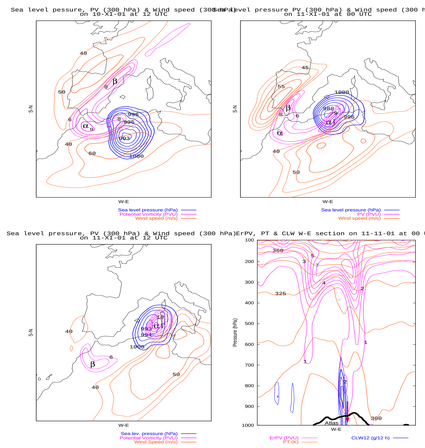

Figure 2: PV evolution

Attributed to a vortex-vortex interaction between two positive PV centers (α & β) PV upper level advections are reinforced (left), that enhanced the deepening process of the cyclone and its steering from upper levels. On November 11th at 00 UTC the cyclone reached the Mediterranean Sea (right). Then diabatic PV generated around the cyclone significantly helped to intensify its mature sate. The diabatic PV generation (2 PVU) is attributed to the latent heat release associated to cloud developments (blue, cloud liquid water concentration per 12h) close to the center of the cyclone (red arrow, on bottom right). The reinforcing relation between the surface cyclone and the upper level PV became cyclolitic as the vertical tilting between both structures changed sign (bottom left).

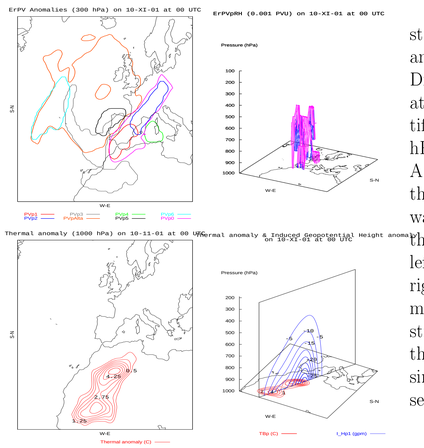

Figure 3: PV anomalies definition

As departures from the 7-day time average state, 8 (positive or negative) upper-level PV anomalies (over 500 hPa) are defined (top). Diabatically generated positive PV anomaly at low levels (bottom left) has been also identified (as the positive PV anomaly below 500 hPa with relative humidity exceeding 70 %). A surface surrogate PV anomaly related to the initial thermal surface positive anomaly was also defined through a modification of the bottom PV inversion condition (bottom left and some effect on geopotential, bottom right). These anomalies has been used to modify the model initial conditions of the case study. Different degrees and combinations of the anomalies are used. 40 resulting forecast simulations are generated and used for the sensitive study.

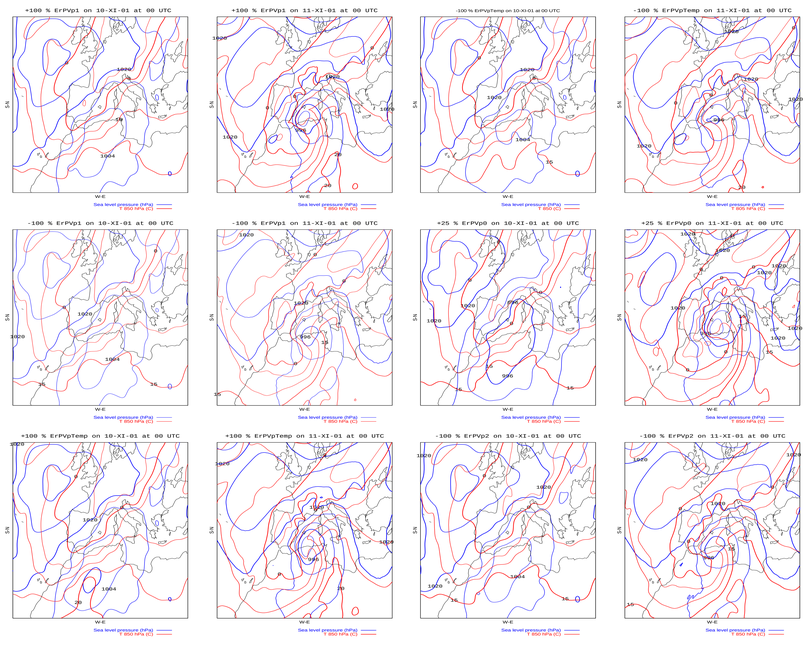

Figure 4: Different modified initial conditions

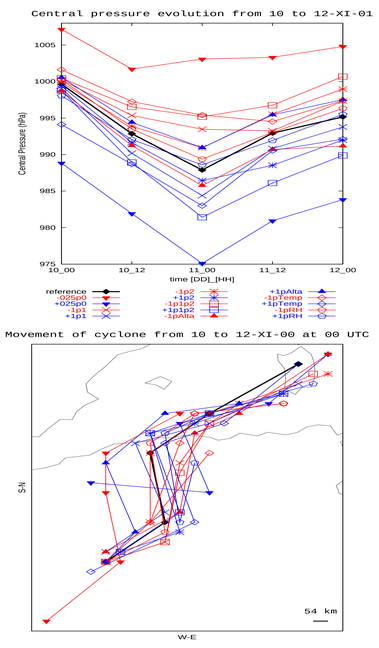

Figure 5: Significant results

Significantly different evolutions of forecast cyclones have been obtained. The most significant are obtained for *positive PV at upper level* (ErPVp0, related to the trough), *surface positive PV* and ErPVpAlta (related to the Atlantic high pressure zone)

- $\pm 25\%$ $ErPVp0$: Deepest(weakest) cyclone intensity and closest(furthest) cyclone's trajectory to the trough path
- $\pm 1\%$ $ErPVpTemp$: Deeper(weaker) cyclone on initial stages. Slower(faster) evolution over the Mediterranean Sea.
- $\pm 1\%$ $ErPVpAlta4$: Weaker(deeper) cyclone and slower(faster) cyclone movement.
- $\pm 1\%$ $ErPVp2$: Significant differences observed during the dissipation stage of the cyclone

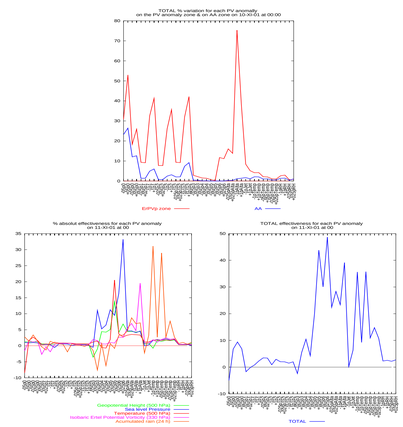

Figure 6: Statistics

Change degree of initial modifications (Nov. 10th at 00 UTC, top). *Effectiveness* (bottom) of the initial modification on the forecasted field (Nov. 11th at 00 UTC). Nonlinear behavior of the initial modification on the forecasted variable (separate results, bottom left). Nonlinearity between the results from different degrees of simulation of the same PV anomaly (total result, bottom right).

3 Conclusions

+ Complete description of an intense episode in terms of PV and dynamics and behaviors of the PV anomalies.
+ Intense effect of the PV upper level features through large and deep interactions between upper levels and surface cyclone.
+ Important deepening effect of the induced moist effects due to the Mediterranean Sea.
+ Surface thermal anomaly can be treated like another PV anomaly.
+ Important role of baroclinic process on the initial stages of the cyclone.
+ Atlantic high pressure area played a significant role on the translational speed of the cyclone and in the enhancement of the pressure gradient.
+ Significant role of the diabatically generated PV in the sense of deepening the cyclone.
+ High nonlinearity by different PV anomalies on different variables.

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