An analysis of the 9-12th November 2001 West Mediterranean storm based on PV inversion

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1 Introduction

A sensitivity study to the initial conditions is performed for a high impact cyclonic situation occurred on the western Mediterranean area on 9-12 November 2001. Numerical simulations with the nonhydrostatic, primitive equations MM5 model are done using a single domain with 54 km horizontal grid resolution and 48 h forecast length starting at 00:00 UTC 10th November 2001. With a nonlinear ***Potential Vorticitiy Inversion technique***, modifications on the initial conditions of the numerical simulations are introduced, considering for that purpose a large number of PV anomalies related with different thermodynamical aspects of the flow. Statistical indexes are used to summarize the results in an objective way.

2 Case description

2.1 Synoptic overview

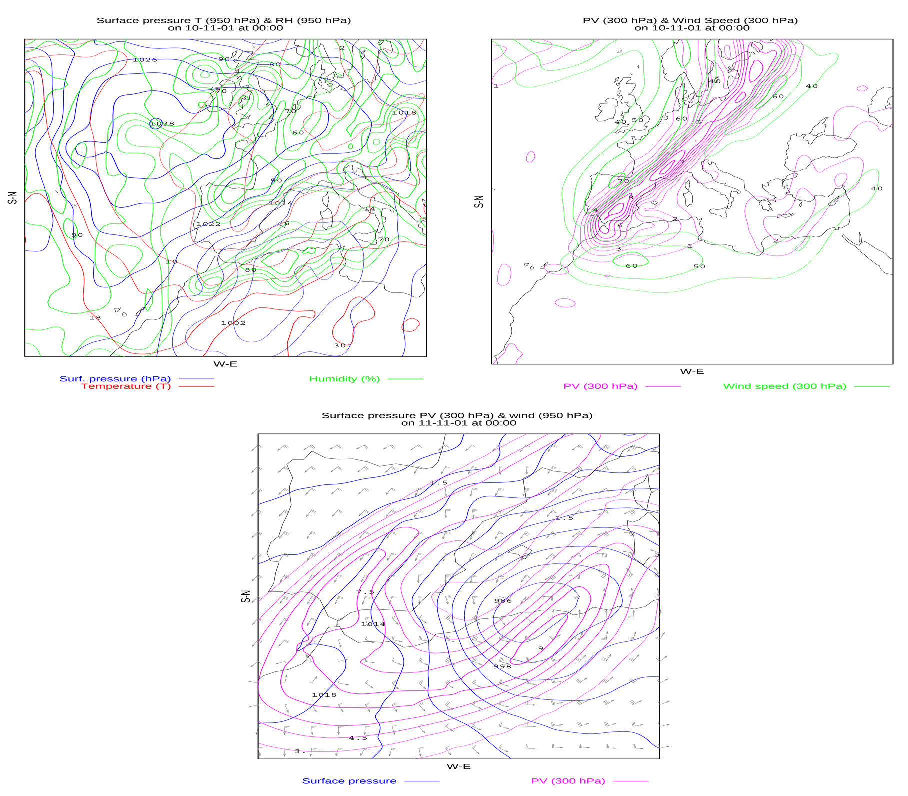

Figure 1: On **10th Nov at 00:00** Strong baroclinic enviroment with warm advection from Africa and cold advection from the european continent over the warm western Mediterranean sea (top left). High PV values along with a southward shift of the jet stream at upper levels over western Europe and north Africa (top right). The mature and most intense surface cyclone was attained on **11th Nov at 00:00** (bottom) with about 988 hPa central pressure, sustained winds about 30 m/s and precipitations exceeding 200 mm/24h in the Balearics. Moreover, 700 victims in Algiers were produced by local floods.

2.2 PV evolution

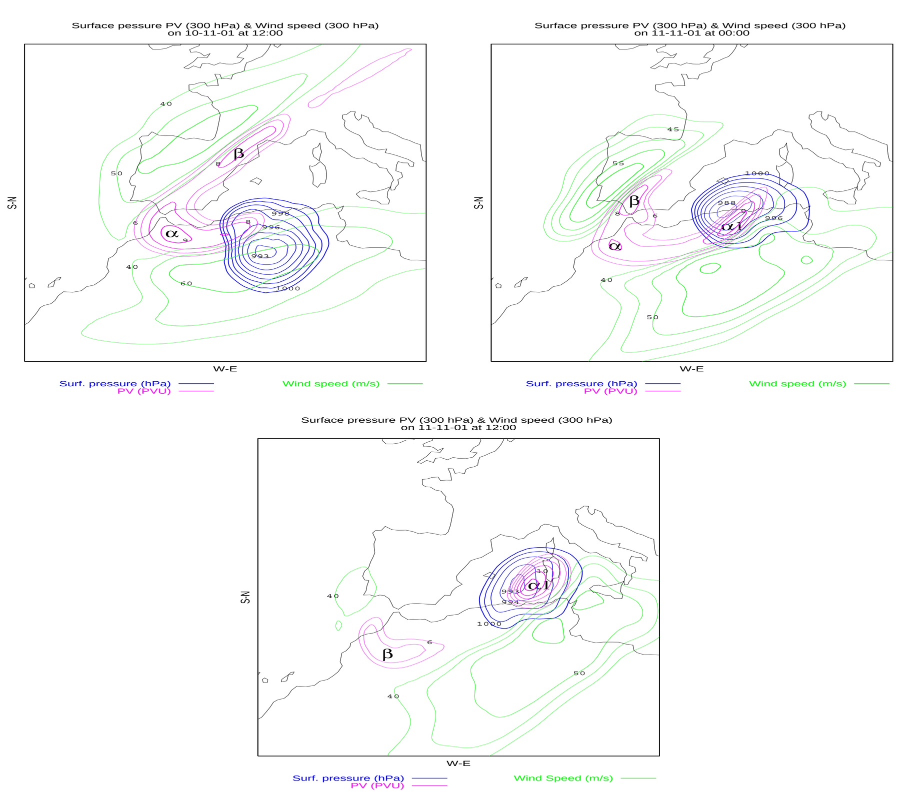

Figure 2: The α, $\alpha 1$ and β PV positive anomalies interaction played a ciclogenetic role. Their mutual interaction reinforced the PV advections and the deeping processes of the cyclone.

2.3 Vertical PV interactions

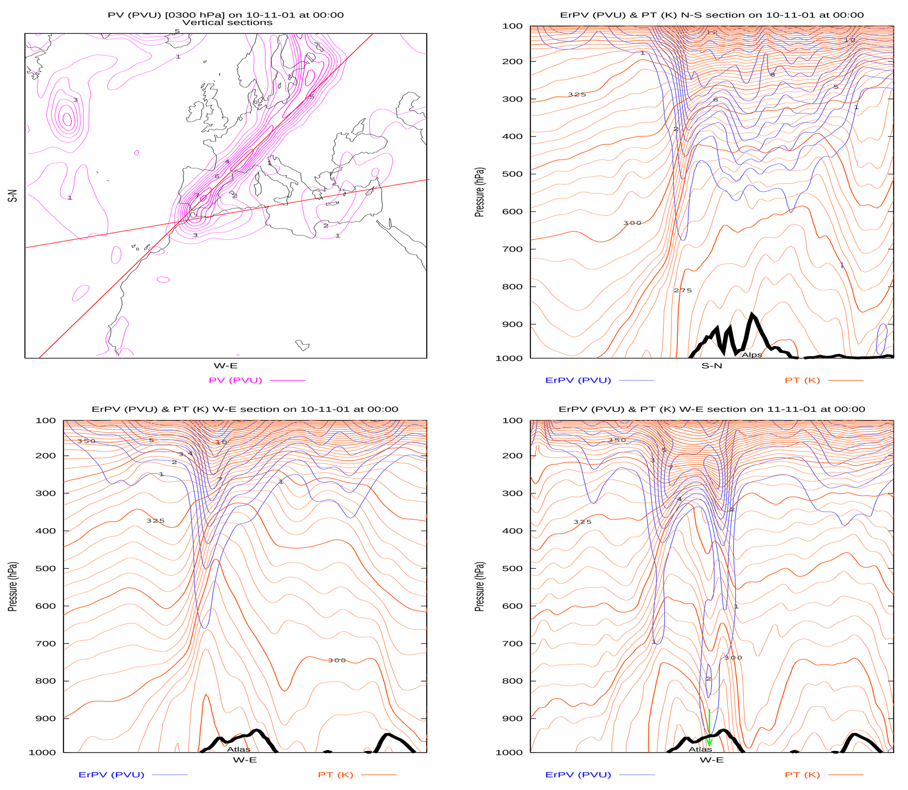

Figure 3: The vertical influence of the PV upper-level anomalies reach the surface. The PV generation due to latent heat release within the cloudy, heavy precipitation areas of north Africa attains 2PVU about 800 hPa. The warm core of the low-level cyclone (green arrow) is clearly visible on 11th Nov 00:00 UTC (bottom right)

3 PV anomalies definition

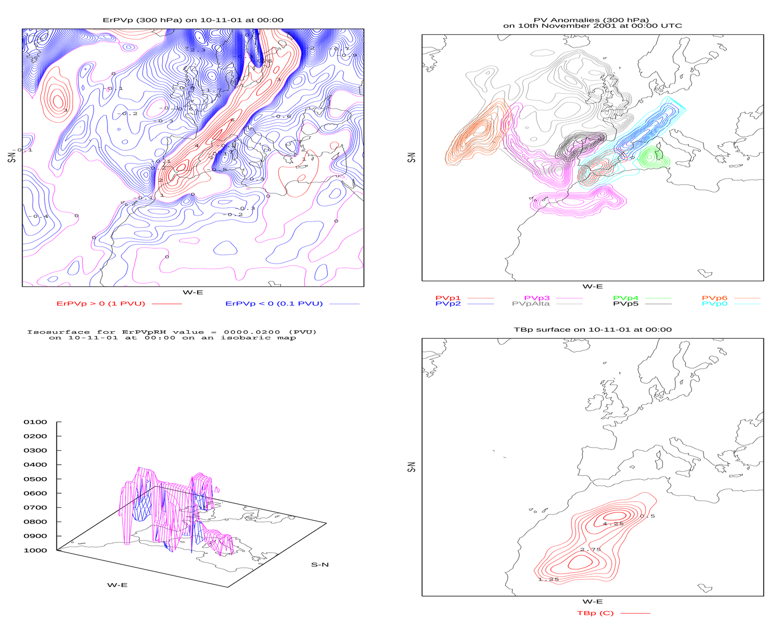

Figure 4: The upper-level PV anomaly field as the departure from the 7-days average is shown at the initial simulation time (upper left). Physically relevant features from the PV anomaly field are defined: the dry PV anomalies (8 in total) at upper levels (100 to 500 hPa; top right), moist (RH > 70%) PV anomaly at low levels (1000-500 hPa; bottom left), and the bottom warm thermal anomaly of african origin (as a surrogate of positive PV anomaly; bottom right). Thus, 10 PV anomlies are defined in this way.

3.1 Thermal positive surface anomaly

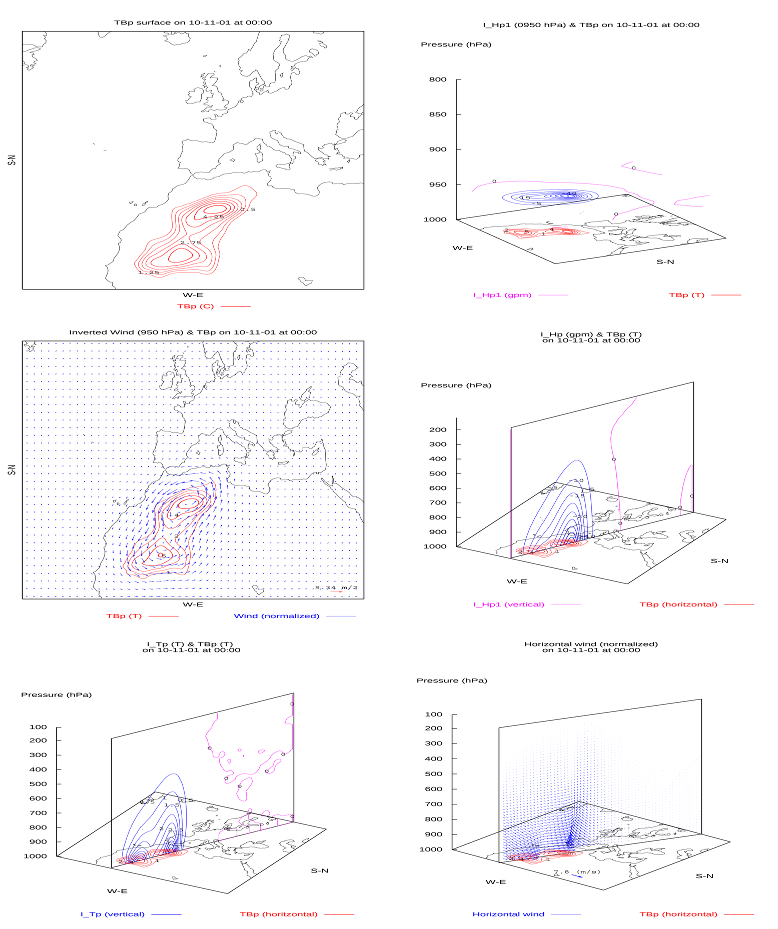

Figure 5: As an illustration of the PV inversion results, the balance flow due to the surface thermal anomaly is shown. The anomaly induces a cyclonic vortex, most intense at surface but extending up into the mid-troposphere. The associated thermal perturbation is also noted up to 400 hPa (bottom left)

4 Results

4.1 Statistical analysis of the PV-perturbed numerical simulations

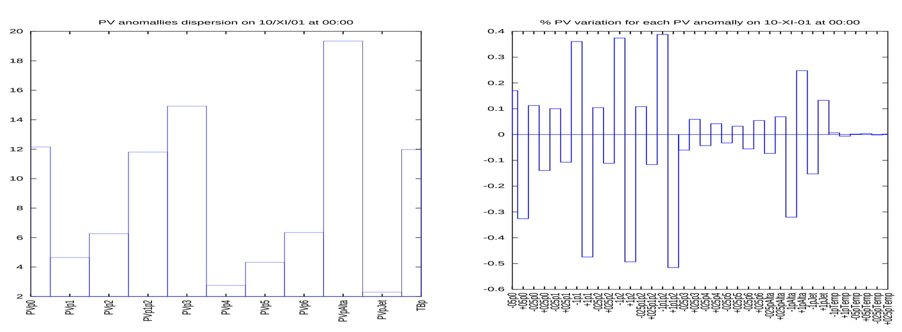

Figure 6: An ensemble of MM5 numerical simulations is designed through the modification of the initial conditions using the PV-inverted fields (by adding or subtracting a percentage of these fields). Left panel shows a measure of the spatial spread of the 10 PV anomalies (plus the combination PVp1p2). Right panel shows the percentual change of the initial PV within each PV anomaly areal coverage

4.2 Effects on forecast fields of the PV modifications

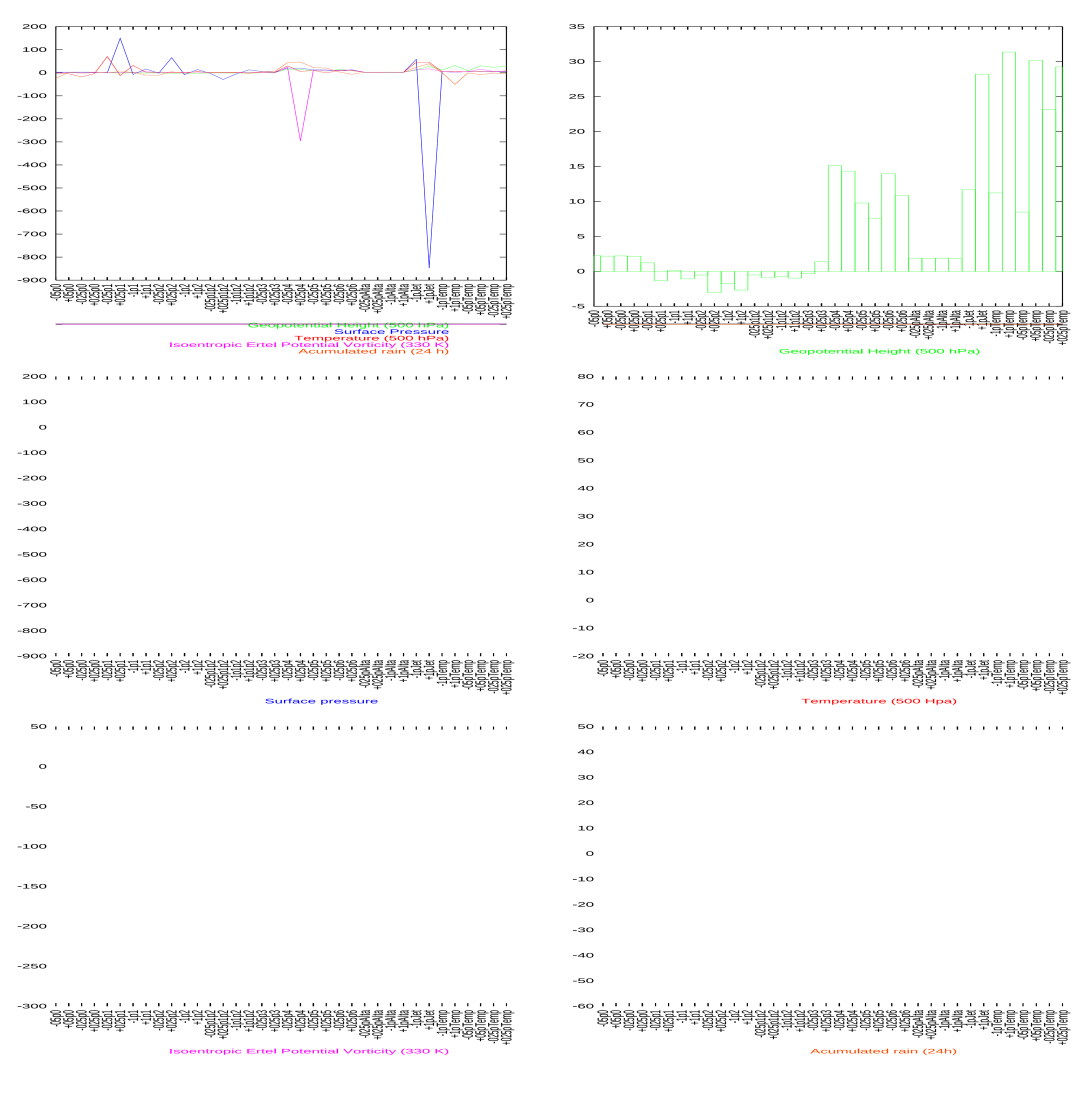

Figure 7: Relative -to the size of the anomaly- effect of each perturbed experiment on several forecast variables across the full domain at 00:00 UTC on 11th Nov: geopotential height at 500 hPa (top right), sea level pressure (center left), temperature at 500 hPa (center right), PV on 330 K isentropic surface (bottom left), 24 h precipitation (bottom right), ant all fields (top left)

5 Cyclone evolution

5.1 Cyclone trajectory

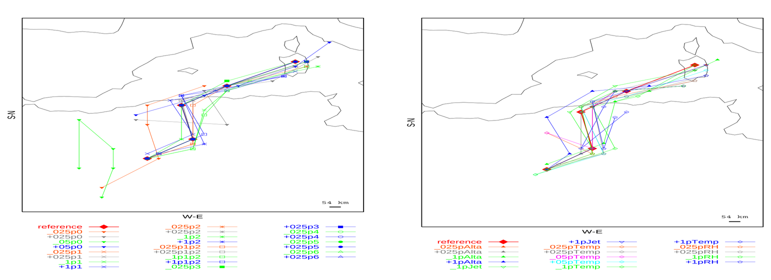

Figure 8: Similar cyclone trajectories for the given range of initial fields modification: The cyclone appears to be strongly controlled by the background upper-level flow and orographic influences. As expected, the greatest changes in cyclone trajectory are related with the strongest PV modifications at upper levels. The effect of the upper-level negative PV anomaly related with the Atlantic anticyclone is particularly notable (westernmost trajectory on right panel)

5.2 Central pressure

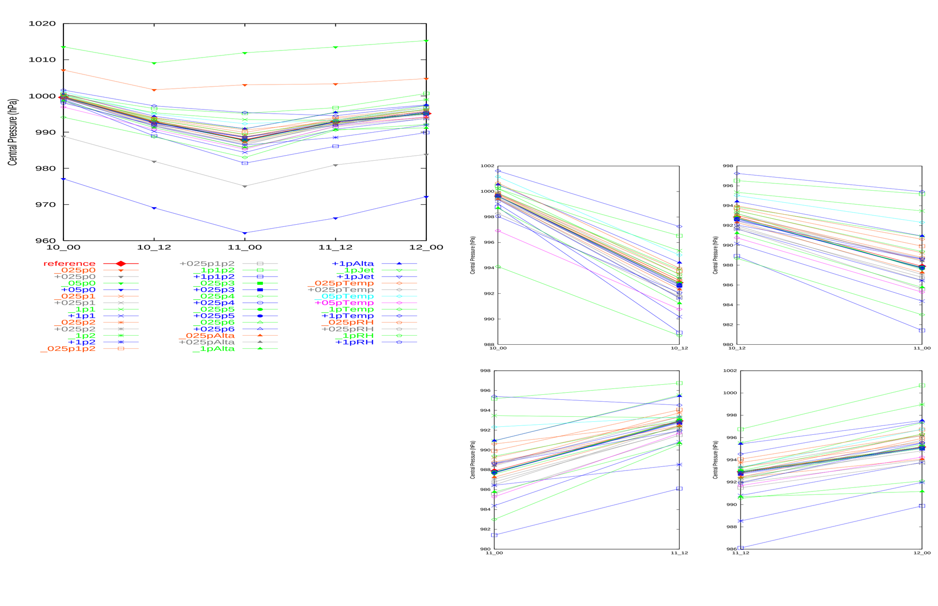

Figure 9: The greatest central pressure modifications are obtained with significant variations of the upper levels PV distribution. Also significant effects are exhibited with modifications of the bottom thermal anomaly. Therefore, features of the baroclinic structure are very relevant for the cyclone central pressure evolution.

6 Conclusions

- Clear description of the intense cyclonic event on the basis of the PV anomalies structure and evolution
- The PV effects are noted over large vertical depths and horizontal distances, the anomalies interacting as a result with each other
- The surface warm thermal anomaly can be treated as a surface positive PV anomaly through the bottom boundary condition of the PV inversion scheme
- Different PV anomalies influenced the forecast fields in diverse ways, with the greatest effect resulting from the upper-level trough configuration, the baroclinic enviromental structure and the Atlantic anticyclone.

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