Mediterranean Storms
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STUDY OF THE METEOROLOGICAL SITUATION WHICH AFFECTED THE WEST AND THE CENTER OF ALGERIA IN GENERAL AND BAB-EL-OUED IN PARTICULAR ON THE 10th NOVEMBER 2001

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ABSTRACT

During the 09th and the 10th November 2001, a great amount of rainfall falls over the western part and the center of Algeria in general and over Bab-el-oued (district of Algiers) in particular. The Area of the disaster is situated at the bottom of a mountain (400 m) and all of the rainfall converged to this area. So, during the period from the 09th November at 18 GMT and the 10th November 2001 at 12 GMT, the amount of rainfall which was registred at the station of Bouzareah (situated on the top of the mountain) was 261.6 mm, whereas the normal of the month for this station is of 96.6 mm. At the station of Dar-el-Beida located about fifteen kilometers far from that of Bouzareah, the amount of rain was only 30 mm during the same period.

The final tool of this disaster was terrible: 776 death (712 at Algiers), 126 disappeared (116 at Algiers), around 1500 families without shelters.
Concerning the economical damages: around 400 cars, all confused categories, was buried, deterioration of the roads, birth of craters of more than 10 meters in diameter, networks of cleansing strongly damaged, silting of the streets, landslide …
The damage caused by the bad weather was estimated at four billion dollars US.

According to the results obtained, the principal ingredients which allowed the focusing and the release of the instability are as follows: strong convergence of moisture at the surface and in the low levels of the atmosphere, in particular on the 10th Novembre 2001 between 06 GMT and 09 GMT, presence at the same period of a small higher anomaly of potential vorticity and of an anomaly of theta at the surface, from where a strong cyclonocity from the surface up to the mean levels, over the bay of Algiers, was established and which strongly contributed in the convergence of moisture in the low levels of the atmosphere, strong latent instability and vertical velocity in the low layers and orographical forcing which focused and triggered this instability. The rains which have affected the district of Bab-El-Oued are the result of the formation of an MCS (Méso-scale Convective System) and not of the occlusion which has affected the other areas of the north of Algeria and the Balearic Islands, as showed by the satellite pictures.

Key words: The Mediterranean sea, cyclogenesis, latent instability, moisture, orographical forcing, potential vorticity anomaly, theta anomaly.

1 Exceptional precipitations of the 09th and 10th November 2001

The quantities of precipitations measured at the metorological stations which are situated near the sinistred zone, shows that the quantities are exceptional and constitute records, the recording existing in the archives indicates that of such quantities on such time (24 hours), did not rised since there opening (more than a hundred years**).**

Stations	Altitude	09/06-18 GMT	09/18-10/ 06 GMT	10/06-10/12MT
Bouzareah	344 m	0.0 mm	129.2 mm	132.4 mm
Alger-port	03 m	26.9 mm	72.0 mm	109.0 mm

The Alger-port station is situated to about two kilometers to the east, from the one of Bouzareah which is situated at the top of Bab-El-Oued (area of sinister).
The quantity of rain of 109 mm, rised this level on 10 november 2001, between 06h20 and 09h30 GMT.
For the same period, and at the following meteorological posts : Mahelma and Staouali, situated to about 20 km to the ouest of Bab-El-Oued, it rised the quantities hereafter**:**

Stations	Altitude	09/06 -18 GMT	09/18 - 10/18 GMT
Staoueli	122 m	0.0 mm	135.0 mm
Mahelma	40 m	9.8 mm	65.7 mm

Nevertheless, at the professional meteorologial station of the airport which is situated to about 15 km to the south-east, from the sinister zone, the recorded rains for the same period are less important**:**

Station	Altitude	09/06-18 GMT	09/18-10/06 GMT	10/06-10/18 GMT
Alger-DEB	24 m	21.7 mm	8.1 mm	1.4 mm

There is place to underline that the quantity of exceptional rain of 261.6 mm was reached at the meteorological station of Bouzareah (situated at heights of the neighborhood of Bab-El-Oued), in a length continues of 18 hours (between the 09th /11 at 18 GMT and 10th /11 at 12 GMT), and of which the half (132 mm) in a lenght of 06 hours (between the 10th /11 at 06 GMT and the 10th /11 at 12 GMT).

2 Synoptical conditions

At the the 500 hPa level, the wave described previously evolved in its northern part, while in its southern part it sanks itself towards Morocco and southwest Algeria (Bechar's region). Simultaneously a hot sprout took birth on the Alboran sea and the southeast Spain and a cutt-off begun to take place. On 10/06, the cold air (-28 °C) was still parked on the south of Spain and the North of Morroco and the hot sprout was still present over the Alboran sea. Next, the cold air evolved very slowly towards the north of Morrocan atlas. After that, the cutt-off was well established with isolation of a minimum (5540 mgp) accompagned with a cold drop of -24 °C and the hot sprout moved progeressively to the Algerian coasts.
The thickness charts 100/500 hPa, confrmed the advection of the cold air towads the north Morroco and the hot sprout overhanding the Northwest of Algeria.
From the 10/12, the minimum begun a very slow evolution towads the northeast, while filling itself lightly.
The thickness charts shows clearly the widespread of the hot air over the Balearic Islands extending towads the coastal regions of the extreme west of Algeria.

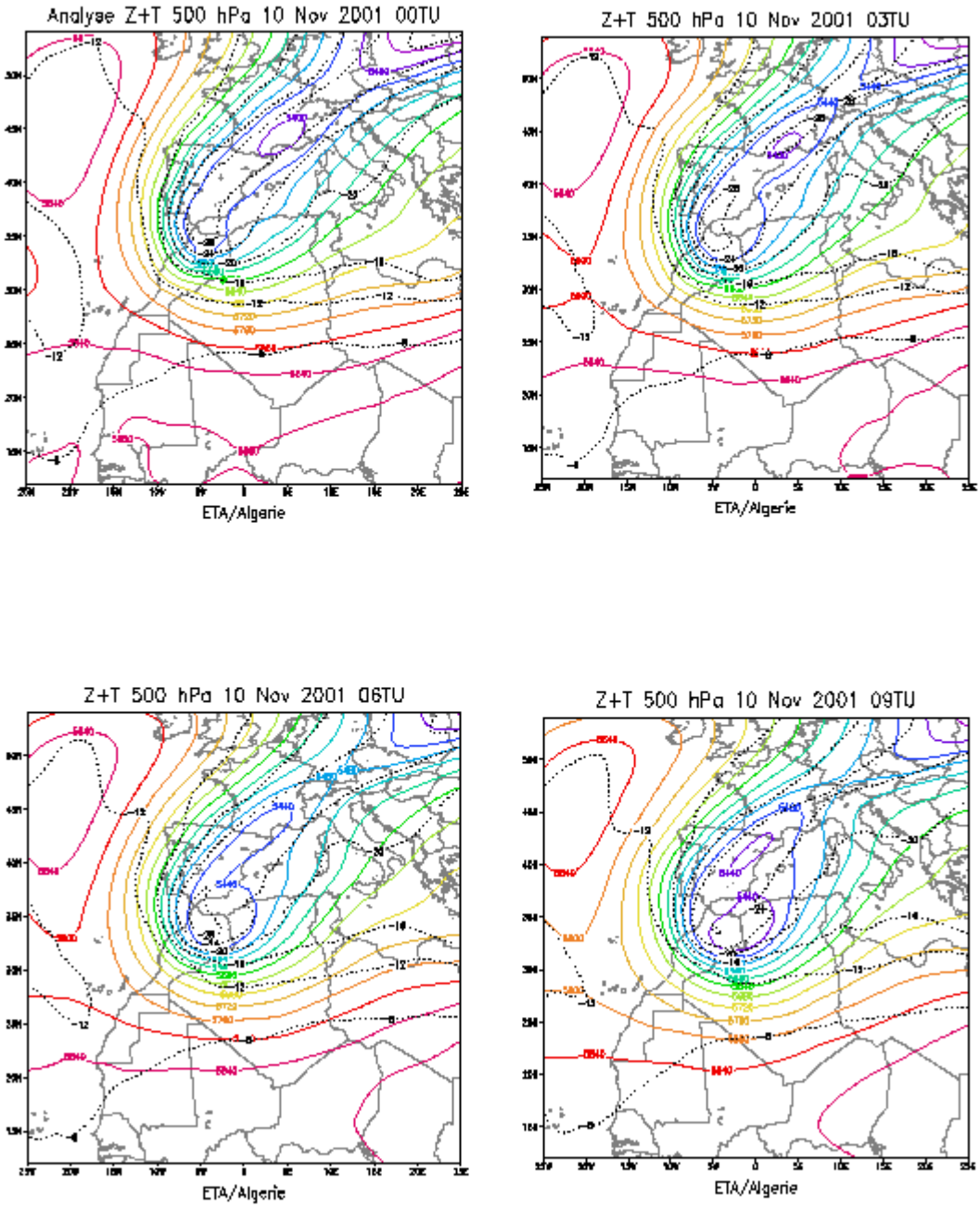

Fig.1 Geopotential and temperature at 500 hPa, from 10/11 at 00GMT to 10/11/2001 at 09GMT

At the surface, on the 10th November 2001, a depression was well formed over Timimoun (south-oest of algeria) as it showed by the surface fieds with a resolution of 10 km. From 00 to 09 GMT on the 10th November, the depression evolved slowly northward with deepening over the Algerian coats.

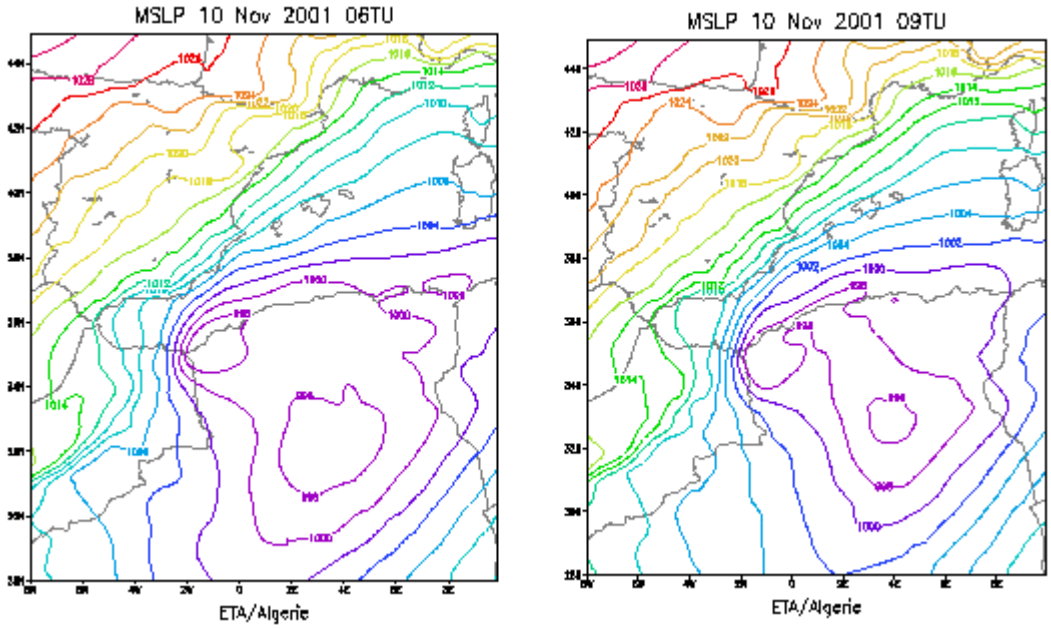

Fig.2 MSLP on 10/11 at 06GMT and 09GMT after ETA model (with 10 km resolution)

3 Analysis of the vertical velocity fields

The analysis of the synoptical vertical velocity at the level 850 hPa of the 09/12, shows two cores, one over the western Algeria and an other one over the centre of Algeria extending to the Algerian sea . Three hours later, these two cores begun to be more strenghten. On the
10/06, the previous core reinforced themselves, one passed from 12 to 16 cm/s and the other one from 10 to 14 cm/s. These two cores are separated by a subsident zone corresponding to a weak rising.
Between the 10/00 and the 10/12, these two cores reinforced themselves, while reamaining quasi-stationnary, this what explain the vigor of the vertical ascent over this regions, especially on the one of Algiers.
Beyong the 10/12, the previous vertical velocities begun to weaken in considerable manner over the centre of Algeria, after the evolution of the perturbation to the Baleric Islands, while it maintained itselves over the west.
To the level 700, as to the level 850 hPa, the analysis of the vertical velocty fields at the 10/03, shows two cores, one over the west and an other one over the centre of Algeria. Between, the 10/03 and the 10/12, these cores reinforced themselves on these regions, passing from 20 to 30 cm/s on the west and from 12 to 20 cm/s on the centre. Beyong the 10/12, the vertical velocities weakened considerably on the centre while it became less vigorous on the west of Algeria. This denotes the importance of the layer at the low atmophere, which was concerned by this ascents.

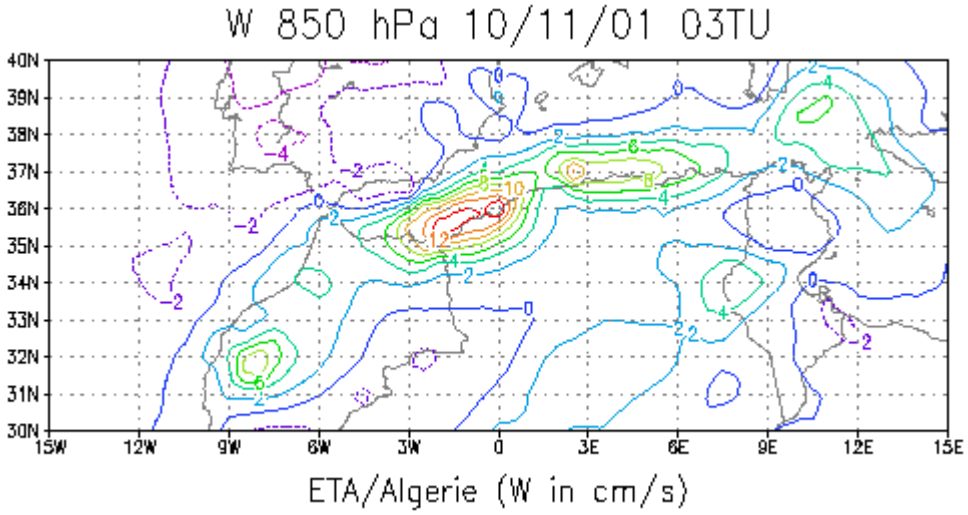

Fig.3 Vertical velocity at 850 hPa on 10/11/2001 at 03GMT

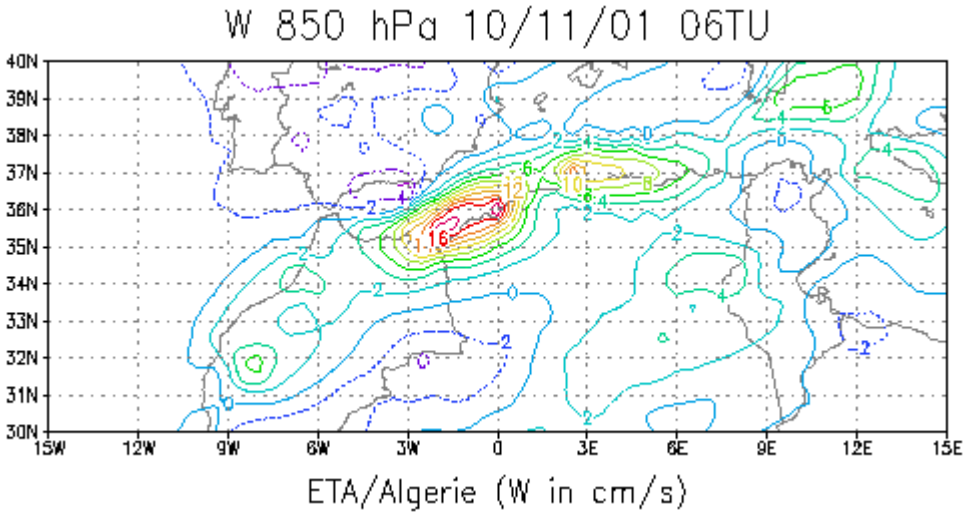

Fig.4 Vertical velocity at 850 hPa on 10/11/2001 at 06GMT

4 Latent and potential instability

The latent and potential instability which is used in this study is based on the equivalent potential temperature. As for the lapot index *W.S Harley* (1992), computed for the layer 1000/850 hPa, which combines the latent and the potential instabilty. The instability is more stronger than the indices are negative.
To the 10/00, the latent instability is too weak, except on the extreme west of algeria where it is on the order of zero in the layer 850/700, while the lapot index is in order of zero in the low levels of the atmosphere. This means that the instability exists but its not well developped yet and the cloudy layer is more dense over the west of algeria than over the centre. Three hours later (10/03), the situation evoloved in a manner remakable in the low levels. One notes a core of -10 to -15 extending from the western coasts to the center of Algeria. The increase of the latent instability, is the result of an advection of humiduity in the bottom of the layer and an advection of cold air in the upper layers on this regions, as we saw it previously during the anlysis of the synoptical situation and the humidity convergence fields. The lapot index for the layer 1000/850 hPa, became equally strongly negative on the same regions. This denotes the presence of a strong potential and latent instability over the Algerian coasts and also over the western Medierranean up to the Balearic Islands.
Between 10/03 and 10/09, the instability became more stengthen, while generalised to the layer 850/700 hPa, in particular over the interior west of Algeria.
The question that there is place to ask here is the following one: what did allow the foccusing and the triggering of the instability.
In the present case, the orientation and the form of the mountains of Bouzareah which peaks to aroud 400 meters and that overhands the Bab-El-Oued neighborhood (sinister area) played a big role in the dynamic forcing of the north east air mass which was near the saturation, to foccus and to trigger the latent instability and then the vertical developements happened on the sea side of the mountain.

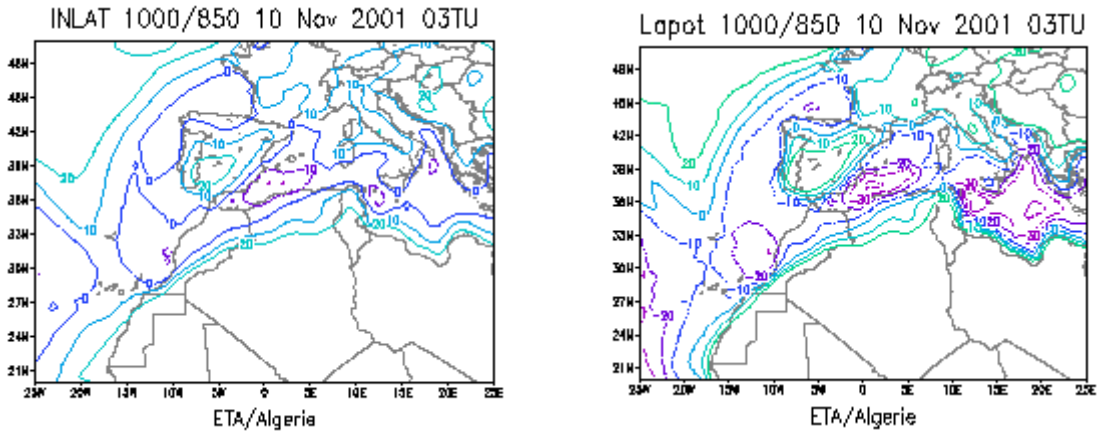

Fig.5 Latent Instability and combined latent and potential instability for the layer 1000/850 hPa at 03GMT

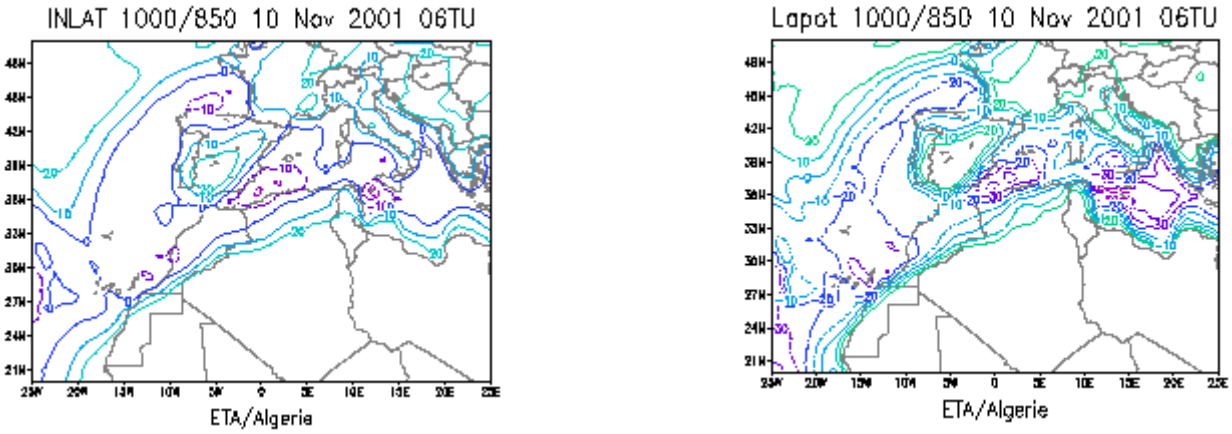

Fig. 6 Latent Instability and combined latent and potential instability for the layer 1000/850 hPa at 06GMT

5 Analysis of potential vorticity fields

The analysis of the potential vorticity (PV hererafter) 330 K field of the 10/00, shows the infiltration of the stratospheric air, after the tropopause folding on te north of Morocco where the Values of PV are greather than 6 PVU (Potential Vorticity Units) , and the centre of Algeria where the Value of PV was around 5 PVU, with a cutt-off on the region of Algiers. Betwen the the 10/00 and the 10/12 strong values of PV continued to be advected towards north Morocco and the western part of Algeria. The consequence was a stenthening of the cyclonic circulation in the low levels. The presence of an anomaly of theta, associated with the anomaly of PV of the upper levels intensified more the ciculation at the sirface and in the low levels of the atmospehere. By this, the pressure falls up to 996 Pa on 10/15 over the Algerian sea.

From the 10/15, the one meet note a cutt-off of PV on the wet of Algeria. As we know, after Hoskins (1985), when superior anomaly of PV becomes cutt-off, the dynamic allowed to the low levels is finished. Therefore, the cyclogenetic effect of the PV anomaly of the mid levels is added to the surface circulation that is induced by the upper level PV anomaly and the hot anomaly of the surface, the consequence was a depenning of the depression at the surface when it moved towads the balearic islands.

The maximum of the precipitation happened at the Algiers region and it seems linked to the interaction between the upper PV anomaly and the surface anomaly of theta, which extends on the centre of Algeria.

These two entities, in addition to the other elements dercribed previously, probably generated an MCS (Meso-Scale Convective System) that afffected the coats of Algiers. The orography also played a dynamic role, in the foccusing and the triggering of the instability.

All this ingredients did favour to a strong rainy activity over the region of Algiers. Besides, we can add the fact, that at this season the sea is still warmer than the continent. This is an other factor which played a role in this extreme event.

A simualton with and without topography of this situation would be very interesting in order to quantify more better the effective effect of the orography in the triggering of the instability and by a consequence way, in the production of the rains.

In addition the computation of the PV inversion would allow to quantify the effective contribution of the two anomalies, in order to better undestand to which level and degree, the upper level anomaly contributes to the developement of the minimum of the low levels, especially between the 10/00 and the 10/12.

Concerning this case, it seems that the anomaly of te low levels played a great role. In here case study *Flocas* (1997) noted that the contribution of the low level anomaly repersents about 50% of the total inversion of the surface winds, and the anomaly of the upper levels about 25 %.

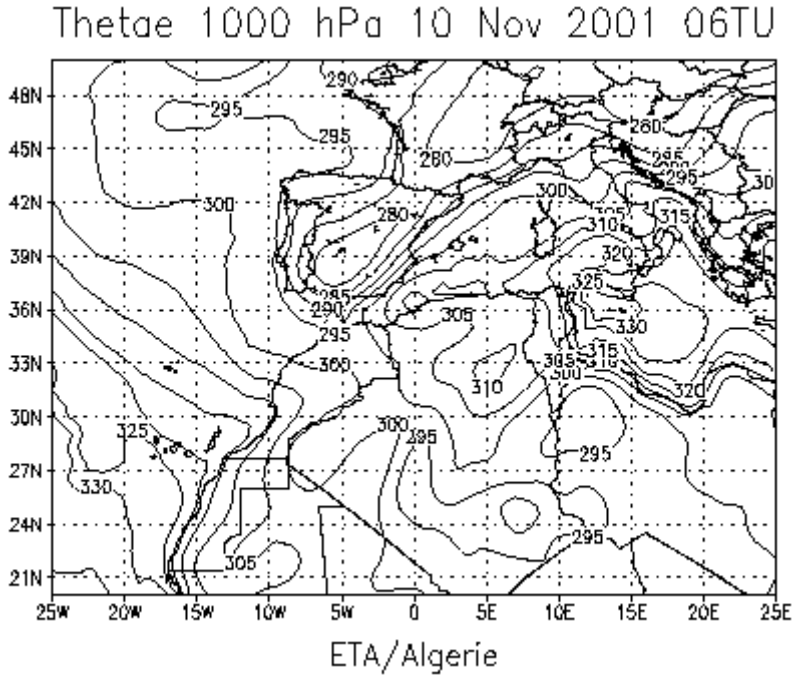

Fig.7 Equivalent potential temperature at 1000 hPa on 10/11/2001 at 06GMT

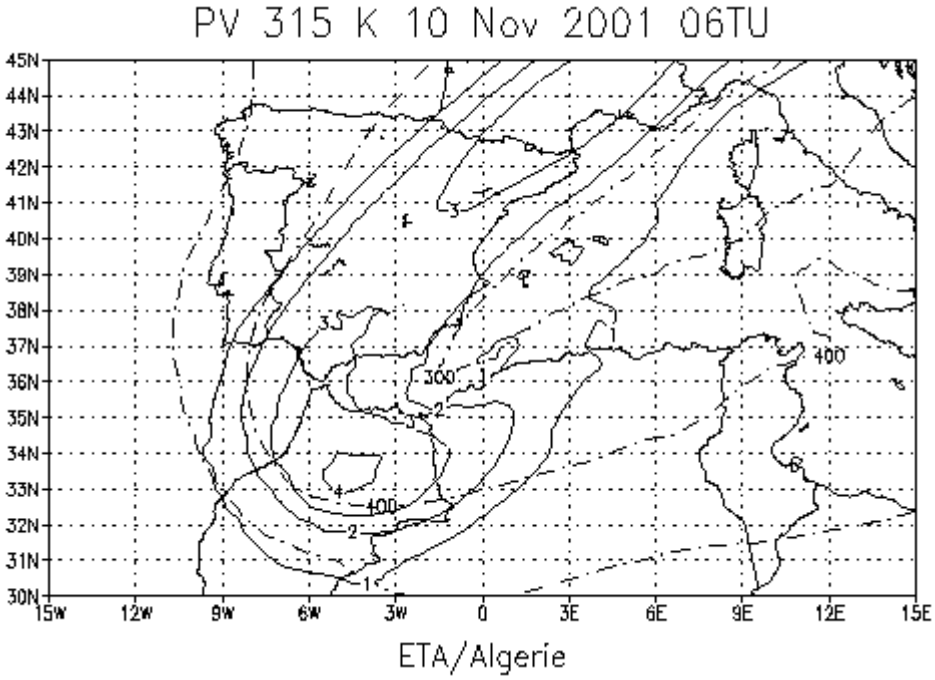

Fig.8 Isentropic Potential Vorticity (315 K) on 10/11/2001 at 06GMT

6 Conclusion

The main aim of this present study was in first approach, to point out the principal elements that can allow us an idea about what happened during this extreme event, during the days 09 and 10 November 2001, while awaiting to complete it by other simulations.
The principal conclusions that we can emit are the following ones:

1) The strenthening of the latent instability at the low levels by the bias of the humidity convergence in the bottom of the layer, was the preponderant element during the 10th November 2001, as it was underlined in the analysis of latent intability index (INLAT).

2) As in most Mediterranean cyclogenesis, the topograpy played a great role in foccusing and triggering the latent instability, as shown by the cross-section of the vertical velocity and humidity at the latitude 36.5 N.

3) The interaction between the upper PV anomaly with the low level theta anomaly did favour to the strengthening of the cyclonic circulation at the surface and at the low levels of the atmosphere, and then to the humidity convergence in the low levesl.

The described characteristics in the conceptual model of *Jansa et al.* (1996), as the advection of hot and wet air in the bottom of the layer, able to replace the big quantities of water evacuated in the form of precipitations, is present in this case study. An other element, as the orographic forcing to destabilize the column of air played equally a role.

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