EXPLOSIVE CYCLOGENESIS OVER THE SOUTH-EASTERN ROMANIA DECEMBER 2 – 3, 2012

M. BRATU[1], C. NICHITA[2]

Abstract. - Explosive cyclogenesis over the south-eastern Romania december 2-3, 2012 . This paper is devoted to the study of the synoptic-dynamical conditions that contributed to the development of an rare explosive cyclogenesis event occurred at the beginning of 2012-2013 winter in southwestern Romania, more precisely between 2nd and 3th of December, 2012. The minimum pressure observed was 980,2 hPa, the lowest ever observed record in the surface of Sulina observation station, and also over the western side of Black Sea during period 1961-2000 and 1965-2004. It was found that the cyclone was not a regular one, but a real „meteorological bomb" one where the central pressure at sea level has recorded an important decrease at about 32,3 hPa in 24 hours, equivalent with 1,7 Bergeron. Comparative by „XX century storms" Lothar and Martin (level 2 and 1 on hurricane scale) which desolated western and central Europe in December 1999, this case of explosive cyclogenesis can be considered one of the extreme for our area concerning both meteorological view as well as the effects.

Key words: *explosive cyclogenesis, Bergeron unit, meteorological bomb.*

1. Introduction

There are quite frequent situations in some areas as Atlantic Ocean, Pacific Ocean and East Coast of USA (Roebber, 1984; Sanders, 1986; Gyakum et al.,1989), also often behind the seas with important surface thermal gradients of the water, where the transformation of a cyclone from the wave status to the maturity status happens so fast and with such an intensity, so that the atmospherical pressure reaches in a short time critical values, being characterized by abundant rains, strong winds (average wind >17 m/s) and dangerous significant wave height (swell) for the human activities, as for sea and air navigations. By definition, the extra tropical cyclone settled to precise latitude, whose pressure decrease in its center with a ratio of least 1hPa/ hour during 24 hours (Sanders and

[1] Regional Weather Forecast Center Banat-Crisana, NMA, Romania,
e-mail: marius.m.bratu@gmail.com
[2] Regional Weather Forecast Center Banat-Crisana, NMA, Romania,
e-mail:cristian.nichita76@gmail.com

Gyakum, 1980) is called „meteorological bomb”. An analysis of the meteorological conditions, such as the heat flux and moisture budget, upper-air circulation features, has been performed by Gyakum and Danielson (2000) and by Strahl and Smith (2001). Analyzing a large number of „bomb” events in a time period of one week over the Pacific, they found that large surface heat fluxes are crucial in the case of explosive cyclogenesis. Recently, Nielsen and Sass (2003) in their study about North Sea severe storms have also identified the dynamic precursors such as potential vorticity (PV) generated by latent heat that brings a major contribution to the deepening of the studied cyclone. Closer to our geographical area, in the Mediterranean sea, where happen the most frequent cyclogenesis that influence the Romania’s weather-climatic condition especially during the cold season, some important studies have been done by Lagouvardos (2006) and Michele Conte (1986).

This work is dedicated to the investigation of a rare explosive cyclogenesis event happened over the South-Eastern of Romania territory and western side of Black Sea Basin, when an absolute record for the lowest atmospheric pressure (980,2 hPa) has been recorded at Sulina meteorological station on December 2 – 3, 2012. This value has been with 37 hPa lower than the previous observed with 23 hours before. Sustained winds and gale winds in eastern Romanian territory and western Black Sea exceeded in average 20-25 m $s^{-1}$with gusts up to 38 m s^{-1}, and they resulted in all the harbors were closed, the trees were lied down, the roofs were dislocated and damaged, the power supply network was interrupted and the wind power supplier was out of order. The gradual filling of cyclone slowly evolved in the next 15 hours (only 4 hPa pressure difference from the lowest one) till it was reached the mature stage. Near and on the back side of the low center, harsh weather conditions swept across the south-eastern Romanian territory, the Pontic Coast and the western Black Sea, also with important total rain accumulations in 12-24 hours (torrential rain between 20-60 l/m², with peaks at about 69...70 l/m² and blizzard in the mountains area - Oriental Carpathian Mountains).

The „bomb” analyzed in this work had a Mediterranean Aegean origin, and its evolution occurred on an unusual trans-balkanic trajectory (Fig. 1), deflected towards north in comparison with the classic one (type 2b’) as it has been settled by C.Sorodoc (1962) and revised by Ecaterina Ion-Bordei (2009). It was conclude that the rapid deepening of the cyclone was associated with a short and rapid trough system (Stratospheric dry air intrusion - Figure 4 a), that, upon the influence of a very intense subtropical upper-level jet, has merged into a steady baro-clinic low-tropospheric environment still existent on the sea coast of Romania and Bulgaria. Prior to the rapid cyclogenesis, the growing trough acquired a negative tilt intensifying the process (Gaza and Bosar, 1990). Based on the WRF-ARW non-hydrostatic mezoscale limited area model simulations, we could conclude that the upper-level dynamic factor (trigger) was not the main reason that led to the growth and decay of the explosive cyclogenesis under study. The significant level of the surface latent heat (diabatic heat) released within the cyclone, during its explosive phase that generates an intense low-levels vortex (potential vorticity values observed at about 3 to 5 PVU for at least 9 hours), has contributed as a crucial factor to its rapid deepening. The most recent studies show that subsequent intensification could be the result of the apparition and growing of a diabatic Rossby wave (DRW) and of the nonlinear interaction of his short wave (mezo-scale 200 km) with the upper-level disturbance (Morre and Montgomery, 2003). This is the first approach to the synoptic setting of this kind of cyclogenesis event over Romanian territory.

Sanders and Gyakum (1980) presented the first complete climatological study over this subject when they introduced the notion of explosive cyclone development or „bomb" cyclogenesis. But their study had focused over the Pacific and North Atlantic regions. In time, many other authors have come with additional interpretations. Recently, few investigations were made in the Mediterranean Basin, but some Greek and Italian authors such as Lagouvardos (2006) and Brunetti (2005) have focused upon this area. The Mediterranean Sea, due to its complex and particular geographical configuration as a closed and warm sea, is the reason why these phenomena are relatively frequent.

Because this phenomenon is very rare at the latitude of Romania, and the majority of cyclogenesis have Mediterranean origins, we have considered useful to have as important reference the studies made by Brunetti and Moretti (2005) in the entire Mediterranean Sea Basin. From 1980 to 2004, 79 such events have occurred over the Mediterranean Sea, a medium of 3 events per year. The meteorological „bombs" started in October and ended in May.

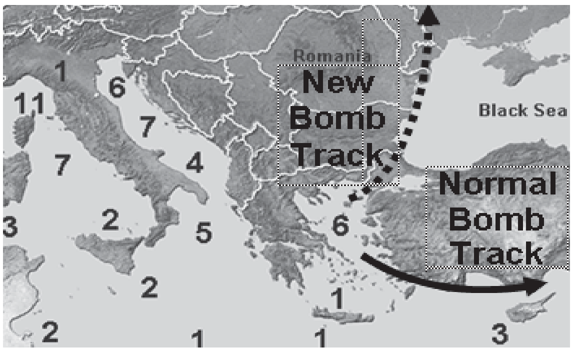

Figure 1. The 25 year's geographic distribution of the meteorological bomb events (cases number). From 1980 to 2004 in the entire Mediterranean Sea Basin (Brunetti and Moretti 2005)

A maximum of events happened in December (18 events), when the sea is still very warm, followed by January with 15 events and the minimum of events happened in May. Fig. 2 indicates the frequency of the critical values expressed in Bergeron units, values observed between 1980 and 2004 (fig,2). The biggest drop of 1,59 Bergeron has been reached only once (on the 21st of January, 1981), when the pressure reached 27 hPa in 24 hours at the latitude of 39ºN. Similar events have never been recorded during June, July, August and September. Brunetti and Moretti (2005) provided also a very useful list of the meteorological bombs from the Mediterranean Sea, which contains the date, the initial and final pressure values and also the differences between them, the recorded Bergeron value, the latitude and longitude of the maximum deepening, the geographical area, the type of cyclogenesis (eg. frontal, continental, African).

An important cyclogenesis is the Aegean type (Fig. 1), with 6 events in a quarter of century.

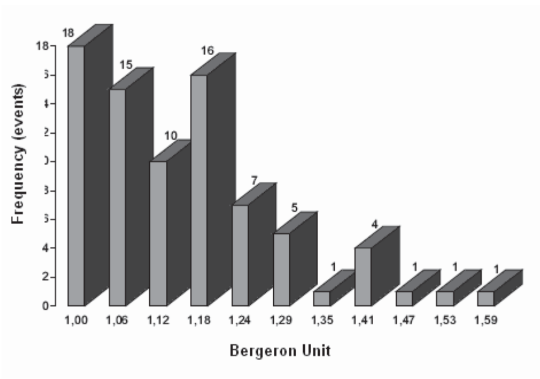

Figure 2. The "Bomb" frequency events over the Mediterranean Basin from 1980 to 2004, (Brunetti and Moretti 2005)

In our case the cyclogenesis has been initiated also in the Aegean Sea Basin, and in less than 24 hours the central pressure of 32,3 hPa measured at 12 UTC, December 2nd, fell to 06 UTC, December 3rd (Fig. 3, left) corresponding to 1,7 Bergeron and thus the low pressure system can refer to a strong 'bomb'.

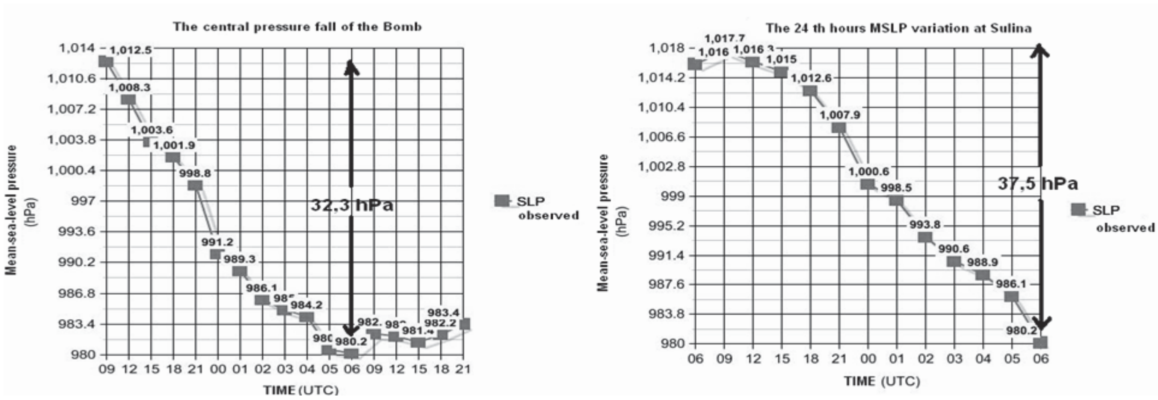

Figure 3. Observed 36-h central pressure fall inside the cyclon (left) and at Sulina weather station (right) from 09 UTC 02 Dec to 21 UTC 03 Dec 2012

According to the MEDEX (MEDiteranean EXperiment) database constructed by ECMWF analyses, this case was the deepest cyclone observed in the entire Romanian area including western Black Sea Basin during 1965-2004 period. At that time the weather station Sulina reported an extraordinary pressure fall of 37,5 hPa in 24 hours (Fig. 3, right) and a minimum pressure of 980,2 hPa; this minimum can be considered a new record after the latest record value of 980,9 hPa (Table 1) according with 1961-2000 NMA database records. There are a lot of studies starting with Sanders and Gyacum (1980) that describe the synoptic upper air aspects of explosive cyclogenesis.

Table. 1 The monthly and annual lowest pressure at Sulina weather station (1961-2000)

	Jan	*Feb*	*Mar*	*Apr*	*May*	*Jun*	*Jul*	*Aug*	*Sep*	*Oct*	*Nov*	*Dec*	**Annual**
hPa	983.0	981.6	983.5	987.3	993.2	989.7	993.5	996.6	988.3	993.7	985.8	980.9	980.9
New Record												**980.2**	**980.2**

The main factors are: horizontal temperature gradient especially for sea water temperature, surface heat fluxes, diabatic heating, air-sea instability, jet influences from high troposphere, tropopause folds. Examining a number of cases, Bruce and Elmar (1988) made an analytical study of continental bombs development over the Eastern United States, making comparisons between a regular cyclogenesis and an explosive one. They found significant signatures especially in divergence, vorticity advection and tendency, latent heating and static stability which allow distinctions between bombs and regular cyclones. More recently, according to Parker and Thorpe (1995), and also to Morre and Montgomery (2003), reexamining the dynamics of short-scale, they established that the diabatic Rossby waves growth mechanism (DRW) may play an important role, being considered a precursor for an explosive cyclogenesis.

2. Data and Methods

The method used in this work has been discovered by Tor Bergeron (1891-1977), who studied for the first time the synoptic climatology and the motion of this process on the extra-tropical cyclones from the North Atlantic Ocean. He has established the following principle to identify a meteorological bomb that is used till today: the pressure in the center of cyclone must decrease with at least 1hPa per hour during a period of 24 hours. The Bergeron definition, undertaken by Sanders and Gyakum (1980) to analyze the concept of explosive cyclogenesis („bomb"), had as reference the 60°N latitude. In order to monitor step by step the intensity and track of the meteorological „bomb", it was used the Bergeron formula:

$$NDR_c = \frac{\Delta p_c}{24} \times \frac{\sin 60^\circ}{|\sin \varphi^\circ|}$$

where Δp_c represents the pressure variation in the center and φ represents the latitude. The Bergeron formula allows us to obtain a critic NDR_c ratio (normalized deepening rate of central pressure) according to the latitude we want to use. When the pressure variation is of 1hPa/hour and φ = 60º, the NDR_c = 1, namely the threshold value of 1B (Bergeron unit) where the explosive cyclogenesis can start to happen.

$$1hPa / hour \times \sin 60^\circ / \sin 70^\circ = 0{,}92 hPa / hour$$

The measure obtained by Bergeron indicates the decreasing speed of the atmosphere pressure in the depression center settled to certain latitude. The critic ratio of 1B is considered a threshold value for an explosive cyclogenesis. This indicator can vary from 28 hPa in 24 hours (at the poles) to approximately 9 hPa in 24 hours (at 20º N latitude), this last value being calculated at the southern limit where the phenomenon was been observed till now. The Italian National Weather Service from the Mediterranean Sea basin has adopted critical value 1 Bergeron that represents a lowering of the pressure in the center of at least 17 hPa in 24 hours (which corresponds to the average latitude of 38° N). In the case of the Black Sea basin, we have considered 19 hPa as the critical value for 1 Bergeron (19,6=24/1,22 ;1 hPa/hour x sin 60º/sin 45º = 1,22 hPa/hour), for the medium value of 45º N.

In our case, the lowest value for the atmospheric pressure was 980.2 hPa (37,5 hPa in 24h) recorded in Sulina, and the highest value of the atmospheric pressure was 1012,5 hPa registrated in in the initial stage of the cyclone over the Aegean Sea. Considering as reference the pressure variation of 32,3 hPa (1012,5-980,2=32,3) in 24 hours in the center of the cyclone, in the case of our country the critic ratio has reached the extreme value of 1,7 Bergeron (32,3:19 = 1,7), comparing with our neighbor (the Mediterranean Sea Basin), where rarely the value of 1,59 was reached (Brunetti and Moretti,2005).

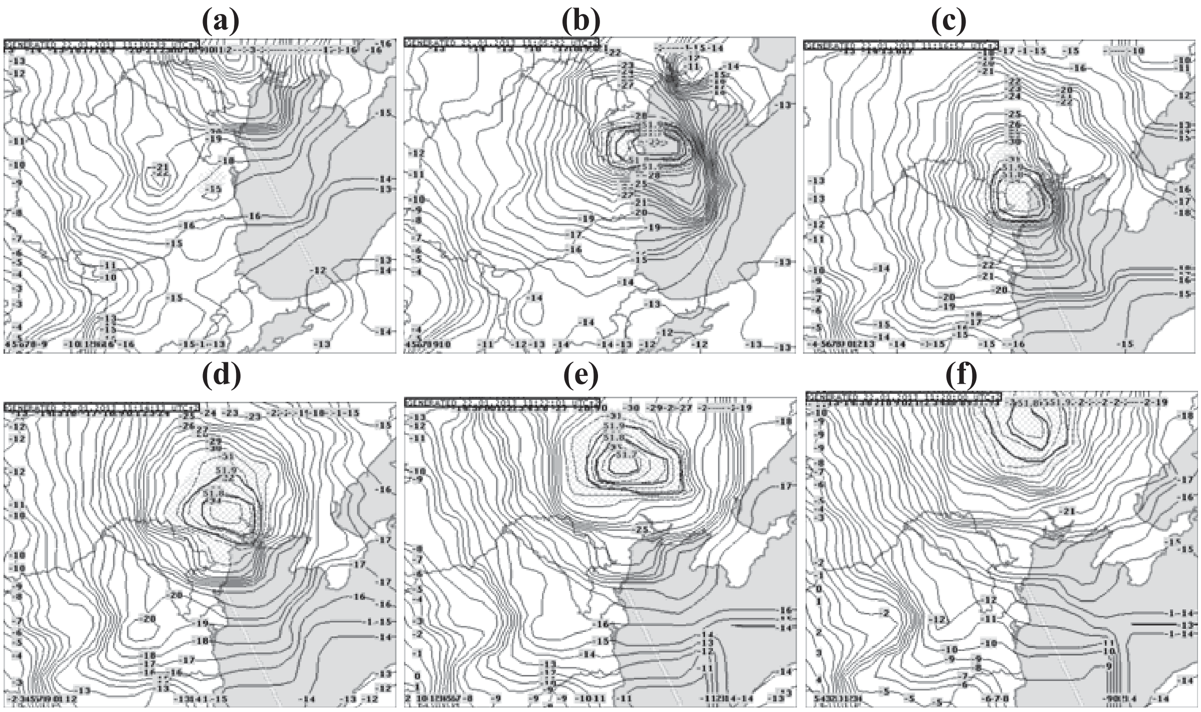

Fig. 4. Analysis of Δp_c in 24 h (black line, contours are labeled in 1 hPa) and $NDR_c \geq 1$ (green aria) at: a) 03 UTC 03 Dec 2012, b) 06 UTC 03 Dec 2012, c) 09 UTC 03 Dec 2012, d) 12 UTC 03 Dec 2012, e) 15 UTC 03 Dec 2012, f) 18 UTC 03 Dec 2012.

In this way the indicator NDR_c has been monitored during 15 hours (at every 3 hours) and the conclusion is that there is a gradual increase of its value from 1 Bergeron to 1,7 Bergeron, from the explosive deepest status of the cyclone (Fig. 4 a, b, c, d) up to the maturity status (Fig. 4 e, f).

3. Results

This event took place in a quite abnormal climatic conditions, with a neutral NAO index and slightly negative AO index (-1...-1.5). A low pressure area dominating the central Mediterranean Basin was linked with a large persistent Rossby wave (geopotential negative anomaly), that remained for 3 weeks in Western Europe (Fig. 4). A maritime arctic air mass came from north-west Europe and reached Italy and Balkan Peninsula. The main cold front that came separated the chill unstable Italian air mass from the warm, also unstable eastern Mediterranean air mass.

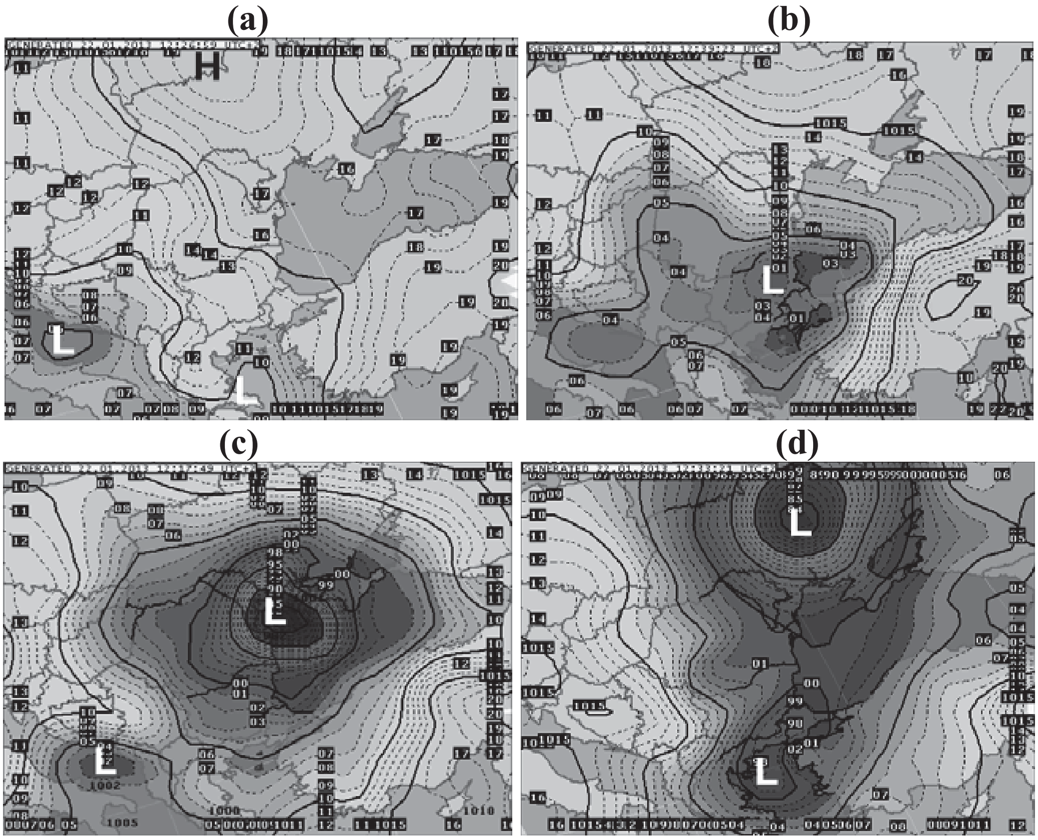

Figure. 5. Analysis of mean-sea-level pressure (contours are labeled in 1 hPa) at: a) 12 UTC 02 Dec 2012 in the incipient phase I, b) 21 UTC 02 Dec 2012 in the incipient phase II, c) 06 UTC 03 Dec 2012 in the explosive phase, d) 18 UTC 03 Dec 2012 in the mature phase

As well, both Mediterranean and Black Sea experienced positive sea temperature anomalies in the surface layer in December. Regarding the Black Sea, the surface temperature was between 11-14ºC, with 3-6 ºC upper than the monthly normal values. At 00 UTC in December 2nd, the cyclone we analyzed here was not formed yet. At 12 UTC 02 December, a low-pressure area in the incipient phase I with 1008,3 hPa in its center, was located in the maritime Eastern area of Greece (Fig. 5, a).

There were two disturbances, a short-wave over the area of the Ionian Sea with its axis extending NV-SE (negatively titled) and a cut-off low over the Sicilian Channel, observed at the 500 hPa level (fig. 6 a, b). A strong upper-level subtropical jet (STJ) accompanied the cut-off wave, reaching a maximum value of ~45 m/s (Fig. 6, b).

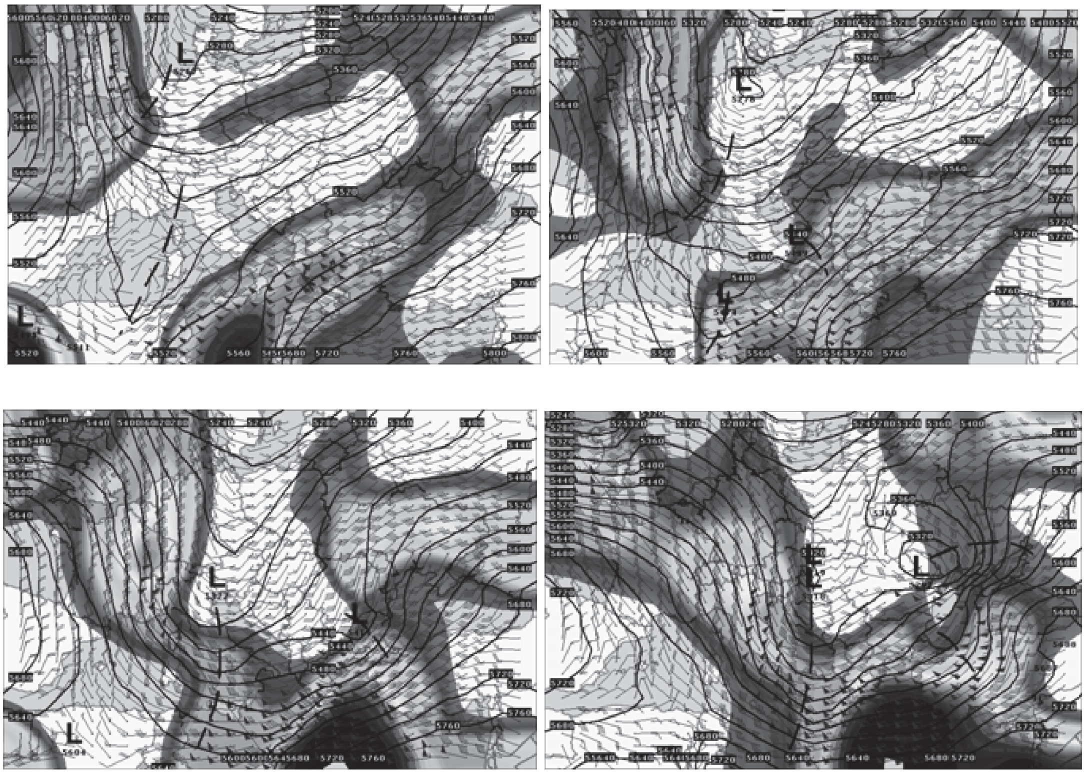

Figure. 6. Analysis of 500 hPa geopotential height (solid line at 40 m intervals and of 300 hPa wind speed - shaded contours at 1 m/s values, greater than 50 m/s are shown) and surface locations (indicated by white circle) of the meteorological bomb at: a) 00 UTC 02 Dec 2012, b) 12 UTC 02 Dec 2012, c) 00 UTC 03 Dec 2012, d) 12 UTC 03 Dec 2012

During the following 12 hours, at 21 UTC December 2nd, the low pressure was in its incipient phase II in southern continental Bulgaria with a central minimum pressure of 998,8 hPa (Fig. 5 b). Regarding the 500 hPa two-trough system (~5500 m above the sea level), we observe geopotential thalwegs: one in the western part (over the Sicilian channel), almost quasi-stationary inoculated in Atlantic polar flux, and another one in the eastern part (over the Balkan area) moving on a SV-NE trajectory under the influence of the Subtropical Jet. At the 300 hPa level it can be observed intensification till 56-60 m/s over the southern edge of trough, and also a detachment over northern edge of the trough of an isolated jets streak (Drift), accompanying the cyclogenesis process (Fig. 6, c).

At the same 500 hPa level, as a band, we can see two vorticity advection areas (Fig. 7 c): one over the east of Aegean Sea, Marmara Sea towards the low centre, and another one, less pronounced, over the eastern part of Romania, Moldavian Republic and southern Ukraine. The trough axis is still negatively tilted, thus generating cyclonic vorticity (Gaza and Bosar, 1990). It can be note that the cyclonic vorticity advection as a dynamical factor begins with 12 hours before the cyclone development (Fig. 7 b) and is more evident over eastern Romania and western Black Sea Basin. Warm advection at the same 500 hPa level is evident over the Black Sea, Moldavia Republic and Ukraine (Fig. 7 b, c). During the following 9 hours in December 3rd, the low pressure system moved northwards, rapidly deepening first to 991,2 hPa at 00 UTC and to 985,0 hPa at 03 UTC (Fig. 6, c).. The explosive phase has just started. The intrusion of stratospheric dry stable air in the troposphere levels, visible on the satellite infrared WV Channel as a black tongue shape (Santurette and Georgiev 2005) indicates the presence of an active dynamic tropopause anomaly.

(a) **(b)** **(c)** **(d)**

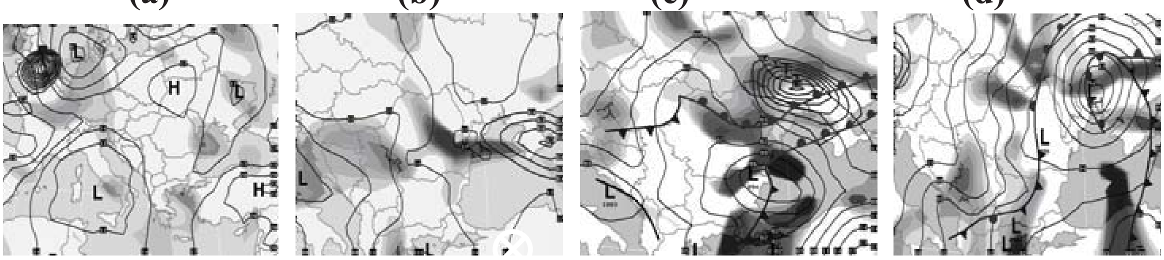

Figure 7. Mean-sea-level pressure, 500 hPa positive vorticity advection ($10^{-8}Ks^{-2}$), 500 hPa temperature positive advection ($10^{-4}Ks^{-1}$) at: a) 00 UTC 02 Dec 2012, b) 12 UTC 02 Dec 2012, c) 00 UTC 03 Dec 2012, d) 12 UTC 03 Dec 2012

That has been identified based on the analysis of the Ertel's potential vorticity (PV) field (magenta contour lines, taking as a reference value 1 PVU from the dynamic tropopause. The maximum potential vorticity area (PV max) became gradually narrower. The intrusion of dry air created local instability and upward motions that led to the organization of deep convection into a line on the eastern flank of the intrusion . At 06 UTC, December 3rd, the mezo-scale low-pressure has reached its minimum pressure (980,2 hPa) over the northern Dobruja (Fig.6 c). According to Sanders and Gyakum model (1980), explosive cyclogenesis occurs when the deepening of the cyclone exceeds 1 Bergeron. In the area over Black Sea (at ~45°N latitude), 1 Bergeron equals 19 hPa in 24 h. Therefore the 24-our central pressure fall from 1012,5 hPa at 12 UTC December 2nd to 980,2 at 06 UTC December 3rd corresponds to 1.7 Bergeron and thus to a strong 'bomb'. Important modifications of dynamic nature have occurred in the upper-level above the 500 hPa level, with 6 hours before the beginning of the explosive phase. The curvature trough amplified and the gradient of geopotential height depeened .At that time in the low-levels, a critical potential vorticity anomaly of about 4.5-5 PVU appeared with a comma shape (Fig. 16, right). As inferred by the strong pressure gradient (~13 hPa pressure change in just 100 km range around the storm center), the prevailing winds, first in the eastern sector and then in the western sector, reached their maximum intensity in south-eastern Romania, over Black Sea coast and western Black Sea (Fig. 8, 9) between December 2nd and 3rd.

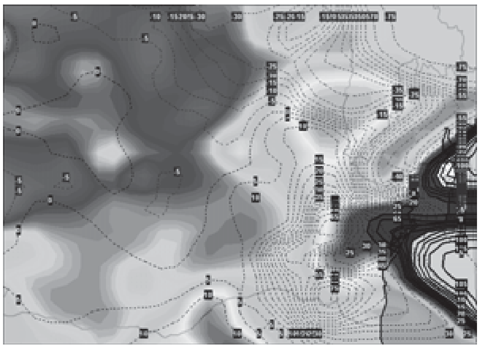

Figure. 8 Analysis of pressure tendency (color dots line at 0.5 hPa intervals) and of average wind speed (shaded contours at 1 km/h values, greater than 60 km/h are shown in black solid lines) in the explosive phase at 06 UTC 03 Dec 2012

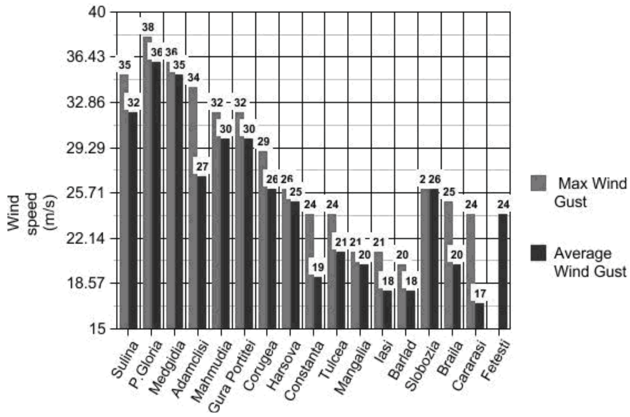

Figure. 9. Surface wind observations from the surface synoptic network during the storm

The local station registrated high intensity winds that exceeded 20 m/s and gusts of over 32 m/s. Max wind gusts at Gloria Oil Platform (15477), Medgidia (15462) and Sulina (15360) have reached 35-38 m s^{-1} which means the first level on the hurricane Saffir-Simpson scale, the same as for the Lothar and Martin cyclones (levels 2 and 1 on hurricane scale), that devastated western and central Europe in December 1999. The satellite images provide a clear overview to describe the mezo-scale evolution of our cyclone.

Short after an explosive stage, a clear defined “eye” along with spiral structured cloud bands was visible from MSG-2 (RGB Channel) satellite images during the morning on 3rd of December at 07 UTC . The polar NOAA-MODIS images show at a higher resolution the location of the low in the neighborhood of Odessa City (Ukraine) with a clearly defined “eye”. During the next 12 hours, the cyclone reached a mature stage .

During the explosive phase, the largest deepening occurs from surface to 850 hPa and is related to an intense moisture convergence field coming from the Black Sea (east-northeast sector) and toward the cyclone center (Fig. 10, 11, 12 left). In December 4th, the cyclone dissipated over the northern part of the Russian Plain, after moving over ~2000 km with an average speed of 50-55 km/h in the explosive phase . This is connected with an intense low level vortex associated with ascending moist air movement that produced a rapid pressure drop, condensation, latent heat release and a thermal profile that is typical for warm cyclones between 850 and 700 hPa.

A closer analysis of potential vorticity anomaly field provided us the idea that the subsequent intensification could be the result of a growing diabatic Rossby wave (DRW) and of the nonlinear interaction of its short wave (small-scale less than 500 km) with the upper-level disturbance (Morre and Montgomery, 2003). The WRF-ARW 3.4.1 non-hydrostatic numerical model was used in a one nested grid configuration, with a finest horizontal resolution of 4.5 km, to simulate the low-level vortex genesis and evolution (potential vorticity) also surface latent heat flux. The simulations were initialized with GFS spectral model at 00 UTC 03 December 2012.

Note that the maximum PV (read shaded contours) coincides very well with maximum moisture convergence area and with the maximum current lines. This means that the appearance of adiabatic waves is tied with the moisture convergence and with the maximum low jet intensity in the south-east sector.

In the mature phase, the lower vortex level was “depleted”, energetically consumed in the upper troposphere levels by the presence of cyclonic vorticity advection. The model maps highlighted that the PV magnitude was maintained at high values at the same previous values (4-5 PVU) for another 5-6 hours while the low-pressure system was away from the Black Sea area. In the next hours, the wave started to rotate (Fig. 11, right), reaching a minimum historical pressure of 980.2 hPa.

The role of surface heat fluxes has been investigated in many cases of explosive (as well as ordinary) cyclogenesis and it is considered to be a crucial feature during the cyclogenetical process (Gyakun and Danielson, 2000). Since 03 December, 03 UTC, the heating flux (just surface latent heat shown) gradually increased during the explosive phase reaching the maximum from 07 to 10 UTC at

Figures 10, 11, 112–right, present a series of 925 and 850 hPa potential vorticity at 01, 03 and 06 UTC 03 December. The Ertel potential vorticity is given in PVU (potential vorticity units) or $10^{-6} km^2 kg^{-1} s^{-1}$.

Few hours prior the explosive phase, around 00-01 UTC December 3rd, near the border line between Romania and Bulgaria (Fig. 10, right), the first high PV values of 3.5 - 4 PVU appeared first at the lower level of 925 hPa (600-700 meters high), while at 850 hPa (1300-1500 meters high) the values were of only 2 PVU. In the next three hours, over the continental part of Dobruja, the PV magnitude will reach the phenomenal 5 PVU on both two levels (Fig. 11, right).

Note that the maximum PV (read shaded contours) coincides very well with maximum moisture convergence area and with the maximum current lines. This means that the appearance of adiabatic waves is tied with the moisture convergence and with the maximum low jet intensity in the south-east sector.

In the mature phase, the lower vortex level was “depleted”, energetically consumed in the upper troposphere levels by the presence of cyclonic vorticity advection. The model maps highlighted that the PV magnitude was maintained at high values at the same previous values (4-5 PVU) for another 5-6 hours while the low-pressure system was away from the Black Sea area. In the next hours, the wave started to rotate (Fig. 11, right), reaching a minimum historical pressure of 980.2 hPa.

The role of surface heat fluxes has been investigated in many cases of explosive (as well as ordinary) cyclogenesis and it is considered to be a crucial feature during the cyclogenetical process (Gyakun and Danielson, 2000). Since 03 December, 03 UTC, the heating flux (just surface latent heat shown) gradually increased during the explosive phase reaching the maximum from 07 to 10 UTC at about 330 W/m^2 (Fig. 12).

For comparison, even if these values are lower than the typical values of a „hurricane-like” system (600-800 W/m^2), it should be noted that the heating fluxes increased leading to cyclone deepening and the latent heat flux is much stronger than the sensible heat flux (not shown), similar as in a „hurricane-like” system.

Phenomena associated with this "meteorological bomb" consisted not so much in the accumulation of precipitation, but especially in wind gusts that reached level 1 on the hurricane Saffir-Simpson scale (85 mph or 137 km/h). Also, in off the Black Sea coast the waves reached 10 meters in high, and the water had retracted with 40 meters toward the coast, recording also very strong rip tides. At that time the local and national Mass media had related the damages of this explosive cyclogenesis. The disastrously effects in Constanta and Tulcea counties, during the night of 02-03 December 2012 were: the winds reached over 100 km/h and tens of trees and electricity pilings were laid down, national roads were

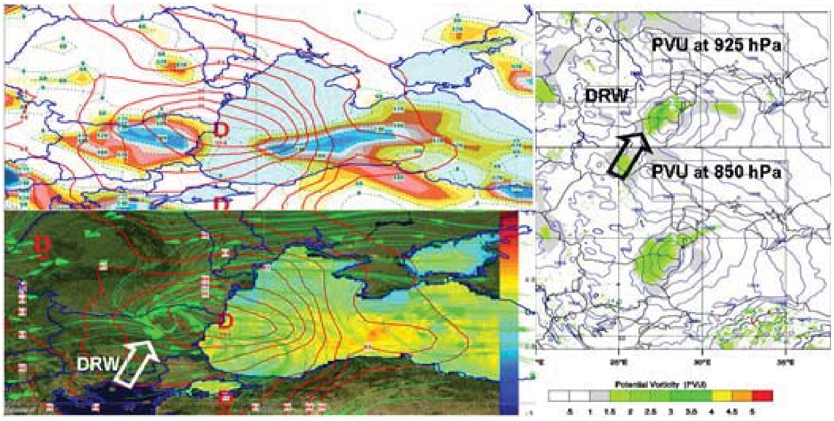

Figure. 10. Observation Analysis of mean-sea-level-pressure (read solid lines at 2 hPa intervals), of surface moisture convergence (shaded color contours), of surface streamlines wind (green lines), and of SST anomaly (shaded contours in Centigrades) at 03 UTC 03 Dec 2012 (left)0Model Analysis of potential vorticity anomaly (shaded color contours at 0.5 PVU intervals) at 00 UTC 03 Dec 2012 (right)

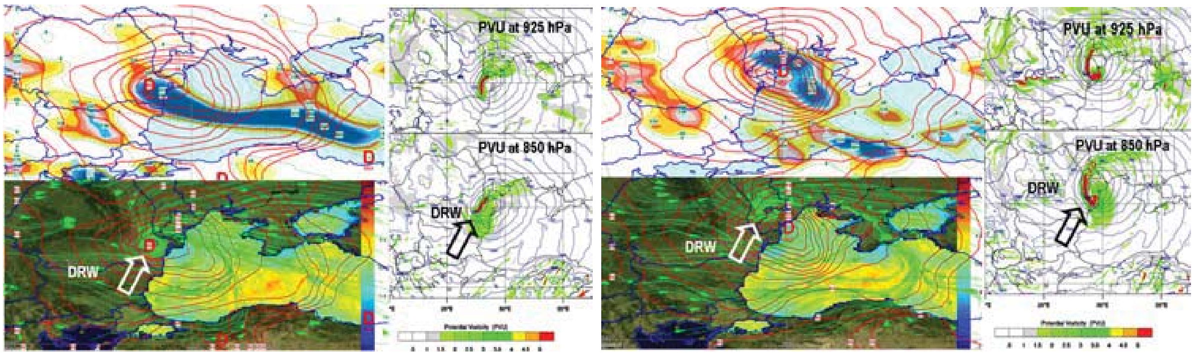

Figure 11. Observation Analysis of mean-sea-level-pressure (read solid lines at 2 hPa intervals), surface moisture convergence (shaded color contours), surface streamlines wind (green lines), and SST anomaly (shaded contours in Centigrades) at 03 UTC 03 Dec 2012 (left). Model Analysis of potential vorticity anomaly (shaded color contours at 0.5 PVU intervals) at 03 UTC 03 Dec 2012 (right)

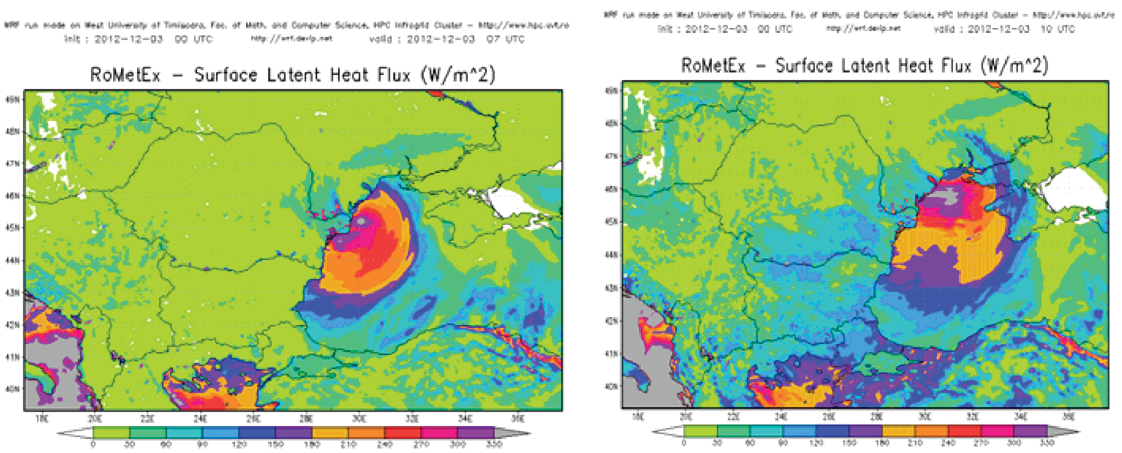

Figure 12. Surface Latent heat flux on 03 December at 07 UTC (left) and 10 UTC (right)

blocked, electricity was interrupted for many hours. Only in Constanta County, 28 cities remained without water, the gas network was damaged, 22 schools and 348 houses were distressed. In the case of schools, the financial loss was around 1.888.000 RON. In Medgidia, the roof of a house was removed, and a high school from Poarta Alba remained without roof, all the windows were broken, and some walls were dislocated. The 8 level storm (on the Douglas scale) started on the sea had forced the local authorities to close the ports at the North Sea. In Galati, the strong wind had removed the advertising panels, had broken the trees, the road signals and a power pit. In Braila, a tree had blocked the tram line, and the storm was followed by a rainfall during all night, recording 40 l/sqm. In all Dobruja area, half of the eolian stations were out of order for at least 24 hours, and the nuclear reactor from Cernavoda was turned off for technical verifications only 3 days after this event finished. The most quantitative rains had recorded in Slobozia and Ialomita counties; during less than 12 hours the quantities of water were recorded values between 30 and 69 l/sqm, as result floodings produced. In Slobozia a pick of 70 l/mp was recorded in less than 12 hours. Important floods were recorded also in Barlad County. There were recorded effects in republic of Moldavia also. The strong winds and rainfalls had interrupted the electricity in 80 villages, had removed the roofs, and in Chisinau many streets were flooded.

4. Conclusions

Analyzed case fits well into the criteria established by Sanders and Gyakum regarding the explosive cyclogenesis, as one predominantly maritime type, specific on cold season (December), having in maximum deepening phase the features of a tropical cyclone (hurricane), both in wind field (powerful wind, devastating hula) and in terms of clouds appearance (spiral shaped cloud system at sub-synoptic scale, eye formed above the cyclone surprised by satellite images). Superficial surface temperature of the water in the western and southern basin of the Black Sea showed a significant discontinuity and a positive anomaly of 3 to 6 Celsius degrees, which, on an eastern circulation, increasing considerably by convergence warm and humid air contribution to the center of the cyclone. Given the rarity of this phenomenon in our geographical region, unprecedented in recent history, it is necessary to reconsider this type of rapid cyclogenesis. On this research which is not an analytical one, we tried to investigate which factors (diabatic or dynamic) have the largest share in its initiation and production. Although cyclogenesis was initiated over the Aegean Sea by a classical processes such the positive advection of vorticity and divergence in the upper troposphere, we found that deepening of the „bomb" in southeastern Romania took place under the diabatic mechanisms rapidly associate to these processes, that generated for a short time (6-9 hours) in low-levels an intense mezoscalar vortex over baroclinic zone (positive PV anomaly) that was depleting it later in upper levels during the mature stage. The major development occurs when the presence of cyclonic vorticity in upper levels continues in spite of the diabatic mechanism tending to weaken it. The surface latent heat fluxes and the pontic marine features (SST anomaly) seem to play a key role in the deepening of the storm and less one during its mature phase. The aim of this paper is to understand the synoptic and dynamic mechanisms relevant to this development inside Romanian geographical environment and to use it further for similar cases. For meteorologist and operational weather forecaster, it is therefore very important to recognize on the satellite analyses and different numerical prognosis maps this phenomena features usually accompanied by high-impact and weather risk.

REFERENCES

1. Sanders F, Gyakum JR (1980) *Synoptic-dynamic climatology of the 'Bomb'. Mon. Weather Rev.* 108: 1589-1606.
2. Bruce CM, Elmar RR, (1988), *Explosive Cyclogenesis over the Eastern United States, Mon. Weather Rev.* 116: 1568-1586.
3. Gaza RS, Bosard LF. (1990) *Trough-merger characteristics over North America*. Weather and Forecasting. 5, 341-331.
4. Gyakum JR, Danielson RE, (2000) *Analysis of meteorological precursors to ordinary and explosive cyclogenesis in the western North Pacific*. Mon. Weather Rev. 128: 851-863.
5. Strahl JLS, Smith PJ, (2001) *A diagnostic study of an explosively developing extratropical cyclone and an associated 500-hPa trough merger*. Mon. Weather Rev. 129: 2310-2328.
6. Nielsen NW, Sass BH, (2003) *A numerical, high-resolution study of the life cycle of the severe storm over Denmark on 3 December 1999.* Tellus 55A: 338-351.
7. Morre RW, Montgomery MT, (2003) *Reexamining the Dynamics of Short-Scale, Diabatic Rossby Waves and Their Role in Midlatitude Moist Cyclogenesis*. J. Atmos. Sci. 61.
8. Parker, DJ, Thorpe AJ, (1995) *Conditional convective heating in a baroclinic atmosphere: A model of convective frontogenesis*. J. Atmos. Sci., 52.
9. Ecaterina Ion-Bordei, (2009) *Rolul lantului alpinino-carpatic in evolutia ciclonilor mediteraneeni*. Printech Press, Bucharest, 82-91.
10. Conte M., (1986), *The meteorological "bomb" in the Mediterranean: a synoptic climatology* .Aeronautical Meteorology Rev, 46.
11. Brunetti, M., Paolo Capizzi, (1996) *Ciclogenesi sul Mediterraneo*. Aeronautical Meteorology Rev, 56.

12. Brunetti, M, Antonio Moretti, (2005*) Le ciclogenesi del Mediterraneo. Un quarto di secolo de osservazioni* . Aeronautical Meteorology Rev, 65.
13. Santurette P, Georgiev C.G., (2005) *Weather Analysis and Forecasting - Applying Satellite Water Vapor Imagery and Potential Vorticity Analysis*. Elsevier Academic Press, Oxford.