SYNOPTIC CONDITIONS ASSOCIATED WITH EXTREME WEATHER EVENTS IN THE WESTERN PART OF THE BLACK SEA. A COMPARATIVE STUDY

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ABSTRACT. – Synoptic conditions associated with extreme weather events in the western part of the Black sea. A comparative study. The genesis conditions and evolution of two violent storm events are investigated in this paper. They were determined by the same pattern induced by the interaction between a high pressure system dominating Europe and a Mediterranean low pressure field with travelling disturbances moving to the Black Sea. The purpose is to understand what regulates the differences between the duration and intensity of these storms. For their comparison, the NCEP-500/850 and SLP analyses, ALARO model outputs, atmospheric soundings and temporal variations of meteorological parameters recorded by the weather stations have been used. The differences between the two storms consist in the dynamics of the cyclones at sea level and in the upper atmosphere.

Key-words: storms, Black Sea, synoptic conditions, model simulations, reanalysis maps.

1. INTRODUCTION.

Previous climatological studies on the genesis and evolution of storms produced along the Romanian shore showed that the most frequent and violent storms occurred in winter during synoptic conditions described as "the coupling" continental anticyclone/Mediterranean cyclone arriving over the Black Sea. The most violent events caused considerable damages to port infrastructure and important modifications of the coast line and breaches in the barrier beaches.

The storm of 1991, studied in this paper, led to the interruption, on December 9, of navigation on the Danube-Black Sea Canal and to the interruption of the offshore oil drillings, where the wind gusts reached 45 m/s (*Cuget Liber* newspaper, December 11 1991). The cyclone developed over the Mediterranean Sea also caused strong winds offshore of Italy and Greece. One of the two ships under Romanian flag, caught up in the storm, required assistance and the other sinked 100 miles East of Sicilian coast, 9 crew members missing (*Cuget Liber* newspaper, December 14 – 15 1991). In January 3-4 2008 the snow falls and blizzards which occurred over the eastern and south-eastern parts of Romania had

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grave consequences on the maritime, road, rail and air traffic in more than 7 counties, including the two coastal departments (Constanta and Tulcea). There was traffic jams, delayed trains, postponed or suspended flights and numerous localities left without electricity.

The purpose of this paper is to investigate the genesis conditions and evolution of these two winter storm events. This could contribute to a better understanding of similar situations in the future and to the improvement of weather forecast, so implicitly to the reduction of risks associated with these phenomena.

2. RELATED CIRCULATION PATTERNS.

More than 50% from the 316 events identified in 32 years (1974 to 2005) are the consequence of the type of circulation described above (Chiotoroiu, 1999; Chiotoroiu and Ciuchea, 2009).

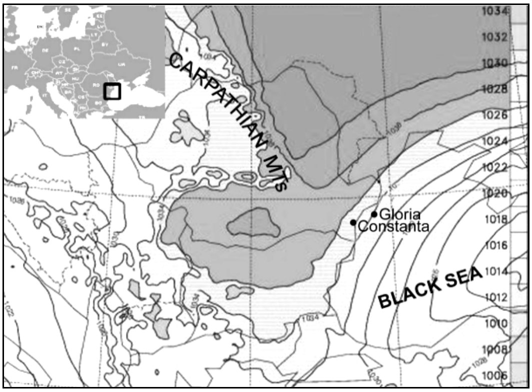

Fig. 1. ***Location of the Romanian weather stations. On the support map from the ALARO model output for January 4 2008, the shaped V bowing of isobars within the area between Carpathians and Black Sea can be noticed***

The location of the polar air at ground level and the warmer "tropical" one above the Black Sea is considered to be a typical situation in winter in the south-eastern part of Europe. A substantial amplification of the planetary-scale flow waves during the development phase of the Mediterranean cyclones that bring cold air to very low latitudes was observed (Tayanc et al., 1998; Maheras et al., 2001; Georgescu et al., 2009). The composites of geopotential height obtained for Black and Aegean Seas by Trigo (2002) showed at 1000 hPa an elongated minimum core distributed between the two basins, beneath the upper-trough extending over northern and eastern Europe. The mature stage of Black sea lows indicates a northward shift of the Aegean-Black sea double geopotential minima and an intensification of the upper-trough. Based on the soundings from Bucharest and Constanta and on the distribution of equivalent-potential temperature field Θ_e at ground level and at 850 hPa, a thermal inversion was observed in the south-eastern part of Romania: the cold air is prevailing at ground level (with associated ENE winds) and the warm air at 900-850 hPa, with associated SSE winds (Draghici, 1988). The interaction between a continental anticyclone and a Mediterranean cyclone was also studied in relation to the genesis of blizzards and regional strong winds "crivatz" in the SE Romania (Draghici, 1988; Draghici et al., 1990; Popa and Soci, 2002; Cordoneanu, 2004; Georgescu et al., 2004; Capsa and Timofte, 2005; Georgescu et al., 2009). This circulation type is generally followed by the extension of the high pressure field over the SE parts of Romania and the Balkans to eastern Mediterranean, Levant and North Africa regions (Saaroni et al., 1996; Tayanc et al., 1998).

As a main characteristic of the „coupling anticyclone/depression" storms, the strong winds constantly blow from north or north-east during winter. Waves' height depends on wind direction: winds blowing from north-east or east generate the highest waves while winds from west the smaller waves. Mean duration, of about 30 hours and maximal duration of storms (more than 130 hours) are recorded also for a north wind direction (Bondar coord., 1972).

3. METHODOLOGY.

In this study two storm events have been selected, which have occurred in December 1991 and January 2008. The main selection criteria were: the similarities existing among the characteristics of the atmospheric circulation at ground level and the storms extreme violence: wind speed reached 40 m/s in 1991 and 23 m/s in 2008 at Gloria and waves' height more than 9 m in both situations.

For the 2008 storm, data were available which permitted us to run the forecast model ALARO. By its good resolution (10 km), this regional prognosis model has the advantage of considering the particularities of the zone for which it works. The parameters estimated by the ALARO model for the 2008 storm event are the geopotential height, the air temperature at 850 hPa, the wind speed and direction at 10 m and the pressure at sea level. NCEP reanalysis maps are also used for the analysis of the distribution of atmospheric pressure at ground level, of the geopotential field 500 hPa and 850 hPa and of temperature at different levels. Atmospheric soundings for Istanbul were used being considered very relevant in describing the characteristics of the warm air advection from the Mediterranean Sea. Constanta and Bucharest soundings were not available for the both cases.

Meteorological and hydrological data (sea surface and air temperatures, wind speed and direction, air pressure and waves' height) were recorded in the weather stations, belonging to the Romanian network (Fig.1). In Constanta station (on the coast, 12.8 meters above the sea level), wind speed measured by the automatic station (from 2005) is used and interpreted for the 2008 storm event. Data from measurements made with the wind vane are used for the 1991 storm. At Gloria weather station (70 km from the coast, on an oil offshore platform), wind direction and speed are measured with an anemograph (42 m above the sea level). Air temperature values are recorded by regular thermometers installed in standard shelters. In both stations, the atmospheric pressure is determined with the mercury barometer. Observations on the wave characteristics are visual and made every 3 hours. The accuracy and quality of the measurements largely depend on the skill and eagerness of the observer.

4. COMPARATIVE WEATHER CONDITIONS AND CIRCULATION PATTERNS.

The common characteristic of the studied cases is the sea level atmospheric circulation: the interaction between a high pressure system located over eastern or northern Europe and a Mediterranean low pressure field extended over the Black Sea. During the climax of the stormy weather along the Romanian coasts, the low pressure covers Turkey and the south/central Black Sea (Fig. 2).The warm and humid maritime air mass in cyclonic twist towards the northwest or west generates a thermal positive anomaly at lower layers, which contributes to the deepening of the surface vortex. This can be very well observed on the reanalysis maps for 850 hPa (Fig. 2).

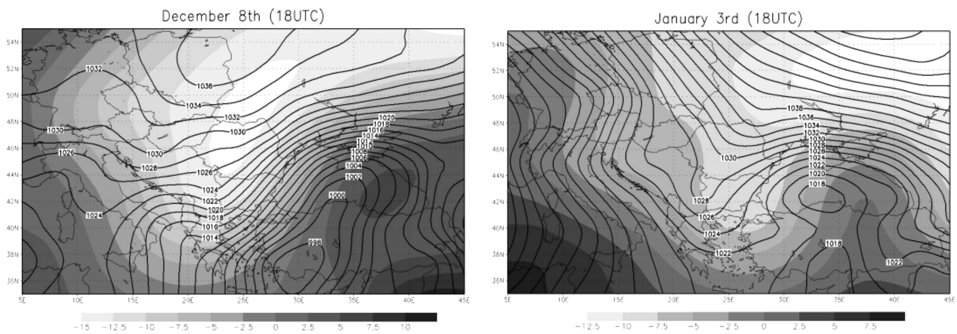

Fig. 2. ***NCEP surface reanalysis for the storms apogee (COLA/GES). Temperatures at 850 hPa are represented in grey.***

In both cases the atmospheric soundings for Istanbul show a typical rain sounding with very moist lower troposphere below 3000 m altitude where the most part of the clouds seem to be concentrated (Fig. 3).

Winds are strong right above the top of the clouds (25 m/s for January 2008), generally with a dominant SW direction. Also, the tropopause is very low in both situations, being situated around 10000 m altitude in 1991 and around 8000 m altitude in 2008.

The differences between the two storms consist in the intensity and persistence of the anticyclones and in the dynamics of the cyclones at sea level.

In 1991 the anticyclone (1030 hPa) is located in N Europe with extension to the central parts while in 2008 it is stronger, with 1055 hPa and located over European Russia. Despite these differences, high pressure values of about 1030 hPa are recorded in both situations on the north of Romania.

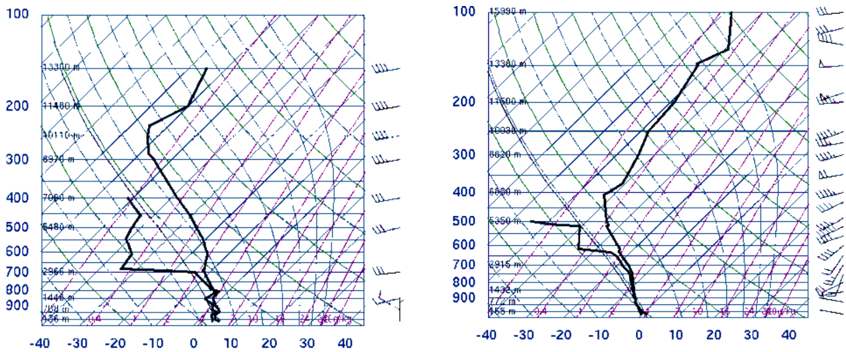

Fig. 3. ***Atmospheric soundings for Istanbul from December 1991 (left) and for January 2008 (right)***

The dynamics of the disturbances explain why winds were more violent during the storms apogee in 1991 (40 m/s on December 8) than in 2008: the low at 1005 hPa, deepened on December 7 over the Aegean Sea due to the polar air advection over the central Mediterranean (in relation to the southern extension of the trough in the middle troposphere), Fig. 4. The cyclone moved then rapidly to the ENE and continued to deepen. On December 8, 06 LST the low was very deep and active (994 hPa) over the Anatolian Plateau. Its trajectory on north-east direction followed the ascendant part of the trough (Fig. 4). This ground trajectory was progressively deviated to the N and "pushed" by the extension of the anticyclone over Romania and the Balkans. On December 9 1991 the cyclone position in the central part of the Black sea determined a high pressure gradient by its "coupling" with the continental anticyclone (about 10 hPa between Constanta and Gloria), Figs. 2 and 6. Violent winds at sea level were consequently due to the dominant N circulation in the low and middle troposphere. The 500 hPa maps in Fig. 4 and 850 hPa maps (not shown in this paper) emphasize a high pressure ridge associated with an omega block circulation with strong winds and temperatures below normal on the right side of the ridge.

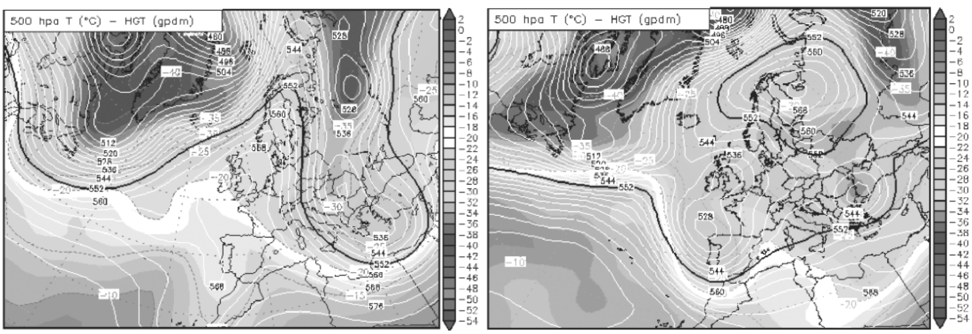

Fig. 4. ***NCEP reanalysis of 500-hPa geopotential heights maps (8 Dec. 1991- left; 3 Jan. 2008 - right); Temperatures are represented in grey***

This also explains the air temperature decrease before the storm apogee* in 1991, compared to 2008 when the temperature decrease was recorded after the climax moment (Fig. 5).

**The apogee corresponds to the maximum wind speed and highest wind waves at Gloria and Constanta (Fig. 7).*

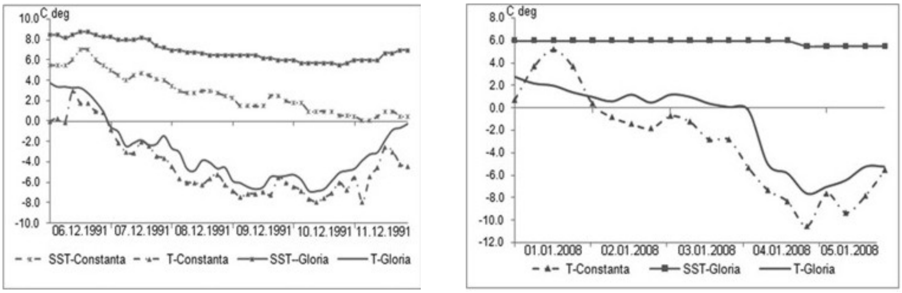

Fig. 5. ***Temporal variation of the 3-hour air and sea surface temperatures recorded by the weather stations in 1991 (left) and 2008 (right).***

Simultaneously with the temperature decrease, the filling of the cyclone over the Black Sea can be observed in 2008.

Unlike the 1991 event, in 2008 the low was at only 1015 hPa during the storm apogee (on January 3 2008 in the evening) and consequently the pressure gradients between the coast and the open sea were less strong than in 1991. Winds maximum speed in 2008 attained 23 m/s compared to 40 m/s in 1991 (Fig. 6).

The geopotential decrease on the Romanian coast is important comparing to the average values in both situations: in 1991 the decrease is about 9 hPa (534 hPa comparing to the monthly average of about 553 hPa) and in 2008 about 9 hPa according to the model outputs and 6 hPa according to the reanalysis maps, comparing to the monthly average. The circulation in the middle troposphere shows an important extension of the geopotential low from the north of Europe towards the Mediterranean sea and the north of Africa in 1991 and a closed circulation with an upper trough detached from the main stream in 2008 (Fig. 4).

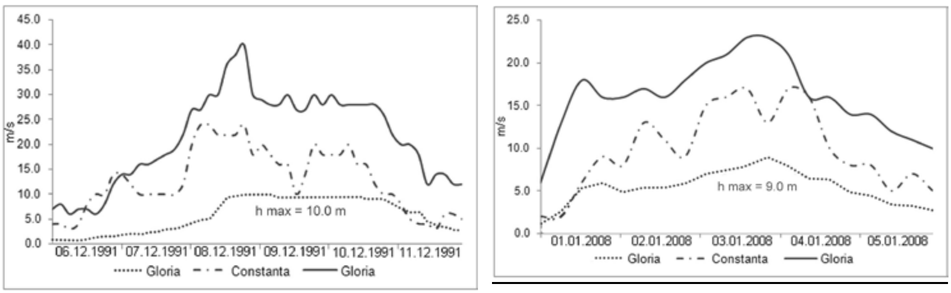

Fig. 6. ***Temporal variation of the 3-hour winds' speed and waves' height recorded by the weather stations during the storms from 1991 (left) and 2008 (right)***

The troughs during the climax of the storm on the Romanian coasts are located south or south-west from the Black sea (Fig. 2).

Dominant winds were from N in December 1991 and from NE to N in January 2008, according to the model outputs (Fig.7).

The direction of the strongest winds is important for the formation and propagation of waves: in 1991, very strong winds from NNW blew 78 hours and determined waves of 10 m height (the fetch is 25 km for this wind direction) while in 2008, weaker winds that lasted only 24 hours generated high waves of about 9 m. On this NE wind direction, the fetch is 260 km (GFS Reanalyse, wetter3.de).

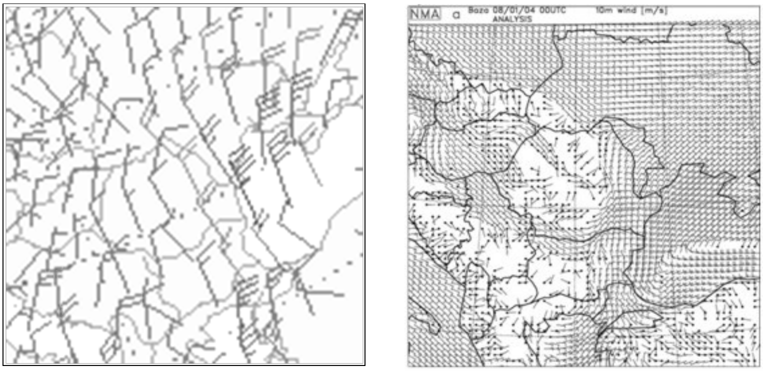

Fig. 7. ***Wind speed and direction from wetter3.de archive for December 1991 and from the ALARO model outputs for January 2008***

CONCLUSIONS

The consequences, sometimes dramatic, that the storms in the western Black Sea had on the natural environment and the economic activities justify the analysis of these extreme weather events. The studied cases are generated by the interaction in the lower troposphere between a high pressure system dominating Europe and a low pressure field in the Mediterranean Sea.

When deep cyclones (994 hPa) develop over the warm Mediterranean Sea and move rapidly over the Black Sea, pressure gradients are high and strong winds blow from north along the Romanian shore, as in December 1991. The rapid movement of the cyclones is favoured by the development of an impressive trough with meridianal extension, the movement being realised on the eastern rear of the trough. During the 2008 storm, the Mediterranean low pressure move slowly, its development being sustained by an upper cut-off low. The pressure gradient is therefore weaker than in 1991 and hence the wind is less strong (23 m/s).

Pressure gradients between the continental anticyclone and the cyclonic low above the Black sea can be reinforced by temperature gradients. These gradients were very strong in December 1991 when the cooling started before the storm apogee (12.9 °C between the air temperature and sea surface temperature at Gloria). The significant cooling and the winds force depends on the intensity and the long duration of the anticyclones, in both cases with very strong development regardless of their different position.

The storm on December 7-11, 1991 had a longer duration: wind of over 14 m/s blew for 108 hours, compared to 84 h in 2008. Winds of over 20 m/s were recorded during 96 h in 1991, compared to 24 h in 2008.

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