Annals of the Academy of Romanian Scientists
Series on Engineering Sciences
ISSN 2066-8570 Volume **2**, Number **2**/**2010**

BLACK SEA STORM RISK FACTOR FOR THE CRITICAL INFRASTRUCTURE OF THE ROMANIAN COASTAL SPACE

Georgeta BANDOC[1]

Rezumat: *Mediul costier românesc este afectat, după cum reiese din analiza hărții regionării fenomenelor de risc din România, de două categorii distincte de riscuri naturale şi anume de riscurile climatice (în principal furtuni) şi de riscurile generate de schimbarea nivelului mării. Riscurile climatice acționează pe termen scurt şi foarte scurt, generând accelerarea tuturor proceselor de țărm şi plajă, provocând schimbări profunde morfologice asupra ecosistemelor şi inducând pagube materiale prin distrugerea amenajărilor, construcțiilor portuare, localităților etc. Riscurile provocate de schimbarea nivelului mării au efect pe termen lung, ritmurile actuale de creştere provocând pagube în viitorii 25…50 de ani. Combinate, aceste două categorii de riscuri naturale induc efecte negative proporțional mai mari pentru infrasteructura critică din spațiul costier românesc.*

Abstract*: Romanian coastal environment is affected, as clearly appears in the analysis of phenomena regions risk map of Romania, by two distinct categories of natural hazards namely climate risks (mainly storms) and the risks arising from changes in sea level. Climate risks act on short and very short term, resulting in acceleration of all coastal and beach processes, causing profound morphological changes on ecosystems and property damage by inducing destruction of facilities, port construction, settlements, etc. Risks caused by changing sea levels have long-term effect, current growth rates causing damage in the coming 25 ... 50 years. Combined, these two categories of natural hazards adversely induce higher proportion of critical infrastructure in the Romanian coastal area.*

Keywords: storm, risk factors, aero-synoptic conditions, critical infrastructure

1. Introduction

Knowledge of the storms in northwestern Black Sea basin is of particular importance in terms of weather (the genesis and evolution of these storms), in terms of wind engineering (evaluation speed and gust of wind characteristics for proper sizing of structures subjected extreme wind action) and in terms of coastal hydraulics (appreciation of the exceptional characteristics of specific storms waves to protect the coastal region and the perimeter port basin of north-western Black Sea). Black Sea Basin aero-synoptic specific conditions are directly related to the field above the European Baric. Thus, knowledge of atmospheric circulation over the Black Sea basin requires knowledge of air traffic within Europe and therefore knowledge of determinants of pressure centers. In Europe, the atmospheric circulation (Fig. 1) is subject to five such centers: Arctic Anticyclone Azores Anticyclone, Asian Anticyclone, Mediterranean Depression and Iceland Depression.

[1] Assoc. Prof., PhD, Meteorology-Hydrology Dept., Faculty of Geography, University of Bucharest, Romania, (e-mail: geobandoc@yahoo.com)

The synoptic processes which often condition the acceleration of wind production in the Black Sea basin are those relating to development of Mediterranean cyclones crossing the Balkans and plays most important role in generating storms. Note that the intensification of wind is higher in winter compared with the hot season.

A direct result of general circulation processes influence weather around the Black Sea is the predominance of movement of air masses from the altitude, from west to east. Both the strong and the normal altitude winds are oriented from west to east. In case of a retrograde movement, the guidelines can be different, but for a short period. The main Baric configurations at European level have no place within our country or in close proximity. Instead, each of them could affect Romania's territory more or less.

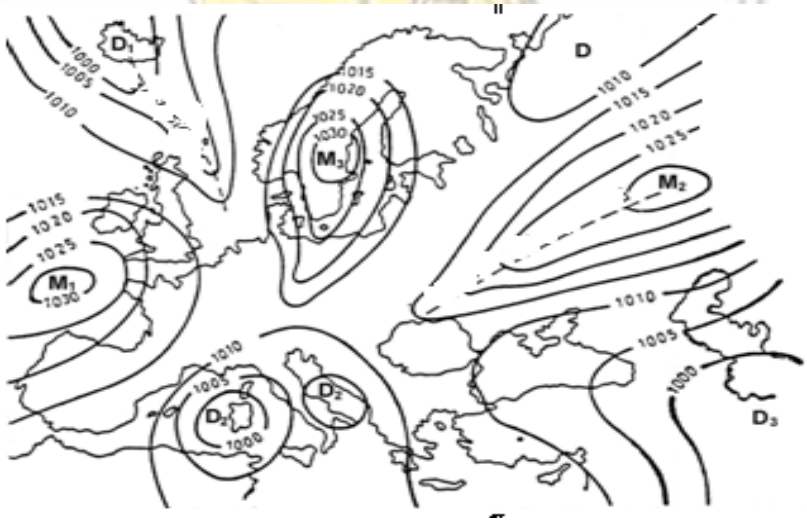

Fig. 1. Baric main centers across Europe
M_1 – Azores Anticyclone, M_2 – Russian-Siberian Anticyclone, M_3 – Scandinavian Anticyclone, D_1 – Iceland Depression, D_2 – Mediterranean Depression, D_3 – Minimum Asian (*after* Mahara Gh).

The analysis of severe weather situations, is leading an important issue, namely that the most important synoptic feature of the Carpathian-Black Sea area is its location in an area of interaction of at least two of the typical formations. In most cases, interaction occurs between Mediterranean cyclone origin and a dual-acting disturbance over the central-western, north-central and central-Asian parts of Europe. Wind characteristics are similar for the entire north-western Black Sea basin. This is explained by the relationship between strong wind regime which is above the Black Sea and evolution of different types of Mediterranean cyclones that are brought here all the time, their action combining with the one of some strong anticyclones fields of the continent.

2. Romanian coastal storms

Acceleration of wind developed in the Black Sea basin - in the northwestern part - presents some peculiarities. For statistical analysis of data obtained from weather stations Sfantu Gheorghe, Constanta and Mangalia, for the period 1961 - 1990 and the meteorological station located offshore platforms Gloria, for the period 1991 - 2000 and references using synoptic more recent period 2000 - 2001, could establish some characteristics of wind acceleration Romanian seaside area. Data analysis reveals that, on the coast, accelerating of the wind is strong and frequent, the dominant lines being due to influence of baric centers across Europe.

Wind speeds exceeding 10 m/s are proper for what is called generic *storm* (wind acceleration). This acceleration of wind, when wind speed values of large and very large with over 72 hours duration, are classed as strong storms and high waves that induce longitudinal currents from shore, determining effects of erosion and great material damages.

It can be noticed that during the year, wind speed and wind frequency in a given direction are not constant, with a gradual change of wind direction within a few hours, depending on changes from slow to fast of the atmospheric pressure or on an atmospheric front that becomes closer or that passes the area.

The wind direction during storms has a relatively stable direction, oscillations are usually on specific sector directions, e.g. from north-west to north and north-east (90^0). An example is the storm recorded in Constanta on: June 8 and 15 - 18 December 1997, 19 - 24 November 1998 and 6 - 7 September 2000. For the storm that occurred on 6 - 7 September 2000, the wind remained in the northern sector, ranging from north-west to north-east. It can be noticed that during a storm, regardless of duration or intensity of wind, the north-east direction is dominant, fact also valid for Gloria recorded storms, station located offshore. The low frequency winds in the wind acceleration period are recorded in the western sector. It should be emphasized that the studies indicate an average of 40 days of the year with strong acceleration of wind, of which most, approximately 40 % occurring in winter season.

The strongest storm recorded on the Romanian Black Sea coast occurred in the period January 30 to February 20, 1962 when the maximum wind speed was 37 m/s (Fig. 2). Also there was a storm in Constanta during 8 - 11 January 1981, the maximum wind speed was 28 m/s and average wind speed was 17.5 m/s.

This acceleration of wind recorded are characterized by a long duration of occurrence for storms taking place on the seashore and not offshore where a storm has a minimum of 80 hours.

It can be noticed that during a storm the wind that has blown kept its direction form the northern sector, ranging from directions northeast and northwest. The main

reason of these two powerful storms (1962, 1981), was the development of Siberian Anticyclone in north-eastern part of the sea, affecting by means of high pressure dorsal. Atmospheric pressure reached 767 mmHg, which resulted in an acceleration of wind from northern sector, the force on the Beaufort scale being 6...9 degrees. Agitation of the sea on the shore area was assessed as grade 5 and in only a few hours to reach level 7 (the highest degree of agitation registered at a coastal station).

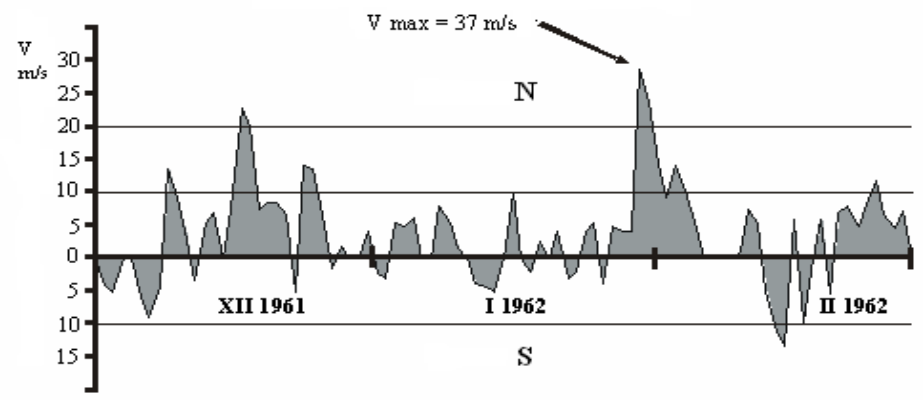

Fig. 2. Distribution of daily average values of wind at Constanta station in winter 1961 - 1962 (*after* E. Vespremeanu, G. Bandoc, A. Stroe)

There is acceleration of the wind also at the end of summer when Siberian Anticyclone has reduced values of its intensity and wind characteristics, time duration, direction and intensity are the same as in the winter season. For all the storms generated by the presence of Siberian Anticyclone (north), and a cyclone of Mediterranean origin (south or south-east), one can say that on-shore wind intensity is almost equal to that from off-shore, in the early hours of the start of the storm, or even higher.

One example is September 1999 or the storm of 18 - 19 October 1993, when on-shore wind speed was close to the values recorded on the open seas, in the same period. This storm of short duration (30 hours) was characterized by a sharp rise in atmospheric pressure due to elongation Siberian Anticyclone dorsal over the Romanian seaside. Note that for smaller storms (several tens of hours), the values that characterize their intensity are greater, especially storms caused by the evolution of a Mediterranean cyclone. For example, storm of 9 - 10 noiembrie1981, the maximum wind speed on land has reached 28 m/s, average speed was 28 m/s and it took only 36 hours.

In order to identify accelerations of the wind over the whole period considered for the Romanian seaside, it should be analyzed the existence of at least two consecutive measurements in which the wind speed exceeded 10 m/s and the minimum period of occurrence was 12 hours. It can be observed a grouping of wind accelerations in the cold period of the year, the months from October to March, when

baric gradients have high values. Studying the total number of cases registered with the wind acceleration with duration of more than 12 hours, 70 % of cases are recorded in the cold period of the year. It should be noted that in cold season of the year, winds from the northern sector are predominant and they can be classified in the category of long duration and high speeds winds, while in the warm season occur winds predominant from south, joining the class of short period and lower speed winds.

The winter wind is intense due, especially, to the advection of cold air from north, comparing to the hot season when intensification of wind are spectacular, but short term, associated mostly with an atmospheric front. After long and strong storms, longer than 72 hours, follows a period when wind speed decreases leading to the atmospheric calm.

Another feature of the acceleration of wind on the Romanian seaside is the presence of gusts, especially when wind speed is much higher than the mean real wind. For the Romanian Black Sea area gusts are mentioned with wind speed between 20 m/s and 25 m/s specific to northern coastline and offshore station Gloria. There are exceptional cases, as recorded in the south at Mangalia station where normally recorded wind values are the lowest.

Isolated cases have been also studied, like the one during the storm of 15 - 18 December 1997, when the average wind speed at Sulina station exceeded maximum of 24 m/s, gusts of 34 m/s and Gloria station, the maximum wind speed was 23 m/s, gusts of 28 m/s.

A characteristic of the Romanian seaside, particulary the northern sector, is the average wind gusts recorded during a mean wind, especially at the beginning or end of storms. Thus, the June 9, 1999, in Sulina, after two days of moderate wind speed, the intensification of the wind range of 10 m/s and 12 m/s, the wind suddenly drops to 4 m/s, but with gusts of 18 m/s. Sulina is considered as a pole of wind for the Romanian Black Sea Basin due to geographic position, altitude, etc. Due to the position of Sulina station which is situated in the eastern part of the city, on a pier, at 6 km from shore, the wind data (average maximum speeds and gust wind speed) can be considered valid with good approximation, for sea areas situated in the proximity of the Romanian Black Sea coast.

Analysis of wind acceleration on the Romanian Black Sea coast has led to the conclusion that there is a fairly large degree of variability of wind during storms, identifying several types of wind development, especially if we refer to significant storm terms of intensity and duration of wind. The *moment when wind speed reaches the maximum value* can be an important criterion in identifying different types of wind acceleration.

Along with this criterion is added *the prevailing wind direction* and according to these criteria, one can identify different types of developments in wind speed during the storm, on the cardinal and inter-cardinal directions of action.
Working method adopted in determining the different types of developments accelerating wind was as follows: it has been established that the wind speed to be equal to 10 m/s or exceed this value, for each recorded storm there should be determined the number of hours wind speed exceeded certain imposed gears namely 10, 15, 20, 25, 30, 35, 40 and 45 m/s. Within each class of wind speed (between two successive gears), duration of the action of wind was calculated in hours. Using this working method three types of wind acceleration acting in the northwestern Black Sea basin have been identified.

A first type of evolution of wind speed during storms (type 1) is that where a slow increase in wind speeds at the beginning of the storm is observed, followed by a rapid decrease in speed.

The second type of development identified for the wind speed during storms (type 2) is characterized by a rapid increase in wind speed at the beginning of the storm, followed by a period of slow attenuation of wind speed by the end of the storm.

The last type of development identified during storms wind speed (type 3) in the northeastern basin of the Black Sea, is one that shows a moderate increase in wind speed at the beginning of the storm, after which there is a slight decrease of wind speed.

Based on calculations for period under study, the following conclusions resulted:

a. The frequency of occurrence of different types of development of wind during storms, with the highest frequency (58 %) corresponds to the type of storm characterized by modestly increasing wind speed at the beginning of the storm, followed by a period of slow attenuation wind speed by the end of the storm (3rd type of evolution of wind speed during the storm). The frequency of occurrence for this type of storm is 58 % of the total number of recorded cases (Fig. 3).

b. In case of the second type of evolution of wind speed during the storm, in which there is a rapid increase at the beginning of storm followed a slow decline until the end of the storm's wind speed, frequency has a value 32 % (Fig. 3.), of the total acceleration of wind occurred in the period under study.

c. It can be noted that for the first type of wind speed evolution characterized by a slow increase in wind speed at the beginning of the storm followed by a rapid decrease in speed, frequency is only 10 % (Fig. 3) of the total number of cases registered with acceleration of wind.

d. On equal parameters as duration and as intensity, type 2 of wind speed evolution during the storm is dangerous because its effect of surprise (Quick release) and type 1

of evolution of the wind speed is dangerous because its hydrologic consequences and its action on the shoreline and upon the construction from the marine space.

e. In most cases, the recorded wind accelerations are due to wind blowing from the northern sector (north, northwest, northeast).

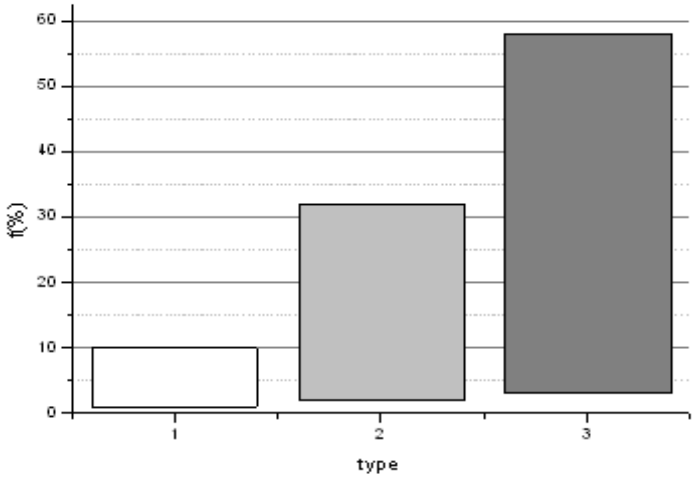

Fig. 3. The frequency of occurrence of the three types of wind evolution during storms

For the powerful storms of the Romanian Black Sea coast, maximum deployment is 230 hours and wind speed may reach a value of 40 m/s. Most frequently, the identified acceleration of wind occurred during winter, spring and late autumn. These storms are characterized by the fact that the wind direction remained unmodified throughout the studied wind acceleration with a powerful influence upon the critical infrastructure.

Climate risks (by the potential dangers they represent), should be considered in terms of widening opportunity for all processes in the coastal area, with effects in profound changes of morphology, ecosystems, coastal environment and, ultimately, causing property damage by destruction of facilities in this space.

For the entire Romanian Black Sea coast the wind is a natural factor of high risk. It is characterized by strong dynamics, which is generated by sea surface that influences atmospheric circulation system and the movement of air masses in the atmospheric boundary layer (SLA) above the sea.

REFERENCES

[1] G. Bandoc, *Accelerările de vânt pe litoralul românesc al Mării Negre*. Conferința Internațională de Ingineria Vântului, Bucureşti, 1998, pp. 17 - 20;

[2] G. Bandoc, *Modele de evoluție ale vitezei vântului în timpul furtunilor pe litoralul românesc al Mării Negre*. Comunicări de Geografie, Ed. Universității din Bucureşti, vol. **III**, Bucureşti,1998, pp. 295 - 297;

[3] G. Bandoc, *Ultimele furtuni de pe litoralul românesc al Mării Negre*. Comunicări de Geografie, Ed. Universității din Bucureşti, vol. **IV**, ISBN 963 420 872 X, ISSN 1453 – 1453, Bucureşti, 2000, pp. 247 - 250;

[4] G. Bandoc, *Typical situations that influence aeolian potential in the North – Western part of the Black Sea area*. International Symposium The Environment and Industry (INCD ECOIND), Academia Română, Bucureşti, 2005, vol. **II**, pp. 285 - 290;

[5] G. Bandoc, *Potențialul eolian al litoralului românesc al Mării Negre*. Ed. Matrix Rom, Bucureşti, 2005;

[6] C. Bondar, M. Podani, *Furtuna maritimă din februarie 1979 şi efectele ei asupra litoralului românesc*. Rev. Hidrotehnica, vol **24**, nr. 9, Bucureşti, 1979, pp. 210...212;

[7] A. Doneaud, *Cercetări asupra ciclonilor europeni cu deplasare retrogradă*. Ed. CSA., Inst. Meteorologic Central, vol. **IV**, nr.2, Bucureşti, 1958, pp.5...83;

[8] N. Ducet, P.Y. Traon, P. Gauzelin, *Response of the Black Sea mean level to atmospheric pressure and wind forcing*. Journal Marine Systems, vol **22**, issue 4, 1999, pp. 311 - 327;

[9] J. P. Ericson, C. J. Vörösmarty, S. Lawrence Dingman, L. G. Ward, M. Meybeck, *Effective sea-level rise and deltas: Causes of change and human dimension implications.* Global and Planetary Change, vol **50**, issues 1 - 2, 2006, pp. 63 - 82;

[10] S. D. Guikema, *Natural disaster risk analysis for critical infrastructure systems: An approach based on statistical learning theory.* Reliability Engineering & System Safety, vol **94**, issue 4, 2009, pp. 855 - 860;

[11] I. J., King, *Statistical analysis in geography*, Englewood Cliffs N. J., Prentice Hall, 1969;

[12] Gh. Măhăra, *Circulația aerului pe glob.* Ed. Științifică şi Enciclopedică, Bucureşti, 1979;

[13] Nilgün Kiran, Orhan Yenigün, Erdem Albek, Osman Borekçi, *Wind induced circulations of Black Sea.* Water Science and Technology, vol **32**, issue 7, 1995, pp. 87…93;

[14] E. V. Stanev, V. M. Roussenov, N. H. Rachev, J. V. Staneva, *Sea response to atmospheric variability. Model study for the Black Sea.* Journal of Marine Systems, vol **6**, issue 3, 1995, pp. 241 - 267;

[15] E. V. Stanev, Elissaveta L. Peneva, *Regional sea level response to global climatic change: Black Sea examples*. Global and Planetary Change, vol **32**, issue 1, 2001, pp 33 - 47;

[16] E. Vespremeanu, *Geografia Mării Negre.* Ed. Universității din Bucureşti, Bucureşti, 2004.