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Aspects on the History of Observations and Measurements in the Black Sea Coastal Zone, Rehabilitation Projects and Marine Modeling Issues

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Abstract – **Over time, the content, scope and objectives of hydrological research in the Romanian Black Sea coastal area varied according to the state of society development, technology development and financial resources. Along with the activities of capitalizing on natural resources, water use, river and sea navigation, there have been demands for knowledge of the water regime and the interaction between the resource potential and the characteristics of the hydrological regime. As a result, hydrographic and hydrological research was started and developed in the Black Sea coastal zone. These researches developed in the first half of the nineteenth century, and then continued throughout this century and later in the twentieth century, with interruptions caused by the two world wars. Among the important activities that have taken place over time, there have been hydro-technical works. The design and elaboration of the projects of these works were based on the knowledge of the hydrographic and hydrological characteristics of the Black Sea coastal zone. This knowledge has evolved over time so that there is currently an important pool of data and information related to the hydrological, morphological, hydrochemical, hydrobiological characteristics of the water bodies mentioned.**

The paper presents briefly the most important moments of the history of the monitoring activity carried out over time in the Black Sea coastal zone, the types of coastal and transitional waters in Romania, coastal rehabilitation projects of the Black Sea, hydrological features, the structure of the marine complex model pom / ersem III) BREG / BSHELF.

Keywords – coastal area, monitoring, hydrological features, rehabilitation projects, marine modeling.

1. INTRODUCTION

Historical knowledge is very important in any field, including in the hydrological field, and if this knowledge is ignored or minimized, then all planning or prognosis will suffer.

In connection with the history of monitoring activities carried out in the Black Sea coastal area, several works have been written over time, which are now rarities.

Examples are: - Grigore Antipa, - "Black Sea" - vol. 1 "Oceanography, Bionomy and General Biology of the Black Sea", Romanian Academy, Fundatia Vasile Adamachi, TOMUL X, Nr. LV, 1941; "The Danube Sinking Zone, Hydrological Monograph" (edited by Diaconu C., Nichiforov I.D.), CSA, Bucharest, 1963; "The Black Sea in the Romanian Seaside Area - Hydrological Monograph", (editorial collective, edited by Bondar C.), 1973, IMH, Bucharest.

At international level, there are a number of oceanographic and marine numerical studies and models developed by various oceanographic institutes: MEDATLAS - a marine climatic model with application, especially for the Mediterranean; General Ocean Turbulence Model (GOTM) - is a 1-dimensional numerical model for simulating vertical exchange processes in the marine environment; MOM - Modular Ocean Model; Pollutant Routing Model, US-EPA; POM - Princeton Ocean Model; SCRUM-S Coordinate Rutgers Model; The GFDL Modular Ocean Model; WAVEWATCH Model; WWW Tide and Current Predictor; ASGAMAGE - ecological model (1, 2, 3 - dimensional) for simulating carbon dioxide exchanges CO2, helium He and SF6 sulfur hexafluoride, using ocean edge edge element, ERSEM - marine ecological model. Marine marine patterns for the Black Sea were developed for example by Bulgaria and Russia. At the national level, there is no significant numerical model for the Romanian Black Sea coastal zone. As a result, an Italian - Romanian cooperation program was launched in March 2003 on the implementation of an integrated Western Black Sea environmental system - WBLESS. One of the objectives of this program was the realization of a complex physico - ecological numerical model. The model is currently incomplete. In order to be complete, it is first necessary to establish the limit conditions, then the monitoring data implementation program and, finally, the testing or calibration of the model.

2. HISTORY OF OBSERVATIONS AND MEASUREMENTS

The Black Sea began to be studied before other seas. In the 5th century BC, the Greek historian Herodot visited the northern shores and described the nature and the climate by naming a few rivers flowing into the sea in these areas.

In the third century, the first map of the Black Sea was drawn up. Ptolomeu commemorates cities, sea promontories and astronomical dots. Later on, the Genoese developed nautical maps and improved sea maps (Visconti's map of 1311).

In 1822, on the basis of the coastal data of the French, the first Black Sea map appeared in Paris. From the chronicles of the times we learn that the first observations and measurements on the Black Sea date back to the 14th century, during the reigns of Mircea the Elder and Stephen the Great. The first scientific studies related to the Romanian territory date back more than a hundred years and were determined by the maintenance of the navigation through the mouths of the Danube and the arrangement of the port of Constanta. These objectives led to the first approach to the knowledge of the meteorological characteristics (establishment of the first meteorological stations Sulina 1857, Constanta 1860), the study of the influence of the Danube alluviums, the study of the sea currents and the waves, as well as the knowledge of the structure of the Romanian seaside. The first hydrographic map of the Romanian coasts (scale 1: 20000) (Antipa, G., 1941, Fig. 1) appears in 1901 (based on plans and maps drawn up by French and British engineers and geographers after the Crimean War) and in the following years other maps have been executed.

In 1903, Stephen Hepites signed the first synthesis of the climatic elements at Sulina.

In 1930, a great pioneer of Romanian oceanography, after Emil Racovita, Grigore Antipa founded the bio-ecological institute in Constanta (today named after him). Since 1926, the Military Navy Hydrographic Service and the General Directorate of Ports and

Waterways have begun to carry out hydrological measurements and observations at the mouths of the Danube and on the Romanian Black Sea coast. From 1928, under the direction of Commander P. Fundateanu, "Marine Magazine" appears on the study of currents, density, temperature and alluvium in the mouth of the Danube mouths. In 1941, the "Black Sea" monograph, drawn up by Dr. Grigore Antipa, appeared. Starting with 1959, albums and oceanographic directories appear. But the extended systematic activity on the problems of sea physics began in 1960, then 1967 by the establishment of oceanographic research stations Constanta, respectively Sulina.

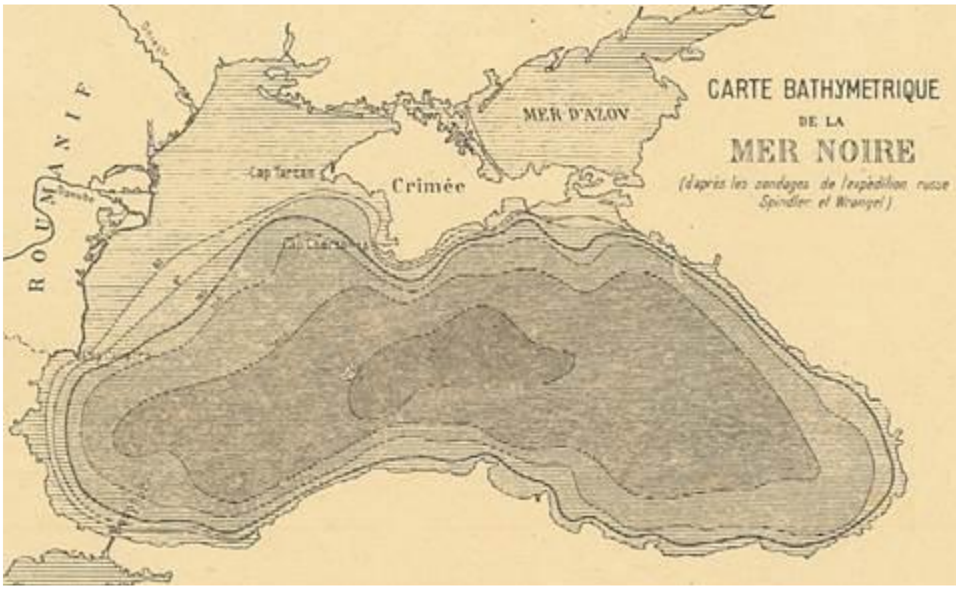

Fig. 1 Bathymetric map of the Black Sea (1901 - after the polls of the Russian expedition Spindler and Wrangler - archive, reproduction document

Another reference work in this field is the "Black Sea in the Romanian Seaside Area - Hydrological Monograph", responsible editor, dr.ing. Constantin Bondar.

The institutes investigating the Romanian Black Sea coastal zone are: INCD Geology and Geoecology Marine (GEOECOMAR), National Institute for Research and Development Marine "Grigore Antipa" Constanta - Romania, National Water Administration - Water Directorate Dobrogea Litoral.

3. TYPE OF WATER AND TRANZITOR WATER FROM ROMANIA

According to one study [2], the coastal area was framed as follows:

'Coastal waters' means the surface water from within to the dry land of a line, each point of which is at a distance of one nautical mile from the nearest point of the baseline from which the breadth of territorial waters is measured, which (if necessary) can be taken up to the outer limit of the transitional waters.

"Transitional waters" are surface waters in the vicinity of rivers, which are partly saline as a result of proximity to coastal waters but which are substantially influenced by freshwater flows.

The types of coastal waters in Romania

The coastal waters of the Romanian Black Sea sector extend from Periboina to Vama Veche (the border with Bulgaria); continues with the coastal waters of the Bulgarian Black Sea sector.

According to the specific criteria of the two systems A and B, the following typological classification of coastal waters in Romania is accepted Table 1:

- Type RO90 - Short sandy coastal waters with sandy substrate on the central seaside area of Periboina to Cap Singol.
- Type RO91 - Deep coastal waters with mixed substrate (sand with rock formations), on the southern sector of the Romanian seaside, from Cap Singol to Vama Veche.

Table 1. Typology of coastal waters in Romania

Type	Name	Depth	Substrate
RO90	Deep coastal coastal waters with sandy substrate (from Periboina to Cap Singol)	small	Sand
RO91	Deep coastal water a little deep with mixed substrate (from Cap Singol to Vama Veche)	small	Sand with island rock formations

Types of transitional waters in Romania

Transitional waters extend across the entire Romanian Black Sea sector from Chilia to Vama Veche, both in the terrestrial area (like river and lake waters) and in the seaside maritime area (as seas).

According to the specific criteria of the two systems A and B, the following typological classification of the transitional waters in Romania is accepted (Table 2):

- Type RO80 - Transitional river waters, on the Danube's Black Sea springs.
- Type RO81 - Transit waters, lakes in the central and southern terrestrial area of the Romanian seaside.
- Type RO82 - Transitional Marine Waters, in the northern sector of the Romanian seaside, from Gura Chilia to Periboina.

Table 2. Typology of Transitional Waters in Romania

Type	Name	Depth	Substrate
RO80	Transitional river waters (the Danube springs)	small	sandy
RO81	Transient lake waters (coastal lakes in the terrestrial area)	very small	sandy
RO82	Ape tranzitorii marine (de la Gura Chilia la Periboina)	small	sandy

4. PROJECTS FOR REHABILITATION OF THE BLACK SEA COAST AREA

Coastal rehabilitation projects include the W-BLESS project, Integrated Coastal Zone Management and the JICA project.

• The W-BLESS project - "W-BLESS - Western Black Sea Integrated Environmental System" and "Integrated Environmental System for the Western Black Sea" initiated in March 2003, being a forward-looking Italian-Romanian project . It is a feasibility project and has several tasks, including:

- Monitoring system - modeling for the Romanian Black Sea coastal zone:
- Integration of the river basin into the management system.
- Identification of sources of pollution and analysis of anthropogenic impacts on large-scale basin water.
- Recognize existing basin infrastructure.
- Classification of insured goods from the environment and services.
- Fixing the monitoring network for the qualitative and quantitative control of water and soil.
- The overall infrastructure plan of the most sensitive water sectors to environmental requirements.
- Simulate impacts from infrastructure investments.
- Securing bank and financial resources.

• Coastal Zone Management - Integrated Coastal Zone Management consists of a decision-making cycle that includes horizontal integration (ie integration of coastal geographic units and co-ordination after different sectors) and vertical integration (ie coordination and communication at different levels of government).

Integrated management includes several systems, including:

- the natural system (which includes non-human domains, namely the atmosphere, the lithosphere, the hydrosphere as well as the dynamics and their interactions in the abiotic and biotic processes and which exist outside the human presence;
- functional users (represents the set of human interests in terms of "users" of the natural system, respecting the users of the natural resourses);
- the control system (the use of functions is governed by, for example, the natural system is guided by infrastructure, in many cases control is necessary, because if it is not present, different stresses and conflicts may emerge).

The JICA project - this project concerns the protection and rehabilitation of the Mamaia Sud and Eforie Nord areas, as well as the Năvodari and Vama Veche areas.

The Ministry of Environment and Water Management, with the support of the JICA International JICA Agency, initiated the project "Study on the Protection and Rehabilitation of the Southern Part of the Romanian Black Sea Seaside". The study aimed at:

• elaboration of a protection plan for the southern part of the Romanian seaside;

• carrying out preliminary actions to promote preliminary projects;

• transfer of knowledge and technologies in the field of coastal protection and management to the Romanian side.

The priority areas were established as: Mamaia Sud, Constanta Nord, Eforie Nord, Eforie Sud and Costinesti.

The works are: rehabilitation of dikes, creeks and episodes, artificial reefs, sanding, decommissioning of existing works etc.; total investment value: 316,000,000 Euro (according to data http://www.mmediu.ro).

5. SOME METEOROLOGICAL AND HYDROLOGICAL CHARACTERISTICS OF THE BLACK SEA ROMAN COSTIAN ZONE

• *Wind direction.* On the Black Sea Romanian seaside air transport in the cold season takes place from the north and north-northwest, and in the hot season in the north and north-east. The average annual transport has a speed of 0.9 m / s at Sulina and 0.7 m / s at Mangalia, having the north - northeast direction. The average wind speed in the cold season is about 8 m / s in the western and northeastern seas, and the south-eastern part of the average wind speed decreases a lot in the cold season as well.

For example, the variability of the wind frequency over four consecutive years, as well as the frequency of calm (percentages) (Fig. 2).

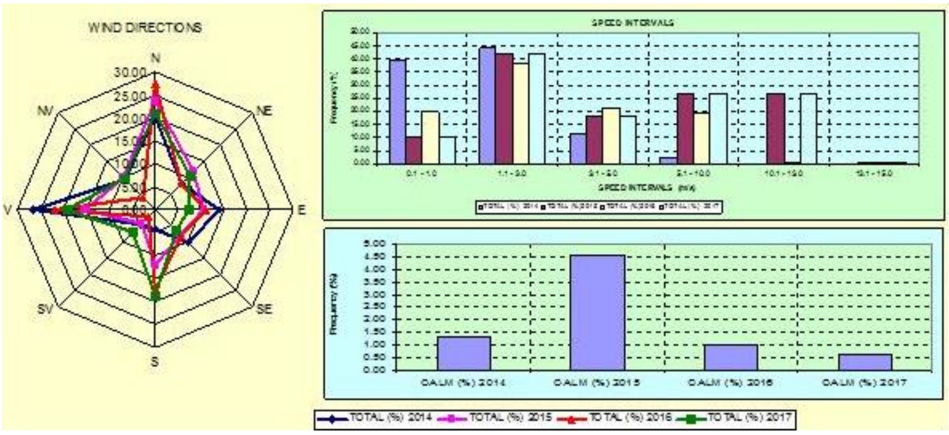

Fig. 2 Frequency (%) of wind direction - s.h. CONSTANTA METEO, 2014, 2015, 2016, 2017

• *The air temperature regime* on the Romanian Black Sea coast is characterized by the existence of a thermal gradient from north to south from September to March and from south to north from April to August.

• *Levels, currents, waves.* The Black Sea Levels on the Romanian seaside - the maximum amplitude of the variation in levels reaches 169 cm in Sulina (sea), 190 cm in Sulina port, 117 cm in Constanta, 129 cm in Sfantu Gheorghe port and 116 cm at Portiţa Mouth.

For example, Fig. 3 shows the variation and trends of the average, minimum and maximum annual levels for the period 1858-2016 per s.h. Sulina Lamp Signal (multi-annual average levels (for medium, minimum and maximum meals).

• *The currents in the Romanian seaside* - are grouped in: coastal currents; currents from the mouth of the Danube (there is a well-defined critical liquid flow above the value of which the salty waters of the Black Sea do not penetrate into the riverbed); the currents between the river mouths (on the Danube Delta, between the mouths of the arms and the baths, the sea currents are conditioned by the wind regime).

For example, Fig. 4 shows the variation of the anode frequency of surface current directions and speed steps at s.h. Constanta Comparator Casino in the years 2014, 2015, 2016. (s.h. - hydrometric station).

The Black Sea Waves in the Romanian seaside area - during the year, about 50% winds with speeds of zero - 5 m/s, 34% at speeds of 5 - 10 m/s, 9% at speeds of 10-15 m/s and about 3% storm winds. The frequency of storm winds (more than 15 m / s) is much higher off the sea (4.2%) at Sulina and the Serpent Island). The very low frequency of calm (2 - 4%) in the Sulina mouth is due only to breeze effects occurring between the sea and the sea; the statistical analysis of the wave propagation directions shows that most of the waves come from the sea, with predominance in the south-eastern sector.

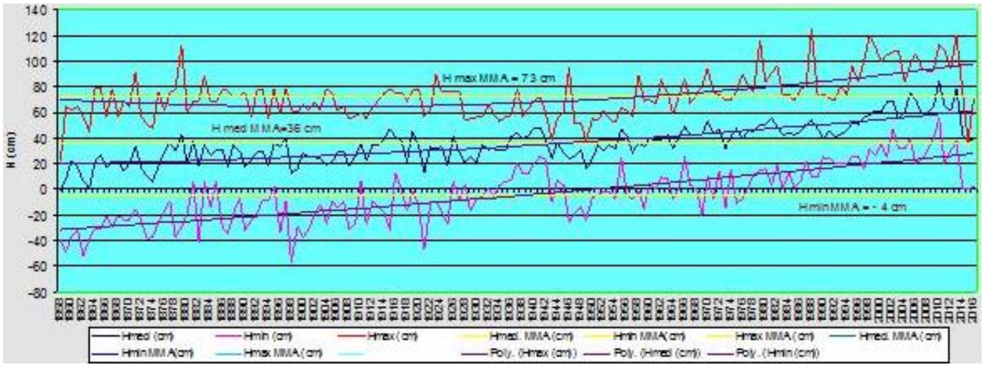

Fig. 3 The variation and trends of the average, minimum and maximum annual levels (period 1858-2016), (Hmed - average level,, Hmin-minimum level, Hmax - maximum level, H - level) s.h. Sulina Semnal Ceata

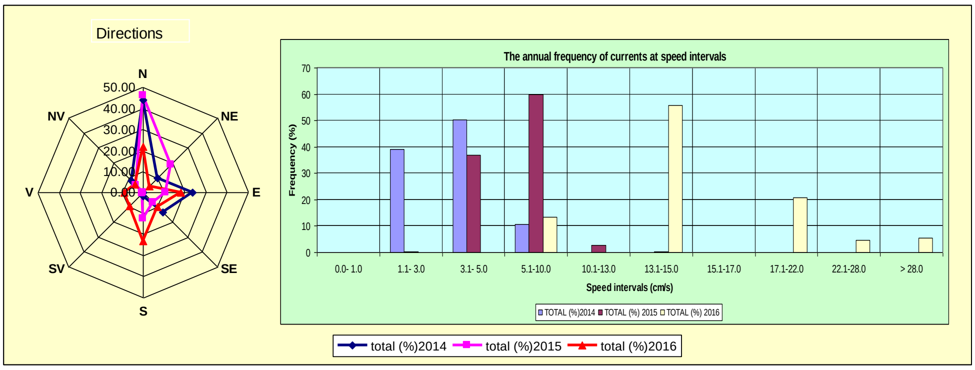

Fig. 4 Yearly variation of surface currents and speeds directions, compared to 2014, 2015, 2016 at s.h. Constanta Casino

As an example, in Fig. 5 and Fig. 6, two histograms representing the annual wave frequencies on height and period steps, at s.h. Mangalia, conquering for 2016 and 2017.

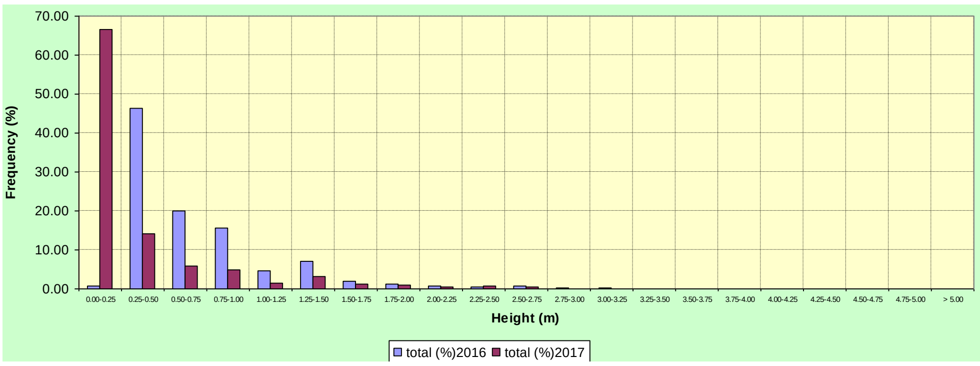

Fig. 5 Yearly wave frequencies by height steps at s.h. Mangalia, compared to 2016, 2017

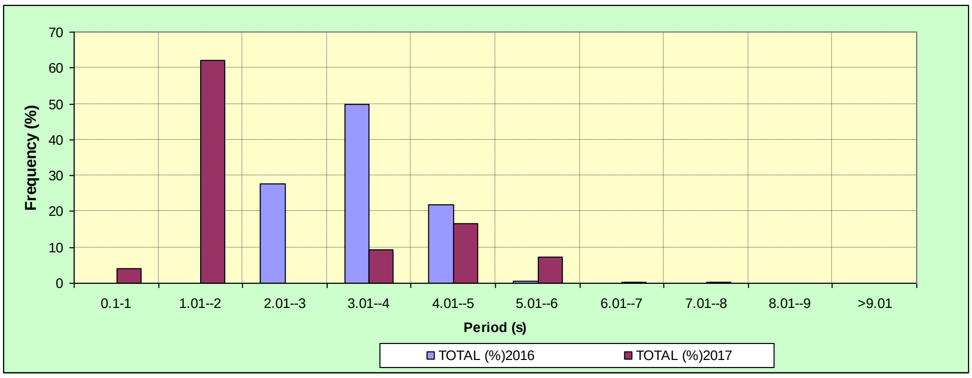

Fig. 6 Annual waves frequencies per period steps at s.h. Mangalia, compared to 2016, 2017

• *Water temperature*. The Black Sea waters in the Black Sea coast are characterized by an average annual temperature of 12.6°C near the shore and 13.0°C offshore. The average annual air temperature at the coast is about 10.7 °C. The maximum sea water temperature sometimes reaches 27°C (surface) in July. Vertically, there is an intense thermal stratification with narrow variations. Highest temperature variations occur in spring in the 10m layer and 10-30m in summer and autumn.

For example, Fig. 7 shows the variation in annual average water temperatures over a period of 1857-2016 per cent. Sulina Port / Sulina Semnal Ceaţă.

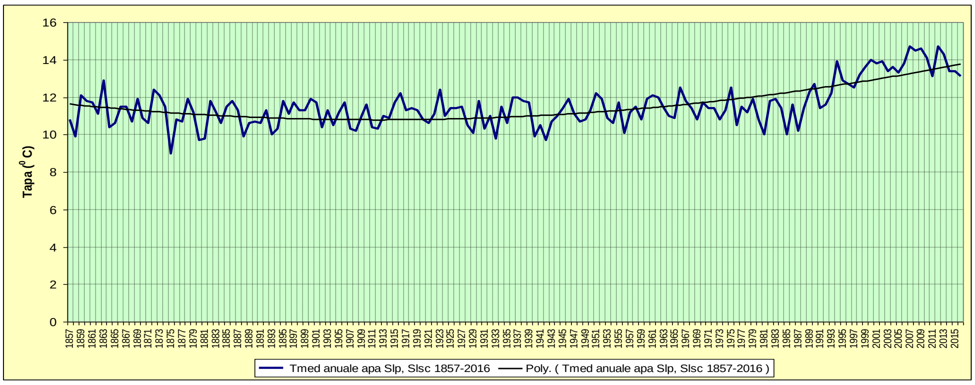

Fig. 7 Variation and trend of annual average water temperature (1857-2016) -s.h. Sulina Port / Sulina Semnal Ceaţă (T water - water temperature)

• *Salinity of water*. Characteristic of the Romanian seaside is that the vertical distribution of salinity suffers variations of place and season. Average characteristics of the vertical distribution of the Black Sea salinity at the Romanian seaside: in the water blanket between the surface and the 10 m deep horizon the salinity has values lower than 15 ‰, being very variable in space and time; isohalina of 17 ‰ is located in the water blanket between the horizons of 10 and 25 m; Between the 25-meter horizon and the bottom of the sea the salinity has values higher than 17 ‰, reaching up to 21 ‰ at depths of 100 m; at depths of 180 m the salinity reaches the value of 22 ‰ and even more.

As an example, in figure 8 the salinity variation of the marine water in s.h. Eforie Sud, in the period 1991 - 2017 (with interruptions); there is a tendency to increase salinity.

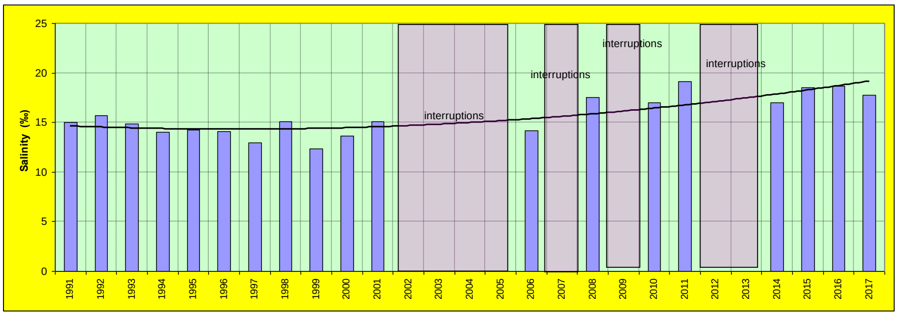

Fig. 8 Variation of salinity of marine water at m.ph. Eforie Sud

• *Chemistry, radioactivity and general physical characteristics of water*. In the Romanian seaside area, due to the process of sweetening of marine waters under the influence of river spills, the composition of the marine water ions varies sensitively depending on the hydrological regime of the Danube. As is known, calcium bicarbonates predominate in river waters, while marine waters predominate sodium chlorides.

Radioactivity of water, sediment or biota is variable. For example, after the Chernobyl accident, aquatic organisms (molluscs and fish) harvested from the Danube Delta and the Black Sea showed concentrations of Cs - 137 that exceeded 50 Bq / kg of dry sediment.

6. CONDITIONS FOR APPLYING THE COMPLEX FOR THE BLACK SEA ROMANIAN COASTAL MODEL

The marine complex model is based on the coupling of two models: a marine physical model - the Princeton Ocean Model (POM) and a marine ecological model ERSEM III.

In order to apply the complex model (ie the coupling of the POM and ERSEM III models) to the Romanian Black Sea coastal area, more conditions have to be fulfilled, the first condition being the adaptation to this area of the complex model. This was done by realizing two models, namely BREG - the regional model for the entire Black Sea surface and BSHELF - the zonal model for the Romanian coastal area; this is because, as has been seen in the previous chapters, the coastal area suffers from the Black Sea influences, considered as a whole aquatic object [5].

These models came directly from the Princeton Ocean Model (POM) and ERSEM III and were written in the programming language (code) FORTRAN 77 and run in the LINUX MANDRAKE 9 operating system. The adapted programs were made by R. Sorgente and M.Zavatarelli, of ICM Sardinia (BREG, BSHELF) and M. Vichi, of INGV Bologna (ERSEM III).

12-month weather climatological data was provided by the ERA-European Center for 6-hourly Re-Analysis for the 6 hour weather forecast. This data set (1° x 1°) contains wind, wind, wind, wind, wind, clouds, and wind velocity averages (averages from 1 January 1979 to 31 December 1993).

The physical parameters considered in the modeling are: the elevation (profile) - eta, the temperature-tem, the salinity-sal, the radiated heat flux, the total heat flow qtot, the wind stress in the x-wsu direction, (wind pressure) in the direction y - wsv, evaporation - emp, pressure in the direction x - ubar, pressure in the direction y - vbar, velocity in direction x - u, velocity in direction y - v, speed in direction z - w. Ecological parameters considered: Elementary structures: C - carbon, N - nitrate, P - phosphate, O - oxygen, I - solar radiation, M - depth (m), R - reduction equivalences; pelagic structures; benthic structures; ecological transport variables.

Some peculiarities (conditions of application) of the complex model:

1. The programs run under LINUX MANDRAKE 9, the running time for each season is about four hours, and the time increases even more with the higher the number of data.

2. Concerning boundary condition.

Very important for internal calculations are the definition of boundary boundary conditions. At this stage, the marginal boundary conditions for the north, east, south directions of the Romanian coastal zone are not strictly specified, this being one of the conditions of applicability (Fig. 9).

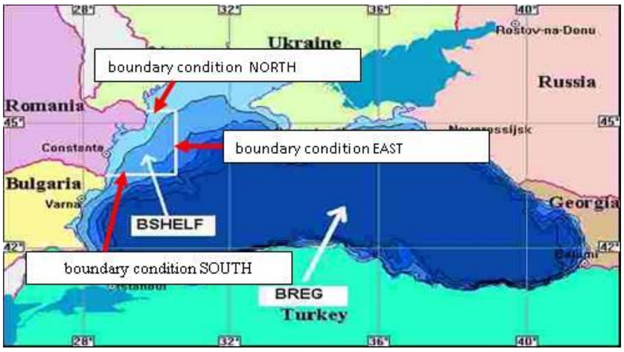

Fig. 9 Delimitation of boundary conditions for the application of BREG / BHSELF to the Romanian Black Sea coastal zone.

3. Another condition for the applicability of the complex model is the existence of a continuous (continuous) implementation of monitoring data.

The data used was provided by the ERA (ERA) for 6 hours of Re-Analysis, being implemented within a strictly separate program included in the BREG / BHSELF program package. Using IM = 105, JM = 92 and KM = 24, then running the program in diagnostic mode and visualizing with the grads program, the following graphical results are obtained, (example: barotropic velocity at the sea surface (Fig. 10); salinity at a depth of 50 m (Fig. 11)).

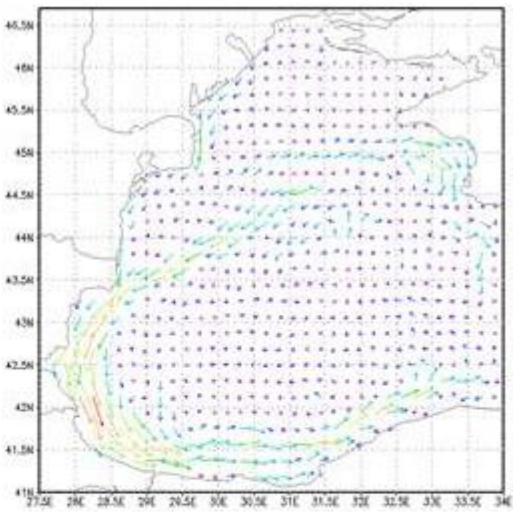

Fig. 10 Barotropic velocity at sea surface during the winter season

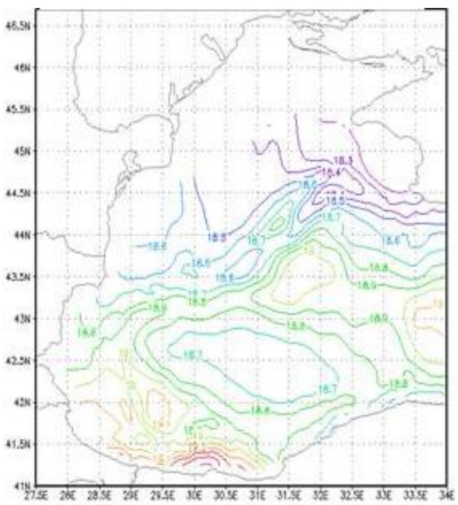

Fig. 11 Salinity distribution (psu) at a depth of 50 m in the winter season

7. CONCLUSIONS

1. Existence of pollution risks, coastal erosion processes and socio-economic activities call for integrated coastal zone management of the Black Sea. Integrated Coastal Zone Management is an ensemble of several systems: the natural system, functional users and the control system, which has the effect of achieving the conditions for sustainable development in the area. Several strategies have been developed in this context, including the legal strategy, law 280/2003, the W-BLESS feasibility program collaboration strategy, as a result of Italian-Romanian collaboration.

2. One of the components of integrated coastal zone management is also the monitoring system of the area and related to the development of some diagnostic and prognostic models of defining parameters for marine physical and ecological processes that are based on in-depth theoretical considerations. In this context, the following elements should be considered: Marine physical environment (physical properties, marine water dynamics, basic equations of fluid dynamics, ocean-ocean interface, ocean circulation, fundamental marine parameters - density, temperature, salinity; elements of ocean and ocean dynamics - waves, currents, fundamental ecological parameters - dissolved inorganic matter, dissolved gases, dissolved organic matter, marine life groups and their dynamics.

3. Over time, various oceanographic institutions have developed different physical or ecological models for the study of marine or oceanic processes. These models include the Princeton Ocean Model (Physical Model) and ERSEM III (Ecological Model) model. By adapting these models to the Romanian Black Sea coastline, the BREG / BSHELF models were developed.

8. ACKNOWLEDGMENTS

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5. REFERENCES

[1] ANTIPA GRIGORE - *"Marea Neagră", 1941 "Oceanografia, bionomia şi biologia generală a Mării Negre",* Academia Română, Publicaţiunile Fondului Vasile Adamachi, vol. 1, TOMUL X, Nr. LV

[2] BĂTUCĂ DAN, GH., (2003) *"Caracterizarea corpurilor de ape costiere si tranzitorii (Studii privind corelarea cu directiva cadru a uniunii europene privind resursele de apa)* - Tema B.9 – Faza 9.3

[3] BONDAR, C., ROVENTA, V., STATE, I., (1973) "*Marea Neagra in zona litiralului romanesc – monografie hidrologica",* Bucuresti

[4] BONDAR, C., (1984) "*Compoziţia chimică a apei Mării Negre în zona Agigea",* Studiu hidrologic, Bucureşti

[5] BORCIA, C. (2004) **"***Aplicarea unui model complex marin in vederea diagnosticarii parametrilor fizico-ecologici caracteristici zonei costiere a Marii Negre",* tema 13, M.M.G.A.

[6] BORCIA, C., BLENDEA, V., GEORGESCU, I, I. (2001) "*Aspecte privind interdependentele dintre unii indicatori calitativi ai apei marine în zona de coastă a Mării Negre*", Sesiunea Comunnicari Stiintifice INMH. Bucuresti
[7] BORCIA, C. (2016) "*Aspecte privind istoricul observaţiilor şi măsurătorilor pe Dunăre, Delta Dunării şi zona costieră a Mării Negre*", manuscris
[8] GEORGESCU, I., I., (1992-1996) "*Determinarea indicatorilor radiochimiciai apei nefiltrate si sedimentelor colectate de pe Dunare si litoralul romanesc al Marii Negre*", Bucuresti
[9] PÄTSCH, J., (2001) "*The Long Term Run the ecosystem model ERSEM: technical guidance for PC application*", Institute of Oceanography Hamburg, December 20
[10] *** Studii hidrologice marine - DADL Constanţa, 1991 - 2017
[11] *** Anuarul hidrologic al Mării Negre, 2014-2017

Black Sea - winter 2006

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