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MODELING OF THE MARINE HYDROLOGICAL PROCESSES IN THE PROXIMITY OF MANGALIA HARBOUR, ROMANIA

Ichinur Omer[1], Dorin Butunoiu[2], Razvan Mateescu[3], Angela Ivan[4]

[1]*Faculty of Civil Engineering, "Ovidius" University of Constanta, 22B Unirii Street, Constanta, Romania, e-mail: ichinur.omer@univ-ovidius.ro*
[2] *County Council Galati, 7 Eroilor Street, 800119, Galati, Romania*
[3] *National Institute for Marine Research and Development "Grigore Antipa", 300, Mamaia Blvd., 900356, Constanta, Romania*
[4]*Free Zone Galati, Romania*

Abstract
To carry out the navigation operations and to establish the local erosion control methods, the knowledge of the hydrodynamic regime in the proximity of the marine harbors and the modeling of the marine hydrological processes are particularly important. The existence of the natural barriers or resulting from human intervention has a significantly influence on the marine movement near the coast and implicitly on the vessel behavior in the vicinity of these. The paper includes the results of the experiments realized near the Mangalia harbour, which confirm the validity of the results provided by numerical models.

Keywords: modeling, hydrodynamic regime, marine hydrologic process, harbour.

1. INTRODUCTION

The climatic particularities of Romanian marine area, determined by location and configuration of the relief, specific to the temperate continental, are characterized by a strong annual cycle over overlapping the medium and small scale variations.

At the Black Sea coast, the climate is considerably affected by the influence of this harbour both thermally and dynamically aspect, by changing the heat balance and the sub adjacent surface roughness. In these conditions, there is a considerable variability in the atmospheric circulation regime, winds recorded with high instability, both by direction and by speed, with no regular winds. The speeds are generally low and moderate and the storms are quite rare. The waves generated by the wind field, especially in seashore, depends strongly on local particularities (direction, duration and intensity of winds).

The agitation character state of the sea in a given region is determined not only by the wind regime, but also the structure and configuration of the area bathymetric and shoreline orientation (depending on which sets the range of the wind - 'fetch') . At some points, especially in the vicinity of seaports, these factors lead to the emergence of the wave fields with different values of the observed parameter characteristics: height, period, length, determined to carry out port operations.

To be entrusted with the direction of the main purpose of the experiment, validating the numerical model results, the main objective was to analyze the wave field in a transition period from summer to winter, a period marked by significant marine agitation with events.

The experiment was realized near the Mangalia port.

Mangalia Harbour is located on the Black Sea coast, in South East of Romania, having the coordinates: Lat: 43 gr. 49 'N Long: 028 gr. 35 'E.

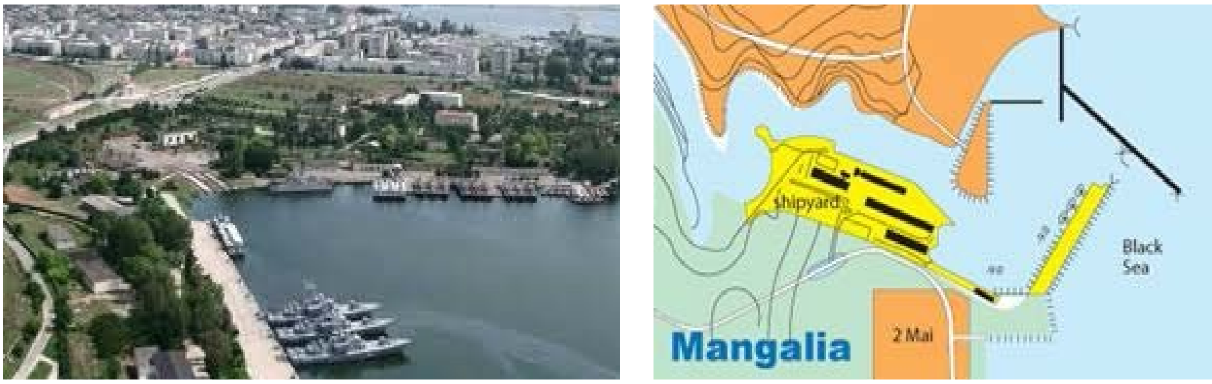


Fig. 1. Picture and map of Mangalia Harbour

Located at the south of the Mangalia city, the harbour is achieved with four dams with a total length of 3.78 km. In this harbour exist the operational berths for general cargo, grain, gravel products, passengers, having a length of 400 m, the maximum depth of the quays is 8 m, four quay cranes with lifting head of 6.3 ft each, the draft at the fairway entrance / output is 6.5 m.

In this harbor, from May 1998, was put into operation one bitumen storage terminal in 5000 t tanks, each with its own system for maintaining the temperature at 160 C. The bitumen is imported from Italy. The domestic delivery is made by 4 car ramps and ramp of rail tankers. Surface storage of goods in harbour is 27000 m^2 and the storage area of 4500 m^2.

In the Mangalia harbour have access ships with capacities up to 10000 dwt.

Until 1995, on the south shore of Lake Mangalia has developed a shipyard called "2 MAI" when it was taken over by Korean corporation Daewoo. During 1975-1984, were made following investment objectives:
- one dock building;
- repair ship with double rooms;
- ship repair dock with room, dimensions of 340 x 60 m;
- a floating dock of 20000 t and two docks of 10000 t;
- reinforcement quays with a total length of about 1600 ml.

2. NUMERICAL SIMULATIONS

The models used for numerical simulations are SWAN and STWAVE, the spectral wave models that are designed for coastal zones and are based on the integration of the balance equation with finite difference schemes to provide the realistic estimates of the most relevant wave parameters.

SWAN is a model much more complex, the advantage is that the model can be calibrated more, concerning the implementation in a particular location and the conditions associated with the various configurations of the environment matrix.

On the other hand, STWAVE is a simple model but faster and more robust (for all the simulations, results the calculation averaged time over STWAVE about 80% of the time required for SWAN), which can be used successfully in many coastal environments and for different situations.

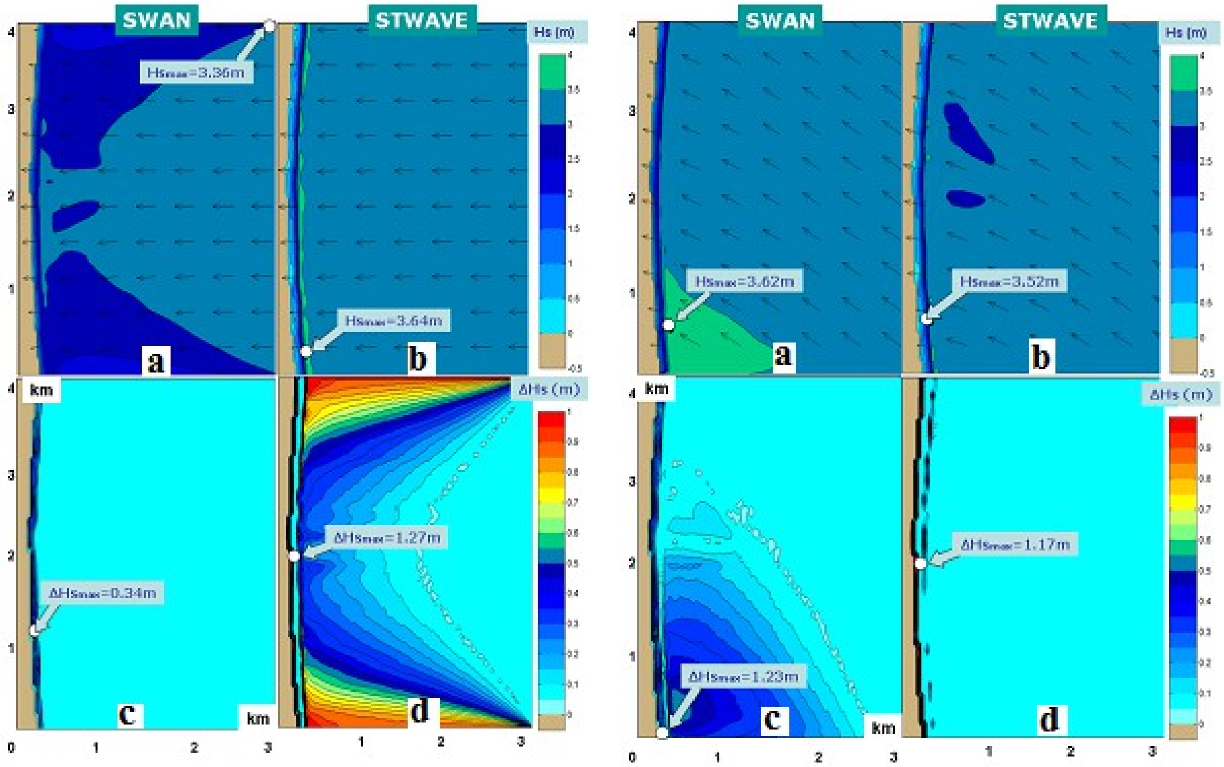
The obtained results show that the border effects induced by SWAN model depends primarily on the external border of wave direction but also depend on the bathymetric configuration of the considered coastal sector.

An implementation of the two models was carried out in the Mangalia zone and some results are shown in Fig. 2. Thus Fig. 2 presents a study case rather high energy for the Black Sea characterized by the following wave values for the external border of the computational domain: Hs = 3.28 m, Tp = 6.4 s, Dir = 92 °. To simulate the SWAN model were considered zero the lateral boundary conditions, as shown in the figure, even when the direction of wave propagation follows approximately the direction normal to the coastline (the case shown in Fig. 2). The differences appear on the lateral borders.

The results of the second study are shown in Fig. 2 and in this case are studied the high enough energy conditions to western of the Black Sea but this time the wave direction is deflected by 39 ° from the normal to the coastline.

Accordingly, this case is characterized by the following values for the wave external border of the computational domain: Hs = 3.42 m, Tp = 7.1 s, Dir = 129 °.

Unlike the previous case, in this case, however, the simulation by the SWAN model considered constant the lateral boundary conditions, although there is a considerable angle between the wave direction and the normal direction l to the coastline border, the effect is much reduced compared with the previous situation.



Input parameters:*Hs*=3.28m, *Tp*=6.4s, *Dir*=92°. Input parameters: *Hs*=3.42m, *Tp*=7.1s *Dir*=132°

Fig.2. The coastal area in Mangalia zone, comparison between SWAN and STWAVE. a) The significant height fields and the wave vectors for the SWAN model simulations, b) The significant height fields and wave vectors for the STWAVE model simulations c) Hs positive variations d) Hs negative variations in absolute value.

It can be appreciated that the specific conditions of the Black Sea, the constant option for boundary conditions of SWAN model is generally viable when the angle between the wave propagation direction and the normal to the coastline is not greater than 40°. If the angles are greater than 40°, an alternative solution to increase the computational domain is to rotate this domain so as to become parallel border to the direction of the waves propagation or even to make a smaller angle.

On the other hand, the model STWAVE not induce any boundary condition, is more robust and faster than SWAN.

The fewer options for modeling of physical processes may be considered a disadvantage because the calibration reduces the possibilities, but also time can be an advantage because it is easier to implement.

However, it should also be noted that SWAN has the advantage that it can be implemented for the entire Black Sea basin as a system with several levels of calculation, but based on the same spectral model (SWAN).

Regarding the coastal areas with higher spatial resolution, both the SWAN and STWAVE models can connect to this system. Though obviously the SWAN is more direct model.

For high-resolution simulations performed in Mangalia harbor were preferred Cartesian coordinates, such the SWAN model is better in following processes: diffraction, reflection, breaking waves and water elevation due to the waves. As we know, for the high resolution simulations in the coastal areas, some processes can sometimes be particularly relevant.

The influence of the marine currents has not been considered in these simulations because the unlike areas such as the mouth of the Danube, in this area, generally, the currents do not exceed 0.2-0.3 m / s, values that do not fundamentally affect the field waves.

The influence of the wind has been considered at this level although such resolution is also not generally relevant, except the case of very small waves coupled with high winds.

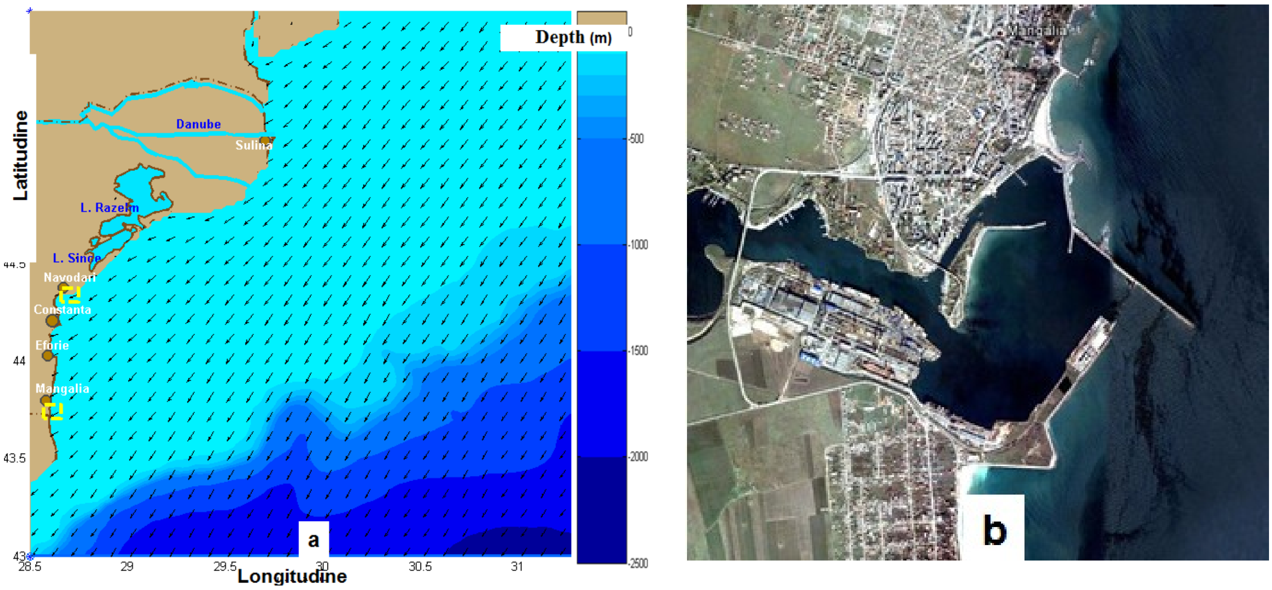


Fig. 3 a) The transformation corresponding the Romanian coastal zone, bathymetric map and the most representative wave propagation direction (corresponding to waves coming from the northeast direction.) b) The area of Mangalia Harbour (Picture from Google Earth)

Some relevant results of the simulations in Mangalia coastal area are illustrated in Figure 4.

Thus, it is shown in this figure, four different energy situations basis on the average values of the incident wave energy (Figures 4a and 4b) continuing with a high energy condition (Figure 4c) and one situation characterized by the power extremes.

They correspond to real situations as shown in numerical simulations of the wave prediction system based on the model SWAN.

Thus the average energy situations illustrated in Figures 4a and 4b correspond to the time points 2009/03/04/h12, respectively 2009/05/17/h21.

The high-energy situation illustrated in Figure 4c corresponds to the time 2009/02/07/h18 and the extreme energy situation refers to the same point of time 2002/03/11/h13.

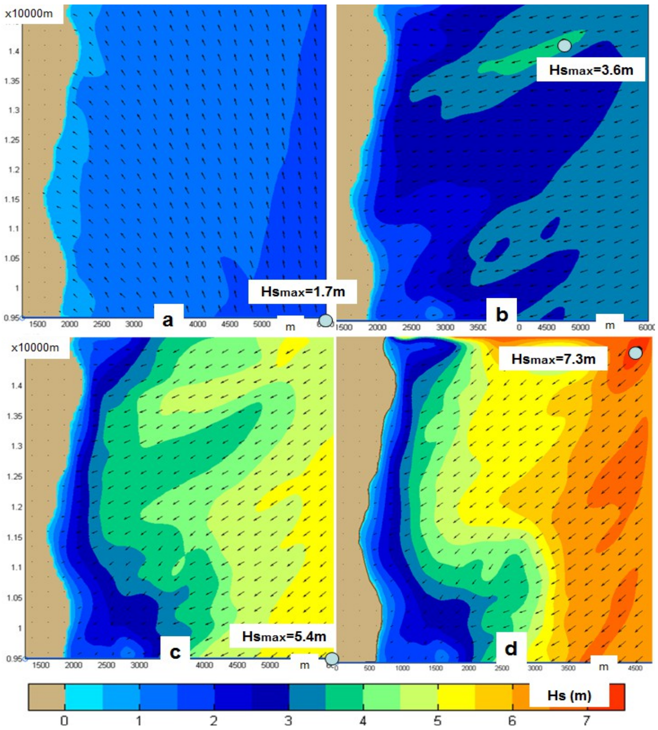


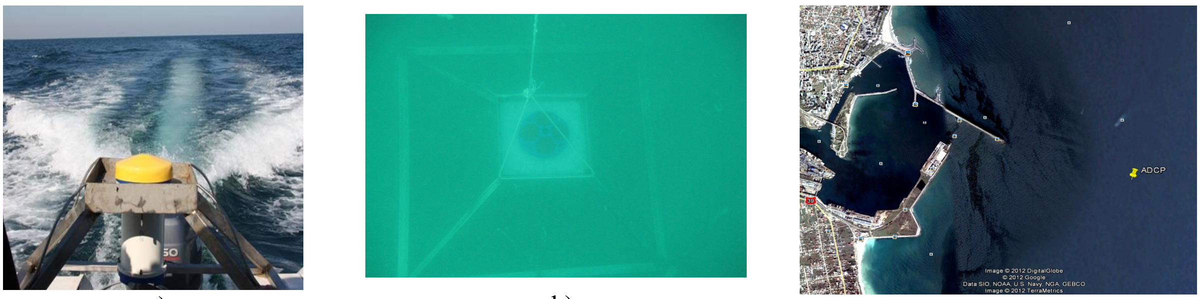
Fig. 4. The high resolution area near the Mangalia Harbour, the significant height fields and the wave vectors: a) The average energy situation 2009/05/17/h21 b) The medium to high energy situation 2009/03/04/h12 c) The high energy situation 2009/02/07/h18 d) The extreme energy situation.2002/03/11/h13

3. EXPERIMENTAL. RESULTS AND DISCUSSION

Between 5 to 25 September 2012, was conducted a data recorder experiment of the waves field in the vicinity of the Mangalia Harbour at the 15 meters depth (43deg. 47.7 'N and 28 deg. 37.1'E).

The measurements were performed with an Advance Doppler Current Profiler (ADCP), produced by Teledyne RD Instruments (USA), in the Workhorse Sentinel 600kHz configuration, suitable for a wide variety of marine and coastal applications, thanks to the 4-bimuri and signal processing on a broad frequency range. Thus, WHS600 with a frequency of 600 kHz, was ordered by a non-magnetic metal structure for recording high accuracy propagation directions / development of the waves and currents.

The ADCP Workhorse Sentinel 600kHz is for the measurements of the periods up to 3 months and is served by an alkaline battery, one memory card and one dedicated software.

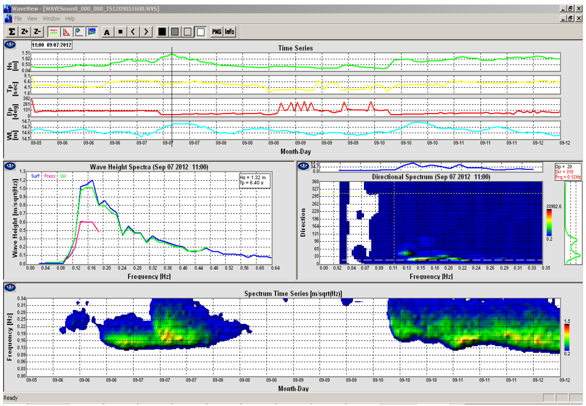


a) b) c)

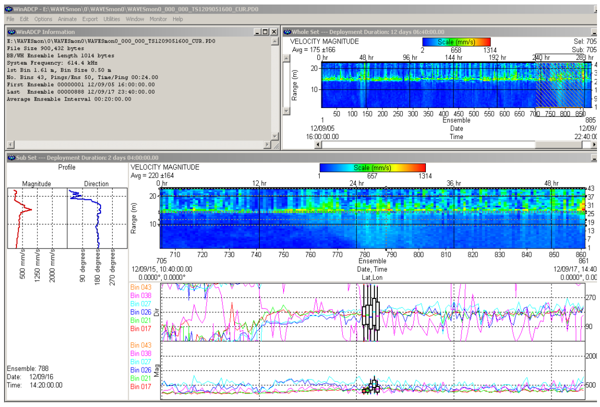
Fig. 5. a) Transportation of the ADCP WH600 with a boat to the dive site b) The diving to 15 meters depth of ADCP WH600, c) The satellite image of the Mangalia Harbour and the mounting of ADCP WH600

To determine the current profile of the water column, the depth is 50-100 m with a vertical resolution / the cell size mediation of 0.5-8 m and standard deviation of 12.9-2.0 (cm / s). For chosen configuration in this experiment were used the depth of 15m, 0.5m cell size and standard deviation of 1.9 cm / s.

To carry out the best conditions, the current speeds at the metering station were planned two expeditions: one of installation and one of uninstallation and were used configurations to set the metering mode depending on the depth and hydrodynamic conditions in the vicinity of the chosen location.

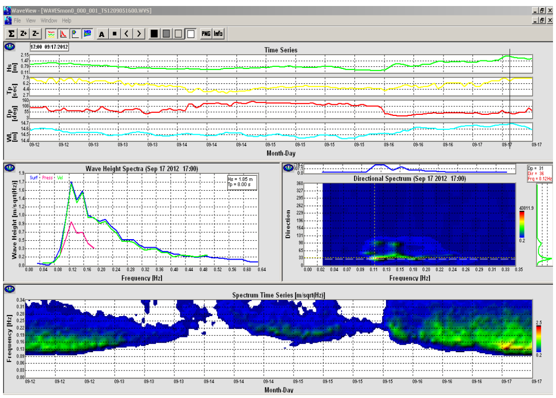


Spectrum of wave height on 7 th September spectral time series - Frequencies

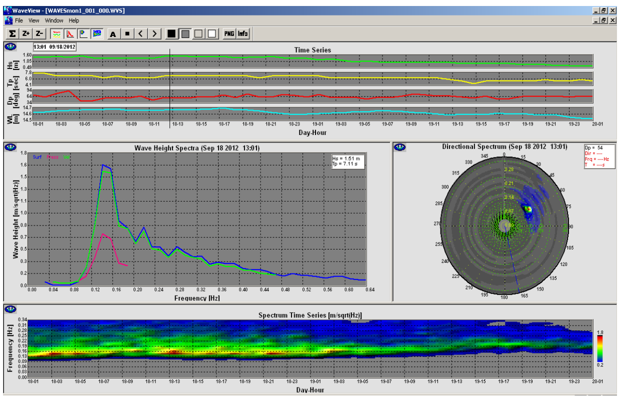


Marine currents parameters registered during 5-12.09.2012

Fig. 6 Wave parameters recorded during 5-12.09.2012



Wave parameters recorded during 12 - 17.09.2012 Height spectrum of waves on 17th September and spectral time series



Wave parameters registered on in the maximum day of storm 17.09.2012. Height spectrum of waves, directional spectrum (NE) on September 17 and spectral time series

Fig. 7 Wave parameters recorded during 5-12.09.2012

In Figure 8 is shown how fighting a marine hydrological event, on 25 September 2012.

As an important observation, it can see the records in cases that the wind from the south direction (SE, S, SW) causes a current jet in the upper layer in the same direction due to the water extraction at the mouth of input / output, relatively small opening, and that certain conditions at the harbor entrance during these particularly difficult operation in the Mangalia Harbour’s entries.

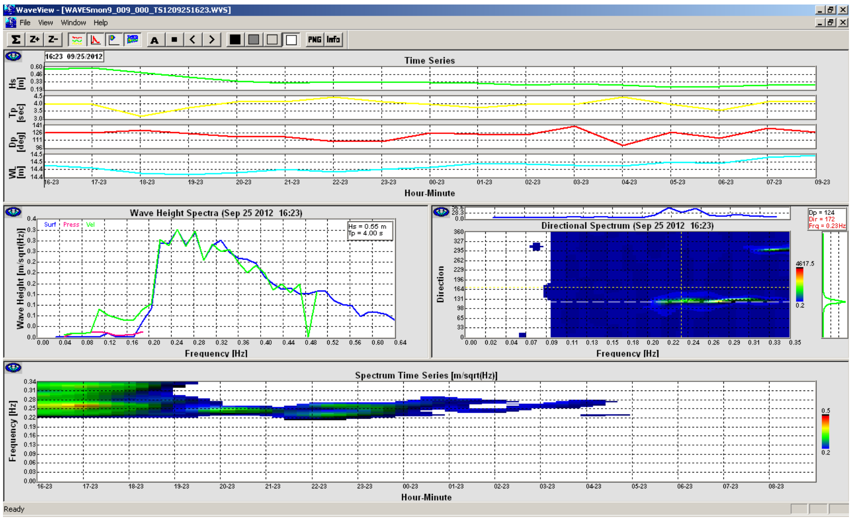


Fig. 8 Wave parameters registered on 25.09.2012.
Height spectrum of wave in the 25th September and spectral time series

The ADCP's extracted data were preprocessed with Wavemon software and is the basis for the development the different analyzes of wave regime in the proximity of the Mangalia Harbour.

Thus, for the considered period, it can be observed, at the 0-15m depth, one variability of the currents.

We have analyzed the results of measurements performed daily between 05.09 - 25.09.2012.

It is found that the frequency of the cases with over 1m wave (wave height greater than 1m) is greater than the regime in the autumn, representing 129% of the multiannual value. Though, these differences are within the natural variability for this season.

The measured heights of 1.85 m to 17/09/2012 and the average values in this period were 0.9m, 0.6m, respectively, 0.7m, located above the values of the regime, while the average times were 5.0s , 4.8s and 4.0s.

Overall, 80% of the waves were higher than 0.8m and the frequency statements of calm was 52%. The recorded currents had values up to 50cm / s and presented a variability in depth, as surface / Ekman spiral.

As an important observation, the records of the cases that the wind from the south direction (SE, S, SW) cause a jet current in the upper layer in the same direction, due to the water extraction at the mouth of input / output, relatively small opening and that certain conditions at the harbor entrance during these particularly difficult operation in the port of Mangalia's entries.

4. CONCLUSIONS

Due to the considerable variability of the wind regime, the wave field characteristics in the study area changes significantly within a year and the large inter annual differences.

In the long term, in the absence of the significant climate change, the process is stationary and the wave regime can be characterized by statistical parameters of the observables elements distribution.

For this study we analyzed the collected data from Mangalia station at 15m depth for a period of 3 weeks.

The evolution of the average annual periods of calm (wave height less than 0.2m – the detection limit of the measurement method) reveal that the periods of calm is close to the minimum in September (52% of the time), which is the medium and long term in October (49.9%).

This reflects the adjustment periods of baric fields over Europe, generating the situations of instability. In January, the high-atmosphere equilibrium is already established. Its modification in early spring occurs important implications on the winds and waves regime. The situation has been surprised by the storm surge reached the maximum height 1.85m, which falls on average lower limit of height. But the situation recorded in September specific special barrel surprised instability regime transition to marine agitation of the cold season, when the maximum height is approx. 4.0m, 0.5m, and the average is more than double that of the other months. This month, the frequency of situations with calm sea is only 52%., compared to an annual average of 62%.

The recorded data allowed validation of the model results and the differences between measured and calculated values fall within an acceptable range of accuracy.

Acknowledgements

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References

1. Alkyon and Delft Hydraulics, SWAN fysica plus, report H3937/A832 (by order of RIKZ/RWS as a part of the project HR-Ontwikkeling), 2002.;
2. Booij, N., Ris, R.C., Holthuijsen, L.H., *A third-generation wave model for coastal regions, Part I, Model description and validation*, J. Geoph. Research C4, 104, p.7649-7666, 1999;
3. Butunoiu, D., Rusu, E. 2012a. Sensitivity tests with two coastal models, *Journal of Environmental Protection and Ecology,* May 2012;
4. Butunoiu, D., Onea, F., Rusu, E., Evaluation of the environmental conditions in the vicinity of the Romanian ports of the Black Sea, Special Issue, *Journal of Environmental Protection and Ecology,* 2012;
5. I.N.C.D.M., Studiul regimului de vânturi şi valuri al litoralului românesc, Institutul Naţional de Cercetare Dezvoltare Marină Grigore Antipa, Constanţa, 1994 / Study winds and waves regime of the Romanian Seaside, National Institute of Marine Research and Development “Grigore Antipa”, Constanta;
6. Leake, J., J. Wolf, J.A. Lowe, P.K. Stansby, G. Jacoub, R. Nicholls, M. Mokrech, S. Nicholson-Cole, M.J.A. Walkden, A. Watkinson and S. Hanson, *Integrated modeling for coastal impacts,* Proceedings of 10th International Conference on Estuarine and Coastal Modelling, Newport. ASCE, NewYork, 2007;
7. Rusu, E., Macuta S., Numerical modelling of longshore currents in marine environment, *Environmental Engineering and Management Journal*, 8, 147-151, 2009;
8. Rusu, E. and Butunoiu, D., Wave modeling in the proximity of Constanta harbour, Proceedings of the *13th International Congress of Maritime Transportation and Exploitation of Ocean and Coastal Resources* - IMAM2009, Istanbul, Turkey, Vol. 2, 633-640, 2009;
9. Rusu, E., Butunoiu, D., Parallel evaluation of the wave energy in Black Sea, *International Environmental Conference - Sustainable Development in Coastal Areas*, 29 June – 1 July, Ioannina, Greece, 2011;
10. Rusu, E. and Butunoiu, D., Wave Modeling in Coastal Zones with Application to the Romanian Nearshore, Publishing House of the Romanian Technical Academy and General Association of the Romanian Engineering - AGIR Ed., Bucharest, 325p (in Romanian), 2011.