# OFFSHORE WAVE REGIME INVESTIGATIONS TOWARDS SAFTY PORT OPERATIONS IN THE TRANSITIONAL ZONE OF THE ROMANIAN COAST

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## ABSTRACT

In situ waves measurements, as well the experimental researches, encompasses complex approaches on the waves fields development, especially related to the marine and coastal waves propagation and interactions towards safety navigation, were become progressively important in the last decades.

The present works on the marine waves hydrodynamics, as a response processes of climatic changes, takes in to consideration the offshore operations and port management activities, and it is extended through several in situ and modeling approaches focused on the waves and currents regime, in the specific conditions of the western Black Sea Basin, afferent to the Romanian coast.

Certain results on the evolution of the main hydrodynamics indicators/parameters at medium and short term for the interest zone will be emphasized. The modeled vs. measured quantities of significant waves parameters, where analyzed on its seasonal/annual and multi-annual variance in relation with its importance on the maritime port management operations developments in the transitional area of the Romanian shore.

**Keywords**: marine environment, wave regime, wave's parameters, extreme waves, statistical analysis, port operations.

## INTRODUCTION

Wave's regime is a marine environment component, crucial in the safety navigation operations within open sea as well in the ports areas. The understanding of the waves setting within marine and coastal area is needed in accurate predictions of the sea-state within the natural and anthropogenous environment. Thus, information on sea waves, provided by wave data analysis in parallel with model results, offers in the same time the grounding support in several navigation operations issues during storms and exceptional weather phenomena, also to avoid incidents which are occurring often in adjacent areas of coastal ports. The understanding of the marine hydrodynamics in the new changing climate permits a proper investigation for development of risk mitigation strategies/methodologies and provides rapid response in case of emergency [1].

At the Black Sea coast, the climate is considerably affected by the influence exerted by this basin both in terms of thermal and dynamic by changing the heat balance and changing the underlying surface roughness. There is a considerable variability in the atmospheric circulation regime, determined by the relief location and the configuration; they are specific to the continental temperate. The winds recorded shows high instability of direction and speed, with no regular winds.

## METHODOLOGY

The work is related to the unified methods for the analysis of wind and collected wave data, dynamic regime and preparation of related scenarios, like extreme on seasonal wave's regimes, in relation with winds and storm surges. It has to be highlighted that the approach is suitable al for the Romanian maritime ports, and navigation routes as well [2].

For the present study were used data from three available data sources of wind and waves. One source was the wave's data from the European Centre for Medium-Term Forecasting (ECMWF) and other sources are the wind measurement and waves visual observations made at Gloria platform four times per day, and the wind measurements and wave data recorded by an Aanderaa sensor at the Midia offshore - oil terminal. The first source is the result of Eurowaves Black Sea project, using WAM model, for the period November 1991 - June 2002, integrating data obtained from four times a day, thus providing the parameters of wave, where wave height was validated and corrected by using the satellite altimetry data received from Topex/Poseidon. For the validation, the correlation coefficient between WAM results and Topex/Poseidon data for the western Black Sea was above 0.85, although the WAM model was developed for deep water waves, this correlation analysis data obtained from model results vs. Gloria station data, located at 38 m depth and Midia station located at 28 m depth – representations of their location in Google Earth for data on available intervals are shown in Fig. 1, [4], [5], [8].

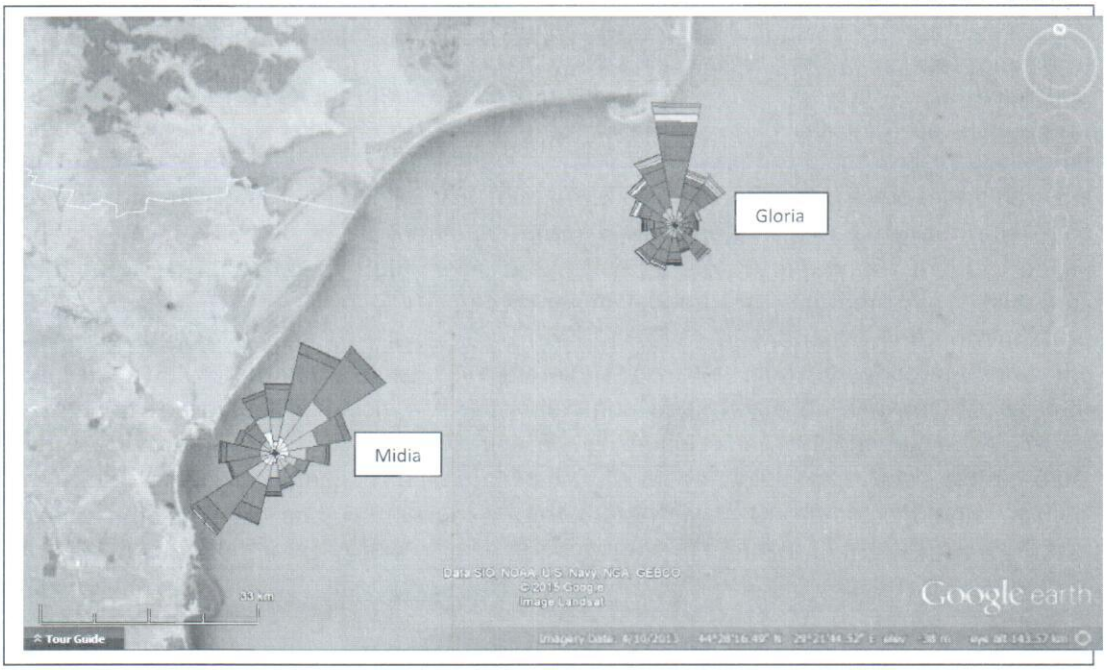



Fig.1. Locations of the two hydrometric stations within Romanian waters
(Wave data for 2007-2012 intervals at Gloria, vs. spring transition of 2010 at Midia)

The accuracy and visual quality measurements depend largely on the experience of the observer and the machine Aanderaa precision which is in centimeters.
Statistical analysis of the wave characteristics on the two stations were limited by several gaps caused by technical problems in the recordings. The locations not exclude the wave transforming phenomena due to its locations relative to the shore orientation.

## RESULTS AND DISCUSSIONS

Analysis of the waves and wind speed regime of the North-Western Black Sea Basin afferent to Romanian waters provide a classification of Romanian marine zone dynamics, in terms of waves and wind dynamics, and identifications of the sea-state regime in adjacent port areas passed by certain navigation routes, can identify unsafe hydrological phenomena affecting the safety of the maritime traffic, and emphasized certain possible impacts/difficulties on the port operations under various marine seasonal wave regimes.
An accurate assessment of the sea state parameters in the coastal environment is essential to ensure economic well-being and public safety. In particular, for the cases of the ecological alerts generated by ships accidents the importance of these problems becomes considerably higher, taking inconsideration that Midia Port is in southern areas of Danube Delta Biosphere Reserve.
The wave climate patterns are evaluated together with the changes that might be expected in the marine environment of the Romanian Black Sea, including the case of extreme events with long term returning periods, [9].
Thus, the wave propagation directions prevailing after ECMWF data are from NE (fig. 2) and E, while data from Gloria multiannual (1992-2012) indicate N and NE in a reduced proportion. The weighted average azimuth direction is 36° by ECMWF and 8° by Gloria. The differences are explained by the data include the effect Gloria wave attenuation due to location near the coast and orientation of the Sahalin sand barrier island influence begins to be felt. The variances are minor for high waves. For the extreme waves (with occurrence probability) were estimated by work afferent to Master plan for coastal protection [10], using the method of the wave peaks above the storm regime setup (considering significant waves Hs = 3.5m). For 46 storms recorded in 11 years of 1991 - June 2002 period were presented in the table:

Table 1. Estimates of extreme wave amplitude and period

| Return period | Wave height (m) | Wave period (s) |
|---|---|---|
| 5 years | 6.08 | 9.9 |
| 10 years | 6.52 | 10.2 |
| 50 years | 7.45 | 10.8 |
| 100 years | 7.83 | 11.0 |

The wave measurements at Gloria platform, determination of the independent global value centennial wave height directions wide (with repeatability once every 100 years) is approximately 14m for direction N, [3].

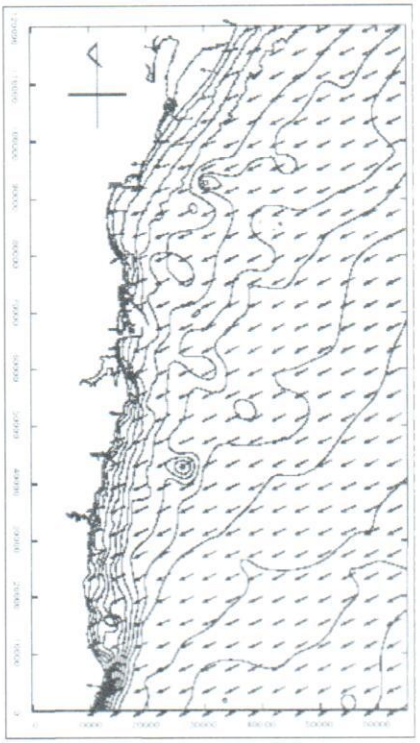


Fig.2 WAM results for the transitional zone of the Romanian coast (JICA, 2007)

The available wind measurements for the interval of 1992-2012 at the Gloria station, highlights its N and NE occurrence frequencies distributions between seasons.

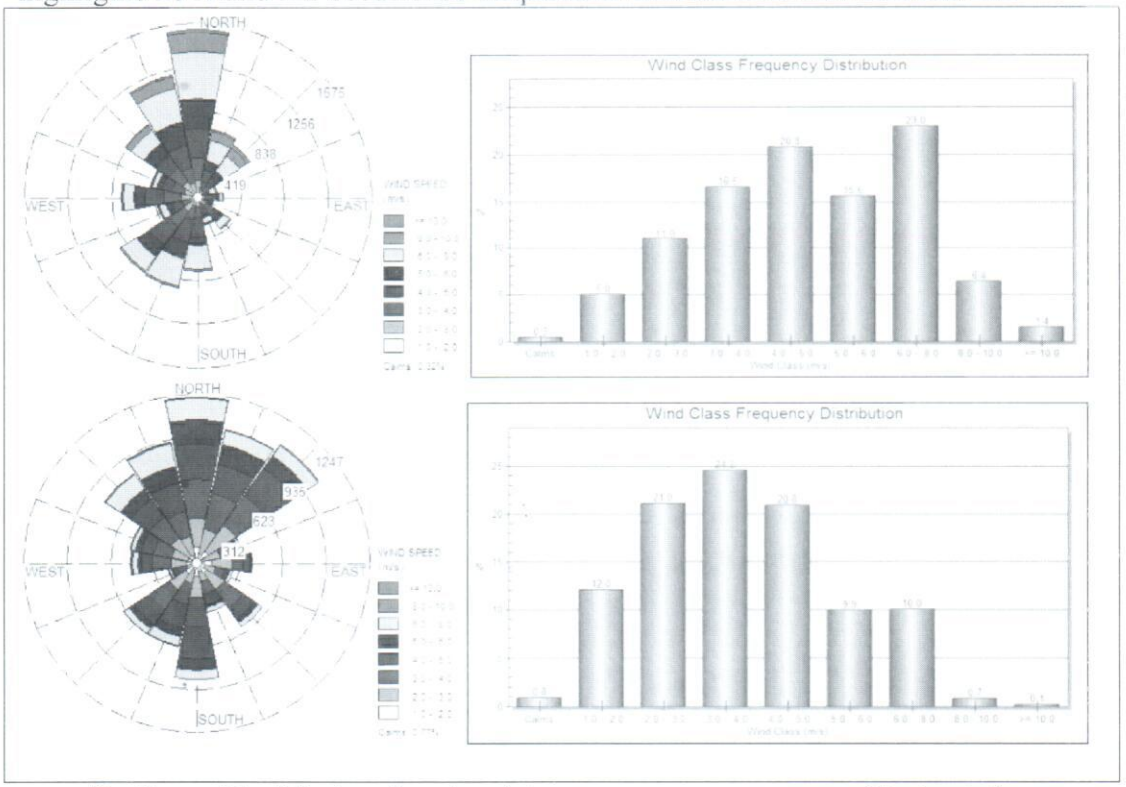



Fig.3.a and b. Wind regime in winter vs. summers season at Gloria station

The data concerning the visual wave measurements of Gloria station don't represent the significant wave height at the definition level; the comparison shown in figure reveals that the local recorded data can be considered representative of the significant wave height.

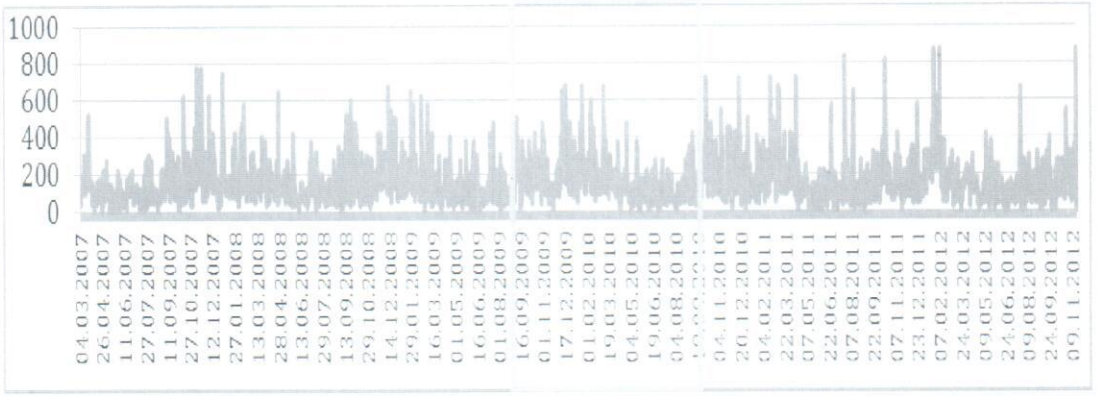



Fig. 4.a. Significant wave high (in cm) at Gloria station between 2007-2012

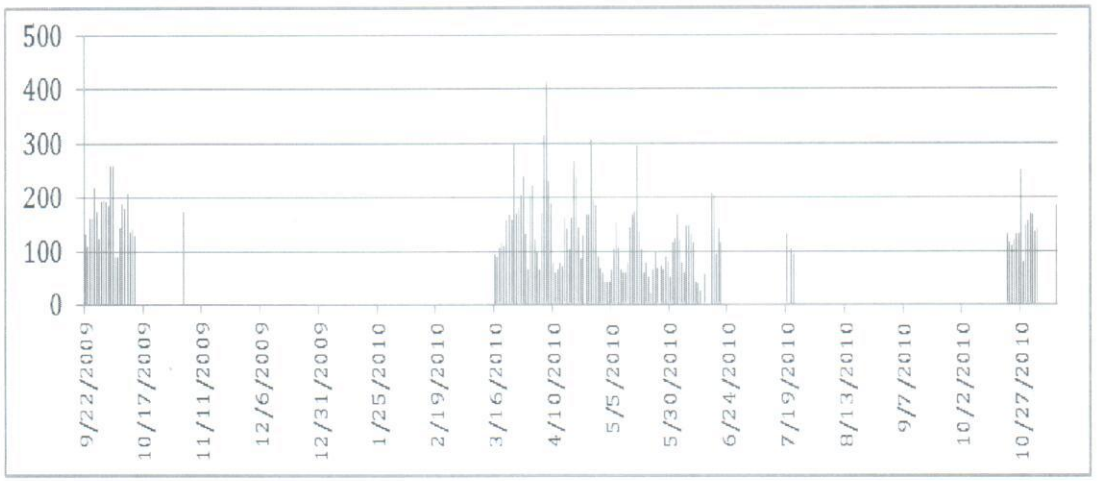
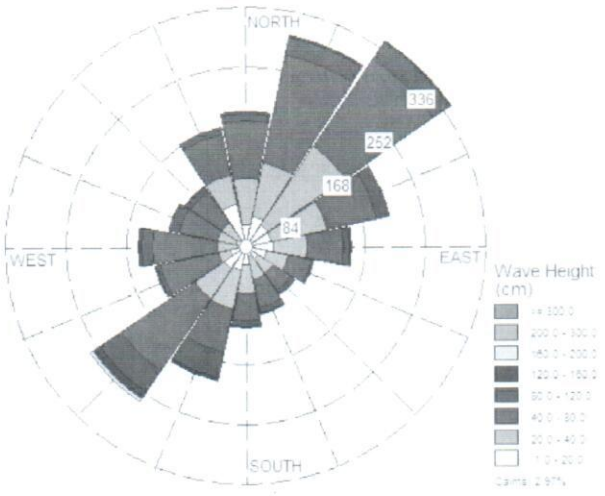


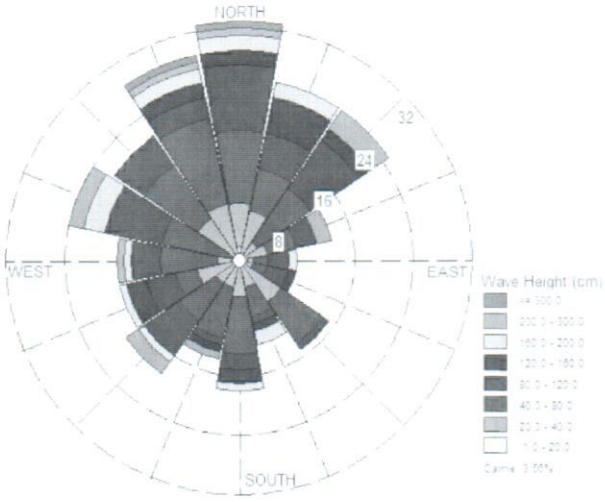

Fig. 4.b. Significant wave high (in cm) at Midia gauging station between 2009-2010

Based on the recording of more than 8500 recordings at 10 minutes, with various discontinuities due to technical causes, were developed several statistical analyses, for the available data recorded on the time interval 09.2009-10.2010, provided by Midia's wave gauging station. Generally exist a good correlation of all wave parameters with Gloria hydrometric station, and data corresponds to a suitable quality standard at seasonal level, for the wave data recorded without discontinuities.

Correlation analyses between data recorded at Midia against available data from Gloria platform (38m isobaths), recorded in the same time period, shows different frequencies on wave roses, probable due to the influence of the shore orientation and the presence of port jetties [7].




Midia station




Gloria station

Fig.5.a and b Difference between frequencies distributions at station Gloria vs. Midia.

The difference between wave highs frequencies over main directions for the time interval of the autumn 2010, supplement the wave climate data for the description of the transitional Romanian sector's wave regime. The data collection includes the mean values for five measurements of the type wave (wind wave or swell), direction, height, length and period, more rarely, the variable wave's velocity. Thus, characteristic wave heights over the space directions as listed above based on seasonal arrangement shows strong asymmetry and give an input for stressed directions orthogonal to the port entrance.

In the long term, in the absence of the significant climate changes, the regime is stationary and the waves can be characterized by the statistical parameters of observables elements distribution. Assuming the process stationary in the long-term, the regime wave (climate) can be determined by statistical methods [9].

For available time period were analyzed the data collected from Gloria station and respective Midia, along two transitional seasons, spring 2010 and autumn of 2009. The seasonal average evolution of calm periods (wave height of less than 0.2 m - the detection limit of the measurement method), reveals that during the calm periods is minimum. This reflects the adjustment periods of baric fields over Europe, which generates the instability situation was established [6]. In winter and summer, the large-balance setting is already set. The change occurs at the beginning of spring with important repercussions on the wind regime and consequently, on the waves. Thus, in April (Fig. 4.b), the maximum height (storm situations) reaches 4.1 m, while the average is in the lower range. A second situation occurs a baric instability in October 2010, when the maximum height was 2.5m, and the average is 1.5m, less than double the other months recorded at Gloria (Fig. 4.a). The seasonal variation at Midia offshore terminal, the frequency of calm sea situations is only 3%, compared to a same average of 3.6% at Gloria station, where the short-time variations are significant, the heavy sea situations representing 18% and 40%.

## CONCLUSIONS

The winds regime over the Black Sea is highly variable. Therefore, the wave's field generated by the wind, especially in seashore, depends heavily on the local particularities (direction, duration and winds intensity), not only by the winds regime, but also the bathymetrical structure of the area (topography of the sea bed) and the shoreline configuration and orientation (depending on the action that sets the distance of the wind – fetch'). In a given point, these factors lead to the waves fields with different values of the observable characteristics parameters: height, period length, and can have unbalanced variability than modeled ones.

The heavy sea state character in a given region is determined wave's regime information on the transitional zone of Romanian shore, extended through waves statistical analysis on multiannual wave recordings can an assessment of wave regime characteristics, in the conditions of a natural and built shore, respectively existence of a natural promontories or port jetties on maritime/coastal sites, inducing certain transformation on wave field.

The correlation analysis is not distinct conclusive in the present stage of wave monitoring activities, and in described conditions of the Midia port situation. In this regard, safe navigation technical specifications within the transitional seasons require certain recommendation for the complimentary solutions in case of emergency rapid response. For the evaluation of the cumulative multiannual impact, the analysis must extend for longer time interval, including calibration studies, together with consideration of different modeling techniques.

Due to the considerable variability of the wind regime, the characteristics of existing waves fields in the area of interest is changed significantly in a year and presents large inter-annual differences.

## ACKNOWLEDGEMENTS

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