ASSESSMENT OF THE MARINE WAVE ENERGY FOR THE NORTH-WESTERN AREA OF THE BLACK SEA

Andra-Teodora NEDELCU[1]
Dinu ATODIRESEI[2]
Alecu TOMA[3]
[1]Eng., "Mircea cel Batran" Naval Academy, Constanta, Romania, andra.nedelcu@anmb.ro
[2]Adv. Instructor, PhD Department of Maritime and River navigation and Transportation "Mircea cel Batran"
Naval Academy, Constanta, Romania, dinu.atodiresei@anmb.ro
[3]Assistant Professor, Eng., PhD, „Mircea cel Batran" Naval Academy, Romania, alecu.toma@anmb.ro

Abstract: The subject of this paper is to assess the wave energy for the north-western area of the Black Sea based for the last years from meteorological costal stations.
Marine waves are a combination of the action of winds, gravity and surface tension of the sea surface. Wave energy is an indirect form of solar energy. The energy potential of waves generated from the north-western Black Sea is modest and efficient exploitation its almost impossible. Due to the irregularity waves and their height dependency during the year, makes the installation of wave energy recovery systems, remain from an idea, a concept.
Keywords: wave energy, NW Black Sea,meteorological costal stations.

1. Introduction

Marine energy or marine power (sometimes under the names: ocean energy, ocean power or hydrokinetic energy) refers to the energy carried by the waves of the seas and oceans, tides, salinity and water temperature differences.

The movement of water in the globe, creates a huge volume of kinetic energy, or energy in motion. This energy can be harnessed to generate electricity for maritime transport industry and not only. The term "marine energy" includes both wave power offshore energy (energy generated by surface waves) and tidal power (kinetic energy obtained from the movements of water masses).

The oceans and the seas have the potential to provide a substantial amount of renewable energy throughout the world..

The theoretical potential of marine energy wraps around 4-18 Tonne of oil equivalent values. In Table 1 is presented the theoretical potential of marine energy resources.

Tabel 1. Theoretical global marine energy on energy sources [4]

Potential (GW)	Per year (TWh)	Resorce
5.000	50.000	Marine currents
20	2.000	Osmotic power
1.000	10.000	Thermal power
90	800	Tide
1.000—9.000	8.000—80.000	Waves

2. Assessment of potential energy of waves in the NV area of Black Sea

In comparison with other waters of the World Ocean, the wave activity of the Black sea is rather moderate. Despite the fact that in certain storms, the wind wave power can reach 1000 kW/m, the average indicators of the wave power can be about 8 -9 kW/m in the Western part of the sea and 2 -3 in the Eastern division.

Fig. 1 shows that long -period variability of the wave power field is most pronounced in the Western part of the sea. The Eastern part of the sea is more homogeneous and is characterized by minor fluctuations.
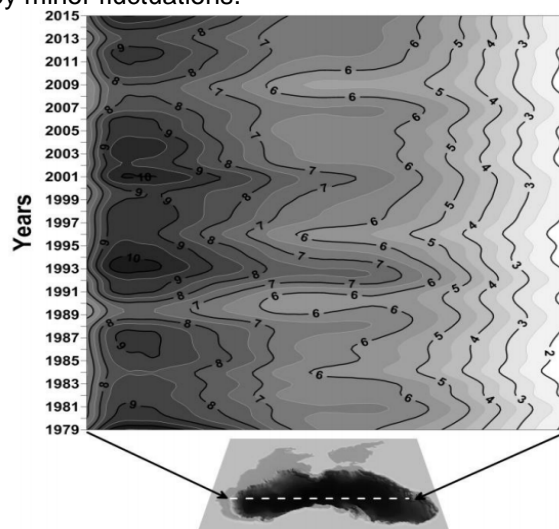

Fig. 1. The meridional crosssection of the average annual wind wave power (in kW per meter of wave front) for the period from 1979 to 2015[1]

The annually averaged spatial distribution of the significant wave height, averaged mean wave direction, which is a vectorial mean weighted with significant wave height, wind speed, and wave energy period during 35 years in the Black Sea are presented in the first panel in Fig. 1. The wave height decreases gradually from the western Black Sea to the coast and the east where the values are relatively lower. The largest value of mean H_m is seen in the coasts of the north-western edge of Turkey and Bulgaria's coasts. In the western Black Sea, H_m decreases gradually in the south-north direction towards Odessa Shelf. The lower values of H_m are observed along the coasts of Ukraine although there are available the stronger winds.

It can be seen in the following figure (fig. 2), winds have the highest magnitude in winter season (December – January – February) and in the western part of the Black Sea and Azov Sea. It is observed as about 8.1 m/s in the western part of the Black Sea and 8.7 m/s in the Azov Sea.
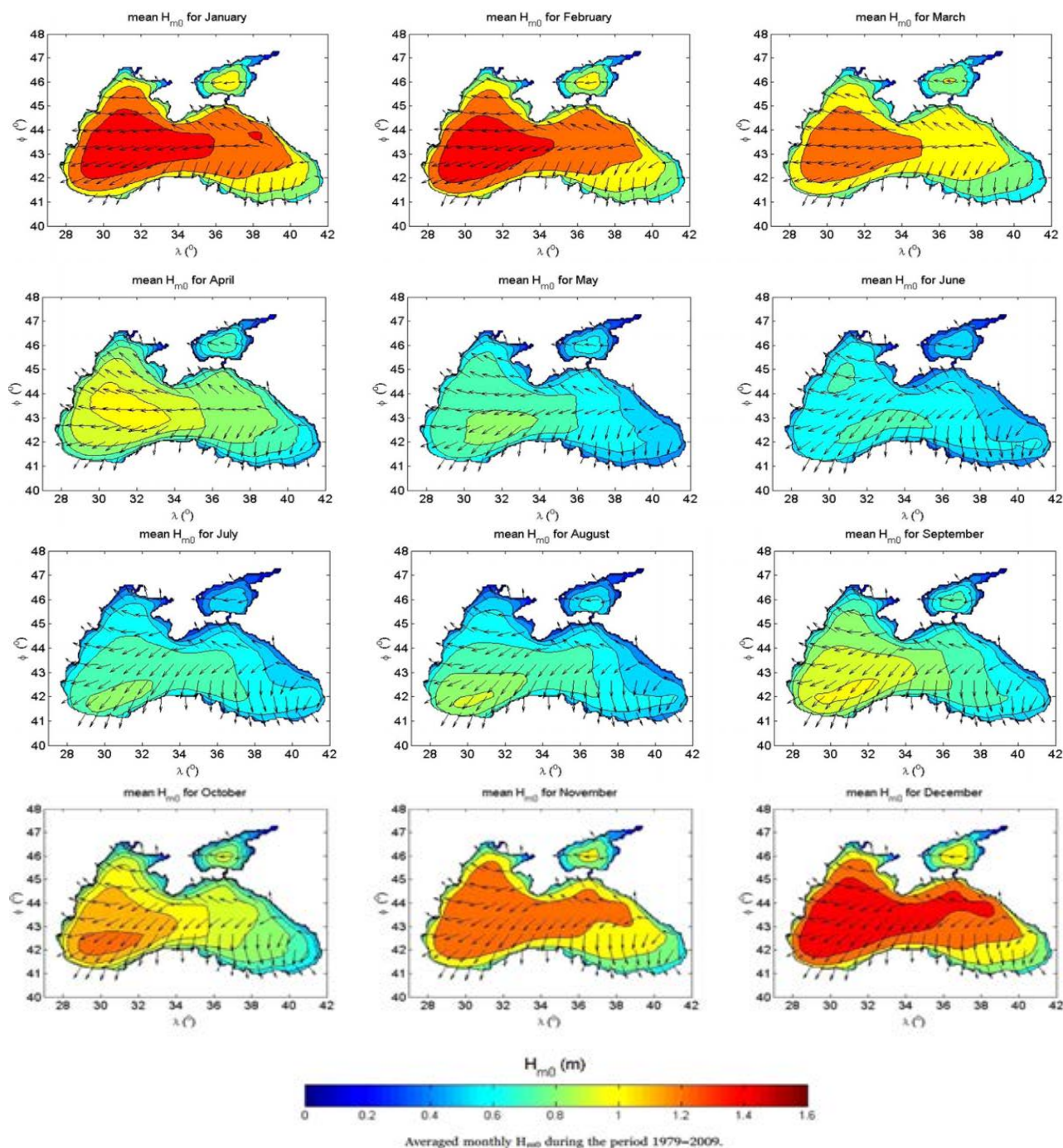

Fig. 2. Distribution of the wave direction during a year

Fig. 3.– Average wave height for 2011 [9]

The waves along and coast of Black Sea have an determining factor in their production of predominant wind direction. Monthly average with the highest value of significant wave height is in January with a value of 1,1m and a length of 7 s. At the opposite end is the summer period (June, July and August), when the significant average value of wave height is only 0.5 m. More than 20% of waves with significant height since February have a height greater than 4 m. The main directions of propagation of the waves offshore are north and northeast from June to October, and for the period from December to April direction is the predominant southwest. Extreme waves, with return period of 1 year, 10 years and 100 years are estimated as having significant height of 4.4m, 5.7m, respectively 6.9m. Analyzing waves through the annual mean values we can say that agitation Black Sea presents two different periods of manifestation, one characterized by calm, belonging summer season (summer months June, July and August) and one characterized by manifestations wider related to winter .

However, extremes wave characteristics in the Black Sea are registered in all seasons. Even in summer, every year, for a short period of time can be seen waves exceeding 4 m high,although the average for this period has values close to 1m.

For example, in 2011 the average wave height was evaluated at 1,56m. February is the month in which the average height of the waves reached the highest value compared to other months of the year, namely 2,48m; followed of 2,12m on March and 1.78m on October[8]. Below in Fig.3 [9] can identify and record other values in other months of the year: for example in April the average height of waves reached the lowest. The highest value of wave heights of 6.5 m was recorded on 17th October at 12:00 UTC.
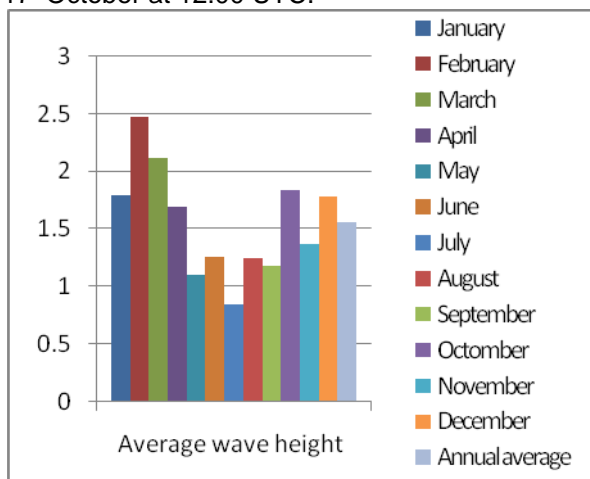
Regarding the direction of the waves, for all 2011 the main annual wave direction was South, direction registered 124 days of the 365 of the year, more than a third, followed by direction SV for about 52 days.
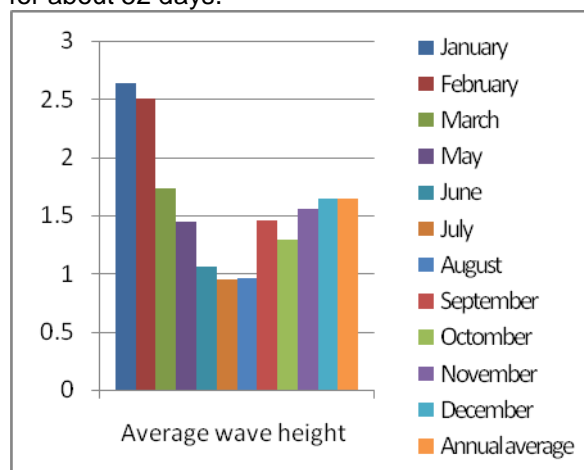
Fig. 4 – Average wave height for 2012 [9]

During 2012, the annual wave height average was set at 1,64m. As shown in Fig.4 [9].in January was the highest amount of average wave height of 2,64m, with 2.50 followed closely by February and December with 2,46m. The highest value of wave height was recorded on 7th February, 2012, 12:00 UTC, it was 7m. The predominant direction of the waves was South.

Tabel 2 - Energy per unit area determined for

Month	Energy 2011 $[KJ/m^2]$	Energy 2012 $[KJ/m^2]$
January	4.03	8.76
February	7.73	7.85
March	5.65	3.76
April	3.63	2.64
May	1.52	1.41
June	1.99	1.13
July	0.91	1.16
August	1.96	2.68
Septembre	1.75	2.09
Octombre	4.25	3.02
November	2.36	3.50
Decembre	3.98	7.60
Annual average	3.06	3.38

2011and 2012

By comparing the results of the two years, we can identify two trends of the average wave height one is down and start at the end of the winter season, in the February and ends up in the middle of summer. July is shaping the second trend, this

time one that continues its upward ascent until January.
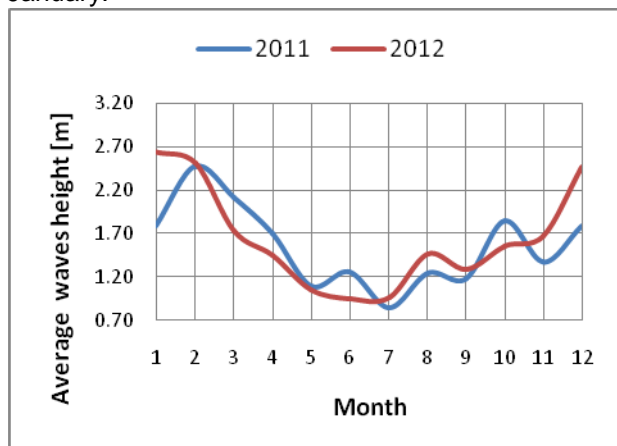
Applying the relation $E = \frac{1}{8} \rho g H_{m0}^2 \ [J/m^2]$[5], knowing that ρ =1025 [kg/m³], and g =9.80665

Fig. 5 - Average wave height graph for the 2011-2012 period

[m/s²] it can approximate amount of energy per unit of surface waves in the two years analyzed, so in case of 2011, according to Table 2 the annual average was set at 3.06 kJ/m² and in the case of 2012 (Table 2) the annual average value reached 3.38 kJ/m², the difference between the two years is relatively small one.

Conclusion

Taking into account the approximate surface due to north-western area of Black Sea, 93877.23 km² can make a rough calculation of the amount of energy on the surface of the waves, so for 2011 taking into account an annual average of 3.06KJ/m² results a quantity of 287.264MJ of energy. And for 2012, with an annual average 3.38KJ/m², the amount of energy equal to 317.305MJ.

The energy potential of waves generated from the NW Black Sea is modest and its almost impossible for efficient exploitation. Due to the irregularity waves and their height dependency of the year, makes the installation of wave energy recovery systems, remain an idea, a concept.

Bibliography

[1] Carbon Trust, Future Marine Energy. Results of the Marine Energy Challenge: Cost competitiveness and growth of wave and tidal stream energy, January 2006
[2] Butunoiu, D., Rusu, L. 2011b Analysis of the impact of the input wind field in modelingwaves in the Black sea, International Environmental Conference"Environmental Capacity Building, 11th -13th november 2011, Bucharest, Romania;
[3] B. V. Divinsky and R. D. Kos'yan Observed Wave Climate Trends in the Offshore Black Sea from 1990 to 2014, *SSN 0001_4370, Oceanology, 2015, Vol. 55, No. 6, pp. 837–843. © Pleiades Publishing, Inc., 2015.Original Russian Text © B.V. Divinsky, R.D. Kos'yan, 2015, published in Okeanologiya, 2015, Vol. 55, No. 6, pp. 928–934.*
[4] International Energy Agency, annual report 2012
[5] Rusu, L., Bernardino, M., Guedes Soares, C., 2014. Wind and wave modelling in the Black Sea. J. Oper. Oceanogr. 7 (1), 5–20.
[6] Copernicus
[7] ***, http://energy.sourceguides.com, Practical Ocean Energy Management Systems.
[8] MeteoInfo
[9] Microsoft office excel