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GIS-BASED ASSESSESMENT OF THE ROMANIAN MARINE AND COASTAL AREAS HYDRODYNAMICAL CHARACTERISTICS AS PART OF MARITIME SPATIAL PLANNING

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ABSTRACT

The Romanian coastal zone is strongly impacted by the marine processes, inducing a continuous emergent process nearly the sea-land interface. The sustainable anthropogenic development of the coastal zone is requiring the preservation of the natural landscape, respectively the natural characteristics and processes belonging of its specificity within different regional coastal areas, including marine natural reserves and marine protected areas/MPAs. Thus, the development and preservation of the marine activities within coastal water bodies, as well as coastal buffer areas, with specific measure of coastal protections or erosion control works, had become an activity of foremost interest. In this regard, the new methodologies and tools of the remote sensing and Geographic Information Systems (GIS) were applied to support the monitoring of the natural factors within regional coastal and maritime planned areas with intense development within Romanian Exclusive Economic Zone (EEZ). Certain results and positive effects on MSP Directive implementation, based largely on various data, are accessible in the present work, in relation with reduction of the ecological impact of the different socio-economic activities, including coastal and maritime transportation, as well as specifically designation of the coastal and marine locations for the installations of the marine energy convertors.

Key-Words: GIS, remote sensing, marine and coastal waves, wave energy, MSP

AIMS AND BACKGROUND

The need for marine renewable energy resources assessment appears from the rapid socio-economic developments, including larger energy necessities, new industrial targets and new requirements reducing the conventional energy consumptions and increasing the renewable energies.

This assessment comprises long-term wind conditions, marine wave, and currents regime, in relations with climatic trends as well as their effect on the evolution of the coastal areas (Rusu, 2015), thus bringing a particularly important aspect in evaluating and planning of the maritime activities.

The Maritime Spatial Planning (MSP) has as main target the harmonization of the maritime activities developed within the same space. Due to this concept, MSP is using certain complex analysis and methods to obtain new rules and regulations based on specific maps, emphasizing the characteristics of the areas of interest, considering the land sea interaction, marine regime hindcasts and forecasts, including marine wave power density assessments, for future deployments and future installations of energy converters. Thus, examining the feasible marine areas in which wave energy converters can be installed, based on the hydrodynamic characteristics of these areas, as well as the additional information on the potential expected situations, composed in various scenarios, in that will contribute to the general understanding of the wind, wave and marine currents fields.

EXPERIMENTAL

The common MSP applied methodology is connected to Geographic Information System (GIS) analysis and marine wave power calculations. Collecting information describing the wave energy (the driving energy of waves), having a high-performance potential of retrieval, it is predictable (up to two days before) and critical for such installations. The approach uses the planed areas that are geographically delimited for different marine activities, the relevant information on marine energy convertors and join them in a GIS environment considering the implemented EU regulations/documents targeting MSP Directive implementation at regional level.

The wave energy depends on the state of the sea, the average energy density (per square meter) at the surface of the water is proportional to the square of the wave height. The average energy density is measured in Joules per square meter and varies with the square of the average wave height.

$$E = \frac{1}{8}\rho \cdot g \cdot H^2 \tag{1}$$

From here, the wave power in W/m^2, varies with the height and period of the wave and is described by the subsequent formula:

$$P = \frac{\rho g^2}{64\pi} H^2 T \tag{2}$$

where:

ρ – density,

g – gravitational acceleration,

H– significat wave high,

T – wave period.

The current distribution of the offshore wave regime was based on the offshore data registered at the Gloria Oil Platform. Thus, the aim was to establish reference values for the significant wave height (eq. 3) and period (eq. 4) that would allow the analysis of marine processes that affect the sustainable use of marine energy converters (Shore Protection Manual).

$$\frac{g \cdot Hs}{U_A^2} = 0{,}283 \tanh \left[0.53 \left(\frac{gd}{U_A^2} \right)^{\frac{3}{4}} \right] tanh \left\{ \frac{0{,}00565 \left(\frac{gF}{U_A^2} \right)^{\frac{1}{2}}}{tanh \left[0{,}53 \left(\frac{gd}{U_A^2} \right)^{\frac{3}{4}} \right]} \right\} \qquad (3)$$

$$\frac{g \cdot T}{U_A} = 7{,}54 \tanh \left[0.833 \left(\frac{gd}{U_A^2} \right)^{\frac{3}{8}} \right] tanh \left\{ \frac{0{,}0379 \left(\frac{gF}{U_A^2} \right)^{\frac{1}{3}}}{tanh \left[0{,}833 \left(\frac{gd}{U_A^2} \right)^{\frac{3}{8}} \right]} \right\} \qquad (4)$$

where:
U_A – wind speed (m/s),
d – water depth (m),
F – fetch (m^2).

The averaged multiannual data of the marine currents within the western Black Sea, the Romanian EEZ, were provided by Copernicus Marine (CMEMS) and its distributions were achieved using GIS' tools.

The following domains were considered with the support of an explicit marine GIS environment:

- Marine environment features (physical, biological/habitats/ MPAs);
- Geographical/physiographical and meteorological conditions of the marine and coastal areas (atmospheric and marine hydrodynamic climate);
- Anthropic induced processes (quality status of the environmental constituents, technological risks, pressures on marine environment);
- Technical infrastructures networks (transport infrastructure, coastal/port management works);
- Marine and coastal activities/zoning - actual situation of marine areas for human uses (transport, fisheries, aquaculture, military training areas and facilities.

RESULTS AND DISCUSSION

The results of the wave data analysis provide an important support for the coastal planning protocols for decisional process regarding renewable energy facilities projects in EEZ (Fig.1).

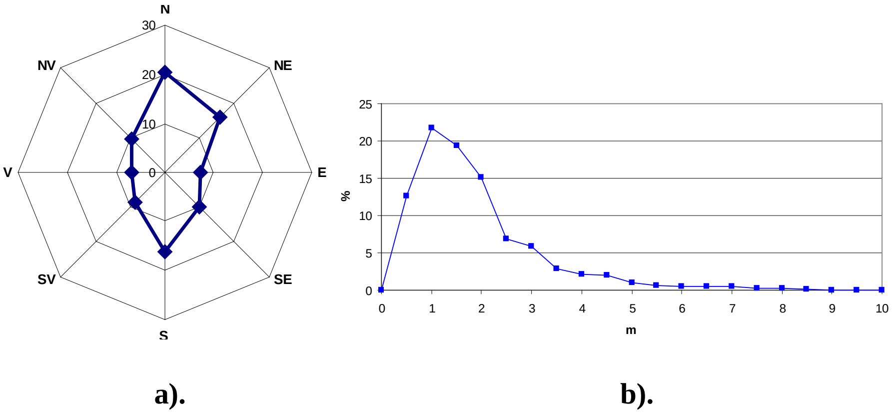

Fig. 1 a and b. Waves distributions on directions and wave high frequencies at Gloria Platform (2003 – 2009)

The calculated data regarding the power per linear meter of wave, using the equations (2), (3) and (4) was analyzed using GIS tools, particularly the Kriging interpolation, in relation with sea depth. This was estimated for concrete cases (even in this case they are calculations of reality within a specific hypothesis framework), considering the situations where the speed, wind direction, storm duration, sea depth, and fetch length are known during a specific storm. For the present simulations the equations describing the significant wave and the period were used. Based on the results of these equations, the wave power between the shoreline 0m and 100m isobaths was calculated. It should be noted that the equations describing the significant wave and its period can be used to describe the values up to the 90m isobath due to uncertainties.

A common situation in the western Black Sea was used (Cristescu, 2015), when the wind is blowing from the northwest direction, causing higher waves in the offshore marine areas, with a strong energetic impact in the coastal area. In order to resolve the equations, the fetch from the Crimean Peninsula to the Romanian shore, the northeast direction was considered as well, since the wind speed from this direction for a storm can reach and overpass at gust, a maximum value of 40 m/s.

Resolving the equations (2), (3) and (4) using the 350km fetch from NE and wind speed of 40m/s, (Niculescu et all., 2016), results a field of very large waves that would have a power between 1 kW and 6000 kW per linear meter of wave (Fig. 2).

Differences in terms of wave power when the wind is propagating from the NE or E direction are small. The shortest distance (15 km) from the shore to the area where the wave power is between 4000 kW/m and 4500 kW/m is in the southern area of the Romanian coast.

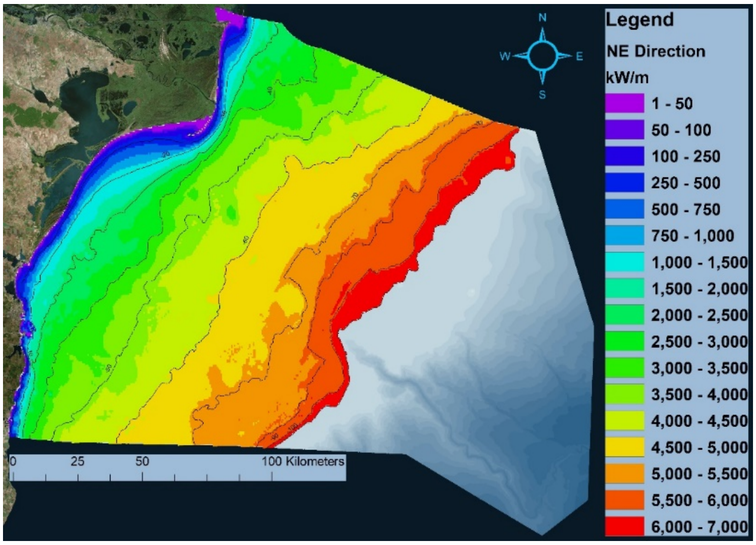

Fig. 2. Interpolated results of the power values for the NE wind waves

The marine space analysis in the context of renewable energy in the Black Sea is considering different sea surfaces all located for MPAs/Protected Marine Areas, shipping lines, port lanes, as well as the prohibited area of extractive industry/areas of oil platforms (Rusu, 2016). The various maps were created using ArcMap tools. In figure 3 the map shows the potential areas for installing the energy converters without the considered surfaces. Figure 4 presents the result of the wave power values map overlapped with the potential areas map.

The installation areas of the wave energy converters must be as close as possible to the shore in order to be connected to an electrical grid, and the power flow of the wave over a year must be as high as possible. These technologies can be created especially for every specific spot, as a converter built for a random place is not economical valuable for the northern Romanian coast, thus this technology is productive in association with different purposes.

Following these distributions, it can be observed that the area closest to the shore where the wave power is between 4MW and 4.5 MW is in the south unit of the Romanian coast, at about 40 km away from the shore. However, converters can be built to operate at a lower wave power (1 MW - 2 MW), specific to the areas, near the shore (the port area of Constanta or further south of the coast) if the protection effect of WEC is desired in specific shore area with touristic destinations. Since the wave field cannot be completely absorbed by a single wave converter park, it would be desired to have another one after it, to convert the remaining power (batteries of converters specifically designed to absorb the power of the remaining waves) from the first row of wave converters without affecting the MPA network (Perez-Collazo *et al*., 2015).

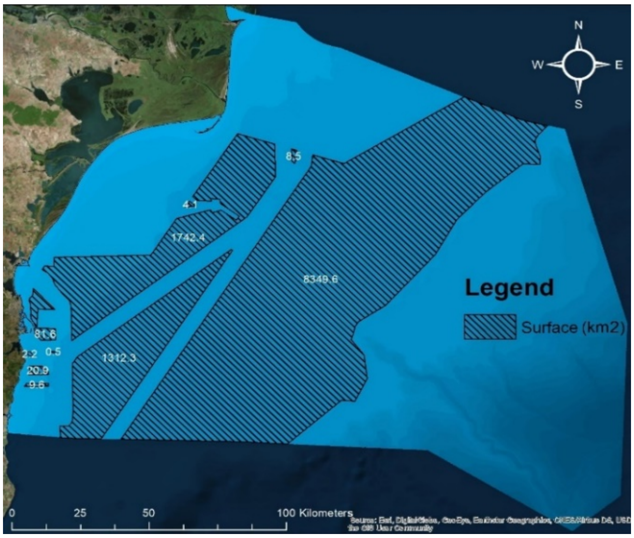

Fig. 3. Potential areas for the wave power converters positioning after protected areas of community interest have been eliminated

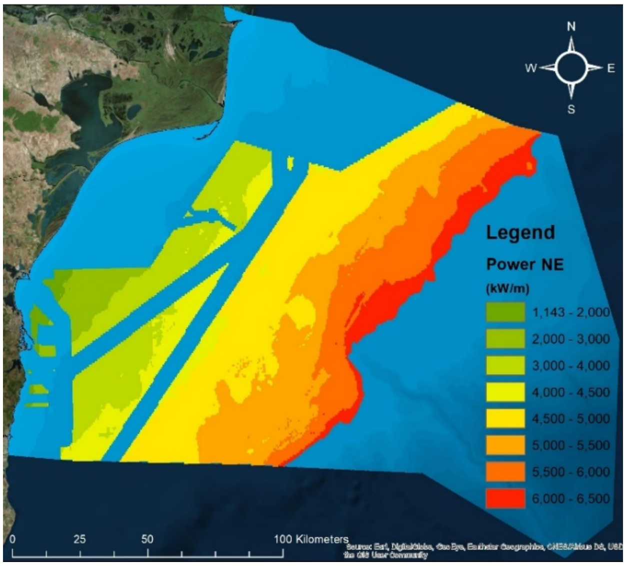

Fig. 4. Wave power intensity map of the remaining surface

The specific and atypical characteristics induced in the wave fields by the presence of marine currents, requires to be studied further as it's an important factor that determines the wave power and propagation (Fig.5).

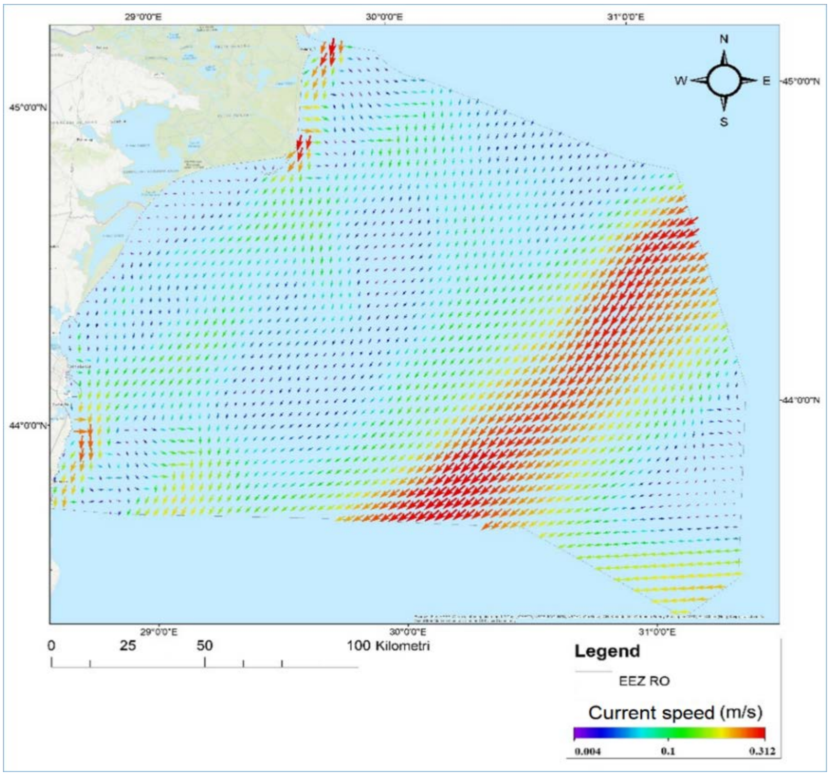

Fig. 5. Marine currents multiannual average distribution, represented in ArcGIS using CMEMS data (Copernicus Marine)

For hybrid convectors, using wave power and marine currents, the best scenario is to install them in areas where the marine current fields are relative opposite to the directions of the incident wave propagation.

CONCLUSIONS

Analysis of the marine space in the context of renewable energy industrial use offers a perspective on the potential of renewable energy in the Black Sea considering the available sea surface for the installation of various types of converters.

The identification methods are useful for selecting and/or identifying the areas of interest for unconventional energy extraction, and the marine processes energy concentration, as well as identifying the models that can be applied to the Black Sea (in case of obtaining access to parameters, results, and statistics), anomalies between the forecasts and the terrain or satellite data to reveal specific local characteristics that can be improved by complex and realistic forecasting procedures.

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