Revue des Energies Renouvelables Vol. 20 N°3 (2017) 377 - 388
DOI: https://doi.org/10.54966/jreen.v20i3.634

Development of a numerical code to simulate the hydrodynamic energy potential, applied at Bou Ismail bay

Khalid Amarouche [1,*], Nour El Islam Bachari [2,†], Fouzia Houma [1] and Abdelhak Boughrira [1]

[1] The Marine and Coastal Ecosystems Laboratory
The National School of Marine Sciences and Coastal Management, ENSSMAL
Campus Dely Ibrahim Bois des Cars, Algiers, Algeria
[2] The Spatial Oceanography Laboratory, Faculty of Biological Sciences
University of Science and Technology of Houari Boumediene, USTHB
P.O. Box 32, El Alia, Bab Ezzouar, 16111 Algiers, Algeria

(reçu le 10 Septembre 2017 - accepté le 30 Septembre 2017)

Abstract - *The knowledge of wave energy propagation in the shallow water allow us to understand the functioning of marine ecosystems and to give answers about several costal phenomena. In the Algerian coast, the waves are omnipresent with an energy that is stripped under different physical forms. The classification of areas with high hydrodynamic energy potential requires a large data flow, concerning the physical hydrodynamic parameters produced by this energy. In this study we have developed a numerical code based on various mathematical theories and equations describing the physical state of the wave, including the formulas of MUNK, Coastal Engineering Research Center, 'CERC' and of the French Central Hydraulics Laboratory, 'LCHF', based on the output data of the SWAN model. This code allowed us to measure several wave's physical parameters sufficiently well in order to understand and quantify the energies transmitted along the coast. A spatial analysis of the obtained results allowed us to classify seven coastal stations with an average wave energy exceeding 20 kW/m in the stormy days.*

Résumé - *La connaissance de la propagation de l'énergie des vagues dans des eaux peu profondes nous permettra de comprendre le fonctionnement des écosystèmes marins et de donner des réponses à propos de nombreux phénomènes côtiers. Dans les côtes algériennes, les vagues sont omniprésentes avec une énergie réduite sous de nombreuses formes physiques. La classification de régions possédant un potentiel élevé d'énergie hydrodynamique nécessite une importante quantité de données qui concernent les paramètres physiques hydrodynamiques produits par cette énergie. Dans cette étude, nous avons développé un code de calcul basé sur de nombreuses théories mathématiques et équations qui décrivent l'état physique des vagues, comprenant les formules de MUNK, du 'CERC' et du laboratoire central d'hydraulique français 'LCHF', basés sur les données obtenues à partir du modèle SWAN. Ce code nous a permis de mesurer de nombreux paramètres physiques des vagues suffisamment bien pour comprendre et quantifier l'énergie transmise le long des côtes. Une analyse spatiale des résultats obtenus a permis de classer sept stations côtières avec une énergie de vague moyenne supérieure à 20 kW/m en temps orageux.*

Keywords: Coastal hydrodynamics - Wave propagation - Wave modeling - Wave energy - Storm waves.

1. INTRODUCTION

Currently, there is no database of the coastal hydrodynamic at the Algerian coast; the knowledge of this data remains paramount in Bou Ismail Bay. This bay has a very strong economic tendency in different sectors: the tourism sector with 20 km of coastline beaches, the aquaculture sector with fish and shellfish farming projects, the fishing sector with six fishing ports, and the maritime engineering sector with more than

---

[*] amarouchekhalid@gmail.com
[†] bacharinouri@gmail.com

Coastal protection structures. Thus, the importance of hydrodynamic data is not limited in these sectors, this data is essential for the study of coastal vulnerability, and the determination of dangerous areas for navigation and swimming. Moreover, these data may contain answers to chemical, physical and biological phenomena.

The waves generated by the winds are in reality under a complex for. These waves disperse in the sea with different wavelength and speed (Bougis, 1993). The energy of the offshore waves is more important than the near-shore waves (Shin *et al.*, 2013) but Coastal zones do not have the same energy potential; the distribution of this hydrodynamic energy depends on several factors, including coastal morphology. There are several measuring instruments that can be used to calculate the wave-energy dissipation, but its use remains very expensive, lasts too long, and still tolerates some percentage error. The In-situ measurements of the wave-energy dissipation in the near shore are difficult. (Bass, 2013).

The numerical simulation of the hydrodynamic behavior remains the least costly method and the fastest, as well the hydrodynamic modeling allows us to simulate the state of the sea according to differ climate condition likely and according to the weather history. Wave modelling using 3rd generation numerical spectral wind wave models from known wind fields and bathymetries, has gone from the art state to the practice state during the recent decade (Christensen *et al.*, 2013). In this study, we have used the numerical Model SWAN (Simulating Waves Nearshore); this model is executable in third generation mode (Booij *et al.*, 1999. Mouakkir *et al.*, 2008).

The purpose of this study is to answer two main problems:

- How can we use the output data of the numerical model SWAN to simulate the coastal energy potential?
- What are the coastal areas with high hydrodynamic activity at the Bou Ismail Bay?

In this study, we processed the energy forms responsible for wave generation and simulated the propagation of this energy in its various forms (current and waves). To achieve this study, we have developed a numeric code, which allows us to obtain more wave parameters from the results of the SWAN model, complemented with the slope data and the coastline orientation.

The aim of ours numerical code is to help us to understand well the process of the wave energy propagation, and to define the areas with high energy dissipation, areas of energy concentration, and the sheltered areas in the more violent storms days which are observed between 2002 and 2016 at Bou Ismail bay.

This work presents also a methodology that allowed us to classify areas with high hydrodynamic potential along the shore using a spatial analysis based on thematic maps such as the wave energy maps, the significant wave height, celerity, energy transmitted to the shore per linear meter, orbital current, elevation mean level of oscillation and the long-shore drift velocity maps. The results obtained in this study have been processed, mapped under ArcGIS10.3 and recorded under a tabular geo-database.

2. STUDY AREA

Bou Ismail Bay extends over à length of 47 km with a wide continental shelf of 11 km (figure 1); it is bounded on the east by the promontory of Ras-Acrata while on the west is limited by the Cape of Mount-Chenoua. This bay presents an important economic area that brings various investments in tourism, industry, fisheries and the energetic sectors. (Houma, 2009). This bay is characterized by a mobile bottom (figure 2), which knows a strong dynamic activity. In the shoreline, twenty protections infrastructures have been installed, which confirms the strong hydrodynamic activity at this bay.

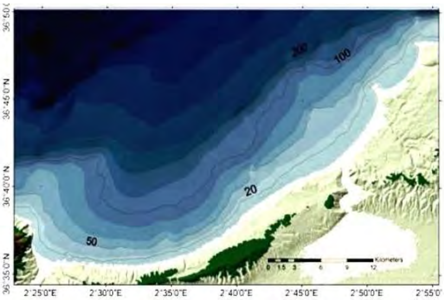

Fig. 1: Bathymetric Map of Bou Ismail Bay (coastal management plan PAC2005)

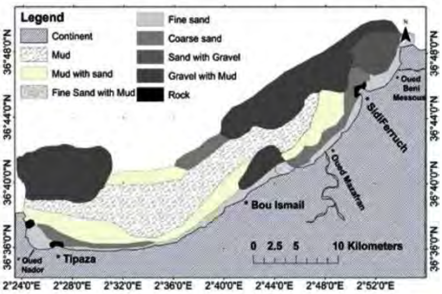

Fig. 2: Sediment map for the coastal management plan (PAC2005)

3. METHODOLOGY

There is no expressed theoretical methods at meso-scale to study the wave propagation. The methods commonly used are continuous wave observations based on in-situ instruments, and numerical forecasts founded on wind data and other forces generating and modifying the wave (Bachari *et al.*, 2017). The best solution to simulate the daily wave's parameters in different sites is by using the digital wave-wind model. (Mondon *et al.*, 2009).

To answer our problematic, we used the SWAN model, that has been already developed, implemented, and validated (Booj *et al.*, 2009). The first step in this study is the collection and processing of the input data such as the wave's generating and modifying forces.

The second step is the preparation of the model execution commands; meanwhile the third step is the development of the numerical code, which allowed us to calculate other wave parameters essential for the understanding of the coastal hydrodynamic behavior, and for the simulation of the nearshore's wave energy propagation.

3.1 Data collection and processing

The input data used in the numerical modeling are the speed and direction of wind recorded every three hours for 14 years, daily sea level anomaly, and the daily absolute geostrophic velocities. The input data used in our program are the output data giving by SWAN such as significant heights, wave period, wavelength, and wave direction in degrees, completed by a digital grid of the slopes and the coastline orientation.

3.1.1 The wind

Wind is the main force responsible for generating waves. The wave height generally depends on the wind speed and its persistence. In this study, we filtered the most violent storm days recorded monthly for 14 years.

We selected this primary condition because during stormy days, we can record the hydrodynamic activity along the coast, even in the most sheltered areas, which allowed us to better observe the wave energy propagation along the coast, and allowed us also to classify the coastal area according to their energy potential. The synoptic wind data is obtained from the coastal weather station, 36° 46'N, 03° 04' E of the National Weather Office, 'ONM'.

The following histogram shows the days with extreme winds speed with persistence that exceeded 13 hours.

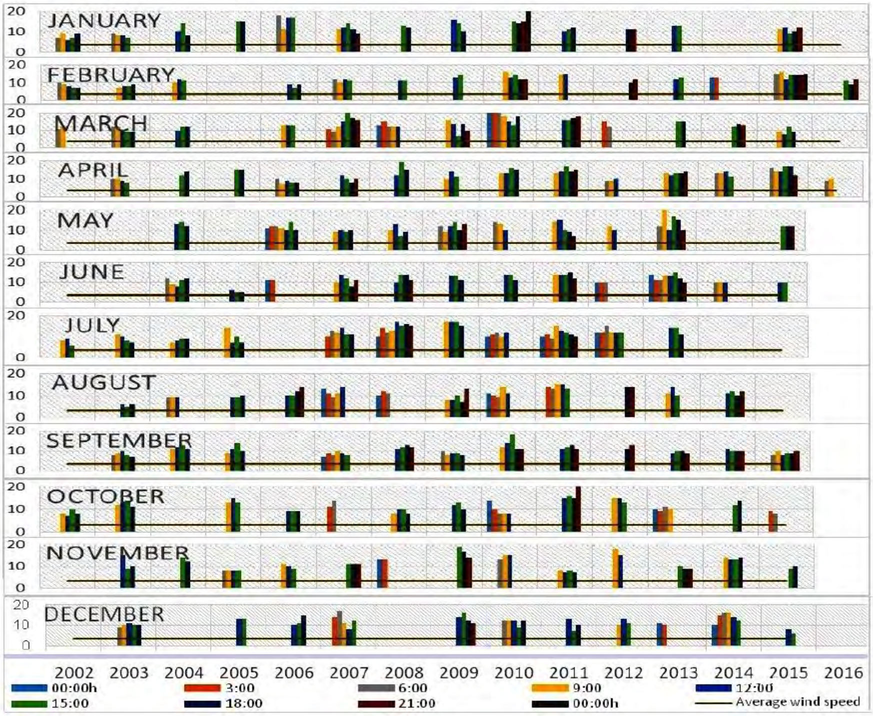

Fig. 3: The wind speeds recorded on the most storms days between 2002 and 2016

The dominant directions of these extreme winds are illustrated by speed classes in the following rose of wind.

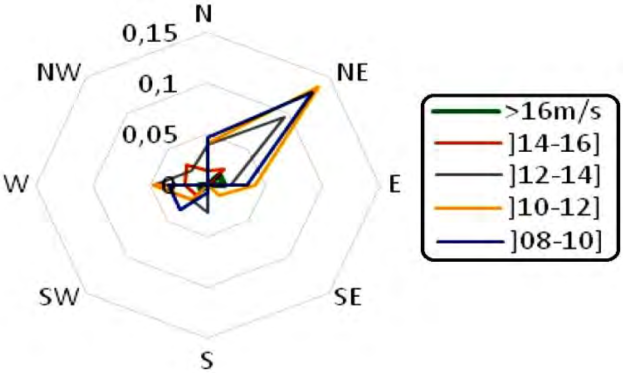

Fig. 4: Rose of the Winds recorded during 121 storms days between 2002 and 2016

3.1.2 Daily sea level and daily absolute geostrophic velocities

In addition to the wind data (wave generating force), we also processed two modifying forces: Daily sea level and daily Absolute Geostrophic Velocities. These two data were processed by the Copernicus Marine and Environment Monitoring Service, CMEMS', and distributed by the Aviso+ website,

(https://www.aviso.altimetry.fr/en/my-aviso.html).

They were provided under NetCdf format, convertible to raster format under ArcGIS 10.3. Therefore, we have digitized this data in order to develop a regular grid to introduce it into the SWAN model commands.

3.1.3 Boundary conditions

To predict the model boundary conditions, we used the Bretschneider abacus; a monogram based on the Sverdrup-Munk-Bretschneiderformulas, improved by Bretschneider in 1977 after treatment of a significant data numbers obtained from the US Coastal Engineering Center (Bougis, 2003).

This formula is recommended by the shore protection manual of US army (SPM), and considered one of the two most widely used formulas in North America with those of Hasselmann. (Jarry, 2009).

4. THE DEVELOPED NUMERICAL CODE

The numerical code developed in this study is able to measure several parameters, essential to understand the hydrodynamic behavior in the nearshore, and essential to identify and classify the area with a high-energy potential. This numerical code was developed using the C++ environment, it is adapted to the output file format of the SWAN model and requires other morphological data to calculate the longshore drift velocity (the slopes and the coastline orientation).

4.1 Parameters measured by the numerical code

The measured hydrodynamic parameters by our code are: the Wave energy (kJ/m^2), Wave Celerity and group velocity (m/s), Energy transport by linear wave meter (kW/m), Elevation mean level of oscillation (surf beat), the energy propagation velocity (m/s), drift velocity (m/s) and the sedimentary transport. These parameters can contribute at different fields in the coastal research.

4.1.1 The wave energy

The deformation of the surface water caused by wind and the transmitted water particles, give the swell a mechanical Energy. This energy is the sum of the potential and kinetic energy; it is considered as the total energy Contained in a wavelength per linear meter of Crest, (Larras, 1979; Damy et al., 1981; Bonnefille, 1992; Dominic *et al.*, 1998; Holthuijsen, 2007). In our numerical code, this energy is expressed by:

$$E = E_p + E_c = \frac{1}{8}\rho \,.\, g \,.\, H_s^2 \qquad (1)$$

4.1.2 Wave celerity and group velocity

The concept of celerity and group wave velocity, are particularly important in the discussion of the wave energy propagation, in our code, the celerity (C) and the group velocity (C_g) are given by the following formulas (Reeve *et al.*, 2004)

$$C_g = \frac{C}{2}\left(1 + \frac{4\pi d/L}{\mathrm{Sh}(4\pi d/L)}\right) \qquad (2)$$

$$C = \sqrt{(gL/2\pi)\tanh(2\pi d/L)} \qquad (3)$$

The group velocity is proportional to the period T, to the square root of the wavelength L, and to the depth d. This wave character allow us to determine the energy flow.

4.1.3 The energy transport

Generally, the transmitted energy by linear meter, referred to the power of the wave (Larras, 1979), it is the result of the stored energy per the surface unit and the wave group velocity. (Bonnefille, 1992).

$$E_t = \frac{1}{16} \rho g H_s^2 \frac{L}{T} \left(1 + \frac{4\pi d/L}{\mathrm{Sh}(4\pi d/L)} \right) \tag{4}$$

4.1.4 Elevation mean level of oscillation (wave set-up)

The mean sea level caused by swell oscillation, was noted by Munk (1949) and Tucker (1950). This phenomenon is caused by short-period wave groups (Nakaza *et al.*, 1991). The formula used to estimate this elevation is that of Miche's wave in the second order of approximation defined by Larras. (Larras, 1979).

$$\zeta_M = \frac{\pi^2 H^2}{2gT^2} \left(1 + \frac{3}{2\mathrm{Sh}^2(2\pi d/L)} \right) \cot h^2(2\pi d/L) \tag{5}$$

4.1.5 Long-shore drifting

When the waves reached the beach with some obliquity, they generate a linear current parallel to the shoreline called the Long-shore drifting. The speed of littoral drift depends on several factors: wave period, wave incidence angle (α) relative to the coastline, height wave breaking H, slope (p) in percent, and the roughness bottom.

To estimate the Long-shore drifting velocity, it exist two formulas that are often confirmed by the verification measures realized on the ground. The formula of Longuet-Higgins (1970) modified by the C-E.R.C. (Coastal Engineering Research Center of U.S.A.). (Paskoff, 1994)

$$u = 20.7 \times \sqrt{gH}\, p \times \sin(2\alpha) \tag{6}$$

and the formula of Putnam, Munk and Traylor (1949), edited by J. Larras (Larras, 1979):

$$u = 2.58 \times \sqrt[3]{\frac{gH^2}{T} + p \times \sin(2\alpha)} \tag{7}$$

Our program uses these two formulas to calculate the drift current velocity.

4.1.6 Sediment transport

Generally, the littoral drift causes a sedimentary transport parallel to the shoreline. These movements can result a significant erosion or accumulation in a local or regional scale (C.E.R.C., 1984), this variation can influence the wave propagation and vice versa.

To estimate the coastline sedimentary transport, we have used the formula of the French Central Hydraulics Laboratory (L.C.H.F).

$$Q = \frac{1.8 * 10^{-6}}{\sqrt{d}\, m} \times \frac{gTH^2 t}{X_0} \times \sin(2\alpha) \tag{8}$$

Q represents the volume transported in m^3 during the action time t. g is the gravity acceleration. X_0 is the waves camber in deep water.

5. RESULTS AND DISCUSSIONS

The output data obtained by the SWAN model and by the developed numerical code were mapped with ArcGIS10.3 to perform a spatial analysis, which allows us to understand the wave propagation along the Bou Ismail bay. A spatial analysis between the different wave parameters performed by maps, allowed us to carry out a first selection of the most dynamic areas.

The parameters used in this analysis are the significant wave heights, orbital current velocities, drift current velocities, the sea level elevation caused by the wave oscillation, wave celerity, Wave energy in kJ/m^2 and the energy transport in kW per linear meter.

21.04.2015 Wind direction: NNE Wind speed: 14m/s Persistence: 15h

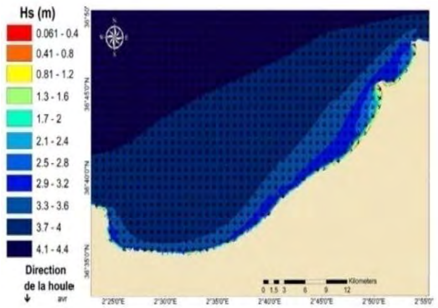

Fig. 5: Significant wave heights. Storm of 21.04.2015

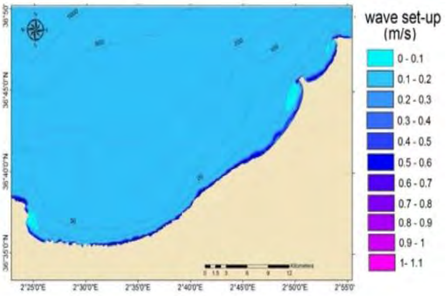

Fig. 6: Mean level elevation caused by the wave oscillation. Storm of 21.04.2015

The results of the significant wave heights (figure 5) recorded monthly during the most violent storm days show that several coastal areasare affected by a significant height that exceeds 3 m, specifically at the western and central part of the bay and at Mount-Chenoua and Ras-Acrata.

This forte amplitude combined with sea-level rise of 0.7 m (figure 6) caused by the wave oscillation, present a real risk of submersion, and an enormous energy that dissipates directly on the shore.

This result confirms that in the Algerian coast, the storms responsible for the wave generation are the main reason of the flooding in the coastal areas and can have disastrous consequences, mentioned by Nacef *et al.*, 2016.

Adding the results of the wave energy propagation velocities (figure 7) and wave celerity (figure 8) to our analysis, we noted that the mean wave energy propagation velocity exceeds 2.8 m/s during the stormy days at the western and central coasts, and exceeds 3.2 m/s at the bay boundaries: Mount-Chenoua and Ras-Acrata.

These results allowed us to give a first improvisation of the coastal zones affected by an important wave activity.

The orbital currents velocity and the coastal drift velocity (figures 9 et 10) are proportional to the significant wave heights and to the coastal morphology.

These results confirm the strong hydrodynamic activity in the central part of the bay and in front of the Mount-Chenoua, where the coastal drift velocity exceeding 2 m/s and the orbital currents exceeding 0.8 m/s on the stormy days. The maximum orbital current velocity and the drift current speeds, which are recorded in front of Ras-Acrata, exceed 0.9 m/s and 5 m/s respectively.

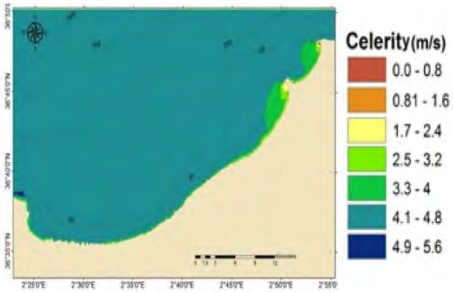

Fig. 7: Waves celerity map. Storm of 21.04.2015

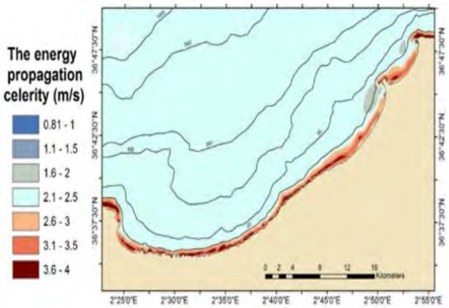

Fig. 8: Propagation velocities of the wave energy. Storm of 21.04.2015

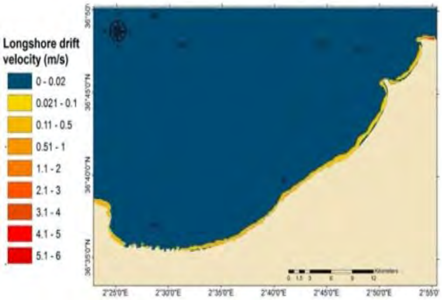

Fig. 9: Longshore drift velocity. Storm of 21.04.2015

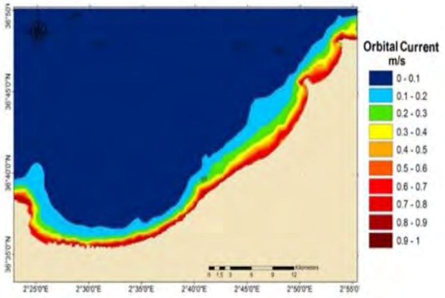

Fig. 10: Orbital current velocity. Storm of 21.04.2015

5.1 Quantification of the energetic potential

Our code allowed us to simulate two important parameters and quantify the energetic wave potential in the nearshore. The mean and maximum energy recorded on the storm days were calculated using a raster calculator under Arcgis 10.3.

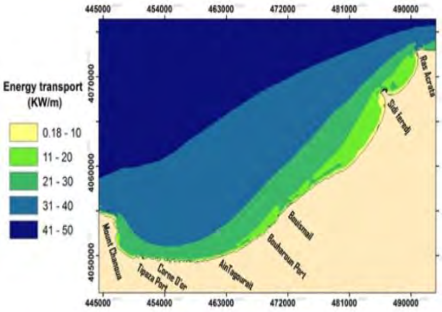

Fig. 11: The monthly average of the energy transport in the stormy days

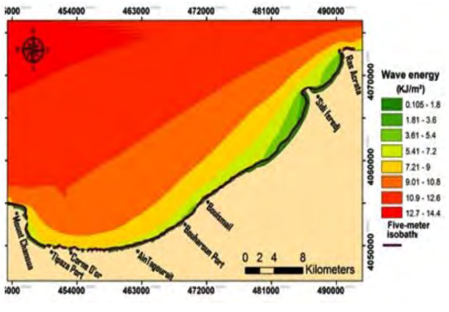

Fig. 12: The monthly average of the energy in the stormy days

From the results of the wave energy per area unit, we noted that storms generate a significant offshore energy that can exceeds 14 kJ/m^2 (Michard, 2014).

The spatial extraction of the average energy (figures 11 et 12) at the 5-meter isobath, allowed us to plot the following profiles.

Thus, we noted that the energy transport exceeds 50 kW/m near the Tipaza port and exceeds 80 kW/m in front of Mount-Chenoua and Ras-Acrata. This energy recorded at these three stations exceeds the highest average energy recorded during winter in France, more precisely at the Bayonne coastal station.

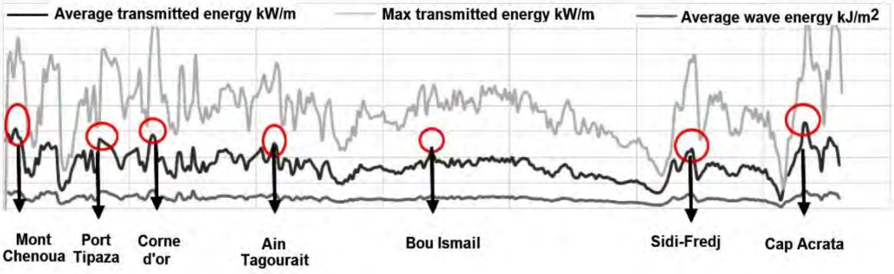

Fig. 13: The wave energy profile taken at the five-meter isobath

These profiles allowed us to record seven major peak, with four coastal stations in the west of the bay, one station in the center and two stations in the east. Five of these stations have an average energy that exceeds 20 kW per linear meter.

The following histograms (figure 14) shows the amount of the monthly energy recorded in these five stations, during the most severe storms.

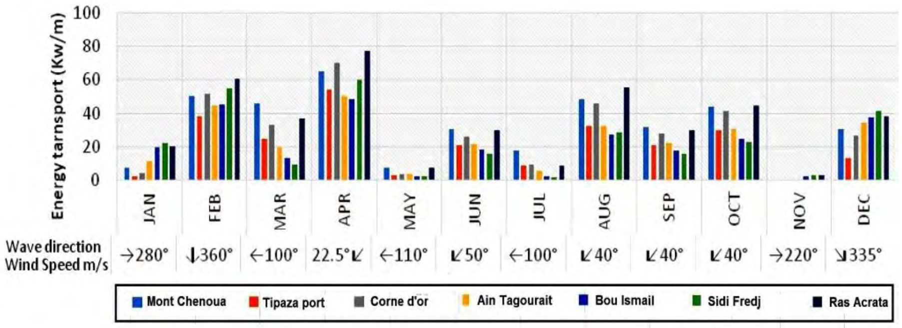

Fig. 14: Histograms of the averages energy transport at the seven stations

These histograms show that the wave energy recorded at these seven coastal stations depends essentially on the direction of the wind. The highest energy potential was recorded in the north and north-north-east wind direction.

The highest energy transmitted to the coast was recorded at Mount-Chenoua and at Ras-Acrata, where the highest orbital currents and drift current are recorded. Such energy near the shoreline can be destructive or constructive in the case of its exploitation.

The bi-conversion of the wave energy and the current energy can be more profitable and economic, if considering its proximity to the shore, and its high potential.

6 CONCLUSION

The marine hydrodynamic activity is a very complex phenomenon that requires the knowledge of several physical parameters. In this study, we developed a numerical code based on various mathematical theories and equations describing the physical state of the wave, including the formulas of Munk, C-E.R.C and LCHF.

This code allowed us to exploit much better the results of the SWAN model, it permitted the measure of several wave parameters, which are essential to understand the hydrodynamic behavior and quantify the energies transmitted along the coast.

A spatial analysis among the different wave parameters performed by numerical maps and explained by graphs, allowed us to carry out a first selection of the most dynamic coastal areas. Seven coastal stations have been classified, with an average wave energy exceeding 20 kW/m in the stormy days.

A combination between GIS, numerical models and programming tools allowed us to simulate the spread of marine energies at the nearshore. Thus, these tools allow us to quantify the energies transmitted in the seven areas at annual scale.

The results of the dissipated energy amount near the coast on stormy days, constitutes a pivotal information for the coastal safety services to identify the areas that constitute a risk for navigation. In addition, it contribute in the coastal engineering projects such as the identification of the vulnerable coastal areas, and the selection of the adequate areas for the aquaculture facilities.

Acknowledgements- The authors wish to thank Dr. L. Nacef of The Spatial Oceanography Laboratory, University of Science and Technology of Houari Boumedien, for sharing their invaluable insights and experiences in meteorology.

Funding- This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors.

REFERENCES

[1] N.E.I. Bachari, F. Houma and K. Amarouche, '*Combination of Satellite Images and Numerical Model for the State Followed the Coast of the Bay of Bejaia, Jijel',* Vol. 4, N°1, 7 p., 2017.

[2] S.J. Bass, '*Ambient Noise and Wave Breaking on a Sandy Beach: Energy Dissipation Estimates*', Journal of Coastal Research, N°65, International Coastal Symposium, Vol. 2, pp. 1721 - 1726, 2013. https://doi.org/10.2112/SI65-291.1.

[3] R. Bonnefille, '*Cours d'Hydraulique Maritime*', 3ème Edition, Masson, Paris, 209 p., 1992. ISSN : 0992-36 5538.

[4] N. Booij, R.C. Ris and L.H. Holthuijsen, '*A Third-Generation Wave Model for Coastal Regions: 1. Model Description and Validation*'. Journal of Geophysical Research: Oceans, Vol. 104, N°C4, pp. 7649 - 7666, 1999. https://doi.org/10.1029/98JC02622.

[5] J. Bougis, '*Les Houles Périodiques Simples*', Institut des Sciences de l'Ingénieur de Toulon et du Var, Université de Toulon et du Var, 1993.

[6] J. Bougis, '*Les Etats de Mer Naturels*', Institut des Sciences de l'Ingénieur de Toulon et du Var, Université de Toulon et du Var, 2003.

[7] CERC, 'Coastal Engineering Research Centre', '*The Shore Manual Protection*', Vol. 1, Department of the US Army, Waterways Experiment Station, Corps of Engineers PC Box 631 9 Vicksburg, Mississippi 39180, 1984.

[8] E.D. Christensen, M. Johnson, O.R. Sorensen, C.B. Hasager, M. Badger and S.E. Larsen, '*Transmission of Wave Energy through an Offshore Wind Turbine Farm*', Coastal Engineering, Vol. 82, 25-12 46, 2013. https://doi.org/10.1016/j.coastaleng.2013.08.004.

[9] G. Damy and M. Gauthier, '*Production d'Energie à Partir de la Houle*', Bretagne: Ifremer Copyright: 1982 CNEXO – COB, 1981.

[10] L.H. Holthuijsen, '*Waves in Oceanic and Coastal Waters*', [Ed.] Delft University of Technology and UNESCO-IHE. NewYork: Cambridge University Press, 387 p., 2007. ISBN- 13 978-0-511-17 27021-5. https://doi.org/10.1017/CBO9780511618536.

[11] F.B. Houma, '*Modélisation et Cartographie de la Pollution Marine et de la Bathymétrie à partir de l'Imagerie Satellitaire*', Thèse Doctorale, Université Paris-Est, 2009. <NNT : 2009PEST0065>.

[12] N. Jarry, '*Etudes Expérimentales et Numériques de la Propagation des Vagues au-dessus de Bathymétries Complexes en Milieu Côtier*', Thèse Doctorale, Université du Sud Toulon Var, 2009.

[13] J. Larras, '*Physique de la Houle et des Lames*', Vol. 36, Eyrolles, 282 p., ISBN13: 978-2-212-23 05189-6. 1979.

[14] B. Michard, E. Cosquer and G. Dufour, '*Projet EMACOP: Evaluation du Potentiel Houlomoteur de 22 Sites Français en Manche et Atlantique*', In XIIIth Journées Nationales Génie Côtier, Génie Civil, 2-4 juillet 2014, Dunkerque. https://doi.org/10.5150/jngcgc.2014.082.

[15] E. Mondon and P. Warner, '*Synthesis of a Validated Nearshore Operational Wave Database Using the Archived NOAA Wave Watch III Ocean Model Data and SWAN Nearshore Model*', Journal of Coastal Research, N°56, pp. 1015 - 1019, 2009.

[16] L. Mouakkir, H. Smaoui, S. Mordane and M. Chagdali, '*Modélisation Numérique de l'Hydrodynamique avec Interaction Houle-Courant*', [Ed.] Université Hassan II. Casablanca, DOI: 10.5150/jngcgc.2008.041-M. 2008.

[17] L. Nacef, N.E.I. Bachari and N. Kessali, '*Climate Variability and Storminess in Algerian Coastal Areas: Approach by Integrating Spatial and Temporal Scales*', Wulfenia Journal, Klagenfurt, Austria, Vol. 23, N°3, pp. 353 - 359, 2016.

[18] E. Nakaza and M. Hino, '*Bore-like Surf Beat in a Reef Zone Caused by Wave Groups of Incident Short Period Waves*', Fluid Dynamics Research, Vol. 7, N°2, pp. 89 - 100, 1991.

[19] R. Paskoff, 'Les Littoraux. Impact des Aménagements sur leur Evolution', Paris, Masson, Edition, 256 p., ISBN 2-225-84324-4, 1994.

[20] D. Reeve, A. Chadwick and C. Fleming, '*Coastal Engineering: Processes, Theory and Design Practice*', CRC Press. London and NewYork: Spon. Press, 461 p., ISBN 0-203-67558-4, 2014.

[21] S. Shin, K.H. Lee, D.S. Kim, K.H. Kim and K. Hong, '*A Study on the Optimal Shape of Wave Energy Conversion System Using an Oscillating Water Column*', Journal of Coastal Research, N°65, International Coastal Symposium, Vol. 2, pp. 1663 - 1668, 2013.