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INTERNATIONAL SYMPOSIUM ON GIS APPLICATIONS IN GEOGRAPHY & GEOSCIENCES



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PREFACE

The International Symposium on GIS Applications in Geography and Geosciences (ISGGG) was held in Çanakkale Onsekiz Mart University during 18-21 October 2017. The symposium brought together various researchers in different fields and enabled participants to share and discuss their ideas and research results.

Approximately 270 people attended to the symposium, which organized as keynote lectures, oral and poster presentations and also "UAV for GIS" certificate program.

There were five keynote lectures covering the different areas of the symposium: Prof. Dr. Paul Bates (University of Bristol, UK) talked on "*Using GIS to Build Global Flood Hazard Models*", Prof. Dr. Tahsin Yomralıoğlu (Istanbul Technical University, Turkey) on "*Geographical Information Paradigm*", Prof. Dr. Magdy Torab (Damanhour University, Egypt) on "*Some Applications in The Usage of GIS in Geo- archaeological Researches*", Prof. Dr. Haluk Özener (Bogazici University, Turkey) on "*Earthquake and Tsunami Information System at KOERI*" and Dr. Fabiana Calò (National Research Council of Italy, Italy) on "*SAR- based Remote Sensing for Natural Hazards Analysis*".

This book contains the full papers those submitted by their authors following the symposium. Papers were organized according to the symposium topics. The editorial board checked only the format of the papers and necessary arrangements have been made. Therefore, authors have complete responsibility for the content of the papers.

We would like to thank all the contributors and attendees. We were honored by your support and participation to the ISGGG 2017.

Editorial Board

Study of the Coastal Wave Energy Propagation Using GIS and Hydrodynamic Model

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ABSTRACT

The monitoring and study of the wave energy propagation along the coast presents a very difficult task, account of the significant daily variation of the sea states. In this study, we have developed a GIS for the analysis, processing and monitoring of the Wave energy propagation along the coast under these different form. The large number of results led us to carry out a spatial analysis using raster calculator tool, which allowed us to better present and interpreted the SWAN output (simulation wave near-shore model). In order to classify coastal zones with high-energy potential we carried out a spatial multicriteria analysis which allowed us to select three zones in the near-shore with an average wave power greater than 35kW/m on stormy days.

INTRODUCTION

Currently more than 40% of the Algerian population is on the coastal strip, which constitutes 1.8% of the country (Kateb, 2003). This high concentration near the coastline is related to considerable economic activity in various sectors (Magnan, 2009), also the climate change and the high human exploitation in these coastal areas make them more exposed to natural hazards (Simav et al., 2013). Our study area (BouIsmail Bay) is located 15 km west of Algiers; it represents an important economic and tourist zone with a coastline of 65 km. Account of the absence of wave and current measuring instruments in this bay, the hydrodynamic regime is unknown. The wave propagation measurements is a fairly expensive and difficult (Bass, 2013; Castelle, 2004) and the number of wave measuring instruments that can be installed in a given period remains limited for economic reasons (Aydoğan et al., 2013). Therefore, we are based on the SWAN model (Simulating Waves Nearshore) version 40.41; a discrete spectral model Based on the wave action balance equation (Booji et al., 1999) add to the meteorological database of 14 years of the weather station located at 36 ° 46 ' N and 03 ° 04' E. Several cases of SWAN model evaluation studies

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in different regions of the world and with different input data sources have shown the good precision of its output results with an underestimation of significantheights and periods in some cases (Akpınar et al., 2012; Bottema and Beyer, 2002; Dragani et al., 2008; Dykes et al., 2002). This underestimation may be related to the input data accuracy (Akpınar et al., 2012).

This study aims to develop a methodology that allows us to study the propagation of the wave energy along the coast and selected areas with high-energy potential. These energies can be destructive or constructive; it may constitute a risk to navigation, mooring, swimming, and erosion, as it may be a favorable resource for the renewable marine energy. The methodology developed is based on a combination between the Swan hydrodynamic model and GIS tools that allows us to represent, communicate and clarify the output data information (Loubersac et al., 2000). GIS allows the storage of multidisciplinary data and allows to inspect the relationships between them in different scales and in a digital format (Szlafsztein & Sterr, 2007). The large amount of numerical information of the input and output data from the hydrodynamic model requires to be stored in a tabular Geodatabases , also a spatial statistical analysis using raster calculator tools has allowed us to better present and interpret our results. To classify the coastal areas with high-energy potential we carried out a spatial multicriteria analysis, which make us to select three station with an average wave power (Et) greater than 35kW/m on stormy days.

Two Geodatabases have resulted from this work, the first includes the input, output data of the hydrodynamic model SWAN, and the second database contains the data processed and analyzed. These data are indicators and tools for decision-making in coastal management projects and for the safety of maritime navigation.

METHODOLOGY

The methodology developed for monitoring the propagation of wave energy along the coast and for the selection of zones with high energy potential can be summarized in two steps:

1- The hydrodynamic modeling: Six offshore wave conditions from the N, NNE, NE, E, NW, and W directions were modeled. These six conditions represent the six most violent storms recorded during 14 years by the weather station of the ONM (National Weather Office) (Table.1). The results of the wave energy propagation on stormy days allow us to better observe their behavior even in the most sheltered areas.

Table 1. Condition of the modeled stormy days

Stormy days	**14/01/2010**	**18/02/2015**	**06/03/2010**	**21/04/2015**	**21/10/2011**	**10/12/2014**
Wind speed	>14	>14	>17	>14	>15	>14
Persistence	9h	18h	>15h	15h	9h	12h
Wind direction	280°	360°	100°	22°	40°	330°
Wave height	2.3 m	3.5 m	4.5 m	4 m	3.2 m	2.8 m
Wave periode	6.7 s	9 s	9.5 s	10 s	8.3 m	8 s

2- Development of a GIS under ArcGIS10.3 for the processing of results and for the classification of areas with high hydrodynamic potential. This part of our work is summarized in three steps:

- Creation of the spatial tabular Geo-database and mapping of model results
- Spatial analysis: It is a spatialized statistical analysis of data (Bachouche et al., 2016). In this section, we calculated the averages, variances, and maximum wave power along the coast using the GIS tool raster calculators.
- •Spatial multi-criteria analysis; to select the nearshore areas with high wave power, whatever the conditions of the offshore wave.

DATA COLLECTION AND PROCESSING

The data used in this study are the wave generating forces and the modifying forces including the winds, the sea level variation and the geostrophic Velocities. Synoptic wind data recorded between 2002 and 2016 were processed to filter out the six most violent storms that blew in six different directions opposite to the coastline. Sea level and current data have been downloaded from the Aviso+ web database in NetCDF format.

RESULTS AND DISCUSSIONS

Numerical modeling of wave energy propagation based on the Swan model allowed us to obtain several results concerning the spatial and temporal variations of the wave physical characteristics in the nearshore whose significant heights, the set-up, the orbital current velocity, the wave energy per area unit and the wave power in Kw/ m. All these results have been mapped and located in the tabular geo-database.

These wave power maps (Figure 1) indicate a significant variation in the wave energy dissipation near the coast. This variation depends mainly to the offshore waves and winds direction. The maximum energies that reach the coastline are observed with storm winds from the northeast sector. According to the National Coast Guard Service (SNGC) the most part of the vessels sinking near the Bouismail Bay was recorded with the winds of North and North-East Sectors.

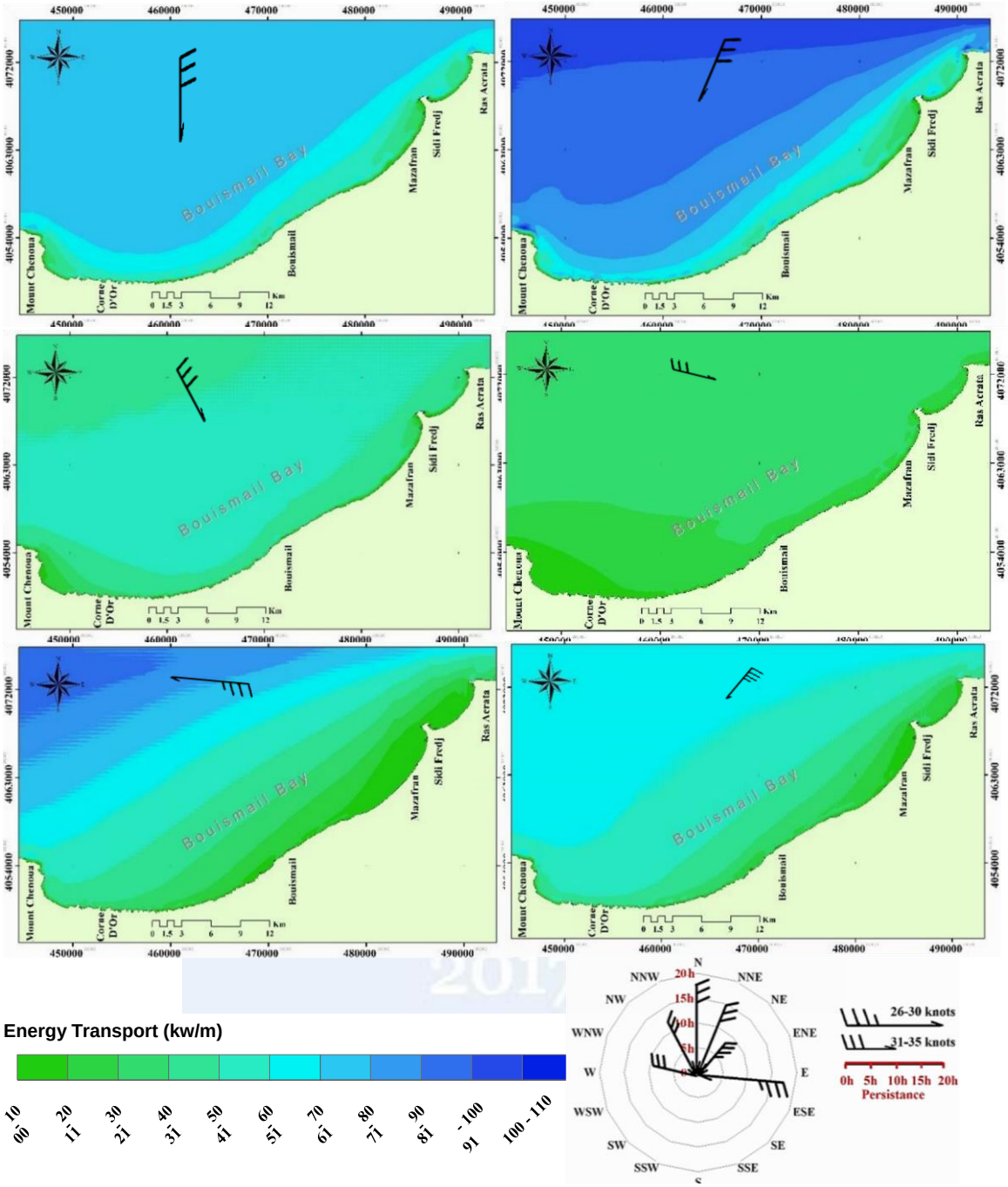


Figure 1. Wave Power Propagation maps of Six Stormy days recorded during the previous 14 years

- **Spatial Analysis Results**

In order to interpret the large number of results obtained after modeling the six most violent storms recorded since 2002 from six different directions, we calculated the mean and the maximum wave power recorded along the bay that can be observed during a storm. These

results allow us to give a first estimation of the zones with high-energy potential and thus estimate the probable coastal risk during the decennial storm.

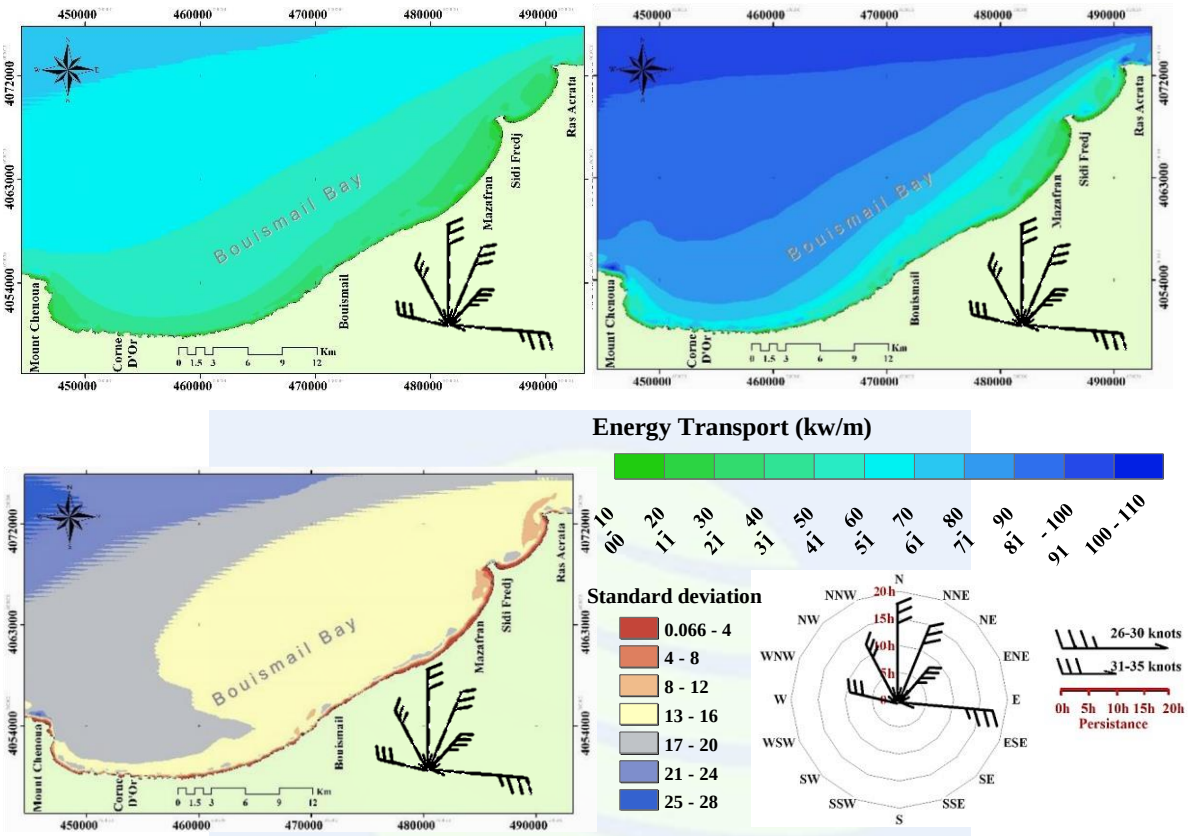


Figure 2. maps of mean and maximum wave powers on storm days and standard deviations

The highest wave power average near the coast was recorded in the western part of the bay and in the Sidi -fredj beach (Figure 2.). Thus, there is an important correlation between the maximum and average energies. The standard deviations map allows us to estimate the zones whose energies recorded during the storm are close to the calculated mean whatever the direction of the offshore waves, to the other hand, the zones with a high standard deviation value have energies that varies greatly according to the conditions of the offshore wave.

The strong energies recorded in the shallow water represent a significant advantage for the wave energy recuperators whereas it is easier to install, maintain and tighten it closer to the electricity grids (Shin 2013). Our objectives are to locate the zones with the highest energy potential whatever the conditions of the offshore swell, ensuring that these zones are close to the coast. To do this we passed to the third step of our studies, which is the multicriteria analysis. Three criteria were the subject of this analysis:

1. Wave power average greater than 25 kw/m,> 30kW/ m and> 35kW/ m 2.
A low standard deviation value (<12)
3. A maximum depth of 20 m.

Results of the multicriteria analysis

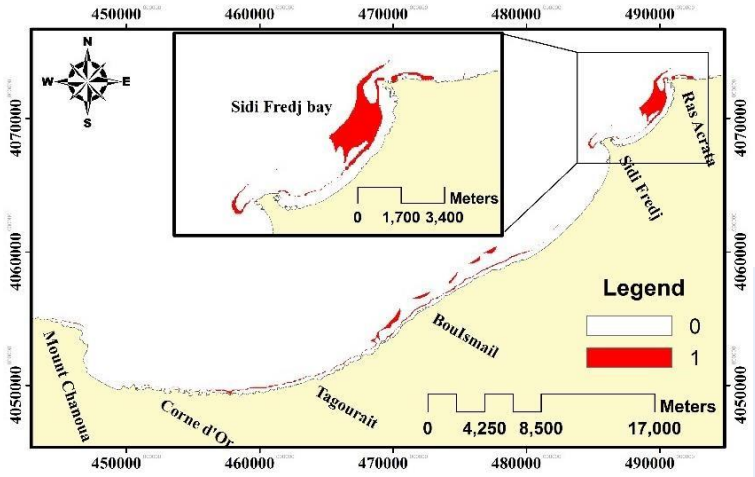


Figure 3. Results of the first multicriteria analysis: Et > 25 kW/m & ϭ <12 & depth <20

This map indicate the zones with an wave power average greater than 25 kW/m, a standard deviation less than 12, and a depth water less than 20 m. The most remarkable zone for its length and area is located in the eastern part of the small bay of Sidi Fredj (Figure 3). This zone has experienced very high coastal erosion during the last decade (Aini & Boutiba, 2014). In order to make the protection of this area more profitable, the implanted of a breack water equipped with a wave energy recuperator (SSG Slot-Cone Generator) can be evaluated by this result; The SSG wave energy collector was optimized during the EMACOP project for a maximum hydraulic efficiency of approximately 27% frome the

total wave energy (Hardouin, 2016).

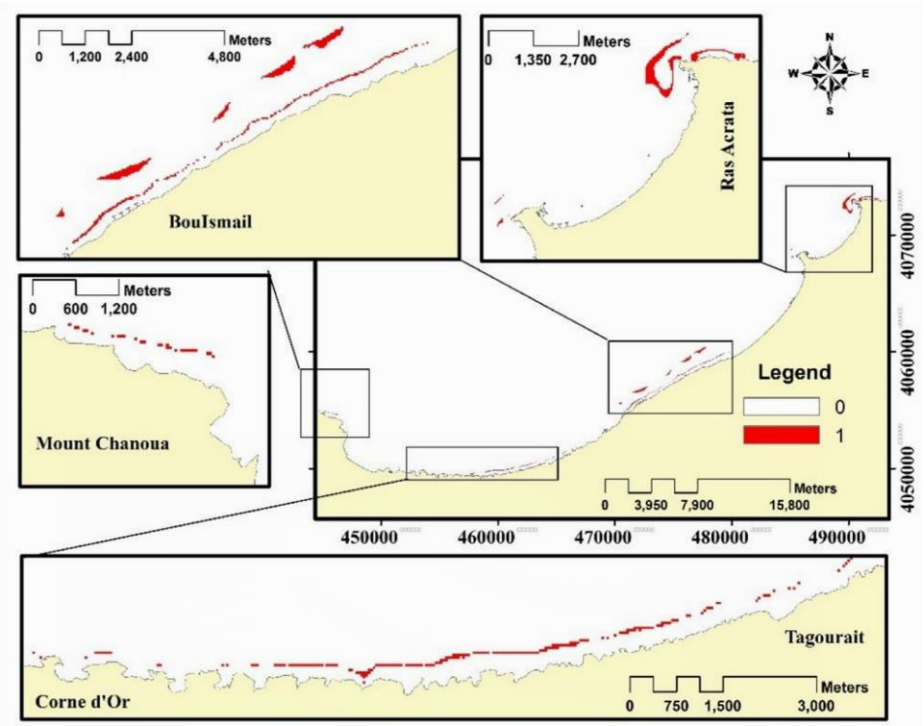


Figure 4. Results of the second multicriteria analysis: Et >30kw/m & σ <12 & depth <20m

The map below (Figure 4) indicate the zones with an wave power average greater than 30kW/m, a standard deviation of less than 12 and a depth of less than 20m. This result enabled us to select the regionally high-potential areas of renewable marine energy, also it allows us to locate areas with high risk of navigation or high risk of erosion. The area that has the highest interest for energy recovery was observed in BouIsmail zone, of which four Breakwaters with a length of 450 m are exposed to a considerable and omnipresent energy.

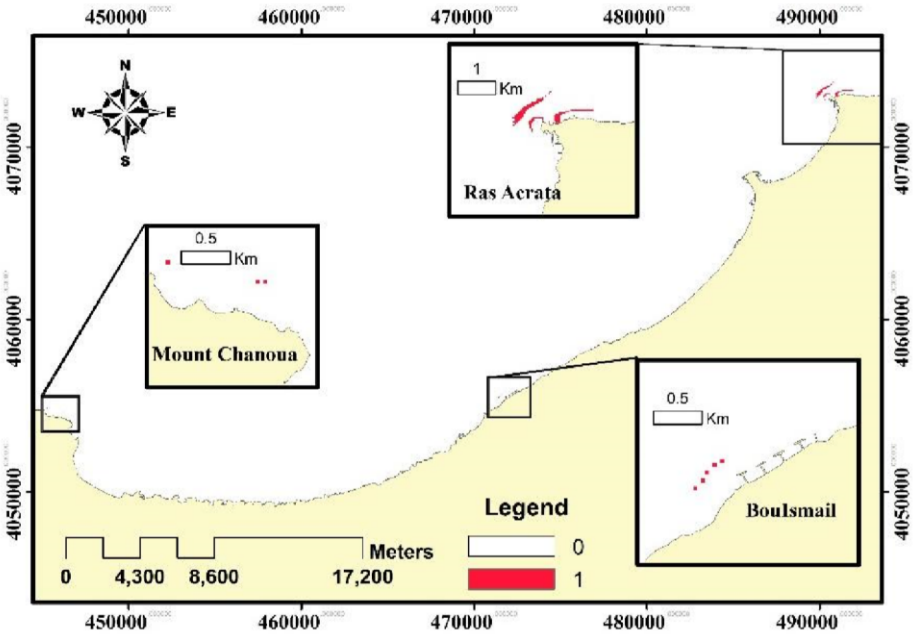


Figure 5. Results of the third multicriteria analysis: Et >35kw/m & σ <12 & depth <20m

The last results of the multicriteria analysis (Figure 5) aims to filter even more the zones that mark the strongest marine energies. Three zones were located with a wave power average on storm days greater than 35 kW/m and a standard deviation less than 12 in depths less than 20m. The most notable area among them is Ras Acrata with a length that exceeds 2 km along the coast, or 70 megawatt of energy. The maximum energy recorded in this zone is 80kW/m with a NNE wind of a speed greater than 14m/s and a persistence of 12heur.

CONCLUSIONS

The coastal areas of BouIsmail Bay do not have the same energy potential; the variation of this energy depends on several factors including coastal and underwater morphology. The wave power transmitted to the coast generally depends on the direction of the offshore wave's propagation; the phenomenon of diffraction and refraction causes a high dissipation of this energy. The use of GIS for geospatial analysis and multicriteria analysis of the hydrodynamic model results (SWAN) allowed us to select the coastal areas exposed to the highest marine energy with a low dependence to the offshore wave direction. These areas can be exposed to a high risk of erosion and presents very dangerous areas to navigation. The installation of breakwaters occupied by wave energy recuperators in the case of a coastal protection project in these areas may be more cost-effective and economical. The geodatabase developed during this study allows us to optimize the choice of the most favorable zones and the most profitable for the development of renewable marine energies. as well this geodatabase it constitute a decision support tool for the ICZM projects, the coastal vulnerability studies and the coastal safety services.

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