Simulating Wind Driven Waves in the Strait of Hormuz using MIKE21

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Abstrak

Simulasi Gelombang Angin di Selat Hormuz Menggunakan MIKE21

Daerah pesisir di bumi adalah salah satu zona paling dinamis yang dipengaruhi oleh berbagai parameter seperti gelombang, arus, dan badai. Untuk mengelola serta mengkontrol zona tersebut adalah penting untuk mempelajari hidrodinamika daerah. Penelitian ini menggunakan MIKE 21/3 coupled Model FM untuk melihat gelombang (wind driven waves) di sekitar Pulau Larak di Selat Hormuz. Untuk mensimulasikan pola gelombang di wilayah tersebut digunakan irregular triangular grid. Pola arus di sekitar pulau dipelajari untuk jangka waktu satu tahun. Ditemukan bahwa gelombang yang ditimbulkan karena arus di sekitar pantai utara pulau relatif lemah. Terlihat pula bahwa gelombang yang ada di daerah tersebut terutama ke arah timur laut. Tinggi gelombang rata-rata di surfzone adalah sekitar 0,5 m., Dengan kecepatan arus sekitar 0,2 m.s^{-1}. Mengingat angin menang dan arah gelombang, disimpulkan bahwa pantai utara Pulau Larak tempat yang cocok untuk konstruksi pelabuhan dan kegiatan memancing.

***Kata kunci:** gelombang, arus, MIKE, Pulau Larak*

Abstract

Coastal areas on earth are among the most dynamic zones which affected by different parameters such as waves, currents, and storms. To manage and control such a zone it is essential to study the hydrodynamic of the area. MIKE 21/3 Coupled Model FM was used to investigate the wind driven waves around Larak Island located in the Strait of Hormuz. To simulate the pattern of the wave in the area irregular triangular grid was applied. The pattern of current around the Island was studied for a one year period of simulation. It was found that the current induced wave break around the Northern coast of the Island is relatively weak. It was also observed that the prevailed wave in the area is mainly toward the Northeast. The averaged wave height in the surfzone is about 0.5 m., with the current velocity of about 0.2 m.s^{-1}. Considering the prevailed wind and wave direction, it was concluded that the northern coasts of the Larak Island are suitable places for harbor construction, recreational and fishing activities.

***Keywords:** Waves Break, Current, MIKE, Larak Island*

Introduction

The first step to design and construct the coastal structures, and to define sediment transport and pollution in coastal area is to study the hydrodynamic of area. These fenomenon was shown gave impact to the environment (Baldock *et al*., 2014). The most important part of this study of course is to research about the current and the cause and the pattern of this current on the area.

Wind, tides, and variation in density are some main reasons for producing currents in the oceans (Stewart, 2004). Among these phenomena tide is the one which play a role in producing current in Persian Gulf (Thoppil *et al*., 2010; Rangel-Buitrago *et al*., 2014; Wen *et al*., 2014). However it should be mentioned that due to the density variation that a current with relatively low density intrude to the Persian Gulf via Hormuz Strait over the top and the dense current exits from the Strait from the bottom (Yao and Johns., 2010). This is the area were our investigation site is located in. It is therefore, a challenge to specify the pattern of current around the Larak Island which is the subject of this study. For this research numerical model of MIKE21 has

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ijms.undip.ac.id
DOI: 10.14710/ik.ijms.20.1.1-8

Diterima/Received : 13-01-2015
Disetujui/Accepted : 10-02-2015

Figure 1. Area under investigation

been considered (MIKE, 2005). For the model calibration and validation some field data and also the results from the research of Sharifi *et al.* (2012) and Li and Xie (2014) have been considered. According to them the maximum wave height of the area was supposed to be in the range of 1.2 m for January 2009.

Larak Island is located somewhere at the middle of Strait of Hormuz with the coordinates of 26° 51” N and 56° 21” E. Queshm Island which is the largest Island of the Persian Gulf is the nearest Island to this study area (see Figure 1.). Lark Island is about 30 km away from Bandar Abbas. As it can be seen in Figure 1 Larak Island is subject to the main currents which flow through the Strait of Hormuz. The area which is considered for this study is part of Persian Gulf water around this Island which covers an area of about 2400 km^2.

Materials and Methods

MIKE21 software, by the Danish Hydraulic Institute, has been employed to simulate the hydrodynamic of the study area (MIKE, 2005). This is due to its user friendly environment and rather precise and satisfying reported results (Remya *et al*, 2012). For this specific study the two-dimensional version of the software has been employed.

The topography of the seabed, wind speed and direction, and wave height and period are some main data which has been fed to the model as input data. These data is provided by Ports and Maritime Organization (PMO), and had been collected under the project Iranian Seas Waves Modeling (ISWM). It should be mentioned that the wind data used in this project is those statistics wind provided by European Center of Medium range Weather Forecasting institute (ECMWF) via Iranian Seas Waves Modeling

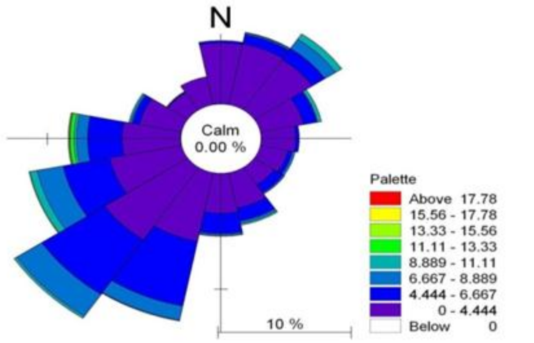


Figure 2. Wind-rose of The study area in 2000 location, 27.00ºN 56.50ºE

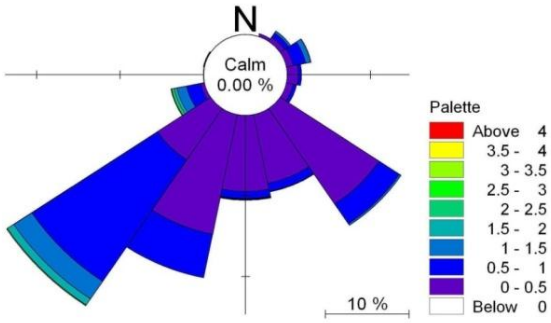


Figure 3. Wave-rose of the study area in 2000 location, 27.00ºN 56.50ºE

(ISWM) project. These data are prepared and available to use in the format of six -hours time step. Figure 2 and 3 show the wind-rose and the wave-rose of the area respectively for the year 2000. It can be seen from the Figure 2 that the there are no calm condition in the area, and the prevailing wind of the area is southwest wind. Figure 3 also shows that the prevailing wave of the area has the same direction as the wind rose.

Boundaries of the model have been considered far from the edges of the Island. Wind data and tidal characteristics have been used as the boundary conditions of the area. The bathymetry of the area also is shown in Figure 4. To create a bathymetry file, those data from the hydrographic map area of the institute of British admiral with the scale of 1 : 350,000 was used. To mesh the area unstructured mesh grid has been used. On this basis 1169 grid points have been generated, in which the accuracy of the results and time consumption for the simulation has been taken into account. Two steps nesting procedure have been applied in order to achieve reliable results. 500,000 square meters is the largest grid space for the far area. The size of the mesh around the Larak Island is about 35,000 square meters, and close to the coast the mesh size reduces to 5000 square meters.

For the modeling Coupled Model FM using spectral techniques and unstructured mesh has been considered. To simulate currents and wave characteristics of the area HD and SW modules was employed respectively. A one year simulation of year 2000 has been carried out. That is, due to the existence of the reliable data for the calibration and validation of the results in this specific time, this period for the simulation has been used.

The time step for the simulation has been found 300 s, on the basis of Courant number. The initiation time of simulation was the first of January 2000. As it can be seen in the Figure 4 for the main model there is a land boundary in the North and three open boundaries in the South, East, and West. There are also other Islands in the area, where their existence in the area may affect the pattern of the current, so they have been considered as dry boundaries (Nami and Pour, 2011). Figure 5 shows the dry and wet boundaries of the second nesting simulation. SW module of the software can be used for wave prediction of the shallow water area as has been used by Rajabi *et al*. (2010) and Farjami *et al*. (2011), where enough measuring data are not available. This can be achieved by the use of recorded statistical wind parameters of the area. Table 1. shows the domain of ability of this module and the values has been applied in this study.

FM module of the software makes it possible to simulate hydraulic performance of the marine environment. This module considers non-linear second order equations for momentum and mass conservation to resolve the finite element equations. Tidal movements, wind stress, variation of the pressure in the atmosphere, wave forces, and currents due to the rivers are some aspects which causes the formation of sea currents and so to simulate them the use of FM module is suggested. Table 2 shows the parameters of the hydrodynamic module which should be specified and the values has been considered for them in this research.

Result and Discussion

The results of the SW module

Figure 6 shows the results of SW model for the area under consideration for the highest high water (HHW) level (A) and the highest low water (HLW) level (B) during the period of simulation around the Larak Island. It can be seen from the figure that the direction of the wave around the Island for both situations are more or less the same. The celerity of the wave however is less during HLW in compare with the HHW.

Table 1. Wave radiation parameters, SW Module

No.	Equations	Applied in this investigation
1	Basic Equations	1. Spectral formulation-fully spectral formulation 2. Time –unsteady formulation
2	Wind forcing	Data from ECMWF institute
3	Energy transfer	Quadruplet-wave interaction
4	Water level conditions	Water level data - data up the mean sea level (the mean tidal level of Bandar Abbas and Hengam Island)
5	Wave breaking	Gamma data with the value of 0.8 The calibration constant factor,(alpha= 1)
6	Bottom friction	Nikuradse roughness (kn= 0.002m)
7	White capping	Dissipation coefficient (cdis=2 and Delta=0.8)
8	Boundary conditions	-The southern and eastern open boundaries-wave parameters (version 1) -The first western open boundary: lateral boundary -The second western open boundary: using data from wave parameters

Table 2. Hydrodynamic parameters, FM module

No.	Equations or Parameters	Applied in this investigation
1	Time	(86400 second X one year)/300 Number of time steps=105120 - Time step interval= 300 sec Simulation start and end date:1/1/2000 12:00AM, 12/31/2000 12:00 AM
2	Bed Resistance	Chezy number= 32
3	Wind forcing	ISWM wind statistics data with time step of 6 hours
4	Eddy viscosity	The Smagorinsky formulation= 0.28
5	Wave Radiation	SW module
6	Boundary conditions	-The southern open boundary: tidal condition of the strait of Hormuz -The eastern open boundary: the tidal condition of Bandar Abbas -The western open boundary: the tidal condition of Hengam Island

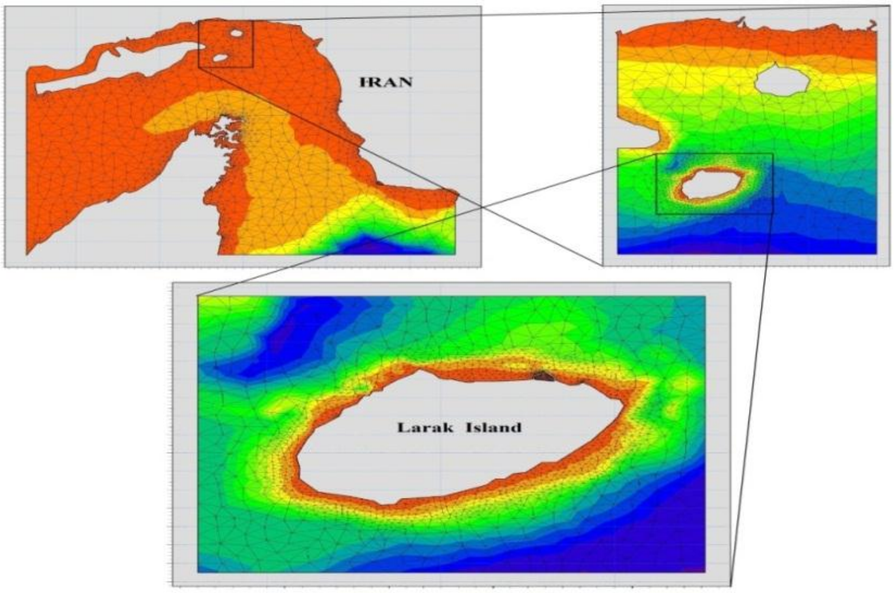


Figure 4. Consequences of nesting and bathymetry of the area

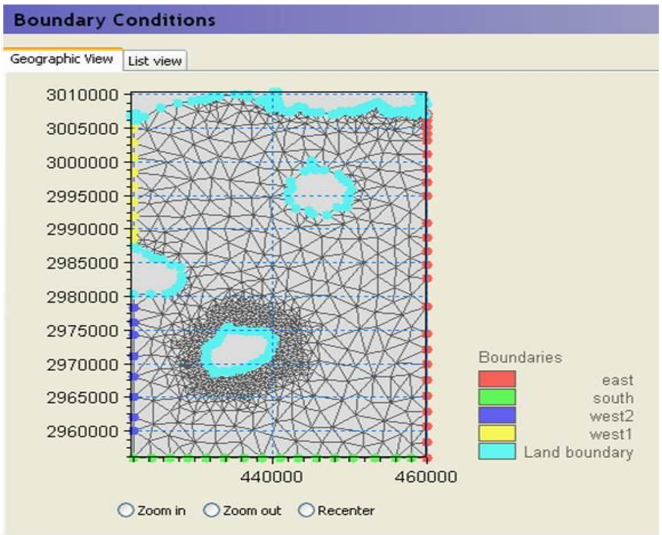
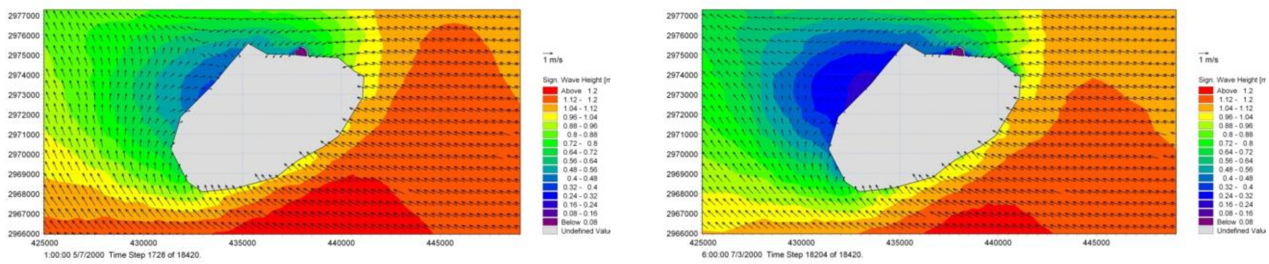
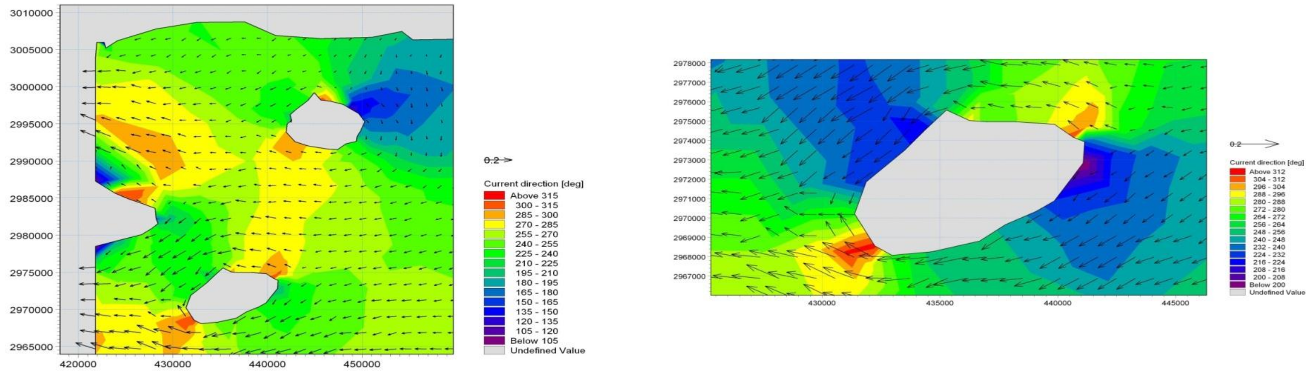


Figure 5. Dry and wet boundaries of the regional model



(a) (b)

Figure 6. The main wave parameters around the larak island. (a) The direction, speed and height of the wave at the highest high water level of the year 2000, (b) The direction, speed and height of the wave at the highest low water of the year 2000



(a) (b)

Figure 7. Direction of surface current in the study area. (a) general direction of surface current in the Strait of Hormuz, (b) Surface current direction around the Larak Island, (b) Significant wave height along the section 9 before (blue) and after (black) the wave break

The results of the Flow Model FM

Figure 7 shows the pattern of current derived from the FM module. Figure 7-A shows the general surface current in the Strait of Hormuz. This pattern can be observed during whole the year. Its intensity however is stronger in summer and weaker during the winter. The mean surface current speed in this strait is between 0.1 to 0.2 m/s. The reason for this relatively slow current flow is most probably due to the transiting depth from the deep water of Gulf of Oman to the shallow water of Persian Gulf (Nami and Pour, 2011). There are also three islands including Queshm, Hormuz, and Lark which act as a barrier against the current and causes the current to slows down.

Figure 7-B shows the pattern of current around the Larak Island. As can be seen in the figure, the Northeastern edge of the island causes the separation in the current. That is, at this edge the current divides into two branches, one crosses the upper boundary of the island and the other crosses the lower boundary. They reunite again in the western edge of the island where they continue toward the Gulf of Oman.

Wave components around the Larak Island

To investigate the pattern of wave around the Larak Island in more detail, the area around the Island has been divided into nine sections, as shown in Figure 8. The components of the wave around the Island are derived from the model for each section. For this simulation the linearly aspect of the model was considered (Figure 8). For each of these sections the distances of up to 200 meters from the shoreline was taken into account for the simulation. This distance has been chosen to define the breaking point of the wave. The results derived from the model showed that the maximum and minimum significant wave height occur in southwest (section 6 of Figure 8) and north (section 1 of Figure 8) simultaneously.

Figure 9 is selected as an example of the simulated distance, for the section 1 in the Northwest of the Island (see Figure 8). The simulation date is 1st of May 2000. As it can be seen the breaking point at this section had happened in about 80 m away from the shoreline. On the basis of these simulations the farthest and the closest braking point happens in section 2 and section 9 respectively. At section 2 the breaking point is about 160 m far from the shoreline and at section 9 the breaking point happens around 5 m from the shore. Figure 10 shows the variation of significant wave height and wave direction before (blue) and after (black) the breaking point for section 1. Variation of significant wave height before and after the breaking point for sections 2 and 9 are shown in Figure 11 A and B consecutively. As it can be seen in the Figure 11-A a decrease of about 1 m in significant wave height has happened at the breaking point of section 2. In section 9 however, this decrease is almost negligible. It can be speculated that there is no wave breaks at section 9.

Since the surface current in the Strait of Hurmoz is influenced by the inflow from the Gulf of Oman, in which is always inward through the Persian Gulf via Strait of Hurmoz (reported by Renolds, 1993; Pous *et al*., 2004; Yao, 2008) the current around this Island is also affected by this inflow current.

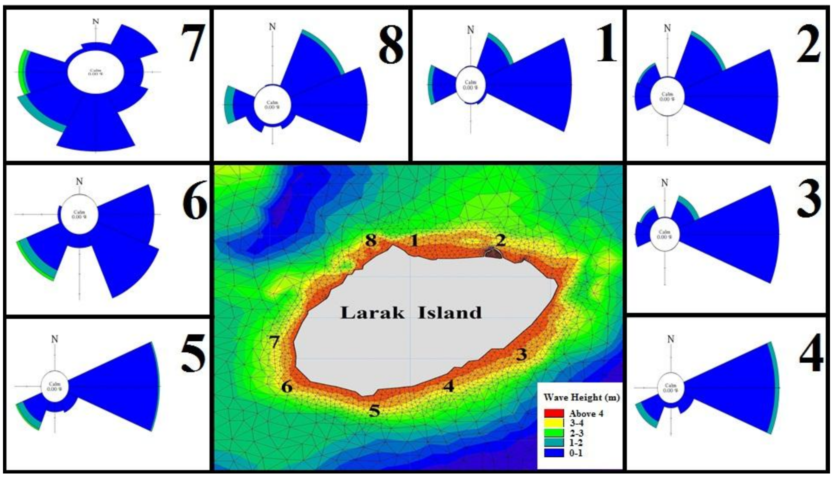


Figure 8. The positions of sections considered around the Larak Island and the wave rose in each section

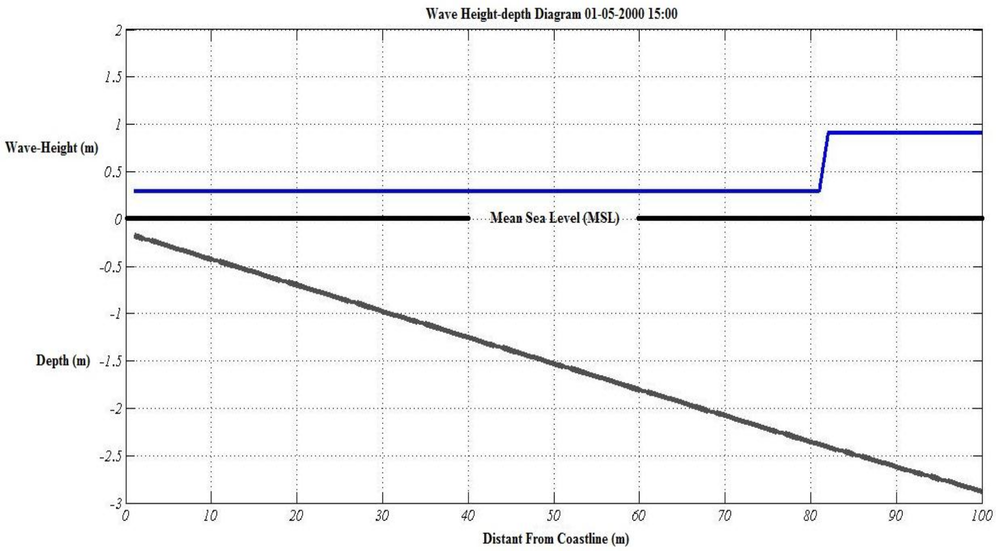
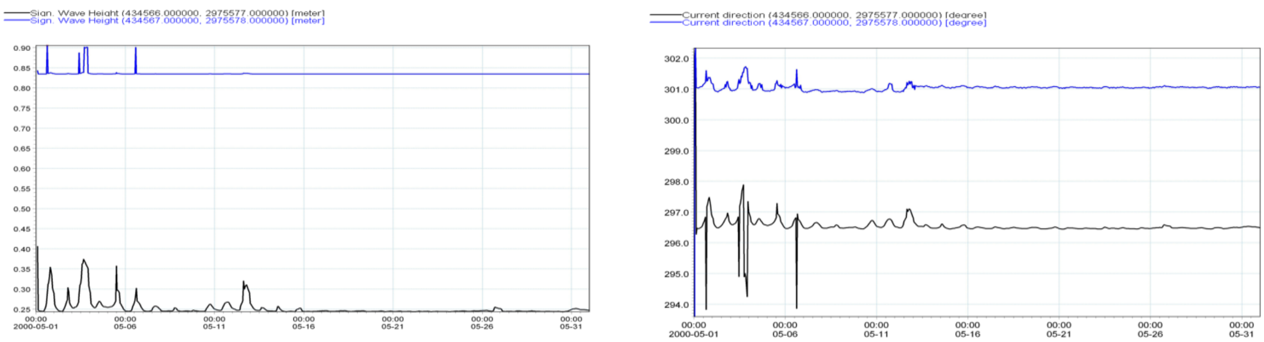


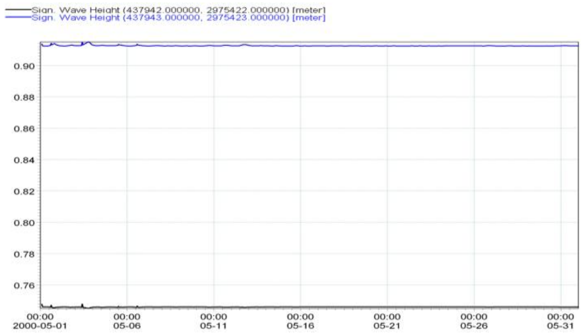
Figure 9. The variation of wave height along the section 1 (Northwest of the Larak Island)



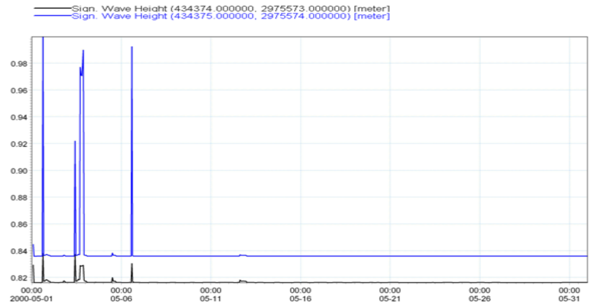
(a)

(b)

Figure 10. Wave characteristics along the sec. 1. (a) Significant wave height along the sec.1 before (blue) and after (black) the wave break, (b) Current direction along the sec. 1 before (blue) and after (black) the wave break



(a)



(b)

Figure 11. Significant wave height for sec. 2 and 9. (a) Significant wave height along the sec. 2 before (blue) and after (black) the wave break, (b) Significant wave height along the sec. 9 before (blue) and after (black) the wave break

The outcome of the model showed that the current is divided into two branches, at the eastern headland. According to the findings the celerity is relatively low (0.2 m/s) at the breaking point, which is due to the short significant wave height and low steepness of the area.

Conclusion

The pattern of wave and current around Larak Island was studied. The surface current is always toward the Gulf of Oman. This current at the headland of the Larak Island in the East is divided into two Northern and Southern branches, which conjunct together again in the West side of the island. It was found that the celerity around this island is between 0.1 and 0.2 $m.s^{-1}$. Wave break happens in the area of about 200 m distance from the shoreline where the water depth is about 2 m. It was found that in the Western half of the Island breaking wave can be better observed than the Western side and that the surfzone is wider in the Eastern side.

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