



Identification of Characteristics Influencing Wave Height and Current Velocity in MIKE Model for Simulation of Wind-induced Ocean Currents and Waves in Southeast of Caspian Sea

S. Heshmat¹, S. A. Hashemi Monfared¹, D. Yousefi Kebria^{2*}, S. M. Banihashemi³

¹ Department of Civil Engineering, University of Sistan and Baluchestan, Zahedan, Iran

² Department of Civil Engineering, Babol University of Technology, Babol, Iran

³ Head of the National Centre for the Studies and Research of the Caspian Sea, Water Research Institute, Iran

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The dominant currents in Caspian Sea, a constituent of which is wind-induced waves, the disconnectedness of Caspian Sea from oceans, complex topography, shoreline configuration, and considerable temperature and density differences, which make it complicated to examine ocean current patterns, are of great importance. This study investigated bottom friction, wave breaking, white capping, solution technique, and the number of directions in the MIKE-SW model and meshes, solution technique, bed resistance, and wind friction in the MIKE-FM module to model the wave height and current velocity. The effectiveness and contributions of characteristics in the simulation were found by the MIKE-SW model as the wave propagation model of the sea waves toward the coastal areas and in the current model. As a result, to perform reliable and realistic simulations, it is required to investigate every component. The investigation of all the simulation indexes showed that the MIKE numerical model yielded acceptable results for the simulation of ocean currents and waves in both MIKE-SW and MIKE-FM modules.

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INTRODUCTION

Although climate change is not an emerging phenomenon, concerns have increased in the past two decades in this respect. Global warming and climate change relate to not only scientific contexts but also the economy, sociology, geopolitics, local policies, and lifestyle. Therefore, it is clearly required to increase the contribution of renewable energies via different resources to preserve resources and deal with climate change impacts. To execute engineering projects under climate change conditions in relation to coasts and sea (e.g., designing seaports and shore and offshore structures), investigate environmental pollutant emissions, and estimate the transfer of sediments, it is required to identify the characteristics of ocean currents and waves. Since the movement of ocean waves is known as a necessary part of the earth's functions to transfer energy and form shorelines, it is necessary to investigate characteristics influencing the modeling of ocean

currents and waves to monitor the movement of ocean waves as a large resource of renewable energy for electricity generation, desalination, and water pumping [1-3].

The limitations of measurements and field observations and the high costs of engineering executions have encouraged researchers to employ developed numerical models, which have enjoyed significant advancements in recent years. Simulation flexibility and reliable analyses under complex computational conditions have made numerical models more satisfactory than physical ones. Several models have been developed in recent years for the hydrodynamic simulation of aquatic media, such as ECOM, DELFT, MICOM, HYCOM, and DHI MIKE. The DHI computer model was introduced by Danish Hydraulic Institute (DHI), which is among the most internationally credible hydraulic research institutes, and was complemented and developed by Water Quality Institute. It offers high computational and graphical capabilities of modeling

*Corresponding Author E-mail: y.kebria@nit.ac.ir (D. Yousefi Kebria)

firths, lakes, low-depth coastal areas, gulfs, and seas. The MIKE21 and MIKE3 are the most well-known numerical models used for the analysis of ocean phenomena [4, 5].

Numerical and experimental studies have been conducted on the modeling of ocean currents and waves to utilize the potential of renewable energy in recent years in China [6], Turkey [7], Philippines [8], Thailand [9], Brazil [10], Latin America and Europe [11], Caspian Sea [12], and Persian Gulf [13]. Moeini et al. [14] employed the SWAN and MIKE21-SW models to study the characteristic wave height and wave period in Erie Lake. According to the results, the white capping had the highest effect on the modeling of the characteristic wave height, while wave breaking and bed resistance had no significant impacts on the modeling. As a result, both models showed acceptable capabilities of wave modeling, based on the statistical parameters. The difference between the models resulted from different input wind data. Moeini and Etemad-Shahidi [5] investigated the modeling of Persian Gulf waves using the numerical SWAN model, wind measurement data, and ECMWF wind data. Wave breaking, white capping, and bed resistance were found to be effective parameters in the simulations. According to the results, white capping was the most important simulation parameter. However, the comparison of the modeled results and measured data indicated that the consistency of model parameters could not improve the modeled results since the calibration of long waves would maximize short waves. Yuksel et al. [15] employed the MIKE21-SW numerical model to examine waves in the western shores of Turkey in Black Sea. A mathematical equation was obtained for Black Sea waves by considering wave breaking and white capping. Greenwood et al. [16] studied the energy of waves in the western shores of Scotland. By considering tide characteristics, wind friction, wave breaking, bed resistance, and white capping, it was demonstrated that the reduction of shoreline had a 5-9.5% effect on wave power. Applying wave return to the model increased the wave power by 7.5% at a distance of 300 m from the energy converter. Liang et al. [17] investigated the energy generation of waves under the influence of the interaction of ocean currents and waves in Qingdao Port, China. According to the results, the optimization of the white capping, bed resistance, and wave breaking yielded a maximum wave power of 210 kW/m in Yellow Sea shores of Qingdao Port. To correctly estimate the sources of energy in low-depth shores, it is required to consider tidal currents.

Although many studies have been conducted on the simulation of ocean currents and waves, the investigation of the entire characteristics affecting ocean current and wave simulations were rarely considered. Therefore, this study utilizes the MIKE aquatic medium simulator to examine the propagation of waves from the sea to the shore under bottom friction, wave breaking, white capping, solution technique, and the number of directions

in the MIKE21-SW and MIKE3 modules for the simulation of flow pattern with the help of the HD module, which is sensitive to the computation meshes, solution technique, bed resistance, and wind friction, in the shores of Amirabad Port, Southwest Caspian Sea.

Simulation description of the case study

The simulation of the characteristic wave height and current velocity using ECMWF wind data obtained from weather forecasting centers, including the velocities U_{10} and V_{10} at an elevation of 10 m from the sea level along with the Mean Sea Level Pressure, was performed throughout Caspian Sea at the coordinates of 41.40° N and 50.40° E. The boundaries of the case study were introduced to the mesh-generator modules, and 5756 elements meshes and 10794 nodes were created in the MIKE3-FM and MIKE21-SW modules. Then, the meshed grid was implemented, as shown in Figures 1 and 2.

Basis of wave computations in the spectral wave module

The spectral wave module is a new spectral model generation of wind-induced waves that was developed based on unstructured meshes. The model simulates the growth, deterioration, and transfer of wind-induced waves in the shore-near and shore-far areas. The



Figure 1. Geometric boundary of Caspian Sea

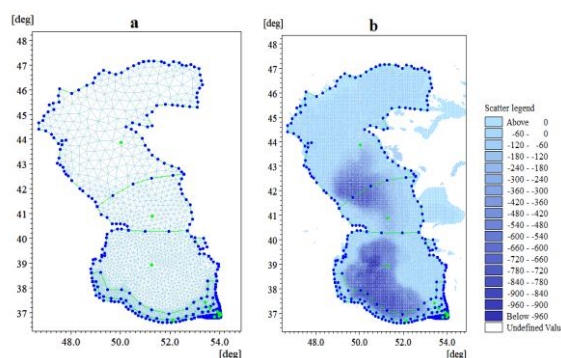


Figure 2. (a) meshes and (b) bathymetry introduced to the model

computation of wave characteristics in mathematical models in mathematical wave prediction models, including the spectral wave module, is based on solving discrete spectral energy equations in the spatial, directional, and frequency dimensions, which are expressed in Equations (1) and (2):

$$\frac{\partial E}{\partial t} + \frac{\cos\theta}{c} \frac{\partial(ECC_g)}{\partial x} + \frac{\sin\theta}{s} \frac{\partial(ECC_g)}{\partial y} + \frac{c_g}{c} \left(\sin\theta \frac{\partial c}{\partial x} - \cos\theta \frac{\partial c}{\partial y} \right) \frac{\partial E}{\partial \theta} = S \quad (1)$$

where $E(t, x, y, f, \theta)$ is the frequency-directional wave energy spectrum, t is time, x and y are two-dimensional Cartesian directions, f is the frequency, S is the spring (or well). The last term on the right side of the equation incorporates the effects of refraction and wave depth reduction. The source term on the right side of the wave transfer equation is defined as follows:

$$S = S_{in} + S_{nl} + S_{dis} + S_{bot} + S_{surf} \quad (2)$$

where S_{in} represents the transfer of energy from the wind to the water surface, S_{nl} represents the transfer of energy from a frequency to another by nonlinear wave interactions, S_{dis} denotes wave energy dissipation due to the white capping phenomenon, S_{bot} denotes wave energy dissipation due to bottom friction, and S_{surf} wave energy dissipation due to low-depth wave breaking [18].

Equations governing the hydrodynamic module

The three-dimensional Navier-Stokes flow equations based on the continuity equation in the Flow Model-FM module are stated as follows:

$$\frac{\partial u}{\partial x} + \frac{\partial v}{\partial y} + \frac{\partial w}{\partial z} = 0 \quad (3)$$

Two momentum equations in the x - and y -directions are defined as Equations (4) and (5):

$$\frac{\partial u}{\partial t} + \frac{\partial u^2}{\partial x} + \frac{\partial uv}{\partial y} + \frac{\partial wu}{\partial z} = fv - g \frac{\partial \eta}{\partial x} - \frac{1}{\rho_0} \frac{\partial p_a}{\partial x} - \frac{g}{\rho_0} \int_z^\eta \frac{\partial \rho}{\partial x} dz - \frac{1}{\rho_0 h} \left(\frac{\partial s_{xx}}{\partial x} + \frac{\partial s_{xy}}{\partial y} \right) + F_u + \frac{\partial}{\partial z} \left(v_t \frac{\partial u}{\partial z} \right) \quad (4)$$

$$\frac{\partial v}{\partial t} + \frac{\partial v^2}{\partial y} + \frac{\partial uv}{\partial x} + \frac{\partial wv}{\partial z} = -fu - g \frac{\partial \eta}{\partial y} - \frac{1}{\rho_0} \frac{\partial p_a}{\partial y} - \frac{g}{\rho_0} \int_z^\eta \frac{\partial \rho}{\partial y} dz - \frac{1}{\rho_0 h} \left(\frac{\partial s_{yx}}{\partial x} + \frac{\partial s_{yy}}{\partial y} \right) + F_v + \frac{\partial}{\partial z} \left(v_t \frac{\partial v}{\partial z} \right) \quad (5)$$

where t is the time, x , y , and z represent Cartesian coordinates, η denotes water level fluctuations, d is the still water depth, $h = \eta + d$ is the total water depth, u , v , and w are the velocity components in the x -, y -, and z -directions, respectively, and $f = 2\Omega \sin(\Phi)$ is the Coriolis parameter, in which Ω and Φ are the rotational

speed and latitude, respectively. Also, g is gravitational acceleration, ρ is the water density, S_{xx} , S_{yy} , S_{xy} , and S_{yx} are the entries of the stress tensor, v_t is the viscosity of the vortex flow in the vertical direction, p_a is the atmospheric pressure, and ρ_0 is the reference density for water [18].

Performance evaluation criteria of the model

To evaluate the performance of the model, the wave and current data of the ADCP machine in a depth of 13 m at the coordinates of 36.91426 N and 53.41114 E, near Amirabad Port. In addition, the modeled results were validated by statistical tests, correlation coefficient, and root-mean-square error (RSME), which are shown in Equations (6) and (7):

$$cc = R = \frac{\sum(x_i - \bar{x}) \times (y_i - \bar{y})}{\sqrt{\sum(x_i - \bar{x})^2 \times \sum(y_i - \bar{y})^2}} \quad (6)$$

$$RMSE = \sqrt{\frac{1}{n} \sum (y_i - x_i)^2} \quad (7)$$

Characteristics influencing the wave pattern

The spectral wave module was employed based on the assumption of waves propagating in all the directions and time- and location-variant wind to model the propagation of waves from the seawater toward the shore in order to evaluate the effects of waves on the current pattern. Simulations were carried out using the MIKE21-SW module and ECMWF wind data for a period of ten days within 24 time-steps for every 3600 seconds. With a change in each of the parameters, a wave model was executed. The comparison of the output wave height variations of the executed models to the measured wave height indicated the overlap of the data. Finally, using the semi-empirical methods subsequently, the accuracy of the model was calculated.

Number of directions

To investigate the directions of the waves and wind, the angle of 360 degrees was divided into 16- and 20-degree arcs.

Solution technique

Equations in the MIKE21 model can be solved by two techniques. In the first technique, equations are solved by adopting a first-order equation based on the explicit Euler method. In the second technique, however, equations are solved by the second-order Runge-Kutta method. The first technique solves the equations in a shorter time.

Wave breaking

Water depth-induced wave breaking occurs when waves reach extremely low-depth areas, and the water depth cannot resist the wave height. In such a case, the bed affects the orbital motion of particles, leading to wave

breaking. Batis recommends a γ of 0.8. Therefore, the wave breaking parameter was considered to be 0.5, 0.8, and 1.0 [19].

Bottom friction

When a wave is propagated from deep water to low-depth water, the rotational motion of wave particles reach to the bottom. In this case, the effect of bottom friction becomes important. The effect of the bottom friction coefficient can be applied in the form of a constant or a variable value to the model. This study utilized Nikuradse roughness as the calibration roughness coefficient.

White capping

The white capping fits the wave growth completion point by the parameters C_{dis} and Δ_{dis} .

Characteristics influencing the current pattern

The numerical current model executed using the MIKE3-FM module incorporated the factors affecting the formation of currents and the topographic and environmental conditions. As in the wave module, this module applied the data of wind speed and direction and surface pressure. The model was executed for a period of ten days within 43200 time-steps, every 60 seconds. The output current velocity variations of the models were compared to the buoy-measured current velocity of Amirabad Port using the equations provided.

Meshes

The sizes of the irregular meshes in the current model were investigated. Through the size reduction of the meshes, better estimates of current characteristics can be obtained. The comparison of the model current velocity results to the measured current velocity data of the Ports and Maritime Organization of Iran indicated the sensitivity of the model to the meshes.

Solution technique

In the current model, the solution technique was considered for high-order and low-order cases. The comparison of the current velocity results to the field data indicated the difference between the two computational methods.

Eddy viscosity

As a velocity characteristic of turbulence flow, eddy viscosity relates the Reynolds stress tensor to the velocity gradient tensor. A measurement error of eddy viscosity causes additional stress in time and location. Eddy viscosity was measured in the horizontal and vertical directions [20].

Bed resistance

Bed resistances incorporates the effect of the bottom friction on the current pattern in the model. The bed

resistance values of 0.001, 0.01, and 0.05 were used for evaluation to execute the current model.

Wind friction

In areas that are not covered by ice, surface stresses are determined by wind above the surface. In the current model, wind friction was executed for different wind speeds.

RESULTS AND DISCUSSION

Investigation of the wave model

Figures 3a-3f demonstrate the findings of the spectral wave module in the MIKE21-SW model and the simulation of characteristic wave height. As can be seen, 18-degree arcs were more suitable than 22.5-degree arcs for the wind parameter (Figure 3a). The solution technique yielded similar results in both methods. However, the first-order equation (Figure 3b) had a higher correlation with the field data. According to Figure 3c, the Nikuradse roughness coefficient shows tangible variations for different values, each of which represented the hydrodynamic conditions of waves. The bottom friction of 0.004 m had the highest correlation. The wave breaking parameter of 1 estimated the most optimal wave height (Figure 3d). Figures 3e and 3f show the parameters C_{dis} and Δ_{dis} of the white capping. A Δ_{dis} of 0.3 and a C_{dis} of 4.5 produced the most realistic wave heights.

Figure 4 shows the correlations of the variables to the characteristics. Based on the computed results, the values with the highest correlations with the observation data were selected. The wave model was executed for a one-month period within 4320 time-steps every 600 seconds in order to validate the most optimal values of the effective characteristics, as shown in Figure 5 and Table 1. The proper selection of the variables in the characteristics can be observed.

According to the results, the MIKE21-SW module had a correlation of 90% and the minimum error and was found to be able to reliability and ideally model ocean waves in the case study. Therefore, it is observed that the variable values of the characteristics were selected properly. Figure 5 and Table 2 represent the effectiveness and improvements of each characteristic in the wave height simulation.

Table 2 shows the enhancement and reduction of the characteristics in the 90% correlation. The effects of considering improper coefficients on the correctness

TABLE 1. Comparison of the modeled and measured results using statistical indexes

| comparison of measured and modeled wave heights | Correlation Coefficient | RMSE |
|---|-------------------------|-------|
| | 0.904 | 0.201 |

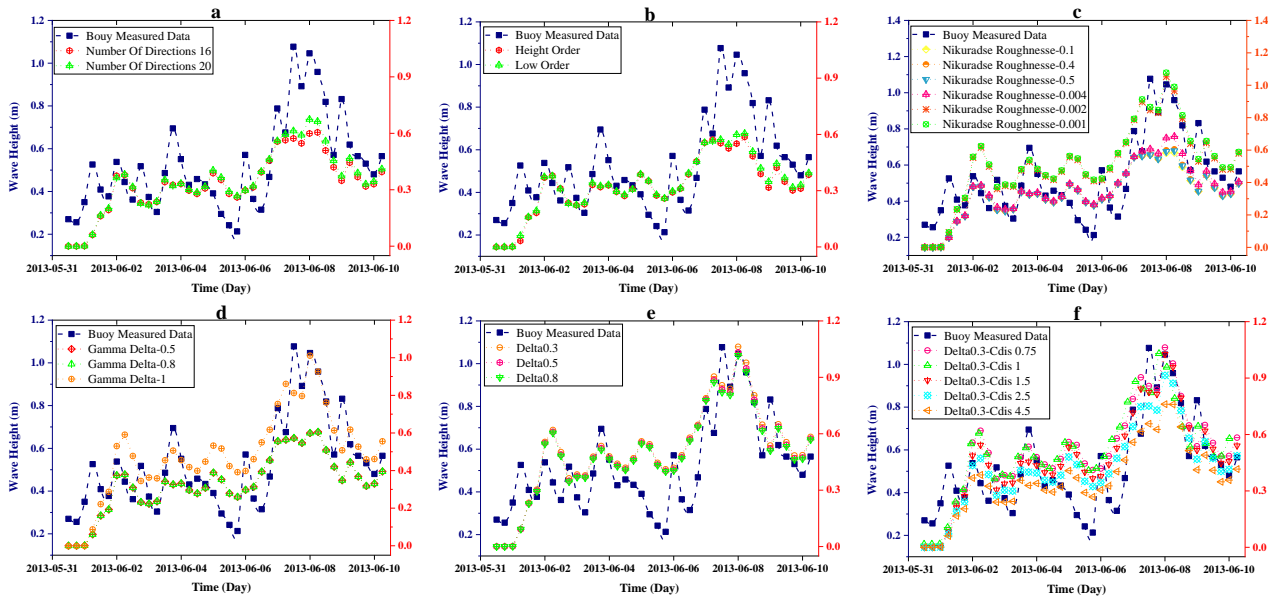


Figure 3. The results of MIKE21-SW model execution and characteristic wave height simulation for (a) the number of directions, (b) equation solution techniques, (c) bottom friction by Nikuradse roughness, (d) wave breaking, (e) DELTAdis, and (f) Cdis

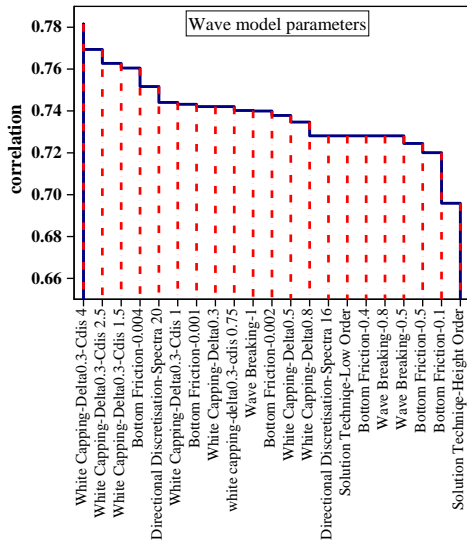


Figure 4. The variable values of the characteristics in the wave height simulation

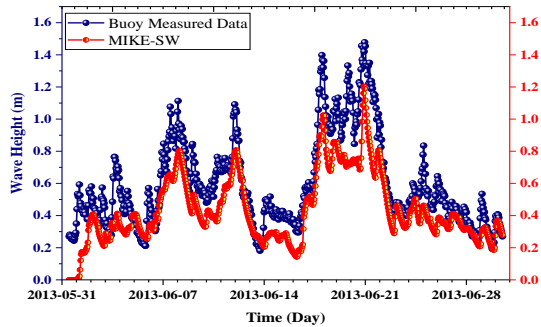


Figure 5. Wave height validation of the MIKE-SW model in June

TABLE 2. Contribution of each characteristic to the wave height simulation correlation

| Wave model parameters | Contribution (percent) |
|---------------------------------------|------------------------|
| White Capping-Delta0/3-Cdis 4/5 | 97.058 |
| White Capping-Delta0/3-Cdis 2/5 | 92.352 |
| White Capping-Delta0/3-Cdis 1/5 | 87.647 |
| Bottom Friction-0/004 | 82.941 |
| Directional Discretisation-Spectra 20 | 78.235 |
| White Capping-Delta0/3-Cdis 1 | 73.529 |
| Bottom Friction-0/001 | 68.823 |
| White Capping-Delta0/3 | 64.117 |
| white capping-delta0/3-cdis 0/75 | 59.411 |
| Wave Breaking-1 | 54.705 |
| Bottom Friction-0/002 | 50 |
| White Capping-Delta0/5 | 45.294 |
| White Capping-Delta0/8 | 40.588 |
| Directional Discretisation-Spectra 16 | 35.882 |
| Solution Technique-Low Order | 31.176 |
| Bottom Friction-0/4 | 26.470 |
| Wave Breaking-0/8 | 21.764 |
| Wave Breaking-0/5 | 17.058 |
| Bottom Friction-0/5 | 12.352 |
| Bottom Friction-0/1 | 7.647 |
| Solution Technique-Height Order | 2.941 |

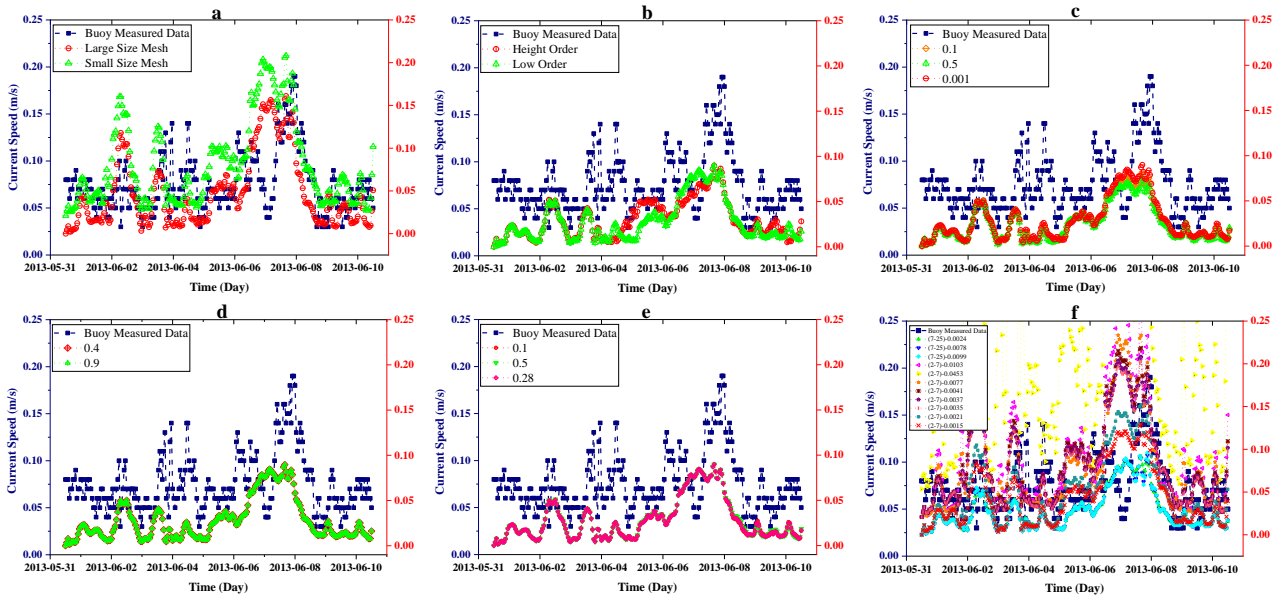


Figure 6. Results of the MIKE3-FM model and current velocity simulation for (a) meshes, (b) solution technique, (c) bed resistance, (d) vertical eddy viscosity, (e) horizontal eddy viscosity, and (f) wind friction

reduction of the simulation results can be observed. The proper selection of optimal coefficients provides reliable simulation. According to Table 2, the white capping made the largest contribution to the wave height simulation by showing an effectiveness of 97%. Bed resistance and the proper number of wind and wave directions were found to be the second and third most effective parameters in the simulation. The other characteristics, such as the solution technique and wave breaking, had small effects on the improvement of the simulation results, even though significant differences are observed between the values selected for the variables. Therefore, it seems to be rational to focus on C_{dis} and $DELTA_{dis}$ in the simulation of waves.

Investigation of the current model

Figures 6a-6f show findings of the MIKE3-FM model and current velocity simulations. According to Figure 6a, the model was sensitive to the mesh size. The reduction of the mesh size was not effective. The solution technique yielded similar results. As in the wave model, the first-order equation had a higher correlation with the field data, as shown in Figure 6b. The bed resistance coefficient was measured by different values, showing no significant difference between the results, as shown in Figure 6c; however, a bed resistance of 0.001 had a higher correlation with the observation data. A Smagorinsky coefficient of 0.1 and a coefficient of 0.4 with a logarithmic formulation were obtained for the horizontal and vertical eddy viscosity components, respectively, as shown in Figures 6d and 6e. Unlike the previous characteristics, wind friction showed significant variations in the current simulation, as indicated in Figure

6f. Unlike the wave model in which different effects of the variable coefficients were obvious, only wind friction indicated considerable fluctuations in the current model.

A significant difference can be seen between the observation data and model results in Figures 6a-6f; the minimum difference is observed for wind friction results. Among the studied coefficients, wind friction at a speed of 2-7 m/s and a friction coefficient of 0.00125-0.0021 simulated the most optimal current velocity.

The execution of the current model with the selected variable values (see Figure 7) with 43200 time-steps every 60 seconds verified the proper selection of the characteristic values, as shown in Figure 8 and Table 3.

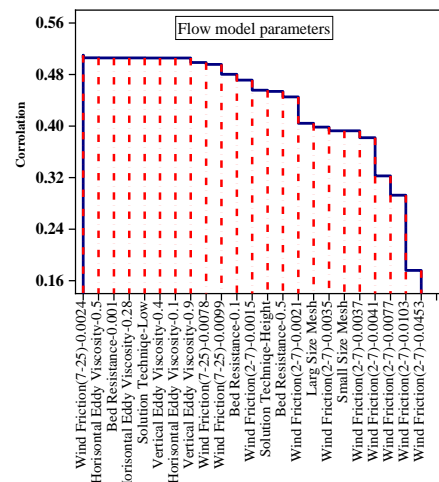


Figure 7. Effects of characteristic values on the ocean current velocity simulation results

The results of the MIKE3-FM module indicates that it is possible to reliability model the current velocity with a correlation of 67% and an acceptable error. Hence, the values of the characteristics were selected properly. The effects of each characteristic to the current velocity simulations are shown in Figure 8 and Table 4.

Table 4 ranks the characteristics based on their contributions to the correlation of 67% with the real-life data. As in the wave model, the consideration of proper values of the characteristics yields more realistic results, while the selection of improper characteristic values significantly reduces the accuracy of the results. According to Table 4, wind friction was found to have the largest effect on the simulation of the current velocity. The other characteristics, such as bed resistance, solution technique, or eddy viscosity, show no considerable difference between the selected values. In addition, the effects of the characteristics on the performance improvement of the model are negligible. Therefore, it is appropriate to consider wind friction for the simulation of the current velocity.

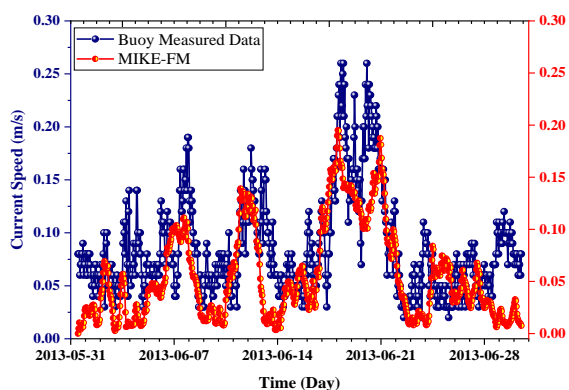


Figure 8. Current velocity validation of the MIKE3-FM model in June

TABLE 3. Comparison of the modeled and measured results by statistical indexes

| comparison of measured and modeled current velocity values | Correlation Coefficient | RMSE |
|--|-------------------------|-------|
| | 0.67 | 0.048 |

TABLE 4. Contribution of each characteristic to the current velocity simulation correlation

| Current speed | Contribution (percent) |
|--------------------------------|------------------------|
| Wind Friction(7-25)-0.0021 | 97.422 |
| Horizontal Eddy Viscosity-0.5 | 89.175 |
| Bed Resistance-0.001 | 85.051 |
| Horizontal Eddy Viscosity-0.28 | 80.927 |
| Solution Technique-Low | 76.804 |
| Vertical Eddy Viscosity-0.4 | 72.680 |

| | |
|-------------------------------|--------|
| Horizontal Eddy Viscosity-0.1 | 68.556 |
| Vertical Eddy Viscosity-0.9 | 64.432 |
| Wind Friction(7-25)-0.0078 | 60.309 |
| Wind Friction(7-25)-0.0099 | 56.185 |
| Bed Resistance-0.1 | 52.061 |
| Wind Friction(2-7)-0.0015 | 47.938 |
| Solution Technique-Height | 43.814 |
| Bed Resistance-0.5 | 39.690 |
| Wind Friction(2-7)-0.0021 | 35.567 |
| Large Size Mesh | 31.443 |
| Wind Friction(2-7)-0.0035 | 27.319 |
| Small Size Mesh | 23.195 |
| Wind Friction(2-7)-0.0037 | 19.072 |
| Wind Friction(2-7)-0.0041 | 14.948 |
| Wind Friction(2-7)-0.0077 | 10.824 |
| Wind Friction(2-7)-0.0103 | 6.701 |
| Wind Friction(2-7)-0.0453 | 2.577 |

CONCLUSIONS

This study evaluated characteristics influencing the simulation of wind-induced waves and ocean currents in the MIKE numerical model. To accurately estimate the maximum wave conditions during large ocean storms, it is important to evaluate the wave climate within shore and offshore areas using the spectral wave module for use in the design of shore, offshore, and port structures. Moreover, the dominant currents in the Caspian Sea, a constituent of which is wind-induced waves, and conditions such as the disconnectedness from oceans, complex topography, shoreline geometry, and considerable temperature and density variations, which make it complex to investigate current patterns in the seas, are of great importance. The spectral wave module was used to model the propagation of waves from the sea toward the shores. The results of the spectral wave module and ocean current model indicated the effects of the characteristics on the simulations. Unlike the current model, which received the highest effect from wind friction, a larger number of characteristics were found to affect the wave model simulation. As a result, to reliability and realistically simulate the waves, it is required to examine all the characteristics. The calibration of the model by only one parameter with a greater effect that can produce a good correlation would increase the error and reduce the realism of the simulation results. In sum, the MIKE numerical model yields acceptable results on the simulation of ocean waves and currents in both MIKE-SW and MIKE-FM modules.

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Persian Abstract

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چکیده

جریان‌های حاکم در دریای کاسپین که امواج ناشی از باد جزو تشکیل دهنده‌ی آنهاست و با توجه به شرایط: عدم اتصال به آب‌های آزاد، توپوگرافی پیچیده، هندسه خطوط ساحلی و تغییرات قابل ملاحظه دما و چگالی که بررسی الگوهای جریان در دریا را پیچیده می‌کند، همواره از اهمیت زیادی برخوردار بوده است. در این مطالعه، مشخصه‌های اصطکاک بستر، شکست موج، سفیدک راس موج، دقت روش محاسباتی و تقسیمات زاویه‌ای، از مدول موج طیفی MIKE-SW و شبکه محاسباتی، دقت روش محاسباتی، مقاومت بستر و اصطکاک باد، در ماژول MIKE-FM برای مدل‌سازی ارتفاع موج و سرعت جریان مورد بررسی قرار گرفتند. طبق نتایج، در مدول موج طیفی به‌عنوان مدل‌ساز روند انتشار موج از آب دریا به ناحیه ساحلی و همچنین در مدل جریان، مقدار اثربخشی و سهم مولفه‌ی شاخص‌ها در شبیه‌سازی مشخص شده است. در نتیجه برای شبیه‌سازی قابل اعتماد که واقعیت‌ها در آن لحاظ شده باشد، باید تمامی مولفه‌ها بررسی شود و استفاده از تنها یک پارامتر با اثربخشی بیشتر گرچه می‌تواند همبستگی خوبی تولید کند اما موجبات آسودگی خاطر را فراهم نمی‌کند. با بررسی تمامی شاخص‌های شبیه‌سازی، مدل عددی MIKE، در هر دو ماژول MIKE-SW و MIKE-FM برای شبیه‌سازی امواج و جریانات دریایی پاسخ قابل قبولی ارائه داده است.
