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SIMULATION OF WAVE CHARACTERISTICS IN CASPIAN SEA USING SWAN

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Key Words: wave hindcasting, SWAN, Caspian sea, QuikSCAT wind field

Abstract

Wave parameters are necessary for many marine and coastal operations. Different methods such as empirical, numerical and soft computing have been developed for wave hindcasting. In this study, SWAN model has been used for the prediction of wave parameters in Caspian Sea. The comparison of obtained results with the Anzali buoy measurements, indicated that this global modeling yields an accurate estimation of wave characteristics.

Introduction

Wave characteristics are one of the most important factors in design of coastal and marine structures. For the prediction of wave parameters, different methods have been developed such as empirical methods (e.g. SPM [1], SMB [2], CEM [3] and Donelan [4]), numerical models (e.g. Mike 21 [5], Wavewatch III [6], WAM [7] and SWAN [8]) and soft computing (e.g. Artificial Neural Network, Fuzzy Inference Systems, Decision Trees and Genetic Programming). Until now different numerical models have been investigated for wave hindcasting ([9], [10], [11], [12], [13] and [14]). In this study SWAN is used for wave modeling in Caspian Sea.

Study Area and Evaluation of the Data

In this study, QuikSCAT wind data have a spatial resolution of 25 kilometer and temporal resolution of 12 hour, were used. The recorded wave data by Anzali buoy at 49.52° E and 37.549° N were used for calibration and verification of the model. The study area, Caspian Sea, has a laterally-prolonged scale of about 800 kilometer in the west-east direction between 47° E and 55° E. Its width is about 1000 kilometer in the north-south direction between 36.5° N and 47° N. The geographical domain has a resolution of 0.0166° E in both x and y directions. Figure 1 shows the considered computational area in the Caspian Sea.

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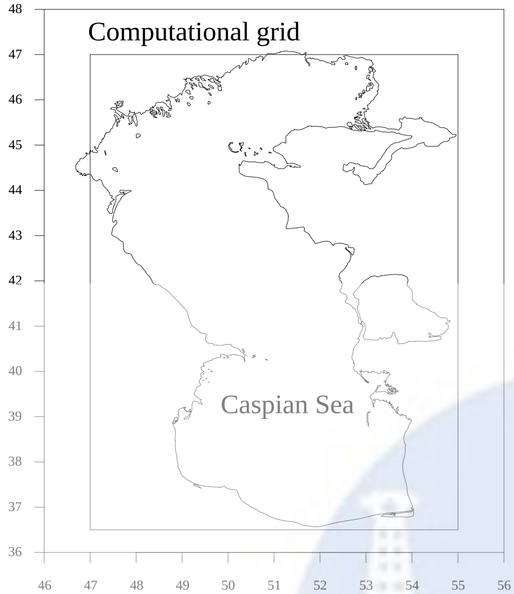

Fig. 1) Computational area in the Caspian Sea

SWAN Model

SWAN is a third generation spectral wind wave model solves the spectral action balance aquation for the cartesian coordinates:

$$\frac{\partial}{\partial t}N+\frac{\partial}{\partial x}c_xN+\frac{\partial}{\partial y}c_yN+\frac{\partial}{\partial \sigma}c_\sigma N+\frac{\partial}{\partial \theta}c_\theta N=\frac{S}{\sigma} \qquad (1)$$

Where N is action density, c_x and c_y is propagation velocities in x and y spaces, respectively. c_θ and c_σ is propagation velocities in θ and σ spaces, respectively. The term *S* on the right-hand side of the equation is the source term in terms of energy density representing the effects of generation, dissipation and nonlinear wave-wave interactions.

Select the Calibration And Verification Periods

For model calibration and verification time series from May, 23th to May, 27th, 2003 and June, 15th to June, 21th, 2003 were selected, respectively. According to the time series of wind and wave data for those periods, there are a good agreement between the variation of wind speed and wave parameters for both calibration and verification periods. Statistics of the wind and wave characteristics for these period are illustrated in tables 1 and 2.

Table 1) Statistical of wind and wave characteristics for calibration period

Parameter	Minimum	Average	Maximum
Significant wave height (m)	0.20	0.45	1.18
Peak period (s)	1.89	4.01	5.88
Wind speed (m/s)	0	3.89	12
Wind direction (degree)	13.33	214.81	350.36

Table 2) Statistical of wind and wave characteristics for verification period

Parameter	Minimum	Average	Maximum
Significant wave height (m)	0.18	0.41	1.56
Peak period (s)	2	3.85	8.33
Wind speed (m/s)	0.04	3.55	17.24
Wind direction (degree)	0.20	206.73	358.68

Calibration of the Model

Time series of the measured and modeled wave characteristics during the calibration period are shown in figures ۲ and 3.

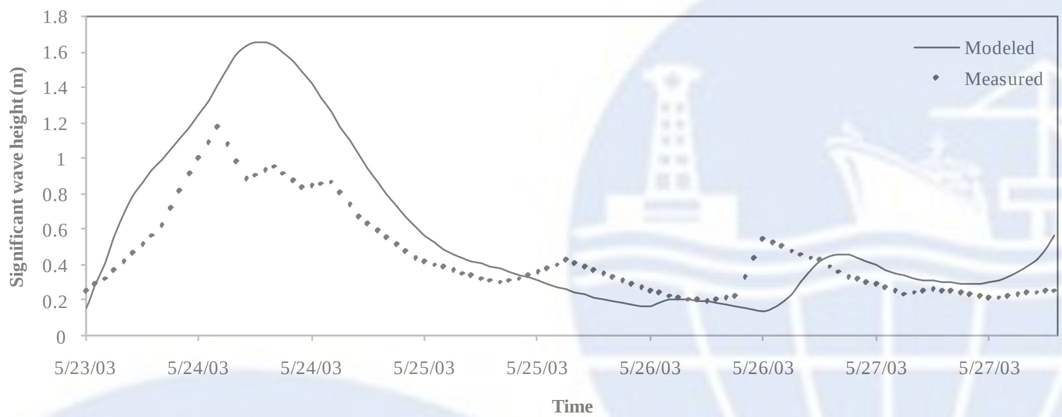

Fig. 2) Time series of the measured and modeled significant wave heights, calibration period

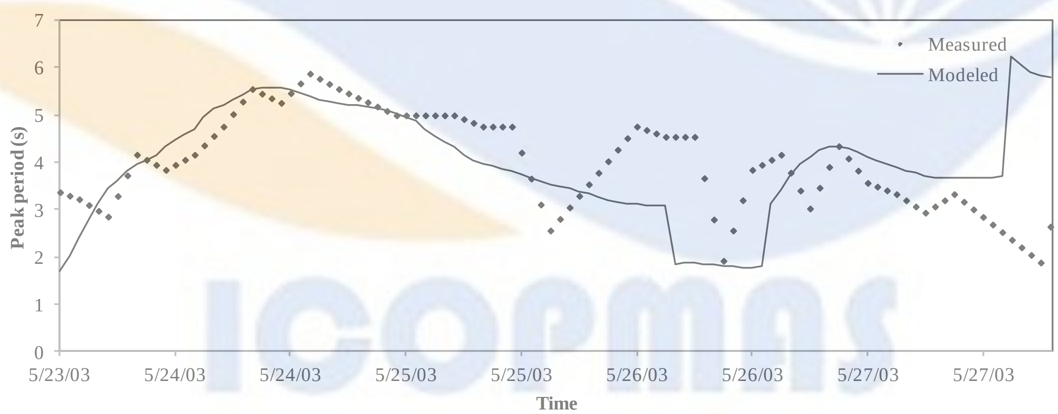

Fig. 3) Time series of the measured and modeled peak period, calibration period

In order to evaluate the results quantitatively, the Bias, correlation coefficient (r), the root mean square error (RMSE) and the scatter index (SI) are calculated:

$$Bias = \overline{p} - \overline{o} \quad (2)$$

$$R = \frac{\sum_{i=1}^{N}\left[\left(o_i - \bar{o}\right)\times\left(p_i - \bar{p}\right)\right]}{\sqrt{\sum_{i=1}^{N}\left(o_i - \bar{o}\right)^2 \sum_{i=1}^{N}\left(p_i - \bar{p}\right)^2}} \quad (3)$$

$$RMSE = \sqrt{\frac{\sum_{i=1}^{N}\left(o_i - p_i\right)^2}{N}} \quad (4)$$

$$SI = \frac{RMSE}{\bar{o}} \quad (5)$$

where, o_i and p_i denote the observed and predicted value, respectively. Moreover, $\bar{o}$ and $\bar{p}$ denote the mean value of them. N shows the number of data.

Table 3) Error indices for calibration period

Error index	Peak period	Significant wave height
Bias	-0.020	0.123
R	0.374	0.917
RMSE	1.209	0.272
SI (%)	30.18	60

Verification of the Model

The results of verification process are indicated in figures 4 and 5 and table 4.

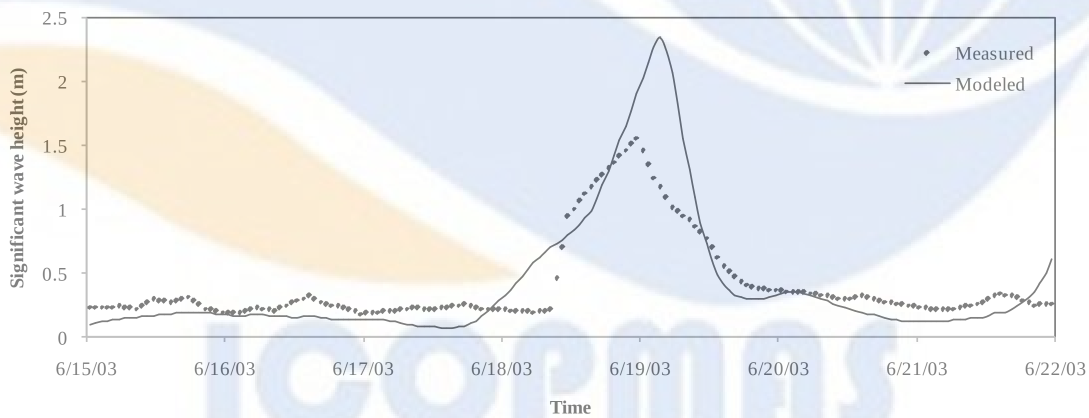

Fig. 4) Time series of the measured and modeled significant wave heights, verification period

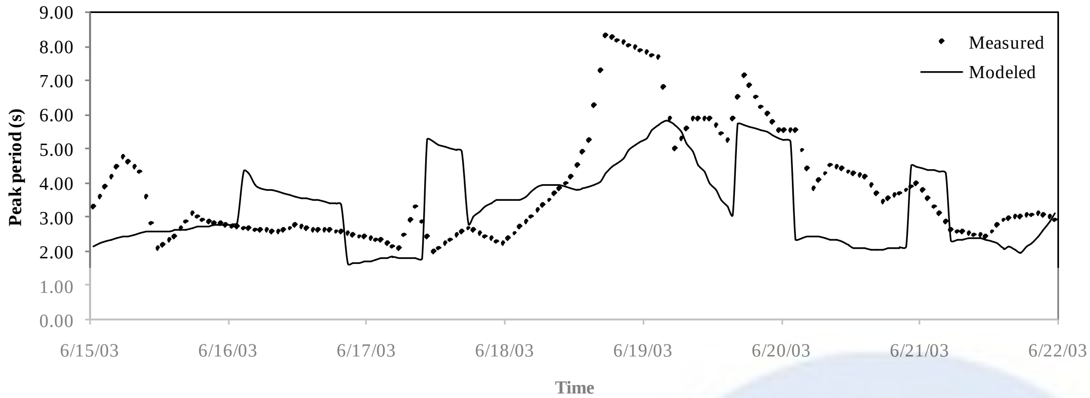

Fig. 5) Time series of the measured and modeled peak period, verification period

Table 4) Error indices for verification period

Error index	Peak period	Significant wave height
Bias	-0.422	0.002
R	0.534	0.903
RMSE	1.487	0.247
SI (%)	38.66	60.53

Summary and Conclusion

In this study SWAN is used for wave modeling in Caspian Sea. The results show that the modeled wave characteristics, were correlated well with observed data in the verification period. Moreover, the statistics of the error show that the model performs well in simulating wave parameters.

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