Application of Simulating WAves Nearshore (SWAN) model for wave simulation in Gulf of Thailand

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Abstract

Evaluation of ocean wave is important matter for human life and activity in coastal area. Understanding characteristic of ocean wave such as ocean wave height can use to determine the fishing area for fishermen, evaluate the coastal erosion, determine ship transportation in ocean and evaluate the ocean wave energy which is the new source energy in recent year for example. Thus, simulation of the ocean wave height by numerical model is presented in this study. The numerical model used in this study is Simulating Waves Nearshore (SWAN) model, which is the third generation wave model and based on wave action balance energy equation. The implementation of the SWAN model, which running 2 periods between March to June and October to December, are clear weather and storm period. The results from SWAN model is compared with the near real time satellite significant wave height from Jason-2 satellite. The scatter plot of observed data with modelled data, comparison of the wind speed between the observed and modelled data from NAVGEM, and monthly validation statistic are presented in this study. The results from this study show an agreement between observed and modelled data. However, some time period shows error. This error is probably due to various times of observed data when compared. The results of this study are a preliminary step to determine the wave energy potential in Gulf of Thailand and will be used as the input data in Computational Fluid Dynamics (CFD) model to generate the ocean wave energy.

Introduction

Thailand is located in South East Asia bounding the Andaman Sea at west side of Thailand and Gulf of Thailand locate at the east side of Thailand. Both 2 seas is the important sea for Thailand such as fishery, traveling, ship transport for example. In Gulf of Thailand, there is a coastal erosion due to reservoir that is constructed in the North part of Thailand, coastal construction that lead to soil erosion in the other area, and ocean wave that eroded the coastal area. Thus, understanding the characteristic ocean wave is important matter for civil management, prevention, and protection the coastal area. To understanding the ocean wave characteristic, the simulation by wave model is presented in this study. Simulating WAves Nearshore (SWAN) model is selected to use in this study.

There are some researches which studied and implemented a simulation of ocean wave height in Gulf of Thailand e.g. Kanbua et al. [1] who implemented the significant wave height in the Gulf of Thailand during Typhoon Linda 1997 by Wave Model (WAM) and Neural Network Approaches, Wannawong et al. [2] studied the wave energy potential in 2011 by numerical model (SWAN model) at Gulf of Thailand, Kositgittiwong et al. [3] simulated the significant wave height by wind-wave model called Waves Model (WAM) in Gulf of Thailand 2011 for computational fluid dynamics simulation based on Navier-Stokes equation, Thanathanphon et al. [4] developed an operational wave forecasting system for Gulf of Thailand by using SWAN model.

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Therefore, the objective of this study is to implement a SWAN model for Gulf of Thailand during March to June and October to December in 2014. The wind data from Navy Global Environmental Model (NAVGEM) in 2014 is used. The bathymetry data is from ETOPO1 which provided by the National Oceanic and Atmospheric Administration (NOAA). The wave simulation model in Gulf of Thailand is a difficult tasks due to lack of wave data from buoys data. Recently, the satellite technology has provided a possible way for model validation. Thus, the significant wave height results are compared with satellite data which provided by Jason-2 data in this study.

Methodology

1. Study area

Study area in this study is the Gulf of Thailand. GOT is bordered by Thailand, Cambodia, and Vietnam. A seabed area is 304,000 km² from 6°N to 13°30' N in latitude and 99°E to 104°E in longitude. The northern of GoT is at the estuary of Chao Phraya River. The southern part of GoT is the line from Cape Bai Bung in southern Vietnam to the city Kota Bharu on Malaysian coast. The Gulf of Thailand is a shallow sea which has 58 meters in mean depth and maximum depth is only 85 meters. In this study, the study area cover 99°E to 103°E and 11°N to 14°N (Fig.1).

2. SWAN model (Simulation of WAves Nearshore)

SWAN model is the third-generation wave model that based on the action balance equation as shown in Eq. 1 [5]. SWAN model solves the spectral action balance equation. It provides realistic estimates of wave parameters in open seas, coastal areas from wind, bottom, and current conditions.

$$\frac{\partial N}{\partial t} + \frac{\partial c_x N}{\partial x} + \frac{\partial c_y N}{\partial y} + \frac{\partial c_\sigma N}{\partial \sigma} + \frac{\partial c_\theta N}{\partial \theta} = \frac{S_{tot}}{\sigma}$$
(1)

The first term on the left-hand side represents the rate of change of action in time, the second and third term represent the propagation of action in x and y axis. The fourth and fifth term are the frequency shift and refraction induced by depth and currents. Where N is the action density spectrum, σ is the frequency, θ is the direction,

c_xand c_y is the propagation velocities in x and y direction.





The right-hand side of this equation represents the effects of generation, dissipation, and nonlinear wavewave interactions. Therefore S_{tot} is the source term of energy density that include atmospheric input (S_{in}), dissipation due to depth-induced wave breaking, bottom friction, and white-capping (S_{dis}), triad and quadruplet nonlinear wave-wave interactions (S_{nl}).

3. Bottom data

The bottom data used in this study is from Earth Topography (ETOPO1) [6], which is the data provided by National Geophysical Data Center (NOAA). The resolution for ETOPO1 is 1 degree resolution or around 1.85 km.

4. Wind data

The wind data is from Navy Global Environmental Model (NAVGEM). The NAVGEM data includes wind data at 10 m above water surface. It is collected every 6 h with resolution of 0.5 degree or around 57 km.

5. Procedure

The procedure in this study is shown in Fig.2. First, provide the data from ETOPO1 in ASCII grid type, which requires program reformat created by using FORTRAN, and transform file data into dat file. While NAVGEM data provide in GRIB format that required to use WGIB program to summation and change into text file. Then, the text file data are reformatted by FORTRAN program. Finally, a bathymetry and wind data are used to input as an input data in SWAN model. The results from SWAN model are presented in map, graph etc. by MatLab program. Last, validation and calibration from observe data are used to conclude the study.



Fig.2 Procedures

Results and discussion

The results from running the SWAN model in the upper part of Gulf of Thailand in this study are compared with Jason-2 data which is a satellite data. The model results are compared with 3 cycles of satellite data in



Fig.3 Significant wave height (H_{1/3}) at the upper part of Gulf of Thailand in 1st April 2014 0800UTC



Fig.4 Significant wave height (H_{1/3}) at the upper part of Gulf of Thailand in 30th May 2014 0800UTC



Fig.5 Significant wave height (H_{1/3}) at the upper part of Gulf of Thailand in 15th November 2014 0800UTC
(a) Significant wave height (b) H_{1/3} comparison between SWAN model and satellite data
(c) Wind speed comparison between SWAN model and Jason-2 data



Fig.6 Significant wave height (H_{1/3}) at the upper part of Gulf of Thailand in 5th December 2014 0800UTC (a) Significant wave height (b) H_{1/3} comparison between SWAN model and satellite data (c) Wind speed comparison between SWAN model and Jason-2 data

each month. Fig.3 shows a map of significant wave height with dash line that shows the satellite moving from point A to point B in 1st April 2014 at 0800UTC, the graph shows the comparison of significant wave height between SWAN model and satellite data and graph comparisons between wind speed from NAVGEM model and satellite data. Fig.4 also shows the map of significant wave height at the upper part of the Gulf of Thailand. The significant wave height from SWAN model trends to decrease at nearshore area due to the wind speed from NAVGEM model trends to drop dramatically. Fig.5 shows a map and comparison of significant wave height with a good agreement between SWAN model and satellite data. The reason with a good agreement from the wind data from NAVGEM model that similar with satellite data. Fig.6 the comparison between SWAN model and satellite data trends to give some error results because the different wind speed data from NAVGEM model and satellite data. The comparison of four figures are selected to show which best agreement on this study. Fig.7 shows the total significant wave height data during March to May 2014 and during October to December 2014. The root mean square error (RMSE) of significant wave height during March to May 2014 is 0.285 m and during October to December 2014 RMSE value is 0.327 m. The RMSE of significant wave height value during October to December 2014 is higher than during March to May 2014. The reason probably because there was a storm happened during October to December 2014 that decrease an accuracy of the satellite data.

Conclusion

This study shows a good agreement between SWAN model results and satellite data from Jason-2. Some time period shows error but still a good tread from various times of observed data when compared, the accuracy of wind data from NAVGEM model and satellite data and small boundary area running due to wave spectrum developing. The accuracy of significant wave height during March to May 2014 is better than during October to December 2014 which is the storm happened in Gulf of Thailand at that time. Future study to simulate

wave by the SWAN model in the large area of Gulf of Thailand to decrease the results error. After validation of SWAN model in the Gulf of Thailand, the main propose is to create a seasonal wave energy distribution map for the Gulf of Thailand.



Fig.7 The relationship of significant wave height between SWAN model and Jason-2 data (a) During March to May 2014 (b) During October to December 2014

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