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RESEARCH ON NEARSHORE WAVE CONDITIONS AT NHAT LE COASTAL AREA (QUANG BINH PROVINCE) BY USING MIKE21-SW

Cham Dao Dinh*, Minh Nguyen Quang, Son Nguyen Thai, Cu Nguyen Van

Institute of Geography, VAST, Vietnam
*E-mail: chamvdl@gmail.com

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Abstract. Research on marine dynamics, including coastal wave motions, is a concern of countries in the world in general and Vietnam in particular. Coastal wave dynamics has a direct impact on human activities including coastal construction, shipping, irrigation, aquatic resources exploitation, etc. The coastal area of Nhat Le, Quang Binh is one of the areas strongly influenced by the coastal wave regime which increases the risk of coastal erosion, estuarine sedimentation, destroys the economic life, affects marine fishing and directly affects the tourist beach area. This article aims to introduce some research results based on the application of MIKE21-SW model of the Danish Hydraulic Institute (DHI) to simulate coastal wave regime in Nhat Le coastal zone, Quang Binh province. The model results are verified by real-time wave data in long-term from the WaMoS® II Radar System at Quang Binh station. The results show that there are many similarities in wave height and direction between the computational model and the actual observation data from the radar system. This result will be an important basis for research and application for coastal protection, reduction in river mouth sedimentation, clearing and flood drainage in the study area.

Keywords: Wave, MIKE21-SW, radar system, coastal area, Nhat Le.

RESEARCH BACKGROUND

Nhat Le coastal area is located in Dong Hoi city, Quang Binh province with geographic coordinates from 17°25' to 17°31' North latitude and 106°35' to 106°41' East longitude. The length of the coast is about 16 km in the direction of northwest - southeast. In this coastal area, there is a dominance of the hydrography of the Nhat Le estuary. Nhat Le is the river mouth of Kien Giang river. Kien Giang river has a basin area of 2,650 km^2, located in the low land area of the Central Coast. The river section from Quan Oanh to Dong Hoi city at Nhat Le estuary is oriented in meridian direction and when pouring into the sea, the river mouth is oriented to northeast direction while the nearby shoreline is oriented to northwest - southeast.

Nhat Le coastal area is the convergence of interactions of sediment dynamics introduced by river and sea. In this area, the outgo of sediment from the river in the combination with incoming tidal currents and waves from the sea have created a very complex picture of dynamical situation. In addition, there are frequent natural disasters such as storms, floods and droughts, which increase the possibility of coastal erosion, estuarine sedimentation, etc. In recent years, erosion of coastal area and estuarine sedimentation are occurring with an increasing trend in terms of both scale and intensity. From 2012 to now, more than 30 boats entering and exiting the estuary have been stranded at Nhat Le estuary causing many boats to be hit by waves. Hundreds of ships and boats entering the estuary to avoid the typhoon

from late October per year cannot return to the sea and have to lie back inside the estuary, affecting the lives of fishermen and development of marine economy of Quang Binh province. Nhat Le river mouth is filled with canals that cannot be easily navigated away from sea and cannot be brought inside the harbor.

Moreover, the coastal areas of Nhat Le estuary are facing the risk of increasing coastal erosion. There is 126 km of coastline over the whole province and there are 25 banks with strong erosion, including the northern bank of Nhat Le estuary. Among of them with the length of the coastline being landslide about 2 km from the river mouth, to the beach tourism and the coastal economy. The beach in the north of Nhat Le estuary is very complex and visitors are sometime in danger. There have been many drowning cases at sea that have been washed away by waves. This results in negative impact on bathing tourism of Quang Binh province.

In order to assess the hydrodynamic regime in Nhat Le coastal area for coastal protection, river mouth clearance, clearing and flood drainage in the study area, the authors of the article research into wave regime in the coastal area of Nhat Le estuary based on the application of MIKE21-SW model verified by real wave data with long-term continuous data from WaMoS® Radar system. The aim of the study is to provide quantitative and qualitative research results that contribute to understanding the wave regime in Nhat Le coastal region of Quang Binh province.

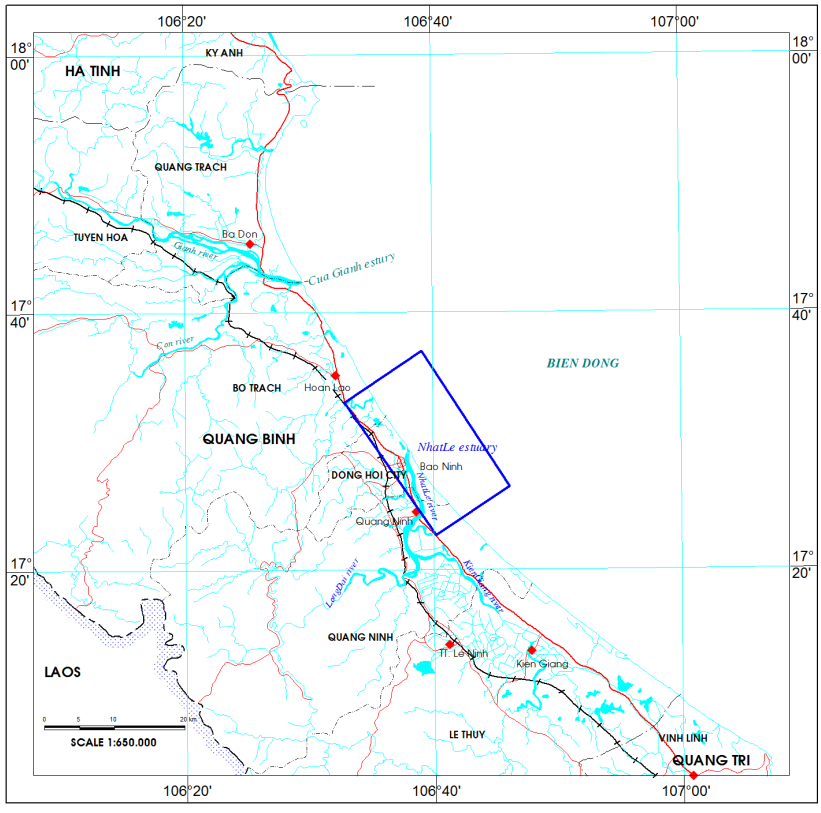

Fig. 1. Study area

DATABASE AND MATHEMATICAL MODELLING

Database. Topography: Topographic maps on 1:10,000 scale are measured by the Institute of Geography, Vietnam Academy of Science and Technology in 2015 and 2016 for the coastal areas of Nhat Le, Quang Binh province and that on a scale of 1:50,000 for offshore areas is

established by the Center for Sea Survey and Mapping, Ministry of Natural Resources and Environment.

Characteristics of wave, current, water level and tide: including NOAA wave data, tidal composition of DTU10, water level measurement, waves (wave height, wave direction and wave period) and flow (velocity, flow direction) by the AWAC (Norwegian) Wave and Stream Monitoring System conducted by the Institute of Geography in 2015 and 2016. In particular, this article uses the results of wave observations using a Radar WaMoS®II system for a continuous period of one year to compare and evaluate with the quality of the mathematical results.

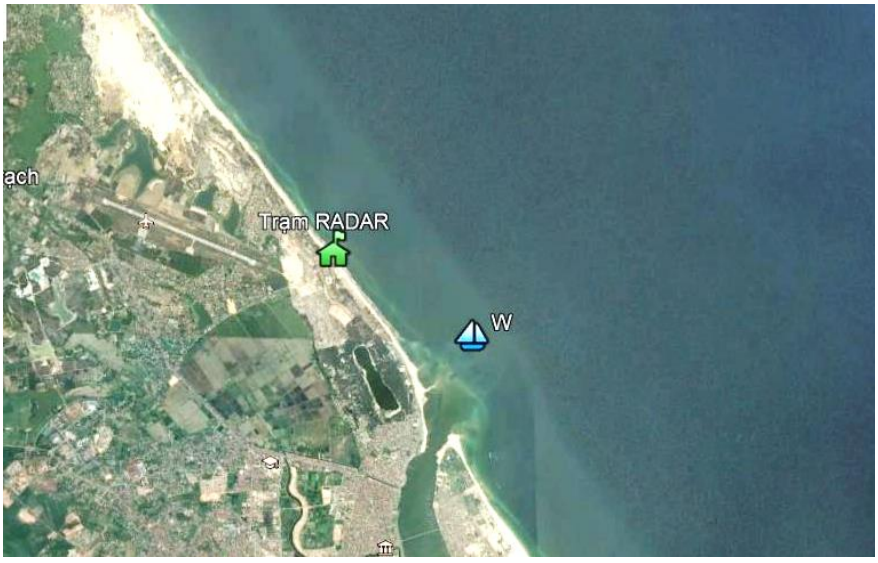

Fig. 2. Location of Quang Binh radar station and W (AWAC) station

Fig. 3. Location of Radar WaMoS®II at Dong Hoi city, Quang Binh province

The WaMoS® II (German) Radar System is a modern system developed to measure sea flow conditions and surface parameters. This system is specifically designed to operate from stationary motion platforms and onboard decks. Thus, the system provides real-time data on marine physics such as wave height, wave period, wave direction and surface flow with

continuous time. This is a very important data that is valuable in research for coastal protection and livelihood activities. The WaMoS® II Radar System is located at Quang Phu commune, Dong Hoi city, Quang Binh province (Quang Binh station), at 106°36'58" East longitude, 17°30'29" North latitude. It allows continuous observation of day, night on marine dynamic factors (wave, surface flow, water level fluctuation). In particular it can observe these marine factors during extreme weather conditions (e.g. monsoon, tropical low pressure, hurricane,...) (fig. 2–3).

Mathematical modeling. Research on wave regime is a very complex issue, requiring sophisticated, modern computing tools and software installed on a highly configurable computer. Nowadays, with the strong development of science, many advanced mathematical modeling tools have been developed for the study of hydrodynamic regimes in general and wave regimes in particular for coastal areas. Therefore, the selection and comparison between the computational models should be carried out to produce accurate calculation results to ensure high quality in the study. To study the simulations of coastal wave regime in Nhat Le we use the modern hydraulic model MIKE21-SW from the Danish Hydraulic Institute (DHI). The model is a tool to perform calculating and forecasting functions based on clear mathematical relationships and with scientific basis. This is important for assessing the effectiveness of proposed scientific and technological solutions, as well as the warning of adverse effects. In addition, based on the analysis of simulation results of the mathematical model, suitable solutions for the coastal protection and reduction of natural disasters in the coastal areas can be selected.

MIKE21-SW is developed by Danish Institute of Hydraulics. The spectral modulus was calculated based on unstructured grid. This module calculates the development, depletion and transmission of waves generated by wind and swell waves in the offshore and coastal areas [1]. MIKE21-SW consists of two different formulas:

Parametric separation of direction;

Full spectrum formula.

The split parameter formula is based on the parameterization of the wave conservation equation. Parameterization is done with frequency domain by introducing zero and first order moments of the wave activity spectrum as independent values [4, 5]. The same approximation is used in the MIKE21-NSW for coastal wind wave module. The total spectral formula is based on the wave conservation equation, described by Komen et al., (1984, 1994) [6, 7] and Young (1999) [8], where the wave propagation spectrum of the active wave is the dependent value. Basic equations are developed in both Cartesian coordinate system with small-scale applications and the coordinate system for larger applications.

MIKE21-SW includes the following physical phenomena:

Waves developed by the wind action;
Nonlinear wave-wave interaction;
Wave dissipation due to the whitecaps;
Wave dissipation due to bottom friction;
Dissipating waves due to breaking waves;
Wave refraction and shallow water effects due to changes in depth;
Interaction between wave and flow;
Impact of changes in depth over time.

The basic equation is the wave equilibrium equation developed for both Cartesian and Polar coordinates (see Komen et al., (1994) [7] and Young (1999) [8]).

The equation for wave operation is written as follows:

$$\frac{\partial N}{\partial t} + \nabla.\left(\vec{v}.N\right) = \frac{S}{\sigma}$$

Where: $N\left(\vec{x},\sigma,\theta,t\right)$ is the activity density; t is time; $\vec{x} = \vec{x}\left(x,y\right)$ is the Cartesian coordinates and $\vec{x} = \vec{x}\left(\phi,\lambda\right)$ is in Polar coordinates, bridged with ϕ as latitude and λ as longitude; $\vec{v} = \vec{v}\left(c_x, c_y, c_\sigma, c_\theta\right)$ is the velocity of the wave group transmitting in four dimensions; $\vec{v}$, σ and θ, and S are the source terms for the energy equation; ∇ is a four-dimensional different operator in space $\vec{v}$, σ and θ.

Set up the MIKE21-SW model for the study area. Construction of computational grid and bathymetry: Based on collected data on topography and boundary conditions, the article is identified to generate grid computing for the model. Bottom bathymetry is based on survey results conducted by the Institute of Geography on a scale of 1:10,000 for the study area and a 1:50,000 topographic map of the sea floor for the offshore area is produced by the Center for Sea Survey and Mapping. The grid consists of a coarse mesh with a large region and a refined mesh with a small domain inside. Fine mesh resolution varies from 10 m in the river mouth to 500 m in the sea with about 20,000 elements. The model extent covers the entire study area outside the East Sea (fig. 4).

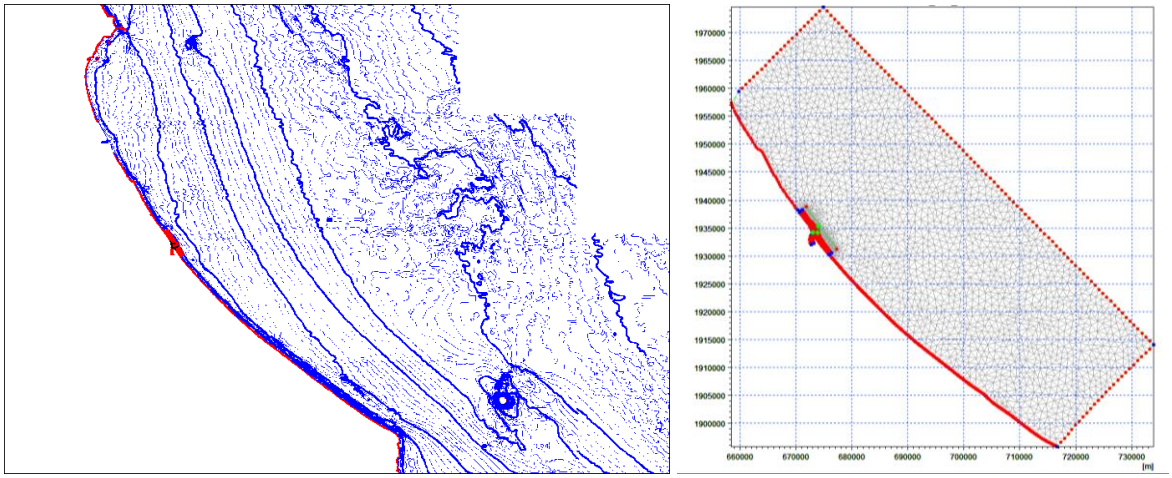

Fig. 4. Topography and grid of the study area

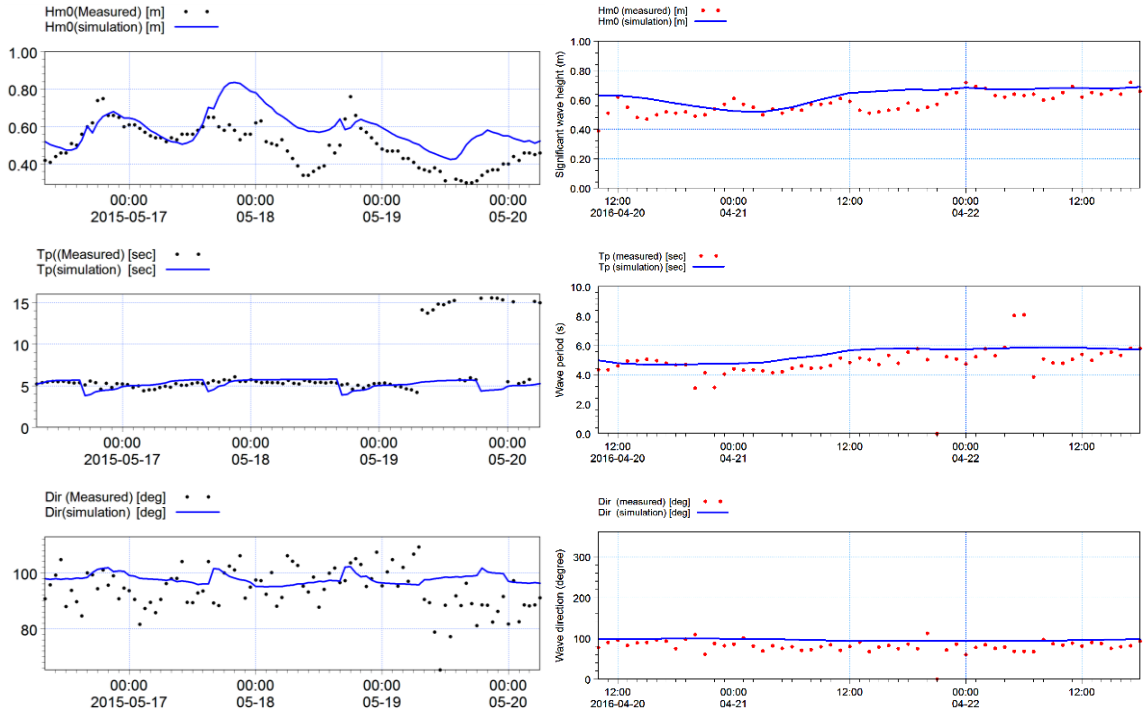

Fig. 5. Measured and calculated wave height, wave period and wave direction at W

Boundary condition: NOAA wave data [2].
The model calibration time is May 2016.
The paper used the Nash-Sutcliffe (1970) [9] indicator to evaluate the agreement between the calculated and the measured results of the MIKE21-SW model.

$$N^2 = \frac{\sum_{i=1}^{n}\left(X_i - \bar{X}\right)^2 - \sum_{i=1}^{n}\left(X_i^{'} - X_i\right)^2}{\sum_{i=1}^{n}\left(X_i - \bar{X}\right)^2}$$

Where: N^2: Efficiency ratio of the model (Nash); i: Indicator; X_i: Measurement value; $X_i^{'}$: Value calculated by model; $\bar{X}$: Average measured value.

The results of the comparison between the measurements and calculations show that the Nash coefficient is quite good: N = 0.85 (fig. 5).

RESULTS AND DISCUSSION

The wave observations made by the radar system at Quang Binh station from November 2016 to October 2017 at 500 m from the coastline show that the average wave height is 1.1 m, the largest one is 5.7 m. Coastal wave regime in Nhat Le coastal area shows a seasonal distinction. As a result of continuous wave monitoring, from November 2016 to April 2017, northwest wave prevails with average wave height of 1.5 m and the largest one of 5.4 m From May 2017 to October 2017, wave height is low, southeast wave prevails with average height less than 1.0 m. Especially, in July, 2017, two typhoons struck the central coastal area and affected Nhat Le coastal area, including typhoon TALAS with wave height of 2,2 m and typhoon SONCA with wave height of 3.86 m.

The results of wave simulation from Mike 21-SW show a seasonal distinction in Nhat Le coastal area.

Fig. 6–10 show the comparison of measured (measured by ***Radar WaMoS***®II) and simulated significant wave height and wave direction (by Mike 21-SW) at Quang Binh station during one year from November 2016 to August 2017.

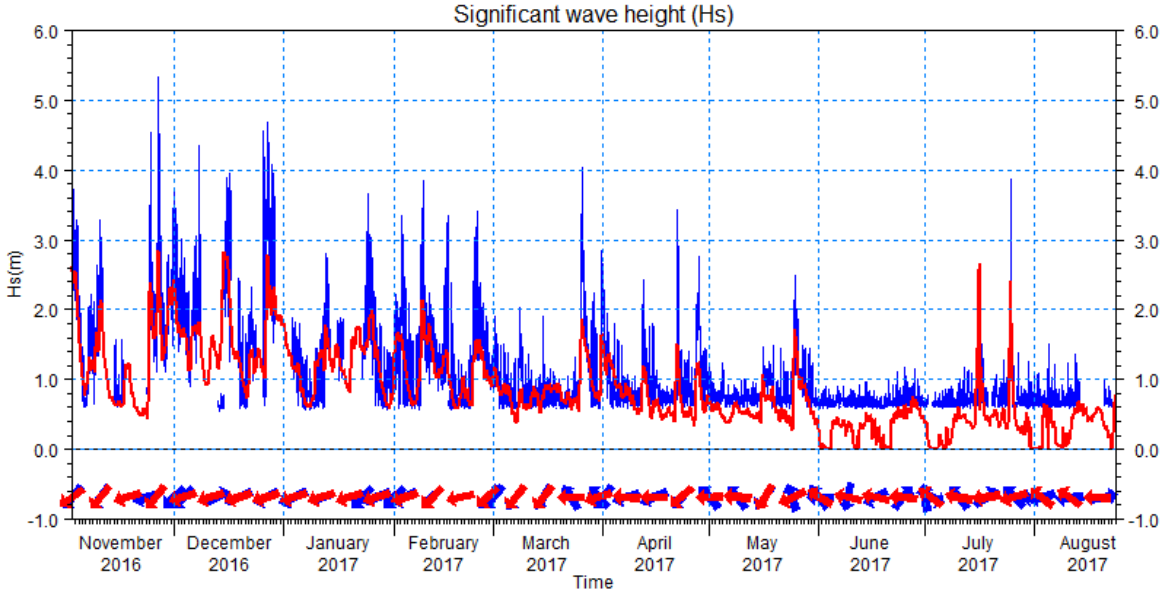

Fig. 6. Comparison of wave height, wave direction between RADAR (green) and Model MIKE 21-SW (red)

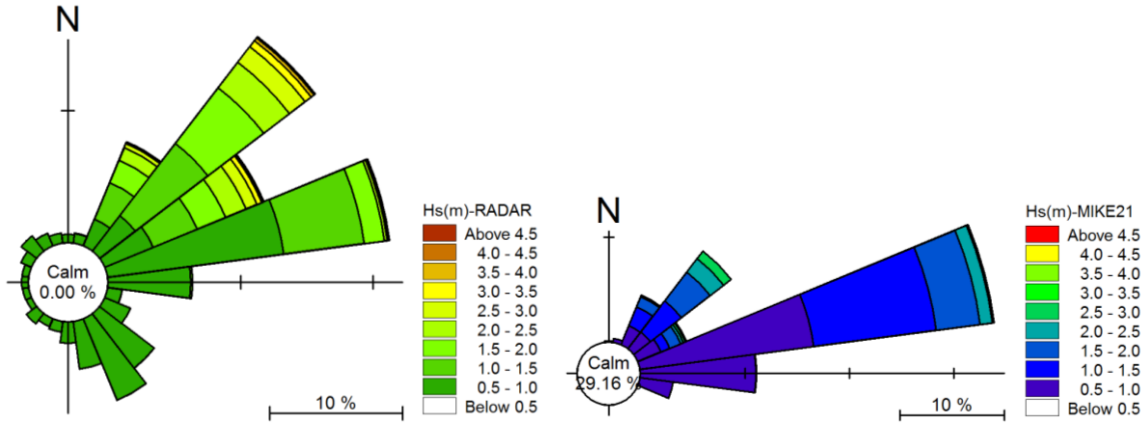

Fig. 7. Wave rose (Radar and Mike 21-SW)

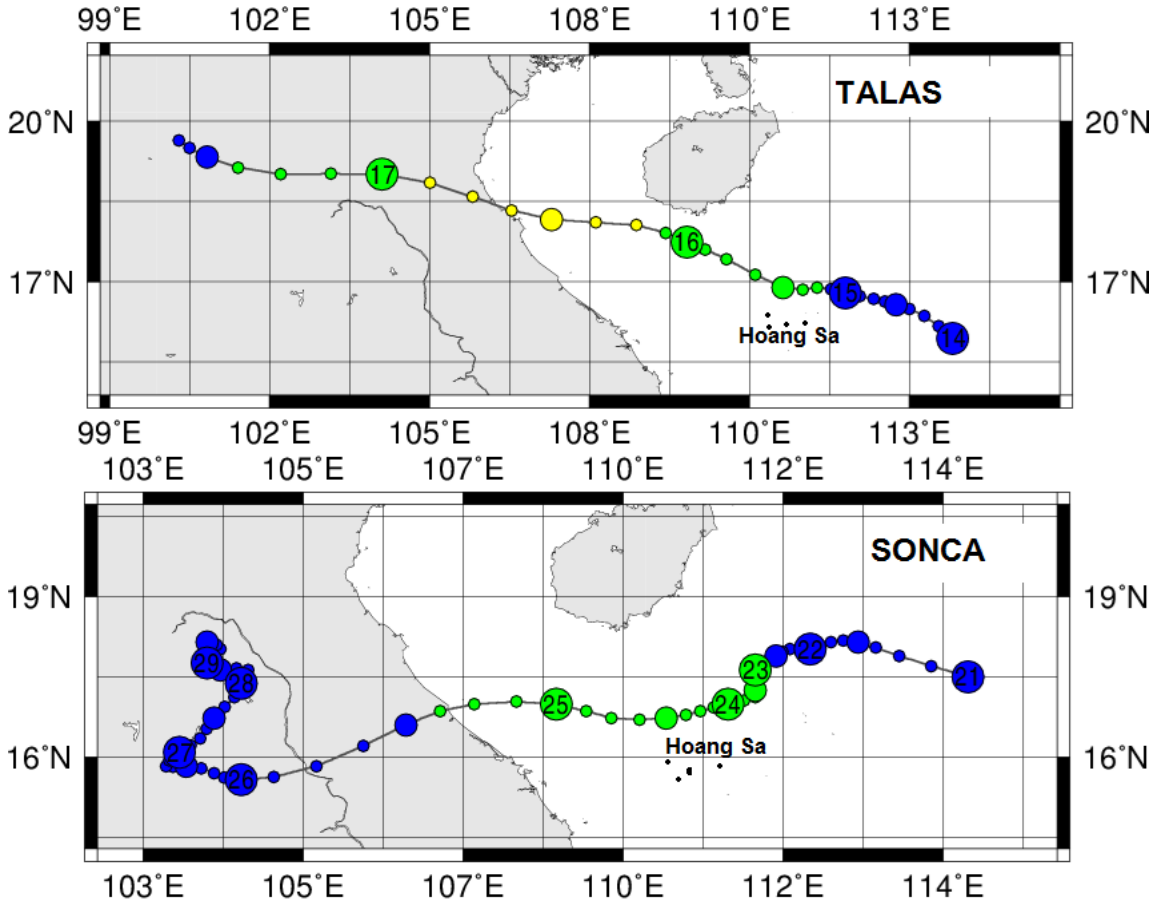

Fig. 8. Tracks of TALAS and SONCA hurricanes [3]

To evaluate the wave simulation capability of MIKE 21-SW in more detail, the article shows a comparison of measured (measured by radar) and simulated significant wave height and wave direction at Quang Binh station during two TALAS and SONCA hurricanes which affected Nhat Le coastal area in July 2017.

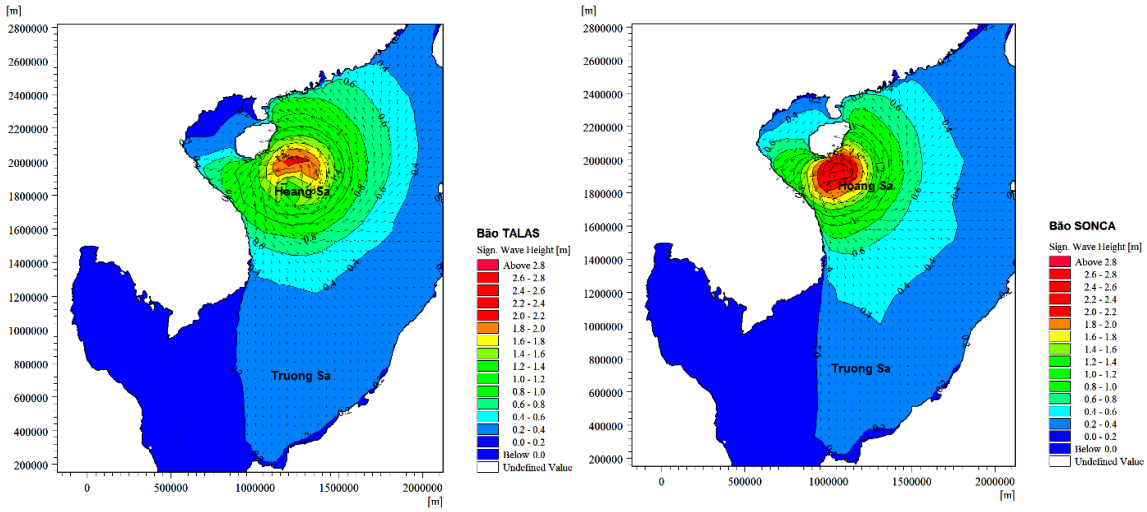

Fig. 9. Extreme wave field and extreme wave direction of TALAS and SONCA hurricanes (July 2017)

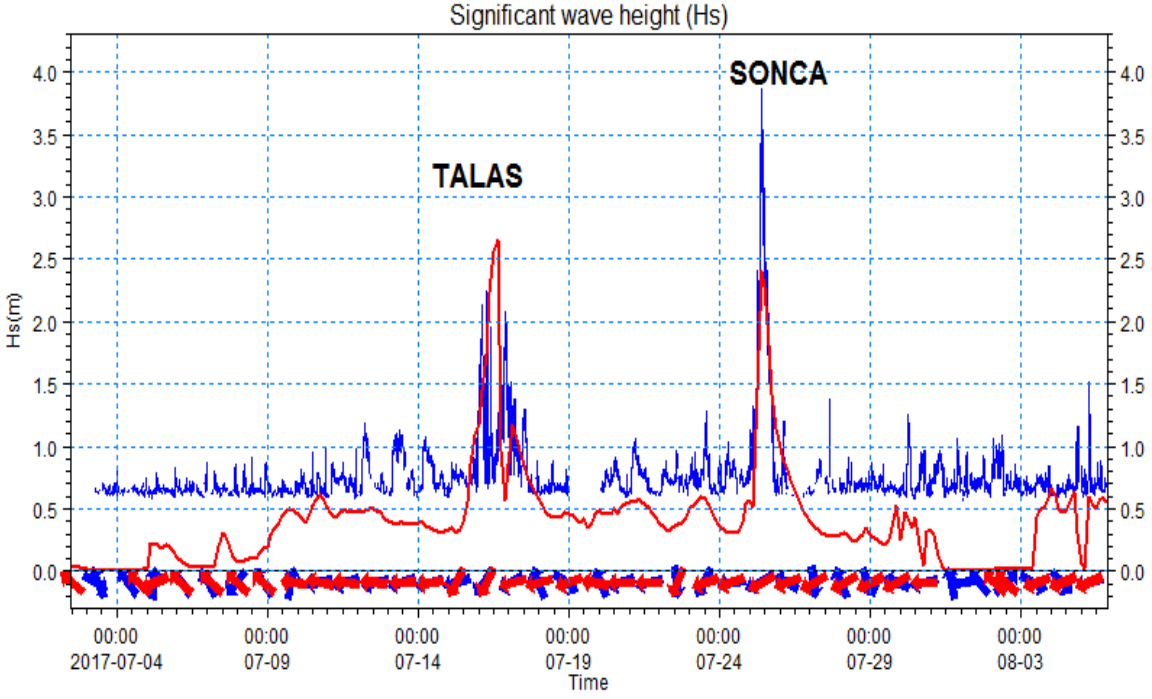

Fig. 10. Comparison of wave height, wave direction between RADAR (green) and Model MIKE 21-SW (red)

In general, the simulated and measured wave phase and wave direction are in good agreement. Wave height measured by radar system is higher than that simulated by Mike 21-SW. This difference is due to input data of Mike 21-SW model which is the unadjusted global wave data with the interval of 3 hours for a data whereas data from the radar system is quite detailed with a cycle time of the order of 5 minutes. Wave roses of radar system and Mike 21-SW for 1 year show that Nhat Le coastal area is mainly affected by northeastern

waves. Especially in case of storm, large waves impact directly on the coast, river mouths which greatly affect coastal erosion activities. In addition, the combination of observation data from radar system and Mike 21-SW simulation model illustrates the big picture of wave regime of Nhat Le coastal region. Large wave height prevails in the winter months which accounts for 80% with wave direction mainly in north-east and east-north-east. In summer months, wave height is quite small.

CONCLUSION AND RECOMMENDATION

Study of hydrodynamic principles in coastal and river estuary areas has great scientific and practical significance. This is the basis for simulating the processes of coastal sediment transport and suspended matter, floating objects on the ocean surface. This will help to protect the coastline, minimize river mouth sedimentation, clear the channel and drain coastal floods. Especially, in the abnormal weather conditions such as monsoon, tropical low pressure, hurricane,… the radar system can provide more realistic and continuous observation data than previous data from observation devices in Vietnam. The measurement data from the radar system is very important in supporting and improving the quality of the results for numerical models (good input data and in case of calibration and validation), which accurately and quantitatively assess hydrodynamic processes (waves and currents) for coastal areas of Vietnam in general and Nhat Le coastal areas in particular.

The results of study have simulated wave regime in Nhat Le coastal area, which show a big picture of the seasonal change in dynamics. The results of this research could be provided to authorities for warning visitors who swim and bathe on the Nhat Le beach. In addition, it also serves for coastal protection, coastal livelihoods and flood drainage in downstream area of Nhat Le river, Quang Binh province.

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