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ESTIMATION OF EXTREME WAVE CONDITIONS IN THE SOUTHERN NHATRANG BAY AREA

LE DINH MAU

Summary: *This paper presents the distribution features of calculated maximum significant wave height in the Southern Nhatrang Bay area corresponding to maximum wind speed of 50 years return periods. Wind data from 1976 to 2006 were taken from Nhatrang Meteorological Station. Weibull distribution function was used to estimate maximum wind speed for different return periods. Dolphin and SWAN models were used to estimate wave characteristics in the offshore and nearshore regions, respectively. The studied results show that maximum wind speeds for 50 years return period were 27, 22, 15 and 17 m/s in NE, E, SE and S directions, respectively. The areas of Southern Tre Island including Nhatrang Port, Mieu, Mot, Tam, and Mun Islands were strongest affected by wave action from E and S directions with significant wave height of 2 – 4 m, and lesser affected by wave action from NE and SE directions with significant wave height of 2 m. The area between Mun Island to Noi and Ngoai Islands, and the coastline from Dongba to Camranh Headlands were strongest affected by wave action from E and NE directions with significant wave height of 4 – 7 m, and lesser affected by wave action from SE and S directions with significant wave height of 2- 3 m. Maximum wind field blown from SW direction (V = 19 m/s) was generated a relatively strong wave field in the study area, especially in the area around Mun and Mot Islands with significant wave height range from 1.5 to 2.0 m. In general, for maximum wind speed of 50 years return period the southern area of Nhatrang Bay was strongest affected by wave action from E and NE directions.*

I. INTRODUCTION

In recent years, the Southern Nhatrang Bay area has become the most attractive place of the economic, tourism, etc. activities such as mari-culture; marine recreation; construction of jetties, shore protection structures, etc. These activities need the supplying of extreme wave conditions for sustainable exploitation and development of the study area. Features of wave condition during typhoons off Khanhhoa coast was studied by Le Dinh Mau (2005), but in the nearshore area which still have not detail studied. Therefore, it is necessary to estimate the distribution of wave characteristics in the study area during extreme wind conditions. The present study applied the following wave numerical models:

- Dolphin model to estimate wave characteristics in the offshore region.

- SWAN model to estimate wave characteristics in the nearshore region.

For incoming wind directions from offshore region such as NE, E, SE and S. The input data of SWAN model are wave characteristics in the offshore region which were estimated by Dolphin model, local wind fields, and bathymetry. Whereas, in case of incoming wind directions from landmass such as SW the input data of SWAN model were local wind field and bathymetry only. Since, the processes of forming wave characteristics at a location in the nearshore region depends on the local conditions such as fetch, direction, duration of wind field; bathymetry and morphology of the study area, and offshore wave condition. Figure 1 shows the feature of study area and computation domain.

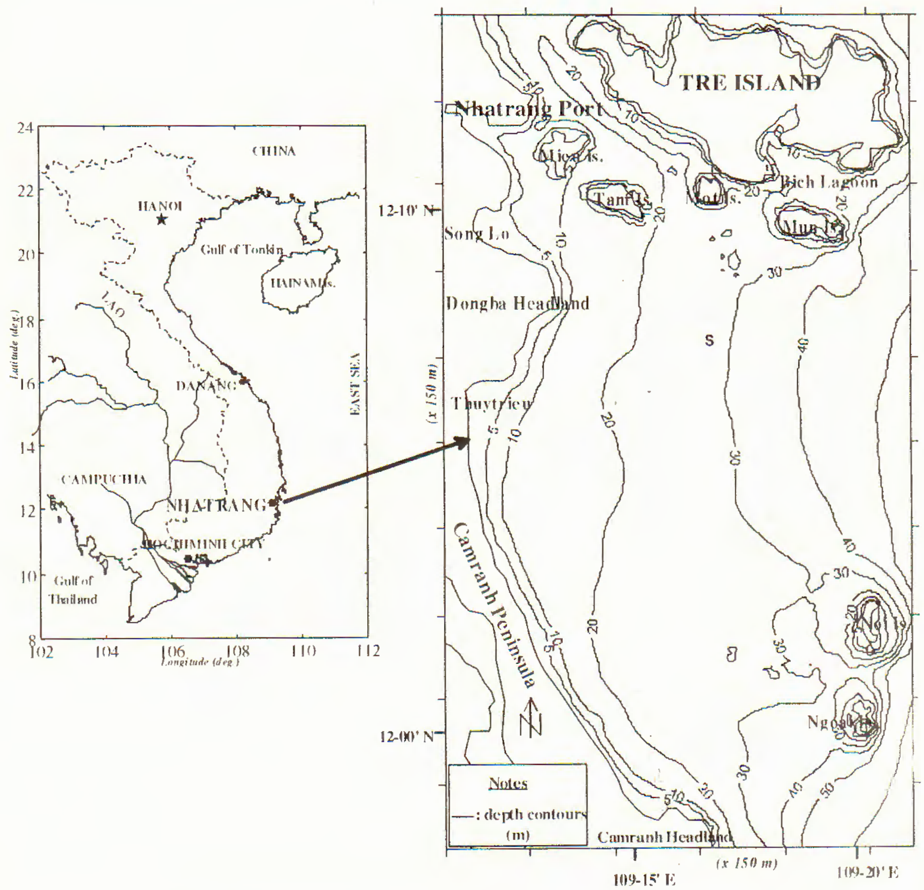

Figure 1. Location and features of study area

In general, the design duration of civil structures in the study area is about 50 years and from the limited size of the paper. So, the study results presented here were only the distribution features of significant wave height corresponding to 50 years return periods.

II. DATA AND METHODS

1. Data sources

- Annual maximum wind speed series during 30 years (1976-2006) in NE, E, SE and S directions were collected from Nhatrang Meteorological Station.

- Bathymetry of the study area was collected from hydrographic map with scale of 1/25,000 published by Vietnamese Navy in 1964.

2. Methods

To estimate wave characteristics in the nearshore region for extreme wind conditions. The following calculated steps were applied:

- Extreme wind speed for different return periods in different directions was estimated by Weibull distribution function.

- Extreme wave conditions of Nhatrang Bay in the concerned directions in which the study area are exposed to the open sea were estimated by the deep water numerical wave model Dolphin.

- Maximum wave characteristics in the nearshore region were estimated by SWAN model, the boundary conditions were offshore wave conditions (which were estimated by Dolphin wave model), local wind fields and bathymetry.

a. Estimation of extreme wind speed.

Wind at a design site may be important for local wave generation, nearshore current generation, nearshore water level, nearshore sediment transport, overtopping, sail forces on moored and moving boats, and harbor circulation, etc. Statistical methods for analyzing long-term information covering many years are an integral part of most design application. Typically the largest parameter values are the primary design concern. Extreme events are often highly variable in terms of intensity and sequencing. By definition, they are rare. The preferred approach to data selection is to take the maximum value from each event to create a partial duration series of extreme values.

According to CEM (2002), a simple approach to data selection is to take the maximum value from each year of record to form an annual maximum series. A record length on the order of 20 years or more (yielding at least 20 data values) is needed for this approach. Generally an extreme data value series is treated as a sample from a process that follows one of the extreme distribution functions such as FT-I, FT-II, Weibull, etc.

Based on this approach, using Weibull distribution function the extreme values of wind speed corresponding to different return periods were determined.

b. Deep water numerical wave model - Dolphin.

Numerical wave model-Dolphin (Mandal and Holthuijsen, 1985) is used to estimate wave characteristics in the offshore region. The energy balance equation for wind waves from direction (θ) can be expressed as:

$$\frac{dE_1(\theta)}{dt} = S_1(\theta) + \int_0^\infty S_2(f,\theta)df \tag{1.1}$$

Where,

$E_1(\theta)$ = the directional energy density of wind waves propagating in the direction considered (m^2/rad.)

$S_1(\theta)$ = the rate of change of $E_1(\theta)$ induced by wind. If E_1 is less than some upper limit, it represents growth, otherwise decay (m^2/rad/s).

$S_2(f,\theta)$ = the rate of transfer of 2-dimensional swell energy E_2 to the wind wave field at the same frequency (m^2/rad/Hz/s).

θ = direction from which wave component approach the point of forecast (Rad).

f = frequency (Hz).

The energy equation for swell from the direction (θ) is express as:

$$\frac{dE_2}{dt} = -BS_{11}(f,\theta) - S_2(f,\theta) - S_3(f,\theta) \tag{1.2}$$

Where,

$E_2(f,\theta)$ = the two-dimensional energy density of a swell component with frequency (f), propagating in the direction (θ) (m^2/rad/Hz/s).

$B = 1$ if $S_1 < 0$

$B = 0$ if $S_1 > 0$

S_{11} = the rate of change of E_2 corresponding to S_1 when S_1 is negative

S_2 = the rate of change of transfer of swell energy E_2 to be zero or positive (m^2/rad/Hz/s).

S_3 = the rate of change of swell energy due to swell-bottom interaction, used only for shallow water.

* Input data are: Location of calculated point, wind (velocity, duration).

* Output data: Significant wave height (H_s), spectral wave period (T_p), coefficient of spectral directional spreading (DSPR) and wave direction (θ).

c. Nearshore numerical wave model - SWAN

The wave characteristics in the study area were computed using SWAN (Simulating WAves Nearshore) model which is a third – generation wave model (Booij, et al., 1999) with which realistic estimates of wave parameters in coastal areas, lakes and estuaries from given wind, bottom, and current conditions can be obtained.

The evolution of the wave spectrum is described by the spectral action balance equation, which, for Cartesian coordinate, is (Hasselmann et al., 1973)

$$\frac{\partial}{\partial t}N + \frac{\partial}{\partial x}C_x N + \frac{\partial}{\partial y}C_y N + \frac{\partial}{\partial \sigma}C_\sigma N + \frac{\partial}{\partial \theta}C_\theta N = \frac{S}{\sigma} \quad (2.1)$$

The first term in the left hand side of Eq. 2.1 represents the local rate of change of action density (N) in time, the second and third term represent propagation of action in geographical space (with propagation velocities C_x and C_y in x and y space, respectively). The fourth term represents shifting of the relative frequency due to variations in depths and currents (with propagation velocity C_σ in σ space). The fifth term represents depth-induced and current-induced refraction (with propagation velocity C_θ in θ space). The term $S = S(\sigma,\theta)$ at the right hand side of the action balance equation is the source term in term of energy density representing the effects of generation, dissipation and nonlinear wave-wave interactions.

The SWAN model accounts for shoaling, refraction, generation by wind, white-capping, triad and quadruplet wave–wave interactions, bottom friction, and depth – induced wave breaking.

The size of the computational grid was 17.5 x 34 km, with resolution of 150 x 150 m (Figure 1). The spectral frequency (f) range was 0.052 – 1 Hz with $\Delta f = 0.01$ H_z and range in direction (θ) was 0 to 360^o with $\Delta\theta = 10^o$. The output data were significant wave height (Hs), peak wave period (Tp), mean wave length (L), mean wave direction (φ).

III. STUDY RESULTS

1. Maximum wind speed for different return periods

Based on the annual maximum wind speed series collected from Nhatrang wind station (1976-2006) in different directions. Using Weibull distribution function and graphical method. Maximum wind speed for different return periods in the concerned directions are shown in Table 1.

Table 1. Maximum wind speed *(m/s)* for different return period in different directions at Nhatrang Station (1976-2006)

No. Sr.	Directions / Return periods (years)	NE	E	SE	S
1	1	16	13	11	11
2	5	20	16	12	13
3	10	23	18	13	14
4	25	25	20	14	16
5	50	27	22	15	17

For SW direction, the measured wind data was not completed to form a series of annual maximum wind data. Therefore, we only consider the maximum wind speed occurred during 1976-2006, V_{max}=19m/s.

2. Maximum significant wave characteristics for different return periods off Nhatrang Bay

Based on extreme wind data (statistic from Nhatrang Station for the period: 1976-2006) corresponding to different return periods on the concerned directions. Using deep sea numerical wave model – DOLPHIN, the extreme significant wave height and peak wave period for different return periods in the offshore region of Nhatrang Bay are shown in Table 2 to Table 5.

Table 2. Significant wave characteristics for different return periods in the offshore region of Nhatrang Bay (NE direction)

Return periods (years)	1	5	10	25	50
Maximum wind speed – V (m/s)	16	20	23	25	27
Significant wave height – Hs (m)	3.5	4.7	5.7	6.4	7.1
Peak wave period - Tp (s)	8.4	9.2	10.1	10.1	11.1
Coefficient of spectral directional spreading - DSPR (deg.)	27.1	27.1	27.0	27.0	26.9

Table 3. Significant wave characteristics for different return periods in the offshore region of Nhatrang Bay (E direction)

Return periods (years)	1	5	10	25	50
Maximum wind speed – V (m/s)	13	16	18	20	22
Significant wave height – Hs (m)	2.6	3.5	4.1	4.7	5.4
Peak wave period - Tp (s)	7.0	8.4	8.4	9.2	10.1
Coefficient of spectral directional spreading- DSPR (deg.)	27.1	27.2	27.0	27.1	27

Table 4. Significant wave characteristics for different return periods in the offshore region of Nhatrang Bay (SE direction)

Return periods (years)	1	5	10	25	50
Maximum wind speed – V (m/s)	11	12	13	14	15
Significant wave height – Hs (m)	2.1	2.3	2.6	2.9	3.2
Peak wave period - Tp (s)	6.3	7.0	7.0	7.6	7.6
Coefficient of spectral directional spreading - DSPR (deg.)	27.3	27.2	27.2	27.1	27.1

Table 5. Significant wave characteristics for different return periods in the offshore region of Nhatrang Bay (S direction)

Return periods (years)	1	5	10	25	50
Maximum wind speed – V (m/s)	11	13	14	16	17
Significant wave height – Hs (m)	2.1	2.6	2.9	3.5	3.8
Peak wave period - Tp (s)	6.3	7.0	7.6	8.4	8.4
Coefficient of spectral directional spreading - DSPR (deg.)	27.2	27.1	27.3	27.2	27.1

3. Distribution features of maximum significant wave height in the Southern Nhatrang Bay area corresponding to 50 years return periods.

Computed maximum significant wave height patterns in the study area are shown in Fig. 2 to Fig. 6.

- For maximum wind field (V = 27 m/s, Direction = NE)

In the offshore region of Nhatrang Bay maximum significant wave height was around 7 m, major wave direction was NE. The most area of Southern Nhatrang Bay area from Dongba Headland to Camranh Headland maximum significant wave height range from 4 to 7 m, major wave direction was NE to ESE. The area around Nhatrang Port and Mieu Island maximum significant wave height was less than 2 m, major wave direction was NE. In the area of Mun, Tam, Mot Islands, and Bich Lagoon maximum significant wave height was around 2 – 4 m, major wave direction was E. In general, the southern region of Mun Island and the coastline from Thuytrieu to Camranh Headland were strongest affected by wave action. Whereas, the southern region of Tre Island which covers the area of Mieu, Tam and Mot Islands was relatively less affected by wave action. (Fig. 2)

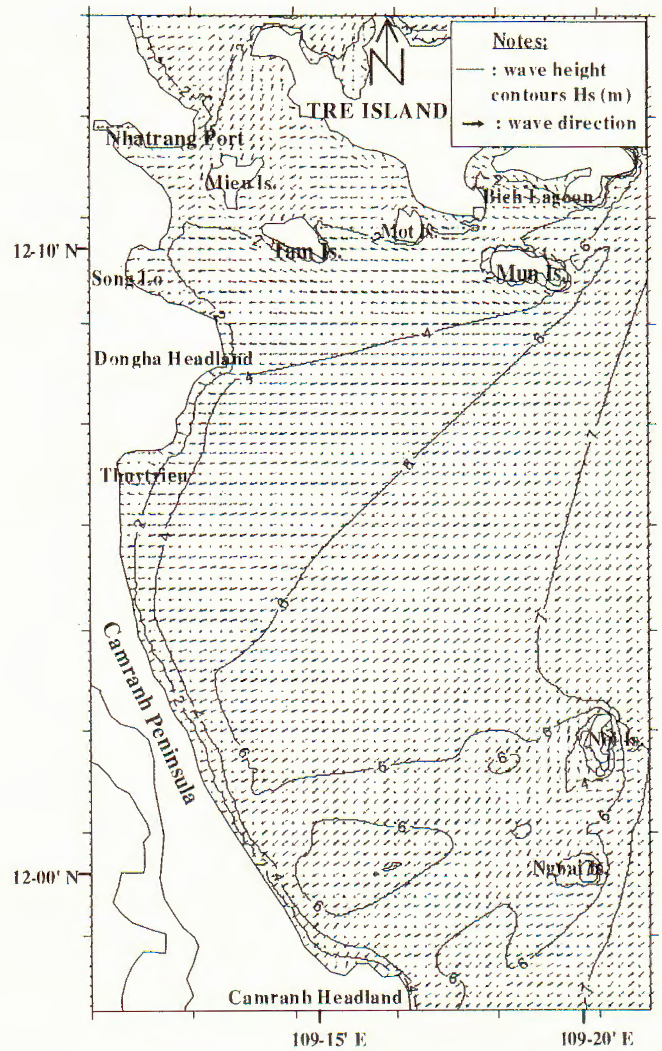

Figure 2. Computed significant wave height pattern in the Southern Nhatrang Bay area (Wind condition: V = 27 m/s, Direction = NE)

- **For maximum wind field (V = 22 m/s, Direction = E)**

In the offshore region of Nhatrang Bay maximum significant wave height was greater than 5 m, major wave direction was E. The most area of Southern Nhatrang Bay from Tam and Mun Islands to Noi, Ngoai Islands and the coastline from Dongba Headland to Camranh Headland were strongest affected by wave action with maximum significant wave height of 4 – 5 m and major wave direction was E. The area around Nhatrang Port and Mieu, Tam, Mot Islands maximum significant wave height was around 2 – 4 m, major wave direction was SE. In general, for 50 years return periods the southern region of Nhatrang Bay was relatively strong affected by wave action. (Fig. 3)

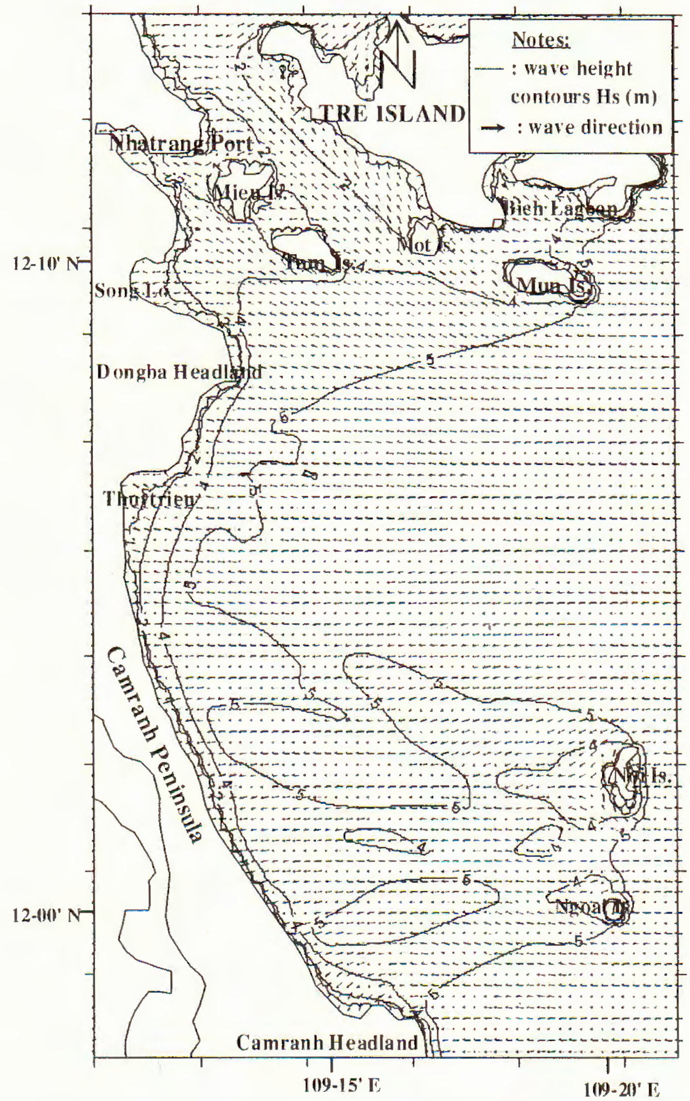

Figure 3. Computed significant wave height pattern in the Southern Nhatrang Bay area (Wind condition: V = 22 m/s, Direction = E)

- **For maximum wind field (V = 15 m/s, Direction = SE)**

With maximum wind speed of 15 m/s which is similar to a strong monsoonal wind field in the open sea. But in the study area which will be generated a significant wave field and serious effects to the activity of mari-culture, tourism, etc. In the offshore region of Nhatrang Bay maximum significant wave height was greater than 3 m, major wave direction was SE. The most area of Southern Nhatrang Bay area was covered by significant wave height of 2 – 3 m, major wave direction was SE. In general, for 50 years return periods the southern region of Nhatrang Bay was relatively strong affected by wave action. (Fig. 4)

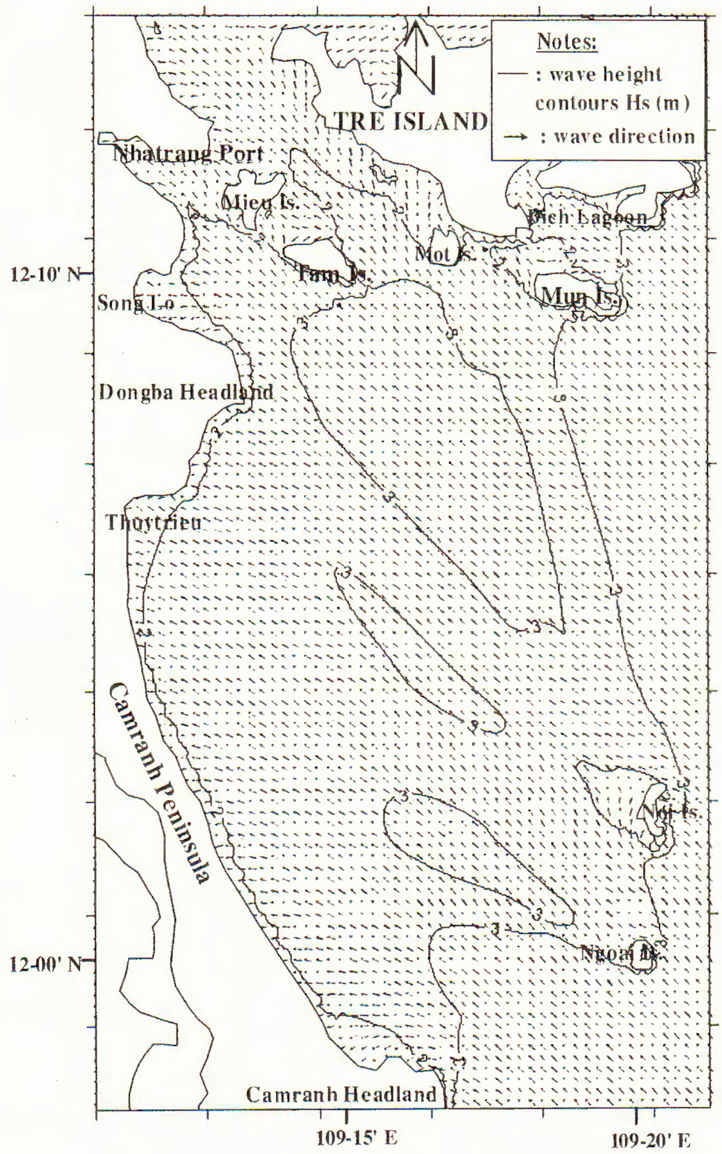

Figure 4. Computed significant wave height pattern in the Southern Nhatrang Bay area (Wind condition: V = 15 m/s, Direction = SE)

- **For maximum wind field (V = 17 m/s, Direction = S)**

In the offshore region of Nhatrang Bay maximum significant wave height was greater than 3 m, major wave direction was S. The most area of Southern Nhatrang Bay area from Tam and Mun Islands to Noi, Ngoai Islands were strongest affected by wave action with maximum significant wave height greater than 3 m and major wave direction was S. The area around Nhatrang Port and Mieu, Tam, Mot Islands, Bich Lagoon and the coastline along Camranh Peninsula were less affected by wave action with maximum significant wave height of 1 – 3 m, major wave direction was SE. In general, for 50 years return periods the southern region of Nhatrang Bay was relatively strong affected by wave action. (Fig. 5)

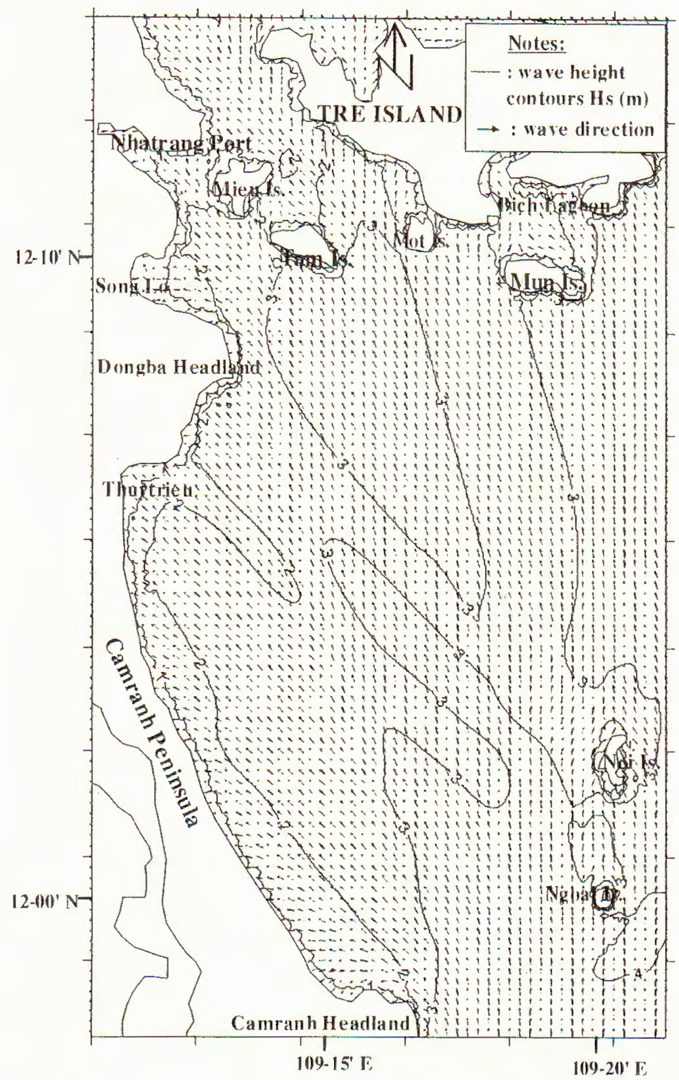

Figure 5. Computed significant wave height pattern in the Southern Nhatrang Bay area (Wind condition: V = 17 m/s, Direction = S)

- **For maximum wind field (V = 19 m/s, Direction = SW)**

The wind field was blown from the landmass area. Therefore, the generated wave field was formed by local wind field only. The nearshore area along Camranh Peninsula and Nhatrang Port have maximum significant wave height of less than 1 m, major wave direction was SW. The remain areas of Southern Nhatrang Bay were stronger affected by wave action with maximum significant wave height of 1-2 m and major wave direction was SW, especially the area around Mun and Mot Islands. In general, the southern region of Nhatrang Bay was relatively affected by wave action with incoming wind from SW direction. (Fig. 6)

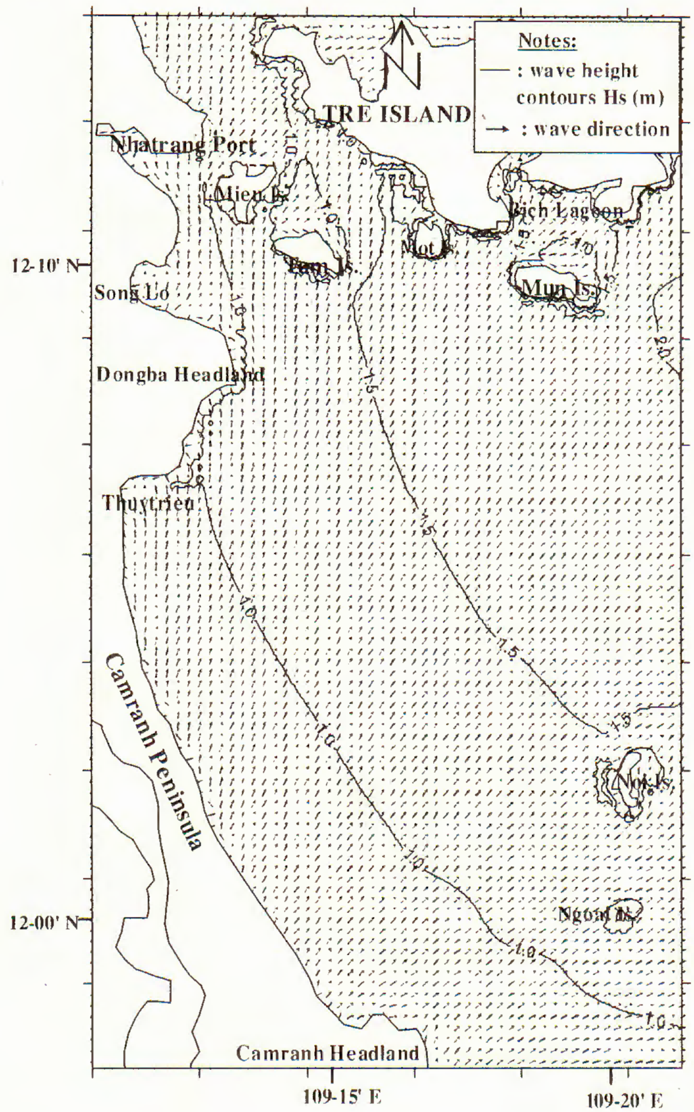

Figure 6. Computed significant wave height pattern in the Southern Nhatrang Bay area (Wind condition: V = 19 m/s, Direction = SW)

V. CONCLUSION

From the study results following conclusions can be reported.

- Estimation of extreme wind speed based on the annual maximum wind speed series collected from Nhatrang Meteorological Station (from 1976 to 2006) gives the maximum wind speed for 50 years return period were 27, 22, 15 and 17 m/s in NE, E, SE and S directions, respectively.

- The area of Southern Tre Island including Nhatrang Port, Mieu, Mot, Tam, and Mun Islands were strongest affected by wave action from E and S directions with maximum significant wave height of 2 – 4 m, and less affected by wave action from NE and SE directions with maximum significant wave height of 2 m. The area between Mun Island to Noi and Ngoai Islands, and the coastline from Dongba to Camranh Headland were strongest affected by wave action from E and NE directions with maximum significant wave height of 4 – 7 m, and lesser affected by wave action from SE and S directions with maximum significant wave height of 2- 3 m.

- Maximum wind blows from SW direction (V = 19 m/s) was generated a relatively strong wave field in the study area, especially in the area around Mun and Mot Islands with maximum significant wave height of 1.5 – 2.0 m.

- In general, for maximum wind speed of 50 years return period the Southern of Nhatrang Bay area was strongest affected by wave action from E, NE directions.

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TÍNH TOÁN CÁC ĐẶC TRƯNG SÓNG CỰC TRỊ TẠI VÙNG BIỂN PHÍA NAM VỊNH NHA TRANG

LÊ ĐÌNH MÀU

Tóm tắt: *Bài báo trình bày kết quả tính toán sự phân bố các đặc trưng sóng cực trị tại vùng biển phía Nam vịnh Nha Trang ứng với tốc độ gió cực trị có hoàn kỳ 50 năm. Số liệu gió được thu thập từ trạm Nha Trang (1976-2006). Tốc độ gió cực trị ứng với các hoàn kỳ khác nhau được xác định bằng hàm phân bố Weibull. Các đặc trưng sóng ngoài khơi được tính toán bằng mô hình Dolphin. Các đặc trưng sóng vùng ven bờ được tính toán bằng mô hình SWAN. Kết quả nghiên cứu cho thấy tốc độ gió cực trị ứng với hoàn kỳ 50 năm là 27, 22, 15 và 17 m/s trên các hướng NE, E, SE và S tương ứng. Khu vực phía Nam đảo Hòn Tre bao gồm cảng Nha Trang, các đảo Hòn Miếu, Hòn Một, Hòn Tằm và Hòn Mun bị tác động mạnh nhất bởi sóng E và S với độ cao sóng hữu hiệu là 2-4 m, và ít bị tác động bởi sóng đến từ hướng NE và SE với độ cao sóng hữu hiệu là 2 m. Vùng biển phía Nam đảo Hòn Mun tới Hòn Nội, Hòn Ngoại và dải ven bờ từ mũi Đông Ba đến mũi Cam Ranh bị tác động mạnh nhất của sóng hướng E và NE với độ cao sóng hữu hiệu là 4-7 m và ít bị tác động bởi sóng đến từ hướng SE và S với độ cao sóng hữu hiệu là 2-3 m. Gió SW cực đại (V=19 m/s) đã tạo ra trường độ cao sóng đáng kể tại khu vực nghiên cứu nhất là tại khu vực đảo Hòn Mun và Hòn Một với độ cao sóng hữu hiệu là 1.5-2 m. Nhìn chung ứng với tốc độ gió cực trị có hoàn kỳ 50 năm khu vực nghiên cứu bị tác động mạnh nhất của sóng E và NE.*

Ngày nhận bài: 01 - 4 - 2008

Địa chỉ: Viện Hải dương học

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