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ĐẶC ĐIỂM BIẾN ĐỔI CÁC ĐẶC TRƯNG SÓNG NGOÀI KHƠI VÙNG BIỂN QUẢNG NAM - QUẢNG NGÃI, MIỀN TRUNG VIỆT NAM

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Tóm tắt Bài báo trình bày kết quả tính toán các đặc trưng sóng ngoài khơi vùng biển Quảng Nam – Quảng Ngãi trong thời gian từ 9/1999 đến 8/2000 nhằm hiểu biết đặc điểm biến đổi của chúng. Số liệu gió 6 giờ 1 lần trên Biển Đông được thu thập từ nguồn số liệu NCEP/NCAR. Các đặc trưng sóng vùng khơi trong điều kiện bình thường được xác định bằng mô hình WAM. Số liệu của các cơn bão đổ bộ vào vùng biển Quảng Nam – Quảng Ngãi được thu thập từ Sở Khí tượng Quốc gia, Hoa kỳ và được sử dụng trong mô hình Young nhằm xác định các đặc trưng sóng vùng khơi trong điều kiện bão. Kết quả nghiên cứu cho thấy rằng vùng biển ngoài khơi Quảng Nam – Quảng Ngãi chịu ảnh hưởng của chế độ gió mùa: gió mùa tây nam (tháng 6 đến tháng 8) và đông bắc (tháng 10 đến tháng 4). Thời kỳ gió mùa tây nam tốc độ gió trung bình là 4,8 m/s, độ cao sóng hữu hiệu trung bình là 1,2 m, chu kỳ sóng trung bình là 6,9 s, hướng sóng chủ đạo là SE đến SW. Thời kỳ gió mùa đông bắc tốc độ gió trung bình là 6,9 m/s, độ cao sóng hữu hiệu trung bình là 1,6 m, chu kỳ sóng trung bình là 8,1 s, hướng sóng chủ đạo là NE đến E. Thời kỳ chuyển tiếp (tháng 5 và tháng 9) tốc độ gió trung bình là 3,7 m/s, độ cao sóng hữu hiệu trung bình là 0,8 m, chu kỳ sóng trung bình là 6 s và hướng sóng không ổn định. Tốc độ gió cực đại là 23,2 m/s, độ cao sóng hữu hiệu cực đại là 5,3 m.

VARIATION OF WAVE CHARACTERISTICS IN THE OFFSHORE WATERS OF QUANG NAM AND QUANG NGAI PROVINCES, CENTRAL VIETNAM

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Abstract A study was carried out to understand the variation of wave characteristics in the offshore waters of Quangnam and Quangngai provinces of Central Vietnam during September 1999 to August 2000. Wind data obtained from the 6 hourly NCEP/NCAR reanalysis wind data over the East Sea (South China Sea) were used in WAM wave model to estimate wave characteristics in the offshore regions for normal condition. Data of hurricanes crossed the coastline of Quangnam and Quangngai provinces were collected from the National Weather Service, USA and were used in Young's model to estimate wave characteristics for hurricane condition. The studied results showed that the offshore waters of Quangnam and Quangngai provinces was subjected to seasonal variability with the reversing SW (June – August) and NE (October – April) monsoons. During SW monsoon period mean wind speed was 4.8 m/s, mean significant wave height was 1.2m, mean wave period was 6.9 s and major wave directions were from SE to SW. During NE monsoon period mean wind speed was 6.9 m/s, mean significant wave height was 1.6 m, mean wave period was 8.1 s and major wave directions were from NE to E. During transition periods (May and September) mean wind speed was 3.7 m/s, mean significant wave height was 0.8 m, mean wave period was 6 s and wave direction was varied. Maximum wind speed of the waters was 23.2 m/s, maximum significant wave height was 5.3 m.

I. INTRODUCTION

Wave climate is the temporal distribution of wave conditions averaged over the years. A wave condition is the particular combination of wave heights, wave periods, and wave directions at a given time. A specific offshore wave condition is the result of local winds blowing at the time of the observation and the recent history of winds in the more distant parts of the same water body. The offshore wave condition depends on the wind velocity, duration and fetch. Offshore wave climate varies among different coastal areas because of differences in exposure to waves generated in distant parts of the sea and because of systematic differences in wind patterns around the Earth. The variations in offshore wave climate affect the amount of littoral wave energy available and the directions from which it comes. The orientation of a shoreline to the seasonal distribution of winds and to storm tracks is a major factor in determining the wave energy available for littoral transport.

Information on waves is obtained either through site-specific measurements or through modeling. Since the site-specific measurements are time consuming and expensive, the wave parameters are usually estimated using numerical models based on the measured/satellite derived wind data and validated with measurements at few locations. Not only the marine fisheries, transportation, petroleum industries, etc. activities in the offshore region but also litho-hydro-dynamic processes, mariculture, environment protection, etc. in the nearshore were mostly depended on the offshore wave climate. Therefore, understanding of the seasonal distribution of wave characteristics in the offshore region is important for the efficient management and development of the coast. The study was taken up with an objective to understand the variation of wind and wave characteristics in the offshore waters of Quangnam and Quangngai provinces of Central Vietnam during September 1999 to

August 2000. The concerned study period was related with two hurricanes (EVE and KAEMI) and available measured wave data.

II. MATERIALS AND METHODS

1. Data collection

- Bathymetry: Bathymetry of the East Sea was taken from 'ETOPO5' bathymetry data set of the National Geophysical Data Center, Colorado, USA, which cover the region between 0^{o}N to 25^{o}N and 100^{o}E to 120^{o}E in 2' x 2' grid.

- Hurricane: The data of hurricanes crossed the vicinity of the Quangnam-Quangngai coastline from September 1999 to August 2000 was extracted from the National Weather Service, USA (www.weather.unisys.com/hurricane). The features such as velocity of forward motion and wind speed were considered to compute the wave characteristics.

- Winds: Wind data series at six hourly intervals during September 1999 to August 2000 based on the NCEP/NCAR data (Kalney, et al. 1996) was used in the study. The reanalysis global wind data in 2.5^{o} x 2.5^{o} grid was extracted and linearly interpolated for the 1^{o} x 1^{o} grid size over East Sea. Wind characteristics for offshore waters of Quangnam and Quangngai provinces was extracted for the location 15^{0} N, 109^{0} E.

- Measured wave characteristics: measured wave characteristics such as significant wave height (H_s) and wave period (T) were recorded using submerged pressure gauge Model AWH16M-1. The measurement was carried out at every 3 hourly interval with measurement period of 20 minutes. In the present study limited wave data measured at Station O3 (15^{o} 27.798'N, 108^{o} 42.789'E) at water depth of 20 m (Trinh, 2000) was used for comparing the estimated values.

2. Young's model

Studies on hurricane-generated waves were carried out by various researchers such as Young and Burchell (1986), Young (1988, 1998) and Ochi (1993). Young (2003) reviewed the methods mentioned in the above study to understand the hurricane wave fields. The Young's model (Young, 1988) was used in the estimation of wave characteristics for the hurricanes considered. The input parameters to the model were the radius of maximum wind speed for the storm, R, together with the maximum wind speed, V_{max}, and the speed of forward motion, V_{fm}. The output was the maximum significant wave height (H_s) and spectral peak period (T_p) within the storm. The JONSWAP fetch-limited growth relationship (Hasselmann *và cs.* 1973) given below is used in the Young's model.

$$\frac{gH_s}{V_{\max}^{\;2}} = 0.0016\left(\frac{gF}{V_{\max}^{\;2}}\right)^{0.5} \tag{1.1}$$

$$\frac{gT_p}{2\pi V_{\max}} = 0.045\left(\frac{gF}{V_{\max}^{\;2}}\right)^{0.33} \tag{1.2}$$

Where,

V_{max} = the 10-m wind velocity (m/s); g = the acceleration of gravity (m/s^2)

F = the fetch length (m)

The speed of forward motion, V_{fm} is extracted from the data set. The equivalent fetch, F is a function of both V_{max} and V_{fm} and dependence on R. For given V_{fm}, V_{max}, and R, an effective radius R' can be defined using parametric model as follows:

$$R' = 22.5 \times 10^3 \log R - 70.8 \times 10^3 \tag{1.3}$$

Where both R and R' have units of meters. The R-values were as a function of the Saffir/Simpson hurricane scale (Hsu and Yan, 1998). Using R', V_{fm}, and V_{max}, the equivalent fetch F is determined as follows:

$$\frac{F}{R'} = aV_{\max}^{\;2} + bV_{max}V_{fm} + cV^2_{fm} + dV_{max} + eV_{fm} + f \tag{1.4}$$

Where,

a= $-2.175\text{x}10^{-3}$; b = $1.506\text{x}10^{-2}$; c = $-1.223\text{x}10^{-1}$; d = $2.190\text{ x}10^{-1}$;

e = $6.737\text{ x}10^{-1}$; and f = $7.980\text{x}10^{-1}$

3. WAM model

The offshore wave climate off Quangnam and Quangngai provinces was computed using WAM (Wave Modeling) model (WAMDI GROUP, 1988; Guenther *và cs.* 1992). WAM describes the evolution of a two-dimensional ocean wave spectrum without additional ad hoc assumptions regarding the spectral shape. It is the third generation wave model and computes the 2-d wave variance spectrum through integration of the transport equation. The model runs on a spherical latitude-longitude grid for an arbitrary region of the ocean. The evolution of the two-dimensional ocean wave spectrum F (f, θ, ϕ, λ, t) with respect to frequency (f) and direction (θ, measured clockwise relative to true north) as a function of latitude (ϕ) and longitude (λ) on the spherical earth is governed by the transport equation.

$$\frac{\partial F}{\partial t} + (\cos\phi)^{-1}\frac{\partial}{\partial\phi}(\overset{*}{\phi}\cos\phi F) + \frac{\partial}{\partial\lambda}(\overset{*}{\lambda} F) + \frac{\partial}{\partial\theta}(\overset{*}{\theta} F) = S \qquad (2.1)$$

Where,

S = the net source function describing the change of energy of a propagating wave group and $\overset{*}{\phi}$, $\overset{*}{\lambda}$, $\overset{*}{\theta}$ are the rate of change of the position and propagation direction of a wave packet traveling along a great circle path.

The source function for the deep-water case may be represented as a superposition of the wind input - S_{in}, nonlinear transfer - S_{nl}, and white capping dissipation source function - S_{dis}

$$S = S_{in} + S_{nl} + S_{dis} \qquad (2.2)$$

Input data for WAM model was bathymetry over East Sea and wind data sets. The computational domain cover the region between 0^o N to 25^o N and 100^o E to 120^o E with resolution of 1^o x 1^o.

Swail and Cox (2000) used a state-of-the-art, third-generation wave model to evaluate the surface wind fields produced in the NCEP-NCAR reanalysis project. They found that storm peak wave height in extra tropical storms were systematically underestimated at higher sea states due to underestimation of peak wind speeds in major jet streak features propagating about intense extra tropical cyclones. In addition, in situ data were incorrectly assimilated and tropical cyclones were poorly resolved. Therefore, to understand the variation of wave characteristics off Quangnam-Quangngai waters the following steps will be applied.

- Using Young's model to estimate wave characteristics for hurricane condition.

- Using WAM model to estimate wave characteristics for normal condition.

III. RESULTS AND DISCUSSIONS

1. Storm variables and wave parameters for hurricanes crossed the Quangnam-Quangngai coastline during September 1999 to August 2000

During September 1999 to August 2000 two tropical storms occurred in the vicinity of Quangnam-Quangngai waters namely Eve and Kaemi which crossed Quangnam-Quangngai coastline in October 1999 and August 2000 (Figure 1).

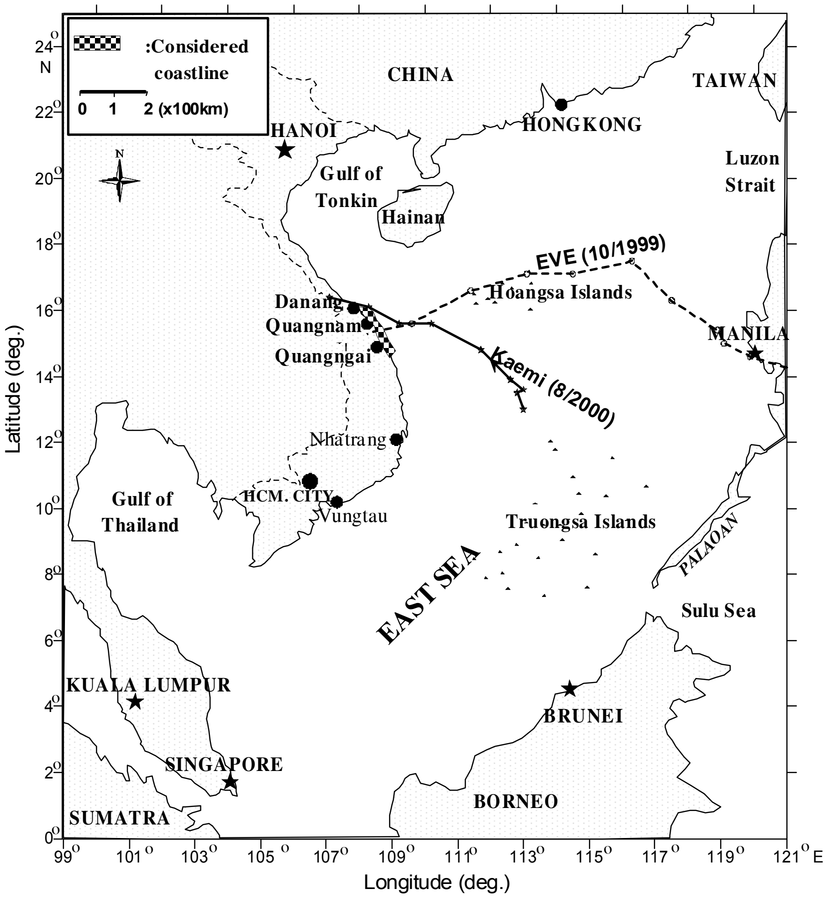

Figure 1. Track of tropical storm EVE (October 1999) and Kaemi (August 2000)

- Tropical storm Eve: The low pressure was formed at 6 hrs on 15.10.1999 at 11.2^0 N, 127.7 ^{0} E (west Pacific Ocean) and crossed the Philippine Islands. It slowly moved in the northwesterly direction and then moved towards the west. It formed a tropical storm at 0 hrs on 19.10.1999 at 15.6^0 N, 109.6^0 E. The maximum wind speed was 23.2 m/s, maximum significant wave height was 5.3 m and peak wave period was 10.1s at 0 hrs on 19.10.1999 (Figure 2).

- Tropical storm Kaemi: The low pressure was formed at 06 hrs on 20.8.2000 at 13.0^0 N, 113.0 ^{0} E in Central East Sea and slowly it moved in the northwesterly direction. It formed into tropical storm at 12 hrs on 21.8.2000 at 15.2^0 N, 111.0 ^{0} E and then continuously moved towards northern portion of Quangnam-Quangngai waters. The maximum wind speed was 23.2 m/s, maximum significant wave height was 5.4 m and peak wave period was 10.1 s at 0 hrs on 22.8.2000 at 15.6^0 N, 109.2 ^{0} E (Figure 3).

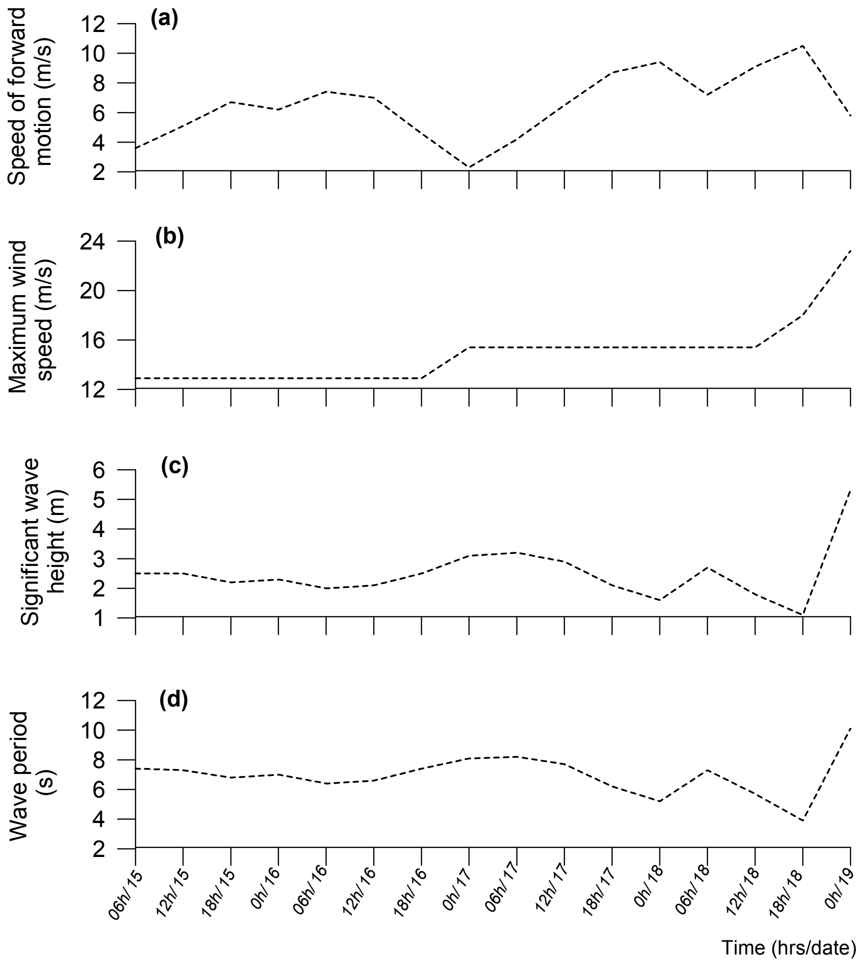

Figure 2. Storm variables and wave parameters for tropical storm EVE (October 1999)

2. Comparison between measured and computed wave characteristics

Limited wave data measured in September 1997 using submerged pressure gauge along Quangnam-Quangngai waters at water depth of about 20 m was used for comparing the estimated values at location 15^o N, 109^o E. The comparison results showed that the maximum absolute difference between the computed and measured wave height was 0.29 m and wave period was 4.4 s. The average relative difference between computed and measured significant wave height was 17.3% and peak wave period was 18.1%. The computed significant wave height is slightly over estimated, whereas the computed peak wave period is under estimated.

3. Seasonal distribution of wave characteristics in the East Sea

Using WAM wave model with NCEP re-analysis wind data set as input, the wave characteristics over the East Sea was estimated for grid size of 1^0 x 1^0 for NE monsoon (12h/02/01/2000) and SW monsoon (0h/19/7/2000) periods. The computed results are shown in Figure 4 and 5 respectively.

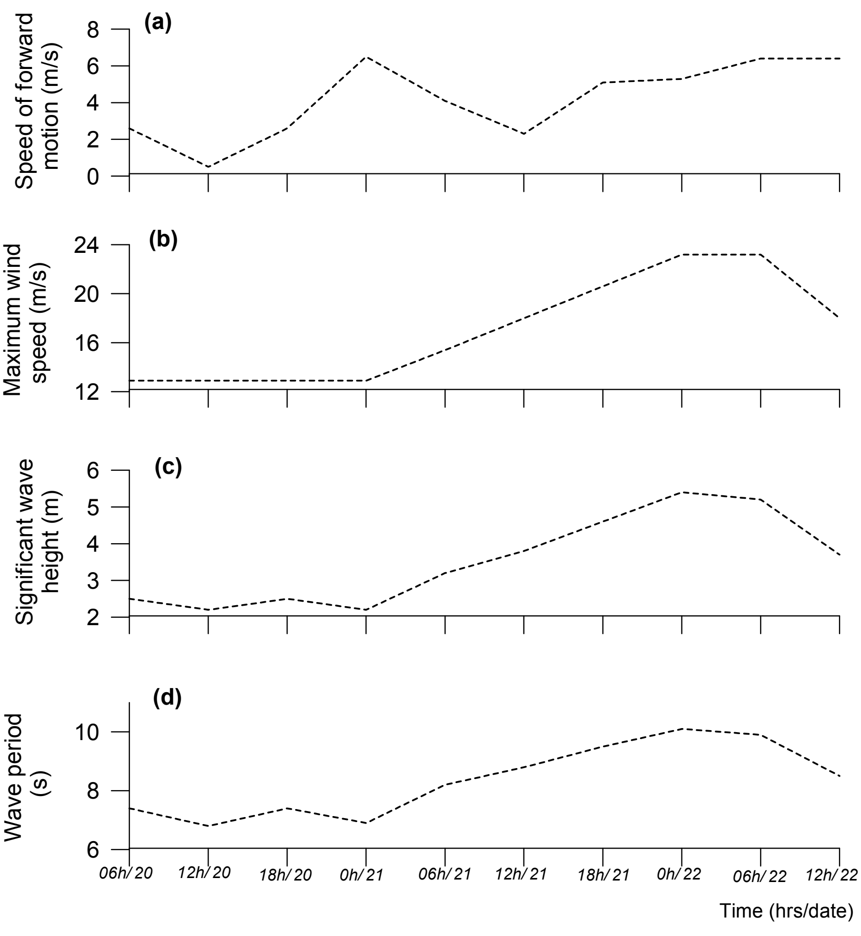

Figure 3. Storm variable and wave parameters for tropical storm Kaemi (August 2000)

During NE monsoon period (Figure 4) over East Sea, the wave direction was predominantly NE with average significant wave height of 2 to 3 m. High significant wave height of 3 to 4 m occurred along the central deep basin. Significant wave height was around 0.5 m, and major direction was NE to E in the area of Gulf of Tonkin. The area of Gulf of Thailand experienced significant wave height less than 0.5 m, and major direction was NE. In the offshore region of Central Vietnam coast, the wave direction was NE, significant wave height was around 1 – 2 m. Wave direction was NE with significant wave height around 2 – 3m in the offshore region of Southern Vietnam coast. In the offshore waters of the Quangnam and Quangngai provinces, significant wave height was around 1 to 2 m from NE direction.

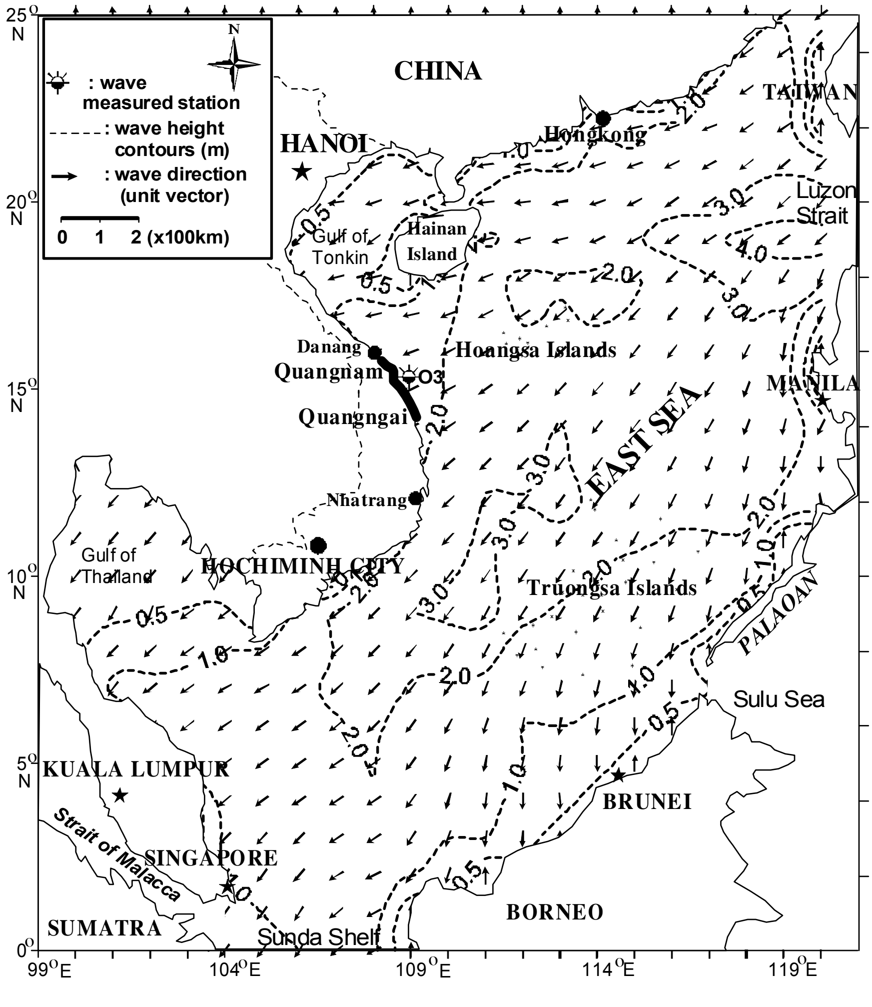

Figure 4. Computed significant wave height pattern over East Sea at 12h/02/01/2000

During SW monsoon period (Figure 5) over the East Sea, the major wave direction was SW with average significant wave height around 1 to 2 m. High significant wave height of 2 to 3 m occurred off southern of Central Vietnam coast. In the area of Gulf of Tonkin, significant wave height was less than 0.5 m, and major direction was SE. Similar to wind conditions, these wave directions were also caused by the landmass around the Gulf of Tonkin. In the area of Gulf of Thailand, significant wave height was less than 0.5 m, and major direction was S. In the offshore of Central Vietnam coast, wave direction was SW to S, with significant wave height around 1 to 2 m. In the offshore region of southern Vietnam coast, wave direction was SW with significant wave height around 0.5 to 1 m. Significant wave height was less than 1 m and coming from S to SW direction in the offshore waters of Quangnam and Quangngai provinces.

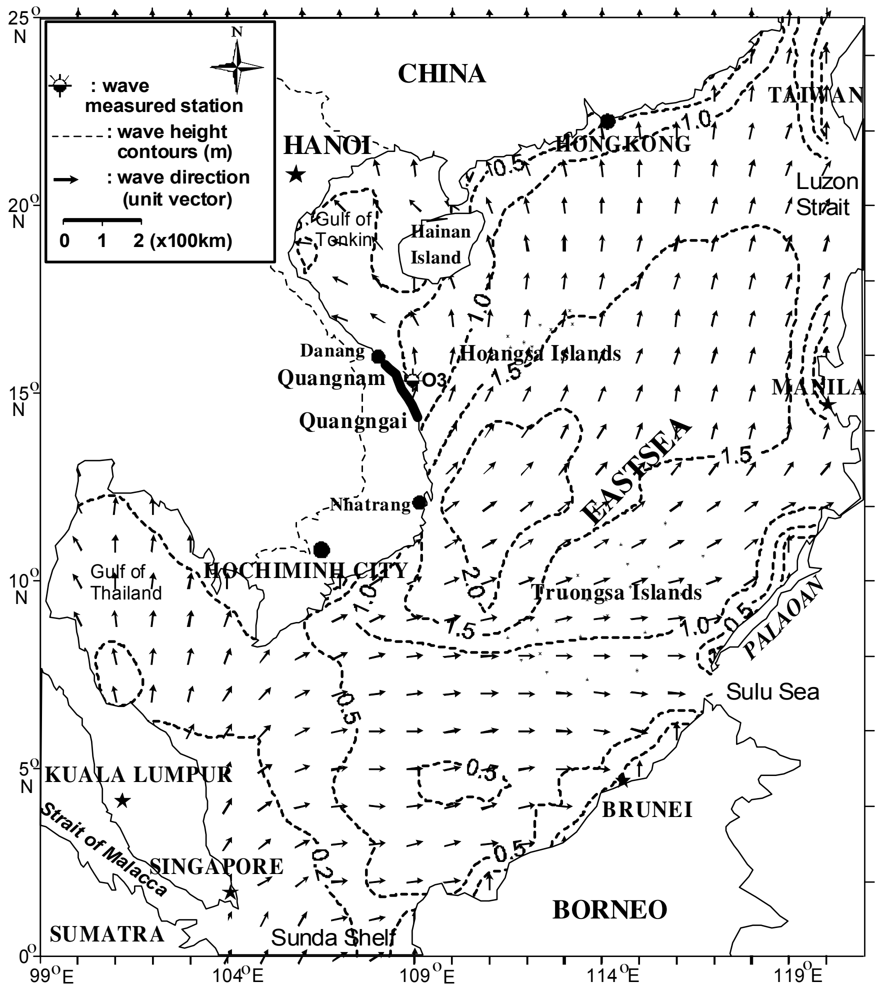

Figure 5: Computed significant wave height pattern over the East Sea at 0h/19/7/2000

From the distribution patterns of wave characteristics during NE and SW monsoons, we can see that the effects of wave energy on offshore waters of

Quangnam-Quangngai provinces during NE monsoon were stronger than that of SW monsoon periods.

4. Variation of wind and wave characteristics during September 1999 to August 2000

In order to get boundary conditions for nearshore wave model, wind characteristics were extracted from NCEP re-analysis wind data set (for normal condition) and from the National Weather Service, USA (for hurricane condition); wave characteristics were extracted from WAM (for normal condition) and Young (for hurricane condition) models output. The wind and wave characteristics off Quangnam-Quangngai waters (location: 15^0 N, 109^0 E) during September 1999 to August 2000 was similar with highlight of seasonal variation, and are shown in Figure 6.

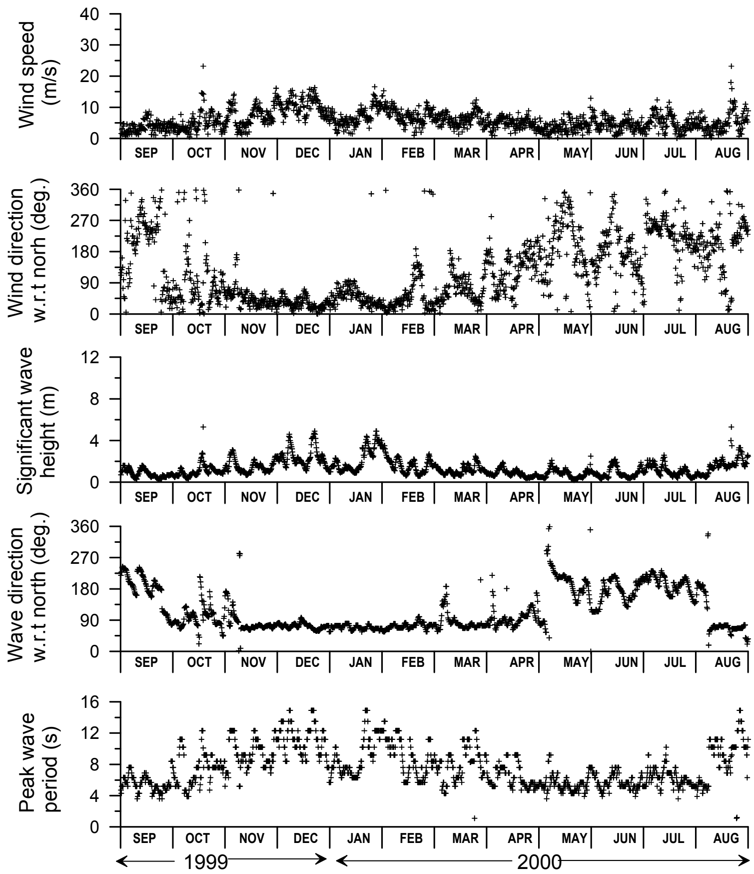

Figure 6. Variation of wind and wave characteristics off Quangnam-Quangngai waters during September 1999 to August 2000

Variation of wind velocity shows that the major wind direction from June to August (SW monsoon) was from SE to SW, mean wind speed was 4.8 m/s. From October to April (NE monsoon) the major wind direction was from N to E, mean wind speed was 6.9 m/s. During May and September, the wind direction was varying and means wind speed was 3.7 m/s. Maximum wind speed was 23.2 m/s, which occurred in October 1999 and August 2000 during tropical storm Eve and Kaemi respectively.

Variation of offshore wave characteristics shows that mean significant wave height during SW monsoon period (June to August) was 1.2 m, maximum was 5.3 m, wave direction was from SE to SW; mean wave period was 6.9 s, maximum was 14.9 s. During NE monsoon period (October to April), mean significant wave height was 1.6 m, wave direction was from NE to E; mean wave period was 8.1 s, maximum was 14.9 s. During transition periods (May and September) mean significant wave height was 0.8 m, wave direction was varying, mean wave period was 5.5 s.

In all, the magnitude of wind and wave during NE monsoon was larger than that of SW monsoon, and maximum wind speed usually coincides with maximum significant wave height. The maximum values of wind and wave characteristics were mostly occurred during hurricanes.

IV. CONCLUSIONS

The offshore waters of Quangnam-Quangngai provinces is subjected to seasonal variability with the reversing SW (June – August) and NE (October – April) monsoons. During NE monsoon period the intensity of wave (mean H_s = 1.6 m) was stronger than that of SW monsoon (mean H_s = 1.2 m), especially during hurricanes.

The major wave direction during NE monsoon were NE to E, whereas, during SW monsoon period the major wave direction were SE to S. The variations in wave direction during NE monsoon were small (45°) compared to other seasons. During transition periods wave height was small, wave direction was varying.

Comparison between measured and estimated wave characteristics for offshore waters of Quangnam and Quangngai provinces shows that the computed significant wave height is slightly over estimated, whereas the computed peak wave period is under estimated.

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