ESTIMATION OF WAVE CHARACTERISTICS DURING HURRICANE IN THE HOIAN AREA, CENTRAL VIETNAM

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Abstract

The data of hurricanes crossed the coastline from 14^0N to 17^0N, in the vicinity of the Hoian coastline, from 1945 to 2003 were extracted from the National Weather Service, USA. The features such as velocity of forward motion and wind speed were considered. Radius of maximum wind speed was estimated using the Saffir-Simpson scale. The maximum significant wave height within the storm and its associated spectral peak period were estimated using the Young's model. Empirical expressions relating wave height, maximum wind speed and wave period during hurricane were derived. The computed results from Young's model were compared with the hurricane wave prediction techniques of SPM (1984). The design wave height for the hurricane condition for different return periods was obtained by fitting a two-parameter Weibull distribution. The study indicates that in all, 69 hurricanes occurred in the vicinity of the Hoian coastline during 1945 to 2003 (with an average of 1.2 times a year), among which include 36 typhoon with maximum wind speed (V_{max})>33 m/s, 20 tropical storm with 17 m/s< V_{max} <33 m/s, and 13 subtropical storm with V_{max}<17 m/s. Occurrences of hurricanes were mostly in September (26.1%), October (30.4%) and November (13%). In general, radius of maximum wind speed of all hurricanes was 34 km. The design wave height was 11.7 m for 1 in 100 year return period.

1.0 INTRODUCTION

Hurricane/storm generated waves play a significant role in the design of almost all coastal and offshore structures in tropical and semitropical regions. SWAMP (1985) gives a comparison of various wave prediction models and also the merits and demerits of each model. The complicated wave generating processes within hurricanes make estimation of the wave conditions associated with a given storm difficult. A more realistic estimation of wave height and period during hurricane can be done using the Young's model, which considers the moving wind field (Young, 1988). The Young's model was developed based on the concept of the equivalent fetch and the standard JONSWAP fetch-limited growth relationships (Hasselmann et al.,

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1973). This model was applied to the cyclones crossed the Indian coast (Kumar et al., 2003).

Extreme wave conditions occur in the Hoian area during severe tropical hurricanes, which are frequent during the beginning of the northeast monsoon (September to November). The severe impacts of typical hurricanes on erosion, deposition and changes of the coastline in the Thubon river mouth region in recent years: 1989, 1997 and 1999 was carried out by Trinh (2000). The objectives of the present study are as follow.

- Analyses of the hurricane data taken from the National Weather Service, USA during 1945 to 2003 (www.weather.unisys.com/hurricane).
- Estimation of the wave characteristics based on the hurricanes which crossed the Hoian coastline.
- Derivation of empirical expressions relating wave height with maximum wind speed and wave period during hurricane.

2.0 METHODS

2.1 Data analyses

The Hoian coastline is not only affected by the hurricanes crossed but also subjected to the impact of hurricanes, which crossed in the vicinity region. The coastline from Binhdinh Province to Quangtri Province (14^0N to 17^0N) was selected to extract the hurricane data (Fig. 1).

The radius of maximum wind speed, R, is required for estimation of deep water wave characteristics. The R values were as a function of the Saffir/Simpson hurricance scale (Hsu et al., 1998).

2.2 Estimation of the wave characteristics

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} and the output were the maximum significant wave height (H_s) and spectral peak period (T_p) within the storm. The JONSWAP fetch-limited growth relationships (Hasselmann et al., 1973) given below are used in the Young's model.

$$\frac{gH_s}{V_{\max}^2} = 0.0016\left(\frac{gF}{V_{\max}^2}\right)^{0.5} \quad (1)$$

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

where, V_{max} = the 10-m wind velocity (m/s), g = the acceleration of gravity (m^2/s) and F = the fetch length (m)

The speed of forward motion, V_{fm} are extracted from the data set. The equivalent fetch, F is a function of V_{max}, V_{fm} and R.

For given V_{fm}, V_{max}, and R, an effective radius R' can be defined using parametric model as follows:

$$R' = 22.5 \times 10^3 \log R - 70.8 \times 10^3 \quad (3)$$

where both R and R' have units of meters. Using R', V_{fm}, and V_{max}, the equivalent fetch F is determined as follows:

$$\frac{F}{R'} = aV_{max}^2 + bV_{max}V_{fm} + cV_{fm}^2 + dV_{max} + eV_{fm} + f \quad (4)$$

where, a= -2.175×10^{-3}; b = 1.506×10^{-2}; c = -1.223×10^{-1}; d = 2.190×10^{-1}; e = 6.737×10^{-1}; and f = 7.980×10^{-1}

According to SPM (1984) for a slow moving hurricane, the deep-water significant wave height (H_s) and period (T_s) are given by,

$$H_s = 5.03\, e^{\frac{R\Delta P}{4700}}\left(1+\frac{0.29\alpha V_{fm}}{\sqrt{U_R}}\right) \quad (5)$$

$$T_s = 8.6\, e^{\frac{R\Delta P}{9400}}\left(1+\frac{0.145\alpha V_{fm}}{\sqrt{U_R}}\right) \quad (6)$$

where, T_s = the corresponding significant wave period (s), U_R = the maximum sustained wind speed (m/s), $\alpha =$ 1.0 (for a slowly moving hurricane)

$\Delta P = P_n - P_0$, where P_n is the normal pressure of 760 mm of mercury, and P_0 is the central pressure of the hurricane.

3.0 RESULTS

3.1 Features of hurricane in the Hoian area

In all, 69 hurricanes occurred in the vicinity of the Hoian coastline during 1945 to 2003 (with an average of 1.2 times a year), among which include 36 typhoon with maximum wind speed (V_{max})>33 m/s, 20 tropical storm with 17 m/s< V_{max} <33 m/s, and 13 subtropical storm with V_{max}<17 m/s (Table 1). The hurricanes crossed the Hoian coastline is shown in Fig. 1.

The Yearly distributions of hurricanes in the study area were not regular. The years of 1964, 1972 and 1995 each have 4 times of occurrences (Fig. 2), especially during 13 to 27/9/1964, 3 hurricanes crossed the Hoian coastline.

Table 1. Classification of hurricanes based on Saffir-Simpson scale.

	Typhoon	Tropical storm	Subtropical storm	Sum
Numbers of occurrence	36	20	13	69
Percentage (%)	52	29	19	100

Occurrences of hurricanes were mostly in September (26.1%), October (30.4%) and November (13%), (Table 2).

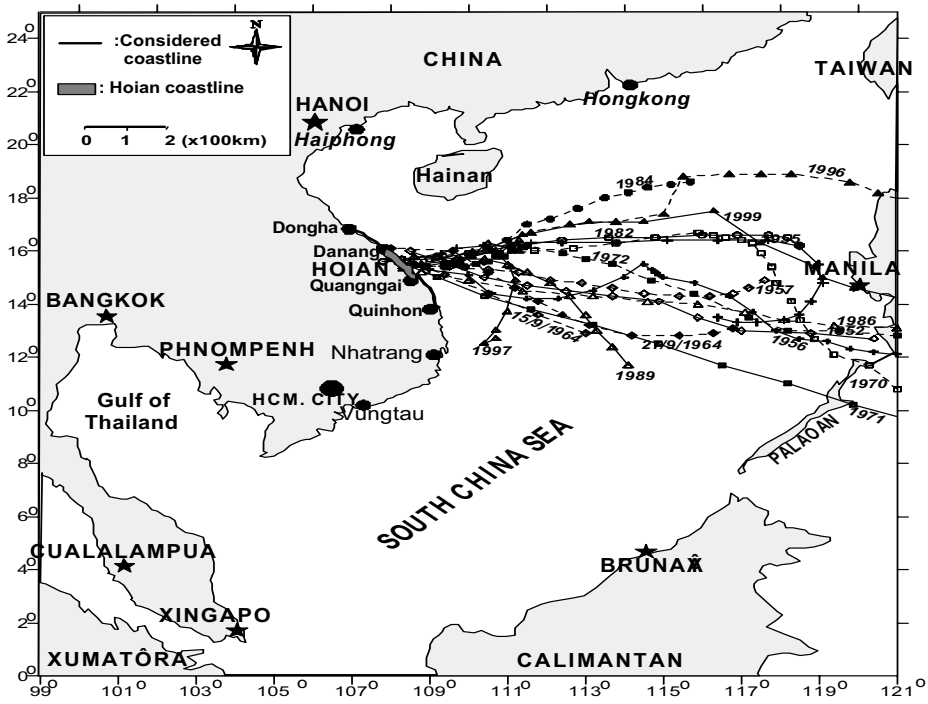


Fig. 1. Tracks of hurricane crossed the Hoian coastline.

Table 2. Monthly distribution of hurricanes.

Month	April	May	June	July	August	September	October	November	December
Numbers	2	5	5	4	4	18	21	9	01
Percentage (%)	3	7	7	6	6	26.1	30.4	13	1.5

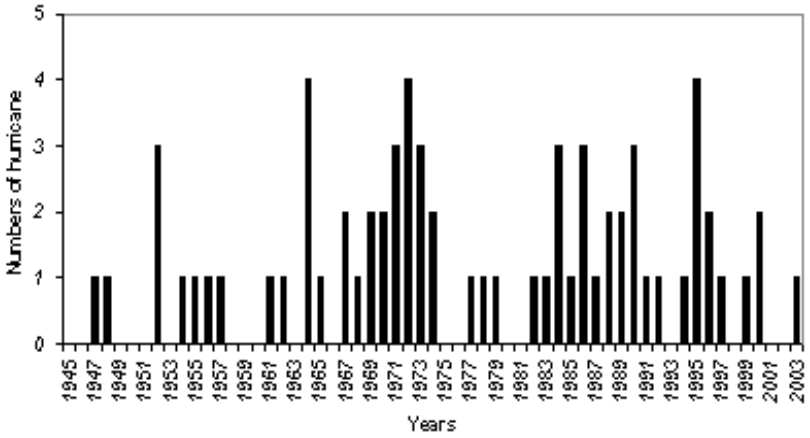
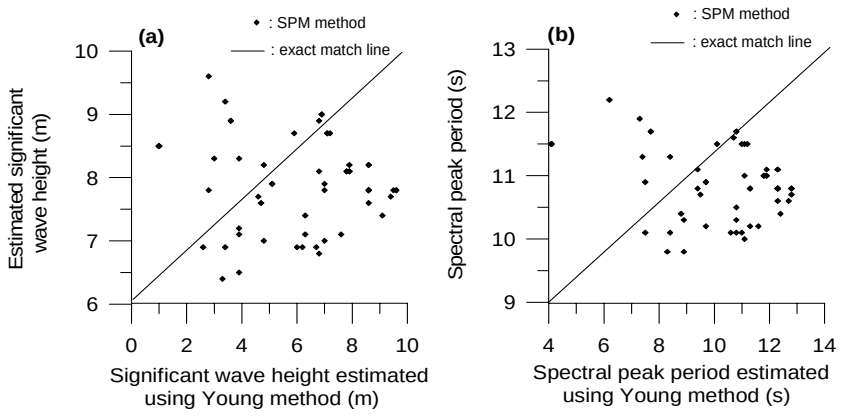


Fig. 2. Yearly distribution of hurricane during 1945 to 2003.

In general, radius of maximum wind speed of all hurricanes was 34 km. Thirty five (51%) hurricanes were formed inside the South China Sea and 34 (49%) hurricanes were formed outside the South China Sea (west Pacific Ocean).

3.2 Comparison of estimated wave characteristics based on Young's and SPM methods

The significant wave height and wave period estimated using the SPM method (Eqs.5 and 6) is found to deviate from the value obtained using the Young's method (Eqs.1 and 2) as shown in Fig. 3a and 3b. The reason for the deviation is due to the fact that SPM method is for a slow moving hurricane, whereas the average speed of hurricanes in the present study is 6 m/s.



(a) Significant wave height *(b) Wave period*

Fig. 3. Correlation between wave characteristics estimated based on Young's and SPM methods.

3.3 Comparison of estimated data with measured data

The computed wave height and wave period using Young's and the SPM model have been compared with the observed ones at station (15^0 53.852' N, 108^0 30.033' E) during hurricane Fritz (September 1997) and is presented in Table 3. In general, the comparison shows a good agreement between the values computed using Young's model and observed wave characteristics.

Table 3. Comparison between computed and measured significant wave height (H_s) and wave period (T_p) during hurricane Fritz (9/1997) off Hoian coast.

Times	Wave Characteristics	Measured	Young's method	SPM method
01h/21/9/1997	Wave height – Hs(m)	0.9	1.0	2.0
	Wave period - T(s)	6.1	7.3	6.1
04h/21/9/1997	Wave height – Hs(m)	1.0	1.0	2.1
	Wave period - T(s)	5.9	7.4	6.2
07h/21/9/1997	Wave height – Hs(m)	1.0	1.1	2.2
	Wave period - T(s)	6.0	7.5	6.4

3.4 Significant wave height and peak period

Significant wave height and peak wave period estimated for different hurricanes that crossed the Hoian coastline along with the input parameters are given in Table 4.

Table 4. Estimated significant wave height (H_s) and peak wave period (T_p) for maximum wind speed of hurricane crossed the Hoian coastline.

Sl No.	Time of occurrence	Latitude (^{0}N)	Longitude(^{0}E)	Maximum Wind speed, V_{max} (m/s)	Speed of forward motion, V_{fm} (m/s)	Fetch F (km)	Significant wave height, H_s (m)	Peak wave period, T_p, (s)
1	18h/30/10/1952	15.7	108.5	20.6	5.7	187.6	4.6	9.4
2	12h/08/10/1955	15.7	108.6	12.9	3.7	149.5	2.5	7.4
3	18h/14/04/1956	15.3	109.0	10.3	5.2	119.2	1.8	6.4
4	6h/12/10/1957	15.5	108.5	33.4	5.2	264.8	8.8	12.4
5	0h/15/9/1964	15.7	108.3	38.6	6.4	281.5	10.5	13.3
6	0h/27/9/1964	16.1	108.0	20.6	6.2	180.3	4.5	9.3
7	6h/25/10/1970	15.7	108.3	28.3	4.7	240.6	7.1	11.4
8	6h/23/10/1971	15.6	108.2	38.6	6.0	284.7	10.5	13.4
9	0h/04/9/1972	15.4	108.9	36.0	3.9	272.5	9.6	12.9
10	12h/06/9/1982	15.7	109.0	31.0	6.2	245.1	7.8	11.8
11	6h/27/09/1984	15.5	108.6	12.8	5.2	138.5	2.4	7.2
12	18h/21/10/1986	15.2	108.8	25.7	4.7	226.6	6.3	10.8
13	18h/24/5/1989	15.8	108.6	36.0	3.1	263.5	9.4	12.7
14	18h/21/10/1996	15.5	108.8	13.0	3.6	150.3	2.6	7.5
15	0h/25/9/1997	15.5	108.8	38.6	3.1	271.9	10.3	13.2
16	0h/19/10/1999	15.6	108.8	23.2	5.8	203.4	5.3	10.1

The variation of the storm parameters with time for a typical hurricane (October 1999) is shown in Fig. 4. The low pressure was formed on 15.10.1999 at 6 hrs at 11.2^{0}N, 127.7^{0}E (west Pacific Ocean) and crossed the Philippines Island. It slowly moved in the northwesterly direction and then moved towards the west. It was a tropical storm on 19.10.1999 at 0 hrs at 15.6^0 N, 109.6^{0}E when crossed the Hoian area. The maximum significant wave height was 5.3 m and peak wave period was 10.1 s at 0 hrs on 19.10.1999.

3.5 Derivation of empirical expression

A regression analysis was carried out between the wind speed and significant wave height and it was found that the following empirical relation holds good for the hurricanes considered in the present study with a correlation of 0.9 (Fig. 5a) when the wave height was more than 2 m.

$$H_s = 0.314\, V_{max} - 1.91 \qquad (7)$$

Spectral peak period, T_p can also be estimated using the empirical relation given below (Eq. 8) from known value of significant wave height, H_s (Fig. 5b).

$$T_p = 4.7\, H_s^{0.45} \qquad (8)$$

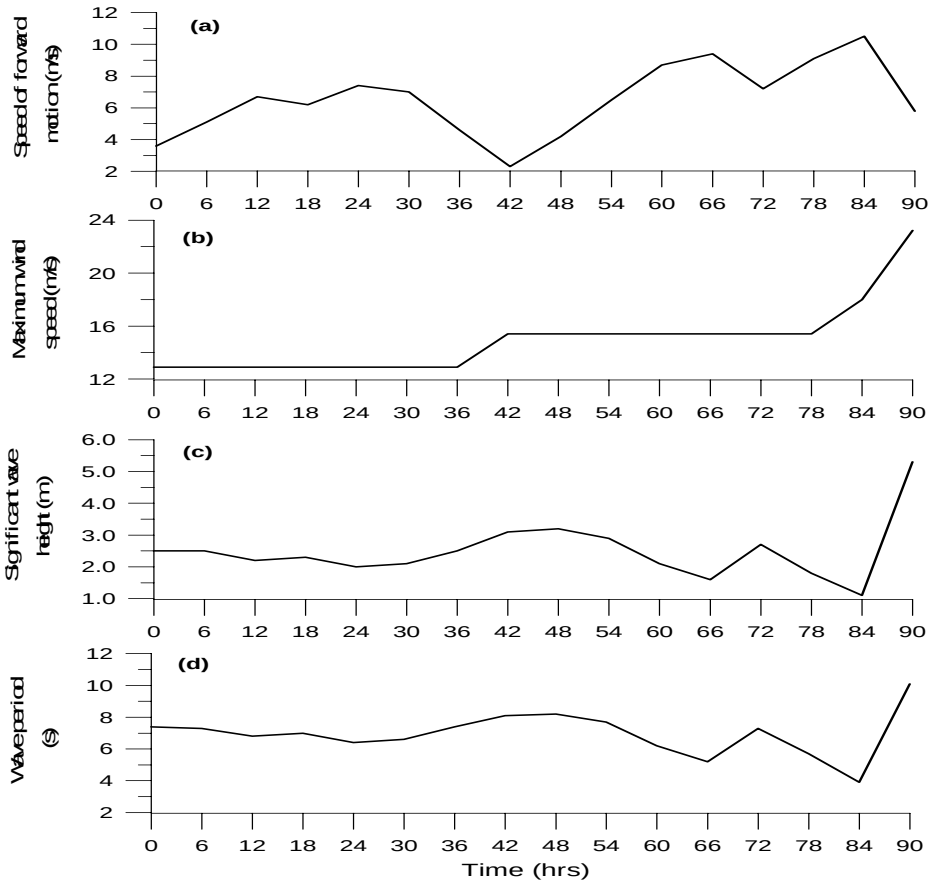


Fig. 4. Storm variables and wave parameters for October 1999 Hurricane.

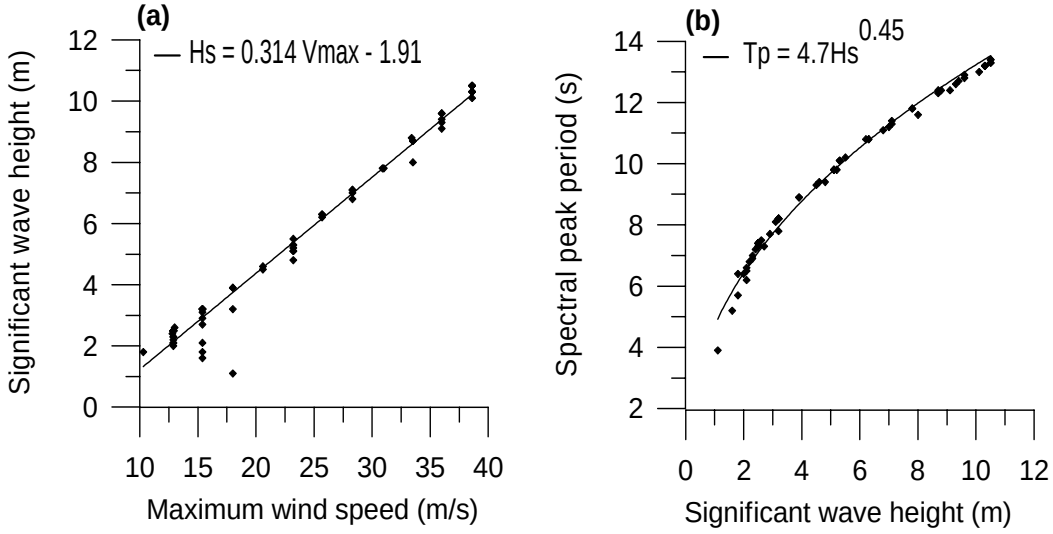


Fig. 5. Correlation between (a) significant wave height and wind speed (b) peak wave period and significant wave height.

3.6 Design wave

Since the hurricanes have not occurred at regular intervals, a Weibull distribution to the estimation of design wave height would not be realistic. However, for design purposes, wave height for different return periods are required. The design wave heights estimated by fitting a two-parameter Weibull distribution are 5.1, 7.1, 9.1, 10.5 and 11.7 m for return periods of 5, 10, 25, 50 and 100 years respectively.

4.0 CONCLUSIONS

- The study indicates that in all, 69 hurricanes occurred in the vicinity of the Hoian coast line during 1945 to 2003 (with an average of 1.2 times a year), which include 36 typhoon with maximum wind speed (V_{max})>33 m/s, 20 tropical storm with 17 m/s< V_{max} <33 m/s, and 13 subtropical storm with V_{max}<17 m/s.
- Occurrences of hurricanes were mostly in September (26.1%), October (30.4%) and November (13%).
- The radius of maximum wind speed of all hurricanes was 34 km.
- Significant wave height can be estimated using the empirical Eq. (7) from the known value of maximum wind speed, also the wave period can be estimated using the empirical Eq. (8) from the known value of significant wave height. The design wave height is 11.7 m for 1 in 100 year return period.

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