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Analysis of Typhoon Waves off the Shores of Northern Taiwan by EEMD Method

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Introduction

The time frequency analysis method introduced by *Huang et al.* in 1998 as empirical mode decomposition (EMD) decomposes time series into a finite number of components, so called intrinsic mode functions (IMFs) [3]. The character of a time series is maintained in all of these zero mean oscillatory modes. While the mean frequency of the oscillation in each extracted IMF decreases with increasing IMF number both frequency and amplitude in a single IMF may vary over time. The original EMD method has recently been modified to overcome the problem of mode mixing [4]. This novel approach, the ensemble EMD (EEMD) uses white noise to extract physically more sound modes from the original signal. For a preselected number of trials, white noise of finite amplitude is added to the original signal which is then decomposed into IMFs. The noise is cancelled out in the ensemble mean which is treated as the final result [6].

Data and Methods

The wave and wind data used in this study were recorded by a marine data buoy moored off the Taiwanese east coast near Su-ao in a water depth of 23 m in 2007. The buoy was deployed by the *Water Resources Agency* of the Republic of China. Hourly mean values of wind speed, wind direction and significant wave height were used. The measuring interval of the buoy is 10 minutes at a sampling frequency of 2 Hz. The buoy location and the bathymetry around Taiwan are illustrated in figure 1.

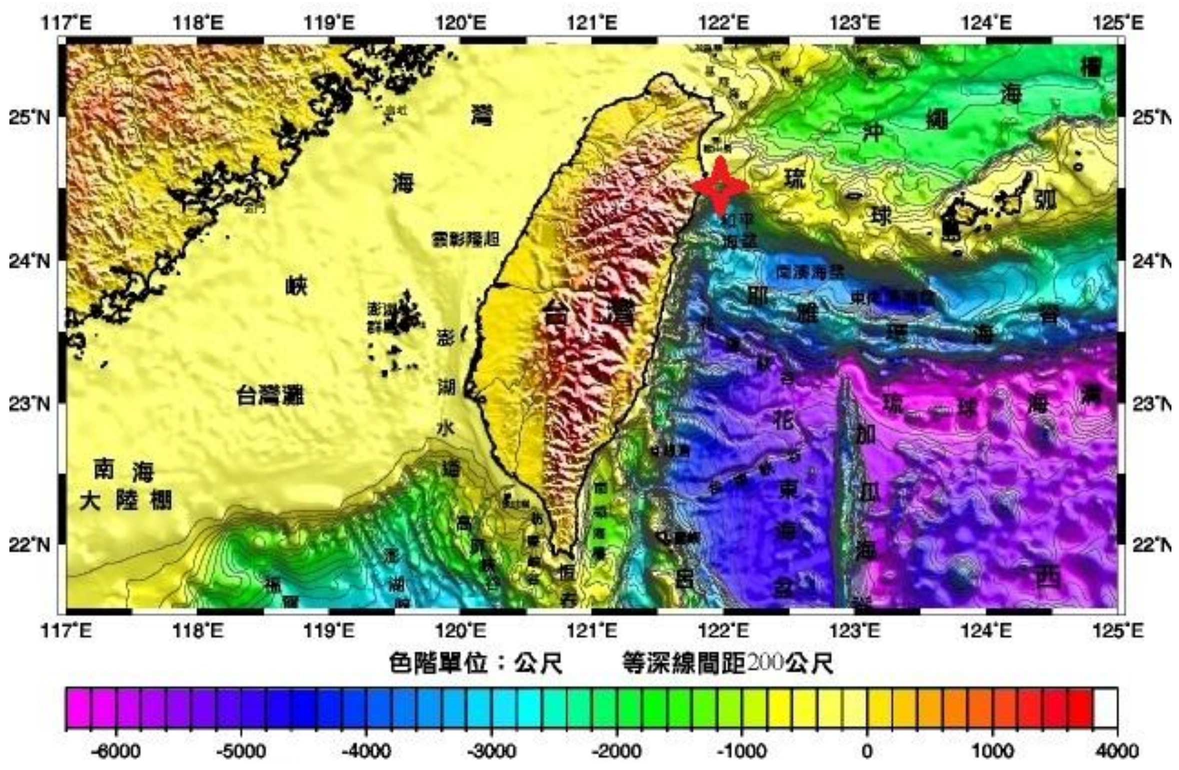

Figure 1: Bathymetry around Taiwan and buoy location (edited from NCOR, Taiwan)

To analyze the effect of typhoon events on the sea state at the buoy site, undisturbed conditions need to be considered first. A 10-day control period without typhoon influence is chosen from 20st July through 29th July 2007. Wind and wave parameters for this period can be found in figure 2.

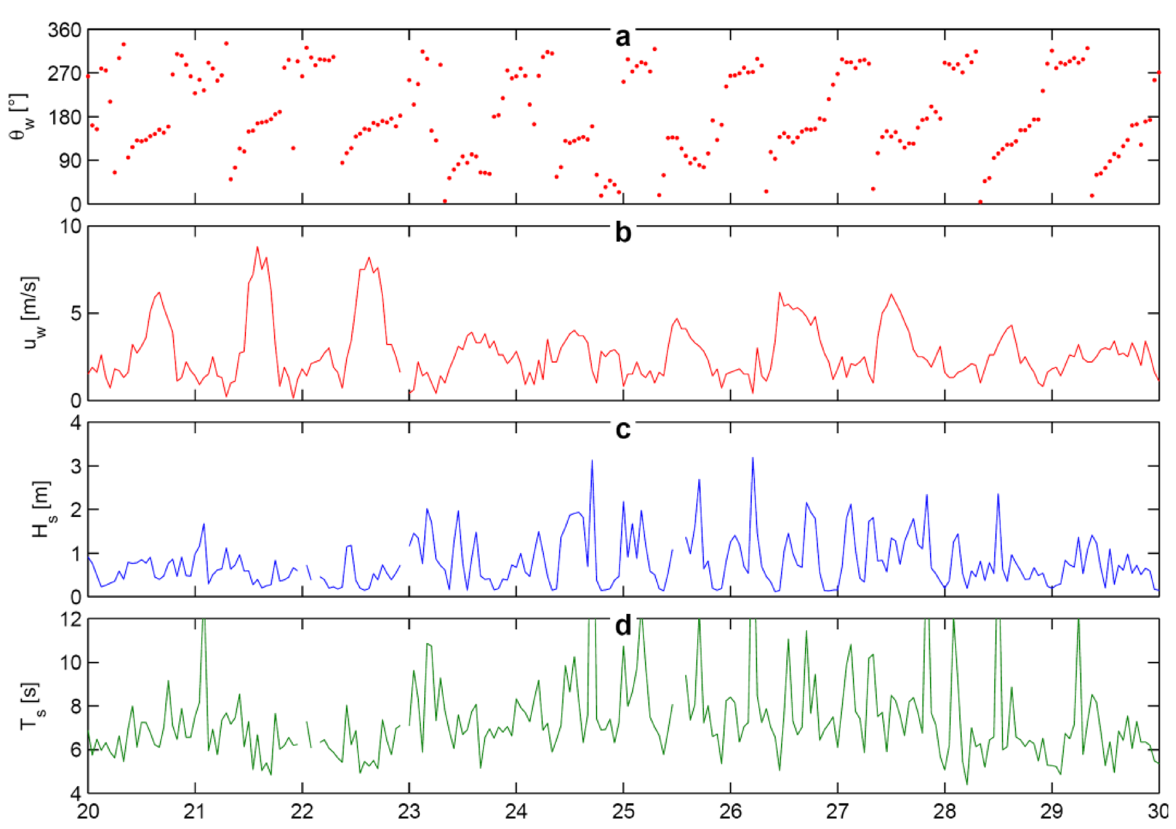

Figure 2: Wind and wave parameters for control period.
a: wind direction, b: wind speed, c: sign. wave height, d: wave period

The analysis period for typhoon SEPAT is chosen from 13th through 22nd August 2007. A typhoon warning was issued by *Central Weather Bureau* from 16th through 19th August [1]. The data for this period are presented in figure 3.

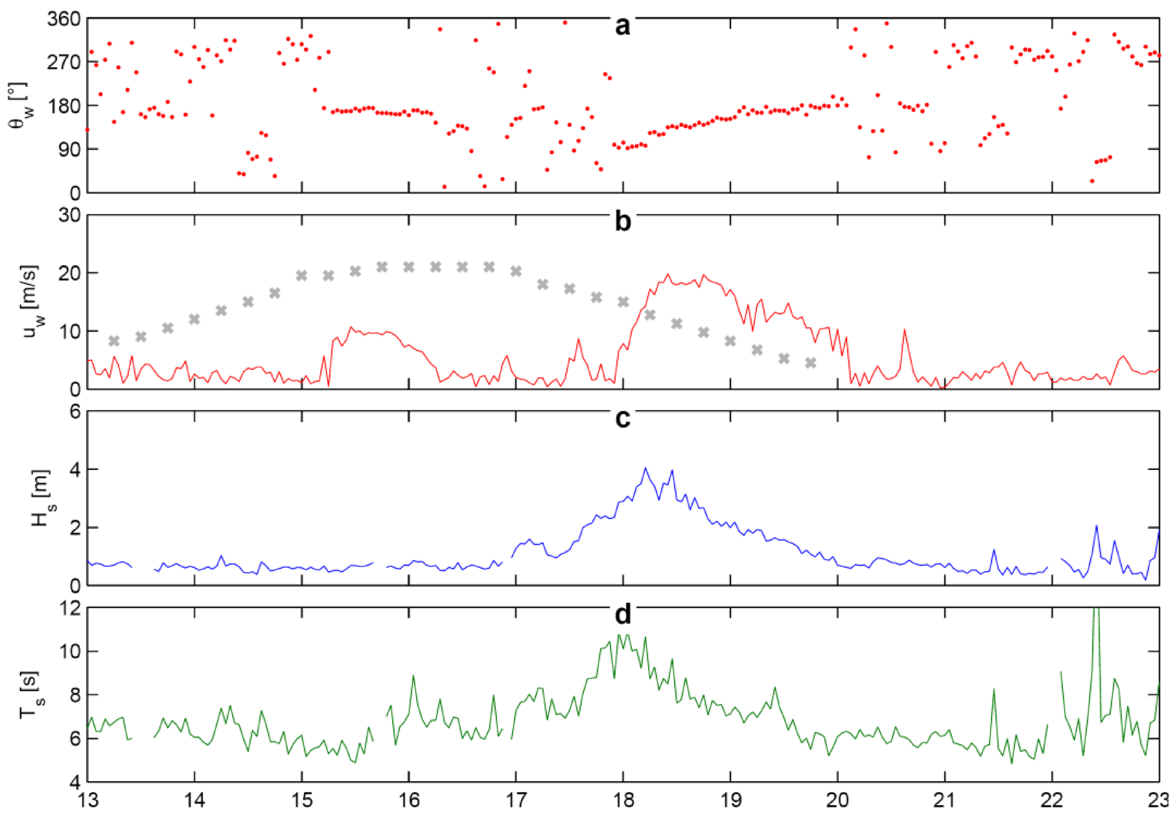

Figure 3: Wind and wave parameters for typhoon period.
a: wind direction, b: wind speed, c: sign. wave height, d: wave period

The decomposition of the time series was performed using EEMD code designed by the *Research Center for Adaptive Data Analysis* [5]. A number of 1,000 ensembles and a white noise ratio of 0.4 was used.

Results

The IMFs resulting from the decomposition of wind speed and wave height for the control period exhibit regular semi-diurnal and diurnal oscillations. Especially for the latter half of the period, the oscillations are almost phase-locked. The decomposition of wind speed and wave height for the control period can be found in Figure 4.

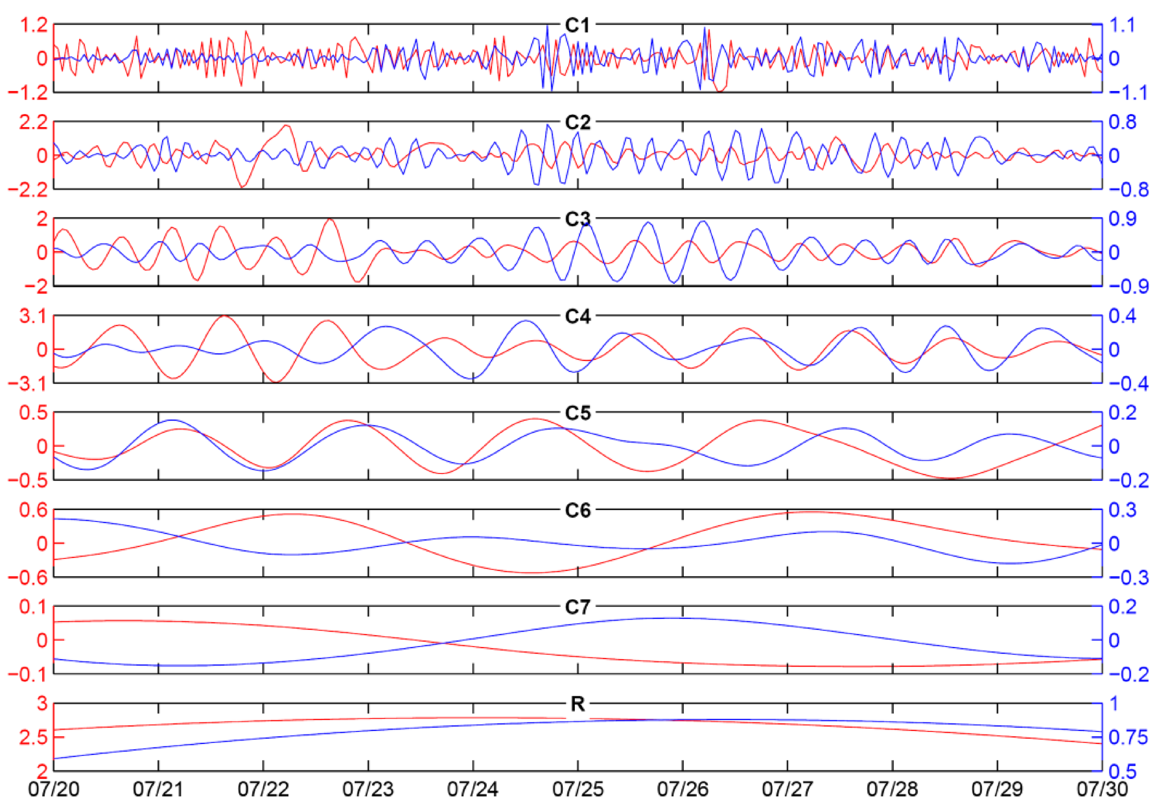

Figure 4: Decomposition of wind speed ([m/s], red) and significant wave height ([m], blue) for control period

These IMFs represent the effects coastal air circulation system studied in detail e.g. by *Hsu* [2]. Onshore winds with high wind speeds prevail during daytime while offshore winds can be observed at night. Under normal conditions, the diurnal oscillations of wind speed and direction are believed to be the driving mechanism for the local generation of waves.

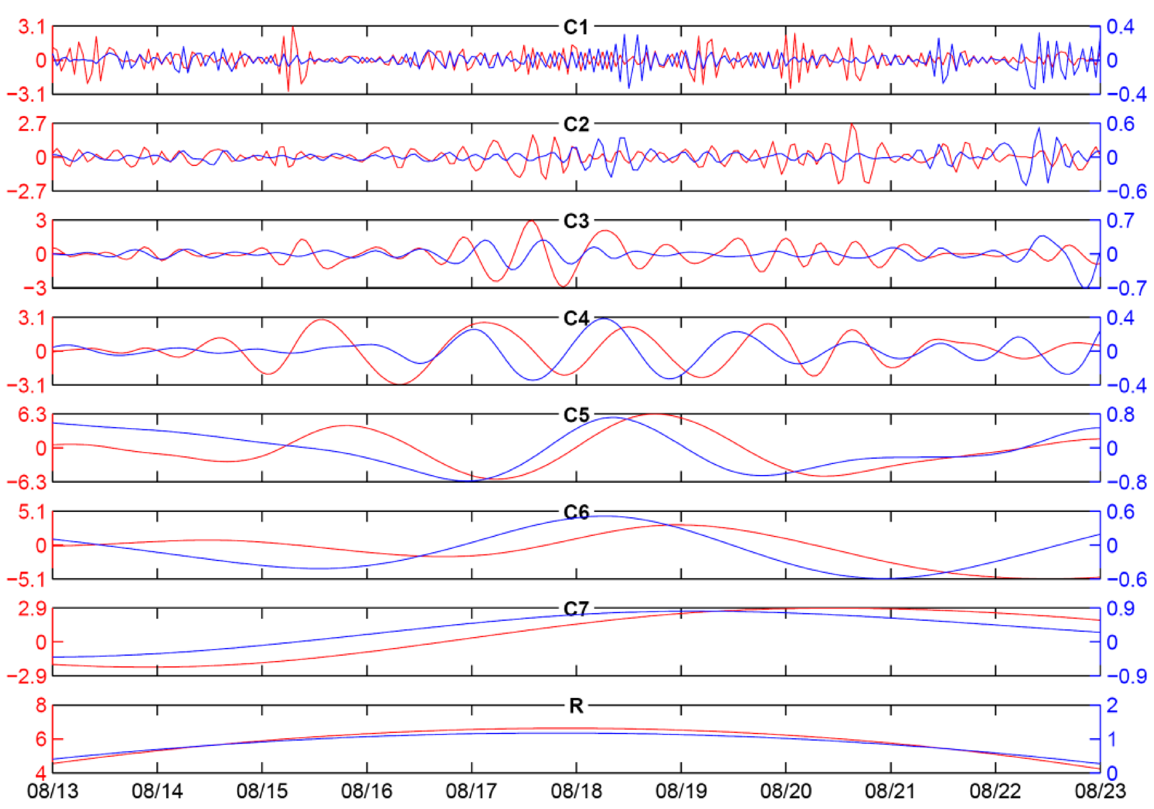

Figure 5: Decomposition of wind speed ([m/s], red) and significant wave height ([m], blue) for typhoon period

The decomposition of wind speed and significant wave height from the typhoon period is displayed in Figure 5. The regular cyclic properties found in IMFs C3 and C4 from the control period become severely distorted due to typhoon influence. The effects of the typhoon upon wind speed and wave height can be found in IMFs C5 to C7, representing time scales of several days. Note that the rise in significant wave height in said IMFs precedes the rise in wind speed. The delay is about 12 hours in IMF C5 and almost a full day in IMF C6.

Discussion

For the control periods, the direct comparison of correspondent IMFs reveals diurnal cyclic oscillation in wind speeds caused by the coastal air circulation system. Under normal conditions, this system is regarded the driving mechanism for the creation of waves in time scales of 24 hours and less. Long term changes in wind speed are attributed to meteorological phenomena like formation and movement of high and low pressure systems and their mutual interaction. The decomposition of the time series from the typhoon periods shows the dominating effects of the typhoon on sea state conditions.

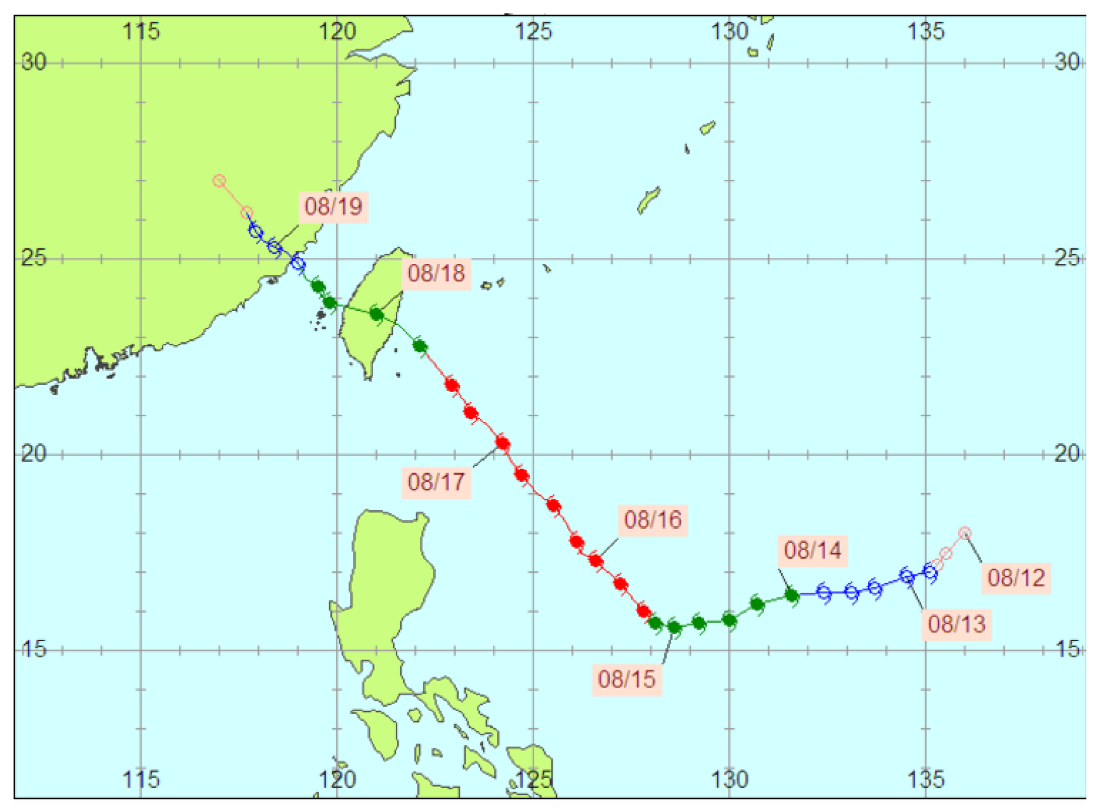

Figure 6: Track of typhoon SEPAT (CWB, Taiwan)

The regular cyclic properties and interrelations between wind speed and wave height are severely distorted. A rise in significant wave height can be observed before any rise in wind speed is noticeable. The delay between the maxima in wind speed and wave height is about 24 hours. This underlines the swell character of the typhoon waves. High waves are generated several hundred kilometers away on the open sea due to typhoon wind acting upon the sea surface (see figure 6). Traveling much faster than the typhoon itself, they reach the shore and lead to a rise in significant wave height and period before a rise in wind speed due to the approaching typhoon may be noticed.

EEMD analysis of time series of wind and wave data enables the detection of physical phenomena governing the parameters and allows to illustrate interrelations between them.

References

[1] Central Weather Bureau. *Typhoon Warning Archive*. Available online at http://rdc28.cwb.gov.tw/data.php; visited on June 11th 2010.

[2] Hsu S.A. (1988). *Coastal Meteorology*. Academic Press Inc., San Diego

[3] Huang N.E., Shen Z., Long S.R., Wu M.C., Shih H.H., Zheng Q., Yen N.C., Tung C.C. and Liu H.H. (1998). The Empirical Mode Decomposition and the Hilbert Spectrum for Nonlinear and Non-stationary Time Series Analysis. *Proceedings of the Royal Society of London. Series A: Mathematical, Physical and Engineering Sciences*, 54(1971), pp. 903–995.

[4] Huang N.E., Shen Z. and Long R.S. (1998). A New view of Nonlinear Water Waves - The Hilbert Spectrum. *Ann. Rev. Fluid Mech.*, 33, pp. 417–457.

[5] Research Center for Adaptive Data Analysis. *Code for the HHT MATLAB Program*. Available online at http://rcada.ncu.edu.tw/research1_clip_program.htm ; visited on June 10th 2010.

[6] Wu Z. and Huang N.E. (2009). Ensemble Empirical Mode Decomposition: A Noise-Assisted Data Analysis Method. *Advances in Adaptive Data Analysis*, 1(1), pp. 1–41.

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