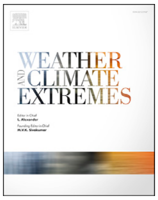
Weather and Climate Extremes 17 (2017) 29–35

Contents lists available at ScienceDirect

Weather and Climate Extremes

journal homepage: www.elsevier.com/locate/wace



Typhoon activity and some important parameters in the South China Sea

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ARTICLE INFO

Keywords:
Typhoon
Sea surface temperature
Latent heat flux
Sensible heat flux
Precipitation rate
South China Sea

ABSTRACT

This study aims to statistically describe temporal and spatial variations of sea surface temperature (SST), latent heat flux (LHF), sensible heat flux (SHF), and precipitation rate with typhoon activity over the South China Sea. The correlations of the parameters and their connections with the physical phenomena are clearly presented. This is fundamental to predict a typhoon's intensity and track. The effects were investigated from 1991 to 2011 based on archived data from the National Centers for Environmental Prediction and the National Center for Atmospheric Research (NCEP-NCAR) and the number of typhoons were sourced from the International Best Track Archive for Climate Stewardship (IBTrACS). The results showed that most typhoons occurred in August and September, which was related to high temperature in the summer season and the southwest monsoon in the area. The maximum mean values of SST in May and June were related to the East Asian Monsoon. The average values of LHF were highest in July, and the mean values of SHF were highest in July and August. SHF varied gradually at different months compared with LHF. In addition, the average of precipitation rate was highest in November, which can be related to the northeasterly winter monsoon. The relationships of the aforementioned parameters were obtained using Pearson's correlation analysis. Moreover, the highest and lowest mean values of the parameters in different areas were considered, and their spatial relationships were analyzed.

1. Introduction

Tropical cyclones (TCs) are large-scale destructive natural hazards that cause serious ecological and human damage. Heavy winds and rainfall from TCs could lead to severe disasters, such as storm surges and flooding. In fact, warm humid air is used as a reinforcement factor for huge “engine-like” TCs. Thus, TCs form over warm water in tropical areas (Anthes, 1986).

According to previous research, the energy source of storms is due to thermodynamical instability between the atmosphere and oceans in tropical areas (Emanuel, 1991). This is related to an actual temperature difference between air and water and also the air saturation of the near-surface. In addition, water evaporation transfers heat from the ocean with a large effective heat capacity in comparison to the atmosphere. Furthermore, among all parameters affecting TC generation and intensification, and from a thermodynamical point of view, SST and heat fluxes have essential roles to play in TC intensity and the cyclones development and stability (Emanuel, 2007; Yu and Weller, 2007).

Moreover, typhoons are important events in the South China Sea, which affect precipitation and cause enormous destruction. In particular, precipitation from typhoons significantly contributes to overall precipitation and can cause disasters such as flooding, man-made disasters, and landslides (Shaluf, 2006). In addition, the movement of TCs over warm oceans represents an air-sea interaction. Some studies have been conducted on the effect of sea surface temperature (SST) on typhoon intensity in different years (Zuki and Lupo, 2008; Dare and Mcbride, 2011a, 2011b). Furthermore, the relationship between heat fluxes and SST and its importance were investigated in different studies (Park et al., 2005; Mcculloch and Culverwell, 2005; Li et al., 2008). Yu and Weller (2007) analyzed a time series of daily latent and sensible heat fluxes during 1981–2005, over the global tropic oceans achieved from satellite and atmospheric reanalysis. They found that latent heat flux (LHF), and sensible heat flux (SHF), are essential parameters in the air-sea interaction. This matter was also represented by Clark (2004). However, limited literature on the interactions between typhoon intensity and parameters such as SHF and LHF is available; thus this study tries to specify those interactions in our chosen study area.

The results of a study by Haghroosta and Ismail (2016) showed that the initial SST value of different typhoons and the SST extent affected typhoon intensity and duration. Moreover, higher LHF caused more rain.

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http://dx.doi.org/10.1016/j.wace.2017.07.002
Received 12 January 2016; Received in revised form 29 April 2017; Accepted 24 July 2017

When SHF anomaly was positive (negative), the initial SST value was highest (lowest). Thus, SST and SHF anomalies were positively correlated. Variations of SST, LHF, SHF, SLP, and precipitation rate and their anomalies in different typhoons were analyzed in the day on which a typhoon had its highest wind speed in comparison with the parameters during the first day. The results showed that temperature for the high-intensity day of typhoon reduced relative to the first day, indicating a typhoon-induced SST cooling effect.

The rest of the paper is organized as follows: the study area and the data used in temporal and spatial analysis are presented in Section 2. The methods are given in Section 3. Section 4 discusses the results. The last section presents the conclusion.

2. Data

2.1. Study area

South China Sea is the largest marginal sea located in the northwestern Pacific Ocean, extending from the equator to 23 °N latitude and from 99 °E to 125 °E longitude (Fig. 1). The area is a semi-closed ocean basin surrounded by South China, Vietnam, Cambodia, Thailand, Peninsular Malaysia, Borneo Island, Indonesia, the Philippines, Taiwan, and the Indo-China Peninsula (Ho et al., 2000; Wang, 2008). The area connects with the east of China Sea, the Indian Ocean, and the Pacific Ocean through the Taiwan Straits, the Straits of Malacca, and the Luzon Straits, respectively. The South China Sea is one of the most important places for TC generation. In this paper, the study area is limited to 1 °N to 16 °N and from 100 °E to 130 °E, in latitude and longitude.

2.2. Data to determine temporal and spatial variations of selected parameters and typhoon activity

For long-term study, values of SST, precipitation rate, LHF, and SHF were obtained from the monthly mean and daily NCEP reanalysis data (Kalnay et al., 1996), available from the Climate Prediction Center (CDC), for the period 1991 to 2011. The dataset is valuable in forecasting and investigating extreme weather events (Grumm, 2005; Hamill et al., 2005). The global dataset has a horizontal grid spacing (resolution) of 2.5° × 2.5°. Data relating to typhoon numbers and exact locations were obtained from the International Best Track Archive for Climate Stewardship (IBTrACS) dataset (Knapp et al., 2010). The typhoons were selected in consideration of their generation, development, and dissipation in the study area.

3. Methods

Statistical analyses were performed using SPSS 21.0 for Windows and significant levels for all analyses were set to 0.05. Normal distribution of data was determined based on Kurtosis and Skewness coefficients. After normal distribution was determined, multiple regression analysis was conducted to study the relationship between the number of typhoons and precipitation rate, SST, SHF and LHF. One-way analysis of variance (ANOVA) method was employed to determine the significant differences between the means of two or more independent parameters (Wilks, 2011). A significant difference between two parameters is determined if the p-value in the ANOVA table is less than 0.05.

In addition, parametric correlations were tested with Pearson's correlation test to establish the relationship between the aforementioned parameters and typhoon activity. Pearson's correlation coefficient (CC) higher than 0.5, indicates strong correlation (Explorable, 2008).

Moreover, the temporal relationships were analyzed between the monthly mean values of SST, LHF, SHF, precipitation rate (from NCEP-NCAR), and the number of typhoons (from IBTrACS). To investigate the spatial variations of the parameters with typhoon activity in different regions, the study area was divided into 10 equal sections geographically (A1 to A10). The map was drawn using Grads software (Fig. 2).

4. Results and discussions

4.1. Temporal variations

The mean values of the number of typhoons, SST, LHF, SHF, and precipitation rate were analyzed by the one-way ANOVA, and results showed significant differences for each parameter across different months ($p < 0.05$). As shown in Fig. 3, the monthly mean values of number of typhoons from 1991 to 2011 are also significantly different ($P < 0.05$). The number of typhoons had a maximum monthly mean value of 2 ± 0.6. The error bar in the figure stands for standard deviation.

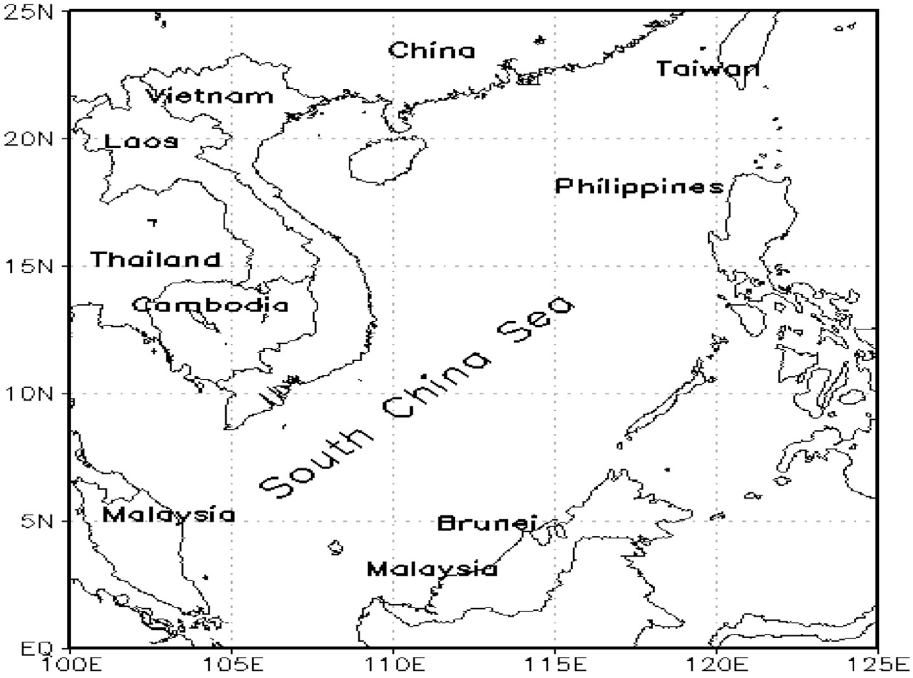

Fig. 1. South China Sea.