Variations of total heat flux during typhoons in the South China Sea

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Abstract

This study, statistically describes variations of the total heat flux during typhoons over the South China Sea. Total heat flux was considered as a sum of the latent heat flux (LHF) and sensible heat flux (SHF). Typhoons in the South China Sea were selected from 1991 to 2011. These effects were examined 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 from the Joint Typhoon Warning Center during the indicated period. A long-term study on typhoons behavior indicated that on average, the trend of overall heat flux is related to the number of typhoons. By contrast, the results showed that the total heat flux touched its maximum amounts in July and August, and prepared the required energy for typhoon generation, so the number of typhoons enhanced during consequent months, August and September which had maximum number of typhoons during the years. Furthermore, from the spatial point of view, most variations in total heat flux were observed in lower longitudes and latitudes.

Keywords: Heat flux; Typhoon; South China Sea.

1. Introduction

The South China Sea is a marginal sea located on the west of the tropical Pacific Ocean. It is a semi-closed ocean basin surrounded by South China, Peninsular Malaysia, Borneo Island, the Philippines, and the Indo-China Peninsula (Ho *et al.*, 2000). Our area of study is from 0° to 7° north and from 99° to 120° east, which includes the Malaysian water environment. Typhoons are significant events in the South China Sea climate, and can cause large-scale damage. In particular, latent heat flux (LHF) and sensible heat flux (SHF) have key functions during a typhoon (Shay *et al.*, 2000).

The heat exchange through the air–sea interface is a major factor that influences the interaction between the atmosphere and the ocean. Moore and Renfrew (2002) claimed that the energy transferred by the heat fluxes has an impact on a wide range of atmospheric and oceanic circulation activities. They

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examined the air–sea heat fluxes over the western boundary currents of the North Atlantic and North Pacific Oceans where large transfers of heat occur from the ocean to the atmosphere. The findings showed that employing the NCAR reanalysis surface layer meteorological fields for the sensible and latent heat fluxes more accurately represents the air–sea exchange of heat and moisture over the western boundary currents.

Among all parameters which affect on typhoons, from the thermodynamical point of view, heat fluxes have essential roles on typhoon intensity and also in developing and maintaining of the cyclones (Byers, 1944). Warsh *et al.* (1972) measured SHF and LHF during July and August of 1968. The data set achieved from a ship and a spar buoy in the east of Barbados, Central America. They compared daily changes of the heat fluxes in details, and the results indicated that the ship generates a turbulent area very different from conditions in an open sea.

Halliwell and Rouse (1989) calculated LHF and SHF as important parameters by two different methods, and compared the results of these methods. Monthly anomalies of the heat flux relevant to variations in sea surface temperature (SST) were examined over the North Atlantic and North Pacific oceans. The monthly heat flux anomalies and the SST anomaly tendency are significantly correlated with anomalous positive or negative heat fluxes associated with anomalous cooling or warming. The connection between the heat fluxes and the SST tendency anomalies is strongest in the extratropics during the cool season when the latent and sensible heat fluxes and their variability are greatest. According to the study by Cayan (1992), the anomalies of latent and sensible heat fluxes are strongly correlated over most of the ocean, so they were considered together as a sum.

An experiment showed the effect of the ocean response to the behavior of storm. The experiments demonstrated that the SST cooling by the cyclones resulted in an important effect on the storm intensity due to decreasing of total heat flux related to the storm over the area of decreased SST (Bender *et al.*, 1993).

Considering rapid intensification of hurricane Katrina that had a correlation by an upper-oceanic thermal structure, the effect of the ocean eddy on cyclone intensity was studied by a simple hurricane–ocean coupled model. The results indicated that rapid storm strengthening happened when the heat flux increased (Wu *et al.*, 2007). Different numerical models were performed by Bao *et al.* (2002) to clarify the effects of roughness length schemes on heat fluxes for a simulated hurricane. It was indicated that there were large differences in the response of the hurricane to those schemes. They showed the necessity of further studies for both theory and observations to decrease the errors in the simulated air–sea fluxes in high wind conditions. Influence of typhoon Noul on LHF and SHF was investigated by Haghroosta and Ismail (2013). Analyzing the daily contour maps showed that the parameters reduced during the typhoon. According to the weak literature in studying of interaction between typhoon and total heat flux in the area, this paper tries to indicate statistically these relations.

2. Material and method

This study covers the 21-year period from 1991 to 2011. The LHF and SHF values during these years were obtained from the data set of the National Centers for Environmental Prediction and the National Center for Atmospheric Research (NCEP–NCAR). It has been shown that this dataset is valuable to investigate extreme weather events and their forecasting (Grumm, 2005; Hamill *et al.*, 2005). This global dataset has a horizontal grid spacing of $2.5^{\circ} * 2.5^{\circ}$. The number of typhoons during the indicated period was obtained from the Joint Typhoon Warning Center (Angove *et al.*, 2012). The interaction between typhoons and total heat flux was investigated by an analysis of the cyclical variations of typhoon numbers, and total heat flux during the period.

3. Results and Discussion

First, the 21-year data of the mean values of LHF and SHF were obtained from the NCEP–NCAR dataset (Kalnay *et al.*, 1996). Based on the study by Cayan (1992), anomalies of latent and sensible heat fluxes are strongly correlated over most of the oceans, so they were considered together as a sum and the total heat flux was calculated. Then, analyzing the data during the period, the two months with the maximum number of typhoons and maximum amount of total heat flux were determined. A review of existing data shows that most of the typhoons occurred in August and September. Furthermore, the average values of total heat flux in the area were largest in July and August. The variations of these parameters, during the years, are reported in Figure 1 and Figure 2, respectively.

A comparison of the mean values of total heat flux from 1991 to 2011 (see Figure 3) indicates that in the area from 99.375° to 105°, and from 110.625° to 120° east longitude, low latitudes showed the most pronounced fluctuations. Meanwhile, heat fluxes in latitudes above 6.66° north had uniform variations and most variations in total heat flux were observed in lower longitudes and latitudes.

The total heat flux status during the typhoons was also investigated. The variations of total

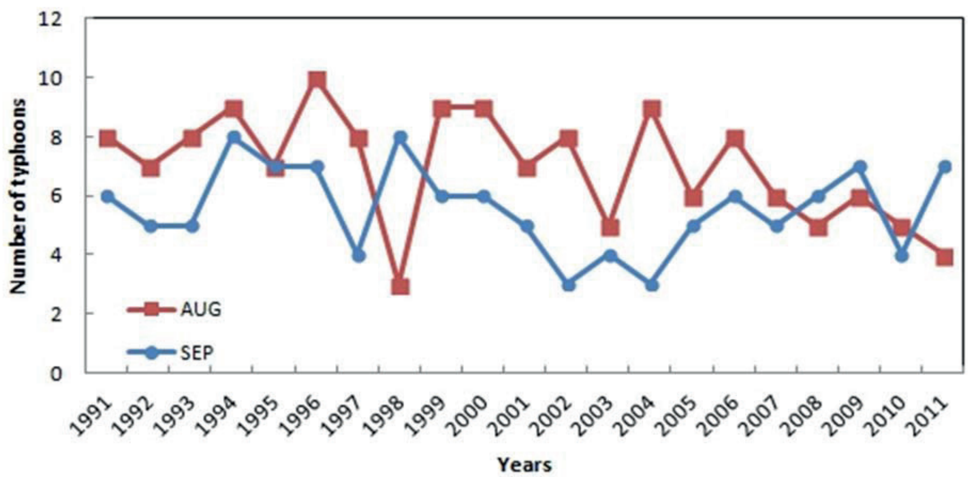

Figure 1. Variation of typhoons number during years in August and September

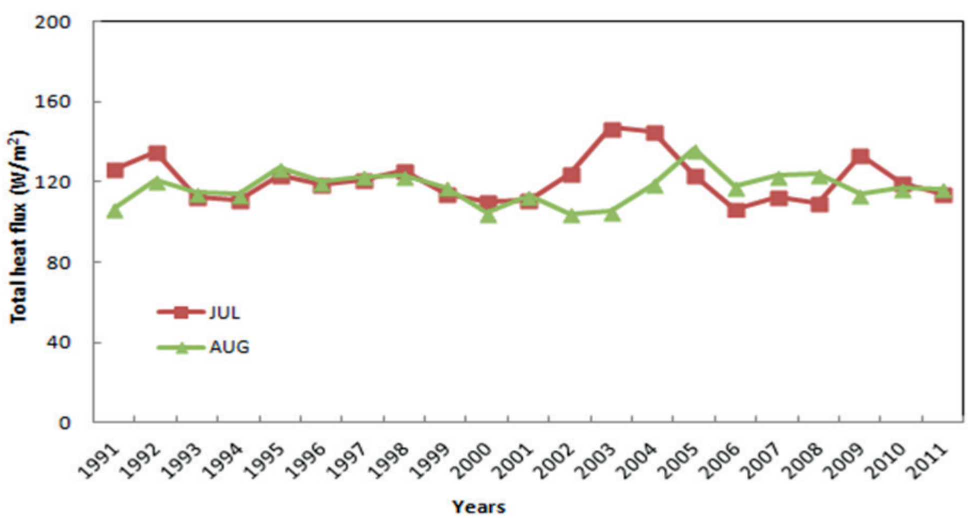

Figure 2. Variation of total heat flux during years in July and August

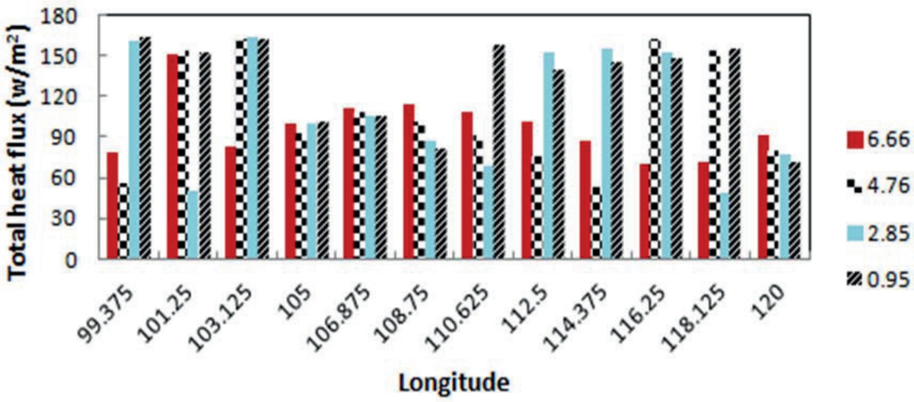

Figure 3. Variations in total heat flux with longitude and latitude from 1991 to 2011

heat flux in August and September, the months with the highest number of typhoons (Figure 1), are presented in Figure 4. Comparing Figure 1 and Figure 4 demonstrates that as the number of typhoons increased or decreased, in most years, the total heat fluxes reduced or enhanced, respectively. The preceding descriptions imply that investigating the effect of typhoons on heat fluxes in the area is essential. In fact, the examination of typhoon behavior indicates that on average, the total heat flux increases before typhoon generation to prepare its required energy. By contrast, an increase in the number of typhoons causes a decrease in total heat flux values.

Conclusion

Predicting weather conditions in advance is necessary. The weather changes every day, and numerous decisions are often based on weather conditions. Due to the lack of studying the relation between typhoons and heat fluxes, this study attempted to fill in the gaps. Herein, the typhoons over the South China Sea, from 1991 to 2011, were considered. The long-term study demonstrated that the number of typhoons and the trend of heat fluxes have a notable correlation. Meanwhile, investigating the various effects of typhoons on the South China Sea suggests that the trend in total heat flux follow the number of typhoons. Most changes in total

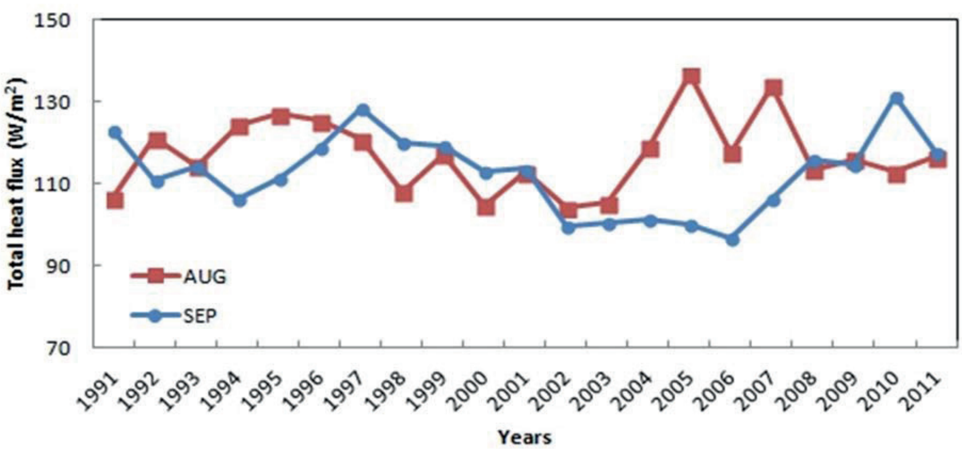

Figure 4. Variations in total heat flux during the months with the largest number of typhoons

heat fluxes (LHF and SHF) in tropical areas were observed in lower latitudes, and in the area from 99.375° to 105°, and from 110.625° to 120° east longitude. Indeed, the typhoon behavior pointed out that on common, the total heat flux enhances before typhoon as an important energy source for a typhoon creation. By contrast, an increase in the number of typhoons was caused a decrease in total heat flux values.

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