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Recent Decline in Typhoon Activity in the South China Sea

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RECENT DECLINE IN TYPHOON ACTIVITY IN THE SOUTH CHINA SEA

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Summary

By applying a low-pass Gaussian filter to remove variations with periodicities that are less than 10 years, a decline in the annual number of typhoons (TYs) and category 4-5 TYs (i.e. TY with 1-minute maximum sustained wind ≧ 114 knots) in Saffir-Simpson Scale in the South China Sea (SCS) since mid-1990s is revealed. In the last 10 years, between 1996 and 2005, the number of TYs and category 4-5 TYs are 3.7 and 0.2 respectively, far below their 1961-1990 averages of 5.5 and 1.9. The present study attempts to investigate the causes of this recent decline in TY activity.

As the numbers of TYs and category 4-5 TYs formed in the SCS were both small (1961-1990 averages of 0.7 and 0 respectively), the decline was mainly due to a decrease in the number of TYs and category 4-5 TYs entering the SCS. A factor contributing to the decrease is a fall in the number of TYs and category 4-5 TYs forming east of 120°E in the western North Pacific (WNP). The spectral analysis of the annual number of TYs forming east of 120°E in the WNP by Multitaper Method indicates the presence of interdecadal modulation on the TY activity. In the last 10 years, the TY activity was in a "quiet" phase. For category 4-5 TYs, a statistically significant (at 5% level) trend of 0.5 per decade was found.

Apart from the formation frequency, a recent shift in TY tracks was also observed. This anomaly in tracks was likely due to a shift in the upper-level flow pattern under which TYs were steered towards the vicinity of Japan rather than into the SCS.

Keywords
Recent decline, South China Sea, interdecadal variations, typhoon tracks

1. Introduction

Typhoons (TYs) are one of the most destructive weather systems. An increase in TY activity can potentially increase losses of life and property, and hence fluctuations in TY activity are of utmost importance to disaster prevention. Many studies in the past examined TY variations in large ocean basins such as the western North Pacific (WNP) [see for example, CHAN et al, 1996] and the Atlantic [LANDSEA, 1996; GOLDENBERG et al, 2001]. In the WNP, an average of about 30 tropical cyclones (TCs) formed every year, the most prolific of all the ocean basins [MCBRIDE, 1995]. Among the 30 TCs, about half of them reached TY intensity. Some occurred in the smaller sea basin, the South China Sea (SCS, defined for the purpose of the present study as the sea area within 10-25°N, 105-120°E), and can pose a threat to the densely populated south China coastal area which is one of the coastlines around the world most frequently affected by TYs [CHAN et al, 2004a]. The present study examines the long-term variations in TY activity over this smaller sea basin.

There has been a vigorous debate on the changes in TC activity due to increasing sea surface temperature (SST) in a warming world [see for example, WEBSTER et al, 2005; TRENBERTH, 2005; CHAN et al, 2004b]. Based on results of climate model simulations, many researchers [for example, KRISHNAMURTI et al, 1998; KNUTSON et al, 1998] have suggested that rising SSTs will likely lead to more and stronger TCs. In contrast, a recent decline in TY activity in the SCS is found in the present study. The present study aims to examine this decline by investigating variations in TY formation, TY tracks as well as the associated atmospheric and oceanic conditions.

2. Data and Methodology

In this study, TY activity in the SCS and the WNP between 1961 and 2005 is represented by the annual number of TYs occurring in these two ocean basins. These TY numbers and also the TY tracks are source from the Hong Kong Observatory's (HKO) best track data. HKO is a tropical cyclone warning centre designated by the World Meteorological Organization for an area of responsibility in the WNP. The best track database it compiles goes back as far as 1884, and best track data from 1987 and onwards are available from http://www.weather.gov.hk/publica/pubtc.htm/.

HKO uses the Dvorak technique without modification for intensity estimation but multiplies the one-minute wind speed by a factor of 0.9 to convert to 10-minute averages. HKO's intensity estimates also take into account available observations from ships and land stations as well as other information such as ocean surface winds from the Sea-Winds scatterometer on board QuickSCAT [WU et al, 2006].

The large-scale sea surface temperature (SST) field and the wind field at different vertical levels are drawn from the United States National Centers for Environment Prediction – National Center for Atmospheric Research (NCEP-NCAR) re-analysis data [KALNAY et al, 1996].

Following the practice of WIGLEY et al [1990] in their study of the natural variability of climate systems, oscillations with periodicities of 10 years and longer are defined as low frequency or long-term variations, and oscillations with periodicities shorter than 10 years are defined as high frequency or short-term variations. In the context of this paper, the former is referred to as interdecadal variations and the latter interannual variations. Spectral analysis by Multitaper Method (MTM) is carried out to determine the periodicities of TY activity, and the spectral peaks obtained are tested against the white-noise spectrum. Compared with Fourier and other traditional methods of spectral analysis, the spectral estimates given by MTM have lower variance and higher resolution [see for example, GHIL et al, 2002]. A low-pass Guassian filter [HANNA et al, 2003] is applied to remove variations with periodicities that are less than 10 years in time series to obtain the interdecadal variations. The linear trend is computed by linear regression and the t-test is employed for testing the statistical significance of the trend. Cluster analysis [WILK, 1995] is applied to analyse the TY genesis positions.

3. Results

Figure 1 shows the time series of the anomaly in the annual number of TYs occurring in the SCS. By applying a low-pass Gaussian filter to remove variations with periodicities that are less than 10 years, a rapid decline since the mid 1990s in TY is revealed (Figure 1a) against the background of global warming. The decline is most obvious for the category 4-5 TYs (1-minute maximum sustained wind $\geqq$ 114 knots) in Saffir-Simpson Scale (Figure 1b). In the last 10 years of 1996-2005, the average annual number of TYs and category 4-5 TYs are 3.7 and 0.2 respectively, far below their 1961-1990 averages of 5.5 and 1.9.

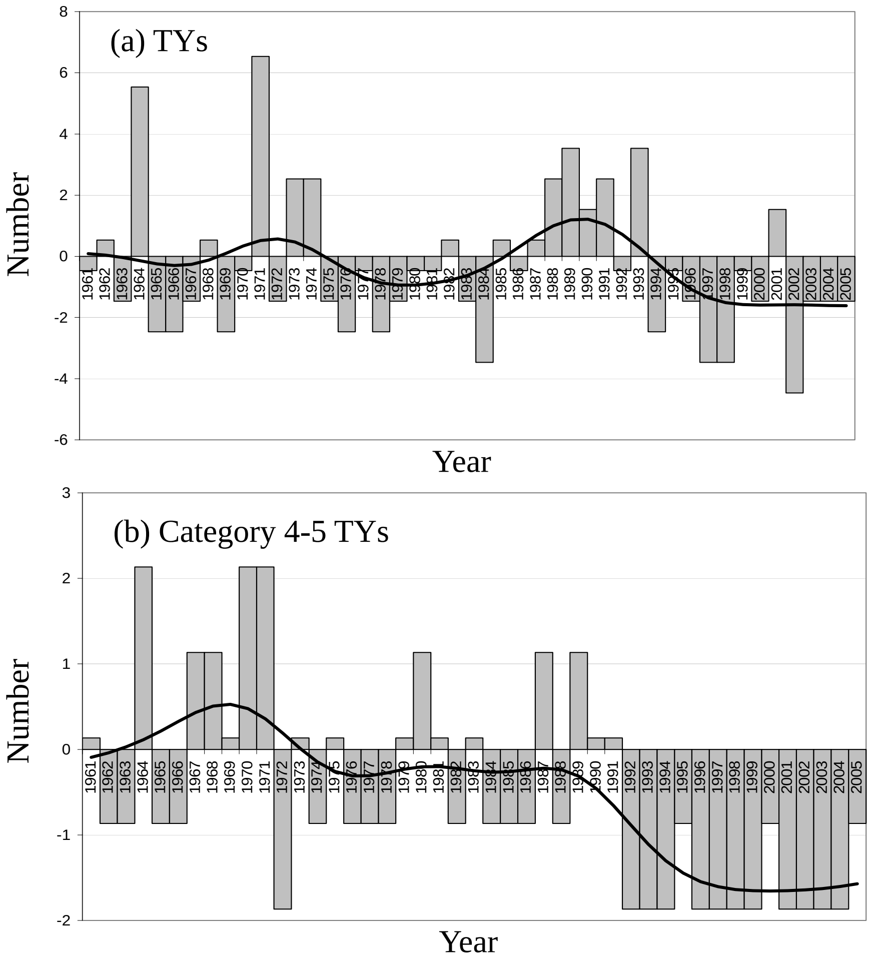

Fig. 1. Anomaly in the annual number of (a) TYs and (b) category 4-5 TYs occurring in the SCS. Anomaly is with reference to the 1961-1990 mean. The dark line shows the Gaussian filtered time series with periodicities of less than 10 years removed.

WU et al [2006] and YEUNG [2006] pointed out that discrepancies in TC records among different centres may affect long-term TC analysis. Here although the TY numbers shown by the three centres HKO, Regional Specialized Meteorological Centre (RSMC) Tokyo and Joint Typhoon Warning Centre (JTWC) differ for individual years, they all revealed a decline in the period 1996-2005 (Figure 2).

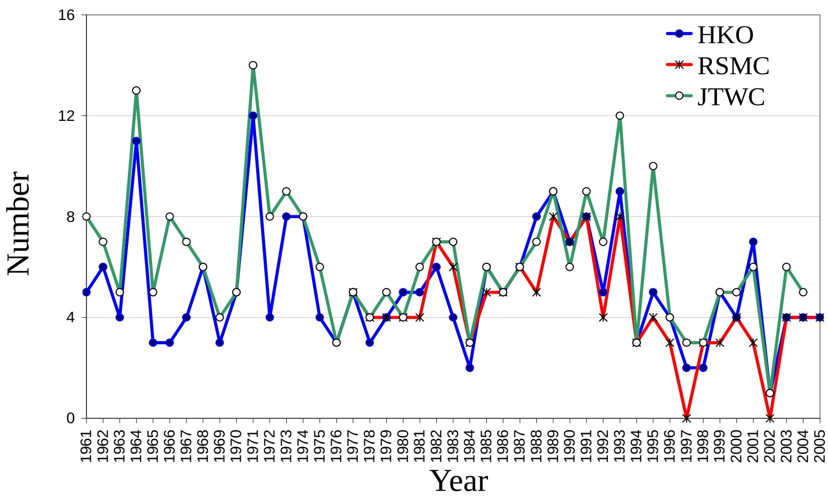

Fig. 2. Annual number of TYs occurring in the SCS based on HKO, RSMC and JTWC best tracks, respectively.

As the number of TYs and category 4-5 TYs formed in the SCS were both small (1961-1990 averages of 0.7 and 0 respectively), the decline was mainly due to a decrease in the number of TYs and category 4-5 TYs entering the SCS. This decrease is related to both a decrease in the number of TYs that formed east of 120°E in the WNP and a shift in TY tracks as discussed below.

3.1 Interdecadal variations of TYs that formed east of 120°E in the WNP

Figure 3 shows the result of spectral analysis by MTM on the annual number of TYs that formed east of 120°E in the WNP. Two prominent peaks of 3.4 years and 17 years that exceed the 95% confidence limit of the white noise spectrum are observed. The 3.4-year peak is closely related to the interannual El Nino Southern Oscillation (ENSO) activity and has been discussed in quite a number of studies [see for example, CHAN, 2000; LEUNG et al, 2002; CHANG et al, 2003; WU et al, 2004].

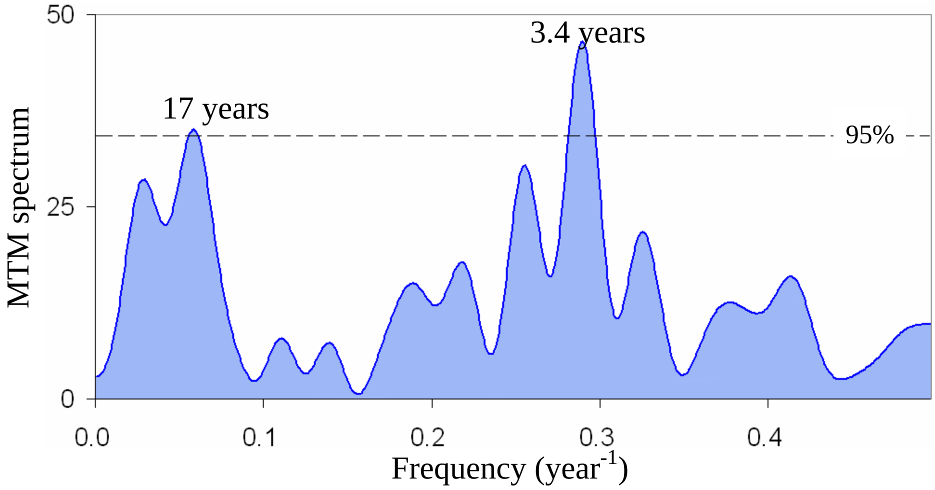

Fig. 3. MTM spectrum of the annual number of TYs forming east of 120°E in the WNP. The 95% confidence level with respect to the white noise spectrum is shown by the dashed line.

The 17-year peak indicates the presence of interdecadal modulation. Periods of "active" phase (1960s and from mid-1980s to mid-1990s) and "quiet" phase (early 1970s to mid-1980s and from mid-1990s to mid-2000s) in the activity of TYs can be identified (Figure 4). The decrease in the number of TYs in 1996-2005 is probably a manifestation of the interdecadal variation in TY activity. The latter may be explained in terms of the oscillations in oceanic and atmospheric conditions between the subtropical western and eastern North Pacific [LEUNG et al, 2006]. For category 4-5 TYs, a statistically significant (at 5% level) trend of 0.5 per decade was found.

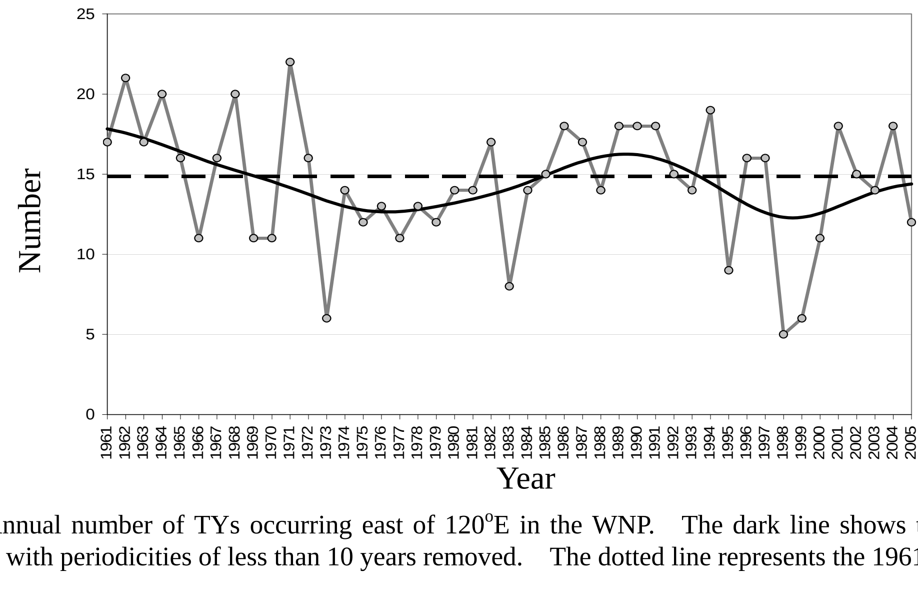

Fig. 4. Annual number of TYs occurring east of 120°E in the WNP. The dark line shows the Gaussian filtered time series with periodicities of less than 10 years removed. The dotted line represents the 1961-1990 average.

3.2 Recent shift in TY tracks

Apart from the frequency of formation of TY mentioned in Section 3.1, a recent shift in TY tracks was also observed.

By using cluster analysis on the TY genesis positions, three clusters can be identified. There is only a slight difference in the genesis positions for the period 1996-2005 compared with 1961-1995 (Figure 5c). For TY genesis positions located in 150-180°E, the percentage of TY entered the SCS are 32.2% for 1961-1995 and none for 1996-2005 (Figure 5a and 5b). For genesis positions located in 120-150°E, the percentage of TY entered the SCS for 1961-1995 and 1996-2005 are 41.7% and 31.4% respectively.

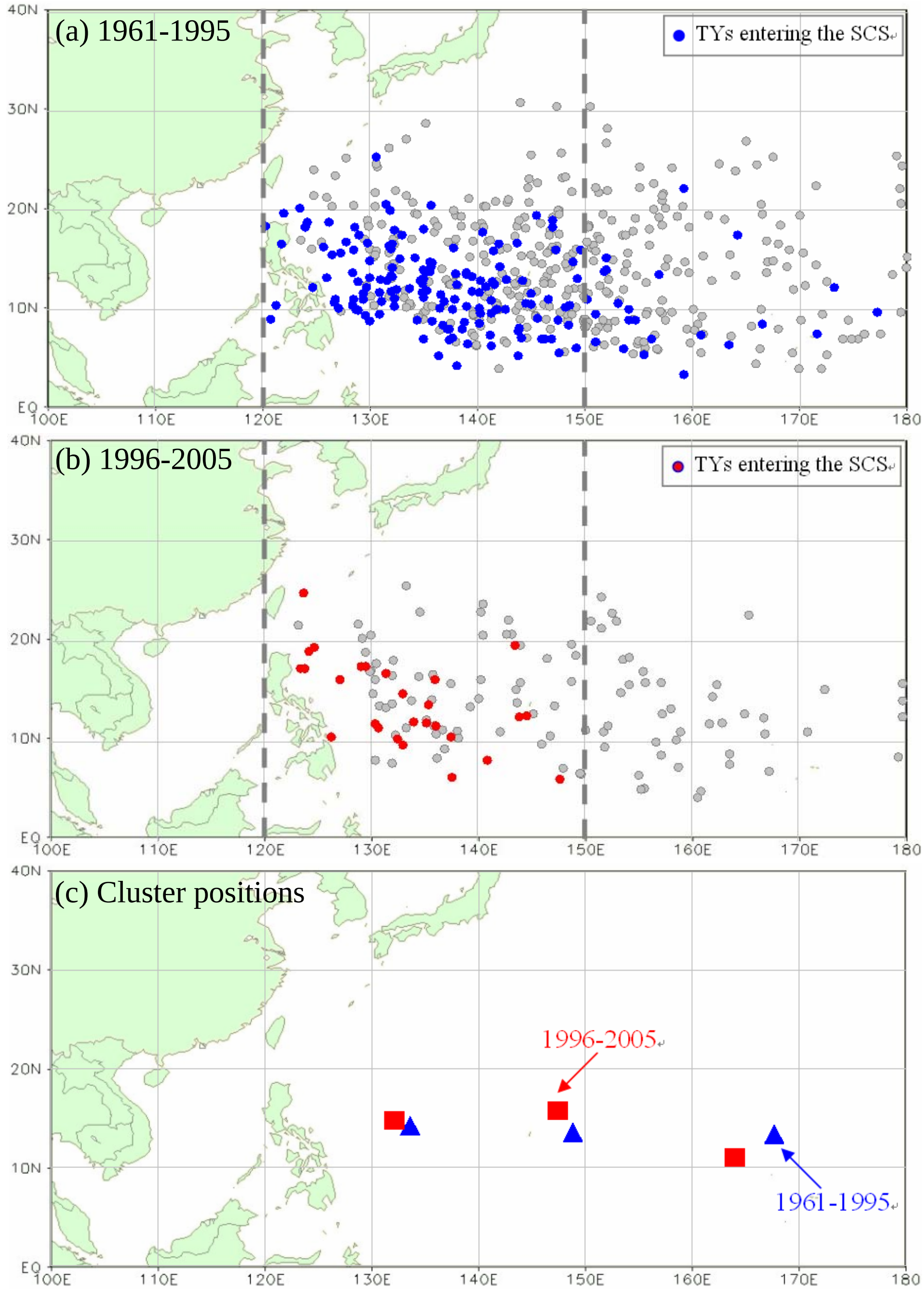

Fig. 5. Genesis position of TYs occurring east of 120°E in the WNP for the period (a) 1961-1995 and (b) 1996-2005. The three cluster positions of the genesis position are given in (c).

Figure 6 shows the TY track density in 1996-2005, relative to 1961-1995. It can be seen that there is a recent shift in TY track with fewer TYs that formed east of 120^{o}E moving towards and entering the SCS. This was likely due to a shift in the 500 hPa flow pattern whereby TYs over the area 10-20^{o}N and 125-150^{o}E, where most TYs formed, were steered towards the vicinity of the East China Sea and Japan rather than into the SCS (Figure 7).

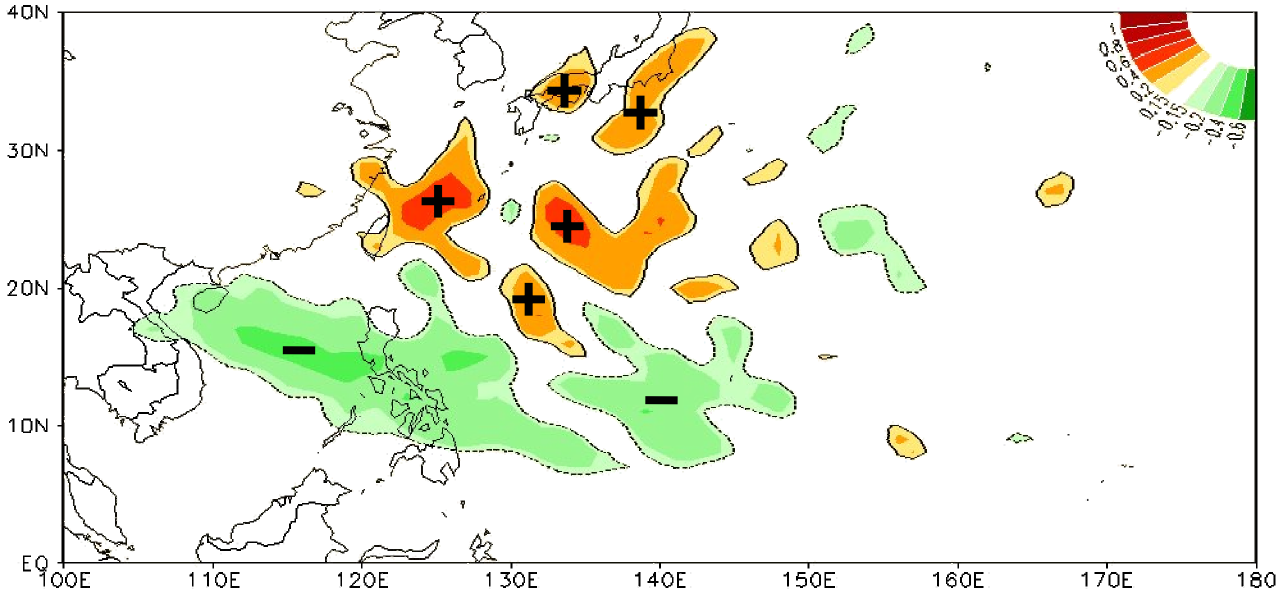

Fig. 6. Typhoon track density (in number per year) in 1996-2005 relative to 1961-1995. "+" and "-" signs in the figure represent positive and negative anomalies respectively.

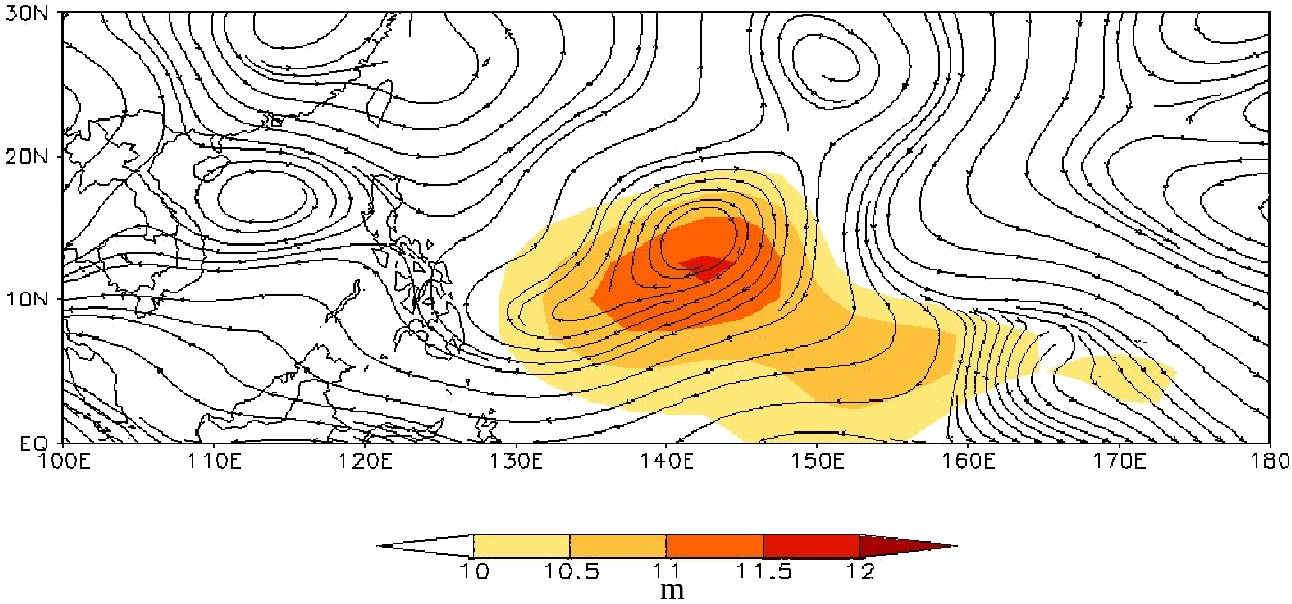

Fig. 7. Difference in the 500 hPa steering flow between 1996-2005 and 1961-1995 averaged over May-November. Shading represents the difference in geopotential height.

The SST in the WNP, especially in the SCS, is in general warmer for 1996-2005 than that for 1961-1995 (Figure 8). Correlation analysis shows that the SST in the SCS is highly and positively correlated (statistically significant at 5% level) to the 500 hPa geopotential height at locations near the anomalous 500 hPa high shown in Figure 7 (Figure 9). Whether global warming would lead to a rise of SST in SCS and associated further a shift in TC tracks is worth further investigations.

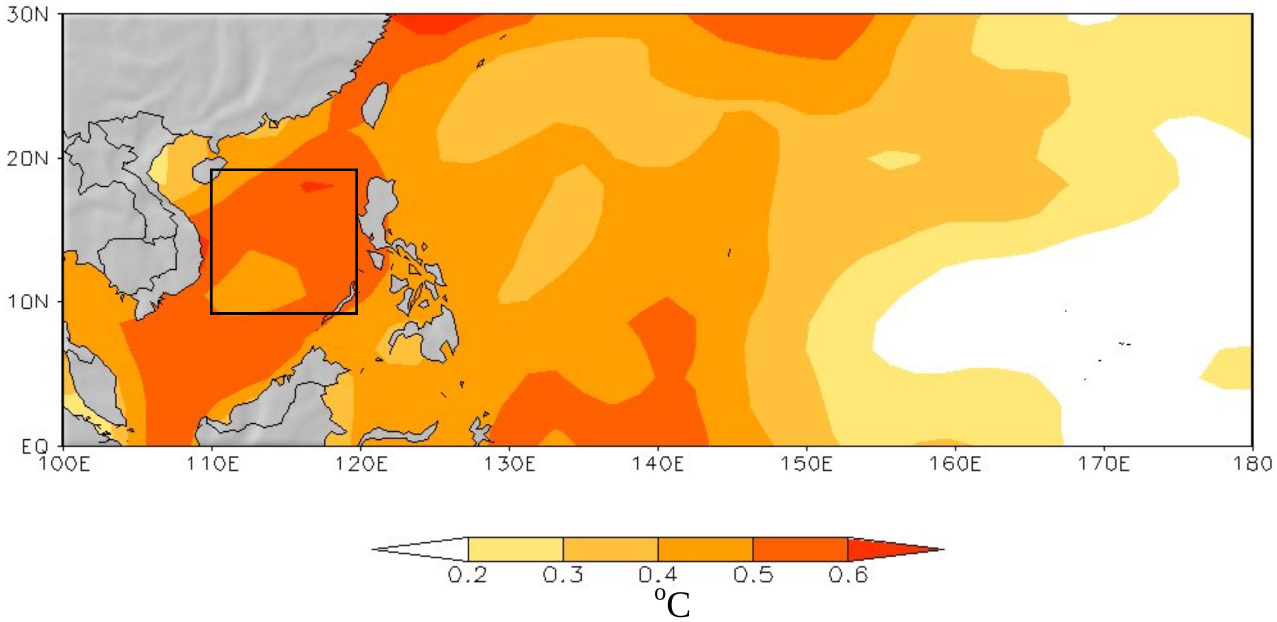

Fig. 8. Sea surface temperature (SST) difference between the period 1996-2005 and 1961-1995 averaged over May-November. The square box denote the area (10-20^{o}N, 110-120^{o}E) chosen to represent the SCS.

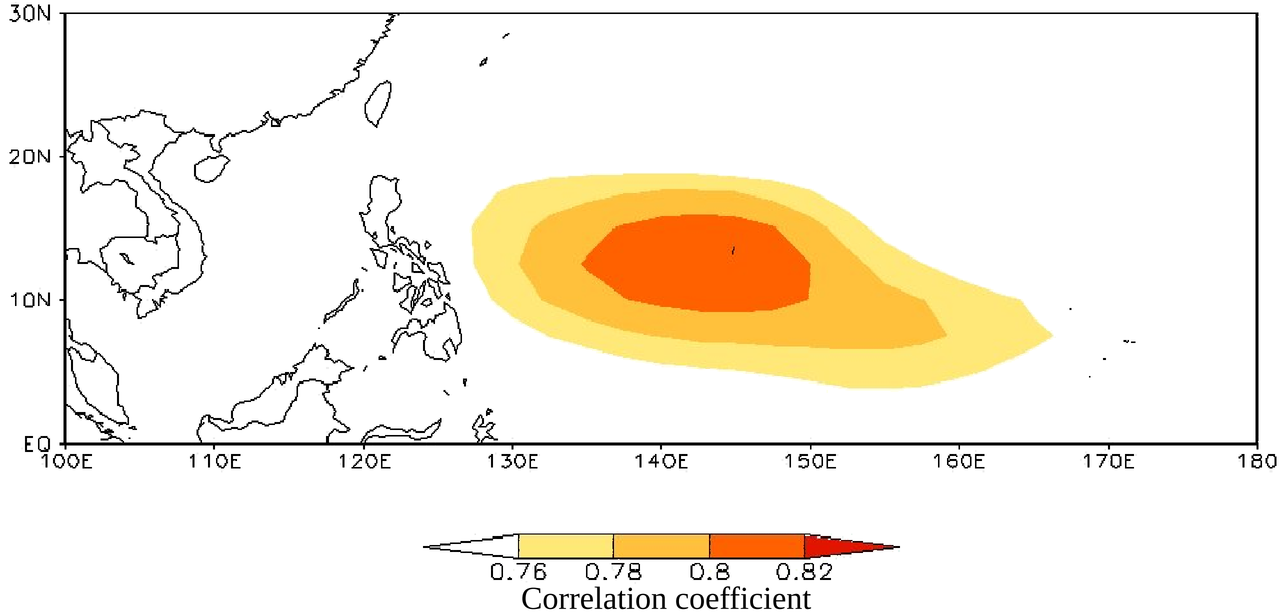

Fig. 9. Correlation between 500 hPa geopotential height and the SST in the SCS during May-November in the period 1961-2005. Only correlation coefficients > 0.76 which are also statistically significant at 5% level are shown.

4. Conclusion

The typhoon activity in the South China Sea has been found to decline since the mid-1990s. Due to interdecadal variations, fewer typhoons formed in the western North Pacific since the mid-1990s. This, coupled with a change in typhoon tracks towards the vicinity of East China Sea and Japan rather than into the South China Sea, contributed to the recent decline of typhoon activity. The change in TY tracks might have been due to a shift in the mid-tropospheric flow pattern which was related to increasing sea surface temperature in the South China Sea.

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