Journal of Zhejiang University SCIENCE A
ISSN 1009-3095 (Print); ISSN 1862-1775 (Online)
www.zju.edu.cn/jzus; www.springerlink.com
E-mail: jzus@zju.edu.cn

Influence of climatic warming in the Southern and Northern Hemisphere on the tropical cyclone over the western North Pacific Ocean

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Received Dec. 1, 2005; revision accepted July 9, 2006

Abstract: Based on analyzing the surface air temperature series in the Southern and Northern Hemisphere and the tropical cyclone (TC) over the western North Pacific Ocean, the relationships between climatic warming and the frequency and intensity of tropical cyclone are investigated. The results showed that with the climatic warming in both hemispheres, the frequency of the tropical cyclone over the western North Pacific Ocean reduces and its intensity weakens simultaneously. A possible explanation might be that the cold air invasion from the Southern Hemisphere weakens due to global warming.

Key words: Climatic warming, Southern and Northern Hemisphere, Western North Pacific Ocean, Tropical cyclone (TC)
doi: 10.1631/jzus.2006.A1923 **Document code:** A **CLC number:** P7

INTRODUCTION

Global warming is a critical environment problem, and has long been a subject of concern for scientists, policy-makers, and many citizens. Increased interest in global warming stems from its potentially disastrous consequences to ecosystems on earth, which may give rise to anomalous regional drought, more frequent and severe floods, intensification of storm, hurricane and typhoon, etc. Concern about mankind's negative impact on global environmental changes gave rise to the founding of Intergovernmental Panel on Climatic Change (IPCC) by United Nations Environment Programme (UNEP) and World Meteorological Organization (WMO) in 1988. First Assessment Report was released by IPCC in 1990, following the Second (1995) and the Third (2000) Assessment Report. The main purpose of those reports was to assess the Emission Scenarios of greenhouse gas and climatic change, then to predict the variation trends of greenhouse gas concentrations and possible climatic changes.

The human system cannot operate independently of meteorological, geophysical, and biophysical systems, whose subtle changes can cause positive effects for exploitation and utilization, or negative effects threatening human communities and be hazards. Oceanic areas, lying 5 degrees polewards and with sea surface temperature >26.5 °C are the cradles of seasonal tropical cyclones, which as elements of the tropical atmosphere-ocean system, play an important role in maintaining the global energy balance through the redistribution of excessive energy from low to high latitudes, and comprise a considerable threat to human communities living in tropical, subtropical and occasionally extra-tropical islands and coastal regions (McGregor, 1995).

China is located in the western coast of the North Pacific Ocean. From statistical data (Wu, 1999), tropical cyclones invading those regions resulted annually in almost half a thousand casualties and average economic loss of RMB 4.16 billion Yuan (USD 503 million) during 1982~1990. Therefore, it is important to study the inherent correlation between climatic warming and tropical cyclone (TC), as well as the implications on China environments.

The formation of TC requires a warm marine surface, where the sea surface temperature (SST) usually exceeds 26.5 °C (Elsberry, 1994), and a deep warm ocean mixed layer (>25 °C down to 50 m depth). It is natural to ask whether global warming is likely to affect the frequency or intensity of TC, and what kind of different influence there exists between the Southern and Northern Hemisphere during climatic warming on TC over the western North Pacific Ocean (WNP). This paper discusses the preceding questions.

In this study, all of the TC data including the frequencies, central windspeeds, and central pressures were obtained from the Chinese Meteorological Administration Tropical Cyclone Yearbook covering 1949 to 2000. The definition of TC mentioned here is based on windspeed and all storms with central windspeed>10.8 m/s. Annual data are analyzed in this study. The number of tropical cyclones occurring over the WNP during one year is defined as TC frequency; the maximum value of its central velocity in each year is defined as maximum central windspeed, and lowest value of central pressure as minimum central pressure. All of those are TC parameters.

The annually average surface air temperature dataset relative to 1951~1980 mean first handled by Hansen, was obtained from Goddard Institute for Space Studies, NASA (http://www.giss.nasa.gov/data). It was named as Hansen temperature series. Wang and Ye (1995) suggested that there are better correlations between Hansen (Hansen and Lebedeff, 1987) temperature series and IPCC, Jones (1988), and Vinnikov *et al.*(1990) surface air temperature series. Hansen temperature series may be used to describe the variation trend of surface air temperature on earth.

Surface air temperature series in 10 regions were used to study the temperature change from 1949 to 2000, involving the tropical, mid-latitude, high-latitude, polar, the Southern and Northern Hemispheric temperature series. The tropical temperature series (EQ~24S and EQ~24N) refer to the series from the equator to 24°S, and to 24°N, respectively. The mid-latitude temperature series (24~44S and 24~44N) are respectively 24~44°S and 24~44°N bands. The high-latitude series (44~64S and 44~64N) are 44~64°S and 44~64°N bands, respectively. The polar series (64~90S and 64~90N) are 64~90°S and 64~90°N bands, respectively. The Southern Hemispheric temperature series (SHem) represent the whole Southern Hemisphere, just as the Northern Hemispheric temperature series (NHem) represent the whole Northern Hemisphere.

DIFFERENCE OF SURFACE AIR TEMPERATURE BETWEEN THE SOUTHERN AND NORTHERN HEMISPHERE

To compare the difference of temperature variation between the Southern and Northern Hemisphere, 5 regions including the hemisphere area, the polar area (64°~90°), the high-latitude area (44°~64°), the mid-latitude area (24°~44°), the low-latitude area (0~24°) are divided. As shown in Fig.1, the variation curves of surface air temperature in the 5 regions of both hemispheres have very different trends, which are obvious especially in mid-latitude, high-latitude, polar, and hemisphere region, maybe due to greater land mass in those areas of the Northern Hemisphere compared to the Southern Hemisphere. While the curves for EQ~24N and EQ~24S (tropical region) are relatively similar maybe due to the similar latitude and the feature of the underlying surface.

The curves of Fig.1 show that the Southern Hemisphere has ascending trends in those regions from 1949 to 2000, except in the high-latitude region where there were descending trends after the 1980s. The Northern Hemisphere (except the low-latitude area) has declining trends before the 1970s and ascending trends after the 1970s.

INFLUENCE OF CLIMATIC WARMING IN THE SOUTHERN AND NORTHERN HEMISPHERE ON TROPICAL CYCLONE FREQUENCY

Fig.2 of the variation of TC parameters over the WNP shows that the general trend of TC frequency curve decreases gradually. The cubic polynomial fit curve exhibits increasing trend before the 1960s but decreasing trend after the 1960s. In particular, the highest surface air temperature in the Northern Hemisphere occurred in 1998 during the period 1880~2000, whereas TC frequency over the WNP lowest in the period 1949~2000.

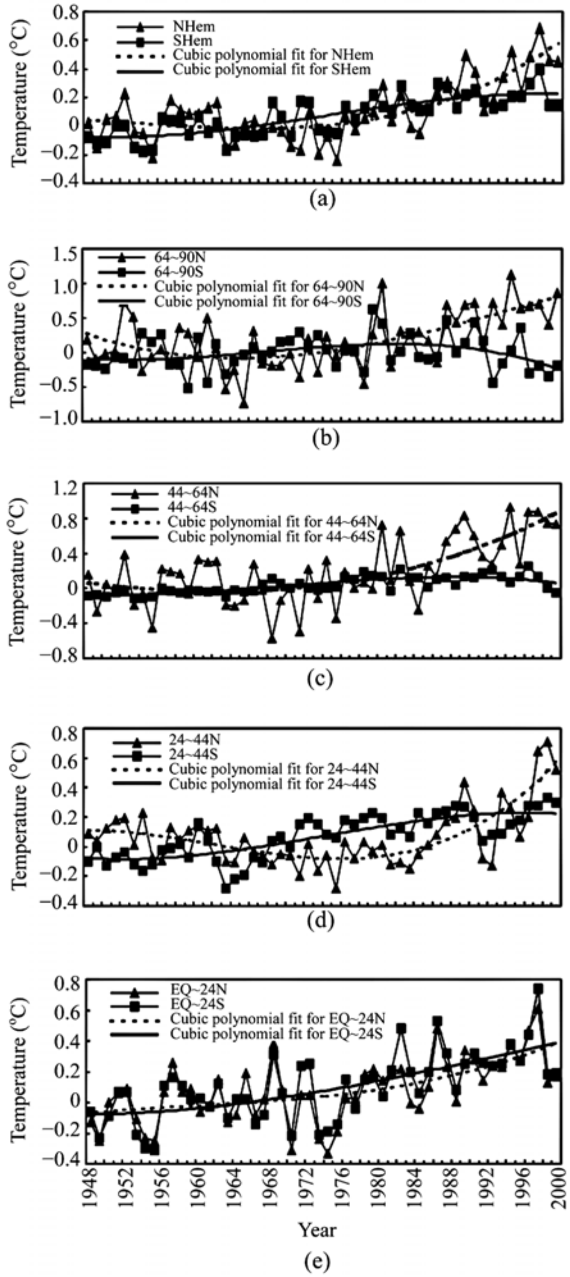

Fig.1 Variation trends of surface air temperature in the Southern and Northern Hemisphere. (a) Hemisphere area; (b) Polar area; (c) High-latitude area; (d) Mid-latitude area; (e) Low-latitude area

The change trend of TC frequency curve is mostly contrary to that of surface air temperature. Correlation analysis was carried out between the TC frequency series and the surface air temperature series of ten regions in both hemispheres to gain understanding of the climatic warming effect on TC frequency. To find the best correlation coefficients, moving means of 3, 5, 7, 9, 11, 13 years for all series should be performed before calculating their correlation coefficients. Improved correlation coefficients were found by increasing the years of running means, with 7 years being enough for explaining their correlations. Table 1 gives the results of 7-year moving means. All correlation coefficients were tested for significance at the 0.05 level.

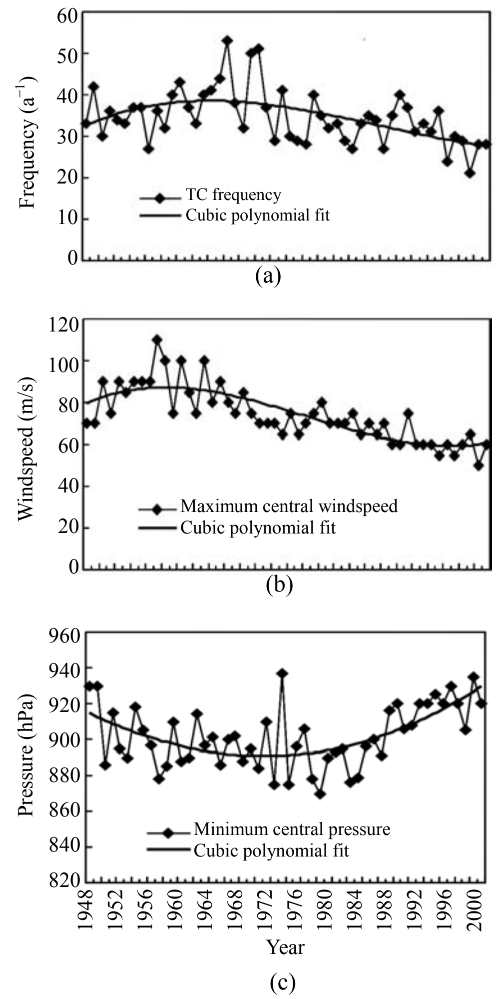

Fig.2 Parameters of the TC over the WNP. (a) TC frequency; (b) Maximum central windspeed; (c) Minimum central pressure

Table 1 shows that all correlation coefficients are negative, indicating TC frequency over the WNP lessens with climatic warming in both hemispheres during the study period. Comparison of those coefficients showed that the larger negative correlation coefficients occur in the high-latitude (44~64°N), polar regions (64~90°N) of the Northern Hemisphere, and the mid-latitude (24~44°S) region of the Southern Hemisphere, suggesting TC frequency over the WNP decreases rapidly with climatic warming in these areas. This conclusion seemingly contradicts the theory of TC formation due to climatic warming might contribute to TC formation according to the mechanism of TC generation (Elsberry, 1994). Although climatic warming may widen the marine regions with temperature exceeding 26.5 °C which is the critical temperature of TC formation, higher sea surface temperature (SST) is a necessary factor (Lighthill *et al*., 1994), although other factors, such as cold air invasion from the Southern Hemisphere, may also be dominant factors for TC formation (CEBPL, 2000; Lee, 2002; Wei *et al*., 1965; Chen and Ding, 1979; Love, 1985). Weakening climatic warming of the Southern Hemisphere cold air invasion into the WNP may be unfavorable for TC formation over the WNP. Comparing the effect of the Southern and Northern Hemispheric warming on the TC frequency over the WNP, we speculate that invading cold air from the Southern Hemisphere may play an important role in the pattern of TC formation over the WNP, and be an important causative reason for the reduced TC frequency over the WNP during global warming.

Table 1 Correlation coefficients between surface air temperature on the Southern and Northern Hemisphere and the TC parameters over the WNP

Region	TC frequency	Max. central windspeed	Min. central pressure
NHem	−0.639	−0.619	0.675
SHem	−0.600	−0.868	0.245*
64~90N	−0.792	−0.651	0.670
44~64N	−0.691	−0.676	0.596
24~44N	−0.451	−0.242*	0.842
EQ~24N	−0.508	−0.653	0.462
EQ~24S	−0.561	−0.785	0.378
24~44S	−0.648	−0.851	0.121*
44~64S	−0.522	−0.873	0.143*
64~90S	−0.104*	−0.435	−0.339

*non-significance at the 0.05 level

INFLUENCE OF THE SOUTHERN AND NORTHERN HEMISPHERE WARMING ON TC INTENSITY

Correlation coefficients among the surface air temperature series in both hemispheres and the maximum central windspeed and minimum central pressure of TC over the WNP were calculated in an attempt to identify those effects of climatic warming on TC intensity over the WNP. Table 1's negative coefficients indicate that the maximum central windspeed of TC over the WNP weaken with the Southern and Northern Hemisphere warming. The maximum negative correlation coefficients between them appear in mid- and high-latitude regions of the Southern Hemisphere where they are –0.873 and –0.851, respectively, with statistical significance at the 0.05 level, suggesting the mid- and high-latitudes regions in the Southern Hemisphere play an important role in controlling the TC maximum central windspeed over the WNP. From the above discussion, it is concluded that the TC maximum central velocity over the WNP weakens with climatic warming in both hemispheres, or that TC intensity will weaken.

Table 1 shows that the surface air temperature series and minimum central pressure series have positive correlation, which means that with climatic warming in both hemispheres, the TC minimum central pressure over the WNP increases, that is, its intensity weakens.

From the analyses in Sections 1 and 2, it may be concluded that as climate warms in both hemispheres, the TC frequency lessens and its intensity weakens over the WNP. However, it is hard to understand how the climatic warming mechanisms in both hemispheres affect TC formation and intensification over the WNP.

Love (1985) analyzed the formation process of typhoon "Billie " using a sequence of mean sea level and upper wind data from the Australian Bureau of Meteorology Tropical Analysis Center and US National Weather Service, and found that the cold surge from the Southern Hemisphere played a key role in the formation process of "Billie". Xue (2003) studied the effects of Southern Hemisphere cold air invasion on cyclone formation, especially on initial vortex genesis by using the fifth generation PSU/NCAR nonhydrostatic mesoscale model (MM5). Data on global mean zonal wind, temperature, relative humidity, etc. from NCEP for 16 August 2000 were used as initial fields. The initial data fields were not disturbed but satisfy the basic requirements of TC formation. Numerical simulation was conducted by regulating lateral boundary conditions to denote different intensity cold surges from the Southern Hemisphere, and found that TC occurred on the ocean surface to the east of the Philippines with invading cold from the Southern Hemisphere, although only disturbances were observed in the absence of cold surges. Therefore, we speculate that although high SST is an important thermodynamic factor for TC formation, cold air invasion from the Southern Hemisphere might be a more crucial factor (CEBPL, 2000; Lee, 2002; Wei *et al*., 1965; Chen and Ding, 1979; Love, 1985; Xue, 2003). Zhang and Wang (1999) suggested that when typhoon forms over the WNP, lower zonal circulation index first appears in the mid-latitude area of the Southern Hemisphere, then cold air burst from Australian anticyclone lowers the equatorial pressure index, following the formation of typhoon group over the WNP, although the coupling between climatic warming and mid-latitude circle in the Southern Hemisphere, and their effects on TC formation and intensification over the WNP in the Northern Hemisphere are still not well understood. Through studying the primary pattern of atmospheric circulation during global warming, Zhu *et al*.(2003) found that zonal circulation index increases obviously in the troposphere of the mid-latitude area of the Southern Hemisphere. It can be inferred from their findings that when global climate warms, the surface air temperature rises, consequently, the zonal circulation index in the mid-latitude of the Southern Hemisphere increases. All these factors weaken the cold air intensity from the Australian high-pressure, and decrease the TC frequency and intensity of the WNP in the Northern Hemisphere. The impact of surface air temperature on the enhancement of zonal circulation requires further research.

Comparison of the relationships between TC over the WNP and surface air temperature in the polar region with mid- and low-latitude bands in the Southern Hemisphere, revealed that the correlations is more significant in mid- and low-attitude than in polar region, and might be affected by the South Polar oscillation (Gong *et al*., 1998).

CONCLUSION

After comparing the relationships between surface air temperature changes in the Southern and Northern Hemisphere and TC frequency, maximum central windspeed, and minimum central pressure over the WNP, the following conclusions can be drawn:

(1) As the global surface air temperature increases, TC frequency over the WNP will lessen, and TC intensity will weaken simultaneously.

(2) Cold air invasion from the Southern Hemisphere is principally responsible for controlling TC formation and its intensity over the WNP through comparing the different influence of climatic warming in the Southern and Northern Hemisphere.

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