Change in relationship between western North Pacific tropical cyclone frequency and the tropical Pacific SST

Sang-Wook Yeh[1], Sok-Kuh Kang[1], Ben P. Kirtman[2], and Cheol-Ho Kim[1]

[1]Korea Ocean Research Development and Institute, Ansan, Korea

[2] University of Miami, Miami, USA

Abstract

We examine the relationship between the number of tropical cyclones (TCs) in the western North Pacific and the tropical Pacific sea surface temperature (SST) during the main TC season (from July to November). Results show that there are periods when TC frequency and the tropical Pacific SST are well correlated and periods when the relationship breaks down. Therefore, decadal variation is readily apparent in the relationship between the TC frequency and the SST variations in the tropical Pacific. We further examine the oceanic and atmospheric states in the two periods when marked contrast in the correlation between the TC frequency and the tropical Pacific SST is observed. The analysis indicates that before 1990 oceanic conditions largely influenced anomalous TC frequency, whereas atmospheric conditions had little impact. After 1990, there the reverse appears to be the case. A role of atmosphere and ocean in relation to the TC development in the western North Pacific changes, which is consistent with change of the correlations between the TC frequency and the tropical Pacific SST.

1. Introduction

Since high SST is one of main factors for TC genesis and intensification (Gray, 1968), an increase in SST would likely bring about an increase in TC activity. Despite this simple argument, it is still unclear whether such a relationship occurs in observations. It is argued that the recent increase in frequency of intense typhoons is likely a part of the large interdecadal variations in the number of intense TCs related to similar temporal fluctuations in the atmospheric environment. Furthermore, it is reported that there is a negative correlation in typhoon intensity with local tropical SSTs (Chan 2006). There are also large discrepancies among various model simulations. Some climate models show an enhanced TC activity due to underlying SST increases and some show little change of TC intensity under an anthropogenic climate change These results require thorough understanding of the relationship between TC activity and SST. There has been little investigation how the SST-TC relationship varies on the low-frequency timescales in spite of massive previous studies on the interdecadal variability of TC activity (Matsuura et al. 2003, Chan 2005). The current study documents observational evidence for variations in a relationship between the number of TCs and SST on the low-frequency timescales. In particular, we will show significant changes in a relationship between the number of TCs over the western North Pacific (WNP) (0°N-60°N, 100°E-180°E) and the tropical Pacific SST during the main TC season (June-July-August-September-October, JJASO) for the period of 1965-2006.

2. Data

We used TC data for the period of 1965-2006 issued by the Regional Specialized Meteorological Center Tokyo Typhoon Center (web site http://www.jma.go.jp/jma/jma-eng/jma-center/rsmc-hp-pub-eg/RSMC_HP.htm). The TC data used in the present study means any of the following: a tropical storm (maximum sustained surface wind speeds between 17.3 ms^{-1} and 23ms^{-1}), a severe tropical storm (23-32 ms^{-1}), or a typhoon (> $33ms^{-1}$) in the WNP. Because satellite monitoring of weather events has become routine since 1965, therefore, we mainly analyze the reliable data and examine the relationship between TC frequency and the tropical Pacific SST for the period of 1965-2006. We also used the monthly-mean global SST data, which were recently released by the National Climate Data Center (Smith and Reynolds, 2004) during the same period.

3. Results

We first show a time series of the anomalous TC number during JJASO for the period of 1965-2006 in the WNP (black bar in Fig. 1). The mean TC number during JJASO for the period of 1965-2006 is 20.3, which covers about 76% of the annual mean of TC number in the WNP (i.e., 26.8). The number of JJASO TCs varies with large amplitude: the maximum number was 32 in 1994, and the minimum number was 11 in 1998. The decadal variations are readily apparent in the time series of the number of JJASO TCs. There are periods when the TC activity is high (i.e., 1965~1972, 1988~1994) and periods when the TC activity is low (i.e., 1975~1987, 1995-2006). Those periods are largely consistent with that based on the annual number of TCs as in previous studies (Yumoto and Matsuura 2001). In addition, one can find significant interannual variability in the time series. The time series of JJASO TC number has significant spectral density on interannual timescales with periods 2~7 years (not shown). We also plotted the NINO3.4 SST index during JJASO in Fig. 1 (red line in Fig. 1). The NINO3.4 SST index is defined as the time series of the SST anomaly (SSTA) averaged over the region, 5°N-5°S, 170°E-240°E. The SSTA is defined as the deviation from the climatological mean during JJASO. Similar to the number of JJASO TCs, the

JJASO NINO3.4 SST index has significant variability on interannual and decadal timescales.

The two time series in Fig. 1 are very weakly positively correlated during the entire analyzed period (a simultaneous correlation coefficient, 0.015). This result suggests that there is little or no relationship between the number of TCs and the tropical Pacific SST during JJASO. In other words, we can not conclude that a warm SST in the central and eastern tropical Pacific favors enhanced TC activity in the WNP and vice versa. Not surprisingly, some previous results suggested that no evidence can be found to link any change in SST to that in TC activity. Conversely, we will suggest here that a weak simultaneous correlation coefficient during the entire period may be too gross of a measure of the relationship between the number of TCs and SST. There are periods when the TC activity and SST are well related and periods when such relationship breaks down. To clearly show changes in the connection of these two time series an 11-year running correlation is calculated (not shown here). The decadal variations are readily apparent in the relationship between the two time series. There are periods where the two time series in Fig. 1 are negatively correlated (i.e., from the late 1970s to the early 1990s) and periods where the two time series are positively correlated (i.e., the mid 1960s and after the mid 1990s). Our result indicates that a marked change in the correlation around the early 1990s is occurred. The maximum positive and negative correlation coefficients between the number of JJASO TCs and the JJASO NINO3.4 SST index are 0.52 and -0.71 for the periods of 1992-2002 and 1981-1991, respectively. Note that the two correlation coefficients, (i.e., 0.52 and -0.71), are significant over 90% and 95% confidence level, respectively, based on Student's *t*-test.

4. Concluding remarks

Understanding the environmental factors that influence TC activity in a changing climate is a topic of profound societal significance and of intense scientific debate. The low-frequency relationship between the TC activity over the WNP and the SST variations in the tropical Pacific has been analyzed in this work.

There is little or no relationship between the number of TCs and the NINO3.4 SST index during summer for the entire analyzed period of 1965-2006, however, we argued that such a weak relationship may be too gross of a measure of the relationship during the entire period. There are apparent decadal variations in the relationship between the variability of TC activity and the SST variations in the tropical Pacific, which may unlikely due to random red noise processes. In particular, the relationship between the variability of TC activity over the WNP and the SST variations in the tropical Pacific significantly changed after the early 1990s.

Reference

Chan, J. C. L., 2006: Comment on “change in tropical cyclone number, duration, and intensity in a warming environment”. Science, 311, 1713-1714.

Chan, J. C. L., 2005: Interannual and interdecadal variations of tropical cyclone activity over the western North Pacific. Meteoro. Atm. Phys., 89, 143-152.

Gray, W. M. 1968: Global view of the origin of tropical disturbances and storms. Mon. Wea. Rev., 96, 669-700.

Matsuura, T., M. Yumoto, S. Iizuka., 2003: A mechanism of interdecadal variability of tropical cyclone activity over the western North Pacific. Clim. Dyna., 21, 105-117.

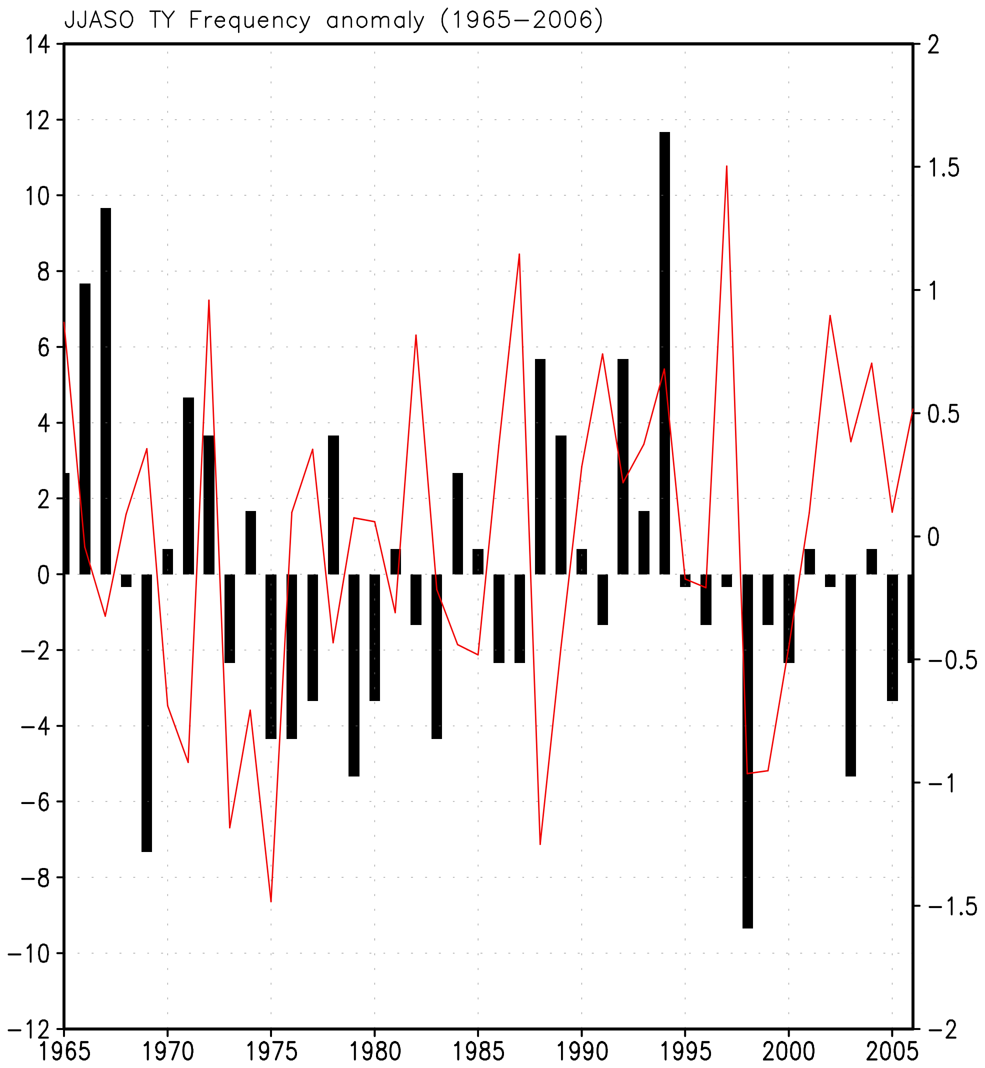

Figure 1 A time series of the anomalous TC number during JJASO for the period of 1965-2006 in the WNP (black bar) and the NINO3.4 SST index (red line).