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GLOBAL WARMING & TROPICAL CYCLONE INTENSITY FROM AN OBSERVATIONAL PERSPECTIVE

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1. INTRODUCTION

During the past decade or so, many researchers have suggested that because of a rise in sea-surface temperature (SST) as a result of the build-up of greenhouse gases, both the number and maximum intensity of tropical cyclones (TCs) will likely be modified. In most of the studies that made use of numerical climate models, the conclusion is that the frequency and maximum intensity of these cyclones will be increased when the SST increases (e.g. Krishnamurti et al. 1998; Knutson and Tuleya 1999). However, Bengtsson et al. (1996) found the number of cyclones decreases in a doubled-CO_2 world. Incorporation of ocean coupling into the model formulation can also give opposite results (Shen et al. 2000; Knutson et al. 2001). The discrepancies among the various model simulations highlight the dependence of the results on the characteristics of the model. In other words, drawing conclusions of what may happen in the future based on these simulations would be difficult.

An alternative to numerical simulations is to examine past data. Lighthill et al. (1994) pointed out that the large interdecadal variations (see e.g. Fig. 1) would likely overwhelm any modification of the TC frequency due to global warming. In terms of TC intensity, Evans (1993) found no statistically significant relationship between SST and the average intensity of TCs although stronger TCs tended to occur over waters of higher temperature. DeMaria and Kaplan (1994) also obtained a statistical relationship between maximum intensity and SST for Atlantic TCs, and Kuroda et al. (1998) drew a similar conclusion for western North Pacific (WNP) typhoons.

This paper presents a study of the relationship between SST over the entire WNP and the maximum intensity of TCs on an individual year basis in order to compare with the results from numerical simulations.

2. Data and definitions

2.1. TC data

WNP TCs during the period 1959–2001 form the basic dataset for this study. To focus only on intense TCs, the following parameters are examined:

- number of typhoons NTY
- ratio of the number of typhoons to the total number of TCs (NTC) during the same year, *RTY = NTY/NTC*
- typhoon destruction potential *TDP*, defined as the sum of the squares of a typhoon's maximum wind speed for each 6-h period of its existence (following Gray et al. 1992)

2.2. SST data

The NCEP/NCAR SST data are used. Since most of the TCs over the WNP generally reached its maximum intensity south of 30°N and east of 120°E (Xue and Neumann 1984), the SST within the domain 120–180°E and 5–30°N are considered. In addition, because most TCs occur between May and Nov, only data within these seven months are considered.

3. VARIATIONS IN TC INTENSITY PARAMETERS AND SST

3.1. Variations in TC intensity parameters

The time series of the three parameters related to annual TC intensity show significant interannual as well as interdecadal variations. The number of typhoons decreases from ~ 20 in the 1960s to ~14 in the late 1970s, and then rises again to ~ 20 in the early 1990s before decreasing again (Fig. 1a). The variation from year to year can also be very large. SST variations certainly do not have similar amplitudes (see Fig. 2). Similar interdecadal and interannual variations in the *RTY* values can be seen (Fig. 1b) although the amplitude of the former is not as large. A slight downward trend is observed during this 40-year period. If TCs tend to become more intense with an increase in CO_2, this value should increase with time. Because *TDP* values increase as the square of the maximum wind speed, an increase in the maximum intensity of TCs should be reflected in an increase in the TDP value. However, a decreasing trend with large interdecadal variations is found (Fig. 1c).

3.2. Variations in SST

SSTs over the WNP generally have rather small variations, with a < 1 °C variation over the period 1960–1999 (Fig. 2). Nevertheless, an upward trend is apparent.

4. RELATIONSHIP BETWEEN TC INTENSITY PARAMETERS AND SST

Due to lack of space, only one set of correlations is given to illustrate the conclusion. The value of *RTY* has a negative correlation with the SST over the WNP (5-30°N and 120-180°E), hereafter referred to as local SST, between May and Nov (Fig. 3). Such correlations are more prominent in the domain 10-30°N, 125-150°E with the strongest correlation (~ −0.6) around 20°N, 140°E. In addition, *RTY* is positively correlated with the SST over the equatorial central and eastern Pacific Ocean, with a mean correlation of 0.58 in the Nino3.4 region (5°S–5°N and 170–120°W).

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Such a result suggests that variations in annual TC intensity may be related to the ENSO phenomenon. Indeed, 9 (8) out of the 11 (11) El Niño (La Niña) years were associated with above-normal (below-normal) *TDP*. The difference between these numbers is statistically significant at 95%.

5. SUMMARY

To summarize, the mean annual intensity of WNP TCs, as measured by the various parameters, does not show any significant increase in response to a rise in local SST. Indeed, an apparent *decrease* in the mean annual TC intensity occurs in the years with above-normal SST. On the other hand, the ENSO phenomenon is shown to have a significant relationship with annual TC intensity. More discussion of these results and the physical explanations will be presented at the conference.

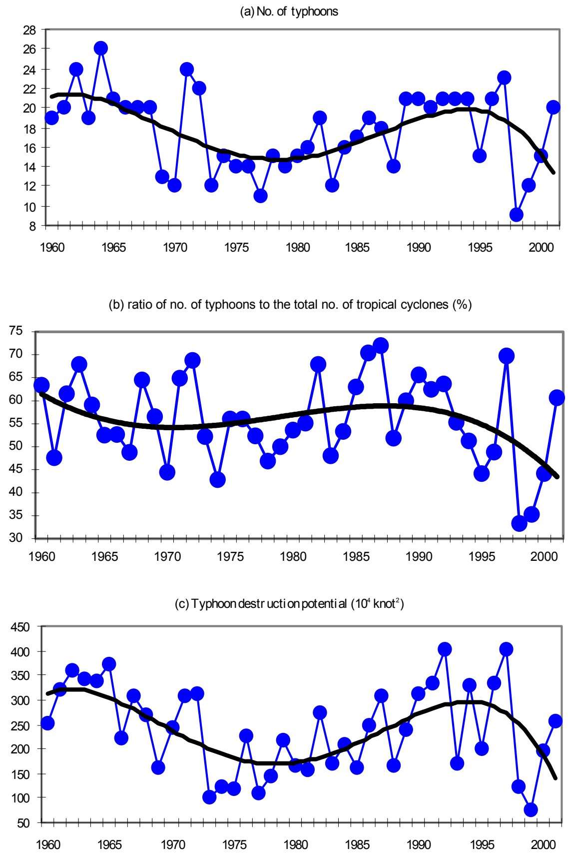

Fig. 1. Time series of (a) the number of typhoons, (b) *RTY* and (c) *TDP* over the WNP during 1960–2001. The thick lines indicate the 4th-order polynomial fits.

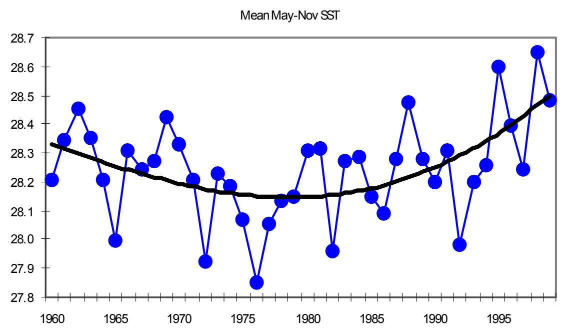

Fig. 2. As in Fig. 1 except for the mean May-Nov SST (^{o}C) averaged over the area 5-30^{o}N, 120-180^{o}E.

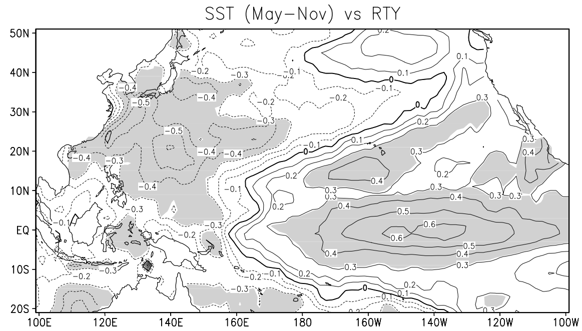

Fig. 3. Correlation coefficients between *RTY* and SST in the periods May–Nov. Shaded areas indicate correlations statistically significant at 95%.

Thus, at least for the WNP, observational evidence does not support the notion that more intense TCs will occur with higher *local* SST. Climate models must demonstrate their ability to simulate this observational result before they can be used to project what might happen in future climate.

REFERENCES

Bengtsson, L., M. Botzet and M. Esch, 1996: Will greenhouse gas-induced warming over the next 50 years lead to higher frequency and greater intensity of hurricanes? *Tellus*, **48A,** 57–73.

DeMaria, M. and J. Kaplan, 1994: Sea surface temperature and the maximum intensity of Atlantic tropical cyclones. *J. Climate*, **7,** 1324–1334.

Evans, J. L., 1993: Sensitivity of tropical cyclone intensity to sea surface temperature. *J. Climate*, **6,** 1133–1140.

Gray, W. M., C. W. Landsea, P. W. Mielke and K. J. Berry, 1992: Predicting Atlantic seasonal hurricane activity 6–11 months in advance. *Wea. Forecasting*, **7,** 440–455.

Knutson, T. R., R. E. Tuleya, W. Shen and I. Ginis, 2001: Impact of CO_2-induced warming on hurricane intensities as simulated in a hurricane model with ocean coupling. *J. Climate*, **14,** 2458–2468.

Krishnamurti, T. N., R. Correa-Torres, M. Latif and G. Daughenbaugh, 1998: The impact of current and possibly future sea surface temperature anomalies on the frequency of Atlantic hurricanes. *Tellus*, **50A**, 186–210.

Kuroda, M., A. Harada and K. Tomine, 1998: Some aspects on sensitivity of typhoon intensity to sea-surface temperature. *J. Meteor. Soc. Japan*, **76,** 1145–1151.

Lighthill, J., G. J. Holland, W. M. Gray, C. Landsea, K. Emanuel, G. Craig, J. Evans, Y. Kurihara and C. P. Guard, 1994: Global climate change and tropical cyclones. *Bull. Amer. Meteor. Soc.*, **75,** 2147–2157.

Shen, W., R. E. Tuleya and I. Ginis, 2000: A sensitivity study of the thermodynamic environment on GFDL model hurricane intensity: implications for global warming. *J. Climate*, **13,** 109–121.

Xue, Z. and C. J. Neumann, 1984: Frequency and motion of western North Pacific tropical cyclones. *NOAA Tech. Memo.* NWS NHC 23, 89pp.