Typhoon Track Changes Associated with Global Warming

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1. Introduction

Global mean land surface temperature and sea surface temperature (SST) have risen significantly over the past half century, and the Intergovernmental Panel on Climate Change (IPCC) fourth assessment report concluded that most of the global surface temperature increase was very likely due to the observed increase in anthropogenic greenhouse-gas concentrations (IPCC 2007). Given the great societal and scientific concerns, the impact of global warming on tropical cyclone (TC) activity has been the subject of considerable investigation in recent years. While progress has been made in assessing the influence on TC intensity and rainfall (Knutson et al. 2010), relatively little is known about the possible change of TC tracks in a warming climate.

TC tracks are controlled essentially by large-scale steering and propagation resulted from the interaction of a TC with its environment (Wang et al. 1998). Based on the output of the Geophysical Fluid Dynamics Laboratory (GFDL) climate model in the IPCC third assessment report, Wu and Wang (2004) suggested that global warming may affect prevailing TC tracks over the western North Pacific (WNP). Using the best track data from the Joint Typhoon Warning Center (JTWC), Wu et al. (2005) further showed that over the period 1965-2003 the subtropical East Asia experienced increasing typhoon influence, but TC activity over the South China Sea has decreased considerably. Recently Tu et al. (2009) also found an abrupt increase in the influence of typhoons in the vicinity of Taiwan after 2000. Due to considerable interannual and interdecadal variations in TC activity over the WNP (Chan and Shi 1996; Wang and Chan 2002； Ho et al. 2004; Zhou and Chan 2007; Liu and Chan 2008), whether the observed TC track changes were linked to the ongoing global warming is still unknown. The objective of the present study is to address this issue using observational data and IPCC climate change simulations in the fourth assessment report.

2. Data and Method

Data This study employs the monthly SST with 2° latitude by longitude 2° resolution and the monthly winds with 2.5° latitude by 2.5° longitude resolution from the National Centers for Environmental Prediction/National Center for Atmospheric Research reanalysis dataset (NCEP/NCAR). The output of the control and global warming experiments from the IPCC climate models in the fourth assessment report is used to examine the possible typhoon track change in the future. The tropical cyclone data in the western North Pacific is the best track dataset from Joint Typhoon Warming Center (JTWC), including tropical cyclone position and intensity also at six hour intervals.

Method The singular value decomposition (SVD) analysis is used to obtain the leading mode associated with global warming. The SVD is conducted with the global SST field, large-scale steering flows in the WNP basin, and the frequency of TC occurrence.

3. A global warming mode associated with typhoon track changes

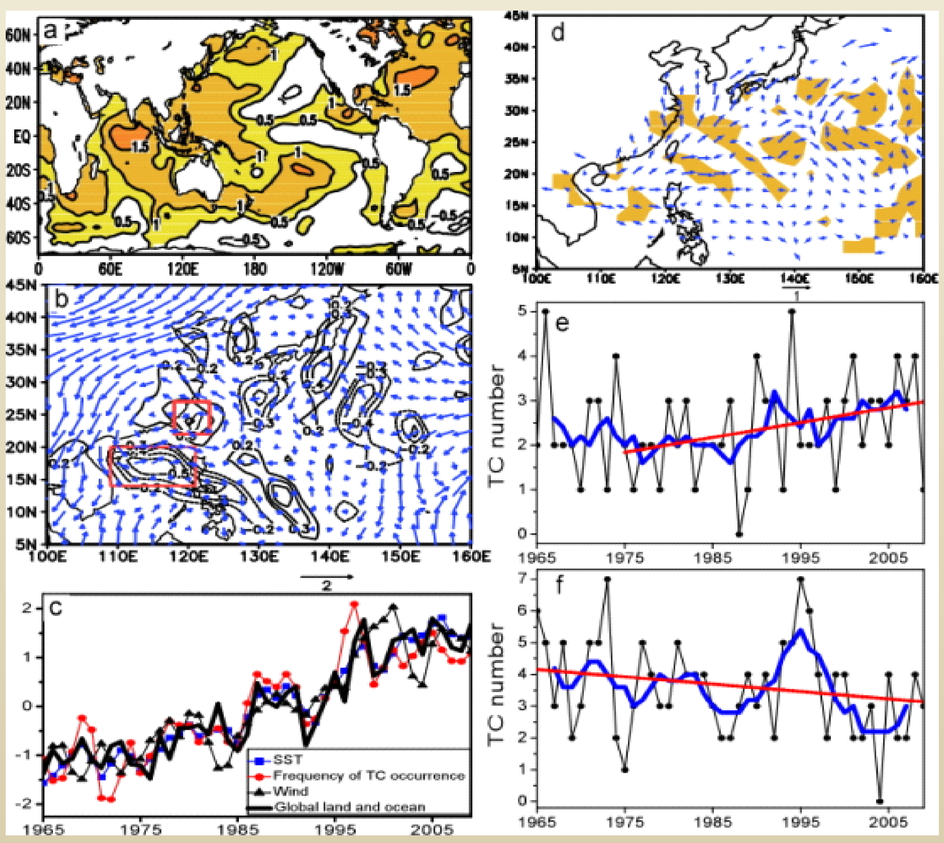
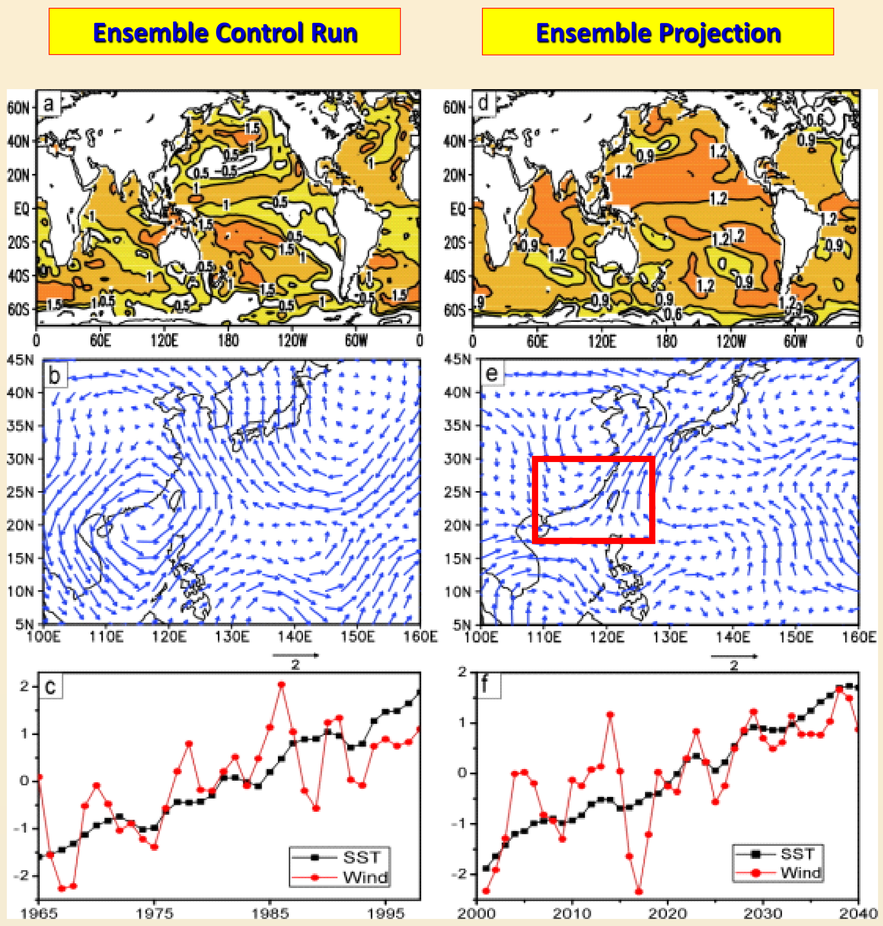


Figure 1 Spatial patterns of the leading SVD mode of (a) observed global SST, (b) large-scale steering flows (vectors) and the frequency of TC occurrence (contours), (c) the standardized SVD time series in comparison with the combined global land and ocean temperature anomalies, (d) linear trends of the mean TC translation velocity (vectors) with 95% confidence (shading), and (e, f) time series of the annual number TCs that entered the two boxes in (b) during 1965-2009. The contour intervals are 0.5 and 0.1 in (a) and (b), respectively, with zero contours suppressed. The blue and red lines in (e) and (f) are for the 5-year running average and linear trends, respectively.

4. Large-scale steering flow changes projected in climate models



The increasing TC influence in the subtropical East Asia and decreasing TC influence over the South China Sea will continue by 2040.

Figure 2 The spatial patterns of the leading SVD mode of (a) the five-model ensemble global SST with contour intervals of 0.5, (b) large-scale steering flows over the western North Pacific basin, and (c) the standardized SVD time series in the control runs during 1965-1998. (d-f) are the same as (a-c), respectively, but for the five model ensemble projection during the period 2001-2040 under the A1B scenario.

5. Summary

•With increasing TC influence over the subtropical East Asia and decreasing TC activity over the South China Sea, the observed TC track changes are linked to the SVD leading mode. The spatial patterns are characterized with global warming in SST, and the associated changes in the large-scale steering flows agree well with the linear trends in the TC translation velocity over the western part of the WNP basin.

•The five selected IPCC models are generally capable of simulating the observed features in global SST warming and the changes of large-scale steering flows in the western part of the WNP basin. The projected changes in the large-scale steering flows are similar to those observed over the period 1965-2009, suggesting that the increasing TC influence in the subtropical East Asia and decreasing TC influence over the South China Sea, which were observed over the period 1965-2009, will continue by 2040.

Reference

Chan, J. C. L. and J. Shi, 1996: Long-term trends and interannual variability in tropical cyclone activity over the western north Pacific. *Geophys. Res. Lett.*, **23**, 2765-2767, doi:10.1029/96GL02637.

Intergovernmental Panel on Climate Change (IPCC). Climate Change 2007: The Physical Science Basis, Cambridge University Press.

Knutson, T. R., J. L. McBride, J. C. L. Chan, K. Emanuel, G. Holland, C. Landsea, I. Held, J. P. Kossin, A. K. Srivastava, and M. Sugi, 2010 : Tropical cyclones and climate change. *Nature Geoscience*, 3, 157-163, doi:10.1038/ngeo779.

Liu, K. S., and J. C. L. Chan, 2008: Interdecadal Variability of Western North Pacific Tropical Cyclone Tracks. *J. Climate*, **21**, 4464-4476.

Tu, J. Y., C. Chou, and P. S. Chu, 2009: The abrupt shift of typhoon activity in the vicinity of Taiwan and its association with western North Pacific-East Asian climate change. *J. Climate*, **22**, 3617-3628.

Wang, B., R. Elsberry, Y. Wang, and L. Wu, 1998: Dynamics in the tropical cyclone motion: A review. *Chinese J. Atmos. Sci.*, **22**, 535–547.

Wang, B., and J. C. Chan, 2002: How strong ENSO events affect tropical storm activity over the western North Pacific. *J. Climate*, **13**, 1517-1536.

Wu, L., and B. Wang, 2004: Assessing impacts of global warming on tropical cyclone tracks. *J. Climate*, **17**, 1686-1698.

Wu, L., and S. Geng, 2005: Growing typhoon influence on east Asia. *Geophys. Res. Lett.*, **32**, L18703, doi: 10.1029/2005GL022937.