# Long-term changes in tropical cyclone rainfall over the North Atlantic and North Pacific

K.-M. Lau[1] Y. P. Zhou[2]
[1]NASA Goddard Space Flight Center
[2]Goddard Earth Sciences Technology And Research Center (GESTAR)/Morgan State University

## 1. Introduction

Rainfall intensities of tropical cyclones (TC) are expected to increase in a warmer climate. However, high quality and high resolution long-term oceanic precipitation data set is still lacking to date to assess the long-term trends of TC rainfall intensity. This study uses TRMM TMPA data and GPCP pentad data (post_SSMI period, 1988-2007) to estimate total rainfall of each storm and that of the entire basins. Decadal trends are estimated from GPCP data for per storm TC-rainfall and total TC-rainfall in major ocean basins along with other TC characteristics. Trends in large-scale environment, i.e., SST that may contribute to the observed trends are analyzed.

## 2. Data

1. Global Precipitation Climatology Project (GPCP) Pentad rainfall (2.5ºx2.5º, 1988-2007).
2. Tropical Rainfall Measurement Mission (TRMM) Multi-satellite Precipitation Analysis (TMPA) 3-hourly product (0.25ºx0.25º, 1998-2007).
3. TC best track data from the NHC for North Atlantic and Northeast Pacific and from JTWC for Western North Pacific (WNP). Additional storm track data from IBTrACS are used for the WNP.
1. The Hadley Center monthly SST data (1ºx1º, 1988-2007).
2. Large-scale environment (Temperature, Wind Sheer) from NCEP/ NCAR Reanalysis I (2.5ºx2.5º, 1988-2007)

## 3. TC Distributions and TC-Rain Calculation

TC-rain is defined as rain that falls within an area of 500 km radius, from the center of the TC within 1-day (TRMM) and 5-day (GPCP) time period when a TC passes. Accumulated TC-rain over life cycle of each tropical storm (EPS) is calculated from GPCP-pentad data from 1988 to 2007 and TRMM 3B42 data from 1998 to 2007. Rain is converted to energy unit. 1mm accumulation over 2.5 degree grid box in equator ~ $1.93\times10^{17}$ Jole. 1EY = $5.68\times10^{20}$ Jole.

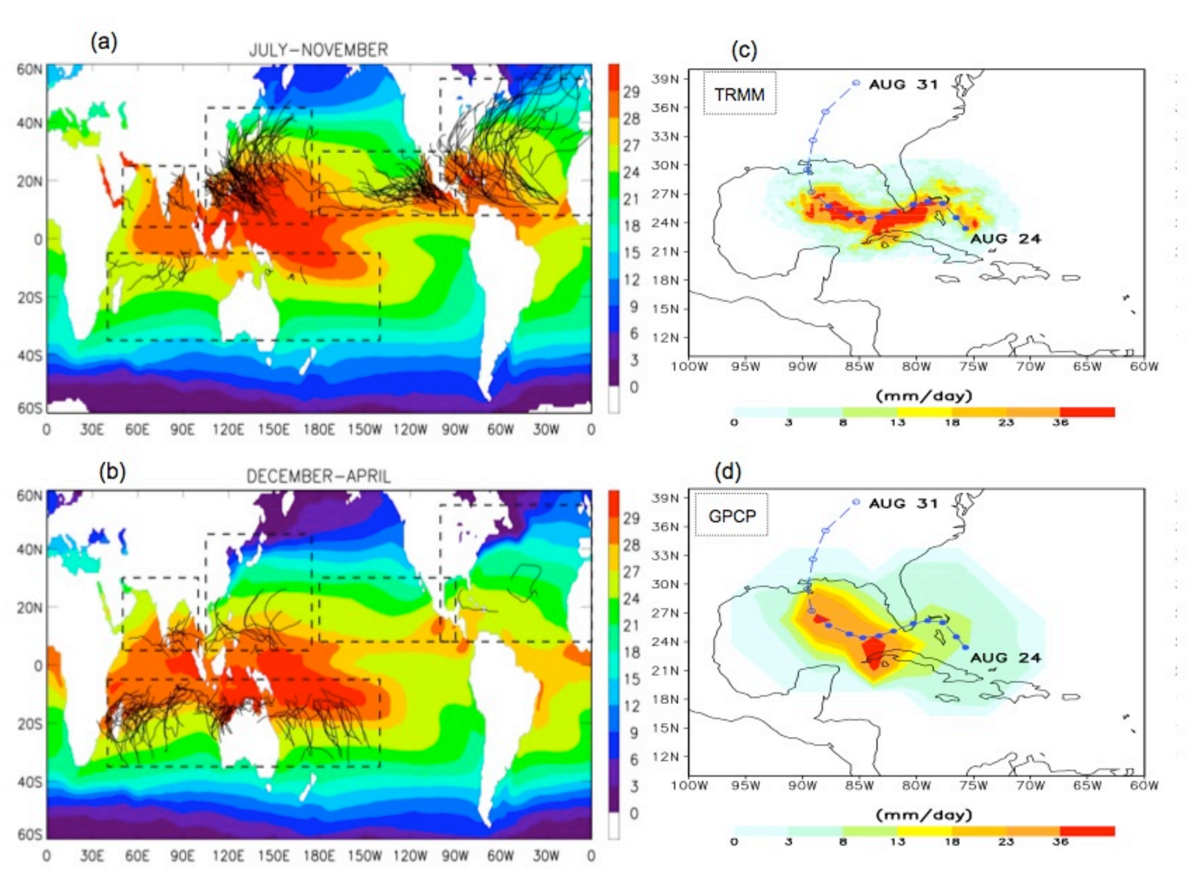

Figure 1. Storm tracks (2004-2008) and mean SST (1979-2006) in (a) July-November (b) December-April show most TCs occur in the warm SST regions in respective seasons. Left figures show spatial patterns of TC related rainfall for hurricane Katrina from (c)TRMM and (d) GPCP.

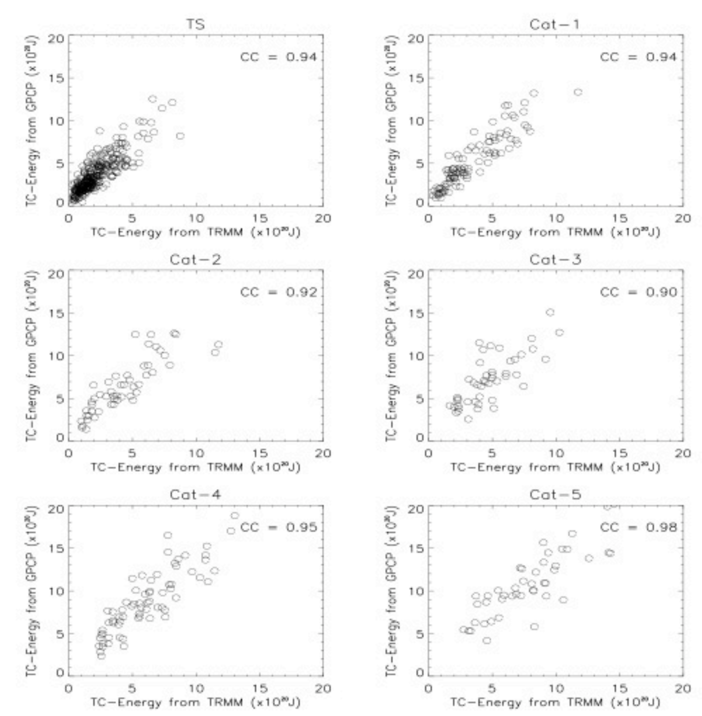

Figure 2. Accumulated TC-rain from GPCP versus from TRMM for each storm during the overlapping period 1998-2007. TC-rain from GPCP is slightly higher than that from TRMM but is consistent through the TC categories and basins.

## 4. TC-rain versus TC-intensity

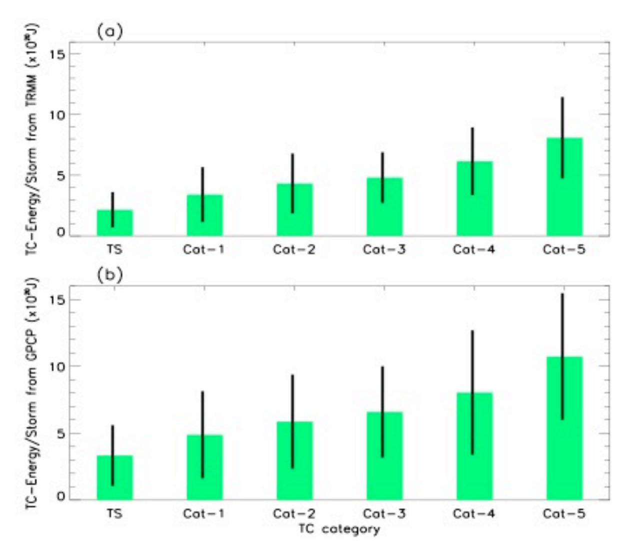

Figure 2. Mean (green bar) and standard deviation (black line) of TC-rain per storm in energy unit ($10^{+20}$ Joules) for different TC categories from (a) TRMM and (b) GPCP.

## 5. Trends in TC-Rain

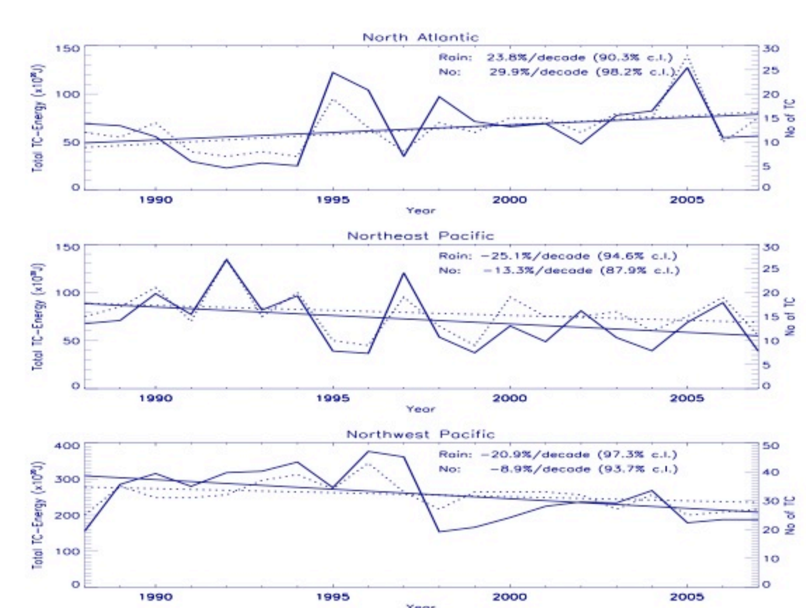

Figure 3. Time series and the linear regression fit of total TC-rain in energy units (solid line) and TC-number (dotted line). The trends are in percentage change per decade.

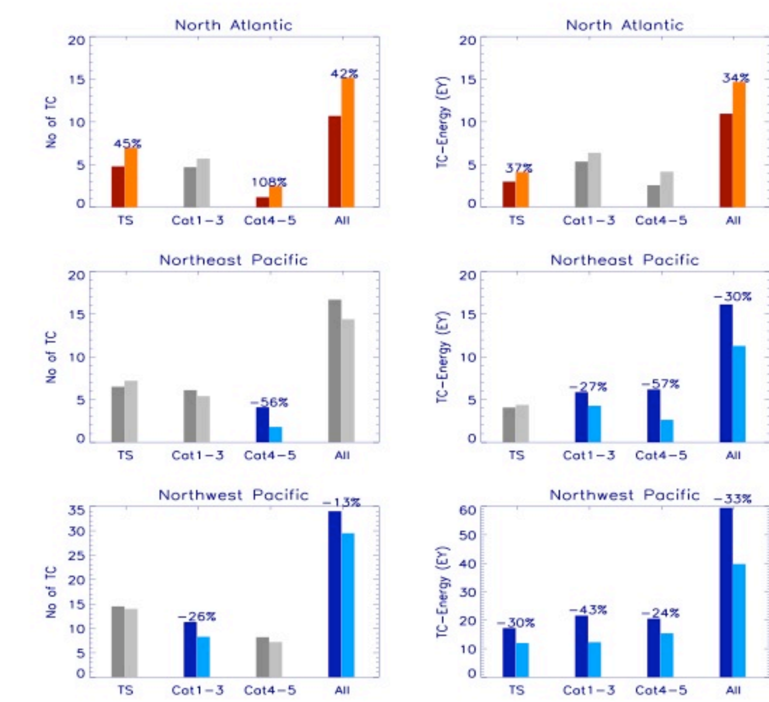

Figure 4. Comparisons of annual mean Number of TCs (left panel) and basin total TC- energy (right panel) for the periods (1988-1997, left bars) and (1998-2007, right bars). Orange (blue) bars indicate significant (above 90% c. l.) positive (negative) Numbers shown are percentage changes.

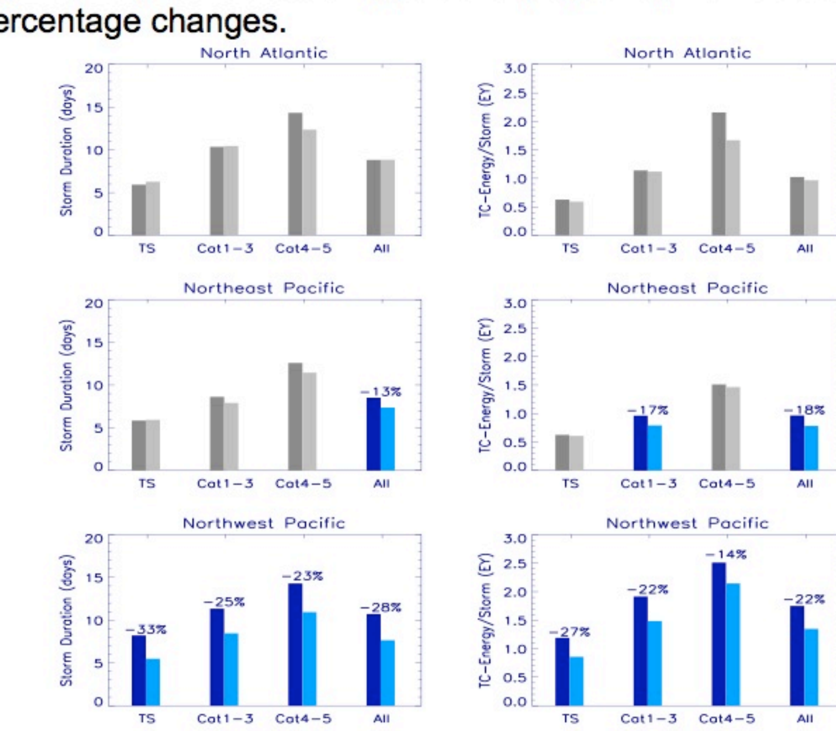

Figure 5. Same as Figure 4, but for the mean storm duration (days) (left panel) and energy per storm (EPS in EY) (right panel) for different TC categories

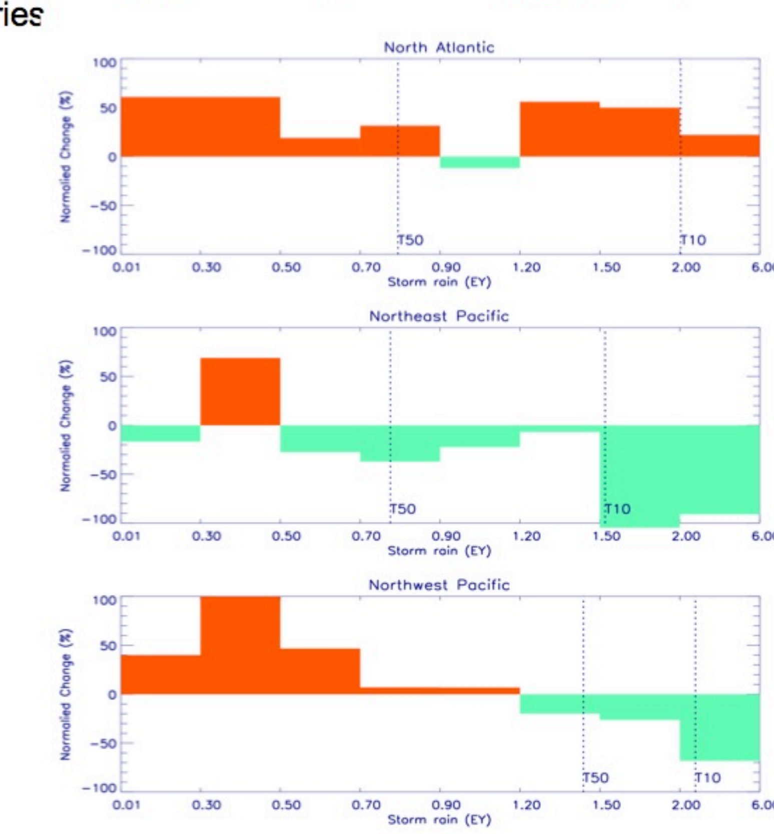

Figure 6. Normalized differences in TC frequency with EPS. The red and green colors indicating positive and negative deviations respectively between the latter 10 years (1998-2007) and the earlier 10 years (1988-1997). The EPS threshold for median, and top 10% EPS threshold are marked by vertical dotted line labeled T50, T10 respectively.

## 6. Results From Using Different Track Data In NWP

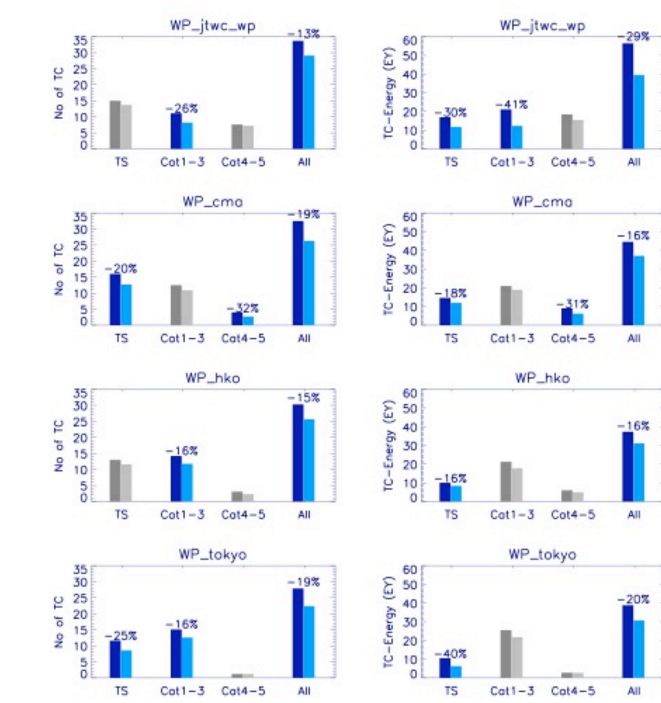

Figure 7.Comparison of annual mean Number of TCs (left panels) and total TC-energy (right panel) for the period (1988-1997) and (1998-2007) for the Northwest Pacific using different storm track data from IBTrACS).

## 7. Trends of large-scale environment on TC-Rain

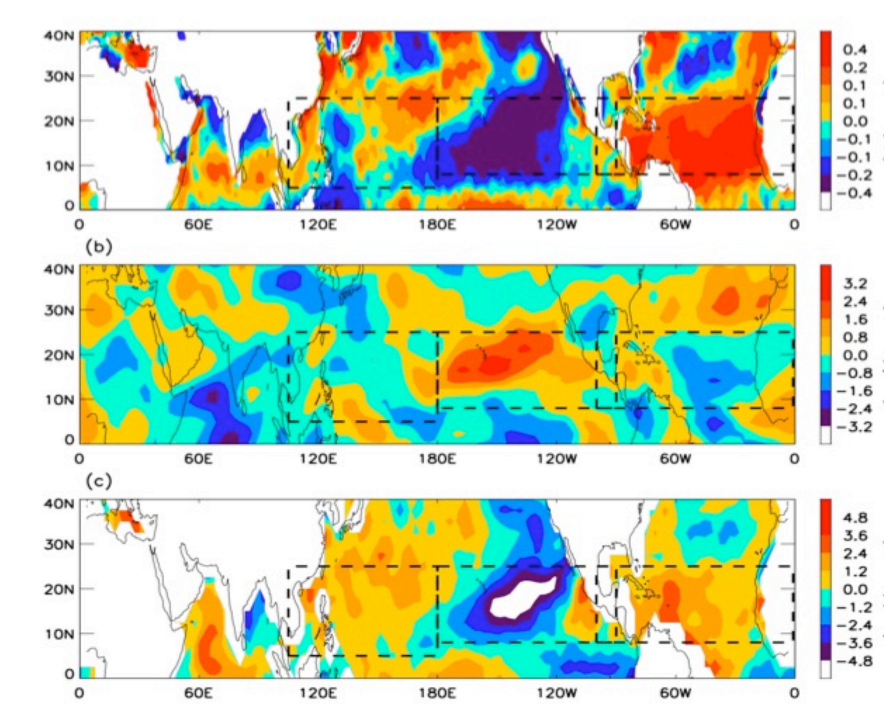

Figure 7. Linear trends of (a) relative SST, (b) vertical wind shear, and (c) relative MPI for wind in July-November that affect TC activities in the northern oceans from 1988 to 2007. The dotted rectangles highlight domains in each ocean basin where tropical cyclones are most likely to develop.

## 8. Summary

Based on post-SSMI (1988-2007) GPCP pentad precipitation and TC best track data, We find that total TC number and TC rain in North Atlantic, Northeast Pacific and Northwest Pacific display distinctly different trends. Only the North Atlantic observes upward trends in total TC number and TC rain, both the Northeast Pacific and Northwest Pacific observe downward trends with the latter largely due to multi-decadal oscillation. The three basins also show distinct trends in storm frequency with EPS.

Storm characteristics such as duration and TC energy per storm remain unchanged for the North Atlantic and the Northeast Pacific while the Northwest Pacific may undergo decreasing storm duration and per storm energy based on best track data from JTWC.

Reference: Lau, K.-M, Y.P. Zhou, Observed recent trends in tropical cyclone rainfall over the North Atlantic and the North Pacific, JGR in revision