Towards Development of a Climate Theory on Tropical Cyclone Genesis

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Objectives

A quantitative theory on the relationship between climate and Tropical Cyclone (**TC**) formation rate still remains elusive [**1**, **2**].

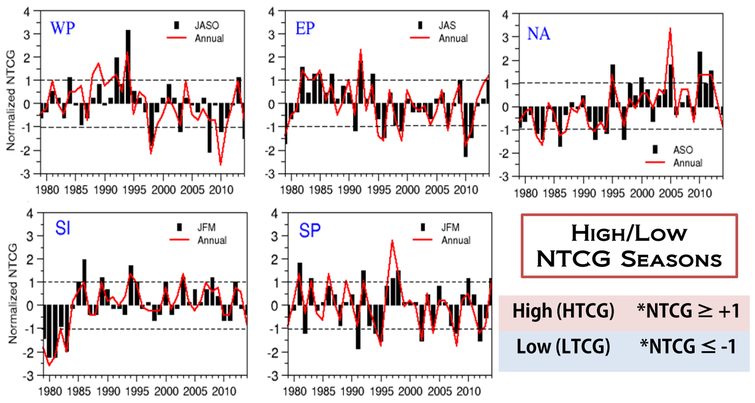
The present study investigates:

- How does the interannual variation (IAV) in large scale tropical climate conditions influence year-to-year variation in the number of Tropical Cyclone Genesis events (**NTCG**) over individual ocean basins?
- How do the competing effects of dynamical and thermodynamical processes affect TC formation?

Data & Methodology

- **I**nternational **B**est **T**rack **A**rchive for **C**limate **S**tewardship (IBTrACS-ALL, v03r08) [**3**]
- ERA-Interim Reanalysis (monthly data) [**4**]
- NTCG Identification → TC_{max_wind} > 33 knots
- Domain of Study : 30°S to 30°N
- Study Period: 1979 -2014 (36 years)
- Model outputs from Hurricane Working Group (HWG) experiments [**1**, **5**]
  - ► GFDL High-Resolution Atmospheric Model (HiRAM)
    - Present-Day (Climatology, seasonally varying)
    - SSTp2K (uniform increase in SST of 2K)

IAV of NTCG



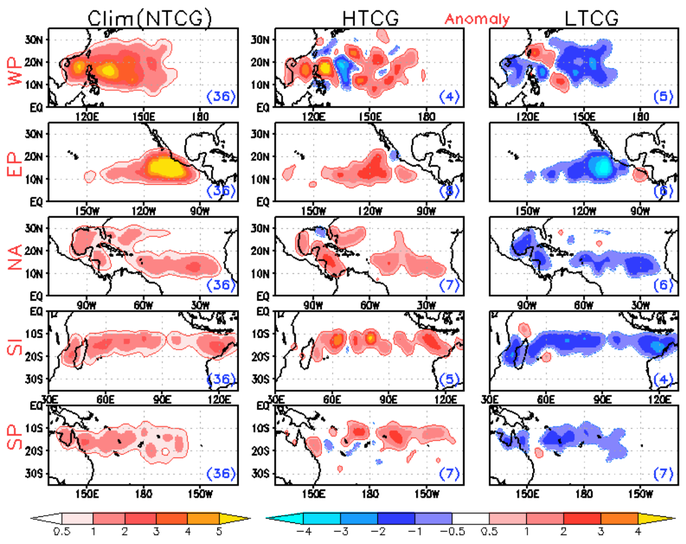
High/Low NTCG Seasons

High (HTCG)	*NTCG ≥ +1
Low (LTCG)	*NTCG ≤ -1

▲ **Figure 1** Time series of normalized NTCG (*NTCG) per peak seasons (*Table 1*) and annual variation (*red curves*) for individual ocean basins. All time series of peak seasons are normalized by their own standard deviations.

Table 1 ▼

Ocean Basins	Peak Season
Western Pacific, WP	JASO
Eastern Pacific, EP	JAS
North Atlantic, NA	ASO
Southern Indian, SI	JFM
Southern Pacific, SP	JFM



▲ **Figure 2** Observed spatial distribution of NTCG climatology (Clim; *left*) over individual ocean basins per 2°×2° grid box for peak seasons over entire period (1979-2014), and for anomalously high (HTCG; *centre*) and low (LTCG; *right*) NTCG seasons. The total number of peak TC seasons considered are shown in brackets.

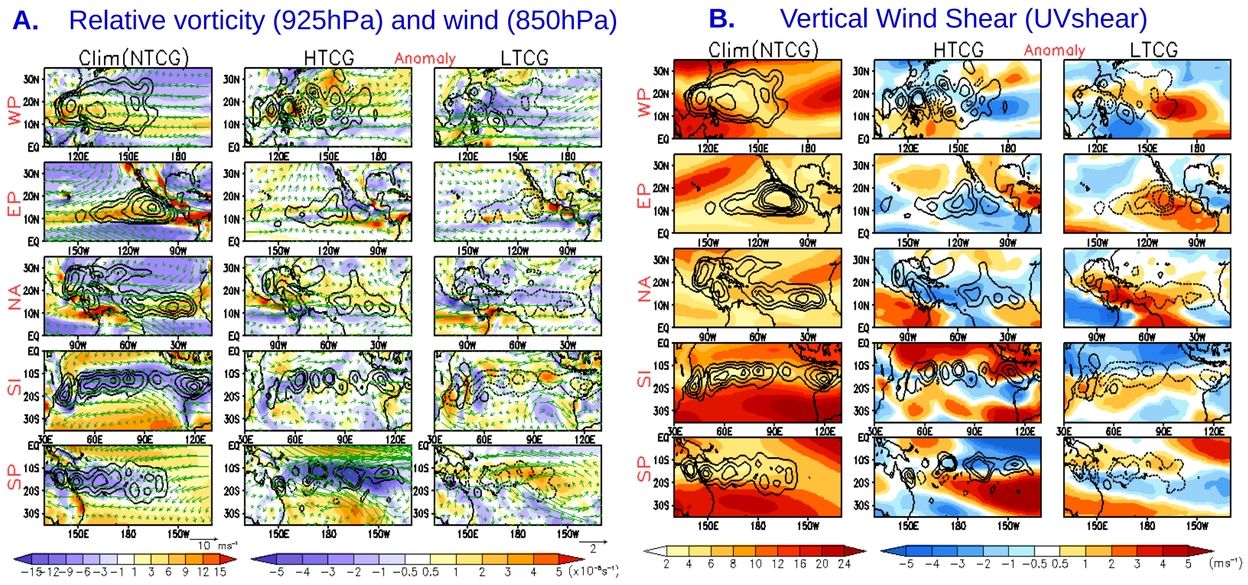
Results & Discussions

Relationship Between Observed IAV of NTCG & Tropical Climate Conditions

Dynamical & Thermodynamical Conditions (during peak season)

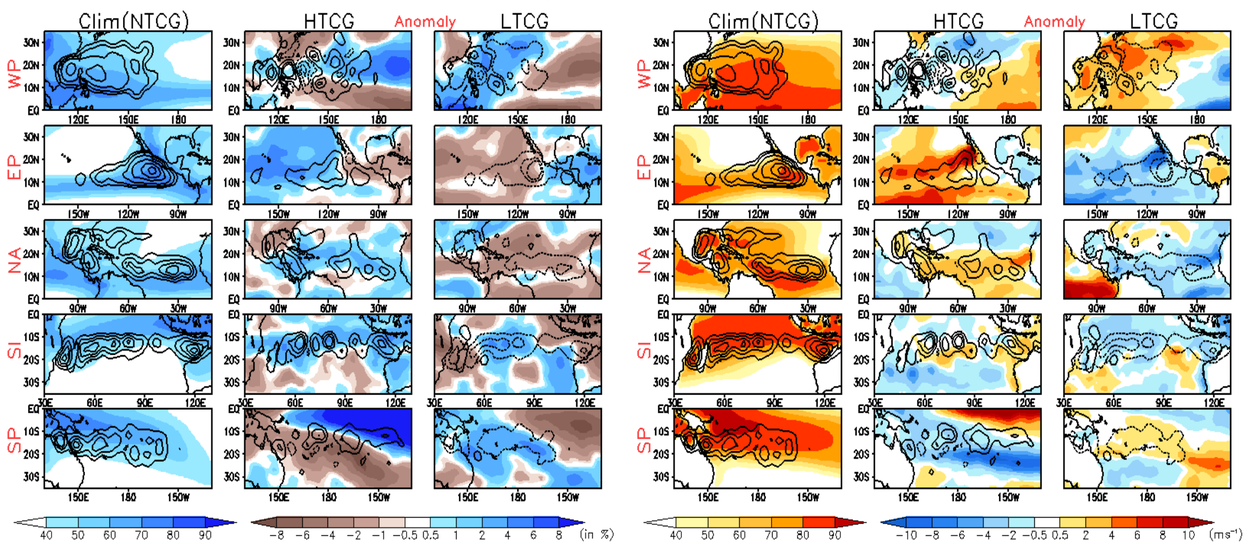
A. Relative vorticity (925hPa) and wind (850hPa)

B. Vertical Wind Shear (UVshear)



C. Mid-Tropospheric Relative Humidity

D. Maximum Potential Intensity (MPI)



◄ **Figure 3A - D**. Observed seasonal large scale patterns of tropical climate dynamical & thermodynamical conditions (*shaded*) overlaid with observed spatial distribution of NTCG (*contoured*) for climatology (Clim; *left*), for anomalous HTCG (*centre*) and LTCG (*right*) seasons over individual ocean basins respectively.

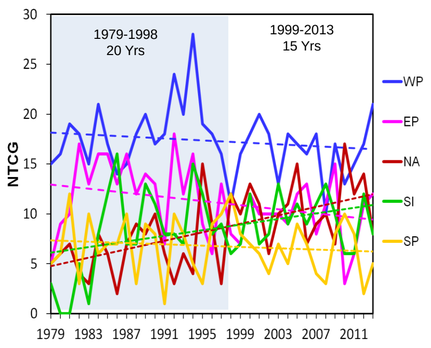
Table 2 ▼

Basins	Key Climate Conditions
WP	Dynamical
EP	Thermodynamical + Dynamical
NA	Thermodynamical + Dynamical
SI	Dynamical + Thermodynamical
SP	Dynamical

- Over WP and SP, the variation in NTCG is mostly influenced by large scale dynamical climate conditions.
- Both the dynamical and thermodynamical conditions affect the variation in NTCG over EA, NA and SI.

- The seasonal vertical wind shear plays the dominant role in changing NTCG over all individual basins.
- The seasonal pattern of MPI influences NTCG over EP, NA, and SI, however it is not so important over WP and SP.

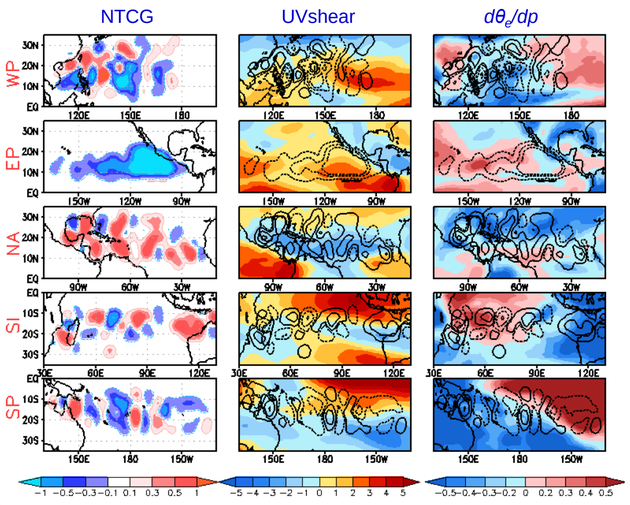
Recent Changes in NTCG



▲ **Figure 4** Time series of NTCG per peak seasons for individual ocean basins for the period 1979-2013. The respective trend lines are shown as dashed lines.

WP / EP / SP — NA / SI

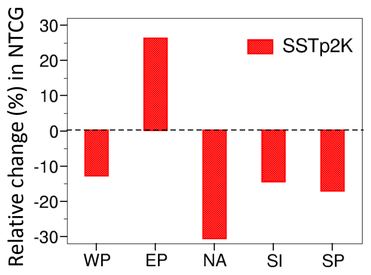
Changes relative to base period 1979-1998
(1999-2013) minus (1979-1998)



◄ **Figure 5** Observed changes in spatial distribution of NTCG (*left*) and seasonal large scale patterns of tropical climate conditions; vertical wind shear (*centre*) and mid-tropospheric vertical gradient of equivalent potential temperature ($d\theta_e/dp$; *right*).

- Increase (decrease) in vertical wind shear is one of the dominant climate factors for decrease (increase) in NTCG over individual ocean basins in the recent decades.

Results from HWG Expts.



▲ **Figure 6** Simulated changes (%) in NTCG relative to Present-climate simulation over each ocean basins (during peak seasons) for SST2K experiment.

Conclusions & Future Work

- The observed seasonal large scale patterns of tropical climate conditions distinctly determine the spatial distribution of IAV of NTCG over individual ocean basins.
- NTCG changes in recent decades are predominantly linked with changes in the large scale dynamical conditions rather than thermodynamical conditions.
- Preliminary results under warmer climate also show dominance of dynamical conditions in changing NTCG over most of the ocean basins.
- Analyses and high-resolution model simulations are underway to quantify the mechanisms responsible for such distinct variations.

- Under a warmer climate scenario, most of the ocean basins (except EP) show a 10-30% decrease in NTCG relative to present climate, consistent with [**5**].
- More analyses are underway to understand the role of key climate conditions.

References

[1] Walsh et al. (2015) BAMS, 96:997-1017
[2] Walsh et al. (2016) WIREs, 7:65-89
[3] Knapp et al. (2010) BAMS, 91:363-376
[4] Dee et al. (2012) QJRMS, 137:553-597
[5] Camargo et al. (2014) JClim, 27:9171-9196

Acknowledgement

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