Summertime Stationary Waves Integrate Tropical and Extratropical Impacts on Tropical Cyclone Activity

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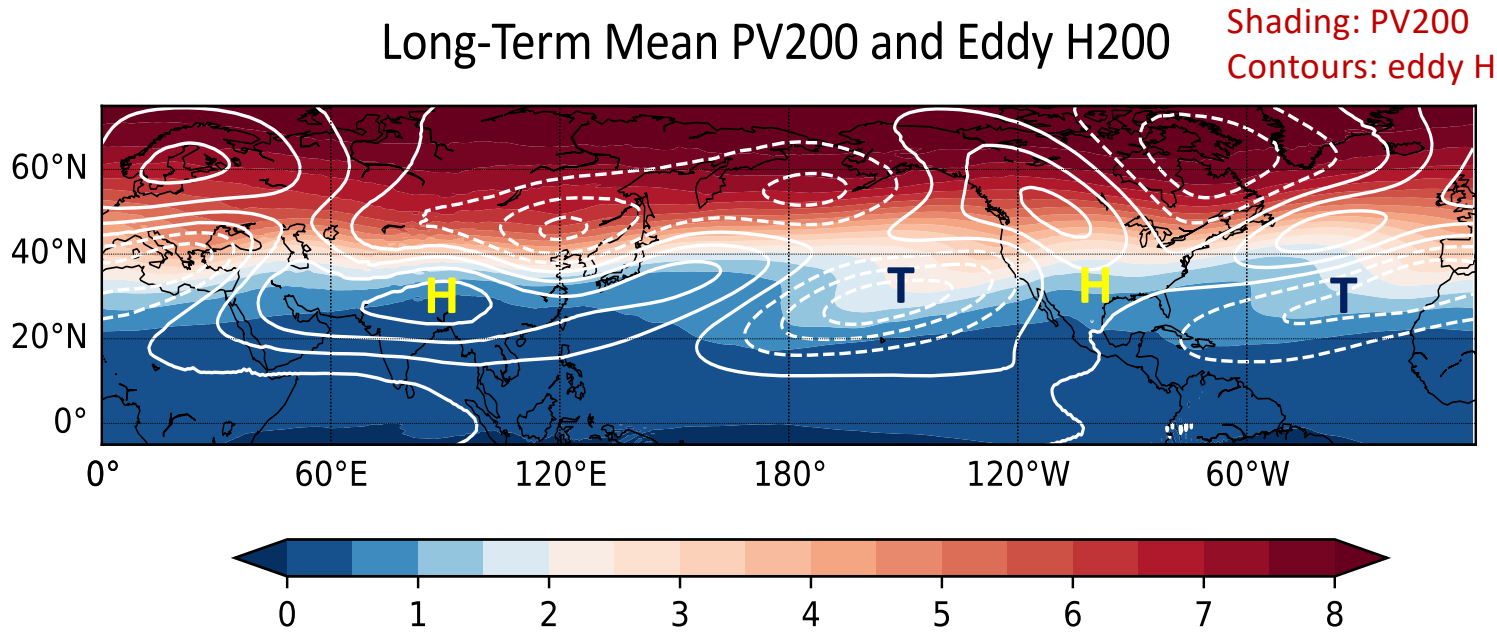
MAPP
Modeling, Analysis, Predictions, and Projections

Wang et al. (2020), PNAS

What modulates tropical cyclone activity?

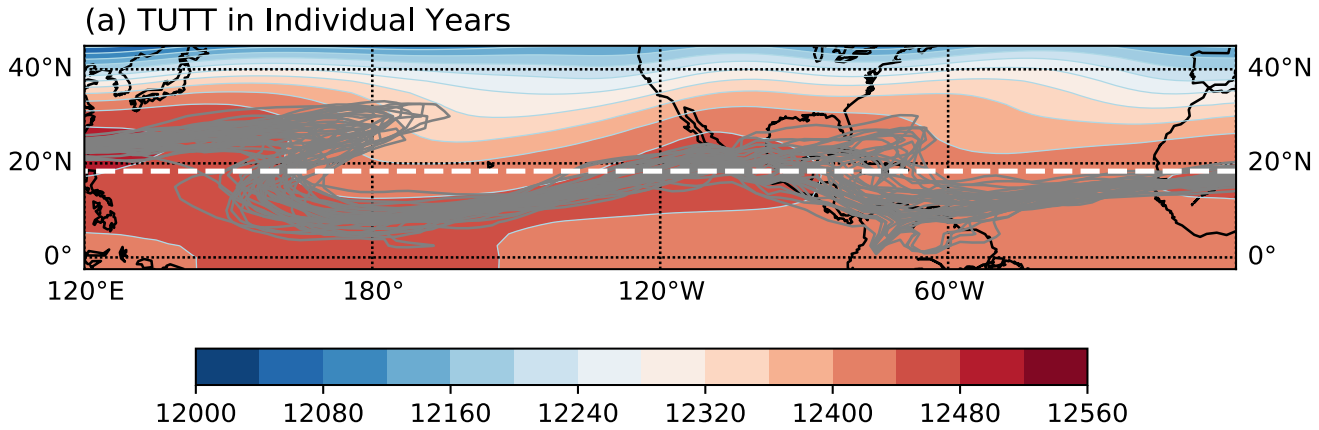
- Tropical cyclones (TCs) are strongly modulated by tropical atmospheric conditions, and the slowly varying tropical ocean conditions provide a source a predictability for on the seasonal and longer time scales.
- Extratropical Rossby wave breaking (RWB) modulates the variability and predictability of Atlantic tropical cyclones on the subseasonal to seasonal time scales (Zhang et al. 2016, 2017; Papin 2017; Li et al. 2018; Wang 2018).
- Semi-idealized numerical experiments demonstrate that the extratropical impacts can exceed the direct impacts of local SST in some years (Chang and Wang 2018).
- Objective of this study: provide a unified framework integrating tropical and extratropical impacts on TC activity, highlighting the tropical-extratropical connection.

Summertime Stationary Waves and Tropical Upper-Tropospheric Troughs (TUTTs)



- Subtropical stationary waves = monsoon anticyclones + TUTTs
- TUTTs: regions of reduced PV gradient and “windows” for active tropical-extratropical interaction
- TUTTs: preferred region of extratropical Rossby wave breaking
- Also associated with variability of tropical atmospheric circ. (shown next)

Tropical Upper-Tropospheric Trough: TUTT

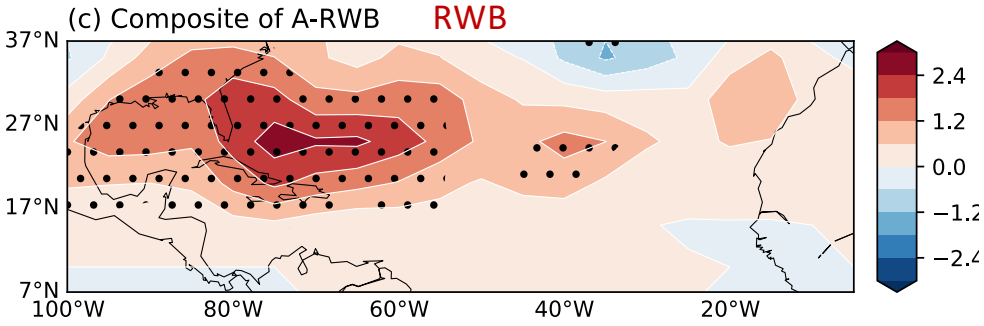


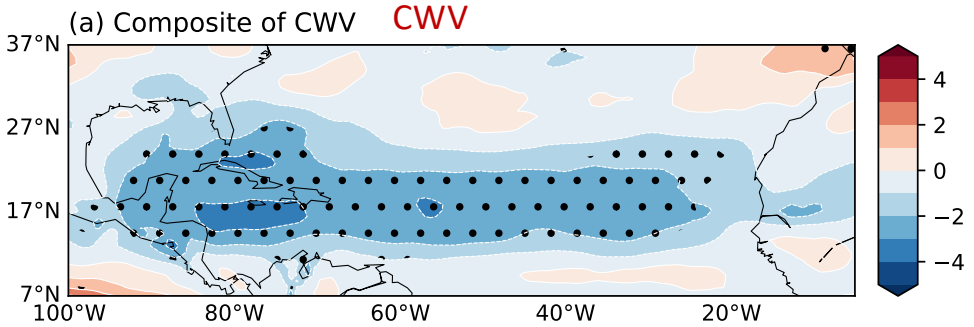
Definition of a TUTT index:

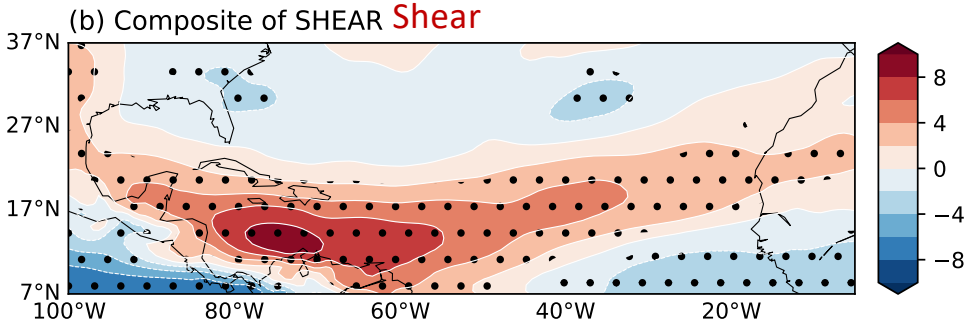
1. **Calculate geostrophic zonal wind using H200:** $u_g = -h_y/f_0$ **where** $f_0 = 2\Omega\sin(15^o)$
2. **Calculate the zonal mean latitude of long-term mean** $u_g = 1.0\ m\ s^{-1}$**, denoted as lat0**
3. **For each JASO season, TUTT is defined as the area of 1.0 m/s contour of ug extending equatorward of lat0.**

Composites based on TUTT_Atl

(8 strong TUTT years minus 8 weak TUTT years)



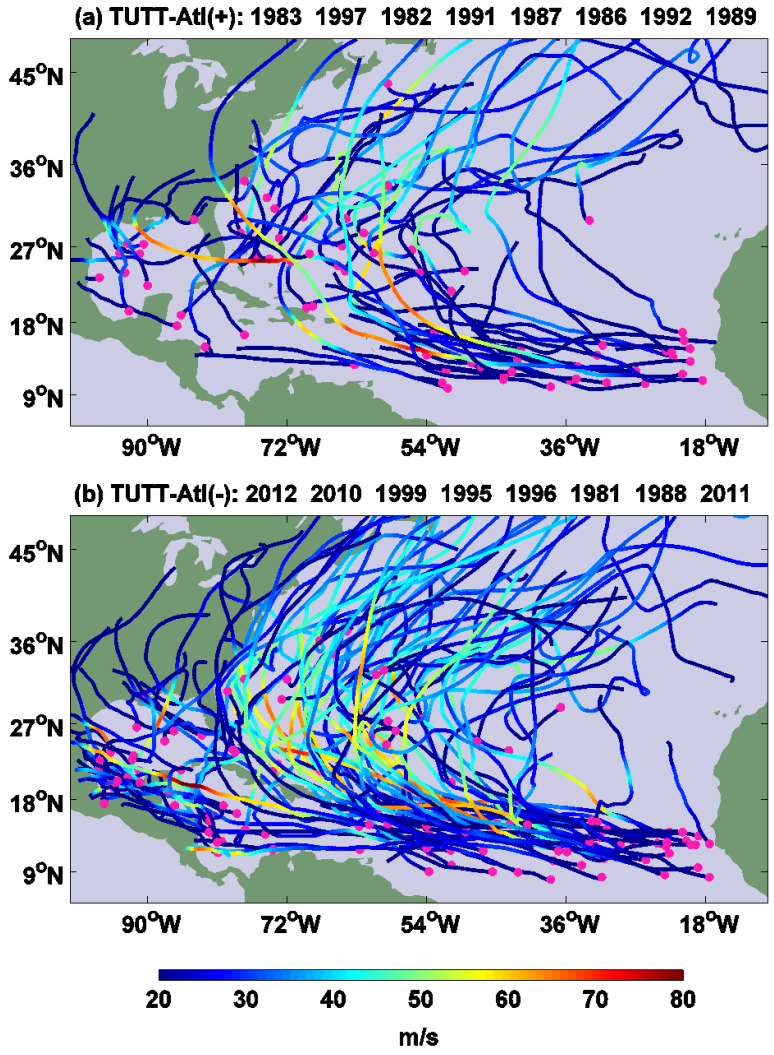




Strong TUTT years

- more frequent RWB and strong mixing between tropics and extratropics.
- reduced CWV is in tropical/subtropical Atlantic
- Enhanced vertical wind shear in the Atlantic MDR

Composites of Atlantic TCs based on TUTT_Atl



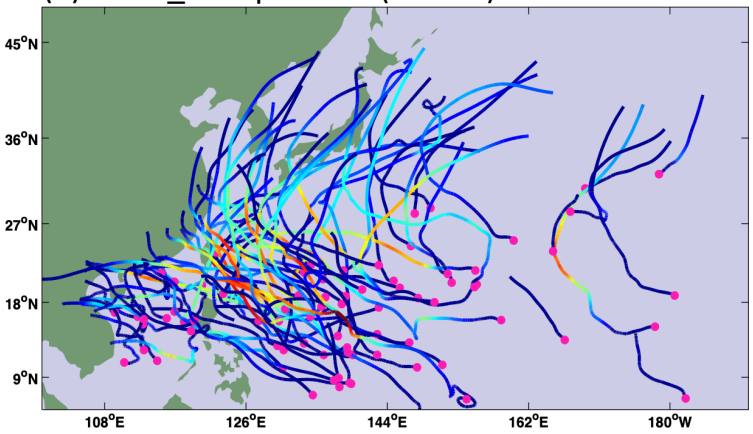
- TC frequency is reduced in strong TUTT years

Corr. with Atlantic TCs (1979-2018)

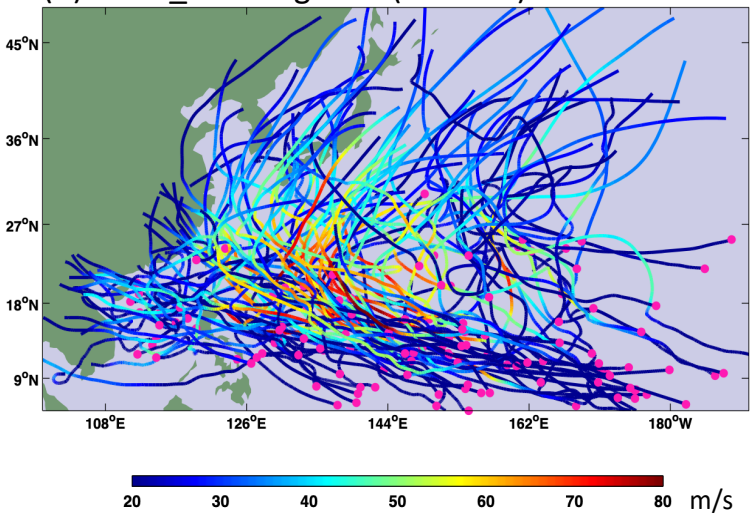
Corr	TC	HURR	ACE
TUTT_Atl	-0.73	-0.76	-0.75
MDR_SST	0.59	0.56	0.55
Nino3.4	-0.34	-0.38	-0.32

Composites of W.Pac TCs based on TUTT_Pac

(a) TUTT_Pac: positive (87 TCs)



(b) TUTT_Pac: negative (127 TCs)



- TC frequency is reduced in strong TUTT years

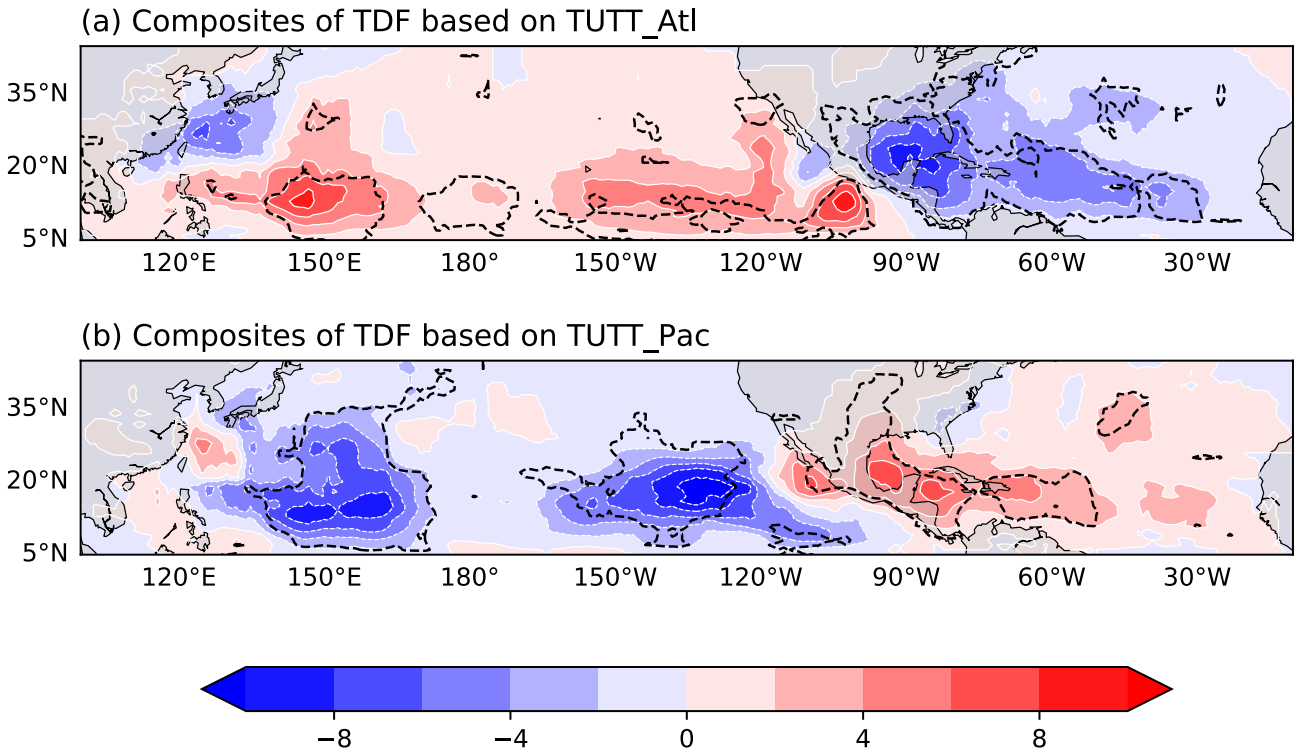
Corr. with W.Pac TCs (1979-2018)

Corr	TC	HURR	ACE
TUTT_Pac	-0.45	-0.53	-0.61
Nino3.4	0.01	0.18	0.56

Corr. with E.Pac TCs (1979-2018)

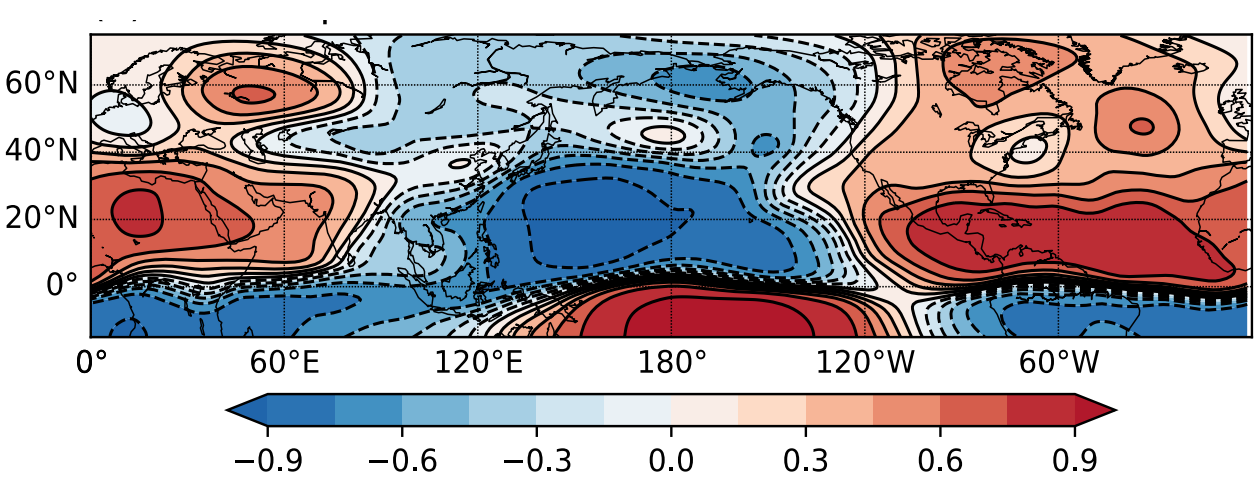
Corr	TC	HURR	ACE
TUTT_Pac	-0.60	-0.58	-0.63
Nino3.4	0.39	0.28	0.46

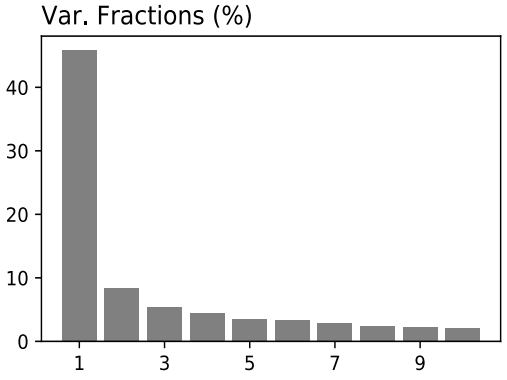
Composites of TC Track Density Function



- Anticorrelation of TUTT_Pac and TUTT_Atl (r=-0.59) contributes to the anticorrelation of TC activity between the Pacific and Atlantic.
- Out-of-phase relation of the TUTTs btw the two basins can be explained by PV impermeability (Ortega et al. 2018): the variability of equatorward PV fluxes over the two TUTTs regions tends to compensate --- rendering the global TCs less variable

EOF1 of Eddy Psi200 (JASO)





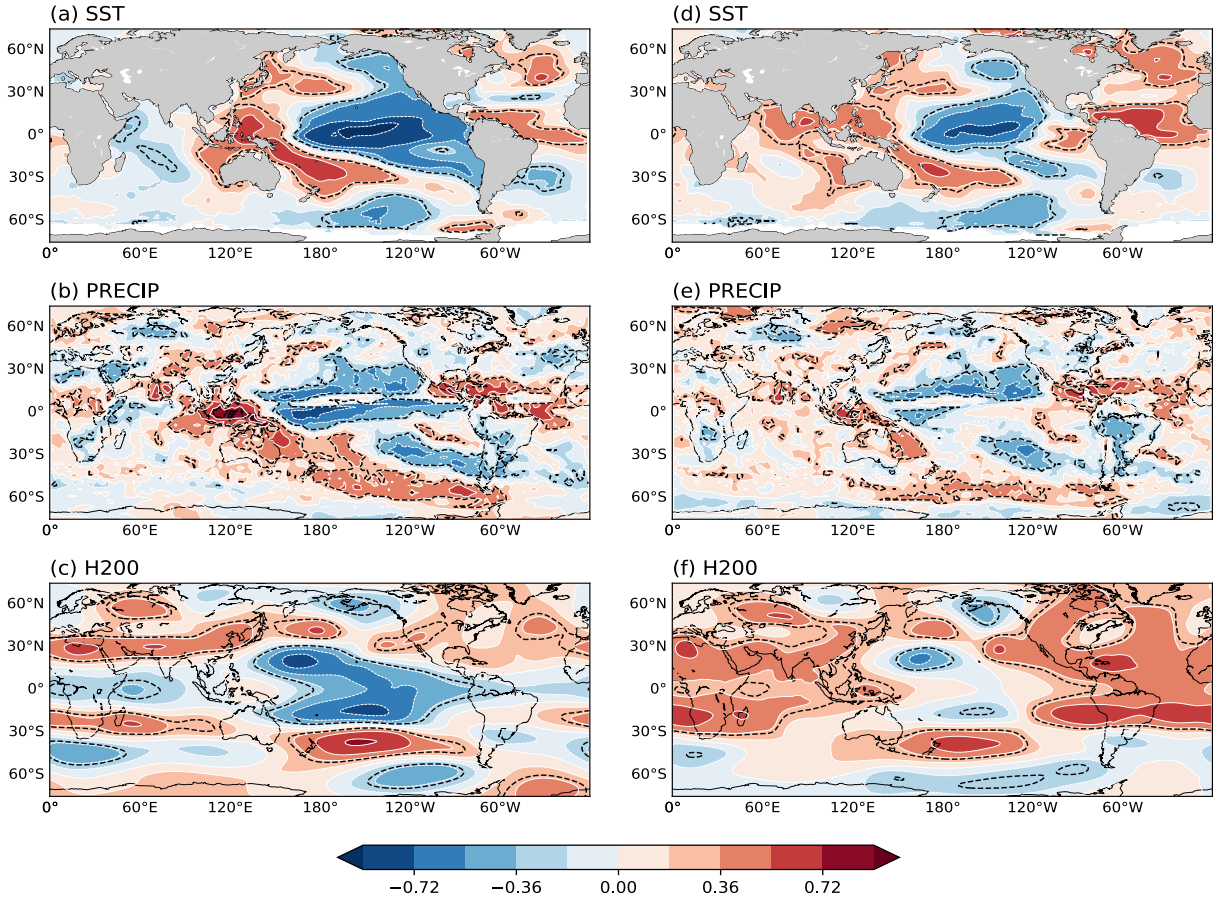
Corr.	TUTT_Atl	TUTT_Pac	ACE(Atl)	ACE(Epac)	ACE(Wpac)
TUTT_Pac	-0.72	0.82	0.50	-0.58	-0.69

- PC1 is significantly correlated with TUTTs and TC activity over the Atlantic, E.Pac and W.Pac.

Correlations of PC1 with SST, Precip and H200

Total Correlation

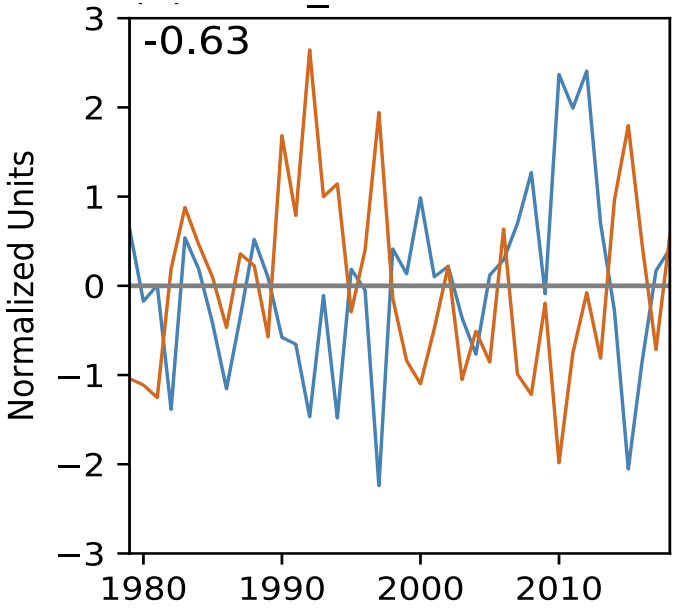
Partial Corr. with ENSO Removed



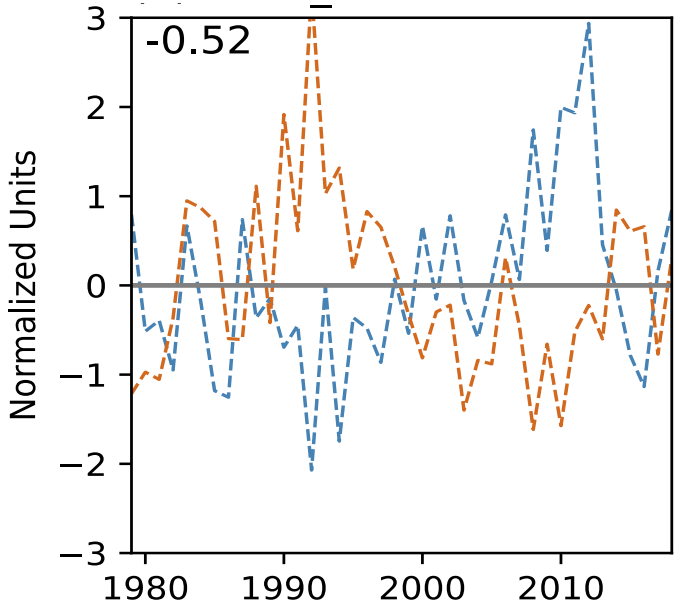
- The variability of the summertime stationary waves or TUTTs cannot be completely attributed to the ENSO

Time Series of TUTT_Pac and E.Pac ACE

Normalized time series



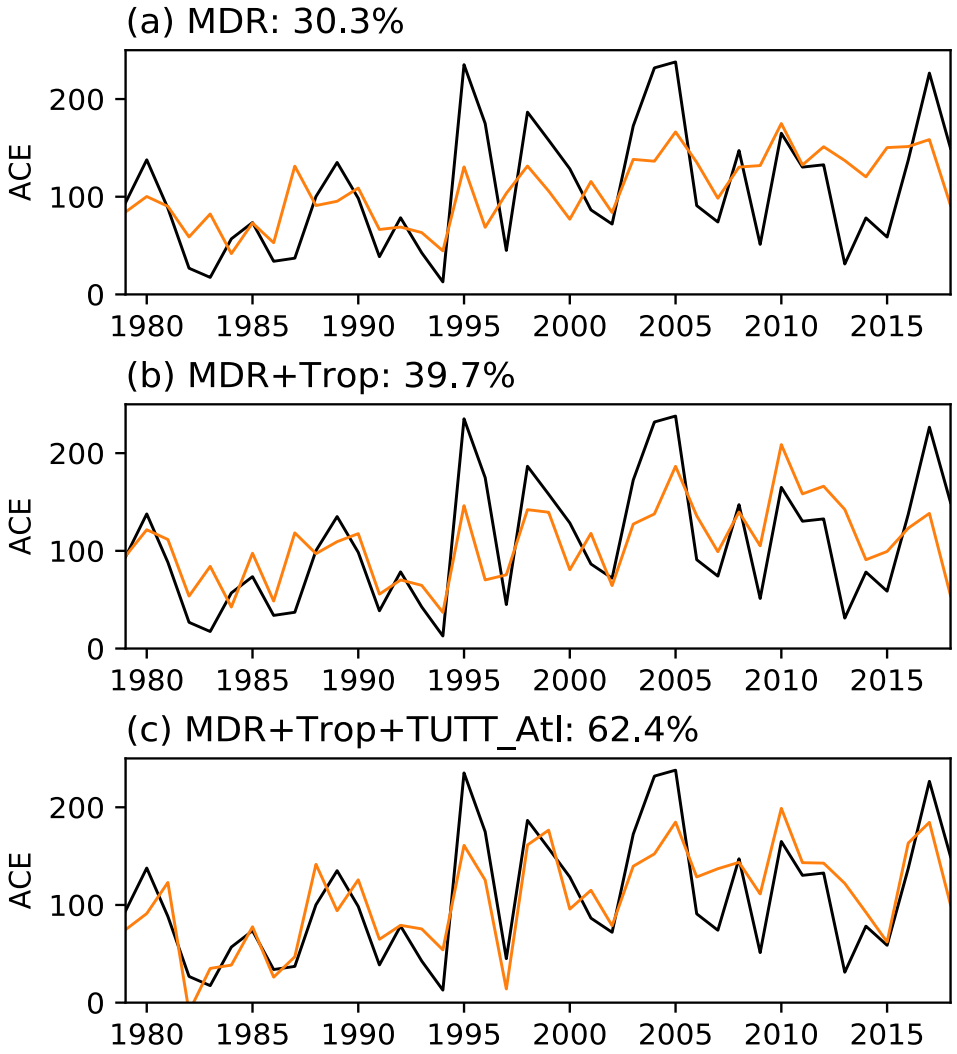
Normalized time series with ENSO removed



Blue: TUTT_Pac; Red: E. Pac ACE

- The strong TUTT-TC correlations cannot be completely attributed to the ENSO

Observed vs. Fitted Atlantic ACE



The Atlantic ACE is reconstructed (orange) based on the linear regression of

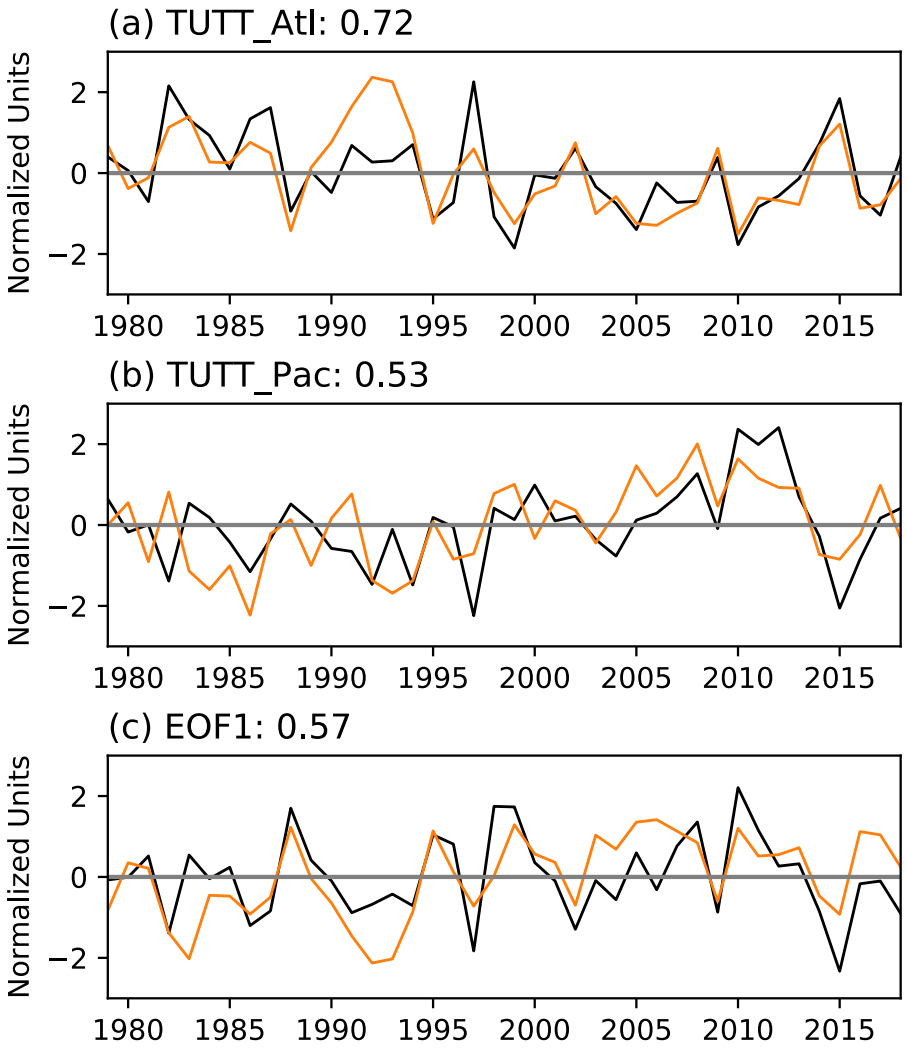
(a) MDR SST

(b) MDR SST + the tropical mean SST

(c) MDR SST, tropical mean SST and TUTT_Atl.

- TUTTs (or stationary waves) not only reflect the contribution from the slowly varying tropical SST but also extratropical impacts.

Are TUTTs and Stationary Waves Predictable?



- Predict TUTTs and PC1 (JASO) using different pairs of possible predictors among the AMO, PDO, Nino3.4 and the Atlantic MDR SST in April-May; multiple linear regression models were constructed.
- The ACC between the predicted and observed time series using the leave-five year-out method are 0.72, 0.53 and 0.57 for TUTT_Atl, TUTT_Pac and EOF1, respectively.

Summary

- We demonstrated the strong link between TUTTs and TC activity over the North Pacific and North Atlantic.
- As part of the stationary waves, TUTTs are connected to monsoons and extratropical Rossby waves, and introduce a factor other than tropical SST for the variability of TC activity.
- We advocate a hemispheric perspective that helps understand the variability and predictability of TC activity over the North Atlantic and North Pacific.