

A New Paradigm for Attribution Study for Extreme Tropical Cyclone Season Using Seasonal Prediction System

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Motivation

- Developing a dynamical model that has skill in predicting **major hurricanes (MHs)** is central to NOAA's mission and highly relevant to society.

Damage cost from U.S. Billion-dollar disaster events (1980–2013)

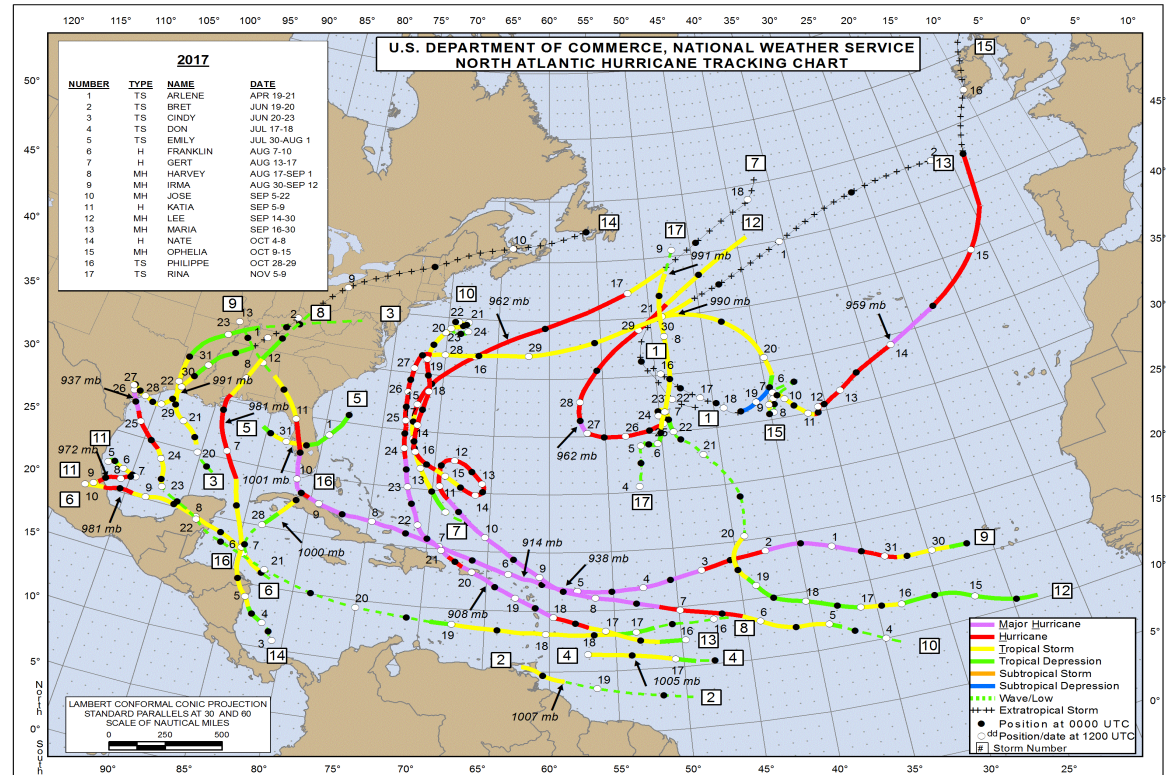
Disaster Type	Number of Events	Percent Frequency	CPI-adjusted Losses (\$ billions)	Percent of Total Loss	Average Event Cost (\$ billions)
Drought	21	12.4	199	19.1	9.5
Flooding	19	11.2	86	8.3	4.5
Freeze	7	4.1	25	2.4	3.6
Severe Storm	65	38.2	143	13.7	2.2
Tropical Cyclone	34	20.0	530	50.9	15.6
Wildfire	12	7.1	26	2.5	2.2
Winter Storm	12	7.1	35	3.4	2.9

Smith and Matthes (2015, Natural Hazards)

Active 2017 Major Hurricane Season

North Atlantic in 2017

- 6 major hurricanes
- Destructive landfalling Hurricanes (Harvey, Irma, Maria)
- Hurricane Harvey ended 12-yr period of no landfalling major hurricanes since 2005.



Public and science community are very interested in the causes for the 2017 active major hurricane season **in real time**.

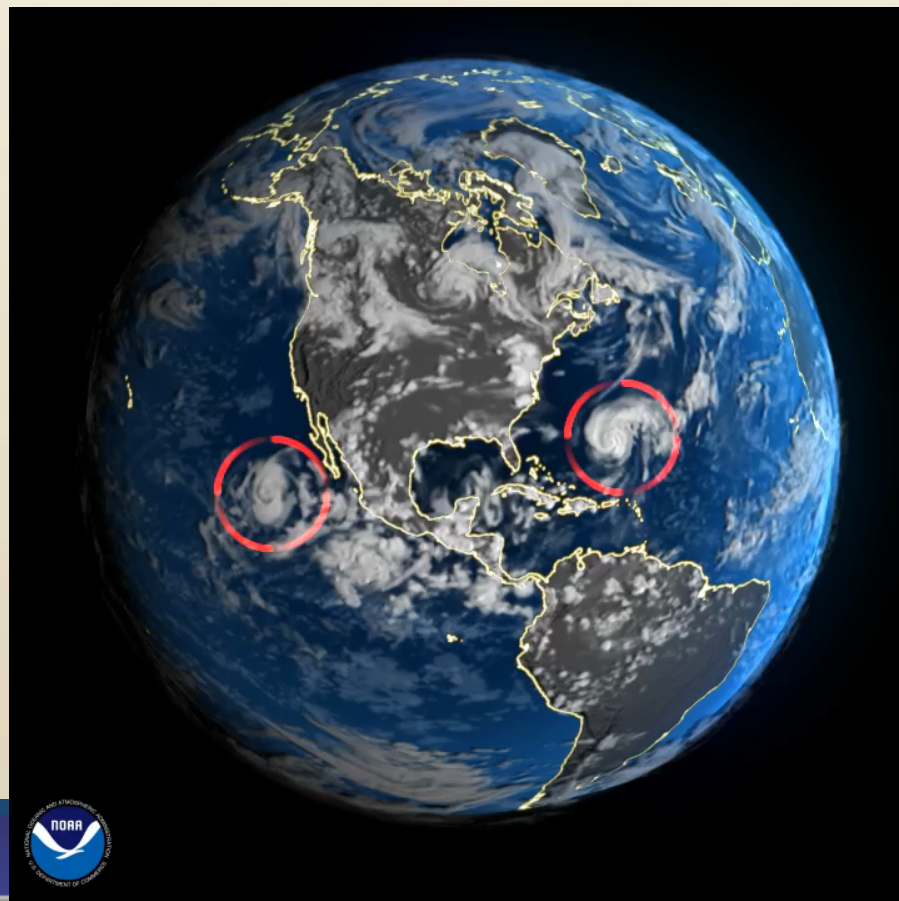
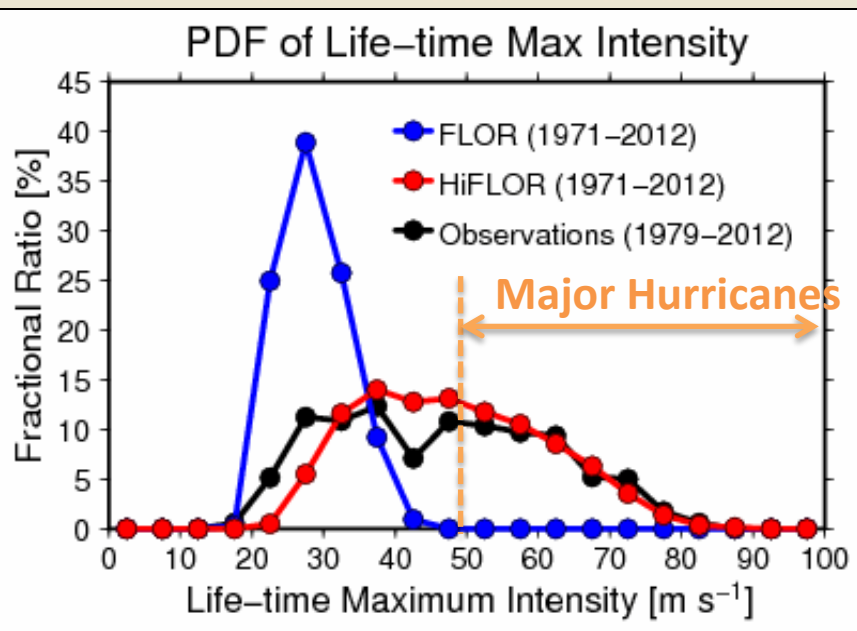
Natural Variability (e.g., ENSO, PMM, AMM, PDO)?
Anthropogenic Forcing (e.g., CO₂, Aerosols)?

HiFLOR (Hi-Resolution Seasonal Prediction Model)

Model	Resolution
FLOR	Atmosphere: 50 km , L32 Ocean: 100 km, L50
HiFLOR	Atmosphere: 25 km , L32 Ocean: 100 km, L50

FLOR : Coupled Global Model

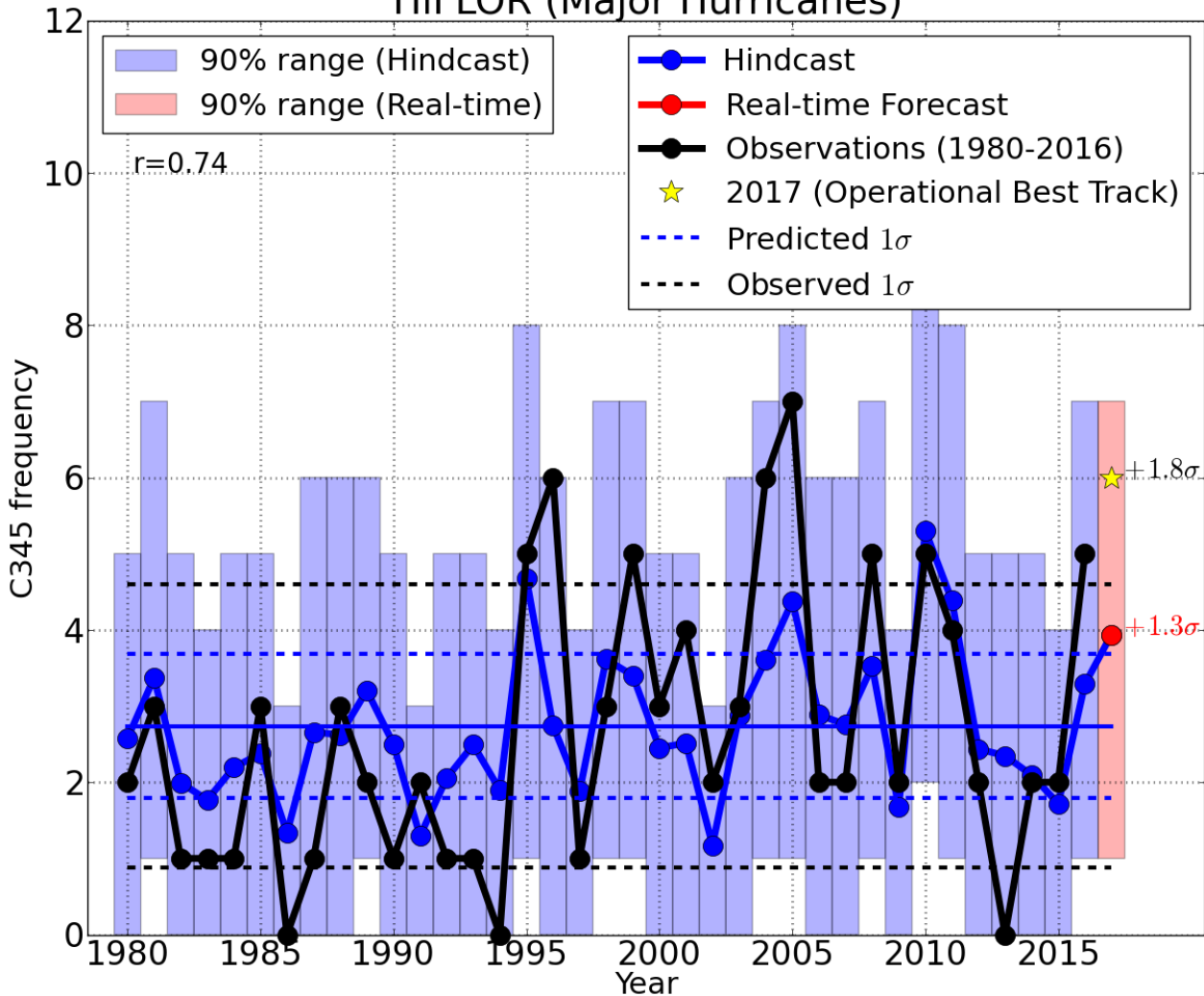
We developed a new high-resolution coupled model, **HiFLOR** to improve prediction of MHs.



Real-Time Prediction for 2017 Summer Season (July Initial Prediction)

Predicted Major Hurricane Frequency

HiFLOR (Major Hurricanes)

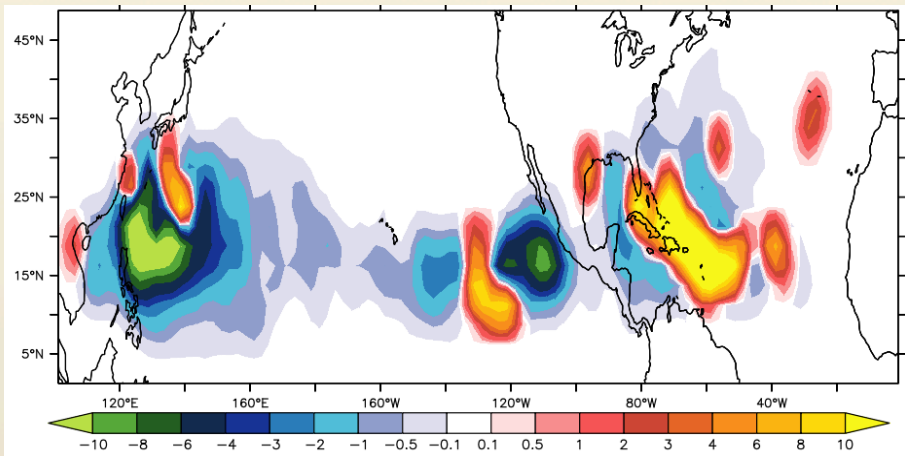


HiFLOR has skill in predicting major hurricanes from July initial conditions. (correlation coefficient =0.74)

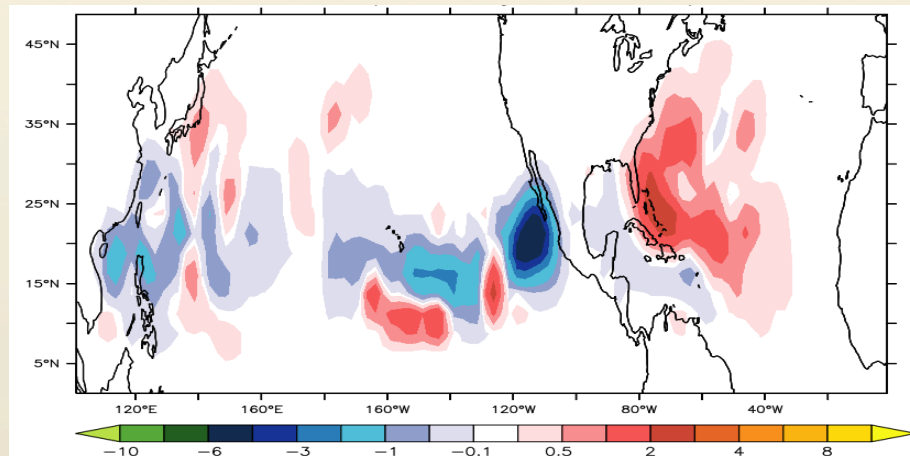
HiFLOR predicted the 2017 active major-hurricane season (+1.3 std) in real time.

Real-Time Prediction for the 2017 Summer Season

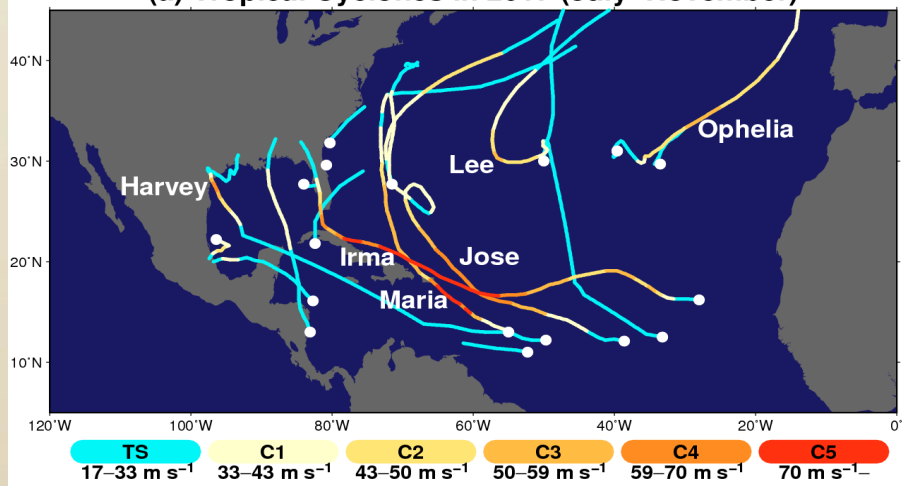
Observed MH Density Anomaly in 2017



Predicted MH Density Anomaly in 2017



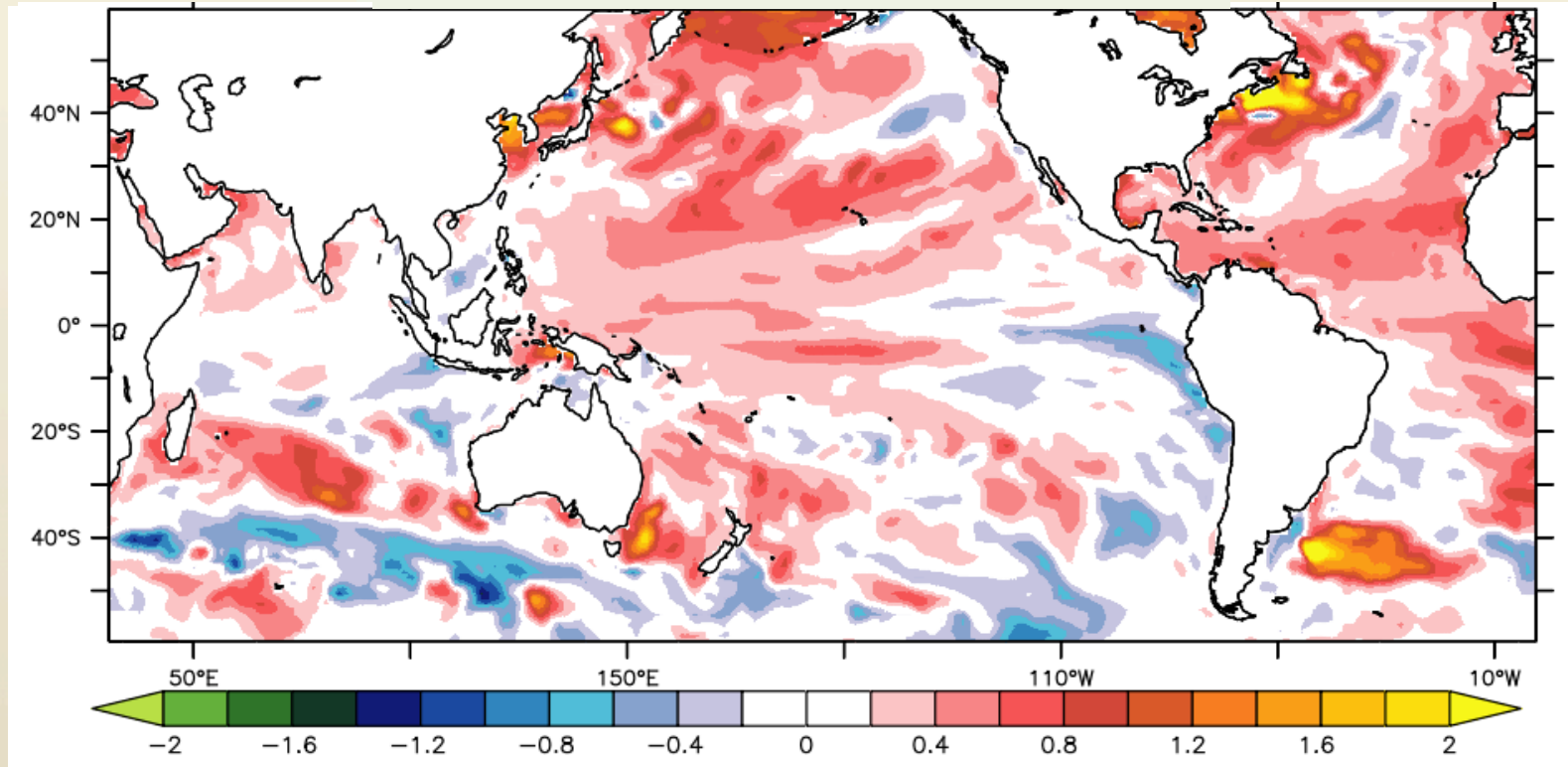
Observed Storm Tracks in 2017 (a) Tropical Cyclones in 2017 (July–November)



HiFLOR could predict the locations of MHs a few months in advance for the 2017 summer.

What caused the active 2017 MH season?

Predicted SST Anomaly in 2017



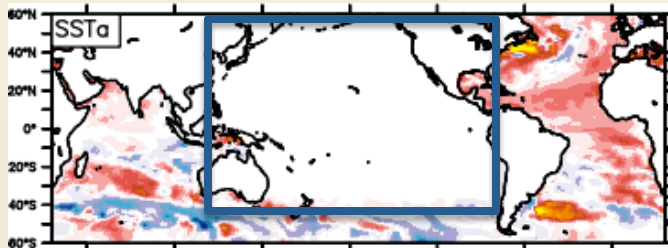
- A. Moderate La Niña?
- B. Warmer Tropical Atlantic?
- C. Warmer off the coast of North America?

Significance of Real-time Attribution

- To assess the relative importance of SSTAs in various regions for the active MH season in 2017, we conducted idealized seasonal predictions using HiFLOR.
- We conducted an “SST-nudging experiment”, in which simulated SST is restored to **the predicted SSTs by the real-time predictions with some modifications.**
- The reason why we utilized predicted SSTs, rather than observed SSTs, is because we don't need to wait for formal observed SST dataset for the assessment, which normally delays a few months after hurricane season. We can do the assessment even as the hurricane season is underway.

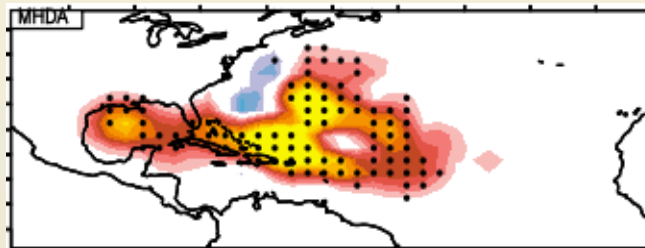
Idealized SST-Prescribed Seasonal Prediction

Prescribed SST Anomaly



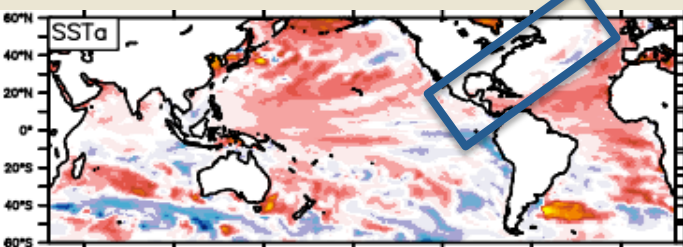
Pacific SST anomaly was removed.

Predicted MH Density Anomaly

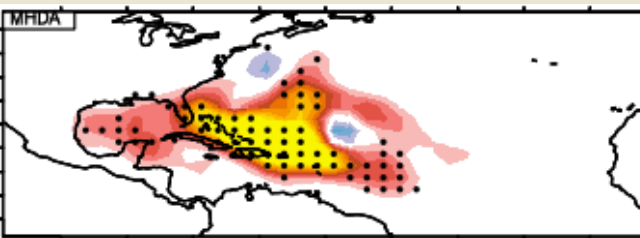


MHs are still active.

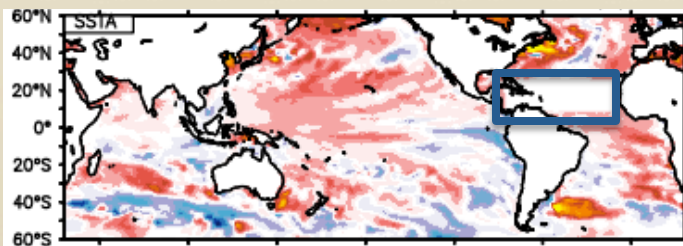
A. Moderate La Niña?



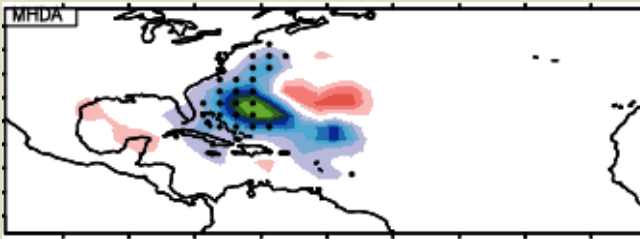
SSTa off the coast of US was removed. MHs are still active.



C. Warmer off the coast of North America?



SSTa in the tropical Atlantic was removed. MHs reduced.



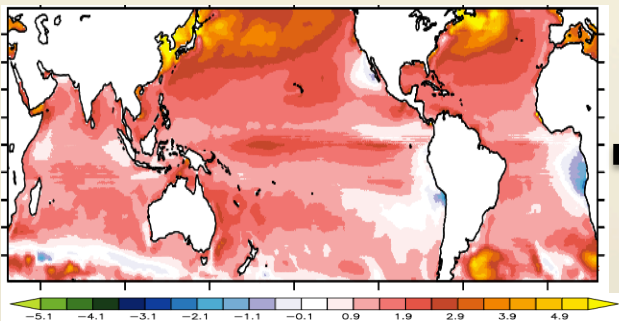
B. Warmer Tropical Atlantic?



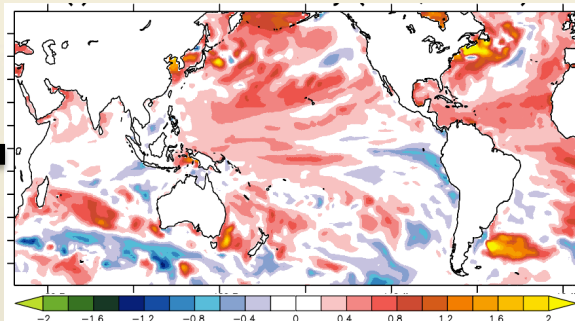
Idealized Prescribed SST Experiments in the Future

RCP4.5

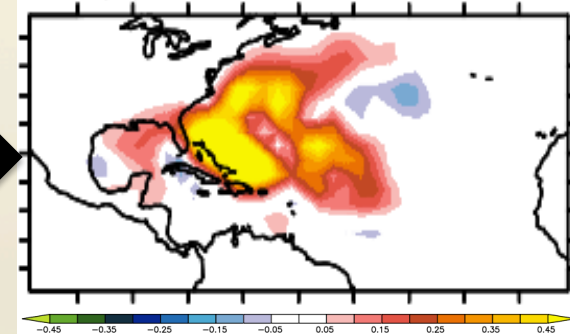
(2080-2099 minus 2015-2025)



2017 SST Anomaly

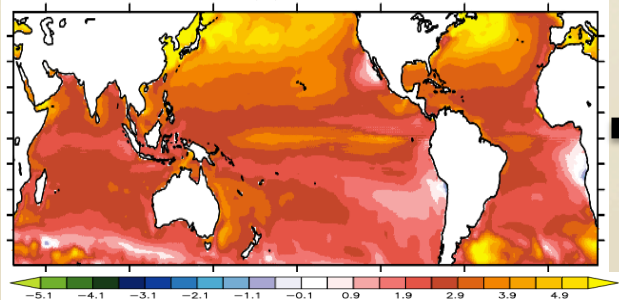


Projected MH Density Anomaly

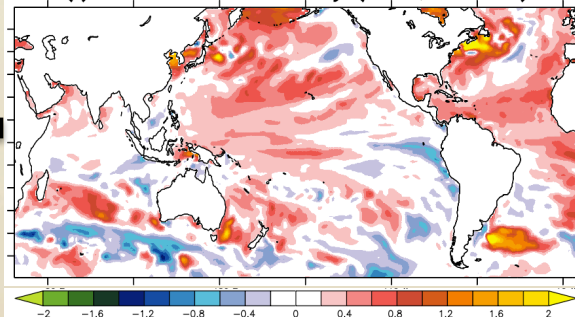


RCP8.5

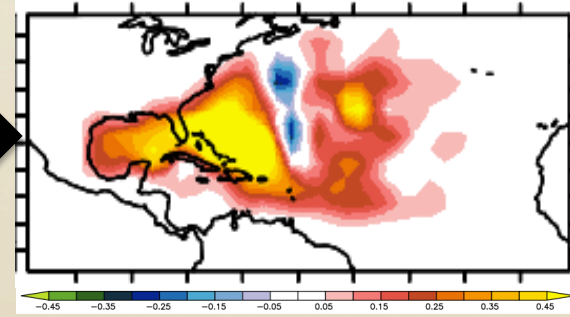
(2080-2099 minus 2015-2025).



2017 SST Anomaly



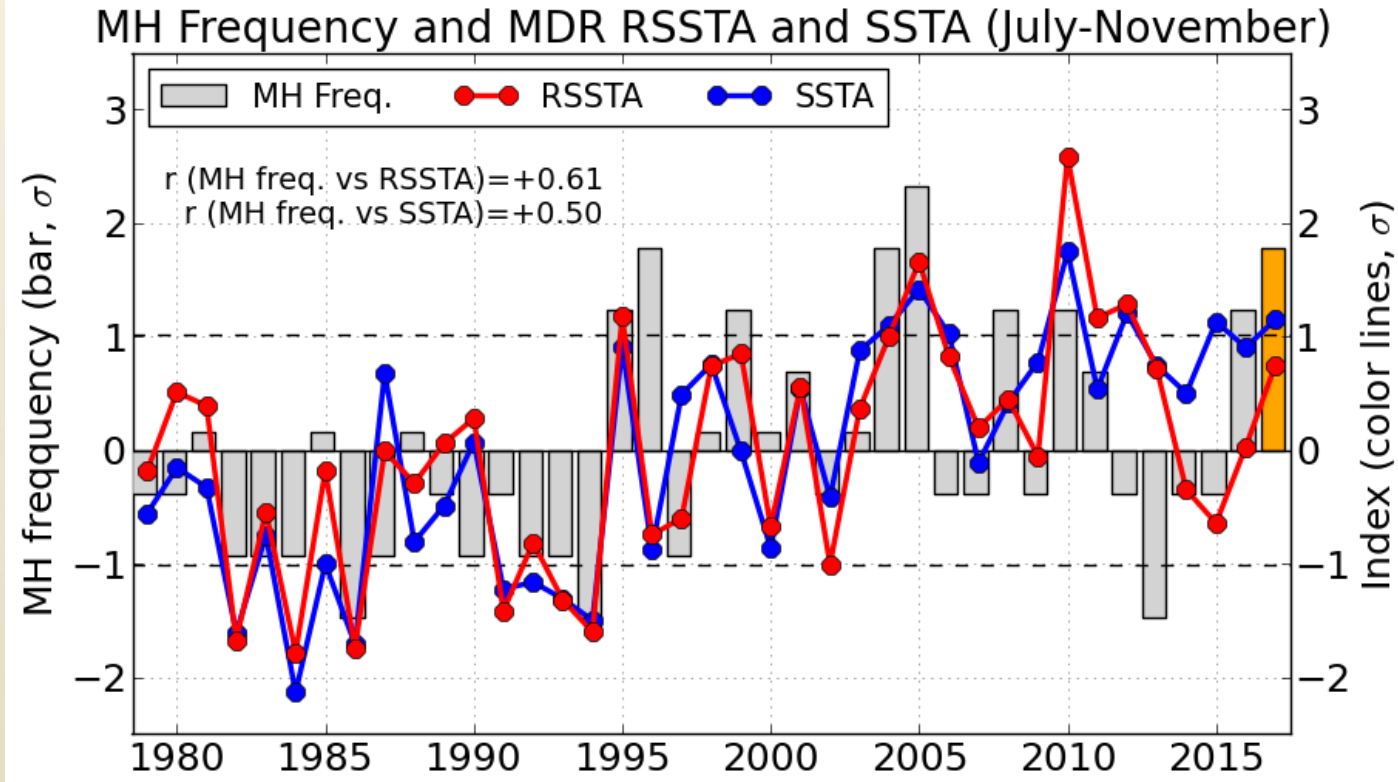
Projected MH Density Anomaly



More active MH season than the 2017 summer is projected in the future even with the same spatial patterns of 2017 SST anomaly, resulting in **amplifying the risk of MHs**.

Which of local SST anomaly or relative SST anomaly is important for frequency of MHs in the North Atlantic?

Observations

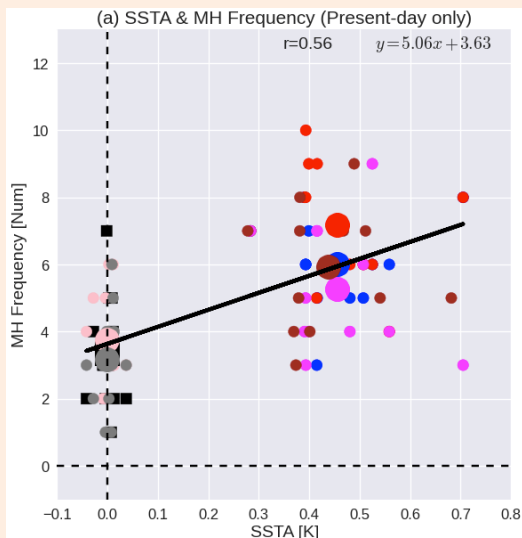


Observed number of MHs (gray bars) is correlated with both **tropical Atlantic SSTA anomaly (SSTA, $r=+0.50$)** and **tropical Atlantic SST anomaly relative to tropical mean (RSSTA, $r=+0.61$)**

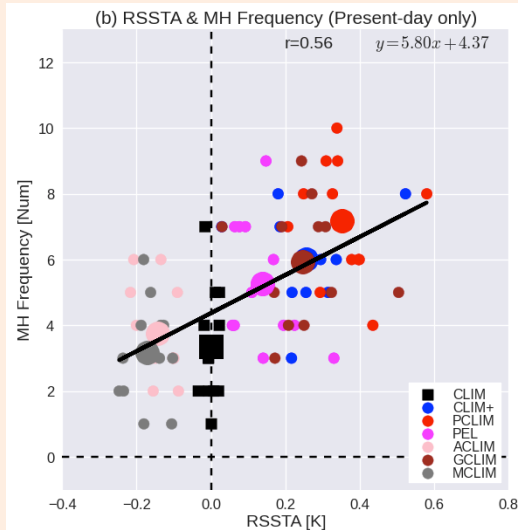
Which of local SST anomaly or relative SST anomaly is important for frequency of MHs in the North Atlantic?

Model

2017 Experiments only

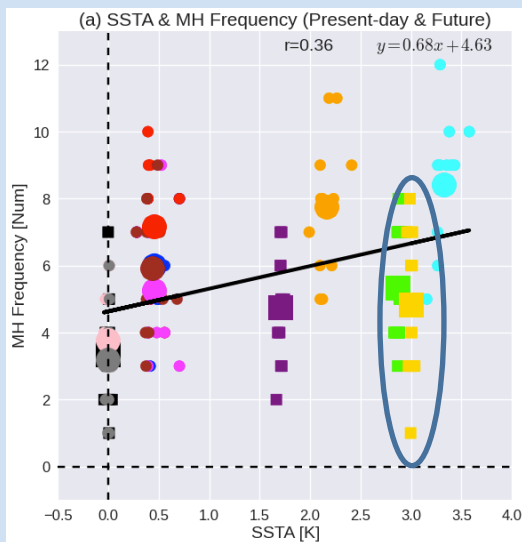


SSTA vs MHs ($r=+0.56$, Slope= $+5.1$)

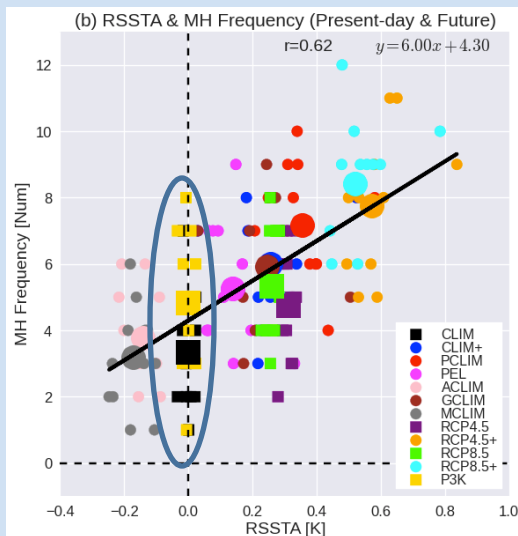


RSSTA vs MHs ($r=+0.56$, Slope= $+5.8$)

2017 Experiments & Future Experiments

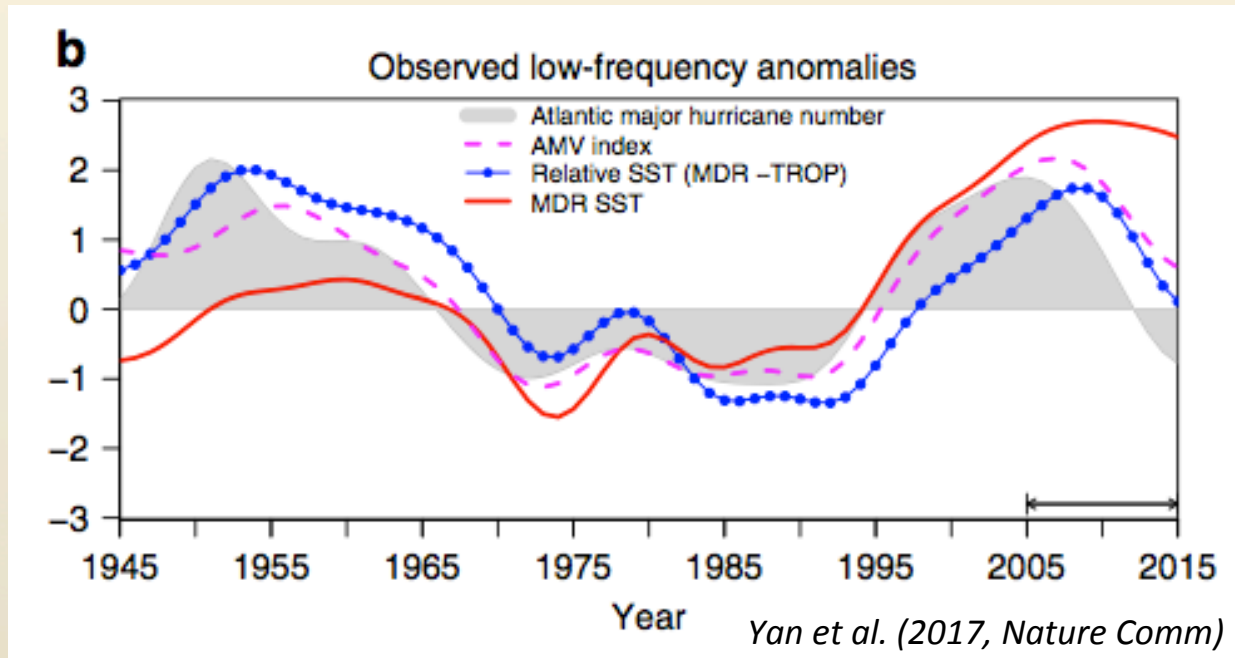


SSTA vs MHs ($r=+0.36$, Slope= $+0.7$)



RSSTA vs MHs ($r=+0.62$, Slope= $+6.0$)

What will happen in the next decades?



AMO (or AMV) index is going to negative?

=> Decrease in major hurricanes in next decades?

Monitoring or predicting natural variability (AMO, AMOC) is a key to predict frequency of major hurricanes in the next decades.

Summary

- We developed a new methodology for attribution study “**real-time attribution**” using real-time seasonal prediction system.
- HiFLOR has skill ($r=0.74$) in predicting frequency of major hurricanes (MHs) in the North Atlantic a few months in advance.
- HiFLOR predicted observed locations of MHs very well for the 2017 summer.
- The active 2017 major hurricanes were controlled by the tropical ocean surface warming in the North Atlantic.
- In the end of 21st century, even given the similar SST anomaly patterns like the 2017 summer, MH could be more active than the 2017 summer season.
- Relative SST anomaly associated with AMO and AMOC is a key for prediction of MHs in the near future.