On the Mechanisms of the Active 2018 Tropical Cyclone Season in the North Pacific

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GFDL/JAMSTEC/MRI/NUIST

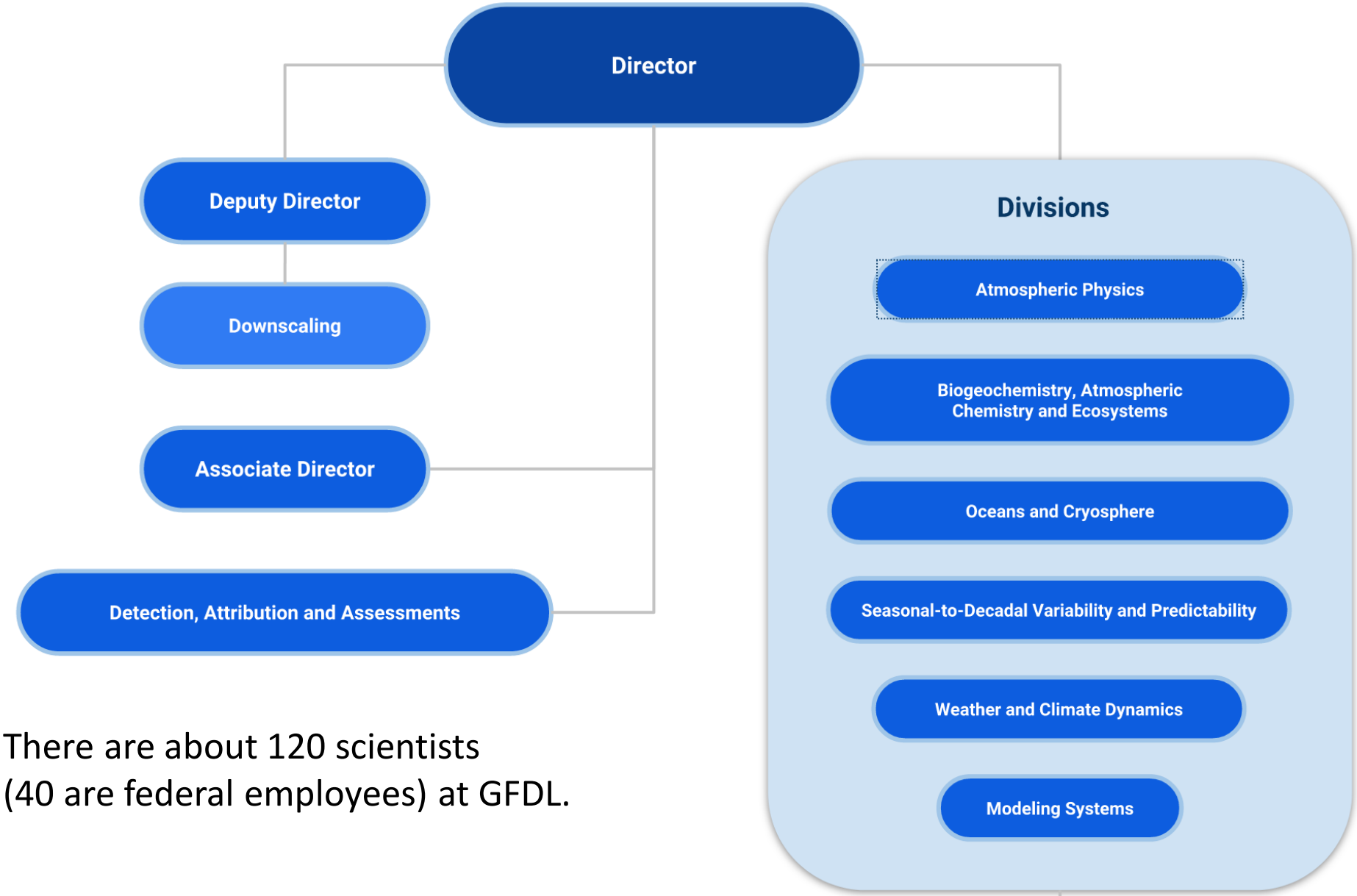
Qian et al. (2019, GRL)

May 30, 2019

About GFDL

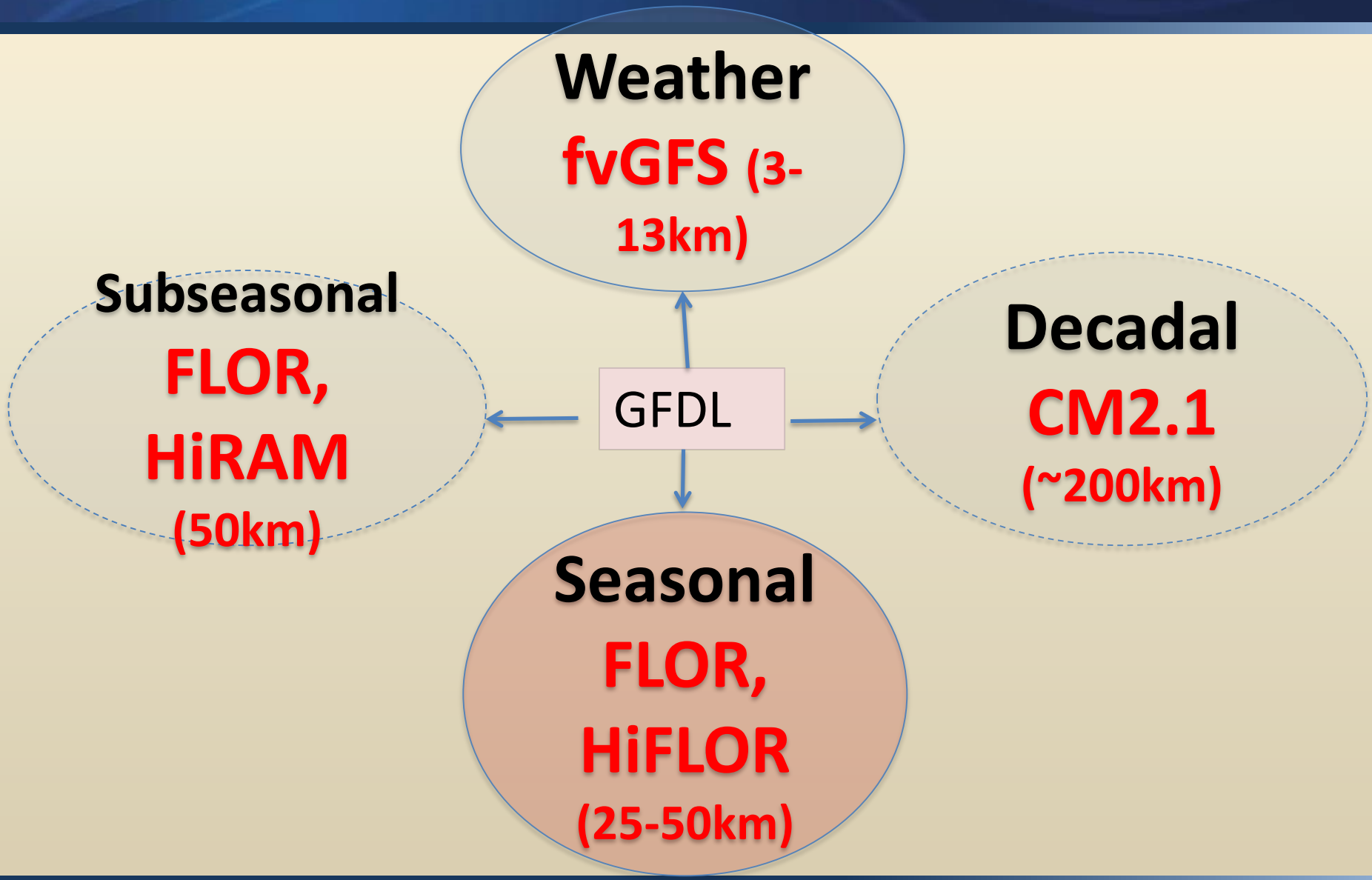
- Geophysical Fluid Dynamics Laboratory
- Office of Oceanic and Atmospheric Research (OAR), National Oceanic and Atmospheric Administration (NOAA)
- Location: Princeton, New Jersey
- Mission: To develop and use earth system models and computer simulations to improve our understanding and prediction of all aspects of the weather and climate system.

GFDL Organization



There are about 120 scientists
(40 are federal employees) at GFDL.

GFDL Dynamical Models for Predictions



GFDL FLOR: Forecast-oriented Low Ocean Resolution version of CM2.5

Goal: Build a seasonal to decadal forecasting system to:

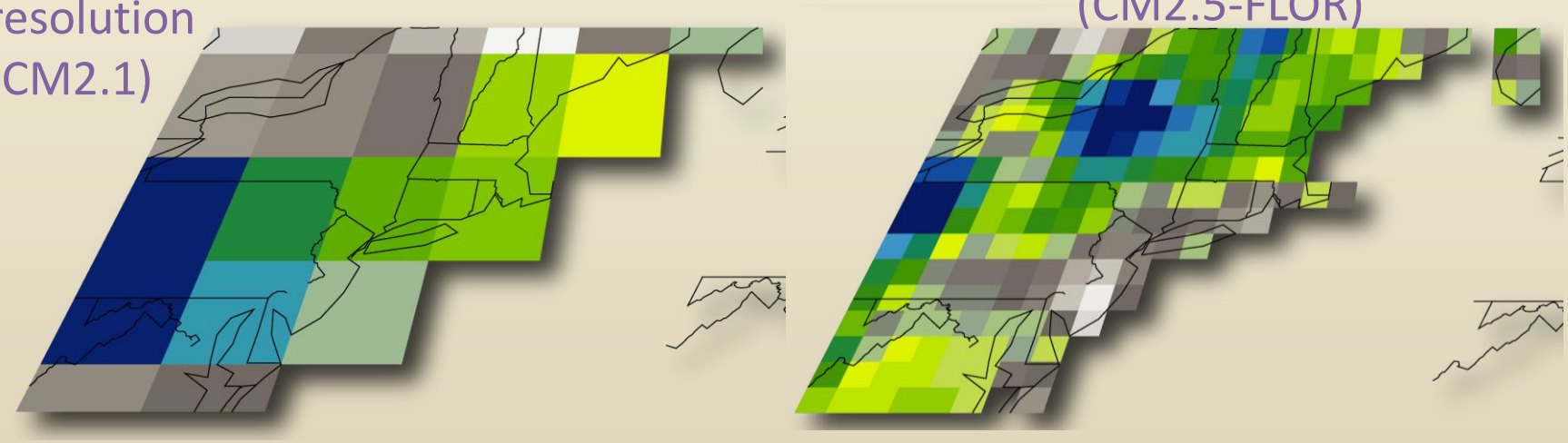
Yield improved forecasts of large-scale climate

Enable forecasts of regional climate and extremes

Precipitation in Northeast USA

Medium resolution (CM2.1)

High resolution (CM2.5-FLOR)



Modified version of CM2.5 (Delworth et al. 2012):

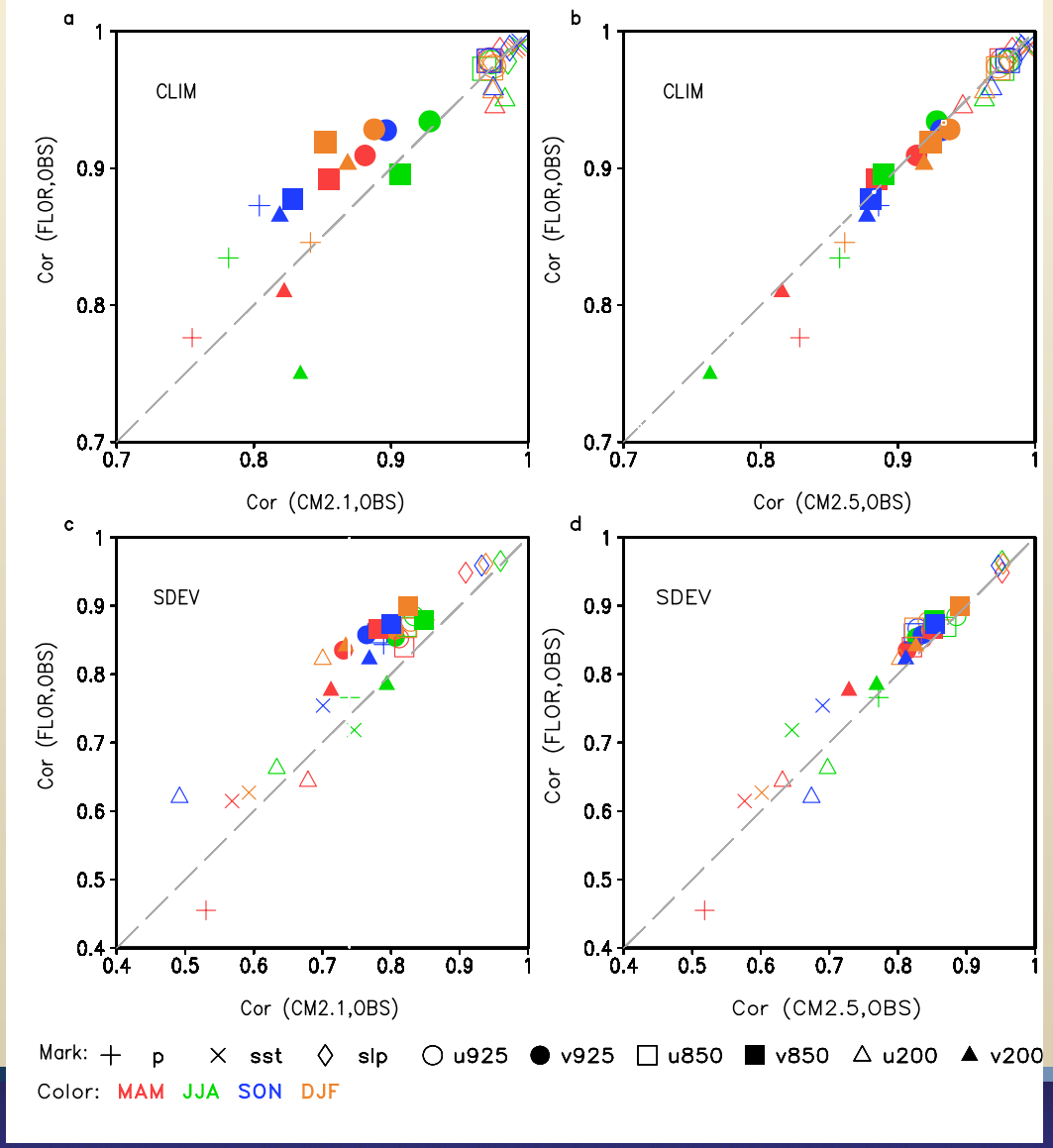
- 50km cubed-sphere atmosphere (Same as CM2.5)
- 1° ocean/sea ice (low res enables prediction work; 0.25° for CM2.5)

~15-18 years per day. Multi-century integrations. 4500+ model-years of experimental seasonal predictions completed and being analyzed.

Hypothesis: Enhanced atmos./land resolution improves climate

	Atm.	Ocn.
CM2.1	200 km	1°
FLOR	50 km	1°
CM2.5	50 km	0.25°

~4xAtmos Res. 4xOcean Res.

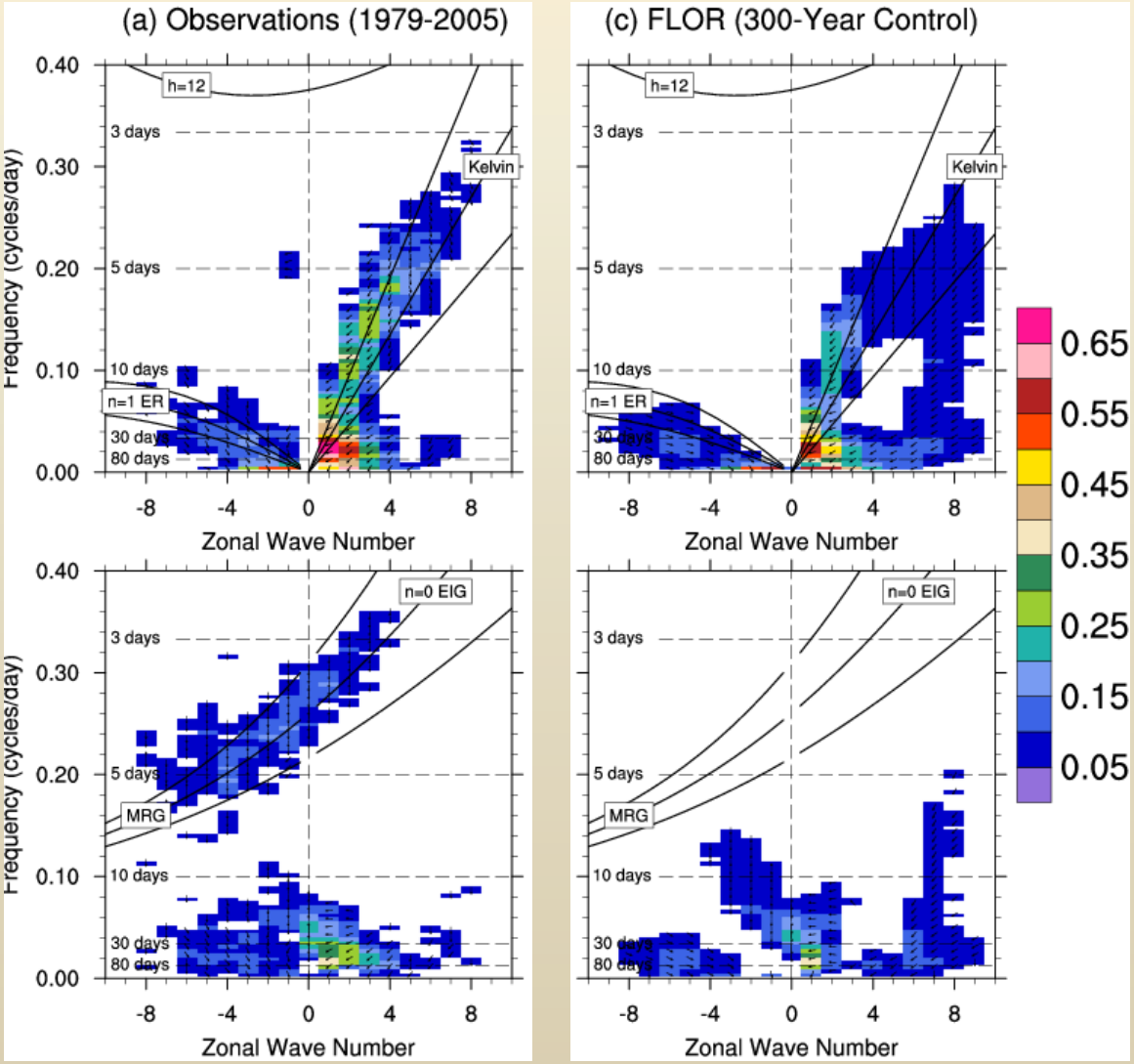


Spatial Correl. Mean

Spatial Correl. Variance

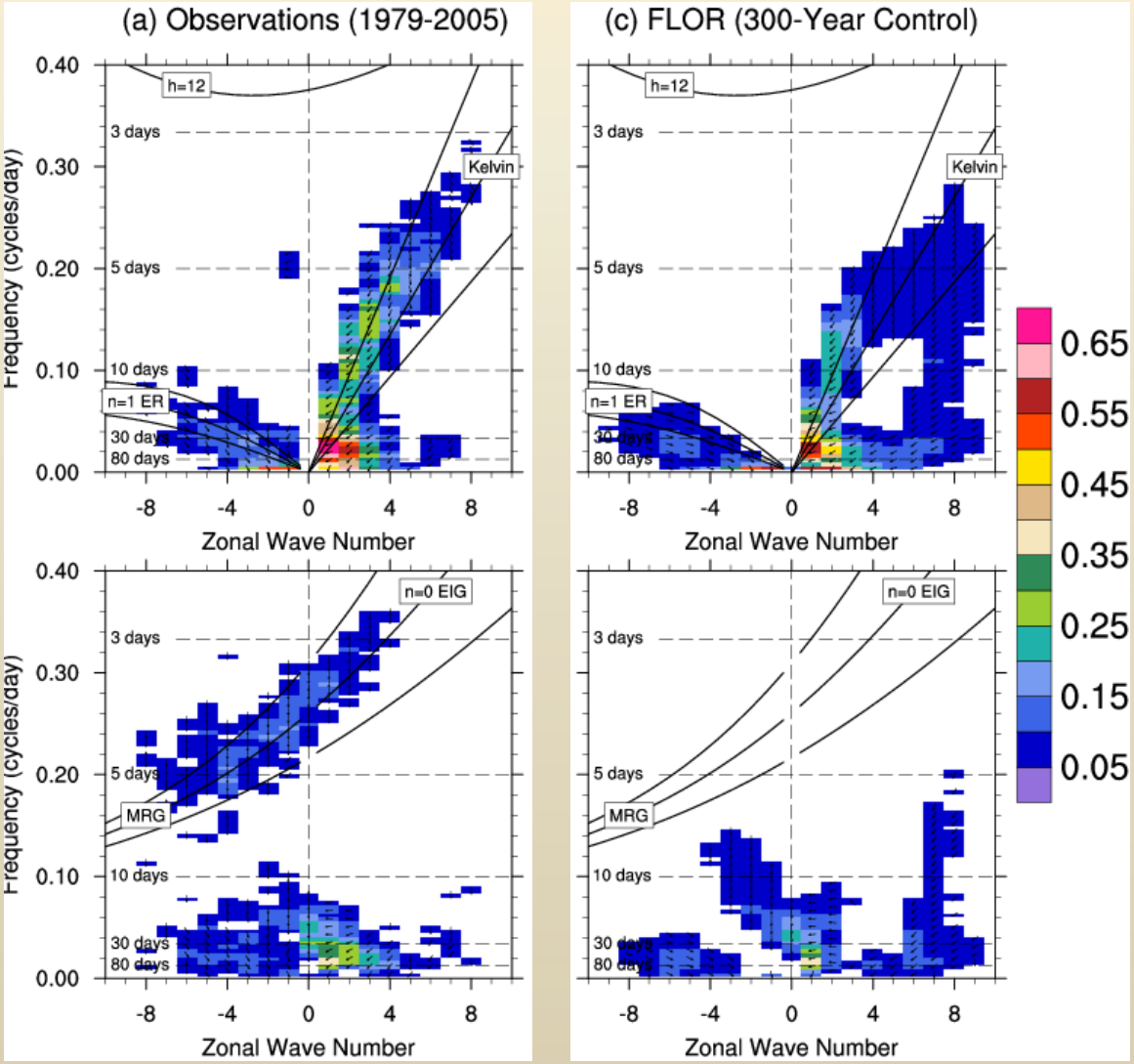
Jia et al. (2014)

MJO Simulation with FLOR



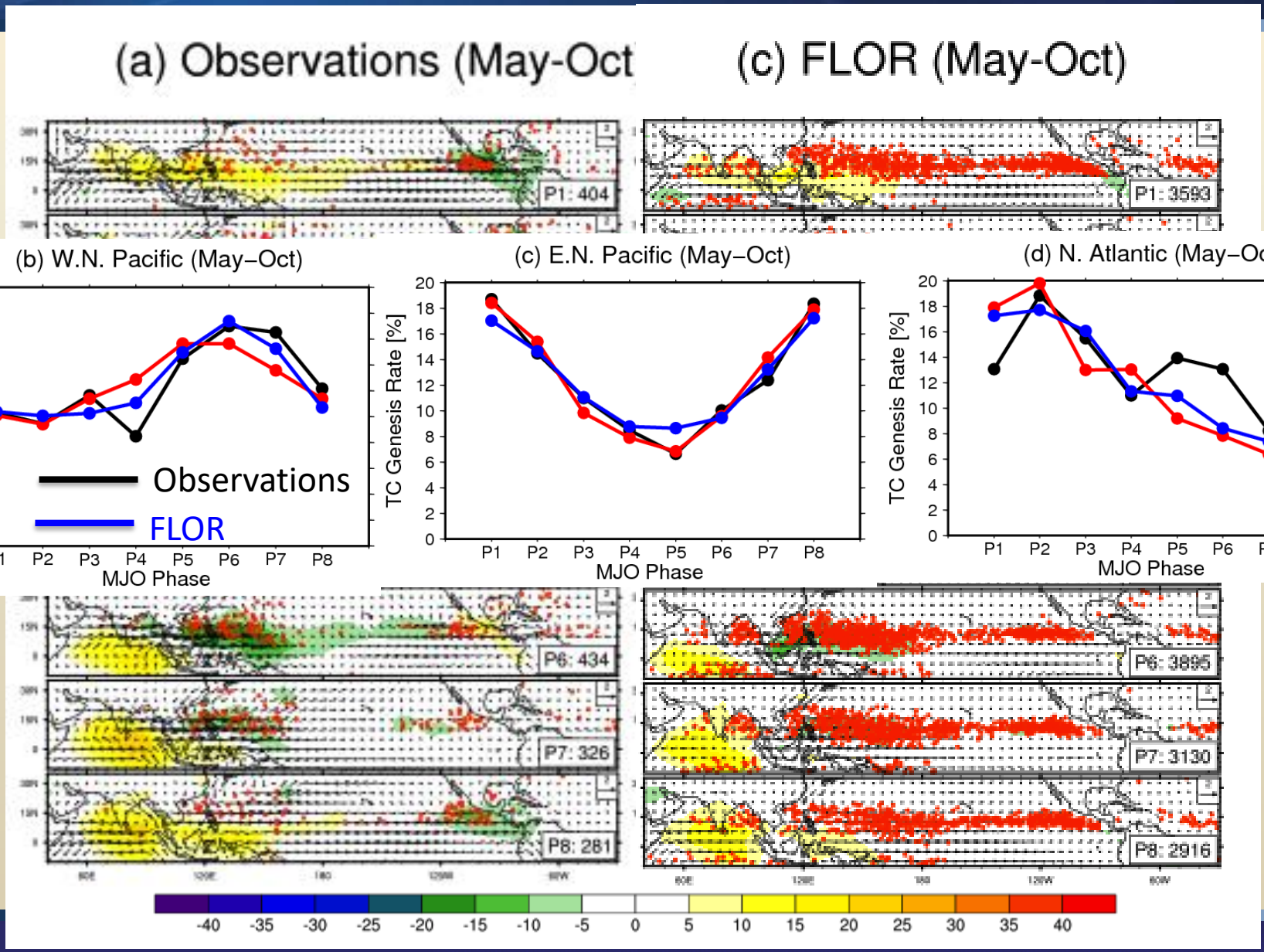
FLOR simulates MJO quite well.

MJO Simulation with FLOR

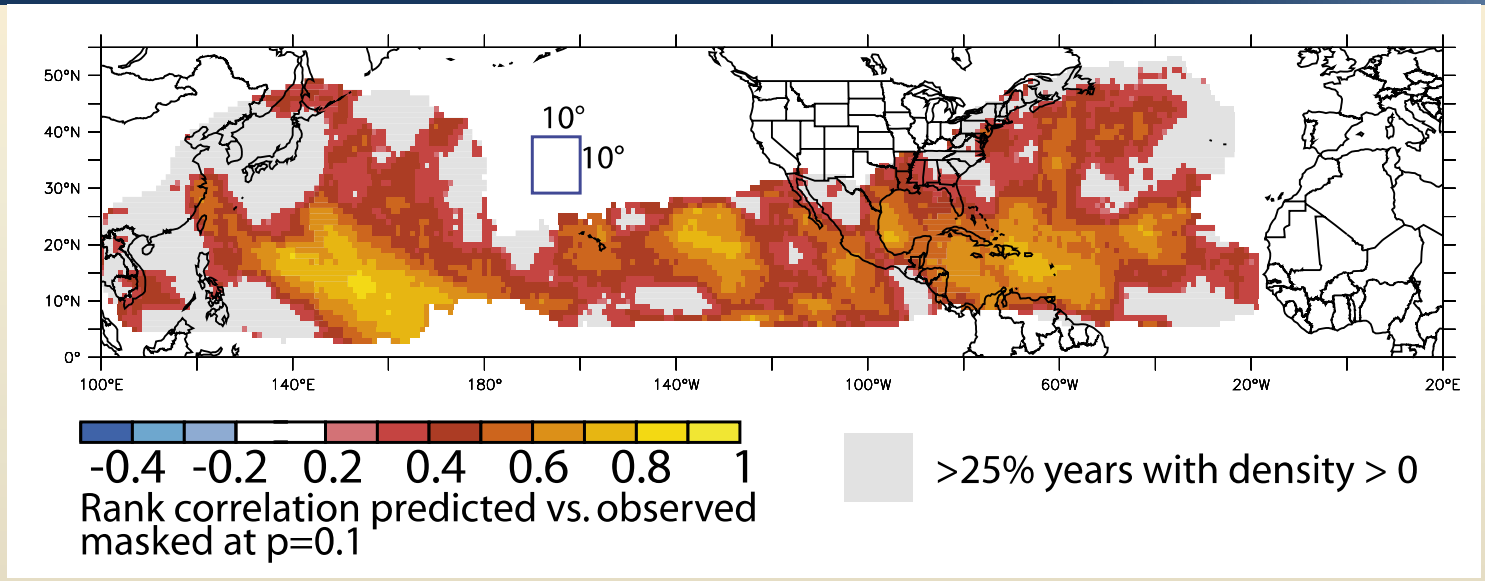


FLOR simulates MJO quite well.

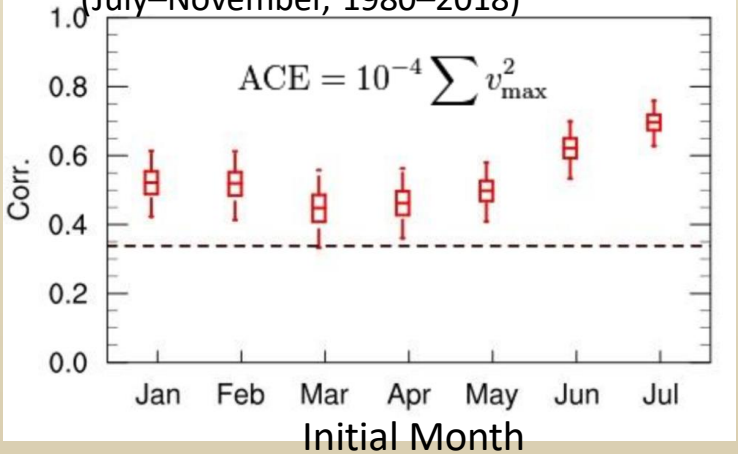
Tropical Cyclone Modulated by MJO



Tropical Cyclone Seasonal Prediction by FLOR



Prediction skill for ACE over North Atlantic (July–November, 1980–2018)



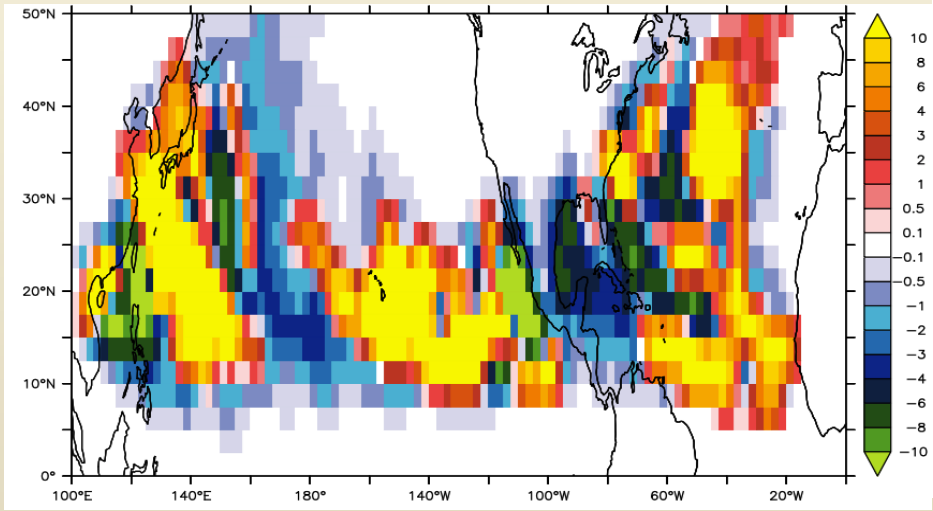
- FLOR has skill in predicting tropical cyclones a few months in advance.

Zhang, G. et al. (2019, *GRL*)

Active 2018 Tropical Cyclone Season in the North Pacific

2018 Tropical Cyclone Season

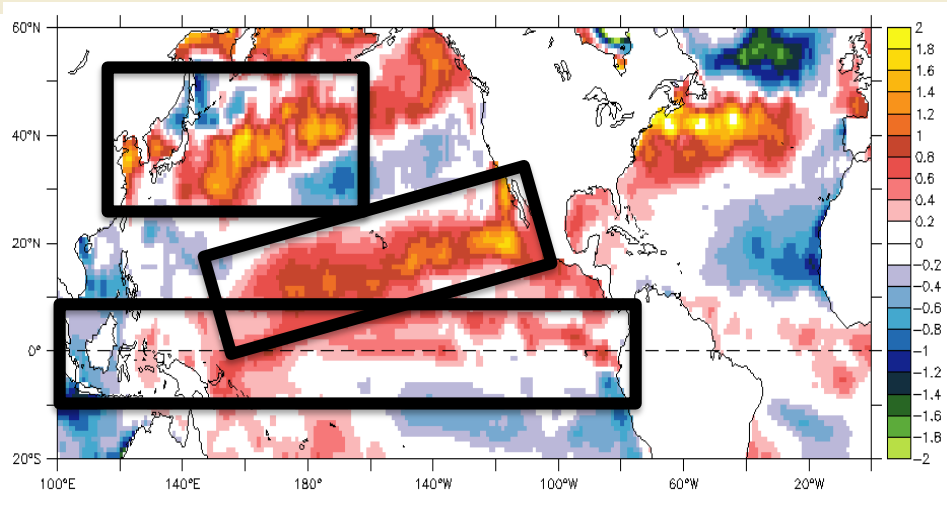
Observed Storm Density Anomaly for 2018 (Jul–Sep)



2018 Accumulated Cyclone Energy (ACE) anomaly relative to 1980–2010 mean

- +60% in the Northern Hemisphere
- +27% in the Western North Pacific
- +140% in the Eastern North Pacific

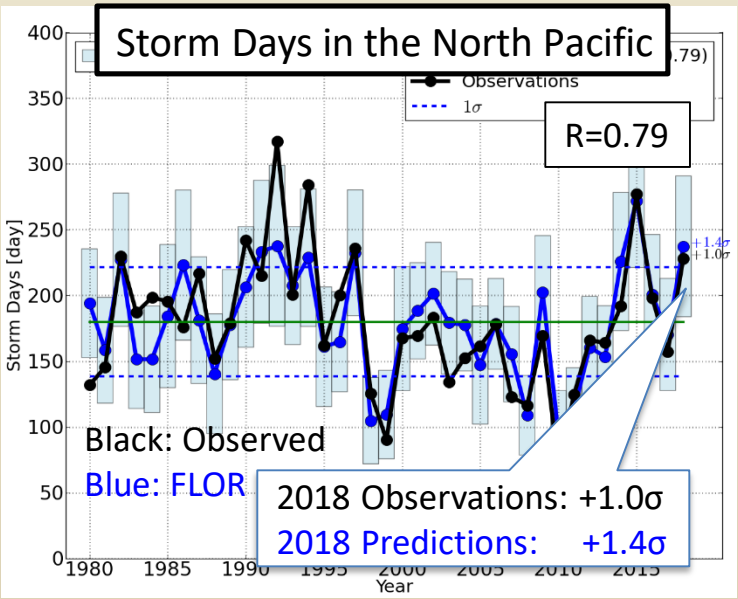
Observed SST Anomaly for 2018 (Jul–Sep)



1. El Niño (Central Pacific El Niño) Development
2. Warmer Kuroshio Current Region
3. Warmer Subtropical Central Pacific (PMM+)

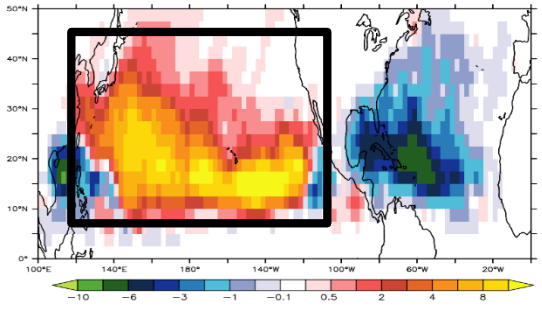
Seasonal Forecasts by GFDL-FLOR

Model	GFDL-FLOR (50km Atmosphere/Land + 100 km Ocean/Ice)
Prediction Period	1-year prediction from July 1st for each year of 1980–2018
Initialization	Ocean is initialized, but atmosphere is not initialized
# Ensembles	36 Ensemble Members (perturbed in initial conditions)

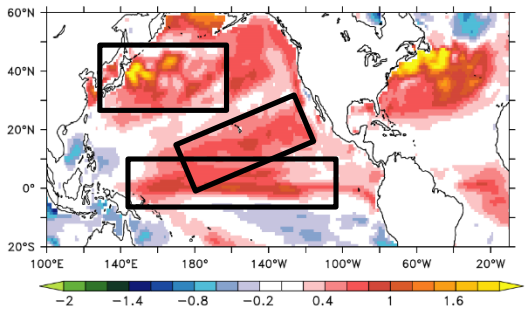


Prediction from 2018 July Initial

Predicted TC Density Anomaly



Predicted SST Anomaly



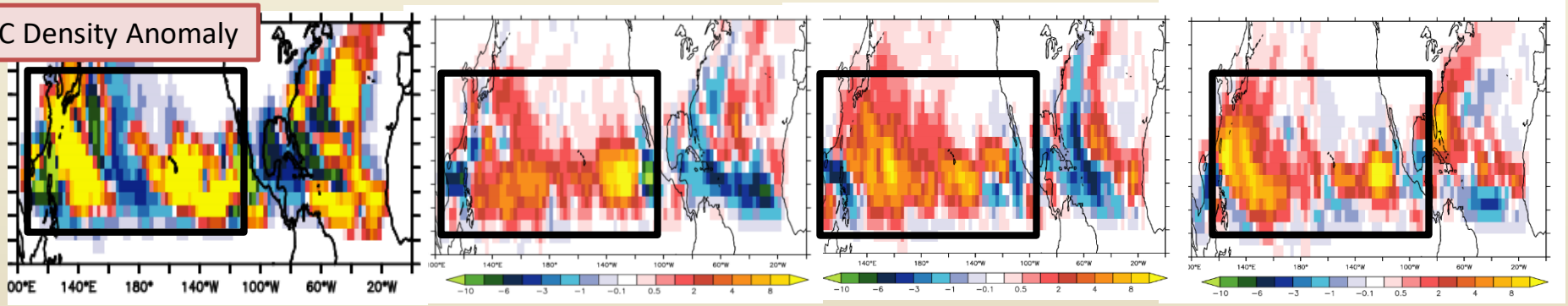
FLOR predicted active 2018 storm season and higher SST in the Pacific Ocean.

Real-time Seasonal Predictions for 2018

Predicted Storm Density Anomaly for **2018 July–November** from different initial months

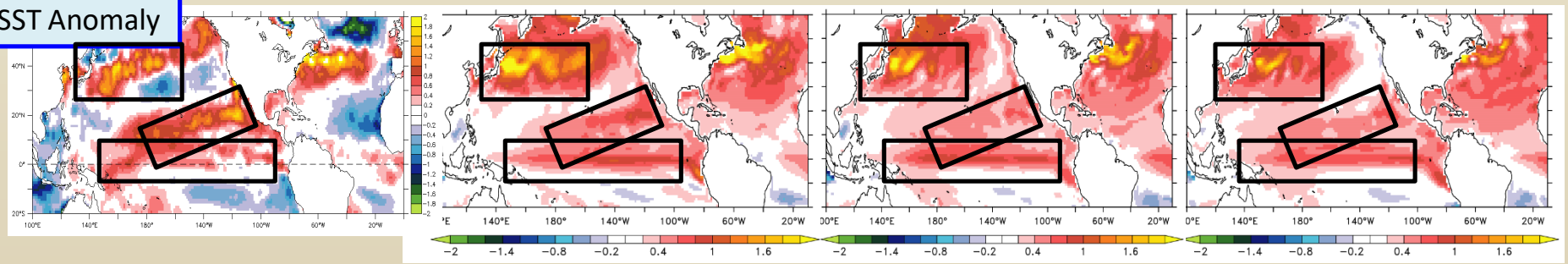
Observations (July-Sep) | *April Initial Prediction* | *March Initial Prediction* | *February Initial Prediction*

TC Density Anomaly



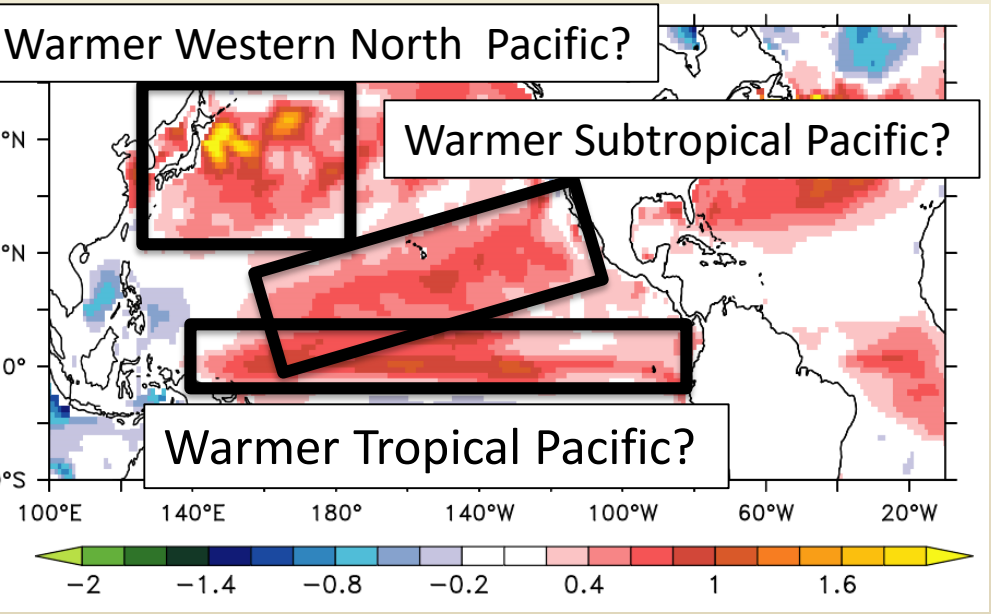
Observations (July-Sep) | *April Initial Prediction* | *March Initial Prediction* | *February Initial Predictiton*

SST Anomaly

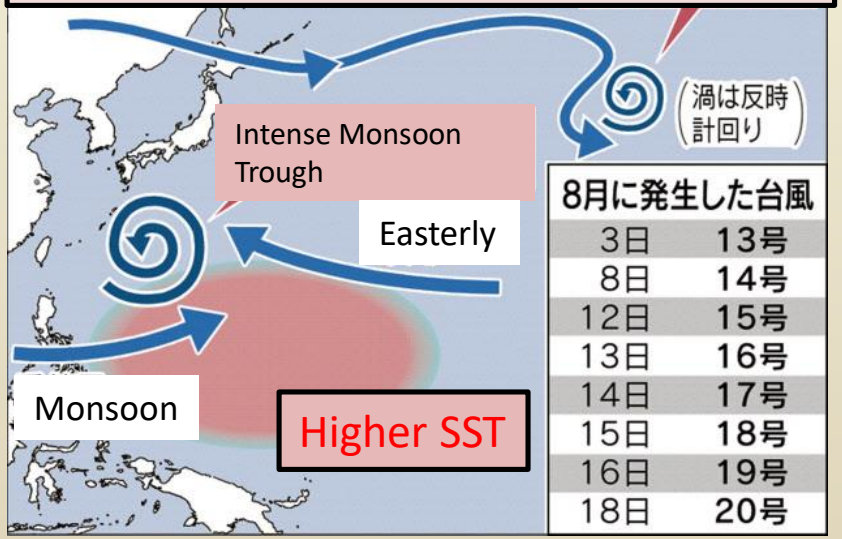


Active 2018 storm season in the North Pacific as well as SST anomaly was well predicted even from Feb 2018.

What caused the active storm season in the North Pacific?



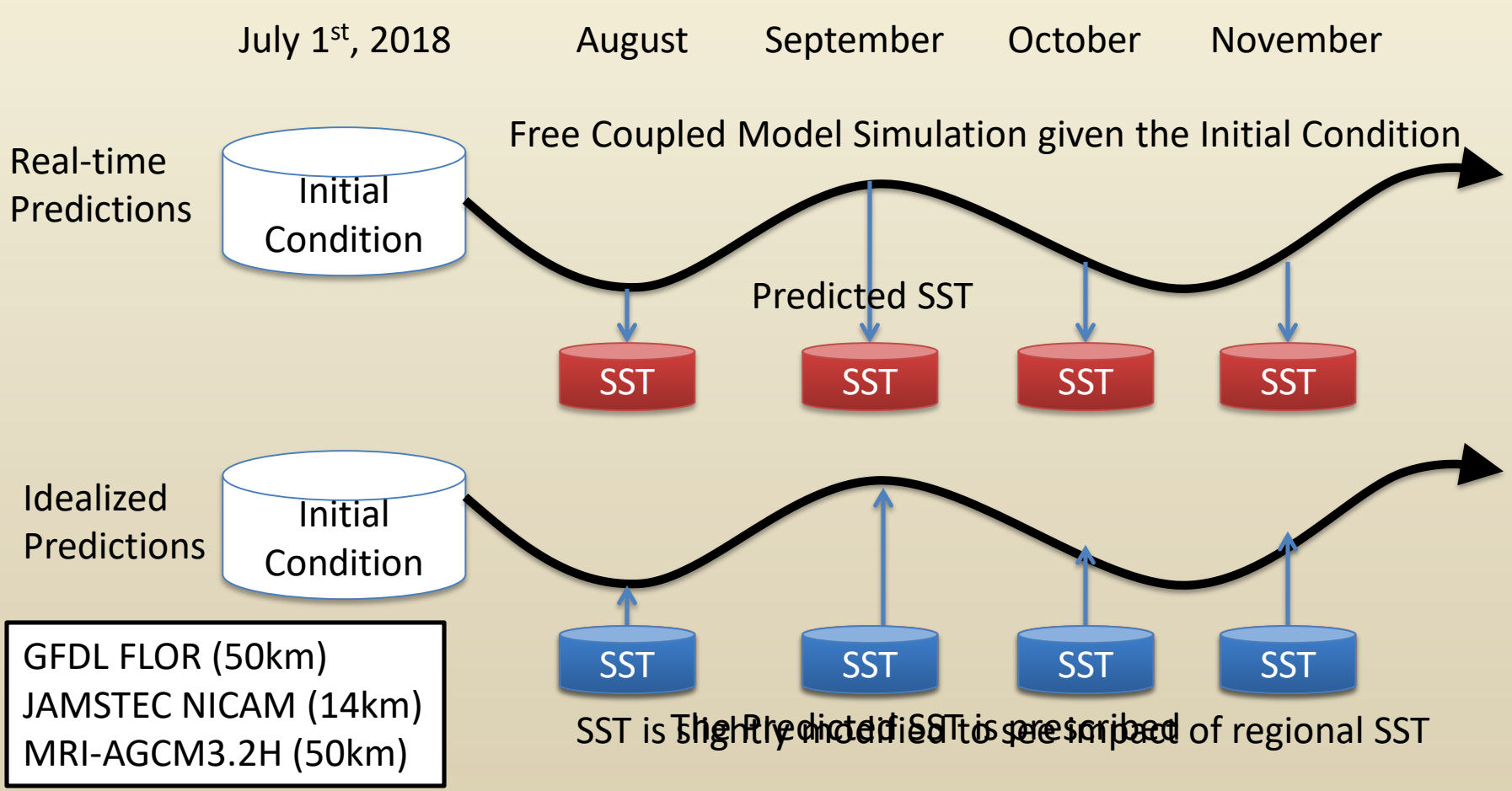
A report issued by JMA on the active typhoon season in 2018



JMA attributes this active typhoons to

1. Higher SST in the Western North Pacific
2. Intense Monsoon Trough

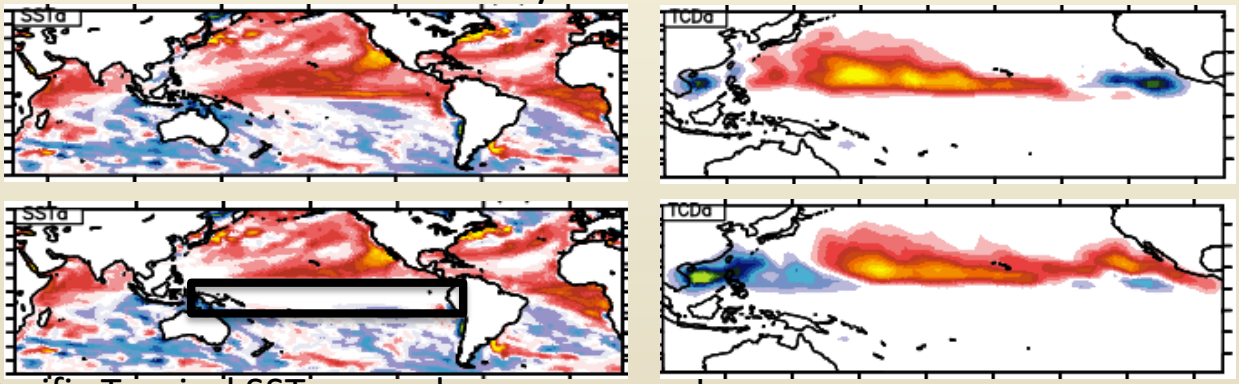
Idealized Seasonal Experiments



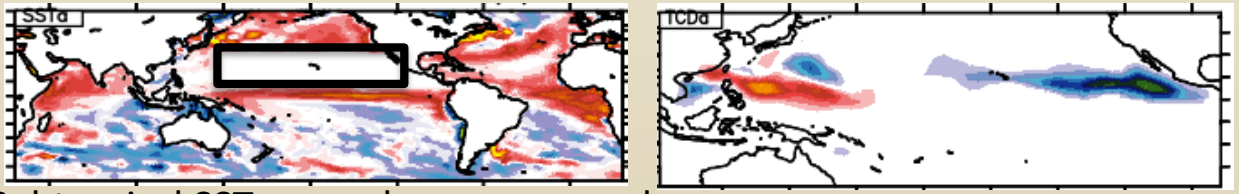
Idealized SST-Prescribed Seasonal Prediction

Prescribed SST Anomaly

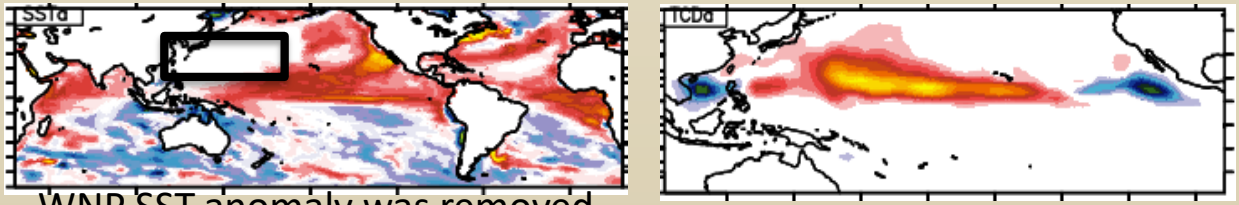
Predicted TC Density Anomaly (3 Model Mean)



Pacific Tropical SST anomaly was removed.



Subtropical SST anomaly was removed.



WNP SST anomaly was removed.

The 2018 active storm season in the North Pacific is explained mainly by the SST anomaly over the subtropical Pacific.

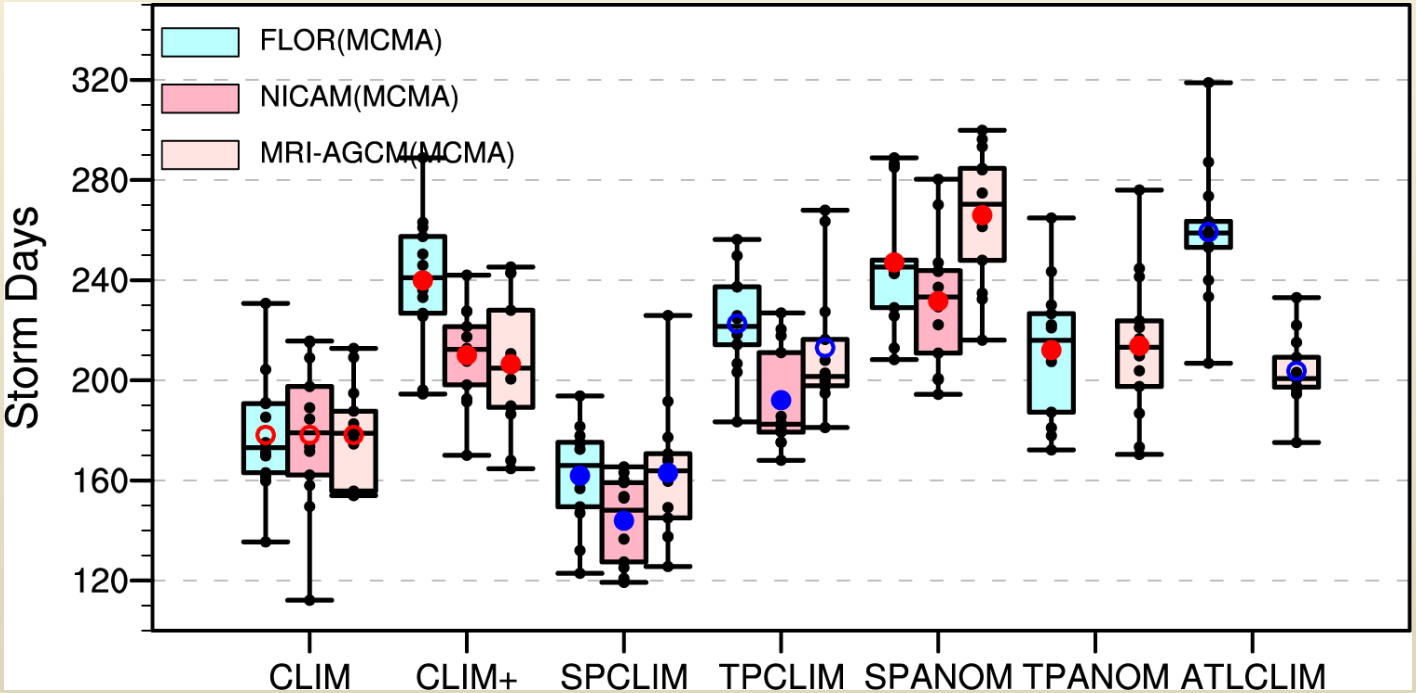
Moderate El Niño ✗

Warmer Subtropical Pacific ✓

Warmer W.N. Pacific ✗

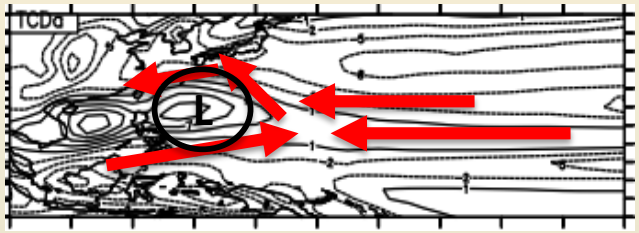
Consistency among the models

Basin-total Storm Days for each experiment and each model



The three models are qualitatively consistent among the idealized seasonal predictions.

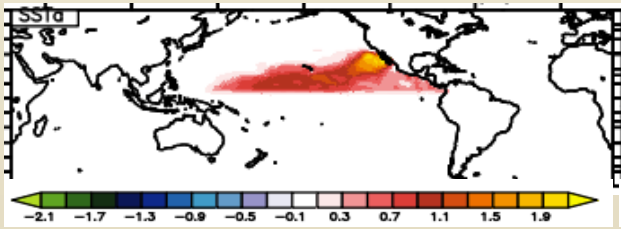
Eastward Shift in Monsoon Trough

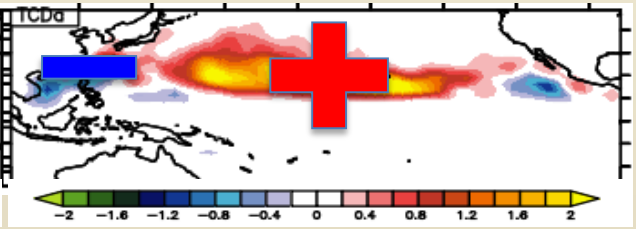


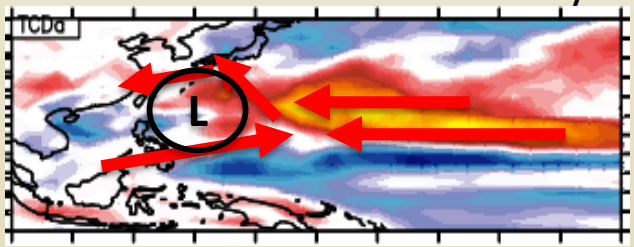
Prescribed SST Anomaly

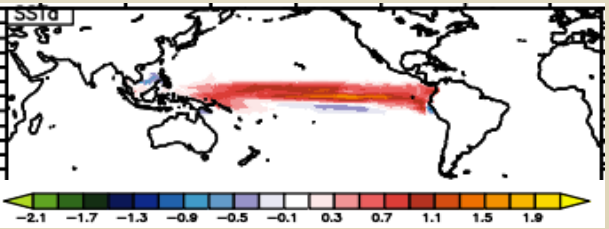
Predicted TC Density Anomaly

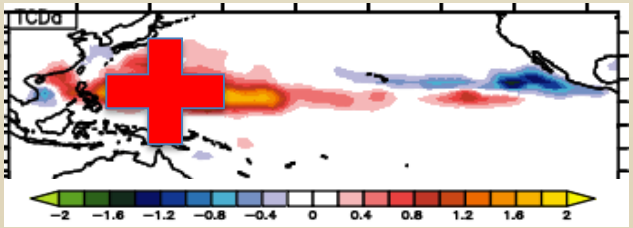
Predicted Vort 850 Anomaly





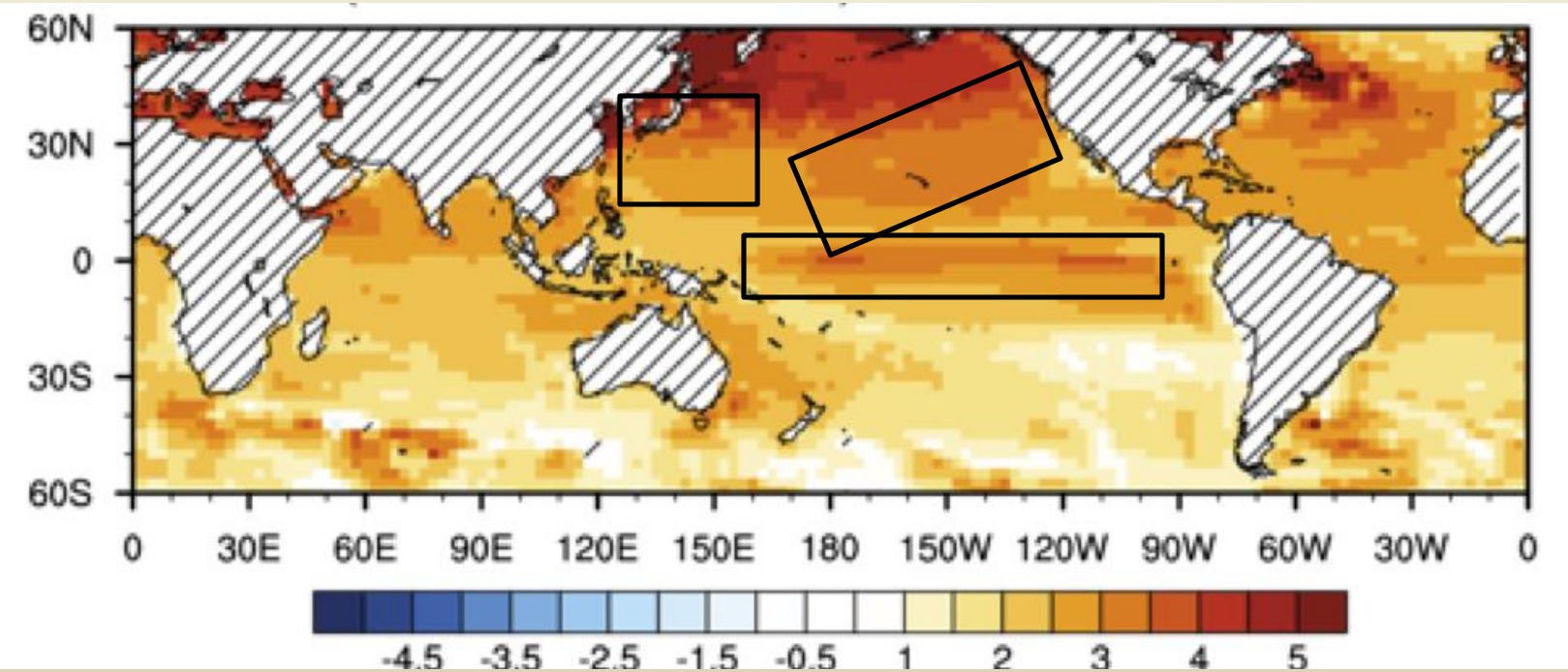






Potential Impact of Anthropogenic Forcing on Active 2018 TC Season in North Pacific

Projected Future Changes in SST by CMIP5 models
RCP8.5 (2081-2100) minus present day (1982-2012)



Similar SST changes to the 2018 SST anomaly.

However, it is impossible to distinguish how much 2018 SST anomaly comes from increases in anthropogenic forcing.

Future Simulations

Present-day July 1st, 2018 August September October November

CO_2=2018 level

Idealized Predictions

Initial Condition

GFDL FLOR (50km)
MRI-AGCM3.2H (50km)

SST_p SST_p SST_p SST_p

SST_p = Present-day Mean SST (1982–2012)

Future July 1st, 209X August September October November

CO_2=2090 level under the RCP8.5 scenario

Idealized Predictions

Restart file from a long-term RCP8.5 simulation

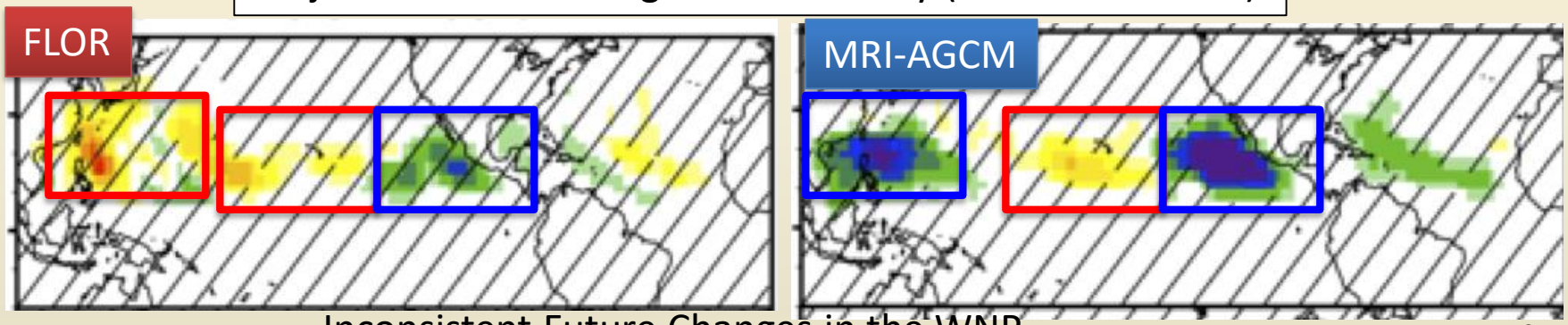
GFDL FLOR (50km)
MRI-AGCM3.2H (50km)

SST_f SST_f SST_f SST_f

SST_f = Projected Mean future SST by the CMIP5 models (2081–2100)

Results of Future Simulations

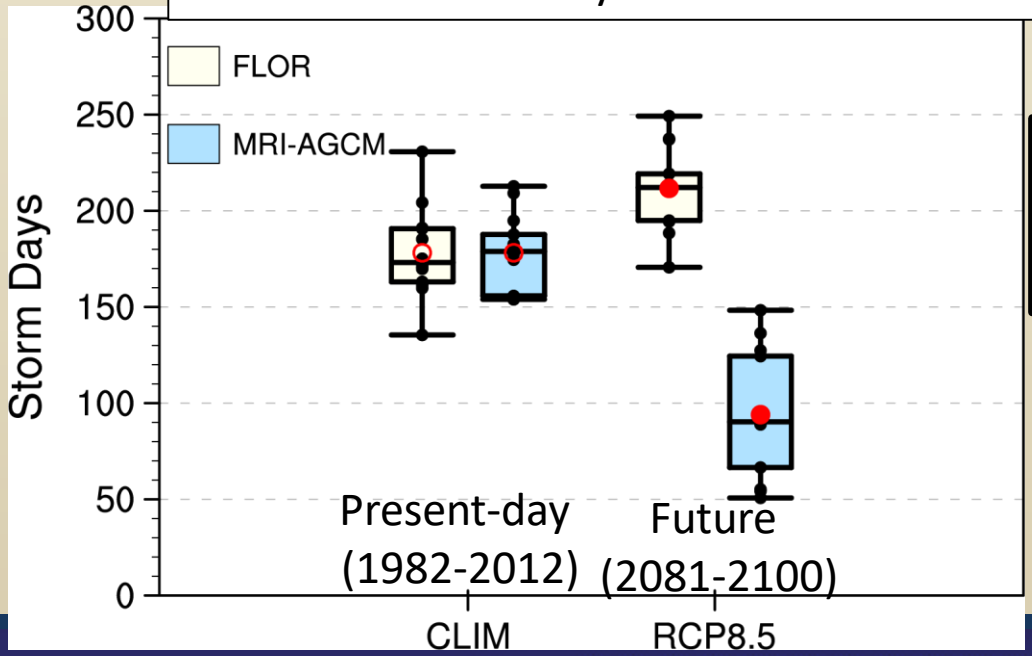
Projected Future Changes in TC Density (Future – Present)



Inconsistent Future Changes in the WNP

Slash : Not statistically significant at 95% level

Basin-Total Storm Days in the North Pacific



FLOR projects an increase in storm days, whereas MRI-AGCM projects a decrease in storm days.

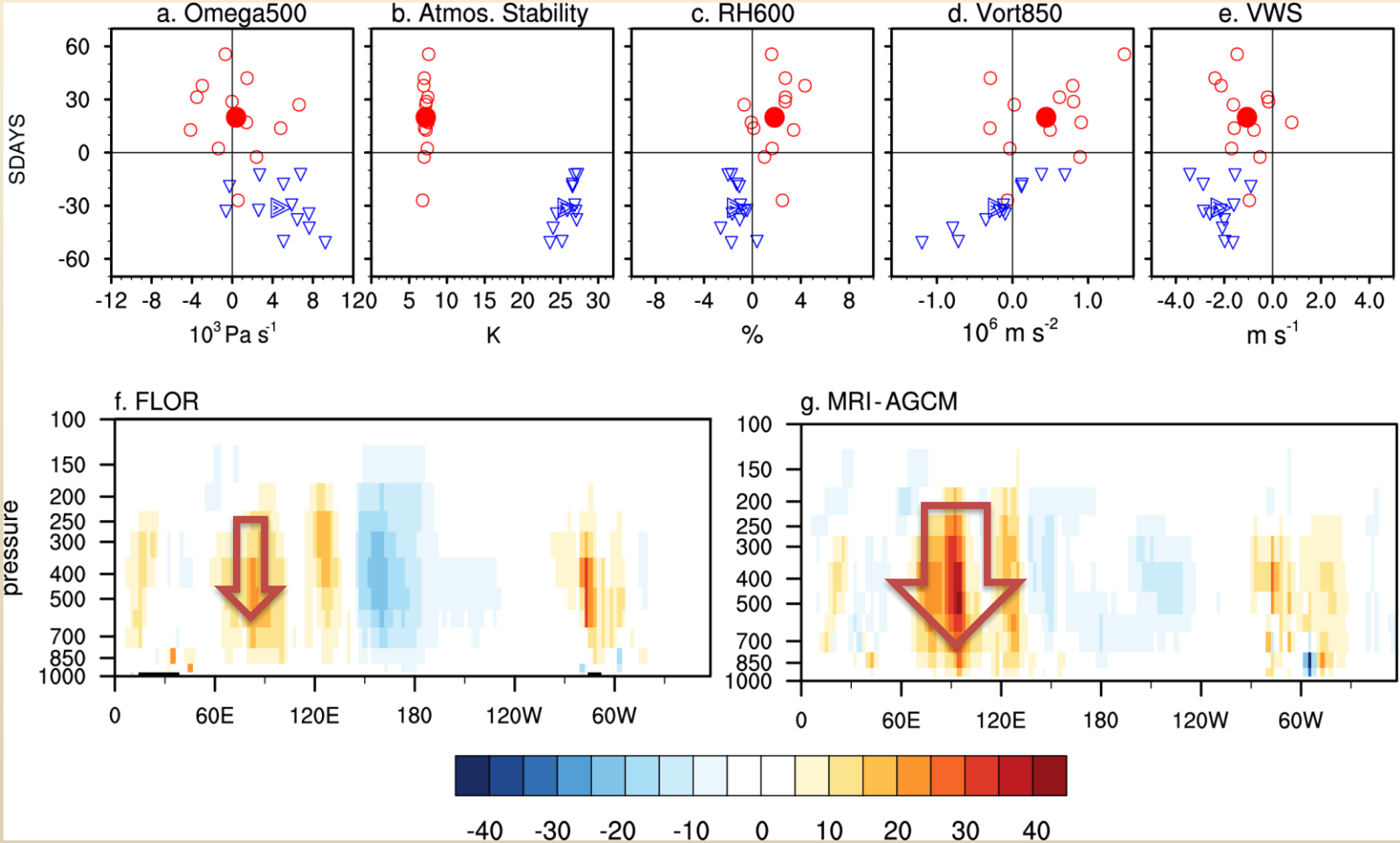
Why is the two model different in future changes?

Storm Days

Red: FLOR

Blue: MRI

Large-scale parameter



Summary

- Seasonal prediction model (GFDL-FLOR) could predict active 2018 TC season in the North Pacific a few months in advance.
- **Subtropical Pacific SST anomaly** associated with positive PMM is a primary reason for the active 2018 storm season in the North Pacific.
- **Three models (FLOR, NICAM, MRI) are consistent** through the idealized seasonal predictions for the 2018 summer season.
- Two models show different sign of the future changes in TC frequency of occurrence in the WNP, resulting in **significant uncertainty in future changes** in TC activity in the North Pacific.