Simulation and Prediction of Category 4 and 5 Hurricanes in the High-Resolution GFDL HiFLOR Coupled Climate Model

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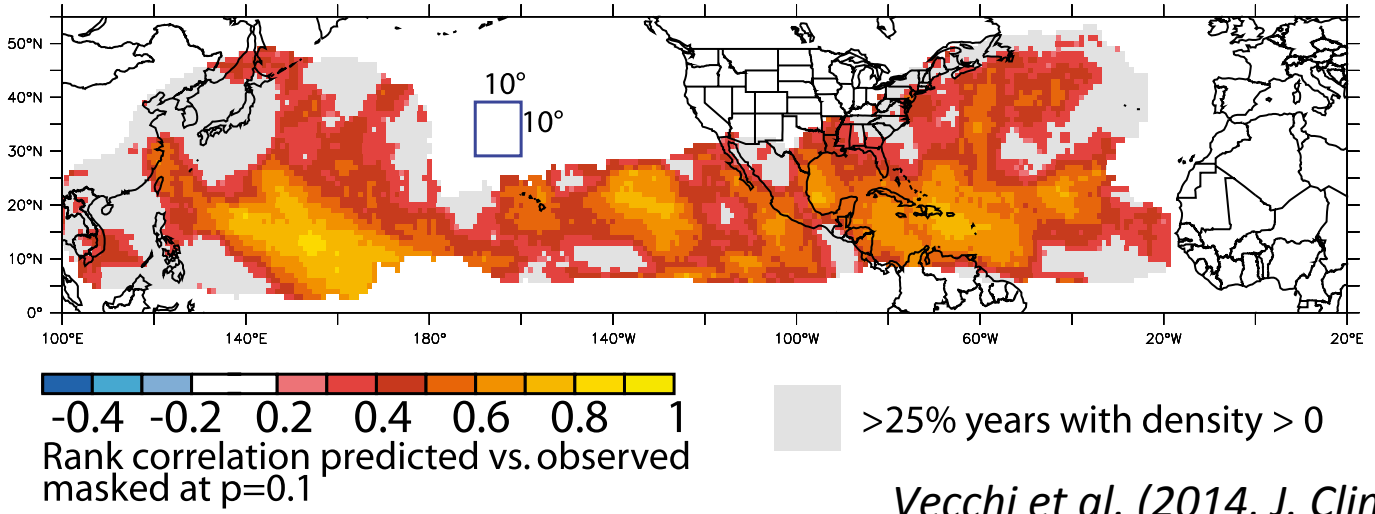
GFDL/Princeton AOS

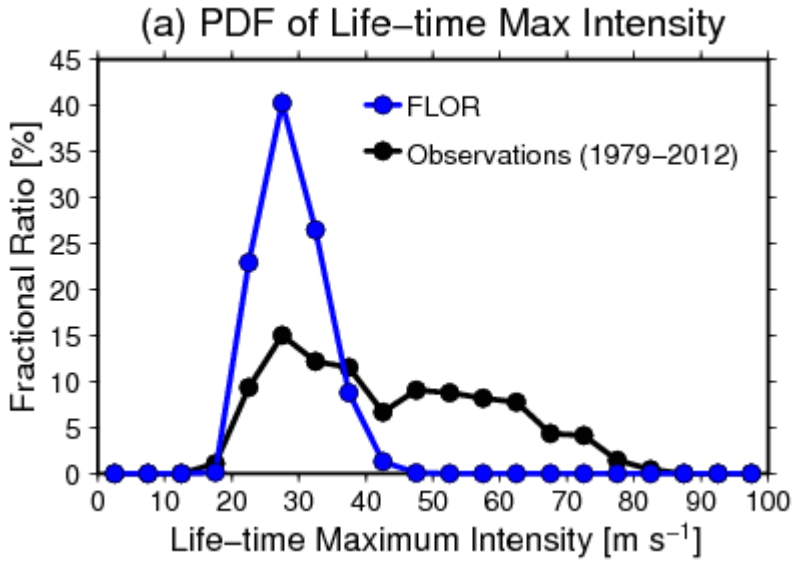
Murakami, H., and coauthors, 2015: Simulation and prediction of Category 4 and 5 hurricanes in the high-resolution GFDL HiFLOR coupled climate model. *J. Climate,* **28,** 9058-9079.

FLOR (**F**orecast-oriented **L**ow **O**cean **R**esolution version of CM2.5)

- CM2.5: Fully coupled model with 50km-mesh atmosphere and 0.25° ocean/sea ice
  FLOR : Fully coupled model with 50km-mesh atmosphere and **1°** ocean/sea ice
- FLOR is a TC-permitting Model



Vecchi et al. (2014, J. Climate)



FLOR critically underestimates frequency of intense TCs of Category 3, 4, and 5.

FLOR vs HiFLOR

	FLOR	HiFLOR
Atmosphere	AM2.5 (Atmosphere model of CM2.5)	
Ocean	MOM4 (Ocean model of CM2.1)	
Resolution	Atmosphere : **50 km**, L32 Ocean: 100 km, L50	Atmosphere : **25 km**, L32 Ocean: 100 km, L50
Dynamics	Hydrostatic, finite difference Dynamical core (Mesinger et al. 1988) with higher-order advection scheme	
Convection	Relaxed Arakawa-Schubert (RAS, Moorthi and Suarez 1992)	
Radiation	Freidenreich and Ramaswamy (1999) Every 3 hour.	
Land Surface	Land Dynamics model (LM3; Milly et al. 2014)	
Minor Changes	‘‘Cubed-sphere’’ grid (Lin 2004; Putman and Lin 2007)	C384 Dynamics (CM4 base): terrine filter.
Simulation Speed	**16-yr simulation per day** using 4000 CPUs	**4-yr simulation per day** using 6000 CPUs

Methodology

Goal To show improvements in climatology, variability and prediction of TCs by HiFLOR relative to FLOR

Experiments

1. SST Restoring Experiment

Period : 1971–2012

Observed time-varying monthly SST is restored at 10-day time scale.

6 ensemble members

2. Control Simulations

300-year free run prescribed by the radiative forcing fixed at the 1990 level

1 member

3. Retrospective Seasonal Forecast

Period : 1990–2015

Initialized at July 1st to predict July-November TCs in the North Atlantic

12 ensemble members

TC Detection

Based on Harris et al. (2016)

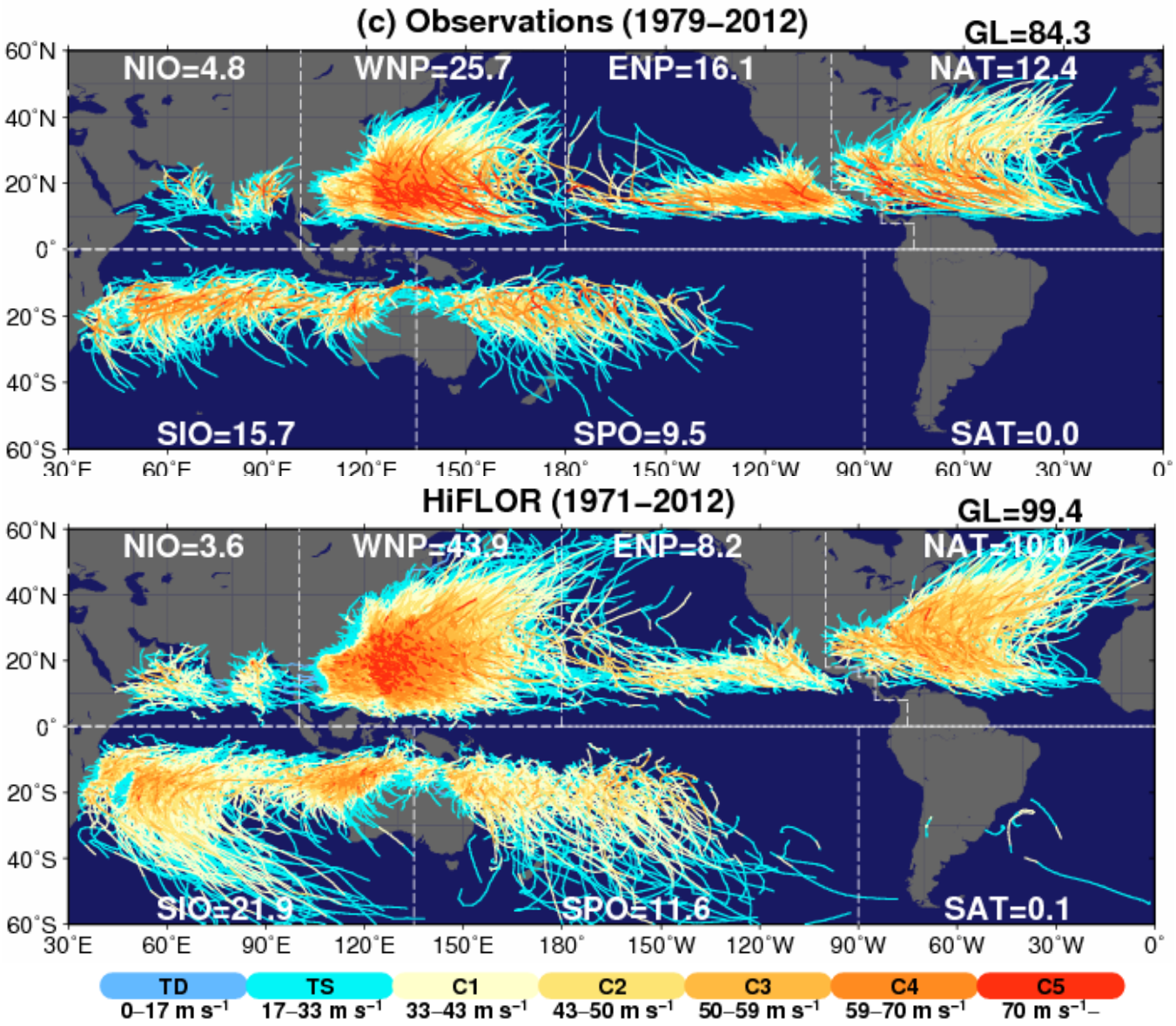
Flood-Fill algorithm is applied to detect SLP minima.

1.0 K (2.0 K) warm core for FLOR (HiFLOR)

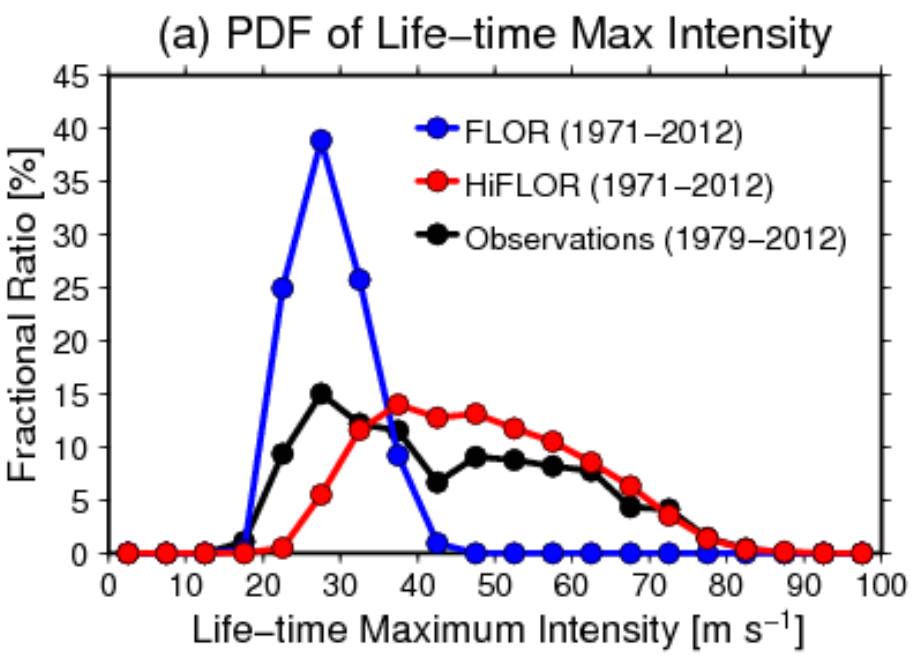
15.75 m/s (17.5m/s) maximum wind speed for FLOR (HiFLOR)

Duration of satisfaction of the above criteria should be more than 36 hours

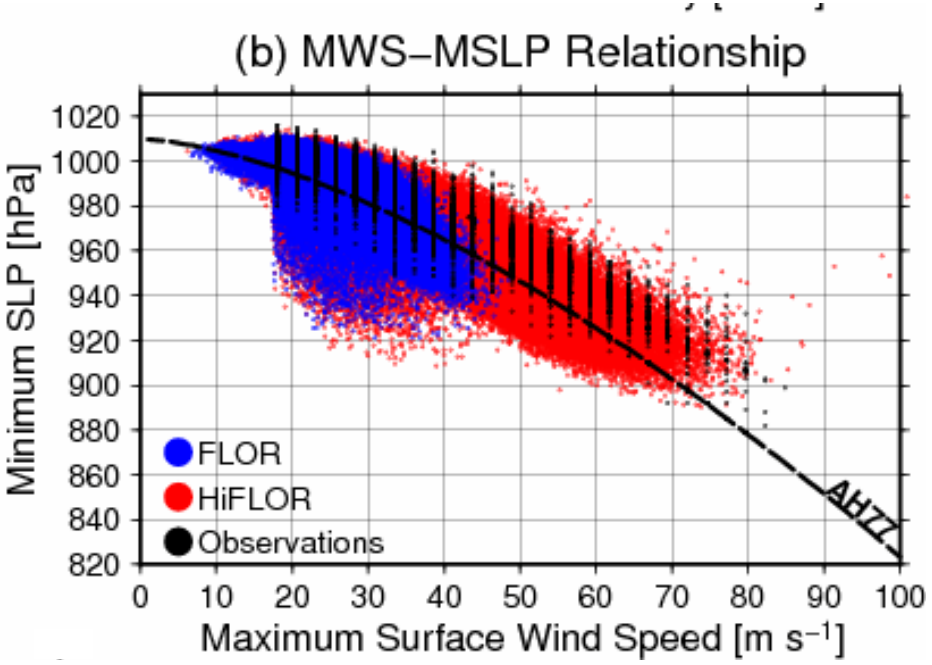
Improved Simulation of Tropical Cyclones (SST Restoring Experiments)



Improvement in TC intensity and TC structure

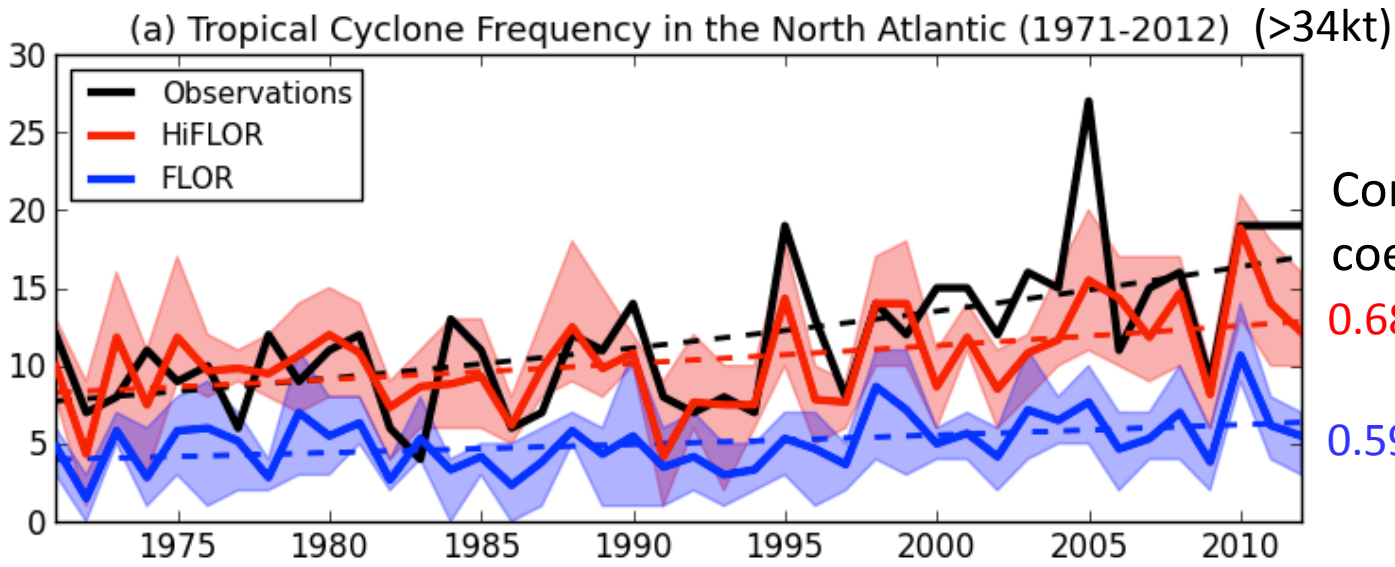


·TC intensity is substantially improved in HiFLOR.



MSW-MSLP relationship is reasonable in HiFLOR

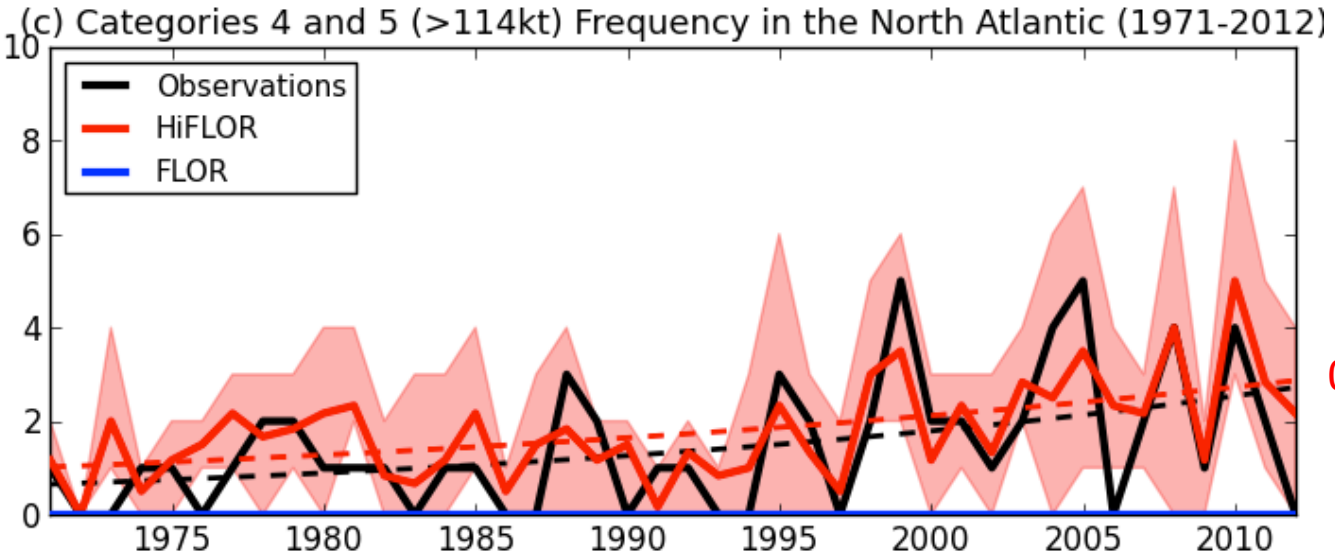
Interannual Variation of Tropical Storms and Cat 4-5 hurricanes in the North Atlantic



Correlation coefficient

0.68

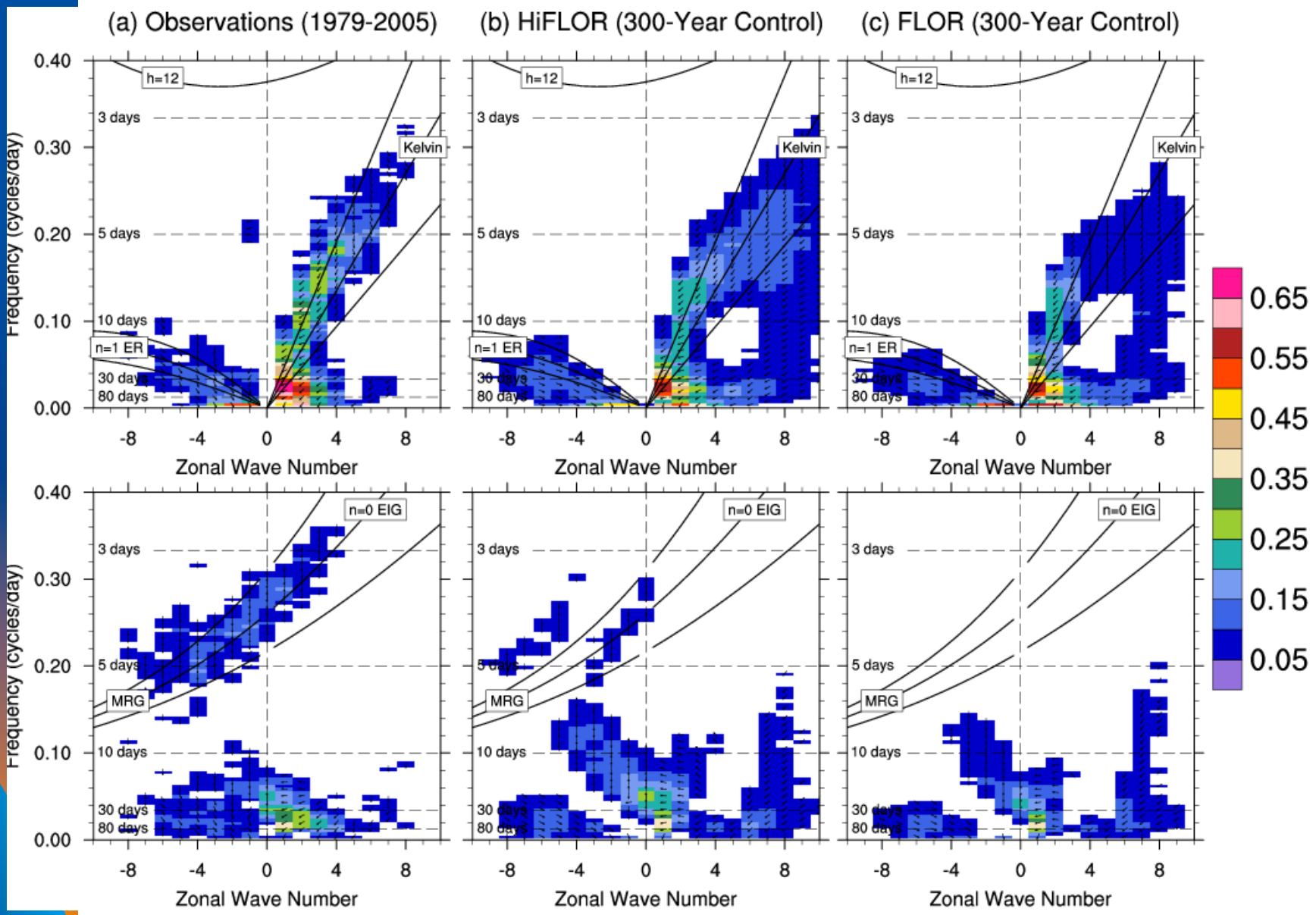
0.59



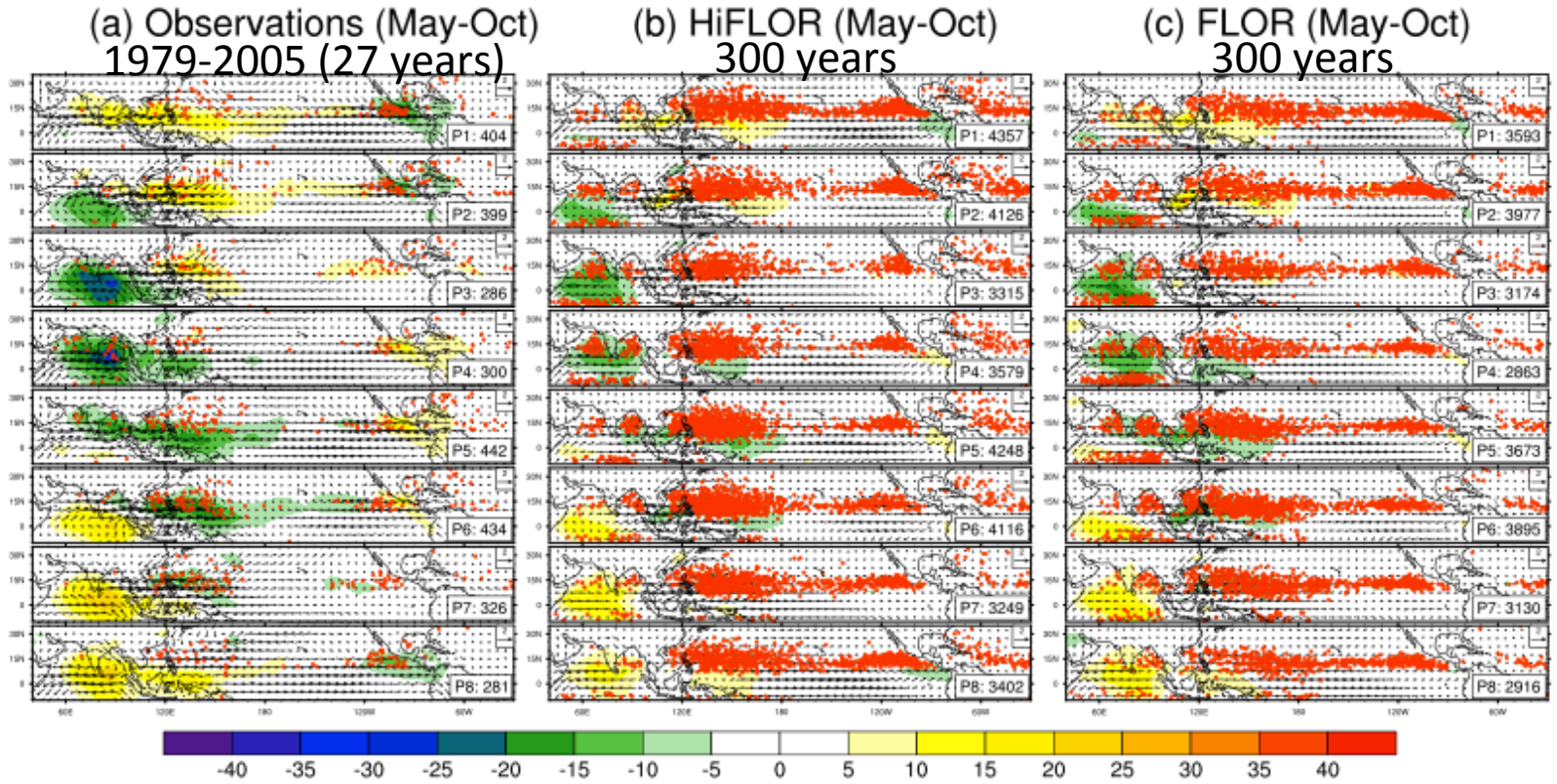
0.63

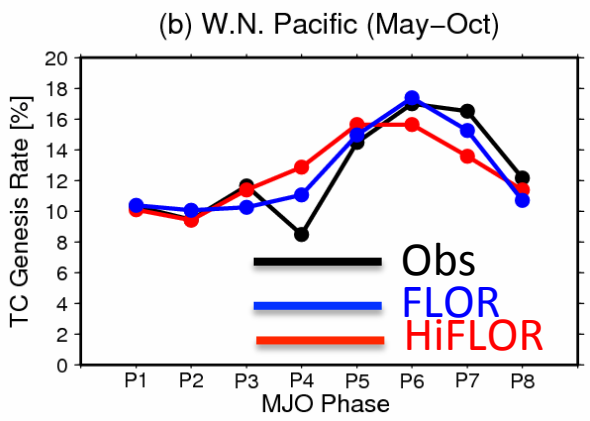
It is for the first time that a global coupled model reproduces observed interannual variation of C4-5 hurricanes.

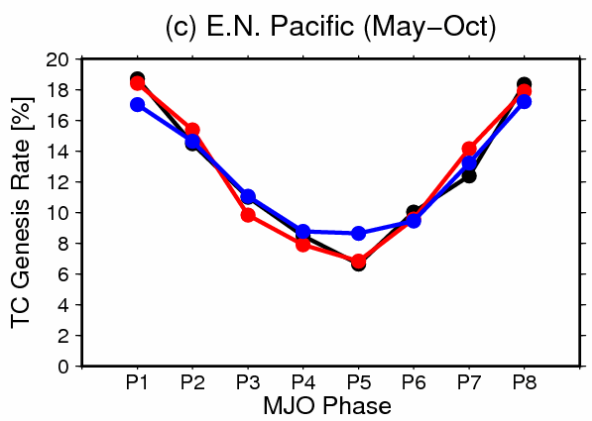
MJO (300-yr Control Experiment)

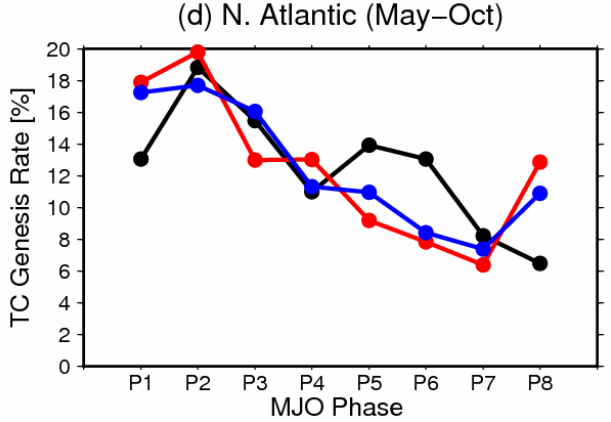


TC genesis modulated by MJO (300-yr Control Experiment)



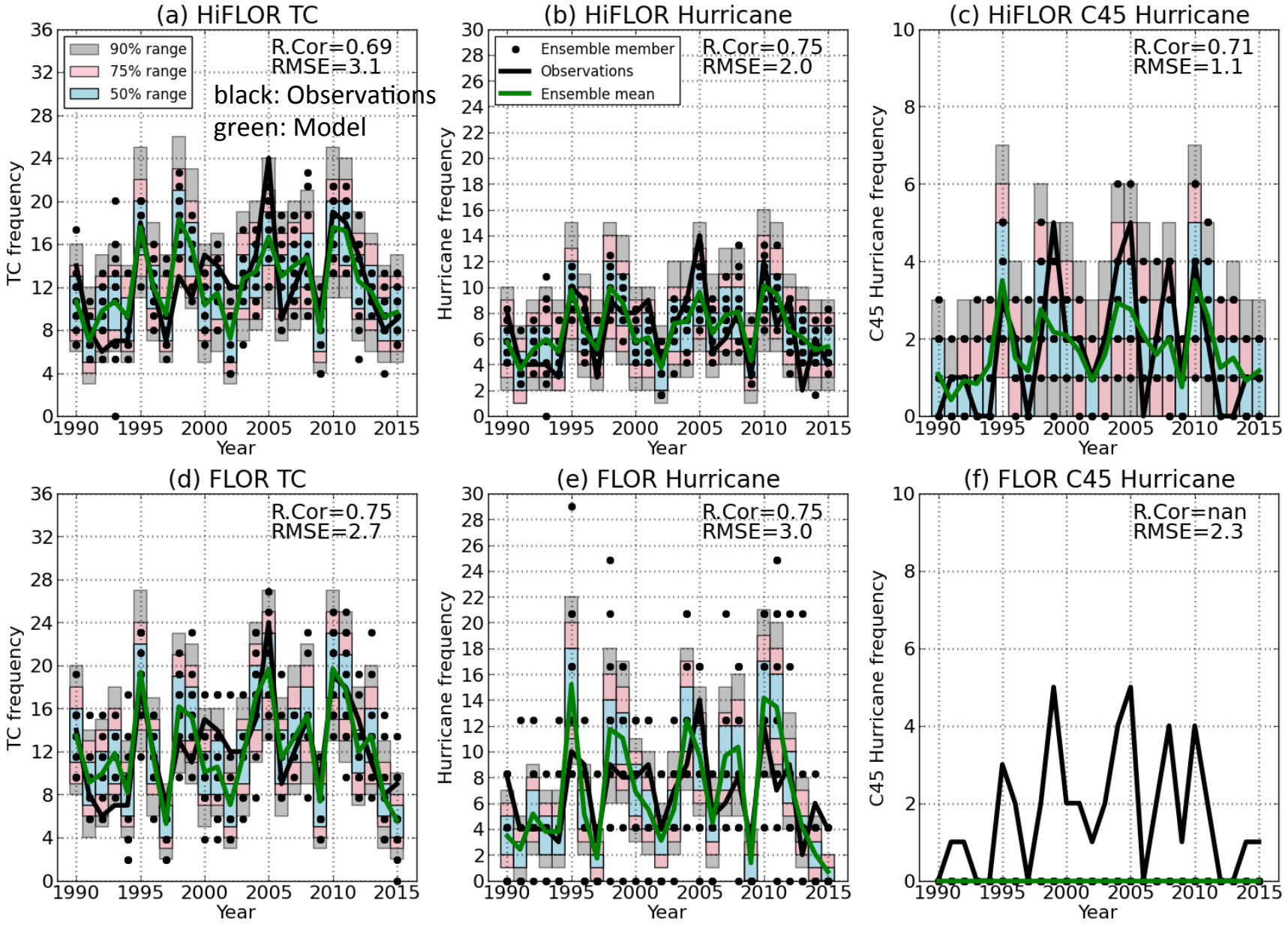




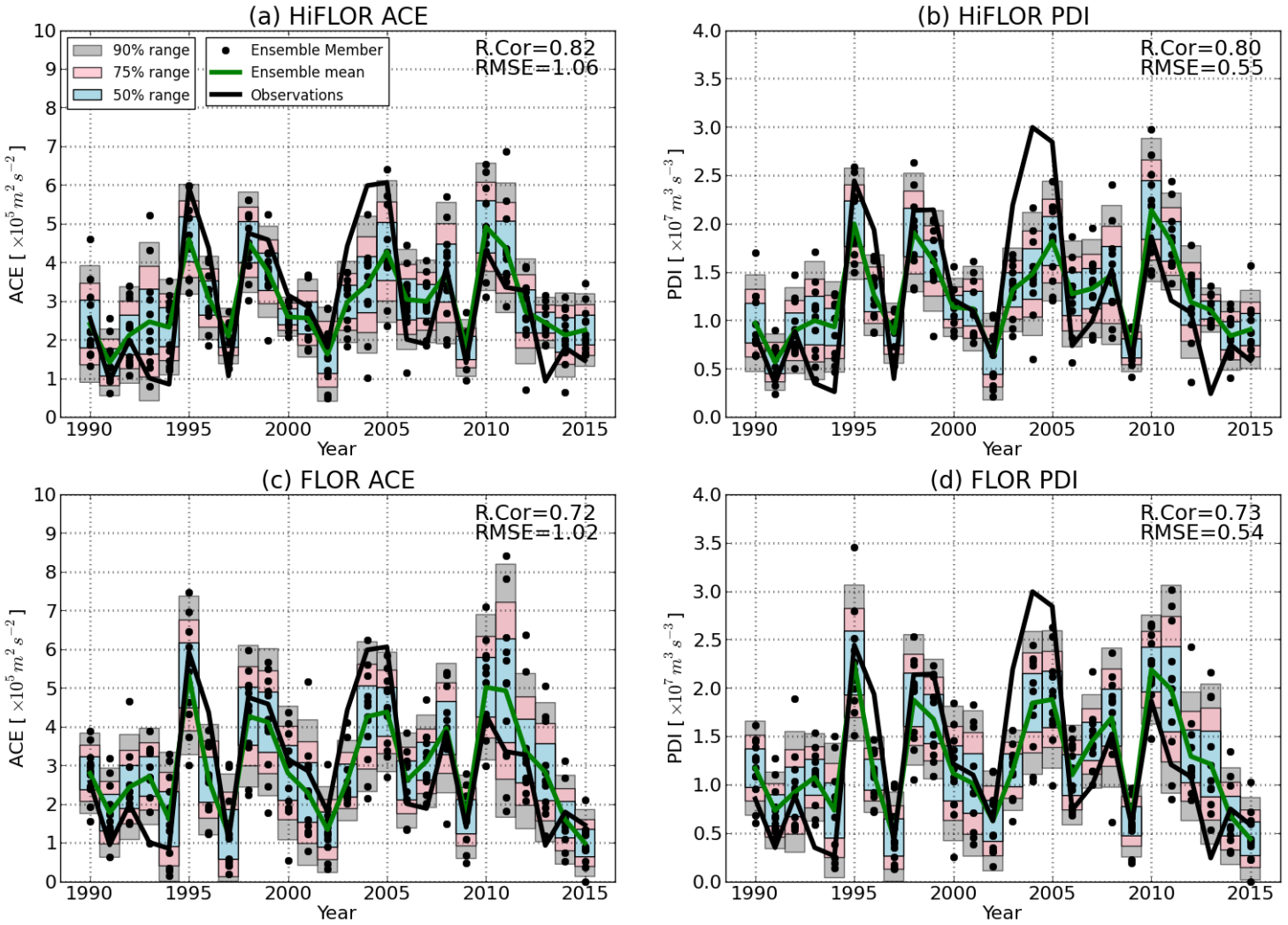


Retrospective Seasonal Forecast

(July initial forecast to predict Jul–Nov TC frequency in the North Atlantic)



Skill in Retrospective TC Prediction for ACE and PDI in the North Atlantic

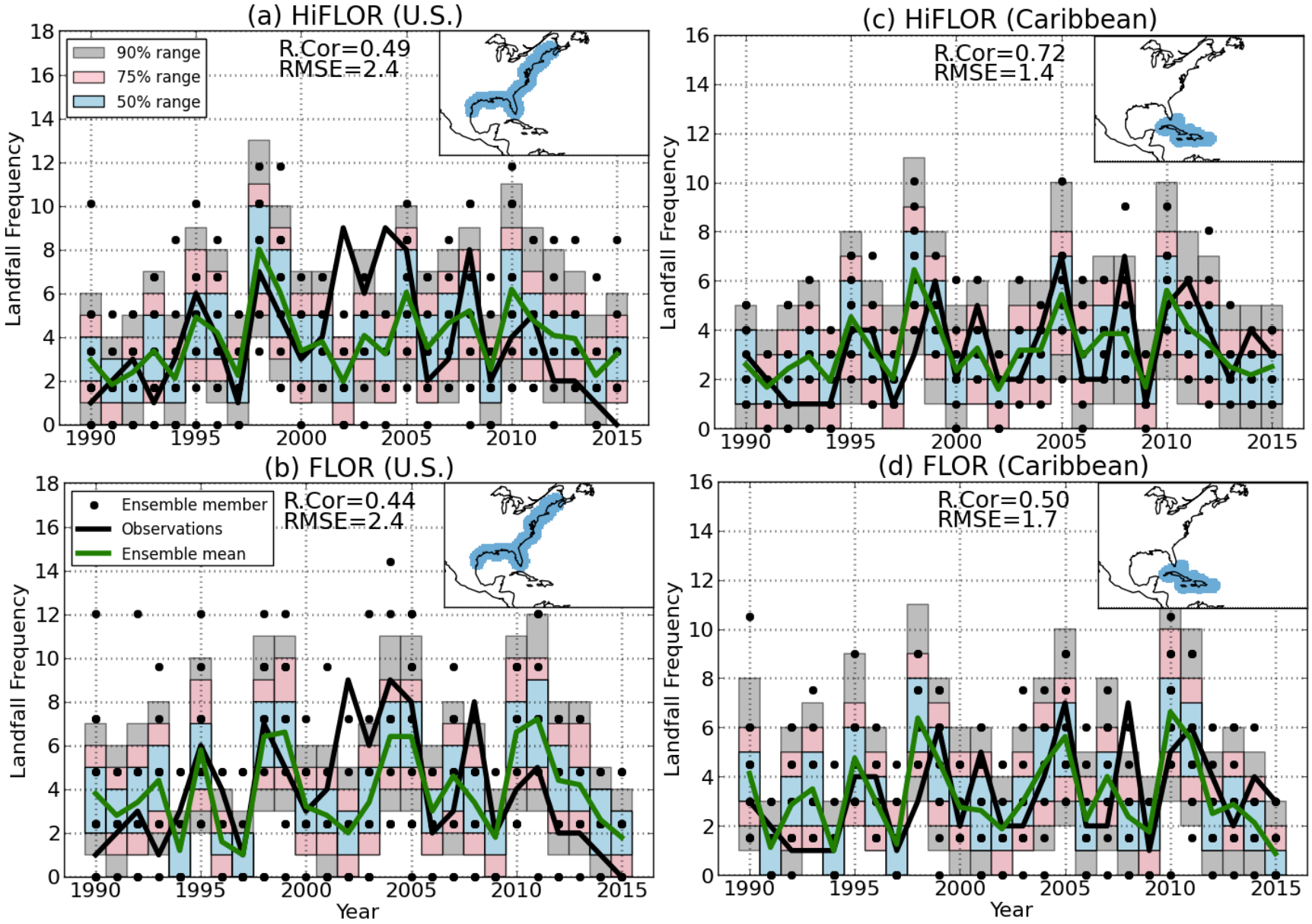


ACE (**PDI**) is defined as an integrated quantity of **square** (**cube**) of maximum surface wind velocity throughout the lifetime of tropical cyclones.

$$ACE \equiv \sum_{n=1}^{N}\sum_{t=1}^{T} w_{\max}^{2}(n,t) \qquad PDI \equiv \sum_{n=1}^{N}\sum_{t=1}^{T} w_{\max}^{3}(n,t)$$

N: Total TC genesis number
T : Life span for each TC

Skill in Retrospective Landfalling TC Prediction



Summary (1/2)

- GFDL developed a 25-km mesh coupled model of HiFLOR.

- HiFLOR is able to simulate extremely intense TCs (Categories 4 and 5) reasonably well compared to observations.

- HiFLOR exhibited high correlation coefficients with the observed interannual variations of hurricanes (r=0.77) and categories 4 and 5 hurricanes (r=0.63) in the North Atlantic.

- Both FLOR and HiFLOR exhibit a strong 30–80-day Madden-Julian Oscillation, whose active phase enhances TC genesis as observed, indicating potential skill in predicting TC genesis events at intraseasonal time scales.

Summary (2/2)

- HiFLOR can skilfully predict year-to-year variations in intense hurricanes of C4-5 in the North Atlantic a few months in advance (R=0.7 for forecasts on 1-July, with July-November being peak hurricane season).

- HiFLOR also has skill in predicting basin total ACE, PDI and landfall TC frequency in a few months in advance.