EXPERIMENTAL S-I HURRICANE FORECASTS FROM WINTER

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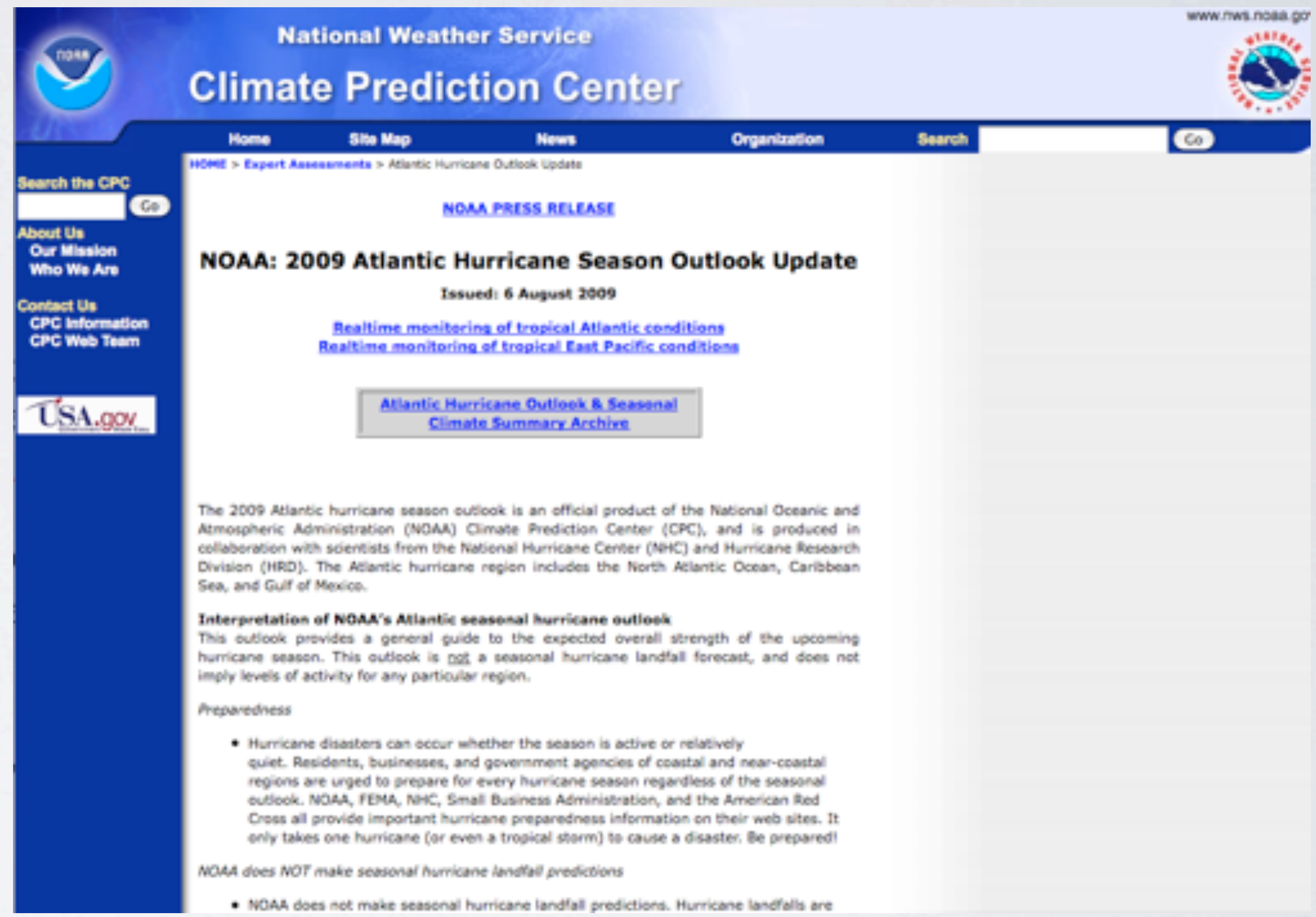
Seasonal Hurricane Forecasts Initialized in Boreal mid-Spring to early-Summer Are: Feasible, Potentially Skillful and Made

- Statistical prediction schemes (e.g., Gray, Klotzbach and Gray, Elsner et al)
- Dynamical prediction schemes (e.g., Vitart , Vitart et al)
- Hybrid schemes (e.g., Wang et al, LaRow et al, Zhao et al)



GOAL:

USE **UNDERSTANDING AND TOOLS** DEVELOPED FOR EXPLORING THE LINK OF **CLIMATE CHANGE AND HURRICANES** TO PUSH WINDOW OF NORTH ATLANTIC **SEASONAL** HURRICANE FORECASTS TO **WINTER**, WITH **SKILL** AND QUANTIFIED **UNCERTAINTY**

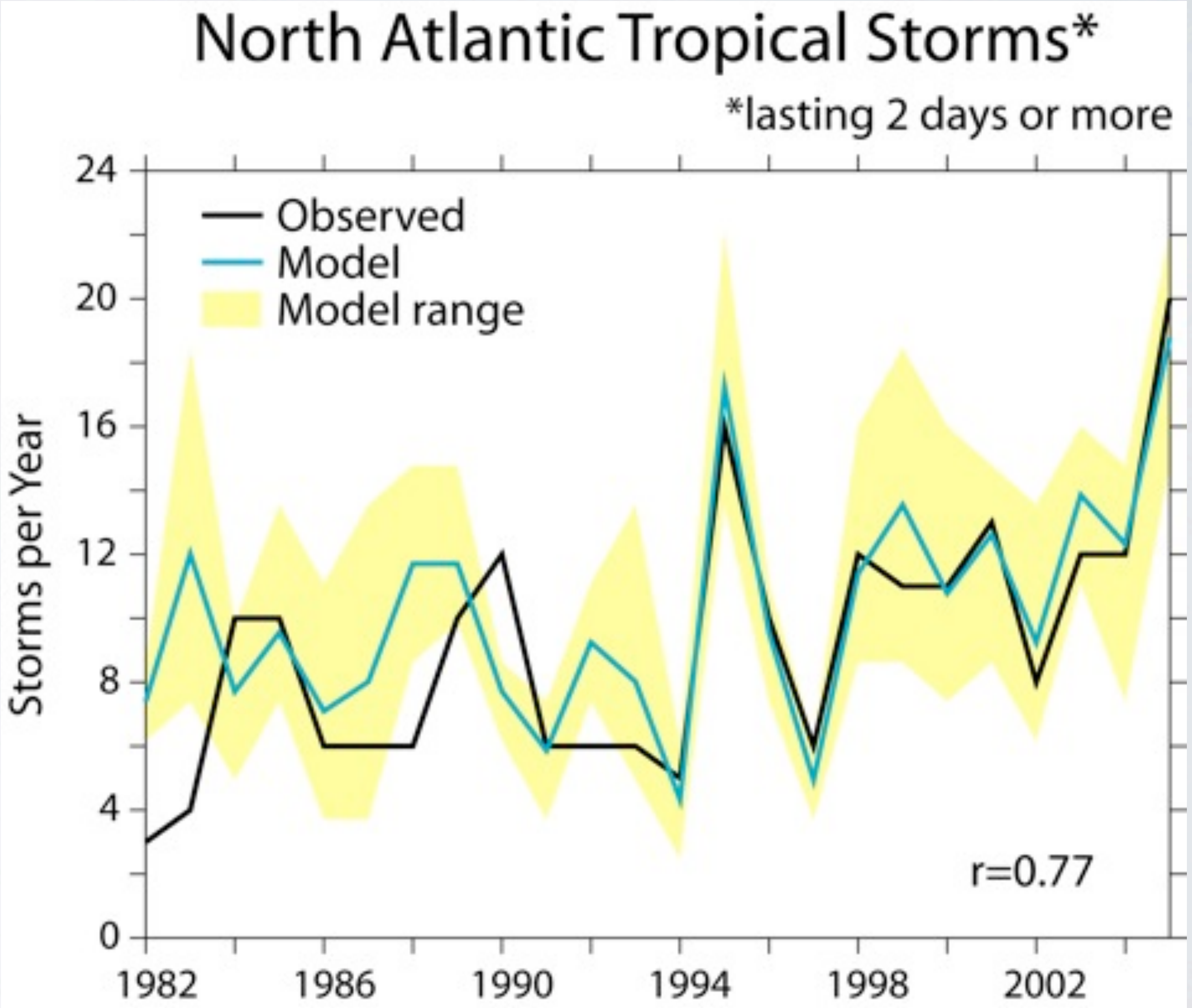
GFDL C-X HIRAM GCMS

Family of global atmospheric models designed for better-representing tropical cyclone frequency. **C90 - 1°, C180=1/2°**, C360=1/4°, C720=1/8°, C2000=5km

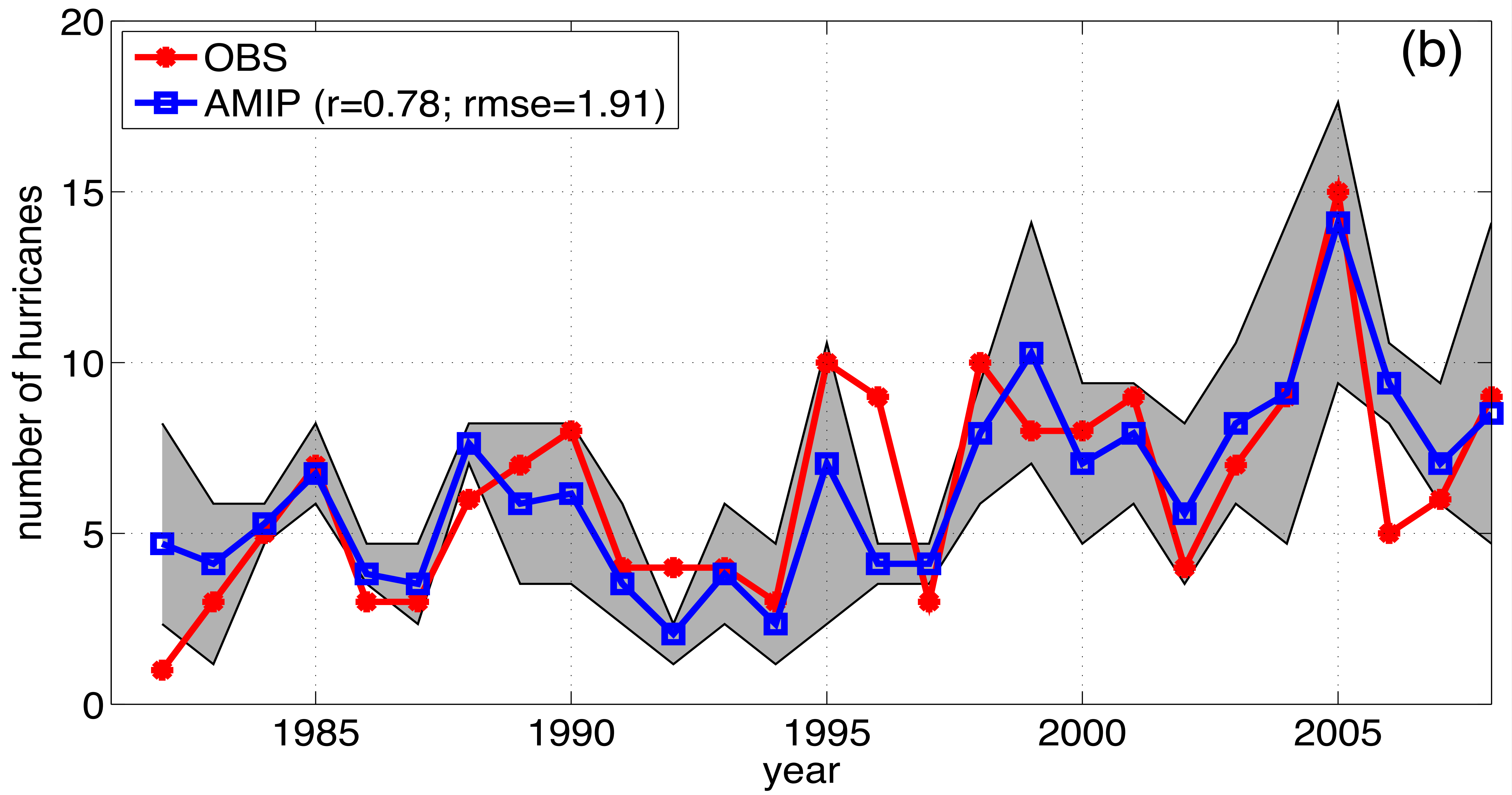
Ref. Zhao et al (2009, J. Climate; 2010, MWR)

Adapted from AM2 with:

- Deep convection scheme adapted from Bretherton, McCaa and Grenier (MWR, 2004)
- Cubed sphere dynamical core
- Changes to parameterizations of cloud microphysics
- C90 Atm. resolution of 1°x1°

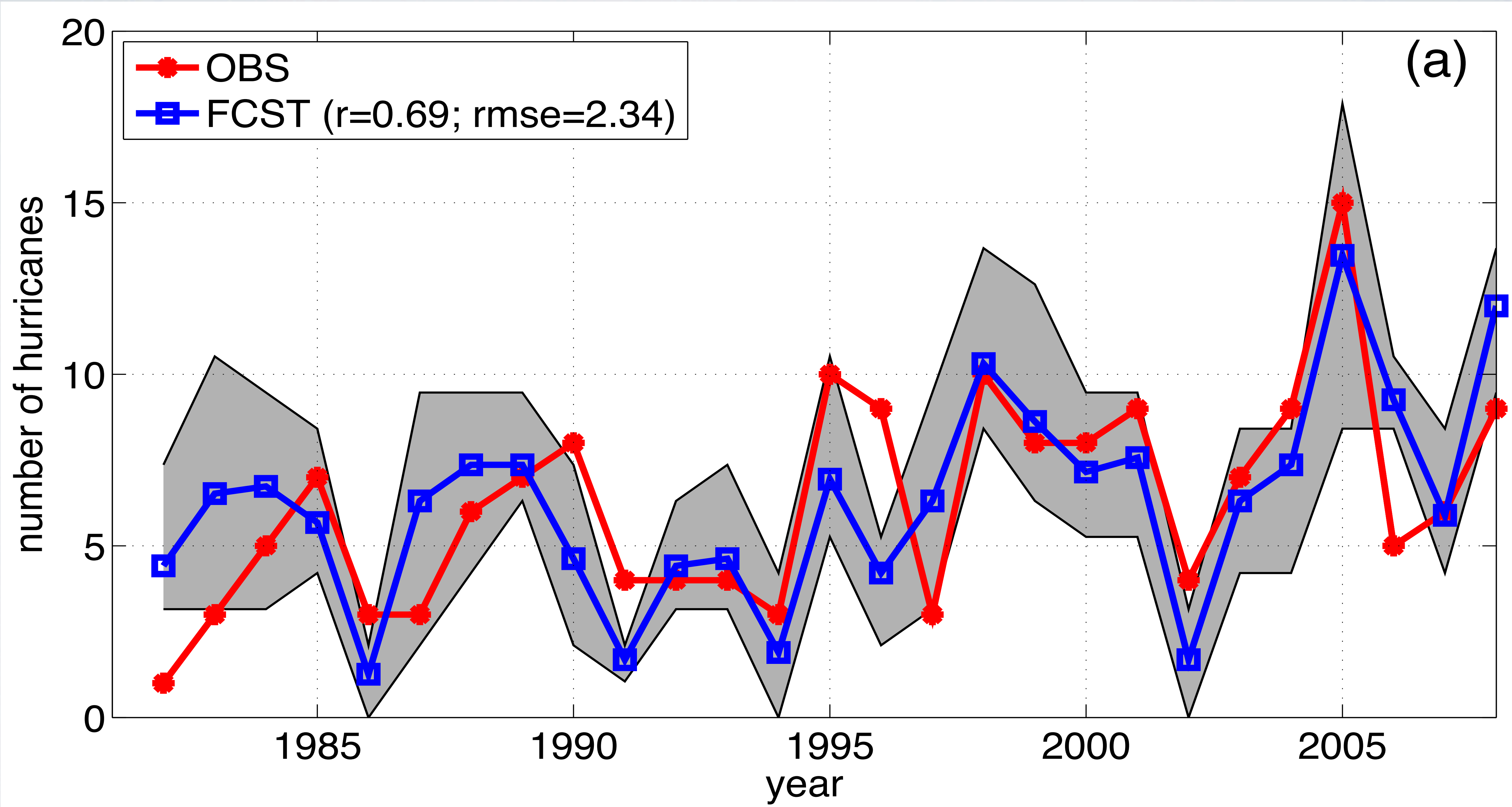


HIRAM C180 AGCM FORCED WITH SSTS RECOVERS NA HURRICANE COUNTS



Zhao *et al.* (2009, J. Climate), Zhao *et al.* (2010, MWR, Sub.)

WITH PERSISTED JUNE SST ANOMALIES (RETROSPECTIVE JULY FCST.), HIRAM C180 AGCM RECOVERS NA HURRICANE COUNTS



Can we extend lead by forecasting SST?

Zhao *et al.* (2010, MWR, Sub.)

Cost of Running Thousands of Retrospective Forecasts with HiRAM-C180 is Prohibitive.

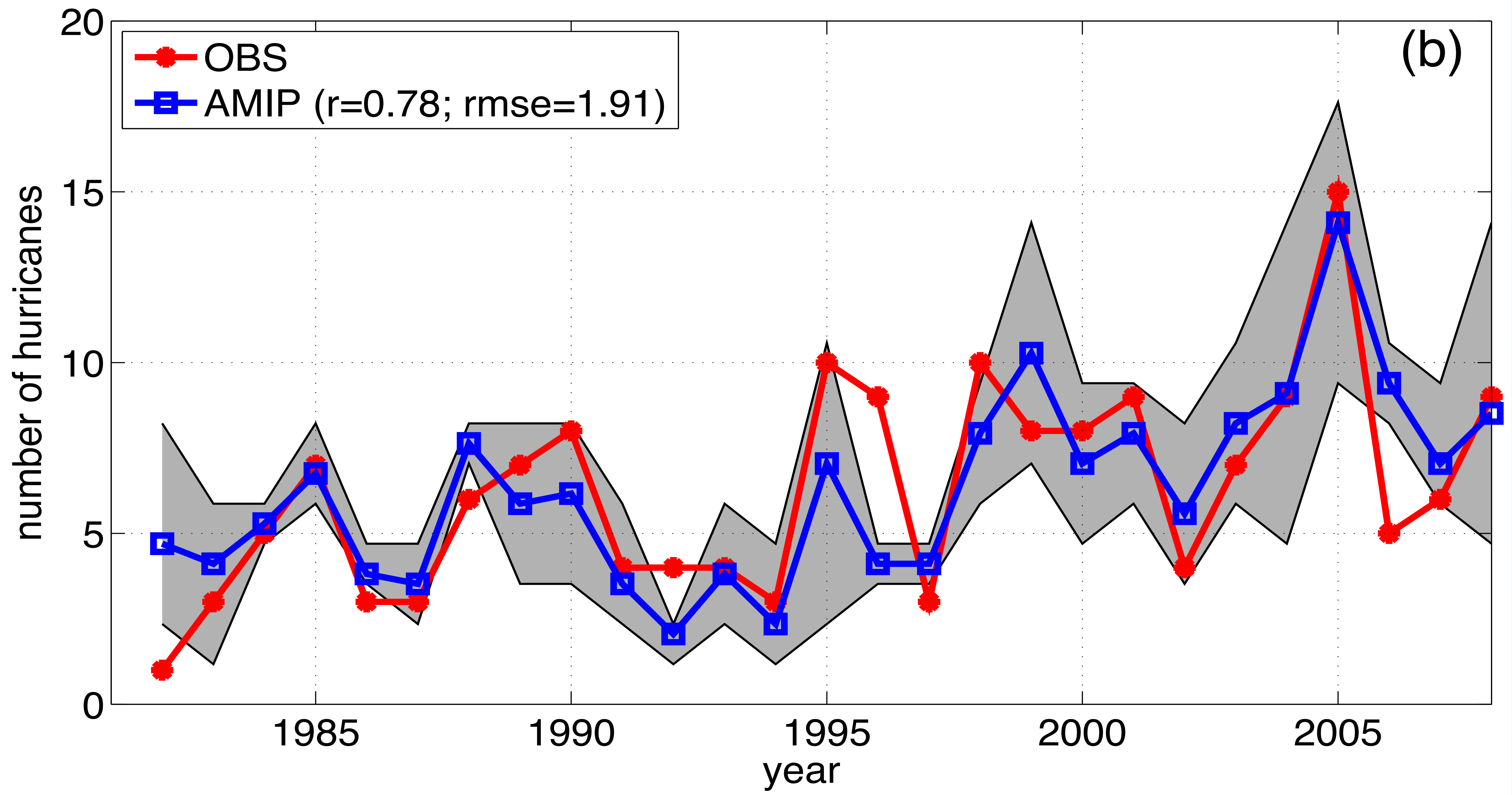
Need to Build a Statistical Emulator of the AGCM.

So: What is a good predictor of Hurricane Frequency?
Catch: It should be predictable itself.

HiRAM-C180 (and other Hi-Res GCMs),
Sensitivity of Large-Scale conditions,
Analyses of Long-term Observations suggest two predictors:

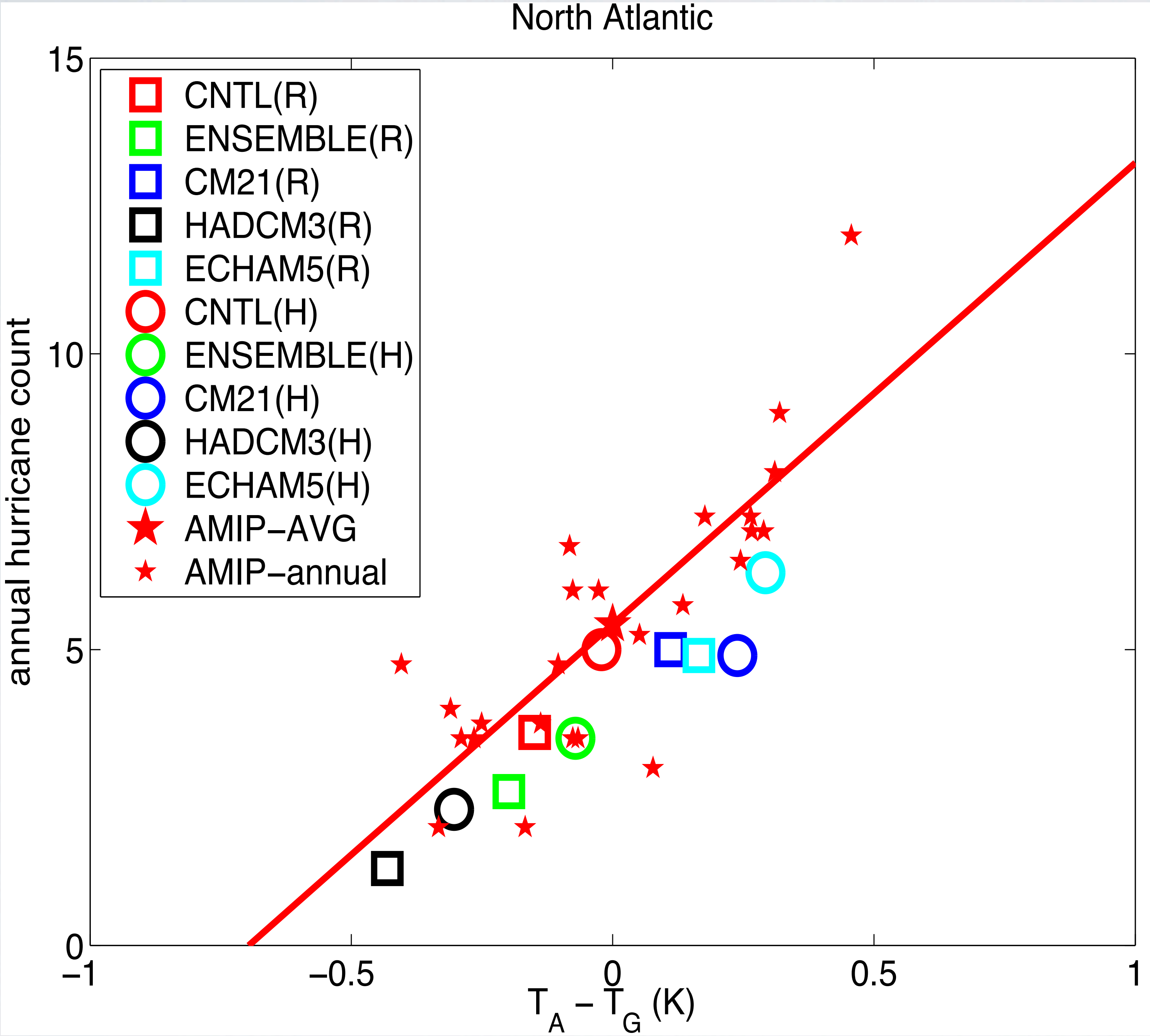
Atlantic SST and **Global-Tropical SST**

HiRAM C180 AGCM Forced with SSTs Recovers NA Hurricane Counts



Zhao *et al.* (2009, J. Climate), Zhao *et al.* (2010, MWR, Sub.)

HiRAM C180 (and observations + controls to large-scale) Suggest **Relative SSTA** as a Predictor



Relative SSTA = Atlantic SSTA minus Tropical SSTA

Zhao *et al.* (2009, J. Climate), Zhao *et al.* (2010, MWR, Sub.)

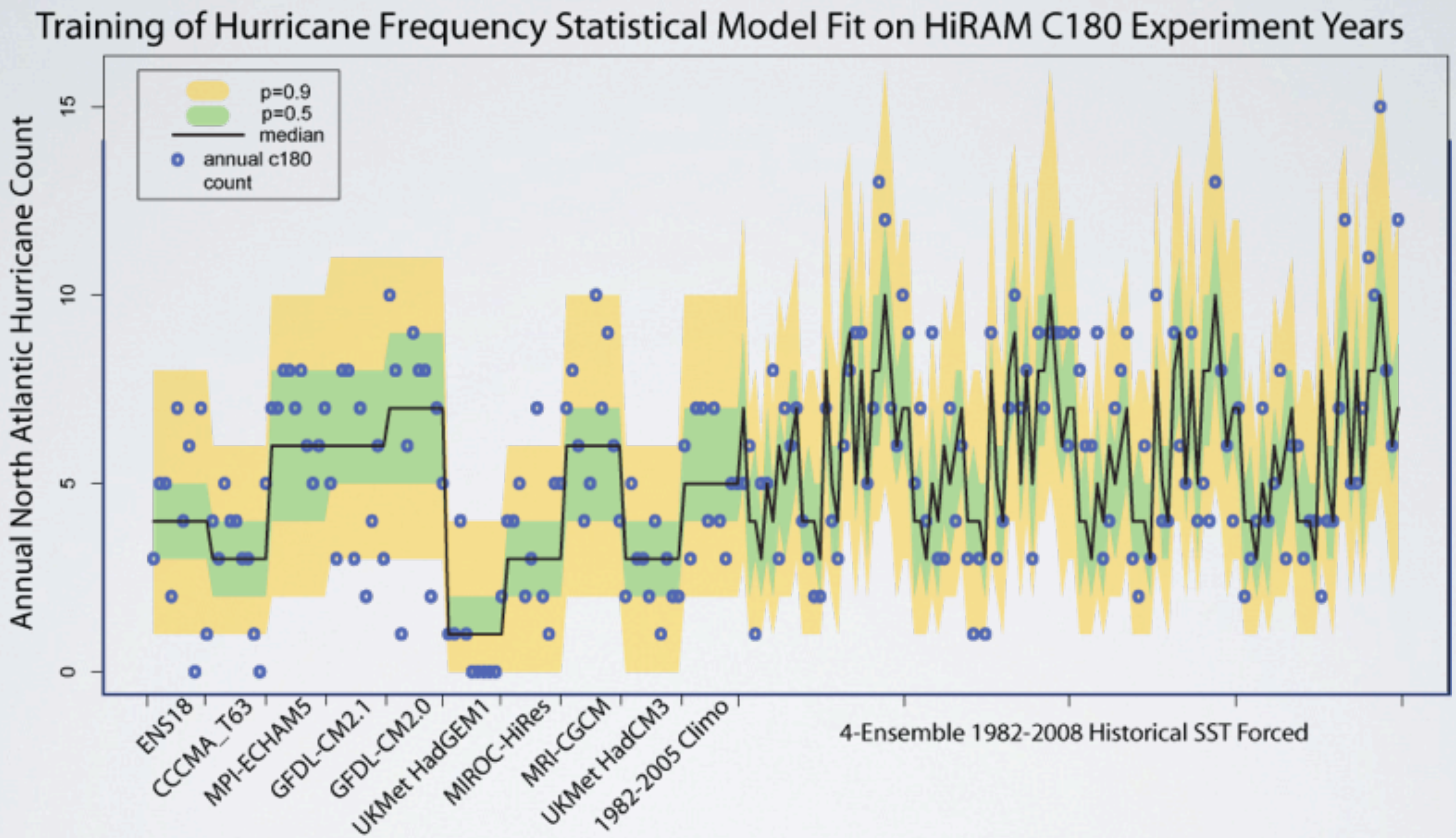
&

Latif et al (2007, GRL), Vecchi and Soden (2007, Nature), Knutson et al (2008, Nature Geosci.), Swanson (2008, G3), Vecchi et al (2008, Science), Villarini et al (2010, MWR, in press)

Seasonal Hurricane Frequency Forecast Scheme

- Build a statistical emulator of HiRAM-C180, two predictors:
  - SST_{MDR} (SST anomaly 80°W-20°W, 10°N-25°N)
  - SST_{TROP} (SST anomaly 30°S-30°N)
- Use S-I forecast models to predict two indices
- Convolve PDF of SST forecasts with PDF from statistical model.

Build a Statistical Emulator of C180-HiRAM Using ASO Atlantic MDR and Tropical-Mean SSTA (Poisson)



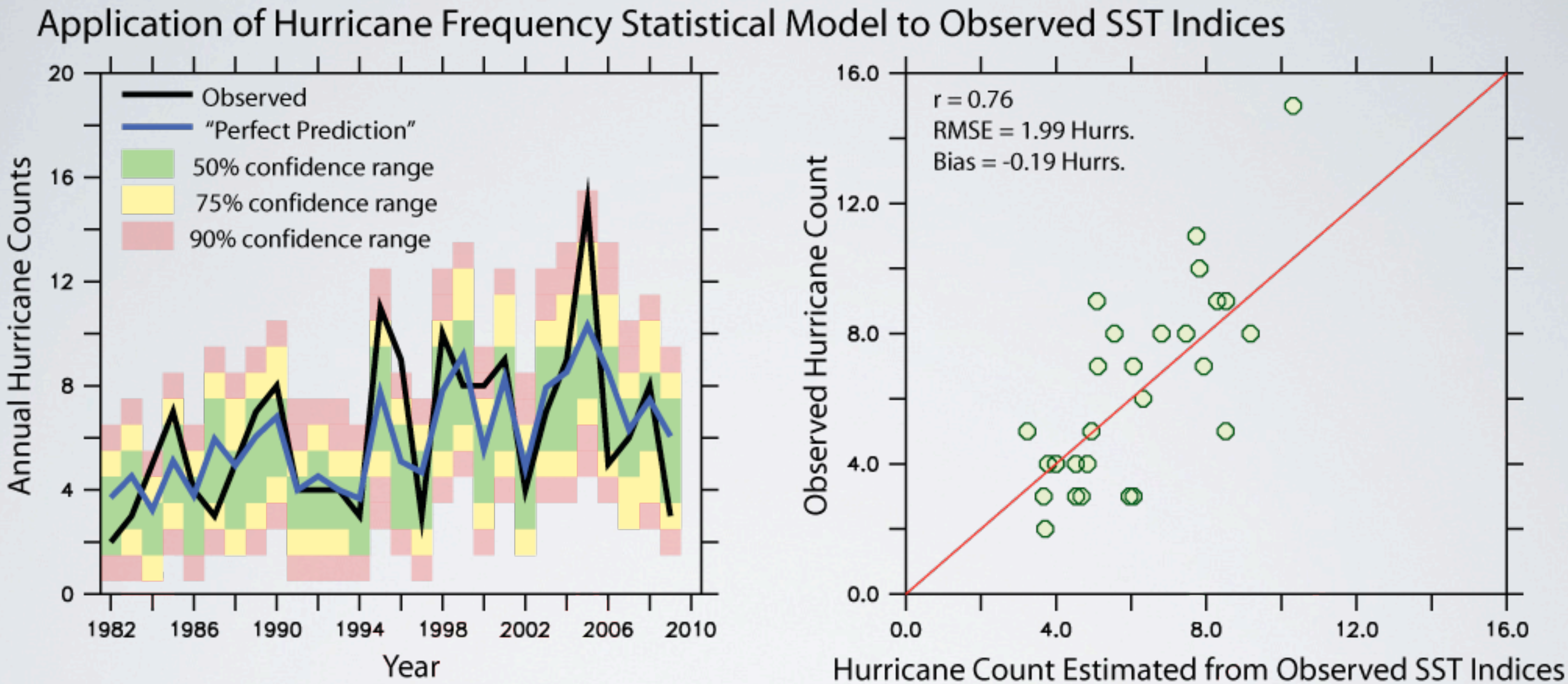
$$p(C=k \mid \boldsymbol{\lambda}) = \boldsymbol{\lambda}^k \cdot e^{-\lambda}/k! \qquad \boldsymbol{\lambda}=e^{(a+b \cdot SSTmdr+c \cdot SSTtrop)}$$

$a=1.707 \quad b=1.388 \quad c=-1.521$

Vecchi *et al.* (2010, MWR submitted)

see Villarini et al (2010, MWR in press) for methodology

Fit of HiRAM-C180 Emulator to Obs. Performs Well

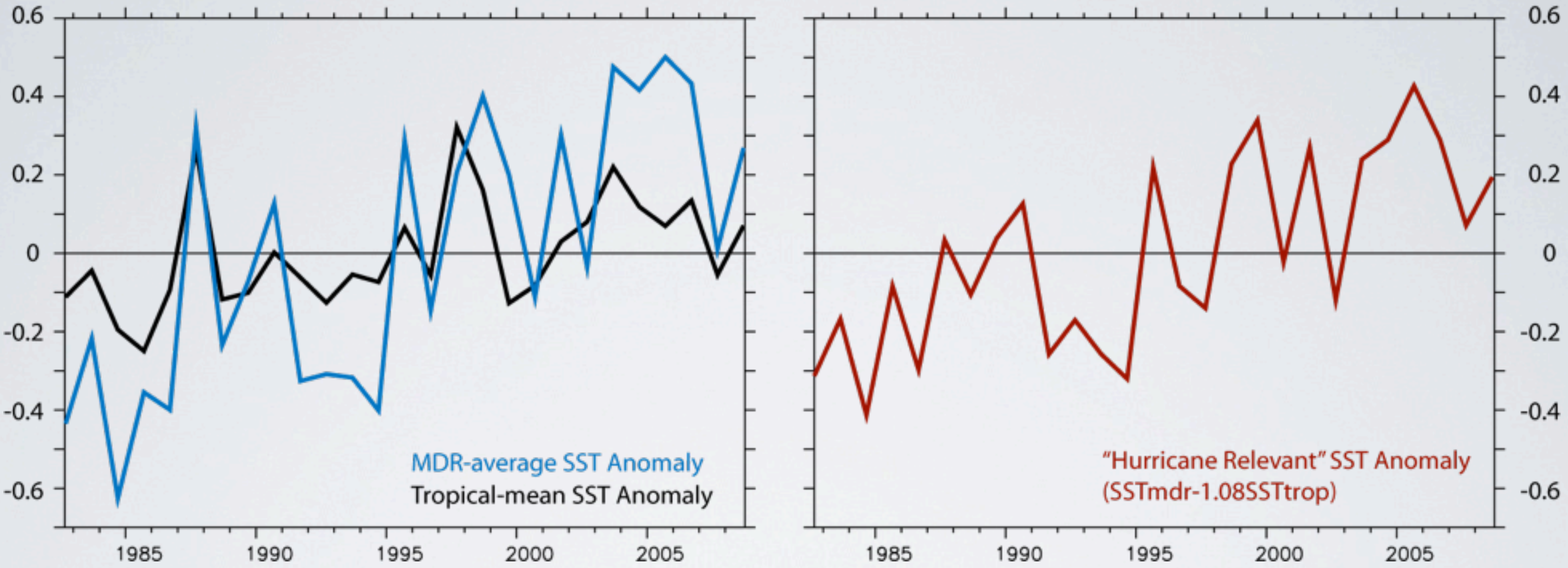


HiRAM-C180 with full SST gives r=0.78, RMSE=1.91

Cannot justify additional predictors at this time

Vecchi *et al.* (2010, MWR submitted)

SST Index Relevant to Hurricanes Complex, More than ENSO and Atlantic SST

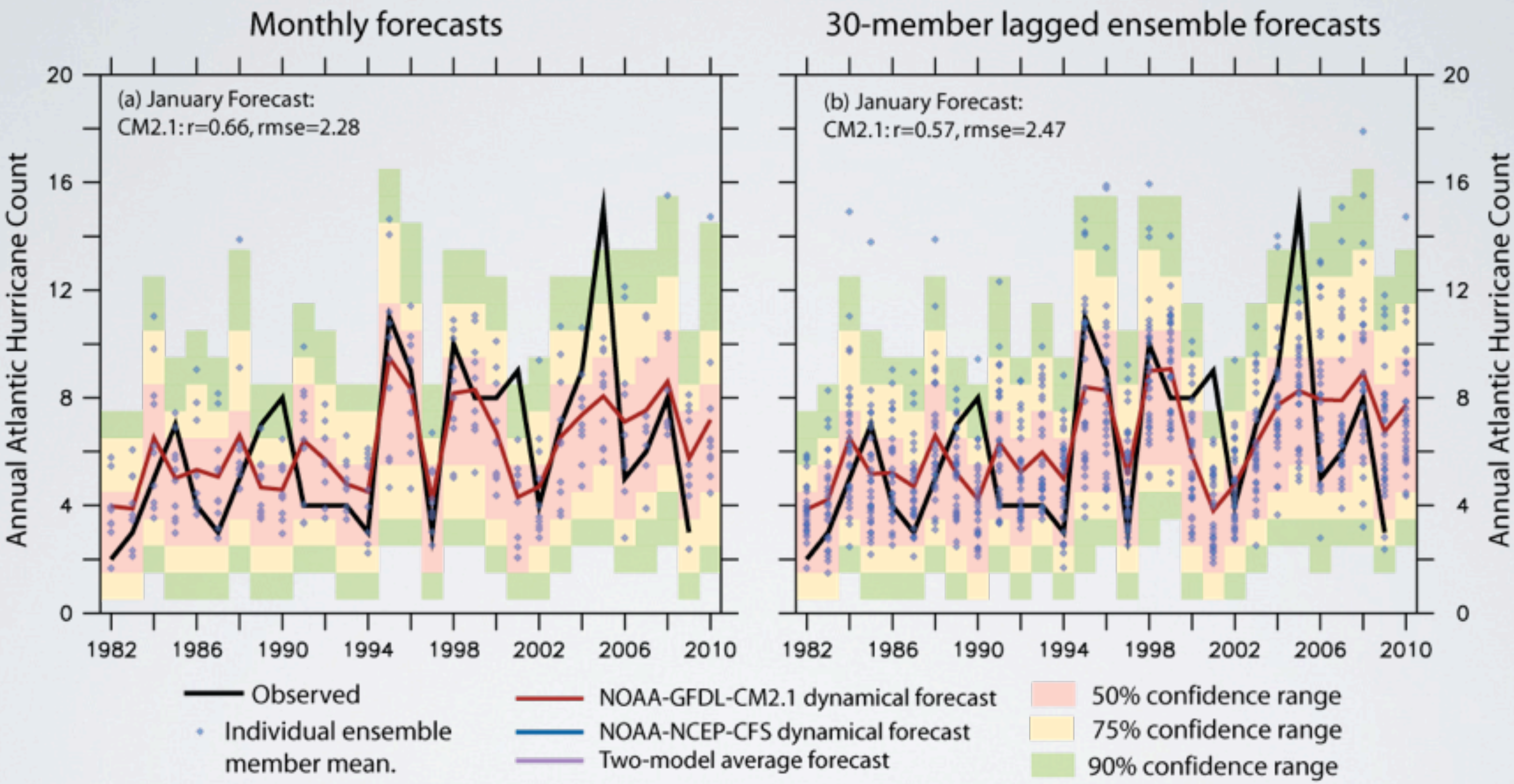


SST_{MDR} and SST_{TROP} share a recent trend, but amplitude differs.
SST_{TROP} more than ENSO, trend, warm mid-2000's, etc.

Explore Two Systems to Forecast the SST Indices

- GFDL-CM2.1 Experimental Forecast System:
  - Ensemble Kalman Filter initialization of GFDL-CM2.1 - Zhang et al (2007), Delworth et al (2006)
  - 12-month retrospective and forward forecasts
  - Basis of GFDL's efforts to understand decadal predictability
- NCEP-CFS Operational S-I Forecast System:
  - GFS atmosphere and MOM3 ocean, initialized to NCEP (atm/land) and GODAS (ocn) - Saha et al (2006)
  - Nine-month retrospective and actual forecasts
  - Used operationally at NCEP

Apply Statistical Hurricane Frequency Model to CM2.1 Retrospective Forecasts of January SST

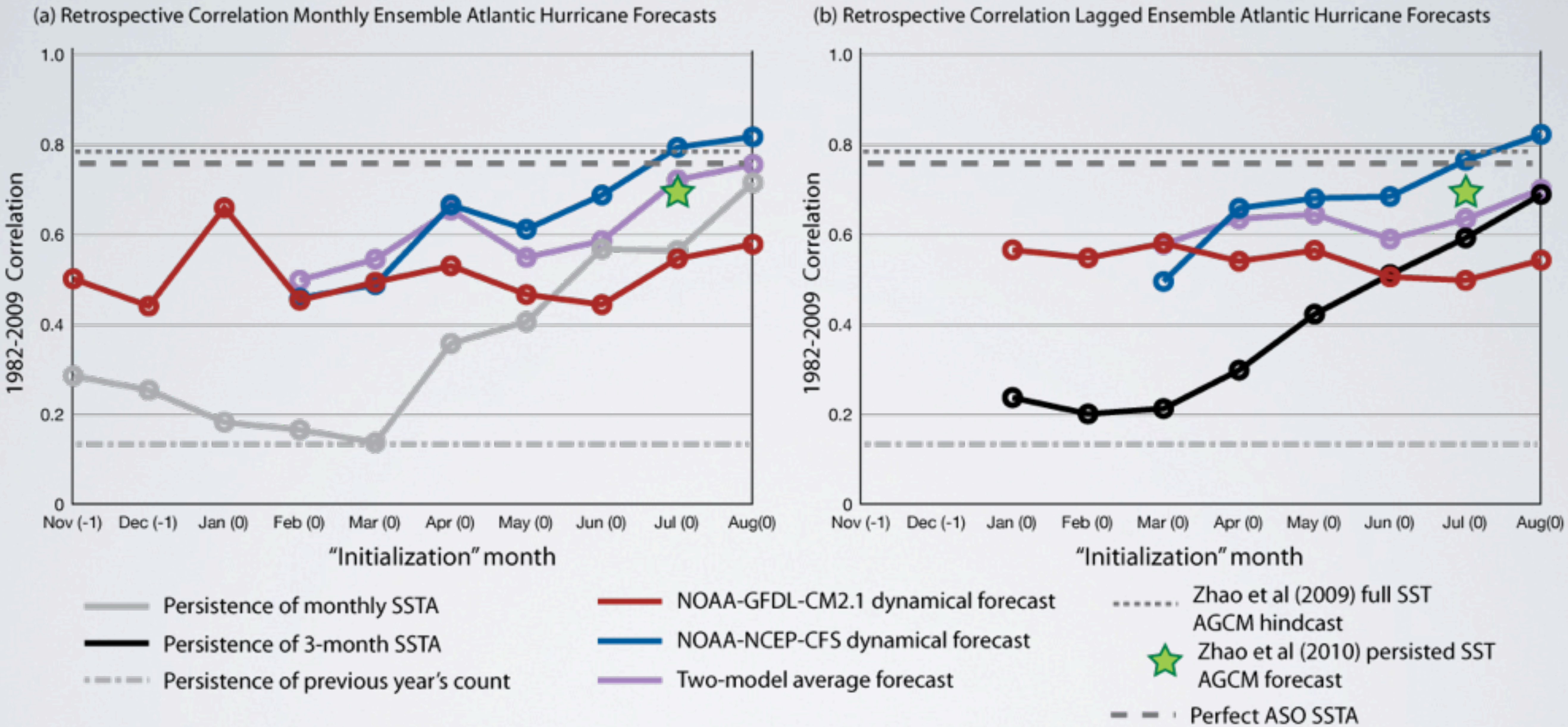


$$p(C=k) = \int_{-\infty}^{\infty} p(C=k \mid relSSTA=x) \cdot p(relSSTA = x)\, dx$$

p(relSSTA=x) from CM2.1 ensemble

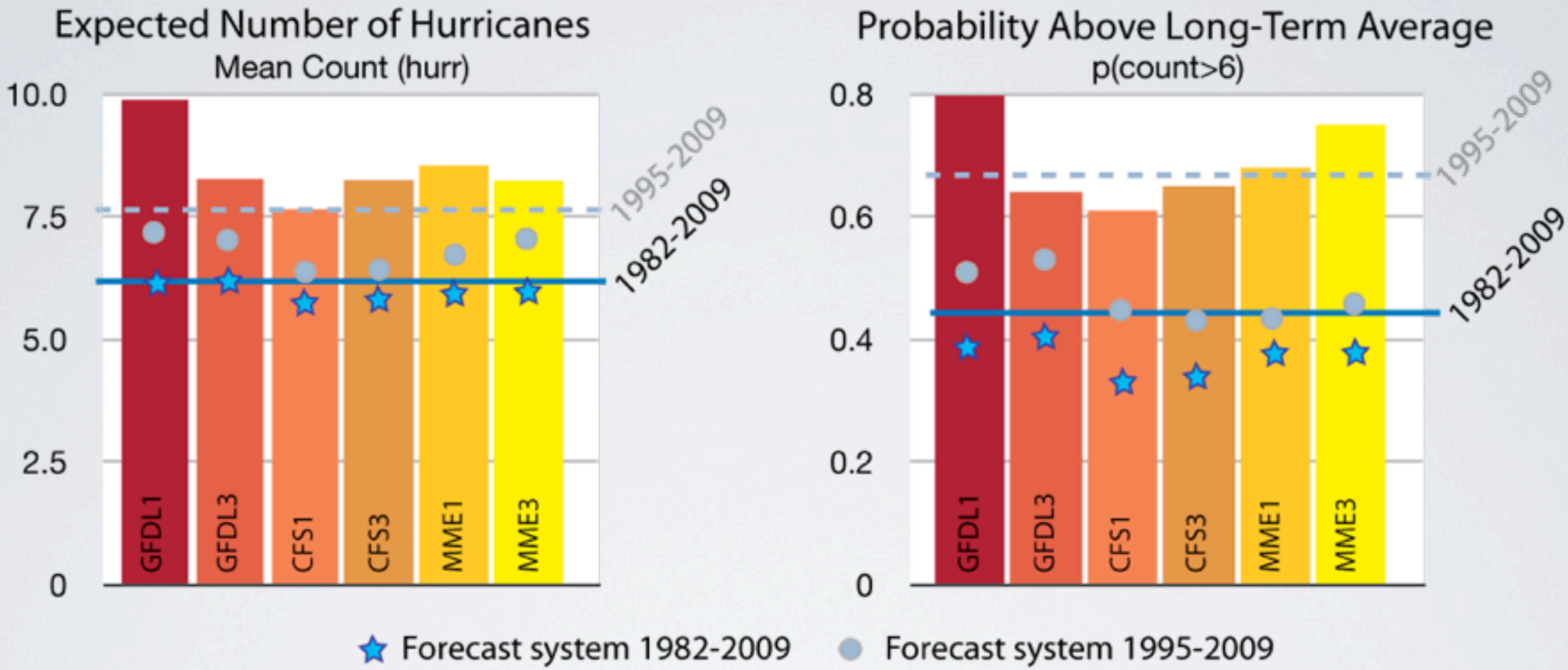
Vecchi *et al.* (2010, MWR submitted)

Hybrid (Statistical-Dynamical) Forecast System Exhibits Potential for Multi-season Lead Forecasts



Vecchi *et al.* (2010, MWR submitted)

Hurricane Forecasts Initialized March 2010
System Anticipates Active 2010

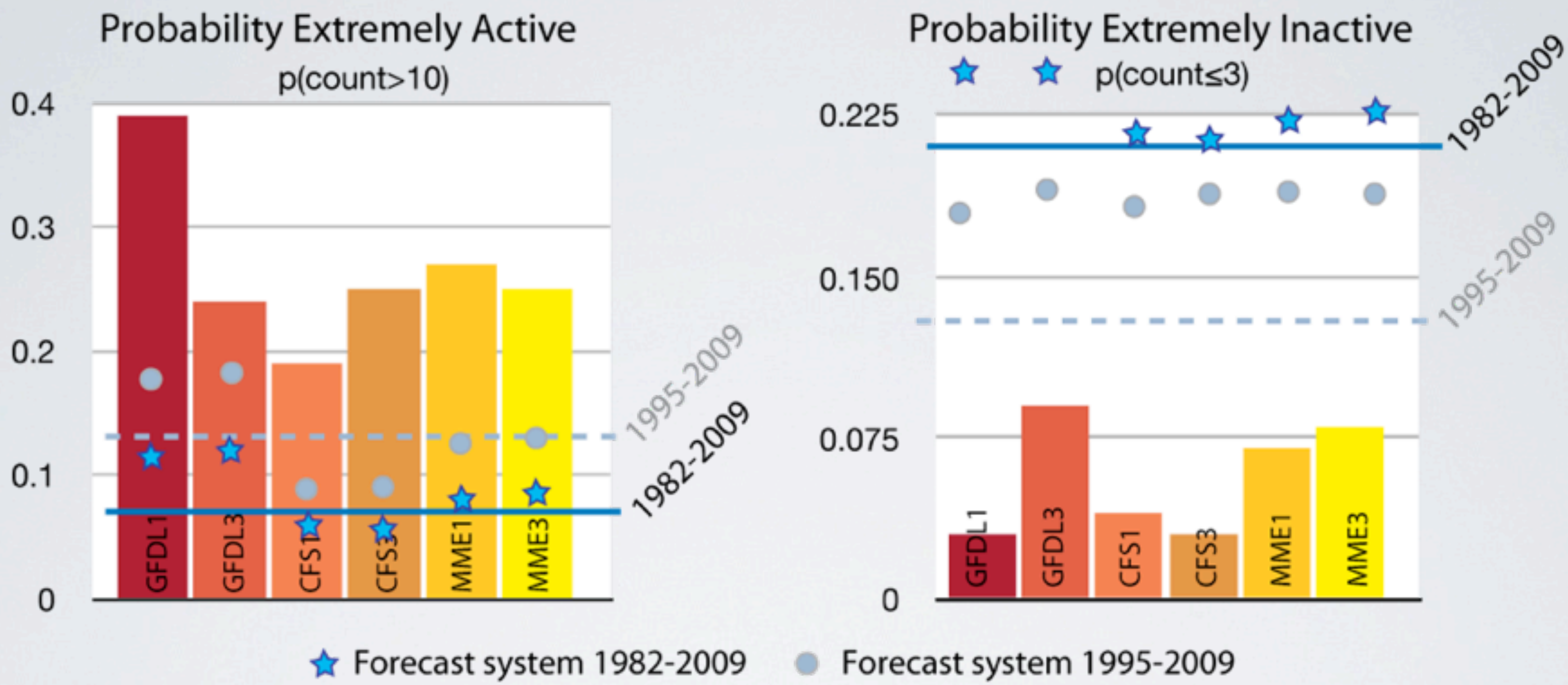


Experimental forecasts suggests 2010 season likely to be above average in hurricane frequency

Vecchi et al (2010, MWR submitted)

Hurricane Forecasts Initialized March 2010

System Anticipates Active 2010



Experimental forecasts for 2010 season
large increase in probability of an extremely active year

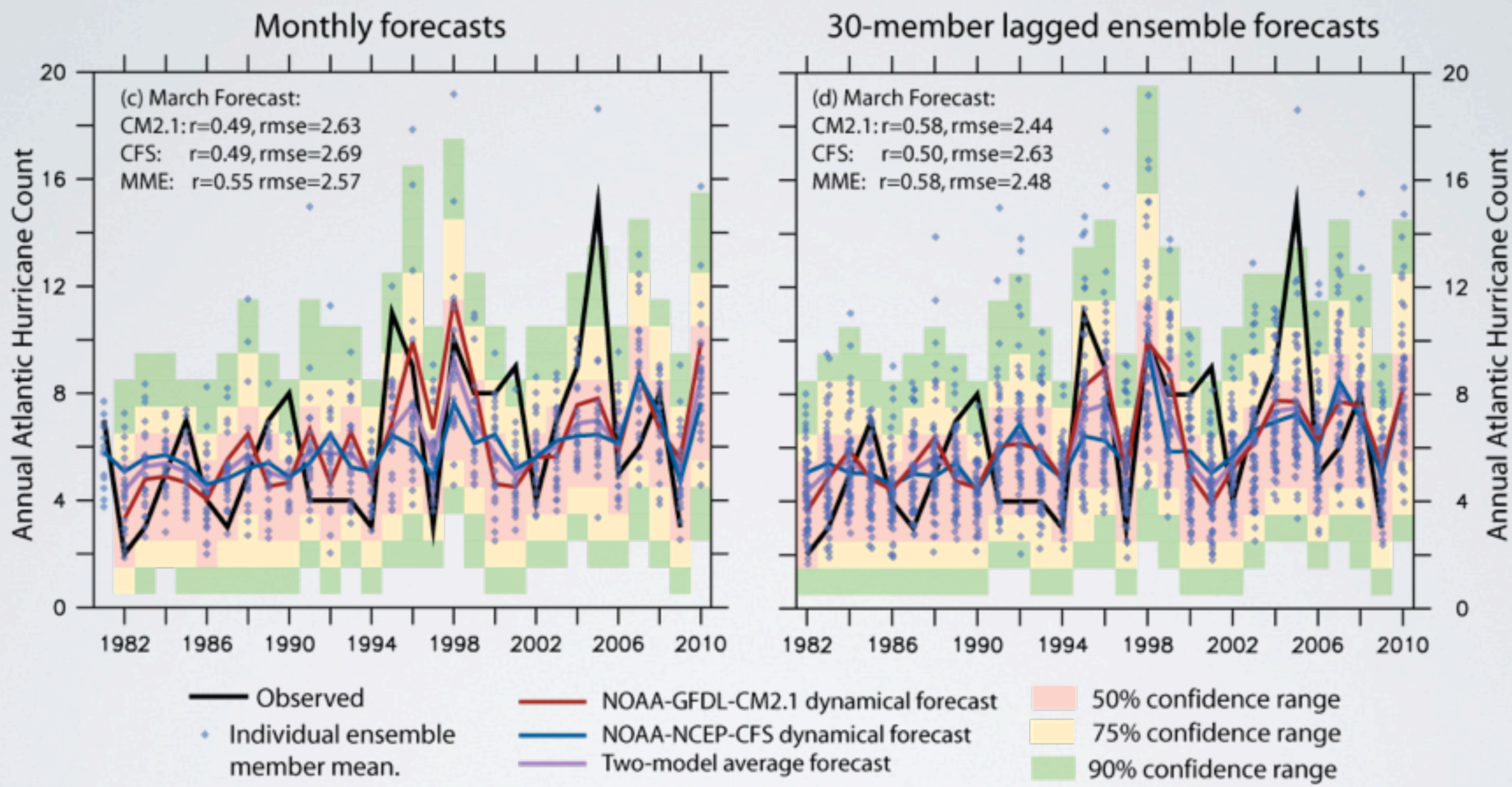
Vecchi et al (2010, MWR submitted)

SUMMARY

- Used understanding built assessing AGW/hurricane connection to build S-I hurricane frequency forecast system
- SST contains a great deal of the information about seasonal Atlantic hurricane activity:
  - Two indices (SST_{MDR} and SST_{TROP}) in ASO contain most
- Existing S-I forecast systems can predict these SST indices with skill from as early as November of the previous year, consistently predicting active 2010 since Nov. 2009.
- "Perfect" retrospective skill from CFS on short leads
- Room for improvement long-range (>6 month) hurricane outlooks from improved SST forecasts.
- How far back can we push it? Was 1982-2009 exceptionally predictable? Can we predict other quantities (efforts at Cat3-5, Cat4-5 and landfall)

BINKY SLIDES

Apply Statistical Hurricane Frequency Model to CM2.1 and CFS Retrospective Forecasts of March SST



$$p(C=k) = \int_{-\infty}^{\infty} p(C=k \mid \mathrm{relSSTA}=x) \cdot p(\mathrm{relSSTA} = x)\, dx$$

p(relSSTA=x) from CM2.1 and CFS ensemble

Vecchi *et al.* (2010, MWR submitted)

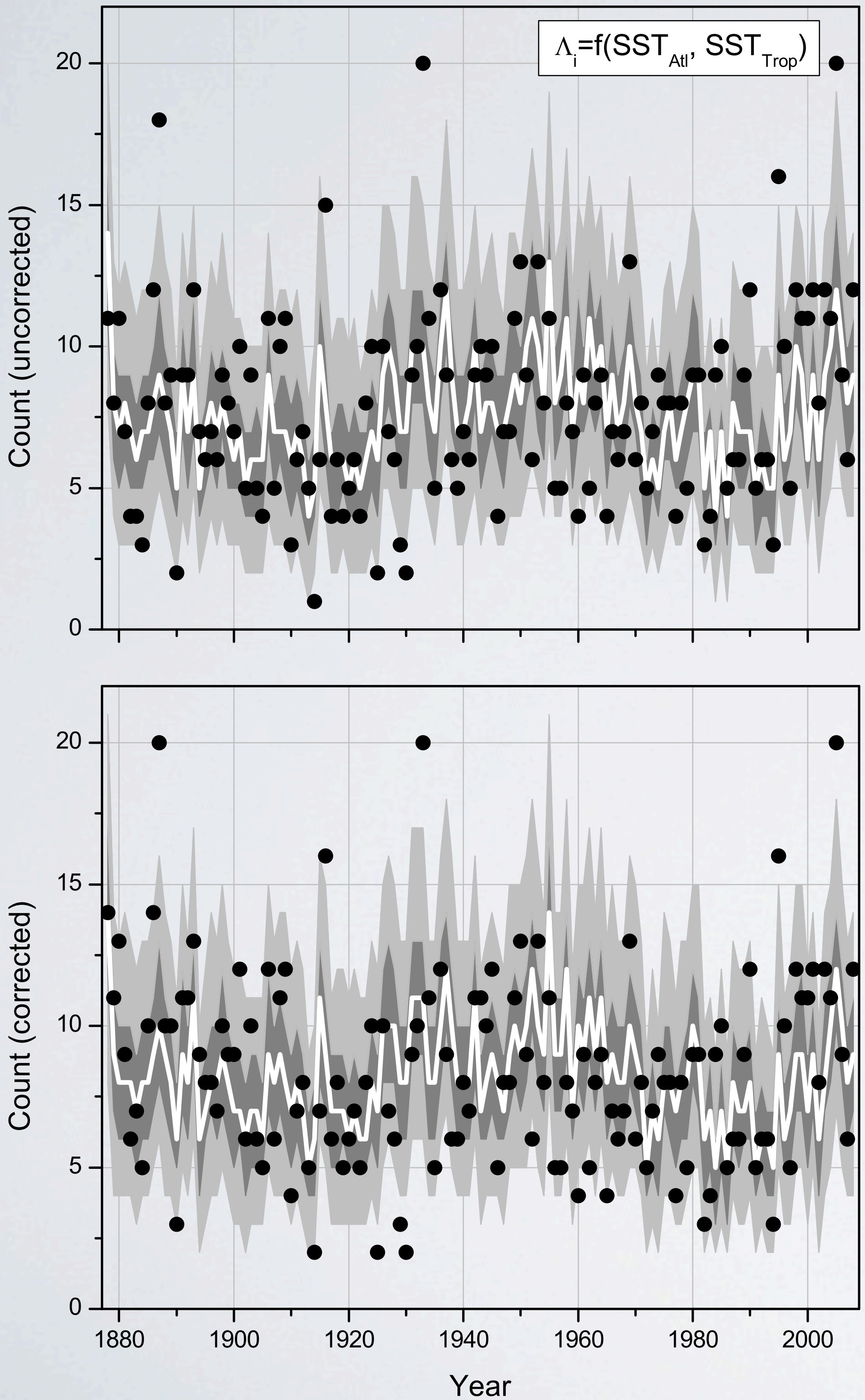
Hurricane Forecasts Initialized March 2010

System Indicates Active 2010

	Mean Count (hurr)	*Median (hurricanes)*	*p(count>6)*	*p(count>10)*	*p(count≤3)*
Observed 1982-2009	6.21	5	0.46	0.07	0.21
GFDL-CM2.1 Simple Ens.	9.88	9	0.80	0.39	0.03
GFDL-CM2.1 Lagged Ens.	8.27	8	0.64	0.24	0.09
NCEP-CFS Simple Ens.	7.64	7	0.61	0.19	0.04
NCEP-CFS Lagged Ens.	8.24	8	0.65	0.25	0.03
Two-model Simple Ens.	8.54	8	0.68	0.27	0.07
Two-model Lagged Ens.	8.23	8	0.75	0.25	0.08

Vecchi et al (2010, MWR submitted)

Build statistical model of basin-wide tropical storms using Atlantic and Tropical-mean SST as covariates



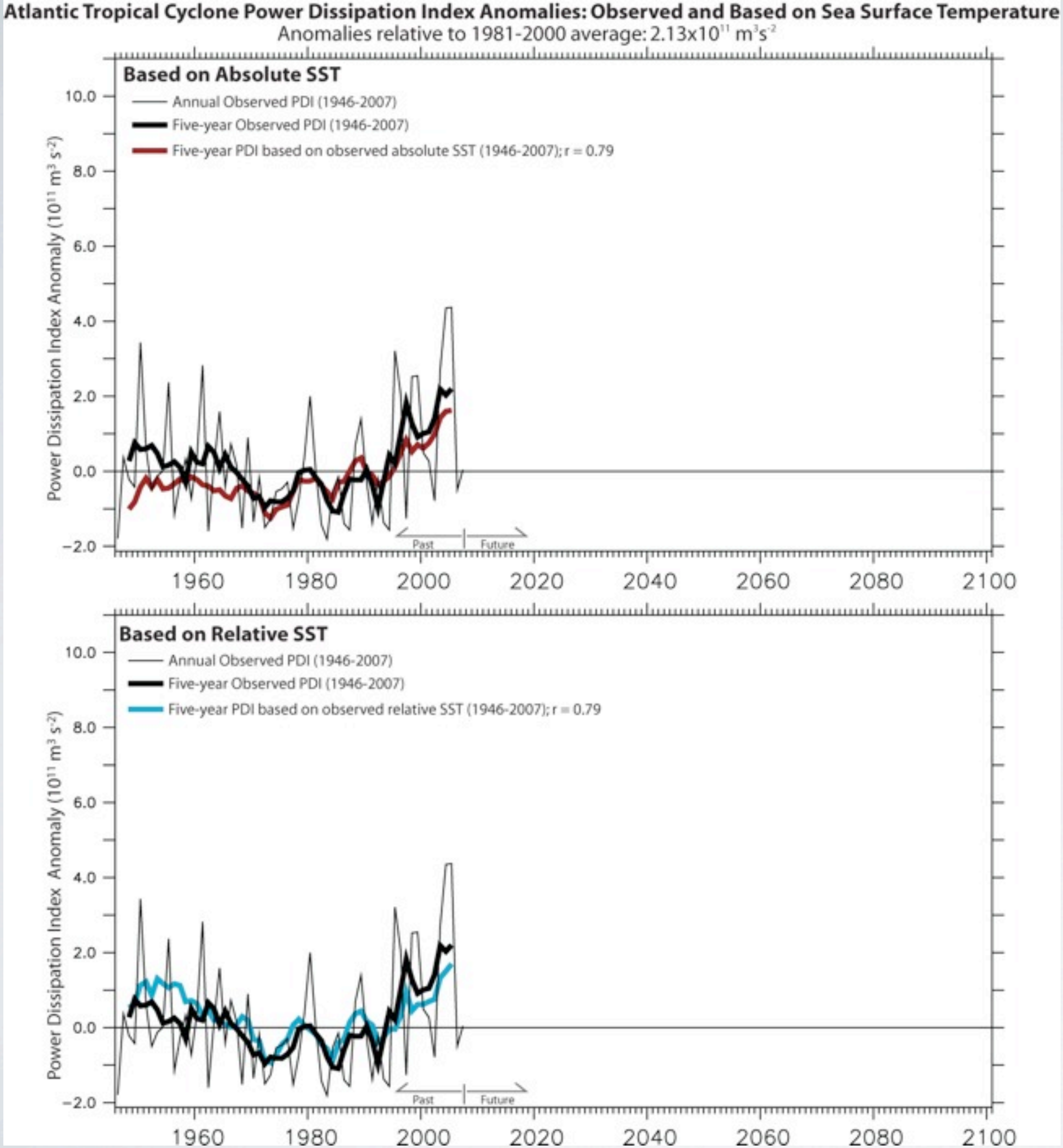
Atlantic SST increases frequency.

Tropical-mean SST reduces frequency.

Factors in fit (w/standard error)

	Uncorrected	Corrected
Intercept	2.03 (0.03)	2.11 (0.03)
	2.03 (0.03)	2.10 (0.03)
SST_{Atl}	1.13 (0.20)	1.05 (0.15)
	1.05 (0.15)	1.02 (0.14)
SST_{Trop}	-0.98 (0.23)	-1.22 (0.22)
	-0.91 (0.20)	-1.05 (0.19)

Villarini, Vecchi and Smith (2010, MWR, in press)



Observed Activity

Absolute MDR SST

see also Emanuel (2005)

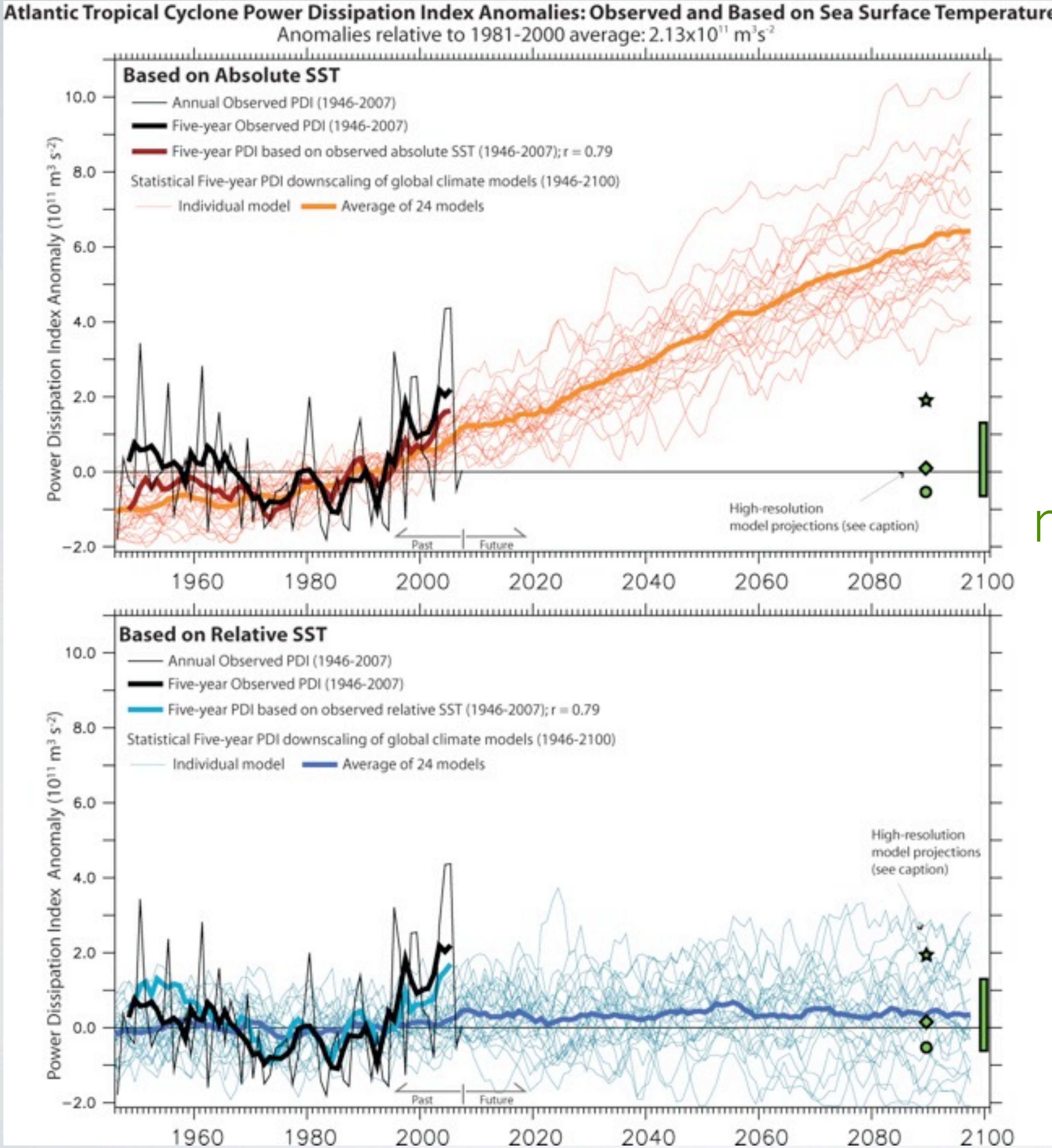
If causal, can attribute to GHG.

Relative MDR SST

If causal, cannot attribute.

see also Swanson (2008)

Vecchi, Swanson and Soden (2008, Science)



Observed Activity

Absolute SST

Model Abs. SST

High-resolution model activity change

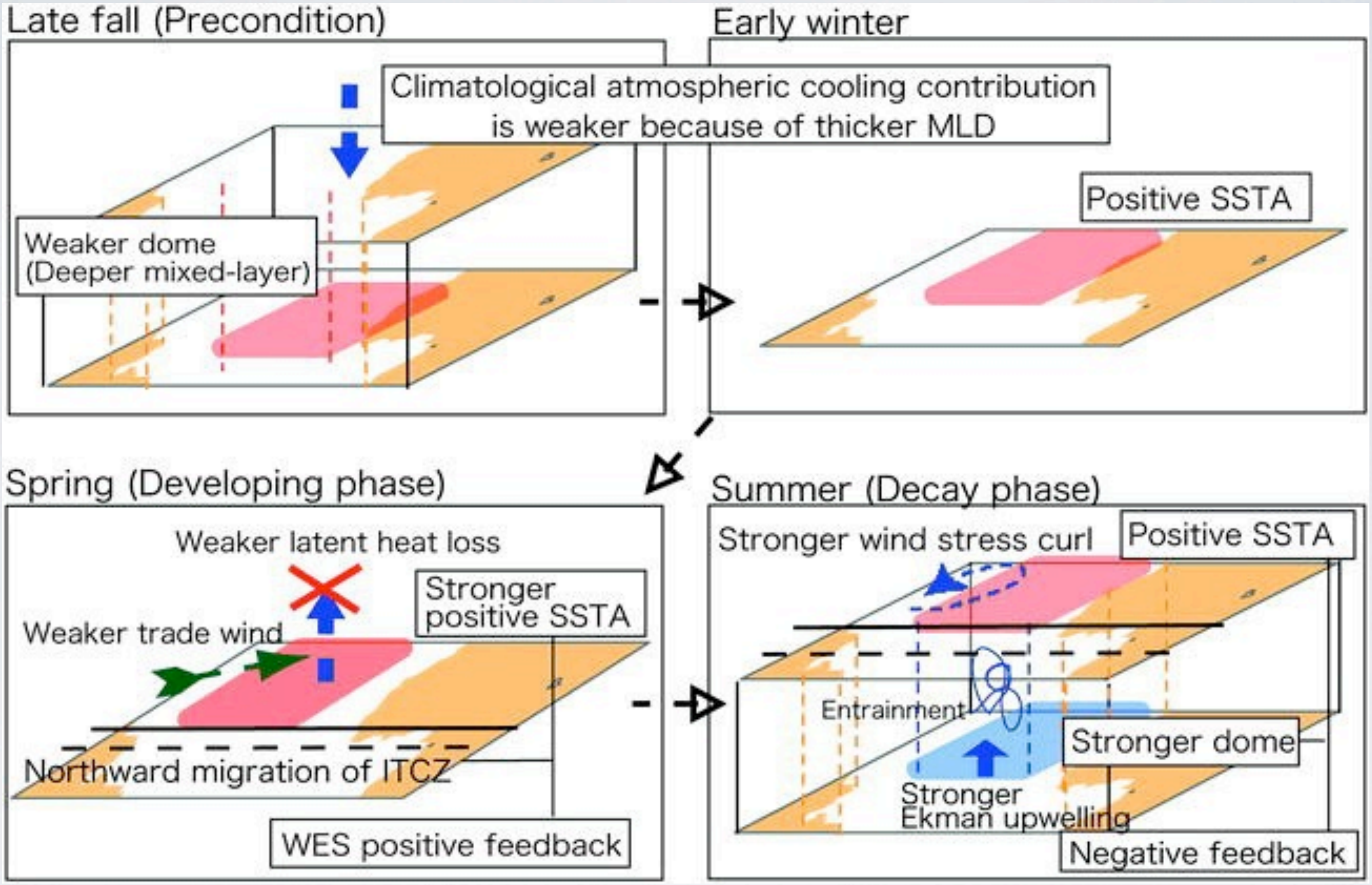
Emanuel et al (08),Knutson et al (08)
Oouchi et al (06),Bengtsson et al (07)

Relative SST

Model Rel. SST

Vecchi, Swanson and Soden (2008, Science)

Processes Controlling Tropical Atlantic Variability are Seasonally Dependent



Doi et al. (2010, J. Climate)

Hurricane-Relevant Large-Scale Conditions Co-vary Constructively With Relative-SST

Interannual Correlation of Large-Scale Conditions to Relative-SST (Aug-Oct - CM2.1 1860 Control)

SLP

Shear

PI

700hPa RH

850hPa vort.

Precip