EXPERIMENTAL FORECASTS OF 2010 HURRICANE SEASON FROM WINTER 2009

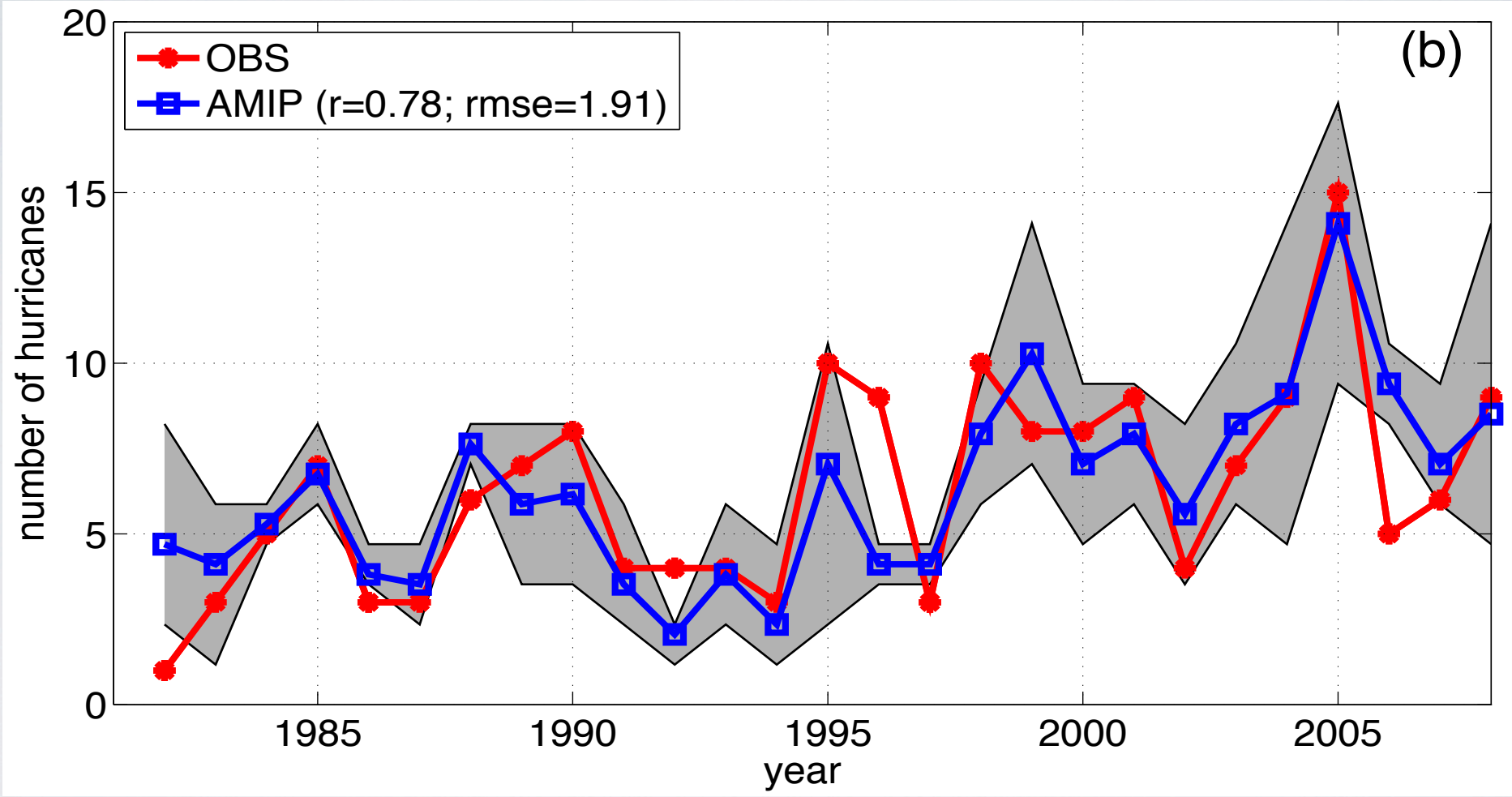
Gabriel A. Vecchi[1], Ming Zhao[1,2], Hui Wang[3,4], Gabriele Villarini[5,6], Arun Kumar[3], Anthony Rosati[1], Isaac Held[1], Richard Gudgel[1]

1. NOAA/Geophysical Fluid Dynamics Laboratory, Princeton, NJ, USA
2. University Corporation for Atmospheric Research, Boulder, CO, USA
3. NOAA/Climate Prediction Center, Camp Springs, MD, USA
4. Wyle Information Systems, McLean, Virginia, USA
5. Department of Civil and Environmental Engineering, Princeton University, Princeton, New Jersey, USA
6. Willis Research Network, London UK

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**

HiRAM C180 AGCM Forced with SSTs Recovers NA Hurricane Counts

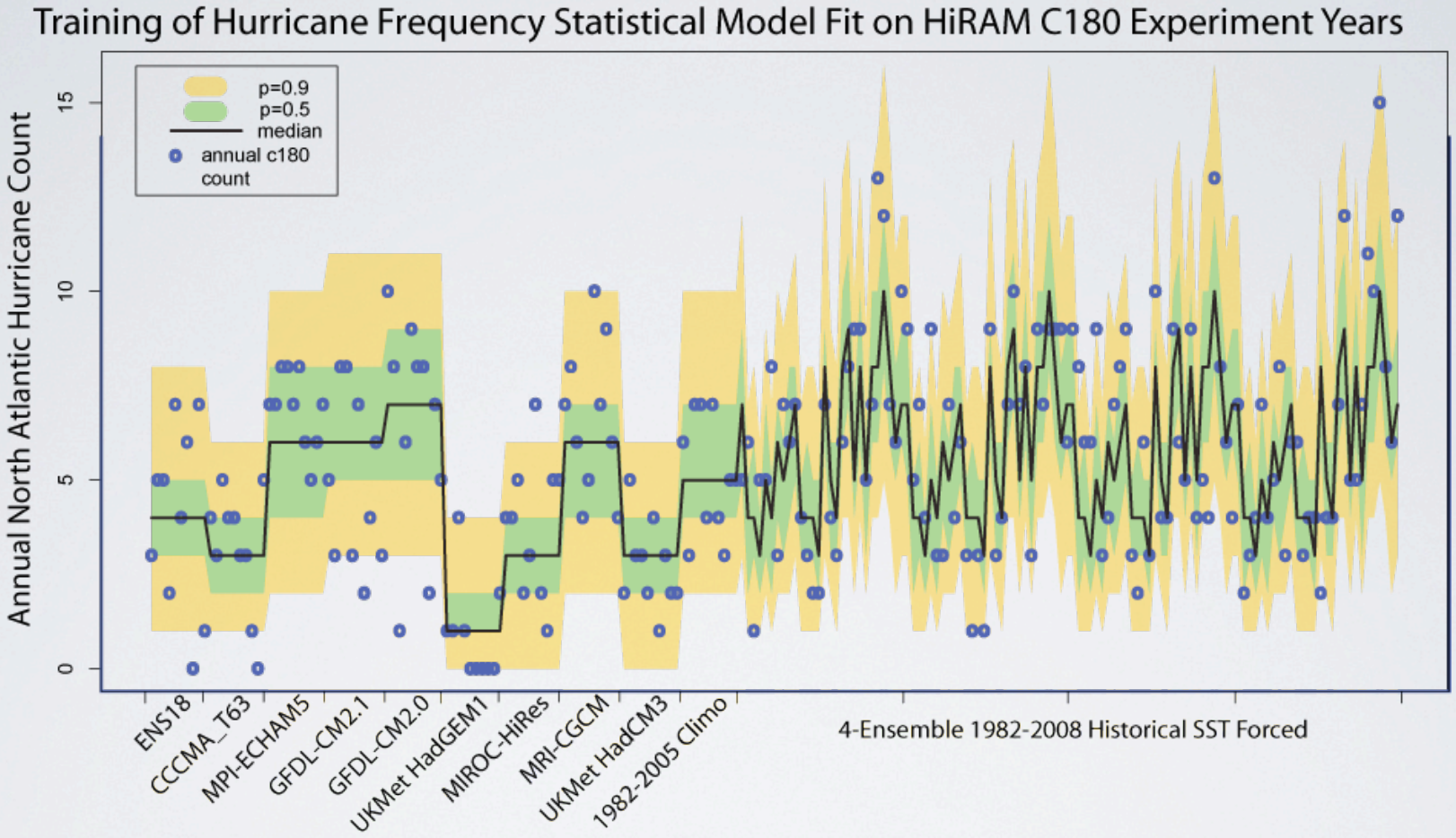


Zhao *et al.* (2009, J. Climate), Zhao *et al.* (2010, MWR, Sub.)

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)

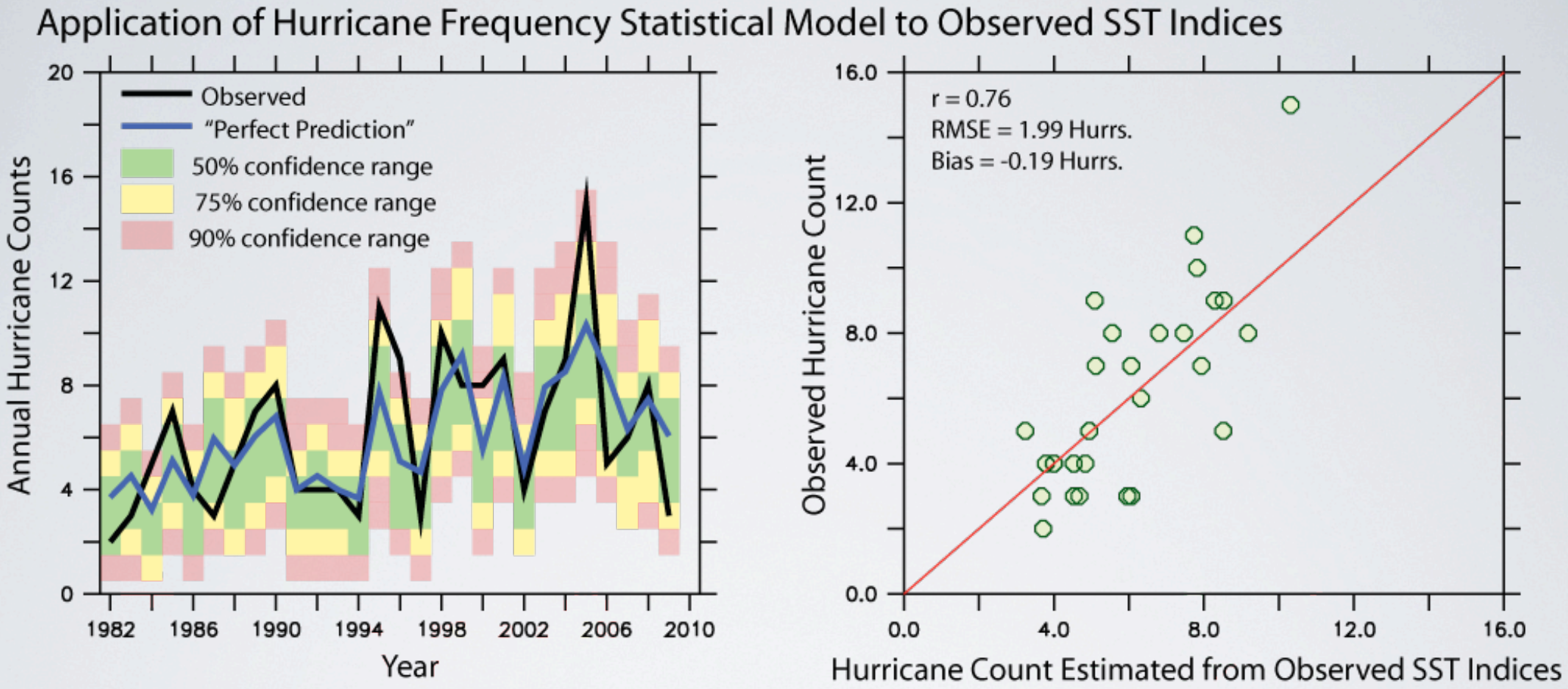


$$p(C=k \mid \boldsymbol{\lambda}) = \boldsymbol{\lambda}^{k} \cdot e^{-\lambda}/k! \qquad \boldsymbol{\lambda} = e^{(a+b \cdot SSTmdr + c \cdot SSTtrop)}$$

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

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

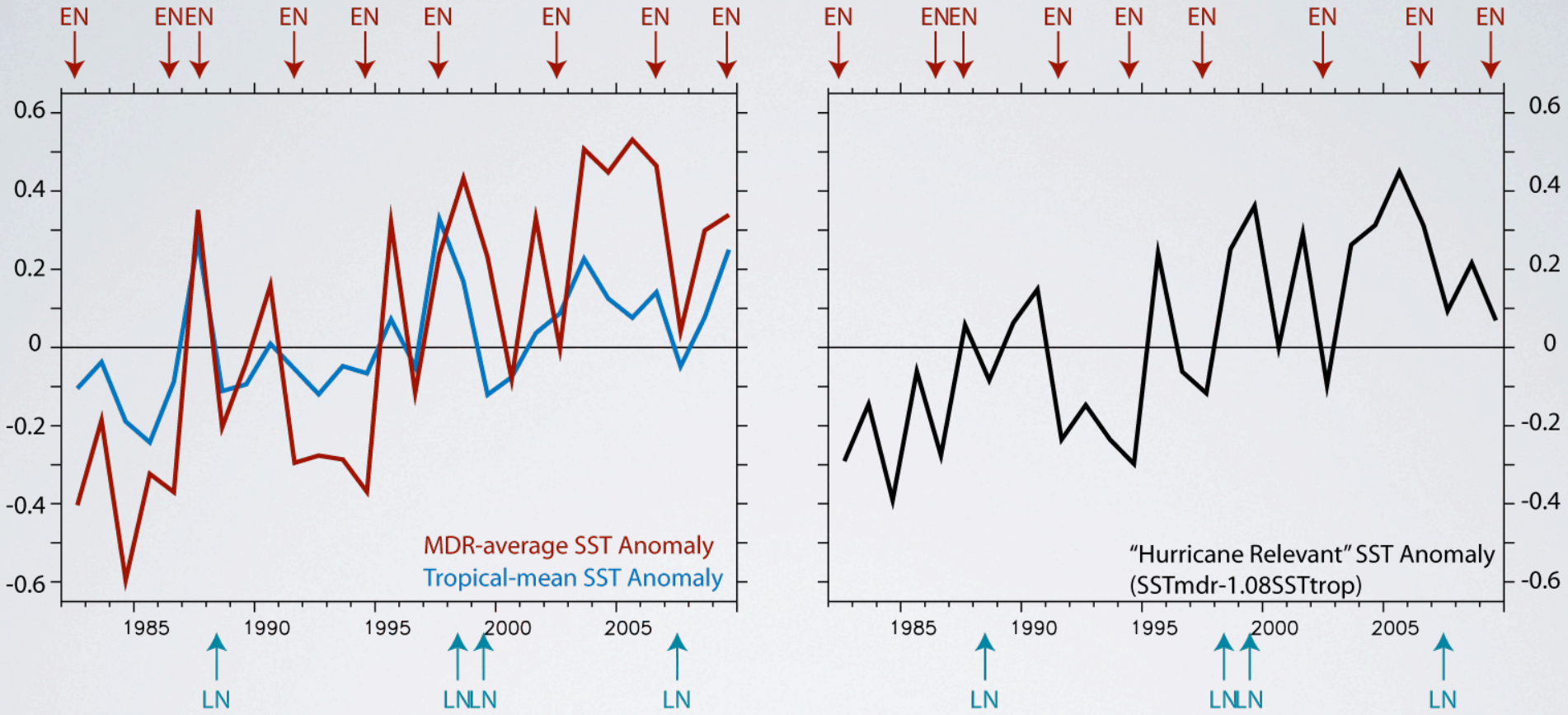


HiRAM-C180 with full SST gives r=0.78, RMSE=1.91

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

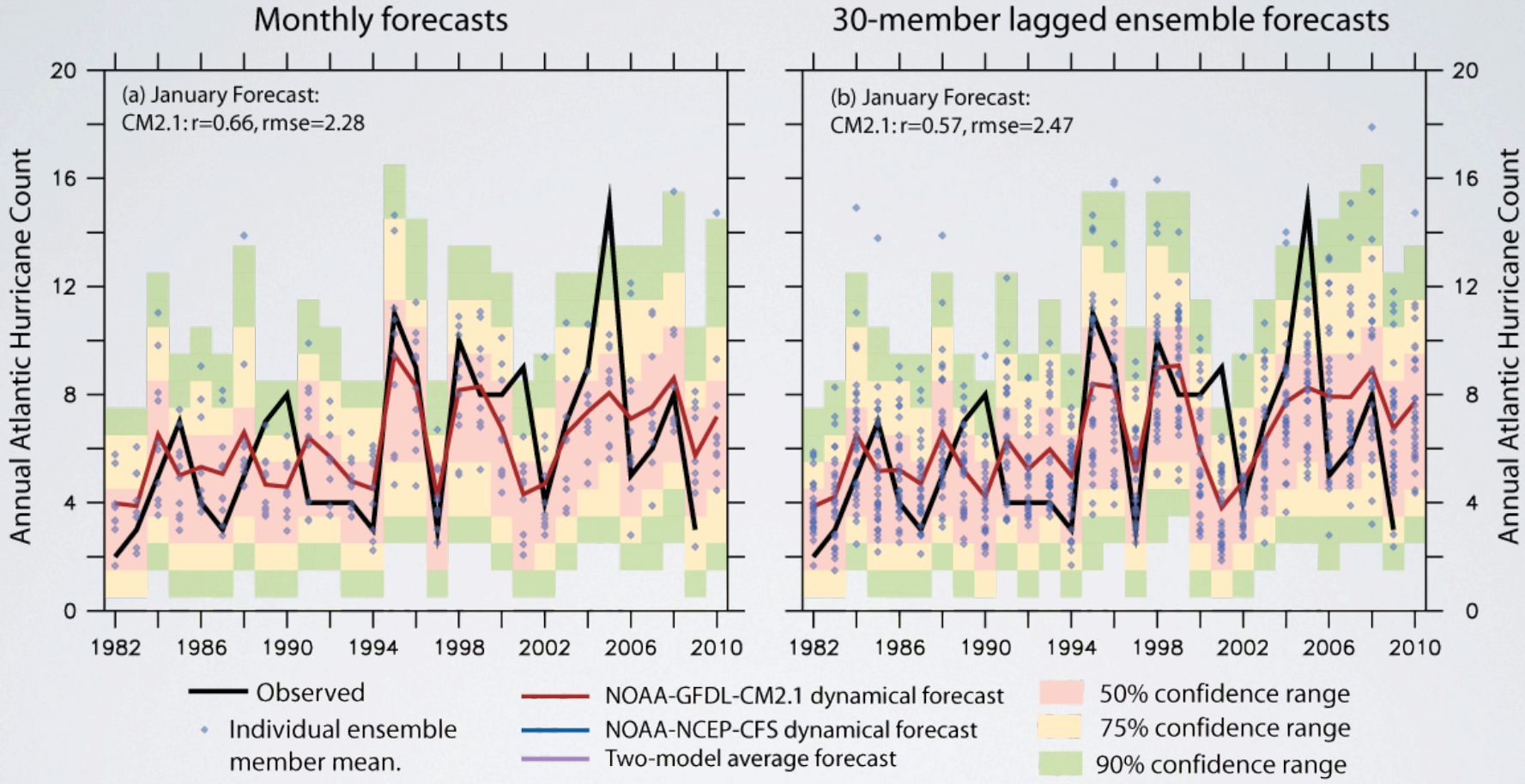


SST_{MDR} and SST_{TROP} share a recent trend, but amplitude differs.
SST_{TROP} more than ENSO, trend, warm mid-2000's, etc.

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

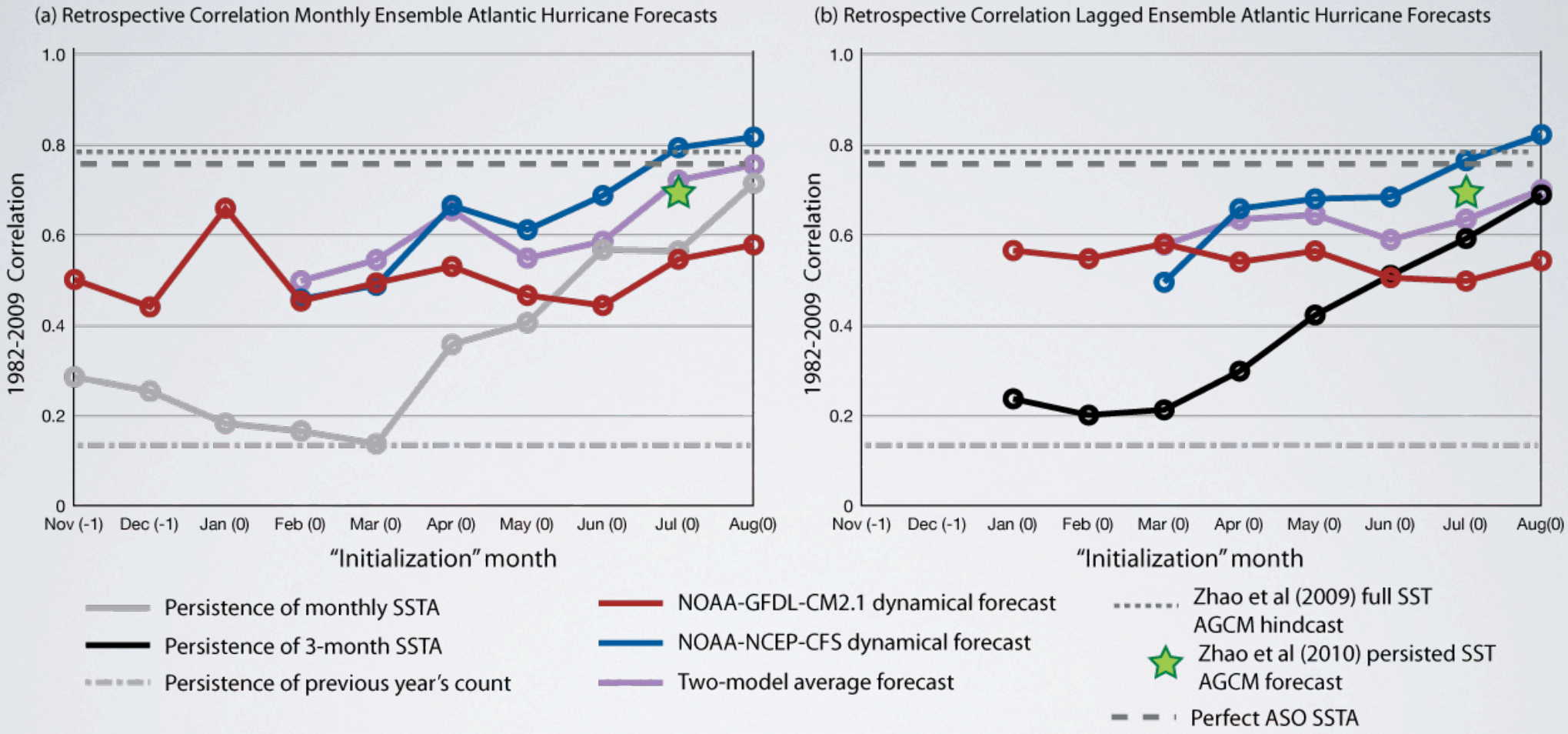


$$p(C=k) = \int_{-\infty}^{\infty} p(C=k \mid \text{relSSTA}=x) \cdot p(\text{relSSTA} = x)\, dx$$

p(relSSTA=x) from CM2.1 ensemble

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

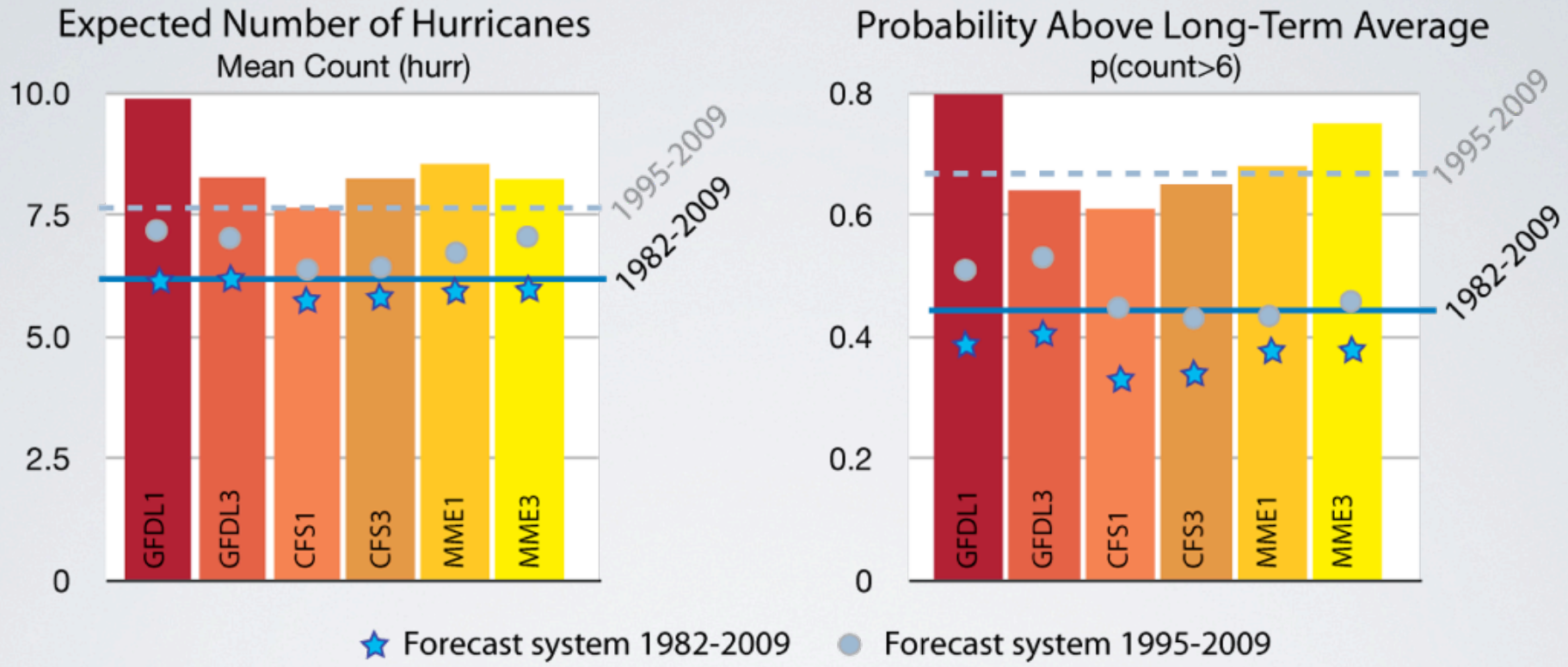
Hybrid (Statistical-Dynamical) Forecast System Exhibits Potential for Multi-season Lead Forecasts



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

Hurricane Forecasts Initialized March 2010

System Anticipates Active 2010

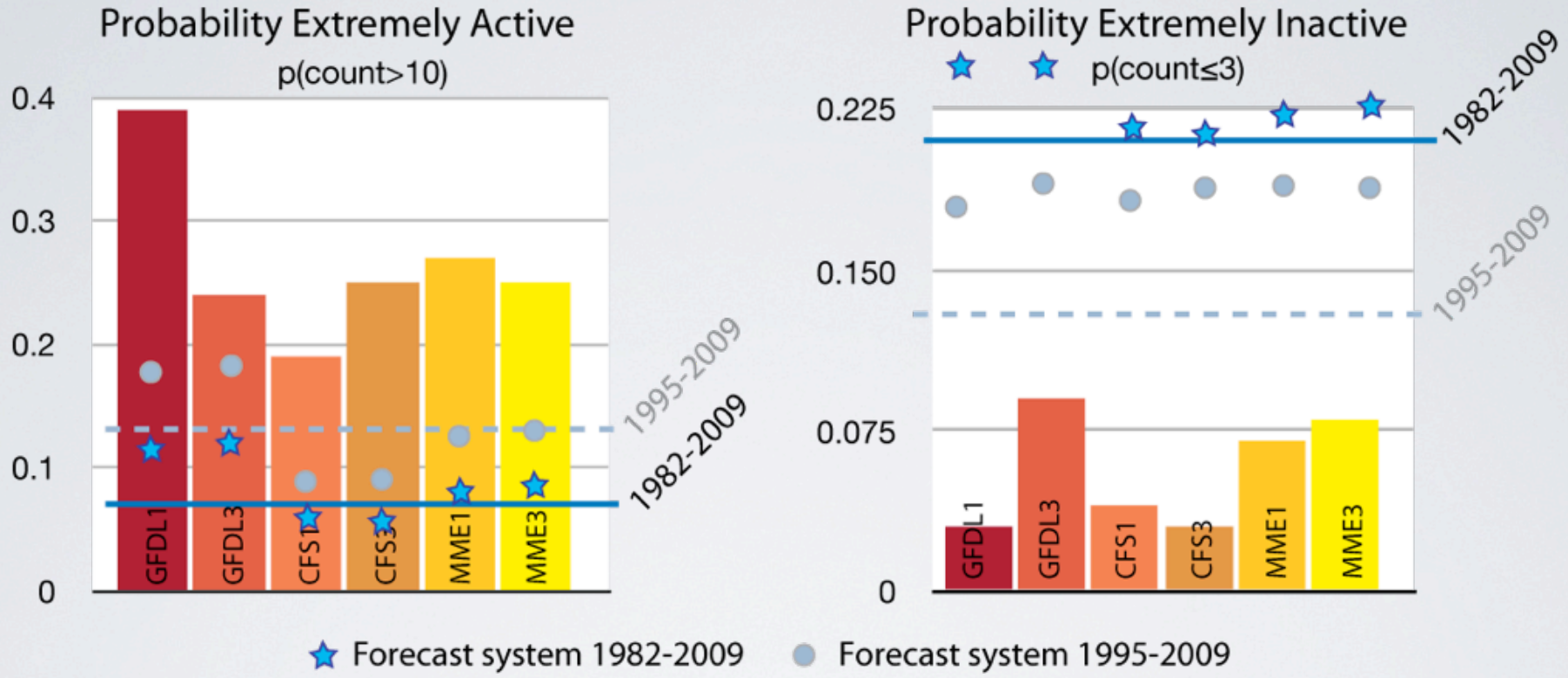


Experimental forecasts suggests 2010 season likely to be above average in hurricane frequency

Vecchi et al (2010, MWR submitted)

Hurricane Forecasts Initialized March 2010

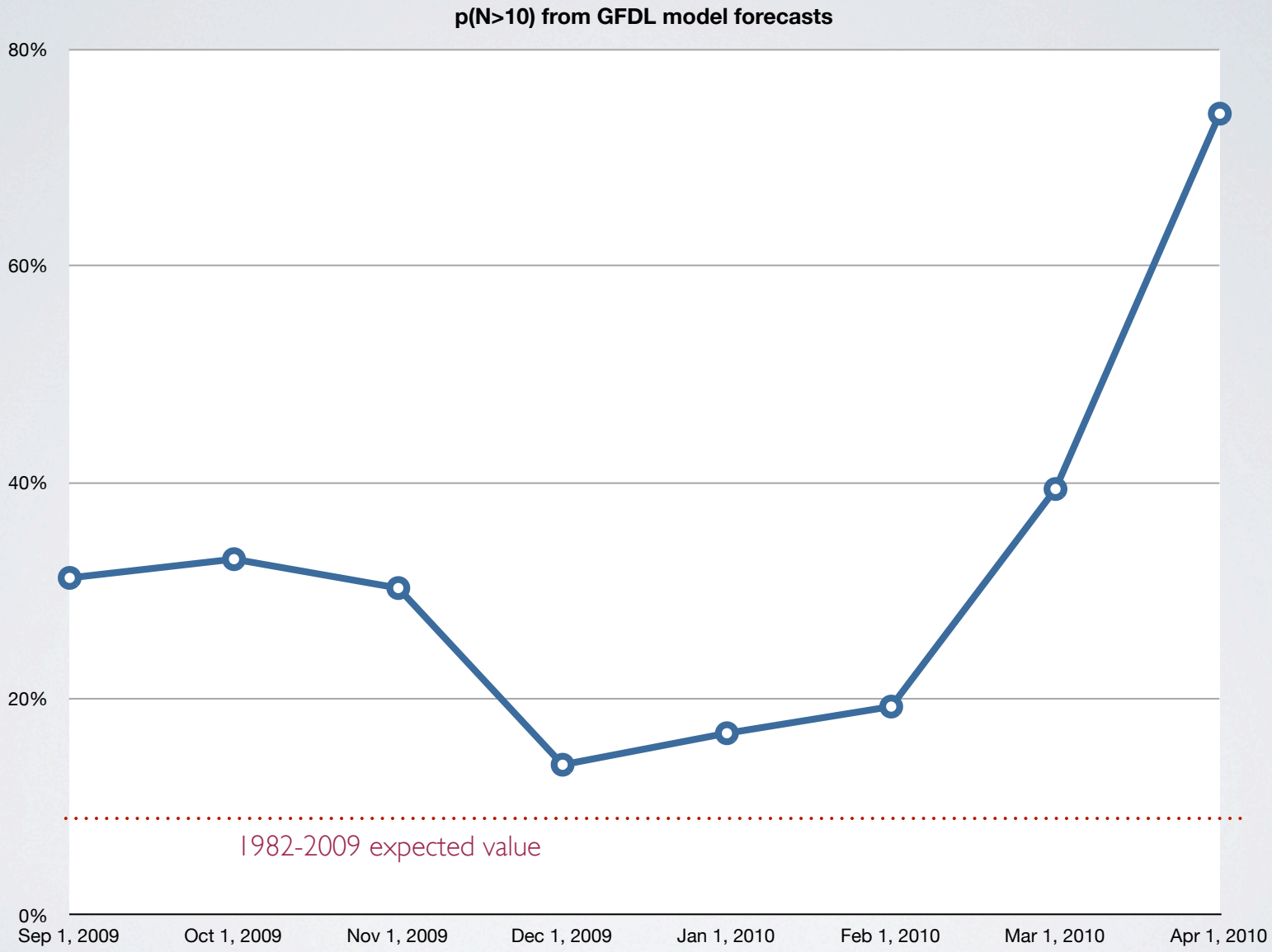
System Anticipates Active 2010



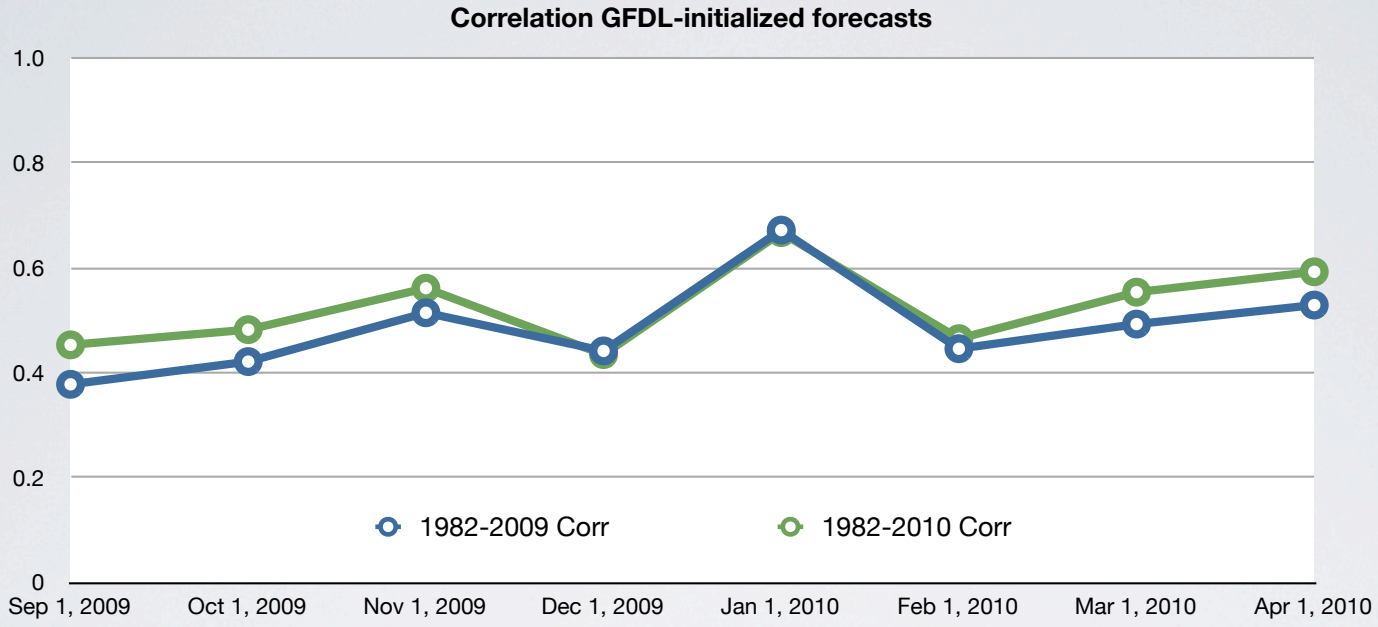
Experimental forecasts for 2010 season
large increase in probability of an extremely active year

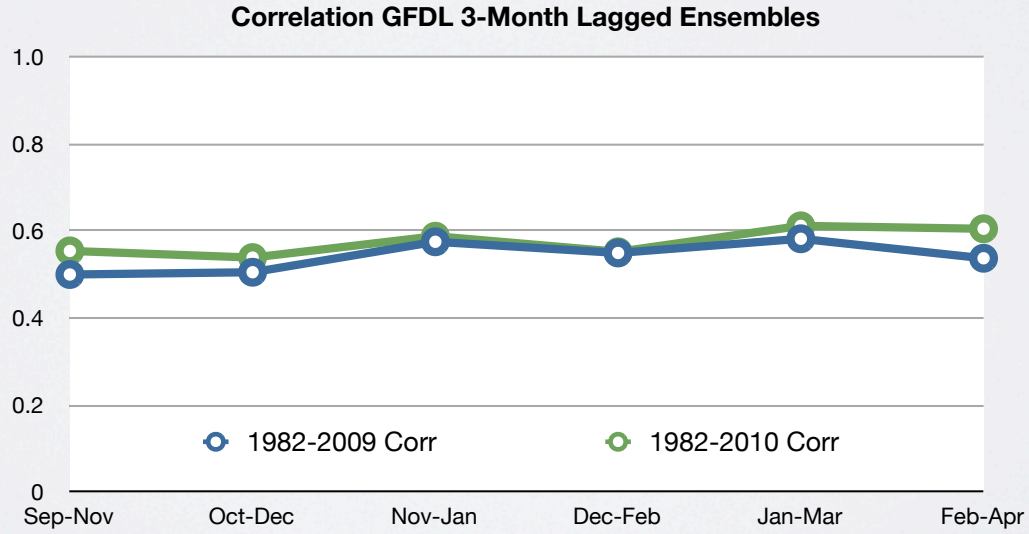
Vecchi et al (2010, MWR submitted)

2010 Seems Preconditioned To Be Active, But Predicted Hyperactivity Shot Up in Spring

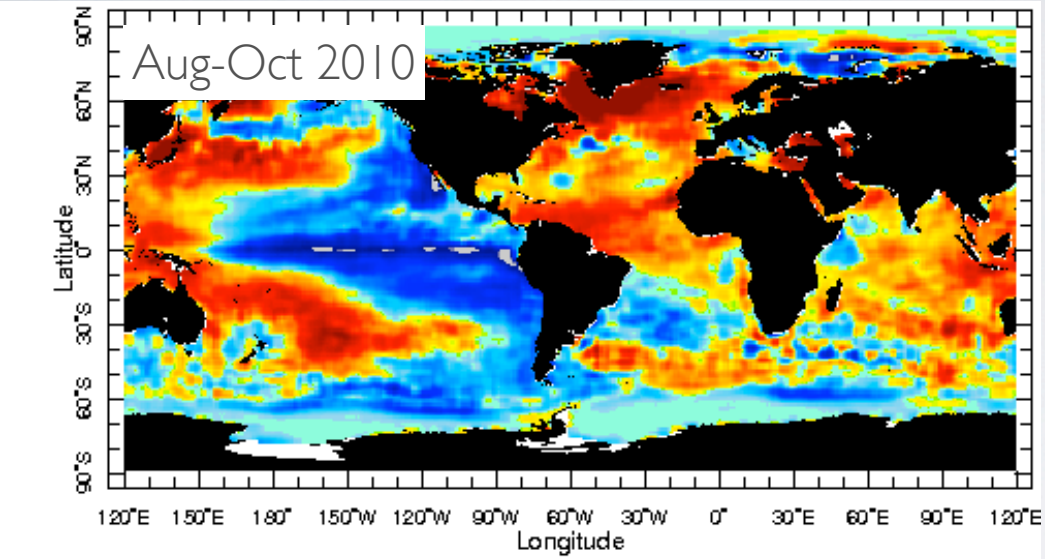


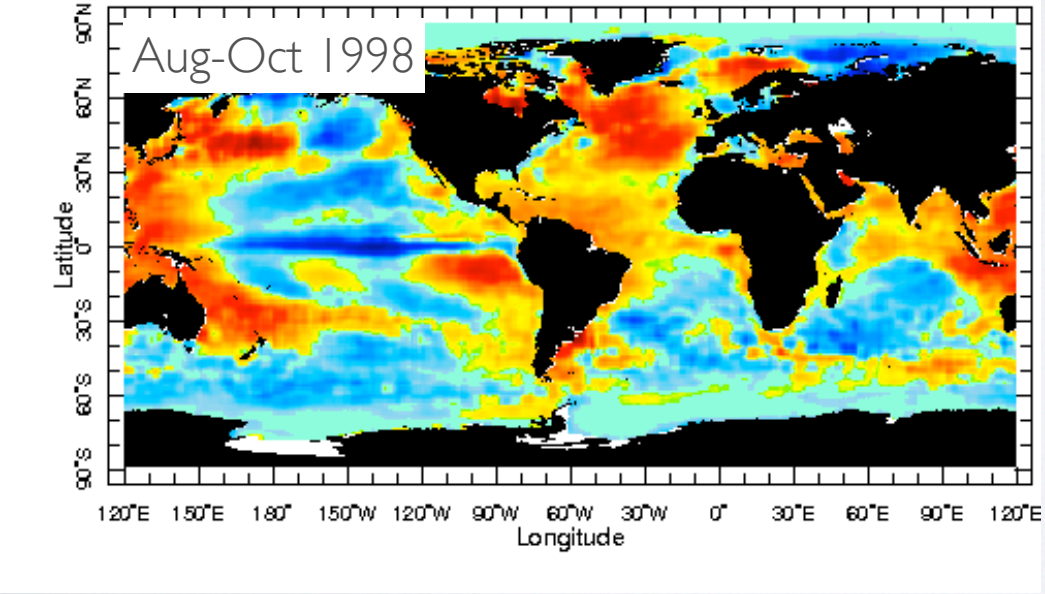
Difficult to Verify Probabilistic Forecast from Single Year, But Inclusion of 2010 (12 Hurr.) Improves Our Retrospective Skill

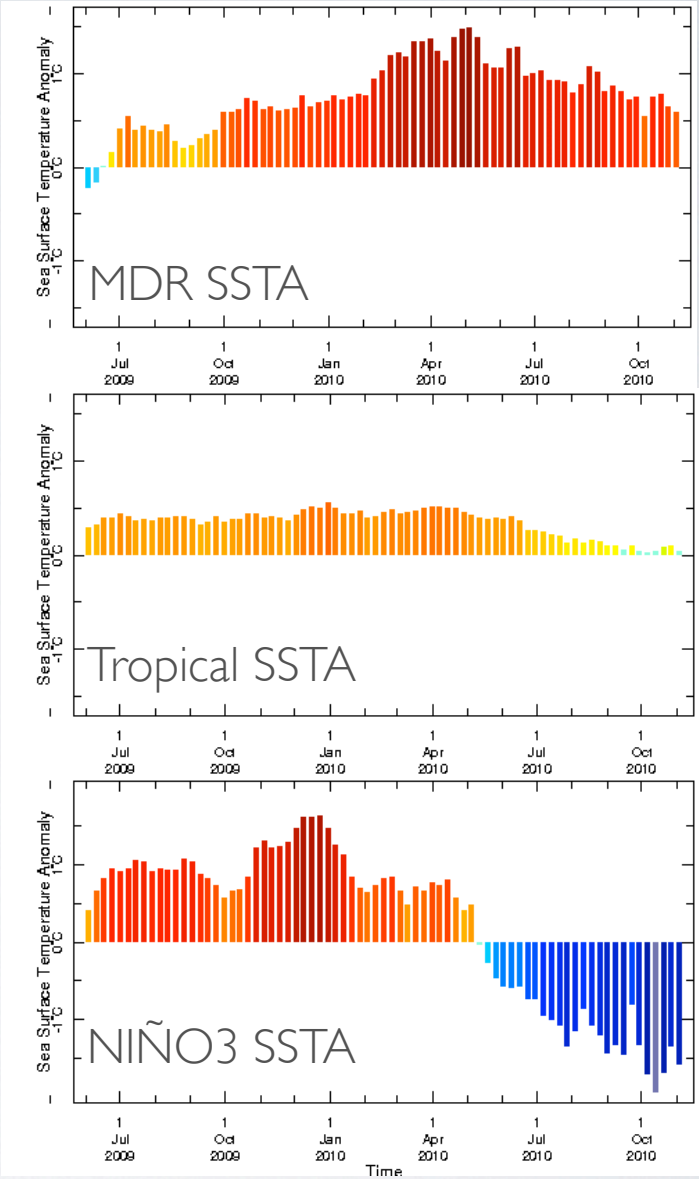




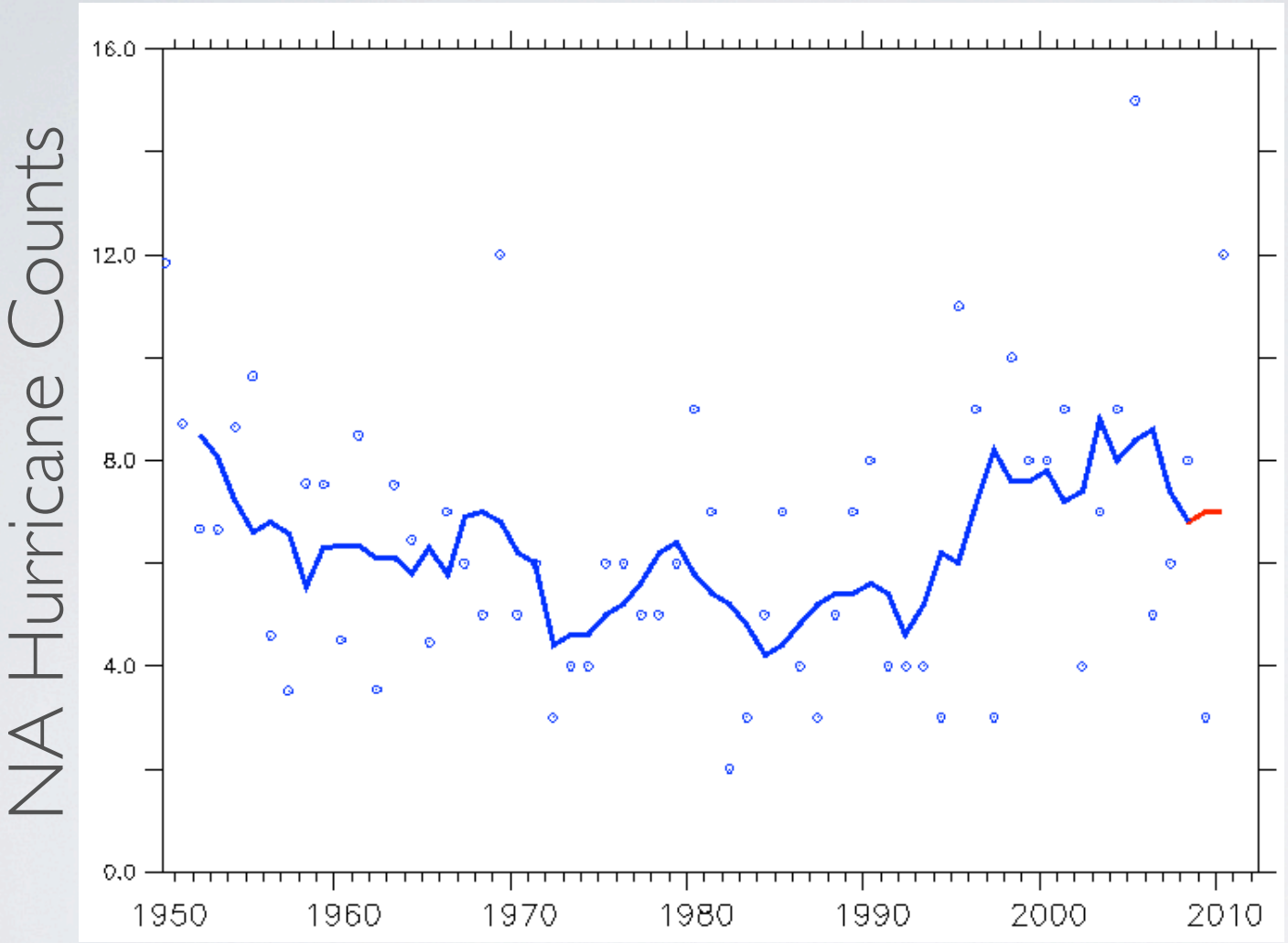
2010 was Unusual in Pacific and Atlantic







Since 2010 Was so Active: **If** We Get Climatological Years in 2011&2012, **then** 2010 Will Have Been Decadaly-Active



GFDL Experimental Forecast for 2011 Initialized November 2010

NOT AN OFFICIAL OUTLOOK, EXPERIMENTAL PREDICTION FOR SYSTEM EVALUATION

- Forecast for slightly above average 2011, with reduced probability of extremely low counts and enhanced probability of extremely low counts:
  - Mean count: 7.47 --- or 1.6 over the system's long-term mean of 5.83
  - Median: 7 --- or two over the system's long-term median of 5
  - p(N.LE.3) = 11.6% --- or less than half the system's long-term average of 27.3%
  - p(N.GT.10) = 18.1% --- or slightly less than twice the system's long-term average of 10.5%
  - p(N.GT.6) = 54.1% --- or somewhat more than the system's long-term average of 37.2%

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

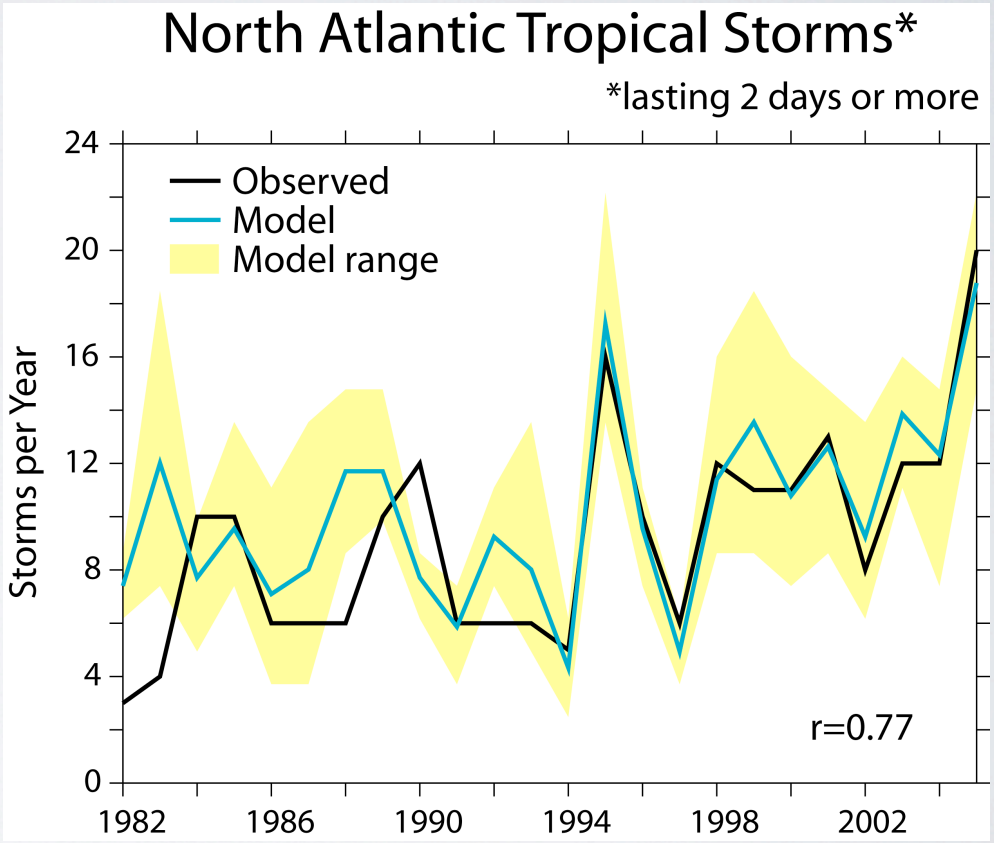
GFDL C-X HIRAM GCMS

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

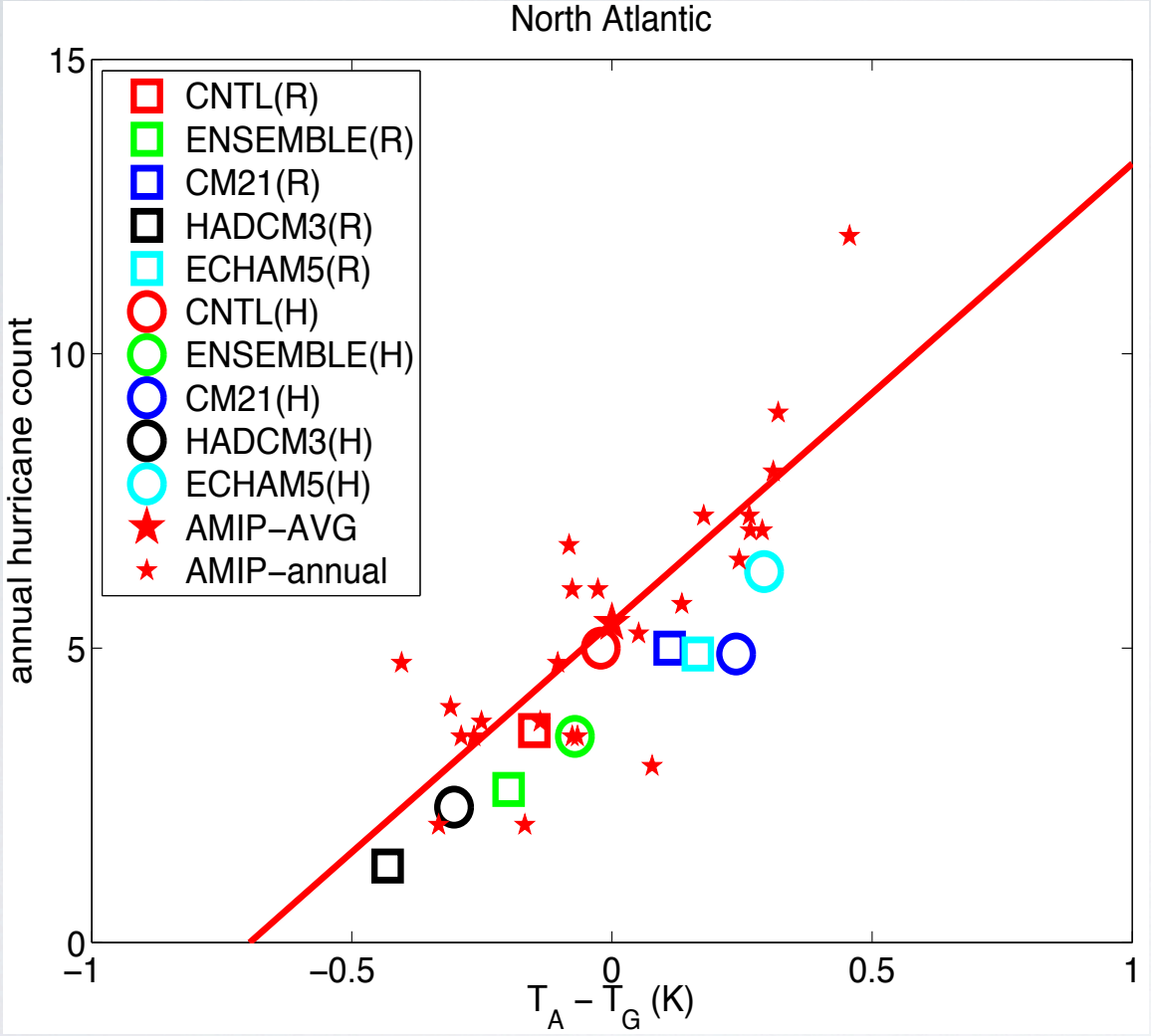
Ref. Zhao et al (2009, J. Climate; 2010, MWR)

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



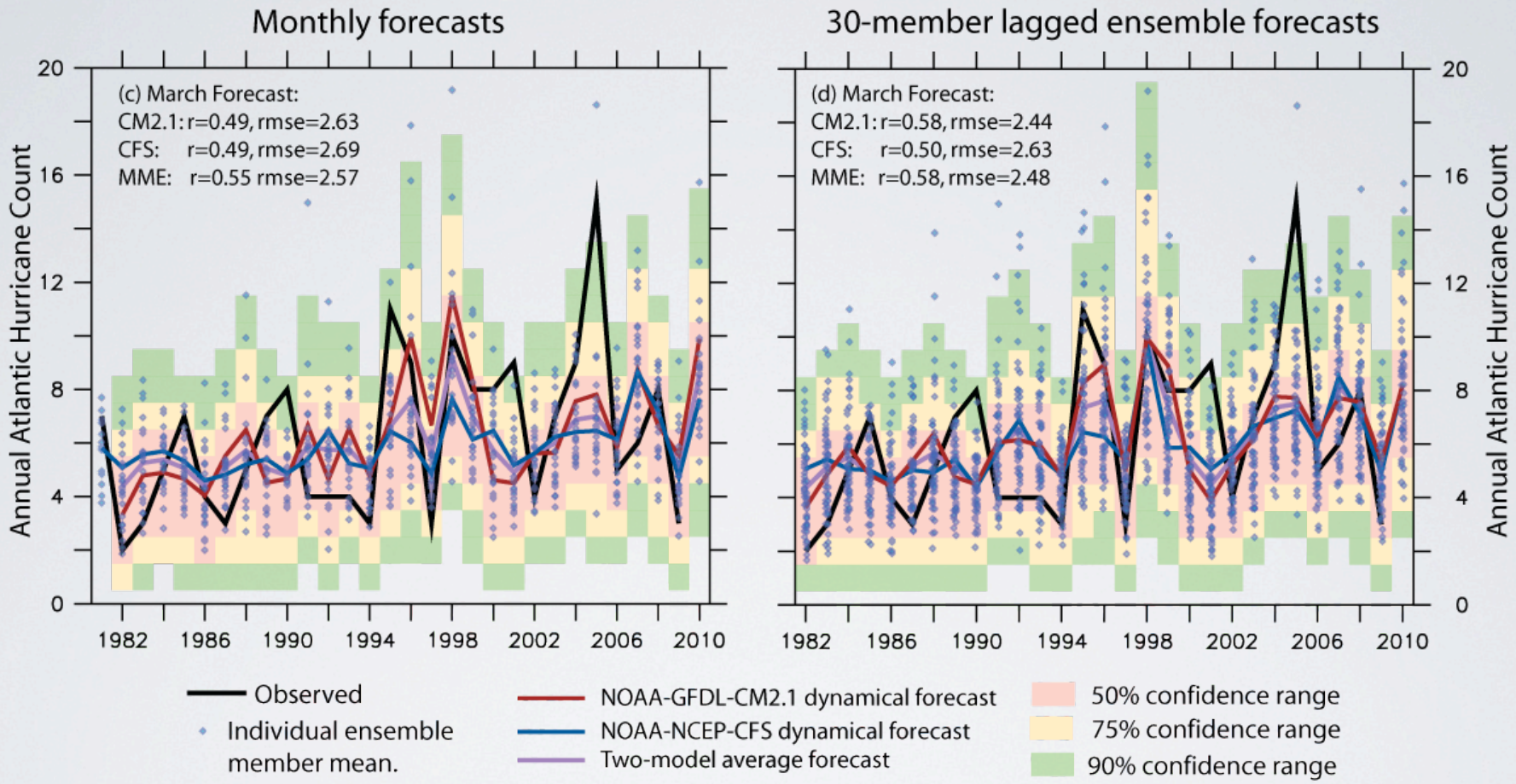
Relative SSTA = Atlantic SSTA minus Tropical SSTA

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)

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



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

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)