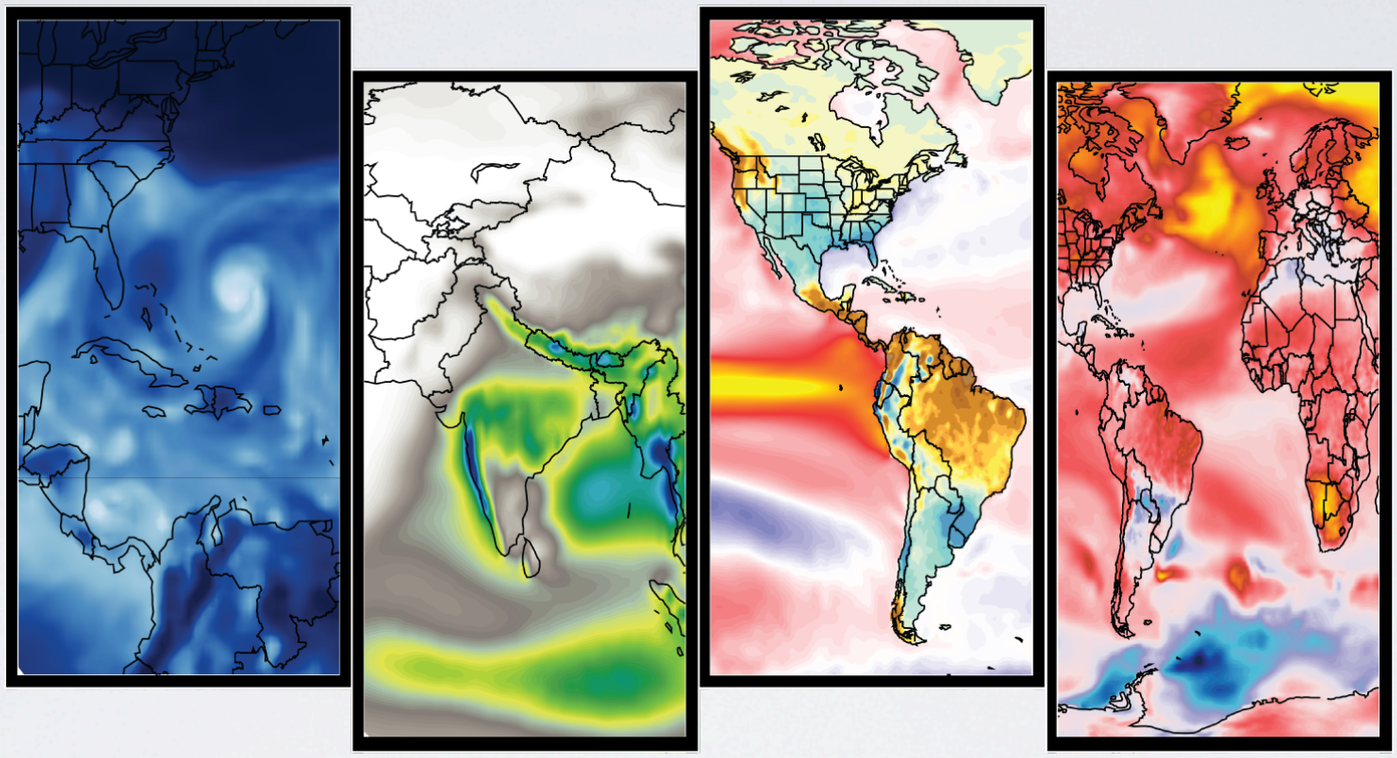
NOAA-GFDL: Prediction Science and the North American Multi-Model Ensemble

Gabriel A. Vecchi for
NOAA/GFDL Climate Variations and Predictability Group



A taste of our predictability/prediction research:

- GFDL and the NMME (one of a number of "real time", now "operational", efforts)
  - GFDL-FLOR: world's highest resolution real-time seasonal prediction model
  - GFDL-HiFLOR: opportunities for extreme hurricanes and regional hydrology

GFDL & the NMME

- CM2.1-based forecasts since inception
- Addition of FLOR (high-resolution) to NMME in March 2014
- Contributed Phase II data from FLOR
- Ongoing Research into predictability & prediction
- Making way for "operational"
- Moving towards "p2" FLOR forecasts (atm/land initialized too)

The GFDL NMME Team:

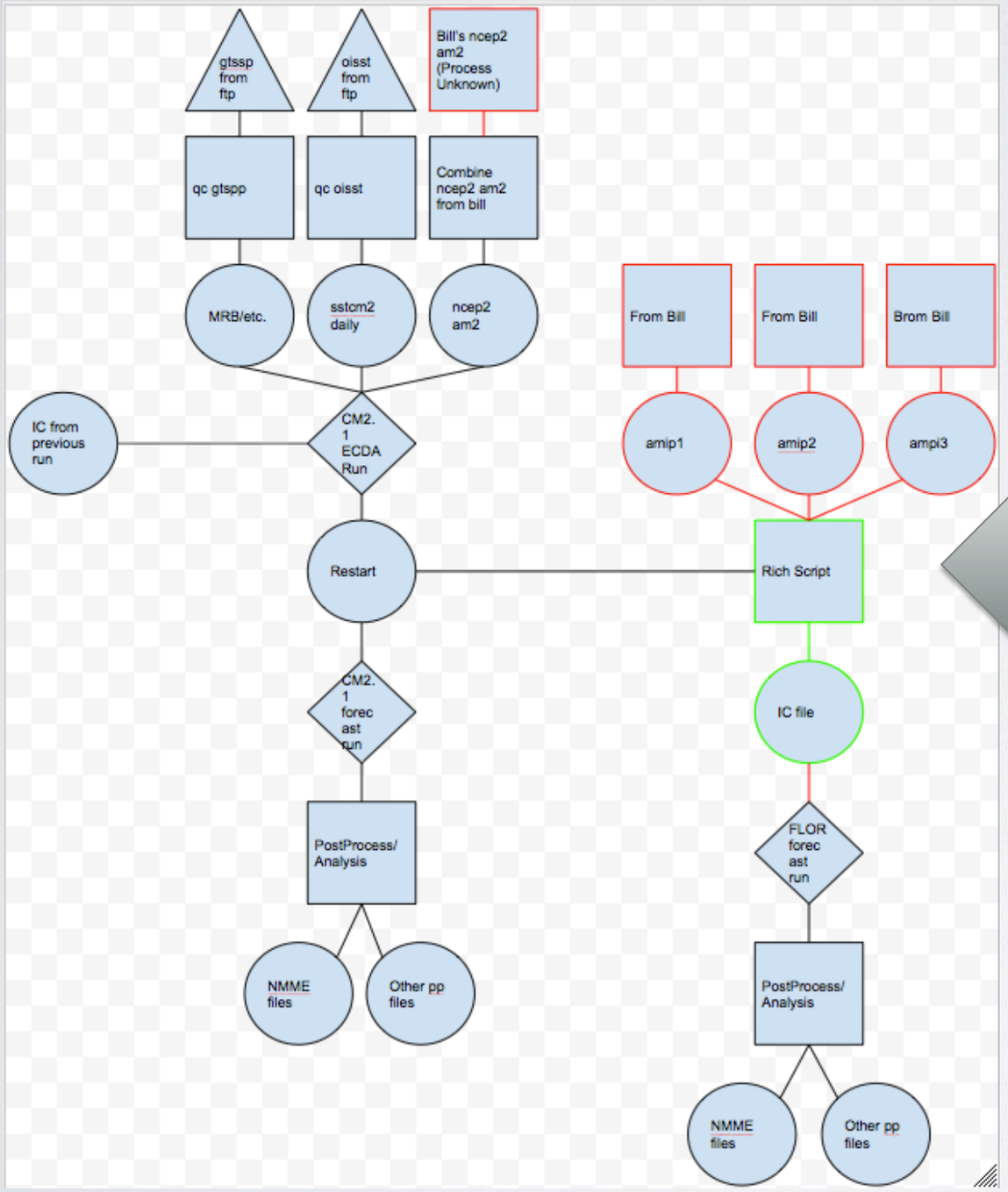
Rich Gudgel (NOAA)

Xiaosong Yang (UCAR)

Seth Underwood (Engility)

Efficient resource use: automation and focus

GFDL Prediction process: every month



- Real-time forecasts a challenge within research environment: human & computer resources as well as culture.

- Fully-automated workflow soon to be our main M.O.
  (thanks Seth Underwood!!!!!)

- We've targeted our tools to prediction problem

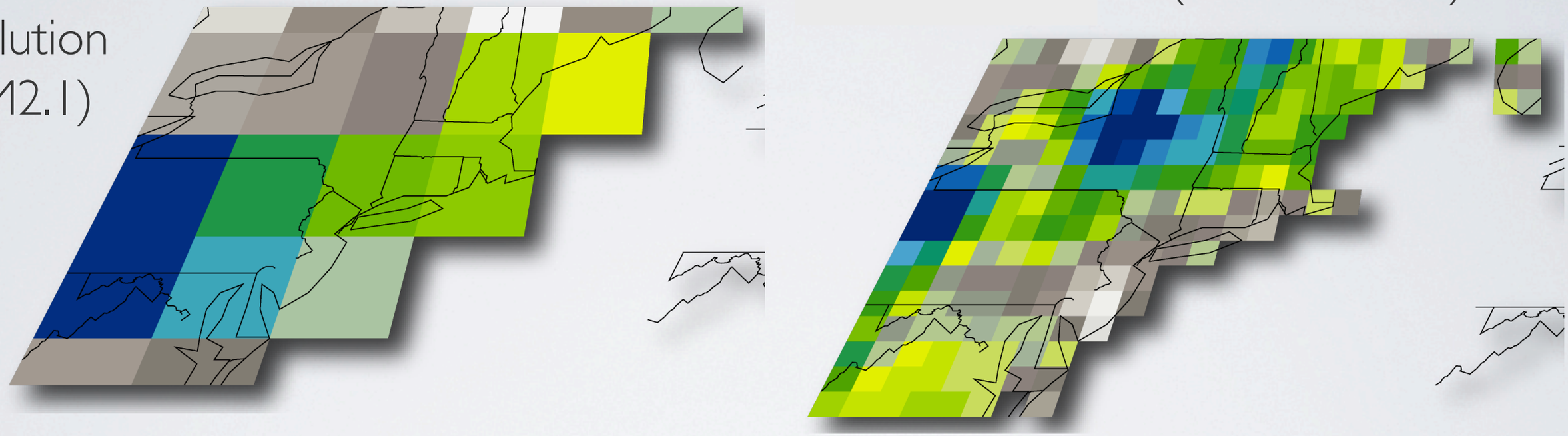
GFDL FLOR: Experimental high-resolution coupled seasonal to decadal prediction system

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)



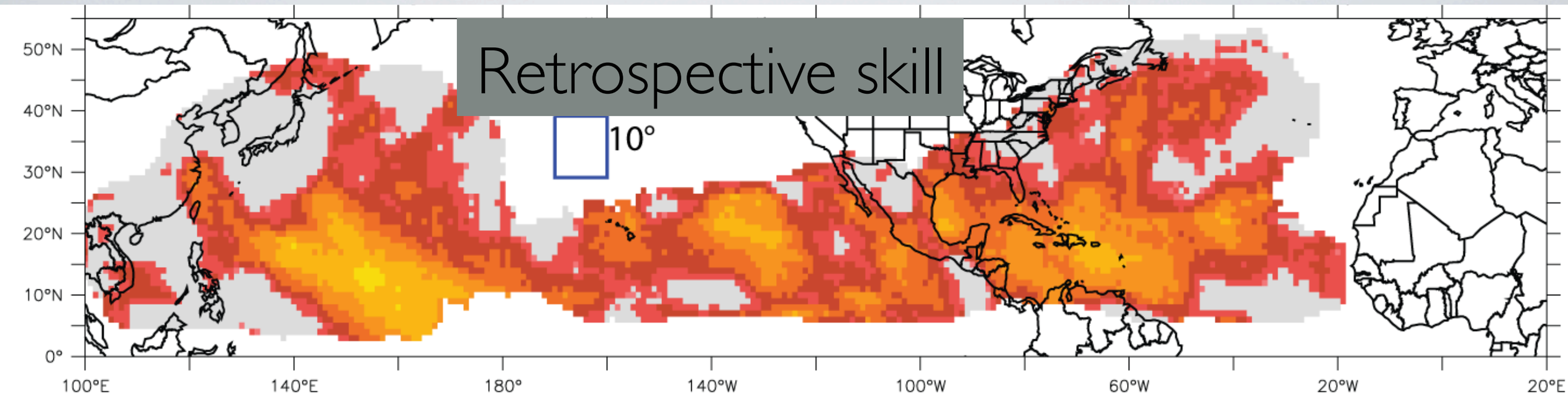
Delworth et al. (2012), Vecchi et al. (2014)

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

- 50km cubed-sphere atmosphere
- 1° ocean/sea ice (low res enables prediction work)

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

Pioneering seasonal prediction of regional tropical storm activity

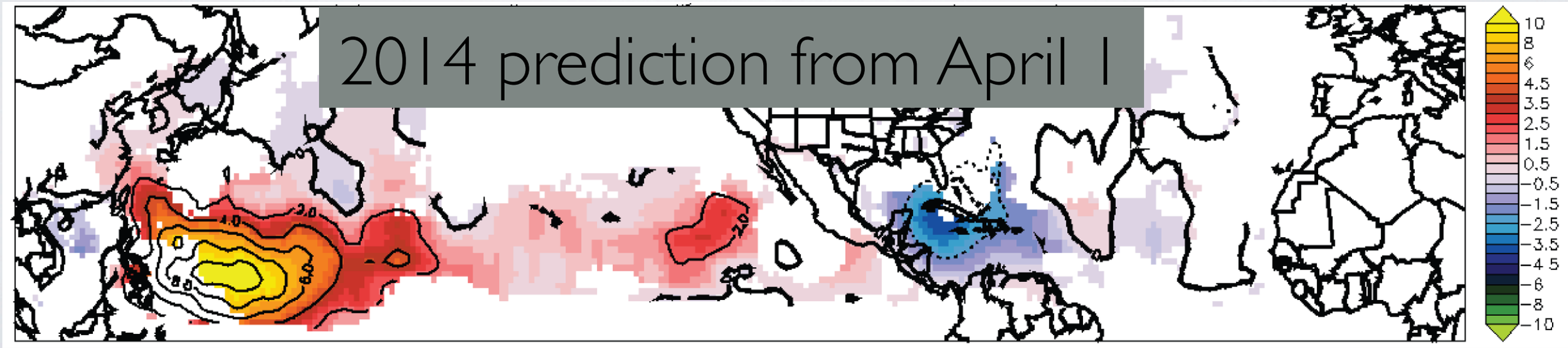


-0.4 -0.2 0.2 0.4 0.6 0.8 1

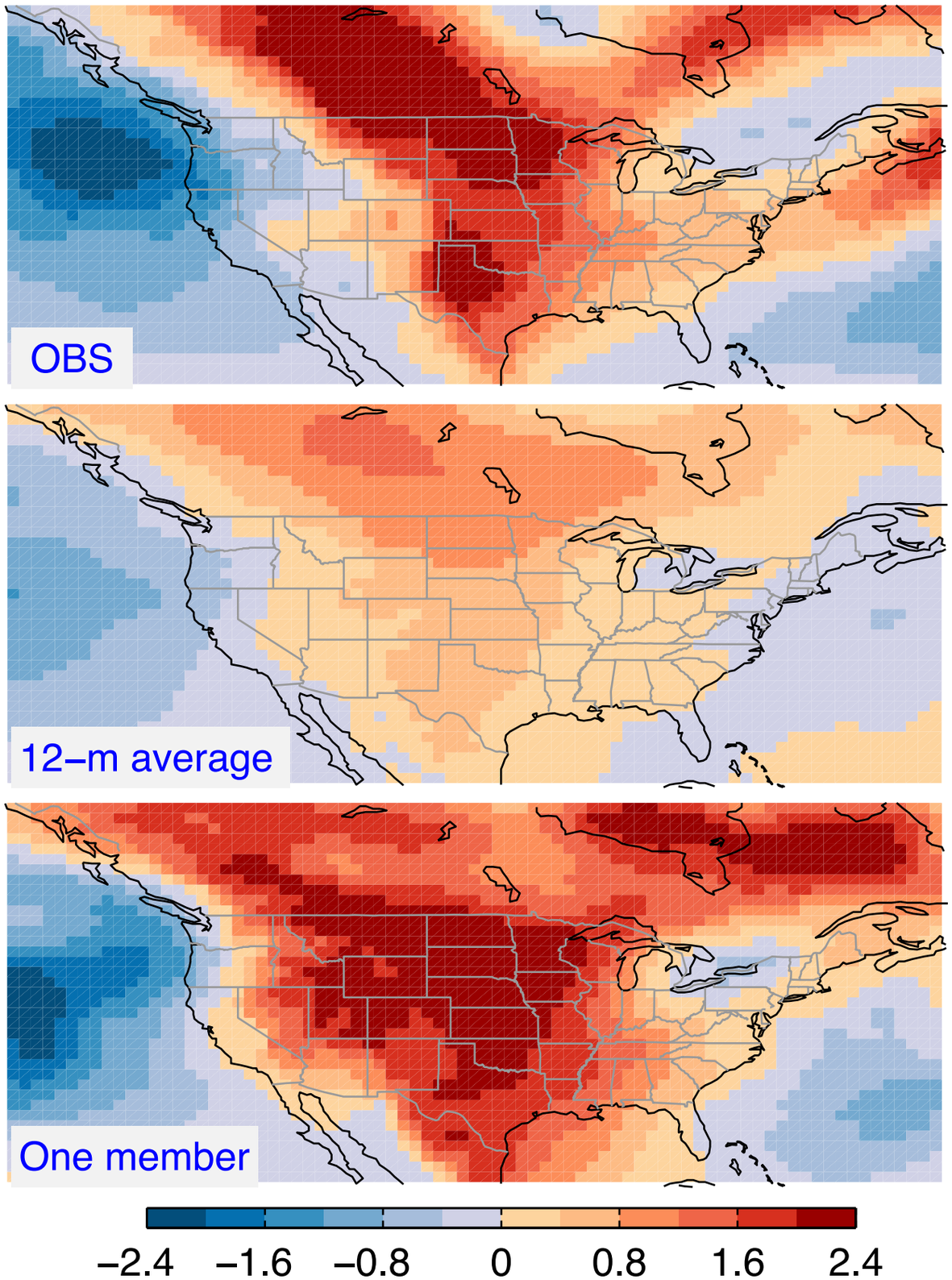
Rank correlation predicted vs. observed
masked at p=0.1

>25% years with density > 0

Vecchi et al., 201



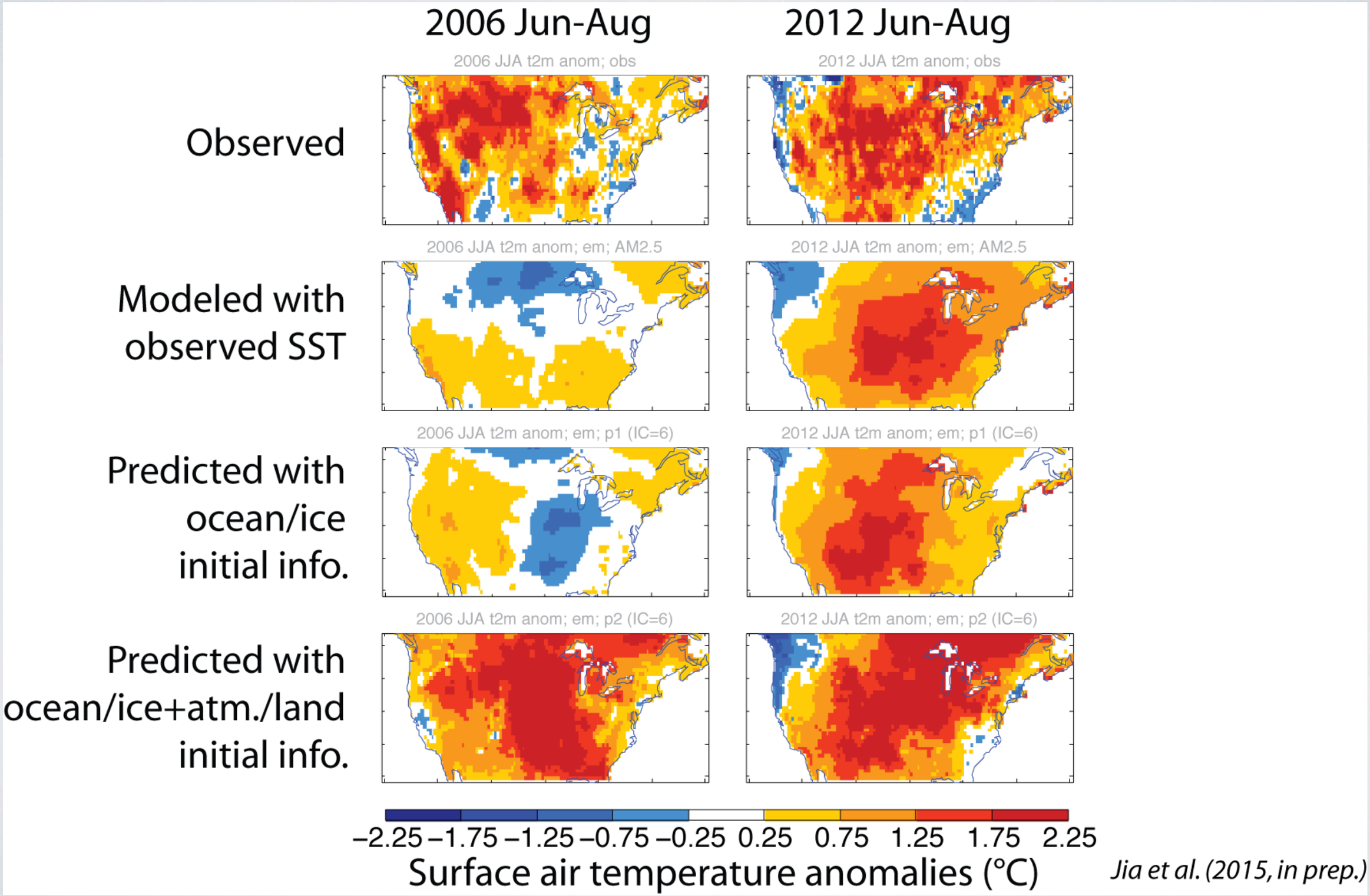
Skillful FLOR-based predictions of anomalous storminess over North America in winter 2013-14



Skill for regional, seasonal extra-tropical storminess over long reforecast set as well.

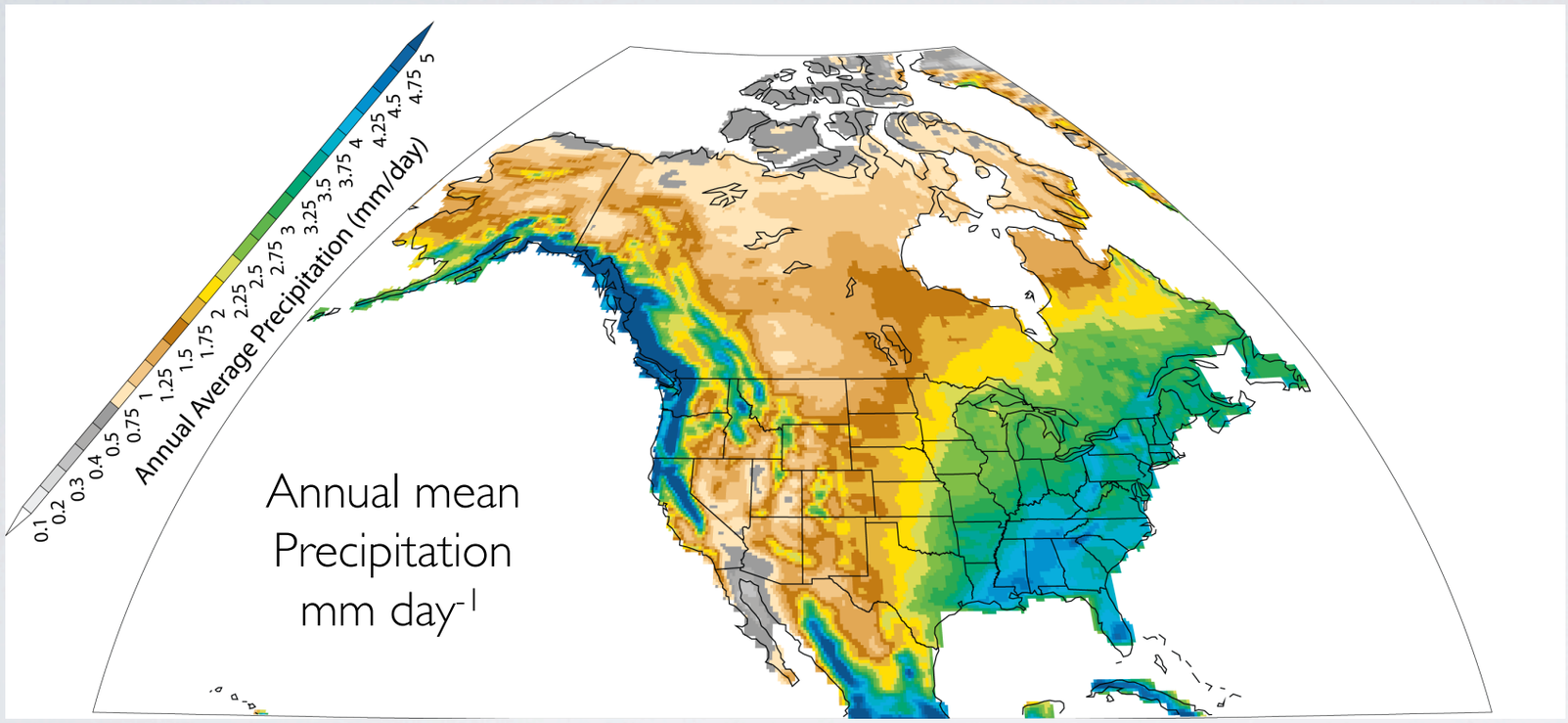
Yang et al. (2015, in press)

Causes of and sources of predictability for summertime heatwaves: need atmos./land initialization, in addition to ocean, in order to predict heat waves.

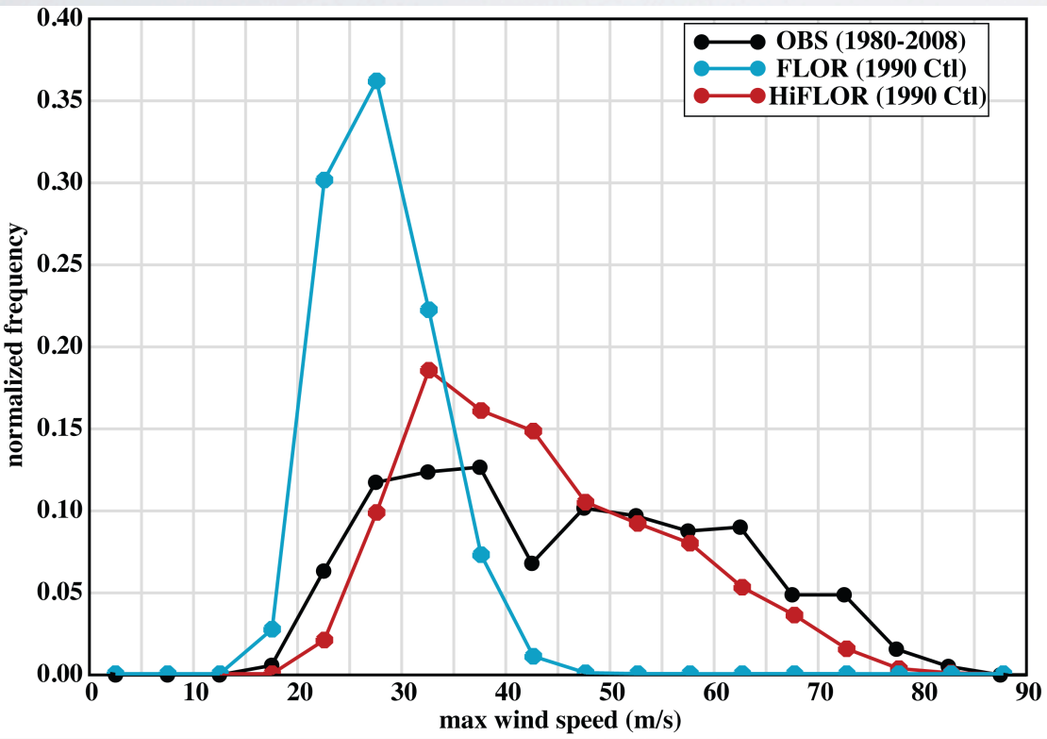


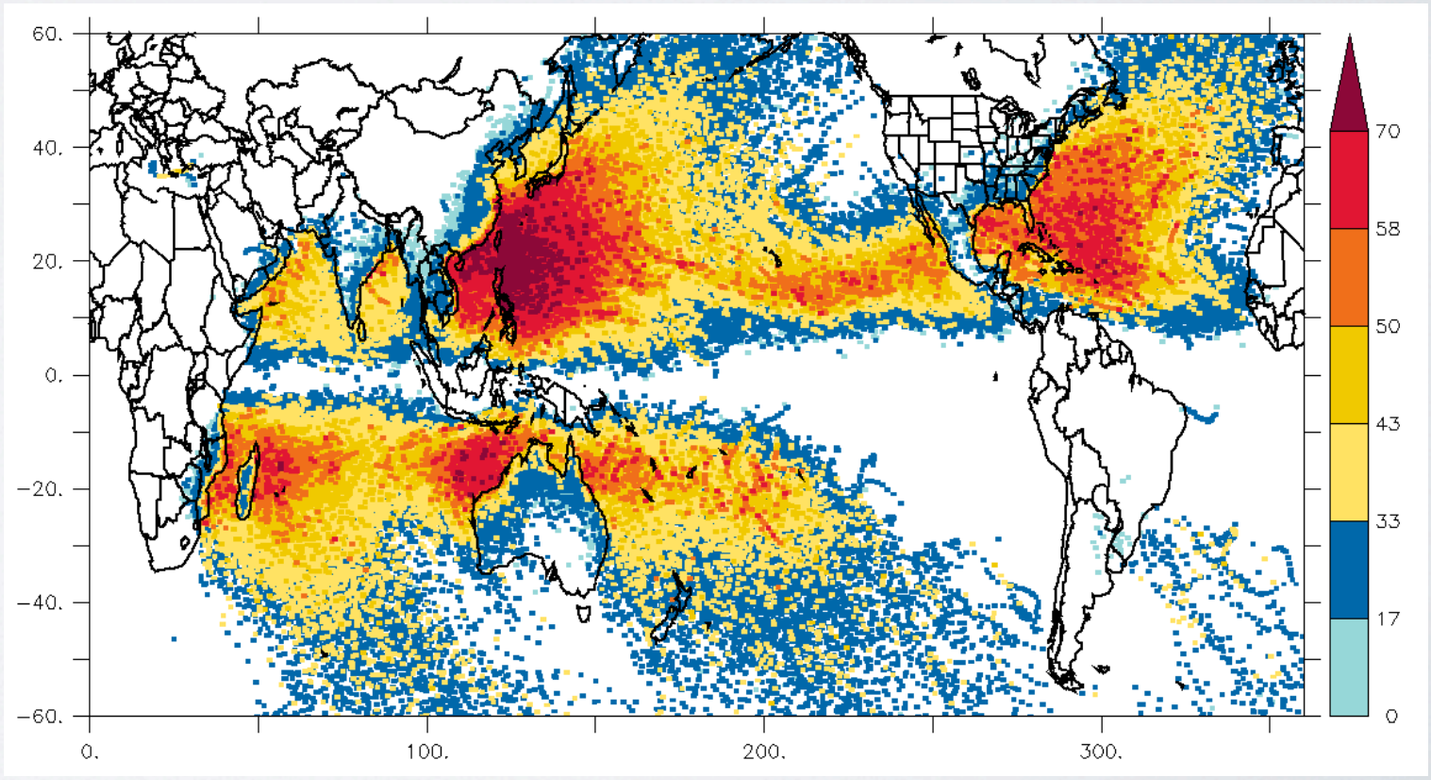
Jia et al. (2015, in prep.)

Opportunities

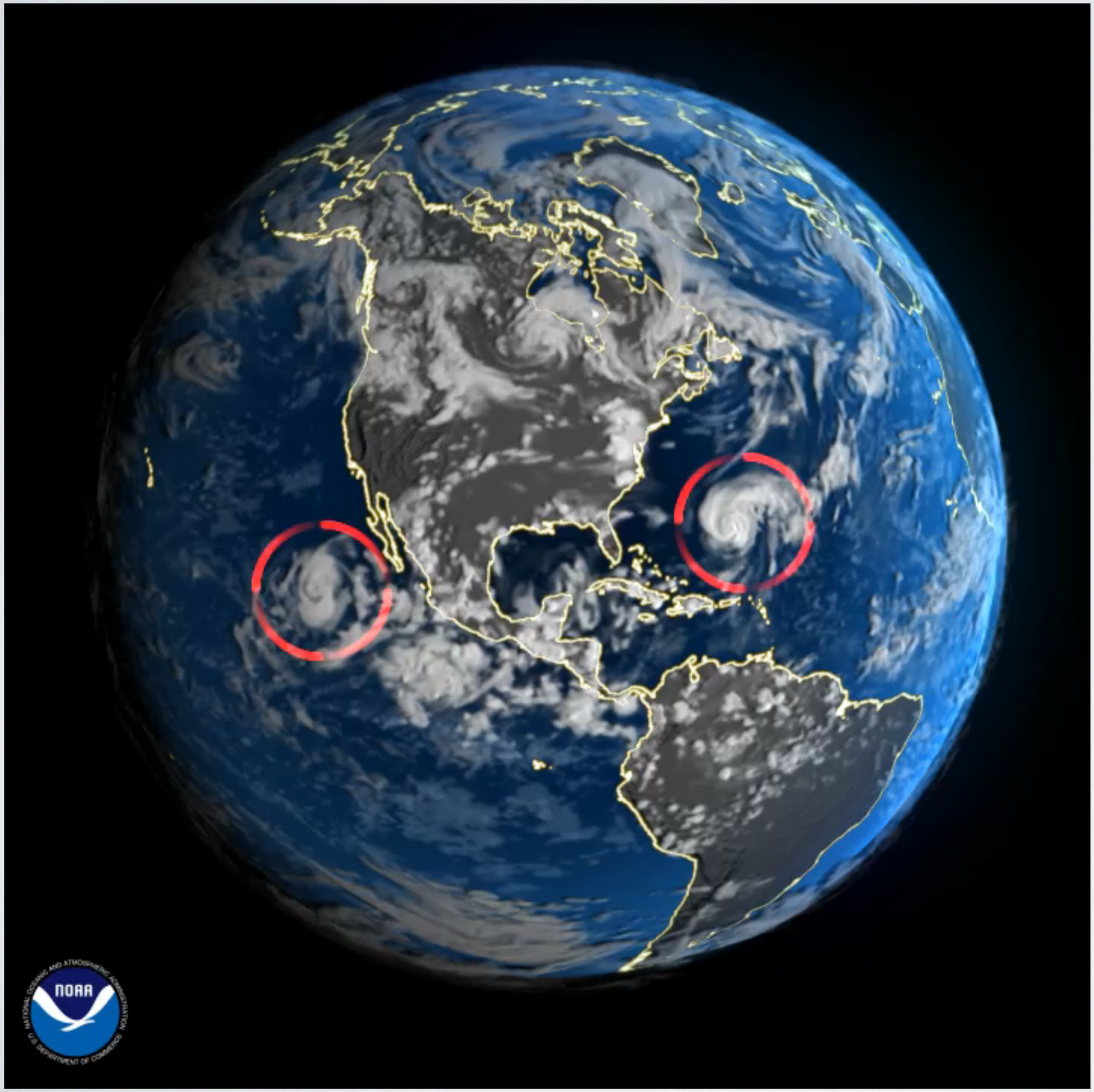


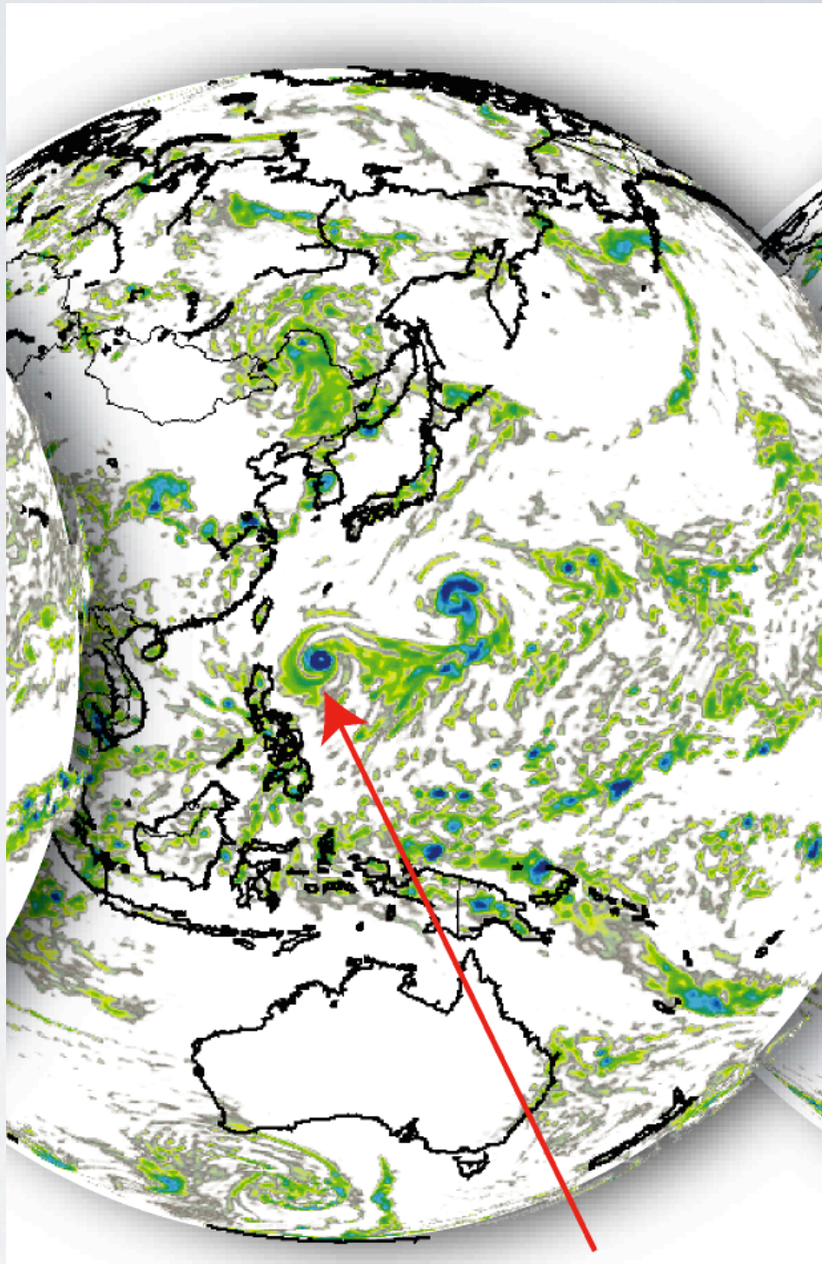
Newly developed "HIFLOR" model
25 Km atmosphere, 1° ocean





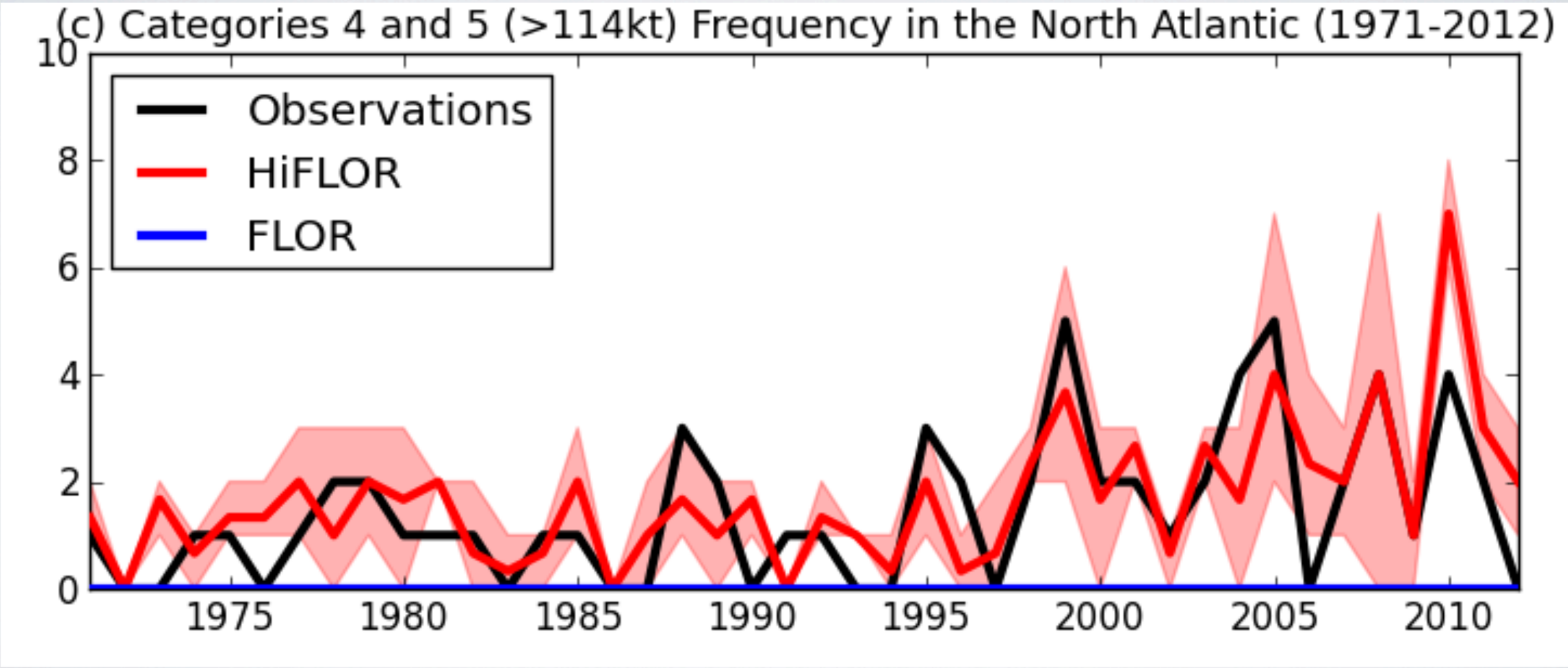
HiFLOR: doubling atmospheric resolution of FLOR (cost 6x) allows us model to simulate Cat. 4-5 TCs (most destructive storms)





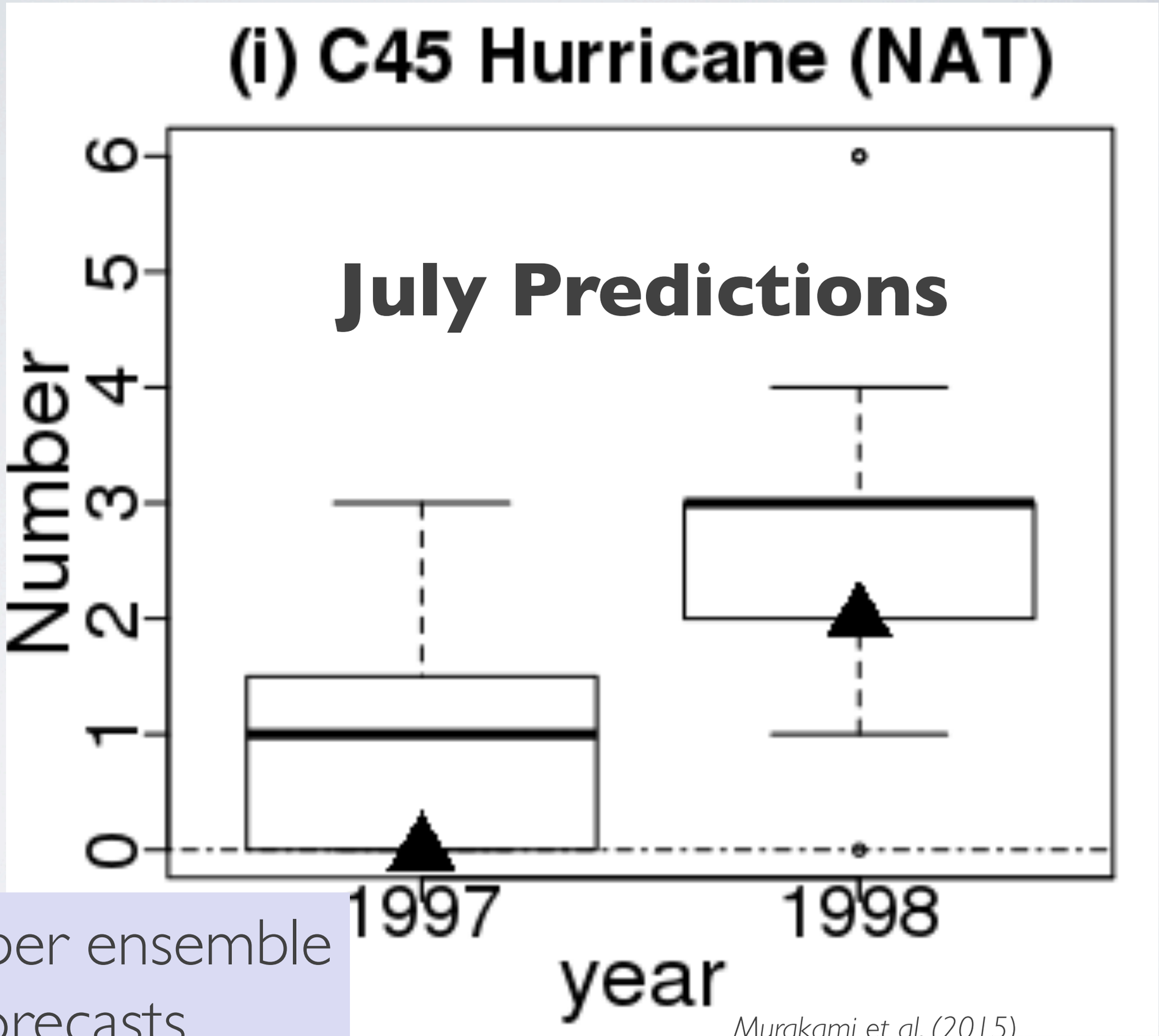
10-Aug.: Cat. 5 Typhoon
(158 knot winds)

HiFLOR prototype NOAA-GFDL prediction model recovers Cat. 4-5 history…



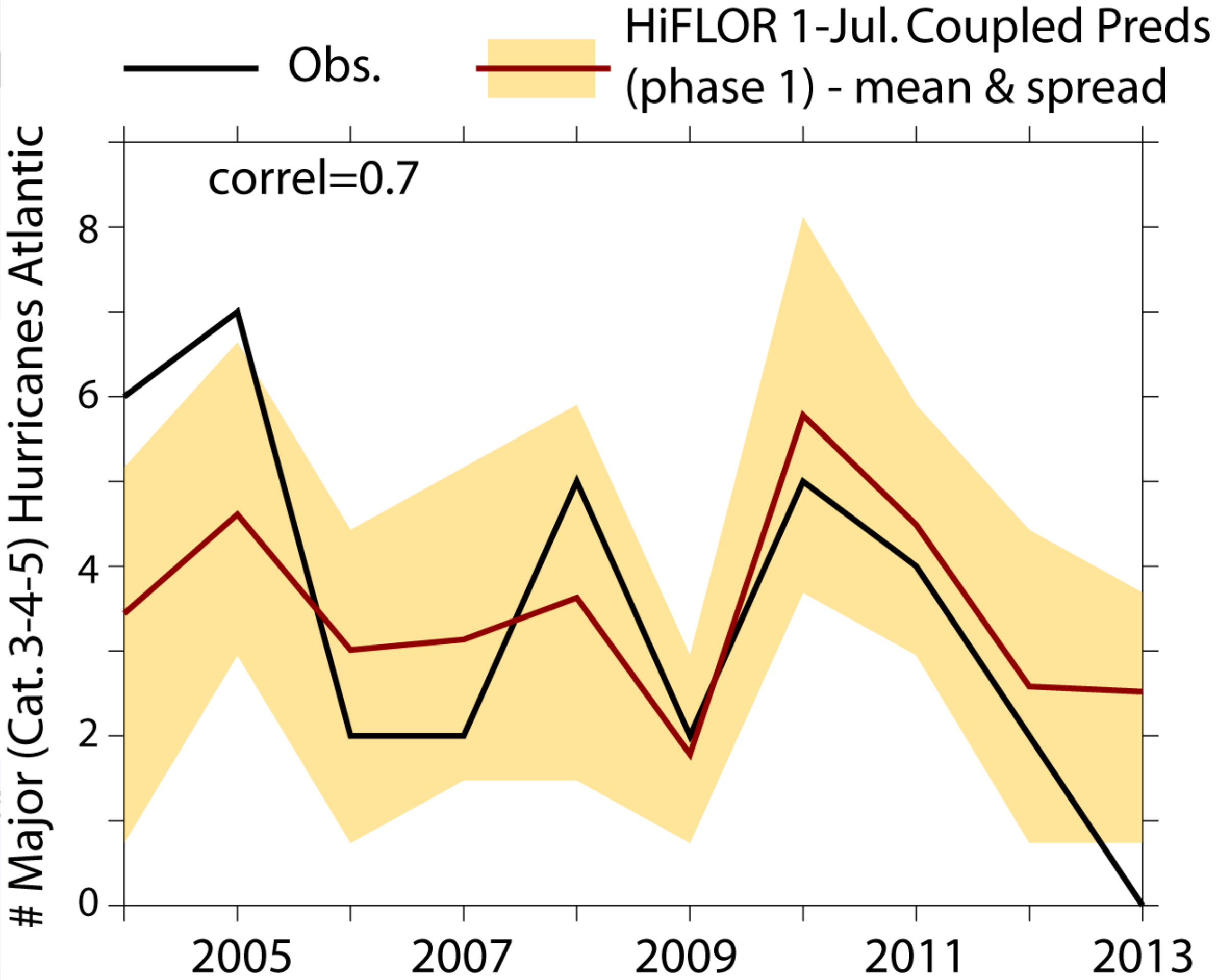
Murakami et al. (2015)

HiFLOR experimental predictions encouraging…

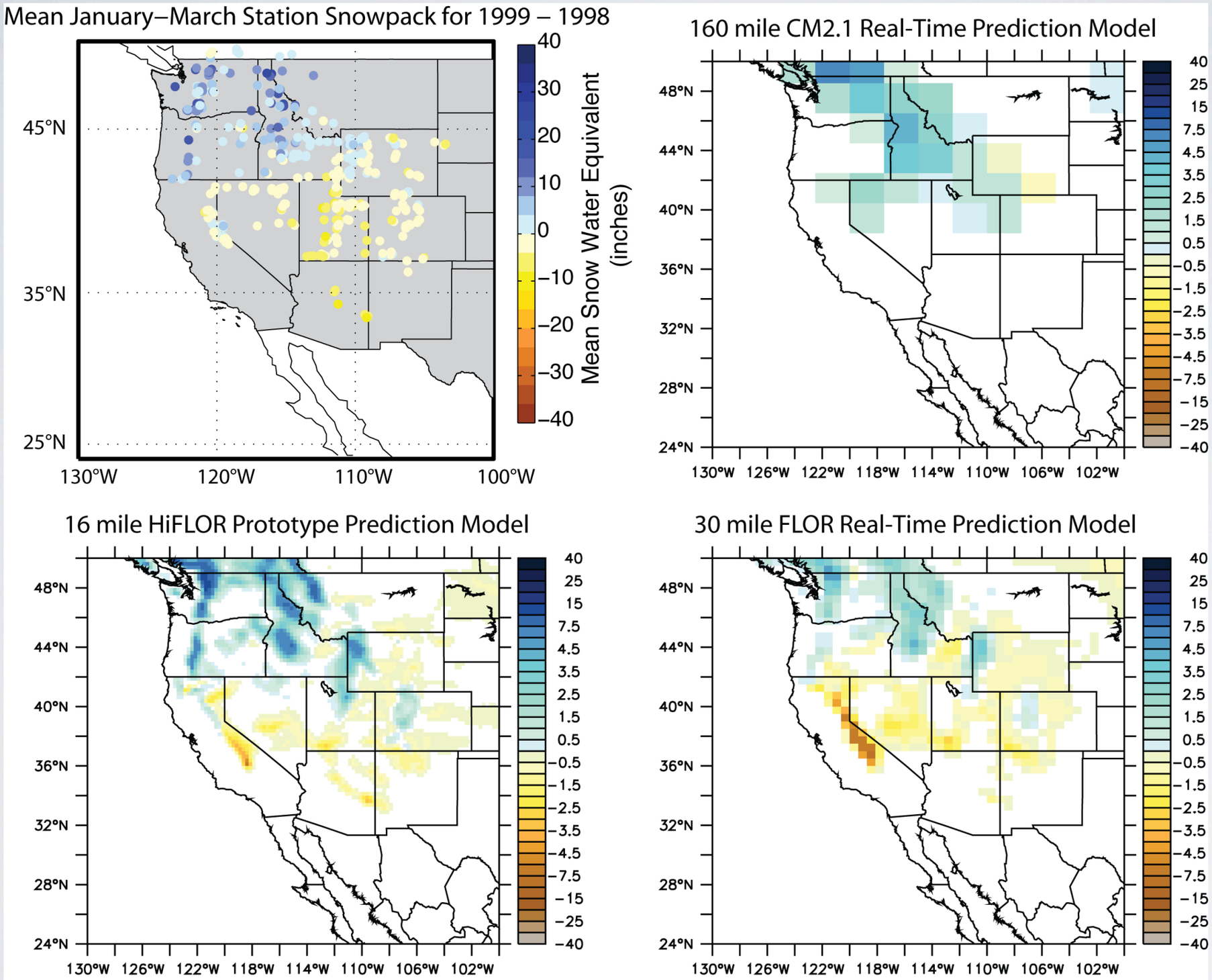


36-member ensemble reforecasts

Murakami et al. (2015)


Obs.
HiFLOR 1-Jul. Coupled Preds
(phase 1) - mean & spread
correl=0.7
# Major (Cat. 3-4-5) Hurricanes Atlantic
0
2
4
6
8
2005
2007
2009
2011
2013

Towards predicting western U.S. snowpack



Observed and Predicted Differences of 1999 minus 1998 January-March Snowpack - Predictions Initialized 1-July of previous year.

Kapnick et al. (2015, in prep.)

GFDL Predictions and the NMME

Key foci: ENSO, hurricanes, water resources, extratropical storms, drought, sea ice, snow, heat waves, data assimilation, intraseasona-to-decadal

Coupled data assimilation

- CM2.1-ECDAv3.1 (1960-present)

FLOR model (50km atmosphere)

- "sweet spot" of quality, speed, readiness
- regional applications, extremes
- seamless predictions: intraseasonal to decadal

Groundbreaking forecast system

- Outstanding forecasts in the NMME
- Highest-resolution seasonal forecasts in the world
- Seasonal hurricane outlook → NOAA
- ENSO outlook → IRI
- sea ice outlook → SEARCH

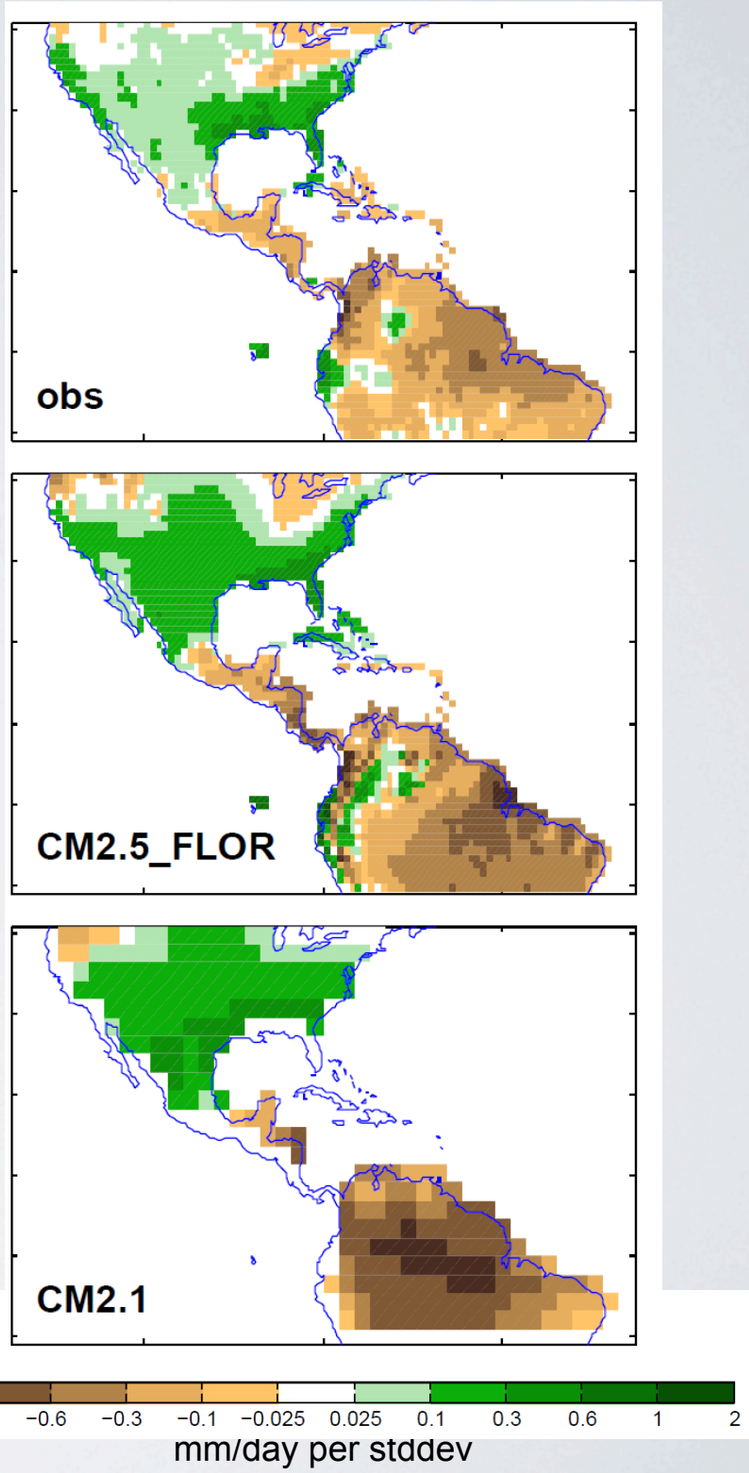
Opportunities (25km HiFLOR)

- To target extreme TCs and ultraregional water resources
- Need resources: "shovel ready"
- Approached DoE, but declined after **great science review**

Strategic decisions for U.S., NOAA & GFDL

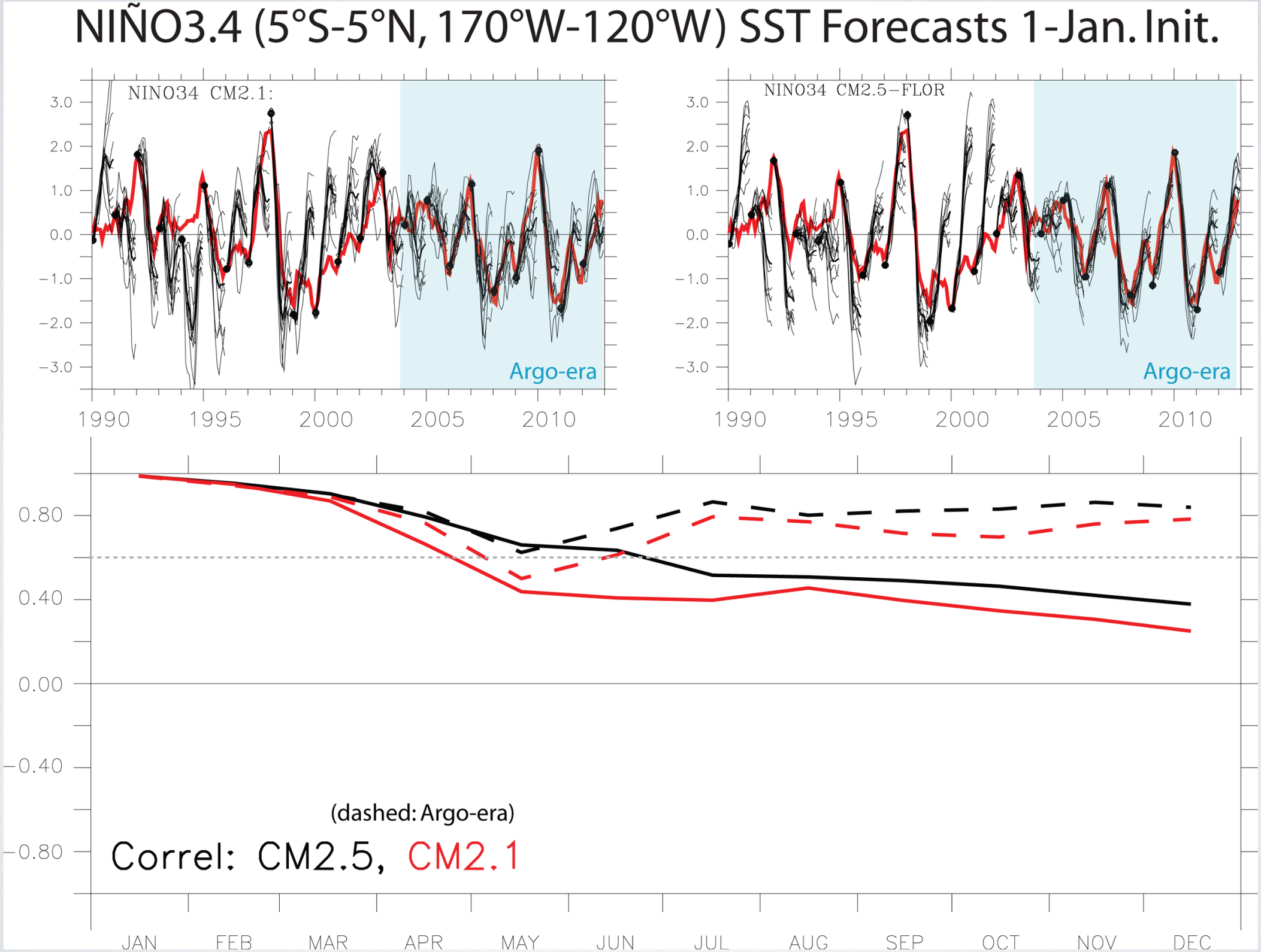
- Developed by small group, building on past efforts
- Transient convergence of unique opportunities
- **Forecasts need resource infusion to continue**
- Computer allocation, personnel, model strategy

ENSO rainfall teleconnections, for the most predictable component of global rainfall over land (Jia et al. 2014)

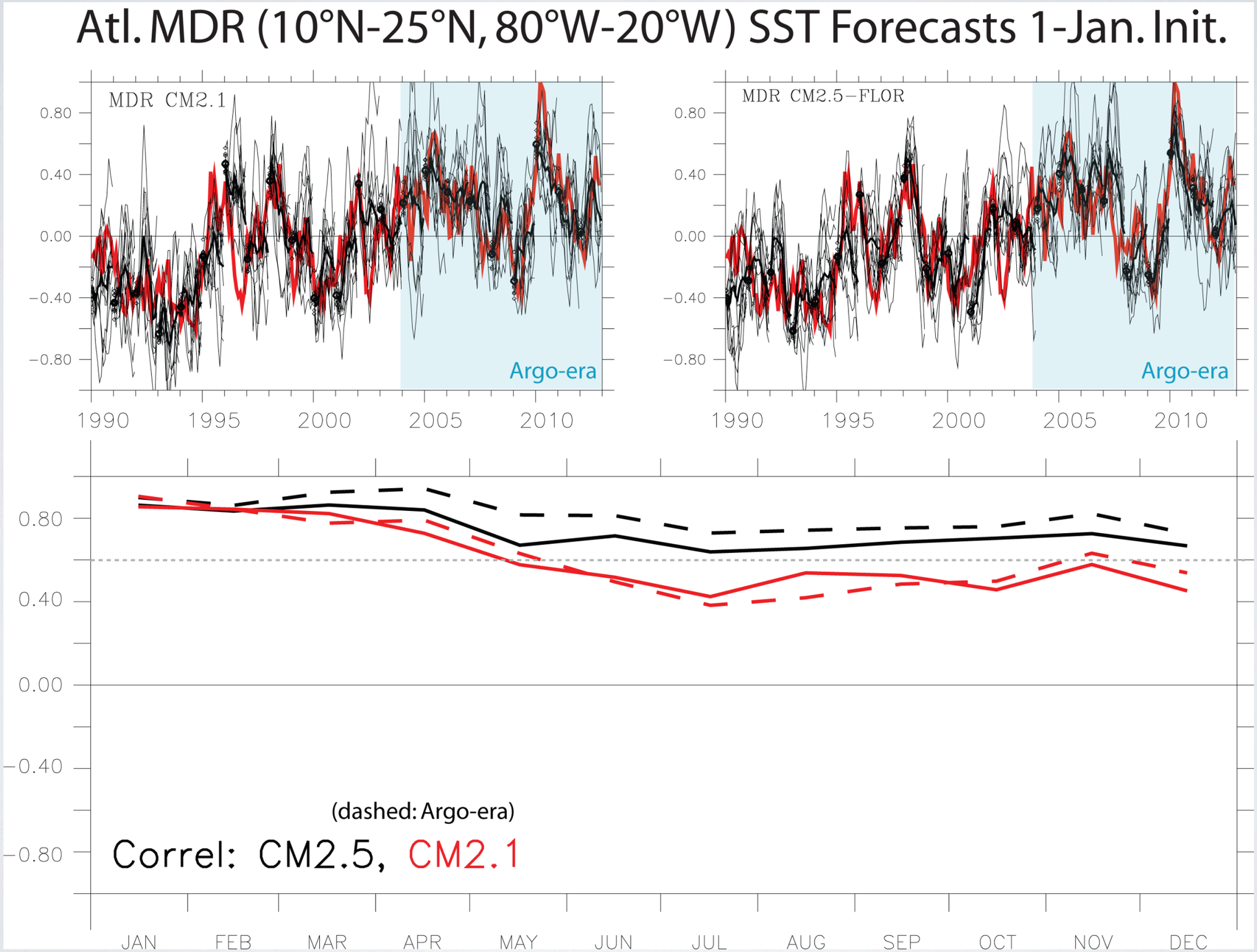


THANKS

FLOR Improves on CM2.1 for SST Predictions



FLOR Improves on CM2.1 for SST Predictions

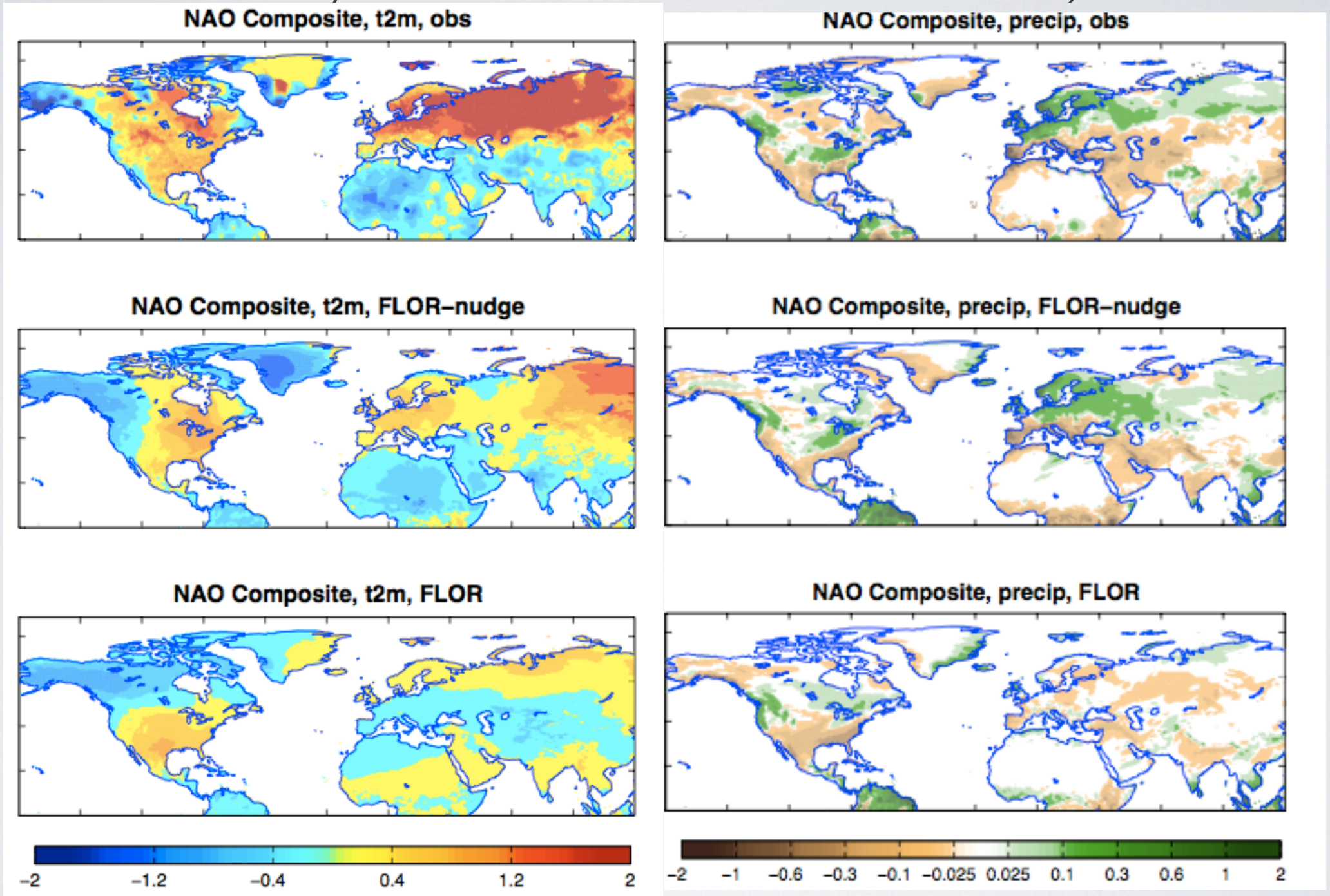


Preliminary analysis of FLOR-P2 predictions: Subseasonal variability over land, Role of Atm. I.C.)

Obs

P2

P1



I.C.: 01Dec

T2m

DJF NAO+ Composite

Precip

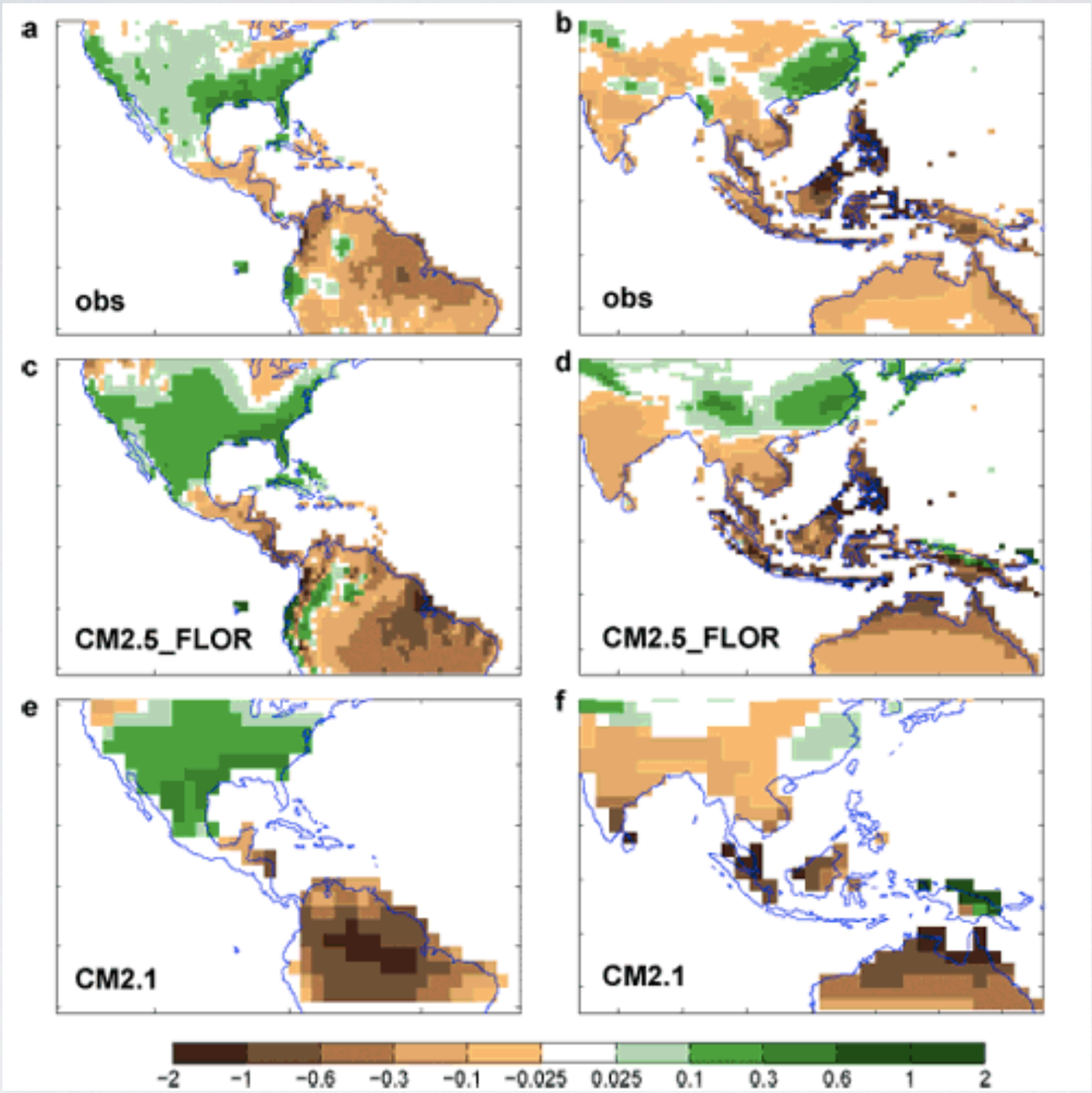
Phased approach to FLOR predictions

Phase 1	Proof of concept, assess value of high-resolution. Targets: seasonal, multi-month lead large-scale as well as regional and extremes (regional TC activity)	Use CM2.1's ocean-ice ICs, atmosphere/land from a long AMIP run. 1980-present forecasts.	Done & ongoing – first real-time forecast delivered to NMME 5-March-2014
Phase 2	Test hypothesis that atmospheric initialization improves predictions. Enable intraseasonal predictions of regional and extremes (e.g., regional TC and XTC activity, sea ice)	Nudge atmosphere to MERRA analyses, CM2.1's ocean-ice ICs, Make 1990-present forecasts. (Exploring subseasonal predictability)	Nudging run done for 1980-present, retrospective forecasts done for 1990-present, evaluating impact of constraining atmosphere.
Phase 3	"Best shot" at predictions of regional and extremes, seamlessly on a weekly to multi-season timescale. Large ensemble spread to provide reliable probabilistic information	Build coupled assimilation on high-res system, run 19XX-present forecasts.	Assimilation in development. Running retrospective assimilation and reforecasts would take huge CP and human commitment. ???

GFDL-FLOR to the NMME (2)

- Initialization of GFDL FLOR P2
  - ✓ Ocean & sea ice initialized from CM2.1 V3.1 EnKF Assimilation
  - ✓ Atmosphere and land initialized from the atmosphere-nudging-to-reanalysis AGCM simulations (*i.e.*, only information contained in atmosphere, SST and radiative forcing in atmos/land ICs)
- Hindcast experiments:
  - ✓ 1990 to present, 12 ensemble members
  - ✓ 12-month hindcasts starting first day each month
- Computational cost for each month (Total core hours ~120,000)
  - ✓ Data assimilation: 384x4
  - ✓ Hindcasts: 2x640x3 (CM2.1), 2x6240x9 (FLOR), 3x1952x1(AMIP-nudging)
- Exploring the subseasonal predictability due to atmosphere component initialization: MJO, NAO, stratosphere-troposphere interactions, et al.
- Preliminary results of FLOR P2: skill difference between P1 and P2, mechanism for the difference

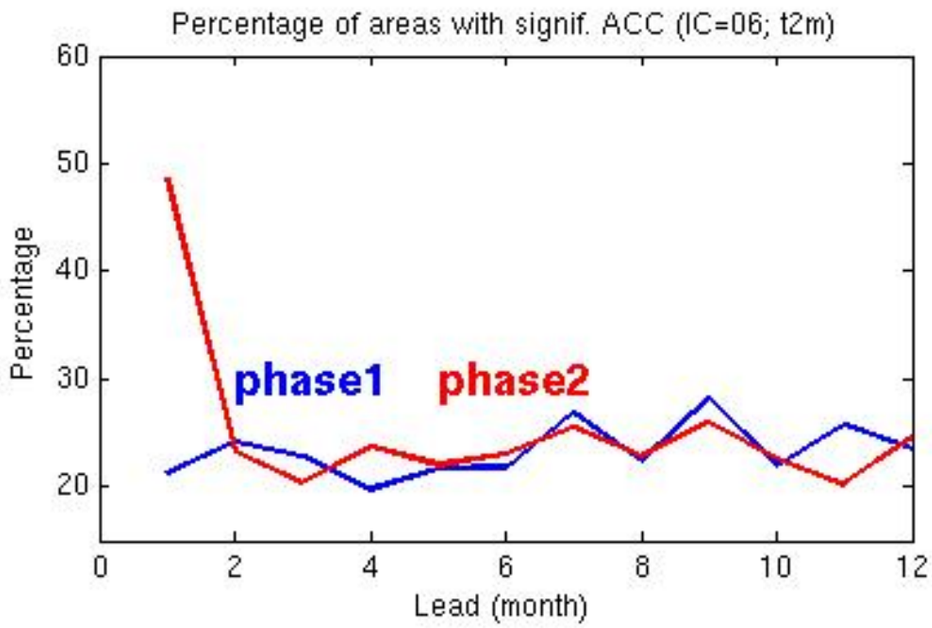
Most predictable pattern in rainfall improved in FLOR

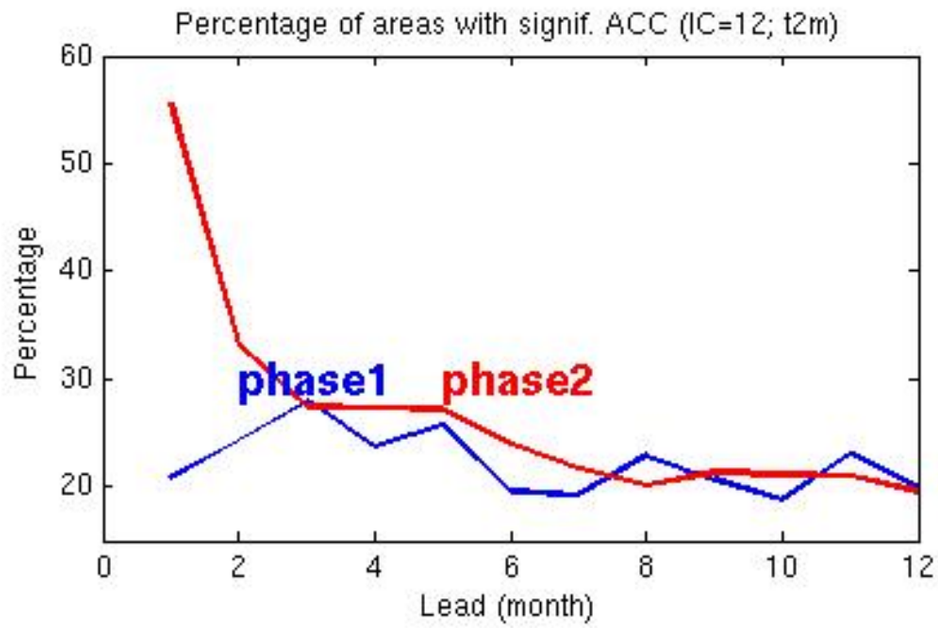


Most predictable precip pattern (mm/day) (Jia et al. 2014, J. Clim.)

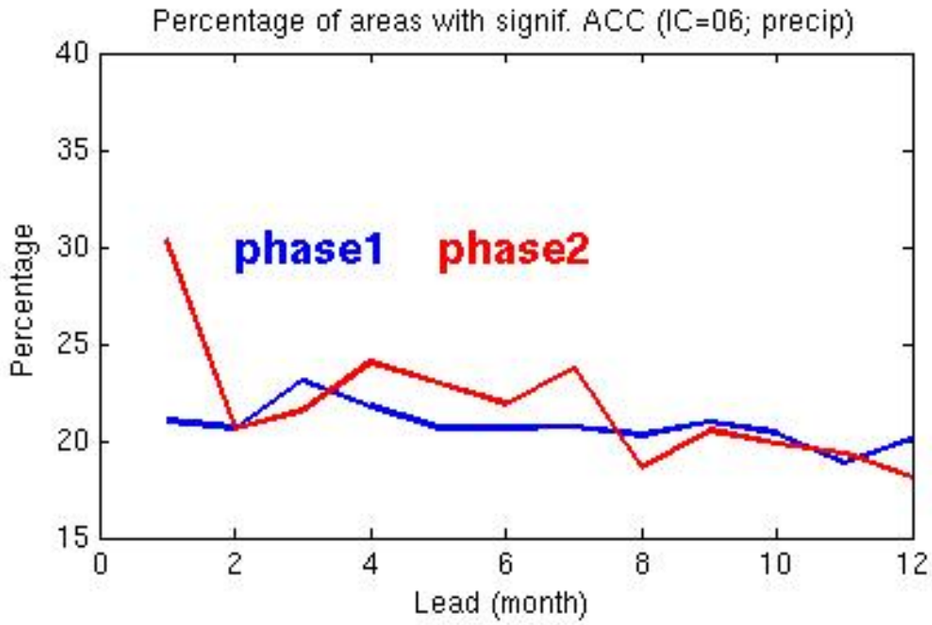
Preliminary analysis of FLOR-P2 predictions: Skill for monthly land temperature and precipitation, Role of Atm. I.C.)

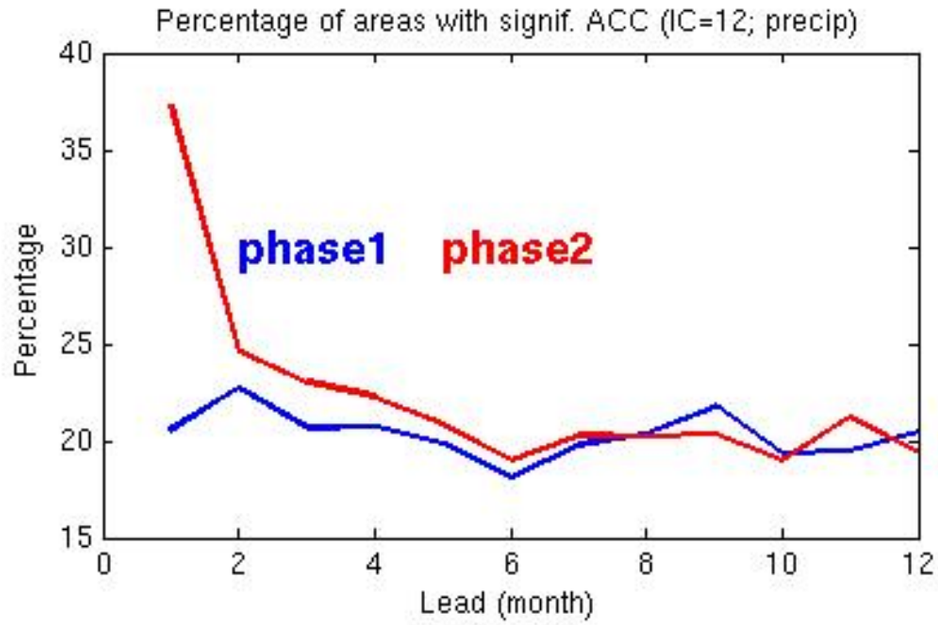
T2m





Precip



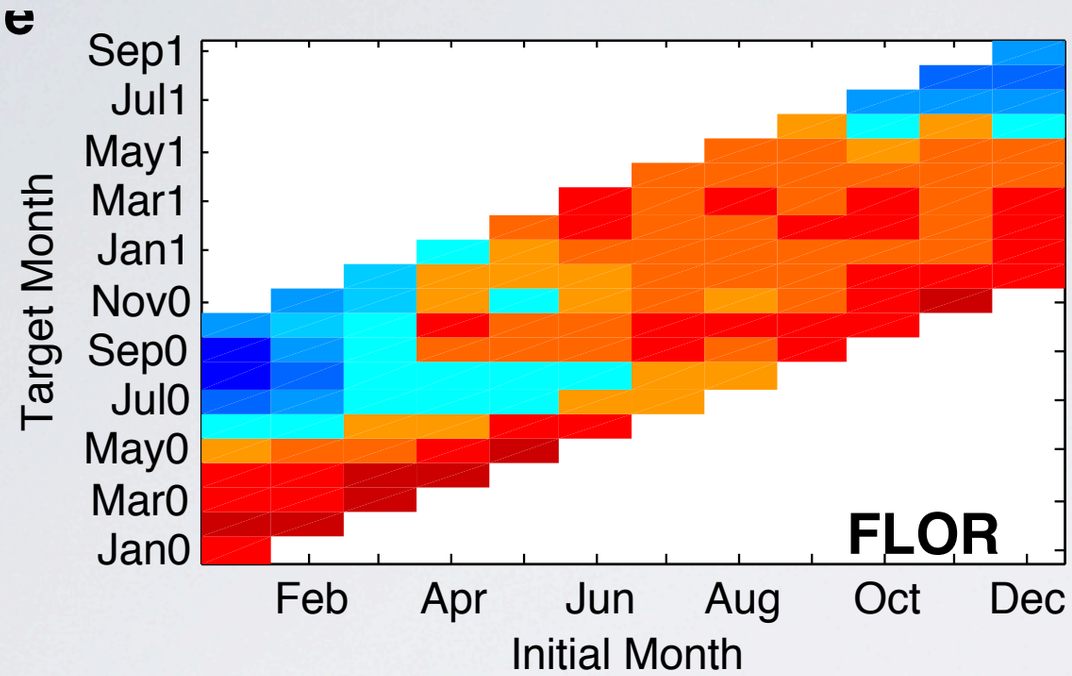


I.C.: 01Jun.

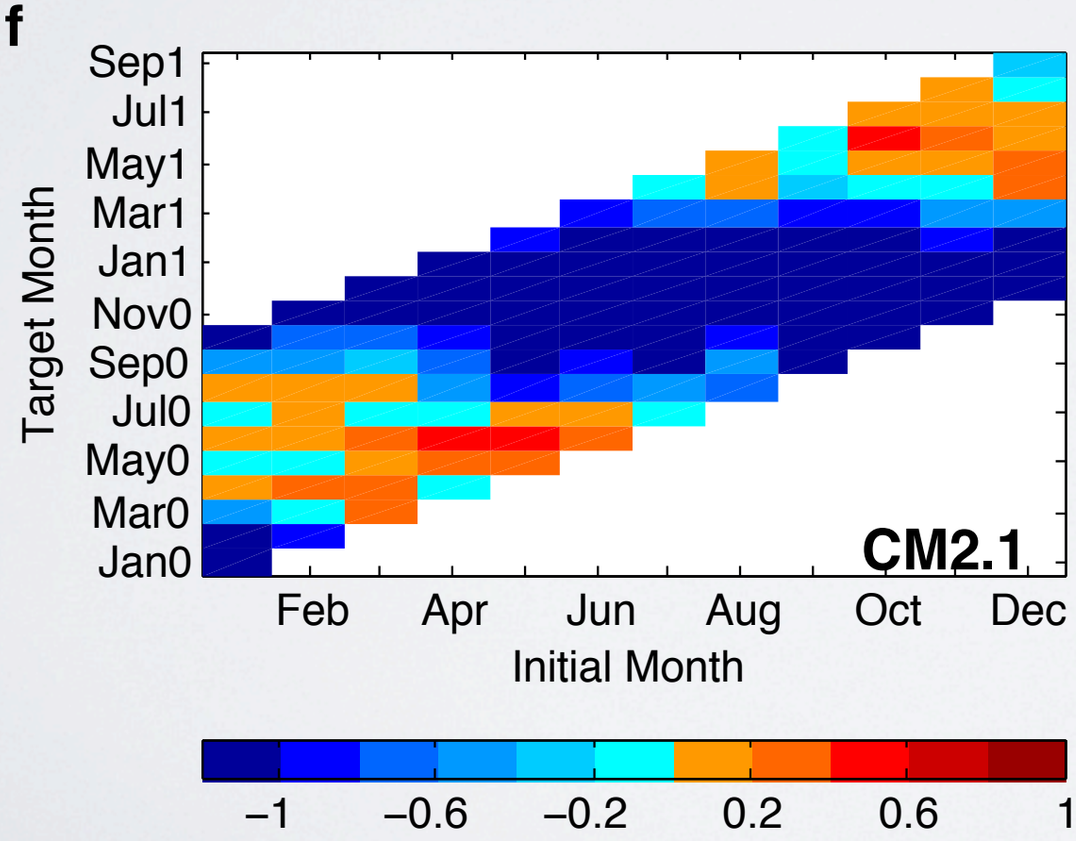
I.C.: 01Dec.

Ratio of areas with skill

FLOR improves prediction skill of ENSO precipitation (and temperature) over land



Hi-res



Med-res

Skill (SESS) of 1981-2012 predictions of ENSO precip

Jia et al. (2014, J. Clim.)