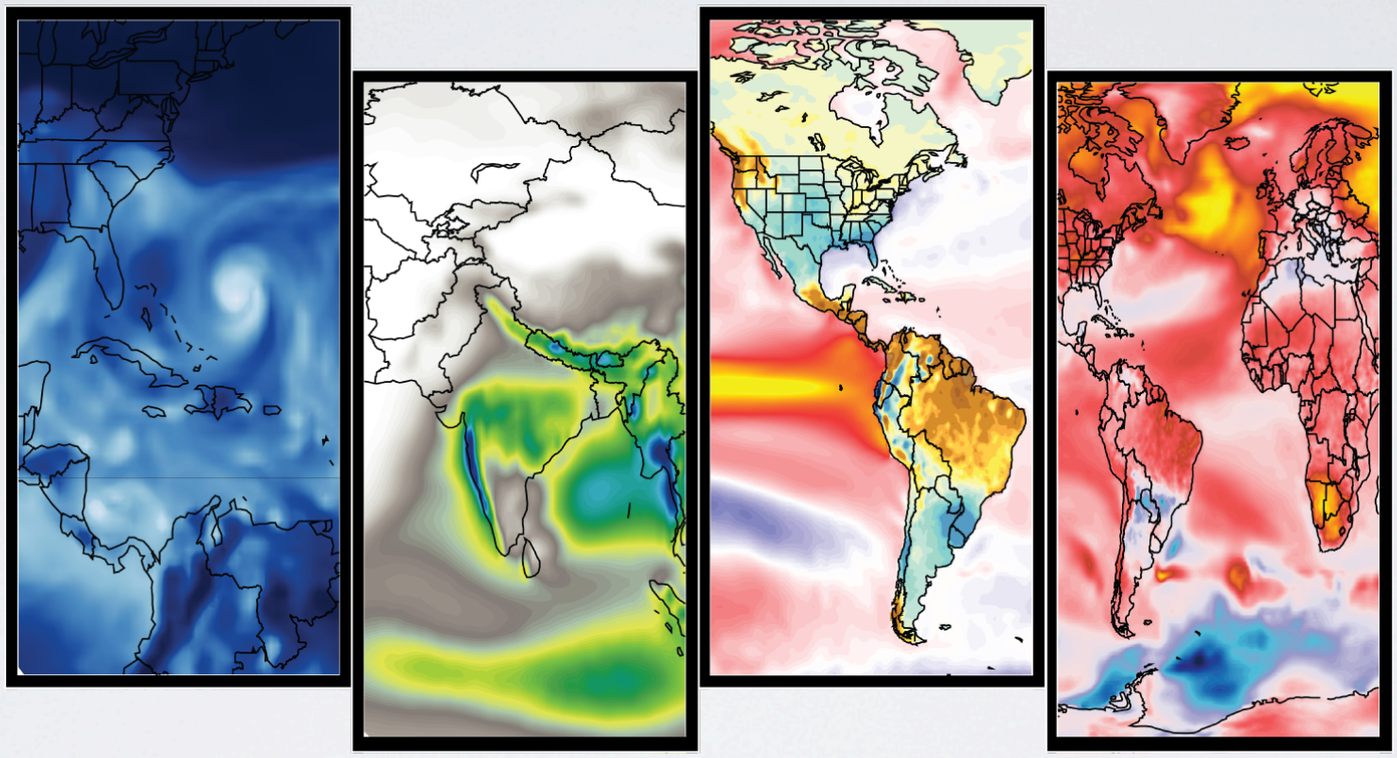
# Towards the Prediction of Regional Tropical Cyclone Activity and Hydroclimate

NOAA/GFDL Climate Variations and Predictability Group



**Hypothesis:** Enhanced resolution & corrected large-scale climate improve simulation and prediction of regional climate & extremes.

**Practical Goal:** Build a seasonal to multi-decadal forecasting system to:

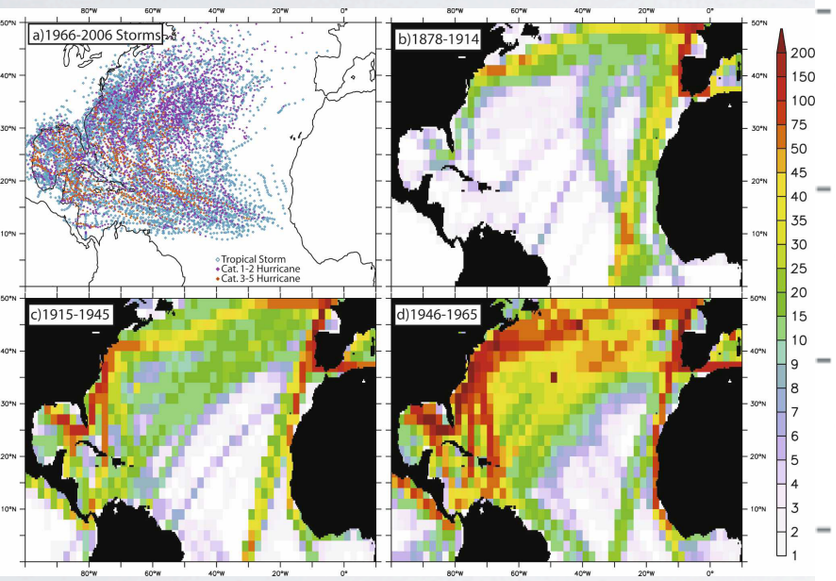
- Yield improved forecasts of large-scale climate
- Enable forecasts of regional climate and extremes

# Miami After Hurricane Andrew

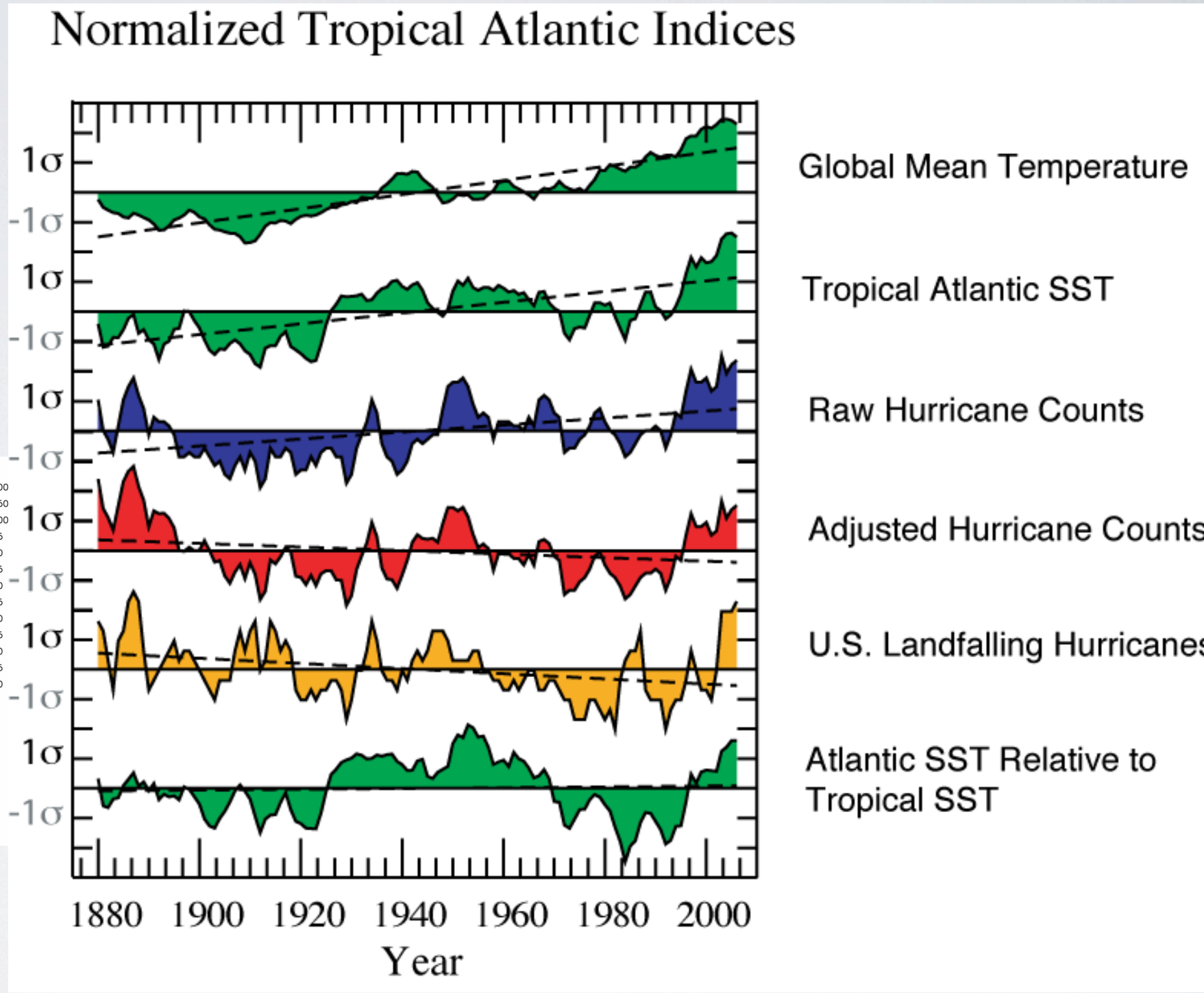
*Source: wikimedia.org*

# Accounting for known observing system changes, no evident trend in Atlantic hurricanes

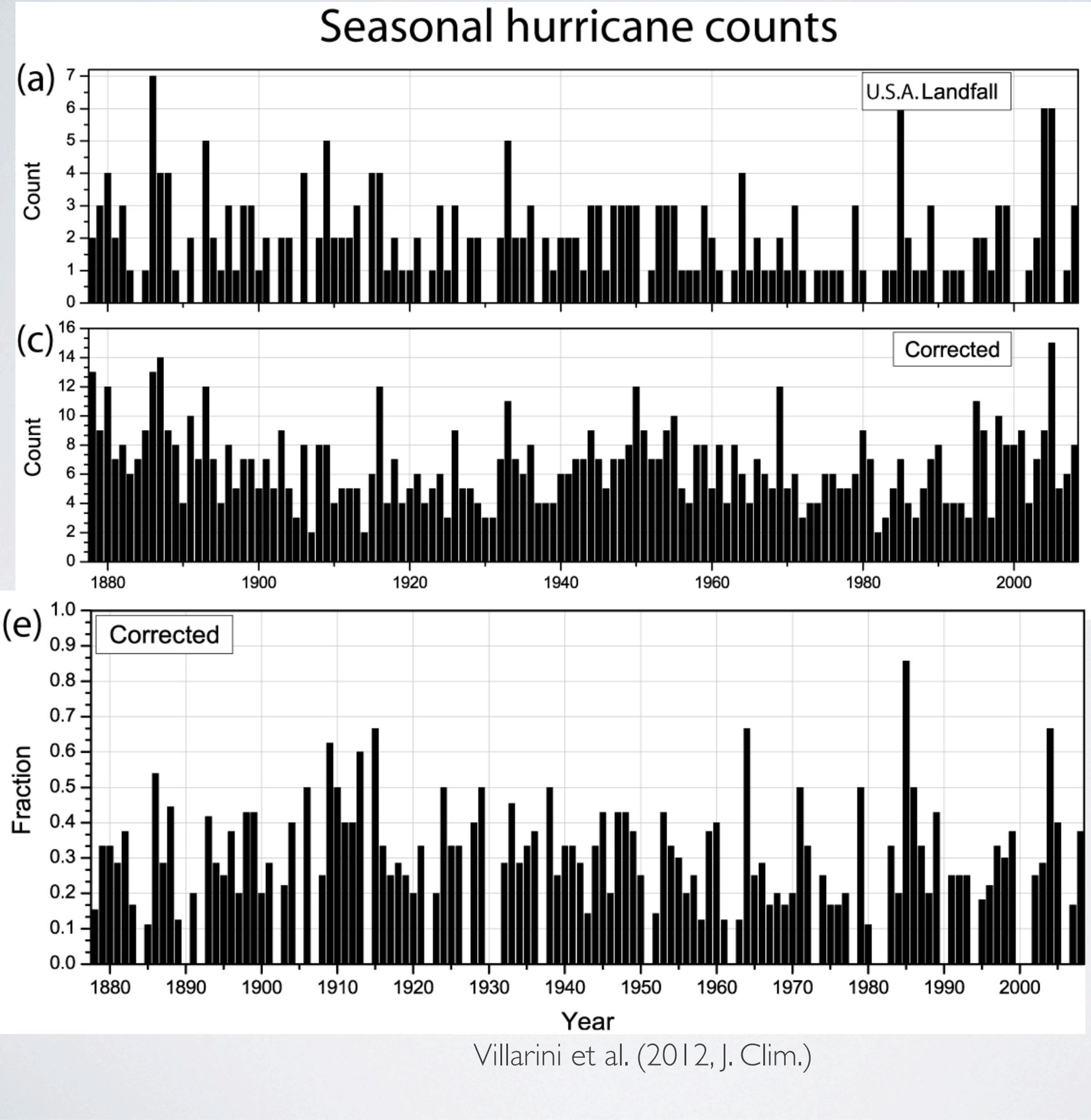
Adjustments to storm counts based on ship/storm track locations and density




*Vecchi and Knutson (2008, J. Clim.)*
*Landsea et al. (2009, J. Clim.)*
*Vecchi and Knutson (2011, J. Clim.)*
*Villarini et al. (2011, J. Clim.)*



# Hurricanes and Landfalling Hurrricanes Exhibit Variabilty




U.S. Landfalling Hurricanes

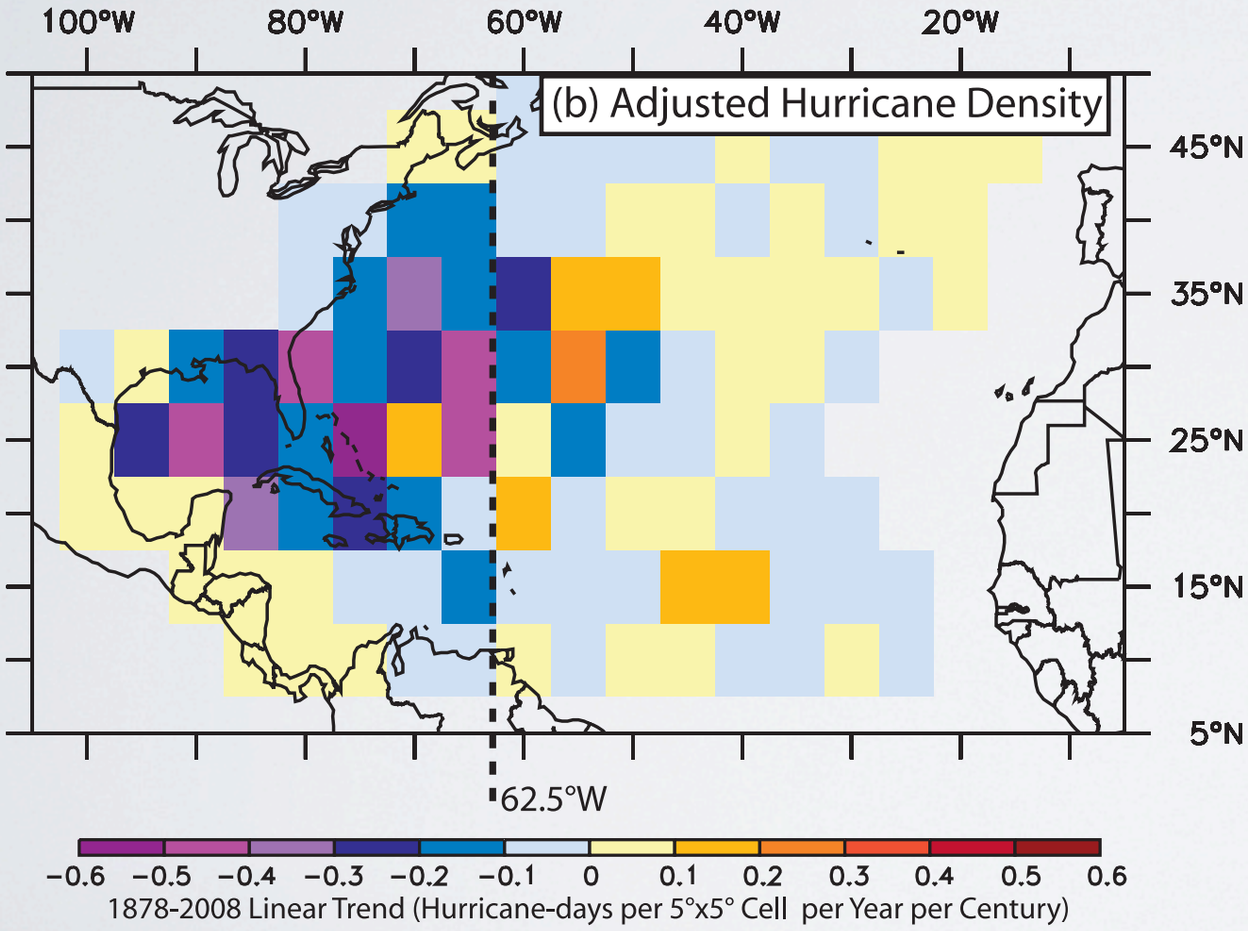
Basinwide Hurricanes

Fraction of Basinwide Hurricanes Making U.S. Landfall

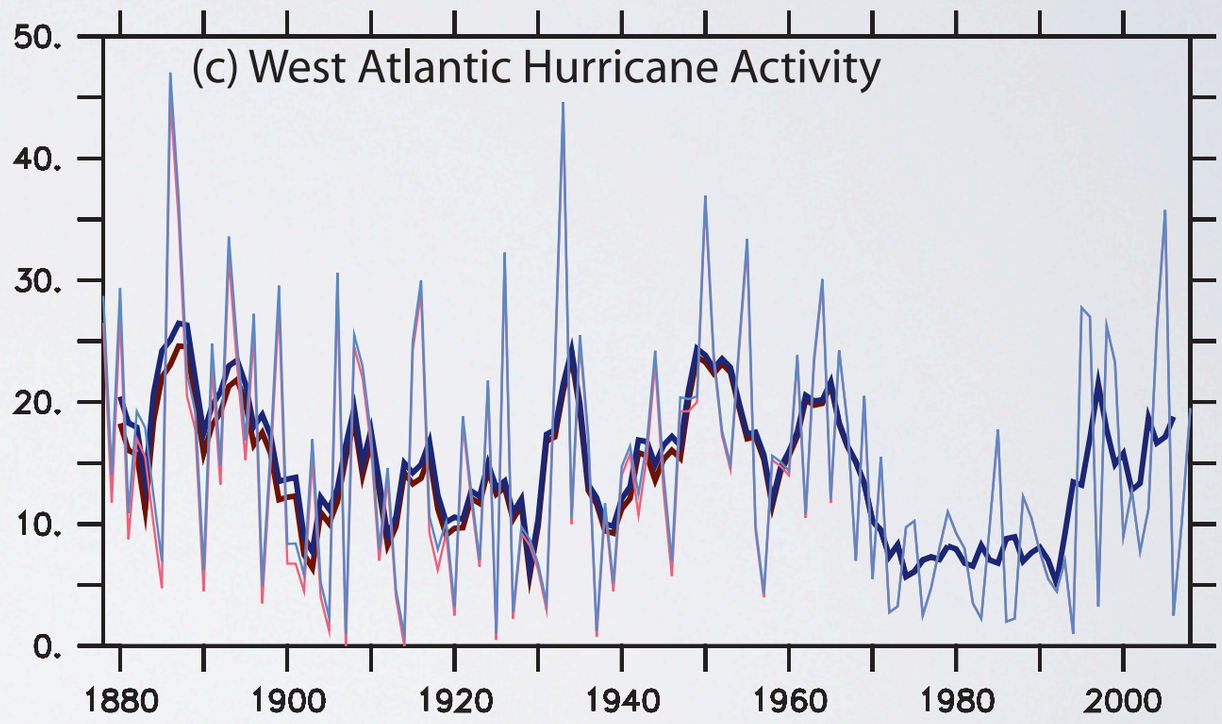
Villarini et al. (2012, J. Clim.)

# Long-term changes in hurricane activity spatially heterogeneous: nominal decrease in West Atlantic, including "deep well" in 1970s-1980s

## 1878-2008 trend in hurricane ·days



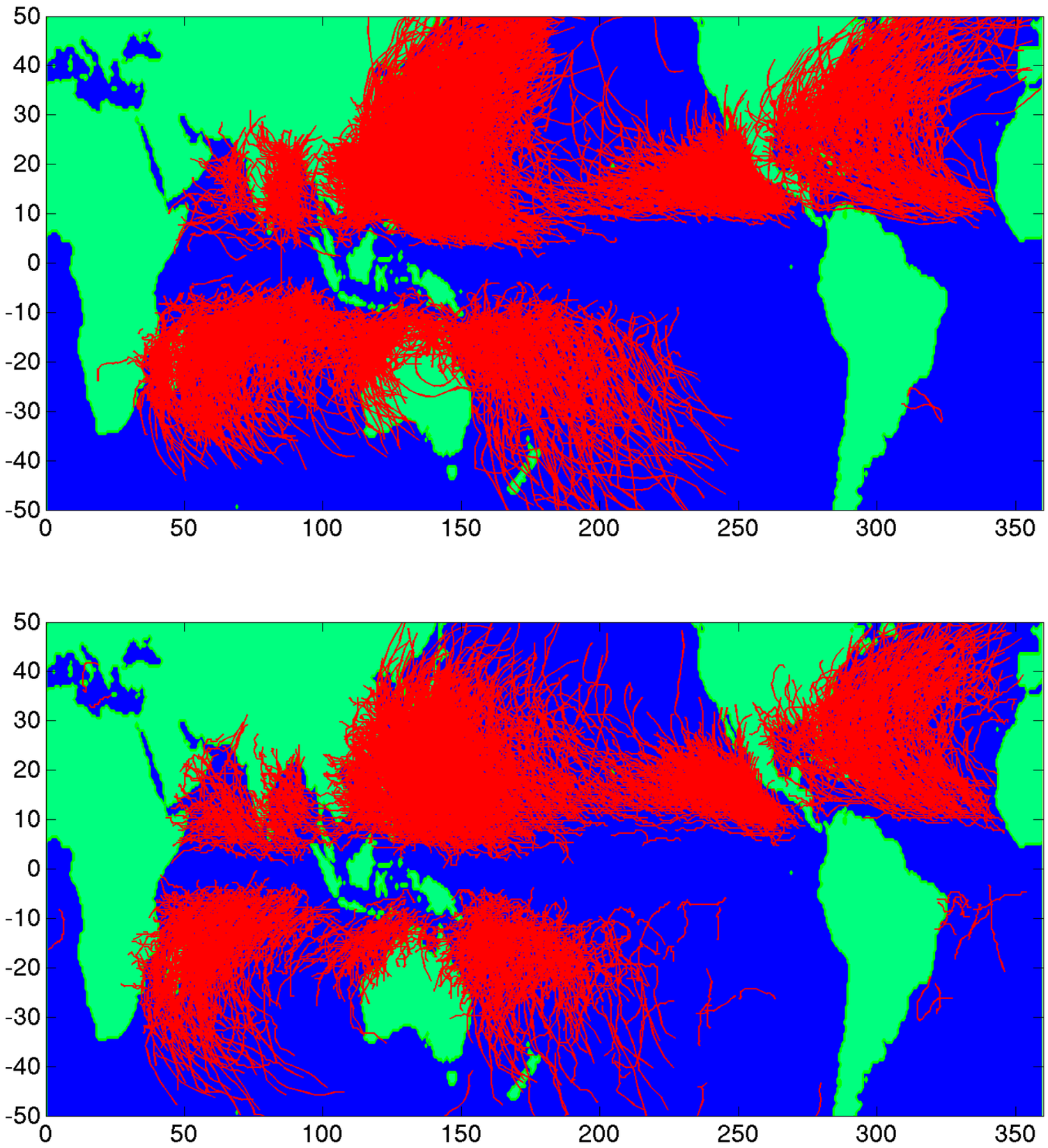

## hurricane ·days in West Atlantic




*Vecchi and Knutson (2011, J. Climate)*

# High-res (50km) dynamical models can recover global TC climatology and interannual variability

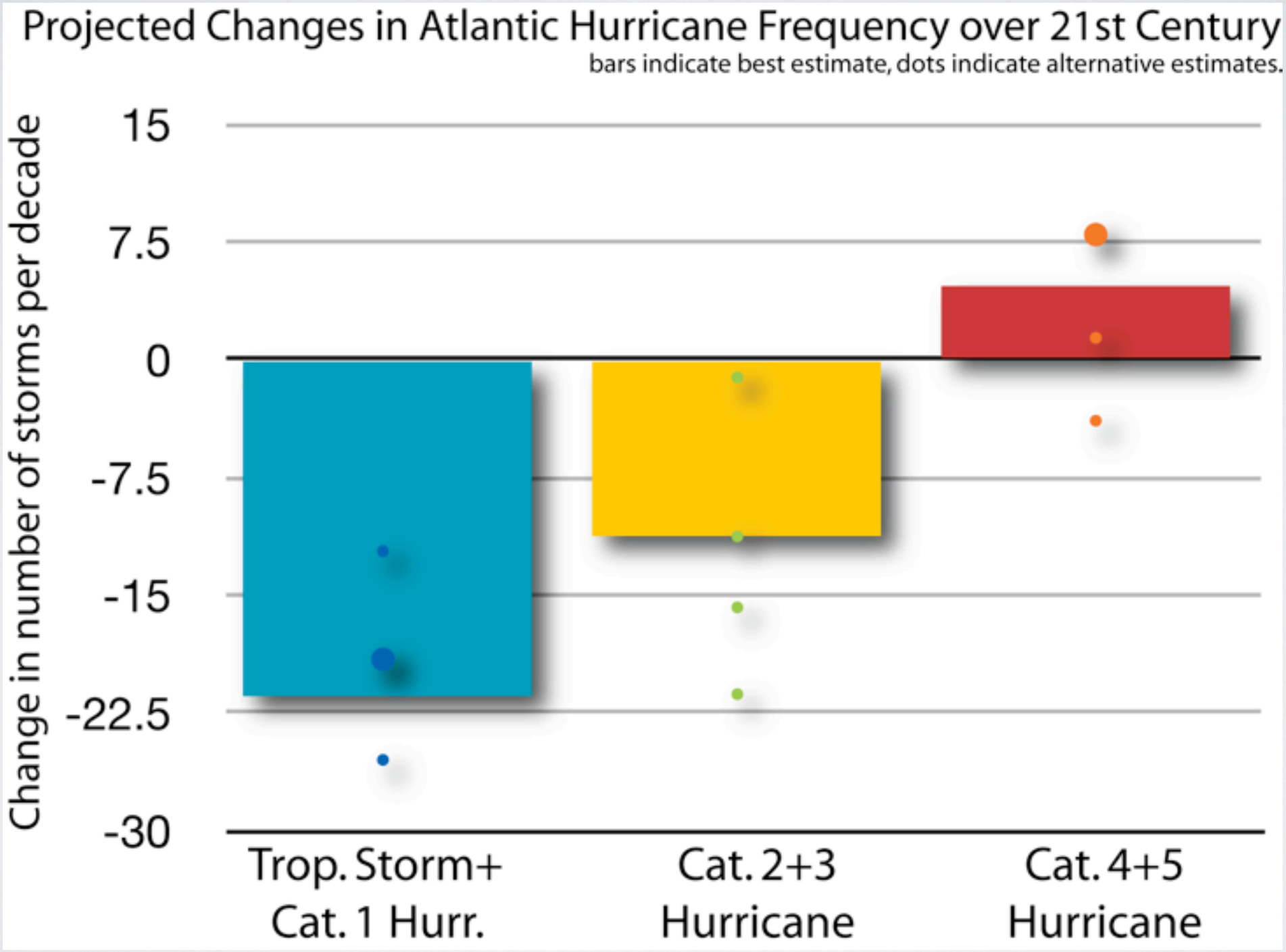
**Observations**




**HiRAM-C180**
**AMIP simulation**

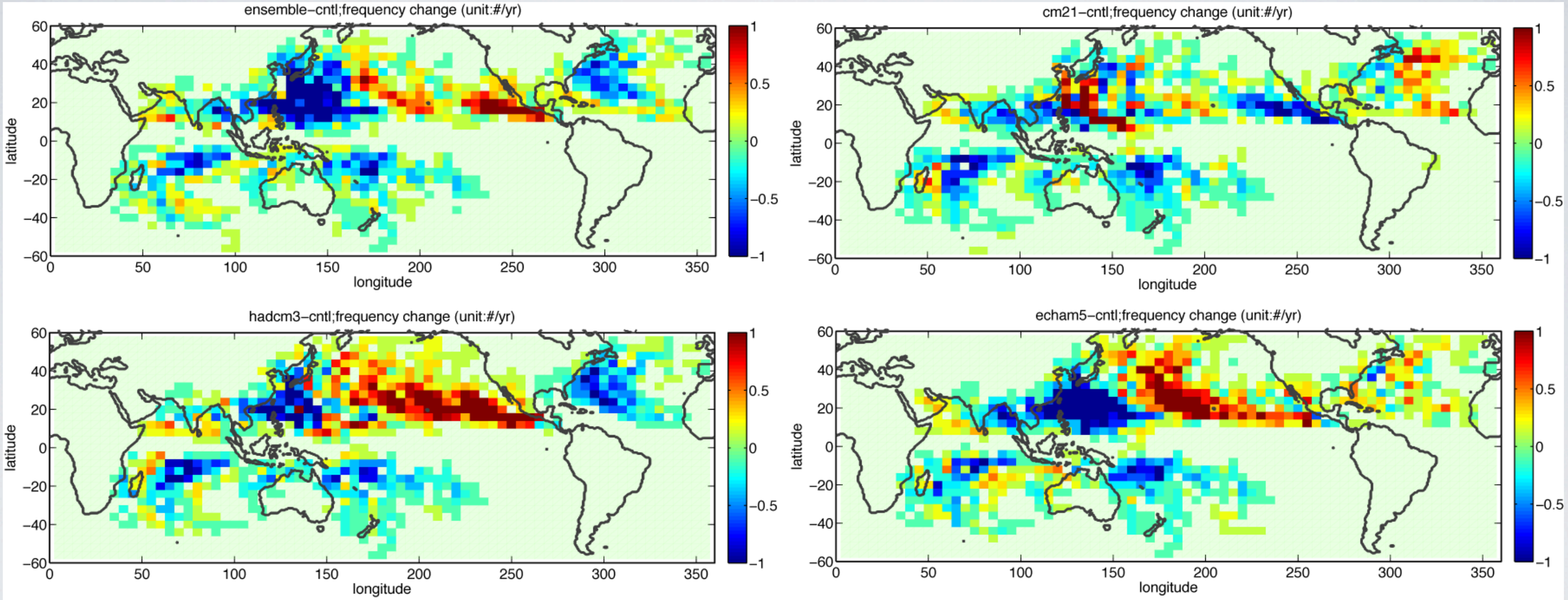
Zhao et al. (2009)
See also LaRow et al. (2009), Gualdi et al. (2007), Chen and Lin (2013), Vecchi et al. (2014)

# Dynamical double downscaling for Atlantic: Overall frequency decrease projected, but more of the strongest storms




*Adapted from Bender et al (2010, Science)*
*see also Knutson et al. (2008, Nature Geosci.); Knutson et al. (2013, J. Clim., in press)*

# Great uncertainty remains in projections of regional TC activity




**Red/yellow = increase**
**Blue/green = decrease**

*Adapted from Zhao et al. (2009, J. Climate)*

Regional increase/decrease much larger than global-mean.

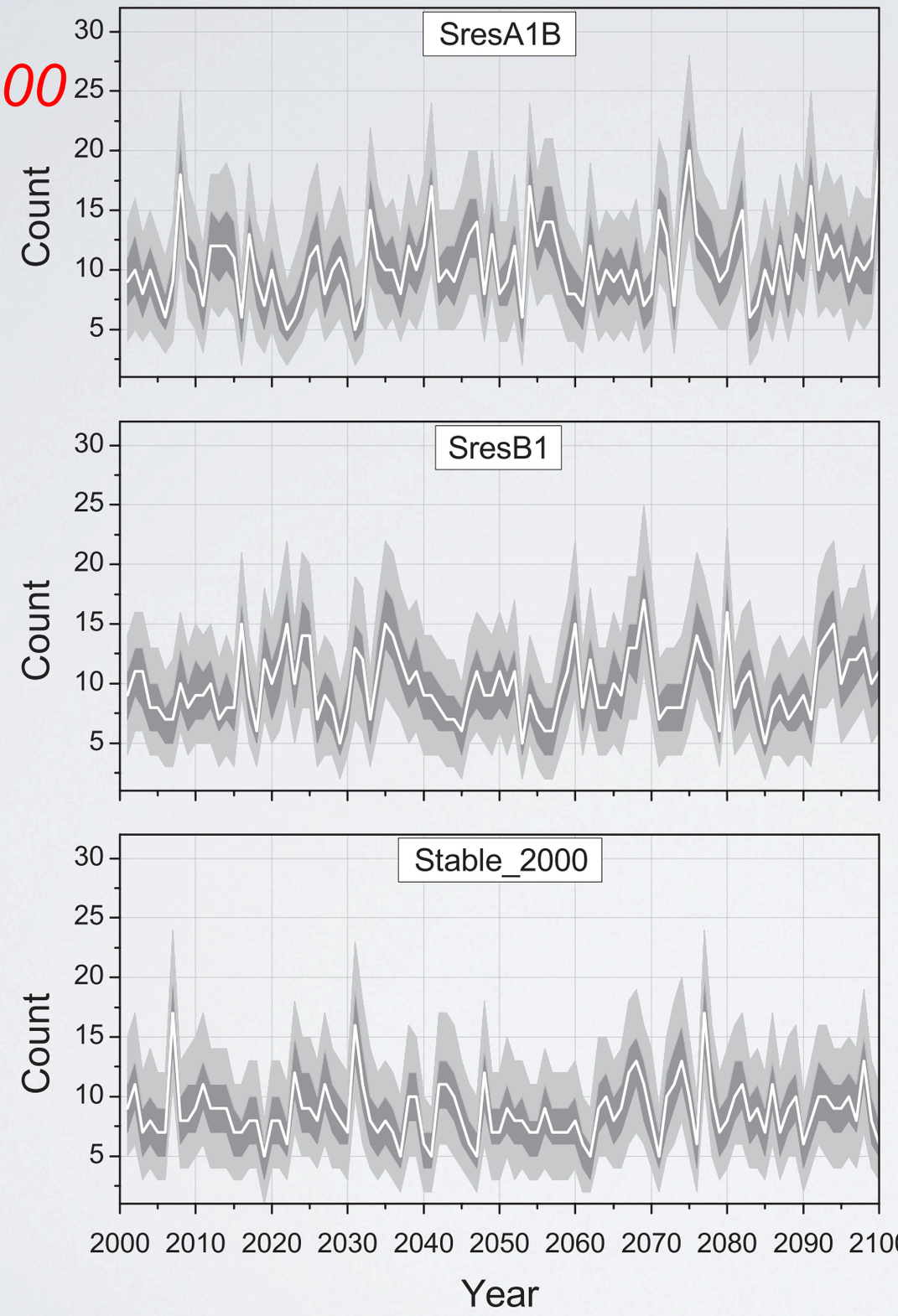
Pattern depends on details of ocean temperature change.

Sensitivity of response seen in many studies

*e.g., Emanuel et al. 2008, Knutson et al. 2008, Sugi et al. 2010, Villarini et al. 2011, Knutson et al. 2013, etc.*

# We expect continued variation of tropical storm frequency

*2x $CO_2$ by 2100*




*Stable $CO_2$ by 2000*

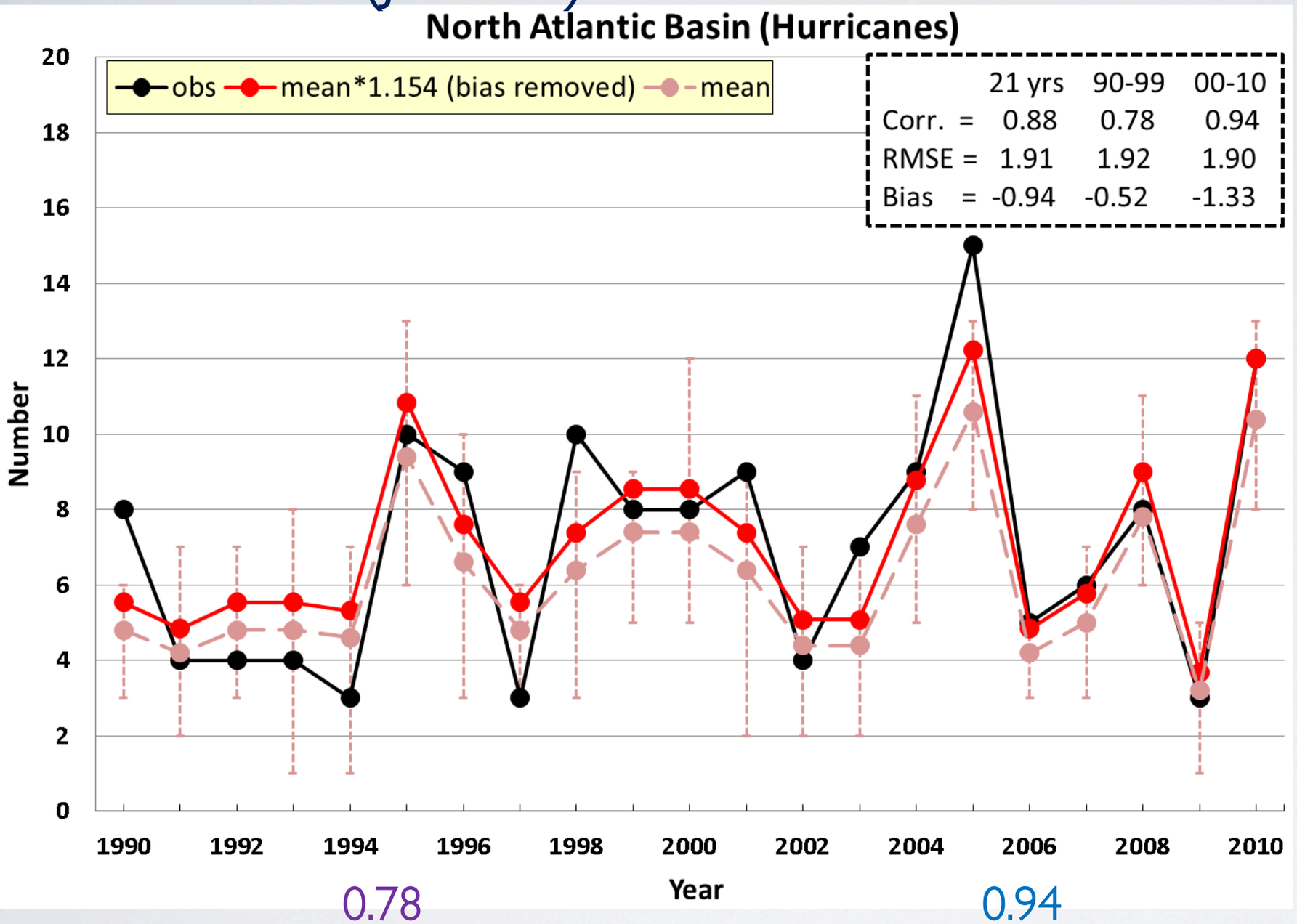
## Projected Atlantic Tropical Storm Frequency

*source: Villarini et al (2010)*

(statistical downscaling of GFDL-CM2.1)

- 25km HiRAM Seasonal hurricane predictions – initialized July 1

- 1990-2010 (Jul-Nov)




Resolution: 25 km, 32 levels

- 5-members initialized on July 1 with NCEP analysis
- SST anomaly is held constant during the 5-month predictions
- Climatology O3 & greenhouse gases are used

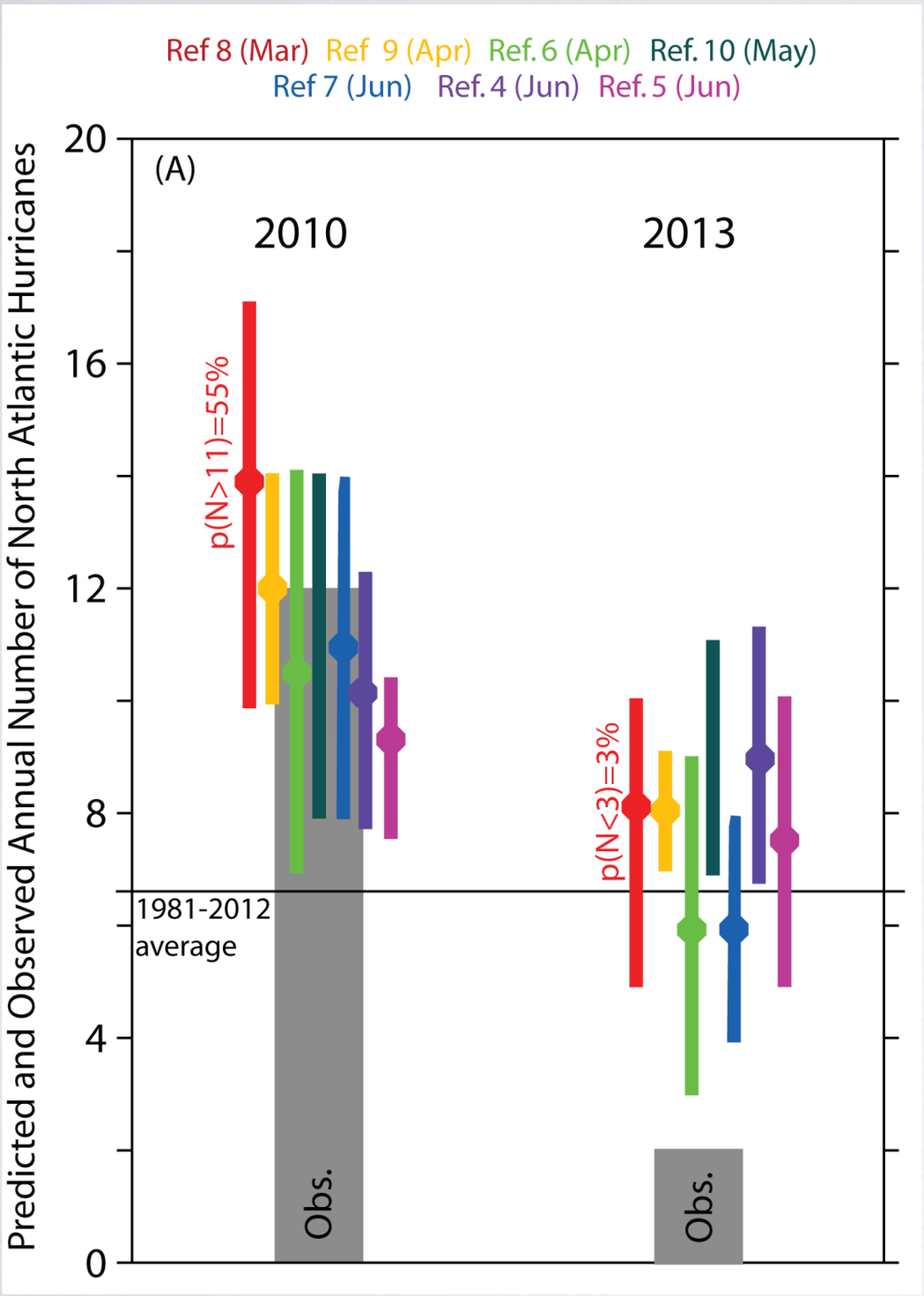

1. Chen and Lin 2011, GRL
2. Chen *et al.*, 2013


0.78 0.94

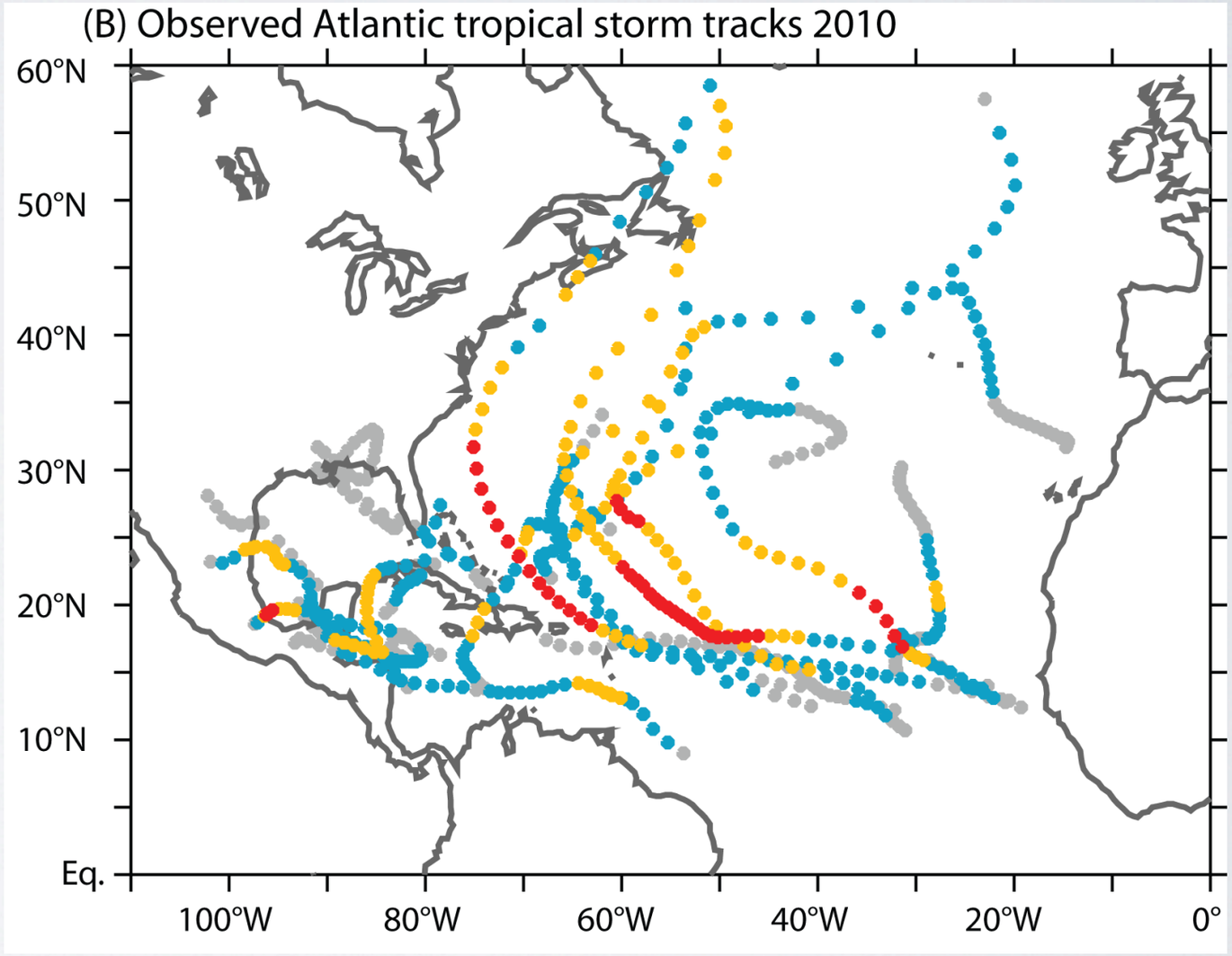
0.88

# Skillful basinwide predictions not necessarily useful predictions.

## Can we reliably predict statistics of storms more regionally than "basin-wide" number?




## Correct predictions of basin-wide active 2010 but not of U.S. landfall absence




*Vecchi and Villarini (2014)*

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

**Goal:** Build a seasonal to decadal forecasting system to:

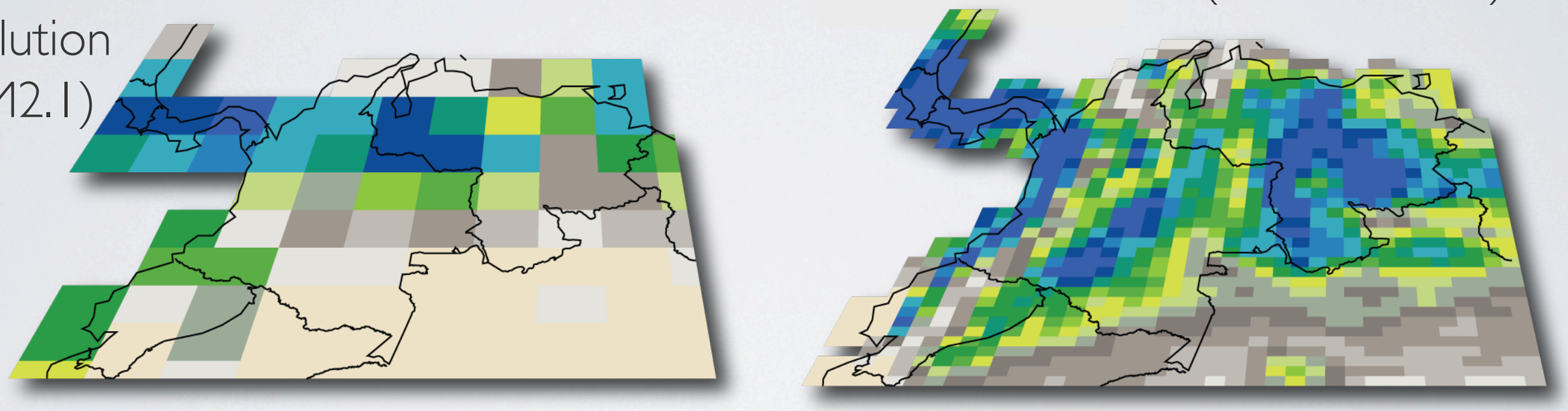
Yield improved forecasts of large-scale climate

Enable forecasts of regional climate and extremes

Precipitation in N. South America

Medium resolution (CM2.1)

High resolution (CM2.5-FLOR)



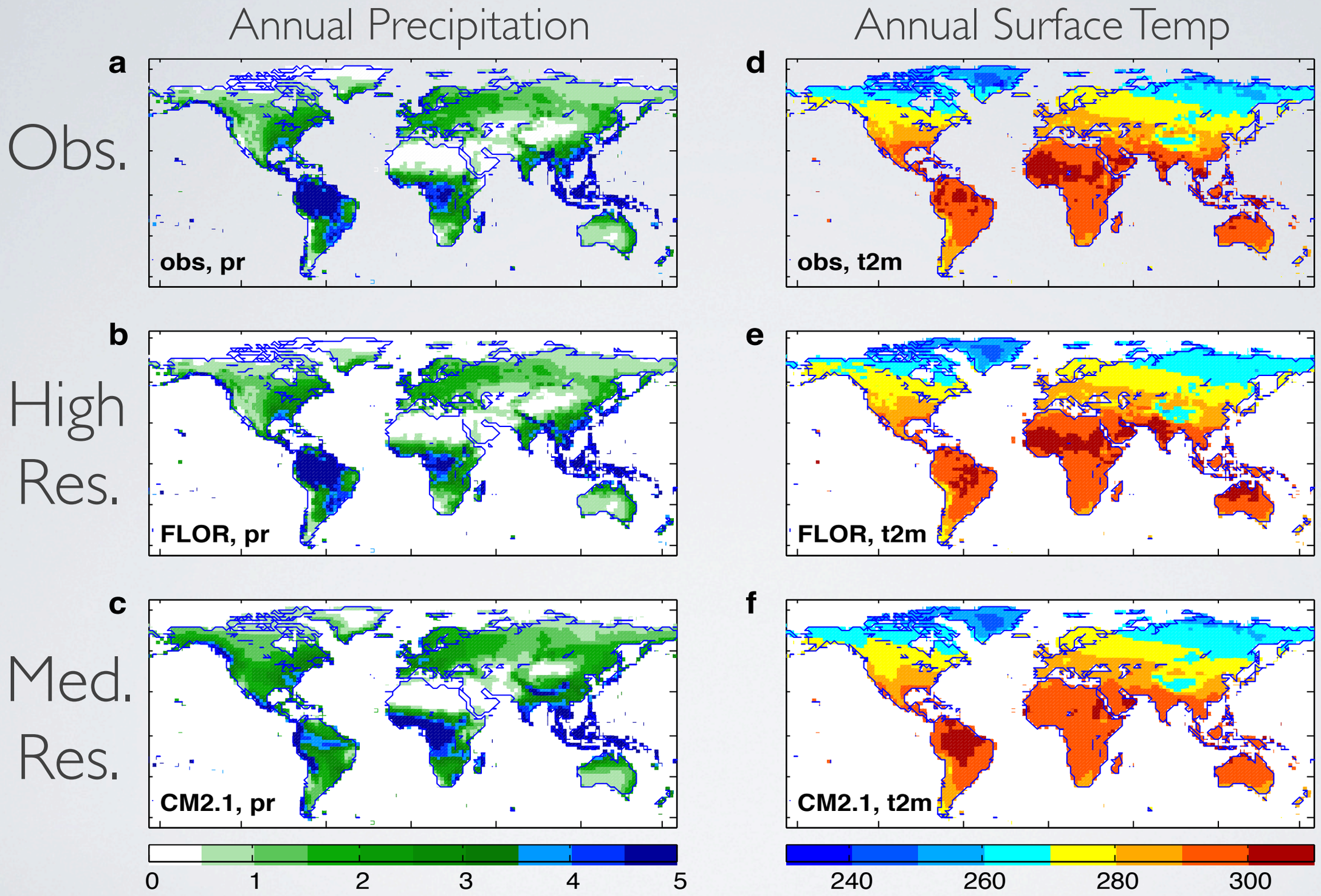
*Delworth et al. (2012), Vecchi et al. (2014, submitted)*

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

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

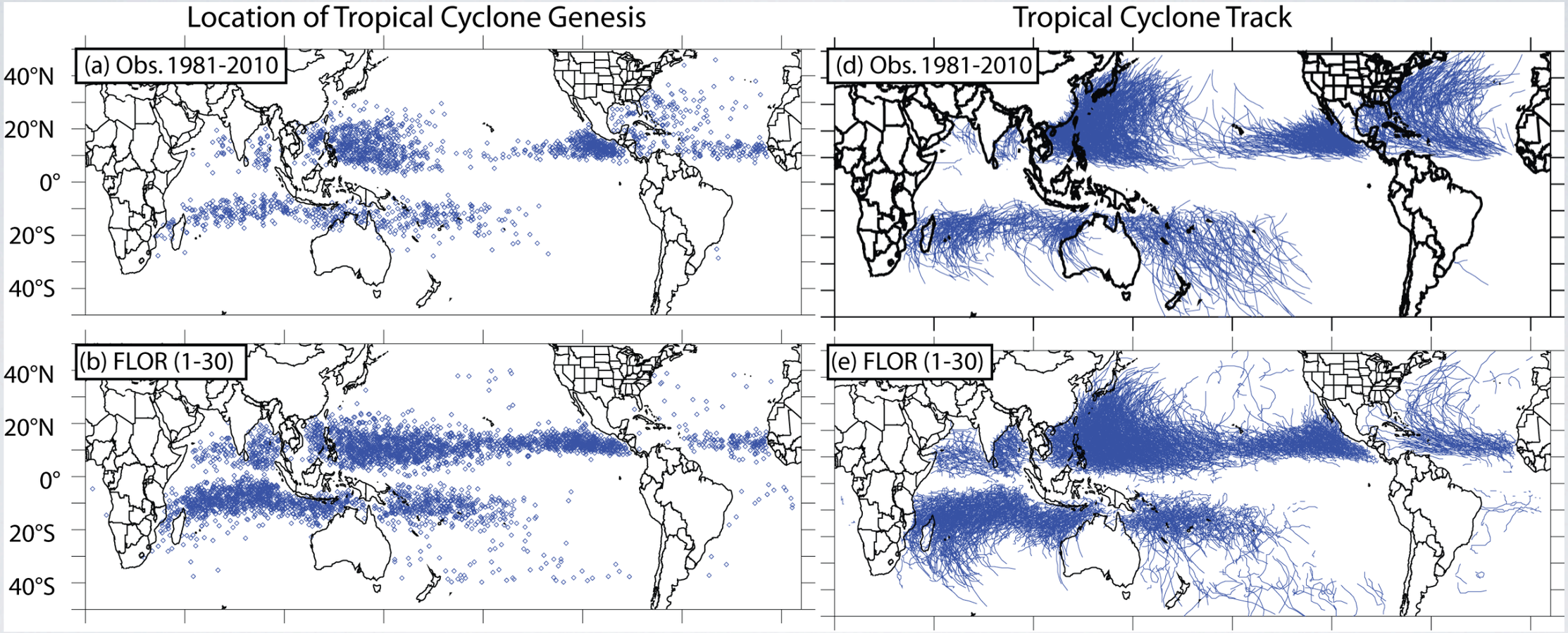
~15-18 years per day. Multi-century integrations. 4500+ model-years of experimental seasonal predictions completed and being analyzed.

# Hypothesis: Enhanced atmos./land resolution improves climate




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

# TC tracks in FLOR decent for a coupled model (better than CM2.5)




*Vecchi et al. (2014)*

# Flux adjustment for predictions of regional TC activity

- **Hypothesis:** Biases in large-scale climate degrade simulation and prediction statistics of regional and extreme climate, so correcting systematic biases will improve predictions.

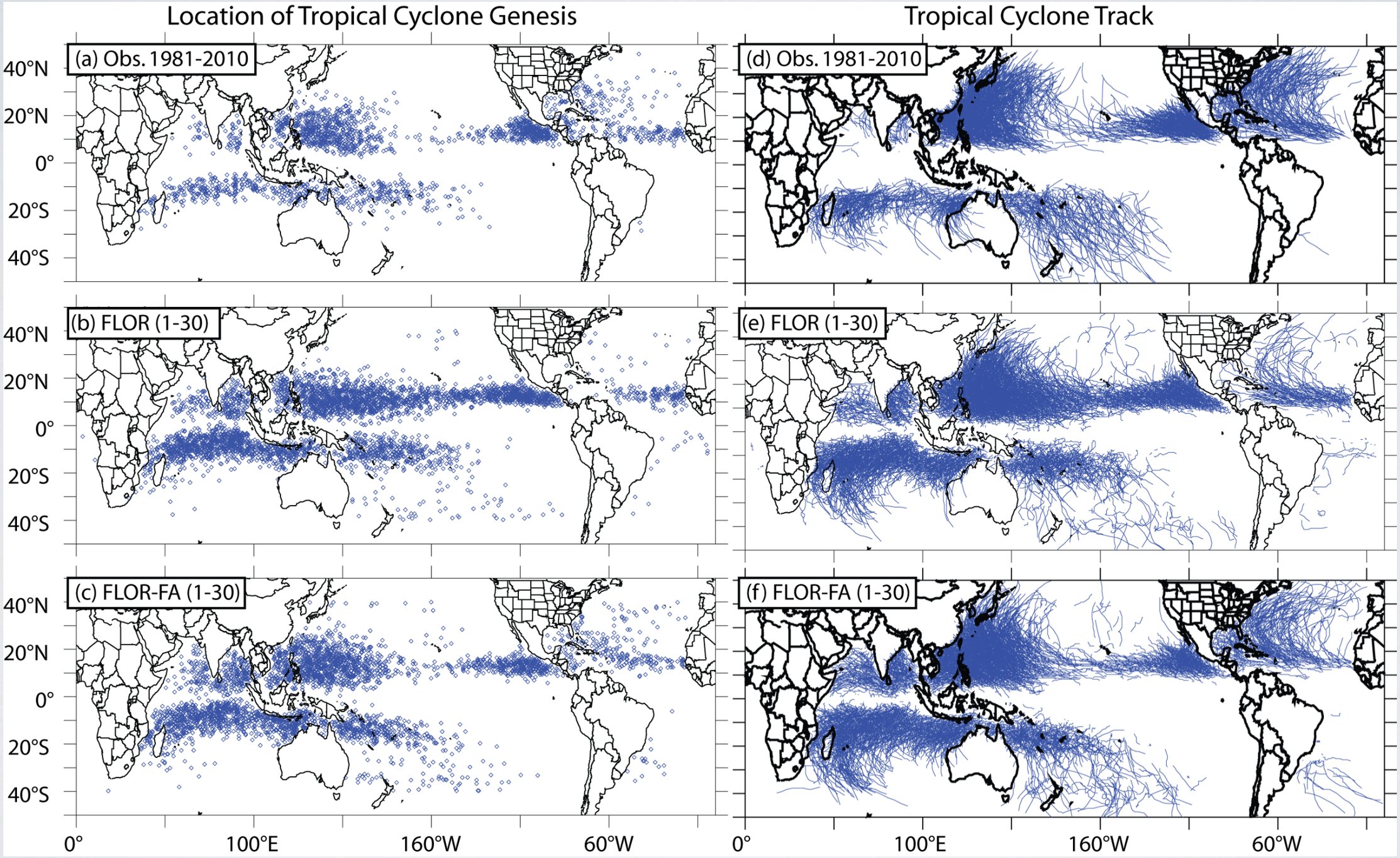
- **Goal:** Improve prediction of regional climate and extremes.

- **Methodology:** FA version of FLOR with climatological (once computed, independent of model state) adjustment to momentum, freshwater and enthalpy fluxes to ocean.

  Repeat simulations and predictions with FLOR-FA, compare to FLOR.

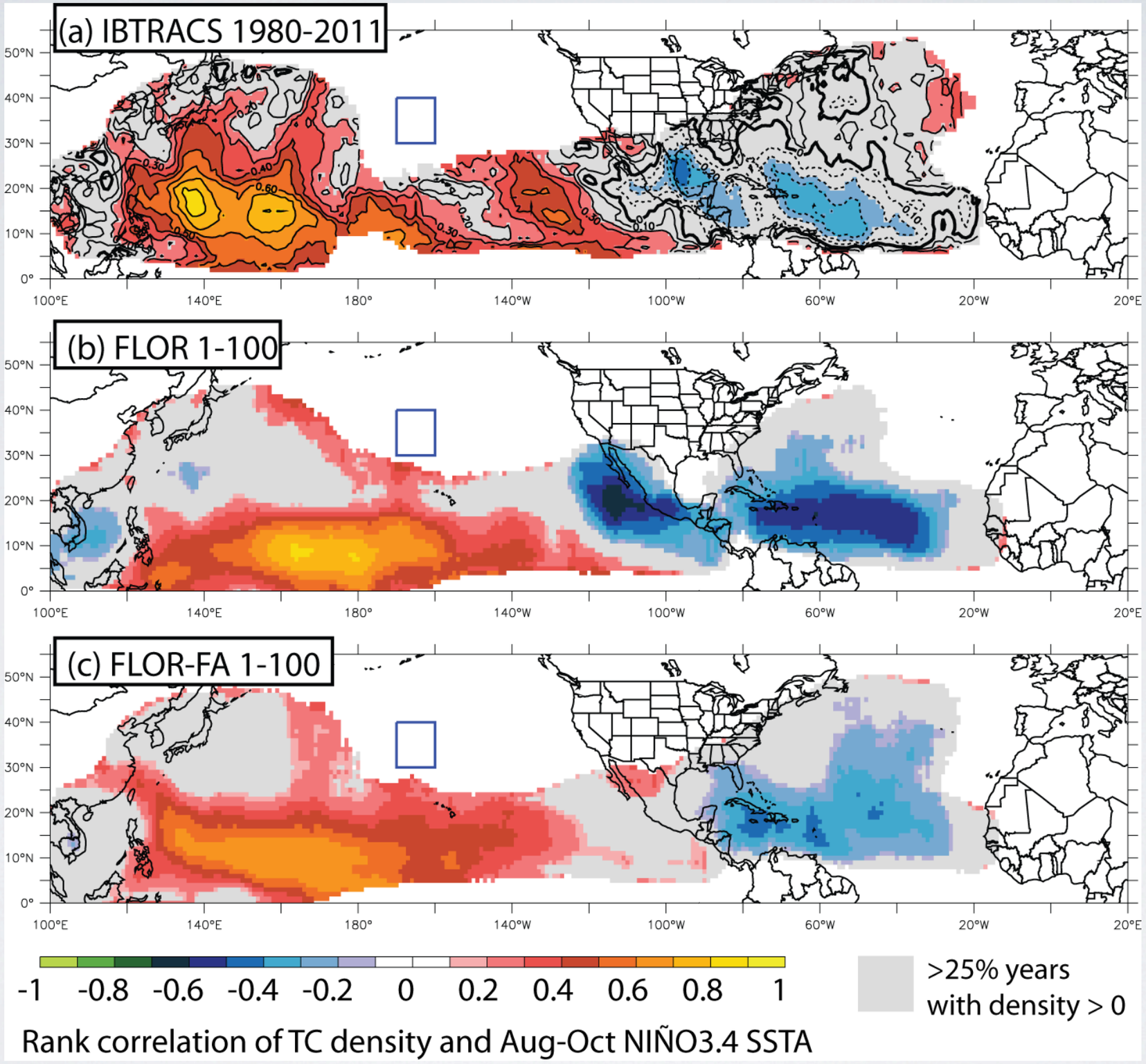
Vecchi et al. (2014, J. Climate, submitted).

# TC tracks in free-running FLOR-FA improved over FLOR particularly in North Pacific and North Atlantic




*Vecchi et al. (2014)*

# TC density relation to NIÑO3.4 improved by correcting systematic errors

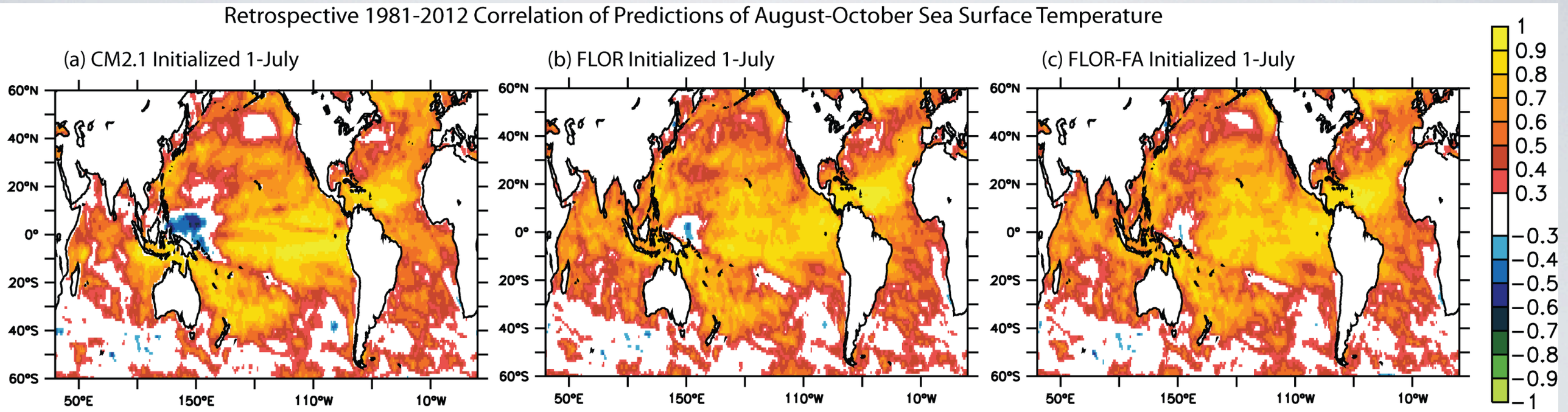



*Vecchi et al. (2014)*

# FLOR Seasonal Predictions (phase 1)

- 1980-2013 retrospective forecasts (12-member ensemble)
- Ocean & sea ice initialized from CM2.1 EnKF3.1 Assimilation
- Atmosphere and land initialized from ensemble of AGCM (*i.e.*, only information contained in SST and radiative forcing in atmos/land Ics)
- Done with two versions of FLOR (A06 & B01, differ in ocean physics) – will discuss B01
- These retrospective forecasts and future real forecasts submitted to NMME starting March 2014 – data publicly available from NMME data server at IRI

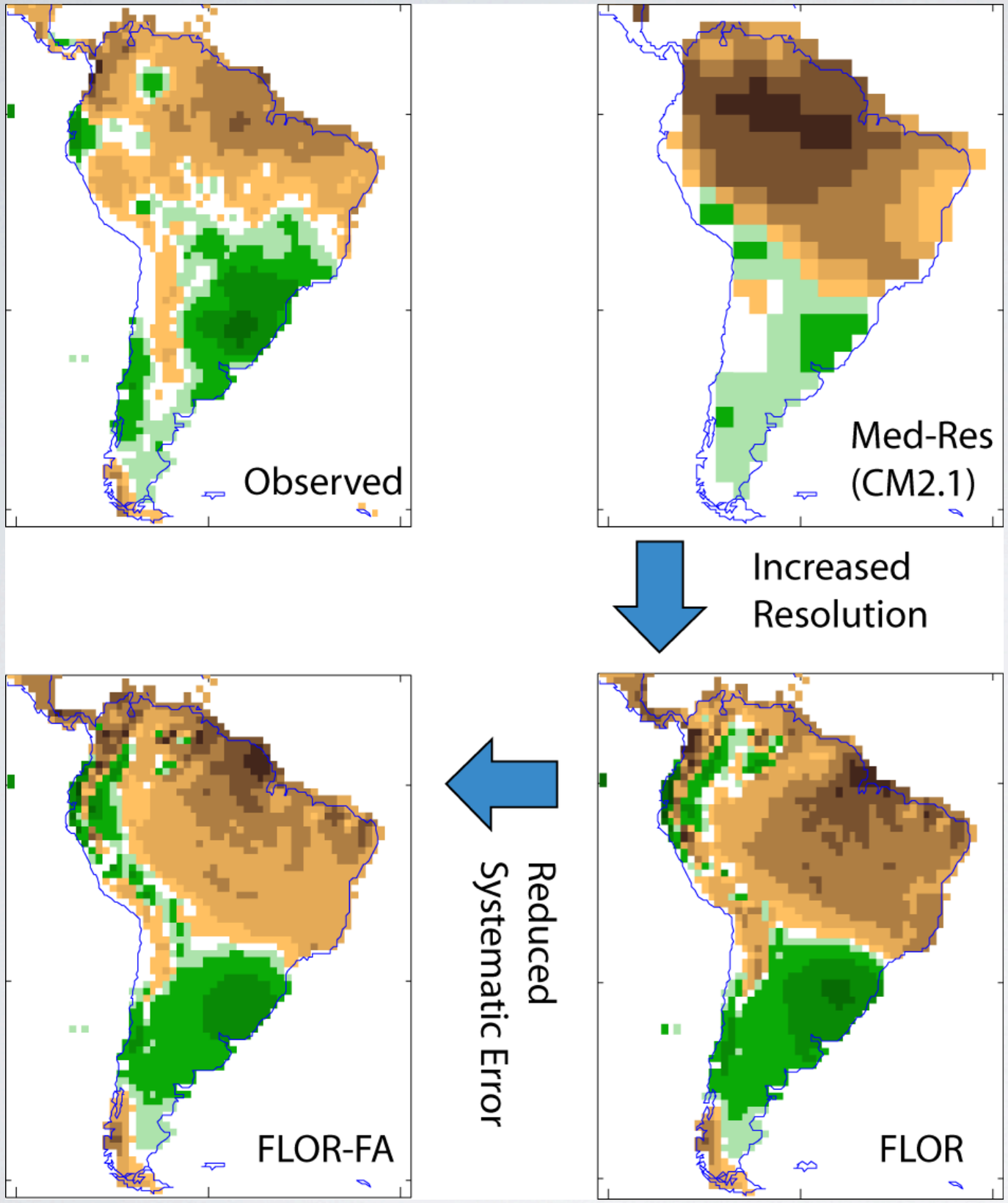
# Retrospective predictions of ASO SST no worse in FLOR-FA than FLOR – both somewhat better than CM2.1




CM2.1 FLOR FLOR-FA

1981-2012 correl. of Aug-Oct SSTA predictions

*Vecchi et al. (2014)*




Most predictable precip pattern

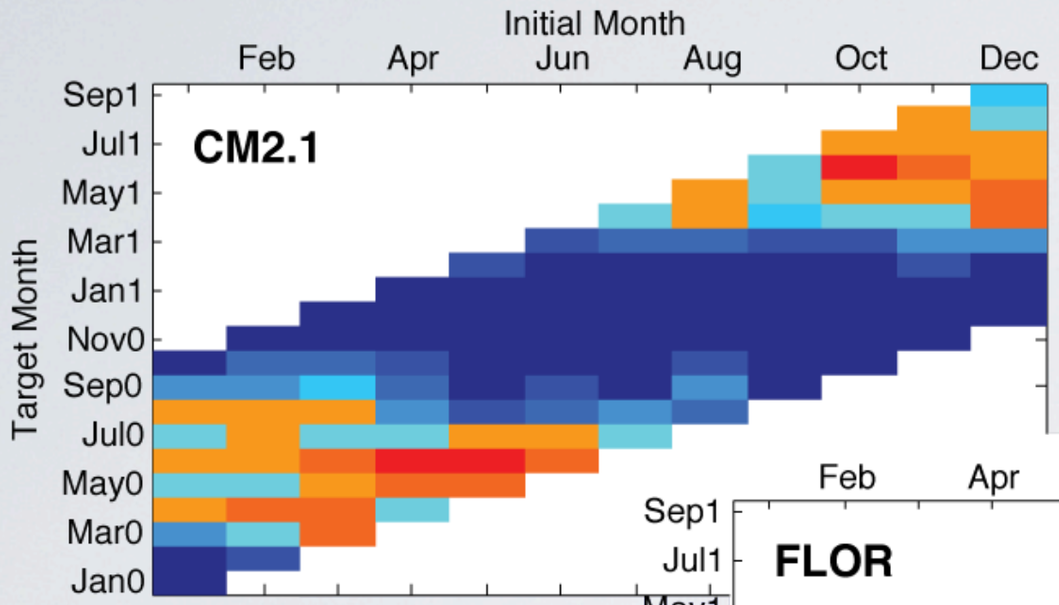
El Niño rainfall recovered better in predictions with increased resolution (lower right) and decreased bias (lower left)

See also poster CM22 (today and tomorrow)

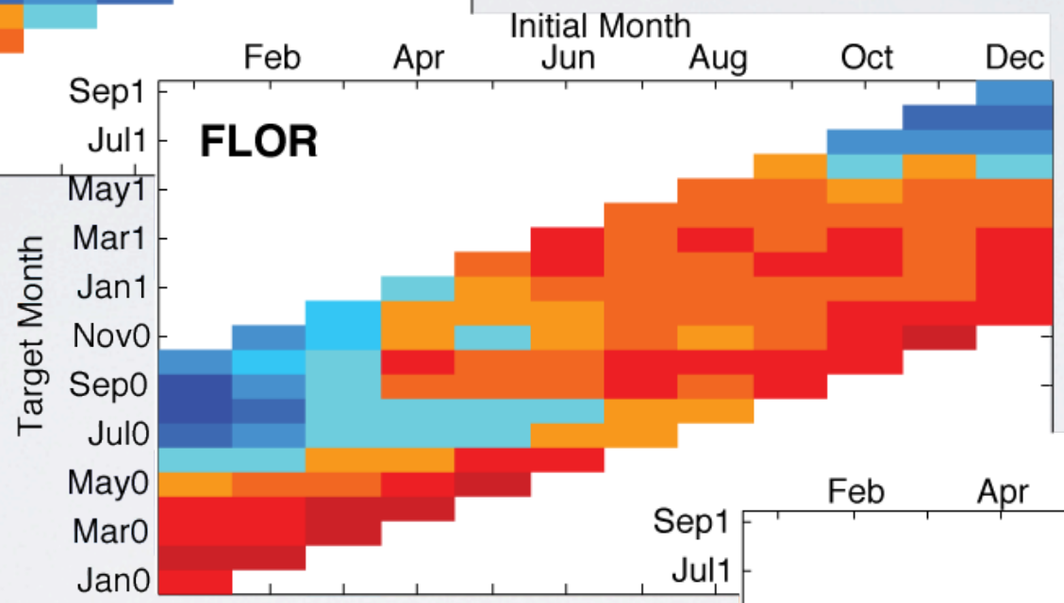
Tom Delworth's talk tomorrow for use of this model to understand historical changes in rainfall.

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

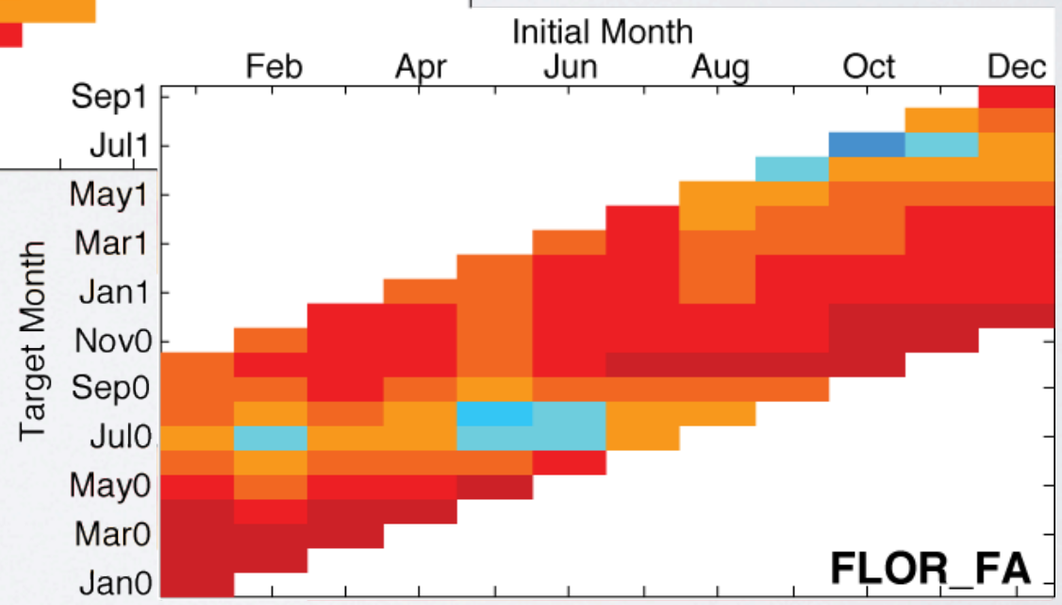
# Enhanced resolution (FLOR) and reduced bias (FLOR-FA) improve prediction skill of ENSO precipitation (and temperature) over land

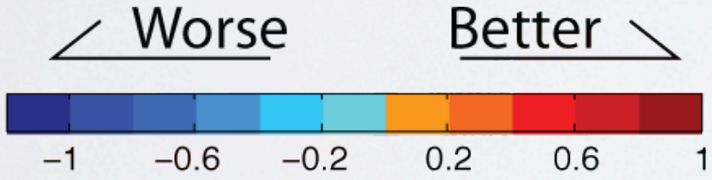



Increased Resolution




Reduced Systematic Error



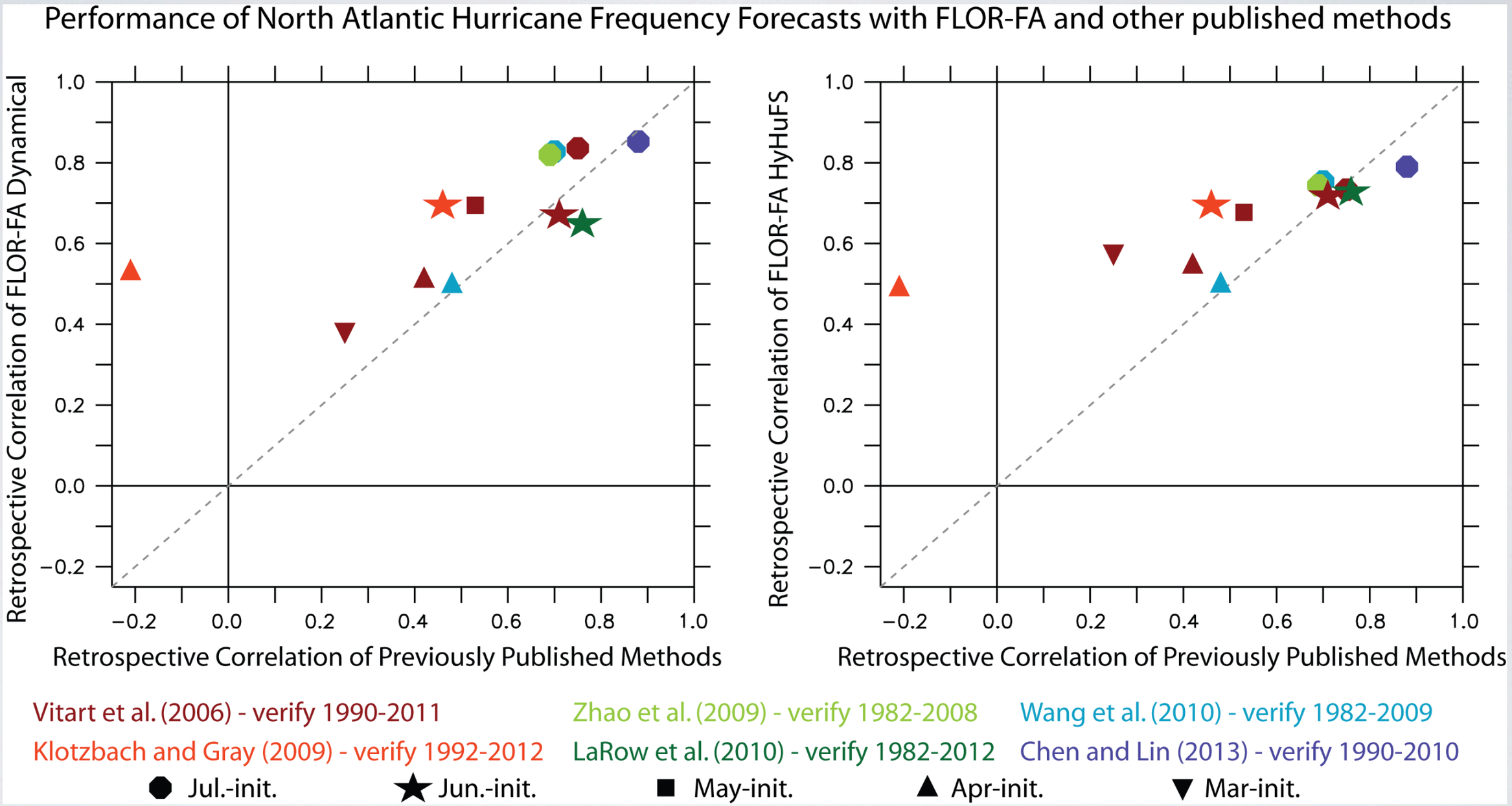




Skill (SESS) of 1981-2012 predictions of ENSO precip

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

# FLOR-FA is among best NA hurricane seasonal prediction systems (symbol above diagonal: FLOR-FA nominally 'better')

FLOR-FA

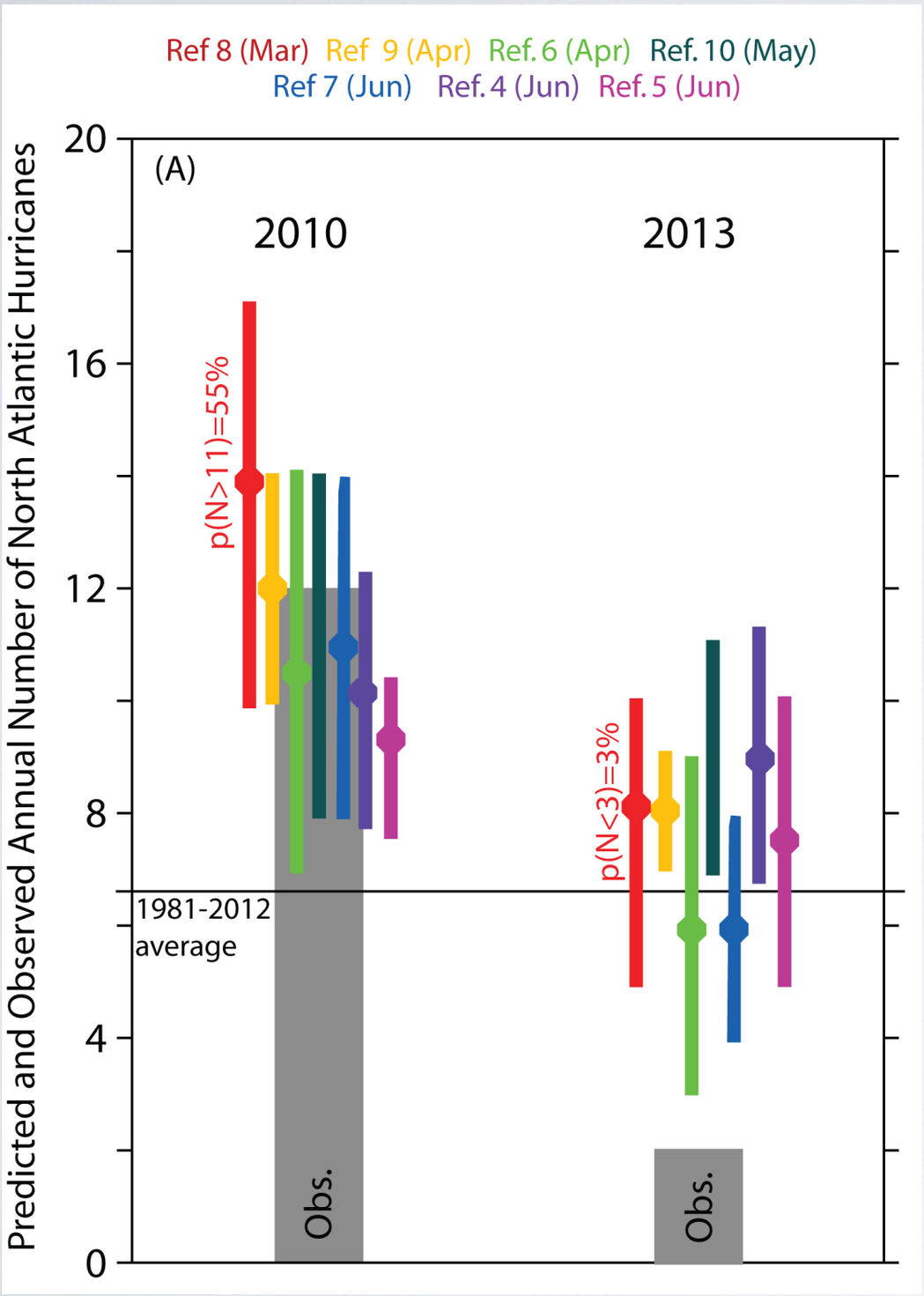



Other systems

*Vecchi et al. (2014)*

# Skillful basinwide predictions not necessarily useful predictions.

## Can we reliably predict statistics of storms more regionally than "basin-wide" number?

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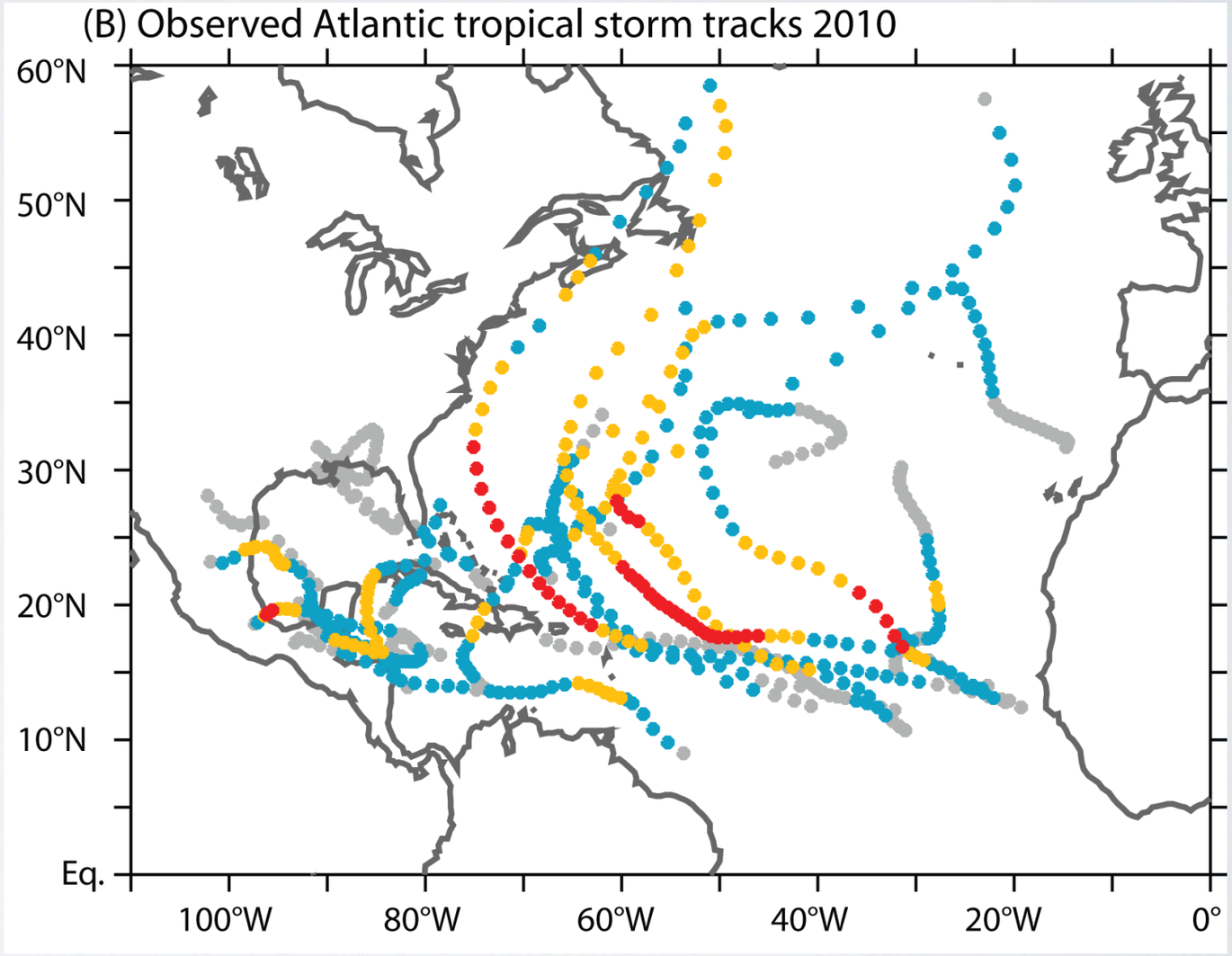
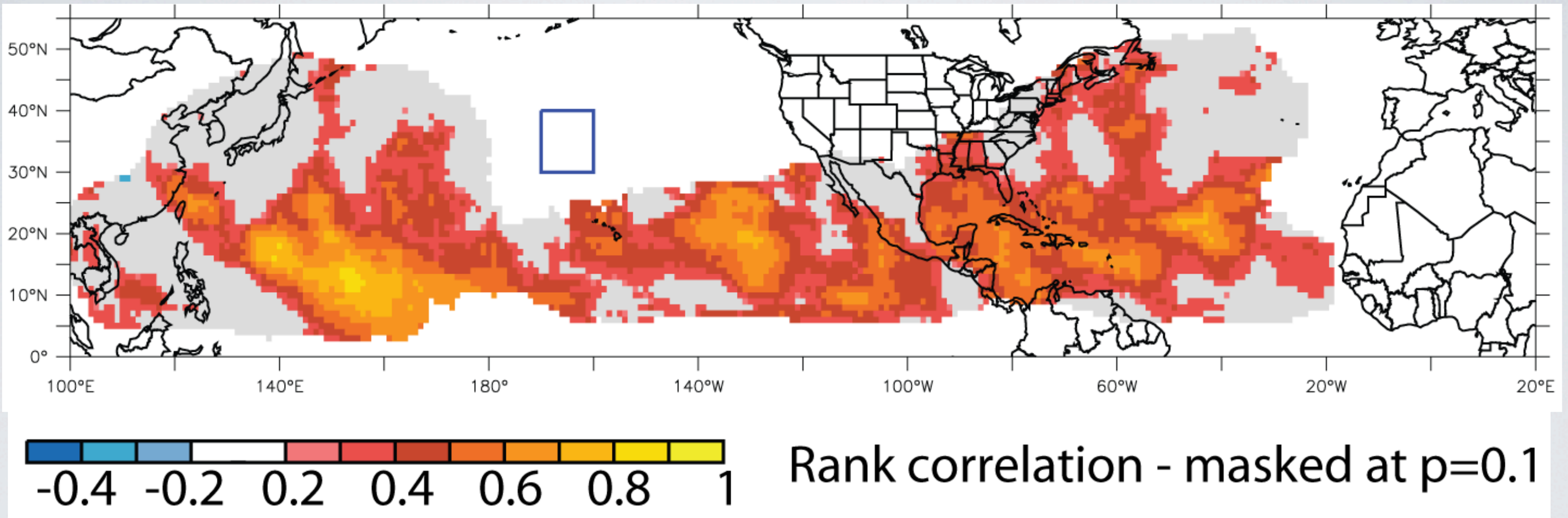



*Vecchi and Villarini (2014)*

# Can we reliably predict statistics of storms more regionally than "basin-wide" number?

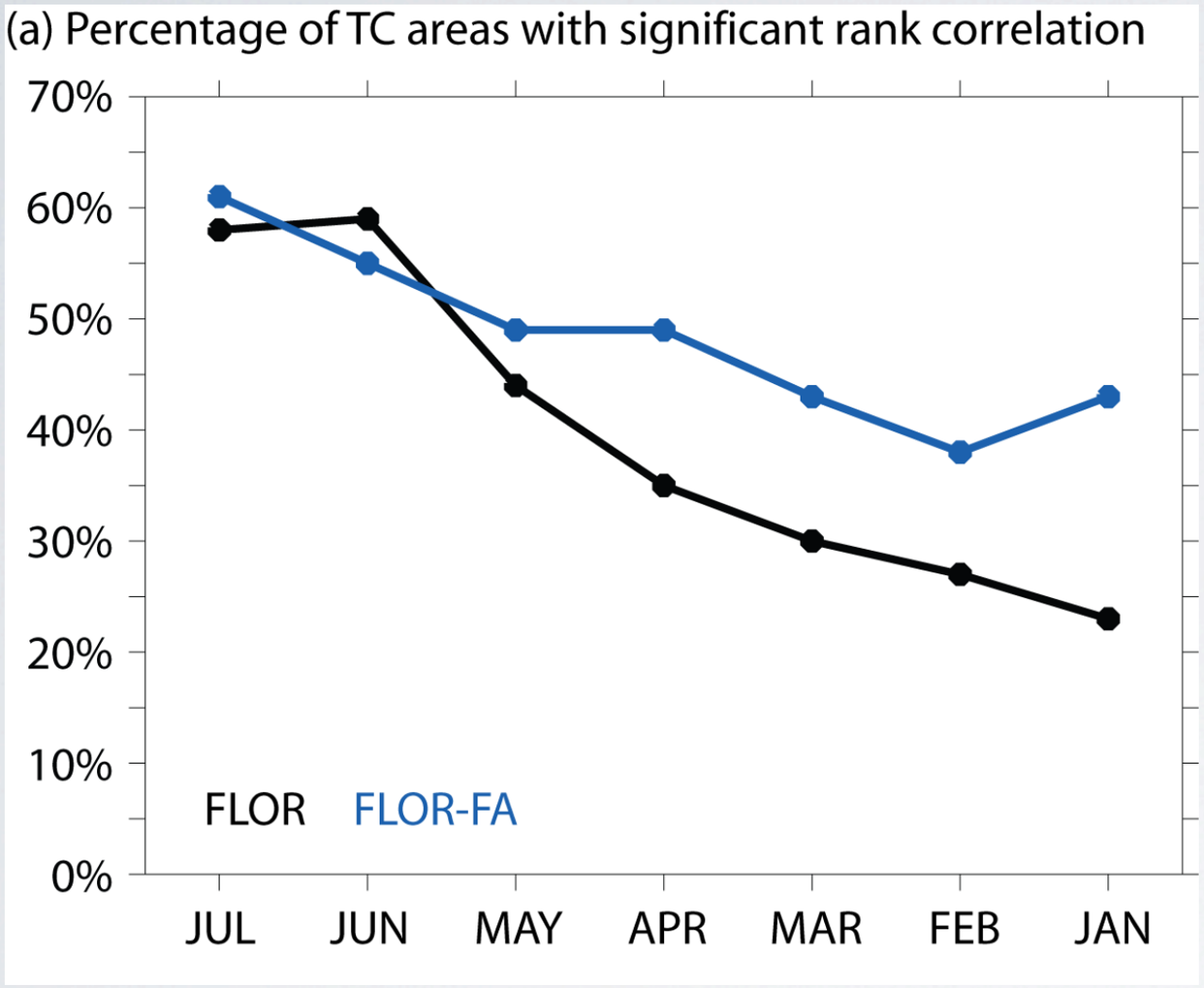
## GFDL-FLOR 1981-2012 1-July Initialized Forecasts for July-December

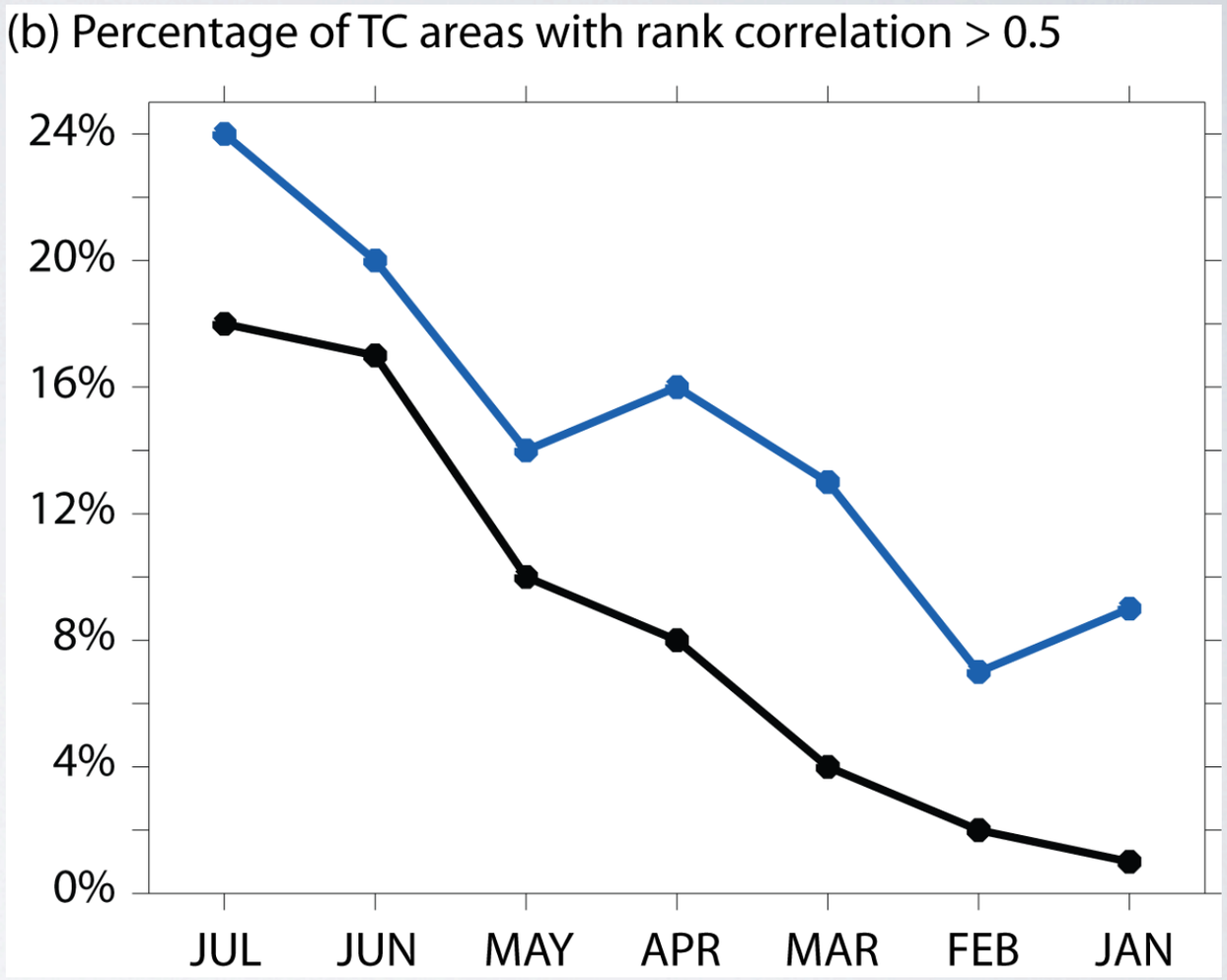



**Rank correlation**: Can experimental FLOR forecasts distinguish years with many and few storms passing within 10°x10° of a point.

*Vecchi et al. (2014, submitted)*

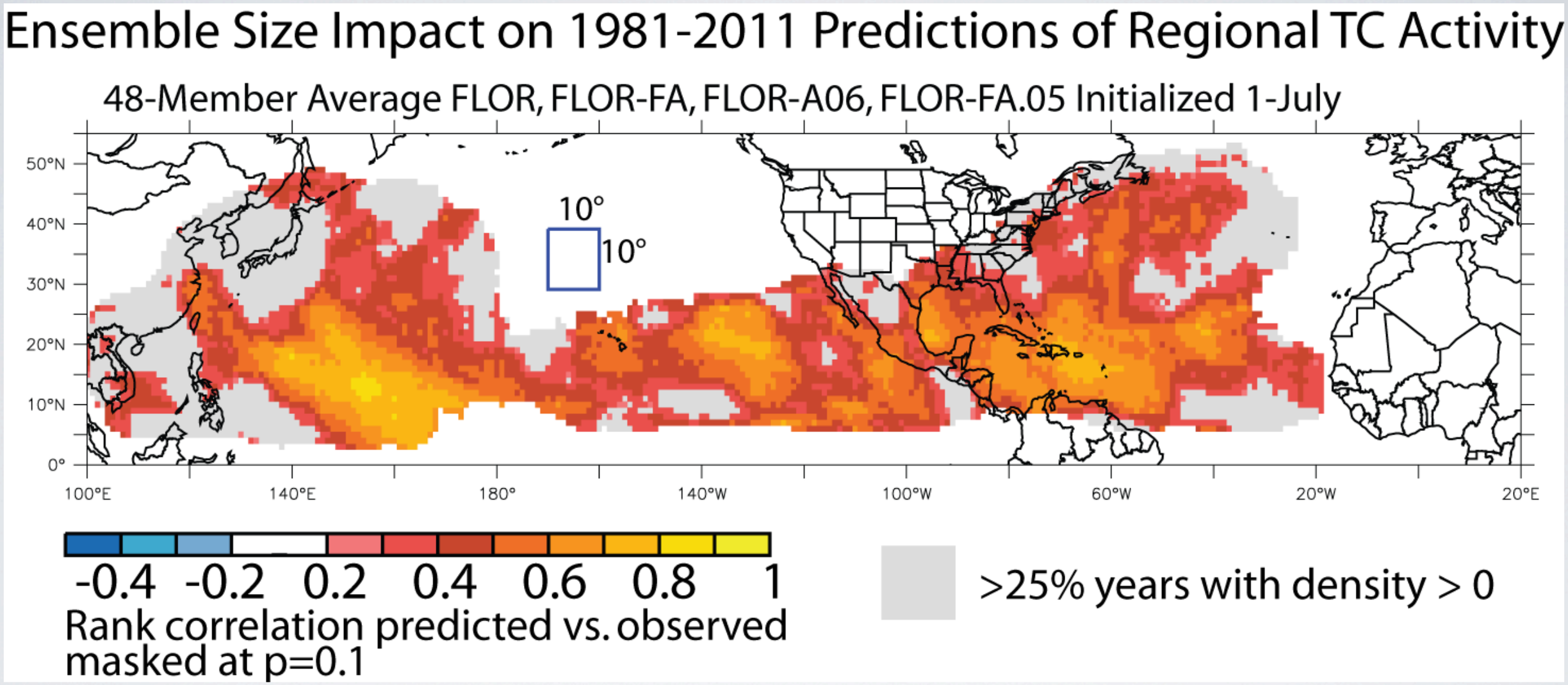
# Correcting systematic model biases (blue) improves predictions of regional (and basinwide) TC activity – particularly at long leads



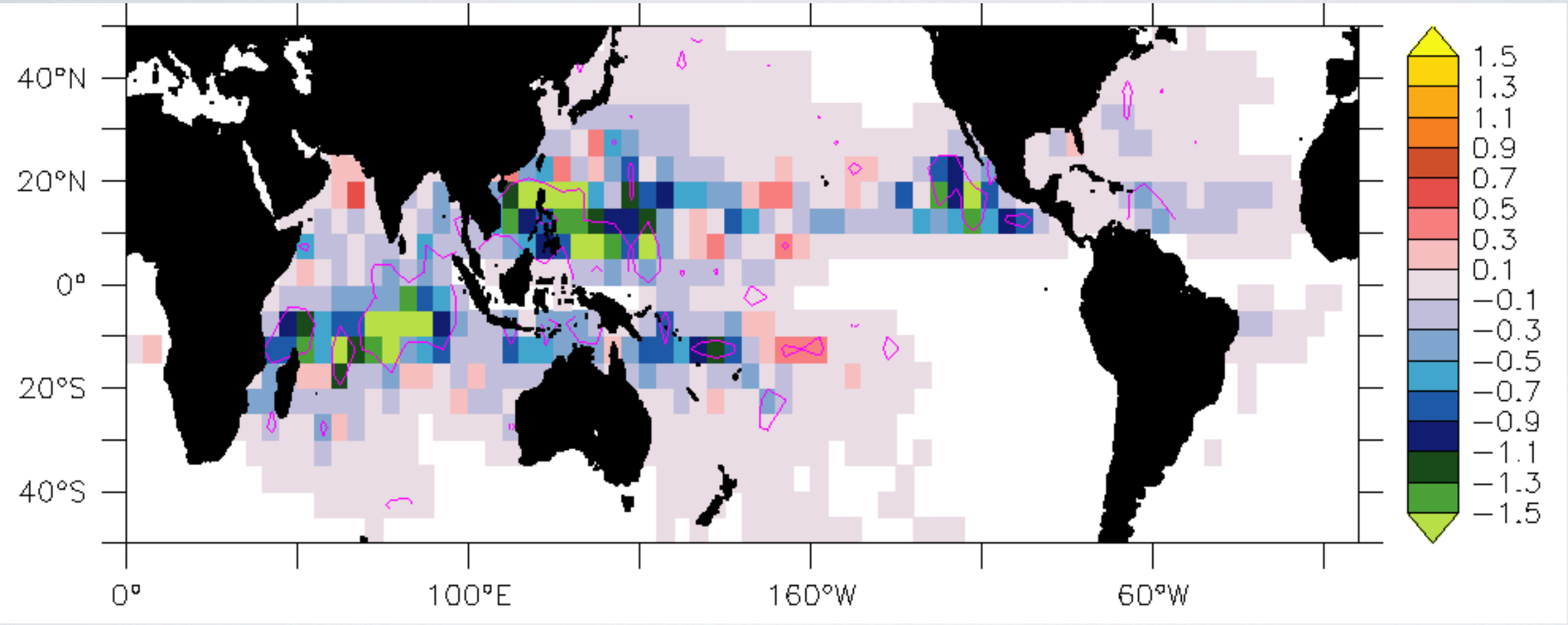




*Vecchi et al. (2014)*

# Increasing ensemble size from 12 to 48 improves regional TC predictions



# Towards seamless (or “lightly stitched”) seasonal-to-centennial TC changes in high-resolution global coupled models




More storms

Fewer storms

CM2.5 Tropical storm density response to $CO_2$ doubling

*(Kim et al. 2014)*

# Summary

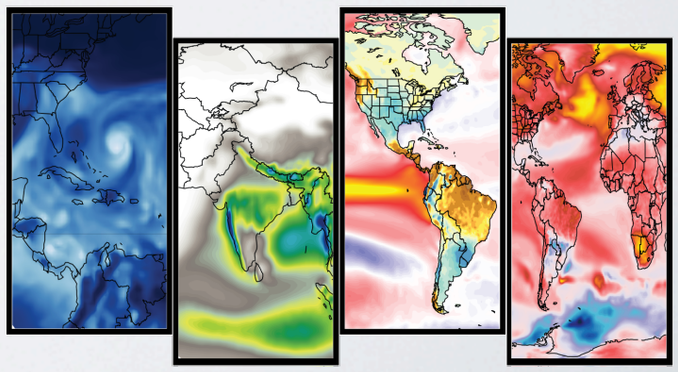
- Regional information often more relevant to decision support than continental/basin-wide information
  Regional information more challenging to generate

- Increased atmospheric and land resolution, and better land model:
  Improves forecasts of large-scale climate
  Enables forecasts of regional hydroclimate and extremes

- Statistical optimization improves predictions – see poster CM22

- Skillful seasonal predictions of TC activity at regional scales appear feasible
  Large (many 10s) ensembles appear desirable

- Reducing systematic error improves simulation and seasonal prediction of regional hydroclimate and extremes.
  FA adds one season to skill in regional TC prediction



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