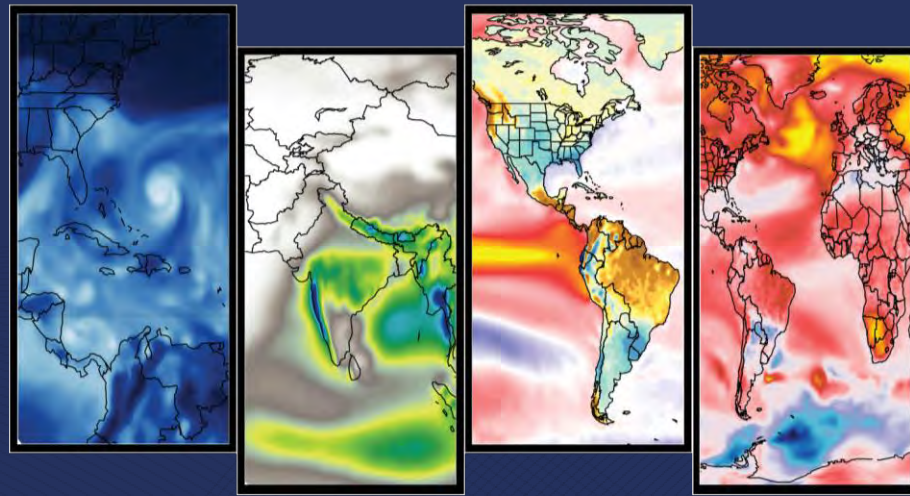


Understanding and predicting regional water and extremes

Presented by

Gabriel A. Vecchi

Geophysical Fluid Dynamics Laboratory Review

May 20 – May 22, 2014

Understanding and prediction

- Unified approaches for variability and change, across time scales and phenomena
- Tools targeted to research objectives, with clearly defined goals
- Judicious & balanced use of complexity, high resolution and large ensembles
- Application and research connected and complementary

Elements of Prediction System of Systems

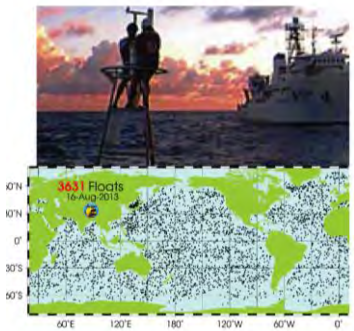
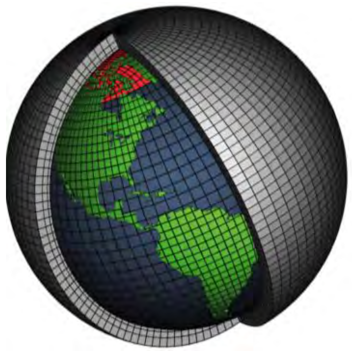
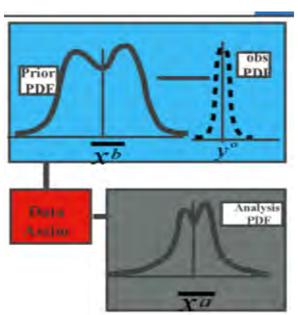


Image sources: NOAA/PMEL and Argo.ucsd.edu

Global observing system: Sparse observations of many quantities across globe.



Dynamical modeling system: Allows forward integration from present state, including expected changes in radiative forcing.



Data assimilation system: Combines sparse observations with model, to estimate present state. Usually based on dynamical model.

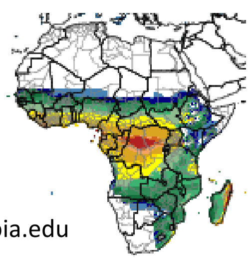


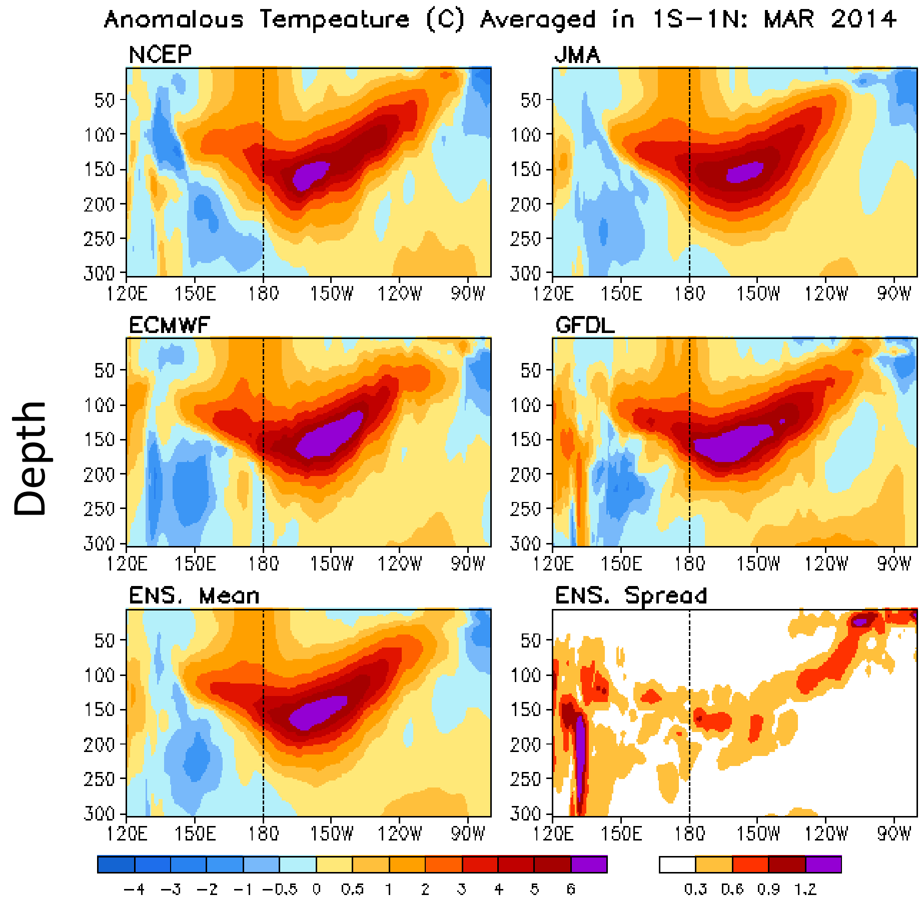
Image source: http://iridl.ldeo.columbia.edu

Analysis and dissemination system: Take output from predictions and produce “useful” information, communicate predictions.

Assimilation and observing system assessment

- Real time prediction and state estimation
  http://www.gfdl.noaa.gov/ocean-data-assimilation
- SLP Assimilation:
  Towards a coupled climate reanalysis and initialization system
- Observing system assessment (*e.g.*, TAO & Argo evaluation OSE)
- Towards high-resolution assimilation (*cf.* Shaoqing Zhang poster today)

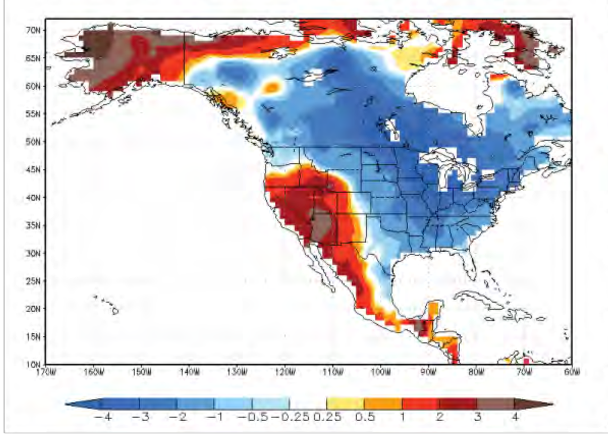
Real-time ocean assessment



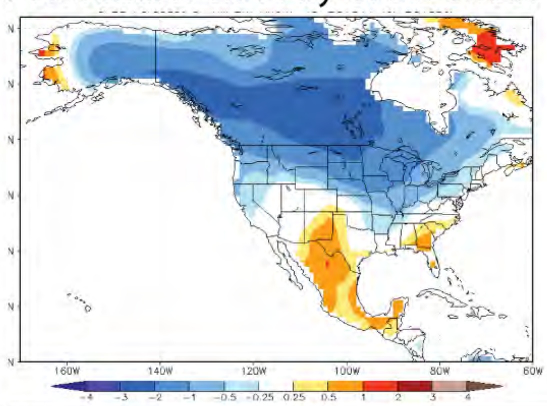
http://origin.cpc.ncep.noaa.gov/products/GODAS/multiora_body.html

Building on success: Prediction of cold 2013-14 winter

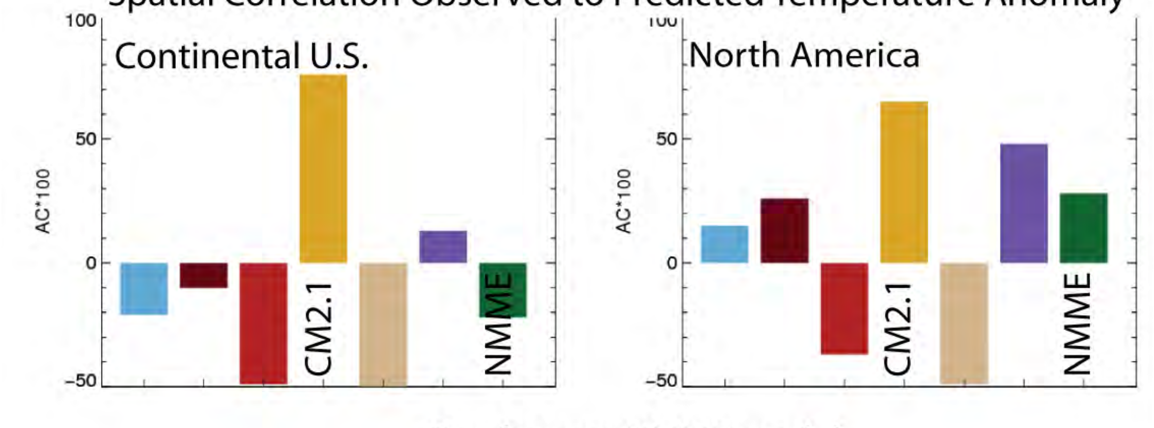
Observed DJF '13-'14 Temp. Anom



DJF '13-'14 Temp. Anom Predicted 1-November-2014 by GFDL-CM2.1



Spatial Correlation Observed to Predicted Temperature Anomaly



One bar per NMME model

Analysis: Emily Becker (NOAA-NCEP)

GFDL-CM2.1 yields world class predictions, delivered pseudo-operationally and evaluated through NMME, IRI, GFDL Data Server

Case study: CM2.1 predicted past winter cold from November 2013.

NMME: No model always best; model-mean most reliably good.

CM2.5: Among best global surface climate simulations

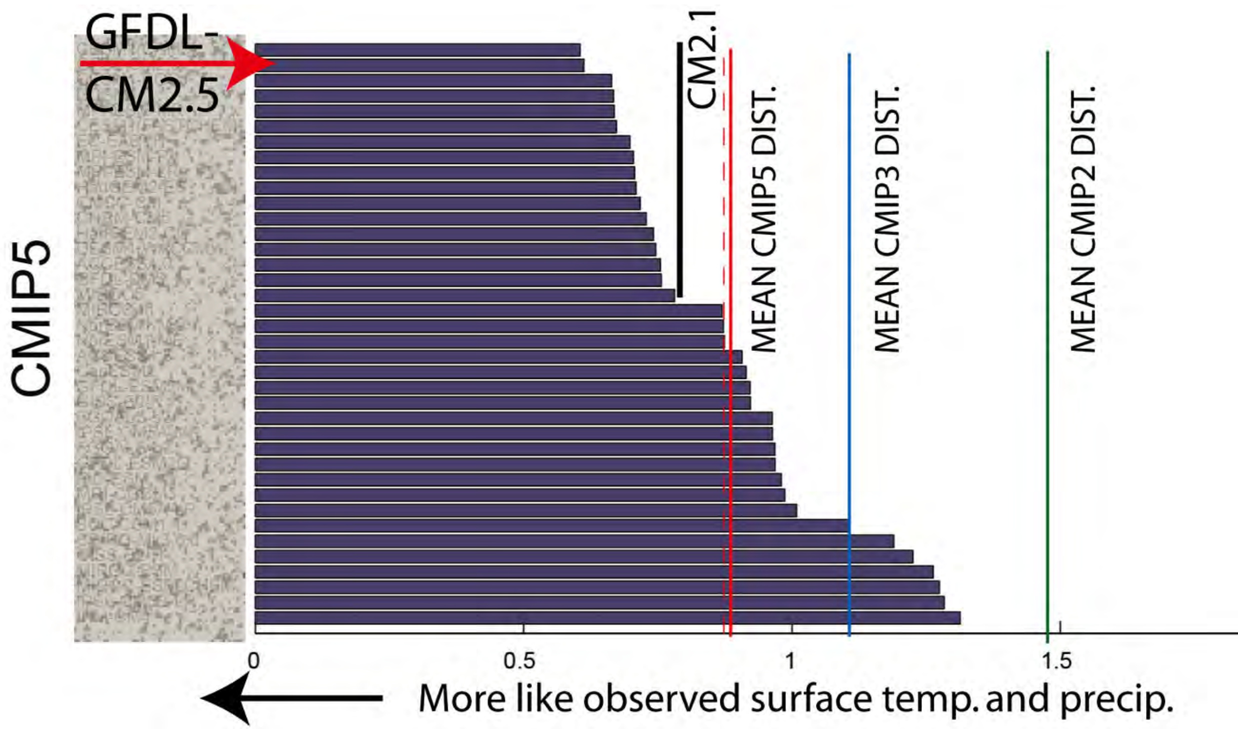
can we harness this for prediction?

CM2.1: 2° atmos/land; 1° ocean/ice, LM2
CM2.5: 50km atmos/land; 0.25° ocean/ice, LM3

Long-lead research and faster computer (Gaea)

High-resolution CM2.5

Significantly reduced biases relative to CM2.1 (and other models)



Knutti et al. (2013)

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

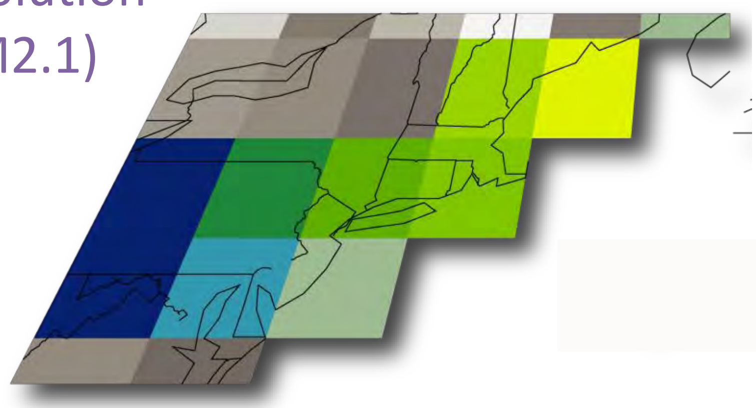
Goal: Build a seasonal to decadal forecasting system to:

Yield improved forecasts of large-scale climate

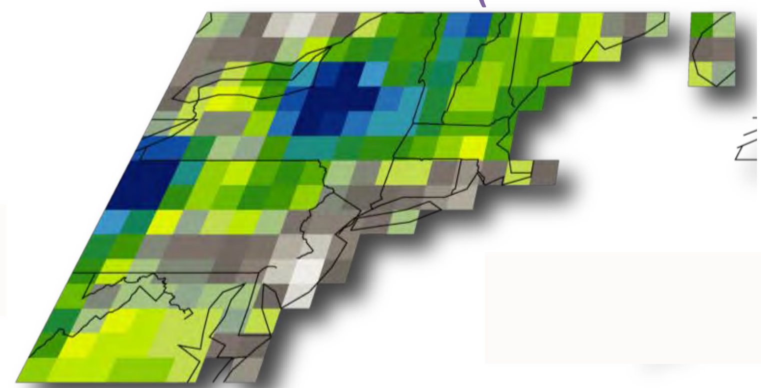
Enable forecasts of regional climate and extremes

Precipitation in Northeast USA

Medium resolution (CM2.1)



High resolution (CM2.5-FLOR)



Delworth et al. (2012), Vecchi et al. (2014), Jia et al. (2014), Yang et al. (2014), Msadek et al. (2014), Wittenberg et al. (2014)

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

- 50km cubed-sphere atmosphere (cf. S.J. Lin's talk)
- 1° ocean/sea ice (low res enables prediction work)

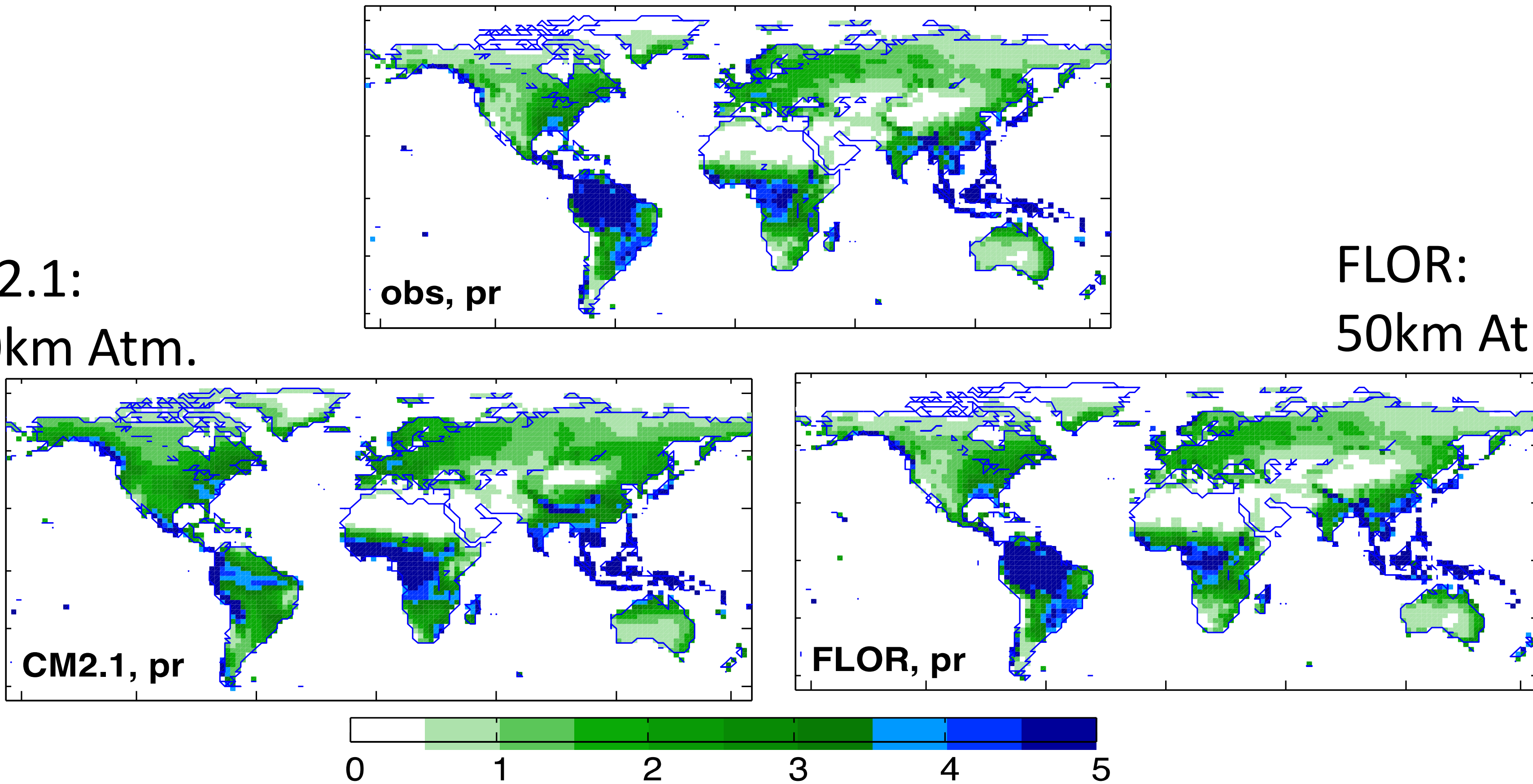
~15-18 years per day. Multi-century integrations. 10,000+ model-years of experimental seasonal predictions completed and being analyzed.

Hypothesis: Enhanced atmos./land resolution improves simulation and prediction

Observed

CM2.1:
200km Atm.

FLOR:
50km Atm.



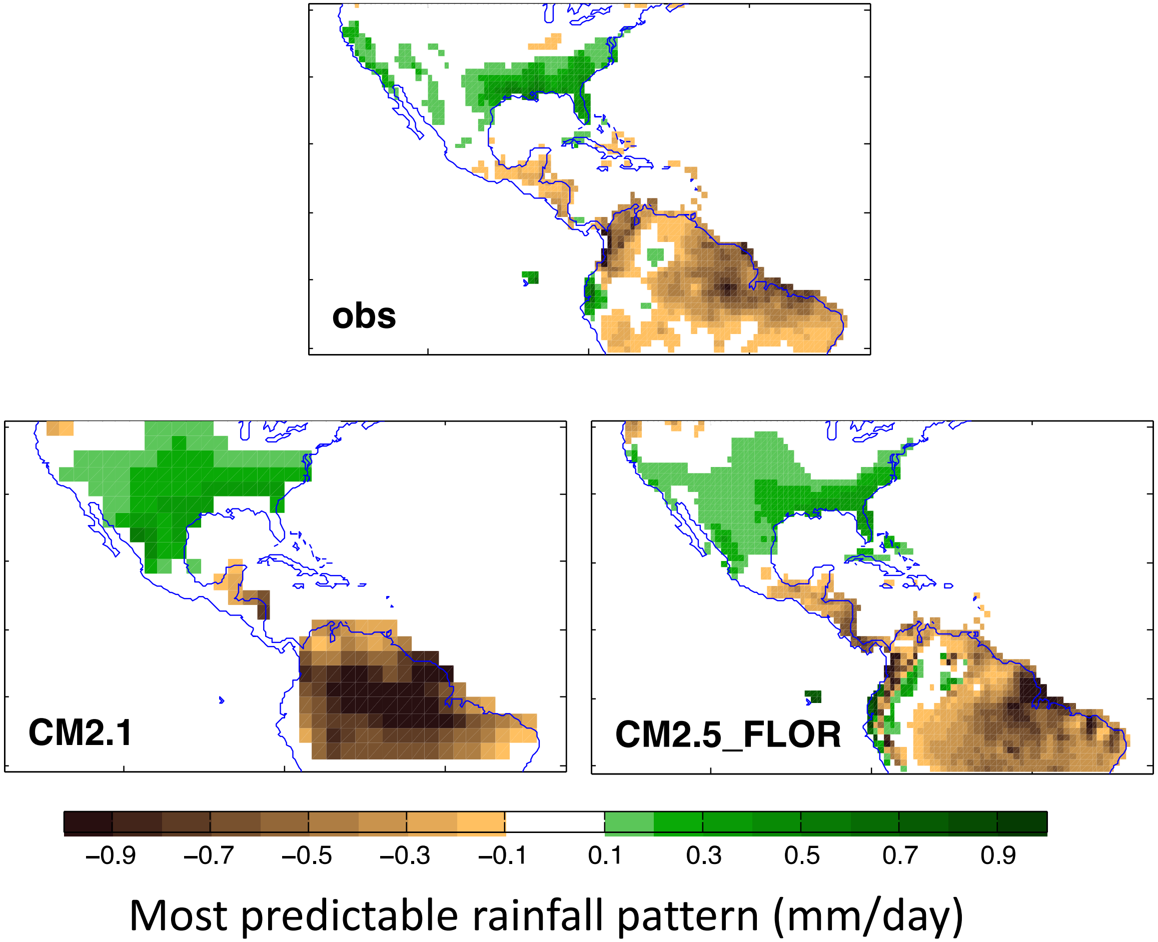
Annual Precipitation (mm/day)

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

Hypothesis: Enhanced atmos./land resolution improves simulation and prediction

Representation and prediction skill for most predictable pattern of rainfall over land improved in FLOR relative to CM2.1

(see Liwei Jia's poster today)



(Jia et al. 2014, submitted)

Tour across scales & phenomena

Rest of morning:

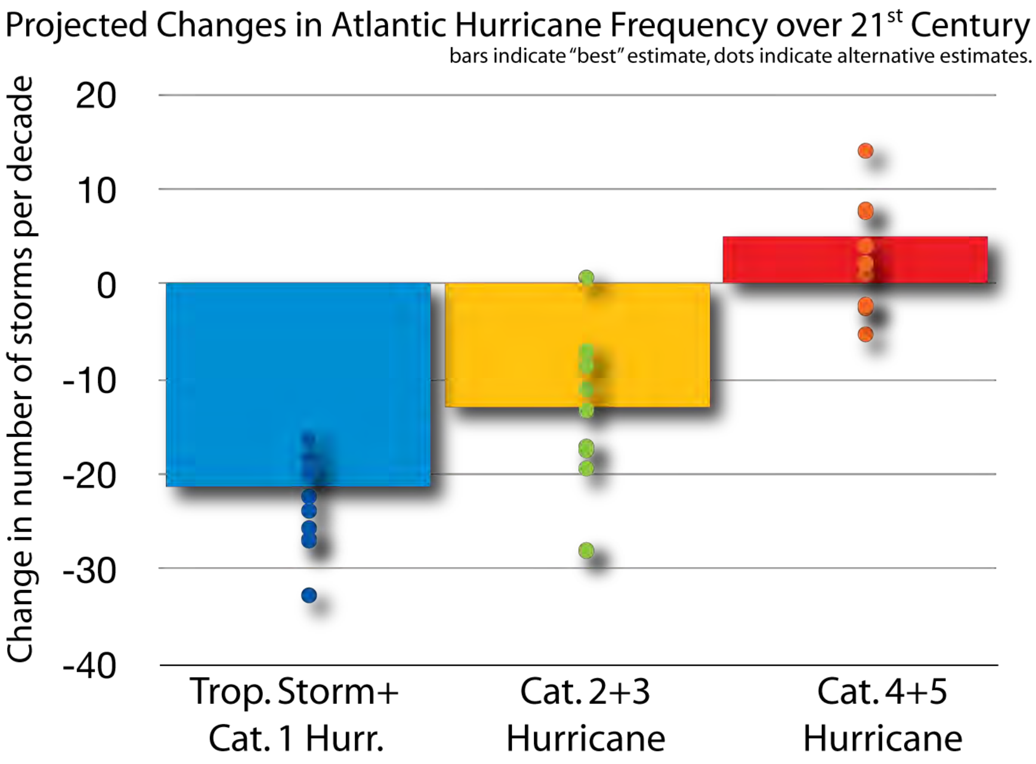
Snow, Ice, Extratropical storms, North Atlantic, ENSO, land precipitation and temperature, atmospheric jets, high-resolution assimilation, understanding and evaluating downscaling methods, attribution of global and regional changes.

- **Rest of this talk:** tropical cyclones across timescales.

Late 21st Century Atlantic Hurricanes: Fewer? Stronger?

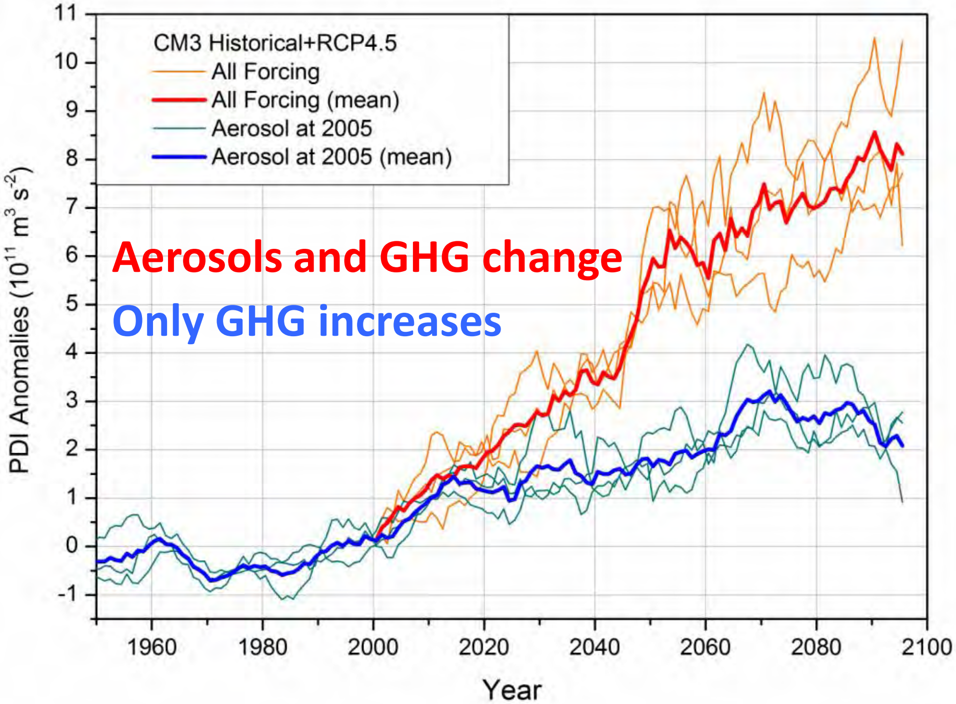
NA frequency decrease & intensity increase: strongest TCs may become more frequent

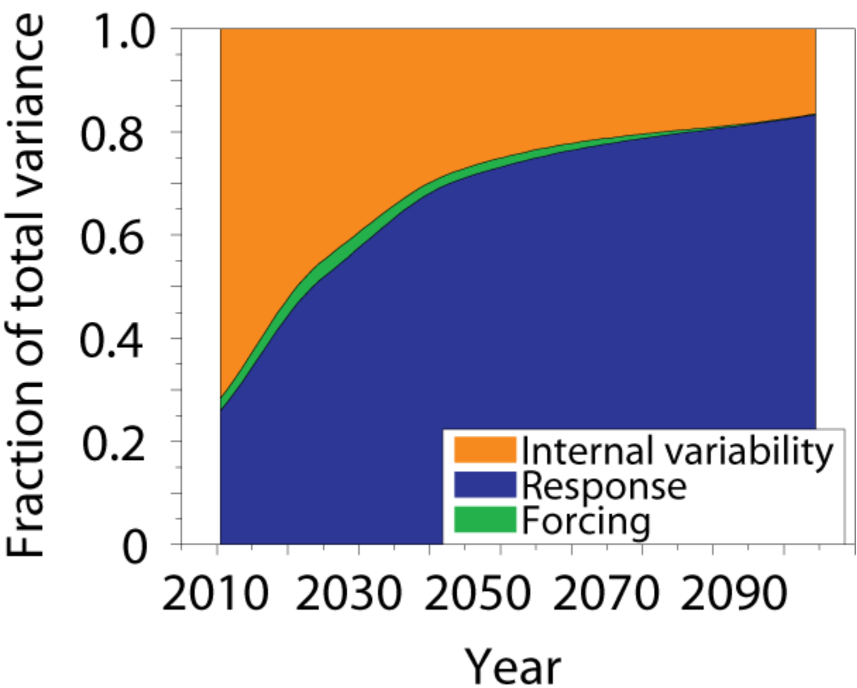
Large spread across various GCM projections.



Adapted from Knutson et al. (2013, J. Clim.). See also: Knutson et al. (2009), Zhao et al. (2009), Bender et al. (2010), Villarini et al. (2011), Villarini and Vecchi (2012, 2013)

Decades: aerosols and variability





Sources of uncertainty (after Hawkins and Sutton, 2009)

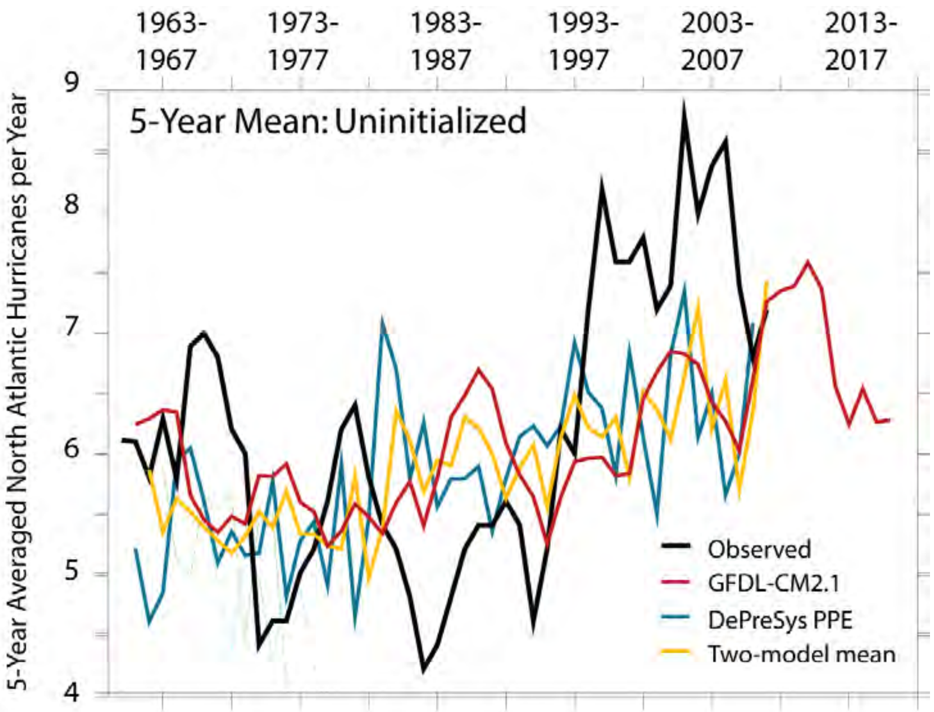
- **Variability: ~independent of radiative forcing changes**
- **Response: "how will climate respond to changing GHGs & Aerosols?"**
- **Forcing: "how will GHGs & Aerosols change in the future?"**

Villarini et al. (2011, J. Clim.); Villarini and Vecchi (2012, Nature Clim. Ch.; 2013, J. Clim.); Knutson et al. (2013, J. Clim.)

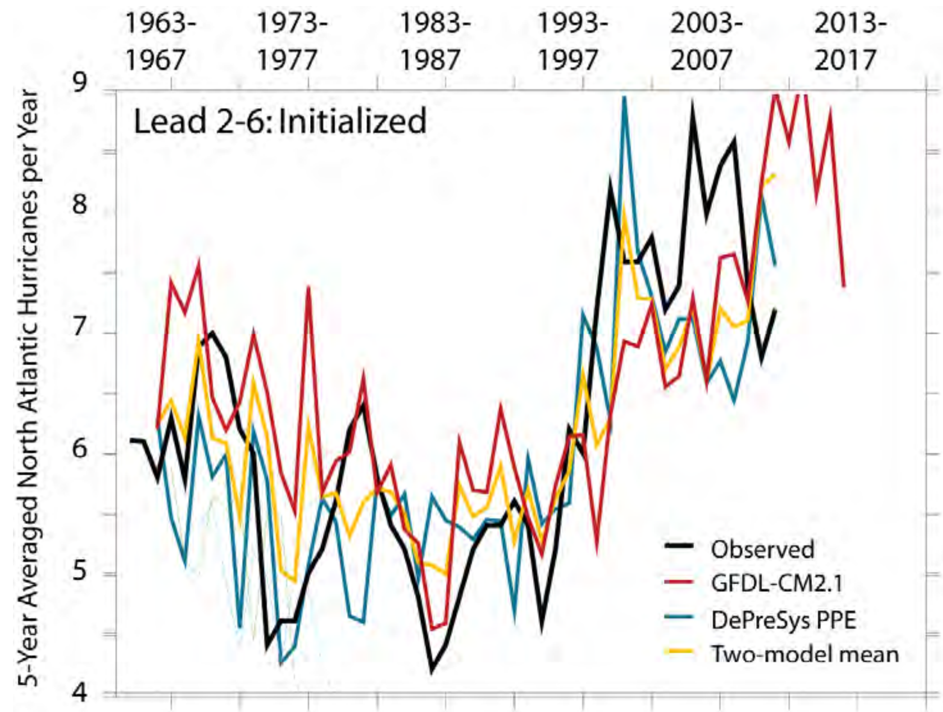
Experimental decadal predictions

Hybrid system: statistical hurricanes, dynamical decadal climate forecasts

FORCED



FORCED & INTIALIZED



- Retrospective predictions encouraging.
- However, small sample size limits confidence
- Skill arises more from recognizing 1994-1995 shift than actually predicting it.
- This is for basinwide North Atlantic Hurricane frequency only.

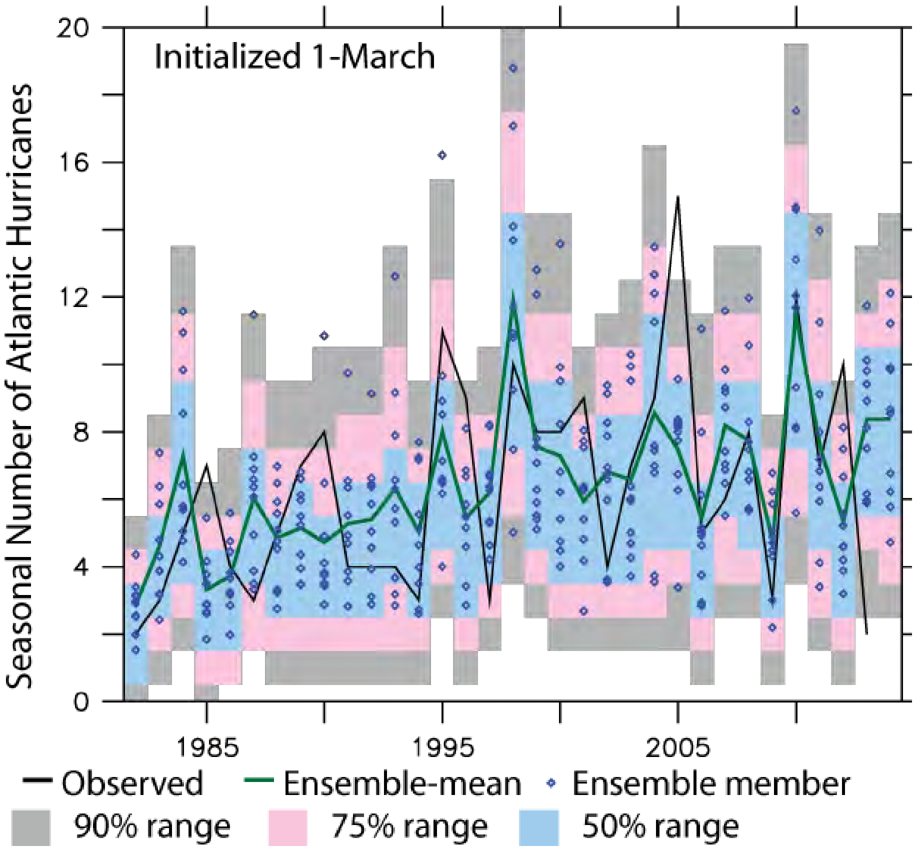
Vecchi et al. (2013 and 2014), Msadek et al. (2014)

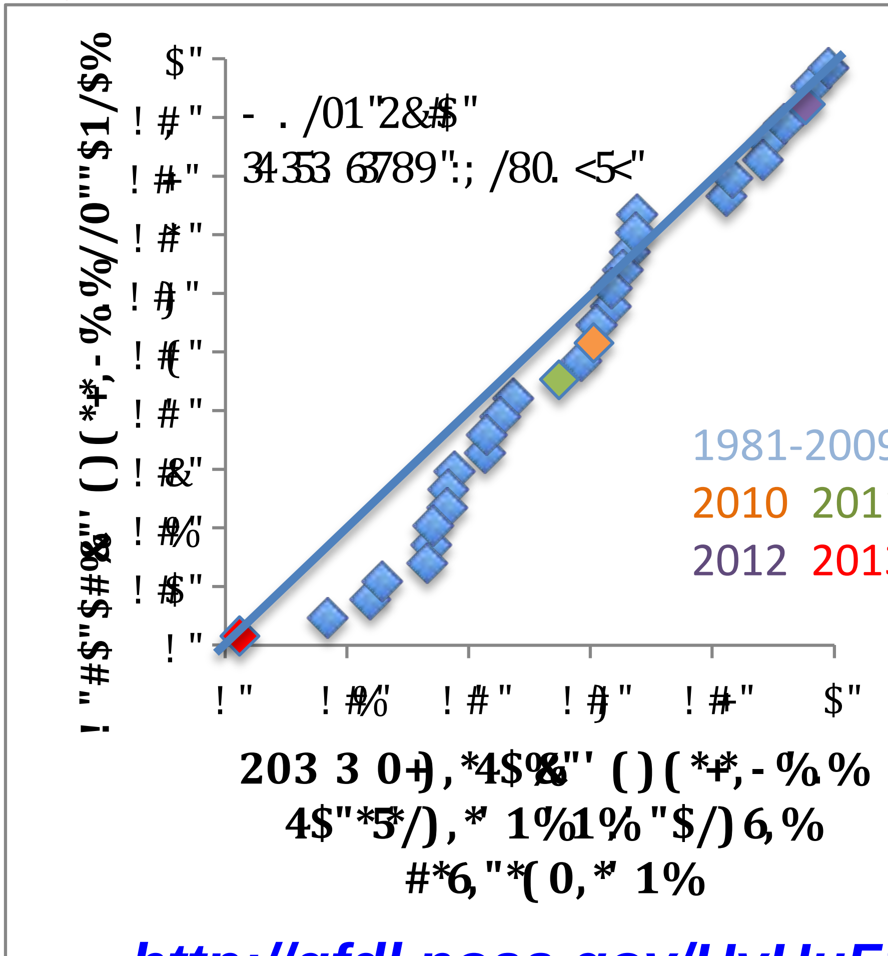
EXPERIMENTAL: NOT OFFICIAL FORECAST

SEASONS: HyHuFS long-lead forecasts system. Skill from as early as October of year before

April-initialized forecasts both 2010 and 2013 ve... but these extremes have occurred at a rate compa... U... of the forecast PDFs. (Figure

Significant deterministic skill (r=0.51) & Forecast PDF reliable





FLOR & HyHuFS forecasts fed to NOAA Seasonal Outlook Team

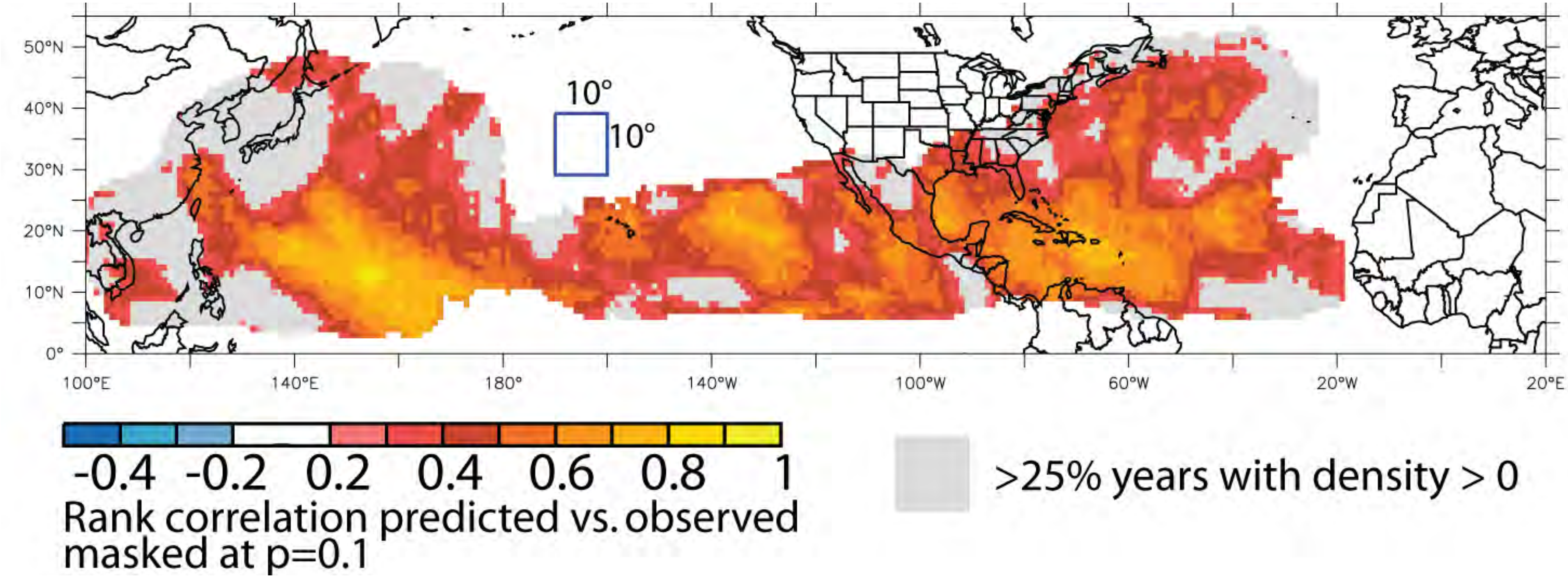
http://gfdl.noaa.gov/HyHuFS

Vecchi et al. (2011), Villarini and Vecchi (2013)

Figure 2: Graphical assessment of probabilistic skill of Hy... probability of the observed number of Atlantic hurricanes ... *probability*), vertical axis shows the order of the verificatio... number of points. For large sample size, a "perfectly" cali...

FLOR: Seasonal predictions of regional TC activity

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

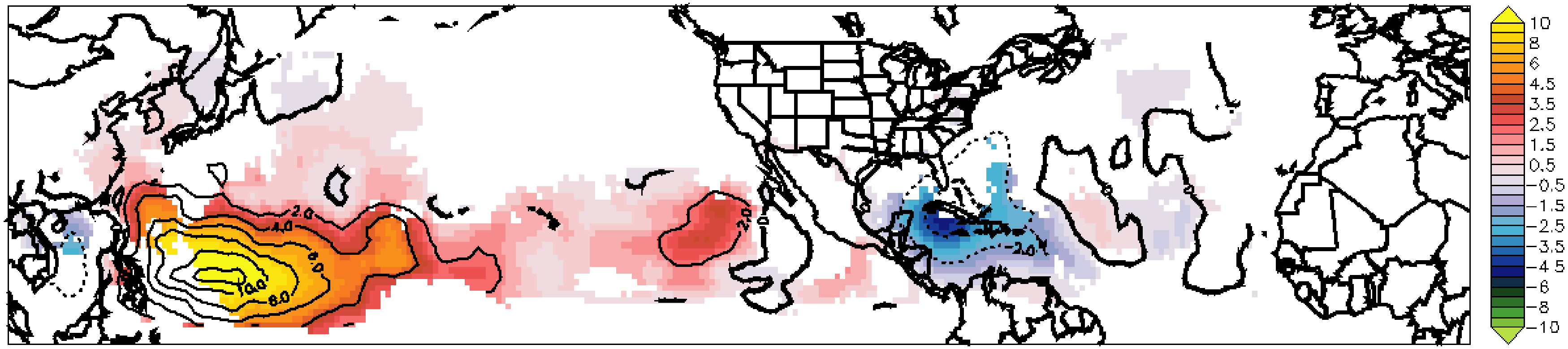


Rank correlation: Can experimental FLOR forecasts distinguish years with many and few storms passing within 10° x10° of a point?

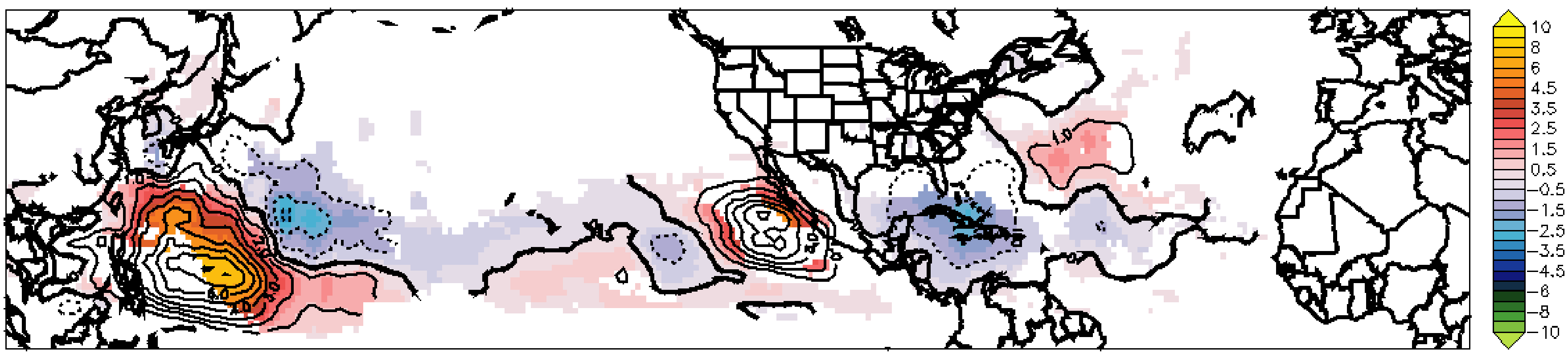
Vecchi et al. (2014, submitted)

GFDL-FLOR Predicted TC density anomaly for 2014: uncertainty in large-scale impacts TC forecast

Initialized 1-April-2014 Reflects in part prediction of strong El Niño



Initialized 1-May-2014 Reflects prediction for El Niño weakens

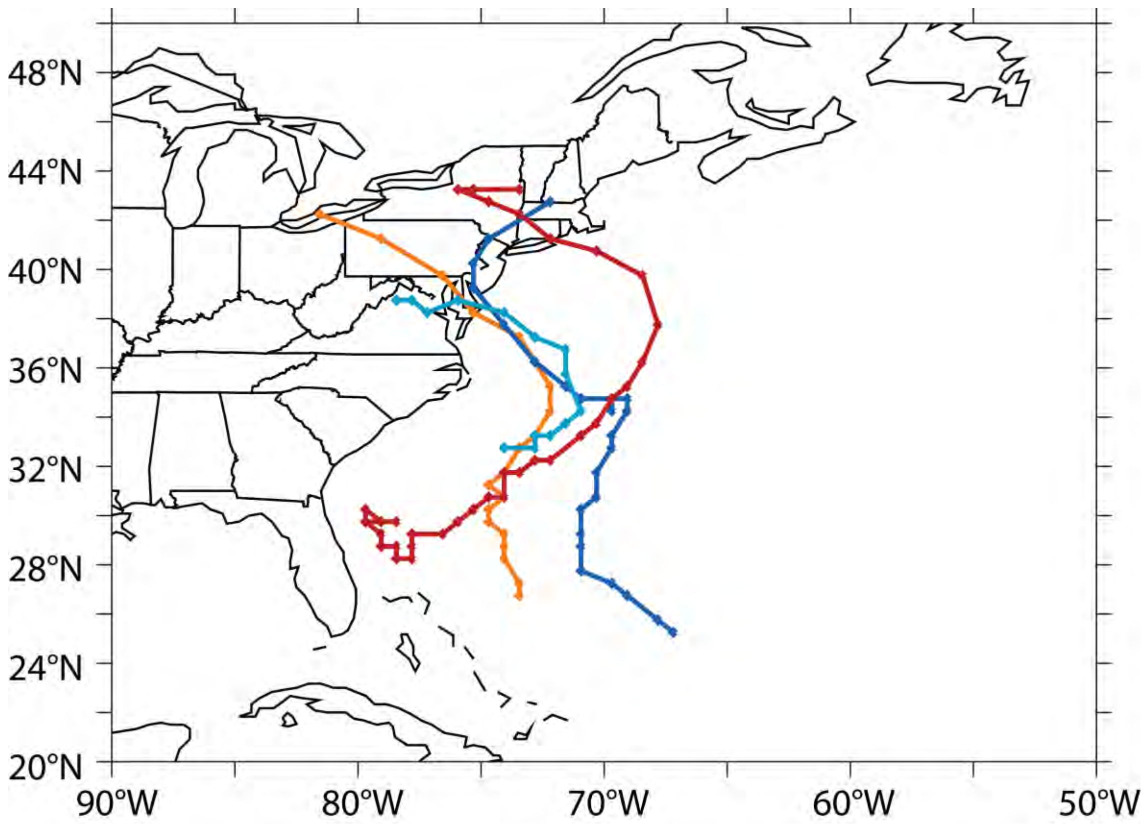


Contoured: TC density anomaly (days over 10°x10° box for year) relative 1982-2005.
Shaded: retrospective p=0.1 significant correlation.

Vecchi et al. (2014, submitted)

High-Resolution Seasonal Predictions for Risk Assessment

Case Study: What are odds of Sandy-like storm?



- FLOR spontaneously produces storms with Sandy's unusual "left hook"
- Retrospective forecasts: 1000s of worlds that "could have been"
- Use these "plausible worlds" to estimate risk of unlikely extremes & understand their causes/predictability.

How do we quantify the uncertainty in these estimates of "unlikely event" return period? We have only seen one real Sandy…

Summary

- Models allow estimates of future TC activity:
  - Next couple of decades: internal variability dominant player (some may be predictable, some not)
  - NA Hurr. Response to CO_2: maybe fewer, probably stronger.
  - Aerosol forcing and response may be crucial to next few decades.
- Encouraging results from long-lead (multi-season & multi-year) experimental TC forecasts
- High-resolution coupled model (FLOR) enables predictions of regional tropical cyclone activity.