GFDL Climate Modeling

ISI to DecCen, Regional to Global Scales: Development and Applications

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1. Brief History

2. Current modeling capabilities and applications

3. Future development pathways

Circa 2005

IPCC AR4 Models

CM2.0,CM2.1 – state of the art physical climate models (1^{o} ocn; 2^{o} atm)

After IPCC AR4, some key questions and issues motivated model development:

a. Need to explore climatic impacts of: (a) aerosol indirect effects, (b) inclusion of atmospheric chemistry, (c) importance of better resolved stratosphere.

b. Need to incorporate biogeochemical cycles (including carbon cycle) and their feedbacks in our models; how sensitive are these processes to ocean formulation?

c. Is there predictability in the climate system on decadal scales based on internal variability?

d. Need to better simulate ***regional climate***, extremes, and role of small scale processes

Circa 2005

CM2.0,CM2.1 – state of the art physical climate models (1° ocn; 2° atm)

Circa 2010

Experimental prediction
- *CM2.1*
- *Coupled assimilation*
- *Seasonal to decadal*

ESM2M,ESM2G
- *Carbon cycle*
- *Vegetation feedback*
- *Ocean formulation*

HIRAM
- *High spatial resolution (atm only)*
- *Time-slice experiments*
- *Climate extremes*
- *Hurricane simulation/prediction*

CM3 (Primary Physical Model)
- *Aerosols, indirect effect*
- *Stratosphere*
- *Convection, Land Model*
- *Atmospheric Chemistry*

CM2.5
- *High spatial resolution (coupled)*
- *Energetic ocea*
- *Variability and*

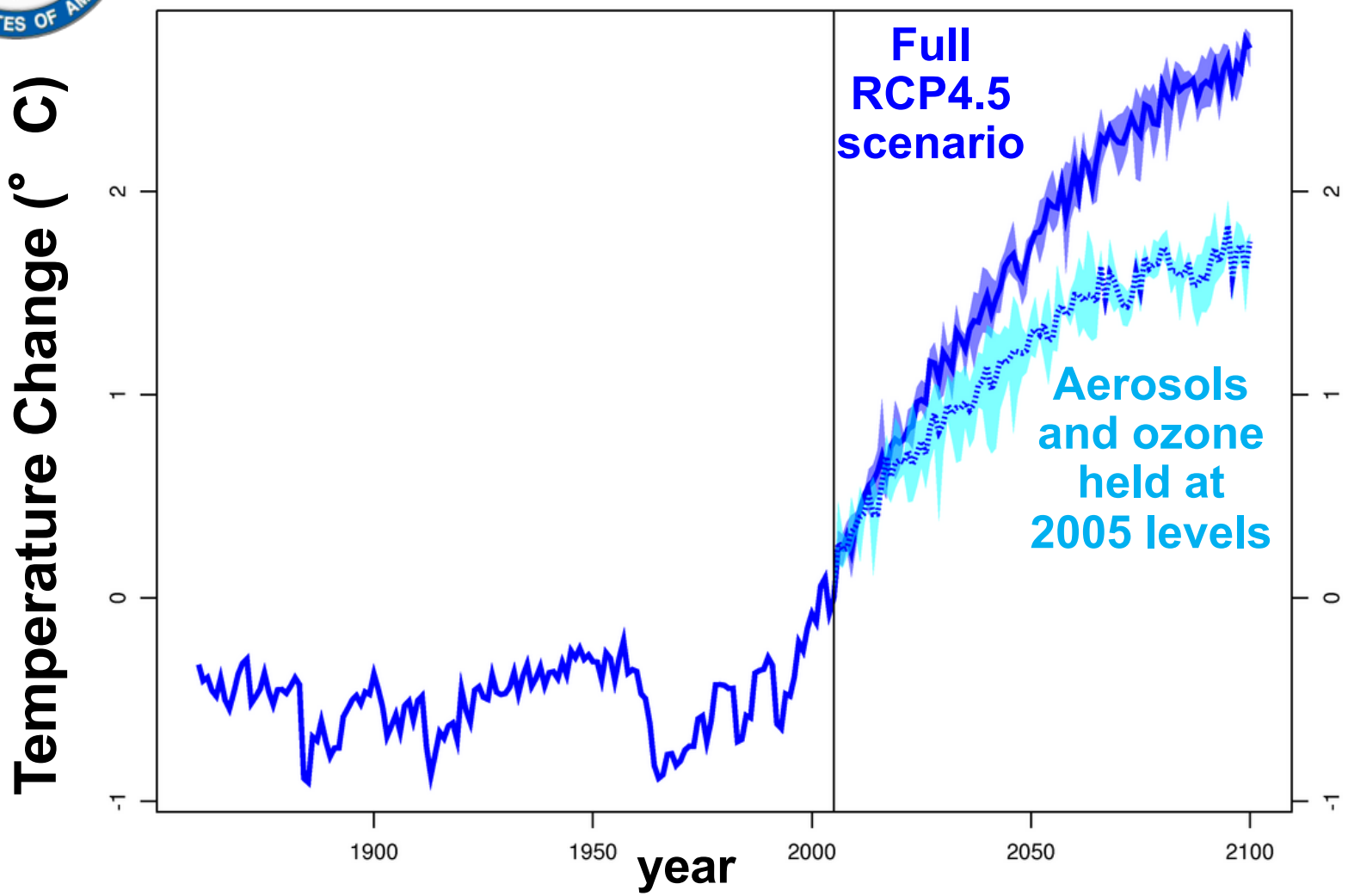
system at high r

Collaboration on regional downscaling with Department of the Interior through the South Central Climate Center

Complexity/Completeness

Spatial Resolution

Surface Air Temperature (RCP4.5 scenario)

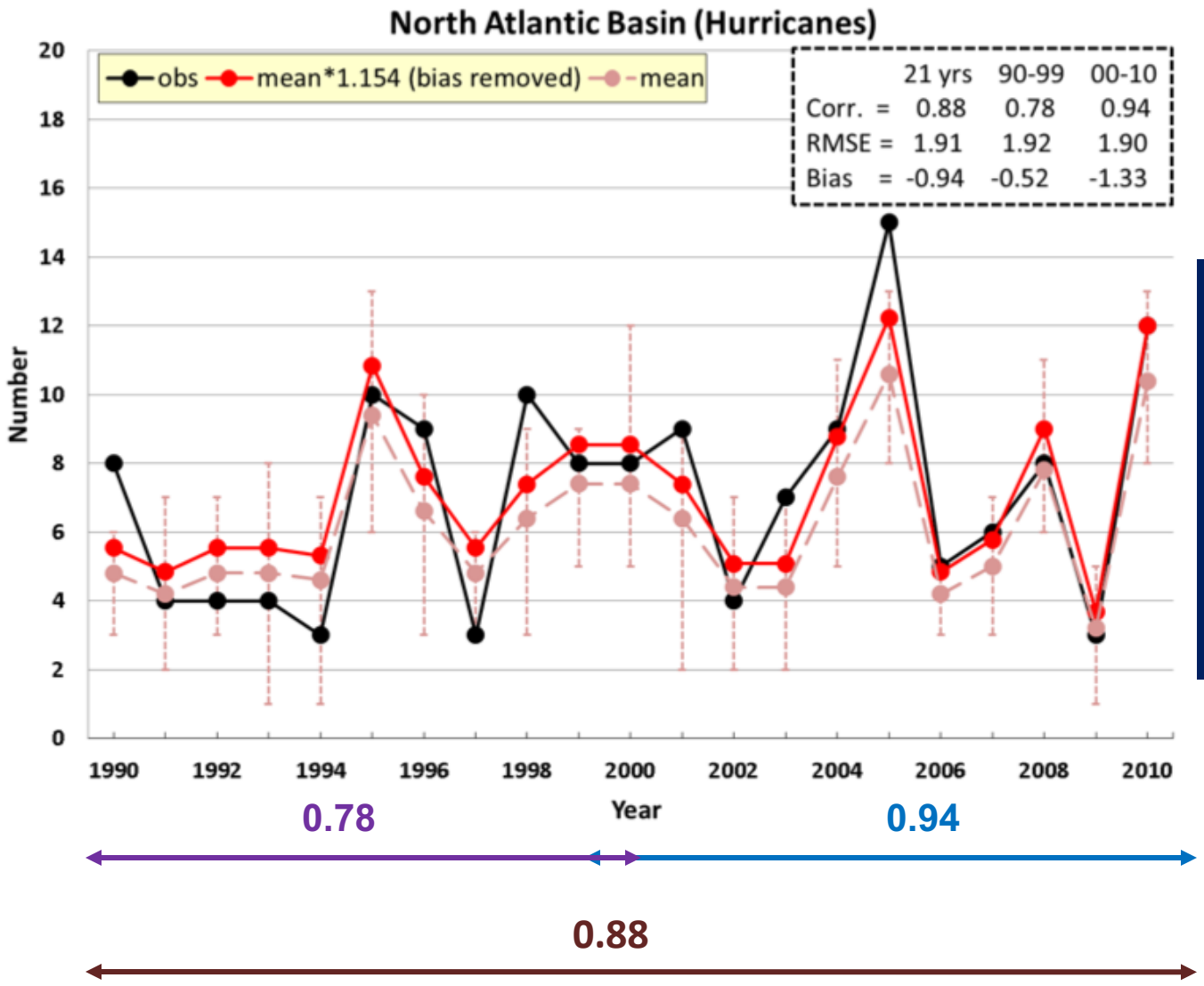


Large additional warming projected from aerosols over 21st century

Slide courtesy of Larry Horowitz

Seasonal hurricane predictions

1990-2010 (Jul-Nov)

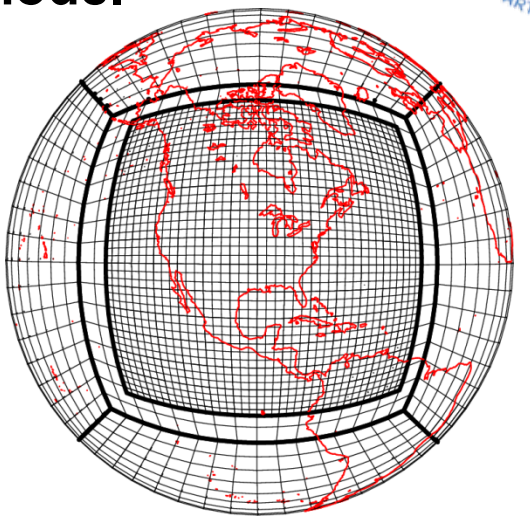


- Resolution: 25 km, 32 levels
- 5-members initialized on July 1 with NCEP analysis
- SST anomaly is held constant during the 5-month predictions
- Climatology O3 & greenhouse gases are used

1. Chen and Lin 2011, GRL
2. Chen and Lin, 2012, J Climate

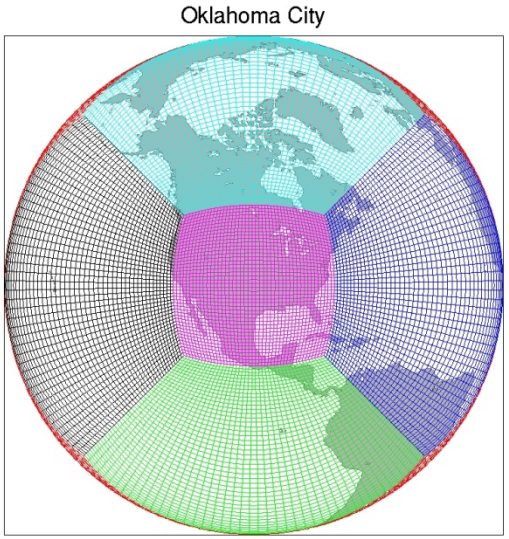
Slide courtesy of SJ Lin

GFDL's plans for ultra-high resolution global "regional climate model"



A. Nested regional-global climate model:

- 3X grid-size reduction; regional component can be run independently (for down-scaling) or coupled with global component to allow feedback to "global" changes

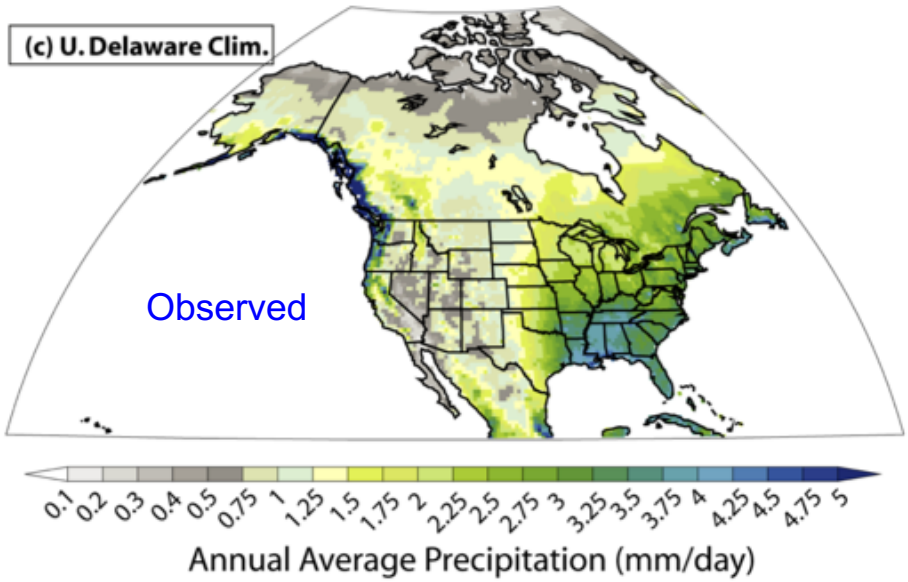


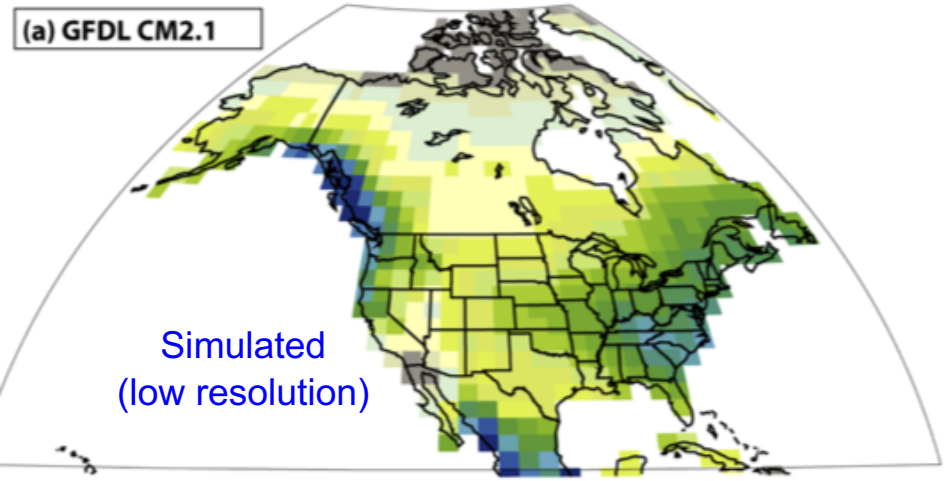
B. Variable resolution climate model

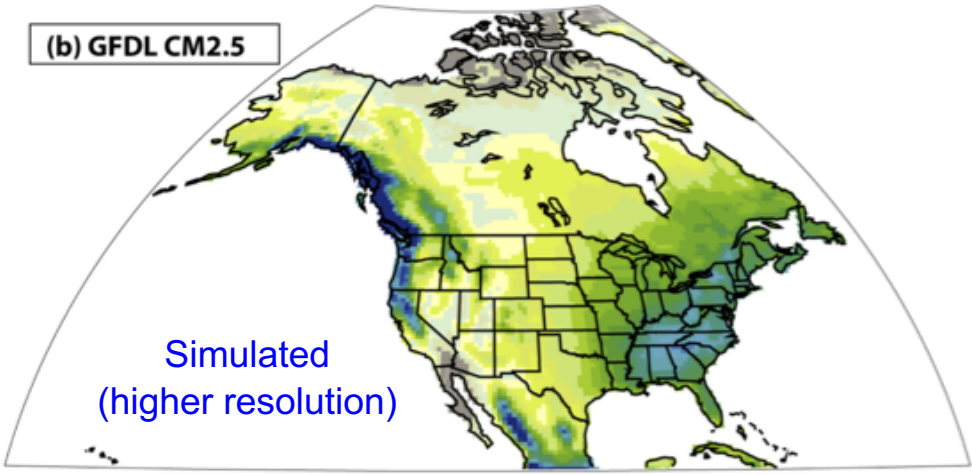
- Single model framework with smooth transition in resolution with 3X grid-size reduction in target region (e.g., NA with ~ 4 km resolution); 3X enlargement on the back side

Slide courtesy of SJ Lin

Observed and simulated precipitation



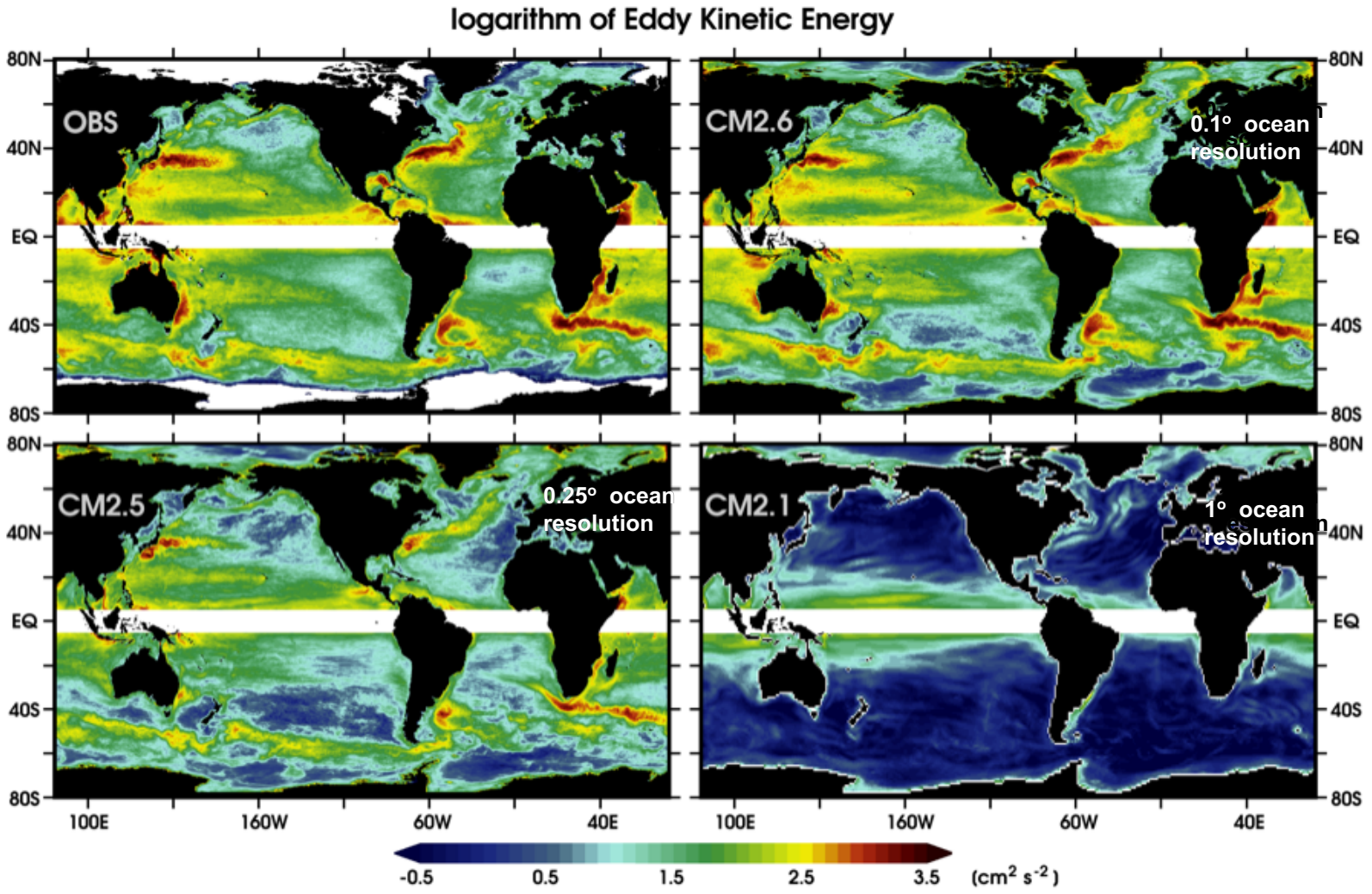




Delworth et al., 2012

Model fidelity may be crucial for simulation of oceanic decadal variability and decadal predictions

Eddy kinetic energy in models and estimated from observations



Initialized prediction research at GFDL

SEASONAL:

- **Experimental predictions for tropical storm activity using both statistical and high-resolution dynamical models**
- **Use CM2.1 global coupled climate model and Ensemble Coupled Data Assimilation System (ECDA) for experimental seasonal prediction; participate in US National Multi-Model Ensemble**

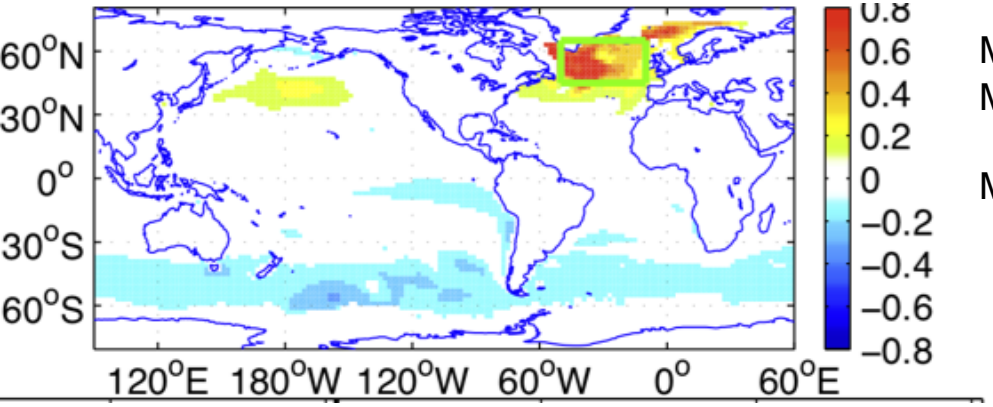
DECADAL:

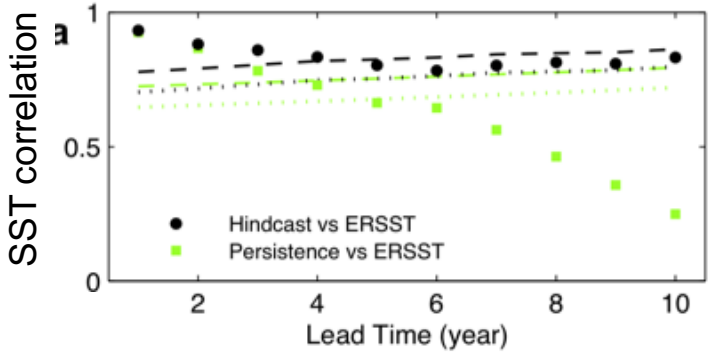
Fundamental research questions:

- **What decadal predictability exists in the climate system?**
- **What are the mechanisms responsible for that predictability?**

Special thanks for support from NOAA CPO's Climate Variability and Predictability Program (CVP) of the Earth System Science group (ESS)

Experimental decadal predictability and prediction: using CM2.1 and coupled data assimilation system, conducted extensive suite of decadal hindcasts and predictions starting in each year from 1961 to 2012 (5000+ simulated years).





Yang et al., accepted, J Clim

Most predictable SST pattern resembles Atlantic Multidecadal Variability/Oscillation

Model output available on web as part of CMIP5.

There are also indications of possible predictability of Atlantic hurricane activity on multi-year time scales, but much more work is needed related to:

- *role of radiative forcing*
- *changing observing system*
- *shortness of observed record*

Vecchi et al., submitted

GFDL plans for model development and applications

1. Transition from CM2.1 to CM2.5 high-resolution coupled model for experimental seasonal to decadal prediction, including high-resolution fully coupled ensemble Kalman filter for data assimilation

2. Continued development of extremely high-resolution atmosphere models using state of the art dynamical core

3. Unification of ocean model development through MOM5 and MOM6 (incorporates capabilities from GOLD model into MOM, incorporates results of Climate Process Teams)

4. Work towards improved physical processes, including clouds and aerosols.

5. Development of next generation climate model CM4 – intended to bring together capabilities in the 4 streams of model development recently completed *(high-resolution, aerosol and chemistry effects, biogeochemical cycles, initialized predictions)*

These pathways present opportunities for increased integration of NOAA modeling.