GFDL CMIP5 Activities

Ron Stouffer et al.

GFDL 4 “Streams”

- ESM – closes carbon cycle by adding ocean and land carbon components
  - ESM2M – MOM (depth vert coor) based ocean
  - ESM2G – GOLD (layer vert coor) based ocean
- CM3 – New aerosol-cloud interactions, HI-TOP and atmospheric chemistry
- Decadal Prediction – used CM2.1 (AR4 model)
- High resolution atm-only: 50 and 25km grids

GFDL 4 "Streams" Data

- All data from at least one ensemble member are available.
- Other ensemble members available in future
- LGM run being set up using ESMs now. At least 1 year away from being available.
- Had to reprocess a few variables to fix problems – fco2…unfortunately

GFDL CMIP5/ IPCC AR5 Accomplishments

Stream	Total Model Years	CMIP5 Data (TB)
Physical Climate	6800	15.3
Earth System	18,500	119.2
High-resolution	500	22.3
Decadal Prediction	5000	7.3
TOTAL	**30,800**	**164.1**

More than the entire world's model data archive for CMIP3/ IPCC AR4 (2007)

	Publications
FY11	**~70**
FY12	**39 to date (+55 submitted)**

GFDL Issues

- *Again* - the process of CMORizing the vbls, QC, and etc was very time consuming/labor intensive
  - Size of task way underestimated at start of process
- Volume of runs and variables requested are very large
- In-house "curator" software either untested or missing parts - written while data publishing occurring
- Variable list kept changing well into process
- METAFOR questionnaire
  - Hard to figure out (bindings!)
  - Questions did not "fit" our models => models not well documented or misleading or both in questionnaire
  - Not clear if METAFOR is of any use to anybody

GFDL Response for Future CMIPs

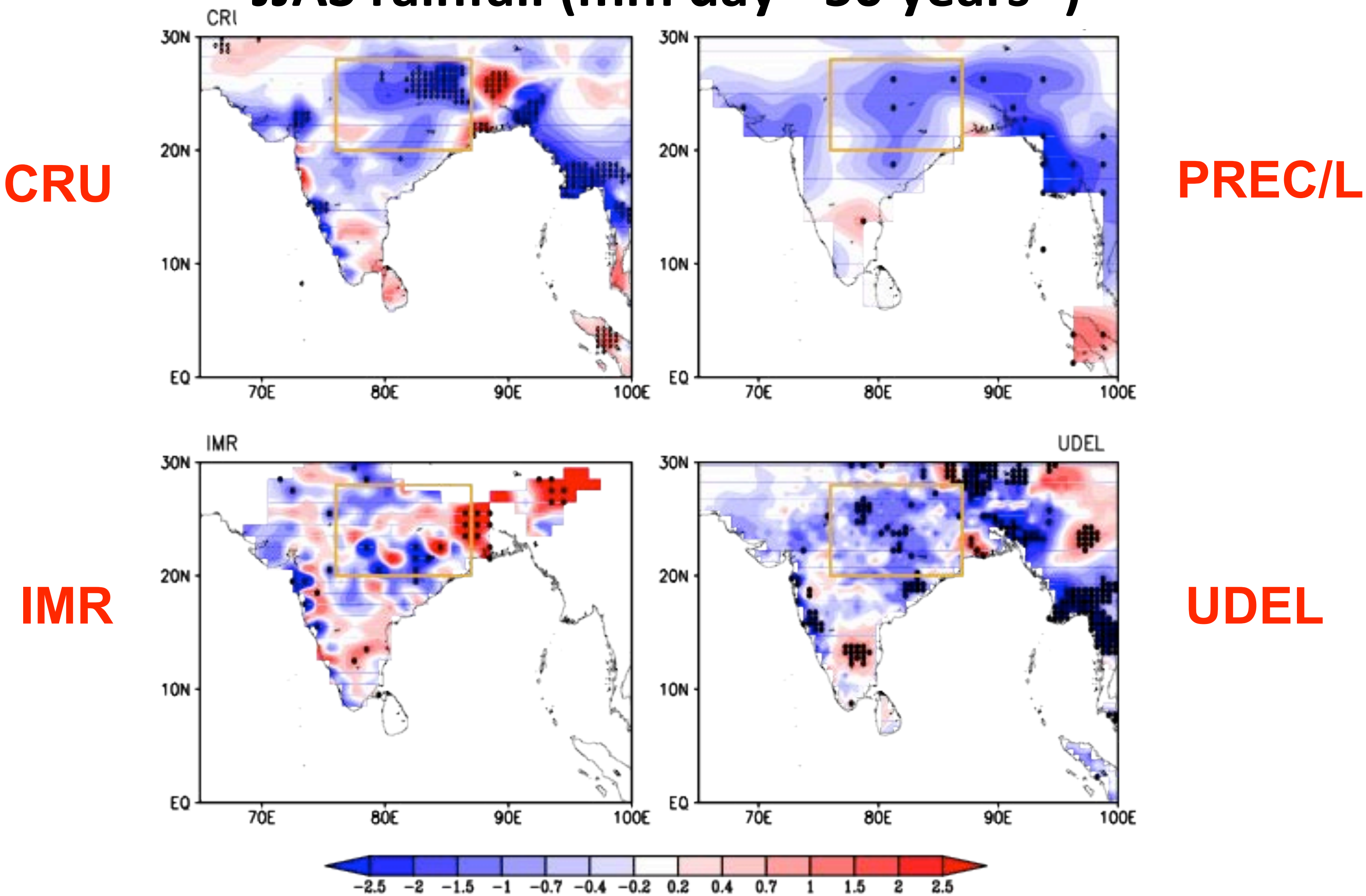
- Attempt to reduce CMIP commitment
  - People
  - Computer resources
- Change model code to output variables in CMIP names, units and conventions
  - => Every analysis script in building needs changed
- Have only 1 or 2 models go through IPCC process
- Disentangle model development from IPCC cycle

CM3 Results

- Indian drying
- **Atlantic hurricane count and aerosol changes**

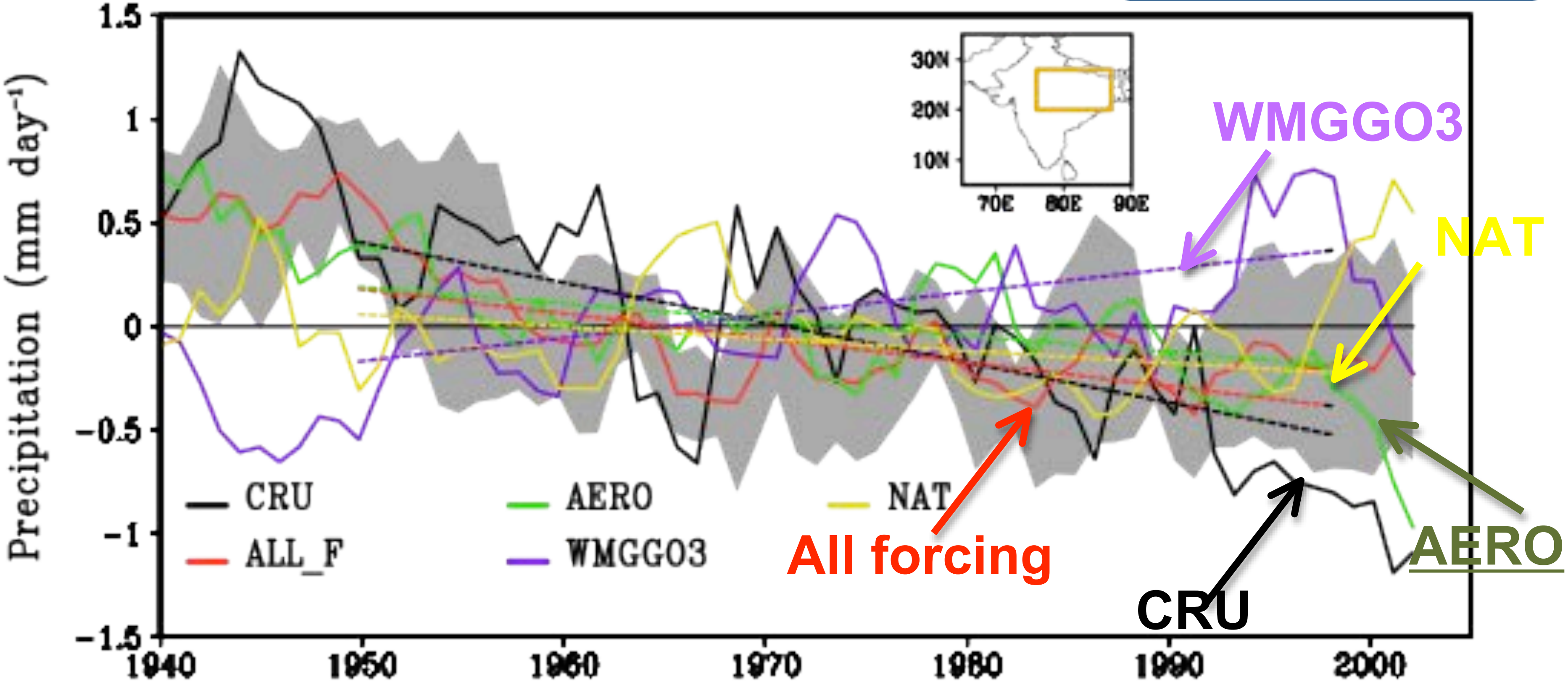
A drying trend over central-northern India during the second half of the 20th century

JJAS rainfall (mm day^{-1} 50 years^{-1})



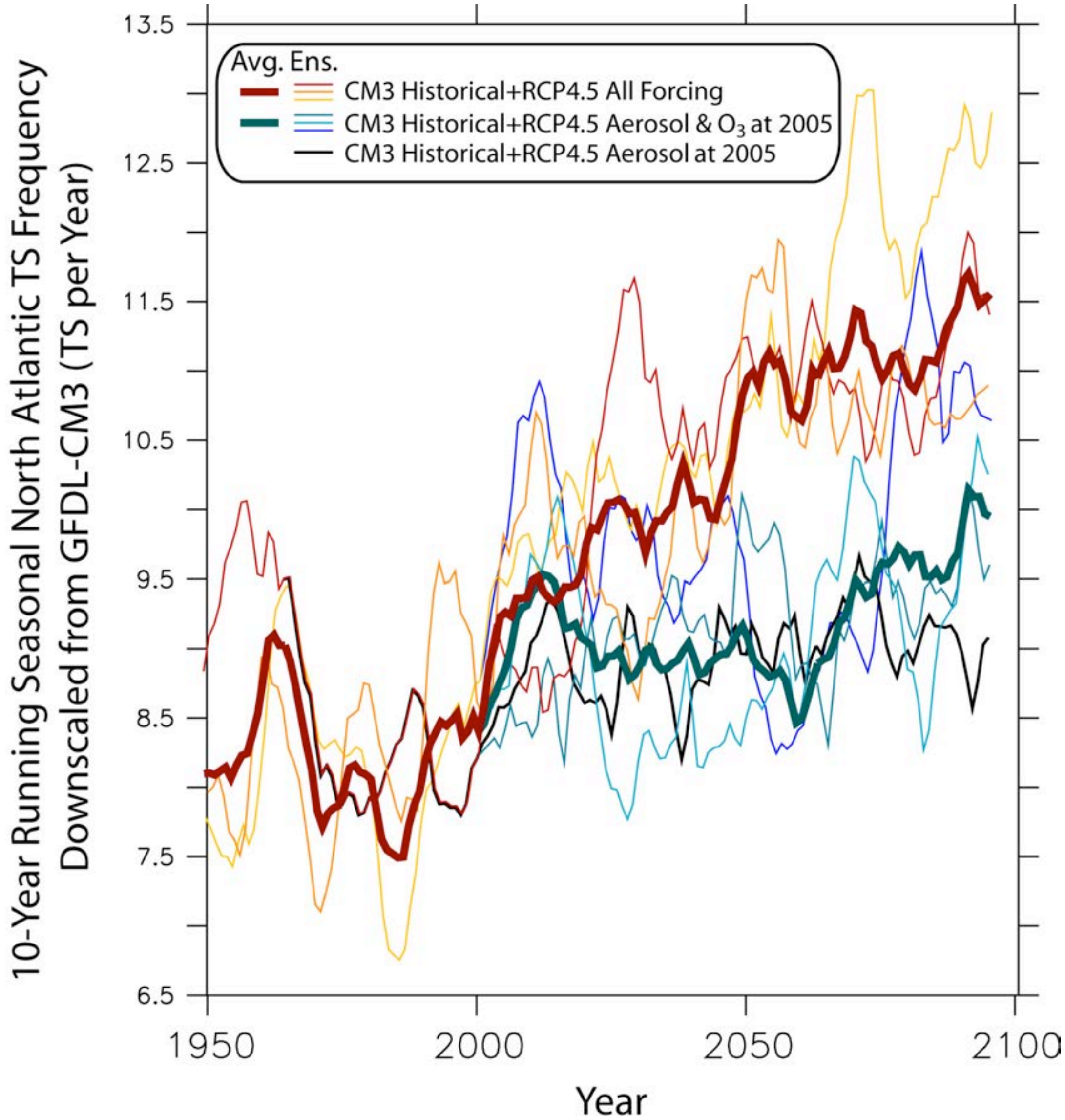
Linear trends of average JJAS rainfall over central-northern Indian (mm day^{-1})

- *AERO trend opposite in sign to WMGGO3*
- *AllForc trend compares well with CRU (Obs)*



Bollasina et al. (Science, 2011)

Aerosols key for NA TS projections
(“Cleaning” out aerosols ➔ More storms)



All Forcing

No future aerosol or O_3

No future aerosol

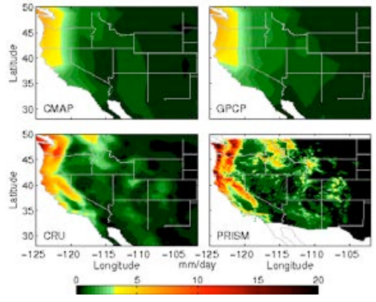
Projected aerosol changes lead to increase in NA TS frequency over 1st half of 21st century

Villarini and Vecchi (2012, Nature C.C.)

Time Slice Experiments:
25km and 50 km atm-only

- **Atlantic hurricane frequency**
- **Heat waves**
- **Intercontinental transport of pollutants (*Global climate and air quality*)**

GFDL models vs. PRISM

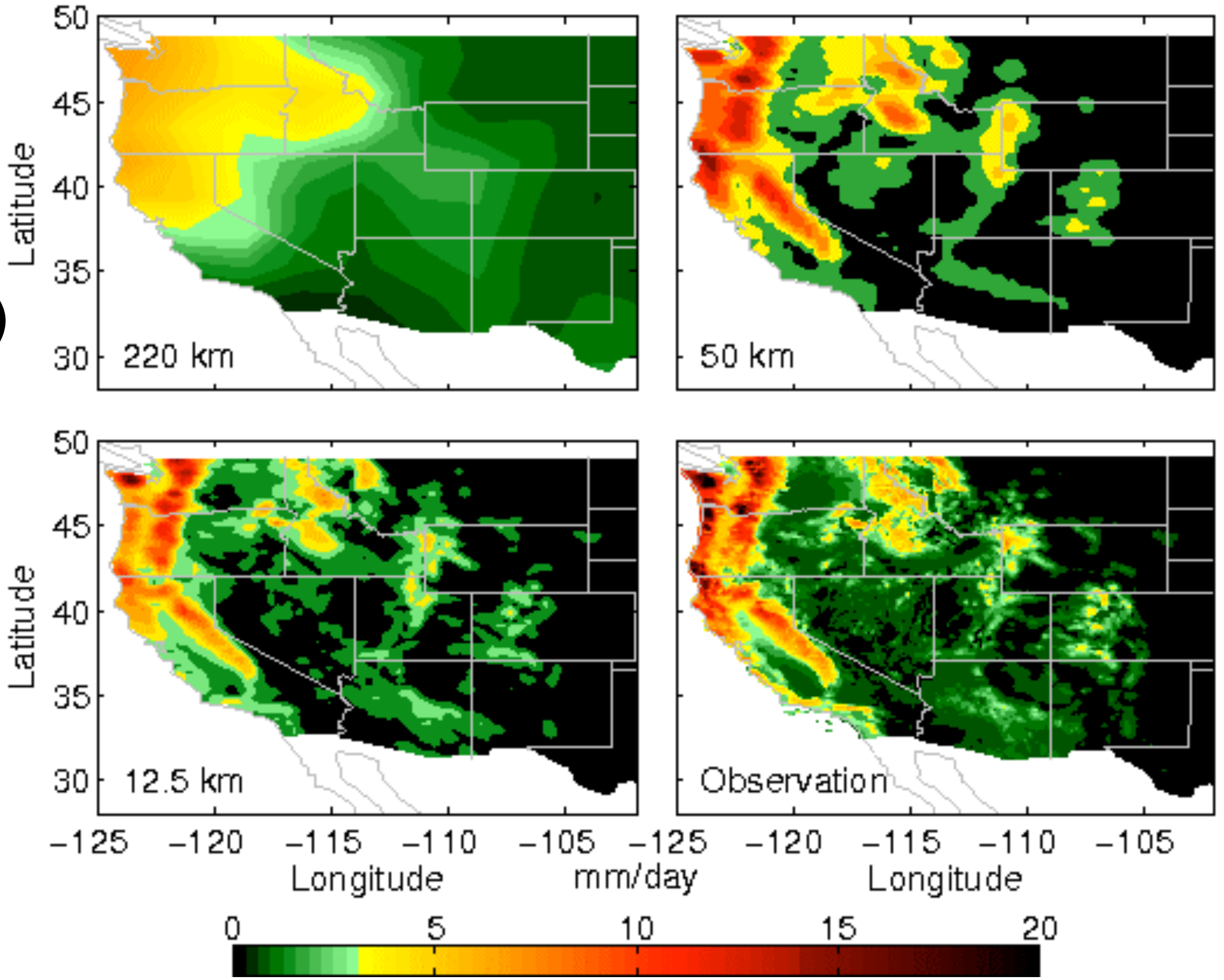


AM2.1 (220 km)

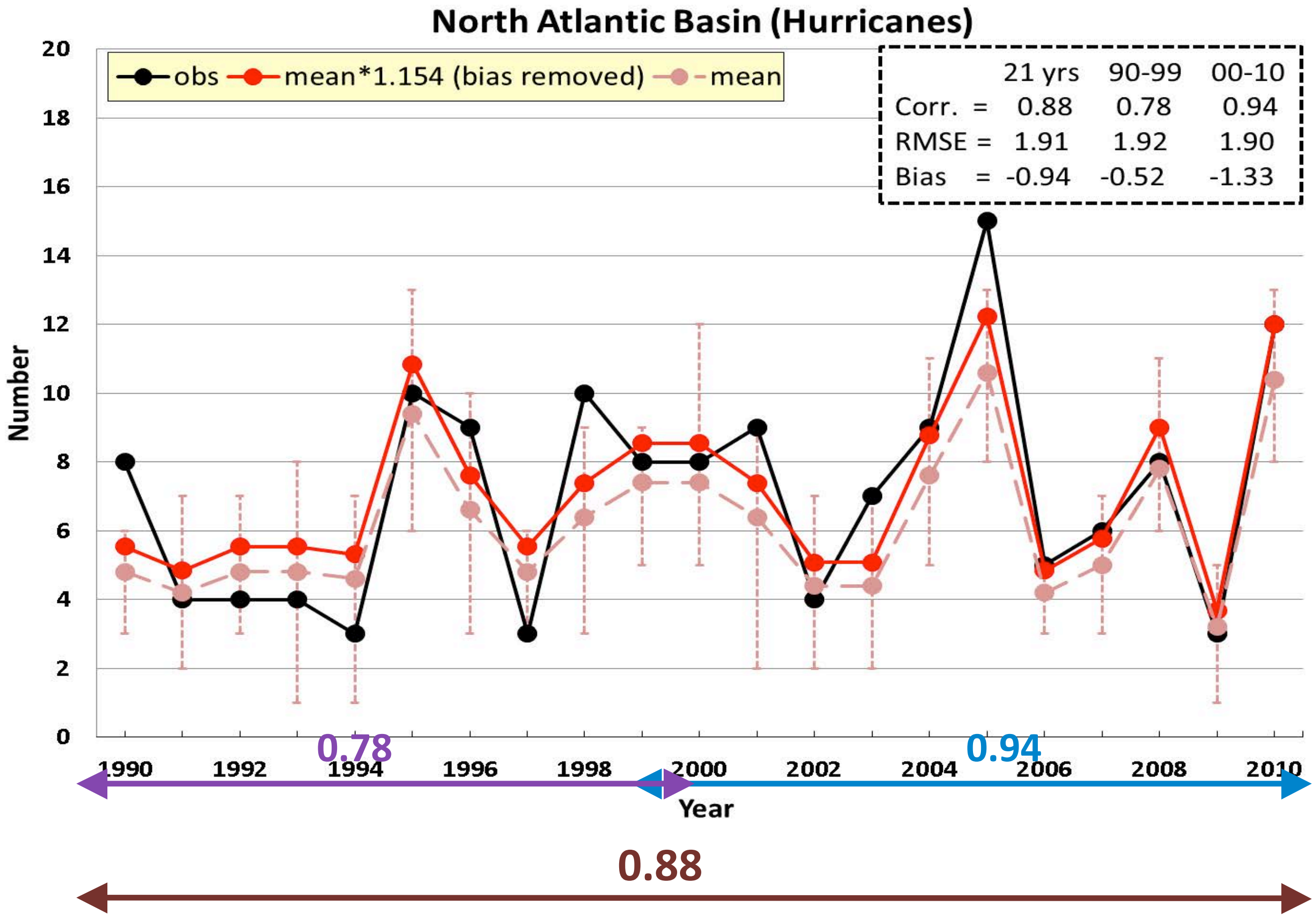
50-km HiRAM

12.5-km HiRAM

PRISM



Retrospective (1990-2010) Seasonal hurricane predictions with GFDL HiRAM

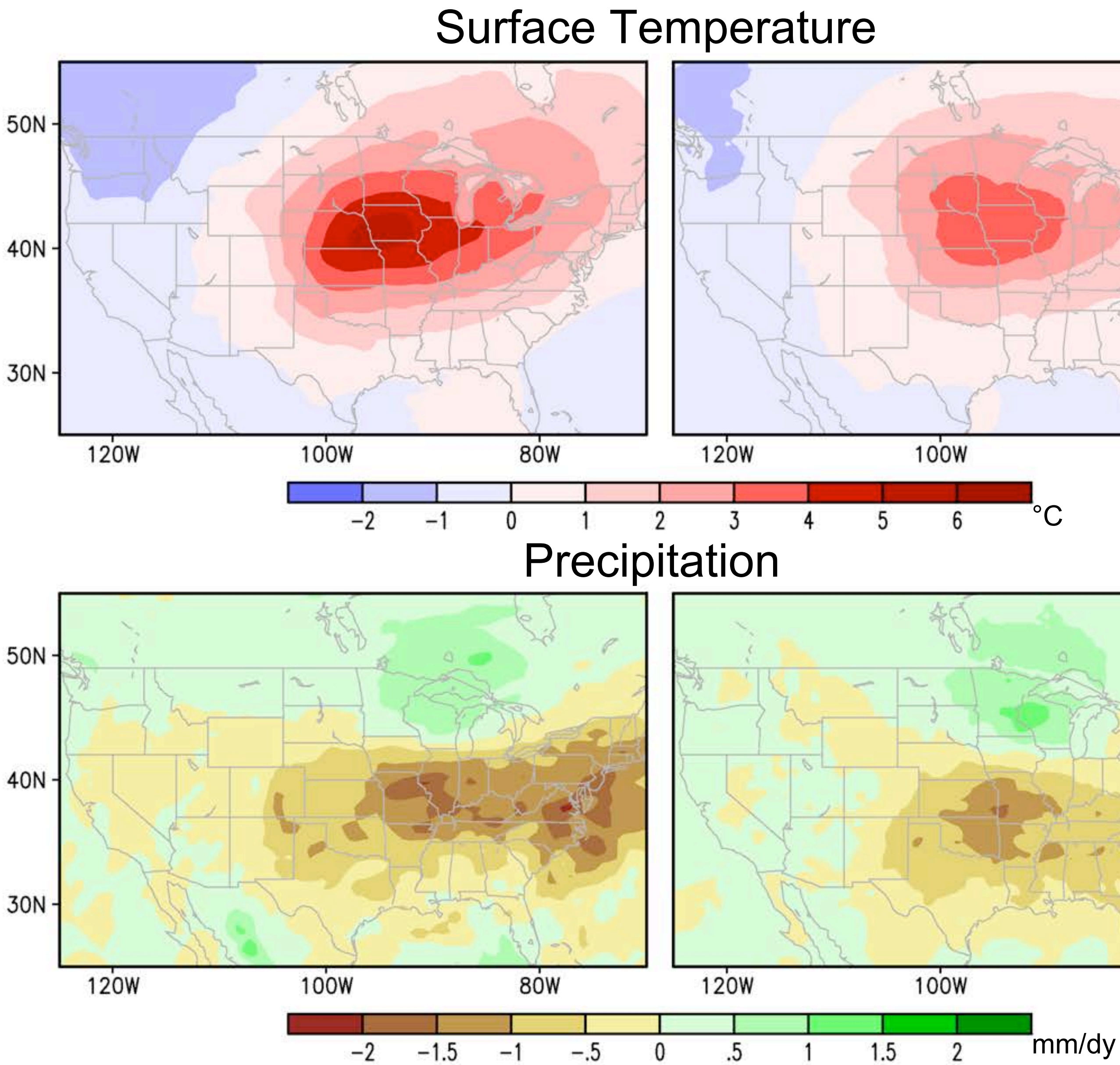


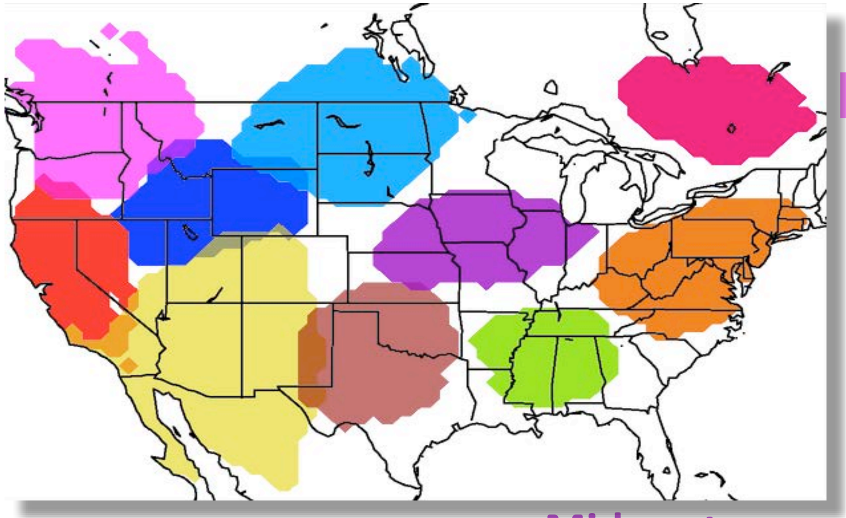
(Chen and Lin 2011, GRL and Chen *and Lin 2012, J. climate)*

Midwest Heat Waves

Lau et al. (J. Climate, 2012)

Model | Observations



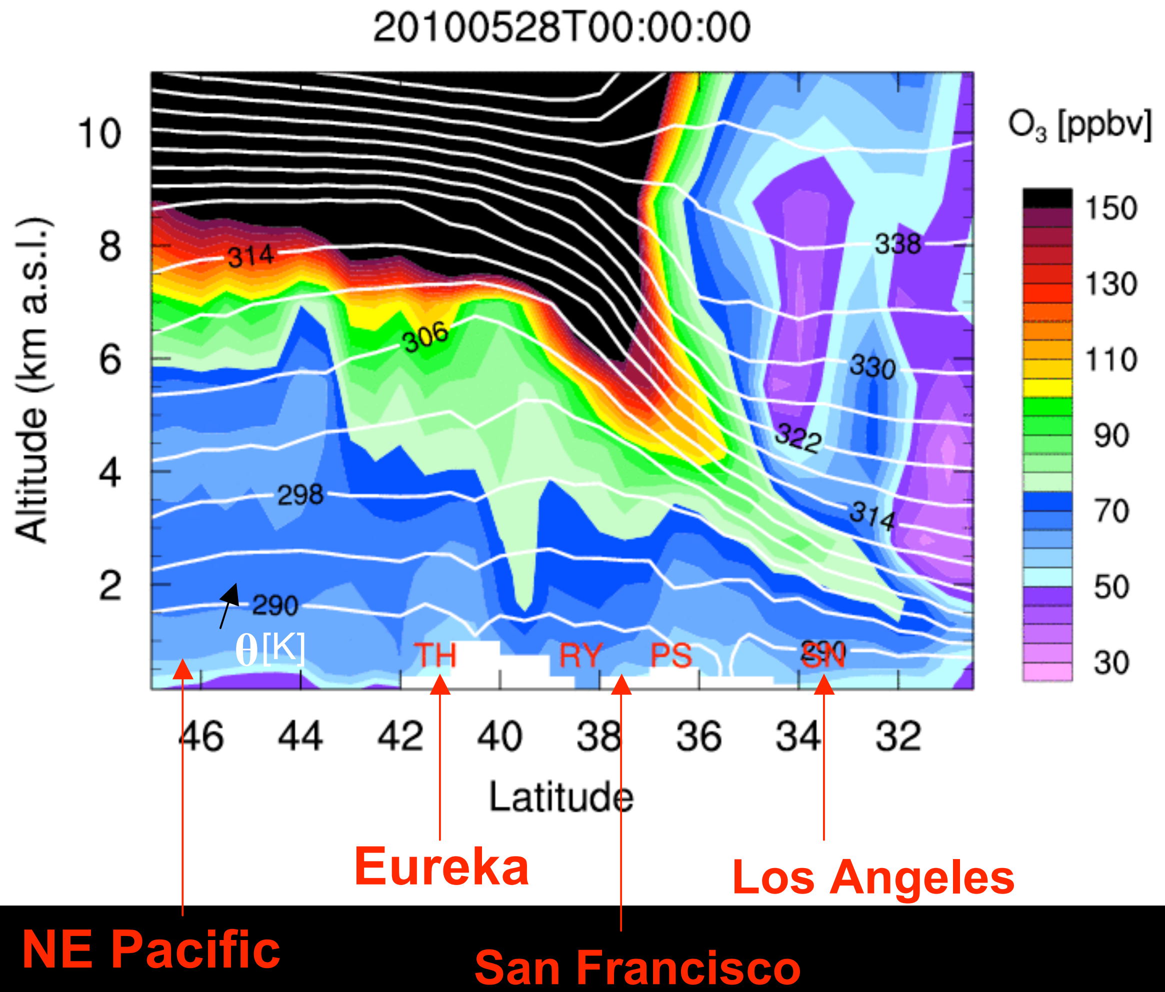


Model Projections
Ratio: 2041-2070 vs 1971-2000

	Duration	# Events/yr	# Heat wave days/yr
Midwest	1.5	2.7	4.0
Northern Plains	1.3	3.8	4.8
Pacific Northwest	1.3	2.4	3.0
SE Canada	1.2	2.5	2.9
Texas-Oklahoma	1.8	2.6	4.5
Mid-Atlantic	1.4	2.7	3.8
California	1.9	2.3	4.3
Gulf Coast	1.2	3.2	4.0
Southwest	2.2	2.9	6.4
Wyoming/Montana/ Idaho	2.2	2.6	5.7

Deep stratospheric ozone intrusions in the new, high-resolution GFDL AM3 model

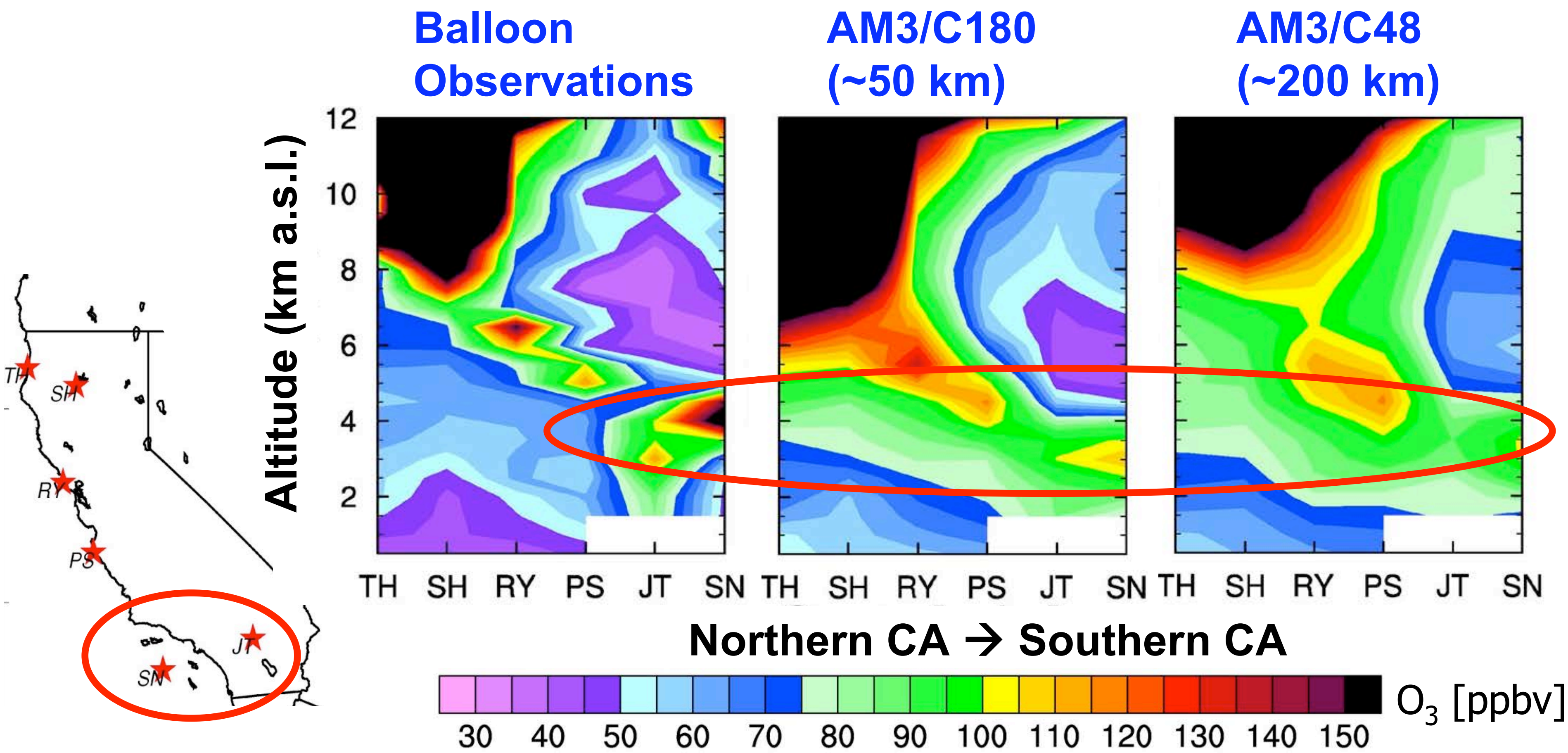
AM3/C180 simulation of a deep stratospheric O_3 intrusion over California



[redacted]

Extensive evaluation with satellite and *in situ* measurements during NOAA CalNex 2010

Subsidence of stratospheric ozone to the lower troposphere of southern California (May 28, 2010)



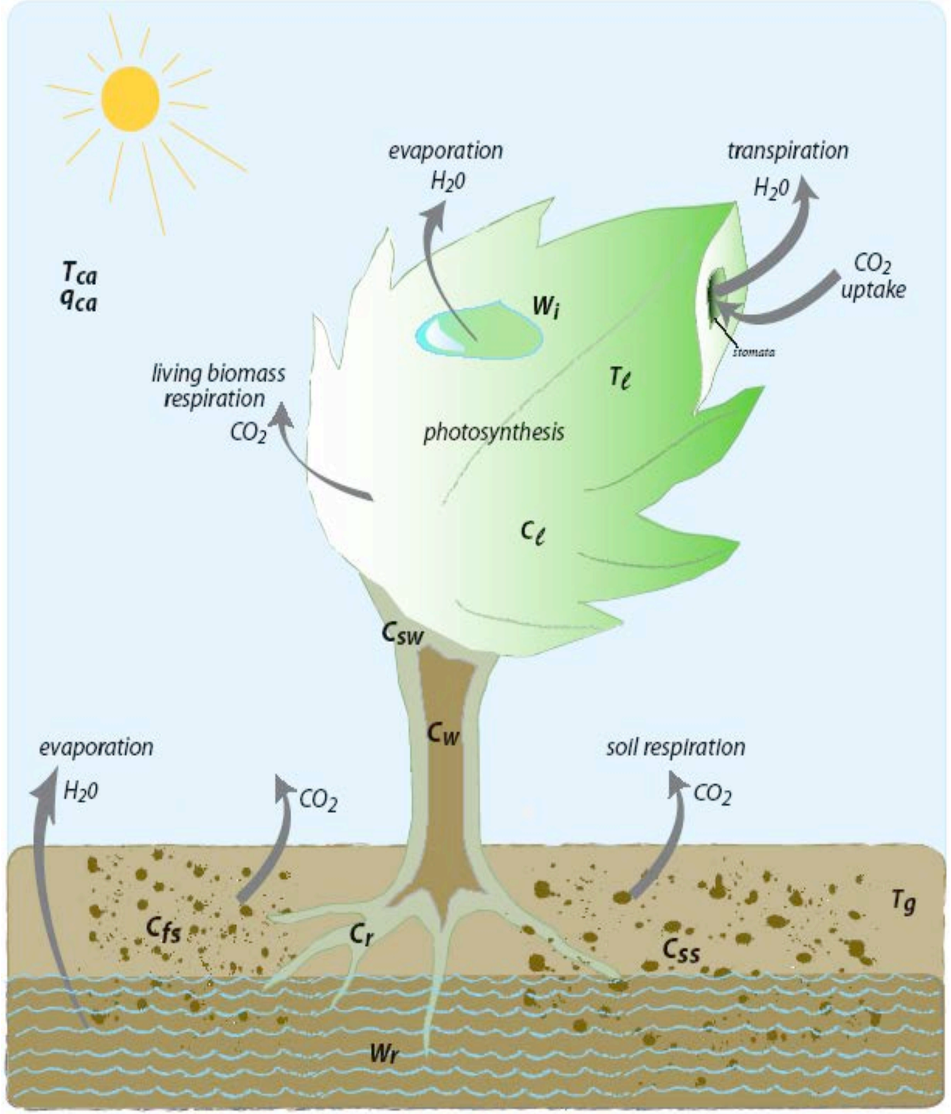
- High O_3 (>100 ppbv) just 2-4 km above southern California
- Affecting surface air quality in densely populated regions

Earth System Model

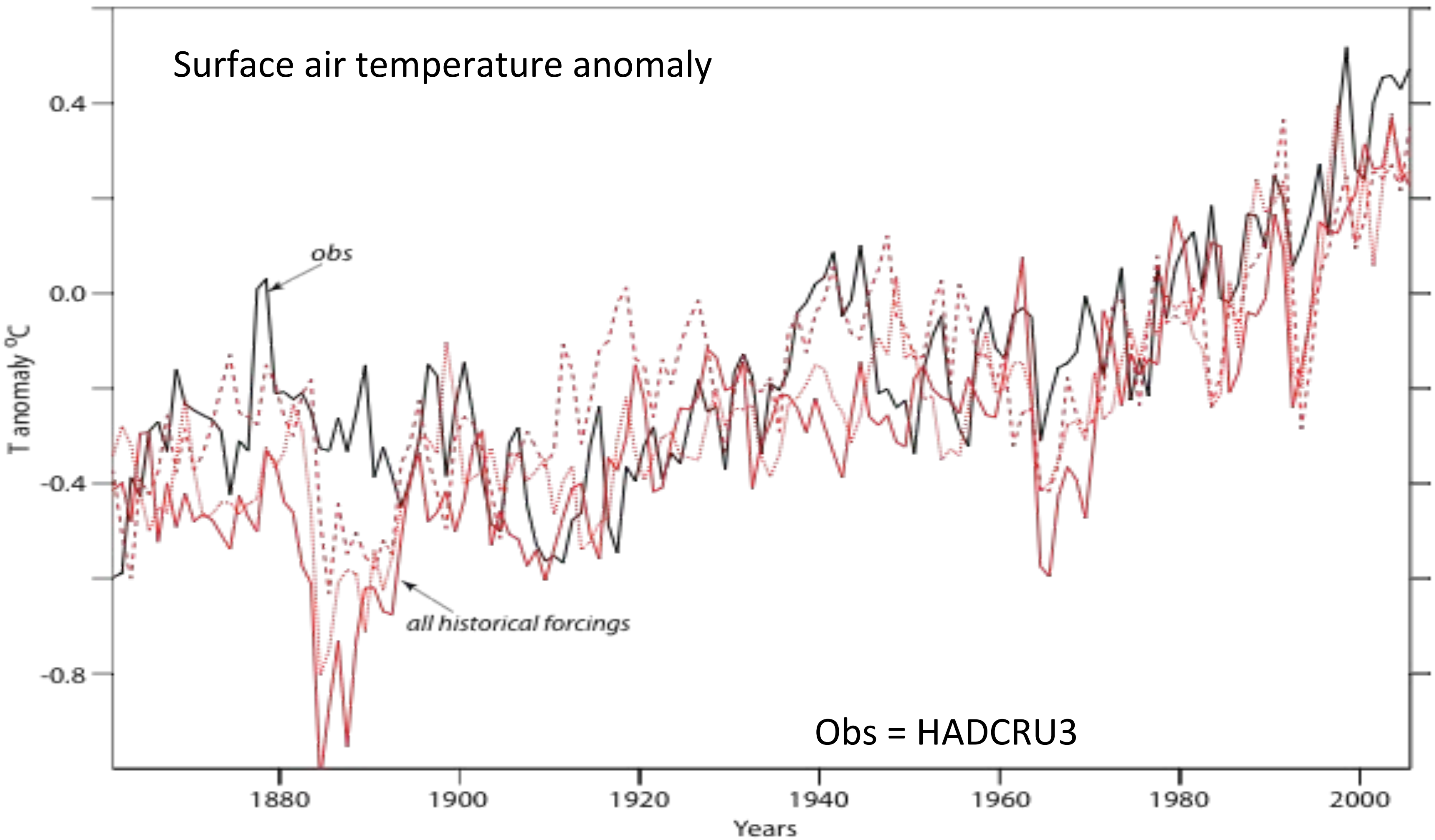
- **Earth System modeling of carbon-climate interactions**
- **Marine ecosystems and climate**

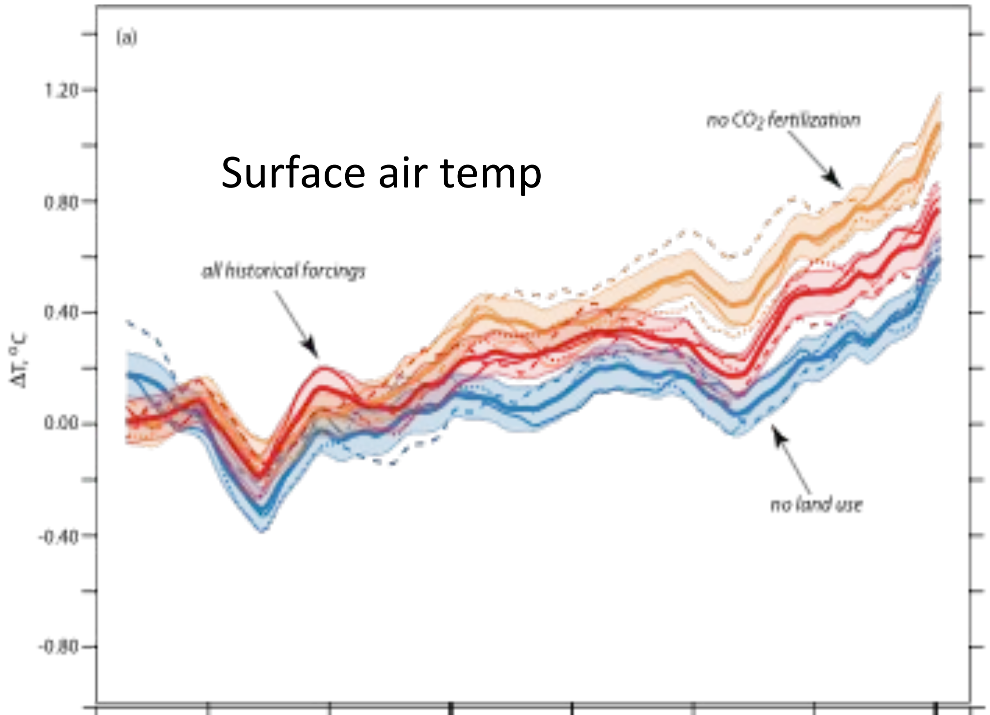
Operate in GFDL's Earth System Models

- **Dynamic vegetation**
- Subgrid **land-use** heterogeneity
- Distinct treatment of **ground, vegetation, & canopy air**
- **Soil water dynamics** (liquid & frozen)
- Multilayer **snow pack**
- **River network** with capacity for tracers and temperature

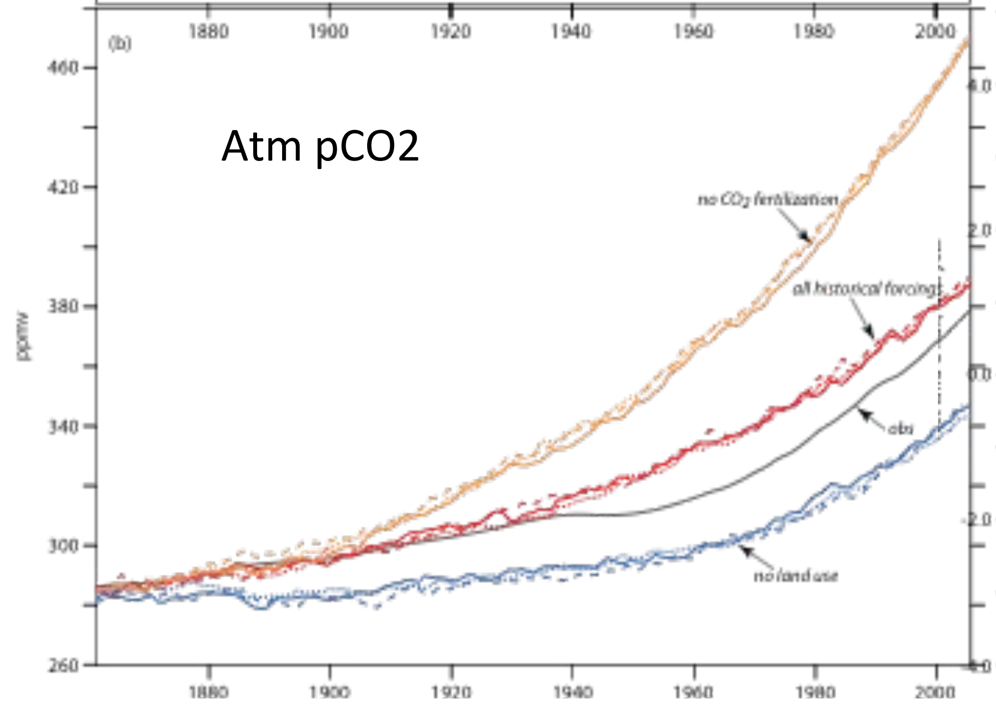


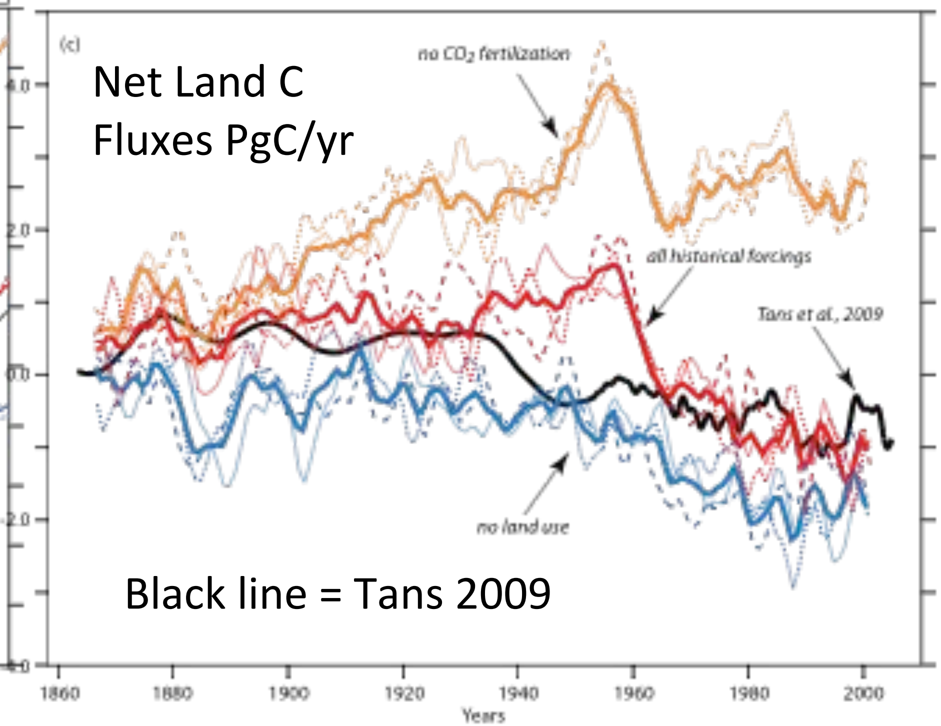
Impact of land use changes on 20th century climate – Shevliakova et al.





- Model does good job of simulating 20th C climate/C chgs
- No land use = less climate change
- No CO_2 fert = more climate change
- 1930s-1940s – may have problems with forest to pasture conversions (Hurtt assessment)





Regional case study: climate impacts on eastern Pacific Leatherback turtles

Climate-forced Population Dynamics Model

Land Component:

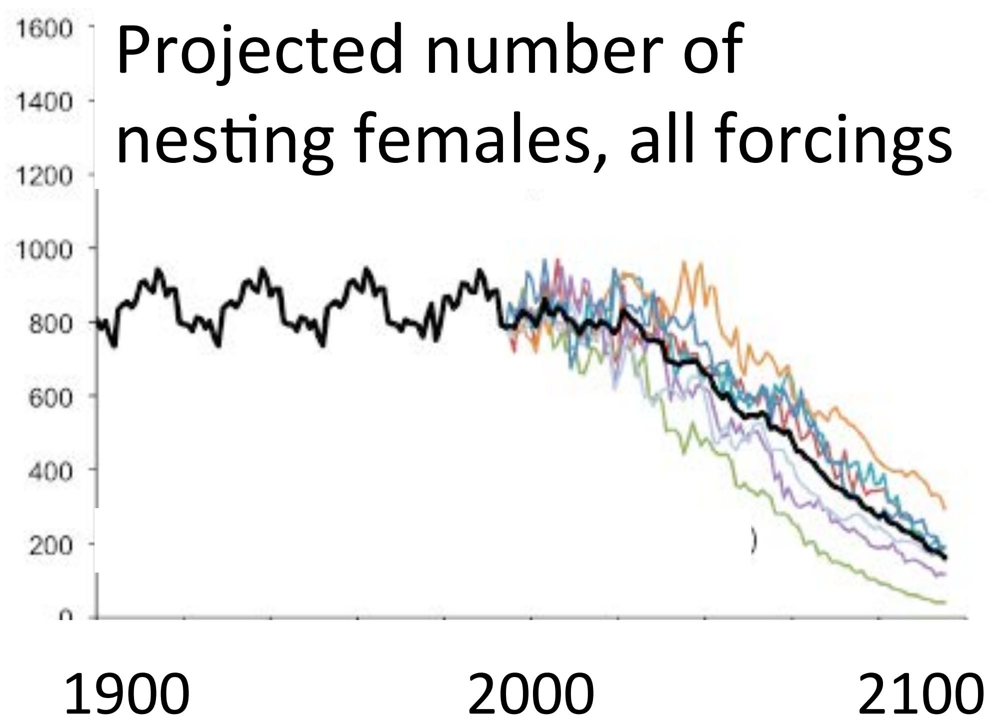
Hatch success = f(SAT,precip)
Emergence success = f(SAT,precip)
Sex ratio = f(precip)

Ocean Component:

Returns = f(Eq. Pac. SST anomaly) (Proxy for El-Nino driven productivity changes)

Saba et al. (Nature Climate Change, 2012)

Negative climate change impact on endangered eastern Pacific leatherback sea turtles



Saba et al. (Nature Climate Change, 2012)

- Predict declining numbers due to lower hatching and emergence rates with increasing temperatures
- Nesting further north unlikely due to extremely dry conditions in sub-tropics
- Mitigation efforts on beach may be possible if predicted impacts begin to manifest

Decadal Prediction

- **Seasonal-to-decadal predictability**

Decadal prediction: New efforts focused on multi-year/decadal predictions: a mixed initial/boundary value problem

Sources of & Limitations on climate predictability

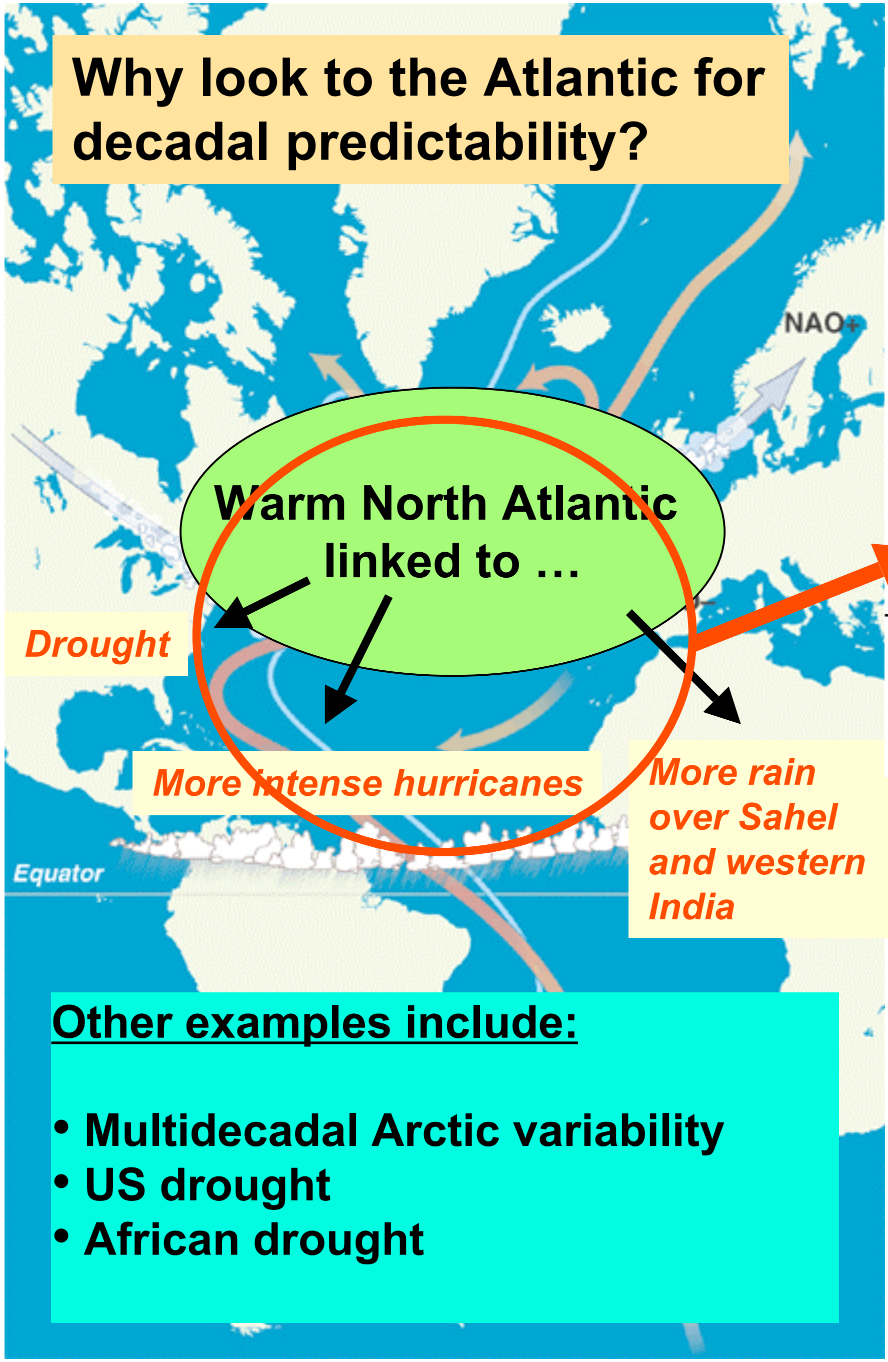
years to decade

hours to a year

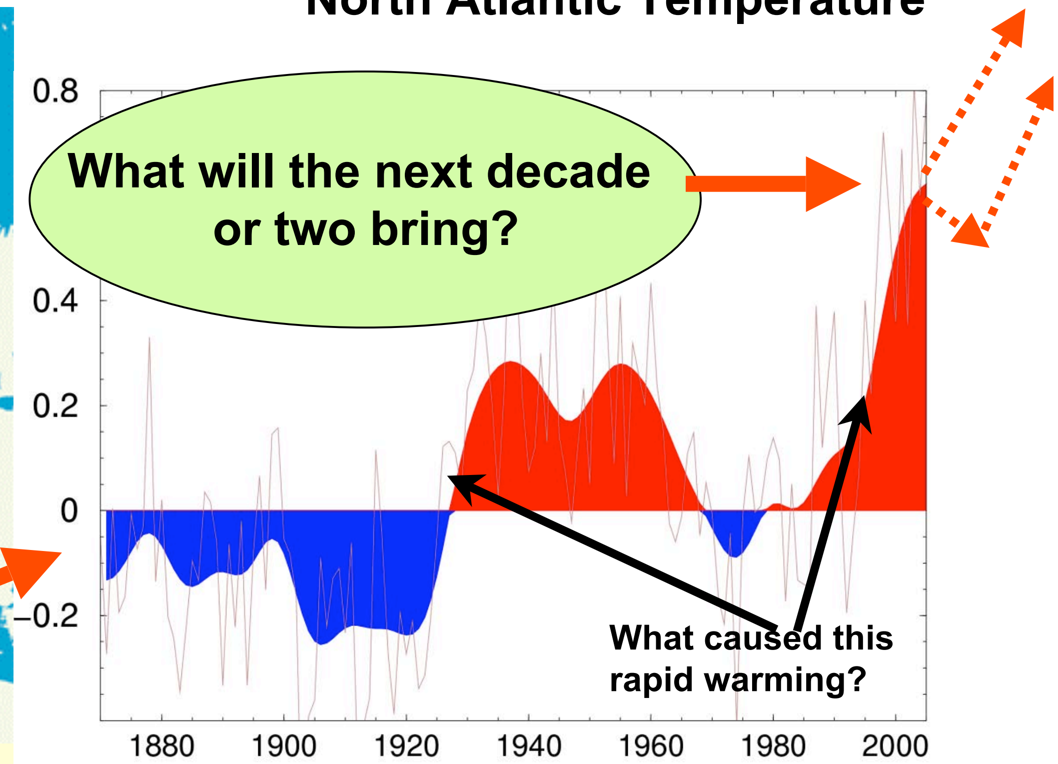
- **Climatology**
  (what happens typically, including randomness)
  need good observations
- **Evolution of initial conditions**
  (e.g., weather or El Niño forecast)
  need good observations, models, initialization schemes
-

Many decades to centuries

Climate response to forcing
(e.g., CO_2, aerosols, sun, volcanoes)
need good models and estimates of forcing



North Atlantic Temperature



Decadal variability:

- ***Significant climate influences***
  - regional to hemispheric
- ***Can phase with longer term warming to cause abrupt change***
- ***Some predictability possible***
- ***Crucial need to attribute observed changes***

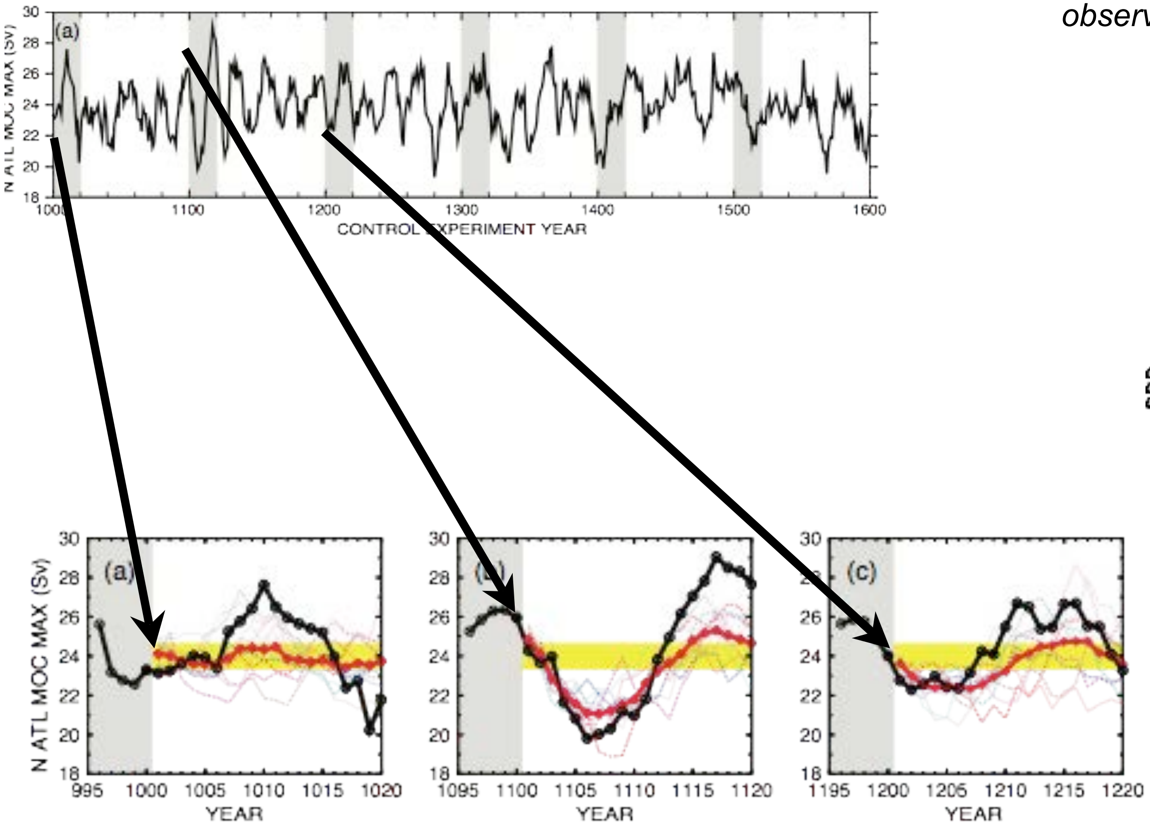
Approaches:

1. Use theory, observations (instrumental and paleo) to improve understanding of decadal variability and its mechanisms

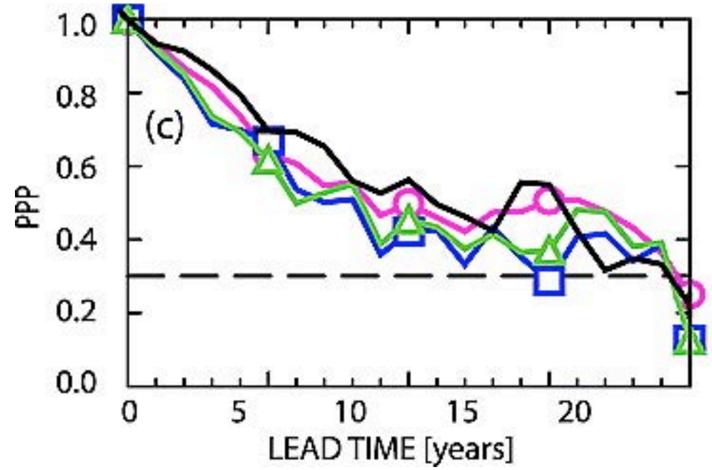
Examples include:

•Collaboration between GFDL, NCAR and MIT on decadal variability across a hierarchy of models

•Collaboration between GFDL, PMEL, Univ Washington, Univ Miami on aspects of simulated and observed Atlantic



Statistical estimate of predictability
Msadek et al., 2010



These suggest oceanic fluctuations could be predictable a decade in advance

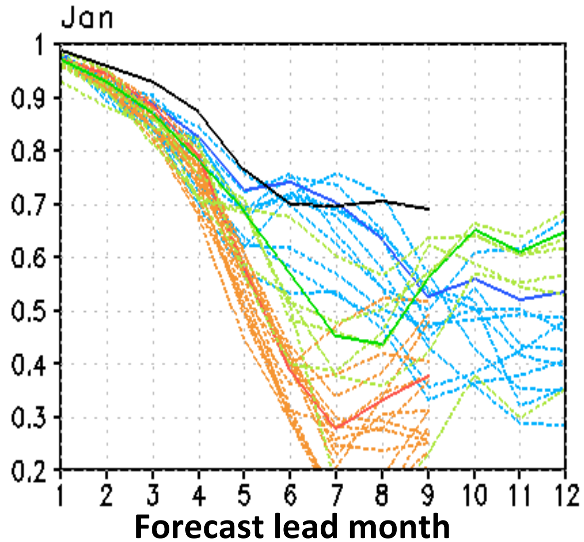
At GFDL, long history of research on prediction systems for seasonal to interannual time scales (ENSO).

<u>*Requires:*</u>
- *adequate, sustained observing system*
- *assimilation system to initialize models*
- *models to make predictions*
- *conduct large sets of hindcasts to evaluate skill*

GFDL research has contributed to NCEP seasonal forecast systems, and is now contributing to a developing national Multi-Model Ensemble (MME).

Preliminary results on forecast skill from MME

ACC of NINO3.4 Index (Jan IC)



NCEP ensemble mean
NCEP members
GFDL ensemble mean
GFDL members
NCAR ensemble mean
NCAR members
MME (NCEP+GFDL+CCSM)

Courtesy of Tony Rosati

Merge multiple tools and understanding to build experimental long-lead hurricane forecast system: skill from as early as October of year before

April & onward forecasts fed to NOAA Seasonal Outlook Team

Hi-Res AGCM in many different climates. Count storms.

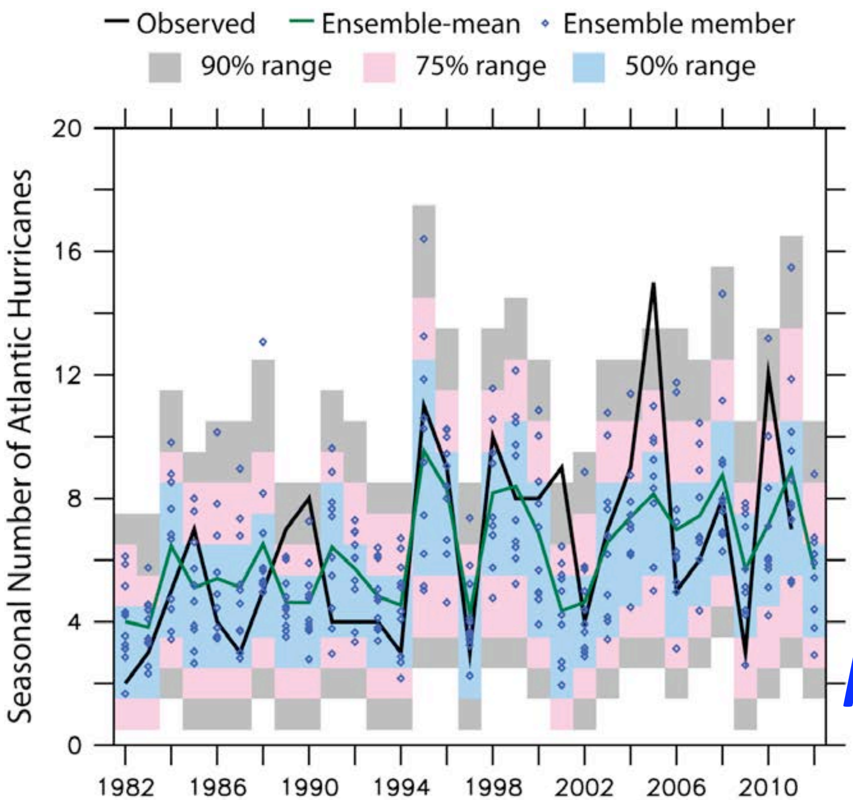
Build statistical model of the response of hurricanes in HiRAM

Use initialized coupled model to forecast future values of SST

Apply Stat model to Predicted SST

Make Prediction of Full PDF of Hurricane Activity

Initialized January: r=0.66

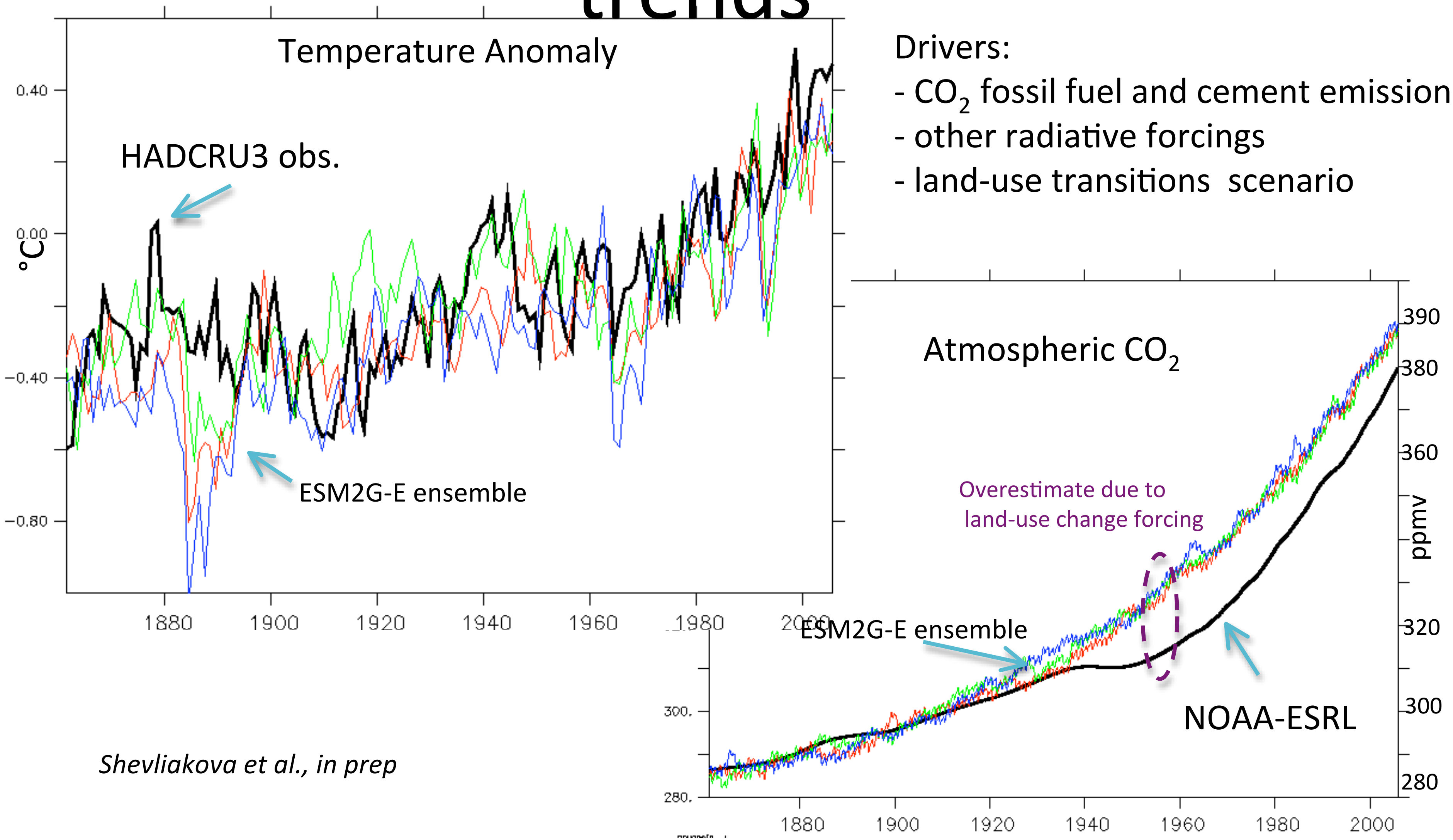


HyHuFS

http://gfdl.noaa.gov/HyHuFS

Vecchi et al. (2011, MWR)

GFDL ESMs capture historical trends



Drivers:

- CO_2 fossil fuel and cement emissions
- other radiative forcings
- land-use transitions scenario

Shevliakova et al., in prep