Regional Climate, Extremes, & Impacts

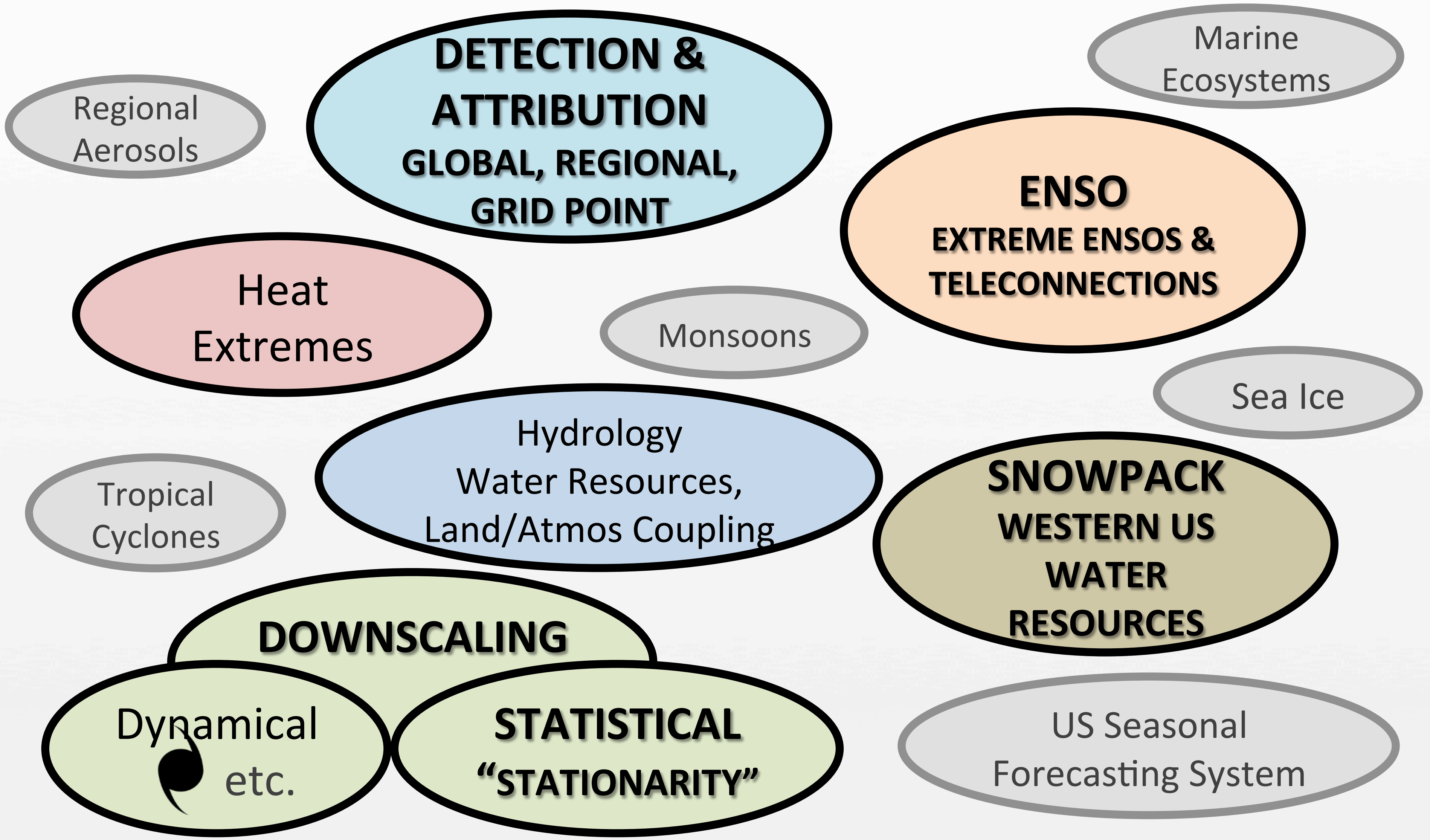
Presented by
Keith Dixon & Andrew Wittenberg

Frontiers in Climate and Earth System Modeling: Advancing the Science

Geophysical Fluid Dynamics Laboratory

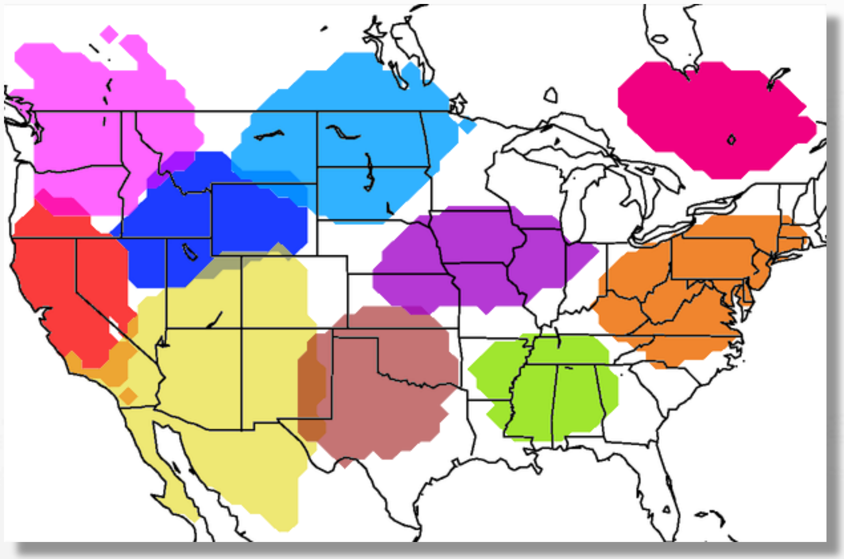
May 20, 2013

Under our regional climate, extremes, & impacts umbrella…



Panel expertise: LAU - Heat Extremes

Gabriel Lau



Lau and Nath (2012), A Model Study of Heat Waves over North America: Meteorological Aspects and Projections for the 21st Century, *Journal of Climate*.

Model Projections
Ratio: 2041-2070 *vs* 1971-2000

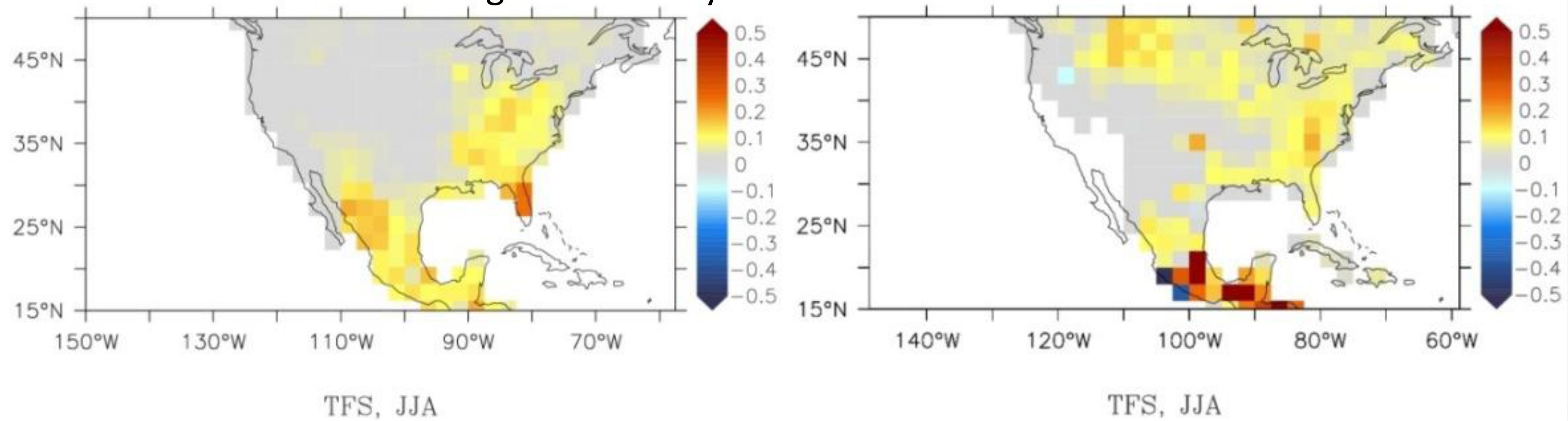
	Duration	# Events/yr	# Heat wave days/yr
Midwest	1.5	2.7	4.0
Northern Plains	1.3	3.8	4.8
Pacific Northwest	1.3	2.4	3.0
SE Canada	1.2	2.5	2.9
Texas-Oklahoma	1.8	2.6	4.5
Mid-Atlantic	1.4	2.7	3.8
California	1.9	2.3	4.3
Gulf Coast	1.2	3.2	4.0
Southwest	2.2	2.9	6.4
Wyoming/Montana/Idaho	2.2	2.6	5.7

Kirsten Findell

Challenging GFDL models with reanalysis-based estimates of the Triggering Feedback Strength: a measure of land-atmosphere coupling strength, Assessing the sensitivity of afternoon convection to before-noon surface fluxes

From the North American Regional Reanalysis

From GFDL's AM2.1



From Berg, Findell, Lintner, Gentine, and Kerr, 2013, J. Hydrometeorology

Panel expertise: MILLY – Water Resources, Land Surface Modeling

Chris Milly

USGS

Land model code development

Analysis of observed and simulated river flows

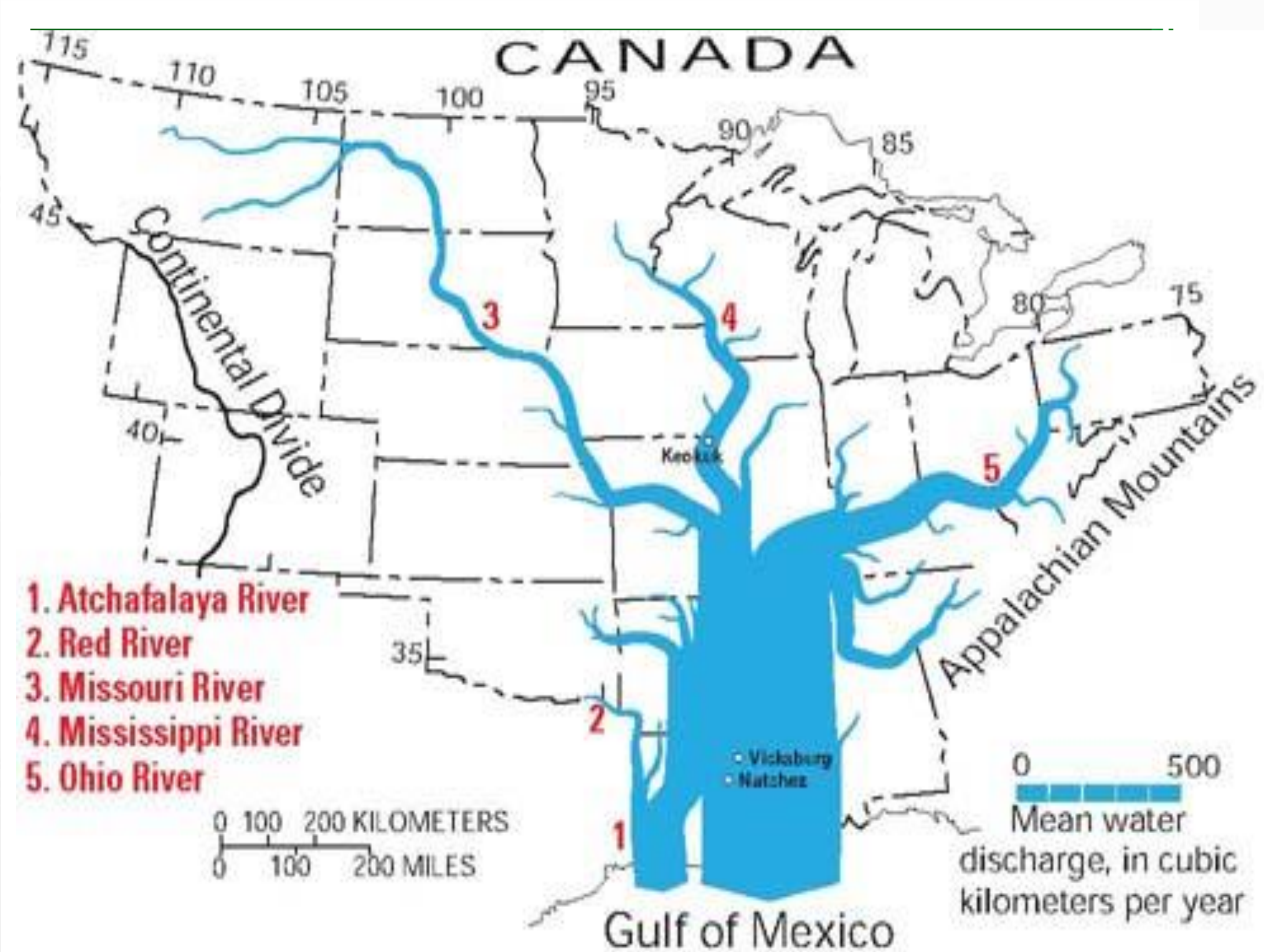


image source: http://pubs.usgs.gov/fs/2005/3020/

Panel expertise: KNUTSON – Hurricane-Climate Atlantic Downscaling, "D & A"

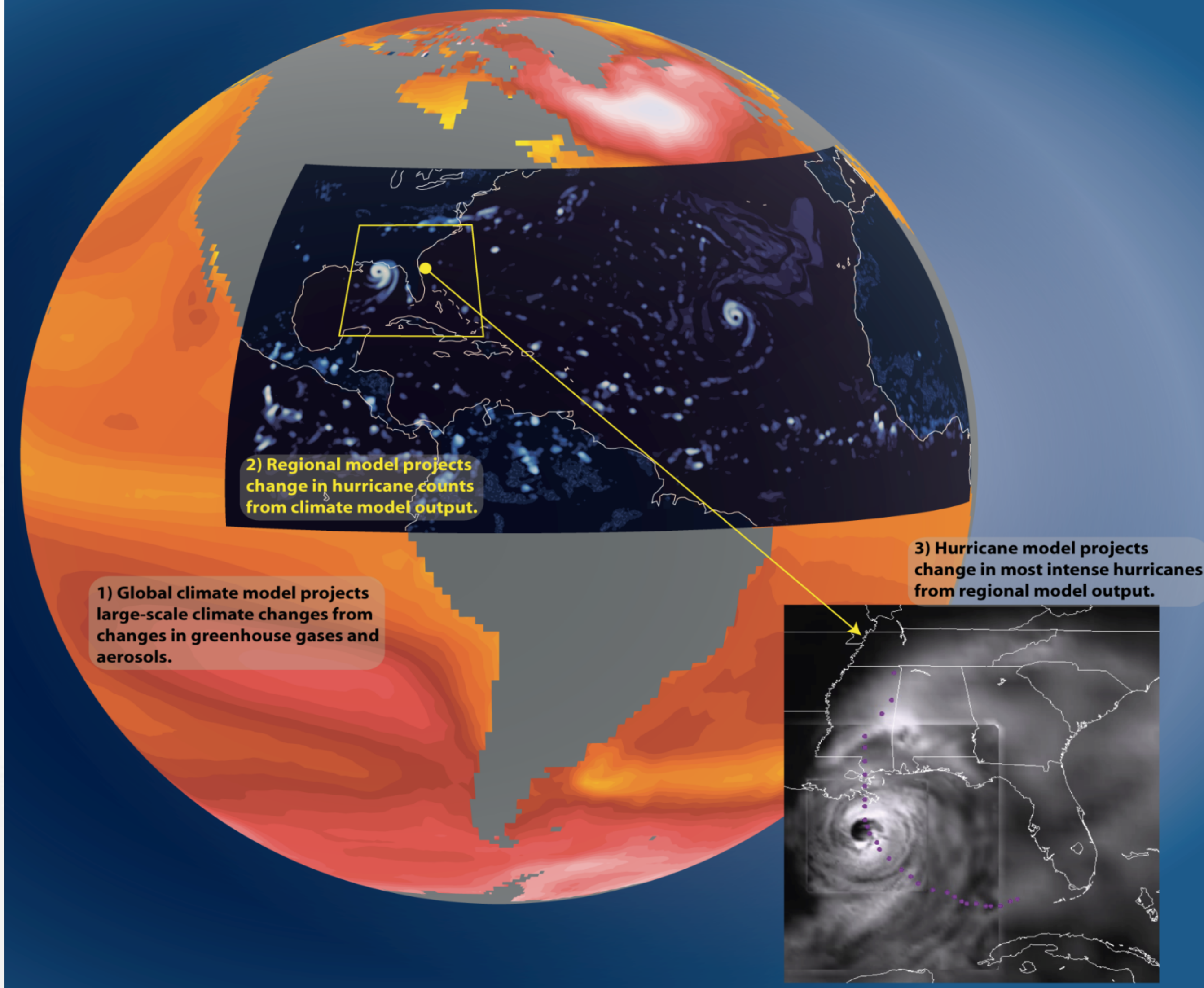
Tom Knutson

DYNAMICAL DOWNSCALING

Modeled Impact of Anthropogenic Warming on the Frequency of Intense Atlantic Hurricanes:

Bender et al., *Science,* 2010

Knutson et al., *J. Climate,* in press.



Under our regional climate, extremes, & impacts umbrella…

DETECTION & ATTRIBUTION
GLOBAL, REGIONAL, GRID POINT

ENSO
EXTREME ENSOS & TELECONNECTIONS

Heat Extremes

Hydrology
Water Resources,
Land/Atmos Coupling

SNOWPACK
WESTERN US WATER RESOURCES

Panel member:
Sarah Kapnick

DOWNSCALING

Dynamical
etc.

STATISTICAL
"STATIONARITY"

Regional Climate, Extremes, and Impacts:

Regional temperature trends, and the 2012 MAM warm anomaly over the eastern U.S.

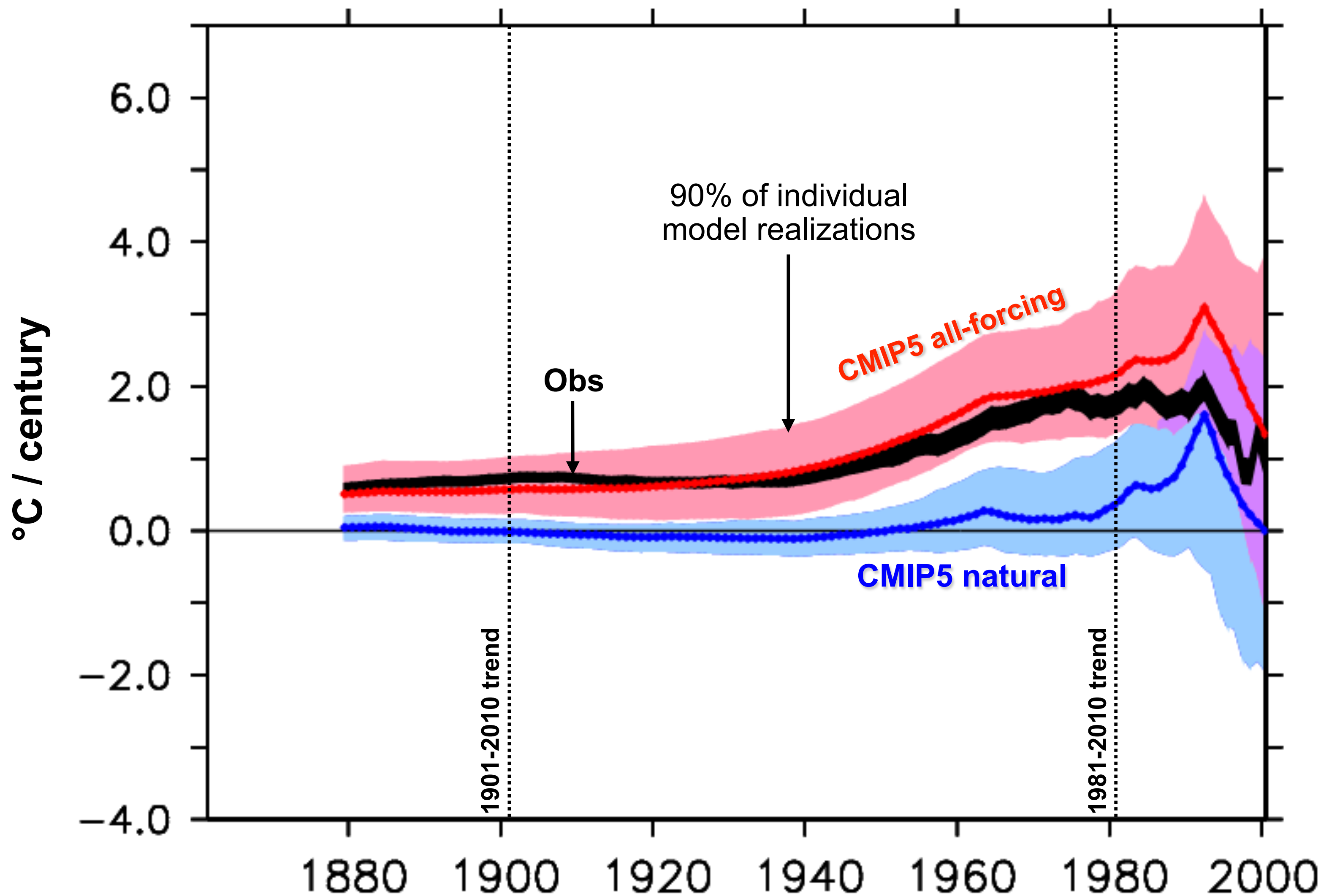
and

Regional impacts of El Niño

Presented by
Andrew Wittenberg

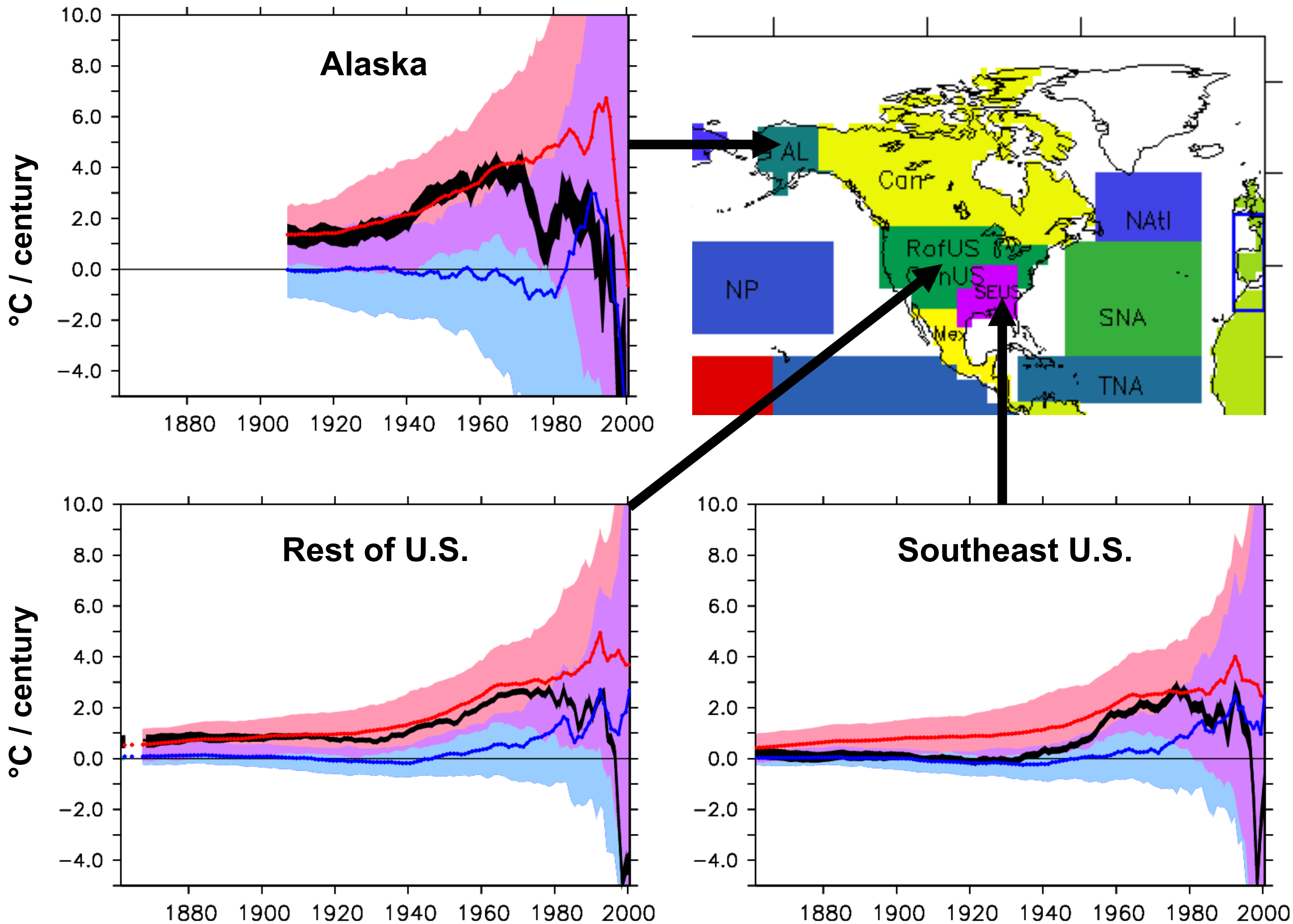
What do the new CMIP5 models say about the causes of regional surface temperature trends?

Global mean surface temperatures: Trends-to-2010



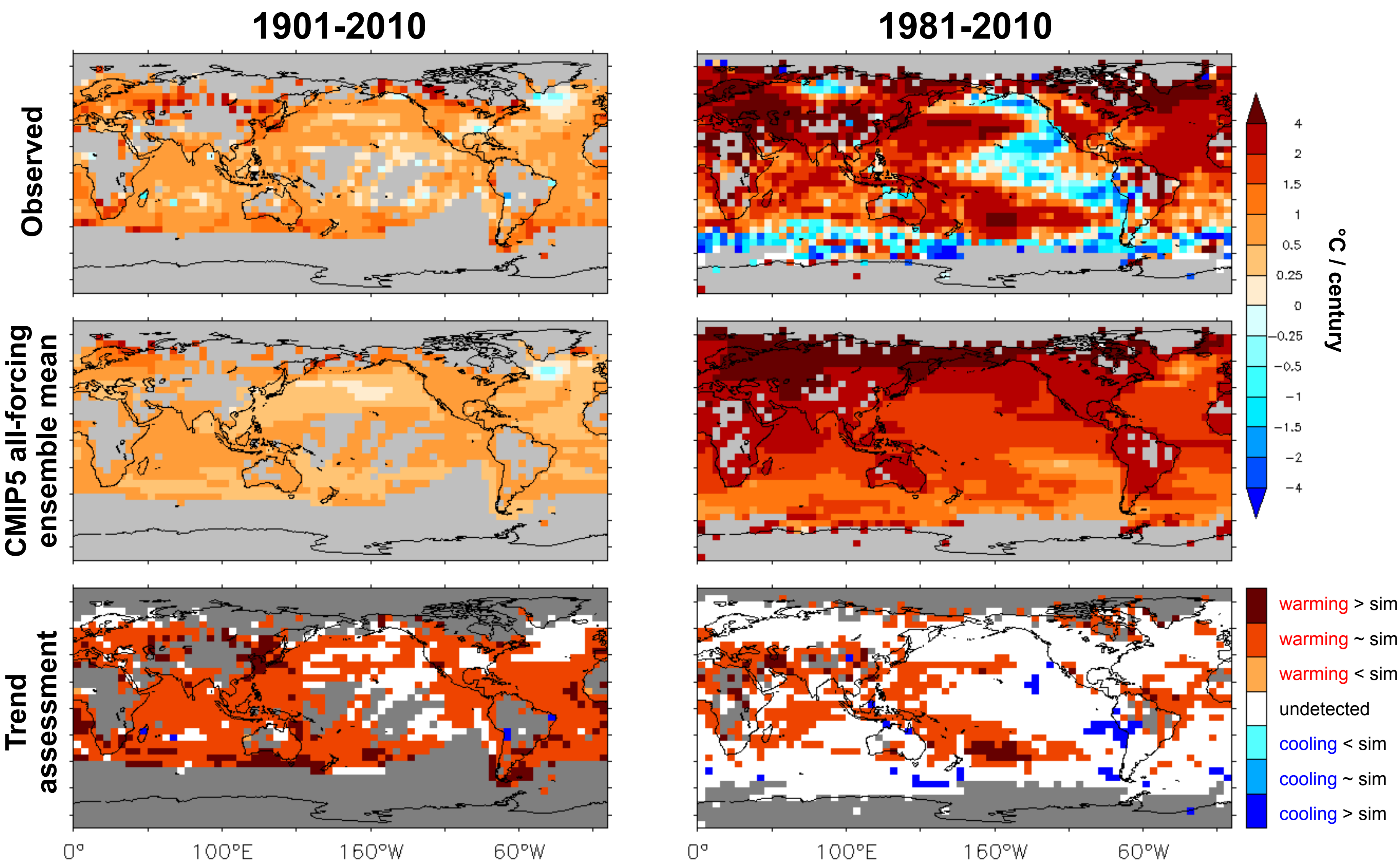
Knutson, Zeng, and Wittenberg (J. Climate, 2013)

U.S. surface temperatures: Trends-to-2010



Knutson, Zeng, and Wittenberg (J. Climate, 2013)

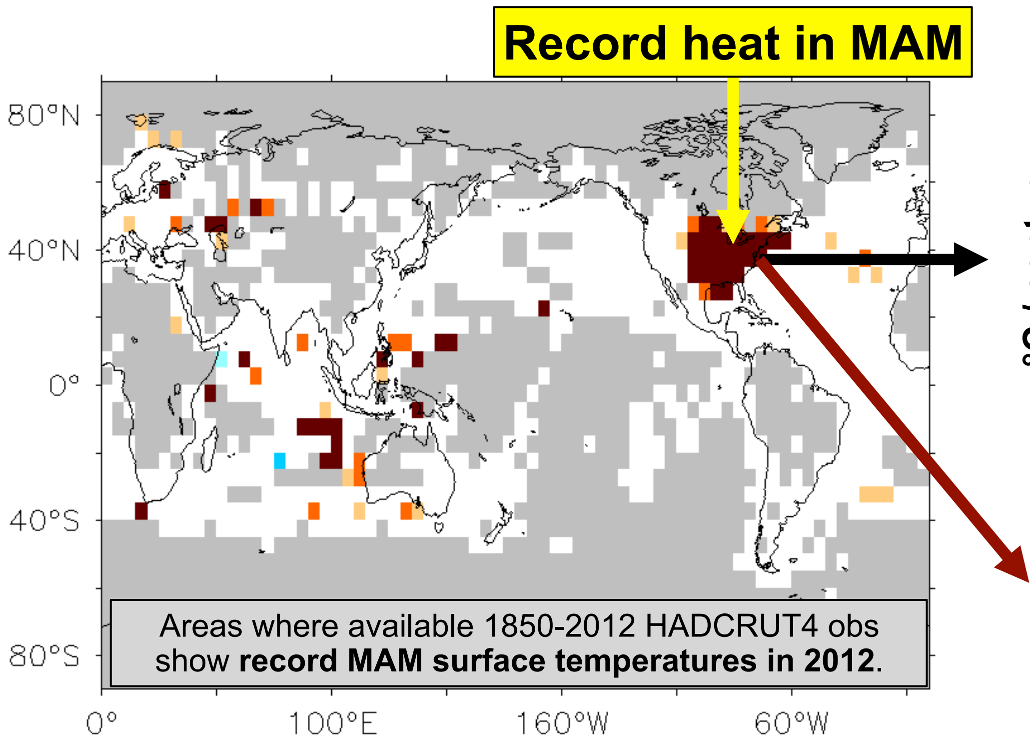
Regional surface temperature trends: 5°x5° boxes

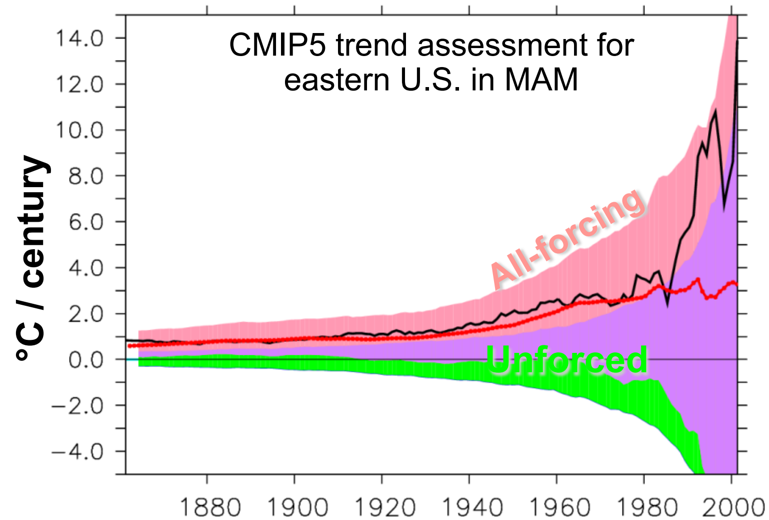


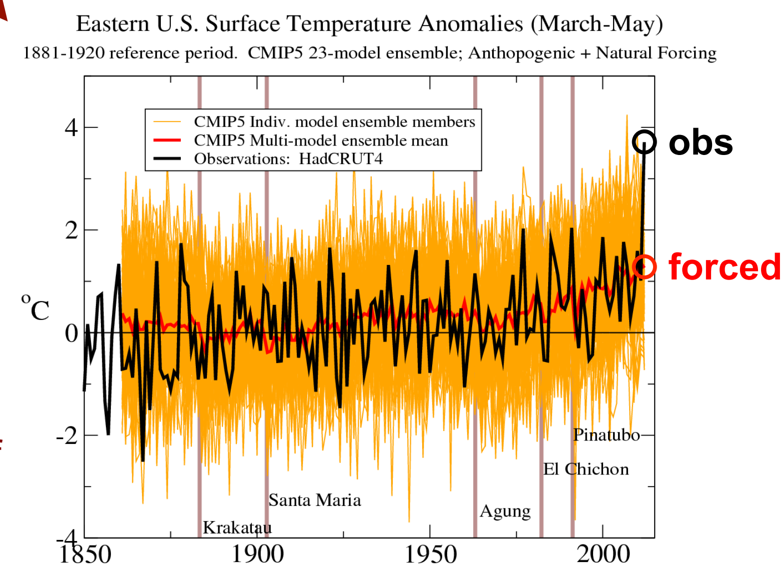
Knutson, Zeng, and Wittenberg (J. Climate, 2013)

2012 warm anomalies over the eastern U.S.

Knutson, Zeng, and Wittenberg (BAMS, 2013 subm.)







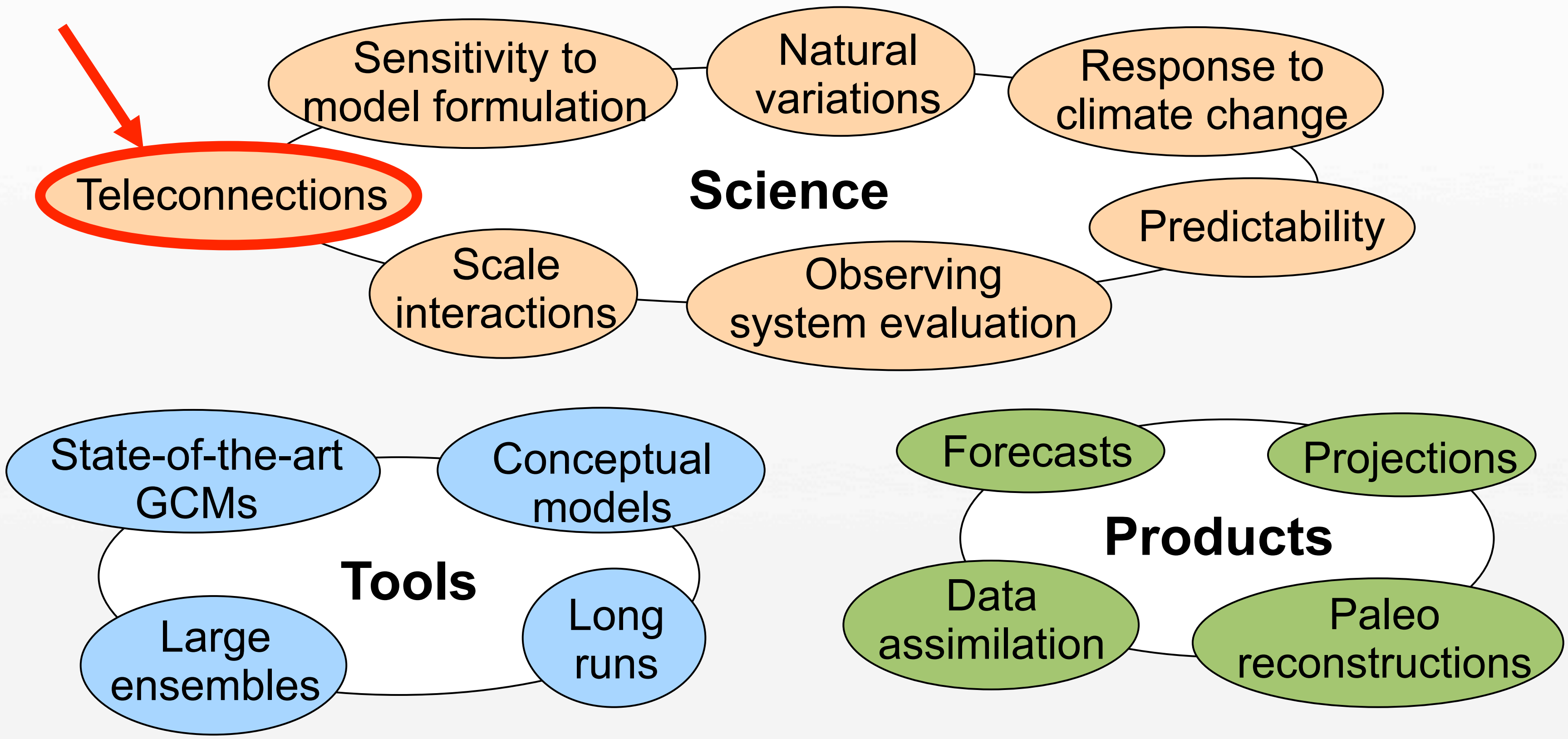
MAM eastern U.S. surface temperatures show:

- long-term trend of nearly 1°C / century
- warming trend exceeding CMIP5 unforced variability
- trend consistent with CMIP5 forced runs

Ensemble-mean CMIP5 forced response explains ~**35%** of the 2012 MAM warm anomaly; remainder was likely internal variability.

Regional extremes are also driven by intrinsic modes of climate variability – the strongest of which is ENSO.

GFDL is leading groundbreaking research on ENSO

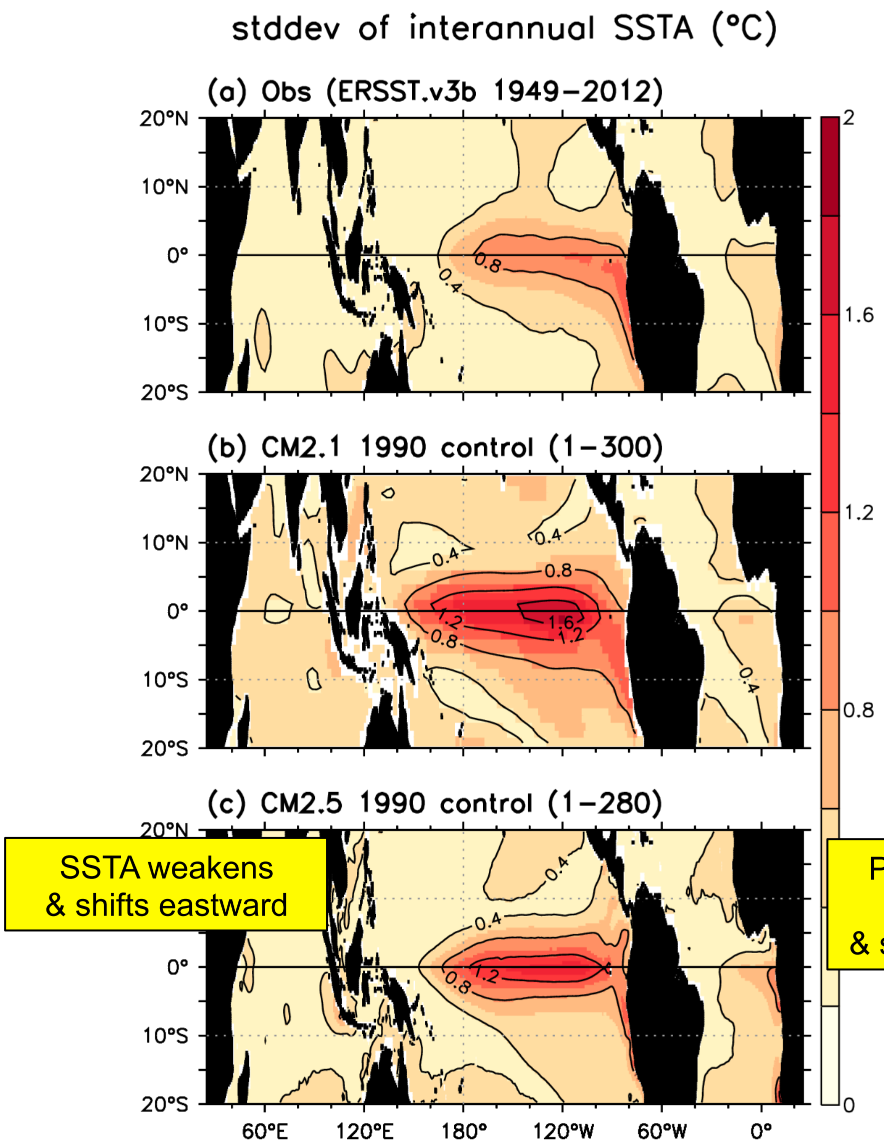


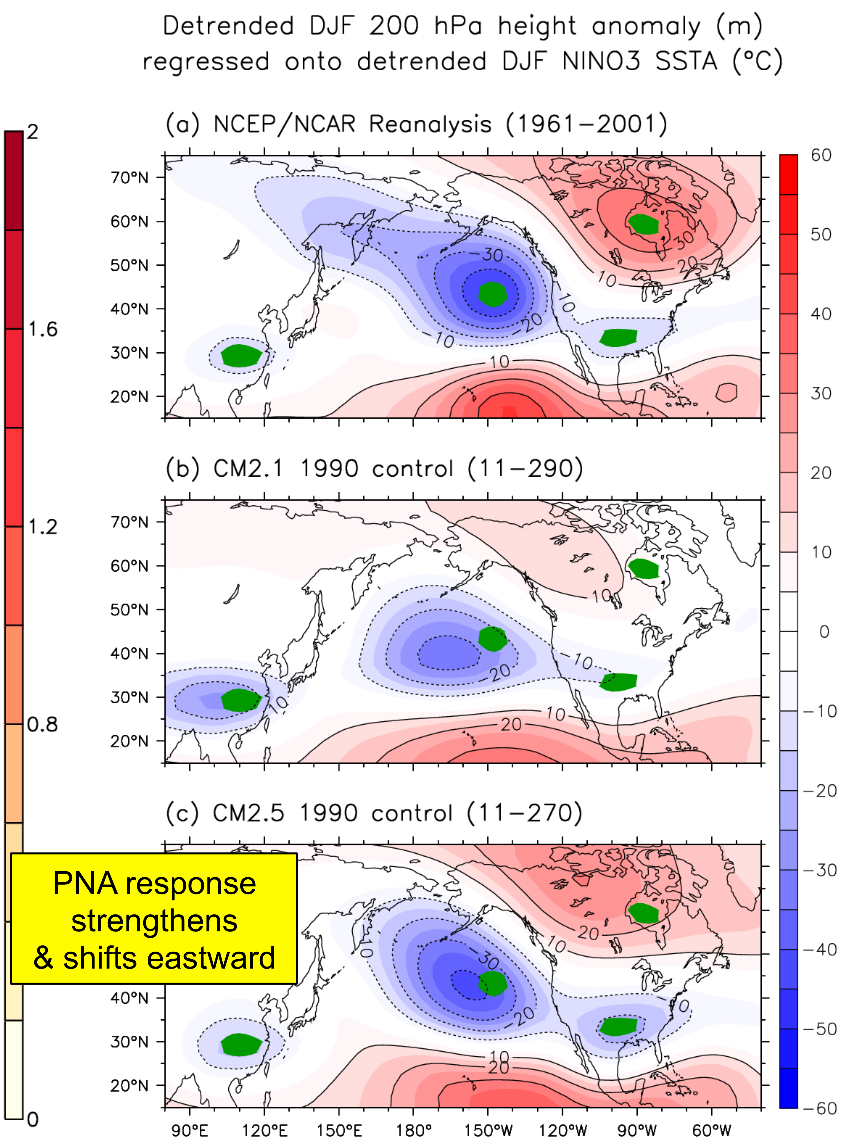
International engagement:

IPCC Fifth Assessment (AR5)
U.S. National Multi-Model Ensemble (NMME)
Working Group on ENSO Diversity (U.S. CLIVAR)
Working Group on ENSO Metrics (CLIVAR Pacific Panel)
ENSO Task Team (CLIVAR)

ENSO improvements at high resolution

Delworth et al. (JC 2012)

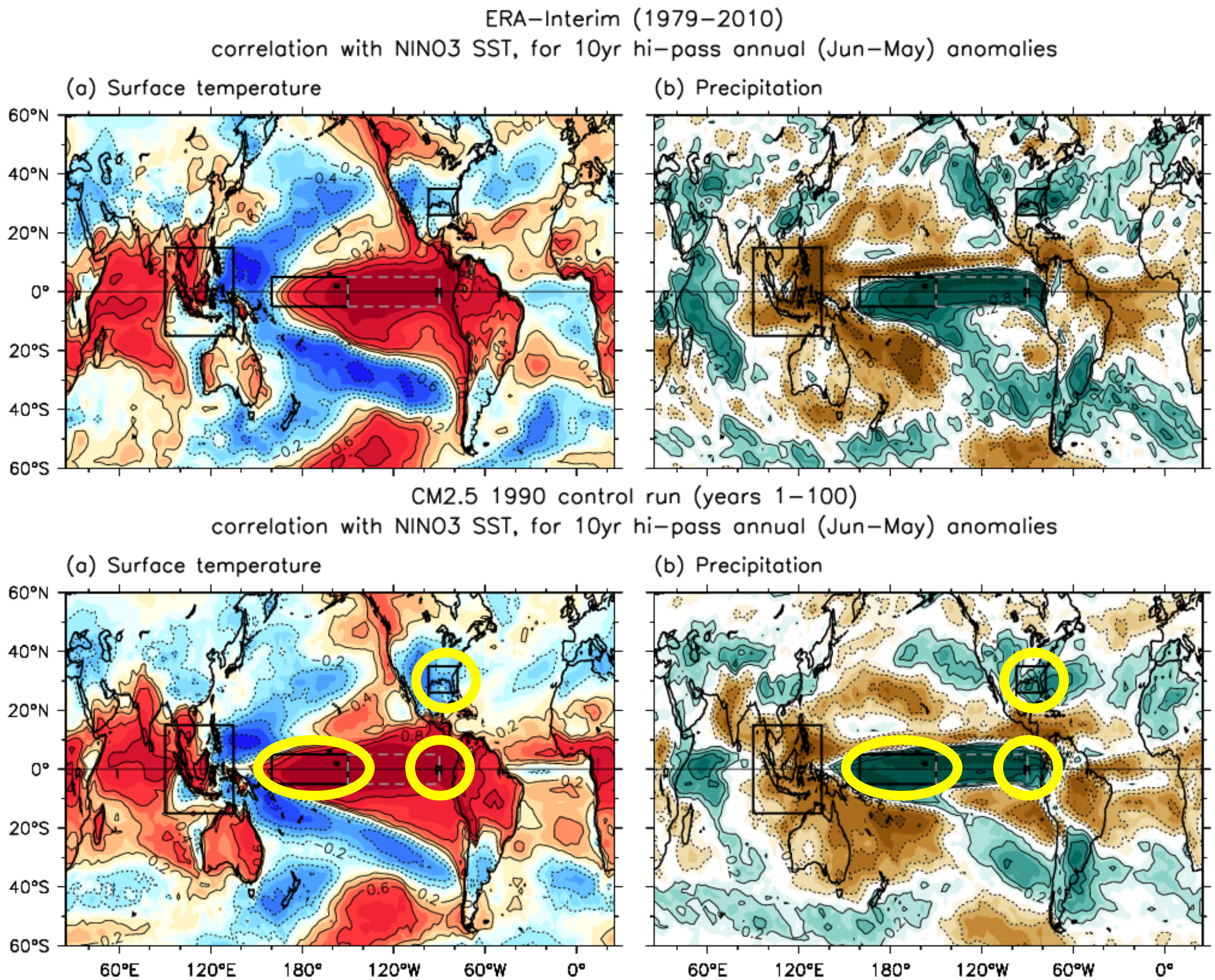




ENSO's impacts on regional climates

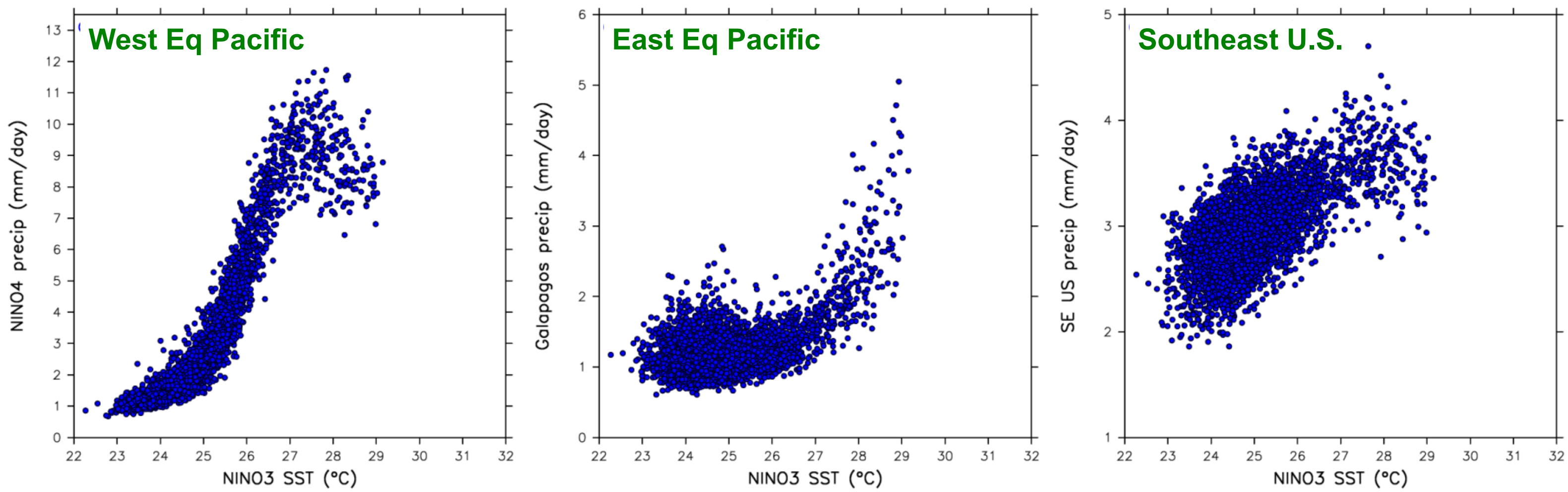
Obs

Model

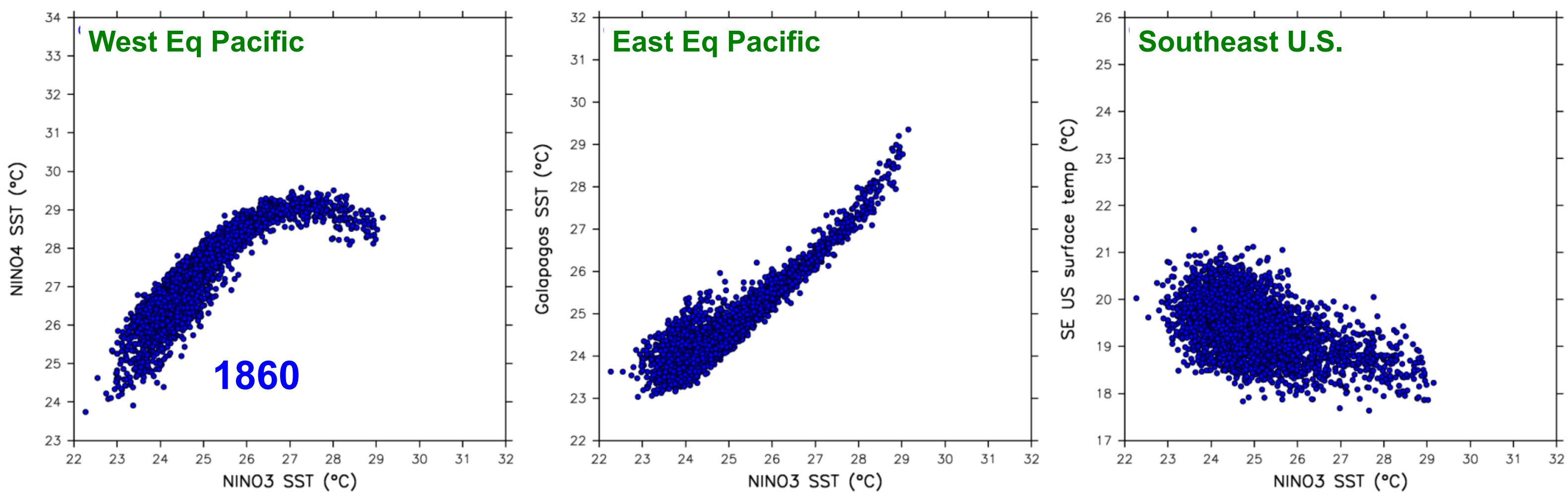


Extreme ENSO events have nonlinear impacts

Rainfall teleconnections in CM2.1 (4000yr)



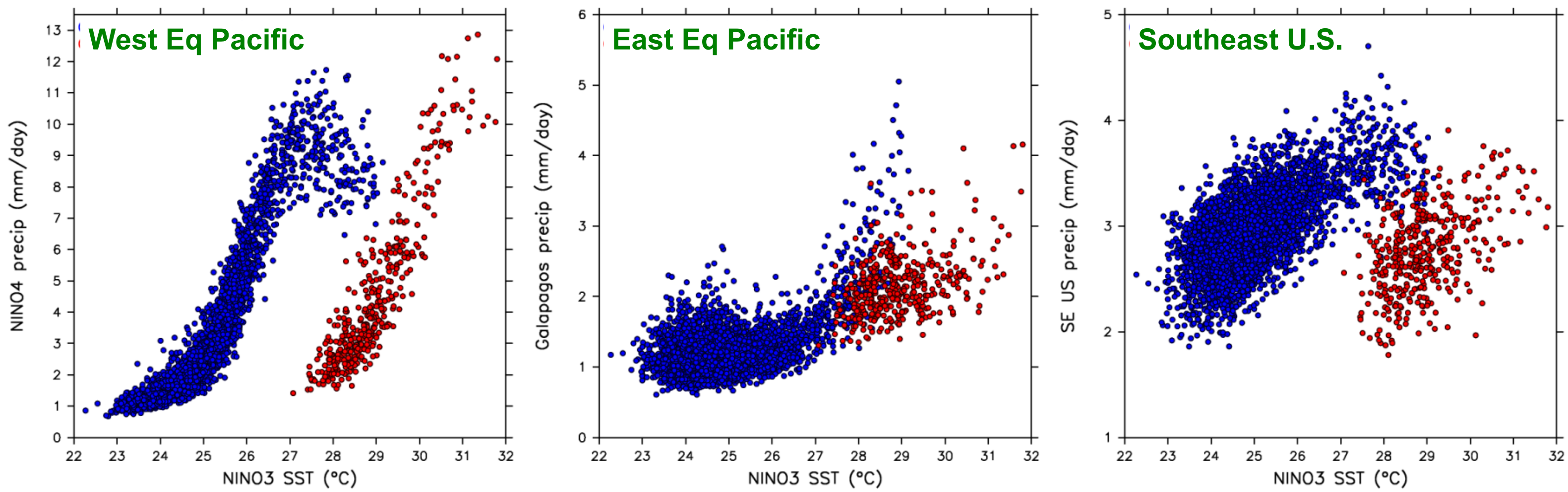
Surface temperature teleconnections in CM2.1 (4000yr)



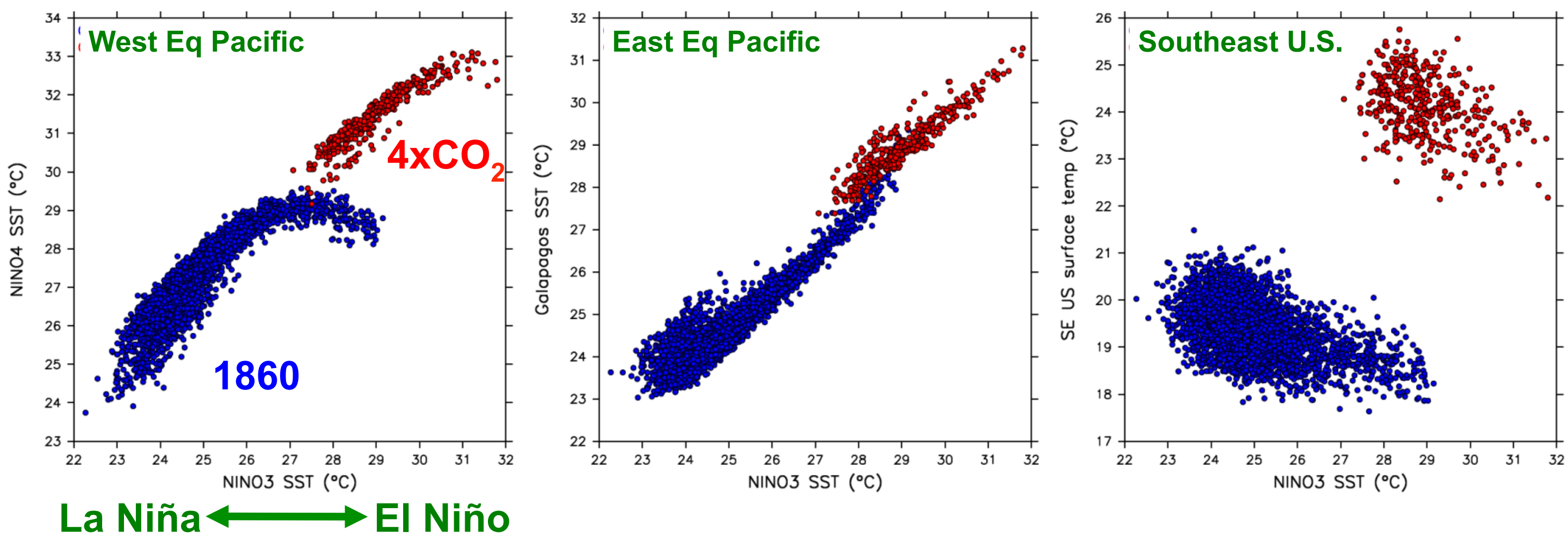
La Niña ⟷ El Niño

Increasing CO_2 alters ENSO impacts

Rainfall teleconnections in CM2.1 (4000yr & 400yr)



Surface temperature teleconnections in CM2.1 (4000yr & 400yr)



Summary

Two key factors affecting future climate vulnerability:

1. Surface temperature trends

a. CMIP5 models capture historical trends in surface temperatures

- so long as both natural and anthropogenic forcings are included

b. 2012 MAM temperature anomaly over the eastern U.S.

- occurred against a backdrop of global & regional warming trends
- models indicate anthropogenic warming accounted for ~35%

2. Intrinsic climate variability (e.g. ENSO)

a. Major driver of regional climate variations

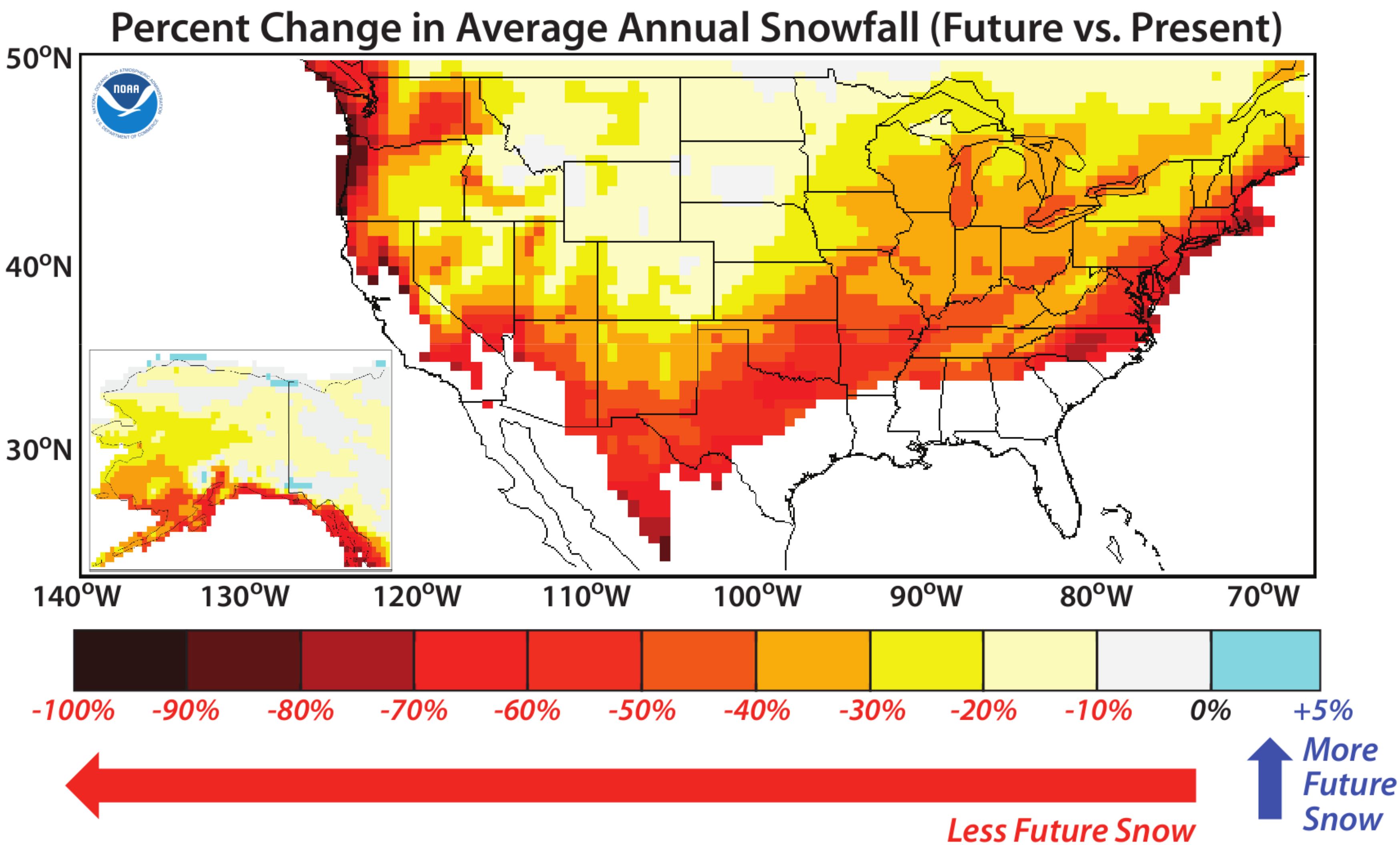
b. ENSO & teleconnections improve with increasing resolution

c. Teleconnections of extreme ENSO events

- can be highly nonlinear
- key to understanding regional climate vulnerability

Controls of Global Snow Under a Changed Climate

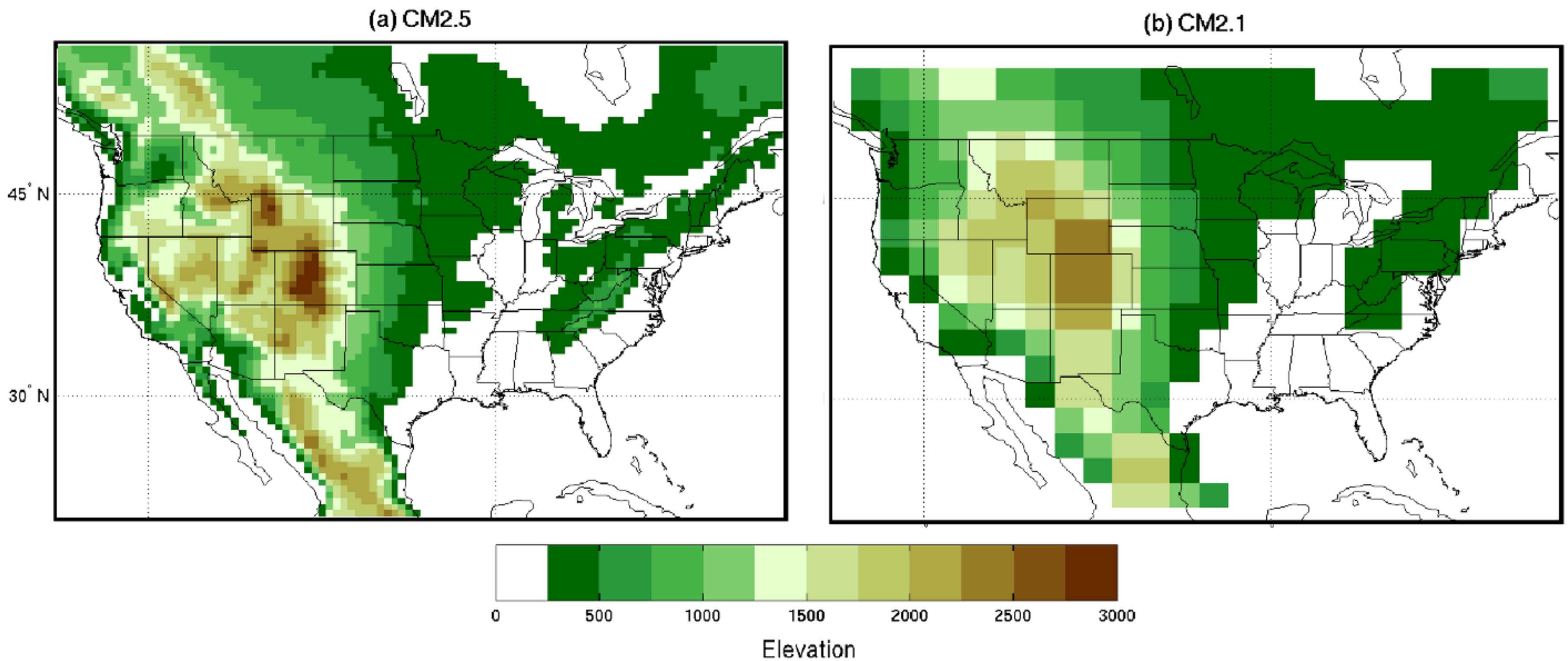
Kapnick & Delworth (2013), J. Climate



Results based on GFDL CM2.5 coupled climate model experiments

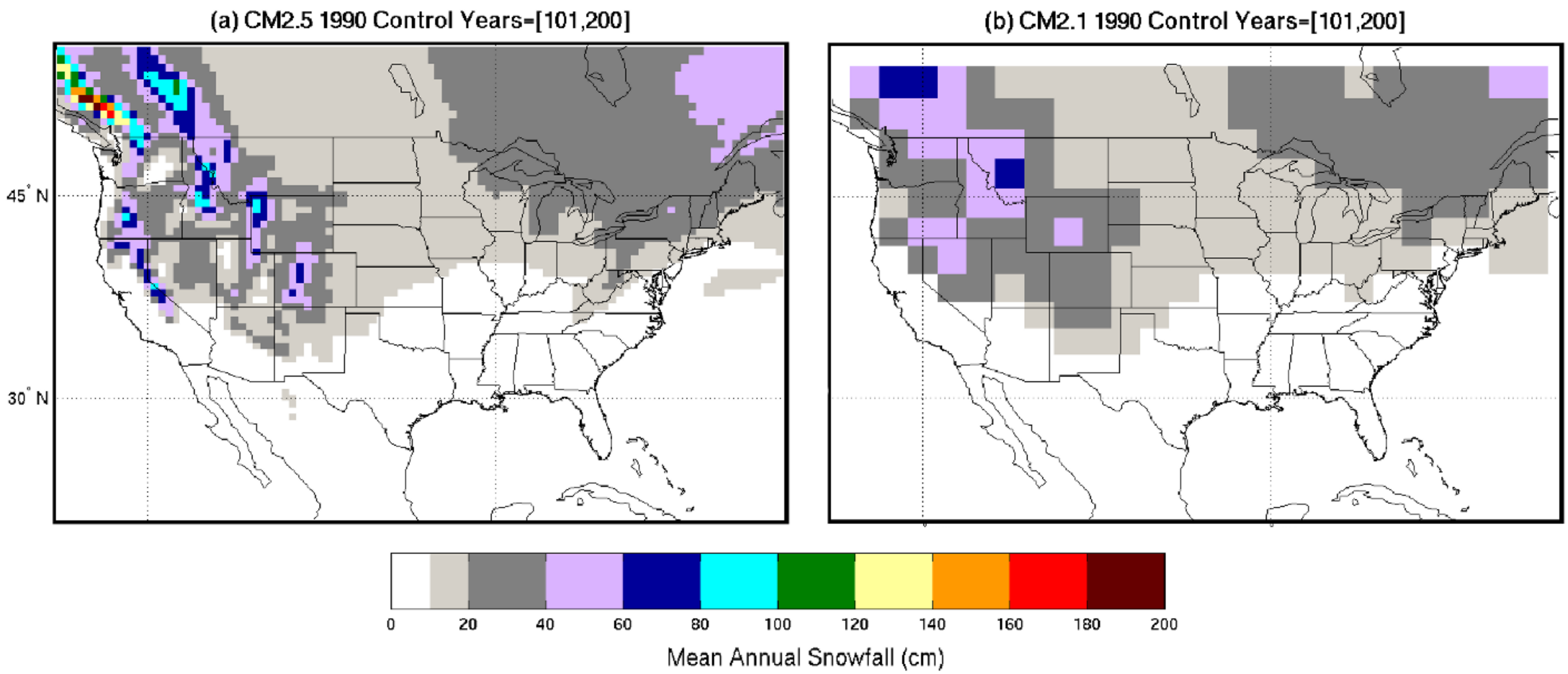
A better representation of topography…

Higher spatial resolution allows for a better representation of topography…

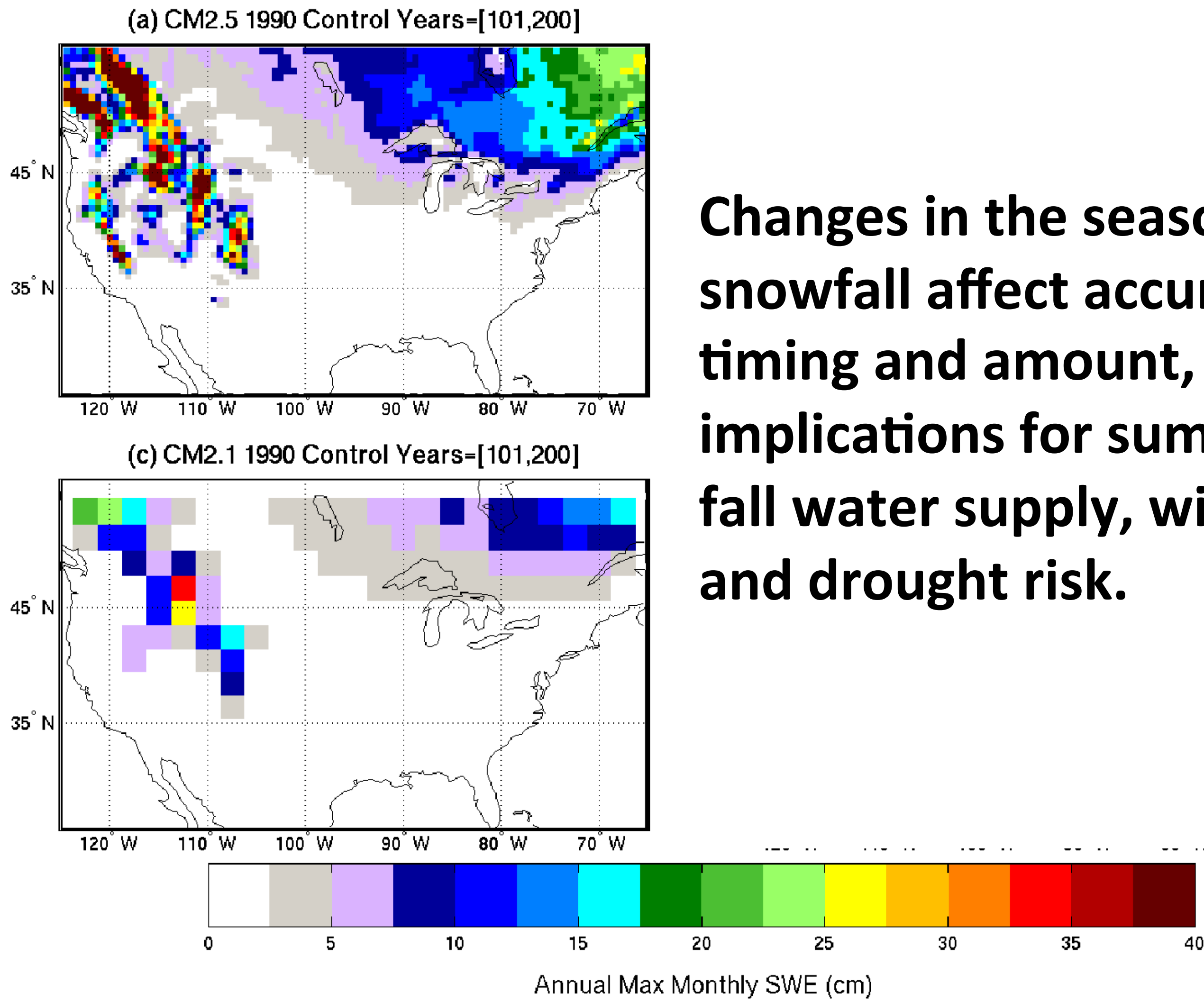


…yields a better simulation of snowfall & snowpack

…which allows for a more detailed simulation of snowfall in the western US.



Implications of snowpack changes



Changes in the seasonality of snowfall affect accumulation timing and amount, which has implications for summer and fall water supply, wildfire risk, and drought risk.

Statistical downscaling & the "stationarity assumption"

<u>Statistical downscaling</u>: when dynamical models don't fully meet the requirements, an additional statistical refinement step may add value (analogous to the MOS in weather forecasting).

- GFDL's angle – integrating efforts with others and leading an effort to assess uncertainty arising from what we refer to as '*the stationarity assumption*'.

NCPP
NOAA/CPO
NOAA/CPO
NOAA / GFDL
TEXAS TECH
UNIV OKLAHOMA
SOUTH CENTRAL CLIMATE SCIENCE CENTER
DOI / USGS

aim to address GCM shortcomings + add finer scale detail

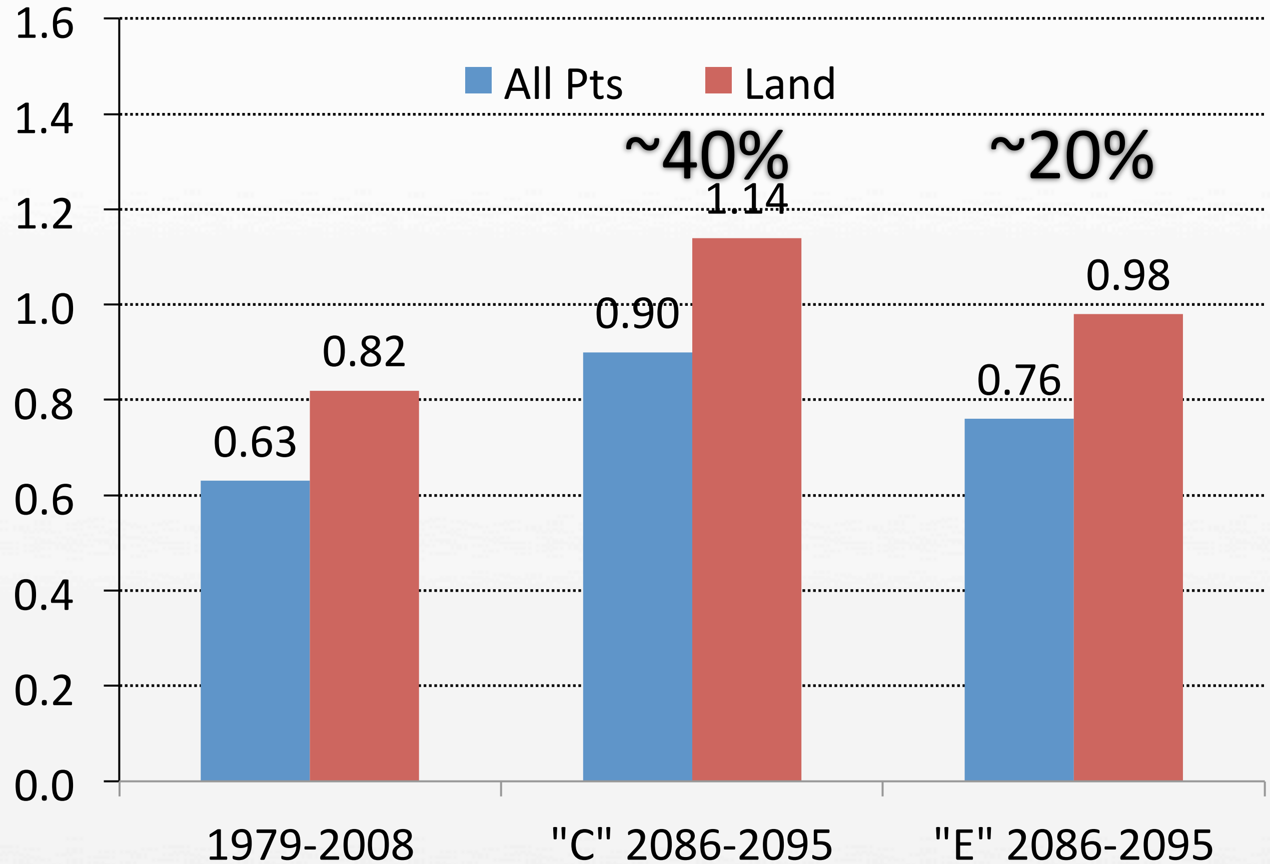
There are numerous statistical downscaling techniques, varying from the very simple, to intermediate complexity, to machine learning approaches, etc.

In our Perfect Model approach, we substitute hi-res GCM output for Observations -and- we substitute a coarsened (via interpolation) version of the hi-res model for the GCM

training

HI RES (25km) GCM OBSERVATIONS 1979-2008 Downscaled vs. Hi ResGCM	*DOWNSCALED EST.* *vs. Hi ResGCM* *2086-2095*
COARSENED (200km) VERSION OF HI RES GCM SIMULATION 1979-2008	COARSENED (200km) VERSION OF HI RES GCM PROJECTION 2086-2095

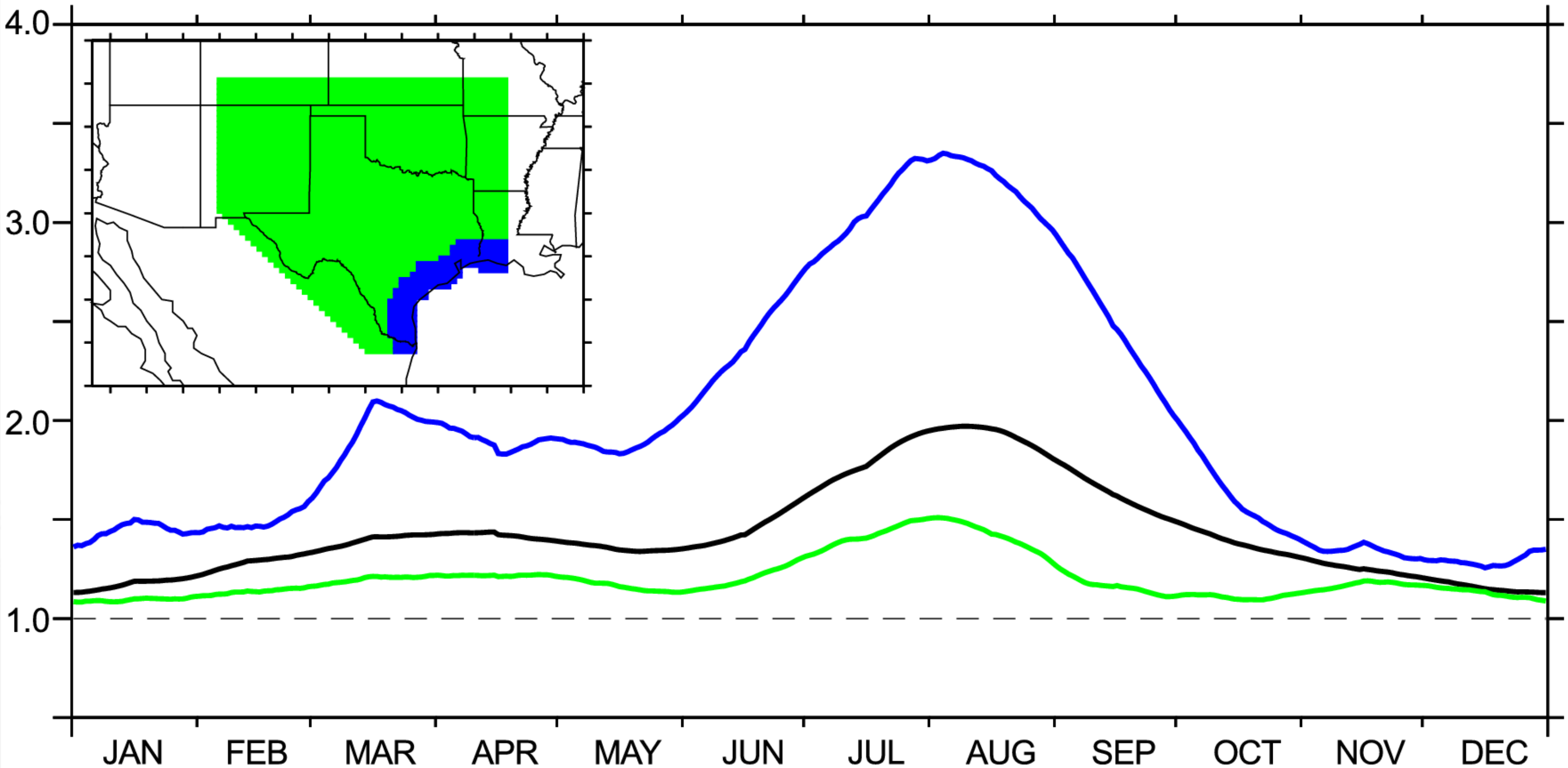
Statistical Downscaling



Area Mean Time Mean Absolute Downscaling Errors

$$\frac{\Sigma \ |\text{(Downscaled Estimate} - \text{HiRes GCM)}|}{\text{(NumDays)}}$$

Guidance to end users & to downscaling developers



For one method tested, downscaling errors were shown to be largest in coastal regions and during the summer (i.e., where & when the stationarity assumption did not hold well)

Research progress on matters of **regional climate**, **extremes, & impacts** has been a outgrowth of several factors including, but not limited to…

- Climate models' higher spatial resolution
- Long model runs and ensembles of runs
- Synthesis of state-of-the-art models, high quality observations, and new theories/understanding of climate system mechanisms

…a combination of **hardware, software, & brainware**

Overall, these efforts map onto NOAA Strategic Goals to…

… advance the understanding of the Earth System across various space and time scales

…provide scientifically credible information that contributes to better informed decision-making and planning for climate variations and trends

Under our regional climate, extremes, & impacts umbrella…