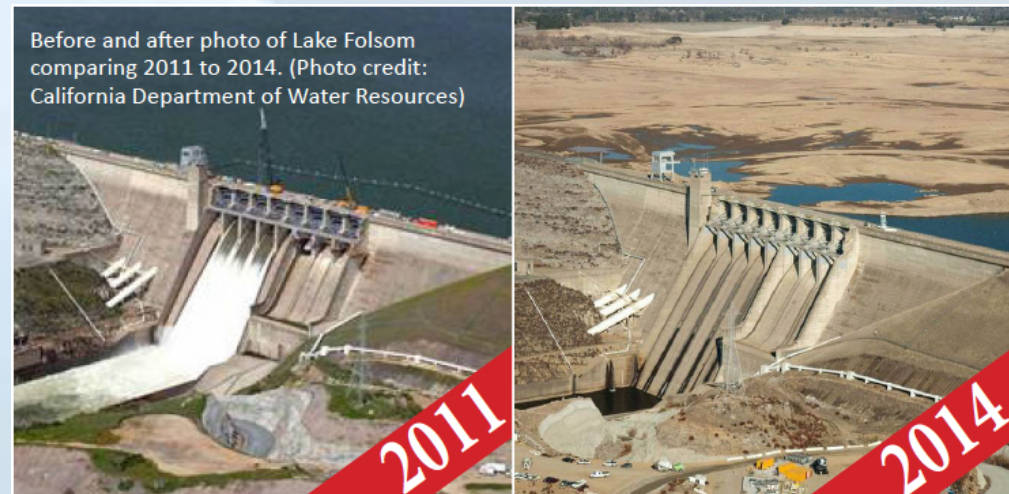# Hydrologic and Climate Science at NCAR

WaterNow Alliance Summit
Boulder,

David Yates – NCAR, RAL
Hydrometeorology Applications
Program
yates@ucar.edu

Before and after photo of Lake Folsom comparing 2011 to 2014. (Photo credit: California Department of Water Resources)
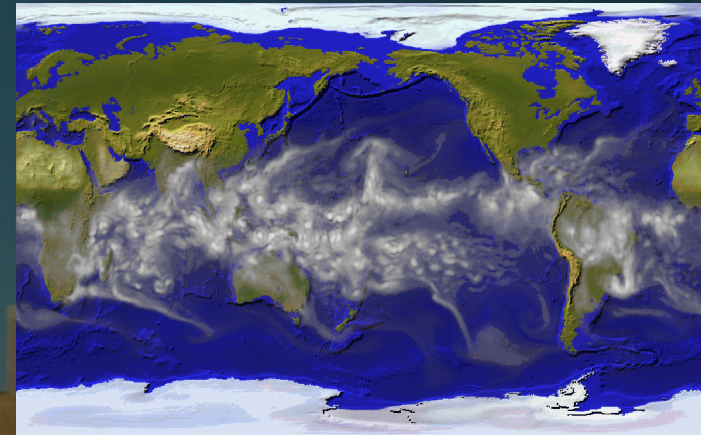
2011

2014

NCAR

NCAR/NSF Scientific facilities

- US National Science Foundation FFRDC
- 900 Staff, 500 Scientists/Engineers, 4 Boulder campuses
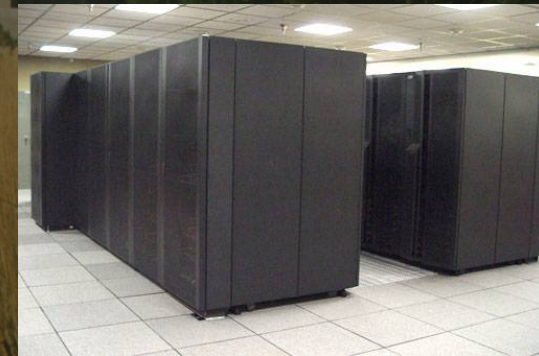- Governed by > 70 universities

EOL
Earth Observing Laboratory

NESL
NCAR Earth System Laboratory

CISL
Computational & Information Systems

RAL
Research Applications Laboratory

ISP: Integrated Science Program (crosscutting)

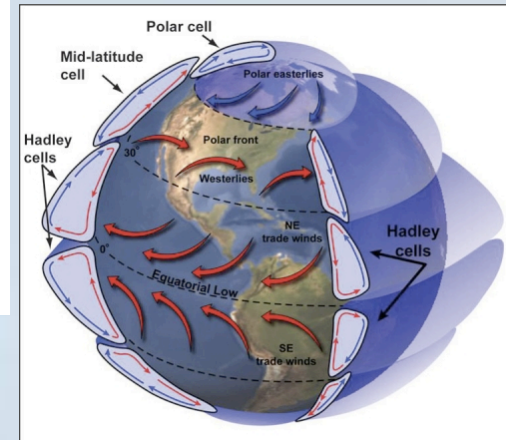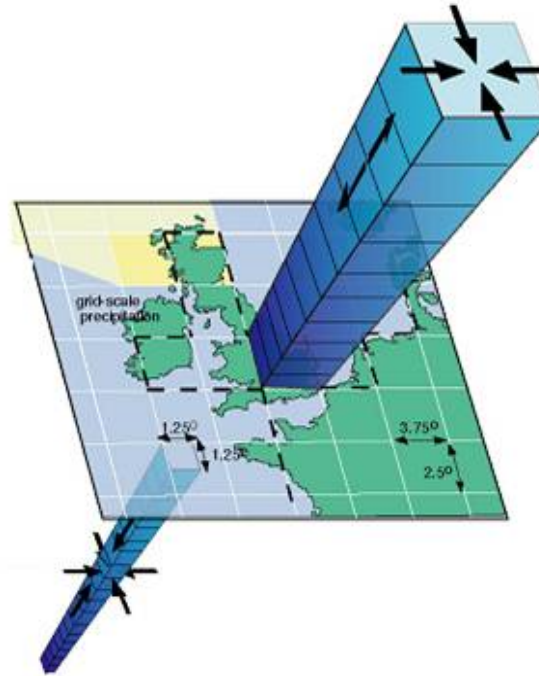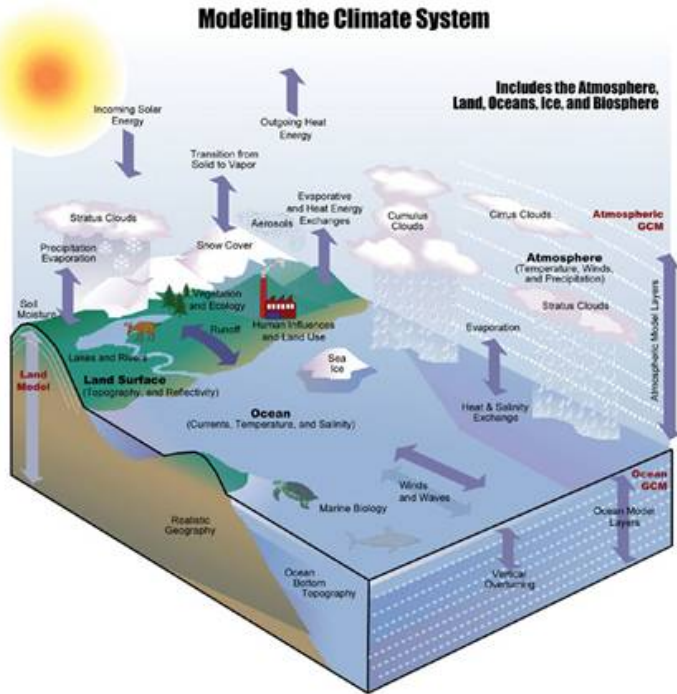Source: *NASA ISS007-E-10807 (July 21, 2003, 35 mm lens).*

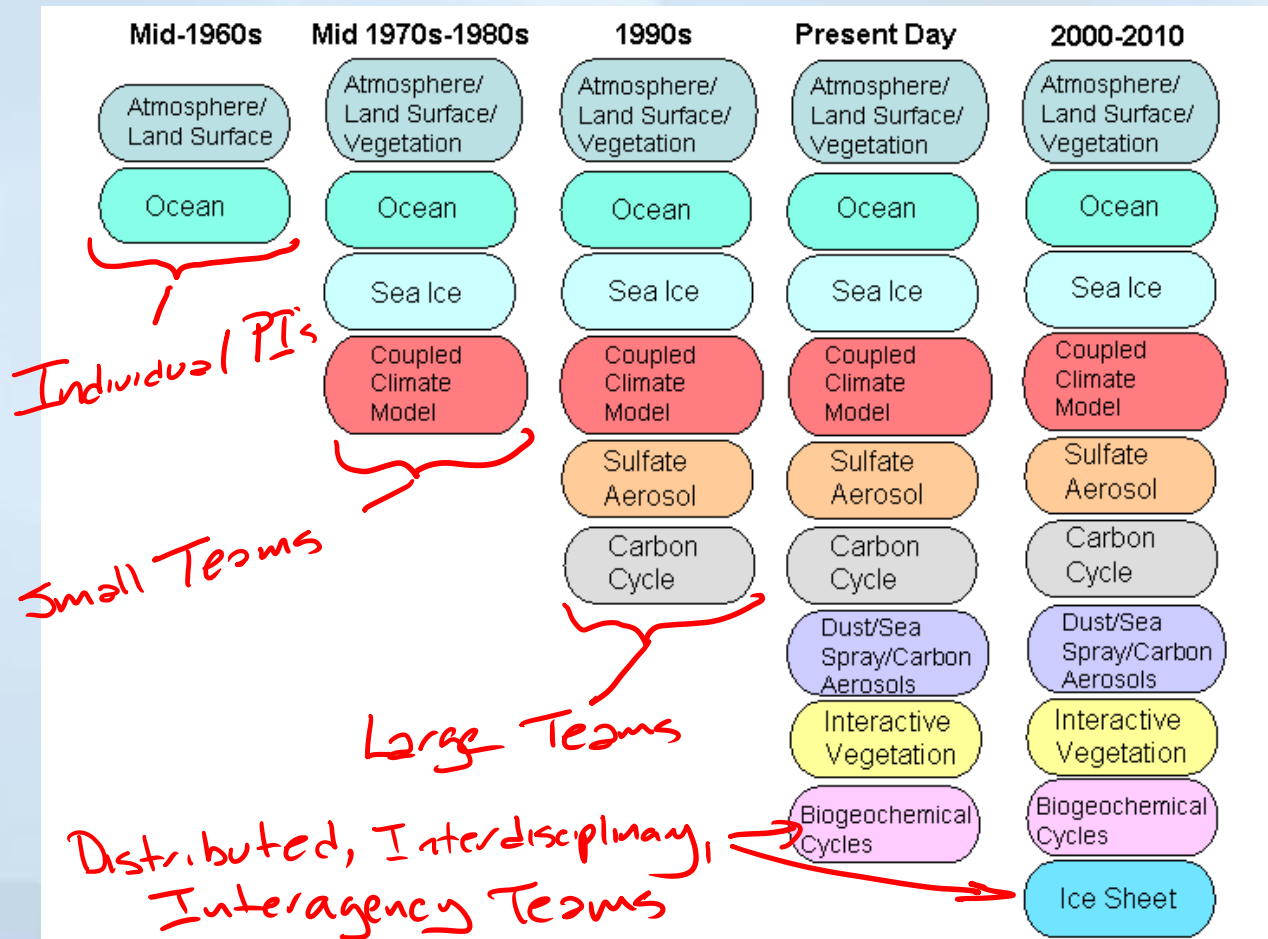At sunset over the Pacific Ocean, anvil tops of thunderclouds cast long shadows

Global Climate Modeling 101

Climate Model Development and their Components
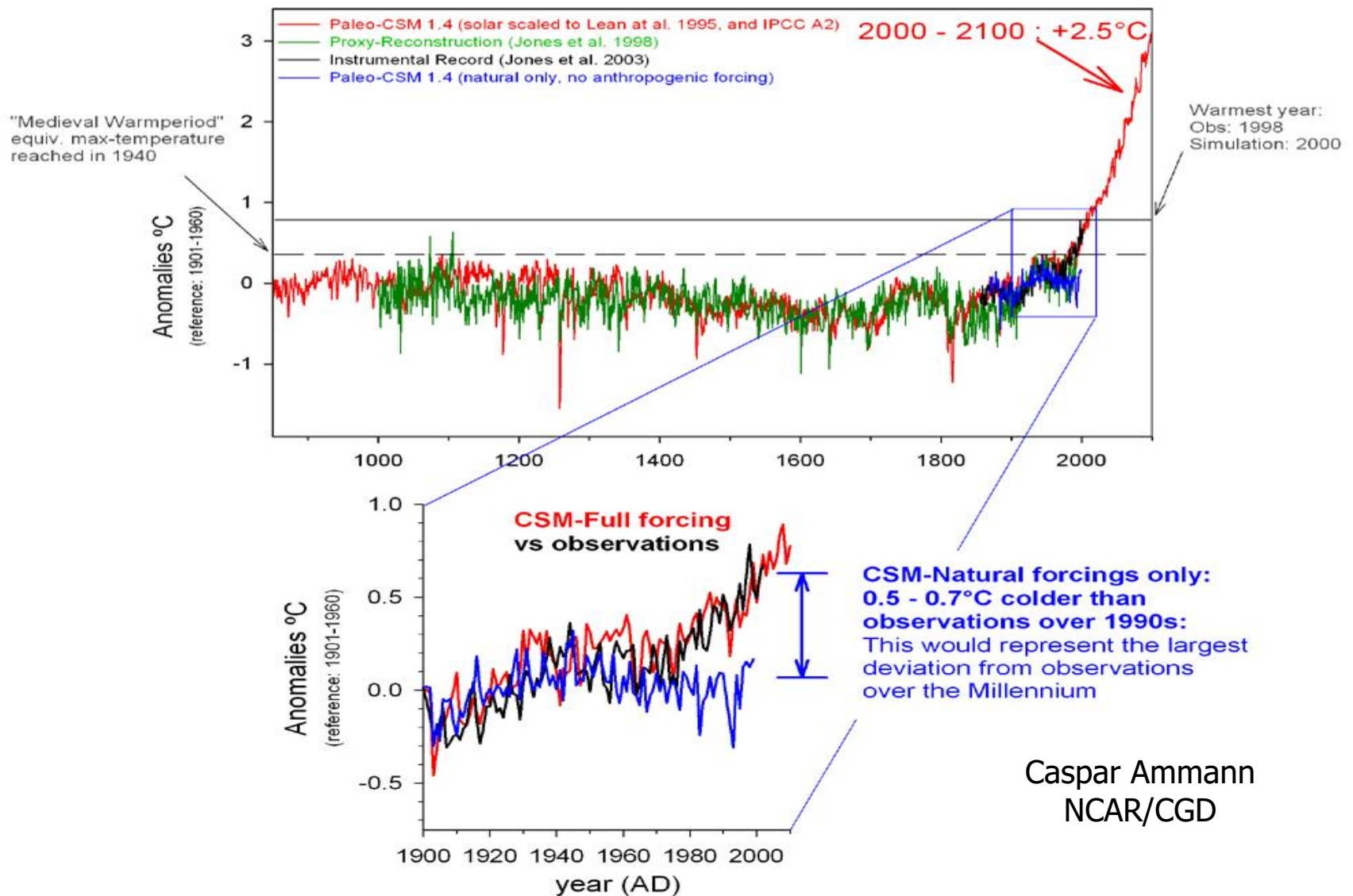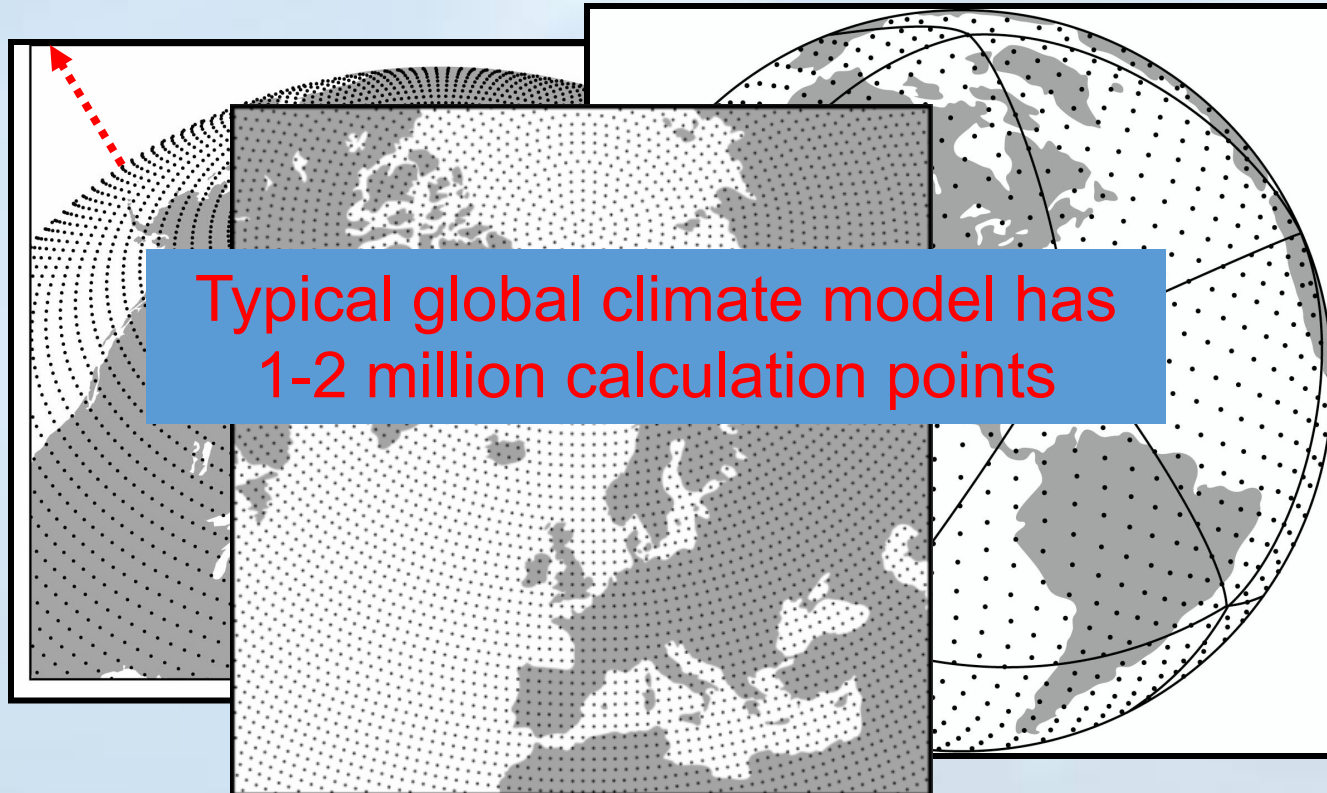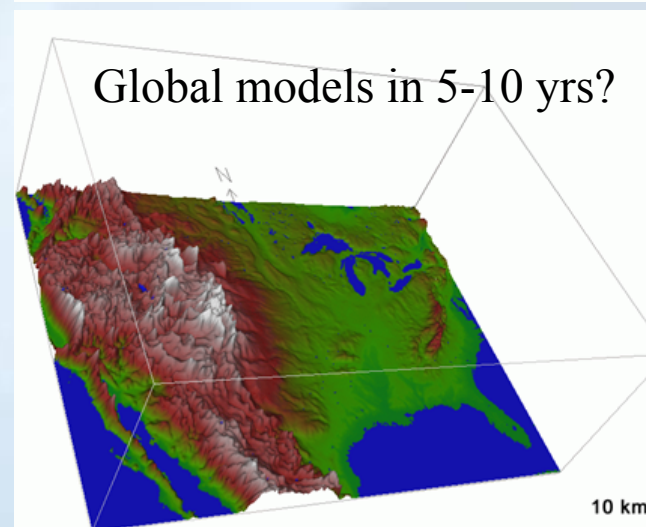
Climate of the last Millennium
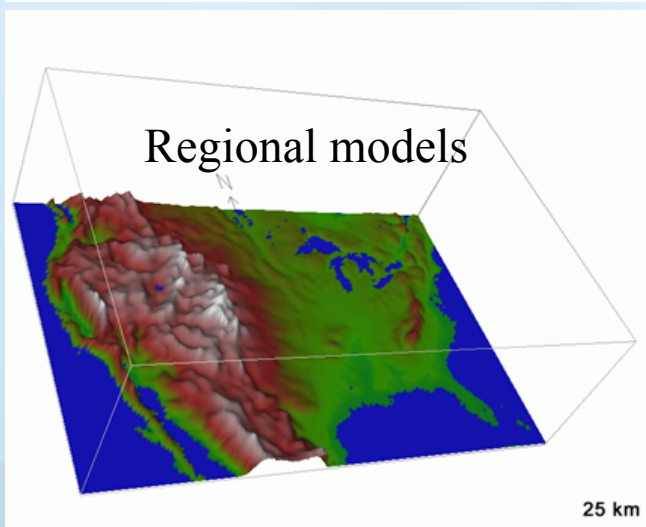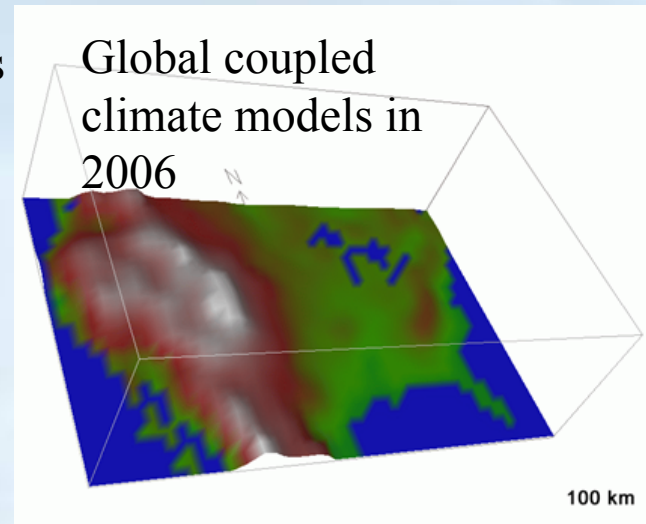

Caspar Ammann
NCAR/CGD

GCM's – A Grid of Points over Earth
(Precipitation is the most difficult modeled variable)

Typical global climate model has
1-2 million calculation points

Resolving the Regional Climate

Climate Models circa early 1990s

Global coupled climate models in 2006

Regional models

Global models in 5-10 yrs?

400 km

100 km

25 km

10 km
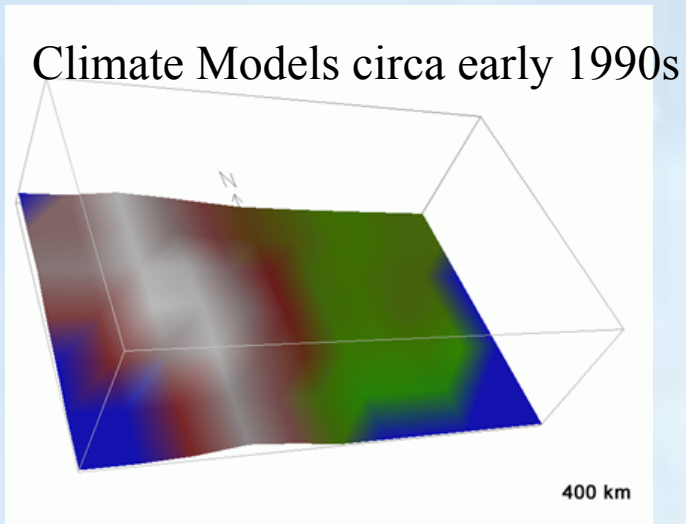
What Does a Climate Model look like?

CCSM CAM3   Aug 01   Hour 00
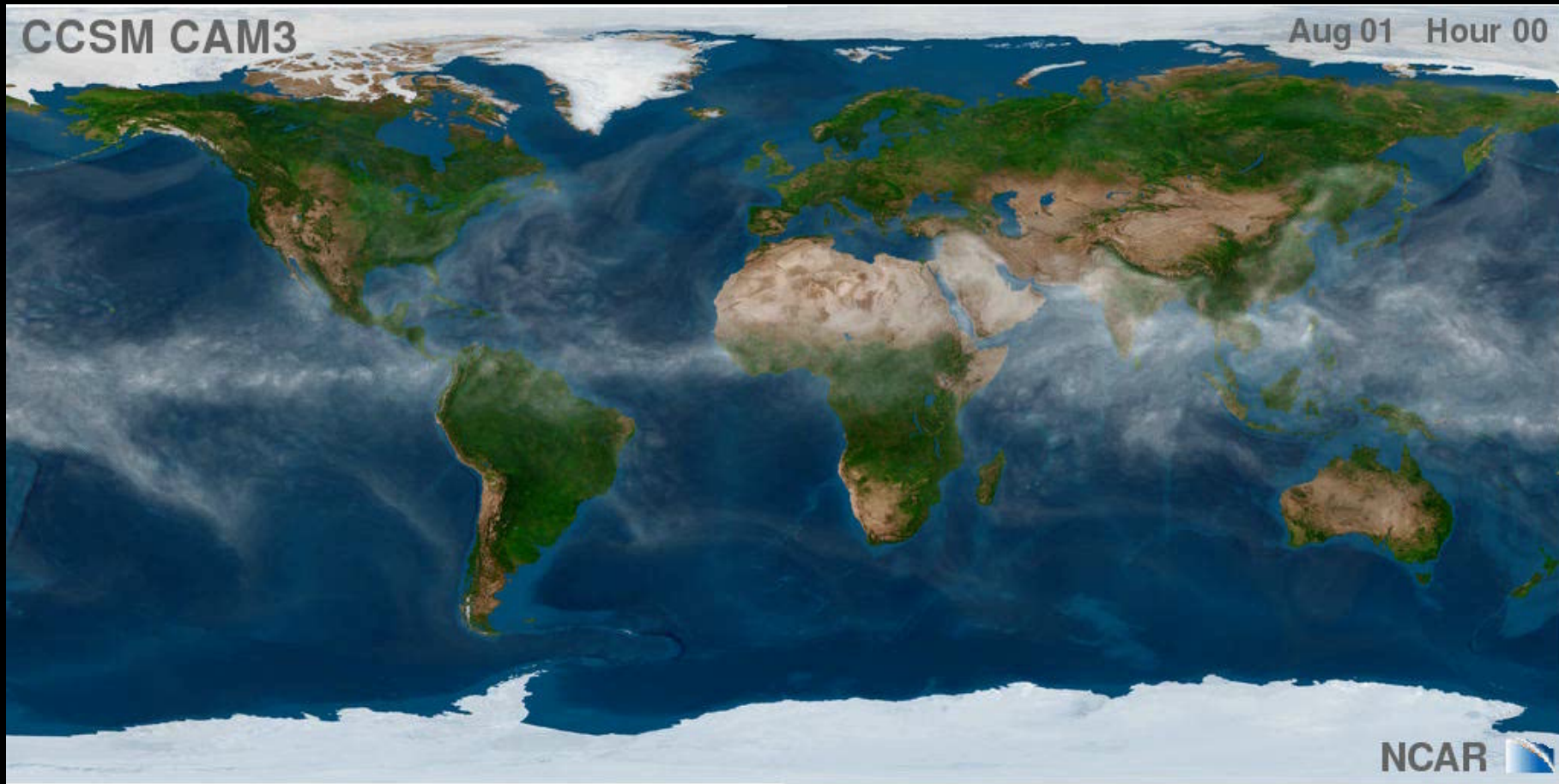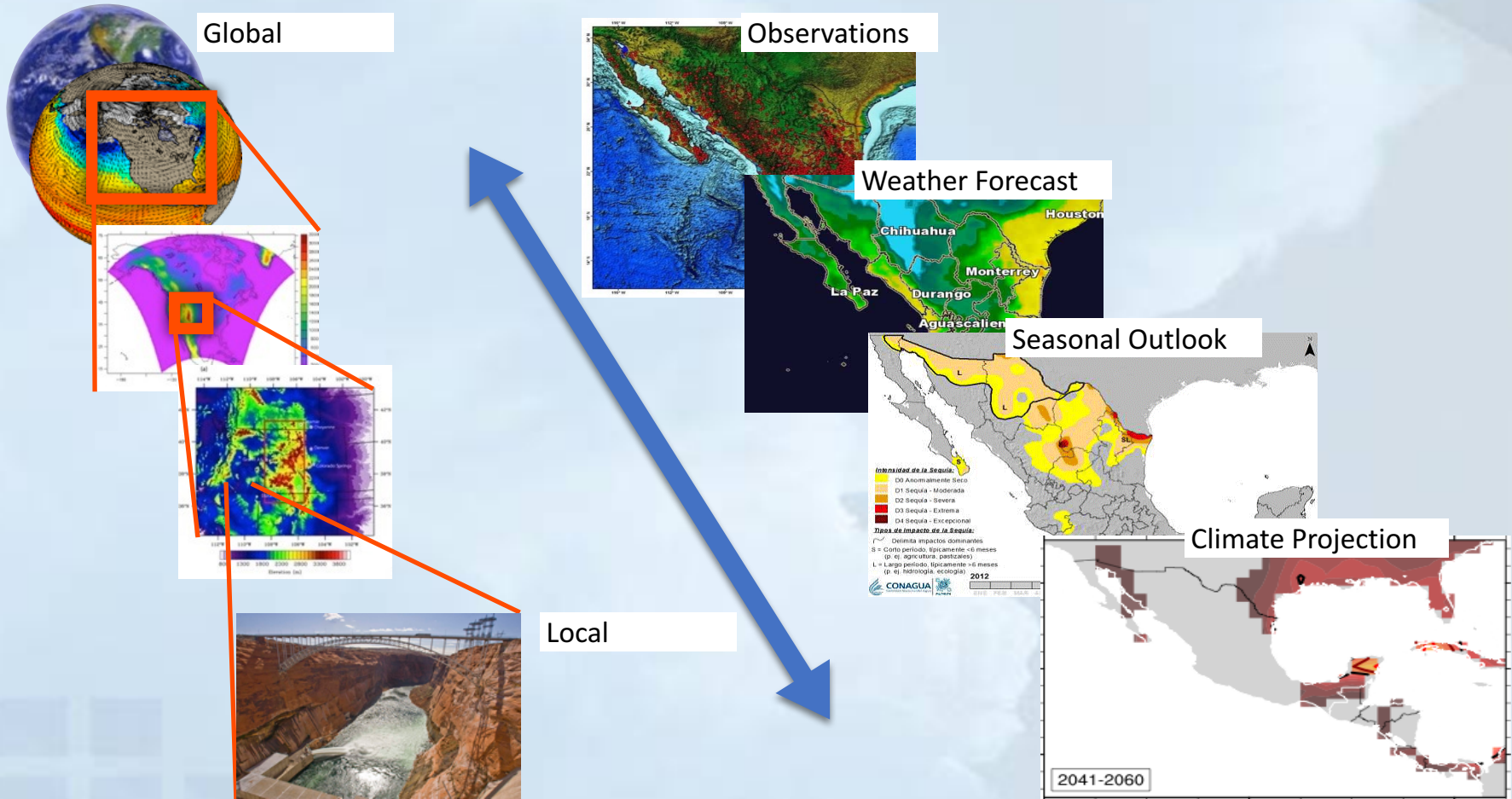
NCAR

NCAR Community Earth System Model

Atmospheric Component: Precipitable Water Vapor

Common Obstacles :

Integrating Spatial Scales

Temporal Needs

Global

Local

Observations

Weather Forecast

Seasonal Outlook

Climate Projection

2041-2060

Water: Precipitation ≠ Precipitation
Application-specific understanding and evaluation needed

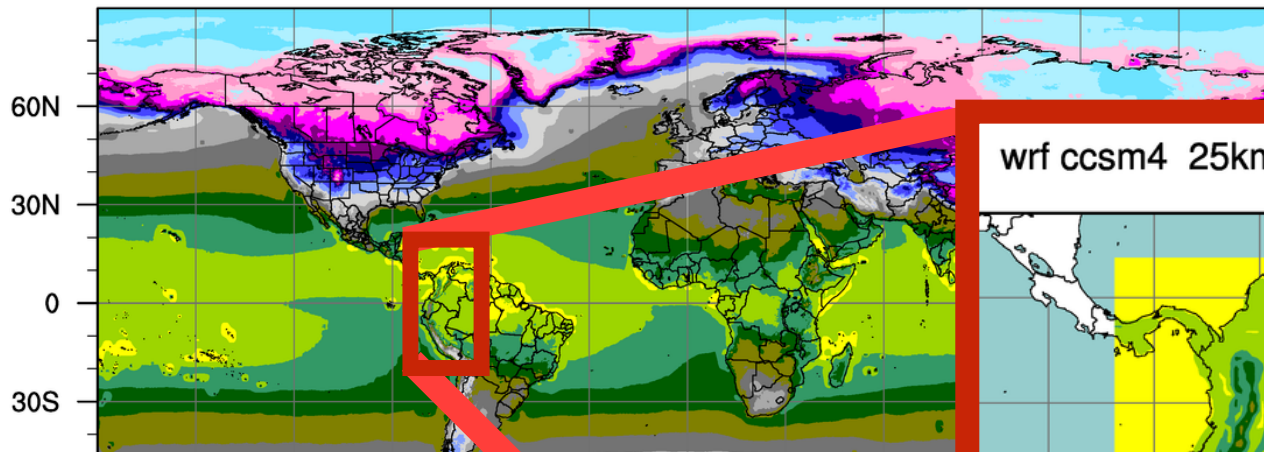Itaipu : Hydropower

Mexico : Drought

Panama : Flash Flood

Haiti : Hurricane

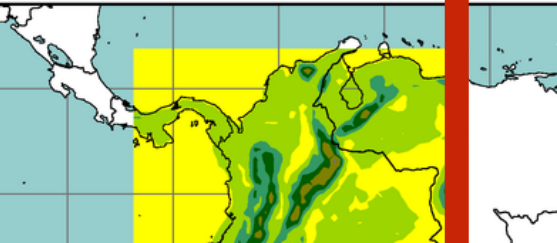# High-resolution analyses and underlying biases in climate fields
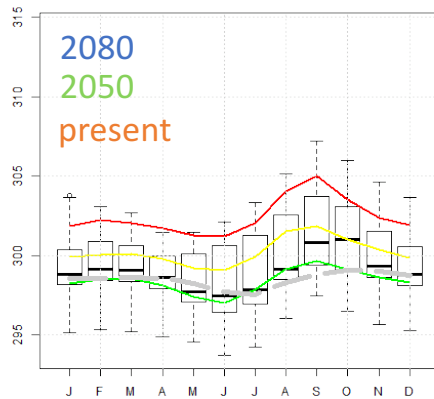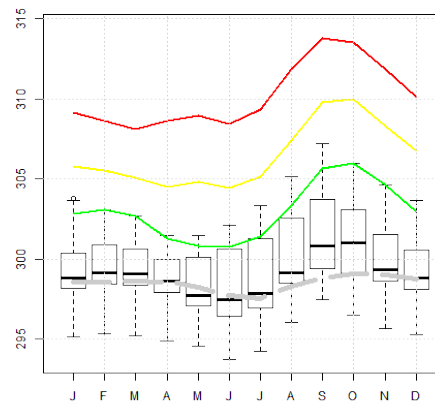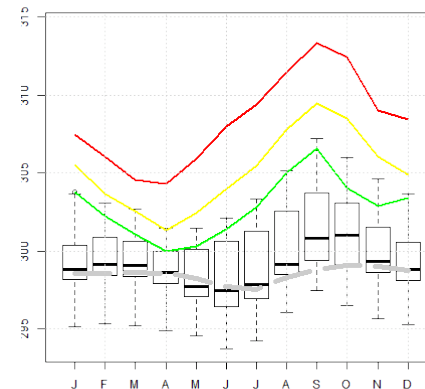
Improving Predictions of Regional Changes in Weather and Climate

The Nested Regional Climate Model

High Resolution Climate Modeling

IPCC (2007)   IPCC (2013)   NRCM

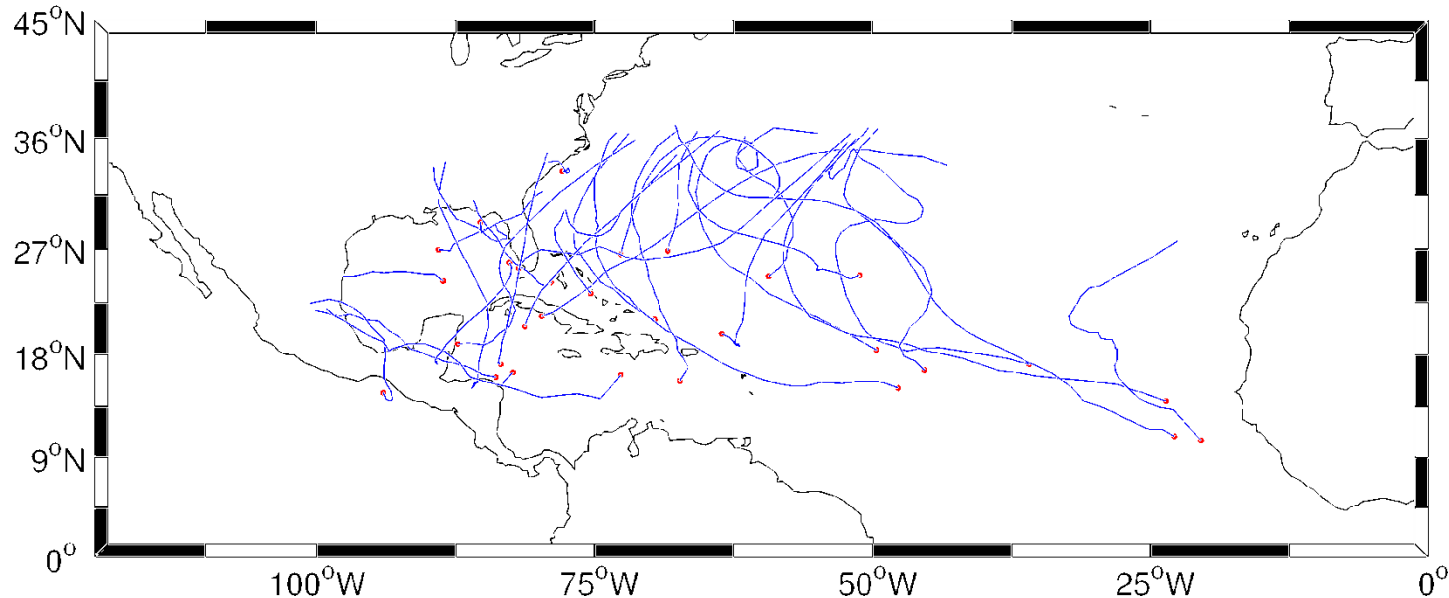Jim Hurrell / Greg Holland
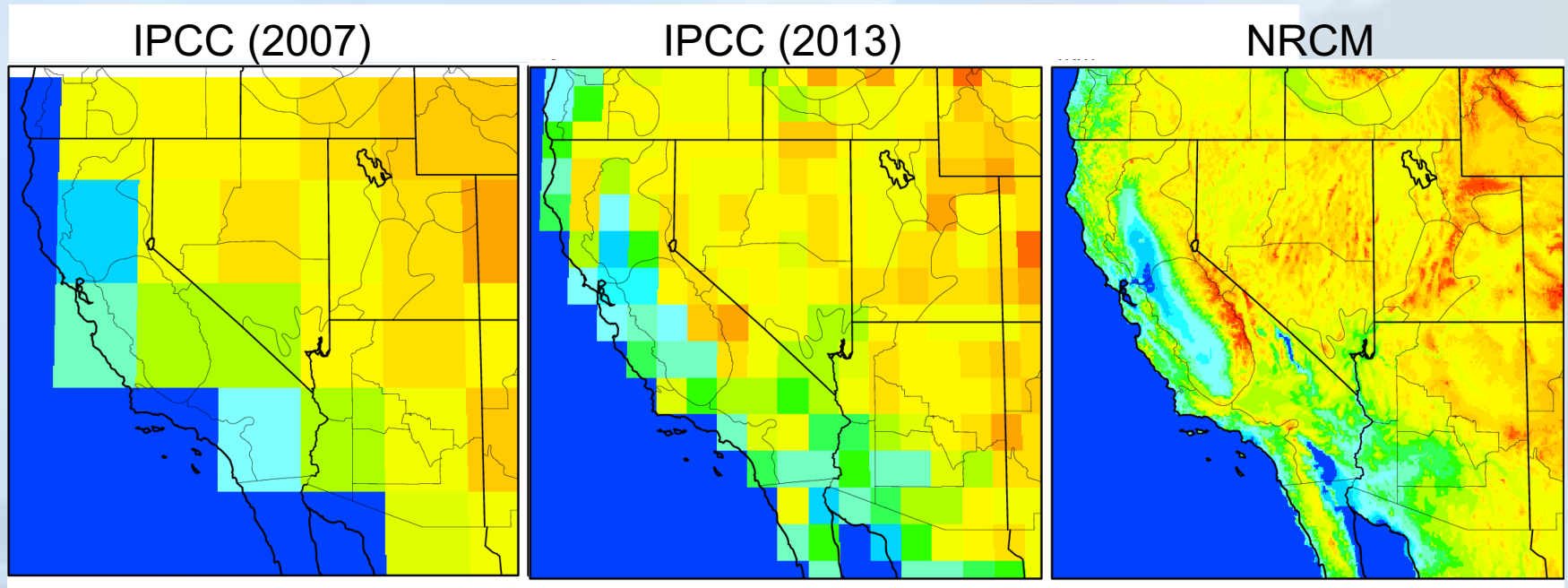
Importance of Resolution
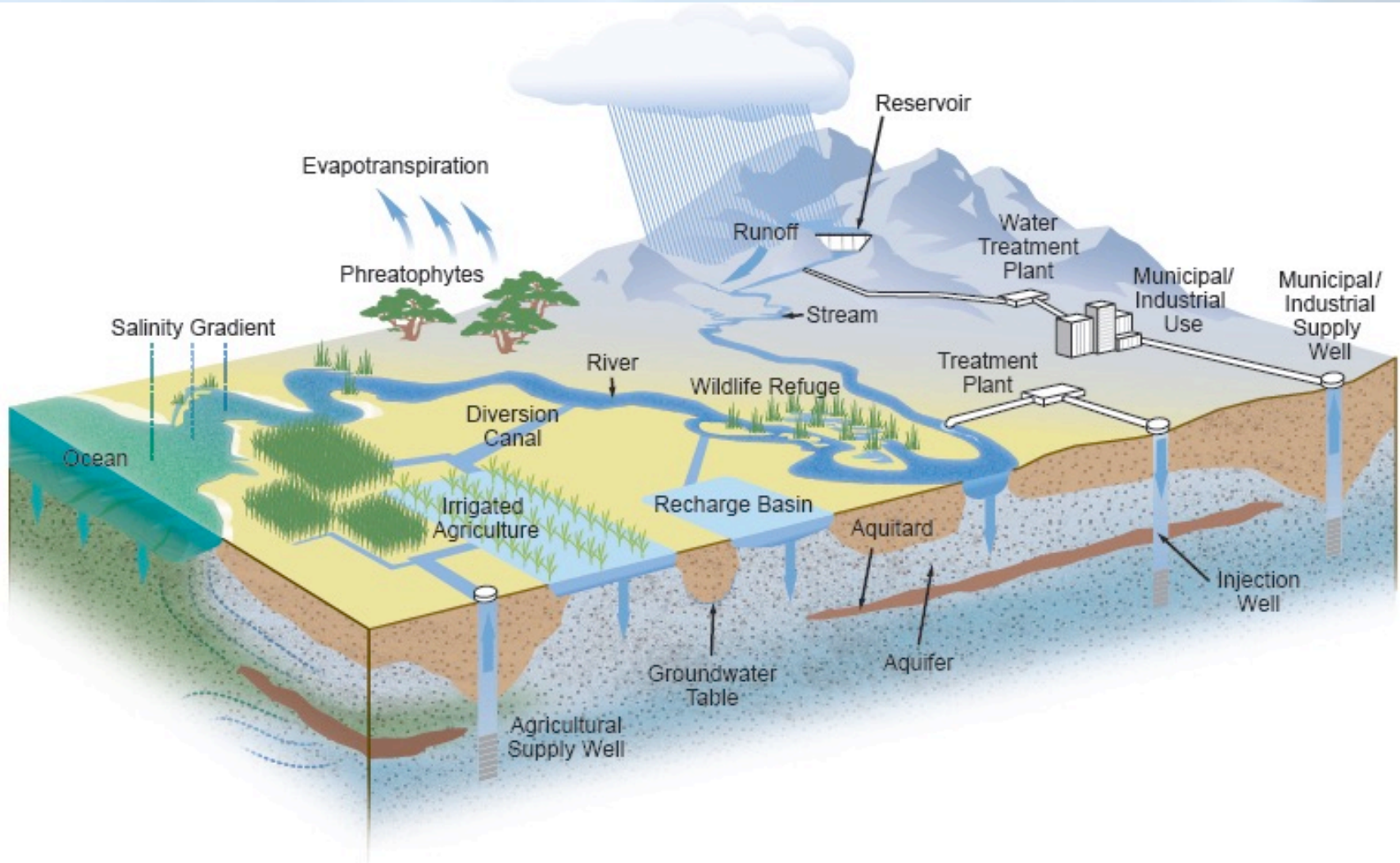
NRCM 36km 2005
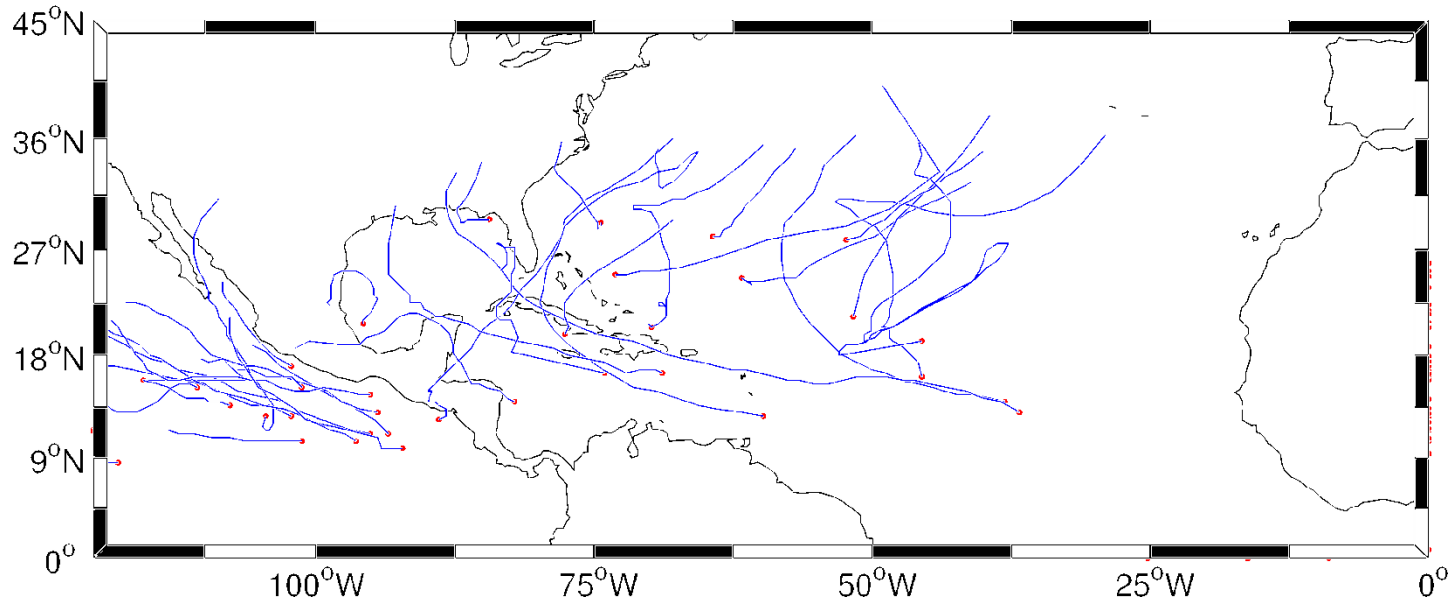
18 storms

NRCM Nested 12km 2005


25 storms

Hurrell / Holland

# Water Planning Need: Ability to model interactions across physical and management systems

High Resolution, Regional Climate Modeling

- V3.4.1 WRF model with a 4-km-spacing domain of *1360x1016x51* points

- Physics parameterizations:

  1. Thompson aerosol-aware microphysics
  2. Noah-MP LSM
  3. YSU PBL
  4. RRTMG radiation

- Use of spectral nudging

- Novel method for devising forcing from CMIP5 projections

  - CMIP5 (19) model ensemble mean climate
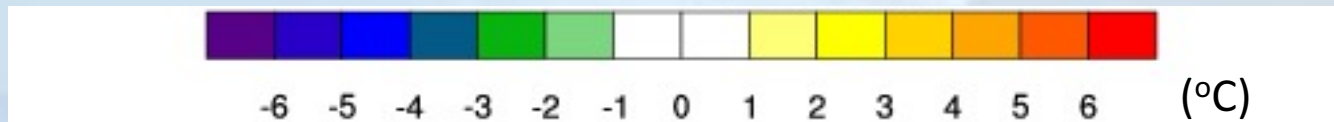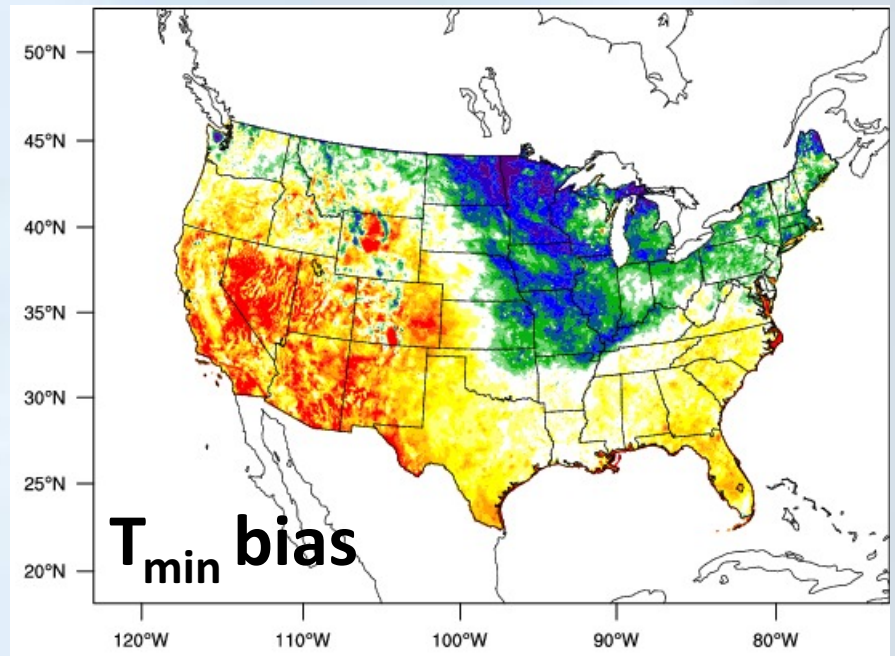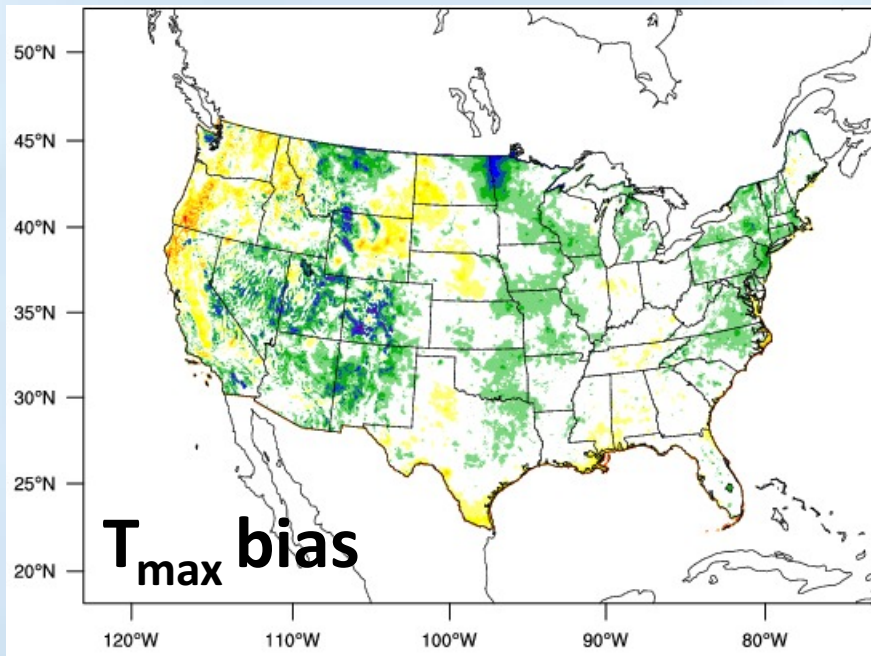 - eliminate natural variations

WRF Model Domain

Headwaters Project
WRF Domain
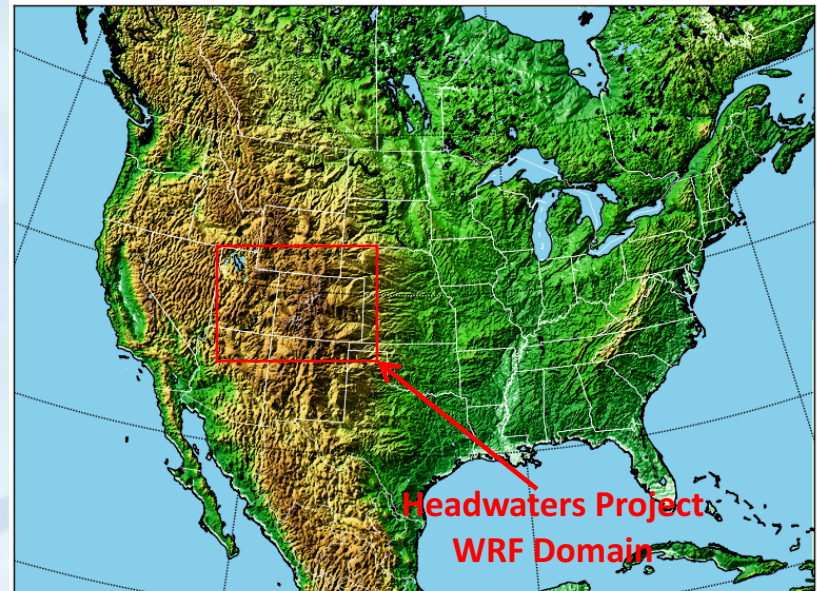
Winter cold biases from test runs Compared to PRISM observations
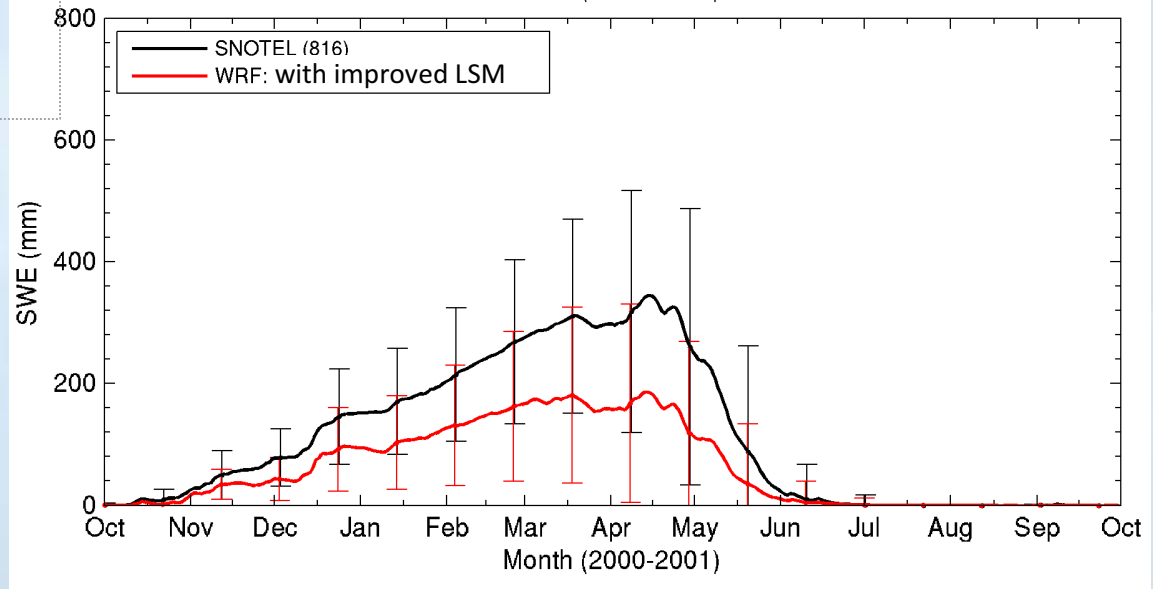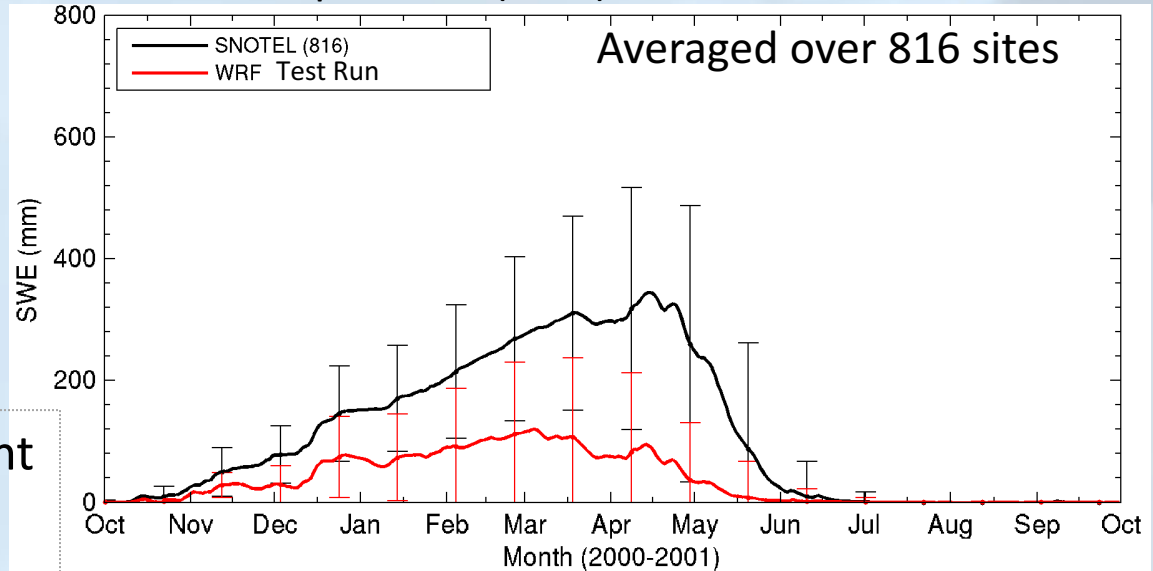

T$_{max}$ bias

T$_{min}$ bias
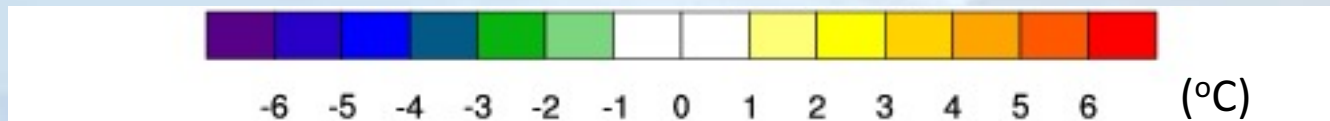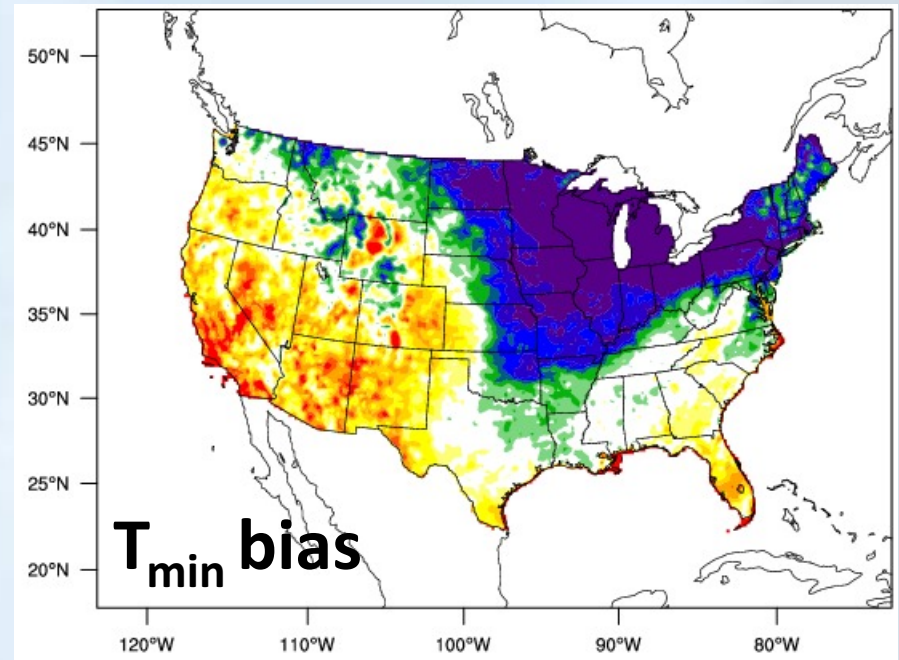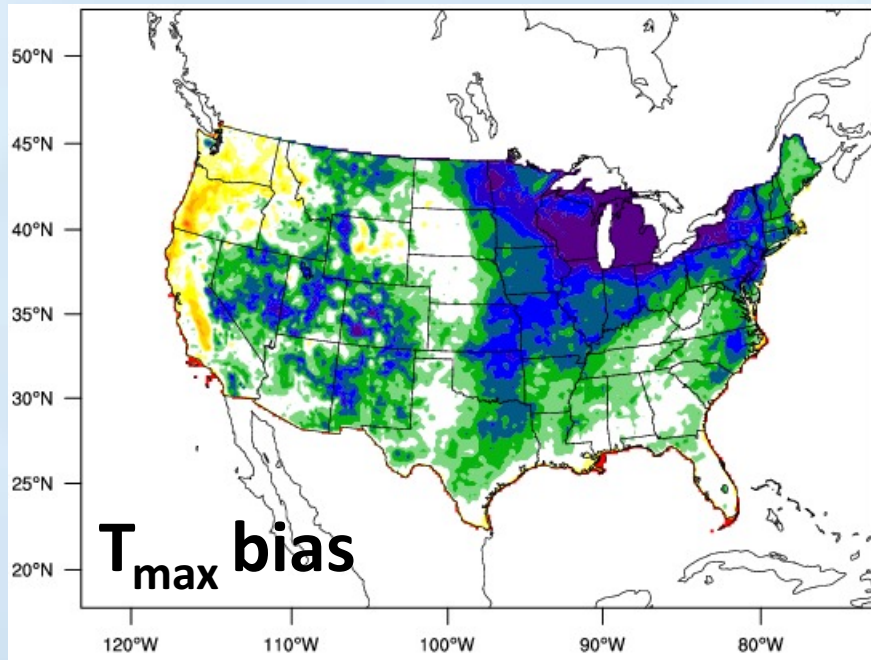
December 2000

Results after LSM improvement
(vegetation-dependent snow fraction/melt curves)

T_{max} bias

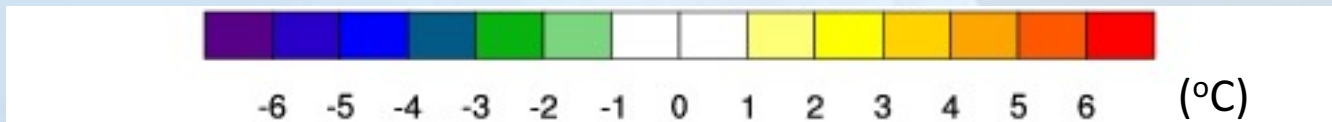T_{min} bias
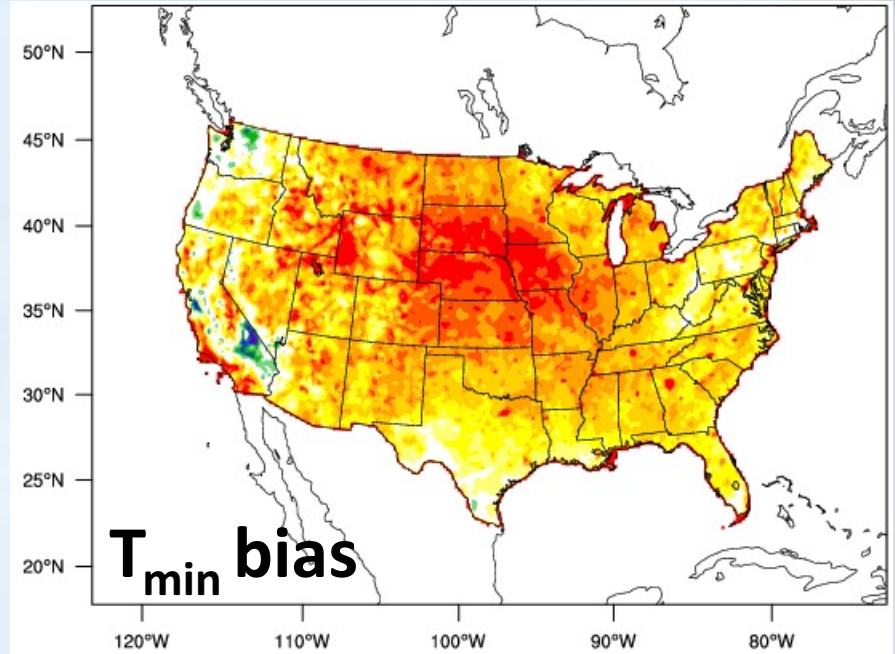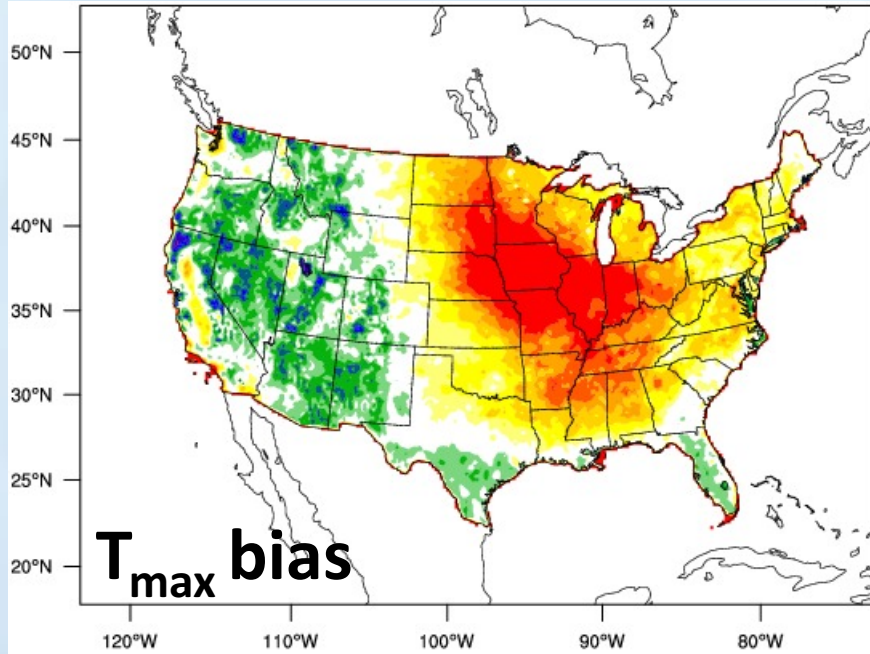
(°C)

December 2000

SWE underprediction from test runs

Snow Water Equivalent (SWE) at SNOTEL sites : 2000-2001

- capability for snow being present at above 0ºC
- microphysics-based rain-snow partitioning

Averaged over 816 sites

Summer warm biases from test runs

T_max bias T_min bias

(°C)

August 2001

WaterRF January 2017

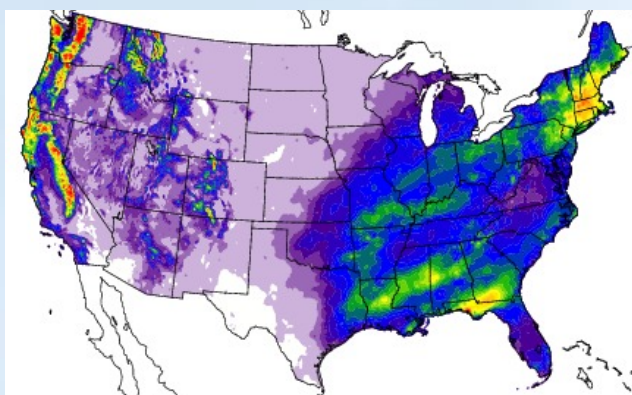# Results with spectral nudging plus optimal selection of physics options in LSM

T_{max} bias

T_{min} bias

(°C)
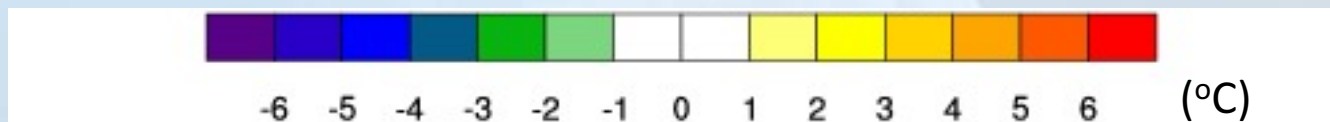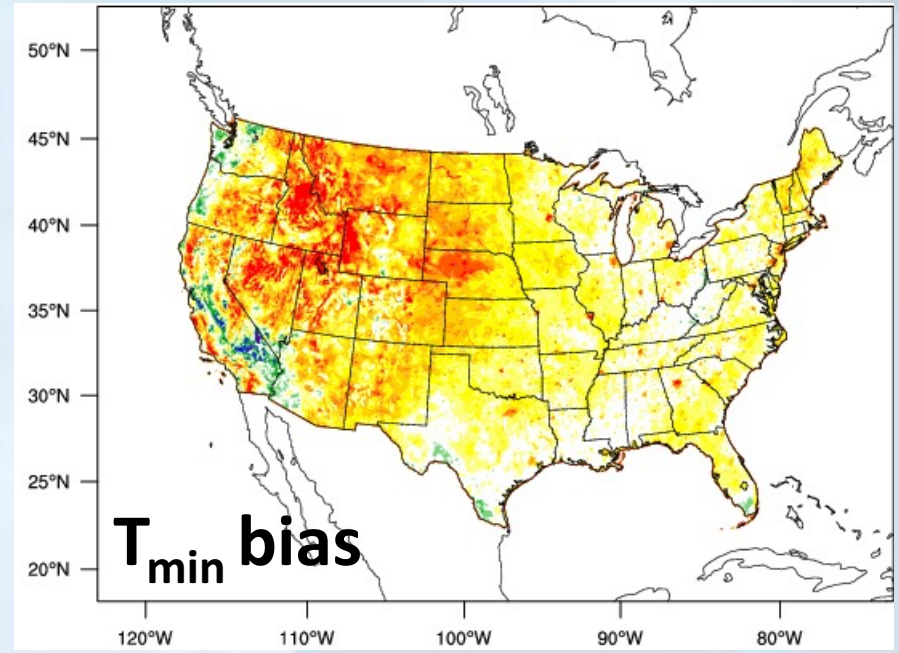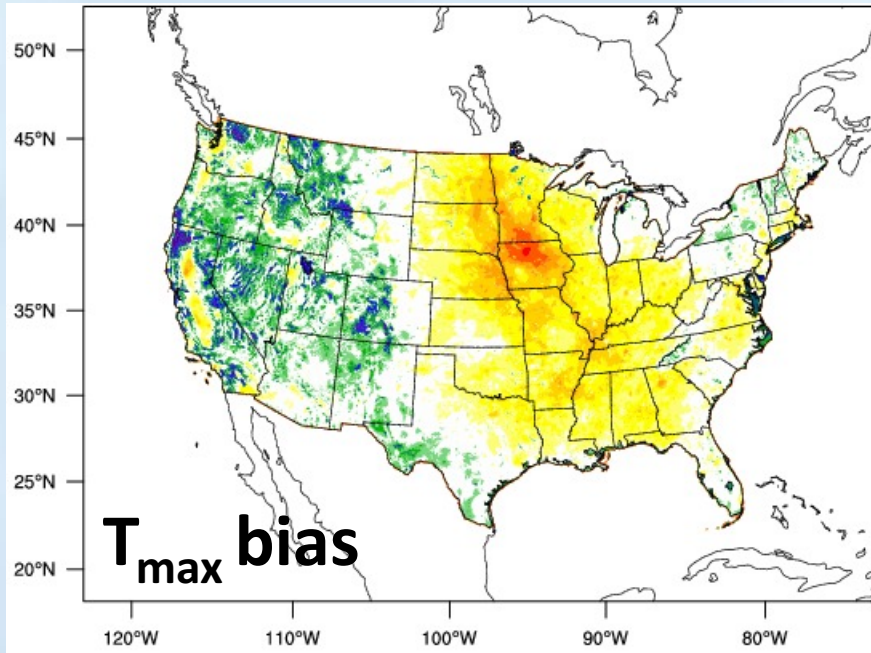
August 2001

2008
January
February
March
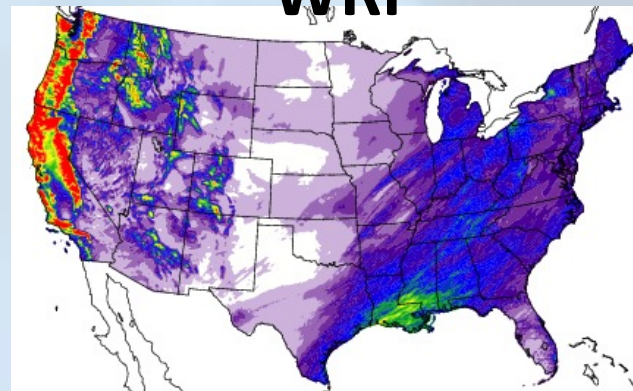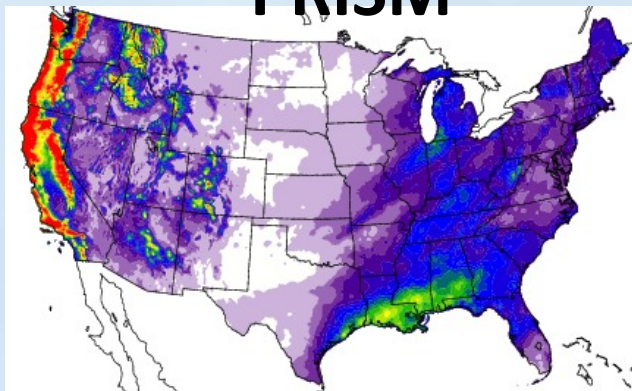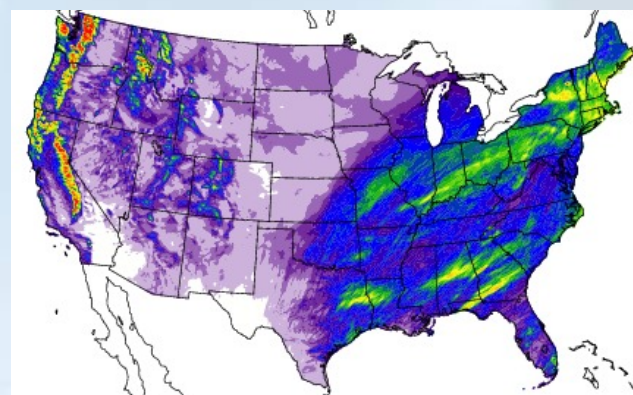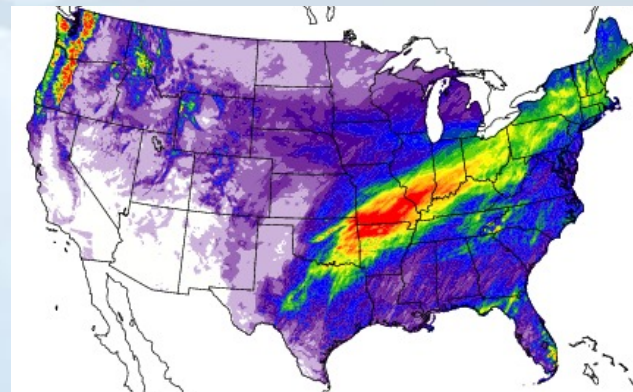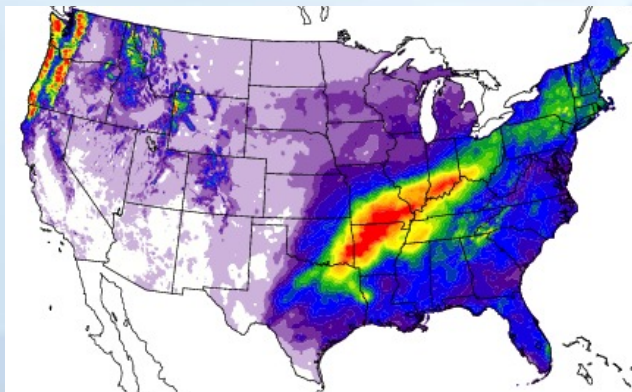
PRISM   WRF

.1   1.1   2.1   3.1   4.1   5.1   6.1   7.1   8.1   9.1   10   (mm/day)

2008

PRISM **WRF**

April

May
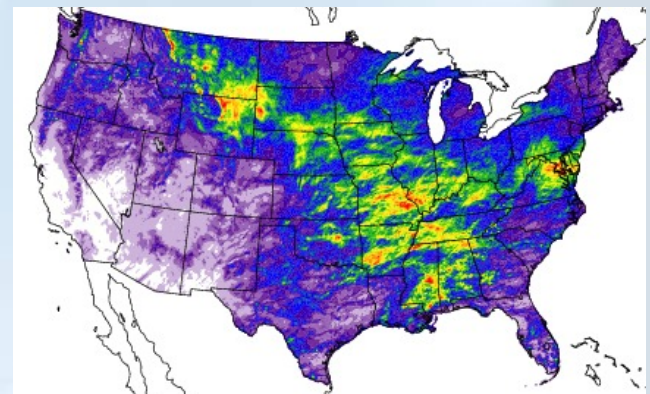
June

.1 1.1 2.1 3.1 4.1 5.1 6.1 7.1 8.1 9.1 10 (mm/day)

2008

July
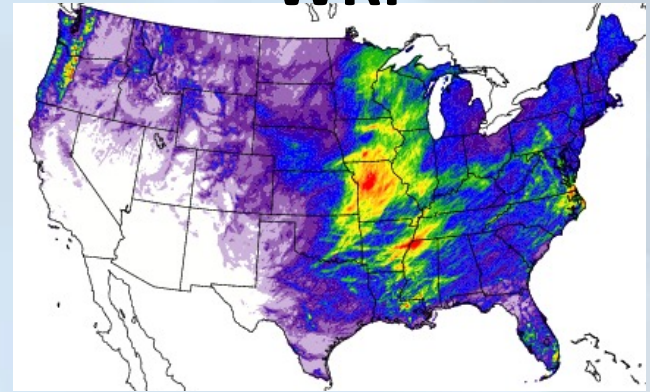
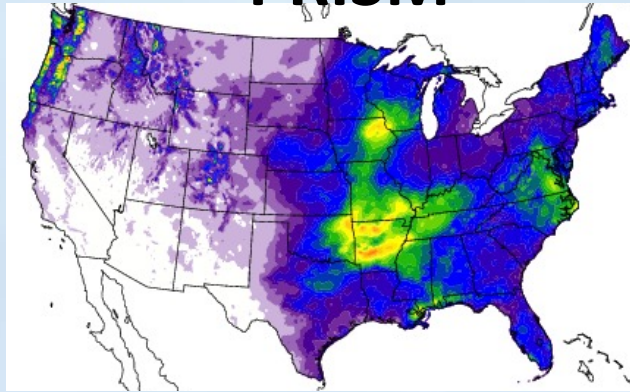**August**

September

PRISM

WRF
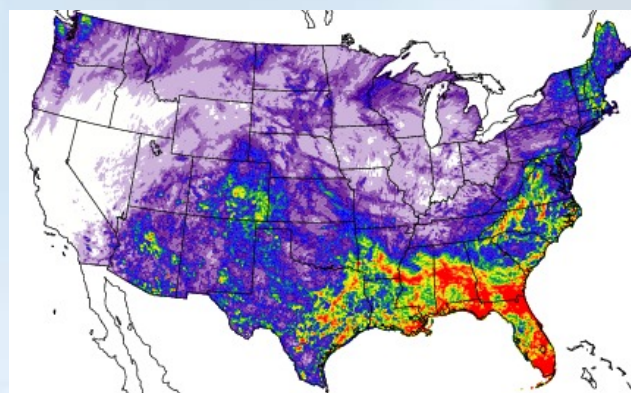
.1 1.1 2.1 3.1 4.1 5.1 6.1 7.1 8.1 9.1 10 (mm/day)

2008

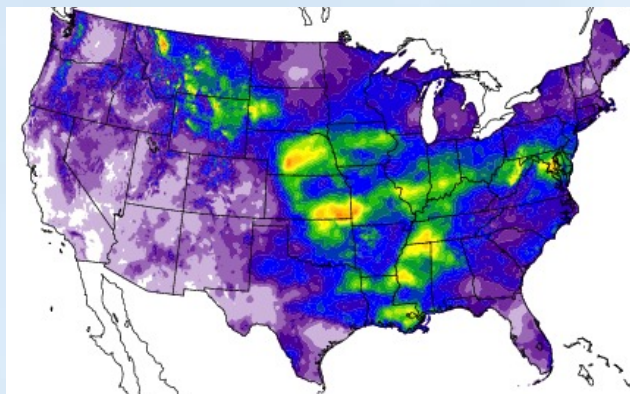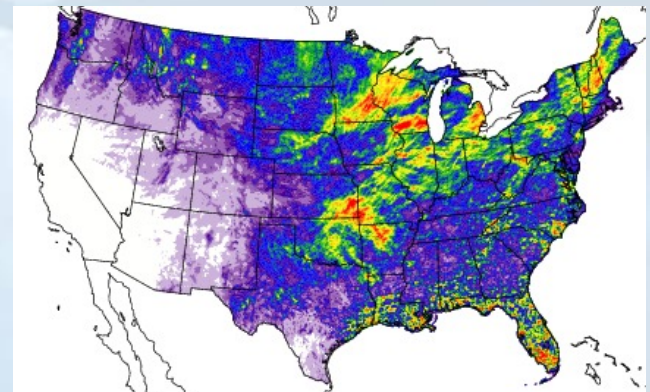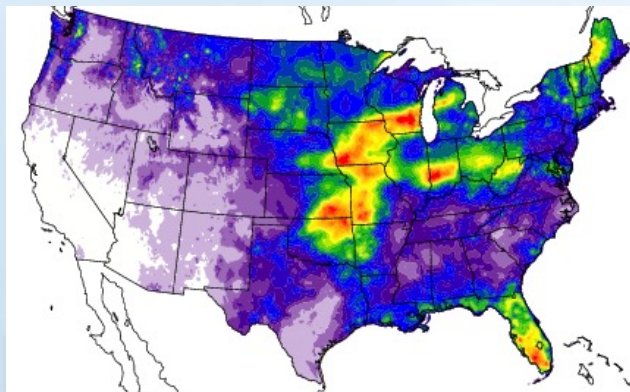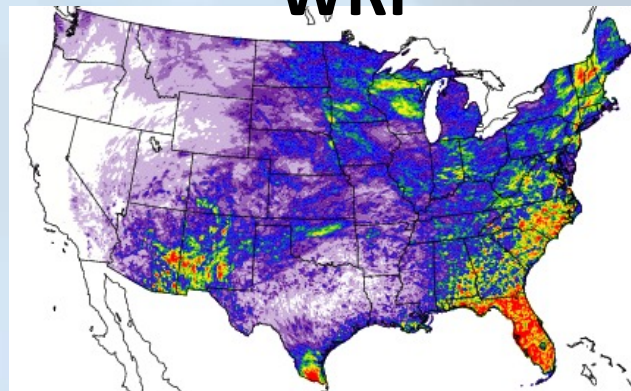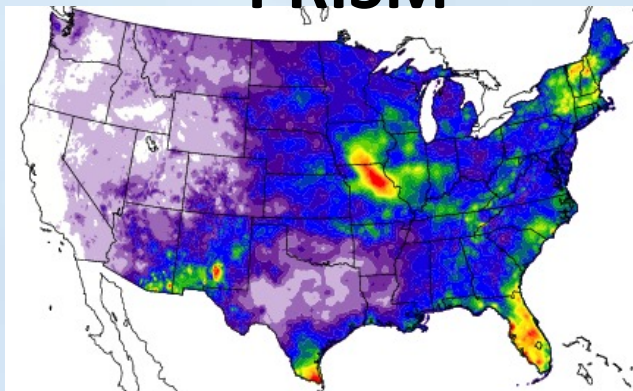PRISM   WRF

October
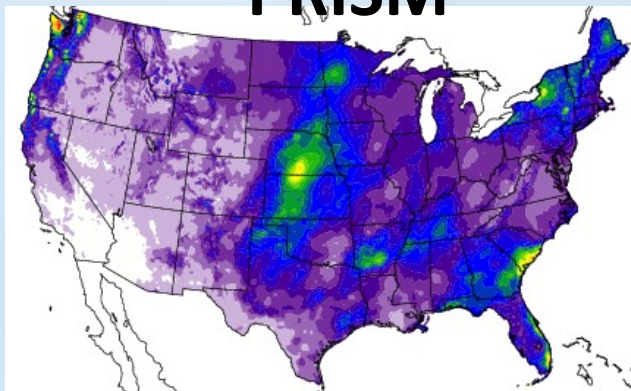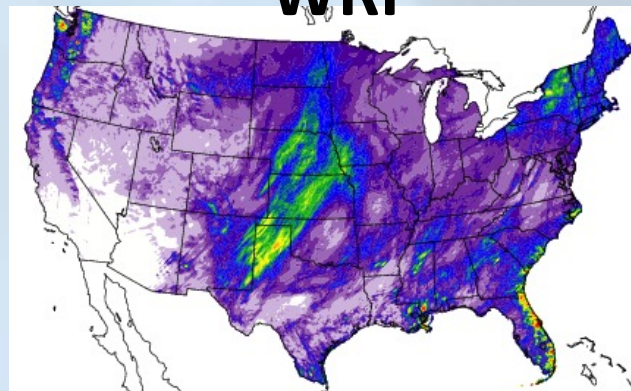
November
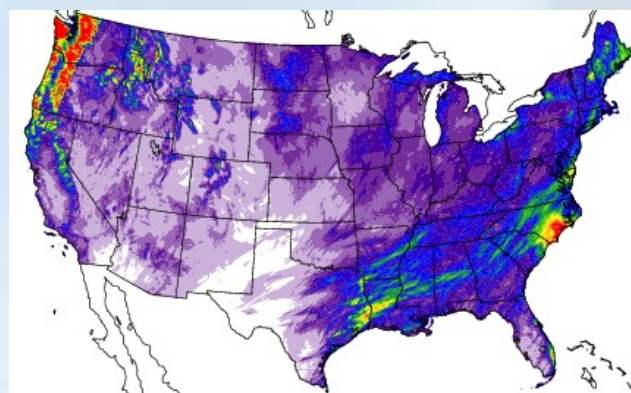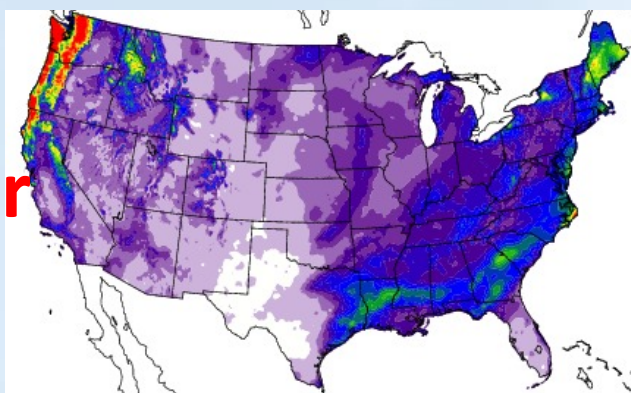
December
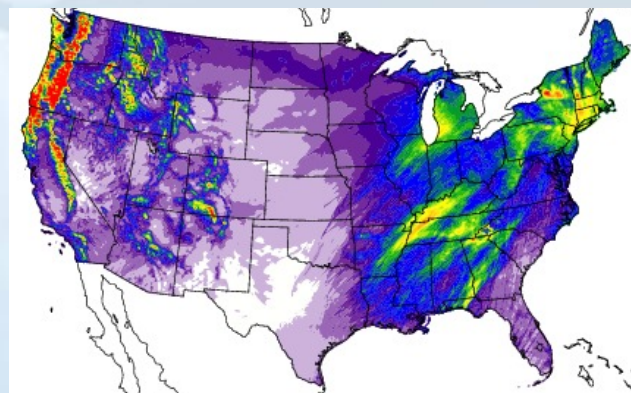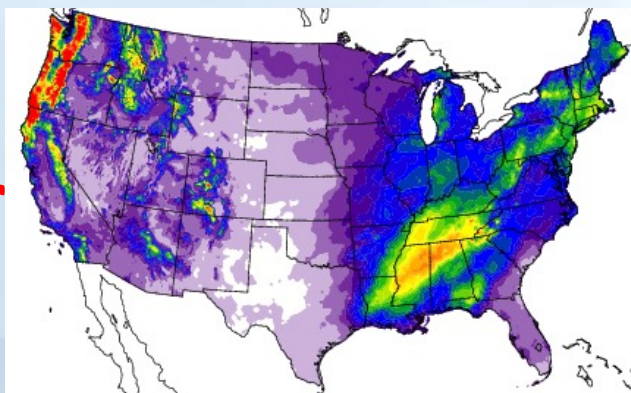
.1 1.1 2.1 3.1 4.1 5.1 6.1 7.1 8.1 9.1 10   (mm/day)

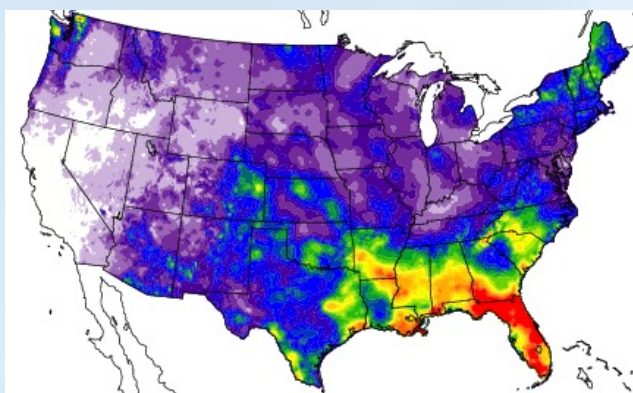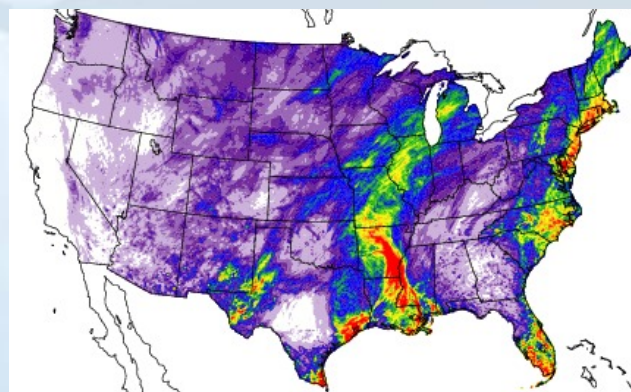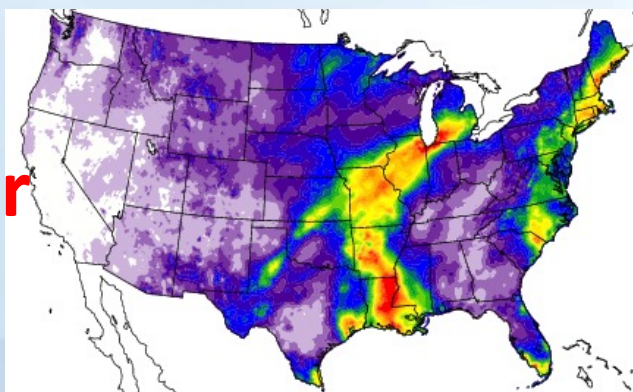# An Example of the Co-Production of Climate Information and Application

Water Interests	Support Agencies	Additional Interest
Aurora Water	Water Research Foundation	Cheyenne Board of Public Utilities, WY
City of Boulder	Western Water Assessment	City of Longmont
Colorado Springs Utilities	Riverside Technology, inc.	City of Westminster
Denver Water	NCAR	Others Welcome
City of Fort Collins		
Northern Water		
Colorado Water Conservation Board		
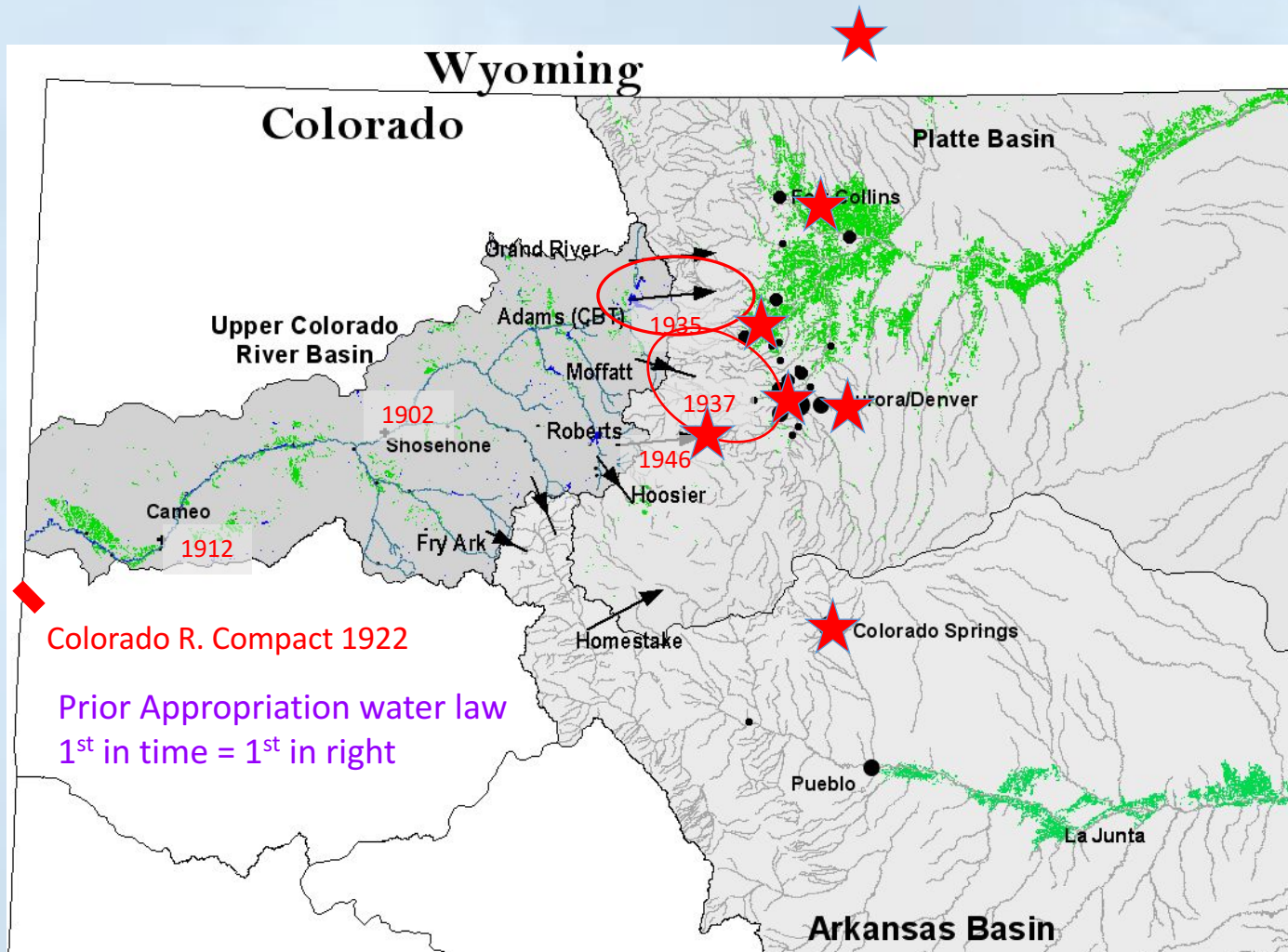
Wyoming

Colorado

Platte Basin

Grand River

Upper Colorado
River Basin

Adam's (CBT)

Moffatt

1935

1902

Shosenone

Roberts

1937

Aurora/Denver

1946

Cameo

1912

Fry Ark

Hoosier

Homestake

Colorado Springs

Colorado R. Compact 1922

Prior Appropriation water law
1st in time = 1st in right

Pueblo

La Junta

Arkansas Basin

Traditional Predict then Plan

Present   Future
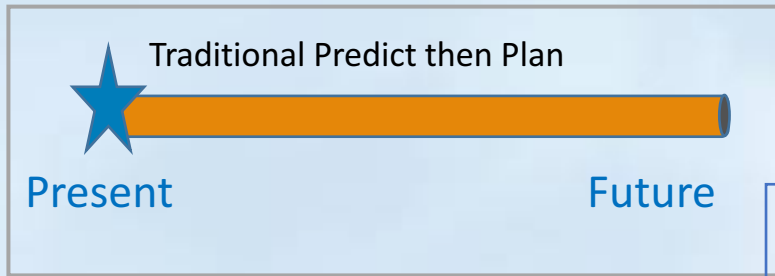
2002: Unprecedented Simultaneous Natural Disasters

Precipitation Change (%)

30 %
20 %
10 %
%
-10 %
-20 %

1° 2° 3° 4° 5° 6° 7° 8° 9° 10°

Temperature Change (Fahrenheit)

NCAR
NATIONAL CENTER FOR ATMOSPHERIC RESEARCH
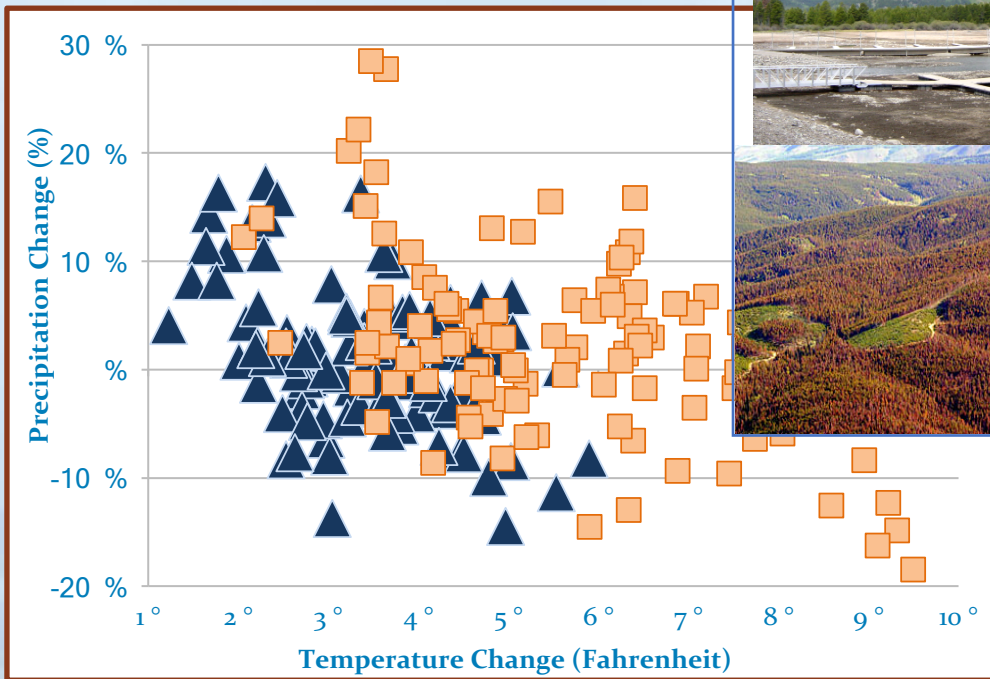
5° F Warming Means	
Reduced Supply	22%
Increased Demand	7%
Additional precipitation needed to offset warming	**10%**

The Cone of Uncertainty
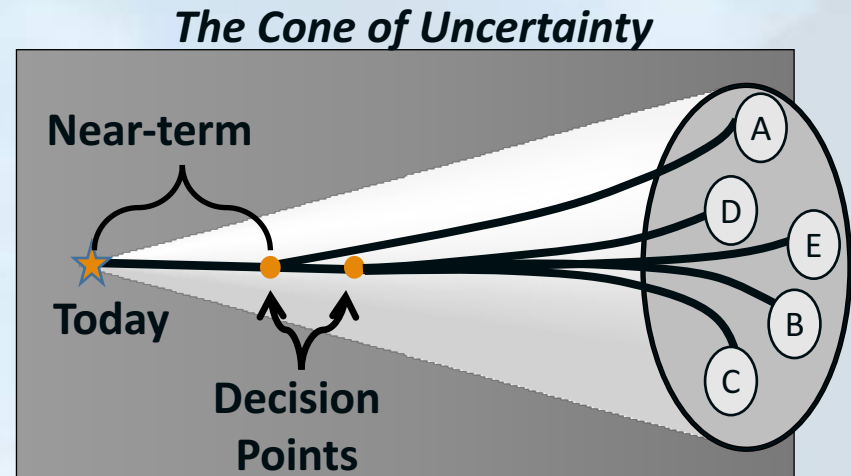
- New planning techniques - multiple futures
- Understanding - uncertainty and science for applications
- Adaptive planning - identifying and preserving options
- Mainstreaming new culture into organization-wide decisions

Questions?

WPB
WEST PALM BEACH