Modeling the Climate

and Projections of Future Climate Change

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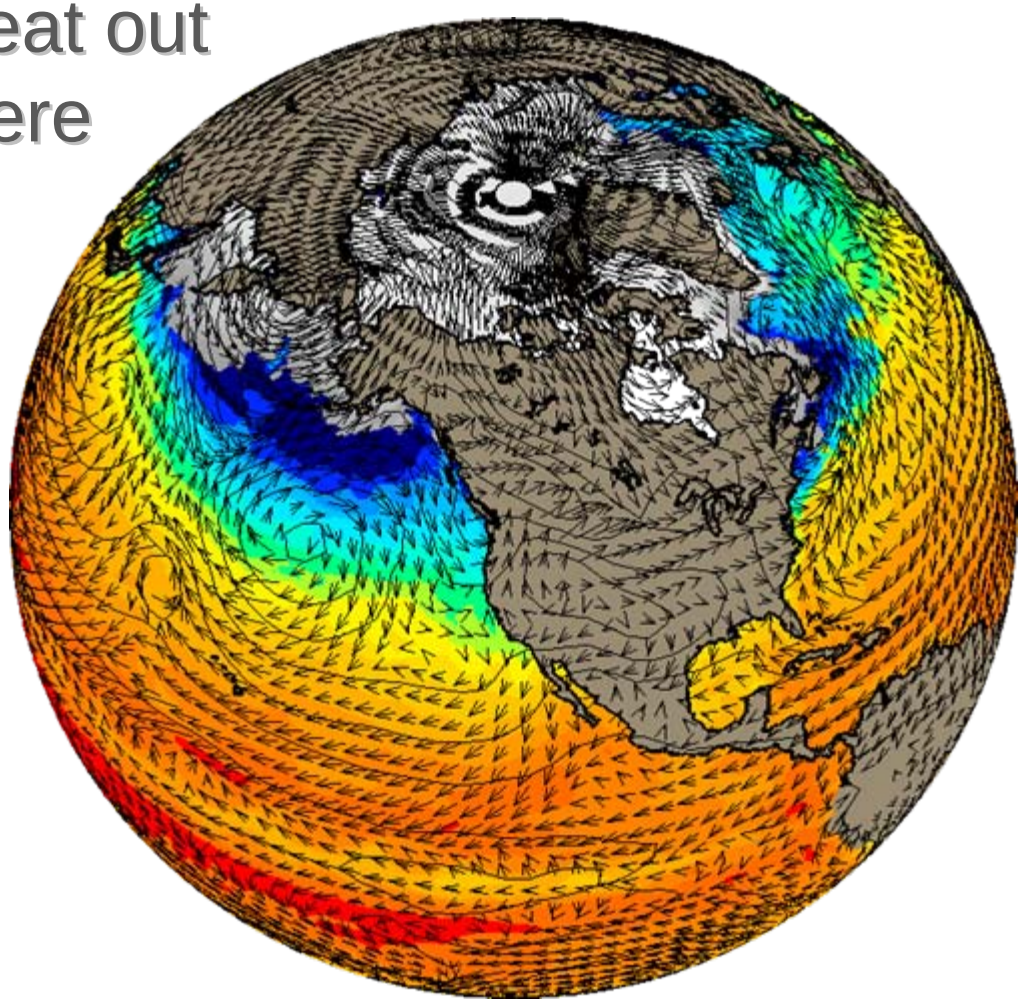
Important Goals for a Productive Dialogue

- Introduction to climate models, examples of how they reproduce the climate system, what we can learn from them about processes and feedbacks, but also what uncertainties we need to keep in mind (dependent on spatial scales: global, continental, regional, local)

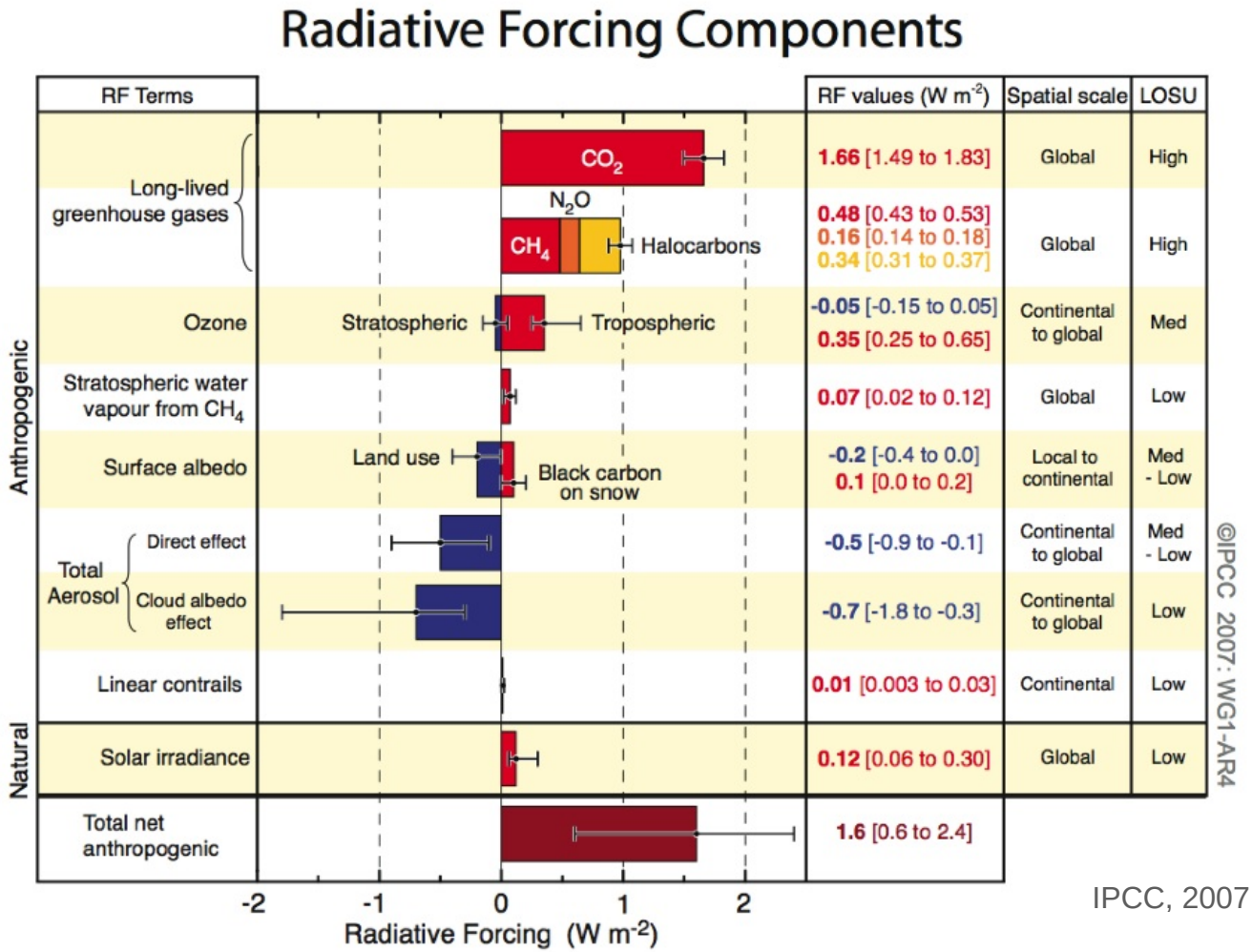
- Models are not necessarily for detection and attribution of Global Warming, but a tool to study and understand processes in a complex system

The mission of the “climate system”

move the excess heat out of the tropics to where it’s colder so the heat can radiate to space



20th Century Forcings



IPCC, 2007

Humans and greenhouse gases

Carbon Dioxide (CO_2) an

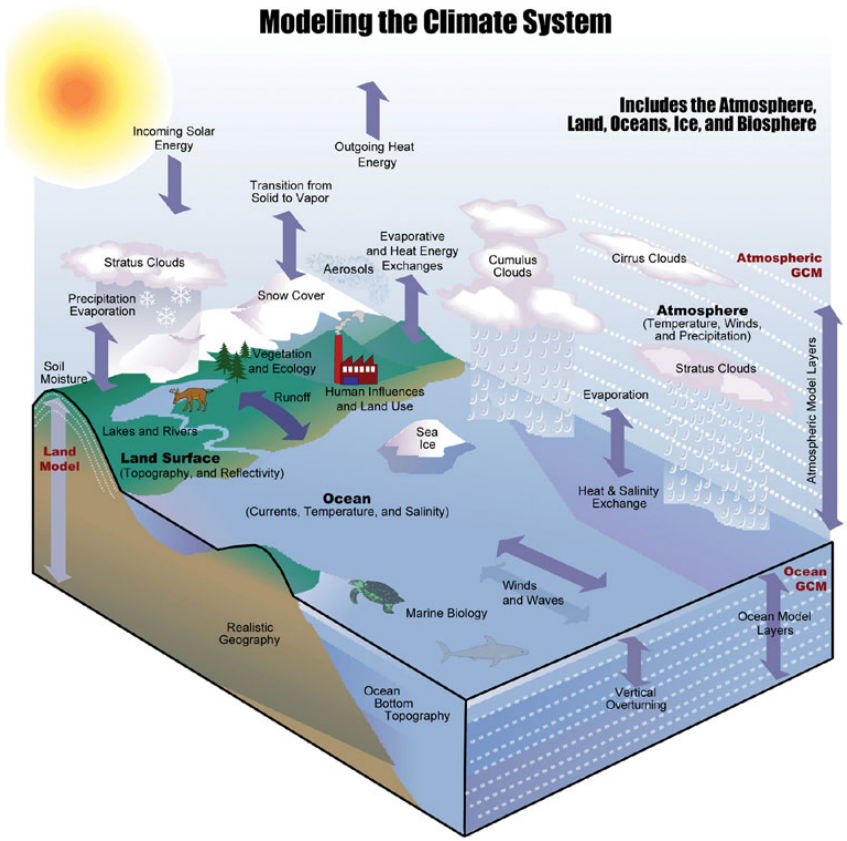
Now:

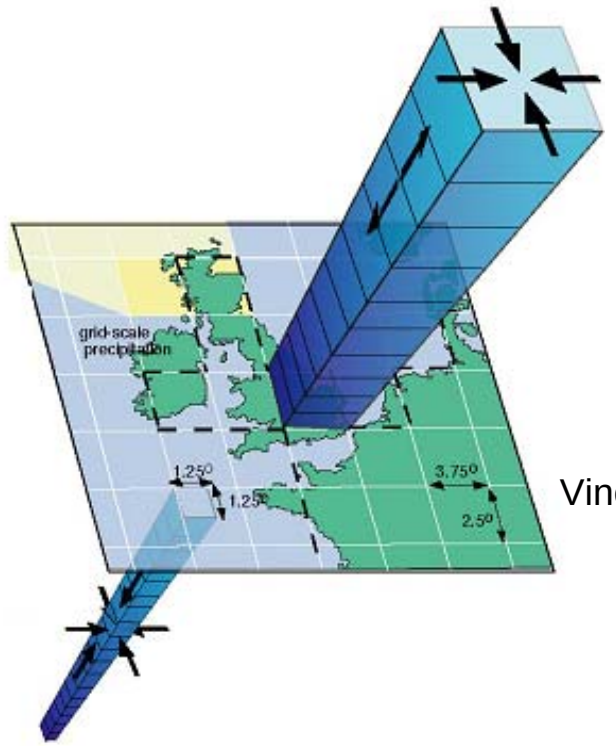
concentrations mu

range over past 40

The "Smoking-Gun" Atmospheric CO_2 concentrations are higher than they have been for 400 thousand years!!

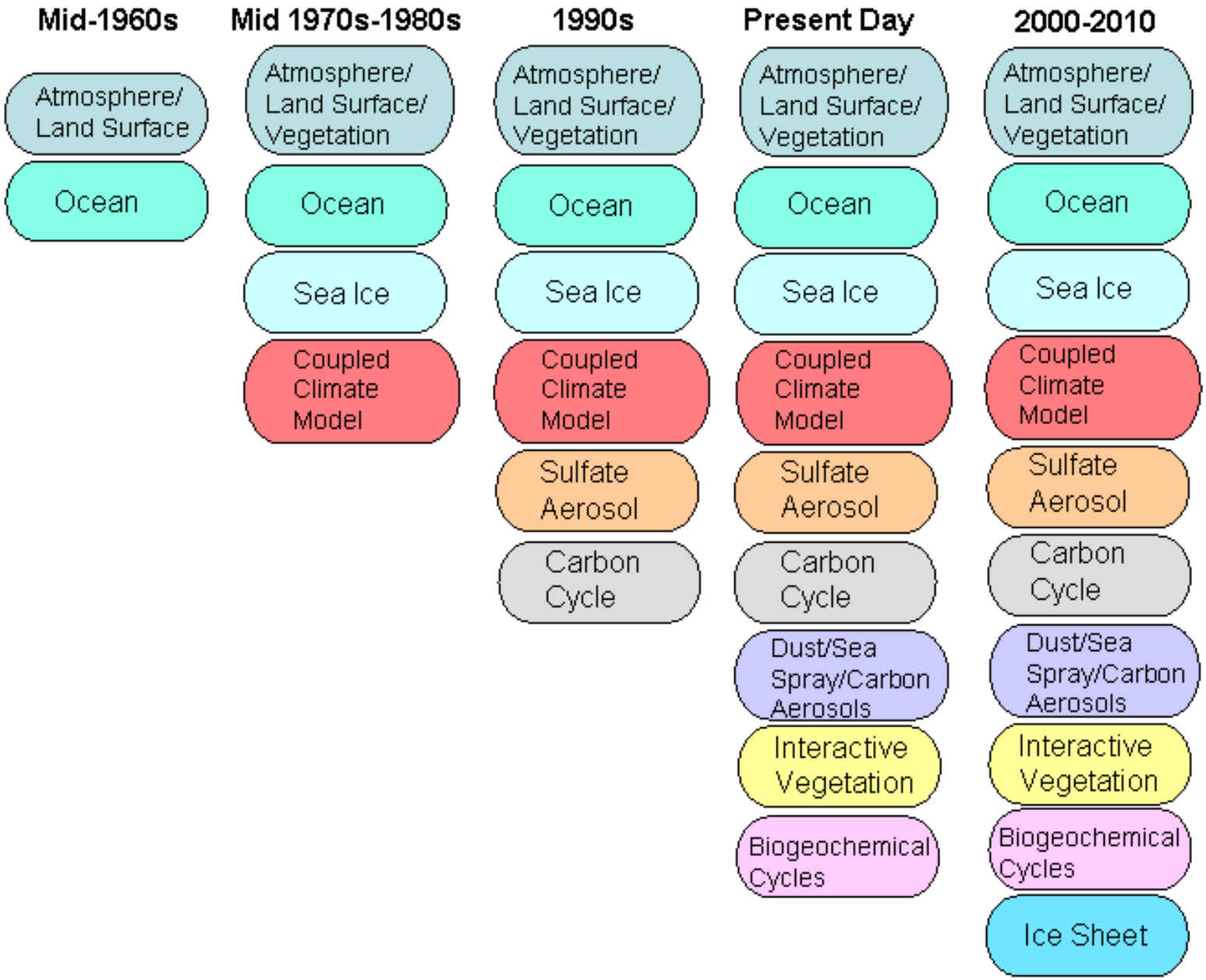
What are climate models?



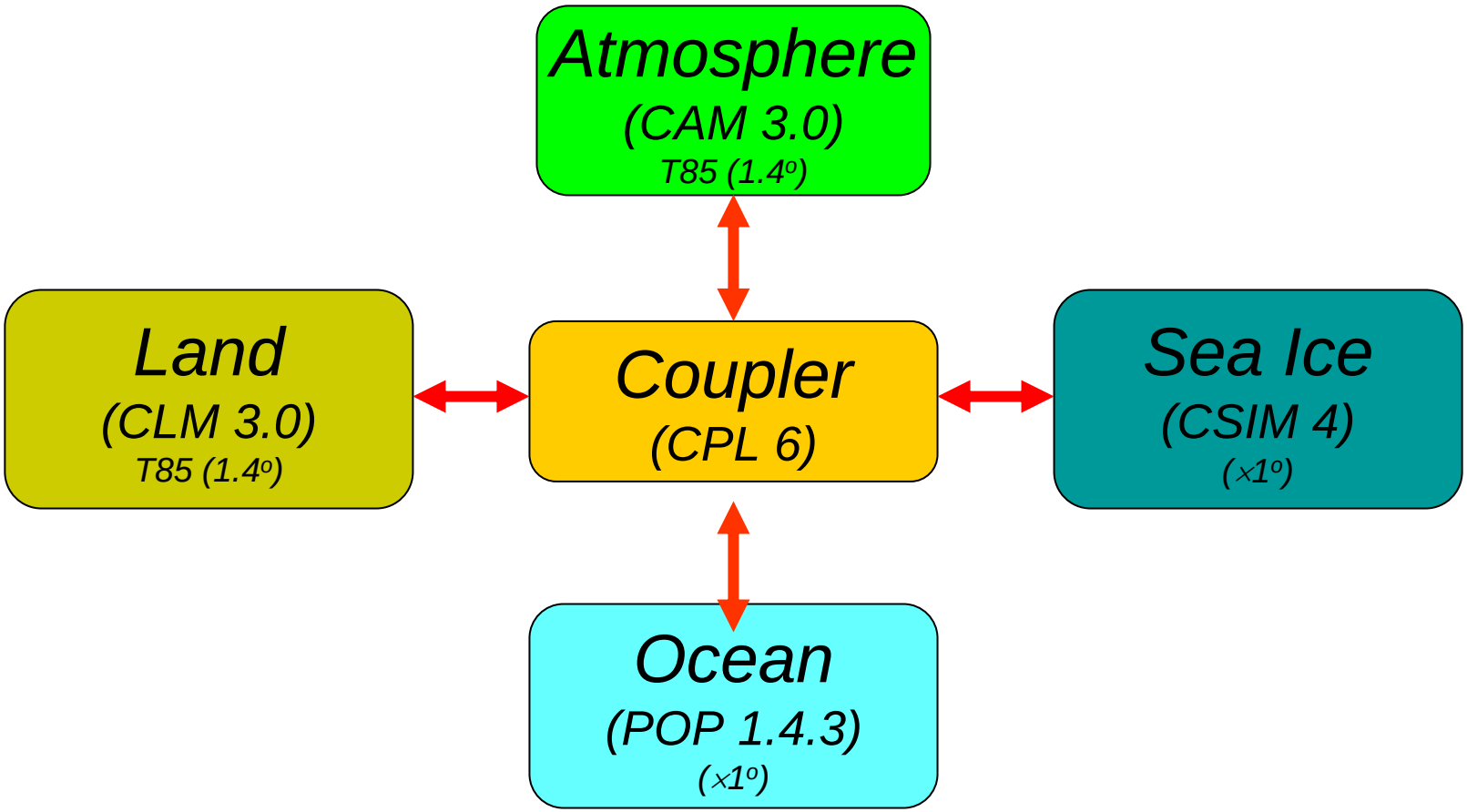


Viner (2002)

Timeline of Climate Model Development



Configuration of NCAR CCSM3



Modern Climate Model Implementations

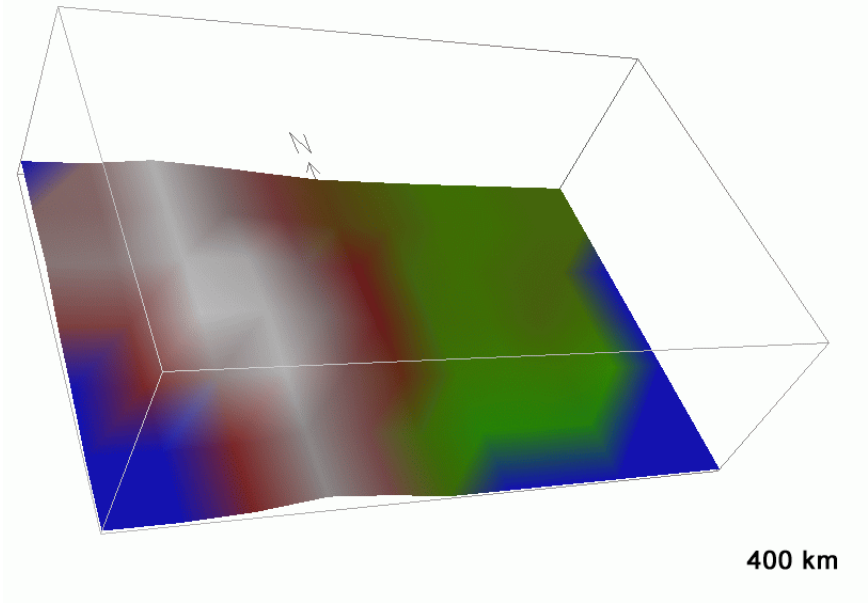
NCAR's Blueice Supercomputer:

- 1600 Processors
- Peak speed: 12 Teraflops

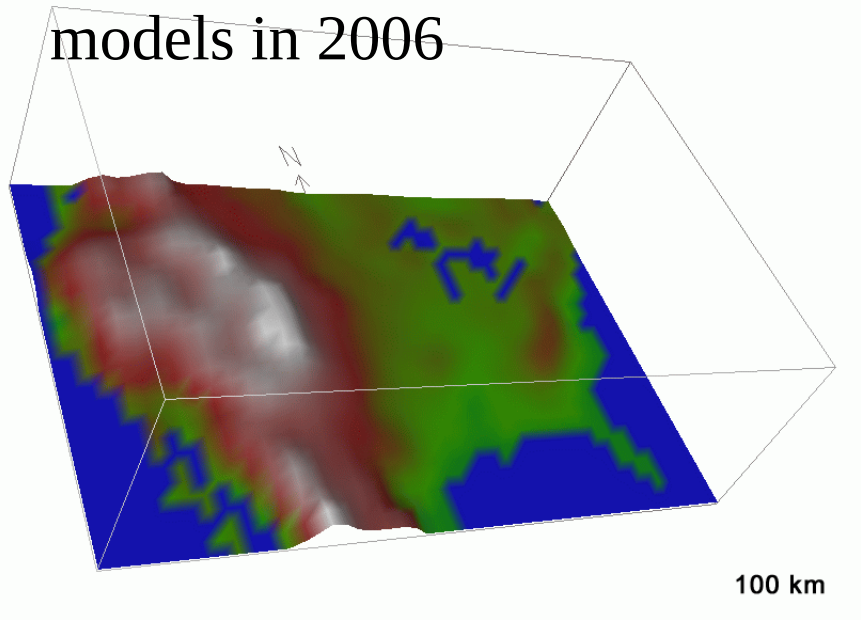
Characteristics of NCAR CCSM3:

- ~1 quadrillion operations/simulated year
- Rate of simulation: 3.5 sim. years/day
- Output: 10 GB/simulated year
- Data volume for IPCC: ~150 TB
- Development effort: ~1 person-century

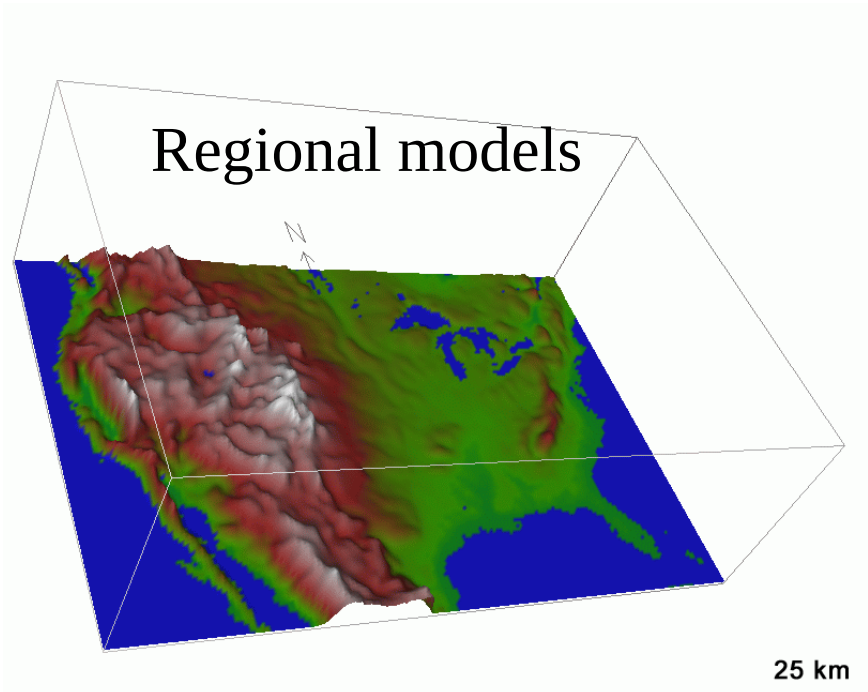
Climate Models circa early 1990s



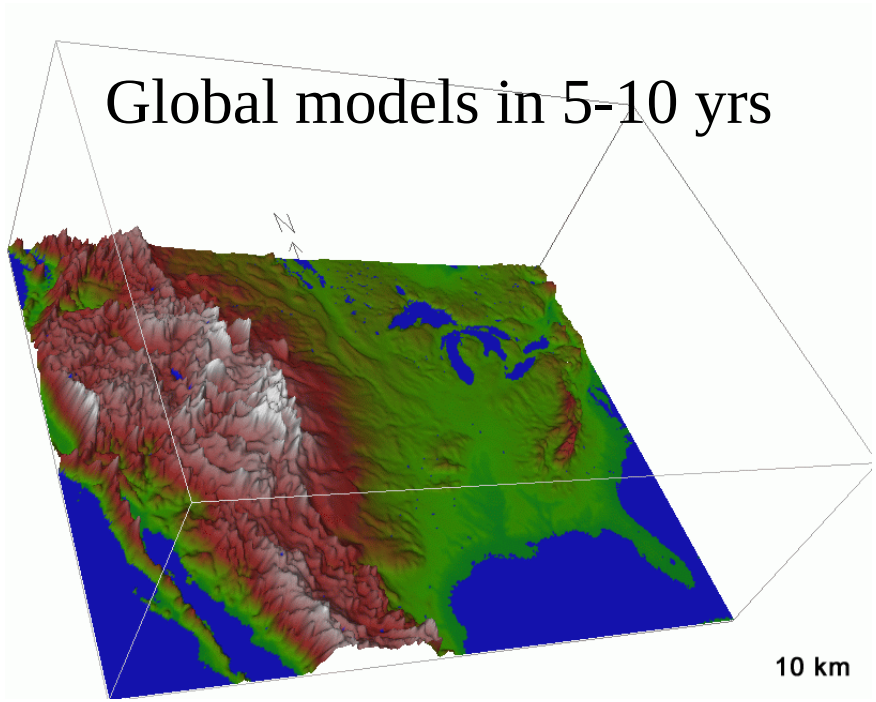
Global coupled climate models in 2006



Regional models

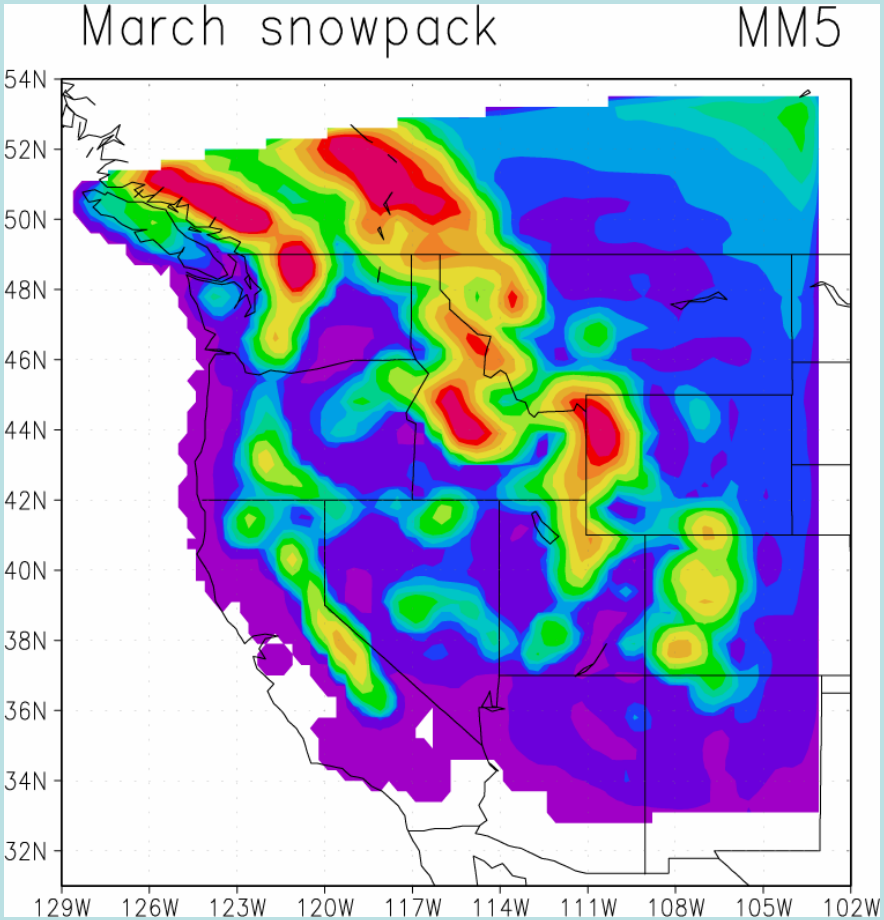


Global models in 5-10 yrs

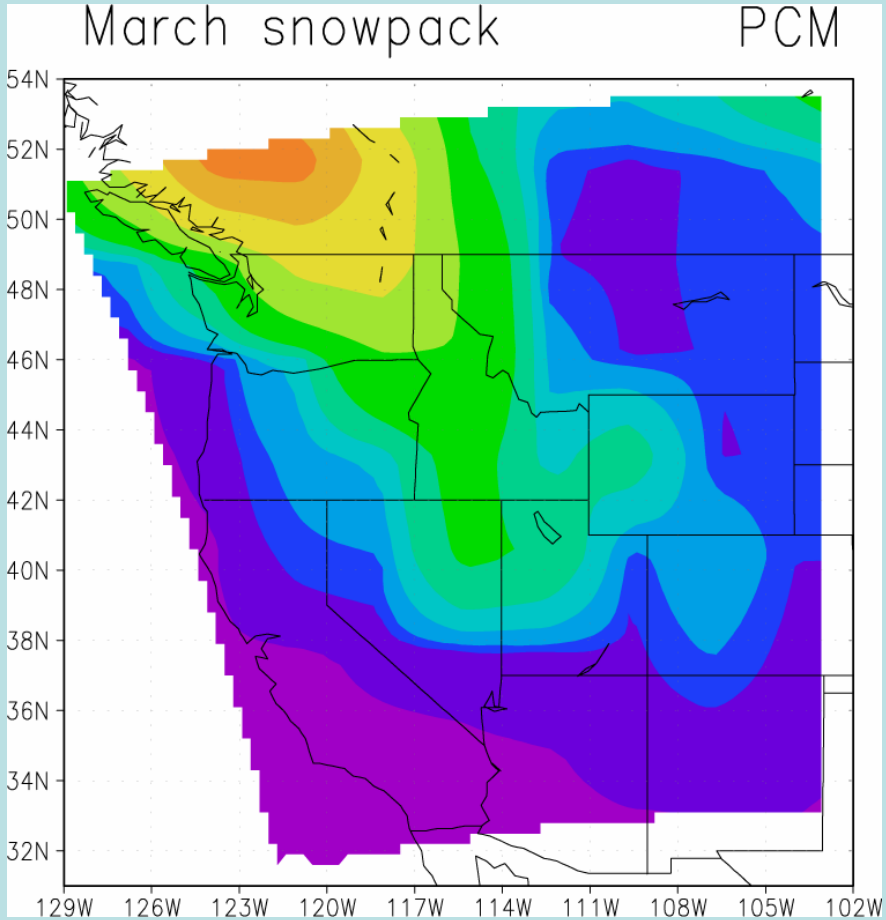


Global / Regional Simulations of Snowpack

Regional Simulation



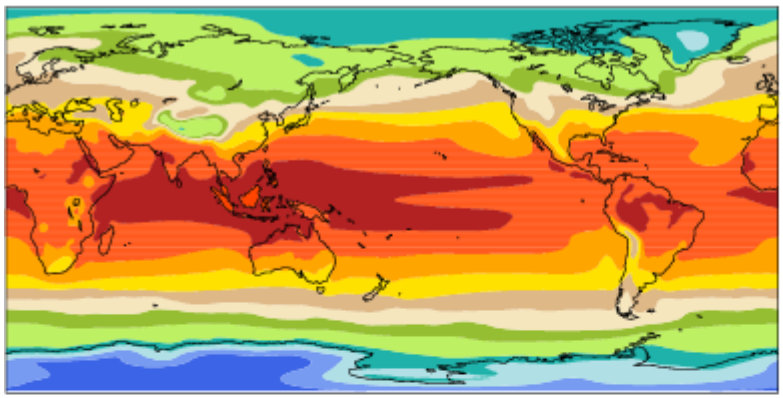
Global Simulation



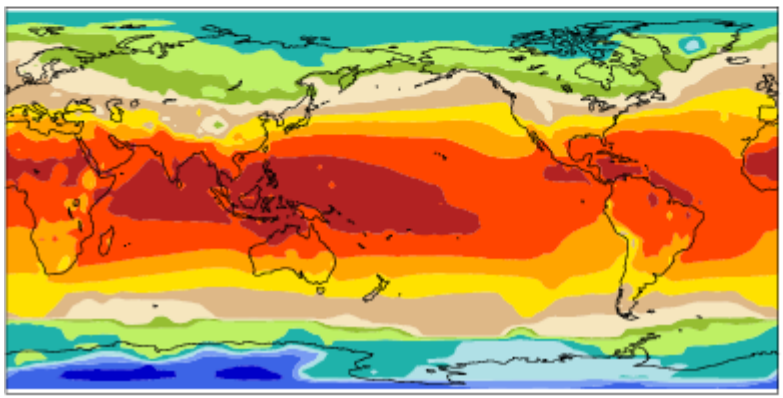
Performance of CCSM-3

Surface Air Temperature

Model

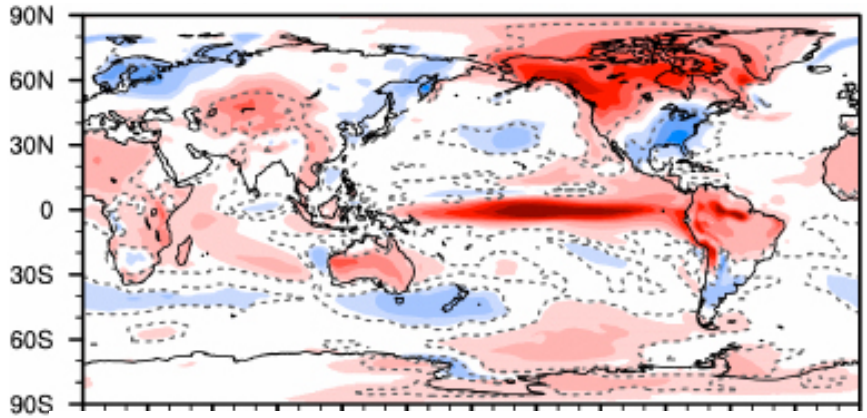


Observations

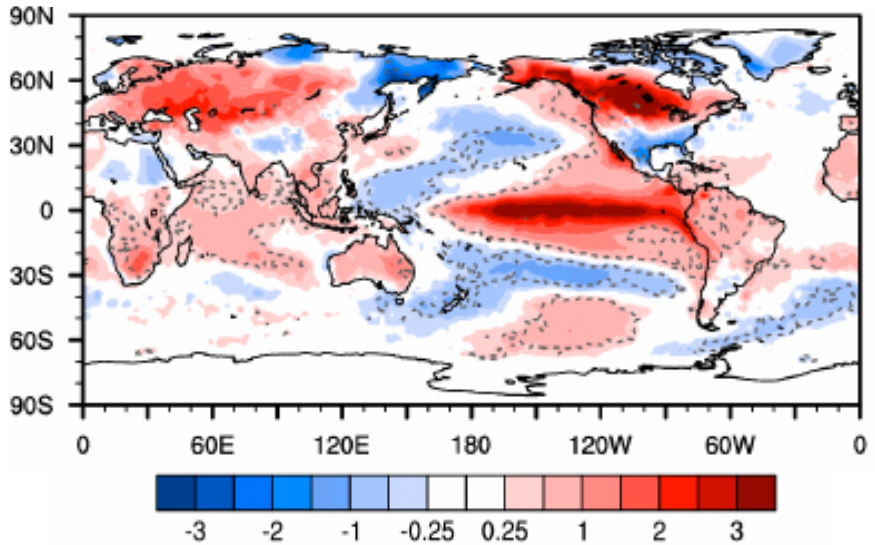


El Niño-Variability

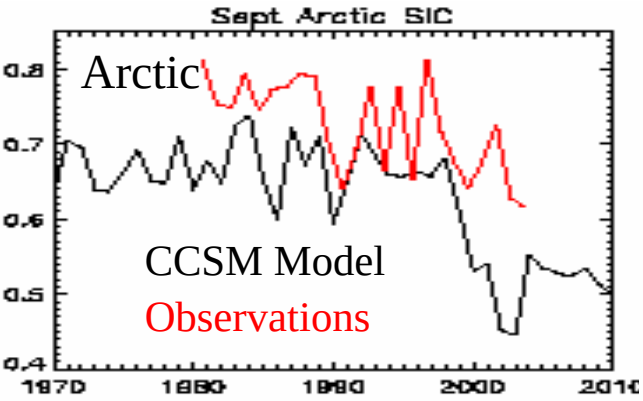
Model

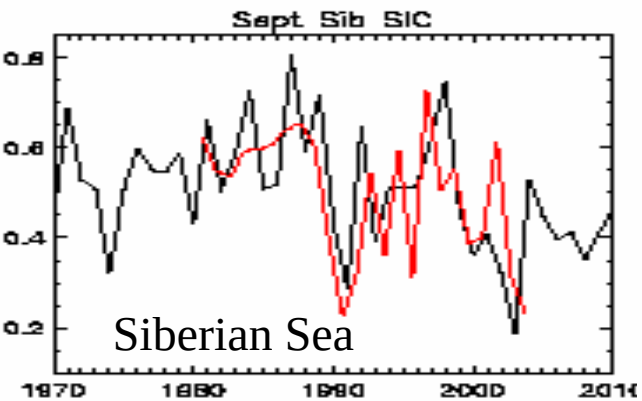


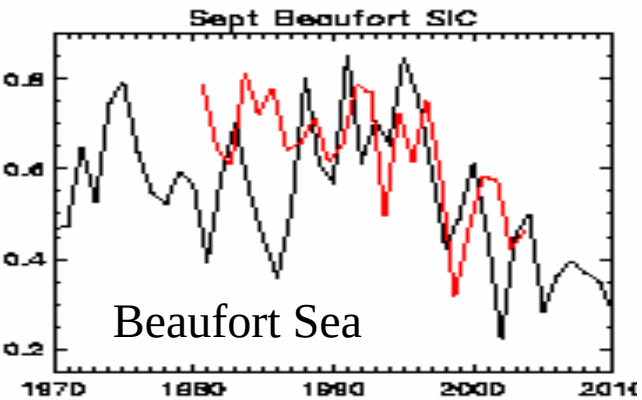
Observations

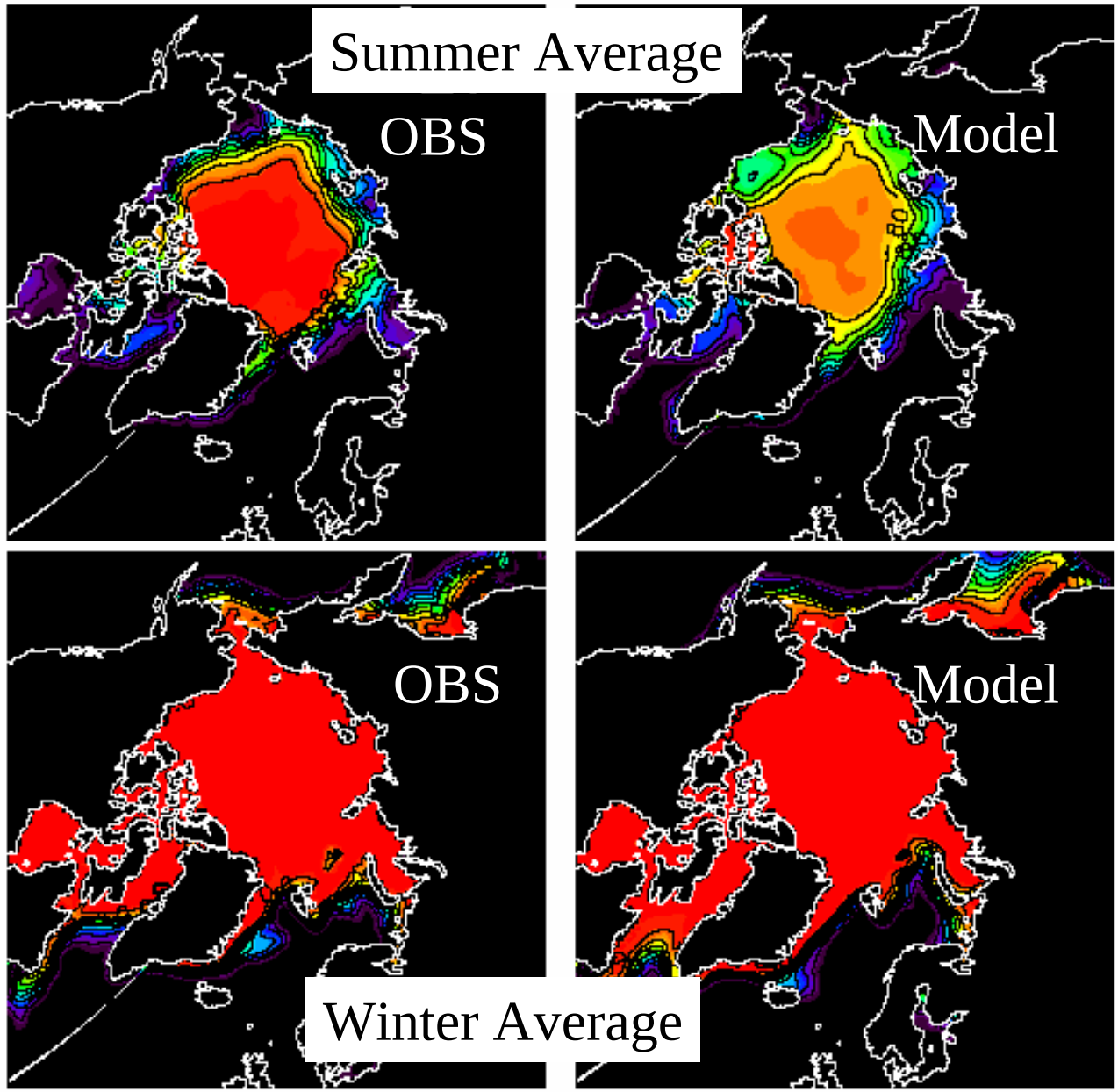


Performance of CCSM-3 : Sea Ice





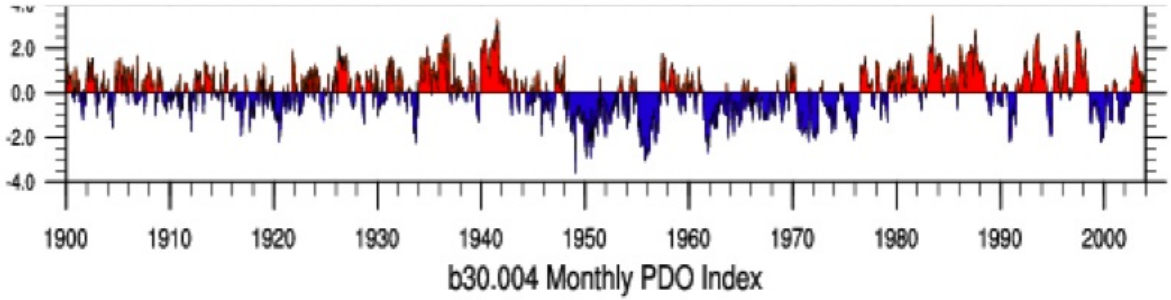




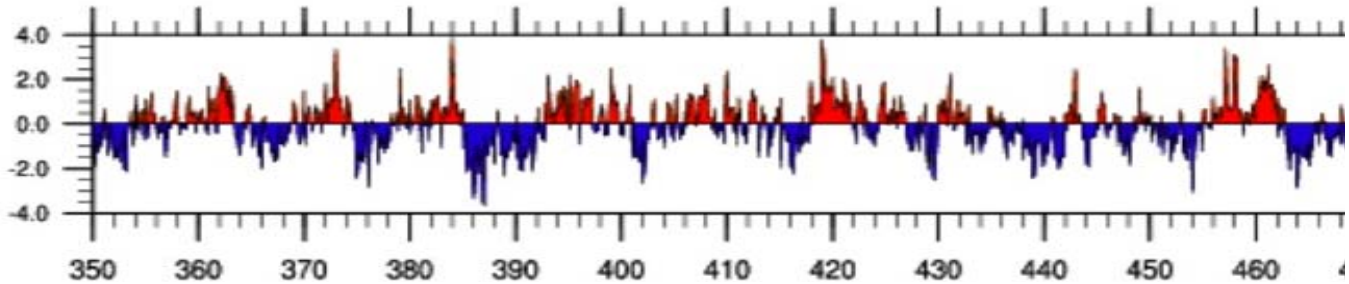
Pacific Decadal Oscillation

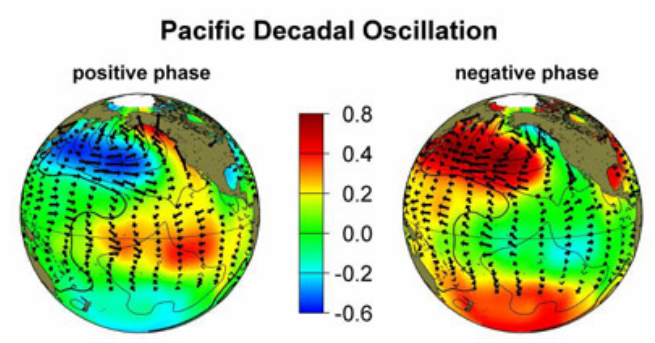
"Pacific Decadal Oscillation" T42 Control Run years 350-492

Observed

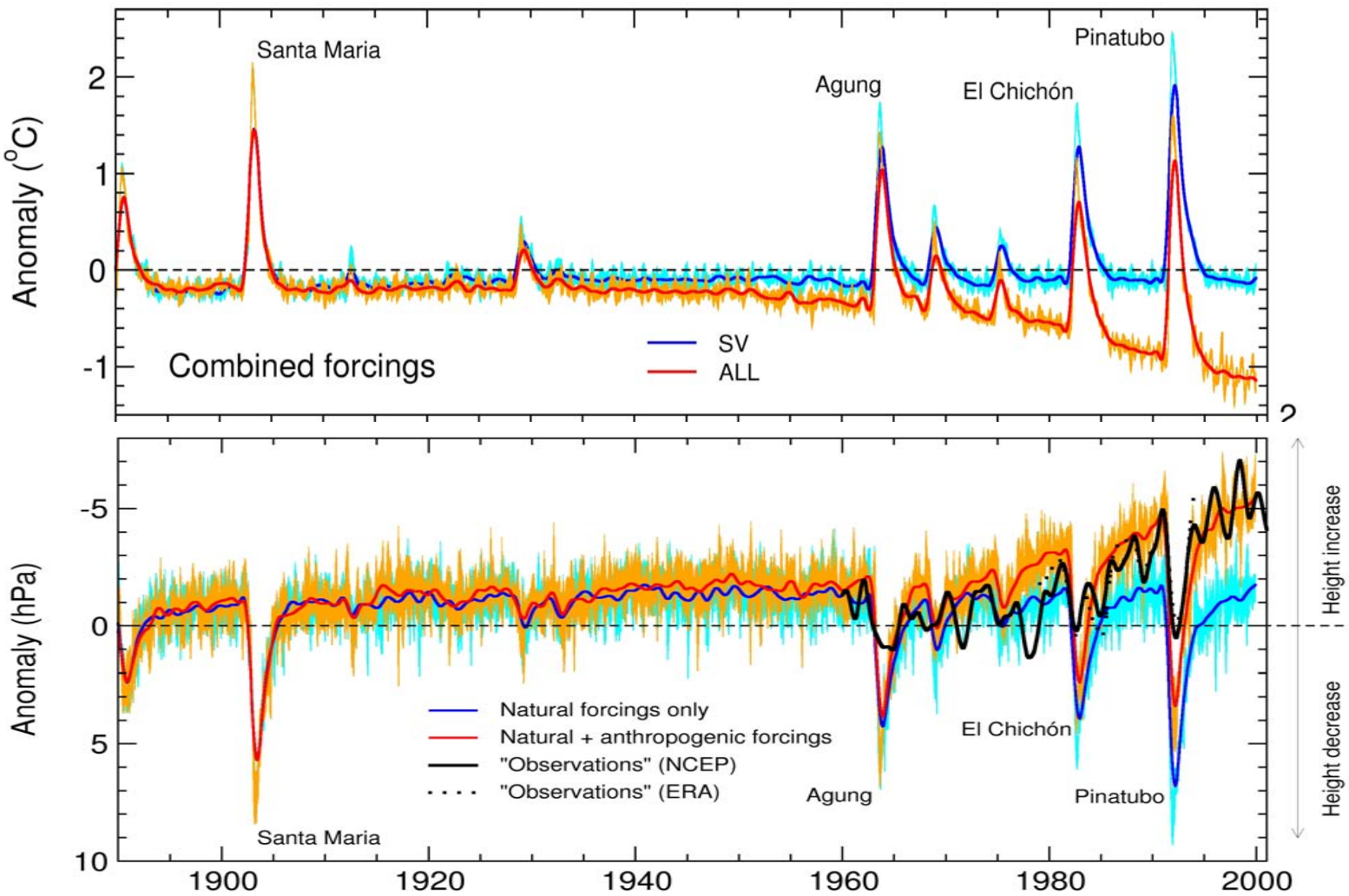


Model





Model: Stratospheric / Surface Temperatures

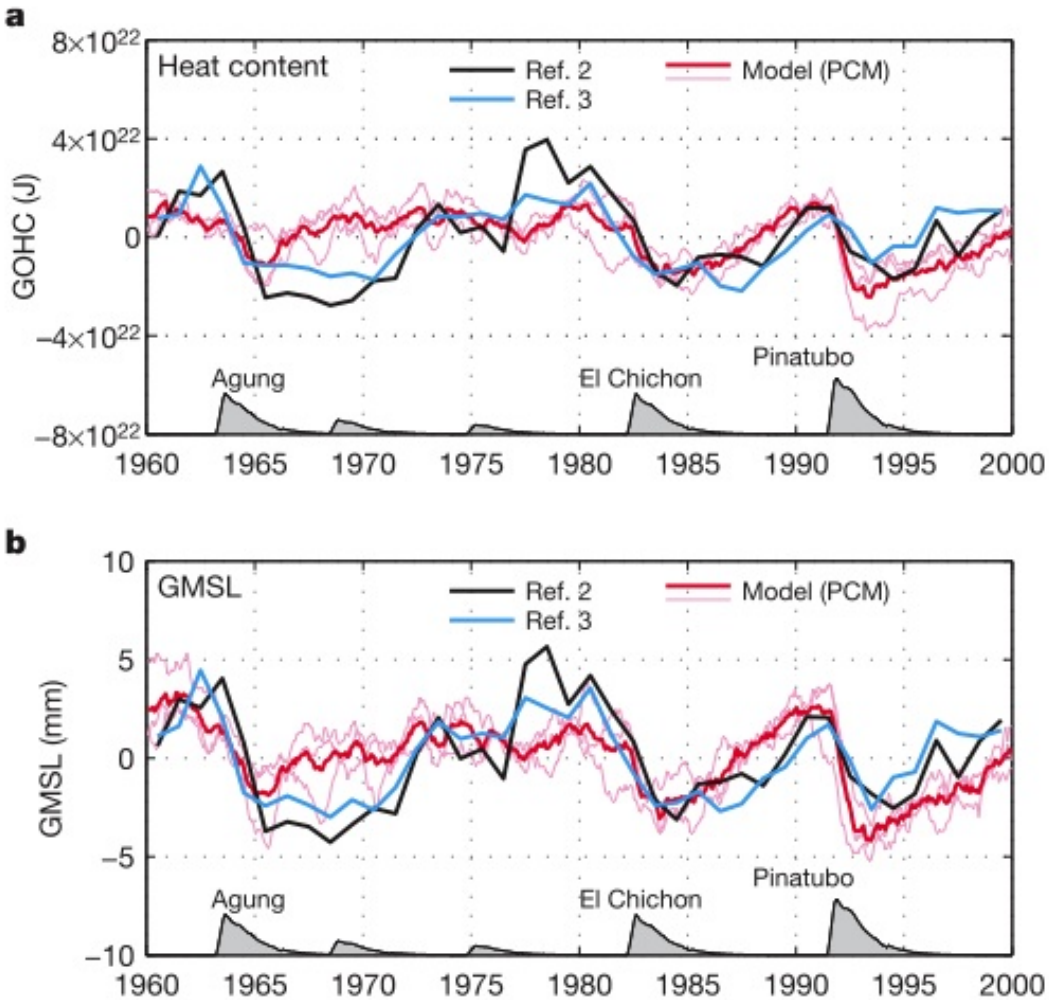


Santer et al. 2005

Ocean Heat Content and Sea Level Changes

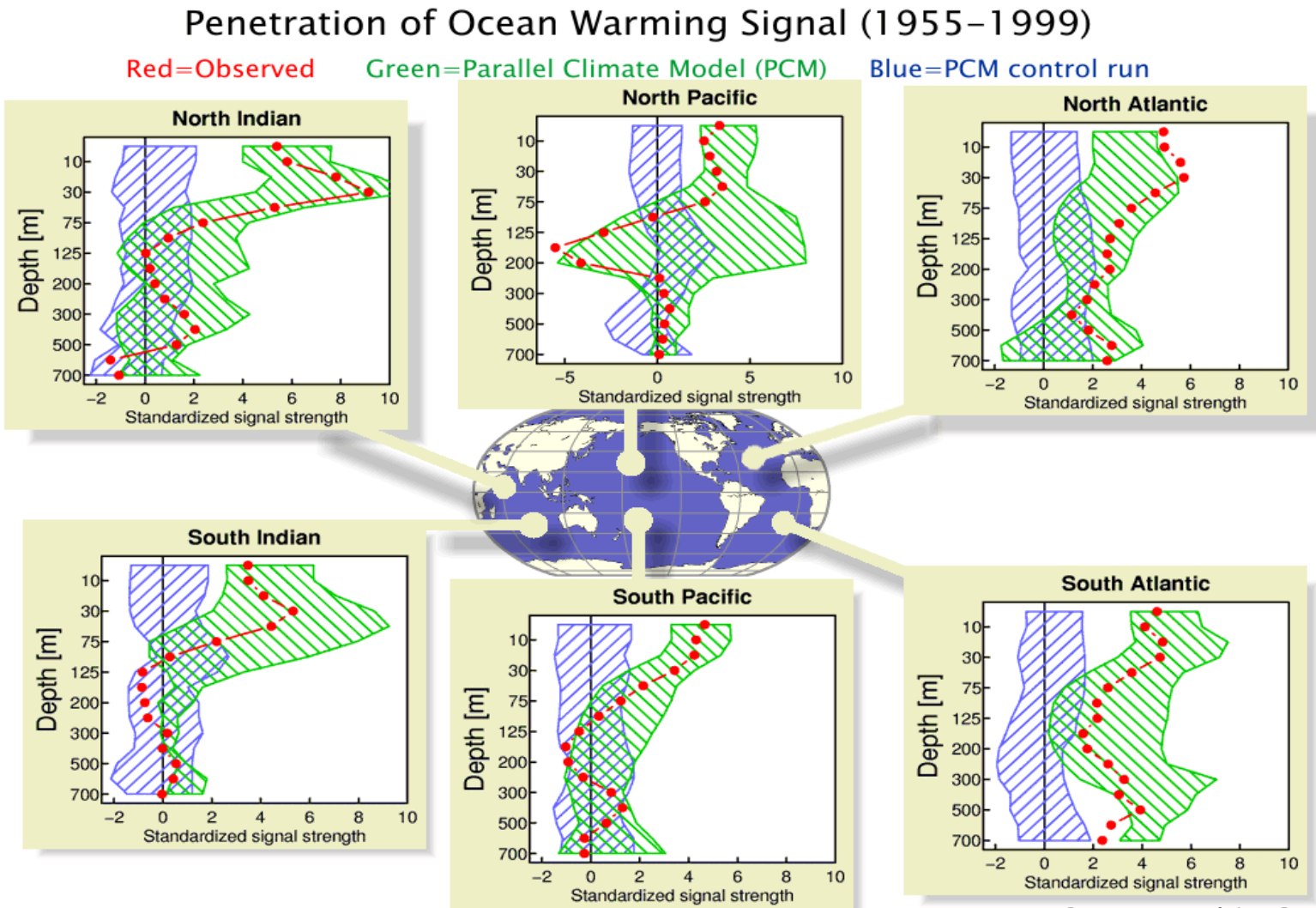
Heat Content

Sea Level



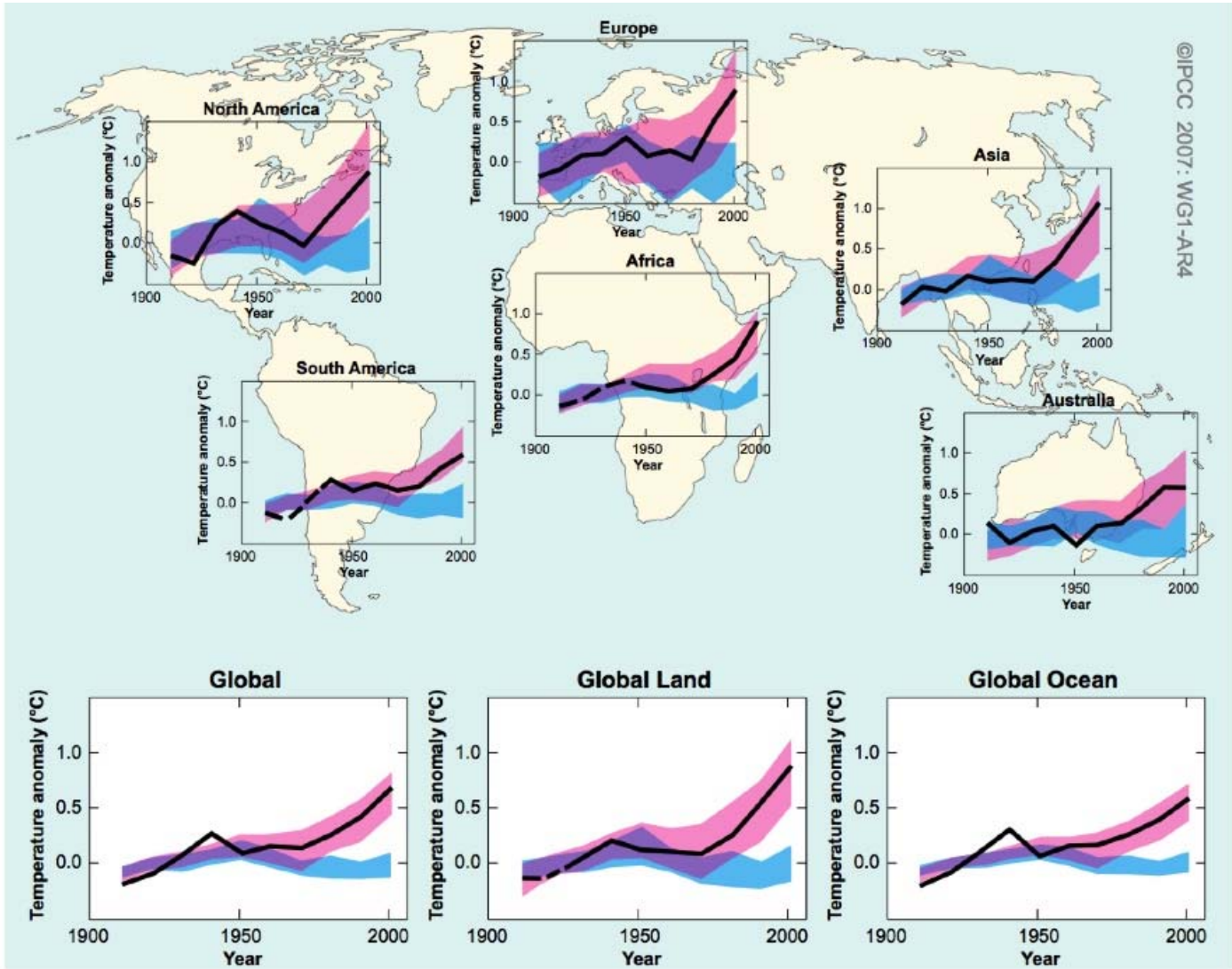
Church et al., 2005

Penetration of Ocean Warming Signal



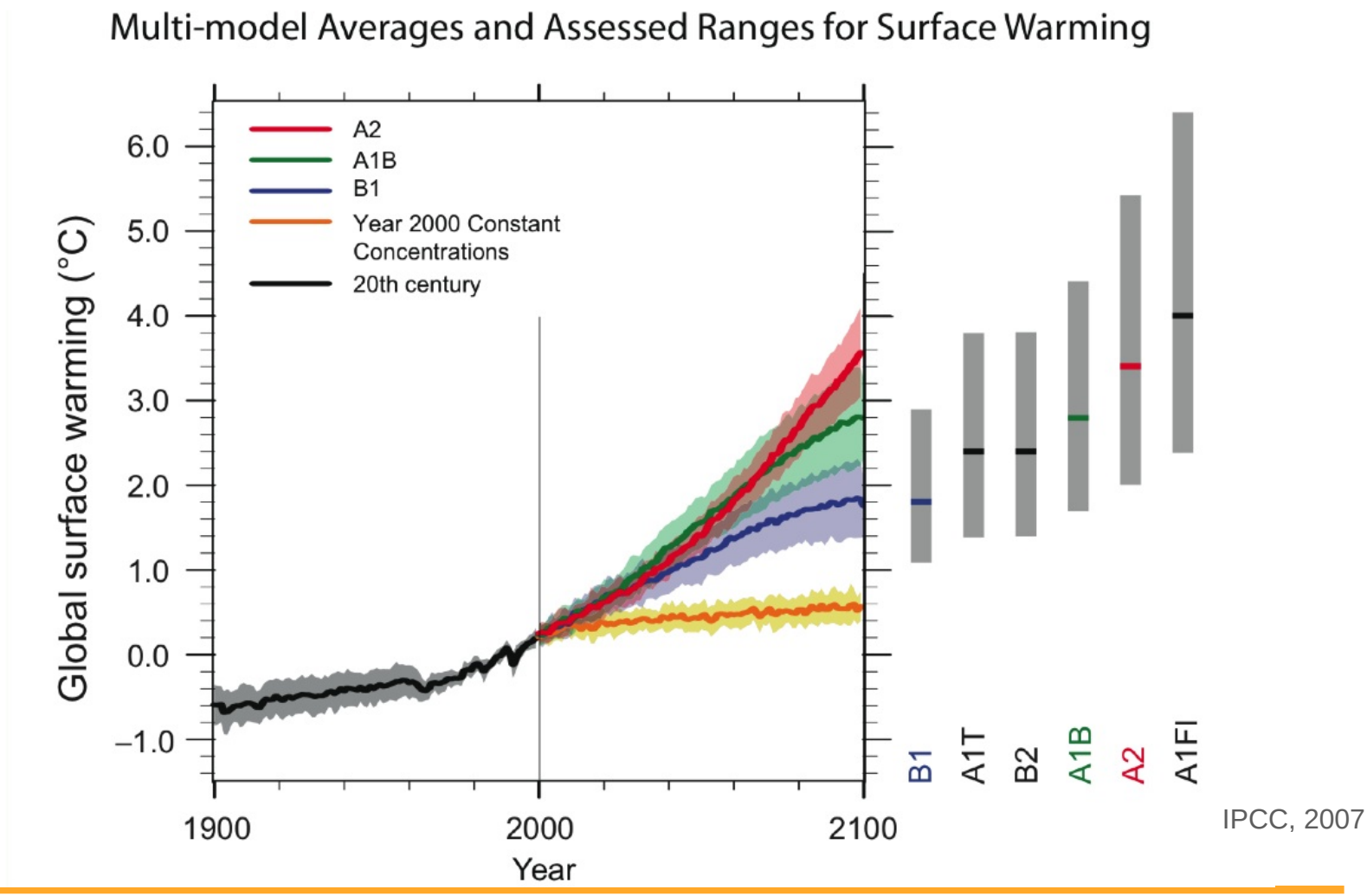
T. Barnett and D. Pierce of SIO

Global and Continental Temperature Change



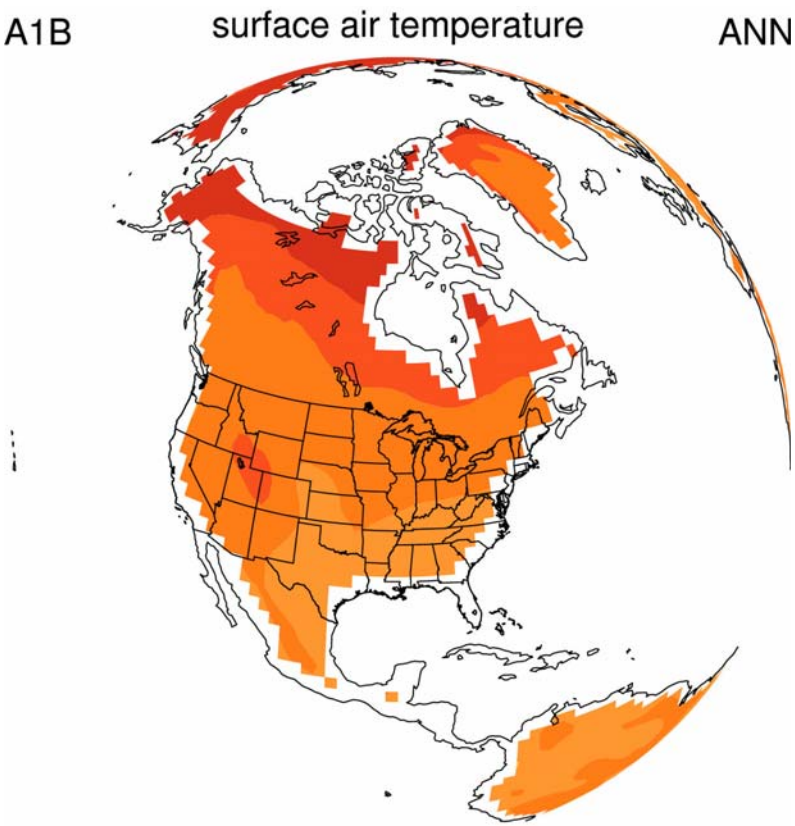
IPCC, 2007

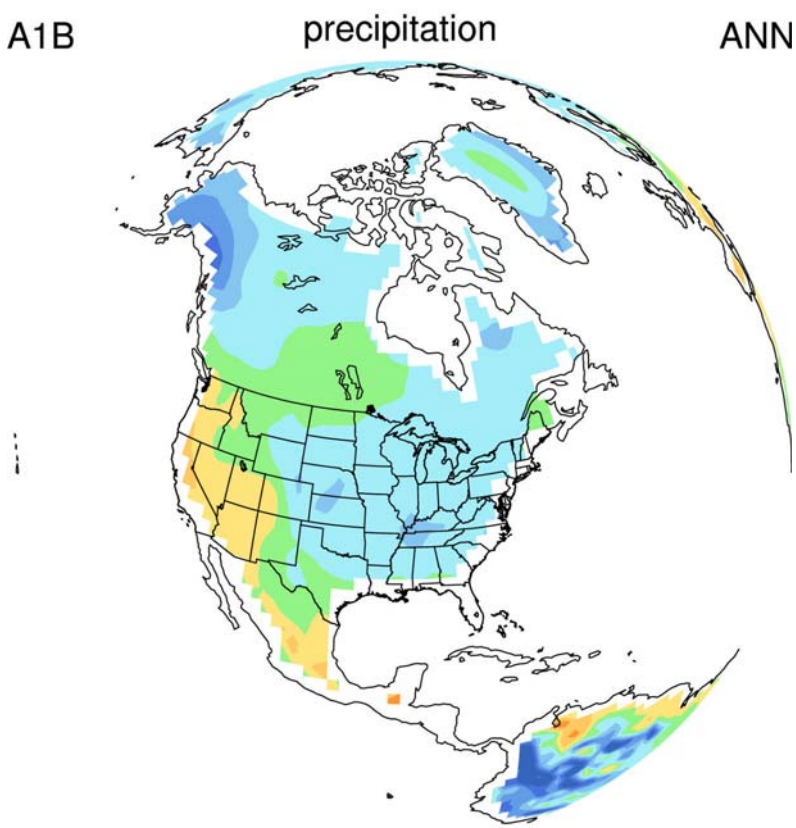
IPCC 2007 : Global Surface Temperature



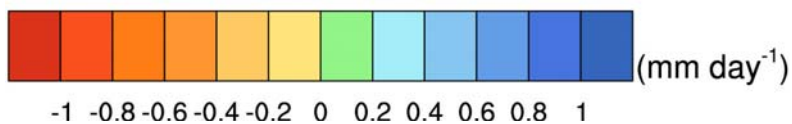
IPCC, 2007

Temperature and Precipitation Trends

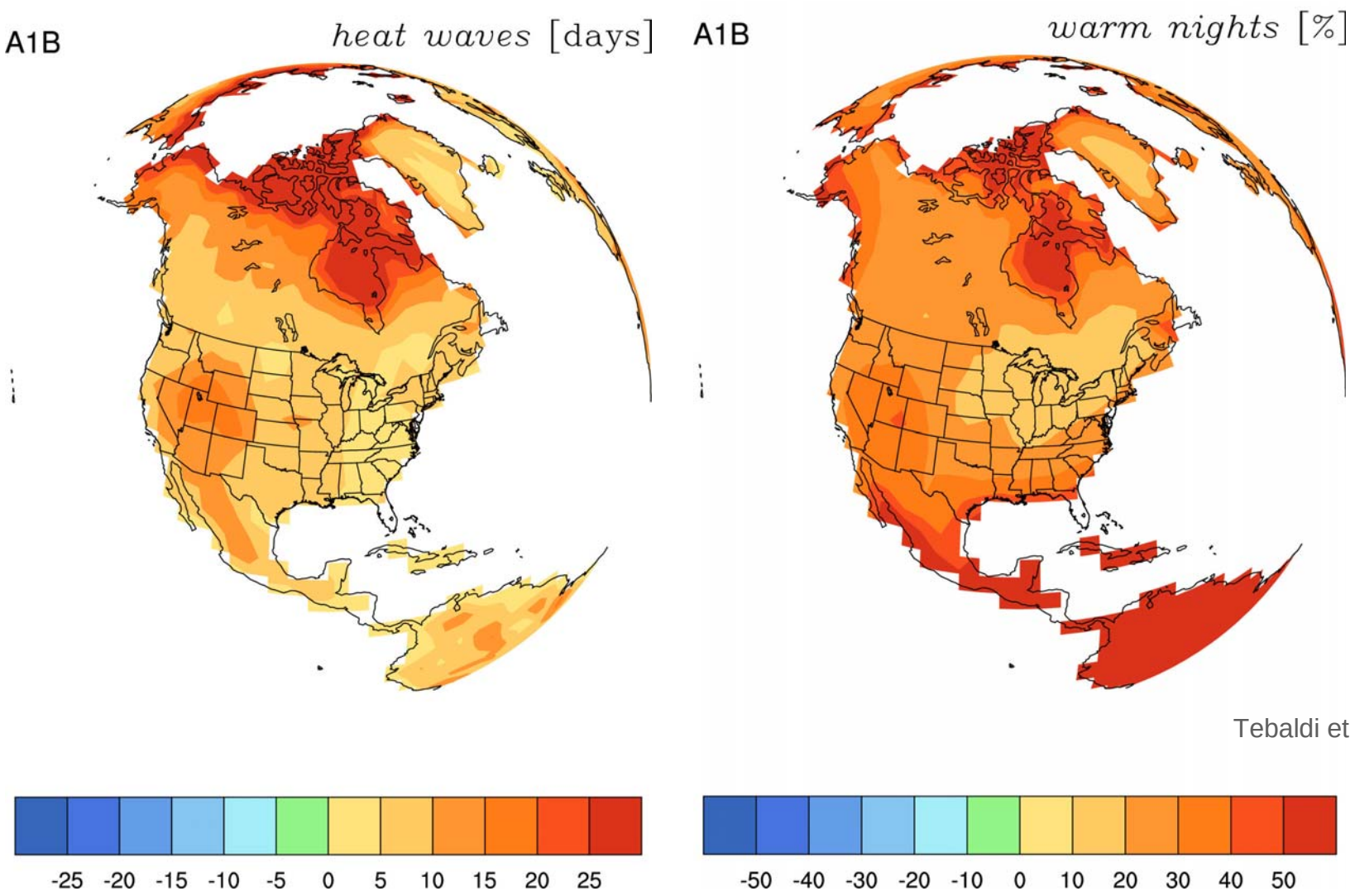




Tebaldi et al., 2007

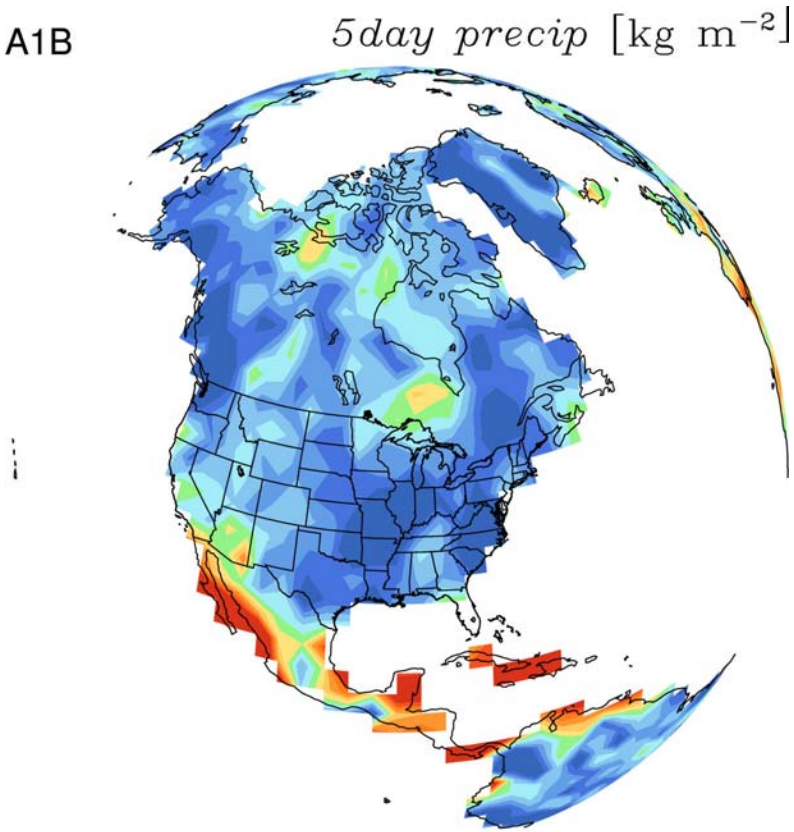


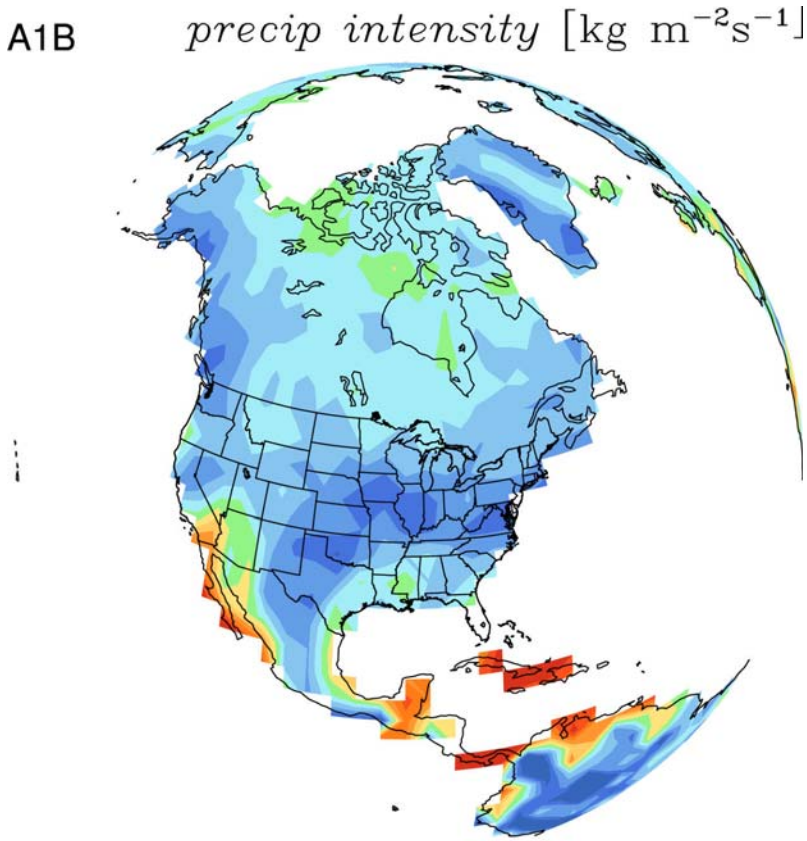
Heat Waves and Warm Nights: Trends



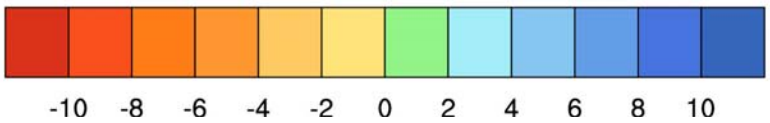
Tebaldi et al., 2007

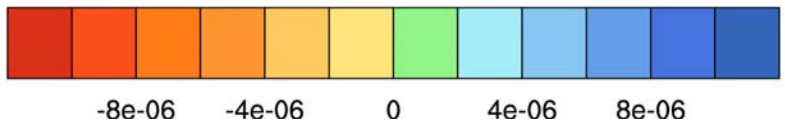
Precipitation 5-day and Intensity Trends



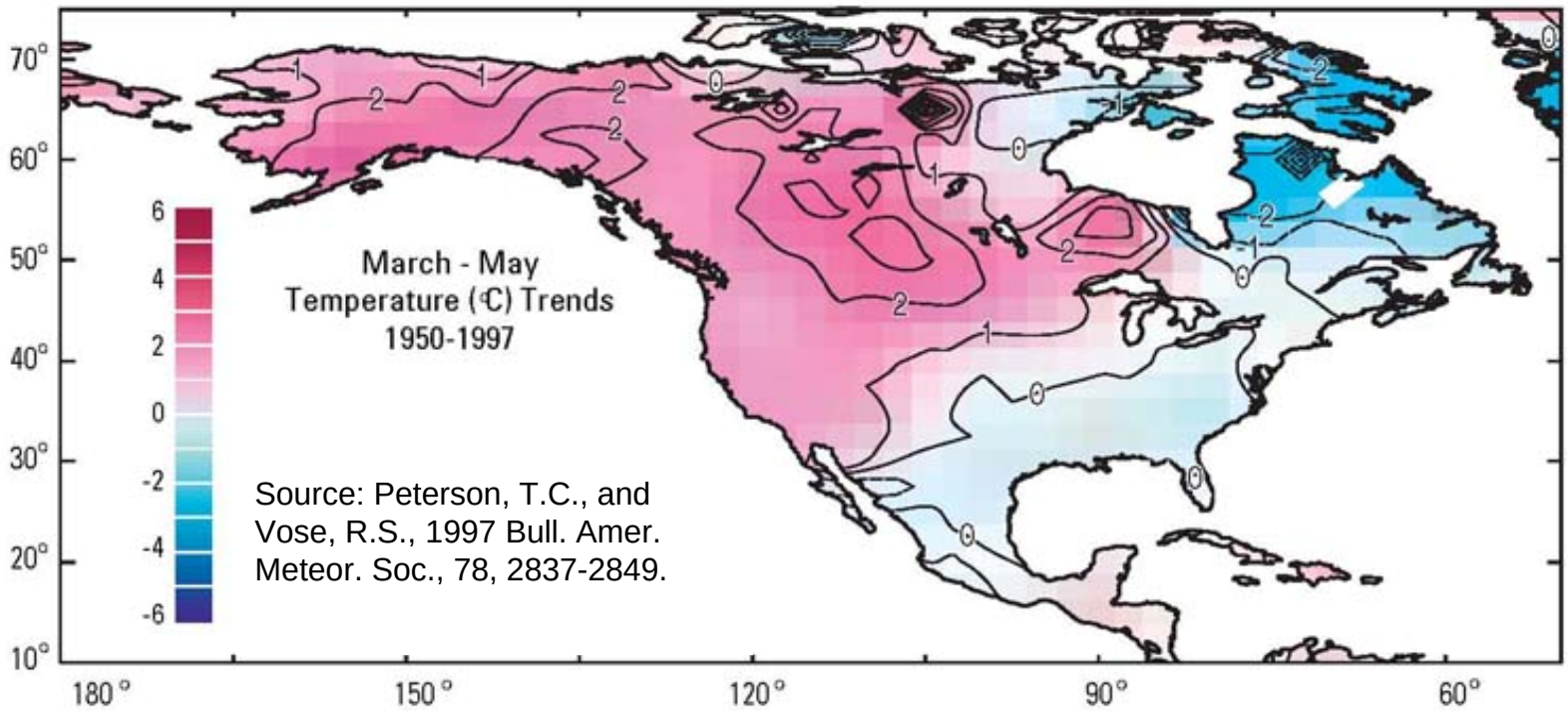


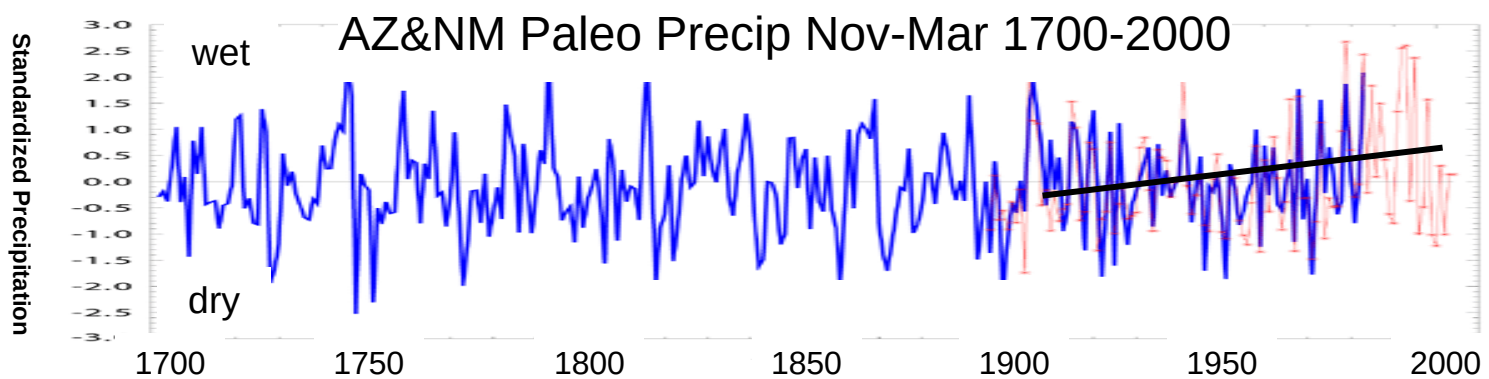
Tebaldi et al., 2007



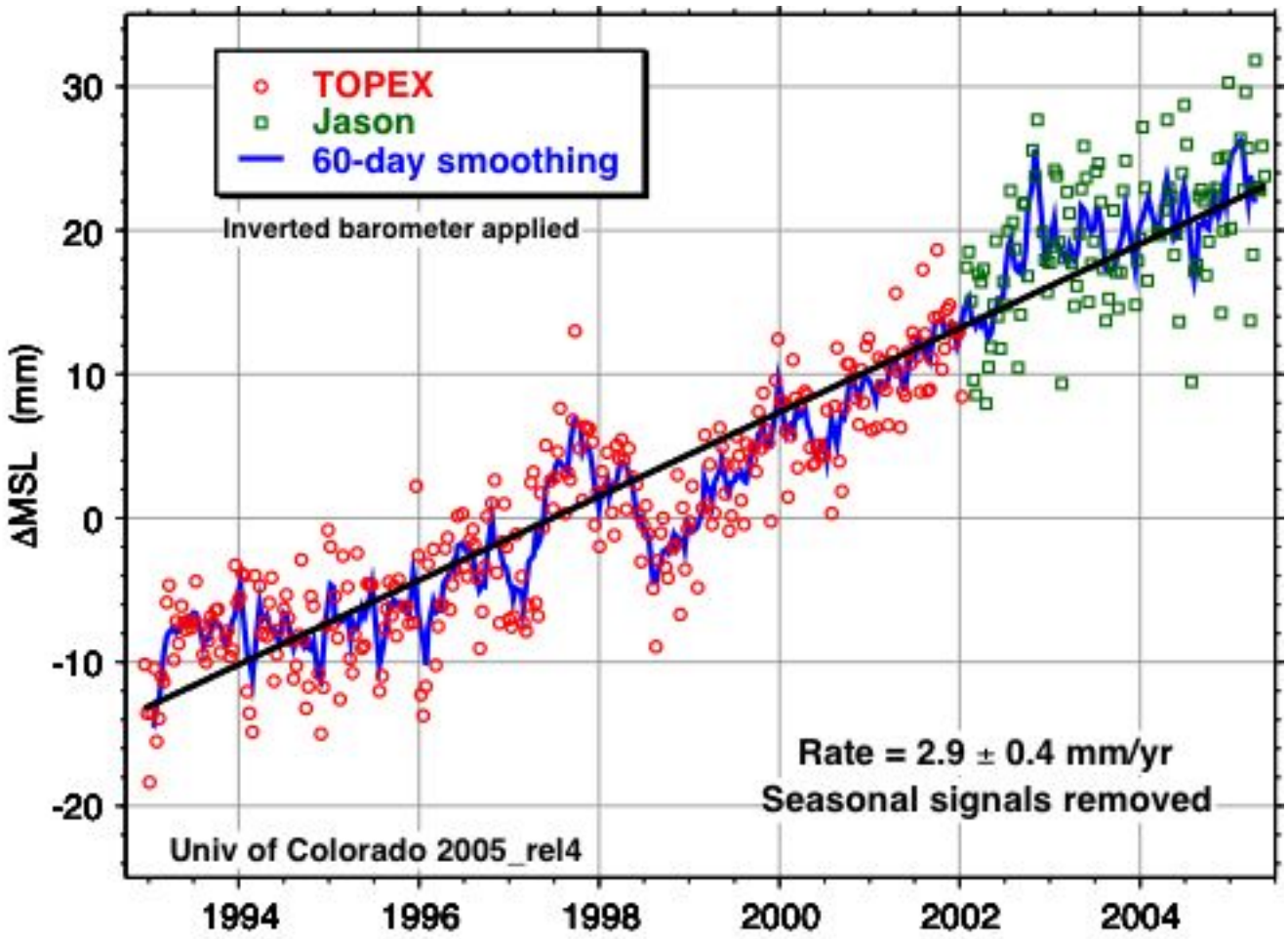


Regional historic climate trends





Sea level is rising:
from ocean expansion and melting glaciers



Since 1993 Global sea level has risen 37 mm (1.46 inches)

- 60% from expansion as ocean temperatures rise,
- 40% from melting glaciers

Steve Nerem

More evidence for reality of climate change

Glaciers melting

1909

Toboggan Glacier Alaska

2000

1858 1974

Grindelwald Glacier Switzerland

A. Circa 1900

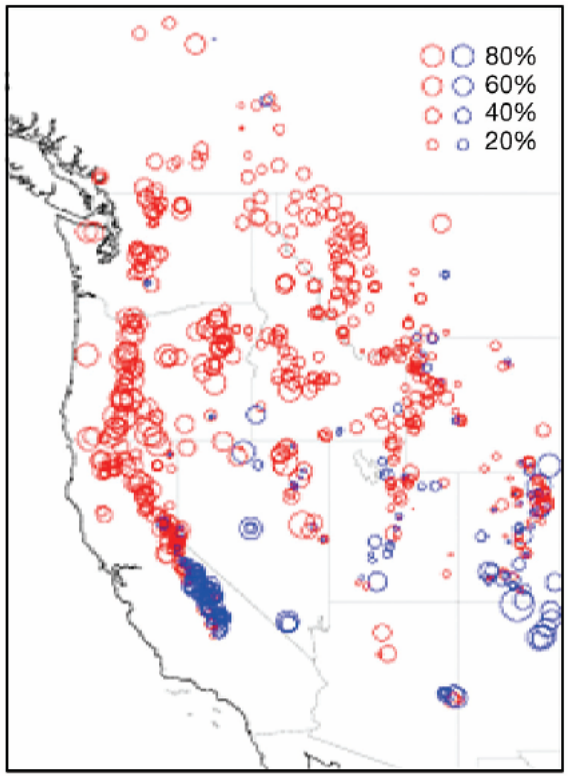
Photo Source: Munich Society for Environmental Research

B. Recent

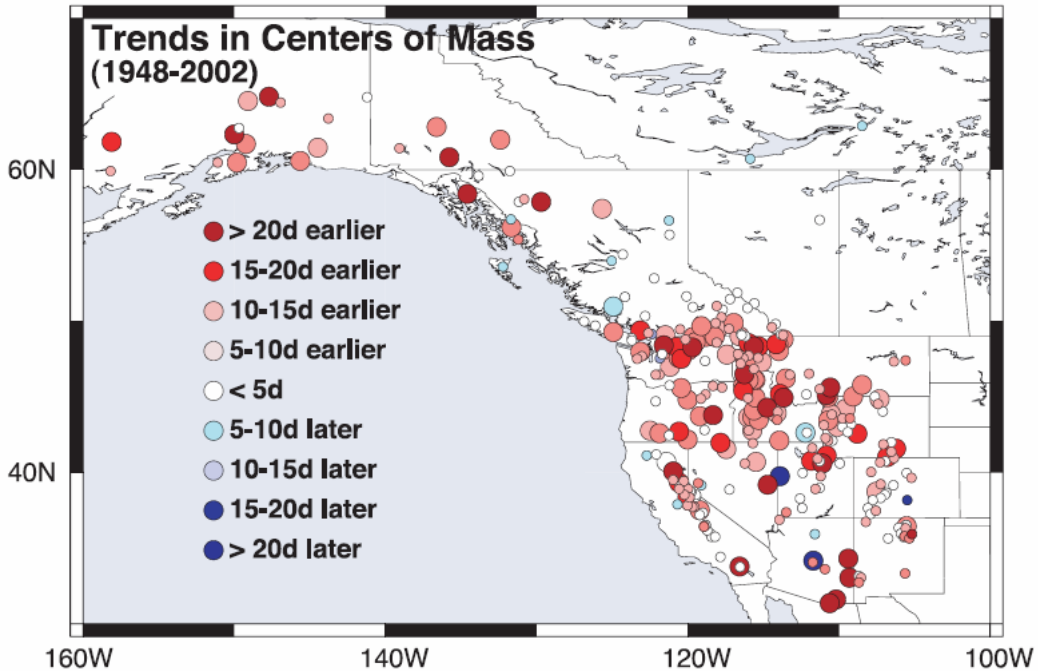
1900 2003

Alpine glacier, Austria

Observed changes in western snowpack and timing of spring runoff



Observed linear trends (1950-1997) in April 1 snow water equivalent (SWE)
Negative trends shown by red circles and positive trends by blue circles.
(Source: Mote,2004, p. 2.)



Large circles indicate sites with trends that differ significantly from zero
at a 90% confidence level;
(Courtesy of Michael Dettinger, based on Stewart et al. 2005.)

Climate Scenarios: From frequencies to time series

How can Impact and Adaptation Models Make use of climate model data?

- GCM ensembles are given as frequency distributions
- BUT.. Models (load, hydro, etc) need time series of P,T, RH, Wind over area of interest
- Spatial and temporal integrity
- Therefore, need to generate multivariate weather data

Precipitation is complex and is not captured in Global Circulation Models

Warming intensifies the hydrologic cycle

Surface temperature increase

Increased Water holding capacity

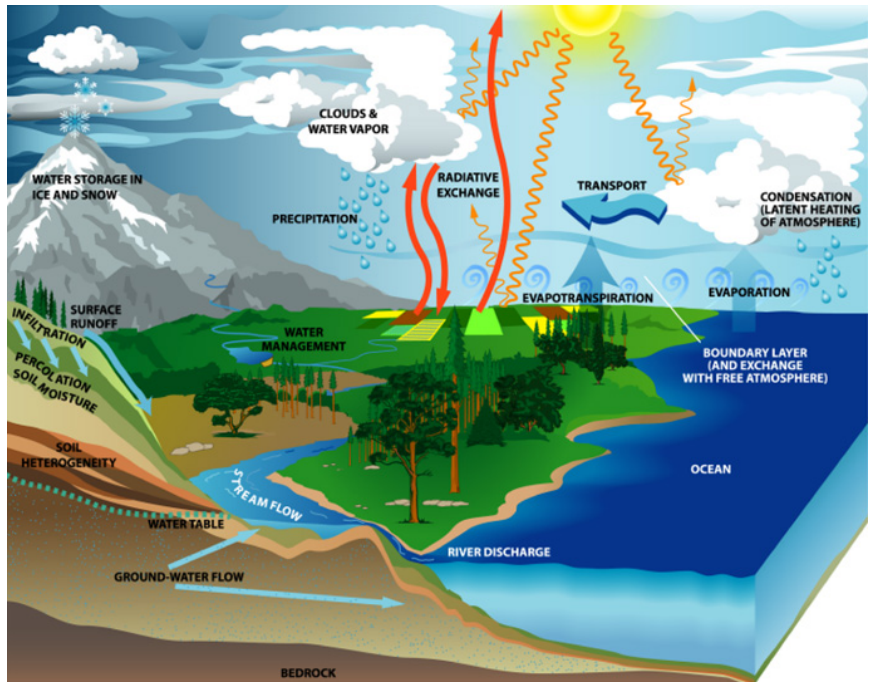
Increased Atmospheric moisture

Changing Frequency

Increased intensity

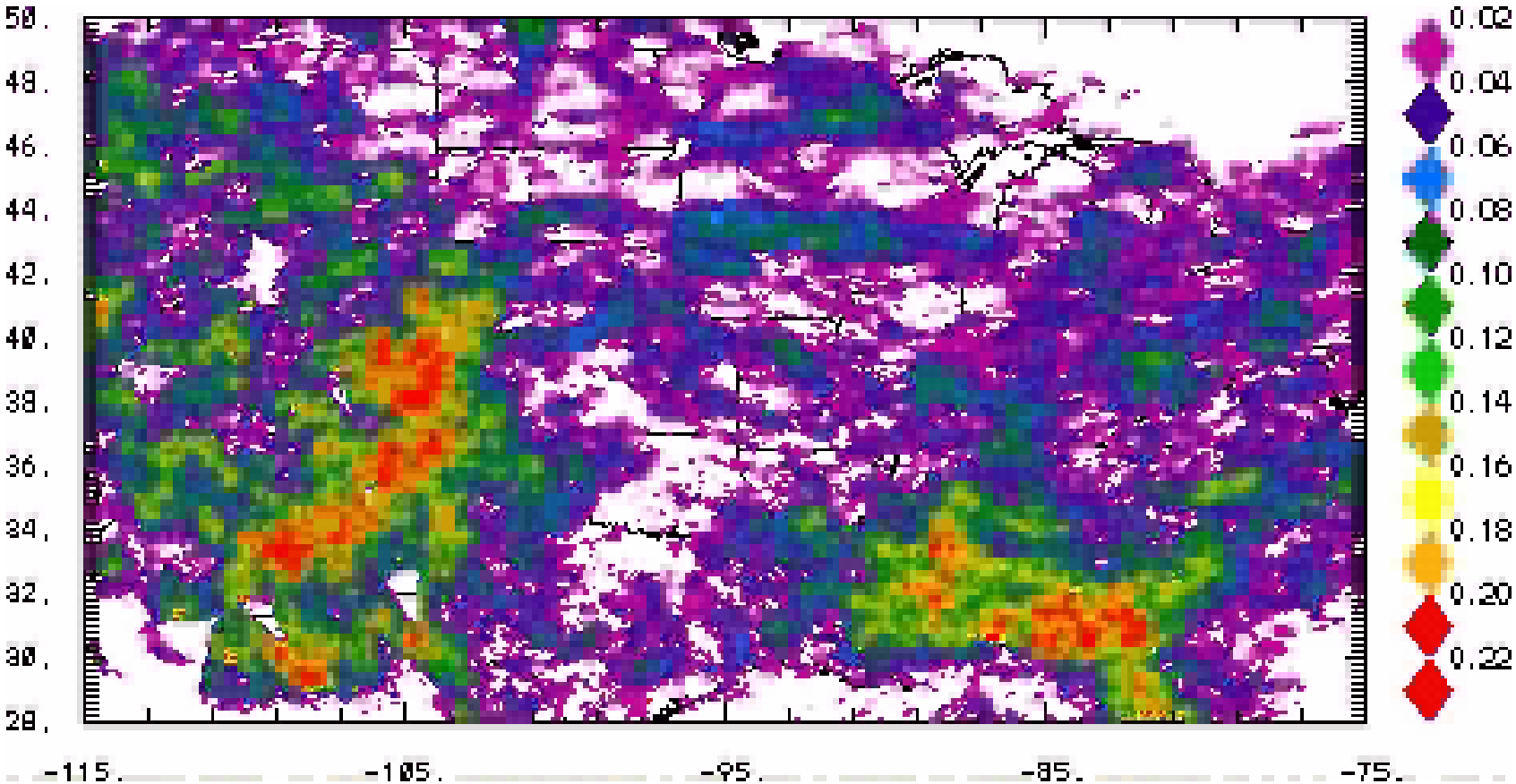
Character of Precipitation?

Droughts & Floods



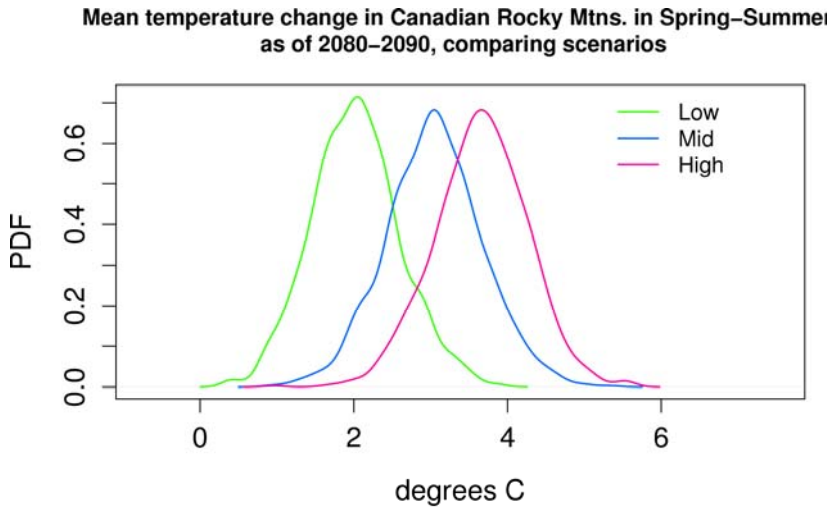
JJA 1996–2002: Average Diurnal Cycle

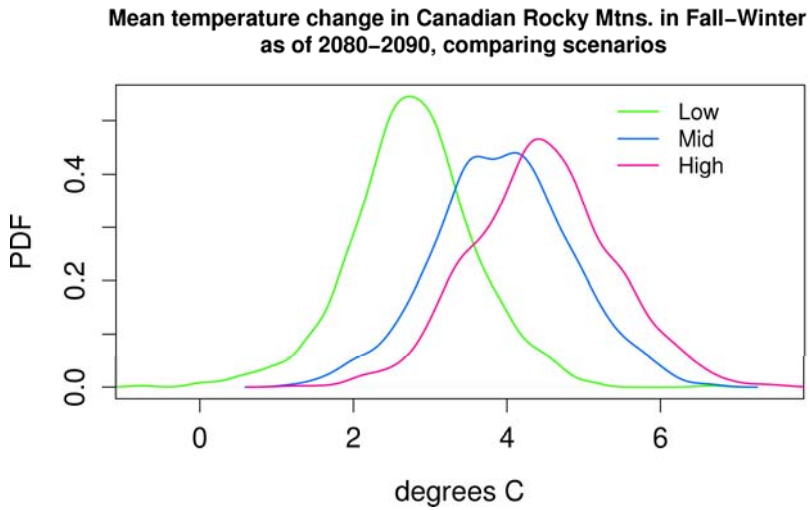
% Time Radar Precipitation Echo



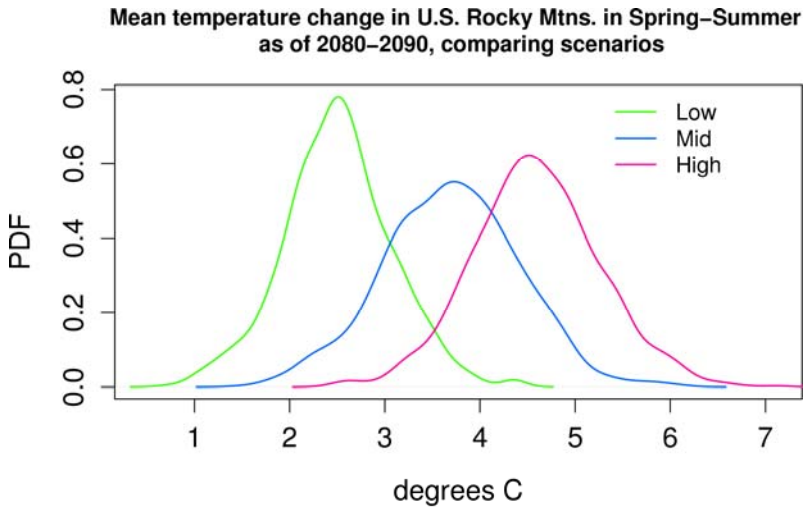
End of century temperature changes

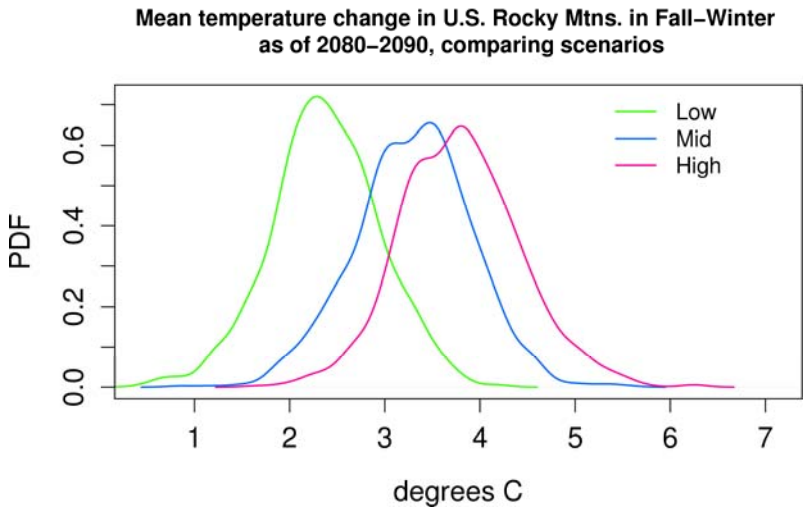
Canadian Rockies





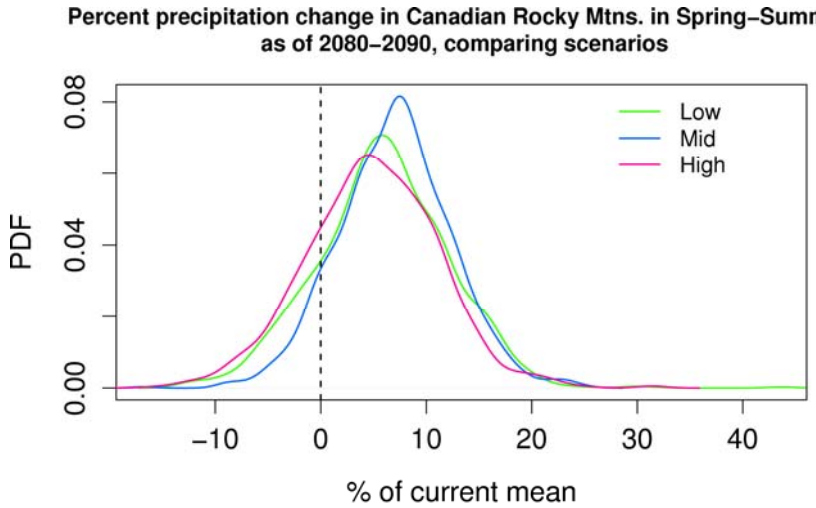
U.S. Rockies

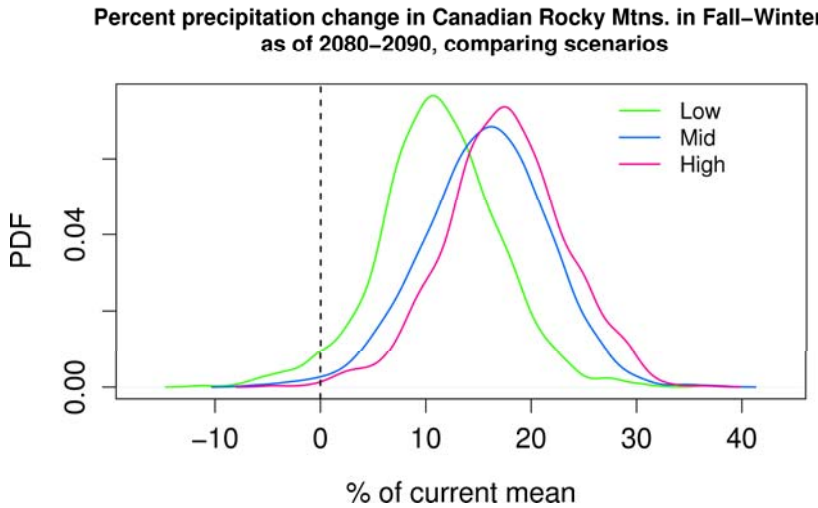




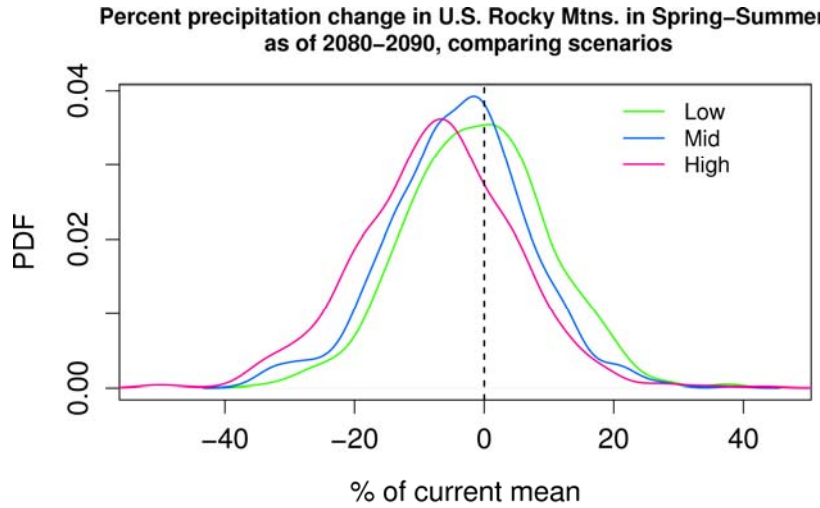
End of century precipitation changes

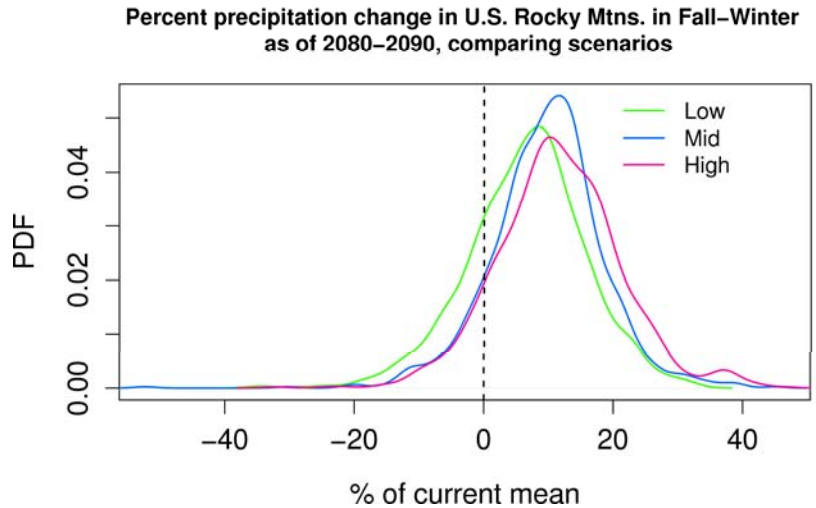
Canadian Rockies



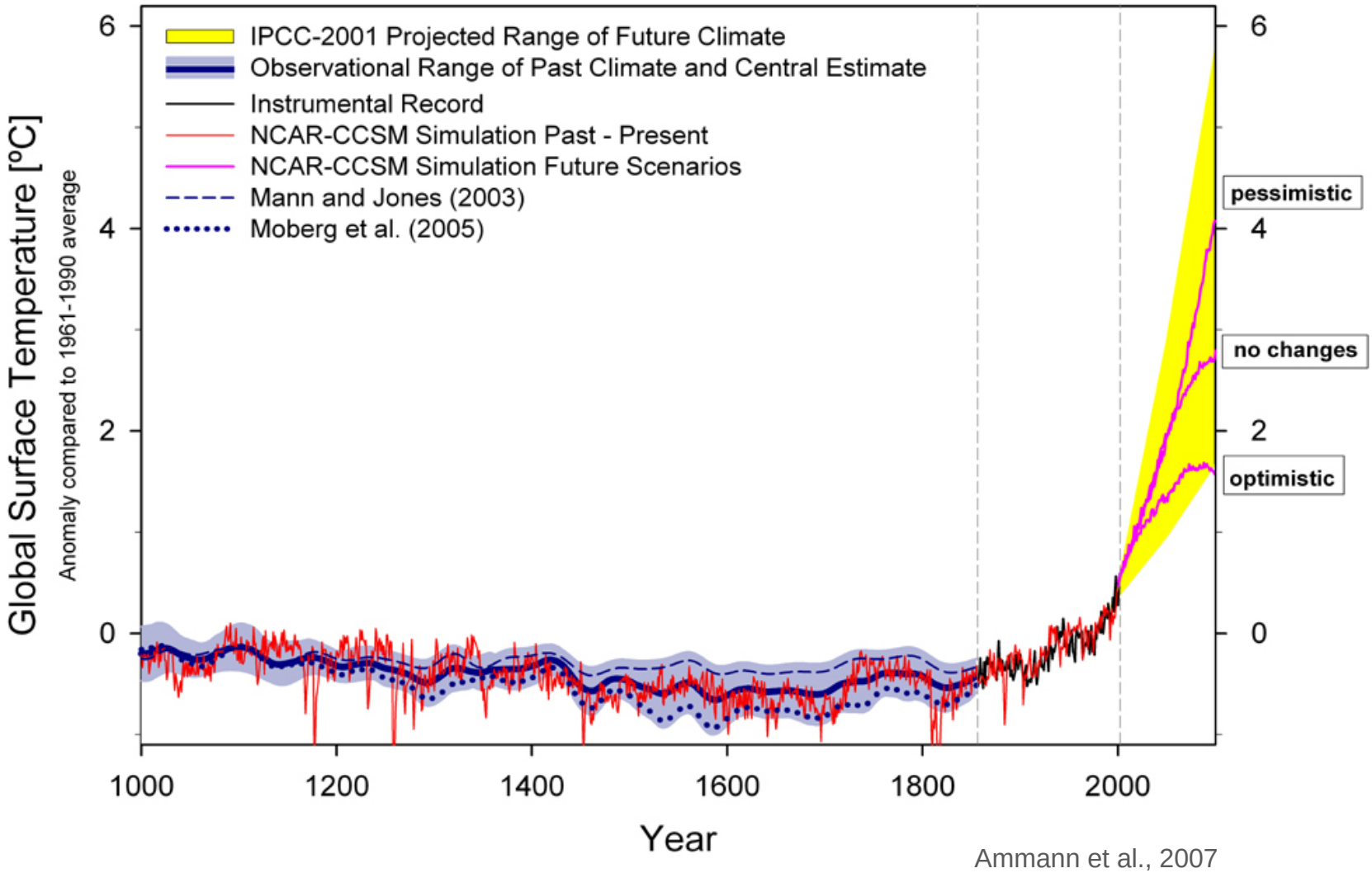


U.S. Rockies





Seamless Past-Present-Future



Ammann et al., 2007

Conclusions

The Message from the Science is very clear:

- Surface temperatures have increased by about 0.6-0.8 degrees.
- The warming signal is consistent with Greenhouse warming: subsurface, ocean heat content, surface and lower troposphere are warming, the stratosphere is cooling.
- The increase in Greenhouse Gases in the atmosphere is man made (isotopic indicators show that the increase comes from fossil fuel)
- Natural forcing factors play a minor role since about 1970.
- Most of the warming over the past 50 years is likely due to human changes to the atmosphere and land surface.
- Future warming will be significant with wide ranging impacts on physical and biotic systems. Best guess numbers are roughly 3 degrees C for $2xCO_2$
- Reduced emissions can limit projected climate changes to (at least) half, but action needs to be taken quickly.
- There are some suggestions that “dangerous interference” is avoided if climate change is held below 2 degrees, which could be achieved with a stabilization around 450 ppm.