The Community Earth System Model (CESM): Update on Releases and CMIP-5 Simulations

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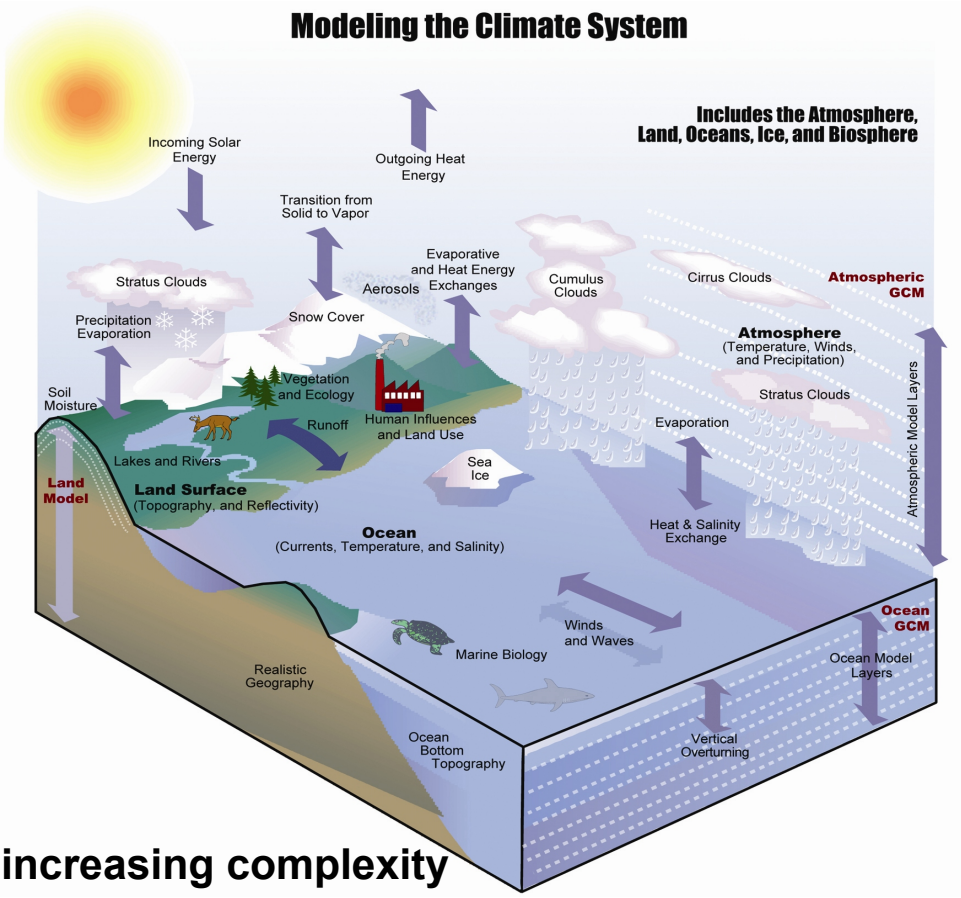
The Community Earth System Model (CESM)

- A comprehensive model to:
  - Investigate and predict seasonal and interannual variability in the climate
  - Explore the history of Earth's climate
  - Estimate future of environment for policy formulation
  - Contribute to assessments
- Collaborations are critical
- Developed by NCAR, National Laboratories and Universities
- Fully documented, supported and freely distributed
- Training
- One code base: runs on multiple platforms and resolutions
- Moving toward higher resolution and increasing complexity



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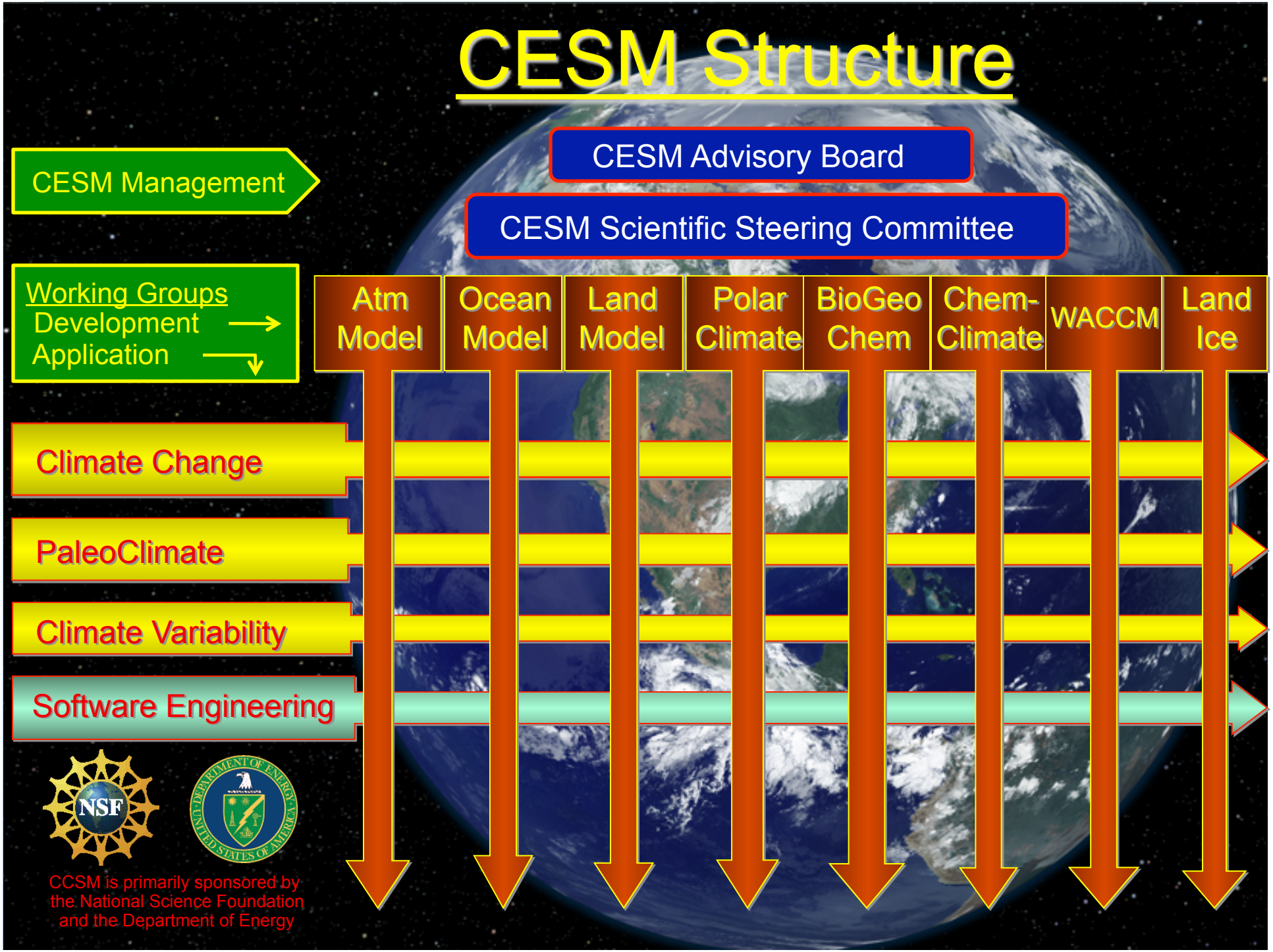
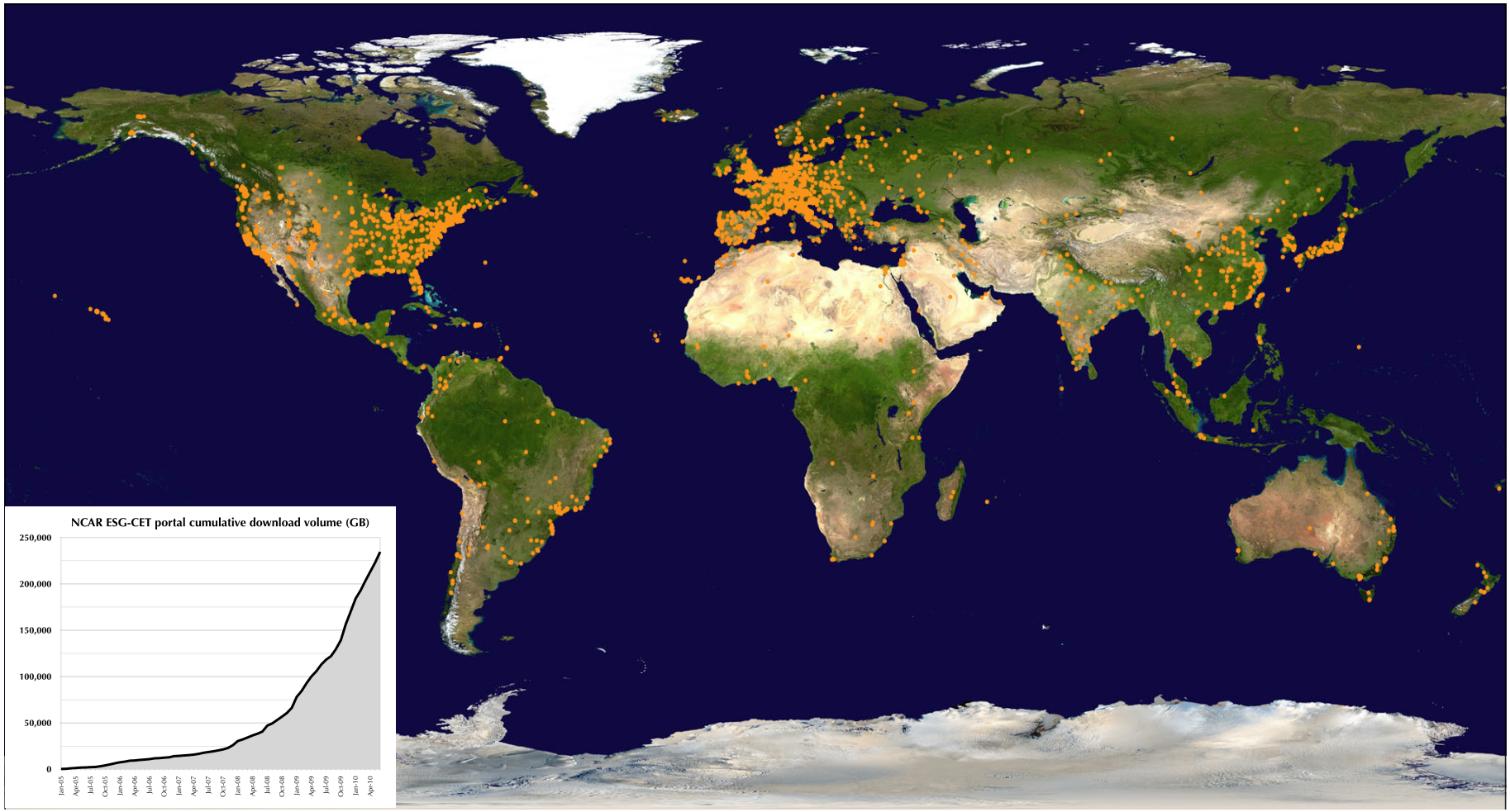
NESL


CESM Structure
CESM Management
CESM Advisory Board
CESM Scientific Steering Committee
Working Groups
Development
Application
Atm Model
Ocean Model
Land Model
Polar Climate
BioGeo Chem
Chem-Climate
WACCM
Land Ice
Climate Change
PaleoClimate
Climate Variability
Software Engineering
NSF
CCSM is primarily sponsored by the National Science Foundation and the Department of Energy

A Community Resource



Over 3,000 sites from 130+ countries

>230 Tb since January 2005

Courtesy Gary Strand

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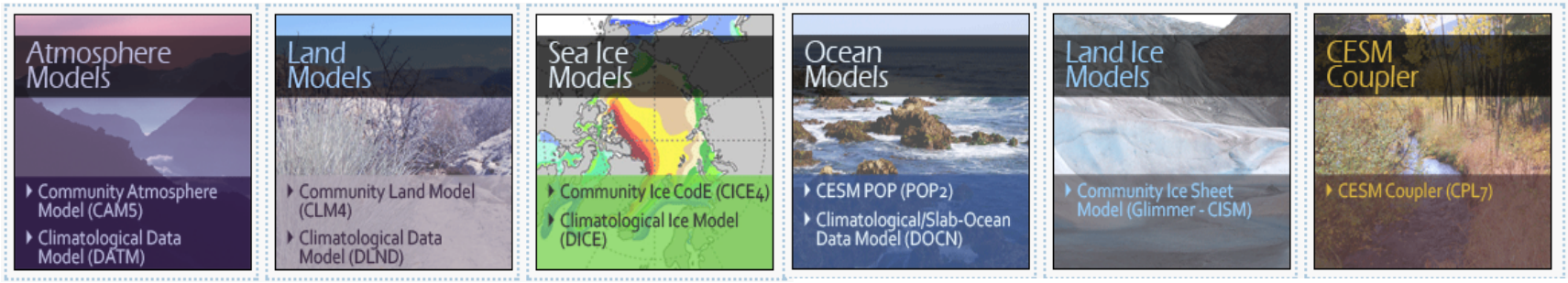
Release Schedule

- January 15, 2010: **CCSM4.0 alpha release**
  - ✓ to subset of users and vendors with minimal documentation (except for general script's User's Guide)
- April 1, 2010: **CCSM4.0 release** (very few problems)
  - ✓ full documentation, including User's Guide, Model Reference Documents, and experimental data
- June 25, 2010: **CESM1.0 release** (1.2M lines of code!)
  - ✓ ocean ecosystem, interactive chemistry, WACCM, land ice, and CAM5.0



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CESM Release Web Page

Notable Improvements

Data, Diagnostics, and Post-Processing Tools

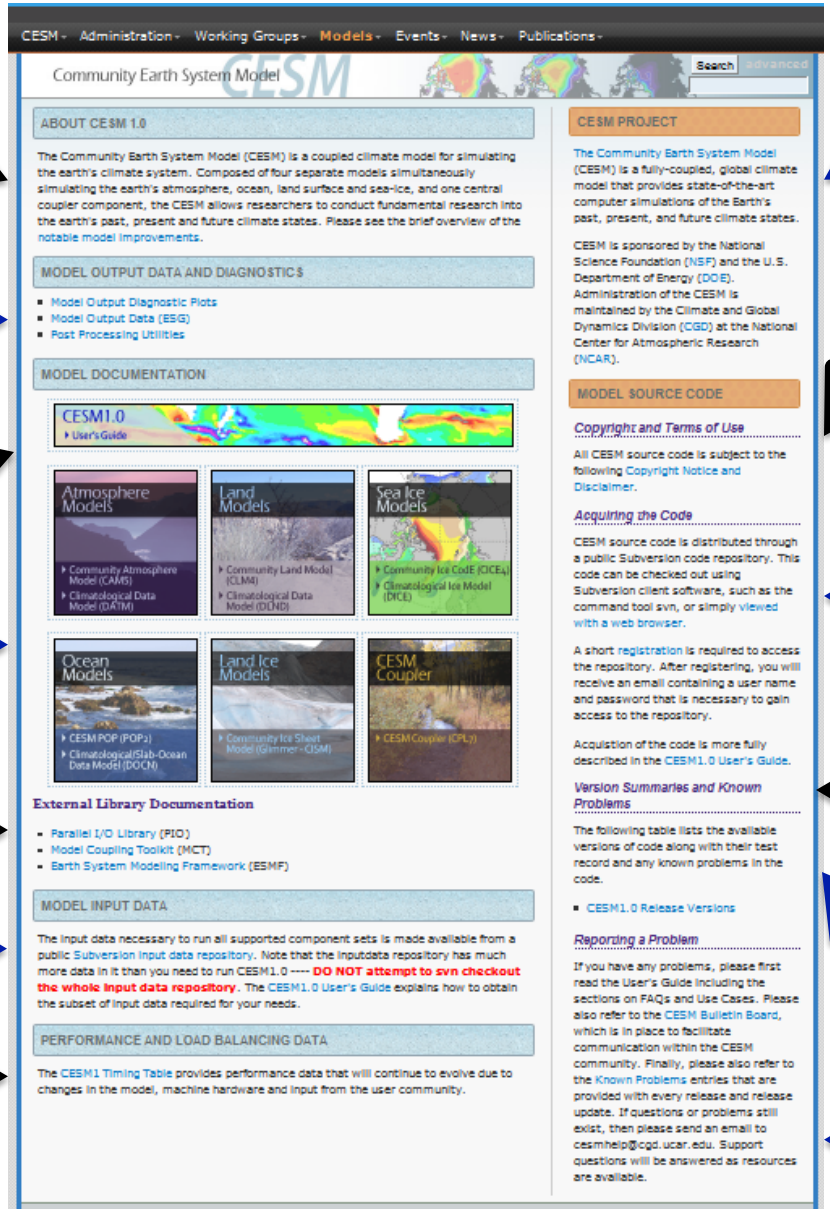
User's Guide

Component Model Documentation

External Libraries

Input Data

Timing Table



Background and Sponsors

Copyright and Terms of Use

How to Acquire the Code

Version Summaries

Known Problems and Reporting Problems

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CMIP-5 Simulations

- CESM and partners will make a major contribution to IPCC AR5 through simulations performed with CCSM4.0 and CESM1.0

- CMIP-5 Experimental Design (Taylor et al. 2009):

  A set of coordinated climate model experiments to:

  - ✓ address outstanding scientific questions from AR4
  - ✓ improve understanding of climate variability/change
  - ✓ provide estimates of future climate change useful to those considering its possible consequences

- CMIP-5 is a 5-year experimental design, but a significant fraction of the experiments will be done in time to be included in AR5

  - ✓ Initialized decadal prediction and long-term climate change
  - ✓ Includes carbon cycle, paleoclimate, whole atmosphere, and land ice
  - ✓ Beginning December 2010: model simulations freely available

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Selected Results

- **See Presentations from 15th Annual Workshop**
  (http://www.cesm.ucar.edu/events/ws.2010/Agendas/agenda.pdf)
- **Pre-industrial controls (CCSM4 and CESM1)**
  - ✓1850 conditions, multi-century, mostly 1º resolution
  - ✓ some comparisons to 1870 CCSM3 (T85)
- **20th century transient simulations**
  - ✓ 1850-2005, some ensembles, mostly 1º resolution
  - ✓ some comparisons to CCSM3 (1870-1999; T85)
- **Observations (best available, common periods)**
- **Mean and Variability**
- **Good and Bad**

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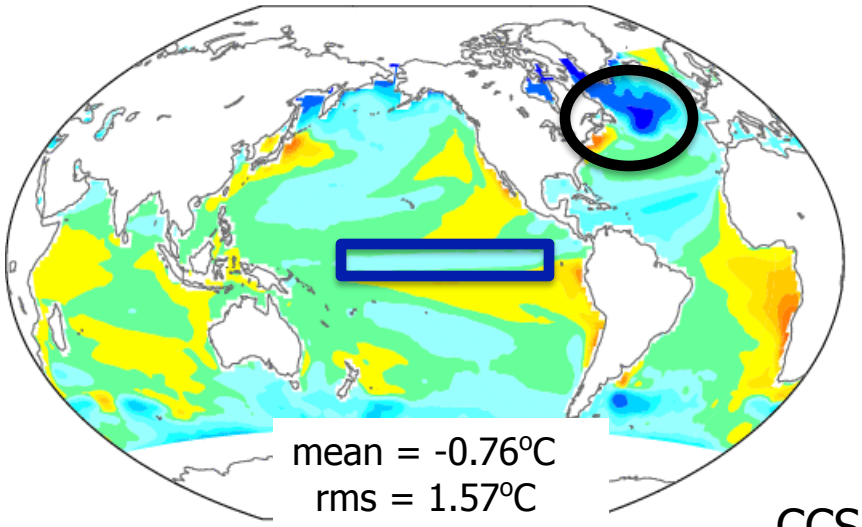
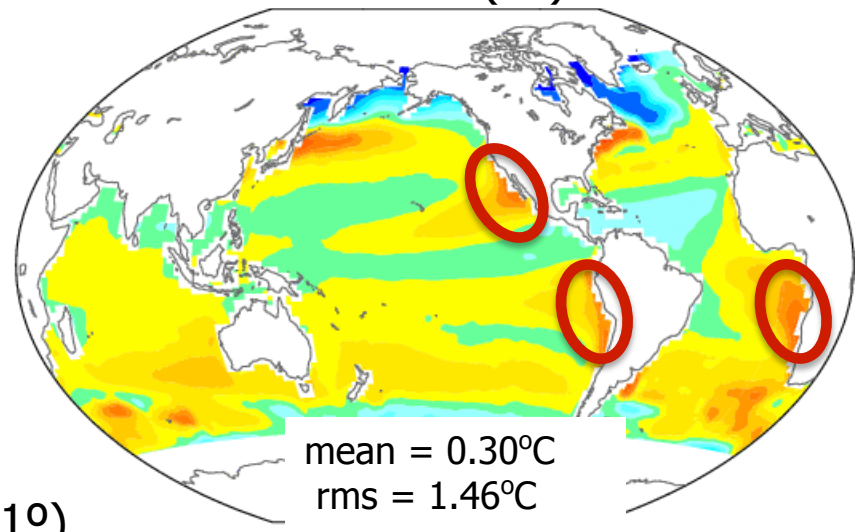
SST Biases

(Pre-Industrial)

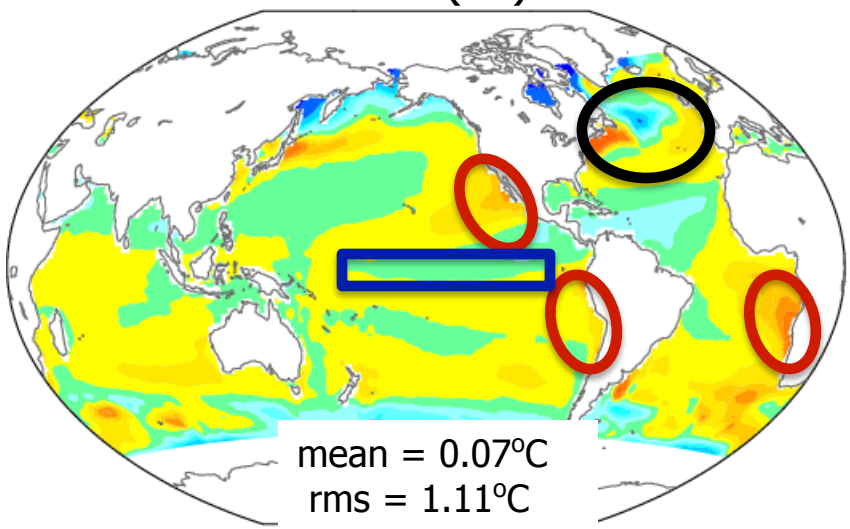
CCSM3



CCSM4 (2°)



CCSM4 (1°)



Overall reduction SST bias, all basins

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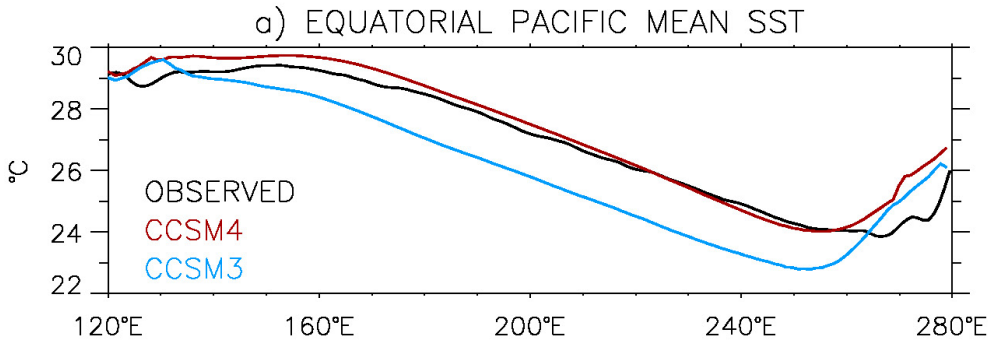
Equatorial Pacific SST

(Late 20th Century)



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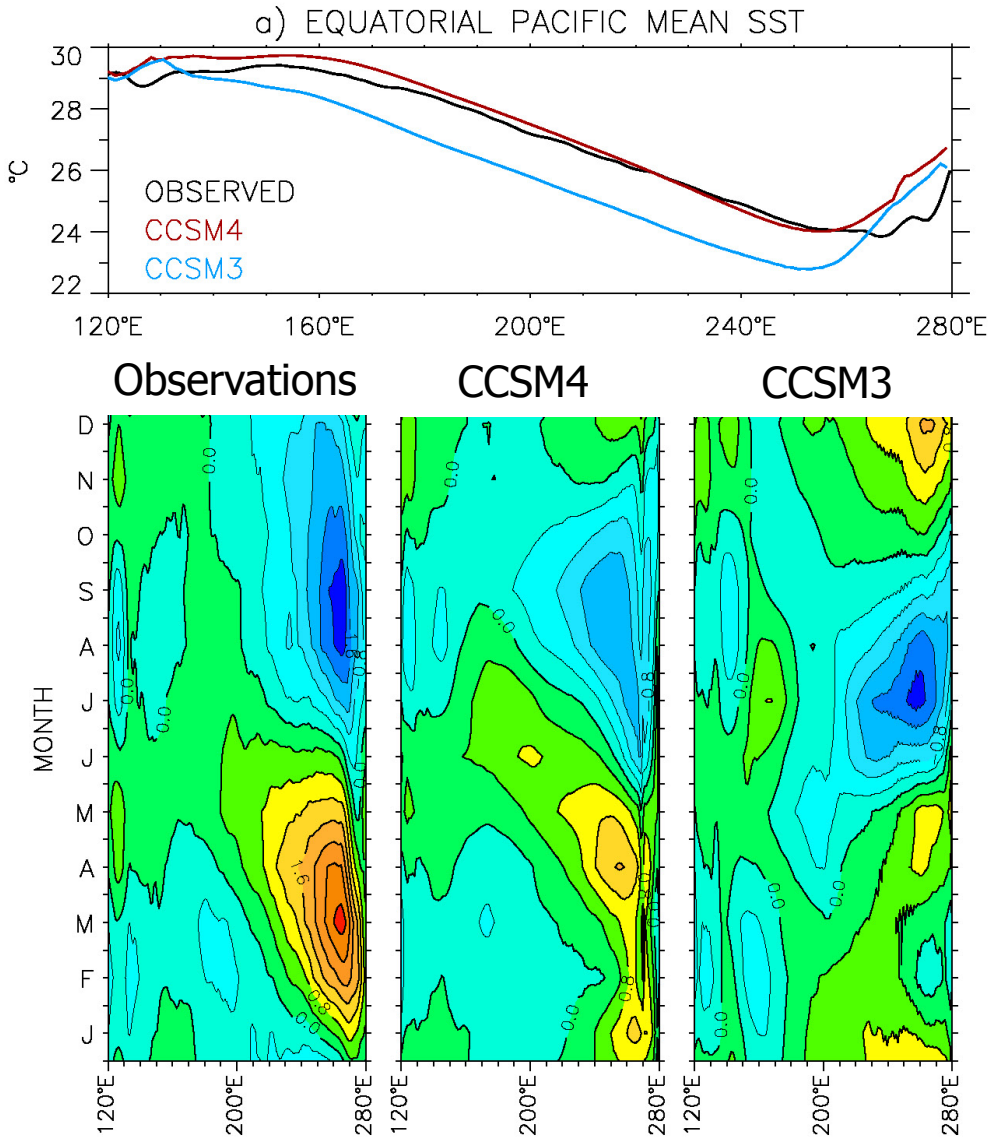
Equatorial Pacific SST

(Late 20th Century)



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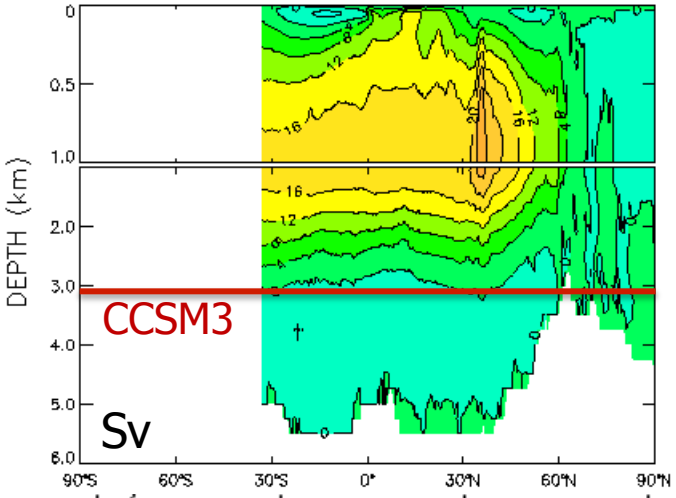
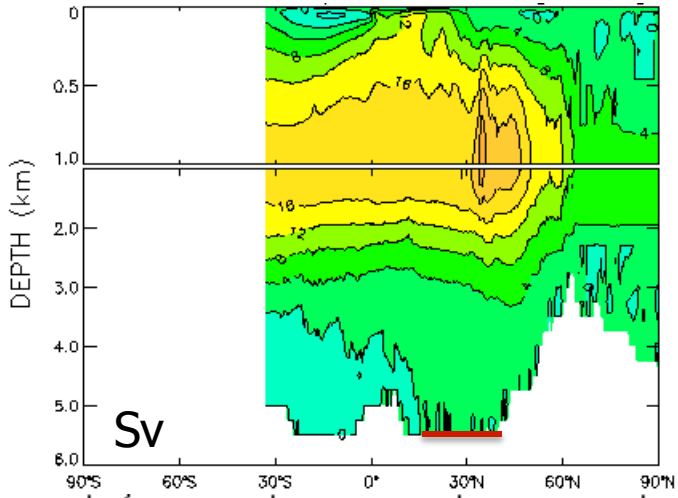
Atlantic MOC in CCSM4

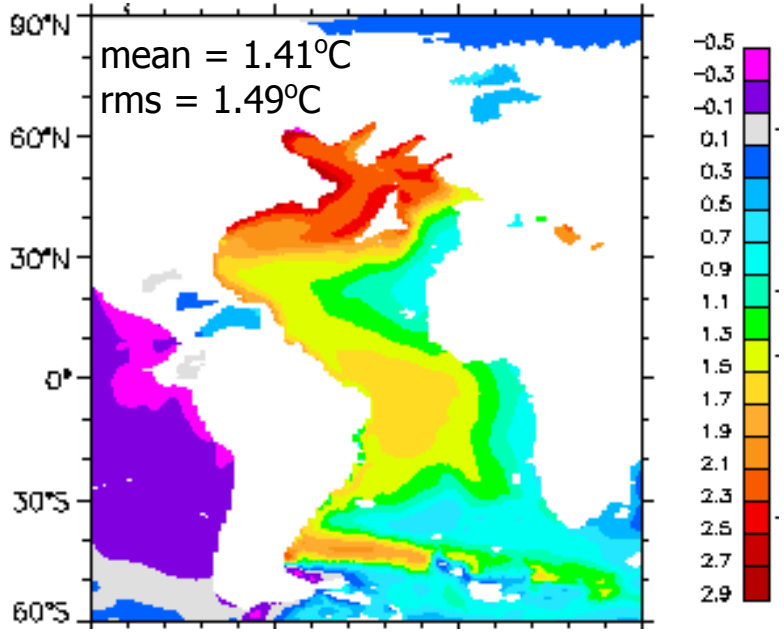
(Late 20th Century)

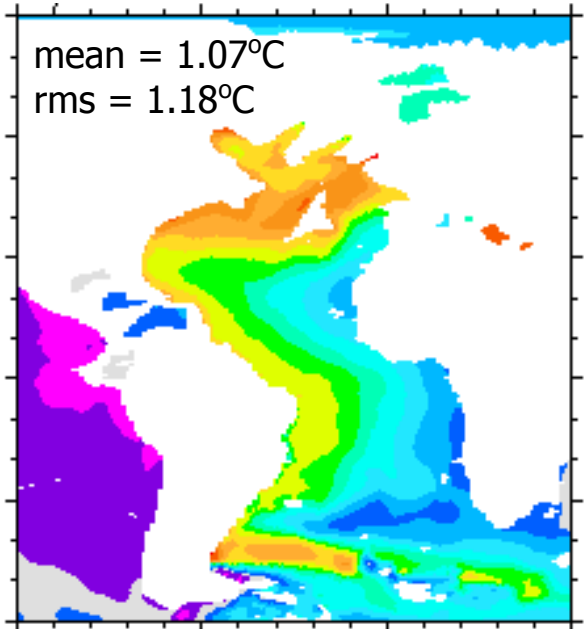
No Overflows

With Overflows









T (2649 m)

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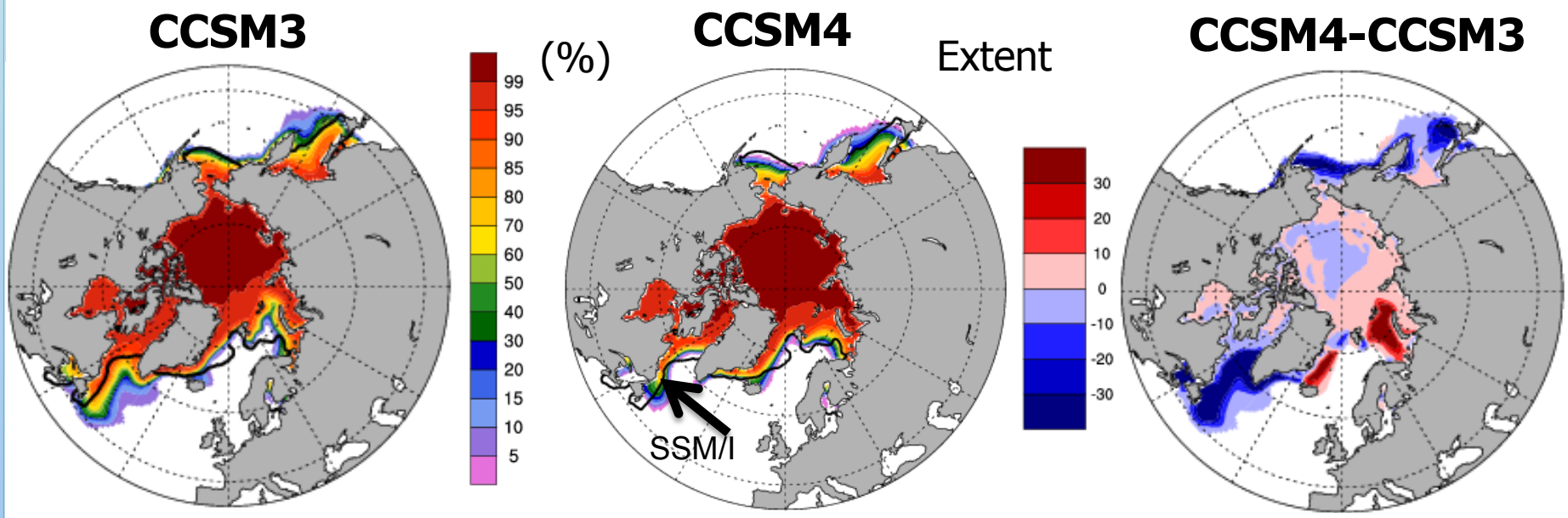
JFM Arctic Sea Ice

(Late 20th Century)



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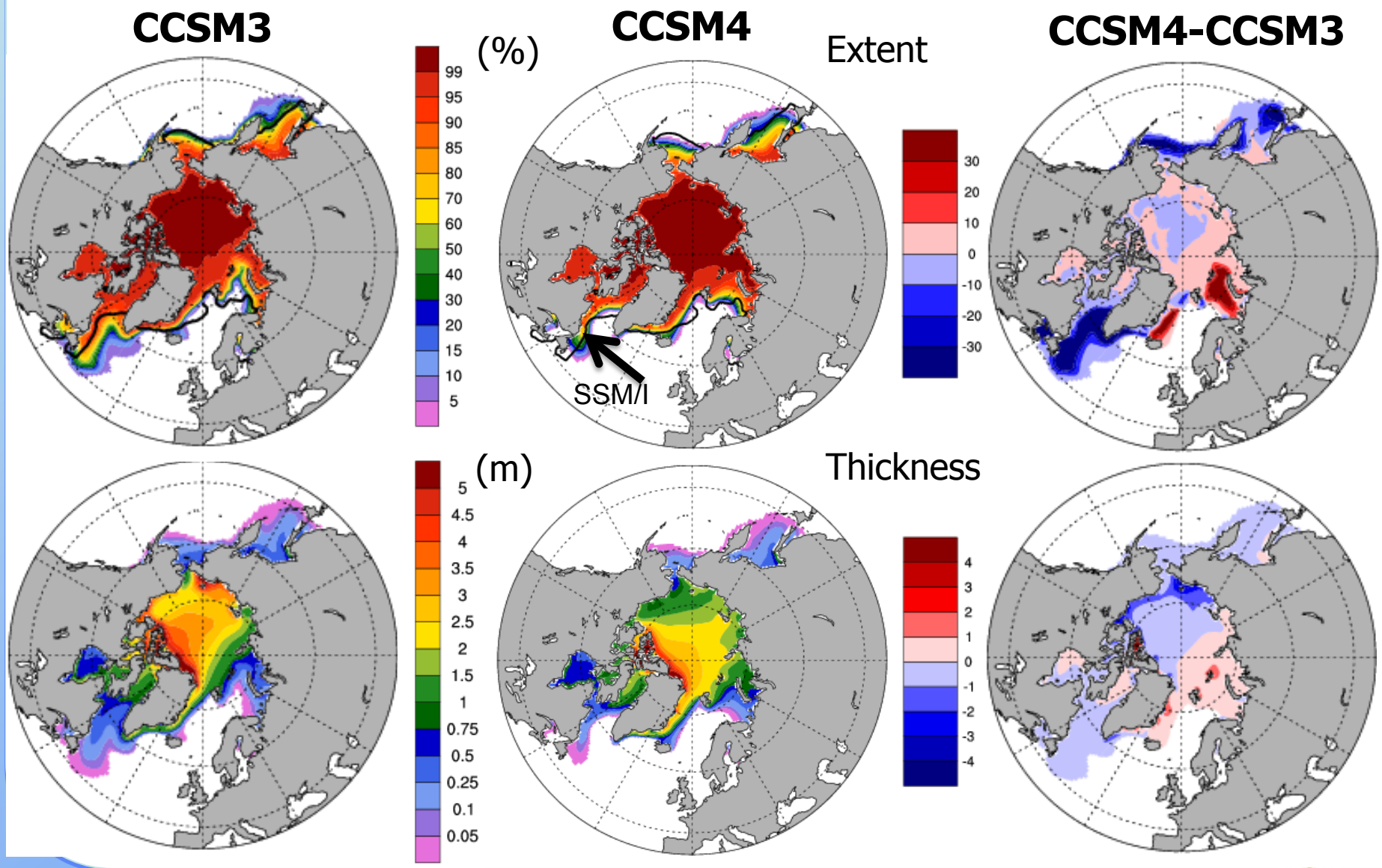
JFM Arctic Sea Ice

(Late 20th Century)



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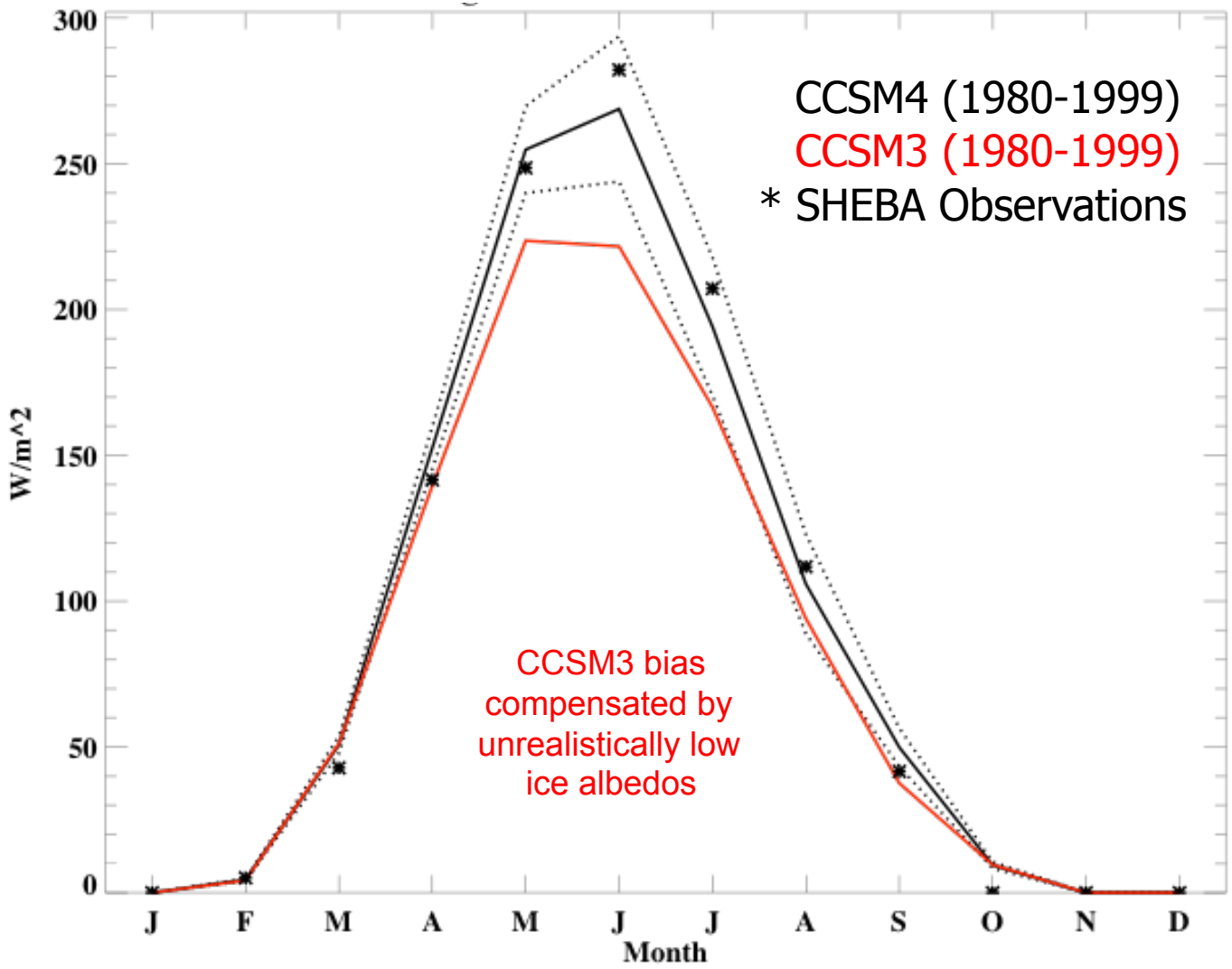
Incoming Shortwave Radiation

(Differences from SHEBA Observations)



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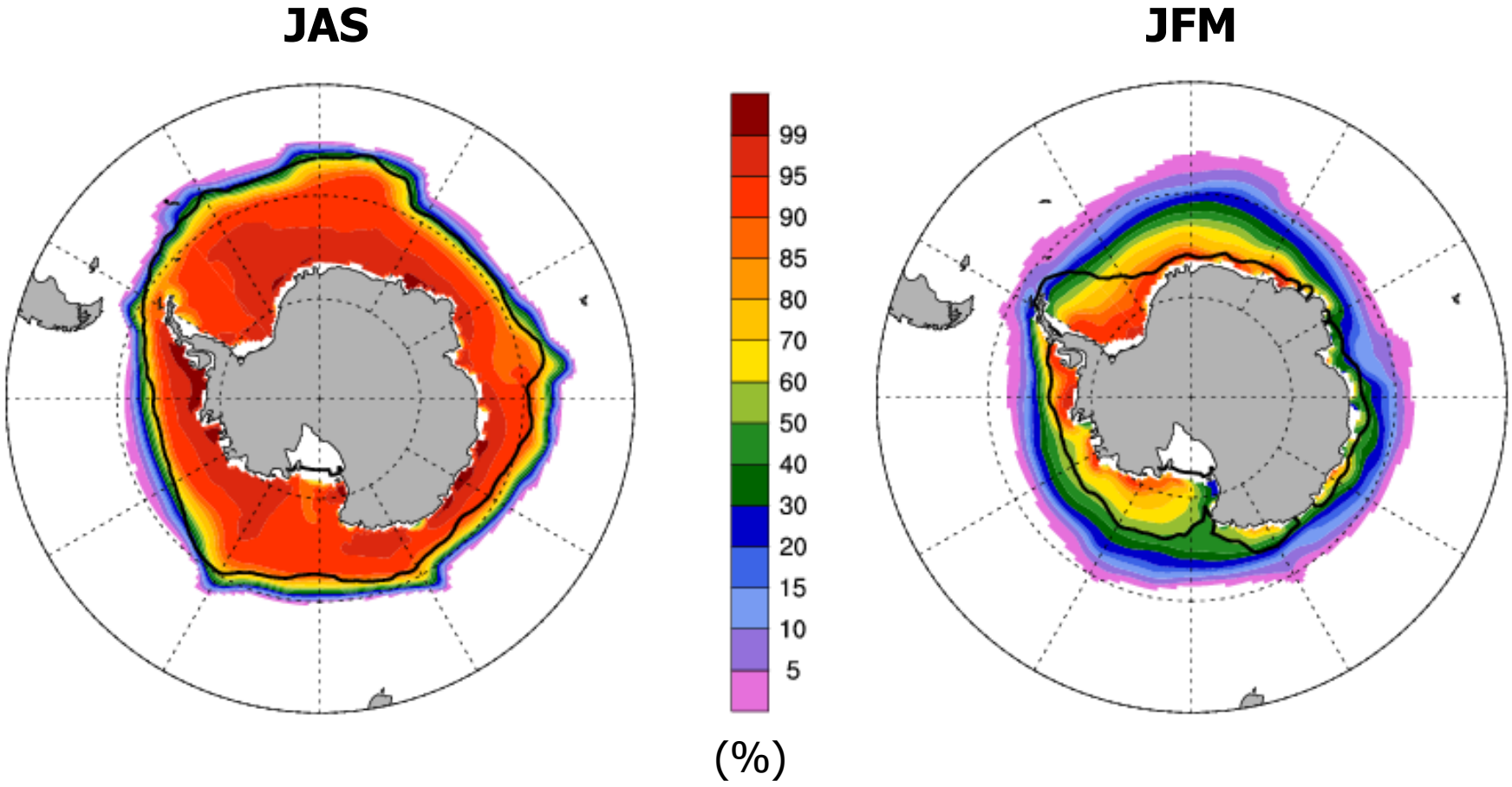
Antarctic sea ice cover

(Late 20th Century)

CCSM4



Too extensive, similar to CCSM3

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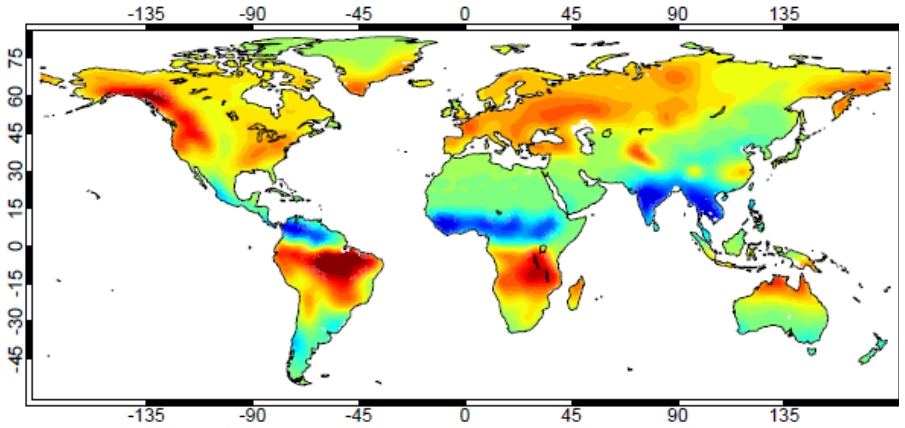
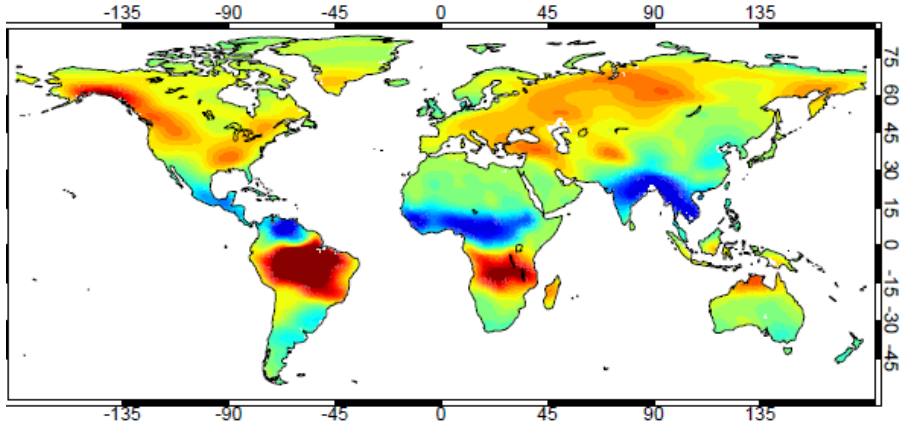
Land water storage (MAM-SON)

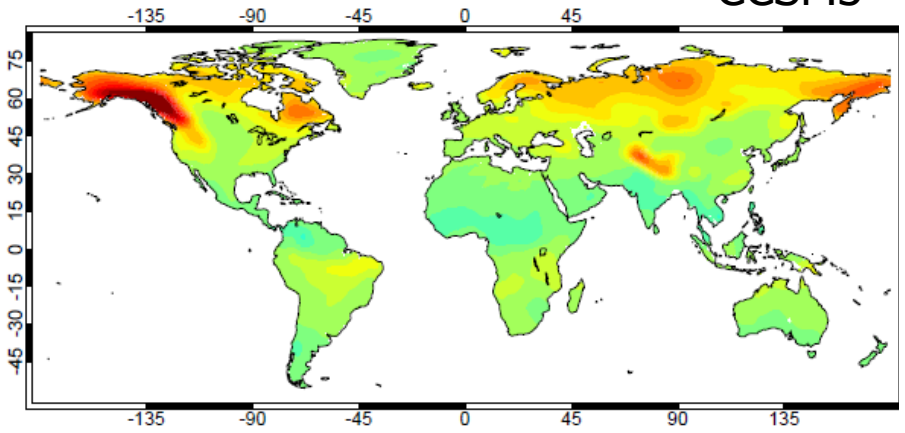
CCSM4



GRACE



CCSM3



300 200 100 0 -100 -200 -300 (mm)

GRACE satellite measures small changes in gravity which on seasonal timescales are due to variations in mean soil and snow water content. CLM4 has improved capacity to store water from one season to the next

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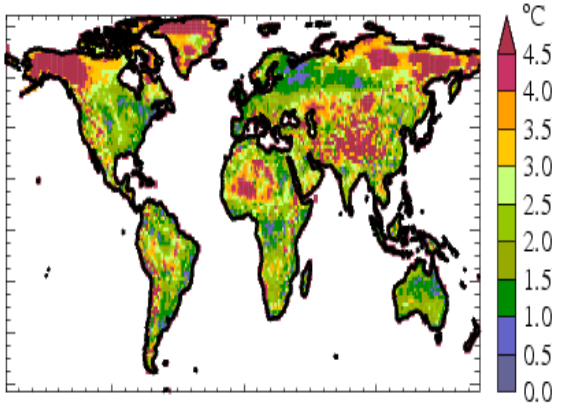
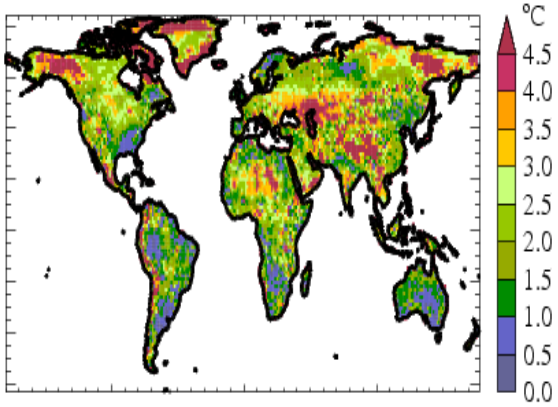
Land surface temperature (annual)

(Differences from Observations: 1950-99)

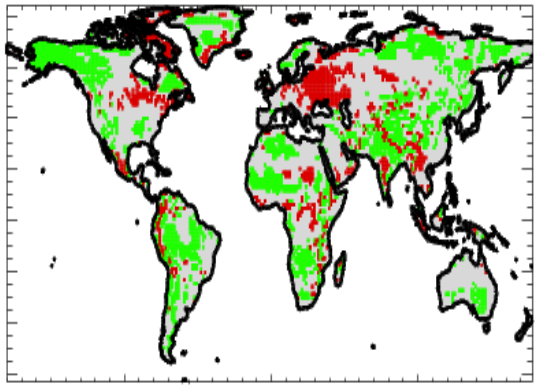
T_{air} RMSE: CCSM3
3.01°C



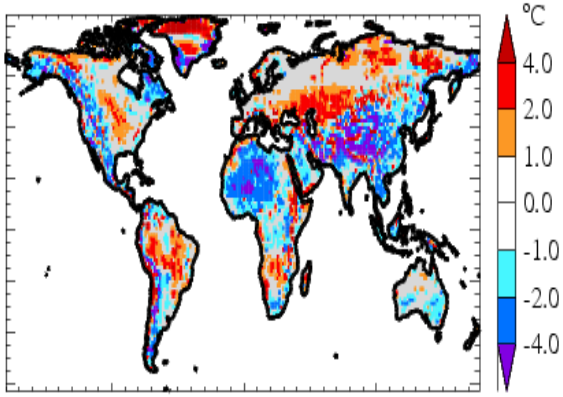
T_{air} RMSE: CCSM4
2.71°C



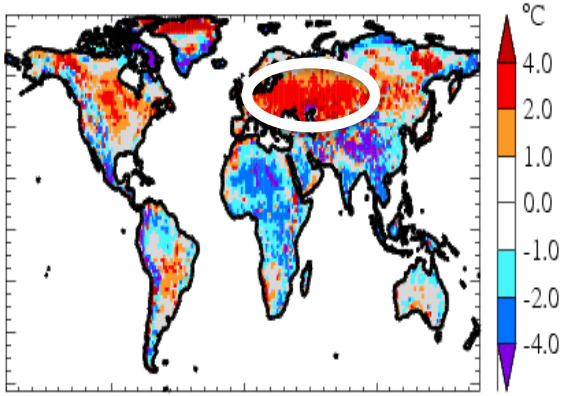
T_{air} RMSE: CCSM4 vs CCSM3
27.1%(+) 12.9%(–)



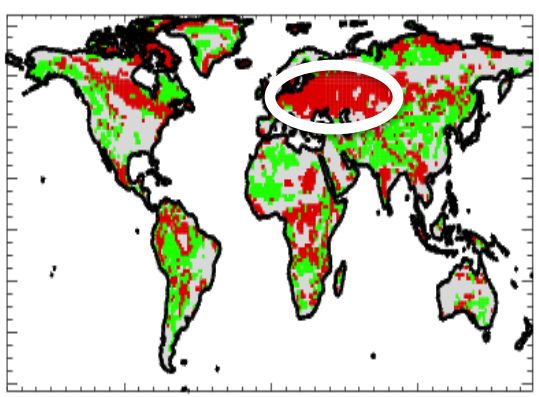
T_{air} ANN Mean Bias: CCSM3
-0.28°C



T_{air} ANN Mean Bias: CCSM4
-0.17°C



T_{air} ANN Mean Bias: CCSM4 vs CCSM3
27.7%(+) 28.3%(–)



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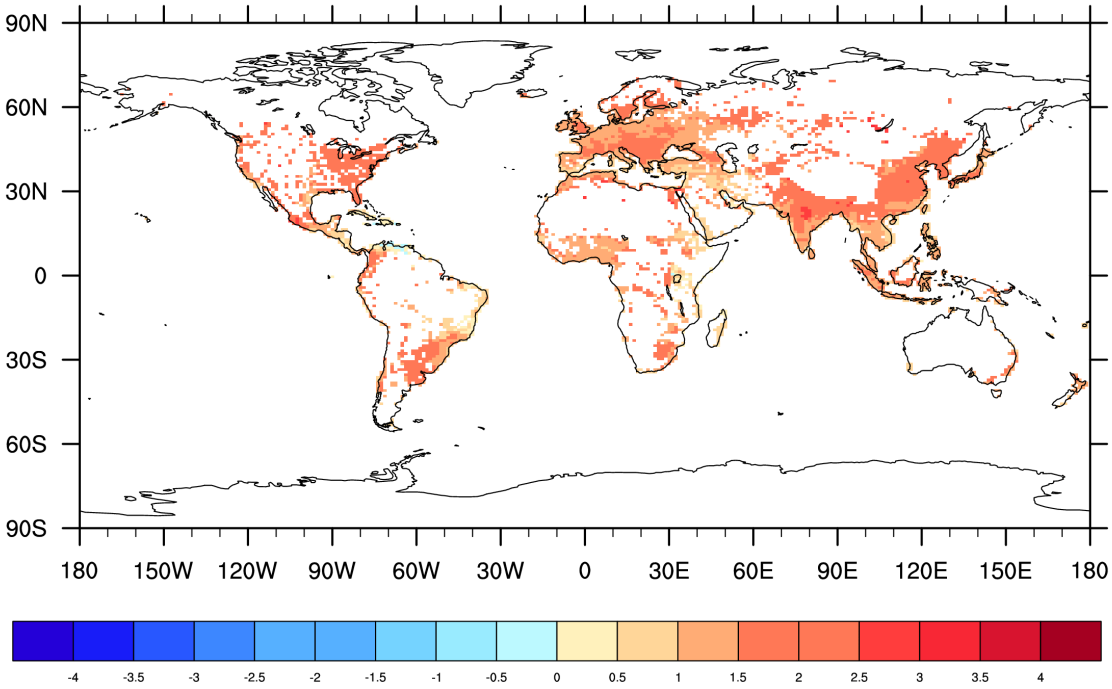
New Capability: Urban Modeling

Present day Urban Heat Island (UHI) simulated by Community Land Model Urban (CLMU) (°C)



- The new Community Land Model (CLM4) includes a representation of urban processes, allowing global simulation of urban environments including the temperature of cities.
- The UHI describes the fact that urban areas are generally warmer than surrounding rural areas.
- The UHI is defined at each grid cell by the difference between the urban and rural (vegetated surface) air temperature
- Modeled UHI ranges from near-zero up to 4C with spatial and seasonal variability controlled by urban to rural contrasts in energy balance.

Oleson, K.W., G.B. Bonan, J. Feddema, M. Vertenstein, C.S.B. Grimmond, 2008a, *J. Appl. Meteor. Climatol.*
Oleson, K.W., G.B. Bonan, J. Feddema, M. Vertenstein, 2008b, *J. Appl. Meteor. Climatol.*

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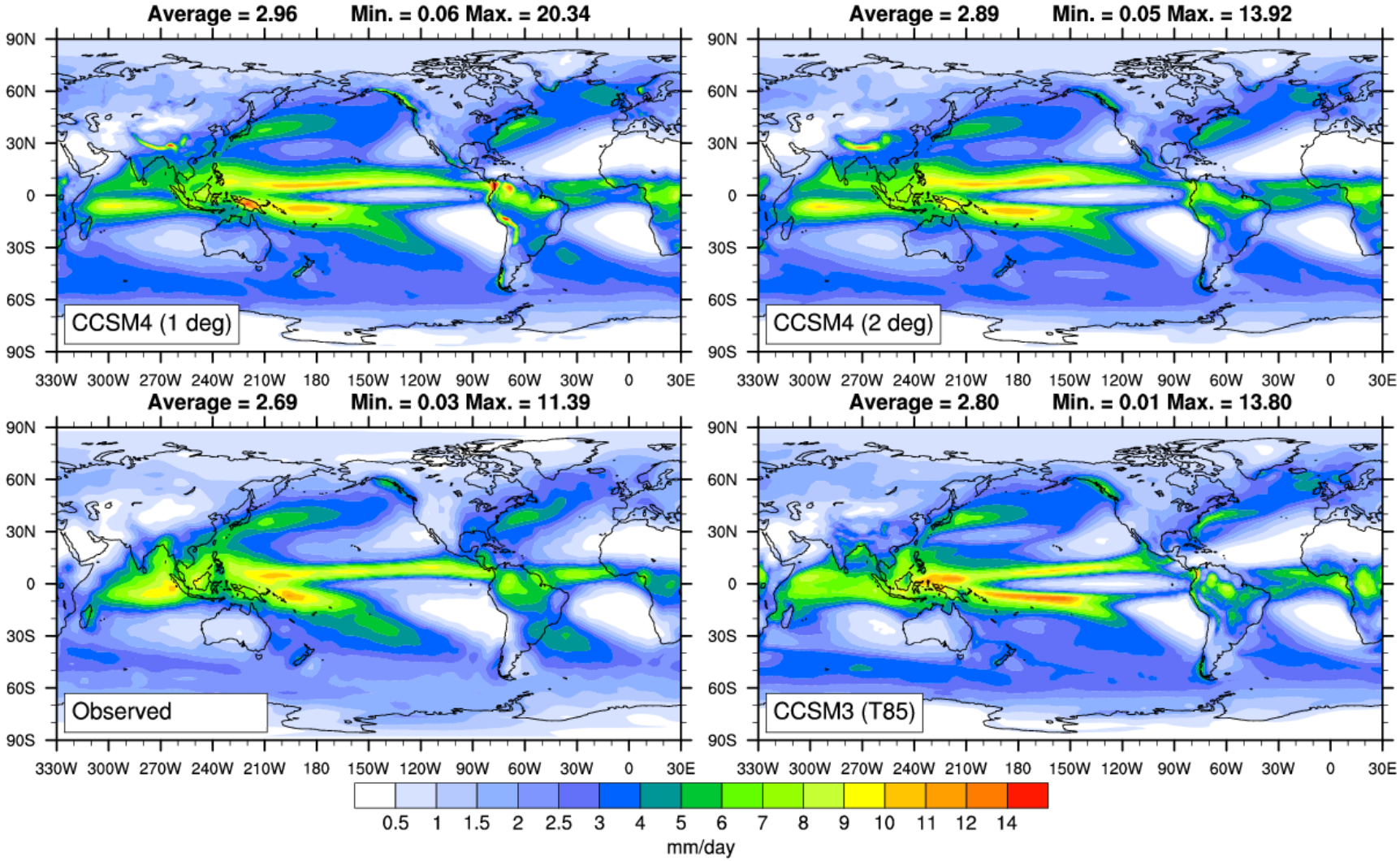
Total Precipitation
(Annual)



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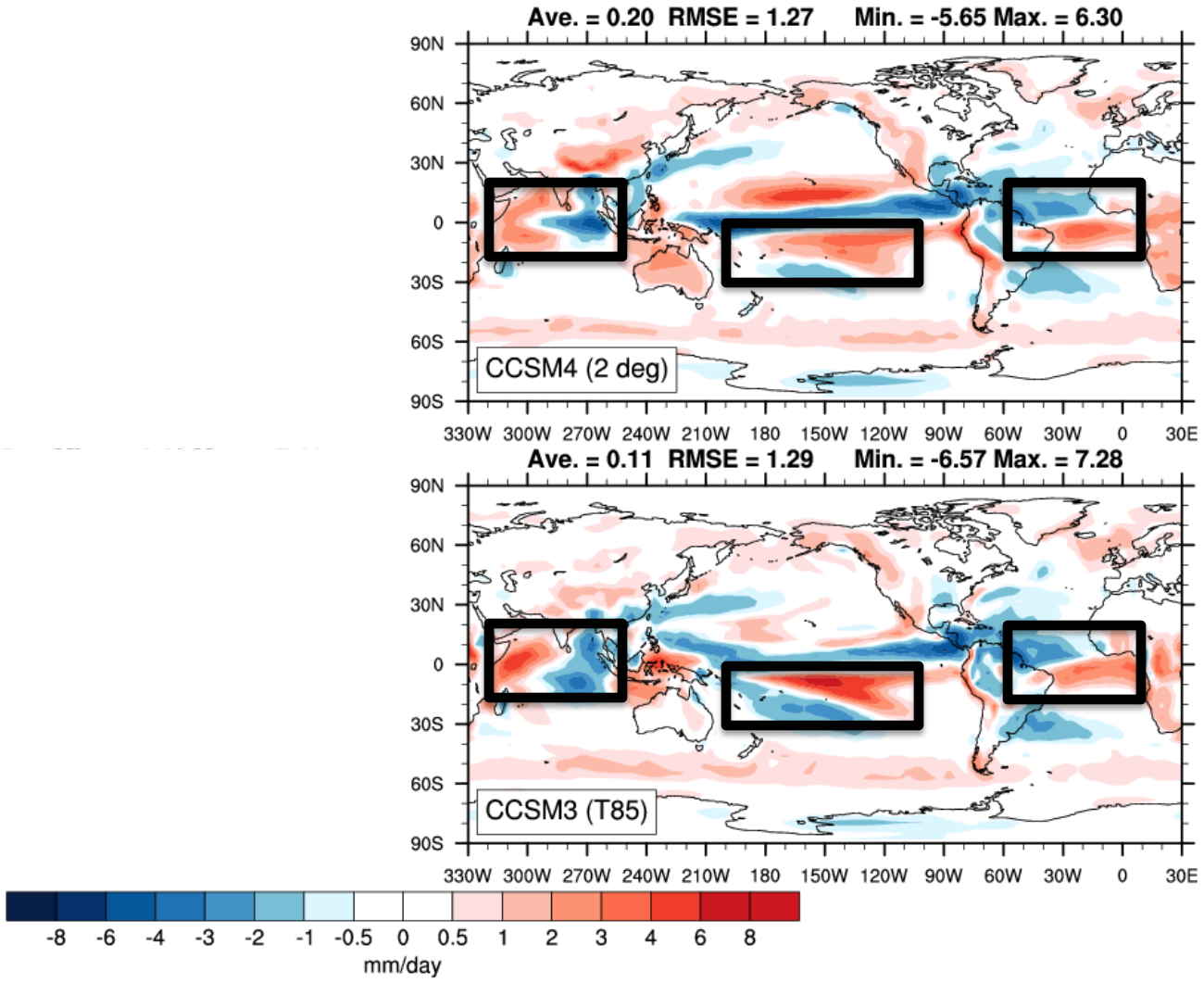
Total Precipitation Difference
(Annual)



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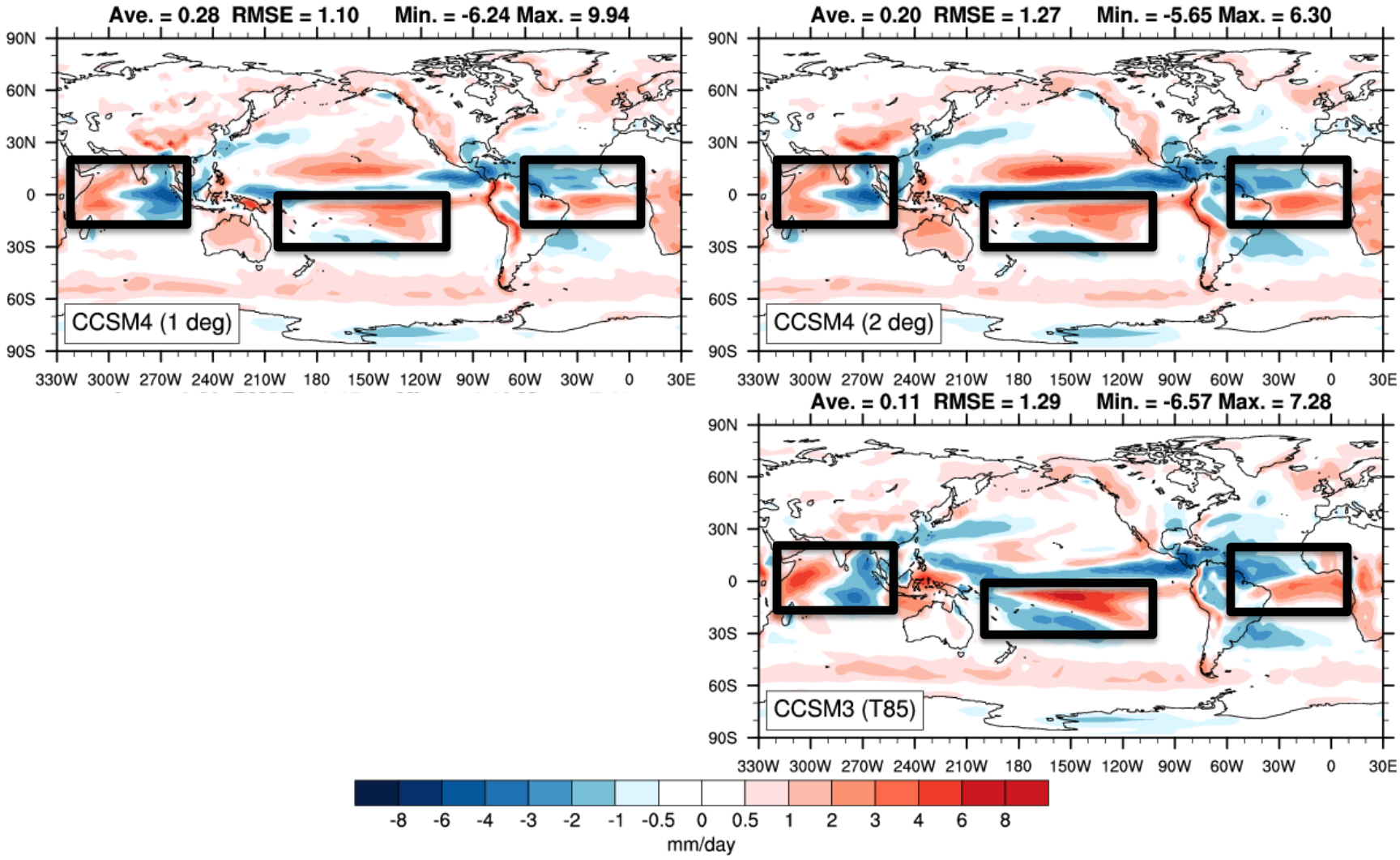
Total Precipitation Difference
(Annual)



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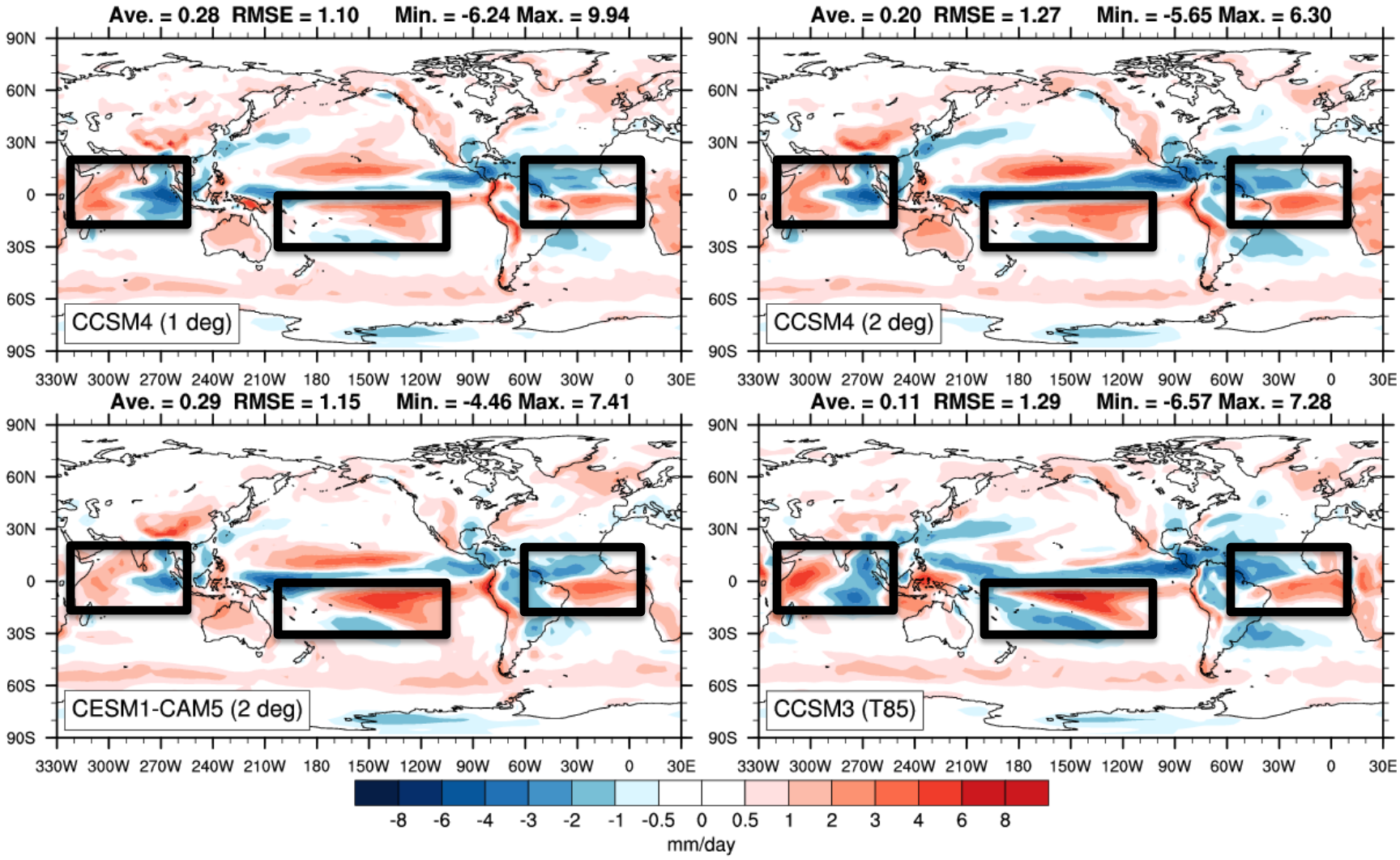
Total Precipitation Difference
(Annual)



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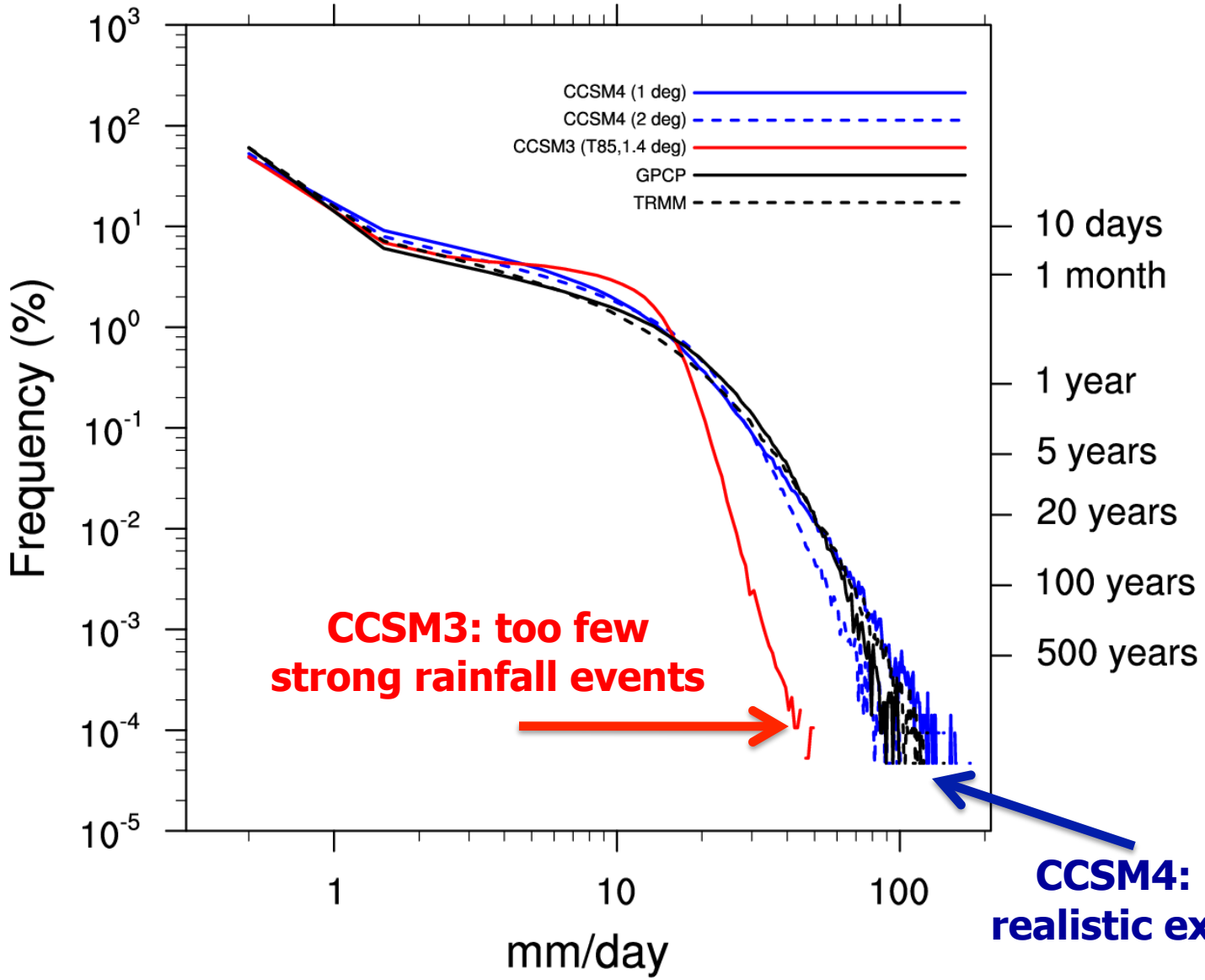
Tropical Land Precipitation

(Frequency of Daily Rate)



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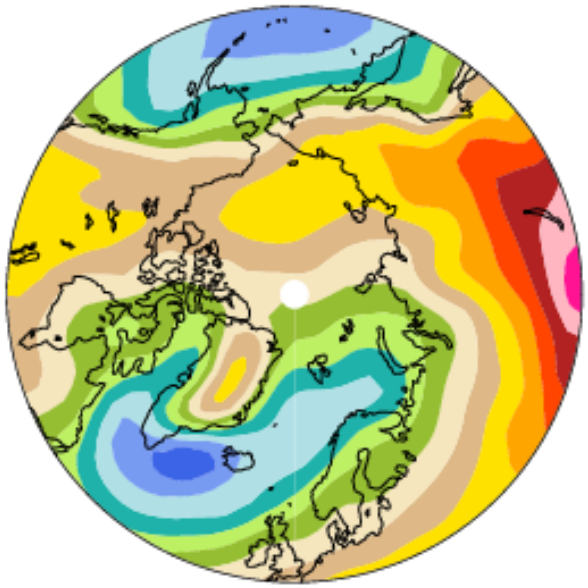
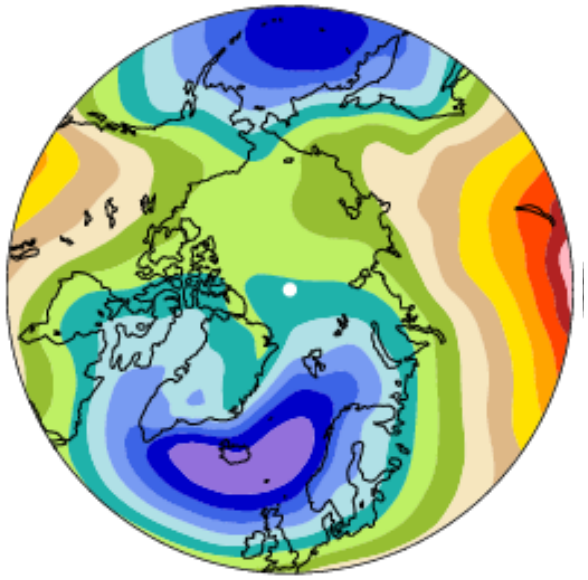
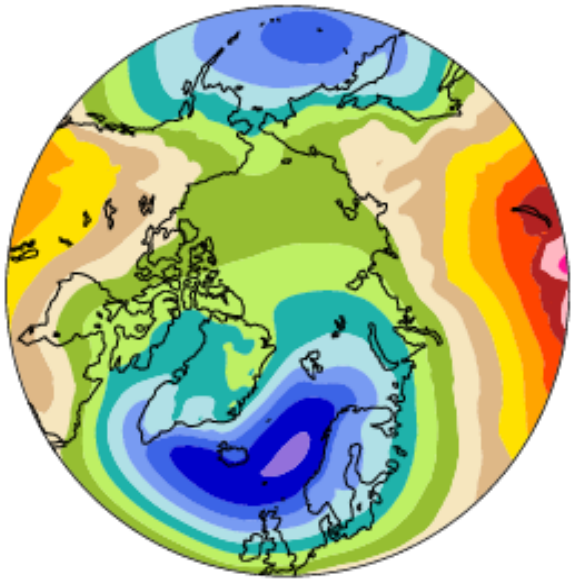
High Latitude SLP (DJF)



Observed



CCSM3



CCSM4

Systematic Reduction in North Atlantic and North Pacific biases

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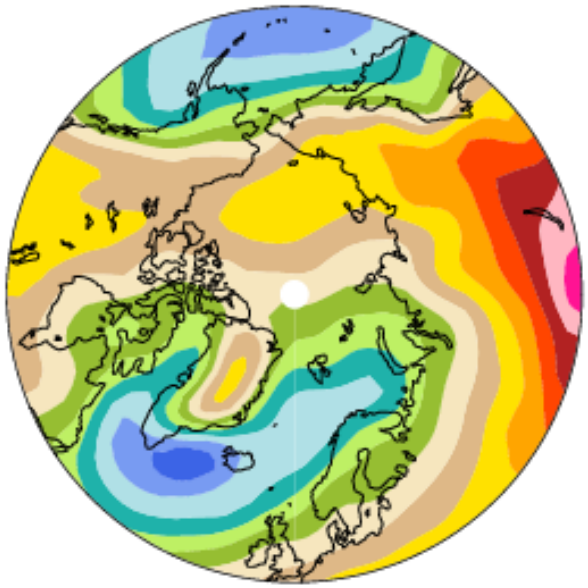
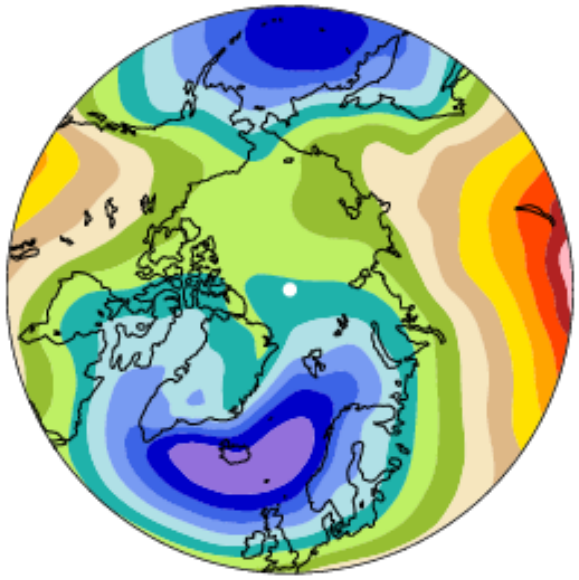
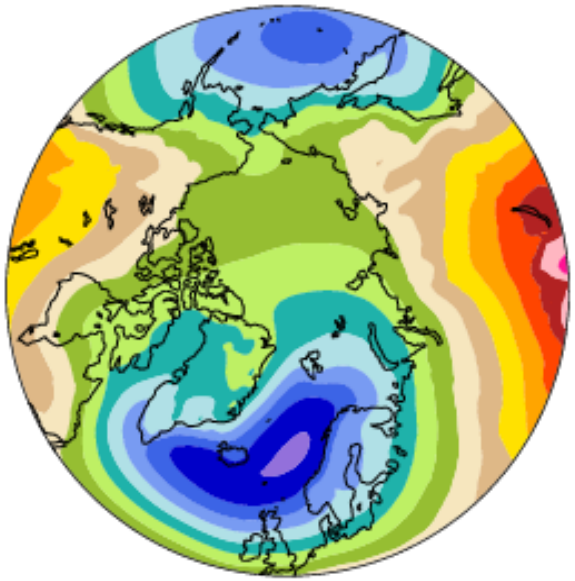
High Latitude SLP (DJF)

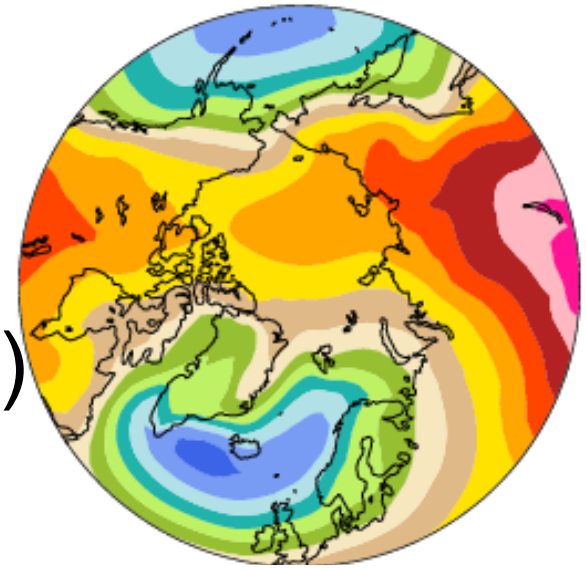


Observed



CCSM3





CESM (CAM5)

Systematic Reduction in North Atlantic and North Pacific biases

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Variability

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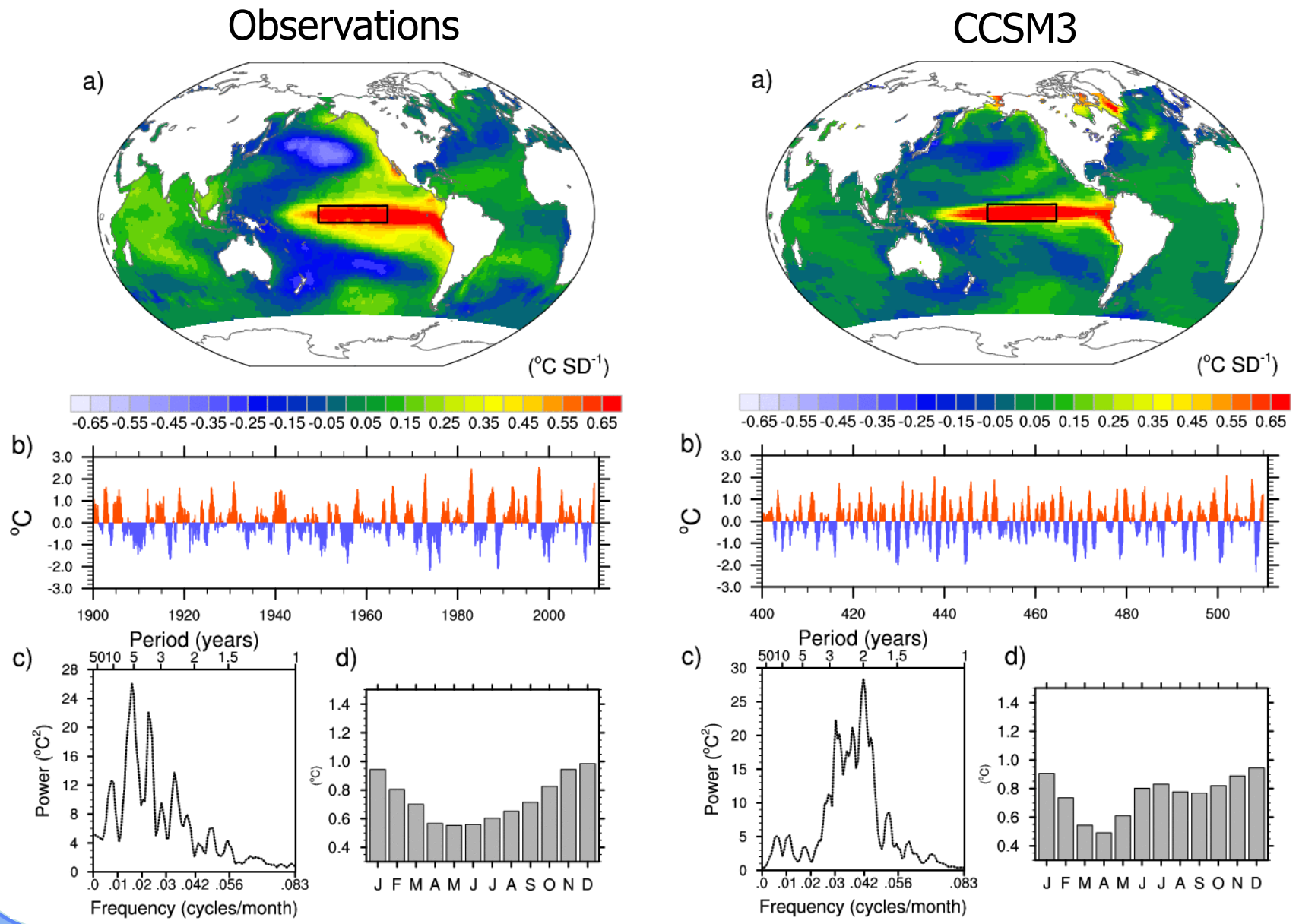
Leading Mode of Global SST Variability



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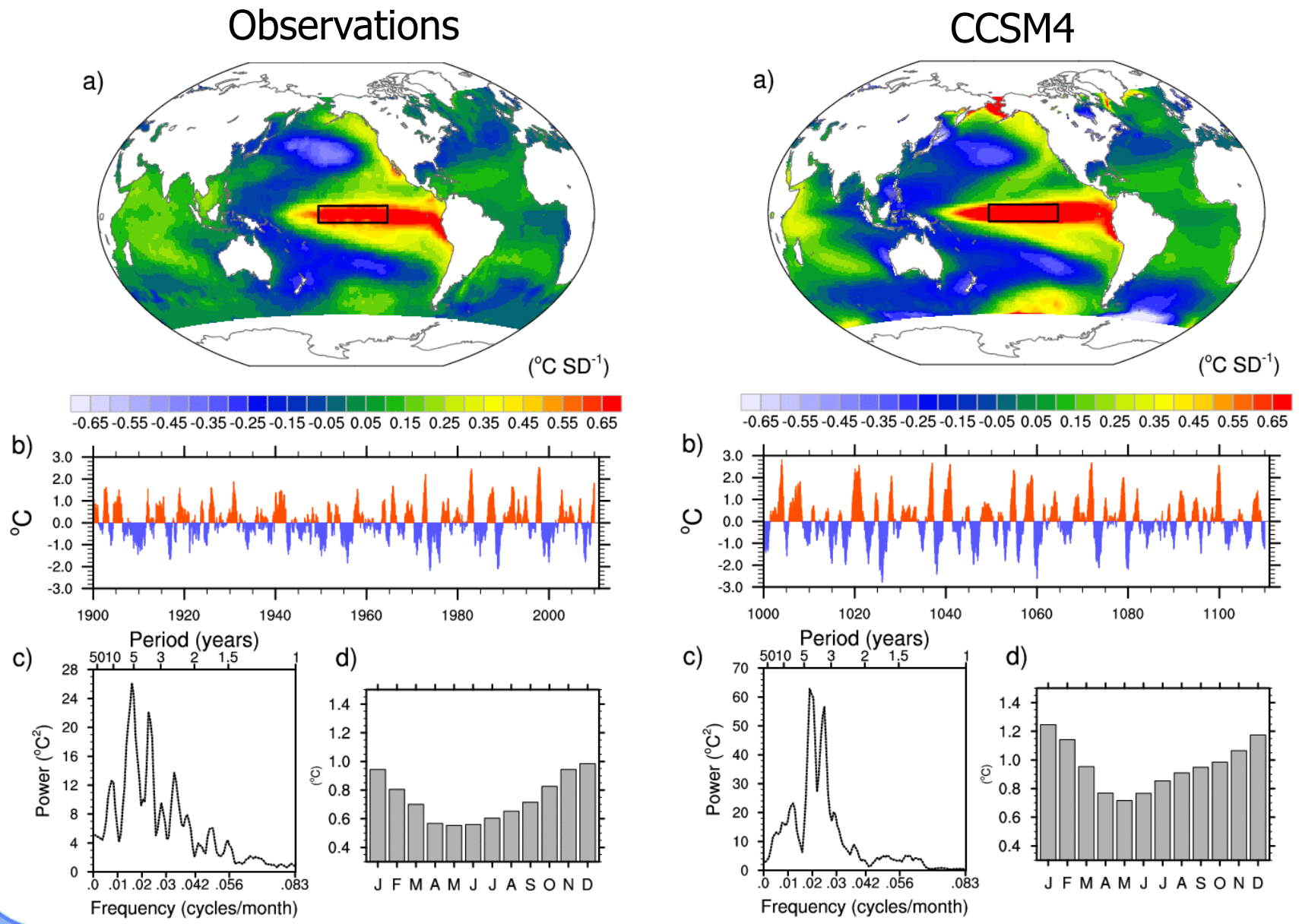
Leading Mode of Global SST Variability



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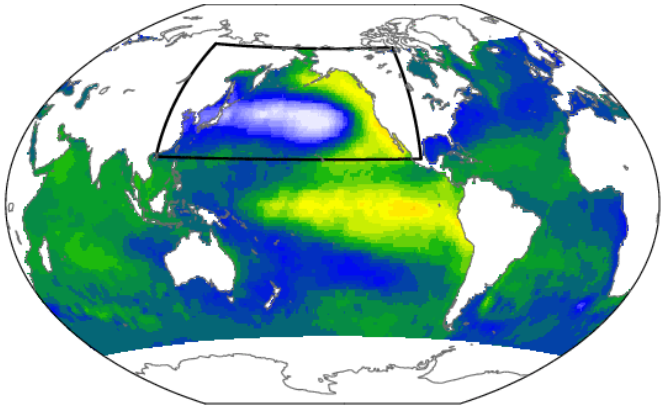
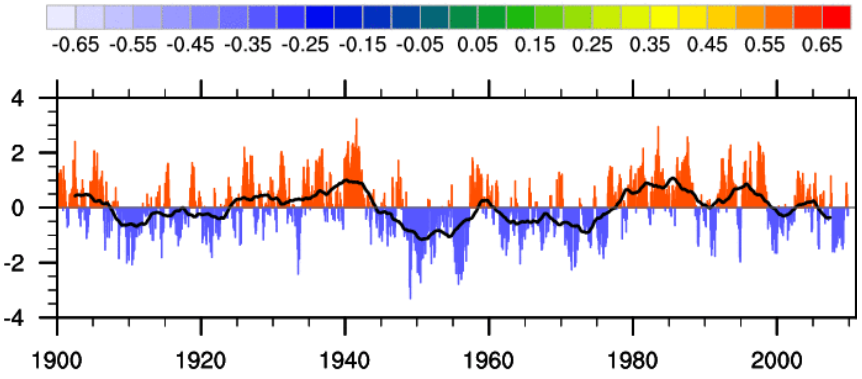
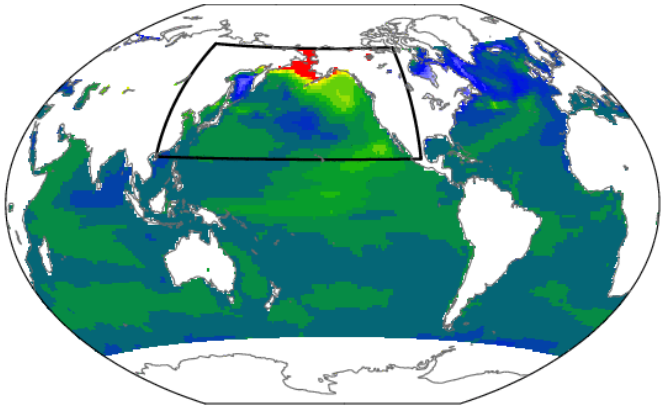
North Pacific Decadal Variability

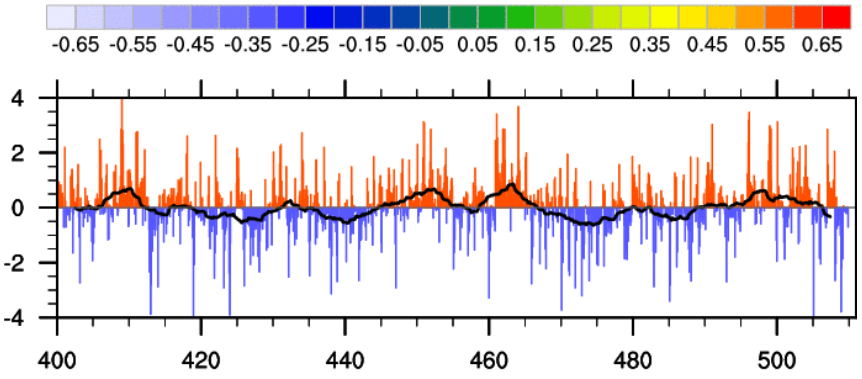
Observations





CCSM3





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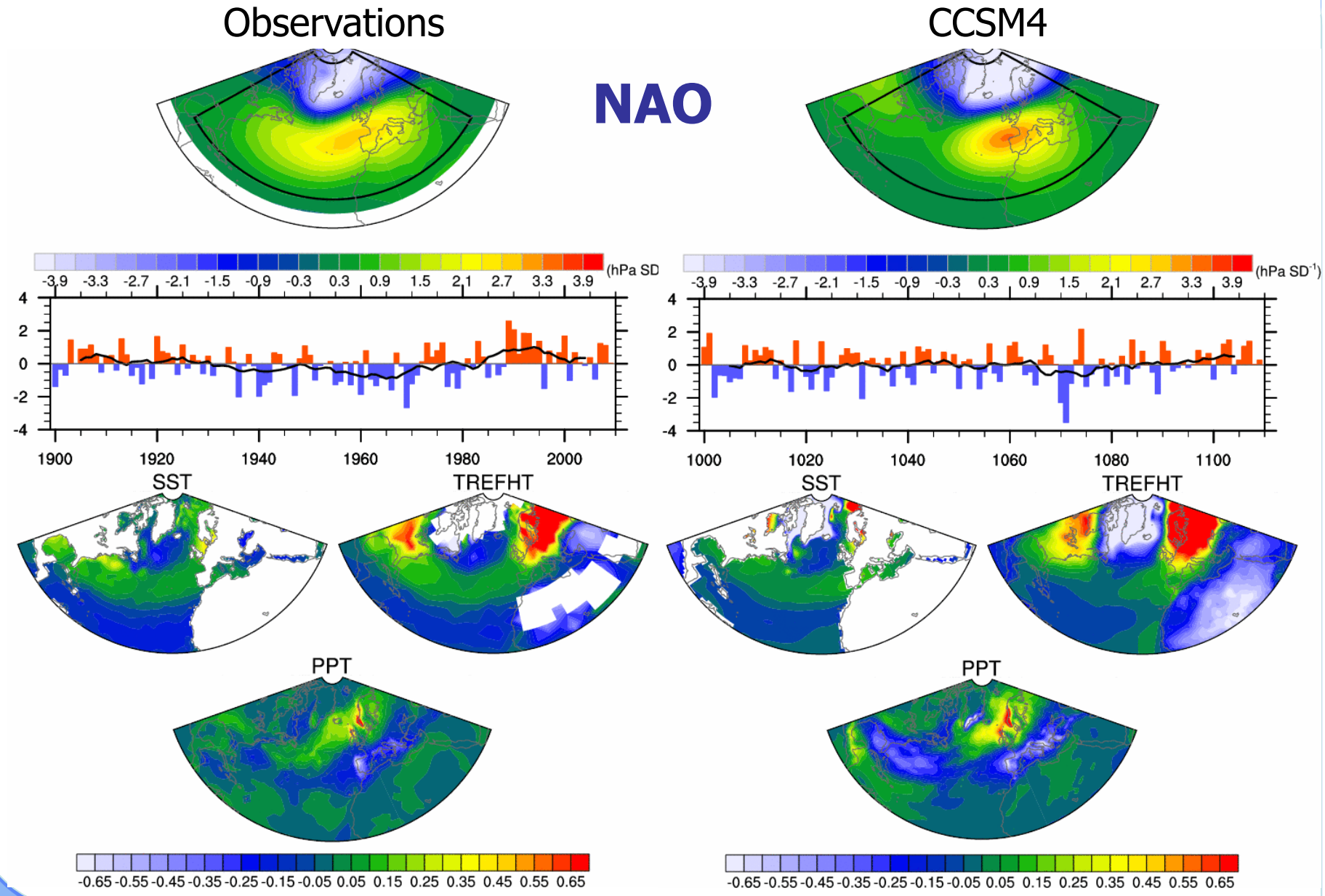
North Atlantic Variability



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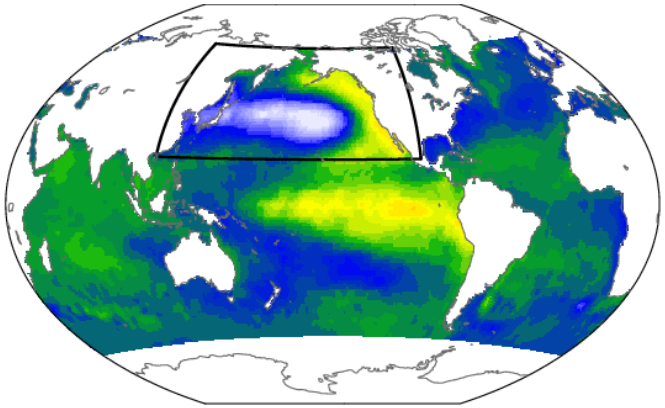
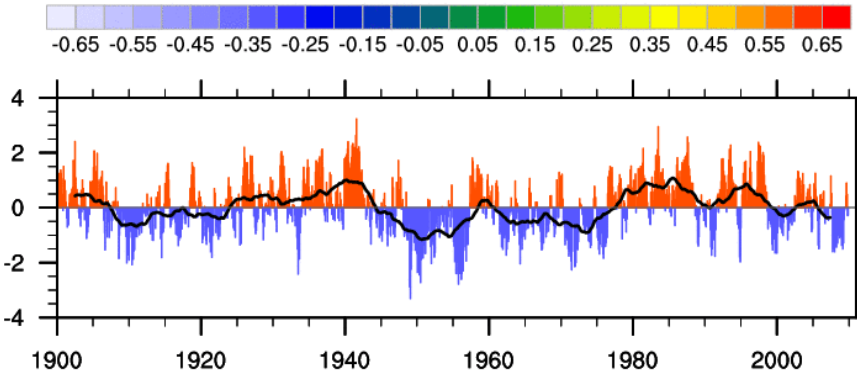
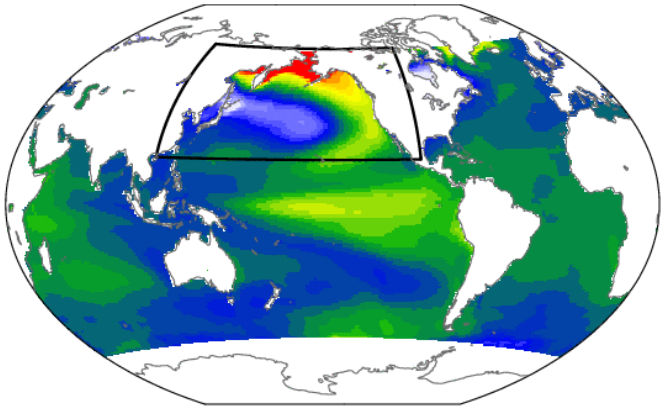
North Pacific Decadal Variability

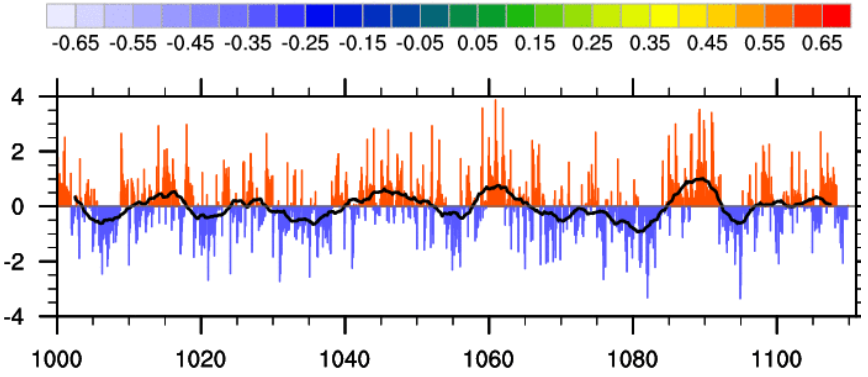
Observations





CCSM4





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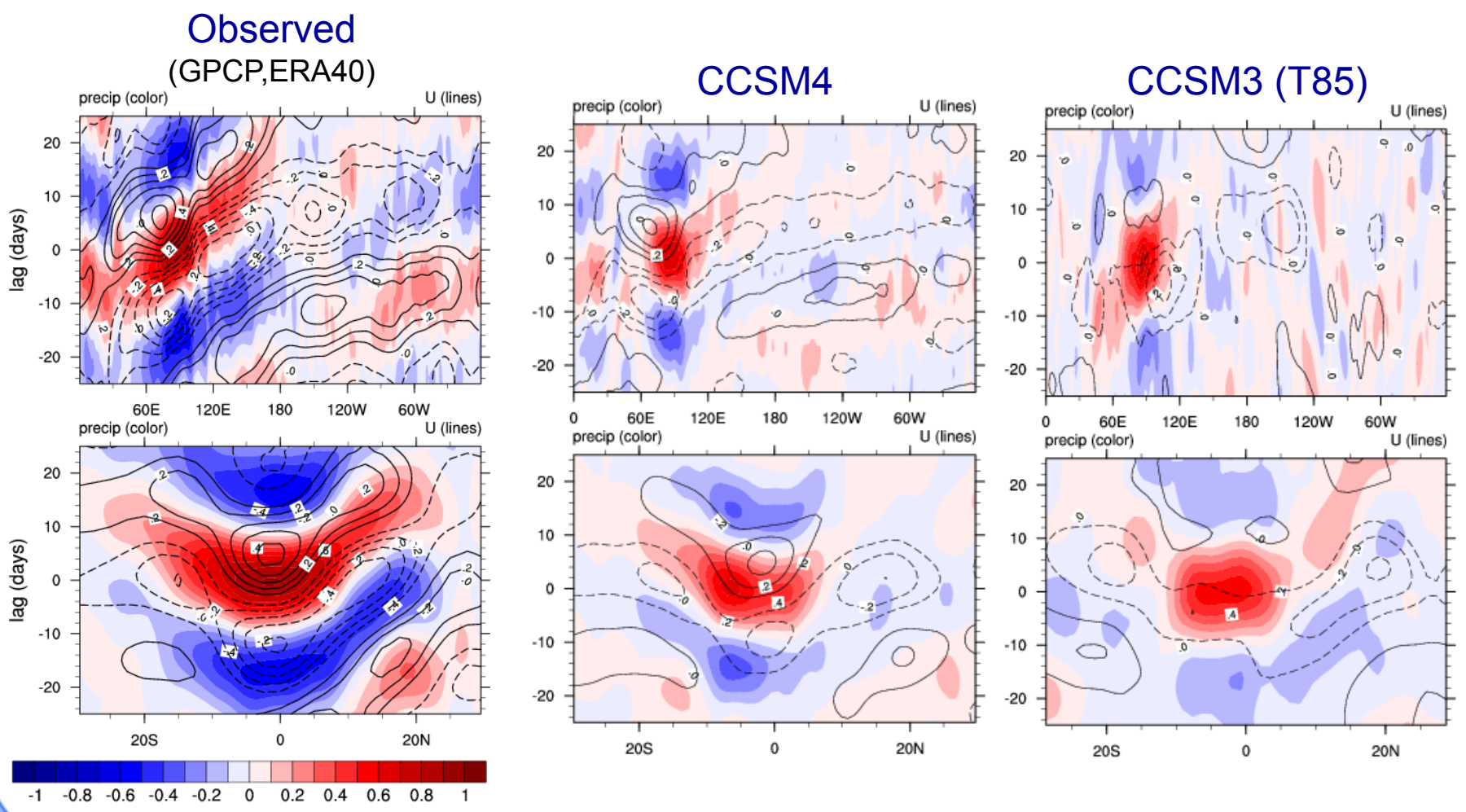
Intraseasonal Variability

Lag correlation of 20-100 day band pass filtered precipitation and 850-mb zonal wind



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20th Century and Future Climate

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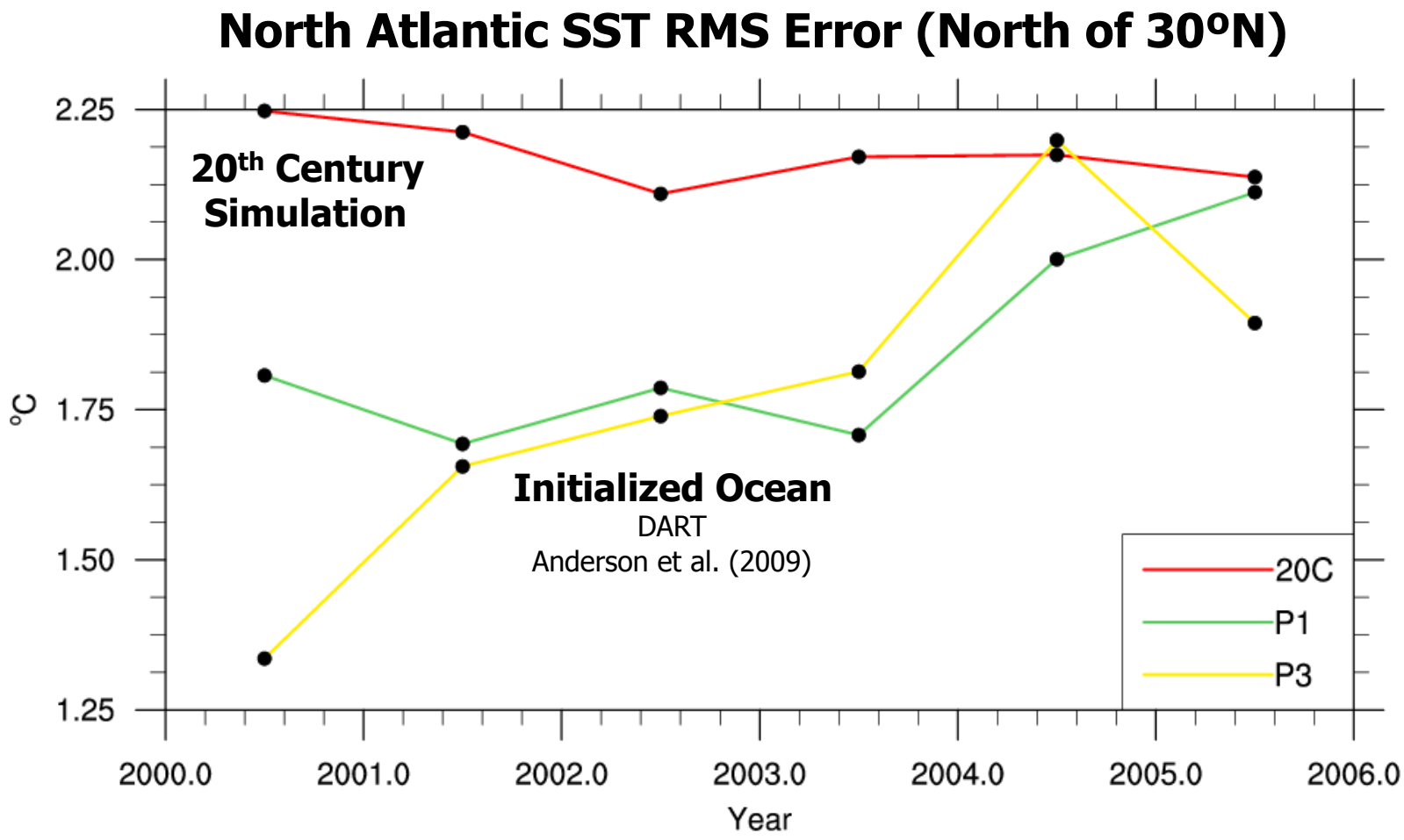
Initialized (Decadal) Predictions with CCSM4



Persistence of large-scale SST bias reduction

Steve Yeager et al. (2010)

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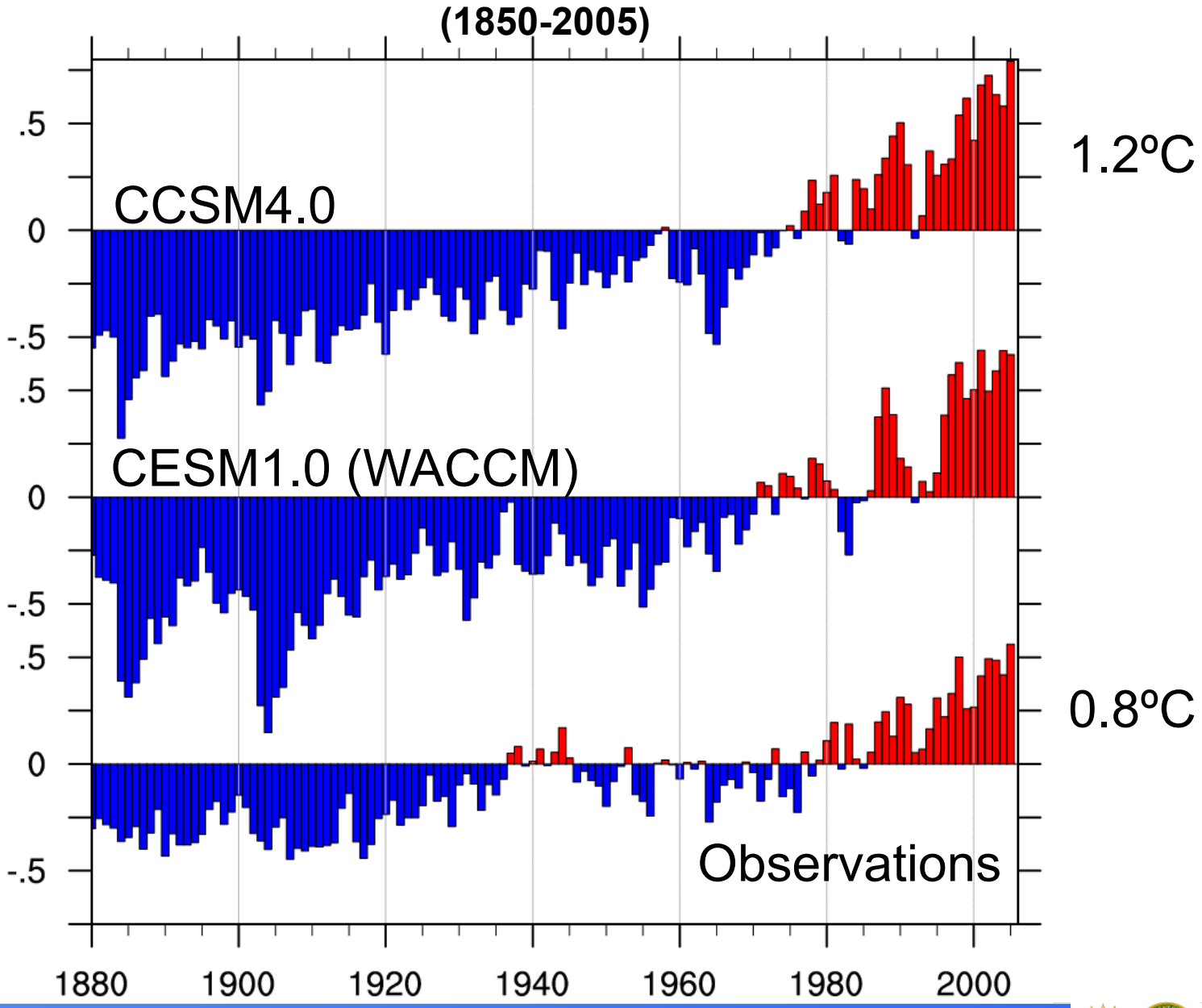
Global Temperature



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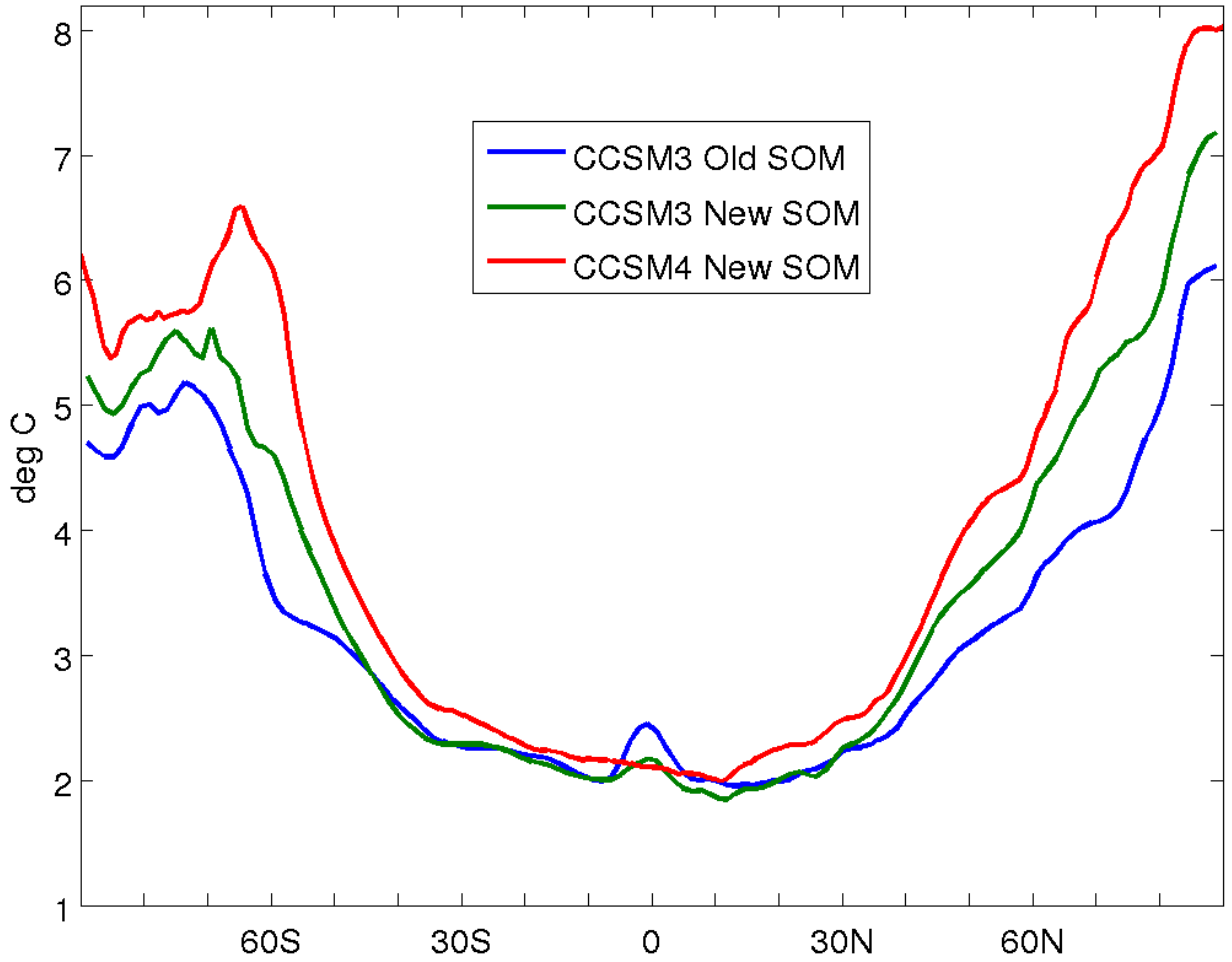
Equilibrium Climate Sensitivity

- Is 3.16°C in CCSM4, which is 0.5°C higher than "official" ECS of CCSM3
- Mostly due (up to 50% of difference) to new SOM method
- About 25% of difference due to new terrestrial snow burial parameterization



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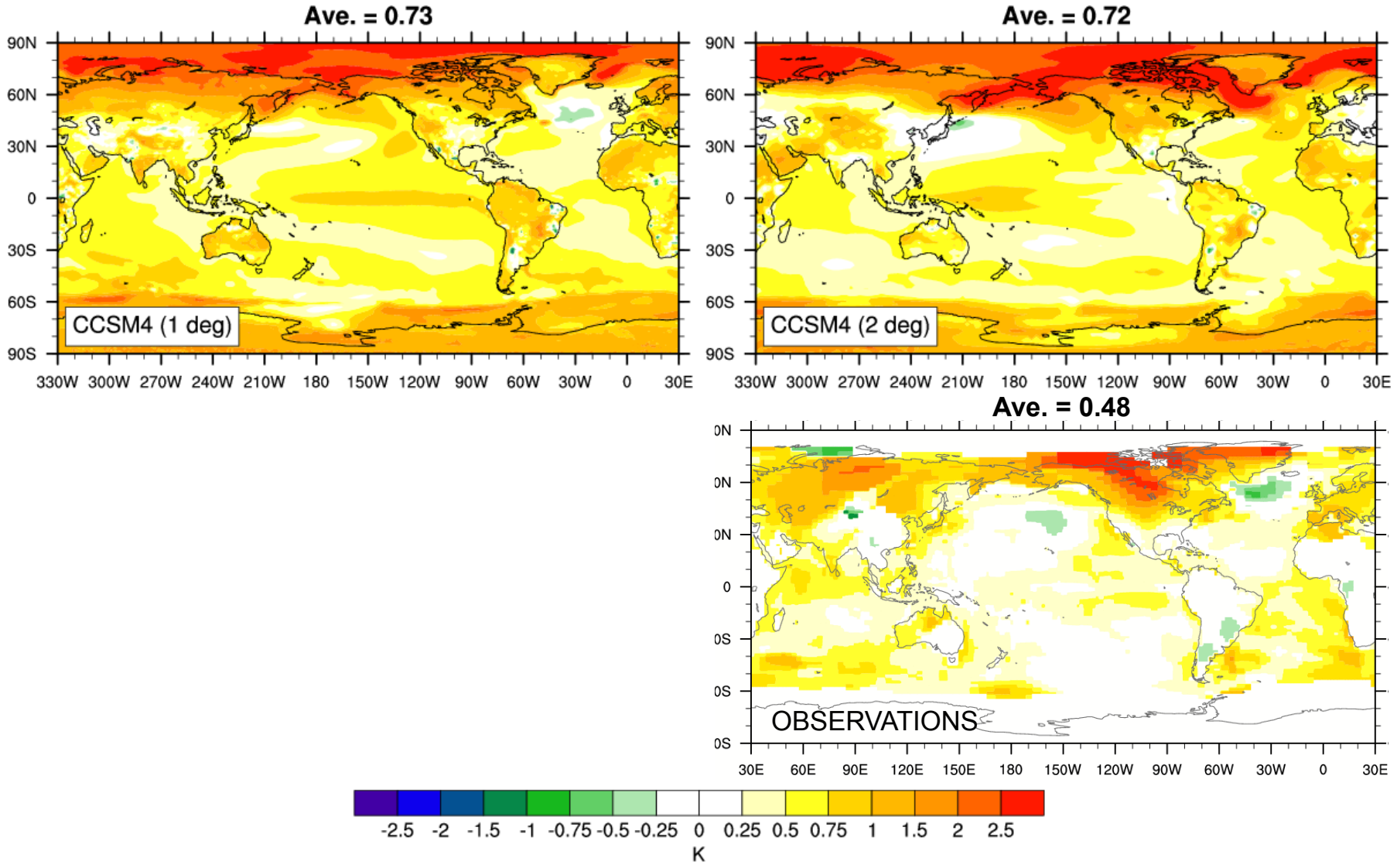
20th Century Surface Temperature Change



Warming too strong in CCSM4.0

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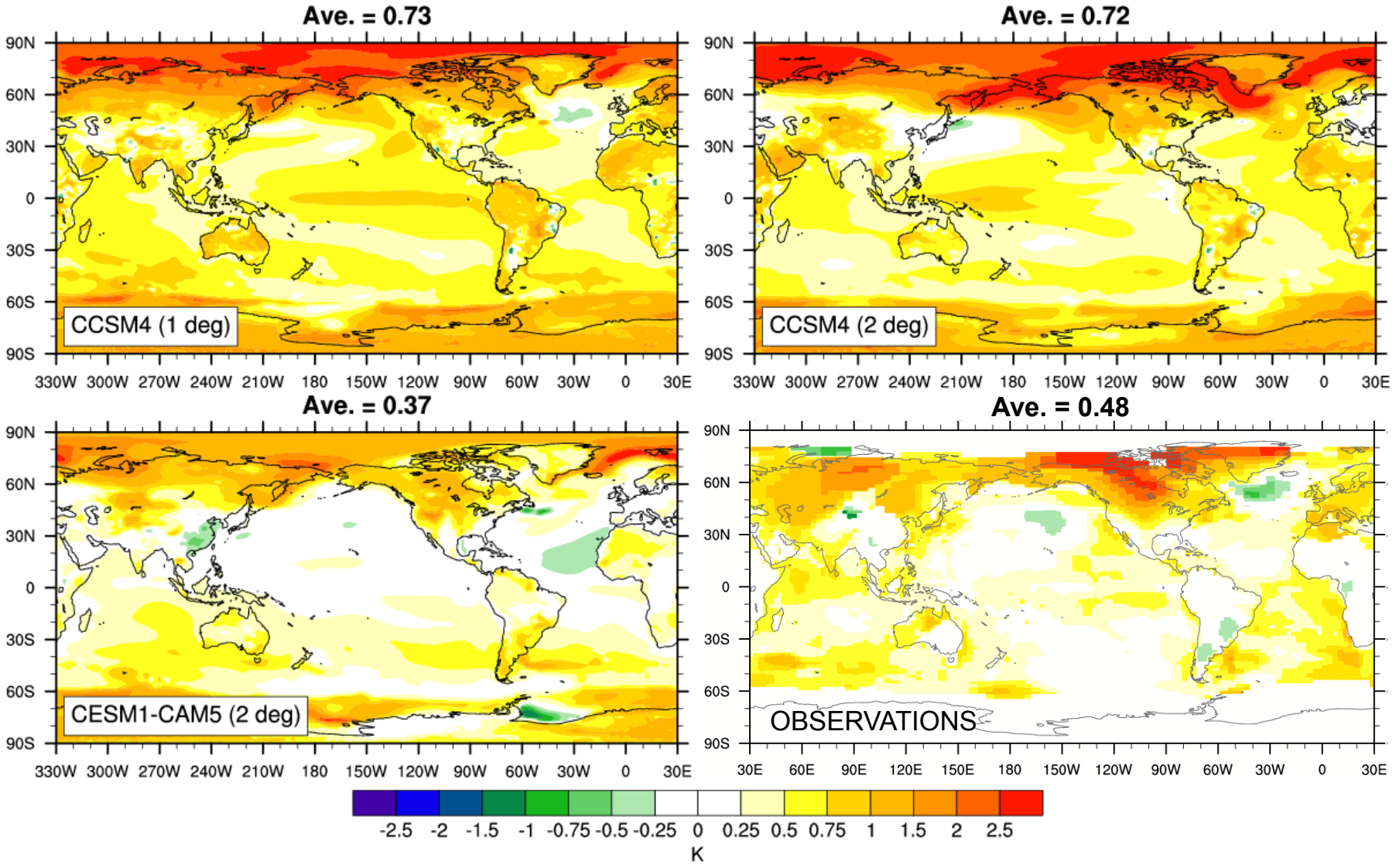
20th Century Surface Temperature Change



Weaker warming in CESM1.0 (CAM5)

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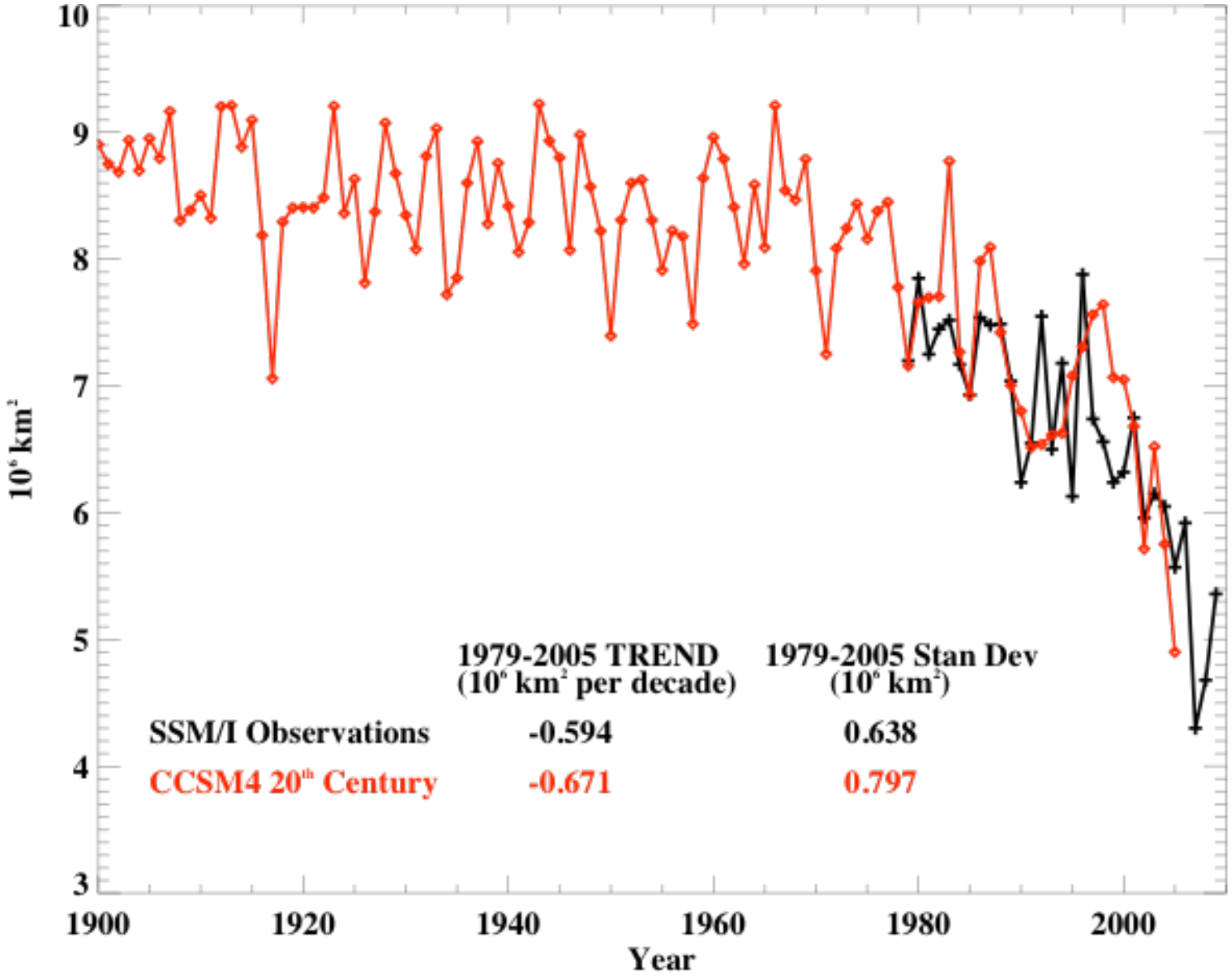
September Arctic Sea Ice Extent



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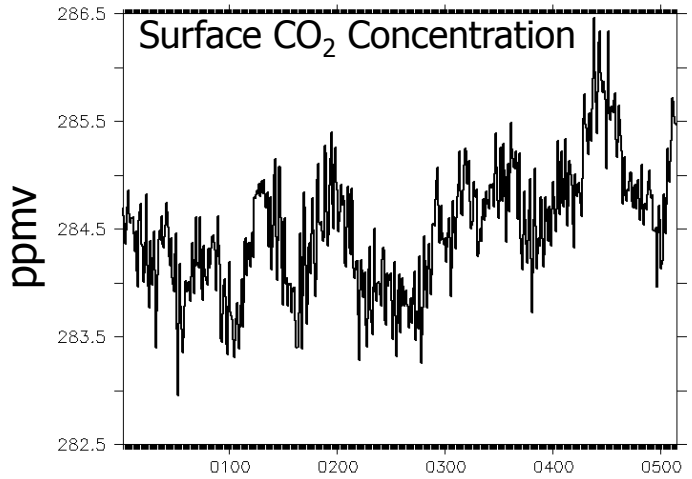
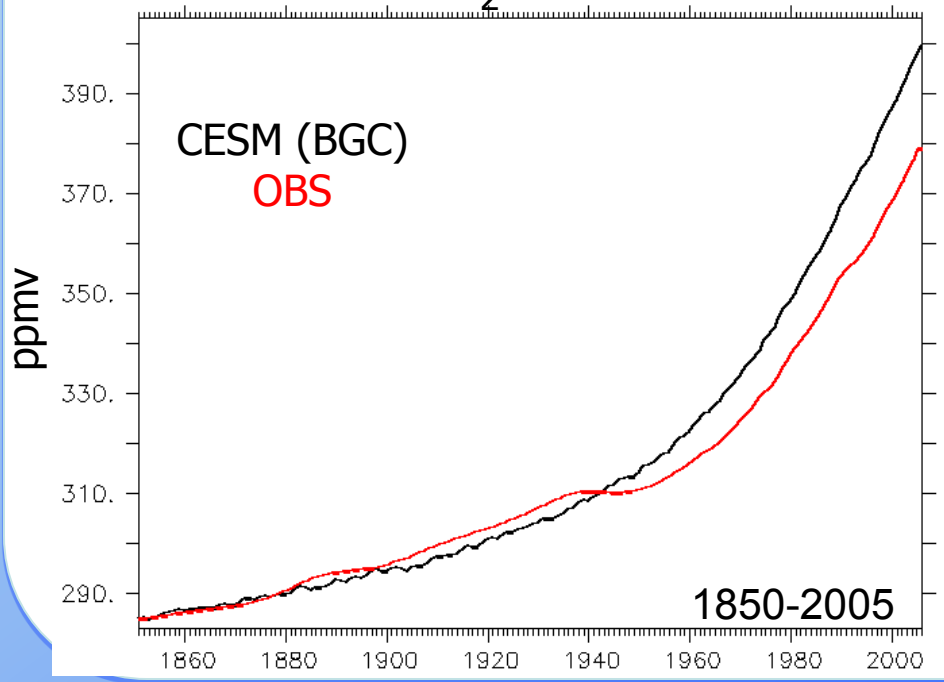
CESM1.0 (BGC) Simulations

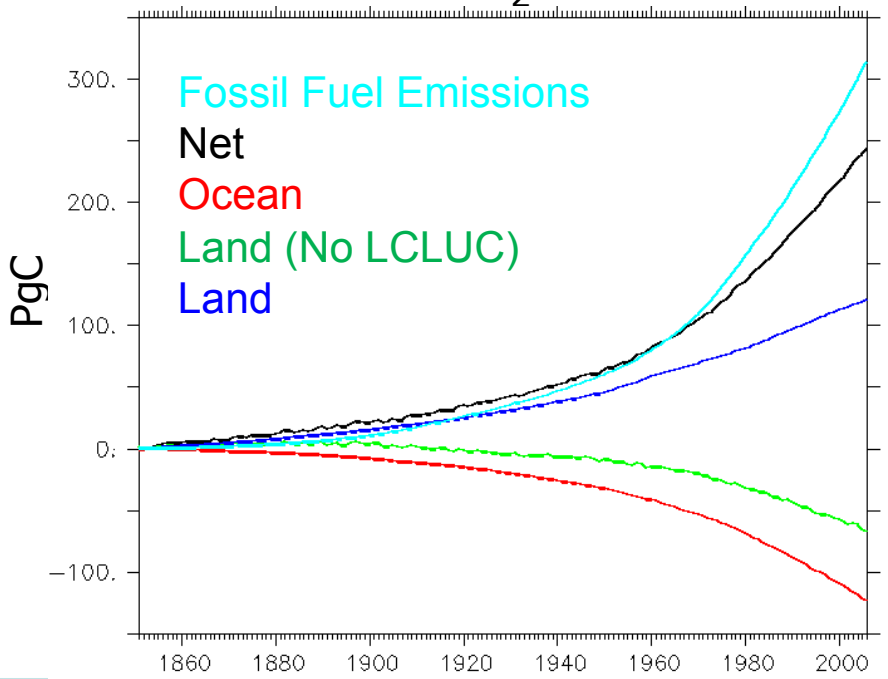


500+ yr Pre-industrial Control

Surface CO_2 Concentration



Cumulative CO_2 Surface Flux



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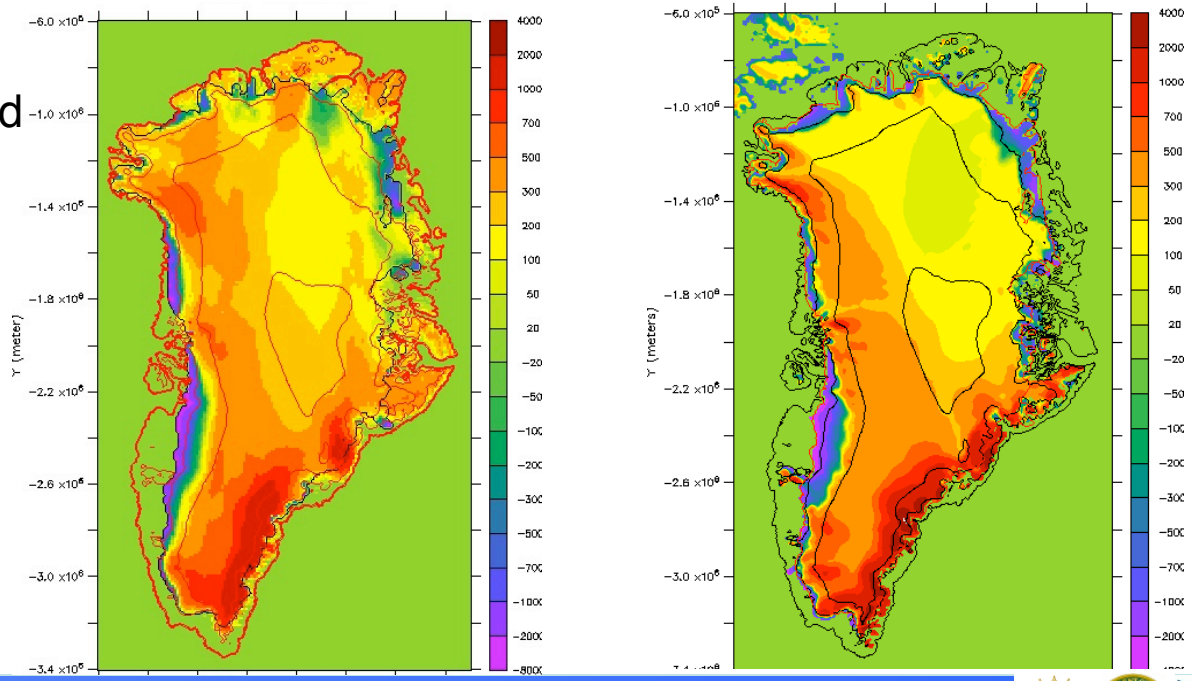
A community ice sheet model in CESM

- CESM 1.0 includes Glimmer, the Community Ice Sheet Model (Glimmer-CISM), an open-source model available at **http://glimmer-cism.berlios.de/**.
  - Currently Glimmer-CISM 1.6 (shallow-ice dynamics)
  - Glimmer-CISM 2.0 (higher-order dynamics) to be added later this year
  - Greenland grids at 5, 10, and 20 km are supported.
- CESM also includes a new surface mass balance scheme for ice sheets in CLM.
  - The surface mass balance is computed on the global land grid, then sent to Glimmer-CISM and downscaled to the local ice sheet grid.

Left: Greenland SMB from CESM: CLM on 1º grid forced by CAM output, downscaled to 10-km ice sheet grid

Right: Greenland SMB from high-resolution regional climate model (RACMO; Ettema et al. 2009)

Red = net accumulation
Blue = net ablation



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CESM Tutorial
12-16 July, 2010 at NCAR ML

- 40 Students + 40 Auditors (190 applicants!)
- Complete tutorial to be available on the web:
  - Video & Presentations of Lectures & tutorials
- Lectures on simulating the climate system
- Practical sessions on running CESM & modifying components
- Covers nearly all CESM working groups
- Organization, Planning, Lectures and Tutorials by CGD staff
- Thanks, in particular, to Andrew Gettelman

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91st Annual AMS Meeting

23rd Conference on Climate Variability and Change

23–27 January 2011

Seattle, Washington

Special Session on CCSM4.0 and CESM1.0

Abstract Deadline: 9 August 2010

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Thank You

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