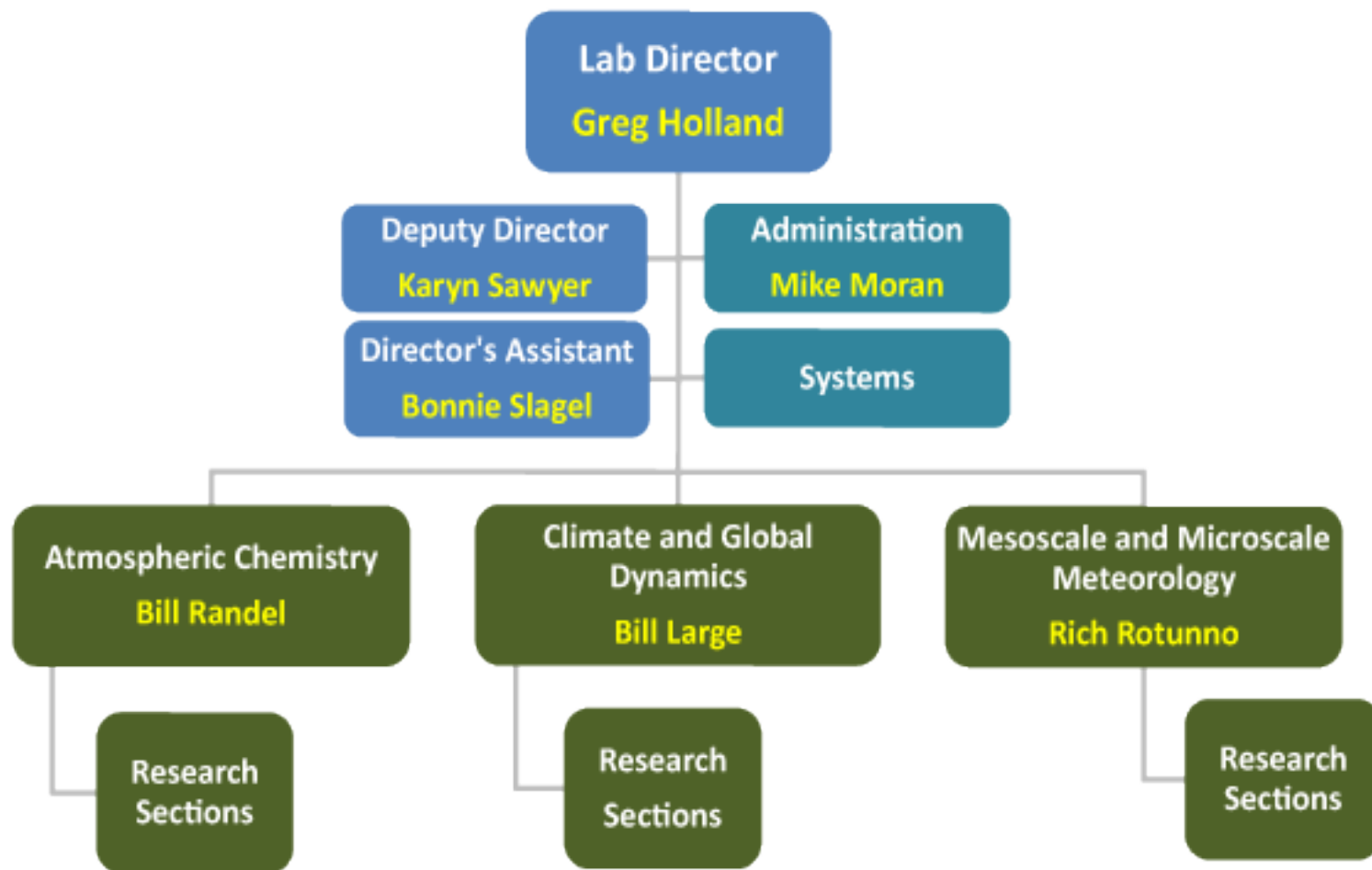


The NCAR Earth System Laboratory: Climate Change Research

James W. Hurrell
(Incoming) Director, NESL
jhurrell@ucar.edu



The Laboratory Structure



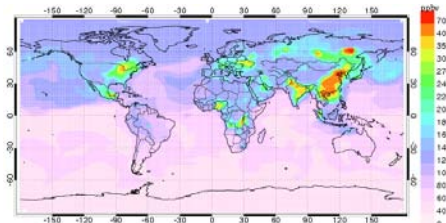
The NESL Mission:

To advance understanding of weather, climate, atmospheric composition and processes;
To provide facility support to the wider community; and,
To apply the results to benefit society.

NESL and the Research Divisions

Atmospheric Chemistry Division

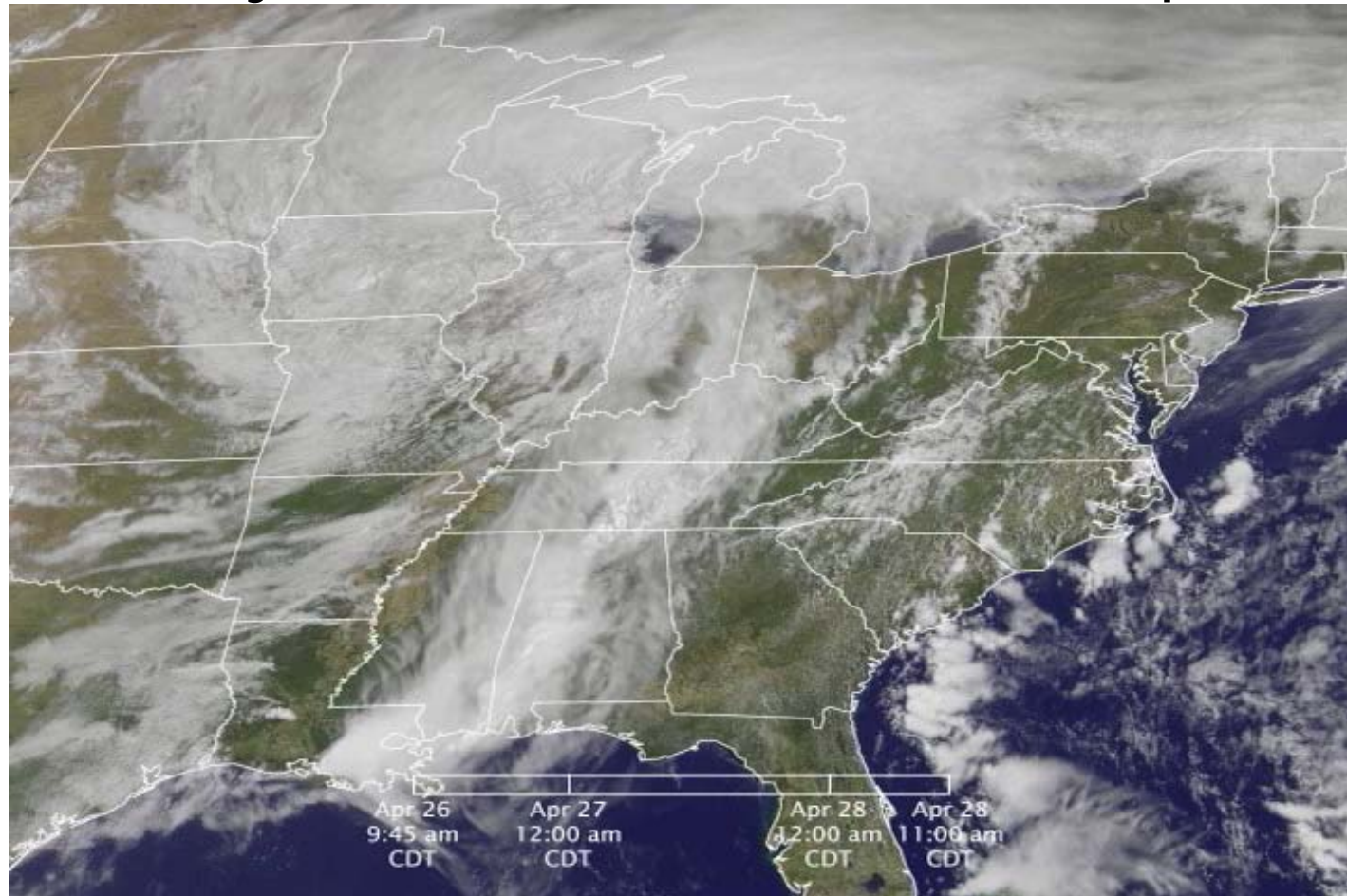
- World-leading research aimed at quantifying and predicting role of atmospheric chemistry in the Earth system:
 - ✓ evaluating effects of emissions, deposition, transport and chemical transformations on atmospheric composition
 - ✓ improving understanding of mechanisms and quantifying coupling of chemical and dynamical processes in the atmosphere
 - ✓ developing and deploying chemistry instrumentation to support the scientific needs of NCAR and the broader community
 - ✓ developing and maintaining state-of-the-science community chemistry and aerosol modeling tools



Mesoscale and Microscale Meteorology Division (MMM)

- Imperative: advance understanding and ability to predict high impact weather
- Maintain and further development WRF modeling system as a major community facility
- Develop advanced data assimilation and forecast techniques at convection-permitting scale utilizing new observations

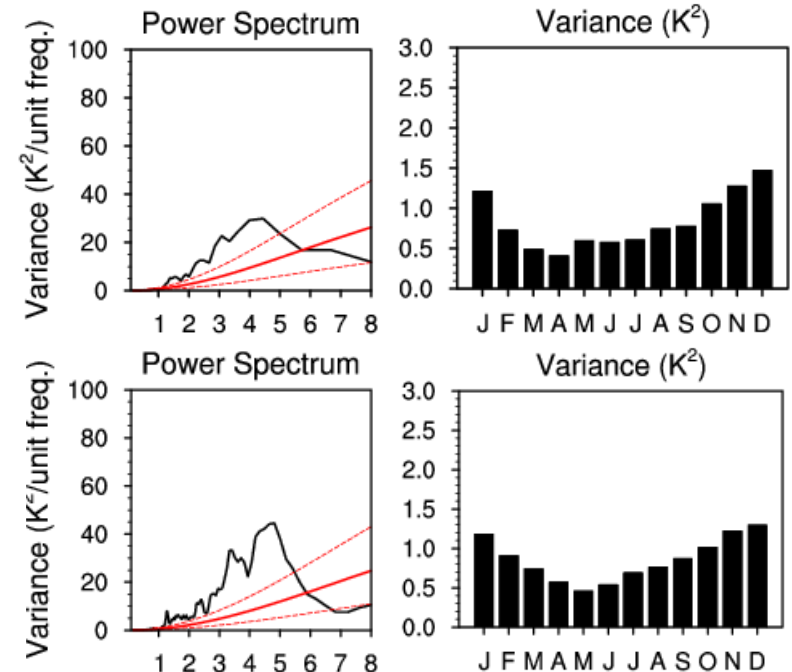
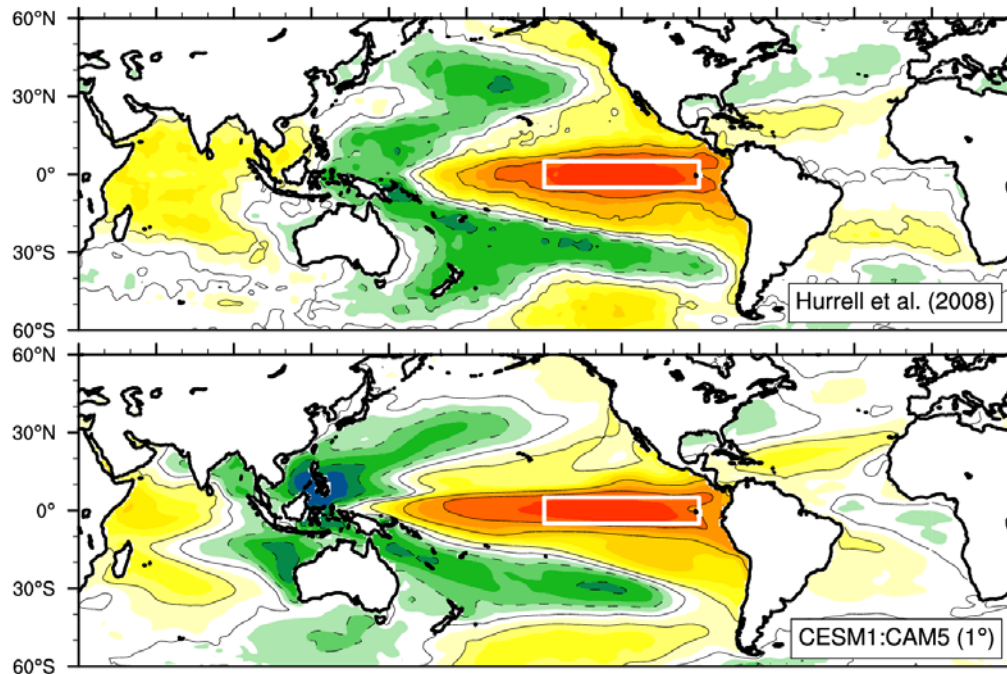
Deadly Tornado Outbreak: 27-28 April



Climate and Global Dynamics Division

- Advance understanding of the Earth's climate system components and the interactions among them;
- Represent this understanding in models of the components and of the coupled system; and
- Further understanding by applying the models to scientific and societal questions and thereby provide a basis for prediction of weather & climate

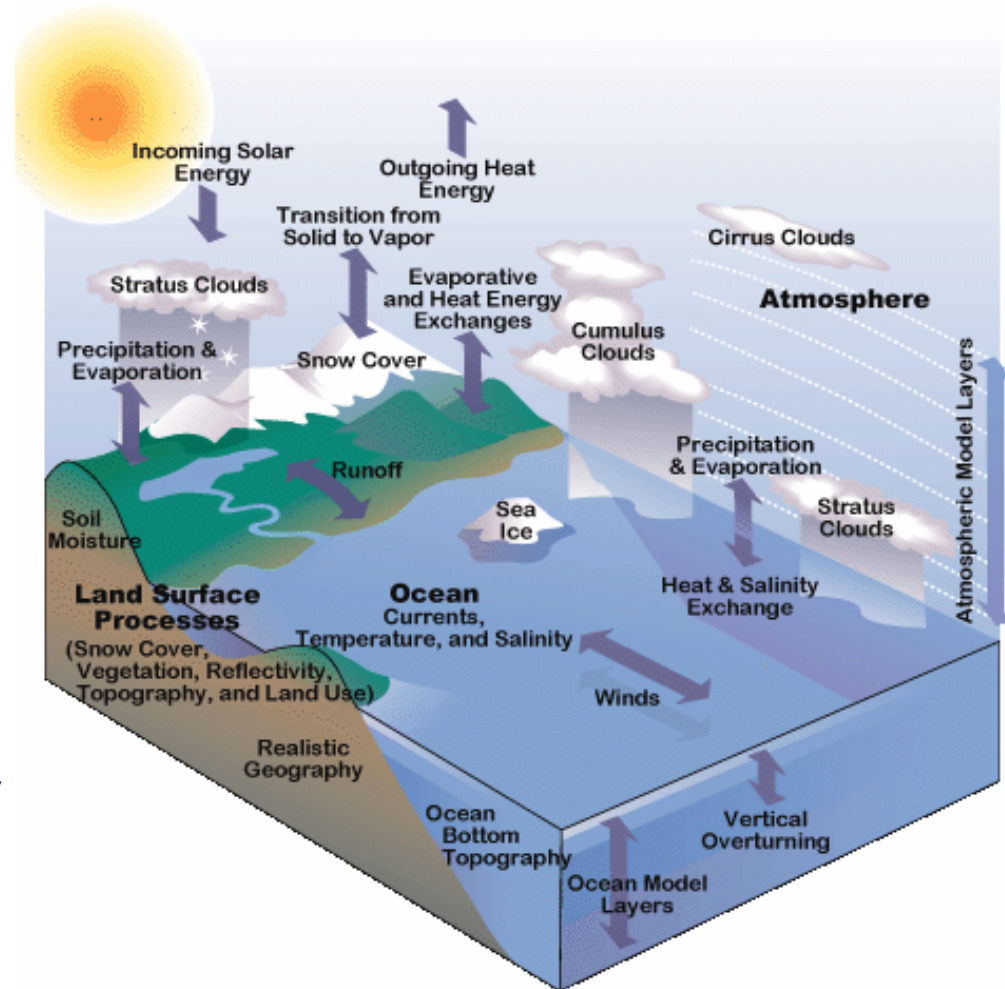
El Niño/Southern Oscillation



The Community Earth System Model

www.cesm.ucar.edu

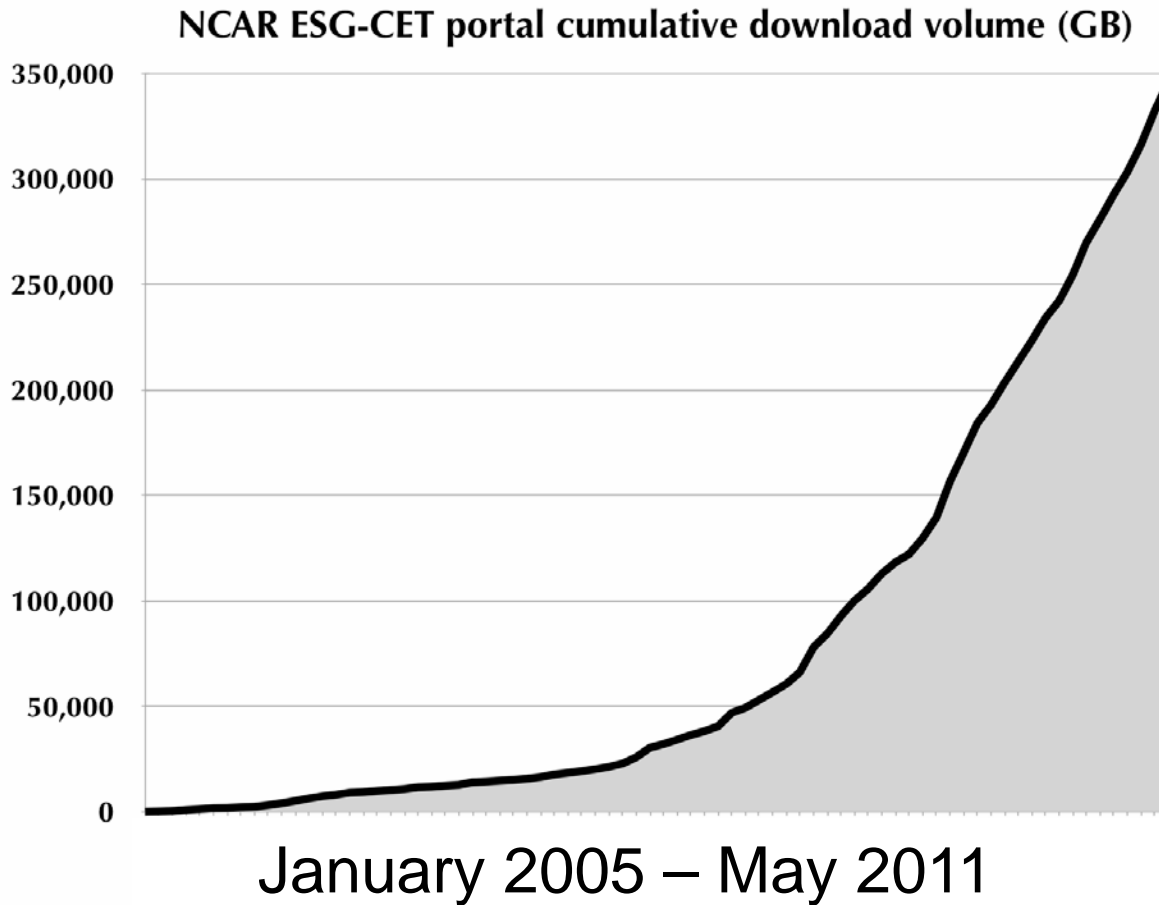
Modeling the Earth System



- **CESM:** a set of different geophysical component models that exchange boundary data via a coupler
- **Code base developed over 20+ yrs:** runs on multiple platforms, resolutions and model configurations
- **CESM is used to:**
 - **Explore Earth climate history and processes responsible for variability and change**
 - **Estimate future of environment for policy formulation**
- **Developed by NCAR NSF, DOE, Universities, National Laboratories**
- **Fully documented, frequently and freely distributed, fully supported releases**
- **Capacity Building (e.g., tutorials and workshops)**

Community Use and Involvement

A Community Resource



Over 3,000 sites from 130+ countries
>320 TB since January 2008
>1500 Registered Users of CESM1.0

Courtesy Gary Strand

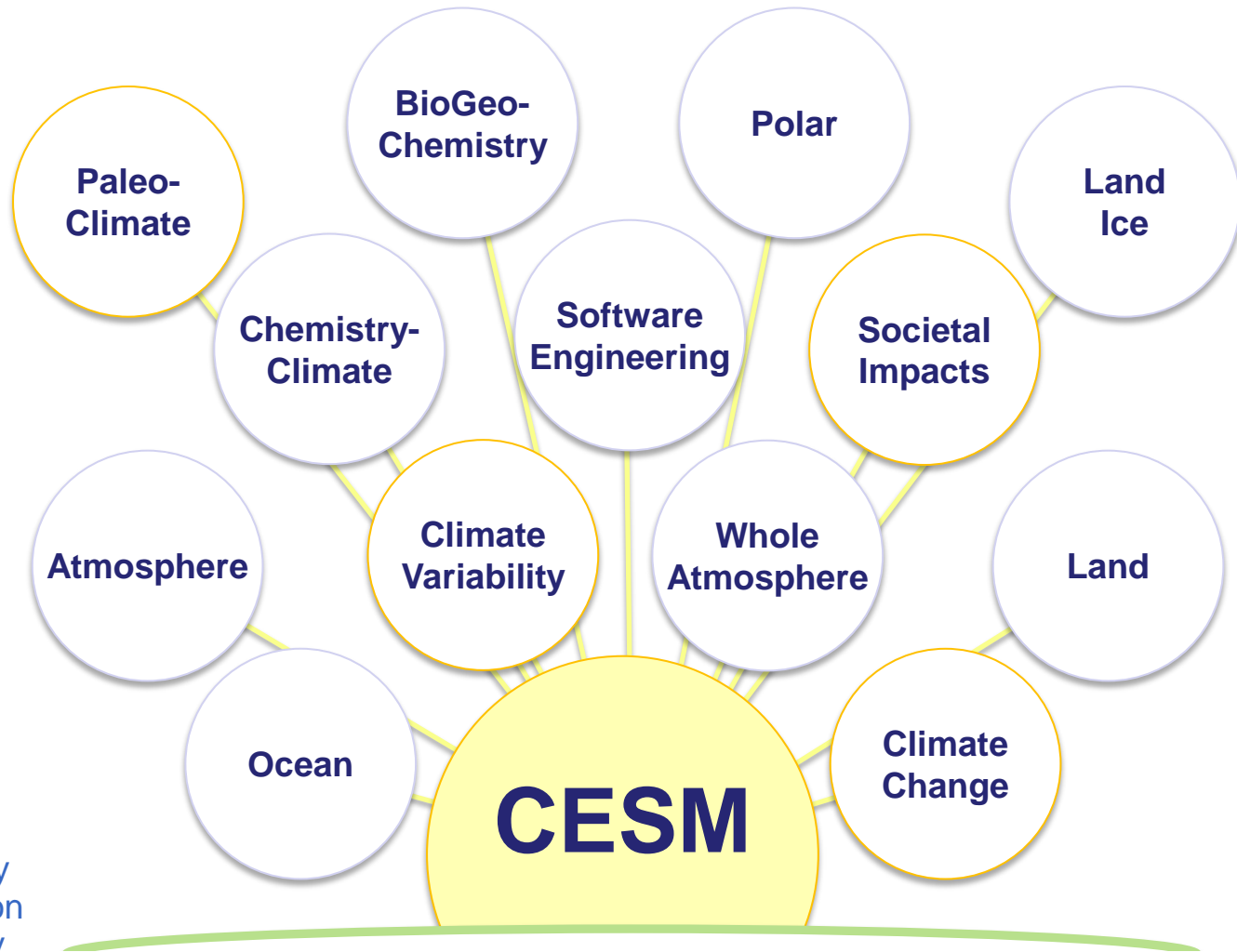
Community Involvement: CESM Management

CESM Advisory Board

CESM Scientific Steering Committee



CESM is primarily sponsored by the National Science Foundation and the Department of Energy



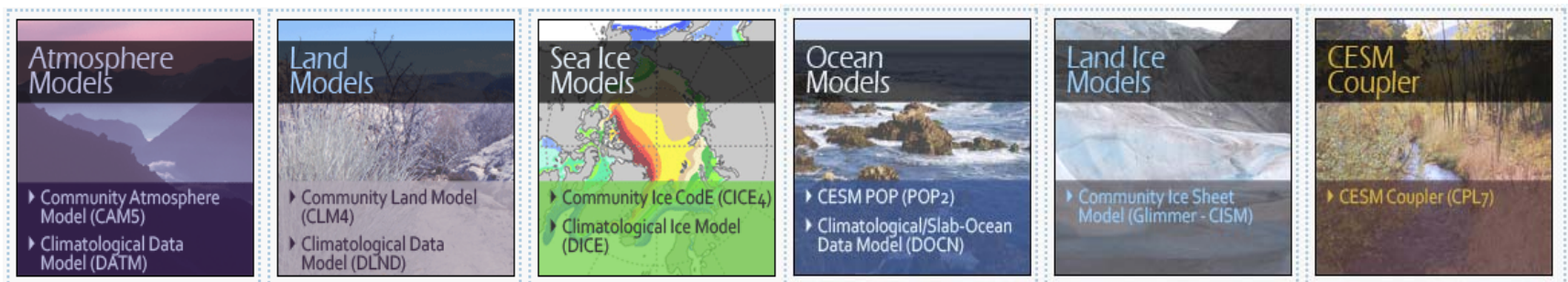
<http://www.cesm.ucar.edu/management>

Major Activities and Achievements

CESM Releases and Simulations

- CESM release mechanism

- ✓ New release infrastructure: code, diagnostics and input data are obtained via subversion servers
- ✓ First version of CESM and supporting documentation was released for community use in June 2010 (CCSM4.0 in April 2010)
- ✓ Enhanced documentation, diagnostics and revamped web pages



- Benchmark and CMIP-5 simulations

- ✓ Control, historical, initialized decadal prediction and climate change
- ✓ CCSM4.0 and CESM (CAM5, CAM-CHEM, WACCM, BGC)
- ✓ All Core, and most Tier 1/2, experiments complete & available (ESG)

CESM Experiments and Diagnostics

CESM1.0 Experiments and Diagnostics

<http://www.cesm.ucar.edu/experiments/cesm1.0/>

Jump To: [Control Simulations](#) [20th Century All-Forcings Simulations](#) [20th Century Single-Forcings Simulations](#) [RCP Simulations](#) [CO2 Simulations](#) [Paleocl Simulations](#)

CONTROL SIMULATIONS

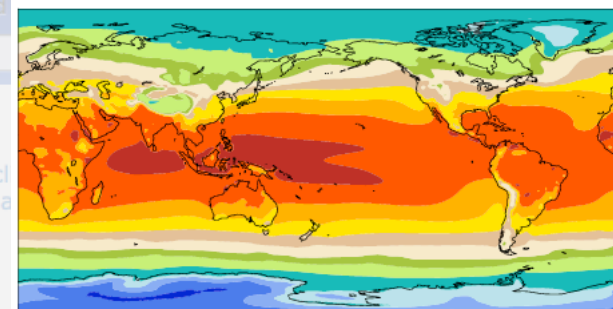
Brief Description	Case Details	
CCSM4 1° Pre-Industrial Control Case Name: b40.1850.track1.1deg.006 Data Location: ESG	Details	863-892 w/obs 863-892 - CCSM3 T85 Pre-Industrial Control
CCSM4 2° Pre-Industrial Control Case Name: b40.1850.track1.2deg.003 Data Location: ESG	Details	501-530 w/obs 501-520 - CCSM3 T42 Pre-Industrial Control
CCSM4 T31 Pre-Industrial Control Case Name: b40.t31x3.037 Data Location: ESG (451-500)	Details	451-500 w/obs 451-500 - 2° Pre-Industrial Control 451-500 - CCSM3 T42 Pre-Industrial Control
CESM1 (BGC) Prognostic CO2 1° Case Name: b40.1850.track1.1deg.006 Data Location: ESG	Details	351-380 w/obs 863-892 - CCSM3 T85 Pre-Industrial Control
CCSM4 2° Pre-Industrial Control Case Name: b40.1850.track1.2deg.003 Data Location: ESG	Details	501-530 w/observations 501-520 - CCSM3 T42 Pre-Industrial Control

b40.1850.track1.1deg.006 (yrs 863-882)

2-meter Air Temp

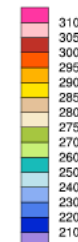
mean= 286.49

K



ANN

Min = 217.66 Max = 302.43

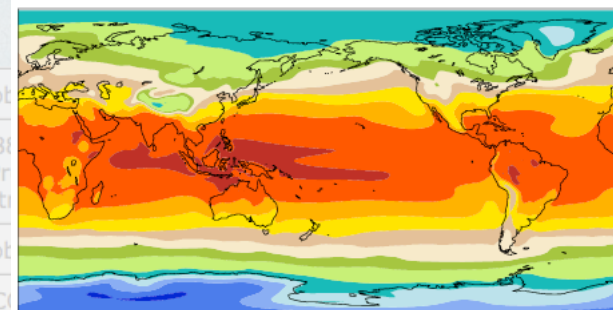


b30.020.ES02 (yrs 501-520)

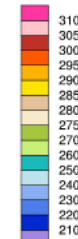
2-meter Air Temp

mean= 286.17

K



Min = 218.62 Max = 302.28

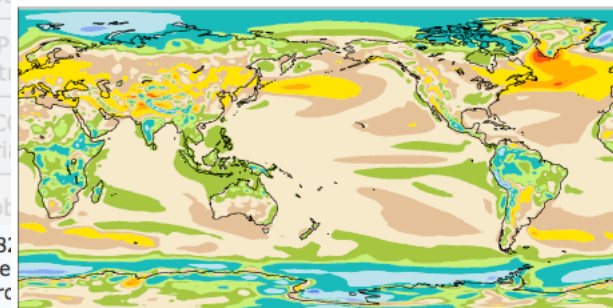


b40.1850.track1.1deg.006 - b30.020.ES02

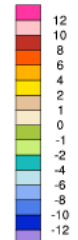
mean = 0.32

rmse = 1.61

K



Min = -9.87 Max = 9.79



Many New Results and Capabilities

Special Collection J. Climate Papers:

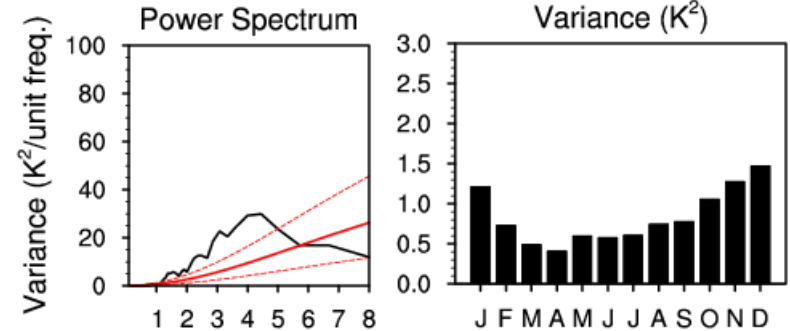
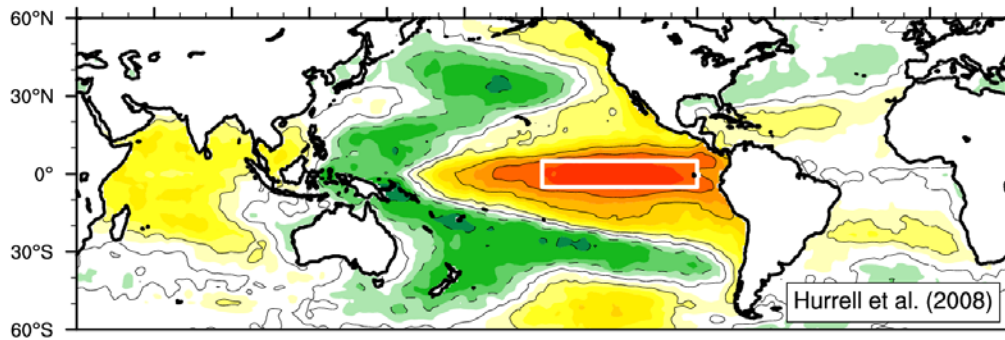
<http://www.cesm.ucar.edu/publications/pub.info.html>

or at AMS:

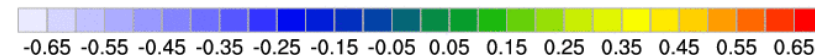
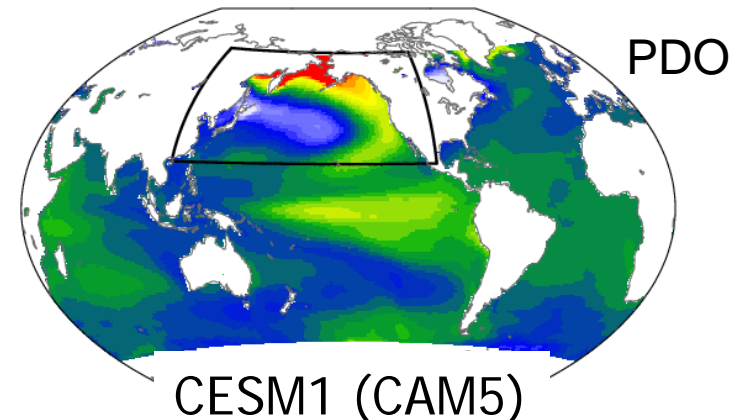
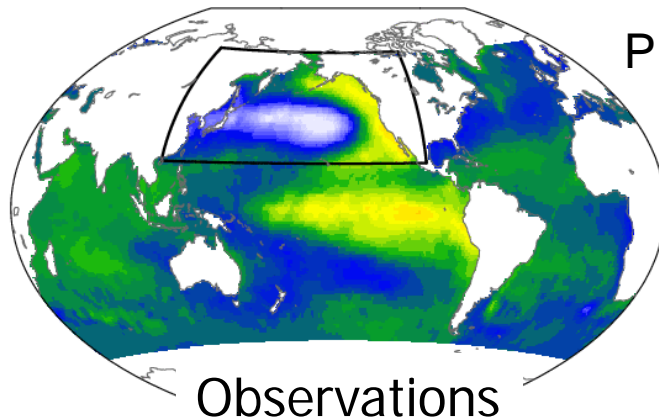
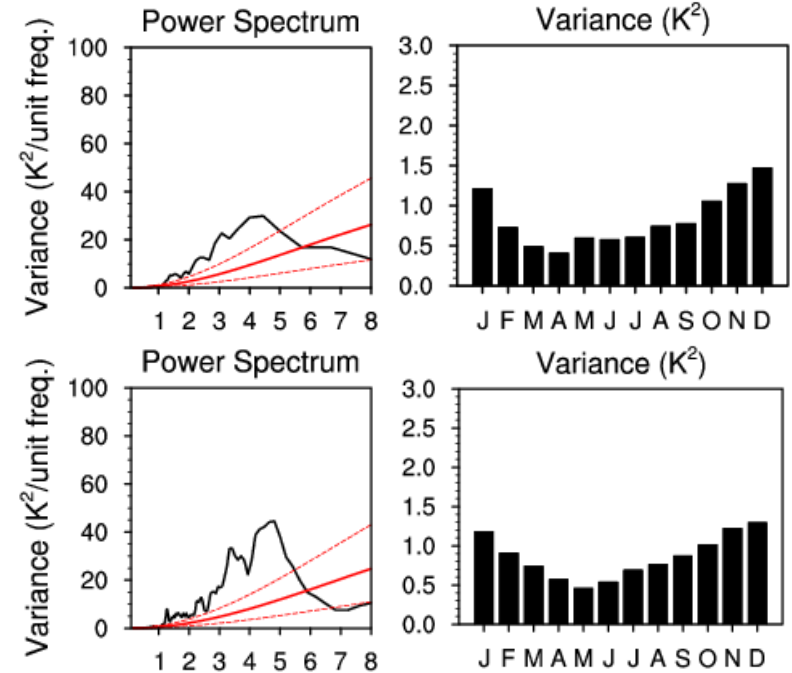
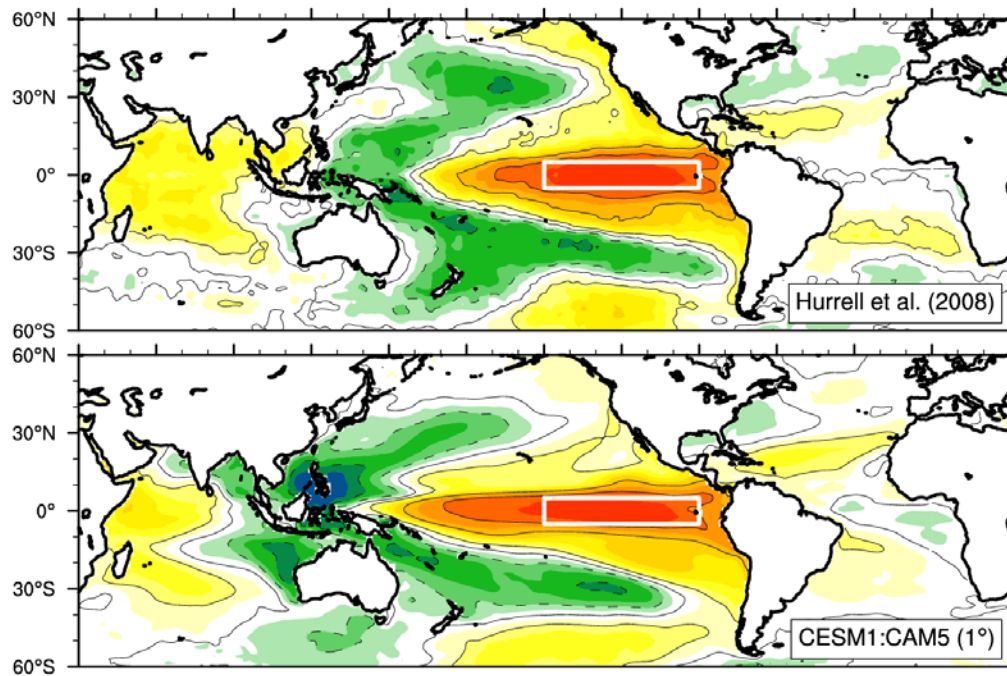
<http://journals.ametsoc.org/page/CCSM4/CESM1>

Improved Variability

Pacific Variability: ENSO and PDO

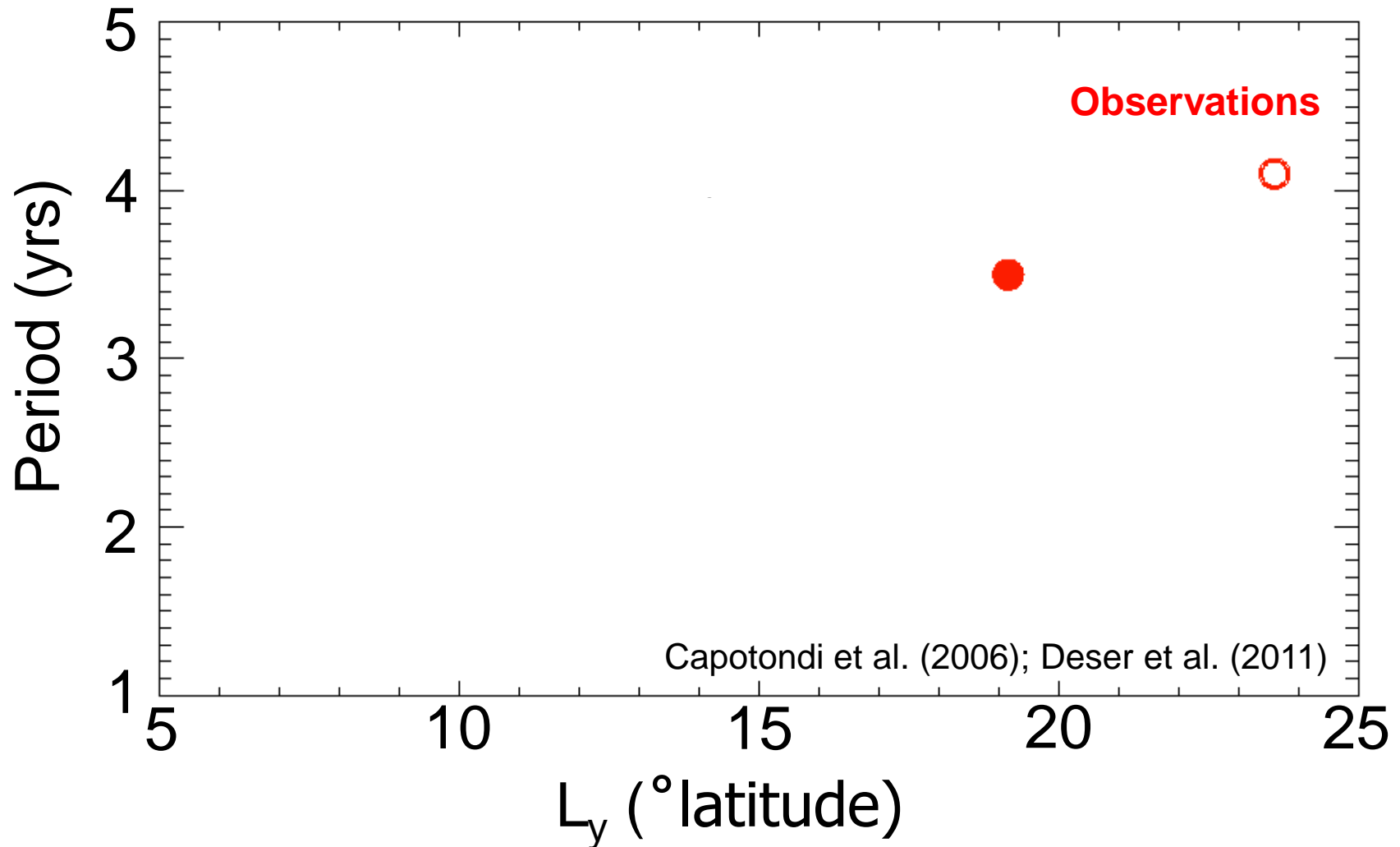


Pacific Variability: ENSO and PDO





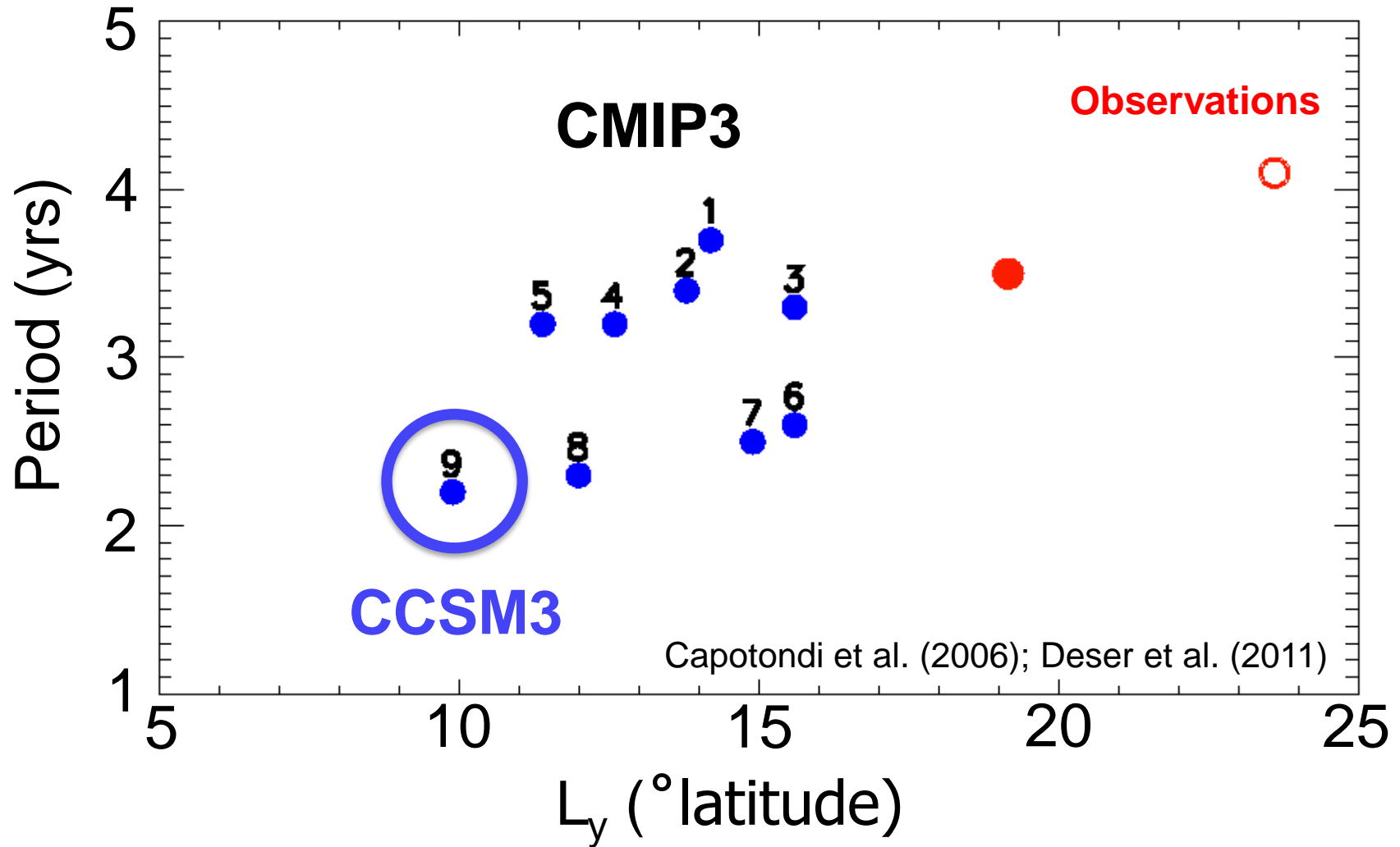
ENSO in CESM and other models



Period → freq of max spectral power of Niño3.4 SST

L_y → width of zonal wind stress anomalies

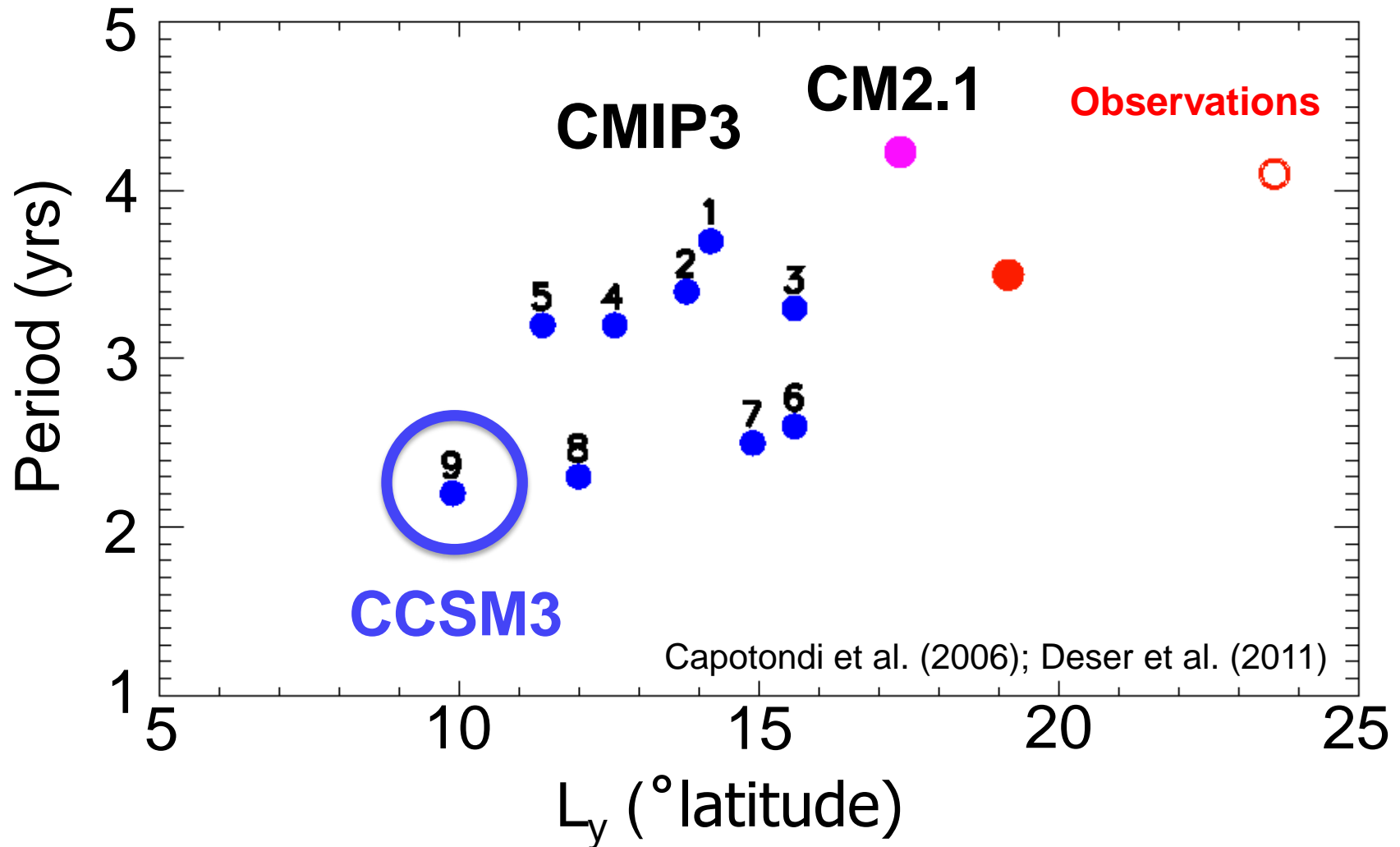
ENSO in CESM and other models



Period \rightarrow freq of max spectral power of Niño3.4 SST

L_y \rightarrow width of zonal wind stress anomalies

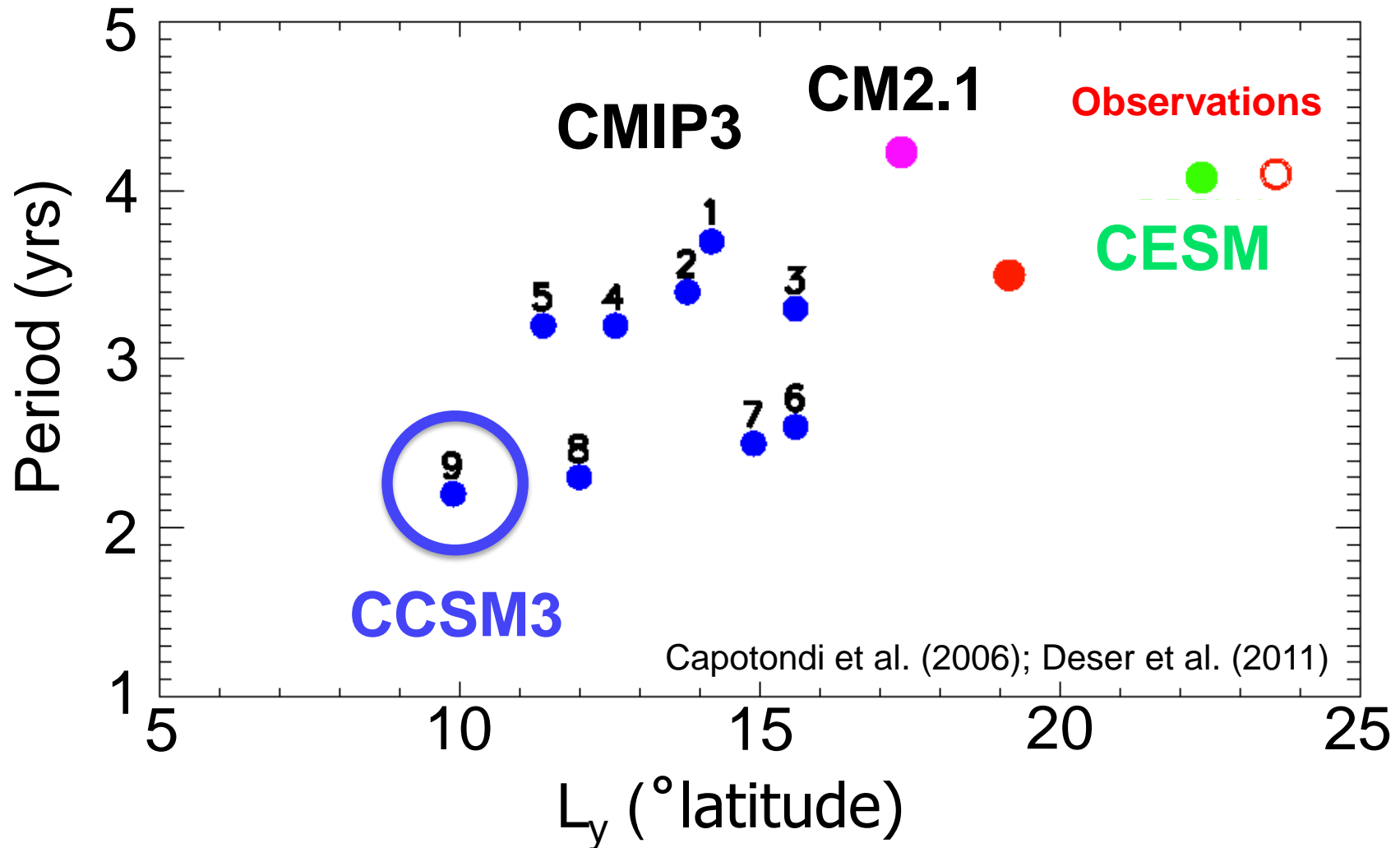
ENSO in CESM and other models



Period \rightarrow freq of max spectral power of Niño3.4 SST

L_y \rightarrow width of zonal wind stress anomalies

ENSO in CESM and other models



Period \rightarrow freq of max spectral power of Niño3.4 SST

L_y \rightarrow width of zonal wind stress anomalies

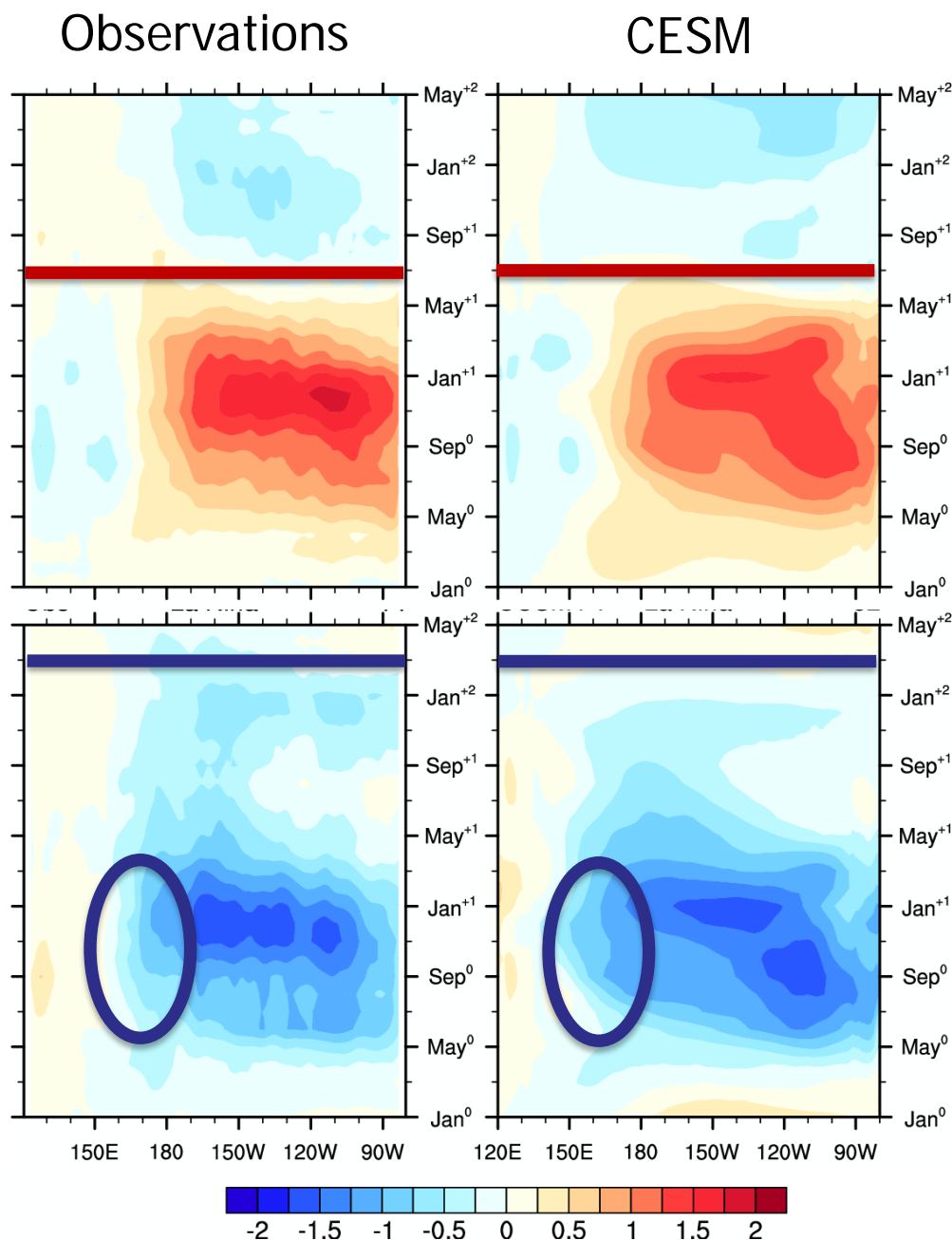


Equatorial SST Composites

El Niño

Latitude/Time cross-sections

La Niña



Deser et al. (2011)

Composite Madden Julian Oscillation (MJO)

CCSM4 1° (1980 -1999)

Observed (1980 -1999)

“Compared to other global coupled models, CCSM4 exhibits relatively high skill in simulating intraseasonal oscillations. [It] has pronounced energy in the MJO band and is comparable to the best models [analyzed in Kim et al. 2009]

Eight phase composite of OLR (color) and 850 hPa winds

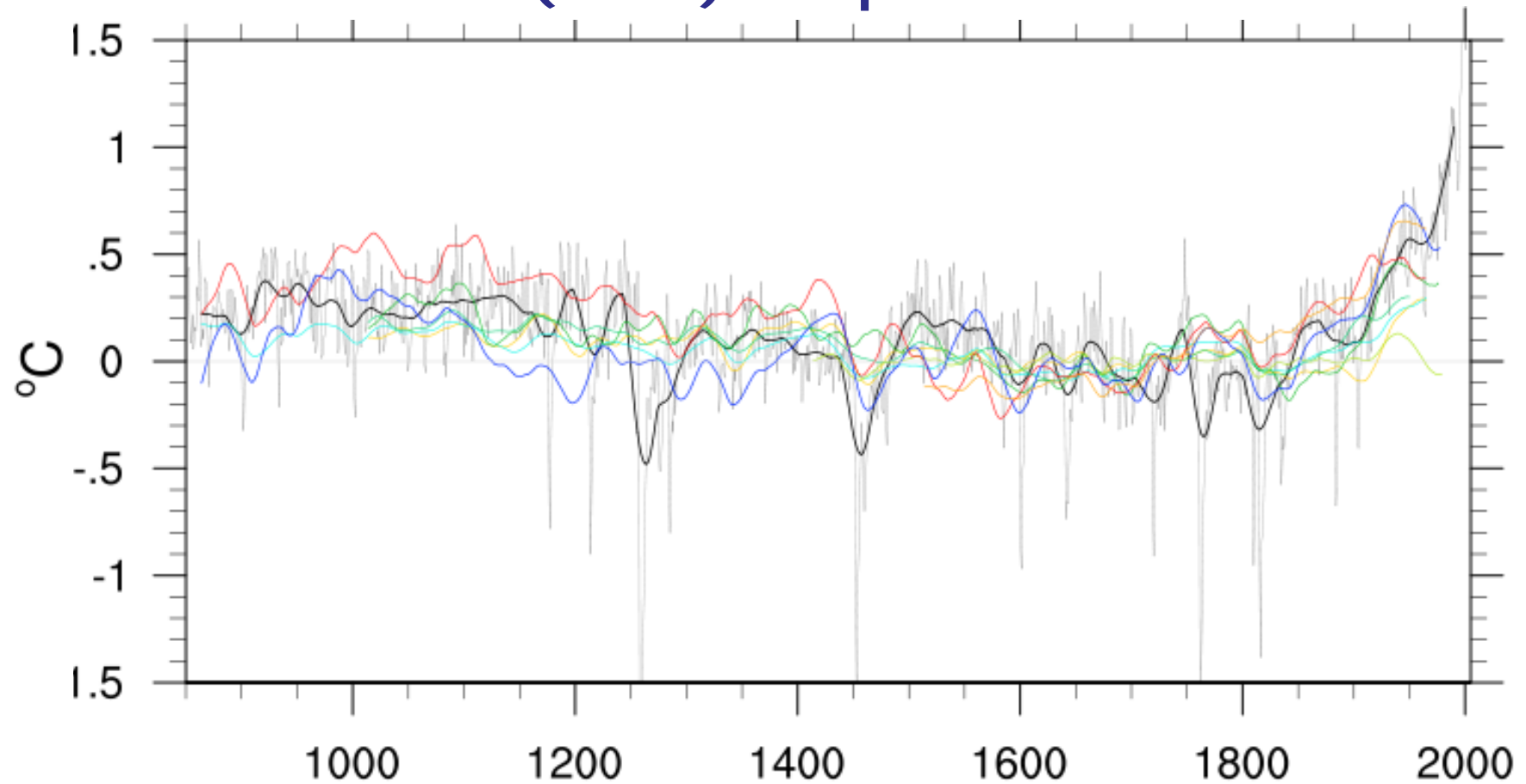
20th Century coupled experiments, Boreal Winter

Subramanian et al. (2011)

Past Climate

Northern Hemisphere Temperature (Last Millennium 850-2005)

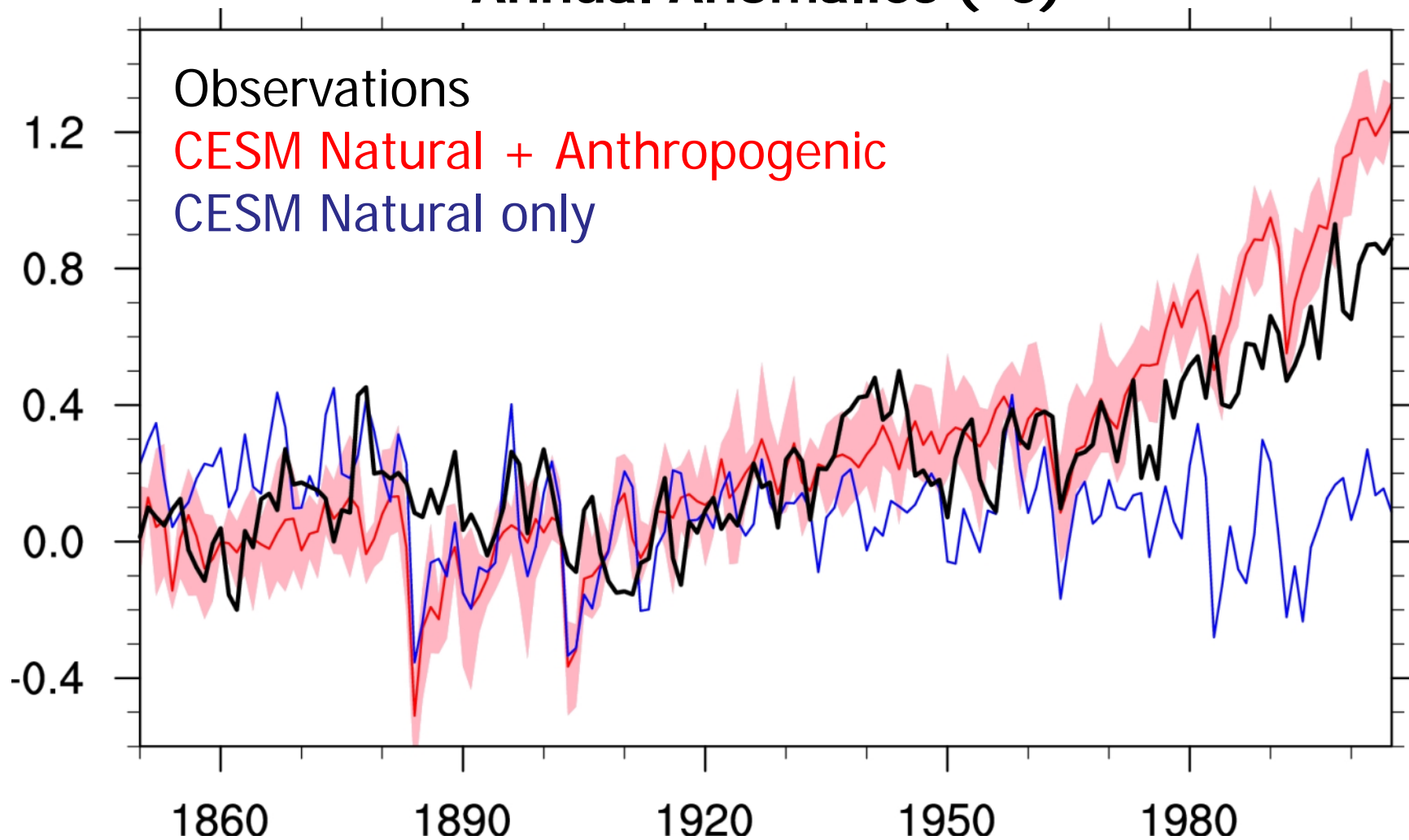
CESM 1° (black) compared to Proxies



Courtesy Bette Otto-Bliesner

Surface Temperature (1850-2005)

Annual Anomalies ($^{\circ}\text{C}$)

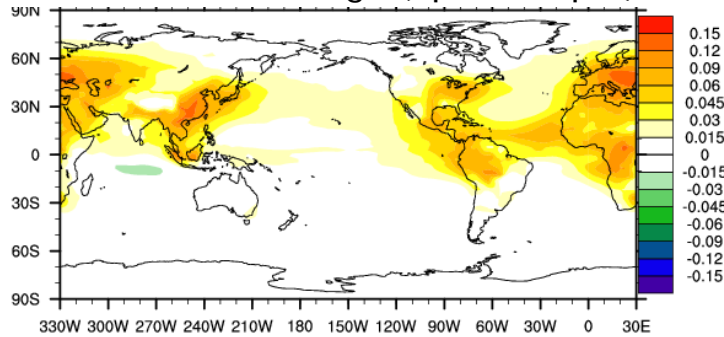


Meehl et al. 2011

Anthropogenic Aerosol Affects: CESM1 (CAM5)

(late 20th century relative to pre-industrial climate)

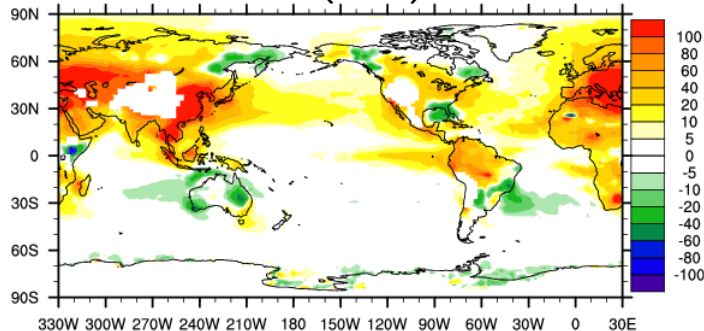
Total aerosol change (optical depth)



✓ Increased aerosol burdens in SE Asia, Europe, NE North America, Brazil

✓ Increased cloud droplet number concentration; strongest over land

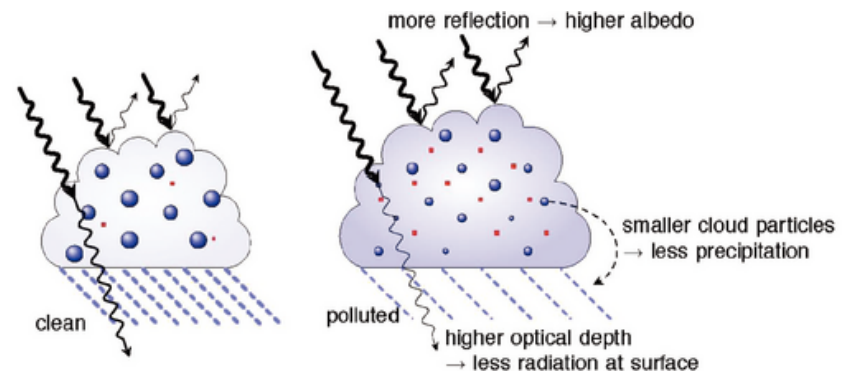
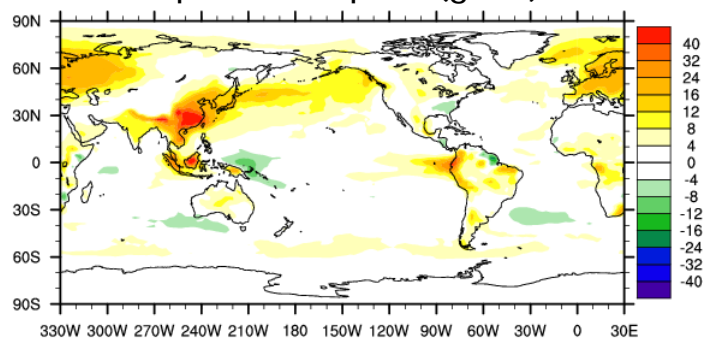
Cloud water droplet number concentration (#/cc) at 850 hPa



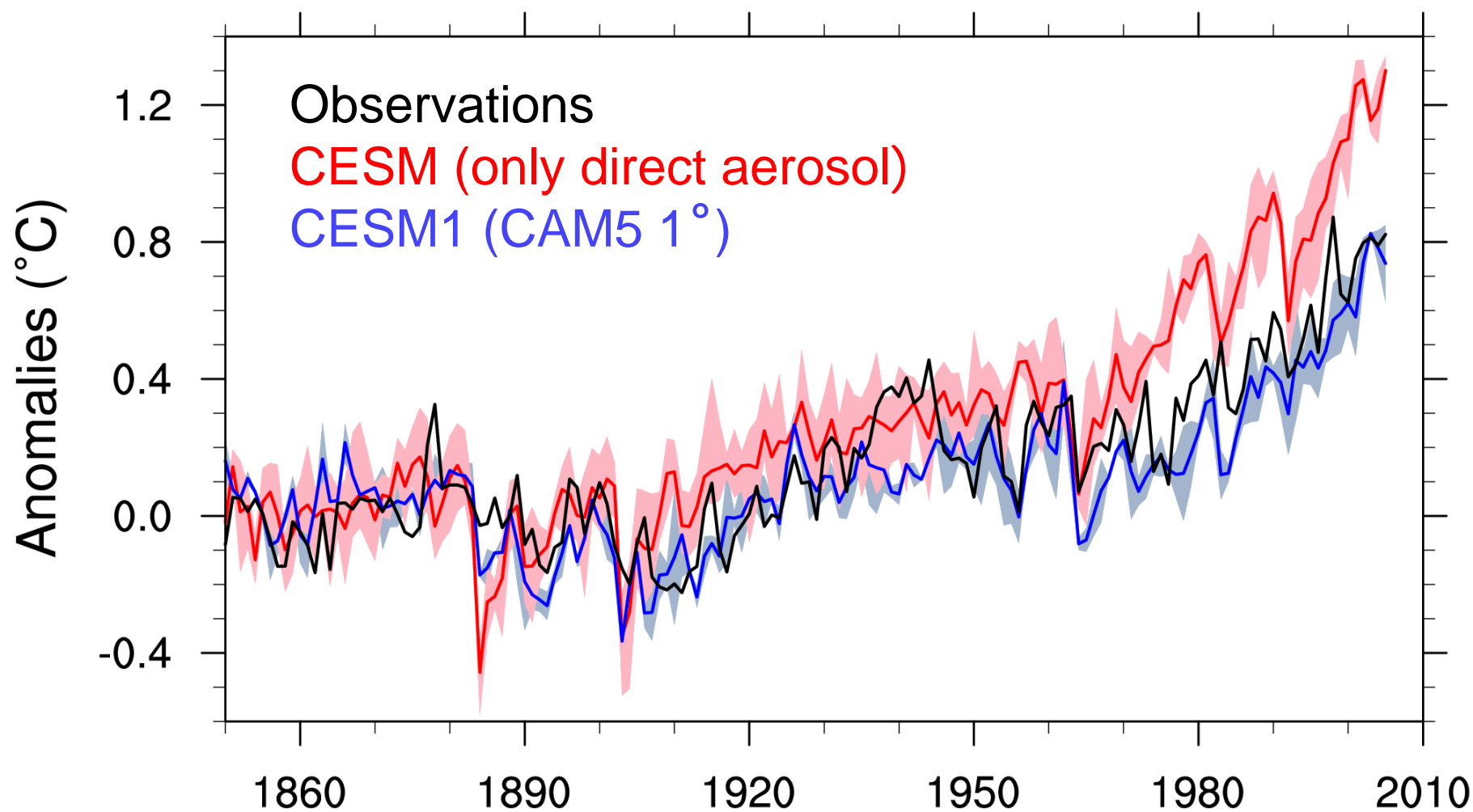
✓ Increased numbers of smaller drops; thus brighter low clouds with more liquid

Low cloud effects: net cooling over 20th century

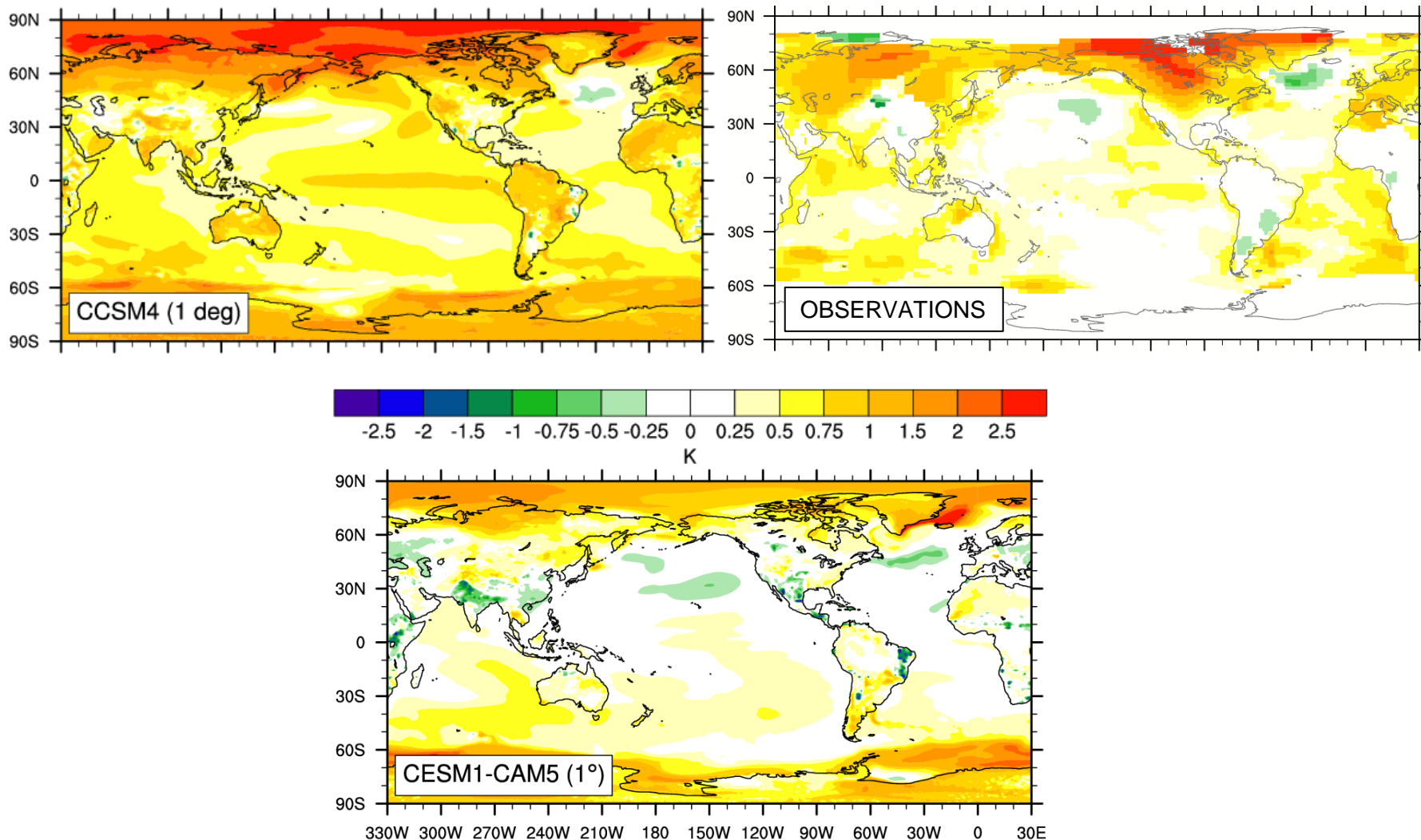
Liquid water path (g/m²)



Surface Temperature (1850-2005)



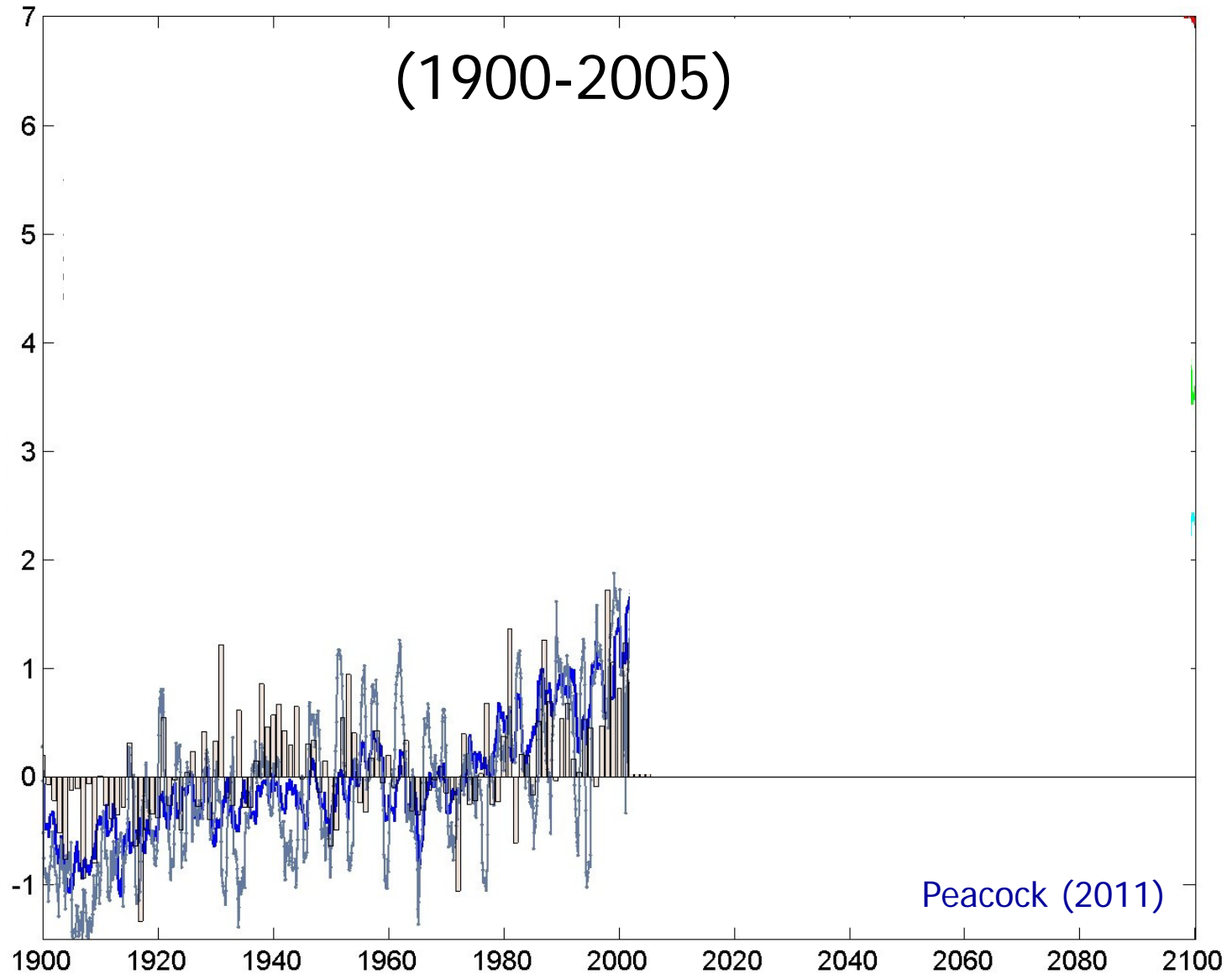
20th Century Surface Temperature Change



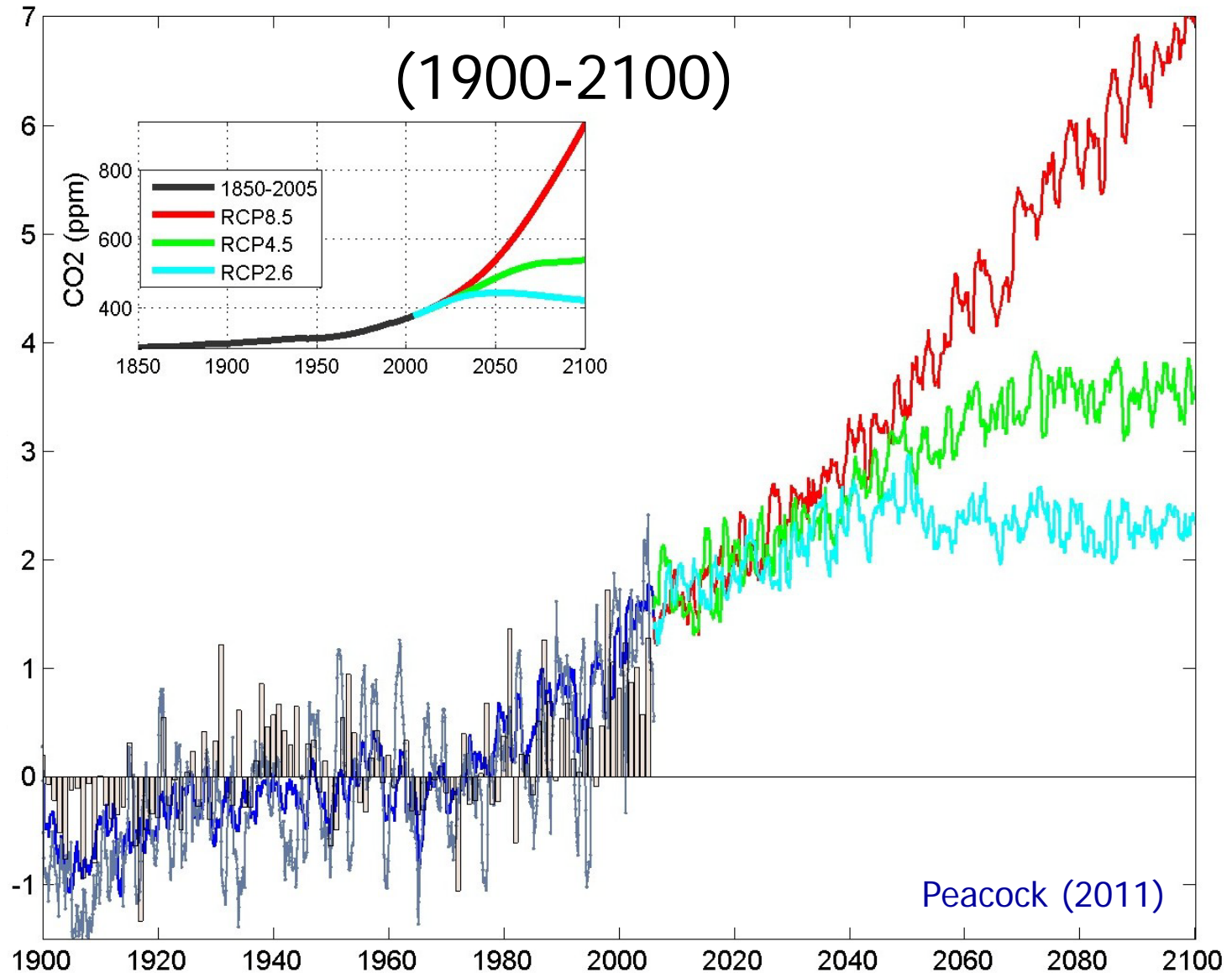
More realistic regional warming

Future Climate

North American Annual Surface T (°C)



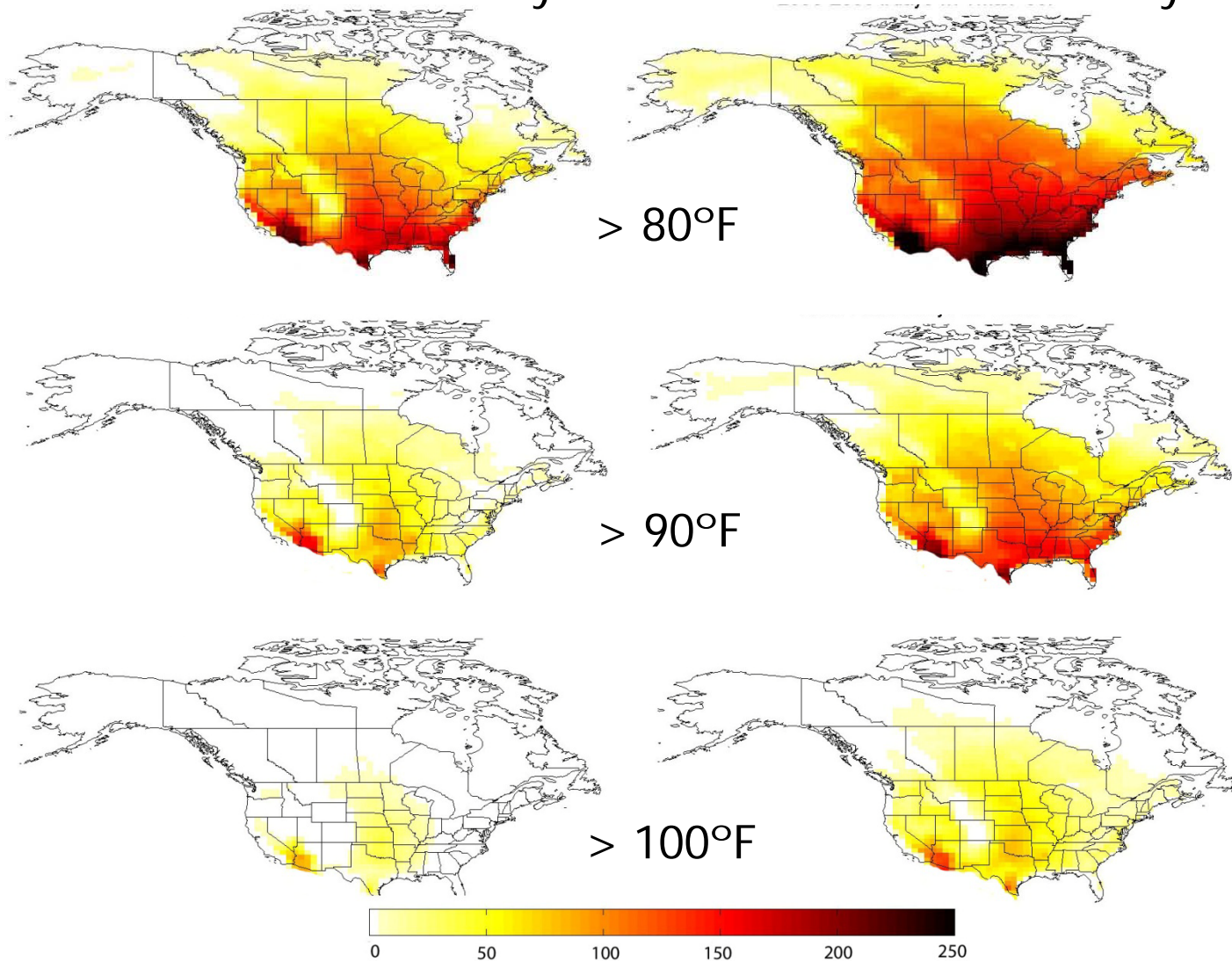
North American Annual Surface T (°C)



Extremes: Number of Warm Days

End of 20th Century

End of 21st Century

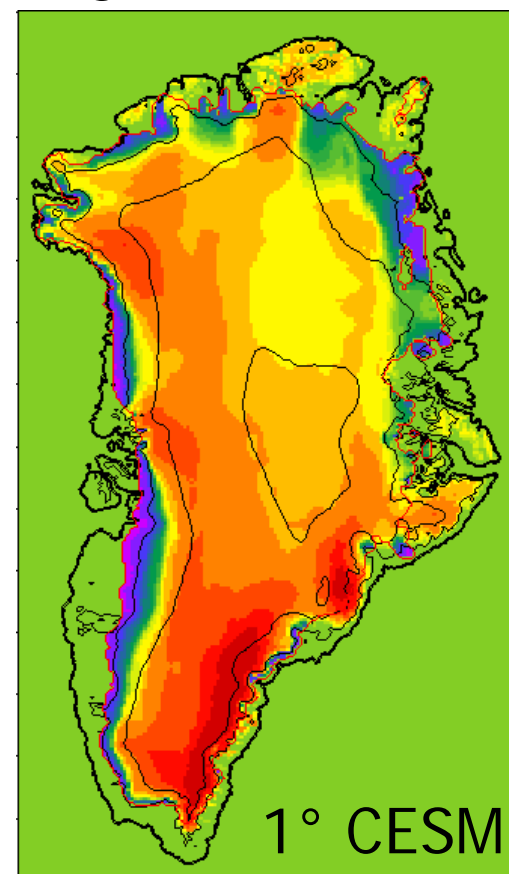
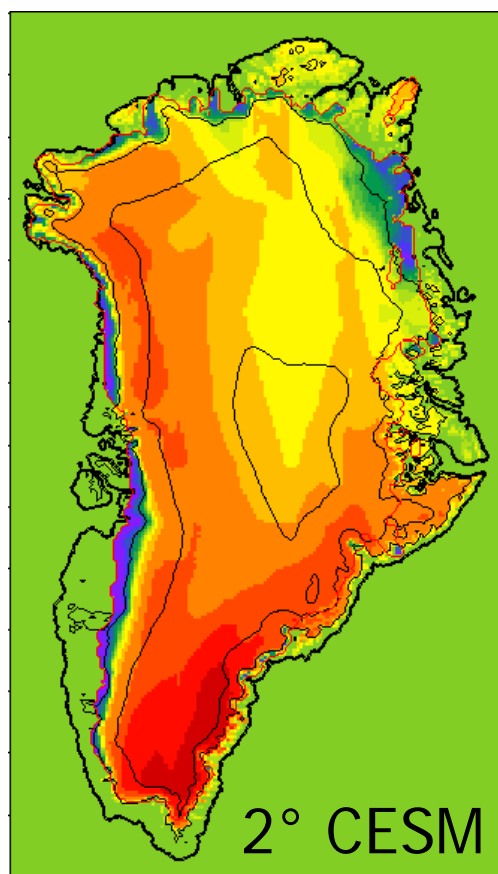
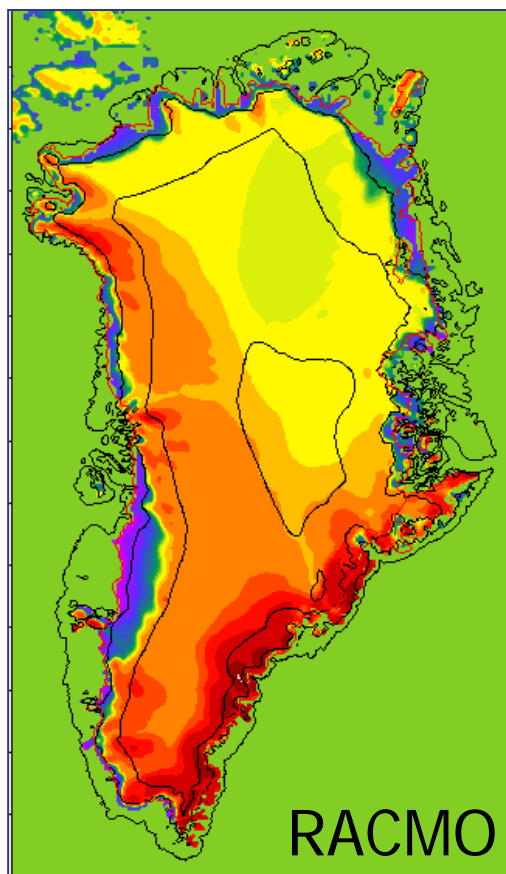


Peacock (2011)

Future Directions: New Capabilities and Higher Resolution

Community Ice Sheet Model in CESM

Greenland surface mass balance (year 2000)



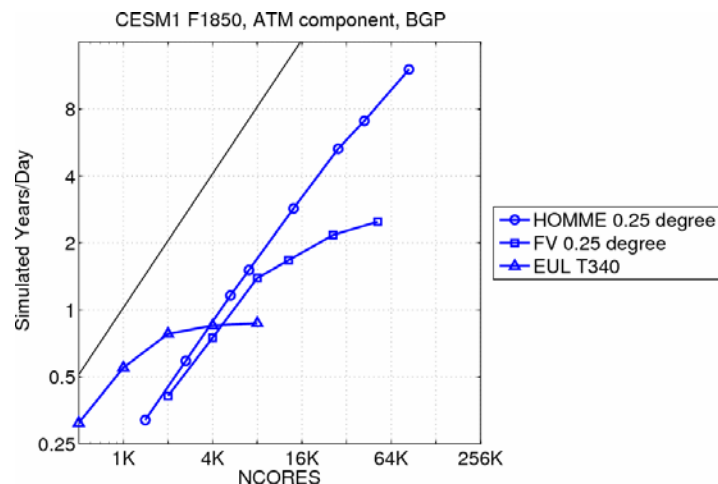
- Greenland grids at 5, 10 and 20 km are supported
- RACMO and 1° CESM in excellent agreement
- Net surface mass balance = 361 Gt yr^{-1} in 1° CESM

Red = net accumulation
Blue = net ablation

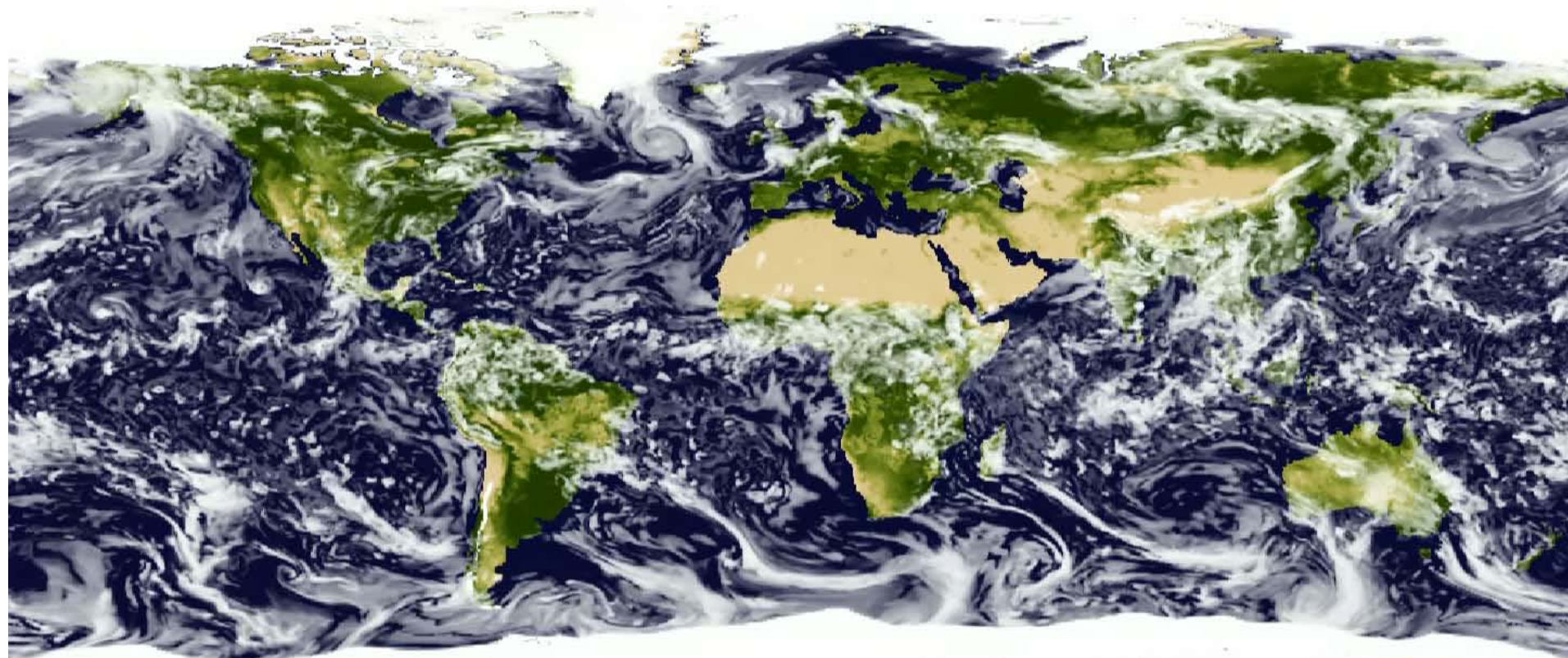
Courtesy of M. Vizcaíno

Preparing CESM for Petascale Computing

- ✓ Significant computing resources are being directed toward high resolution, climate-length runs (e.g., 25-km atmosphere and 0.1° ocean simulations for several decades)
- ✓ Higher resolution and regional mesh refinement in CESM (cubed sphere based dynamical core)
- ✓ Experiments with new NESL (MPAS) dynamical core underway



High Resolution Global Climate Simulations



20 Jul 00 h



NCAR is sponsored by the National Science Foundation