The Community Earth System Model: A Framework for Collaborative Research

www.cesm.ucar.edu

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Outline

- Overview and Community Use/Involvement
- Major Activities and Achievements
  - ✓Model releases
  - ✓CMIP5 simulations
- Selected Science Highlights
  - ✓ Variability
  - ✓ Past Climate
  - ✓ Future Climate

The Community Earth System Model

www.cesm.ucar.edu

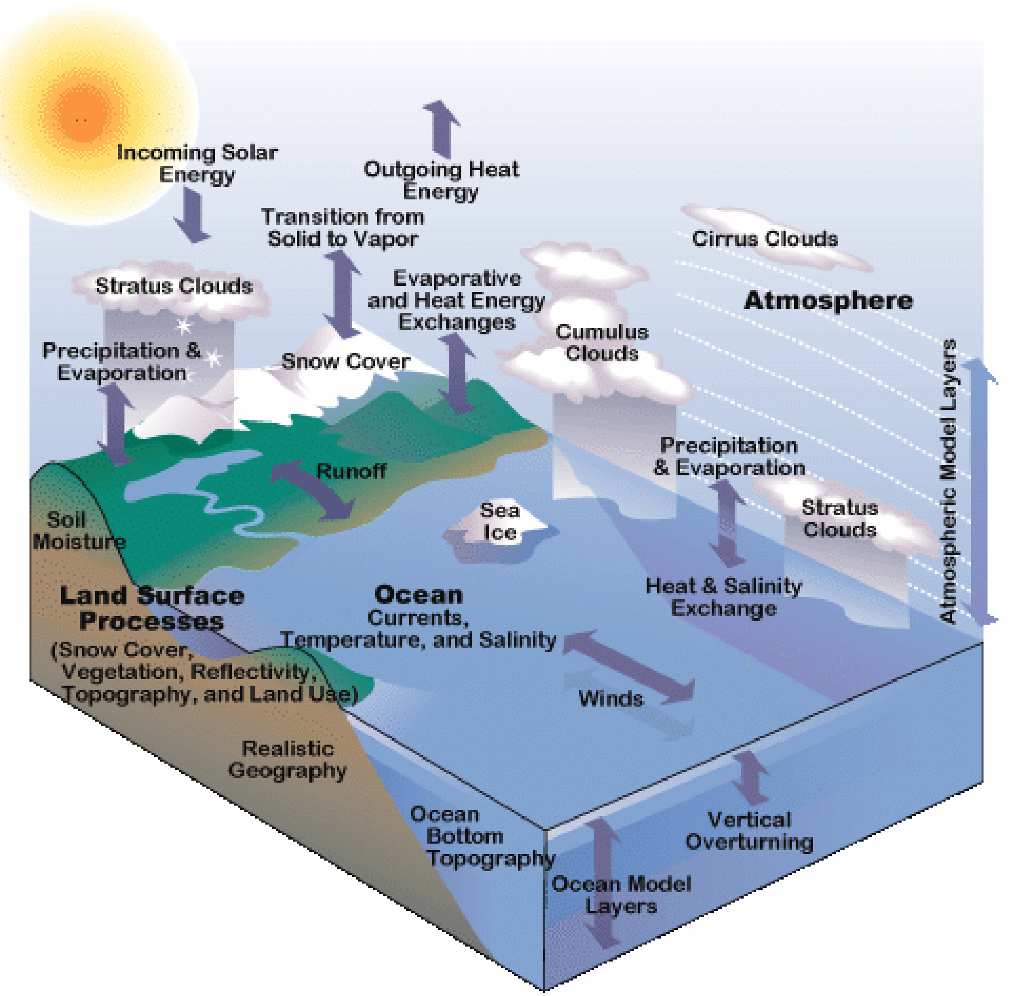
- **CESM: a set of different geophysical component models that exchange boundary data via a coupler**
- **Code base developed over 20+ yrs: runs on multiple platforms, resolutions and model configurations**
- **CESM is used to:**

– **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)**

Modeling the Earth System



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Community Use and Involvement

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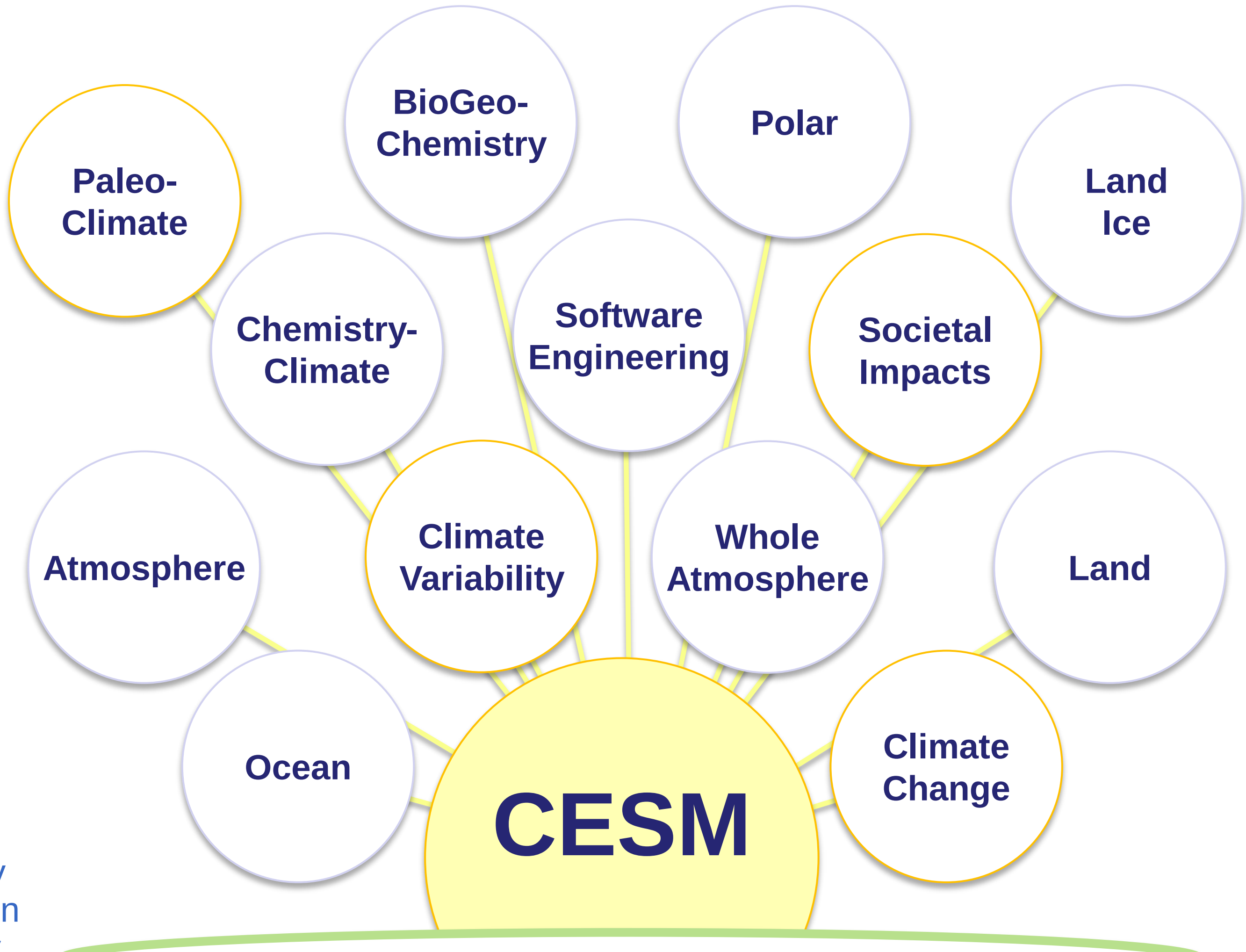
Community Involvement: CESM Management

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

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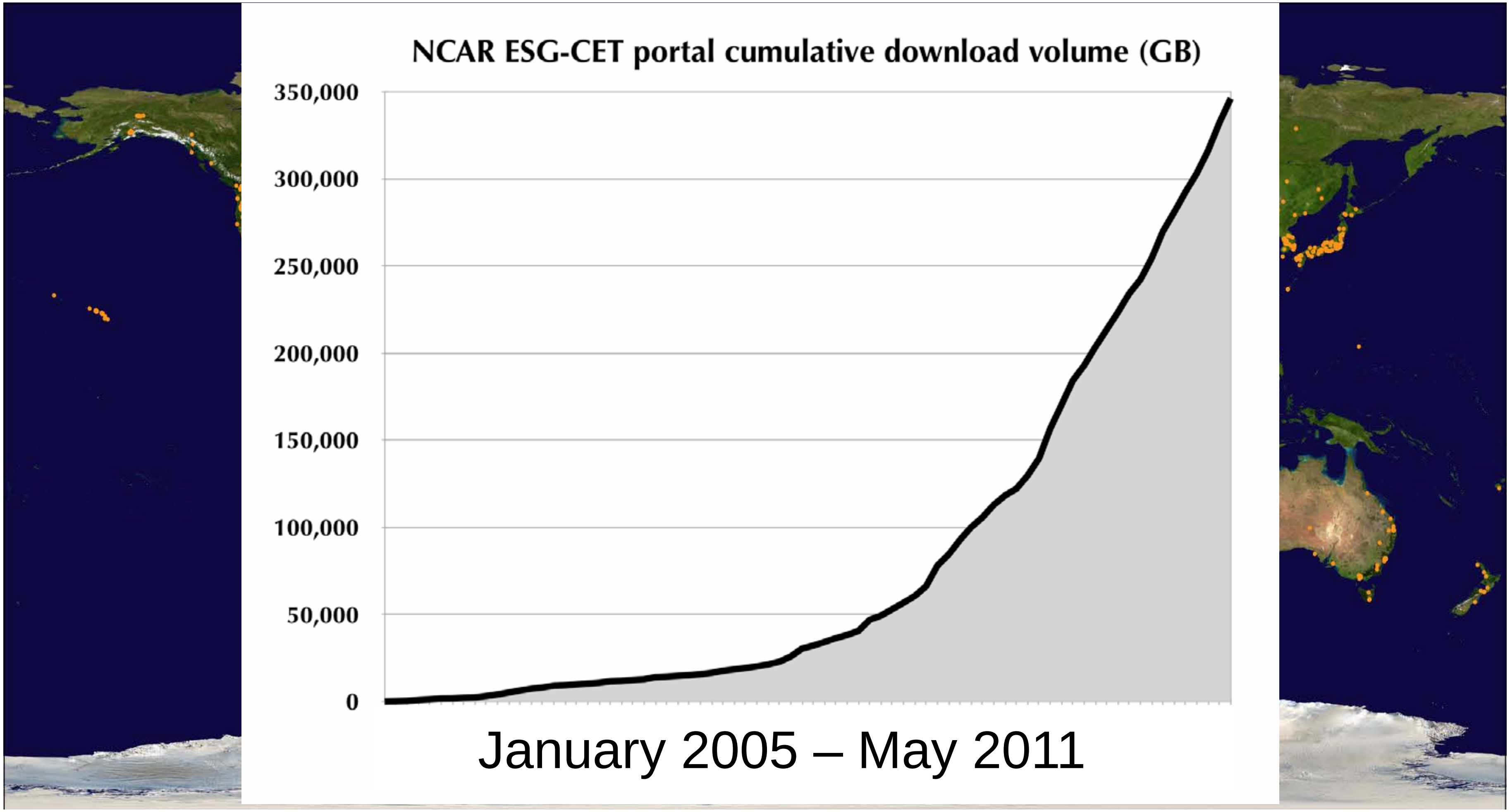
A Community Resource



Over 3,000 sites from 130+ countries

>320 TB since January 2008

>1500 Registered Users of CESM1.0

Courtesy Gary Strand

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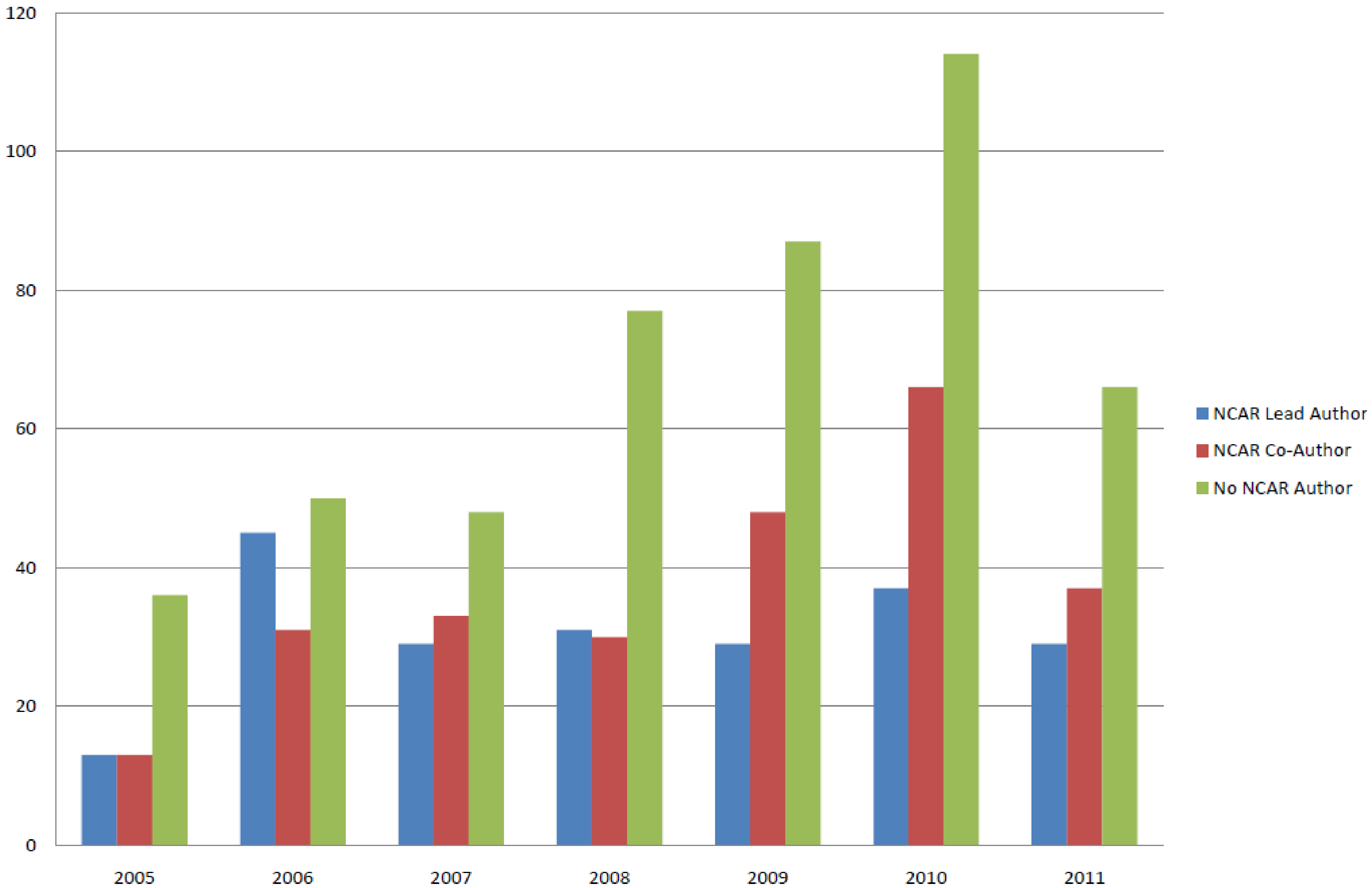
CESM Publications

http://www.cesm.ucar.edu/publications



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Major Activities and Achievements

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CESM Releases and Updates

- CESM release mechanism is excellent (credit to SEWG)
  - ✓ 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)
  - ✓ Many and growing number of registered users
- Release updates support more science
  - ✓ Three updates since CESM1.0
  - ✓ Progressive support of greater model complexity and scientifically supported configurations in each update
  - ✓ CESM1.03 includes capability of running CMIP5 20th Century and RCP simulations as well as new science capabilities for several components: see *"Notable Improvements"* on release web page

CMIP5 Simulations

- Major contribution of CESM and its partners to IPCC AR5 through simulations performed with both CCSM4.0 and CESM1.0
- CSL, NCAR and DOE computer resources decisive
- CMIP5 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

- CMIP5 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
  - ✓ CCSM4.0 and CESM (CAM5, CAM-CHEM, WACCM, BGC) and paleoclimate (>600 Tb history output)
  - ✓ All Core, and most Tier 1 and 2, experiments complete & available (ESG)
  - ✓ Beginning to format and release to formal CMIP5 data base too

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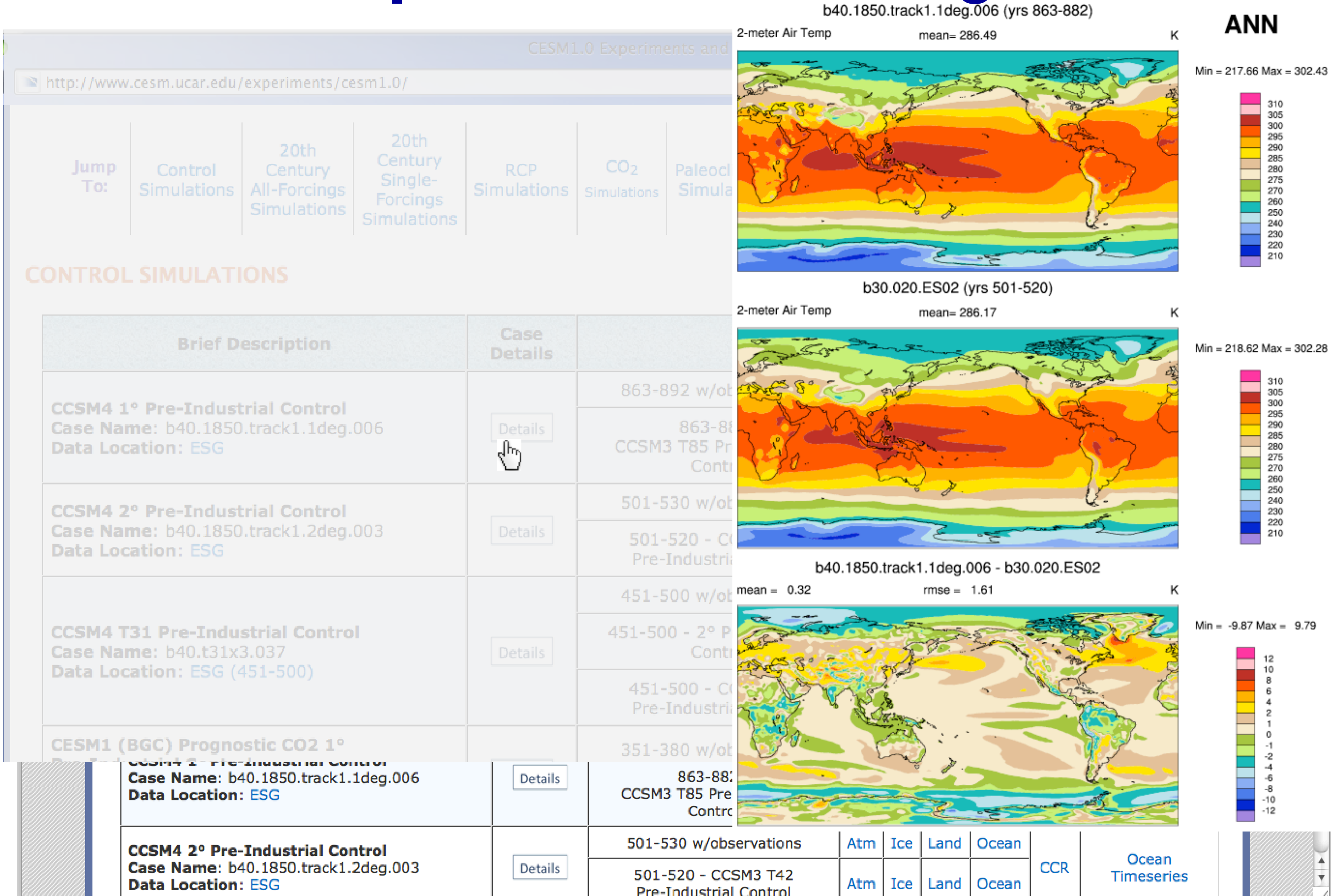
CESM Experiments and Diagnostics



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

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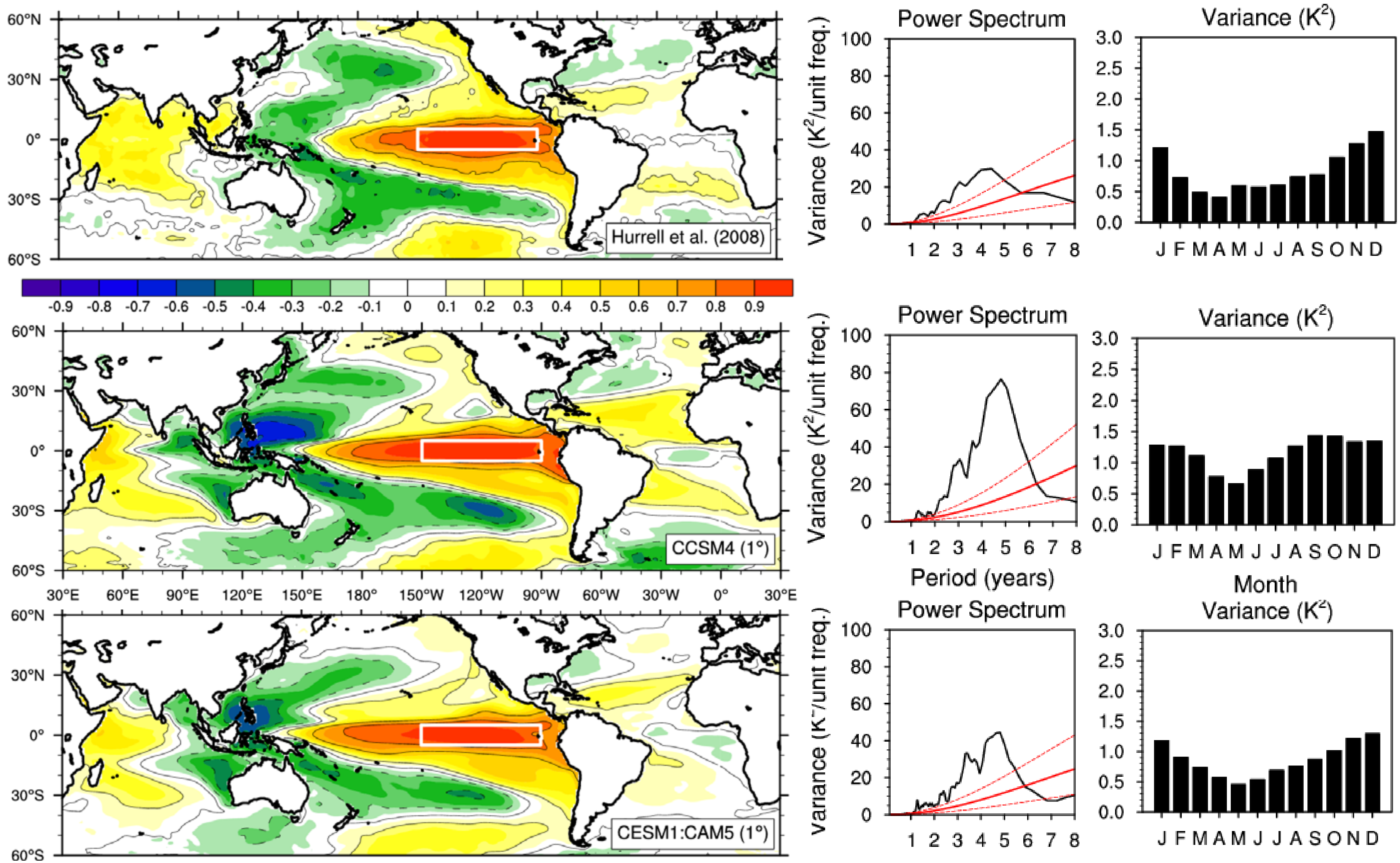
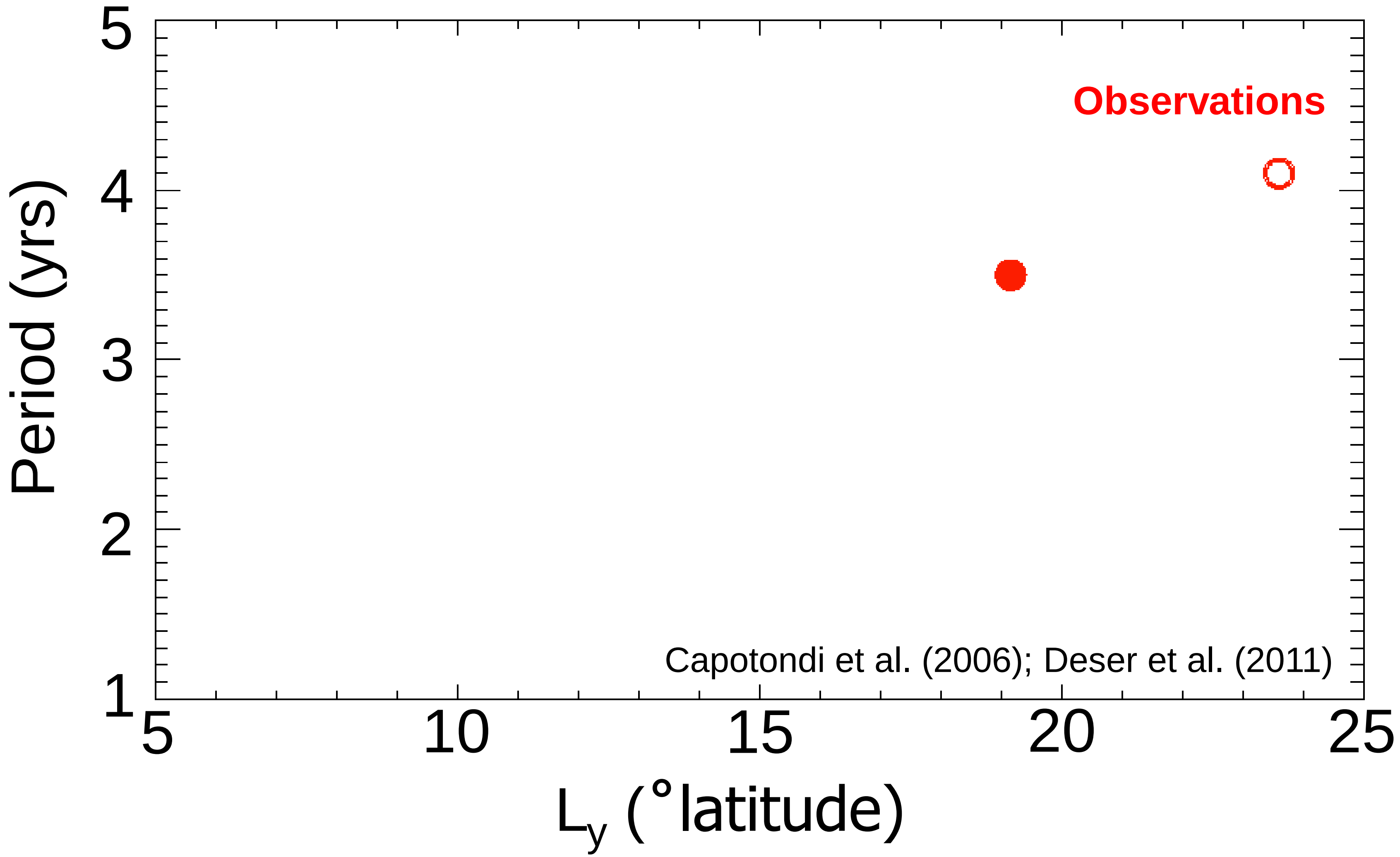
Pacific Variability: ENSO



Neale et al. (2008); Deser et al. (2011); Gent et al. (2011)

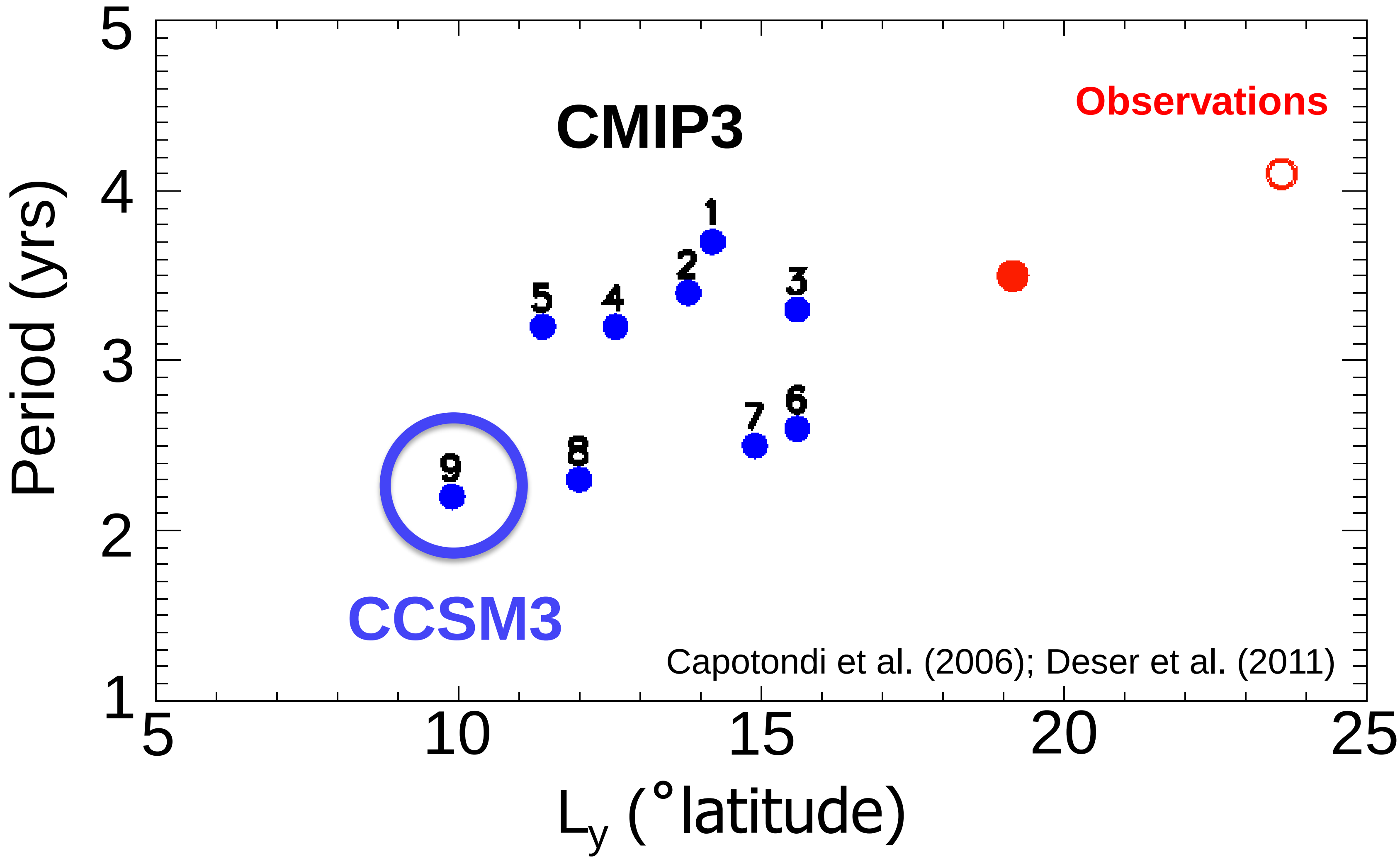
ENSO in CCSM4 and other models



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

L_y → width of zonal wind stress anomalies

ENSO in CCSM4 and other models



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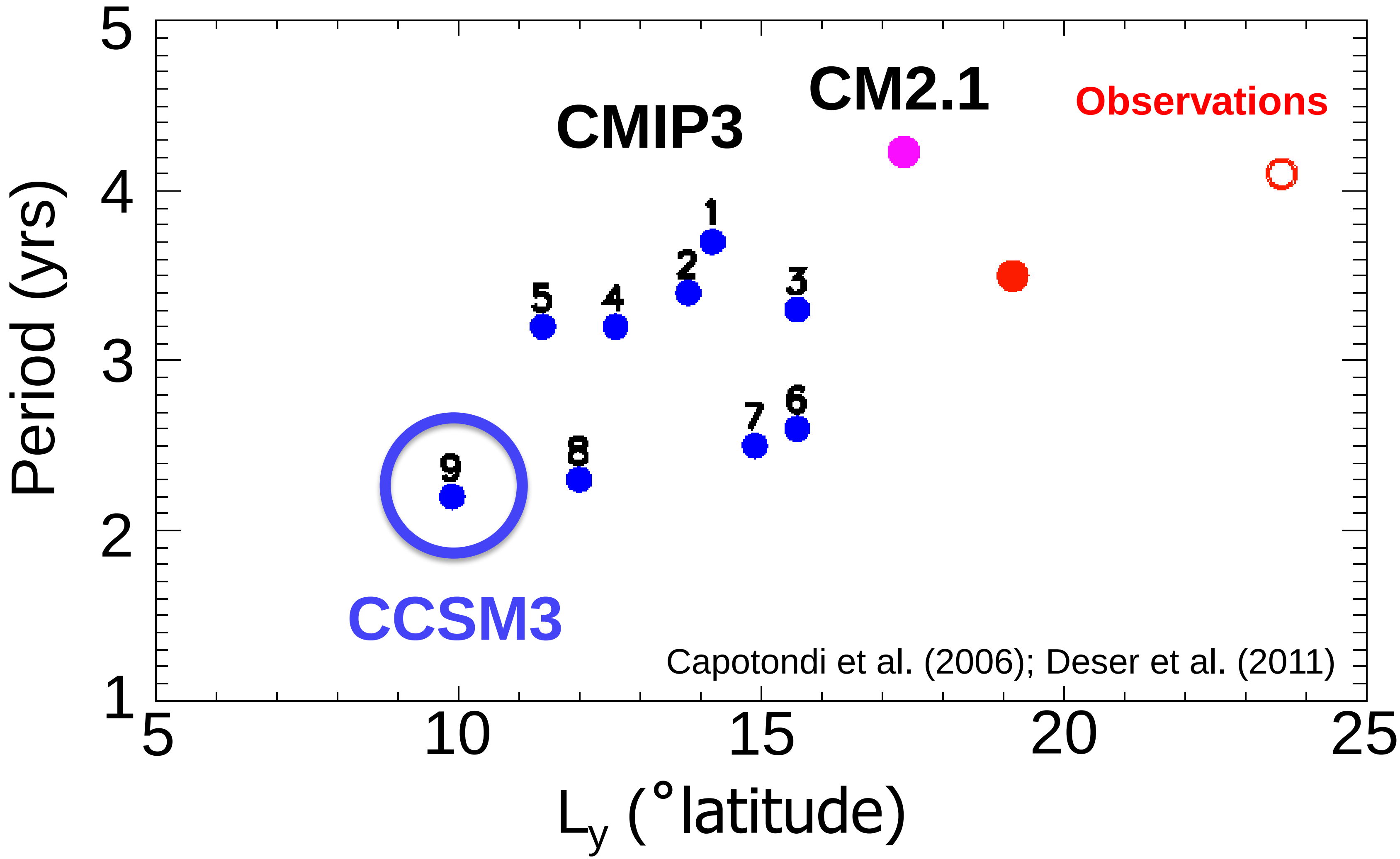

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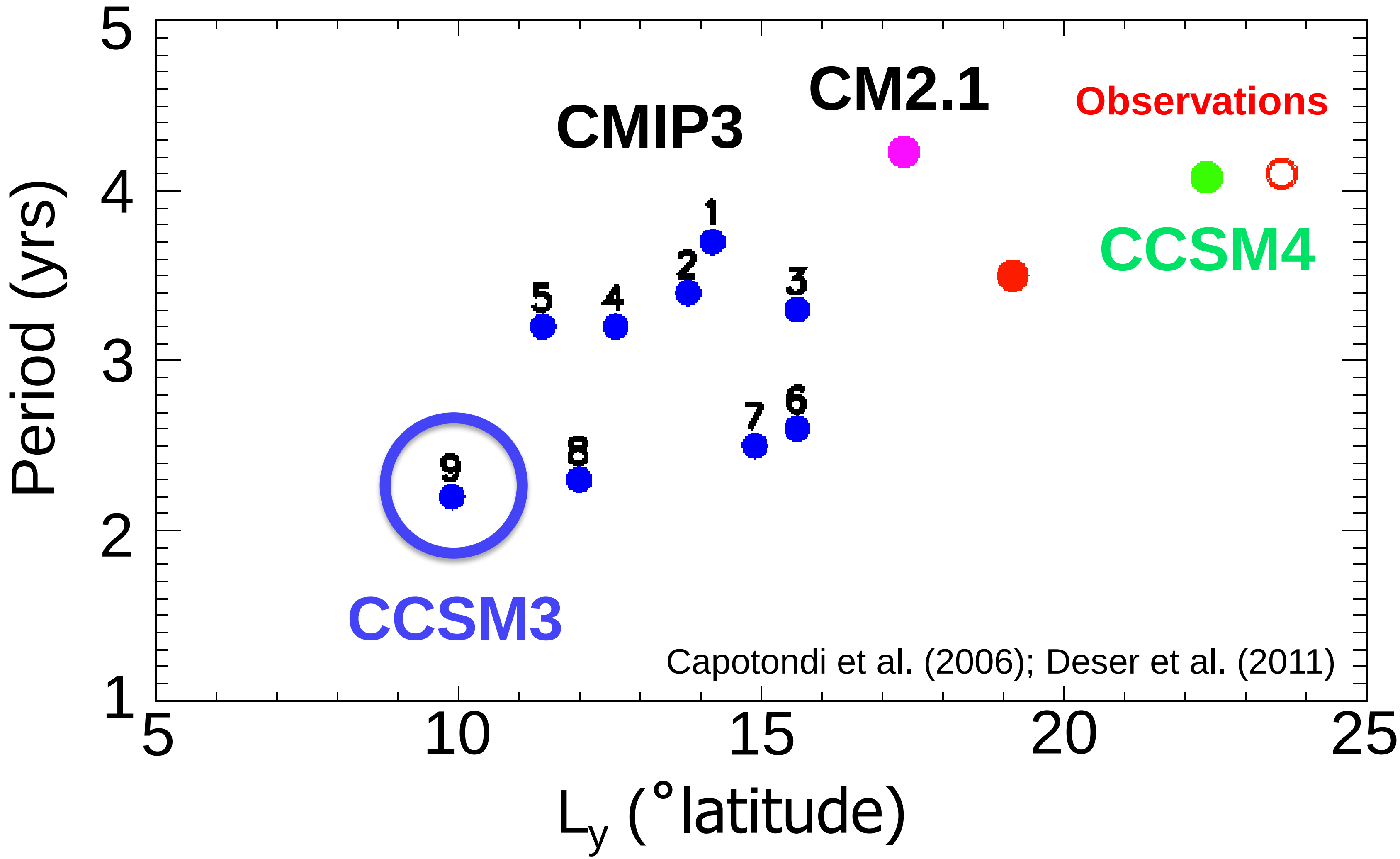


Period → freq of max spectral power of Niño3.4 SST

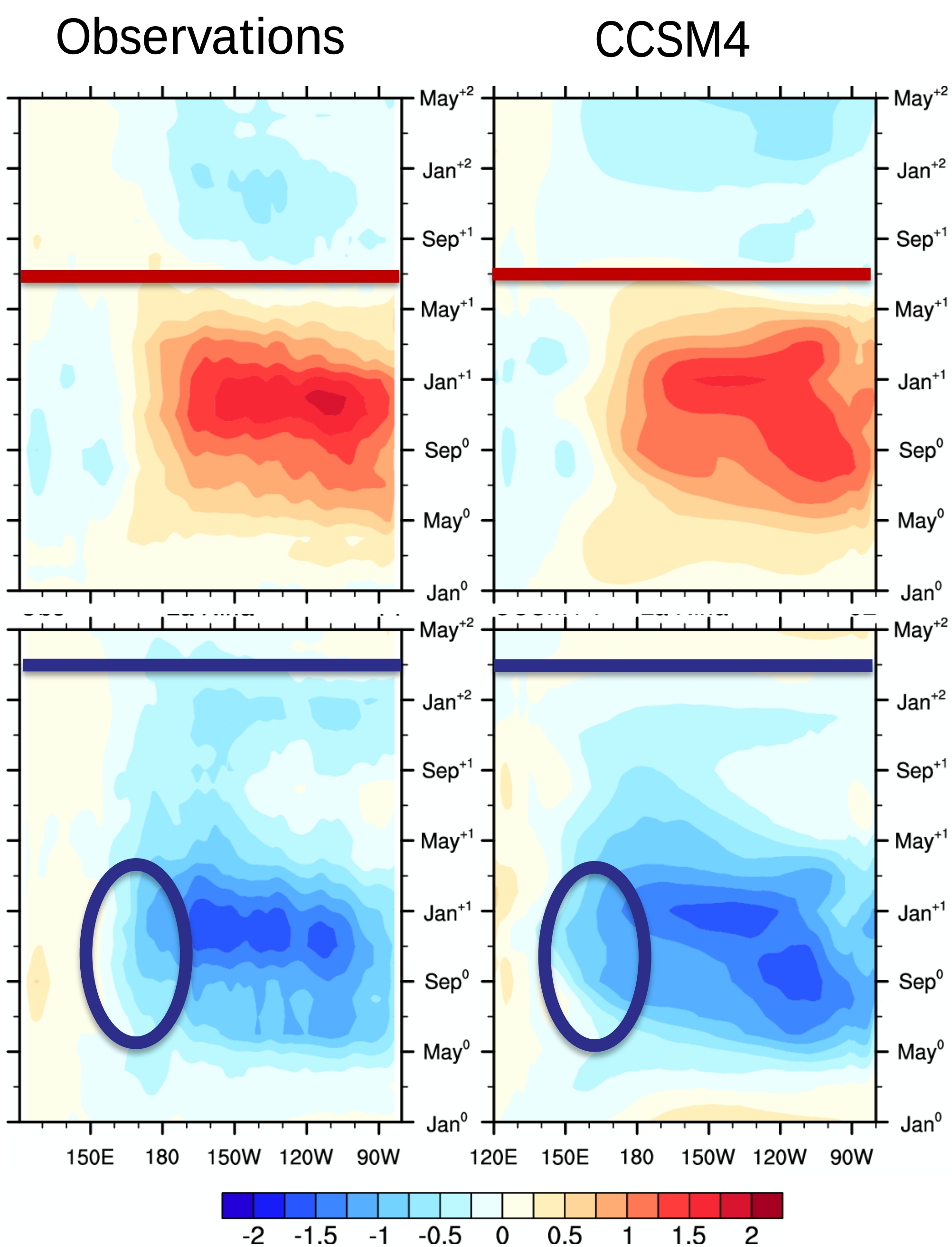
L_y → width of zonal wind stress anomalies

Equatorial SST Composites

El Niño

Latitude/Time cross-sections

La Niña



Deser et al. (2011)

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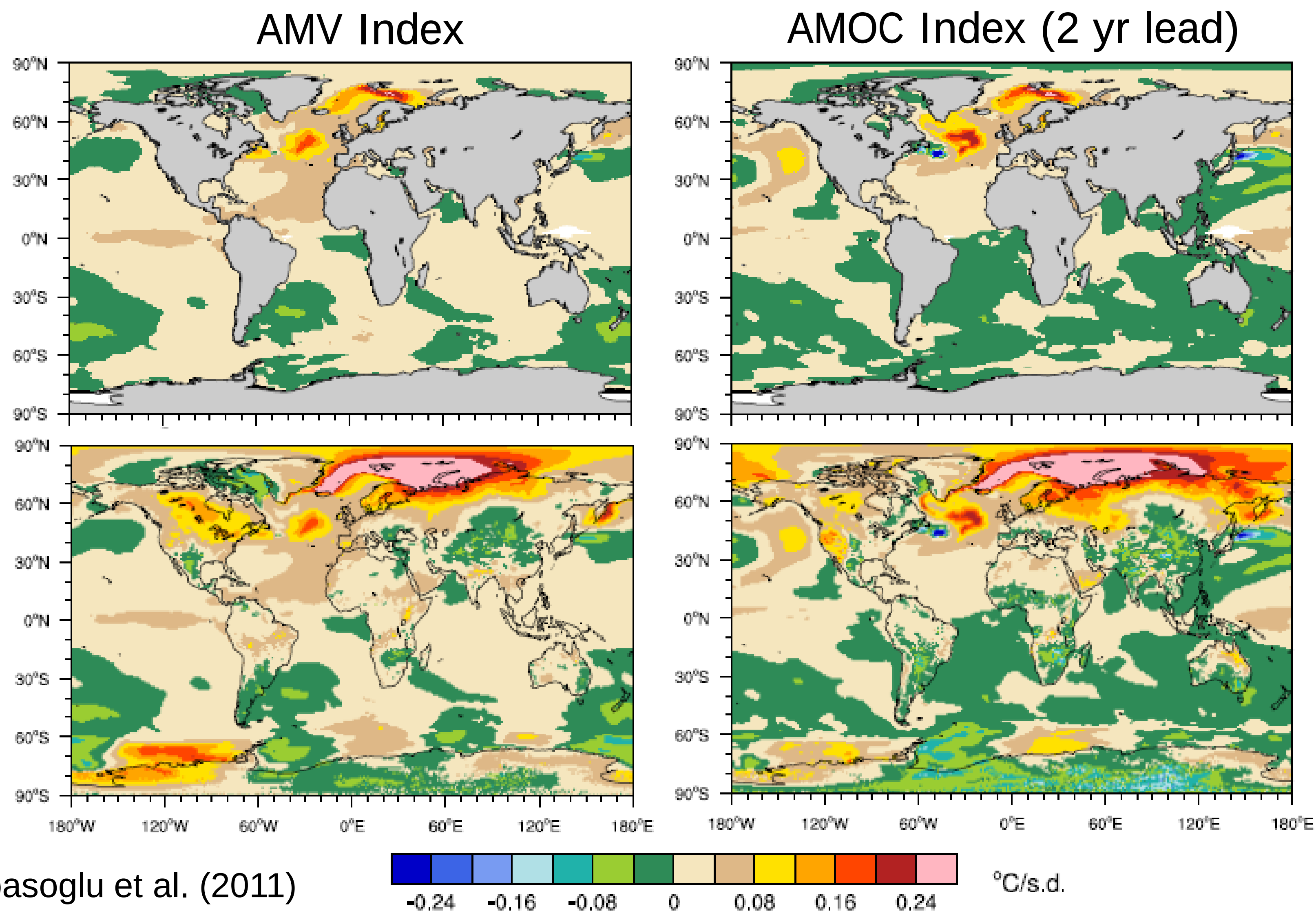
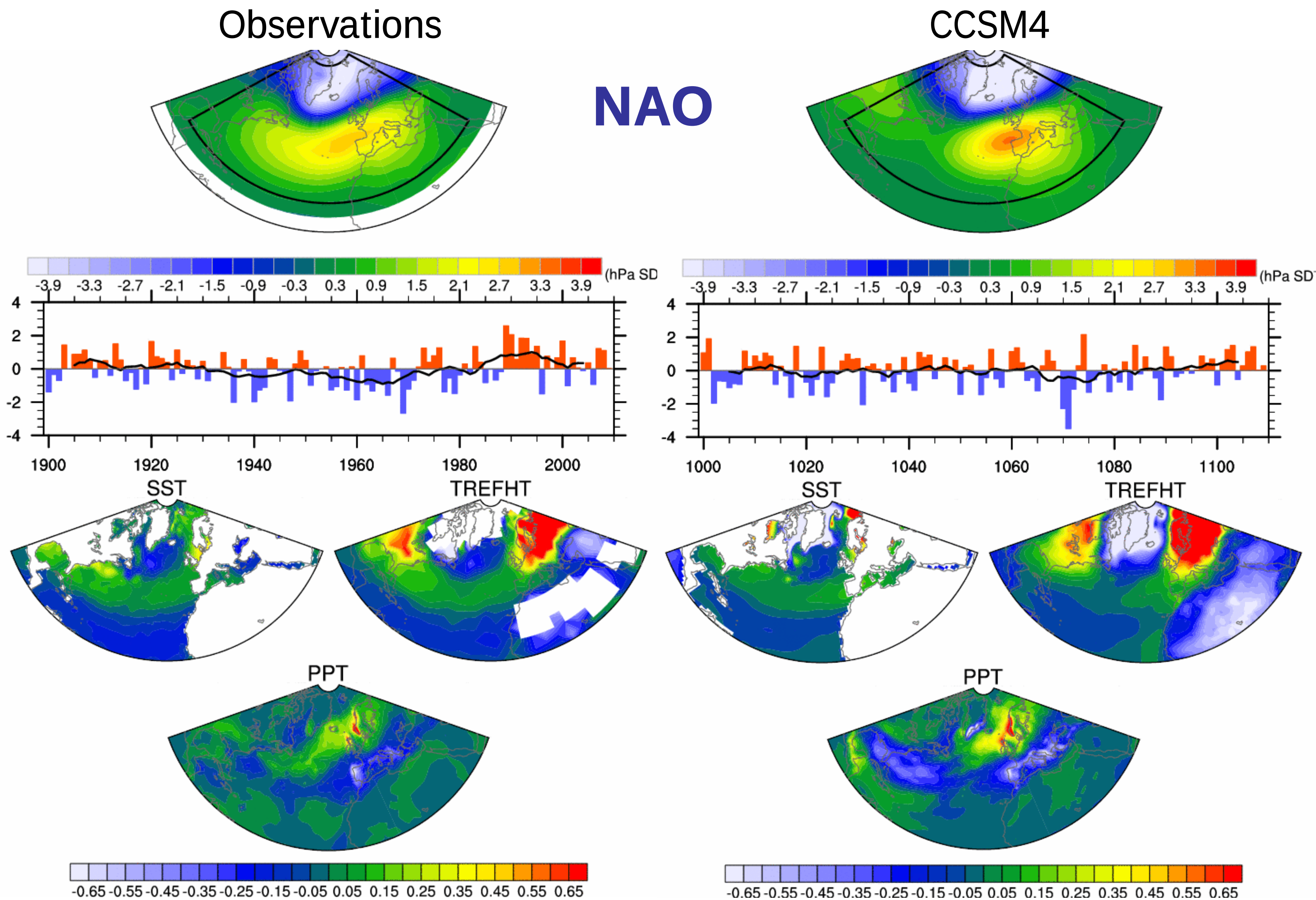
Atlantic Multidecadal Variability

CCSM4 Annual Mean SST and Surface T regressed on:



Danabasoglu et al. (2011)

North Atlantic Variability



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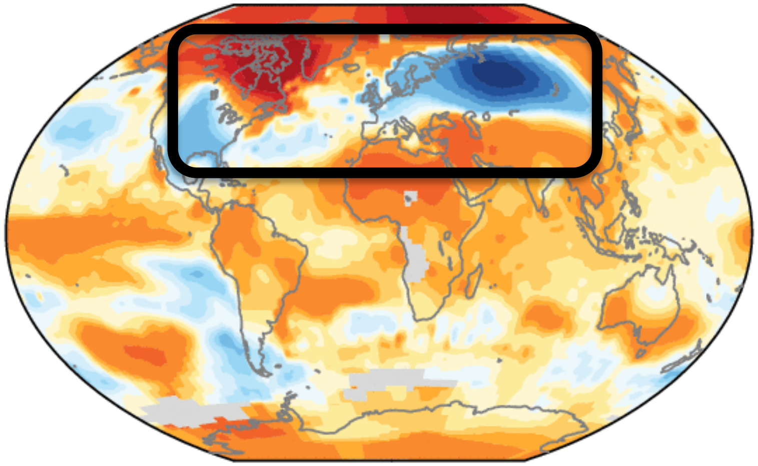
Anomalous Persistence of NAO

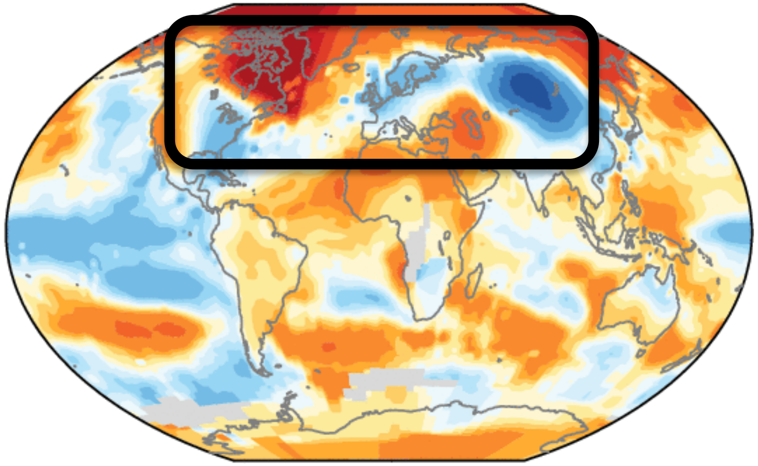
Winter Surface Temperature Anomalies

Total Observed

2010



2011



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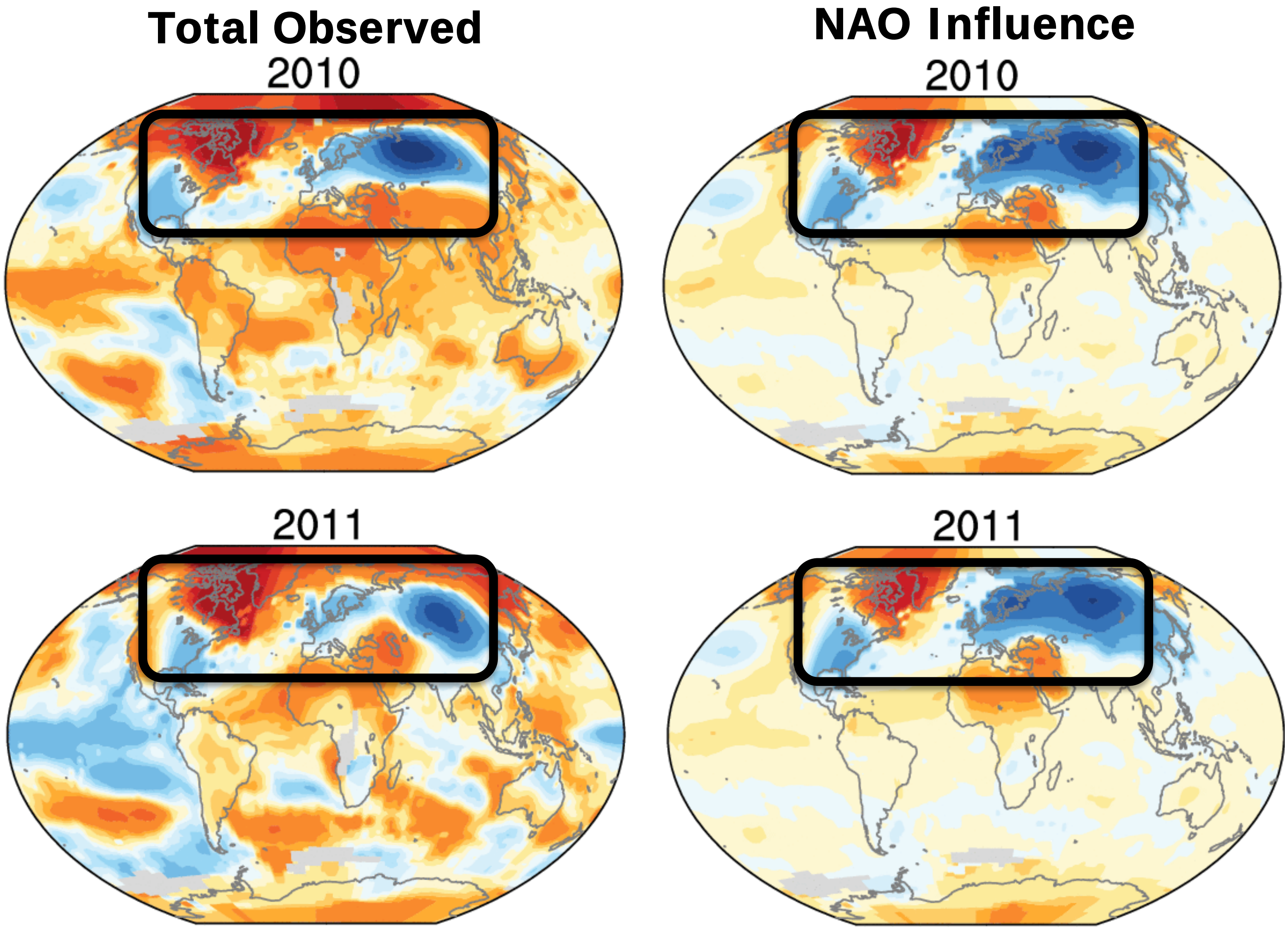
Anomalous Persistence of NAO

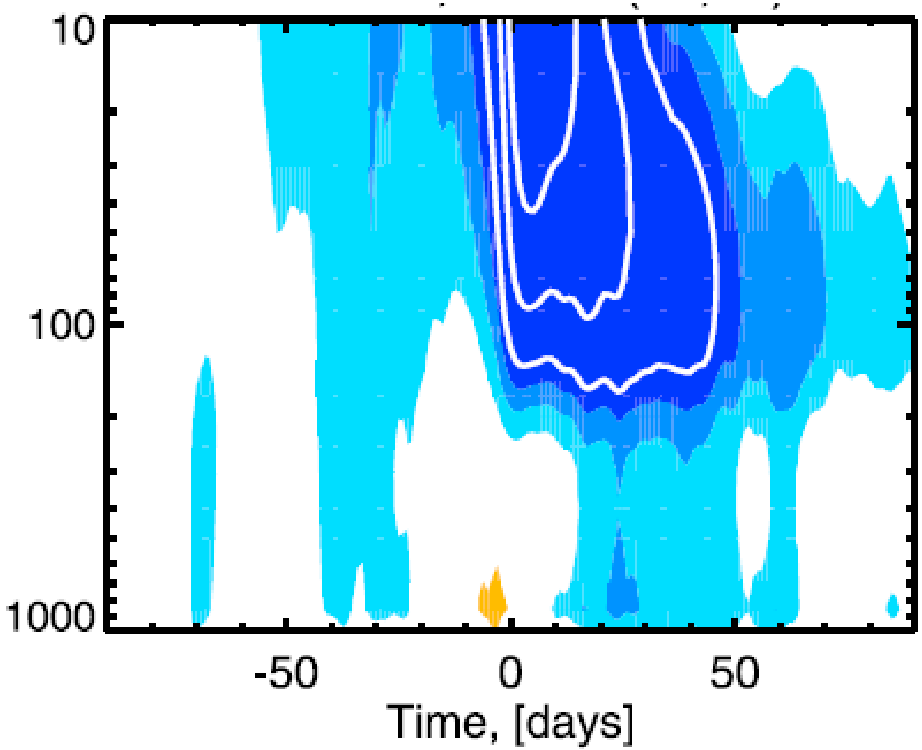
Winter Surface Temperature Anomalies



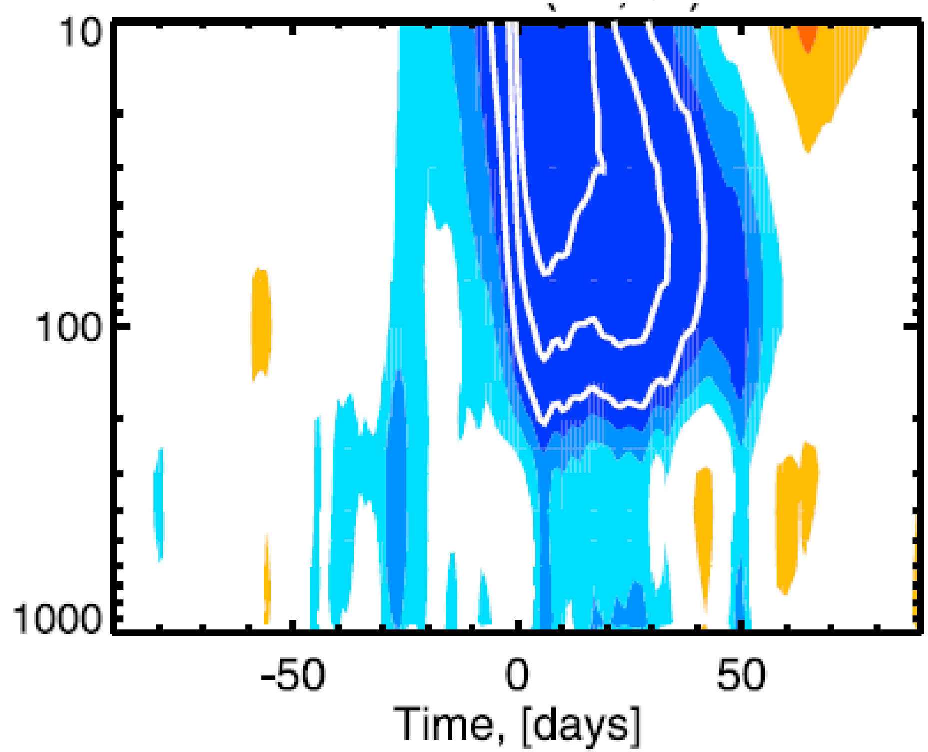
Composite Differences of NAO Index

Strong and Weak Stratospheric Events

WACCM (2 AMIP runs)



ECMWF Reanalyses



22 strong, 65 weak events

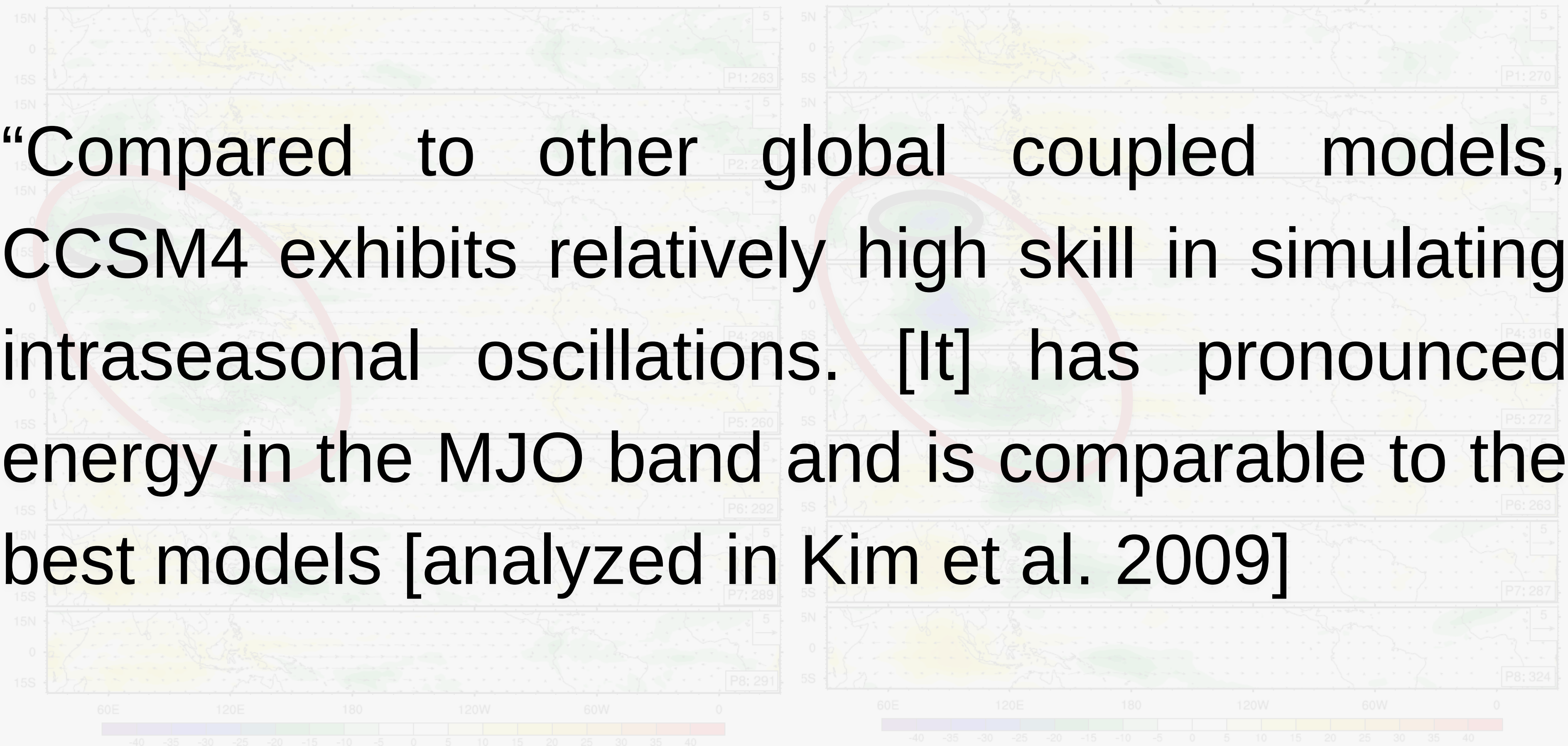
12 strong, 36 weak events

Gerber et al. (2010)

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

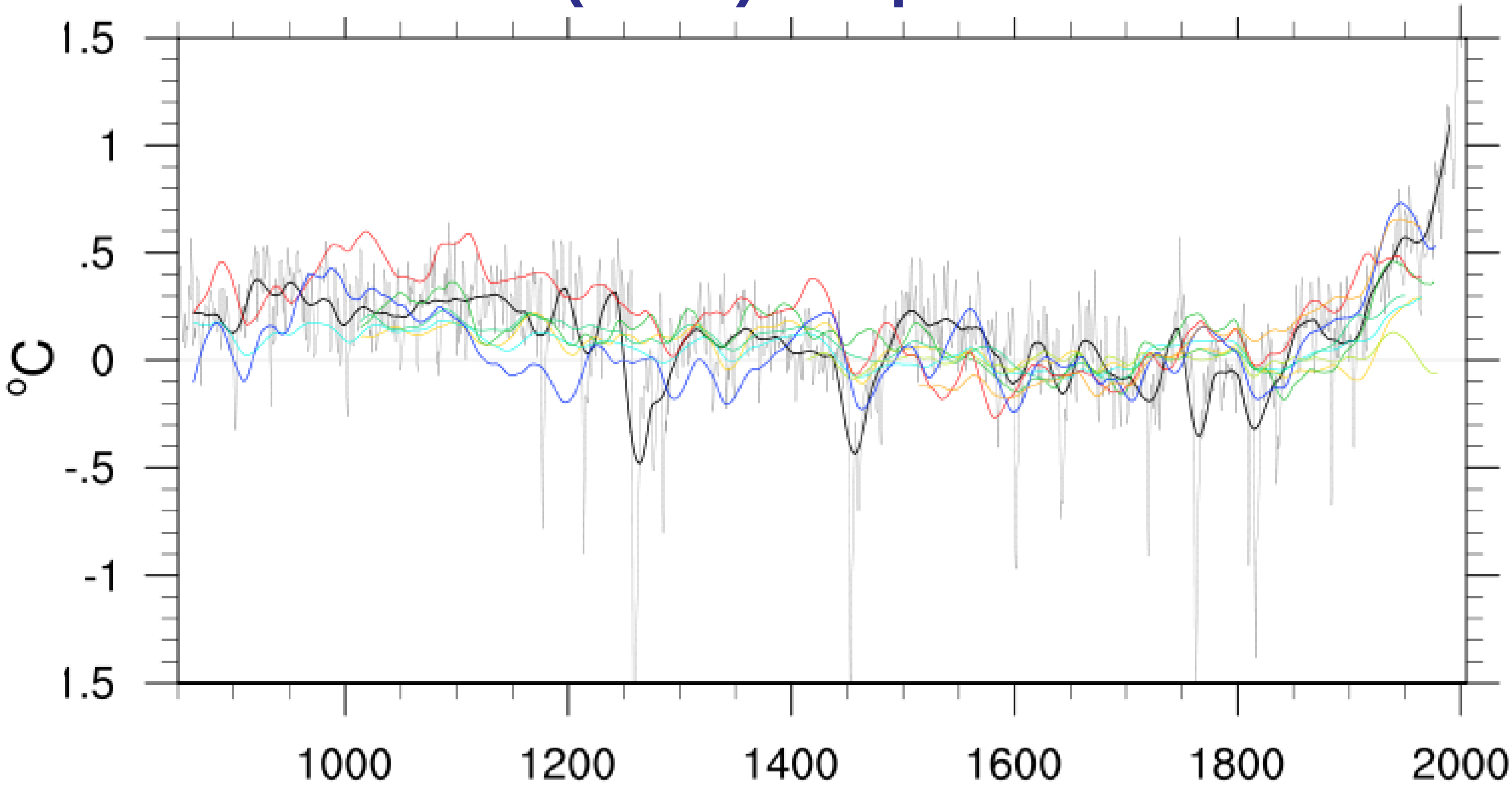
Subramanian et al. (2011)

Past Climate

Northern Hemisphere Temperature

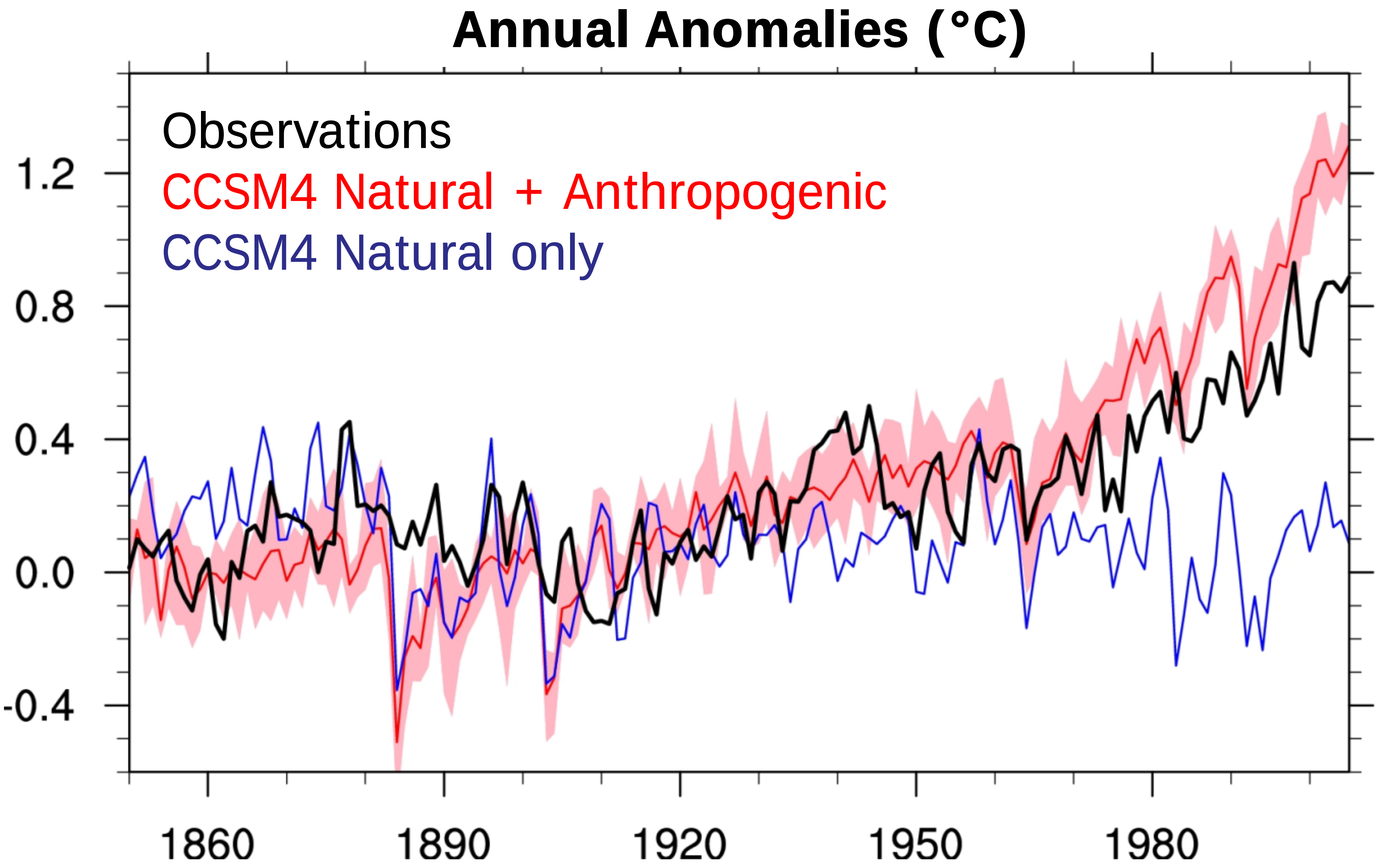
(Last Millennium 850-2005)

CCSM4 1° (black) compared to Proxies



Courtesy Bette Otto-Bliesner

Surface Temperature (1850-2005)

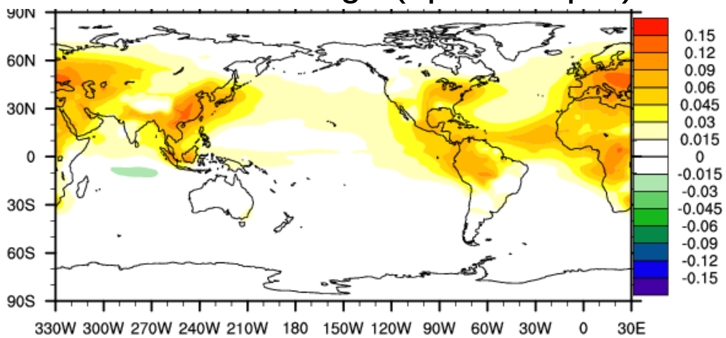


Meehl et al. 2011

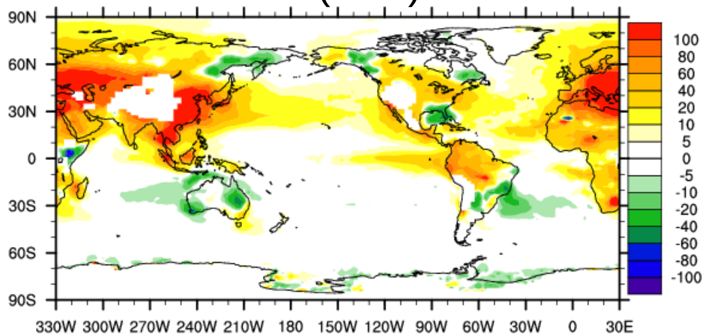
Anthropogenic Aerosol Affects: CESM1 (CAM5)

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

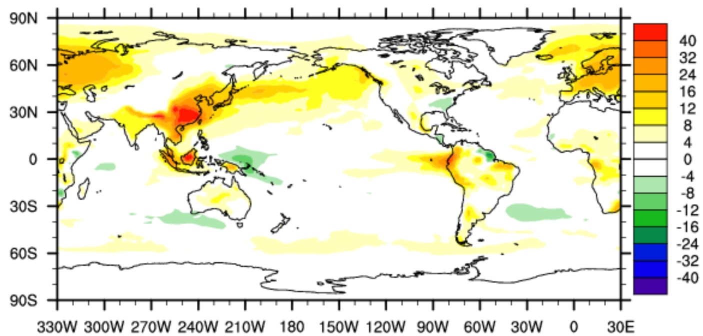
Total aerosol change (optical depth)



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



Liquid water path (g/m^2)

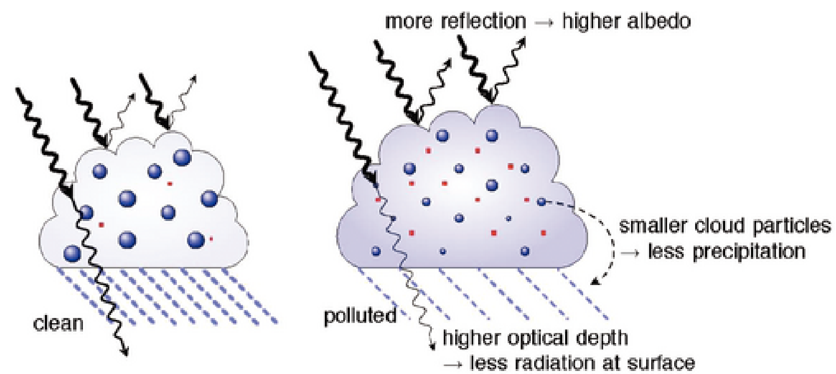


✓Increased aerosol burdens in SE Asia, Europe, NE North America, Brazil

✓Increased cloud droplet number concentration; strongest over land

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

Low cloud affects: net cooling over 20th century



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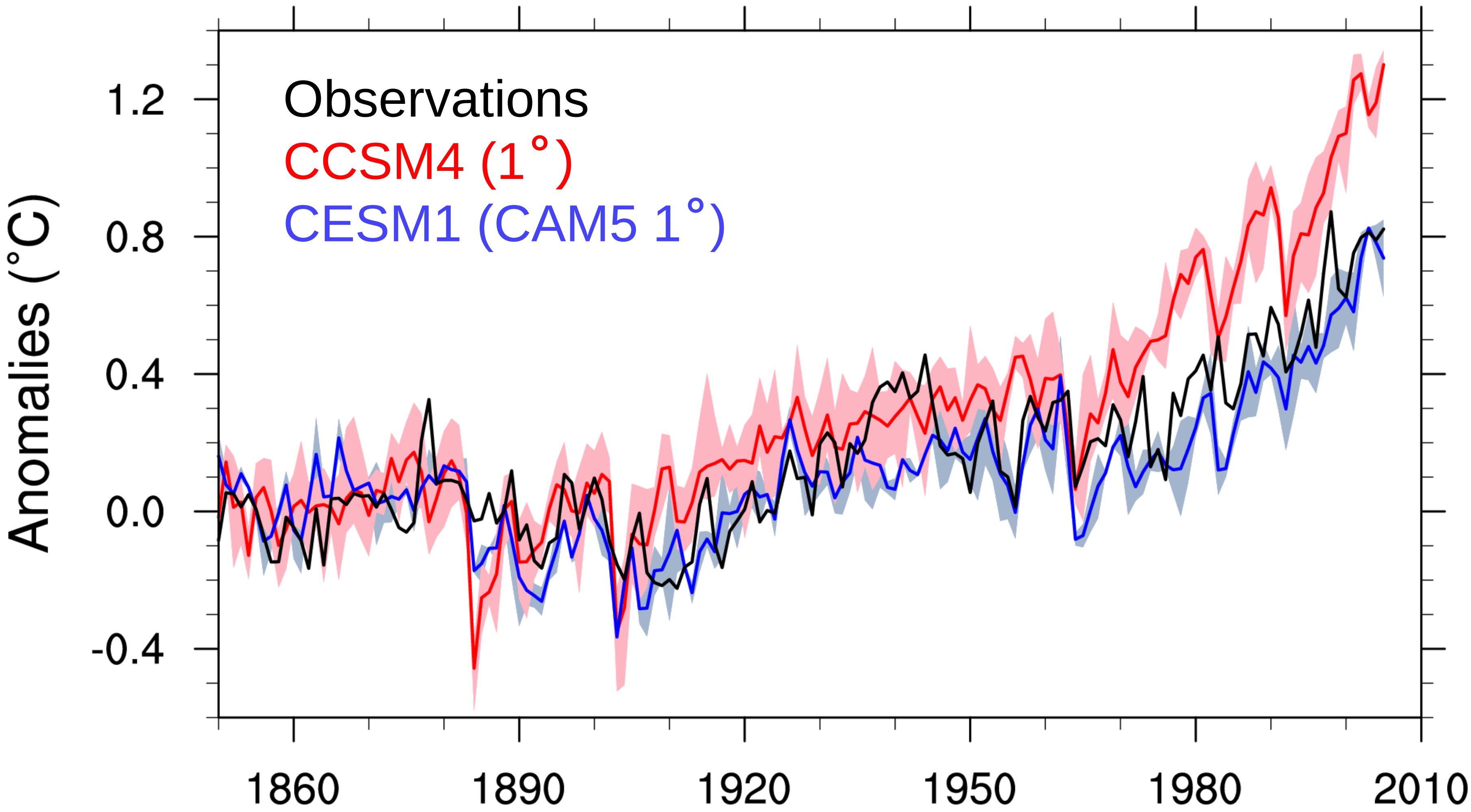
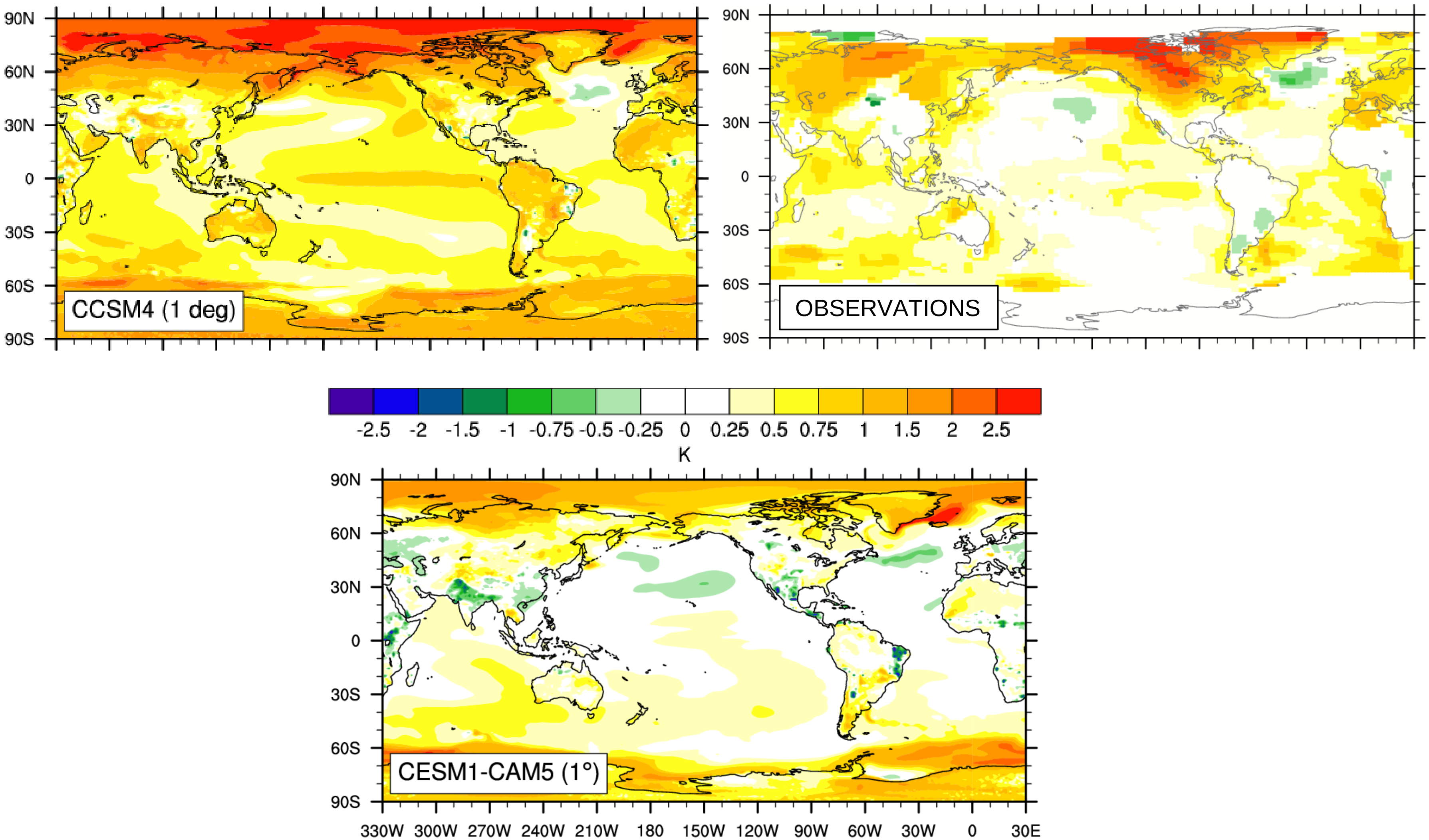
Surface Temperature (1850-2005)



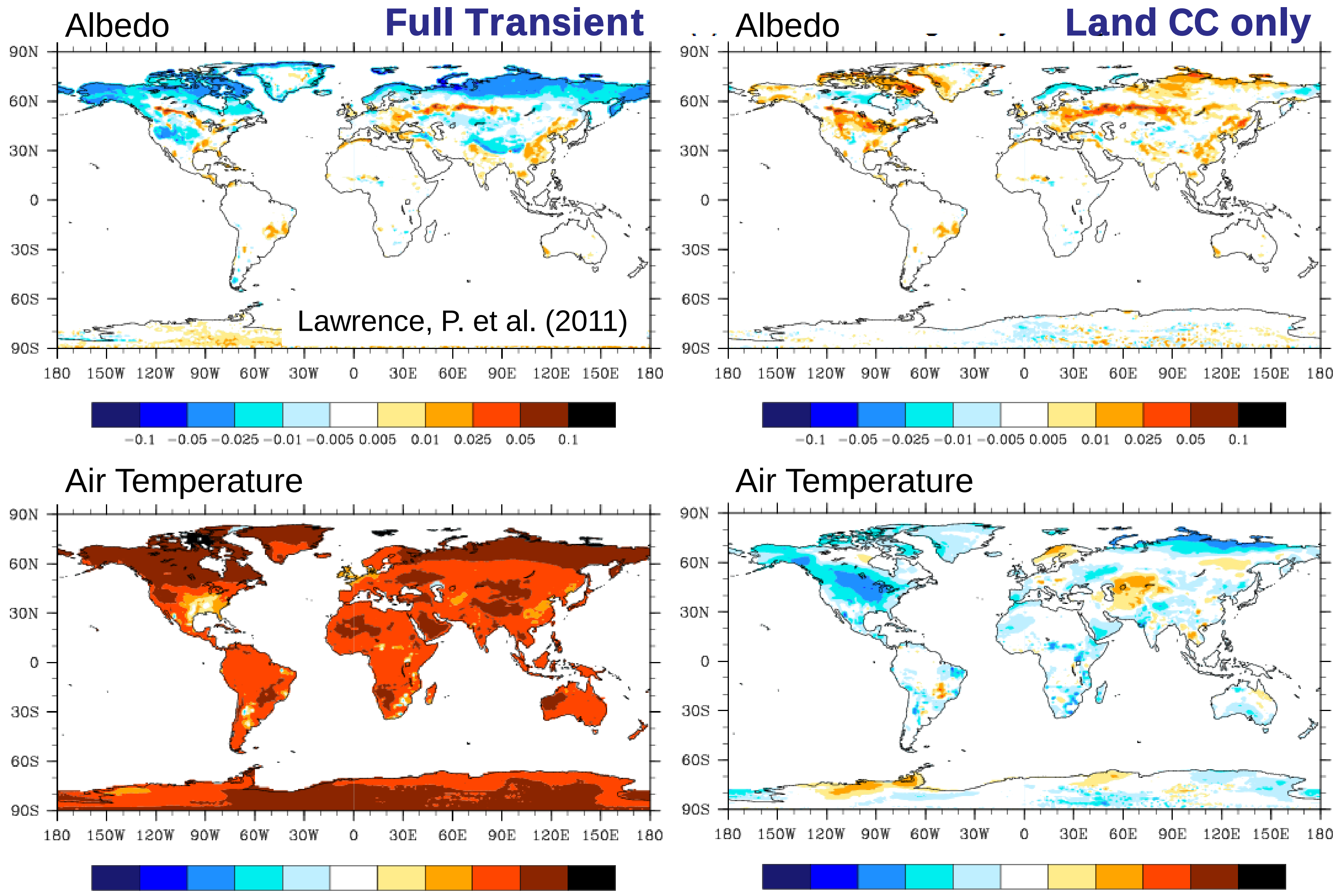
20th Century Surface Temperature Change



More realistic regional warming

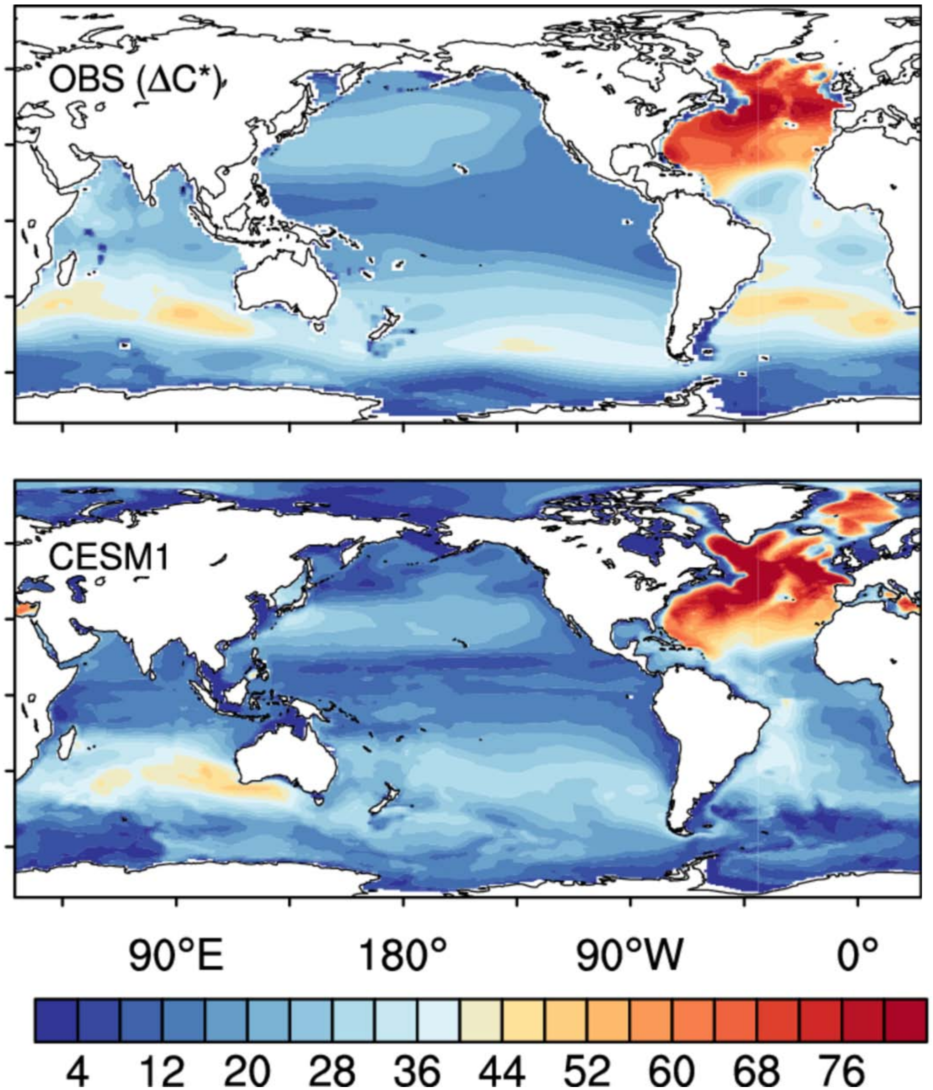
Impact of land cover change

(1976 to 2005 minus 1850-1879)



CESM1: Prognostic Ocean Carbon Cycle

Ocean Inventory of Anthropogenic CO_2



Total

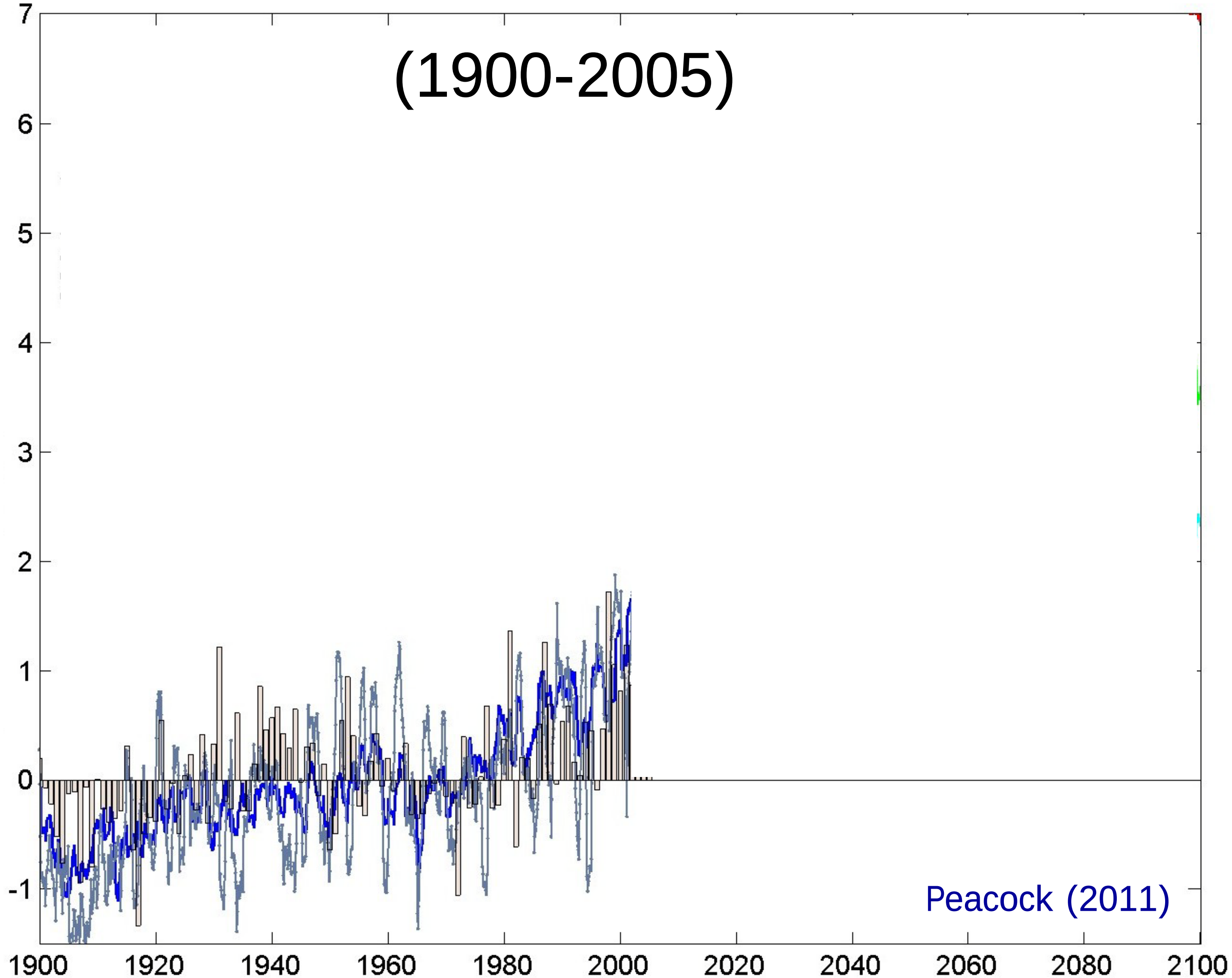
118 Pg C (±18)

90.3 Pg C

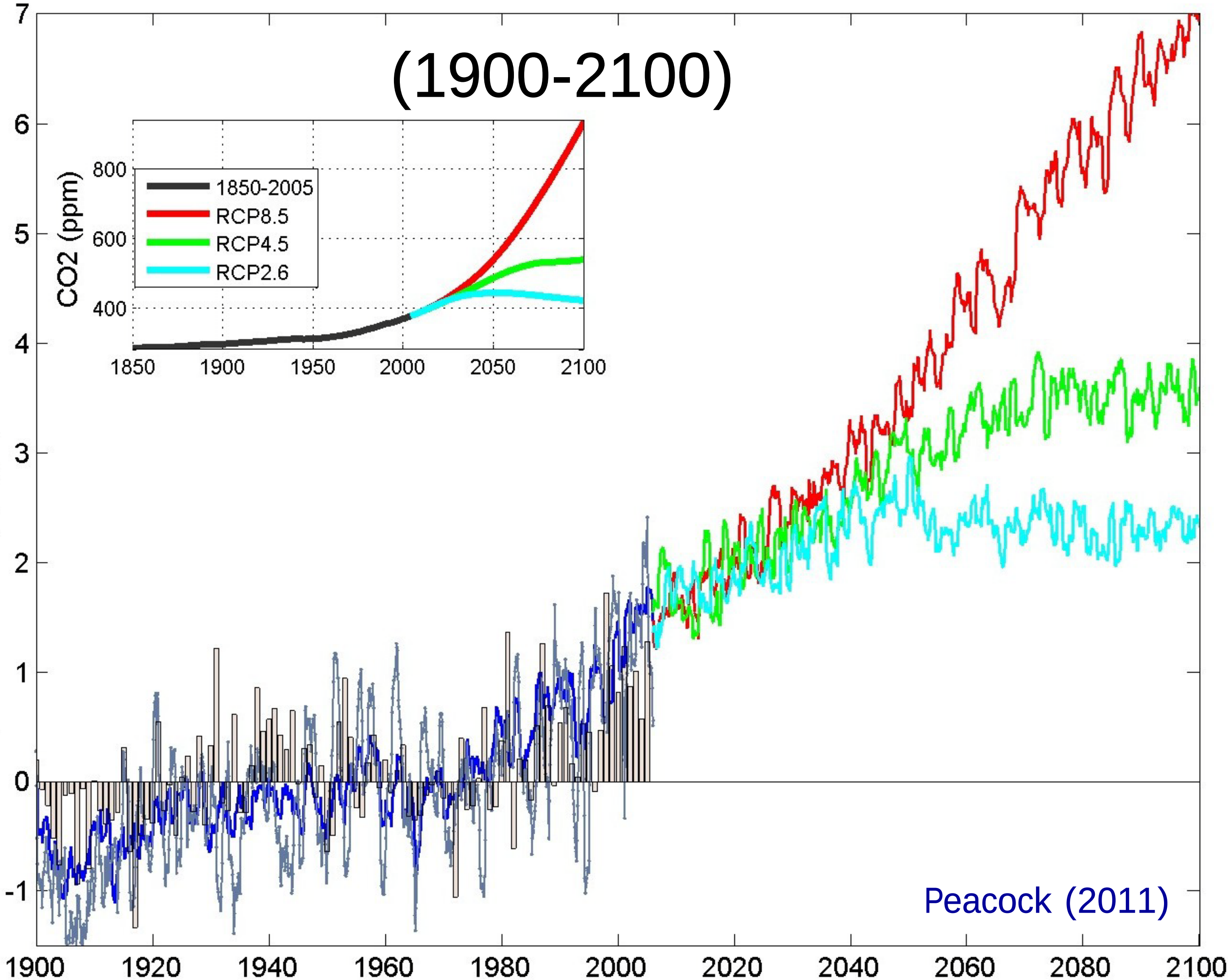
Courtesy Matt Long, ASP

Future Climate

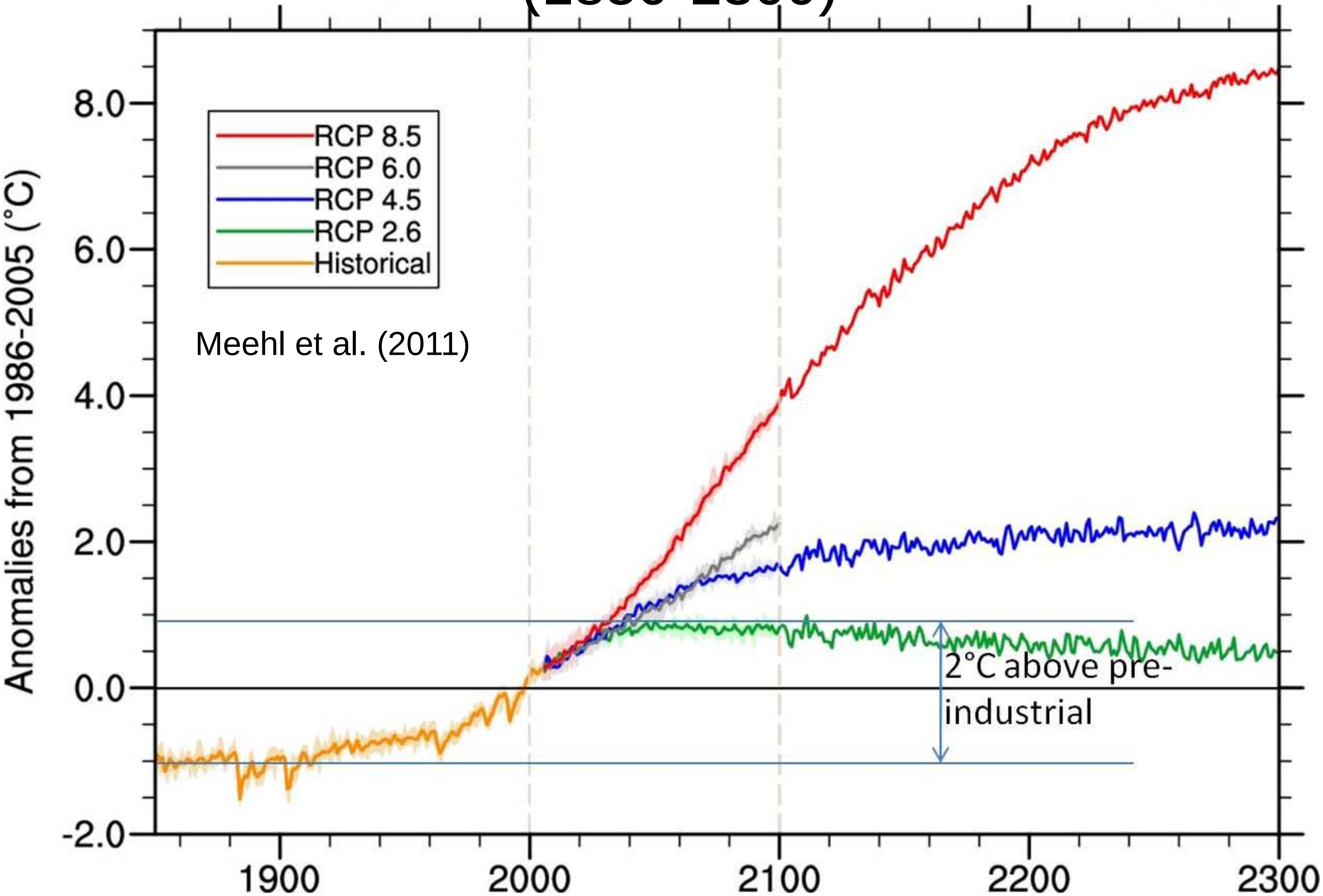
North American Annual Surface T (ºC)



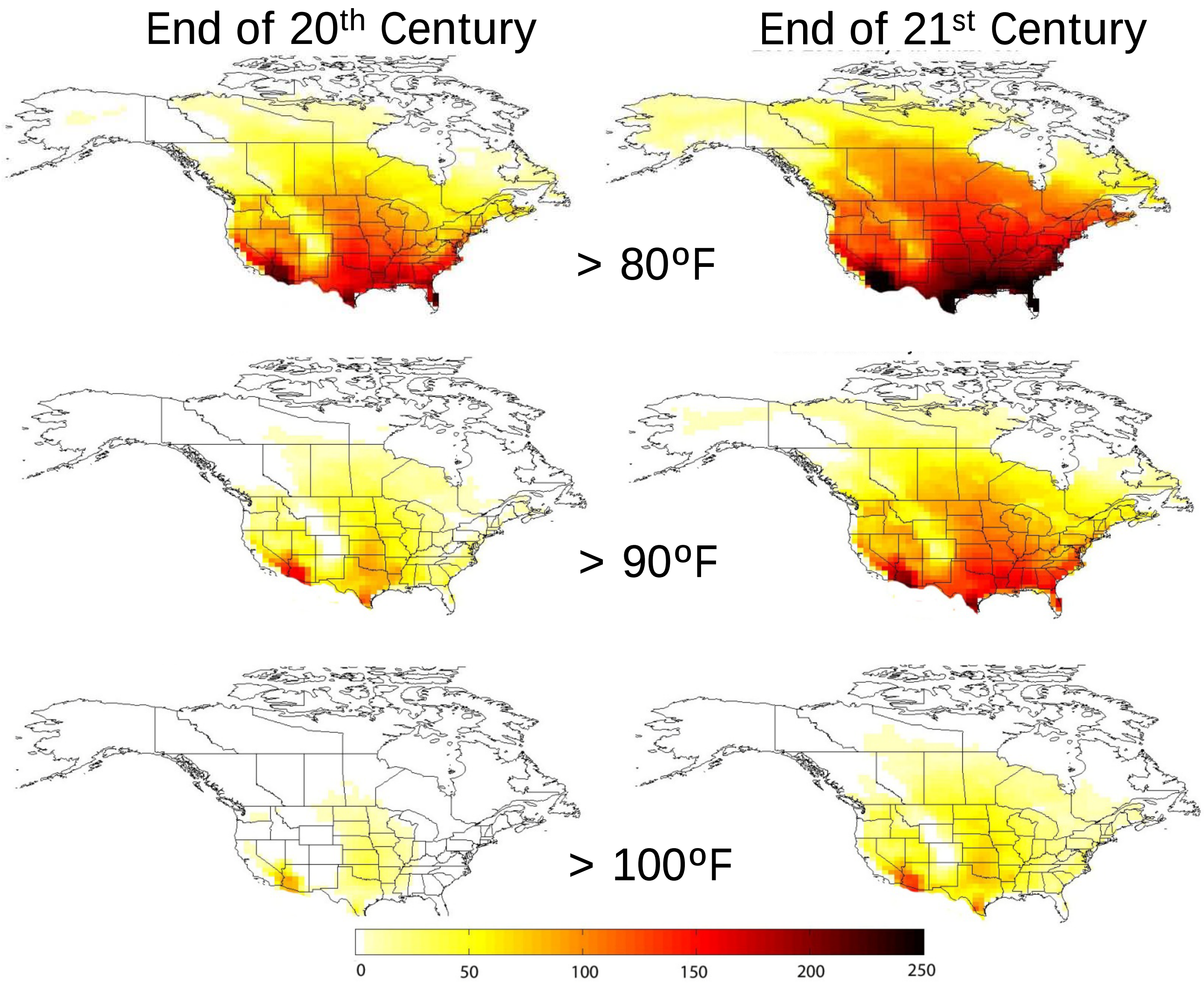
North American Annual Surface T (ºC)



Global Surface Temperature
(1850-2300)

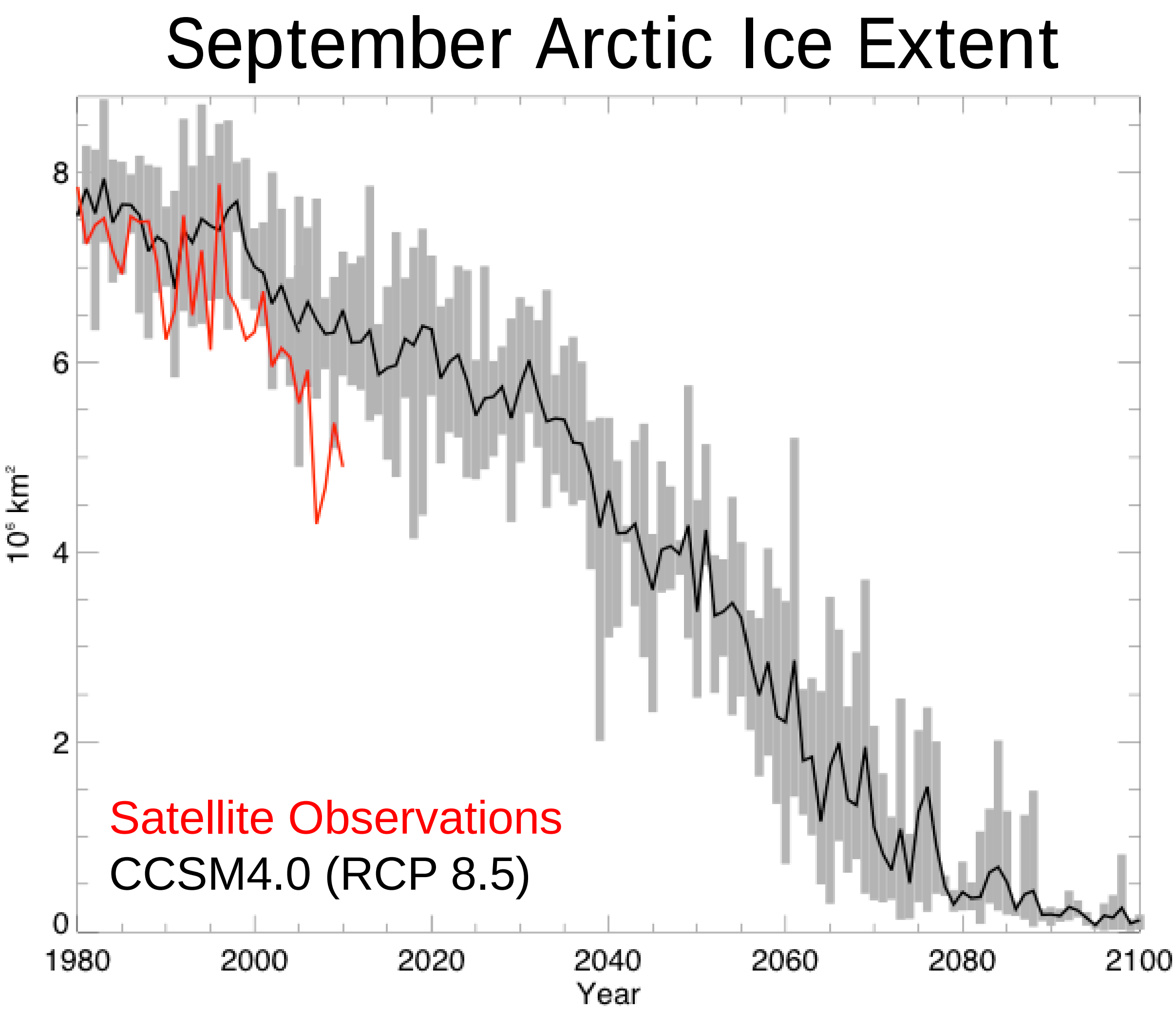


Extremes: Number of Warm Days

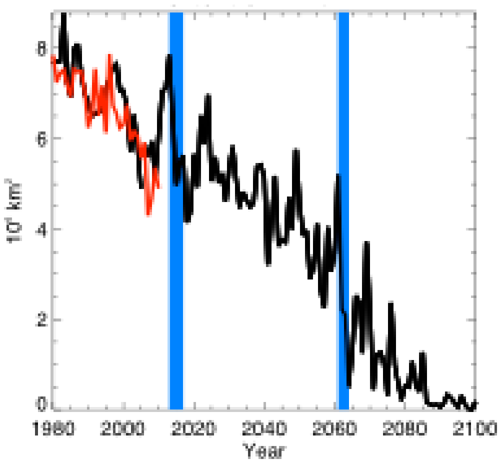


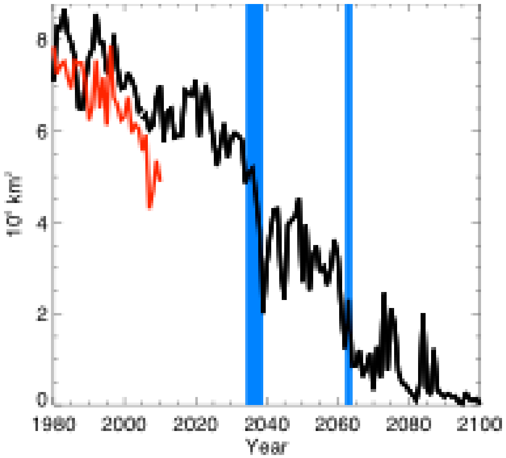
Peacock (2011)

Simulation of the 21st Century



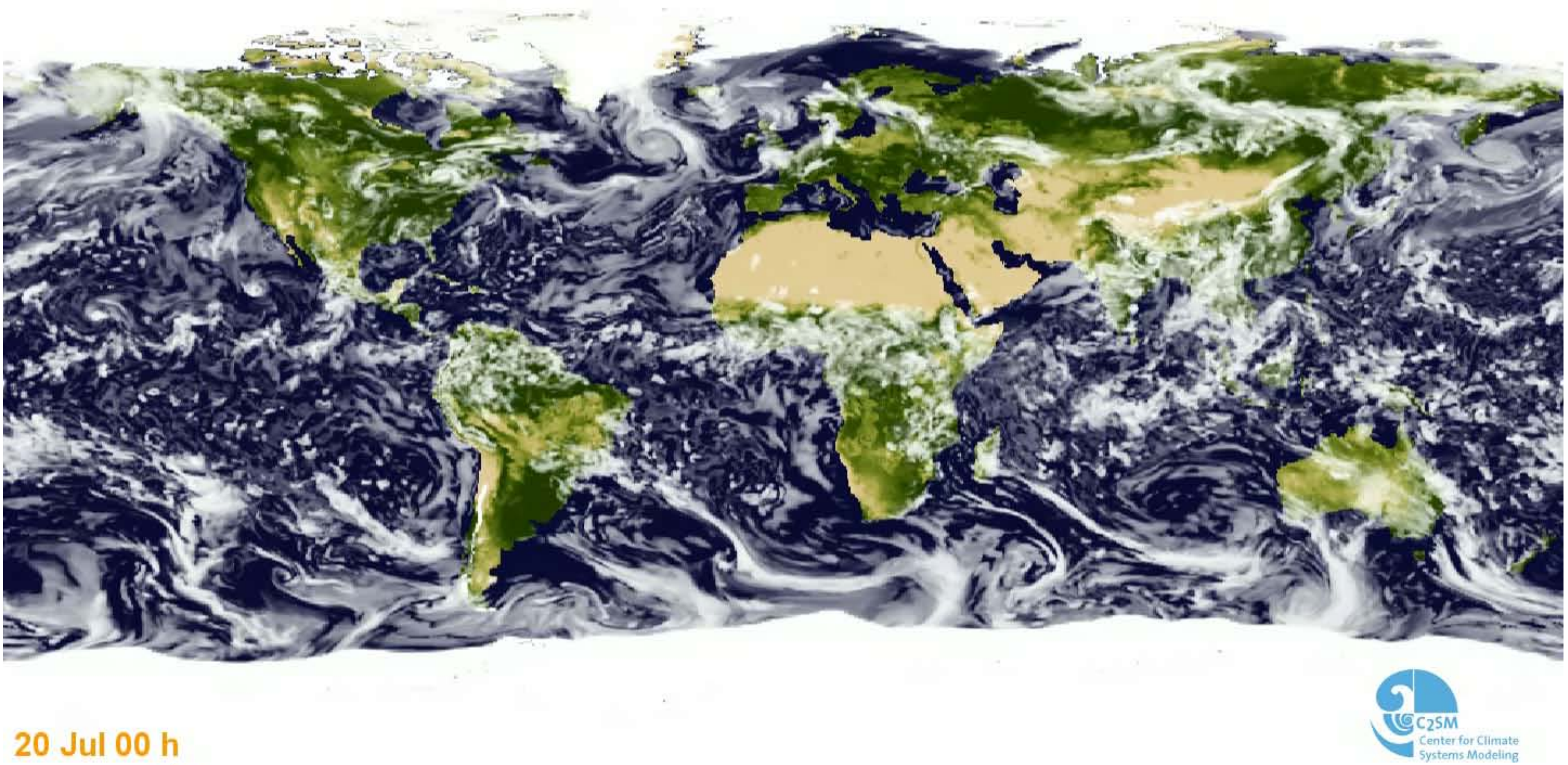
Abrupt Changes





Vavrus et al. (2011)

High Resolution Global Climate Simulations



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