

The Community Earth System Model: A Framework for Collaborative Research

www.cesm.ucar.edu



James W. Hurrell

Chief Scientist, CESM and Community Climate Projects

Climate and Global Dynamics Division, NESL



20 June 2011

The Community Earth System Model
16th Annual Workshop

Jim Hurrell
jhurrell@ucar.edu



The Community Earth System Model

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Outline

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



Community Use and Involvement



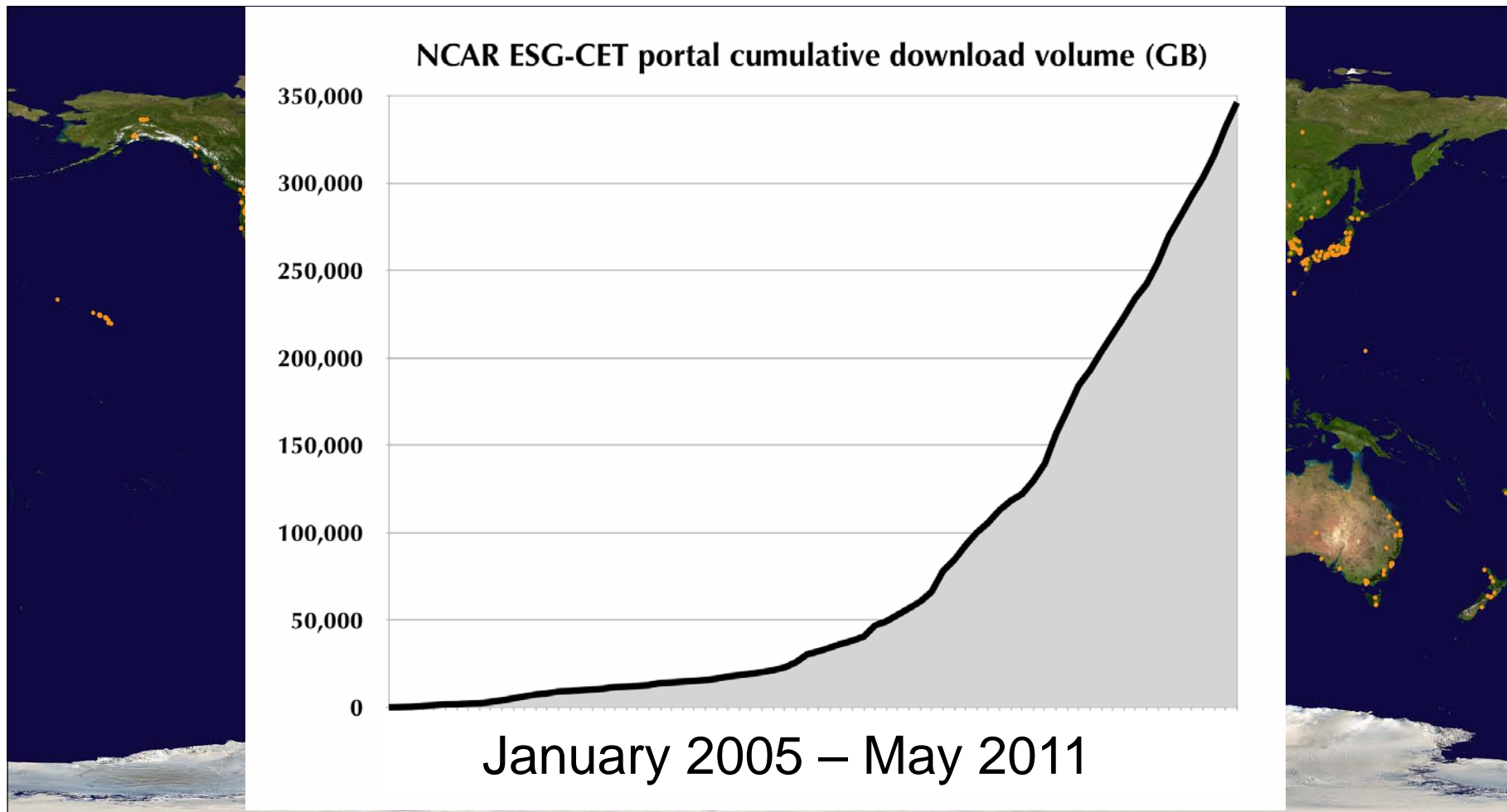
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jhurrell@ucar.edu



A Community Resource



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

Courtesy Gary Strand

Major Activities



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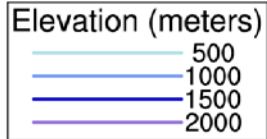
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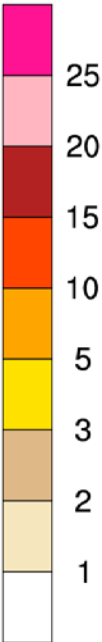
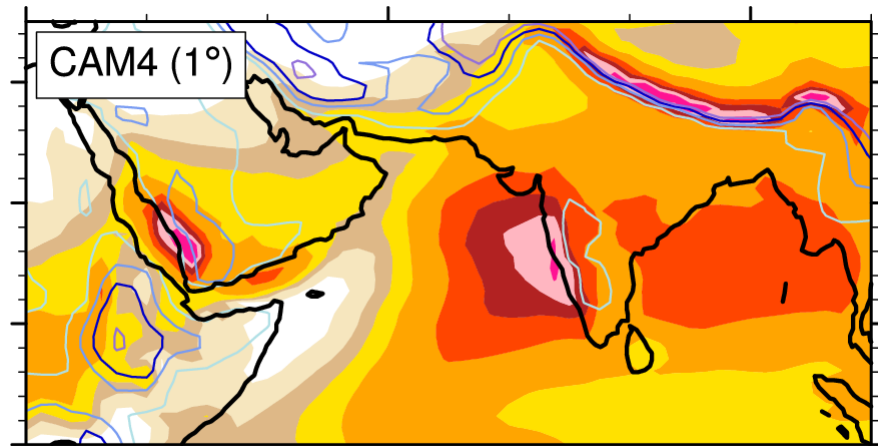
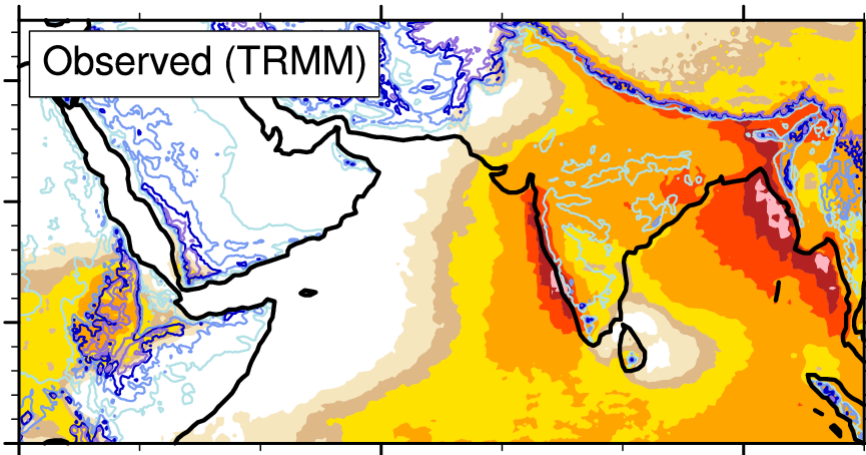
CESM Updates and Releases

- CESM release mechanism is working (credit to SEWG):
 - ✓ First version of CESM and supporting documentation was released for community use in June 2010
 - ✓ Many and growing number of registered users
- Release updates support more science
 - ✓ Progressive support of greater model complexity and scientifically supported configurations in each update
 - ✓ Substantial increase in number of “out of box” configurations (104 in CESM1.03, nearly double those in CESM1.0)
 - ✓ 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
- Increased capabilities and support for higher resolutions
 - ✓ All CESM components now support parallel I/O → key requirement
 - ✓ CESM1.03 supports 1/8° CAM/HOMME, 1/4° CLM, 1/10° POP/CICE

Total Precipitation (JJA)

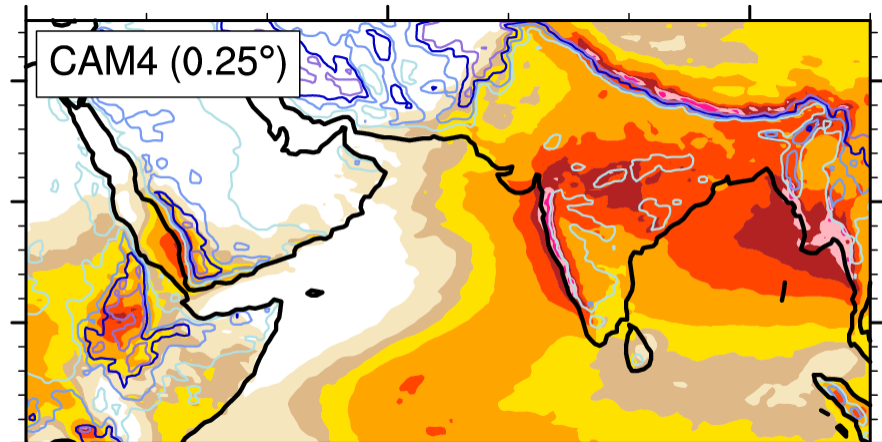


(mm day⁻¹)



Much improved spatial pattern and magnitude of rainfall

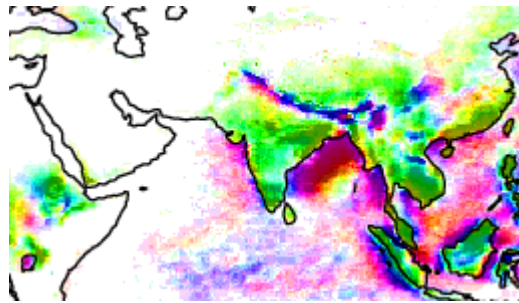
- Western India and Bay of Bengal
- Longstanding wet bias over Yemen, Oman and Saudi Arabia
- Somali jet more realistic



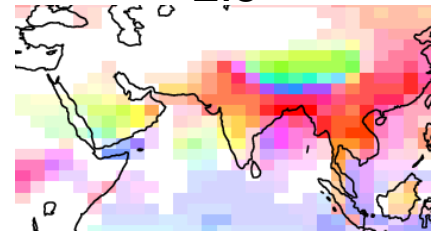
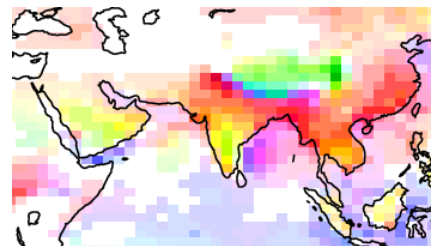
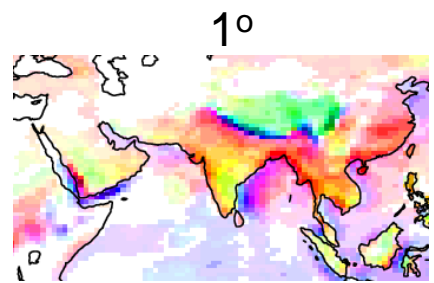
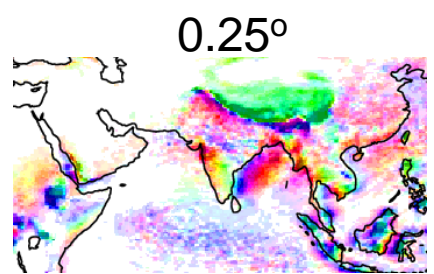
Courtesy Rich Neale

Resolution Impacts

JJA Precipitation



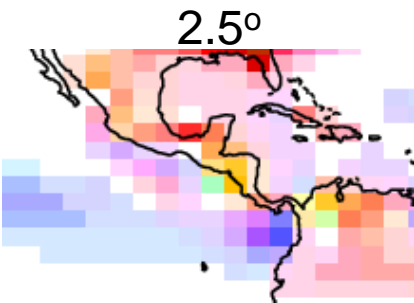
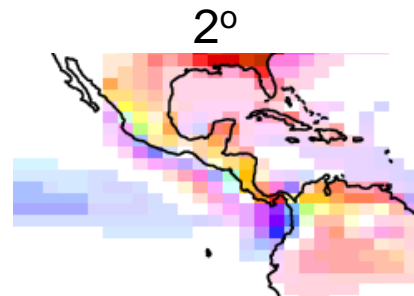
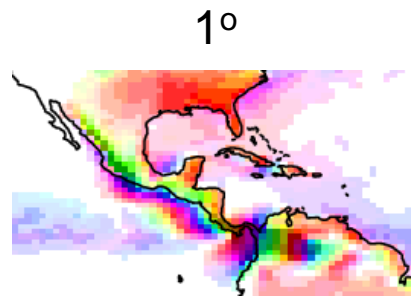
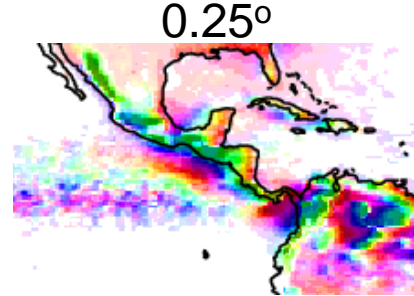
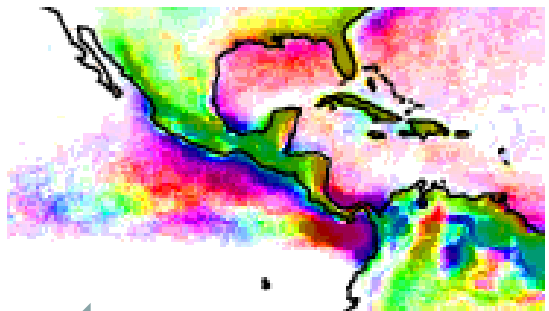
TRMM



Diurnal Cycle
Timing (hour)
Amp. (mm/day)



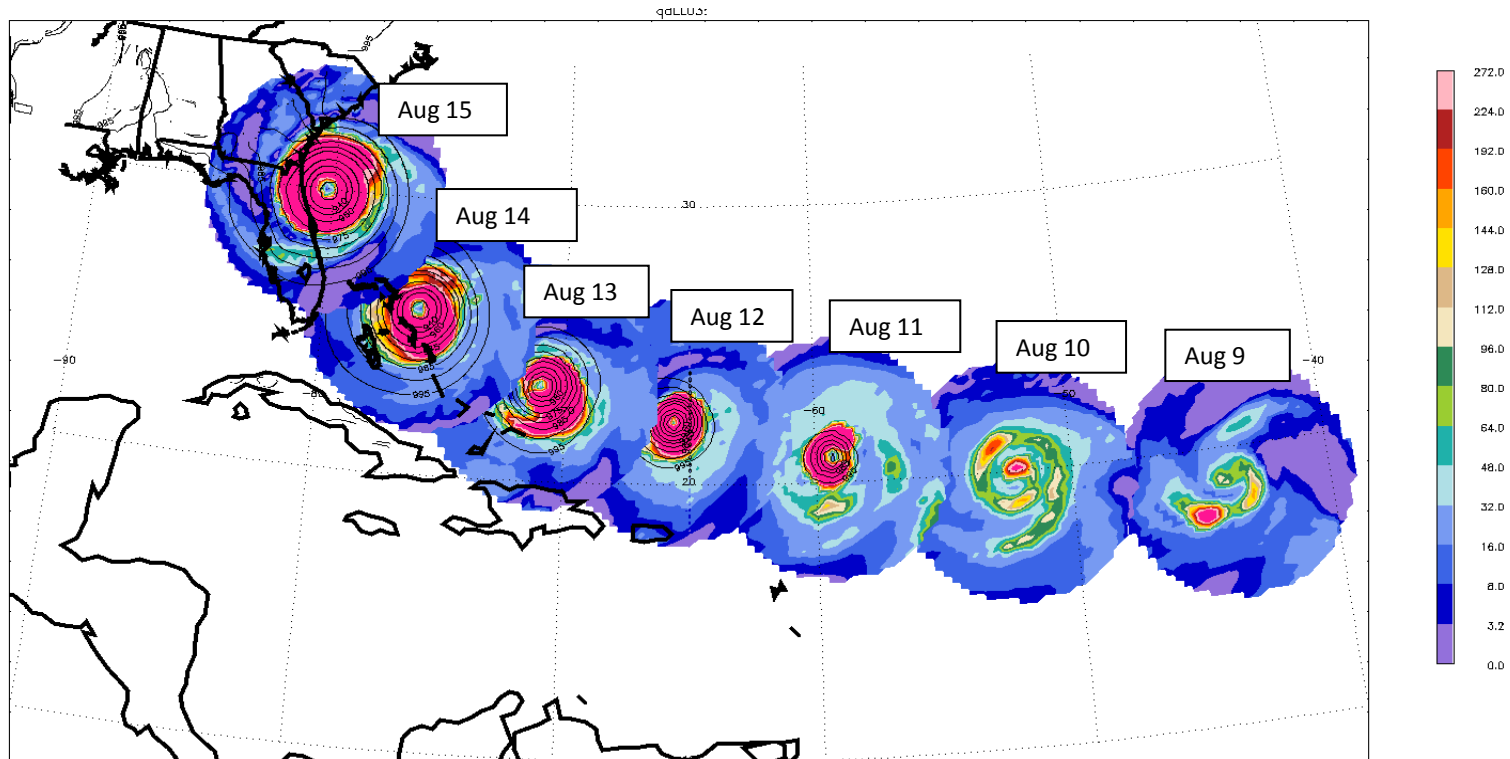
TRMM



Courtesy Rich Neale

Intense Atlantic hurricanes (AMIP 1/4°CAM5)

Precipitation within 500 km of storm center

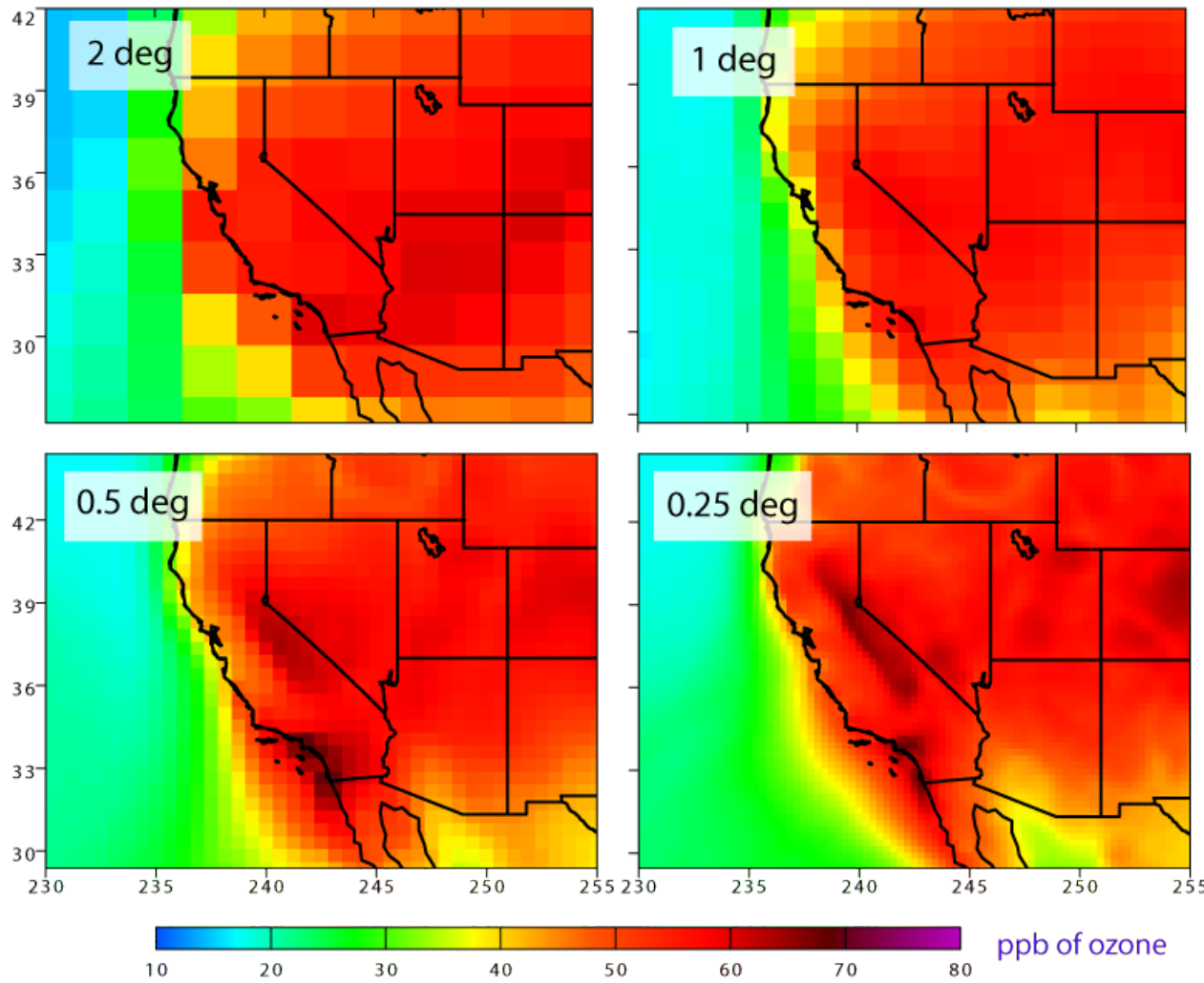


- Minimum pressure ~910 hPa and maximum winds ~140 mph
- Realistic “Cape Verde” storm (note dry eye)

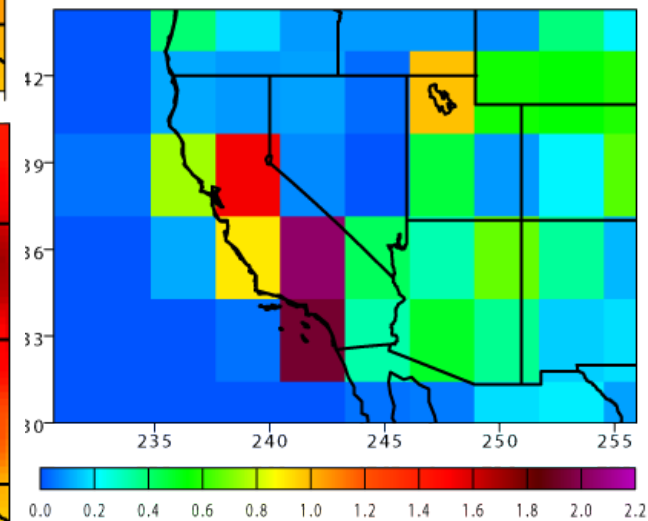
Courtesy Julio Bacmeister

High-resolution Chemistry in CAM

Surface Ozone (July)



Emission of NO (10^{11} mol/cm²/s)



Philip Cameron-Smith, Art Mirin, Cathy Chuang, Dan Bergmann (LLNL)



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jhurrell@ucar.edu



CMIP-5 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
- 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



CISL
Computational & Information Systems Laboratory



- 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
 - ✓ 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 CMIP-5 data base too

CESM Experiments and Diagnostics

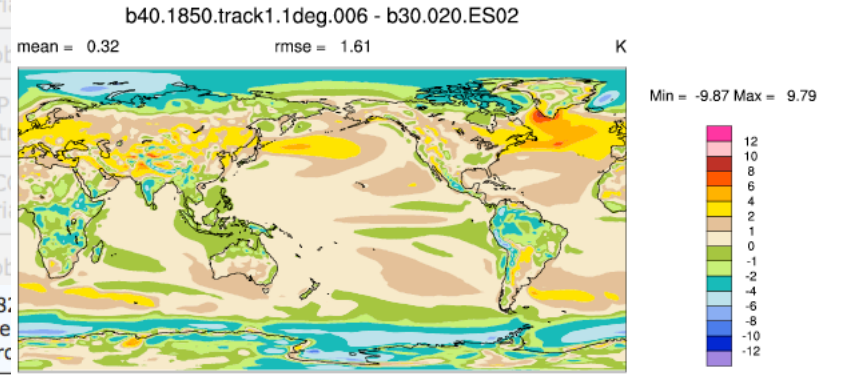
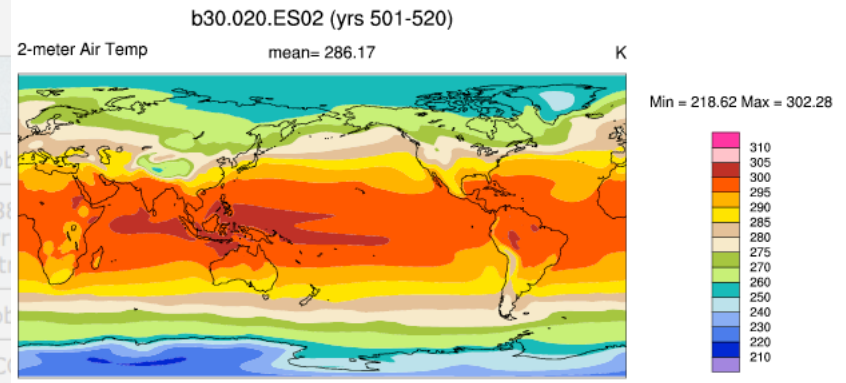
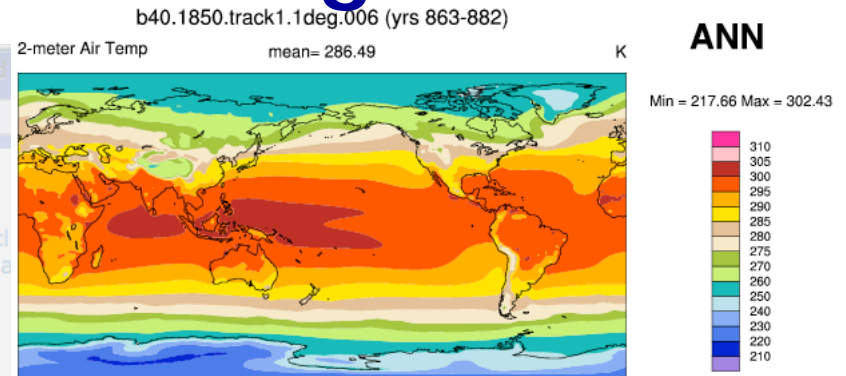
CESM1.0 Experiments and Diagnostics

<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](#) | [Paleo Simulations](#)

CONTROL SIMULATIONS

Brief Description	Case Details
CCSM4 1° Pre-Industrial Control Case Name: b40.1850.track1.1deg.006 Data Location: ESG	863-892 w/ob 863-892 - CCSM3 T85 Pre-Industrial Control Details
CCSM4 2° Pre-Industrial Control Case Name: b40.1850.track1.2deg.003 Data Location: ESG	501-530 w/ob 501-520 - CCSM3 T42 Pre-Industrial Control Details
CCSM4 T31 Pre-Industrial Control Case Name: b40.t31x3.037 Data Location: ESG (451-500)	451-500 w/ob 451-500 - 2° Pre-Industrial Control 451-500 - CCSM3 T42 Pre-Industrial Control Details
CESM1 (BGC) Prognostic CO2 1° Case Name: b40.1850.track1.1deg.006 Data Location: ESG	863-888 863-888 - CCSM3 T85 Pre-Industrial Control Details
CCSM4 2° Pre-Industrial Control Case Name: b40.1850.track1.2deg.003 Data Location: ESG	501-530 w/observations 501-520 - CCSM3 T42 Pre-Industrial Control Details



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



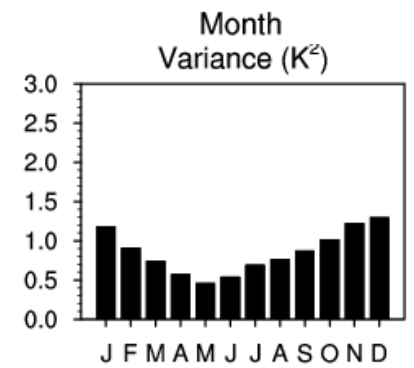
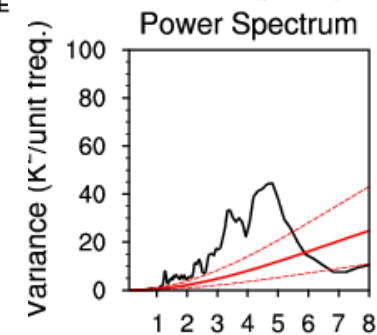
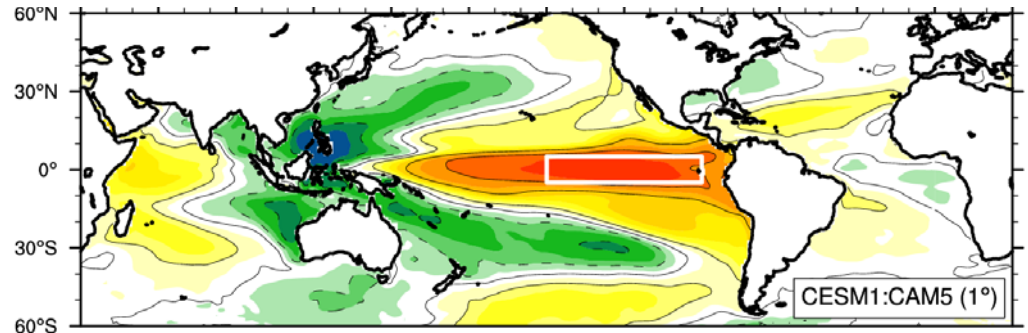
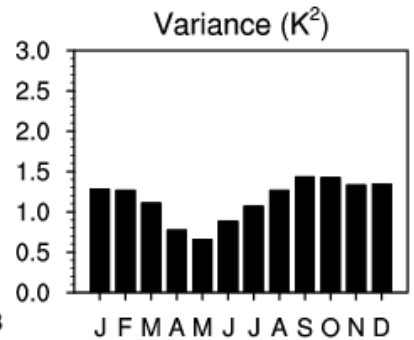
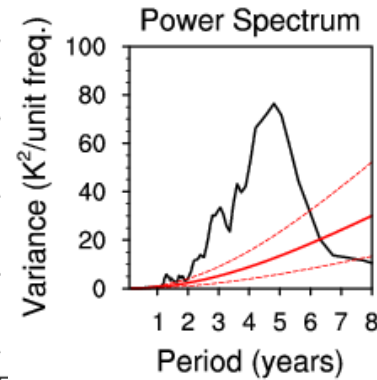
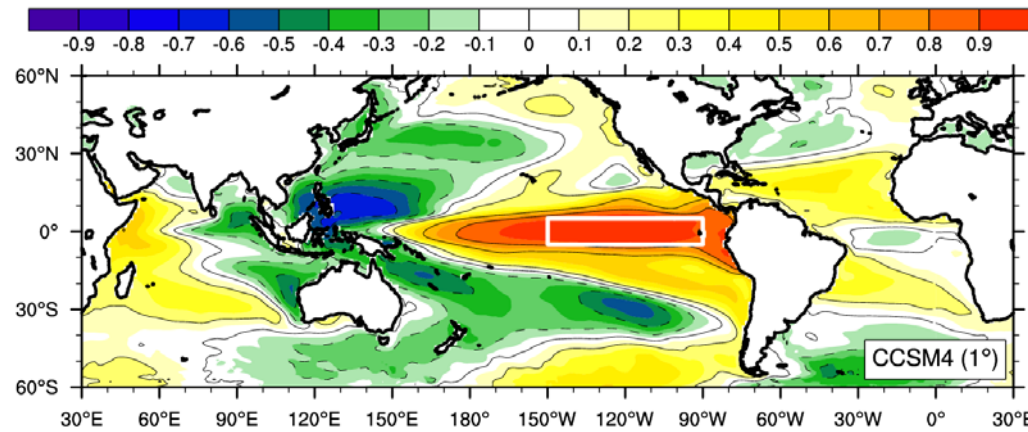
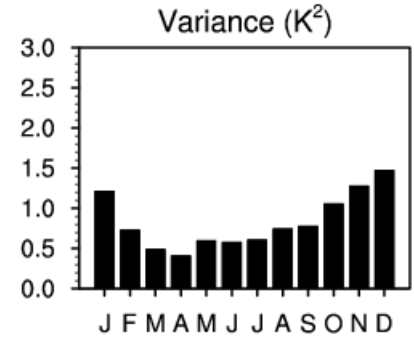
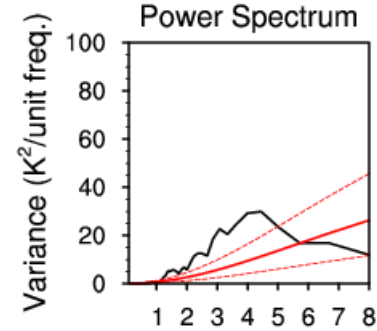
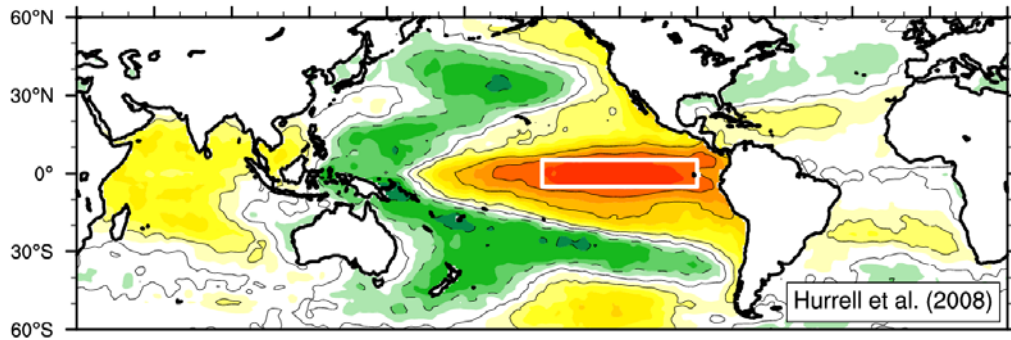
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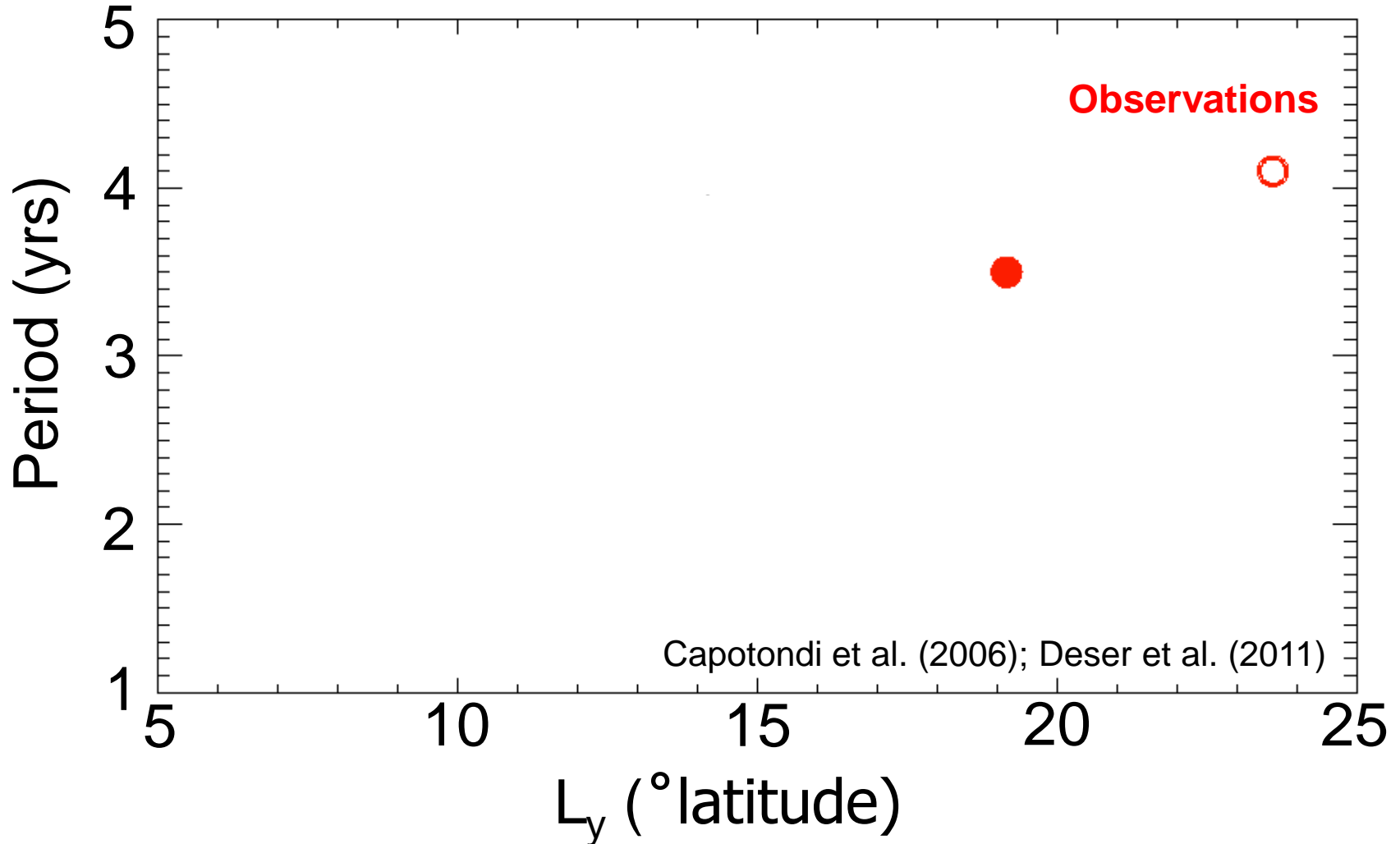


Pacific Variability: ENSO



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

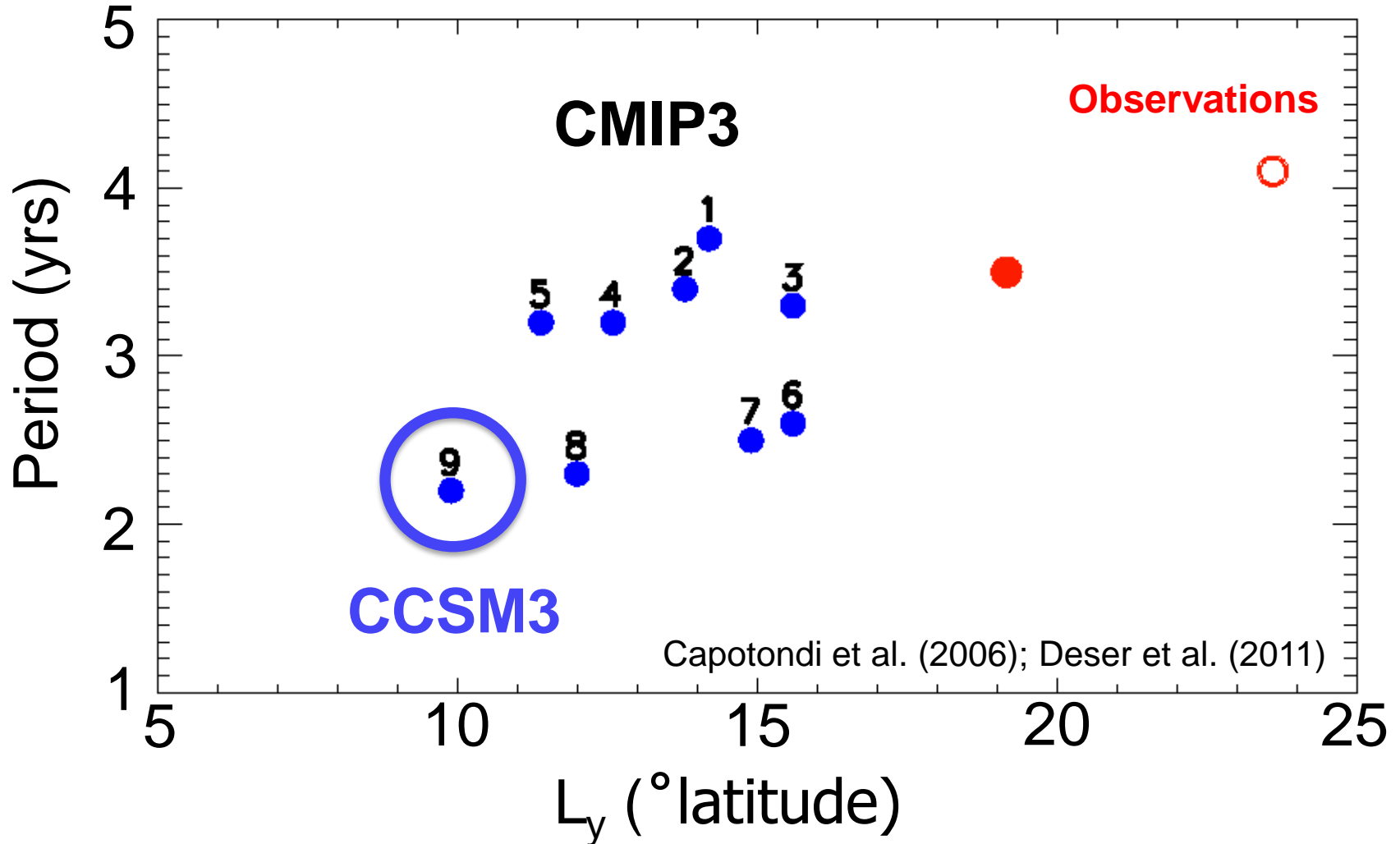
ENSO in CCSM4 and other models



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

L_y \rightarrow width of zonal wind stress anomalies

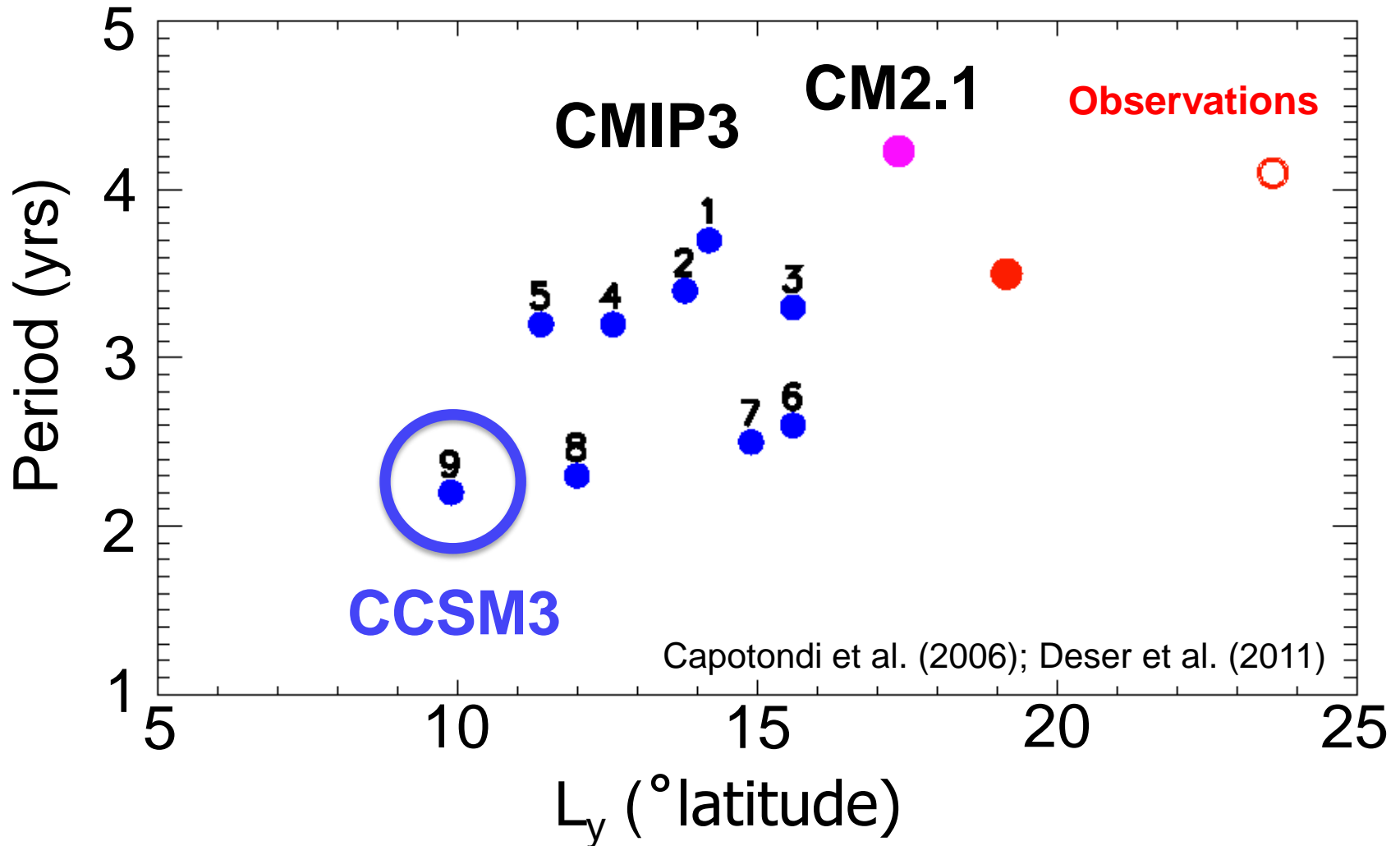
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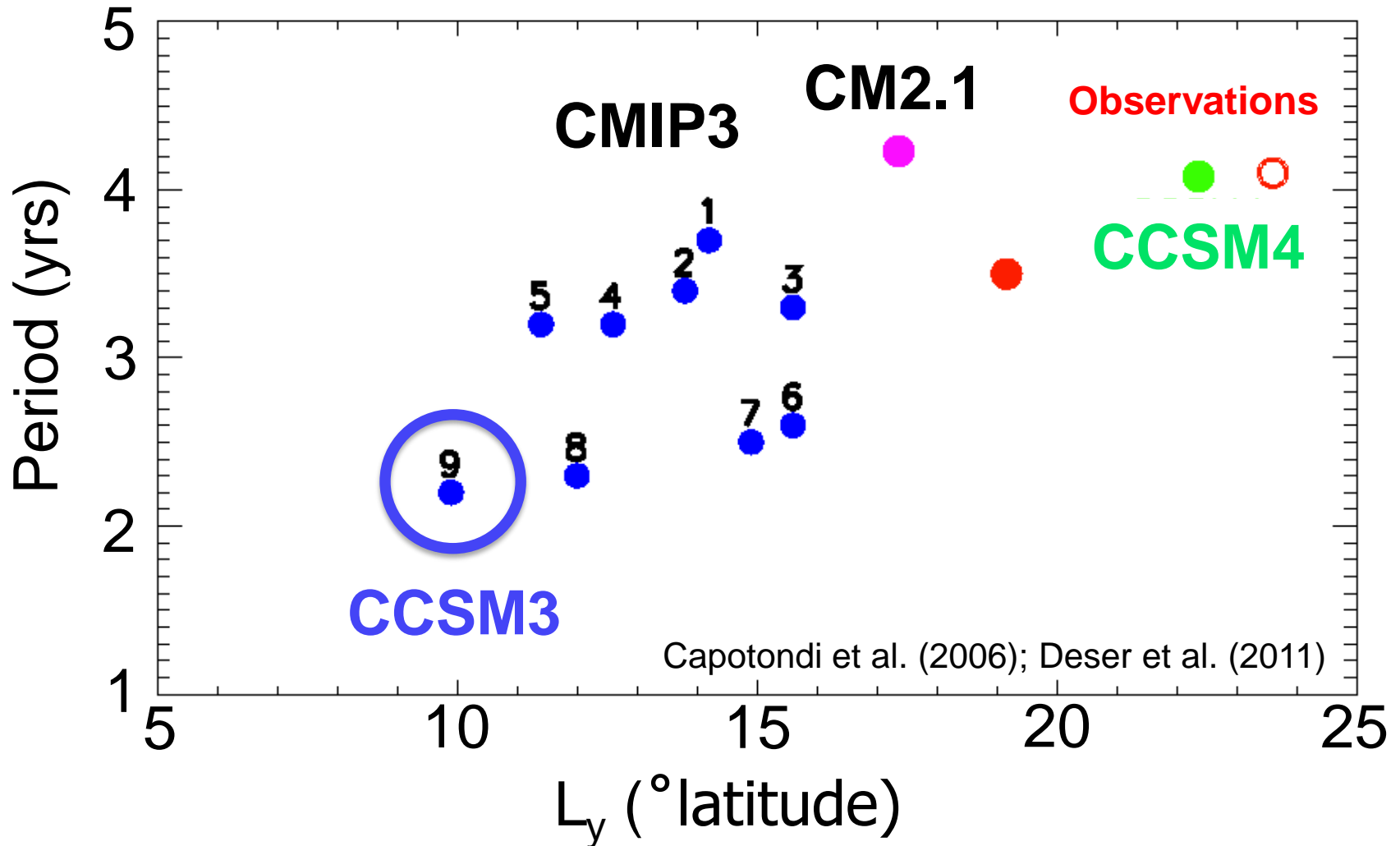
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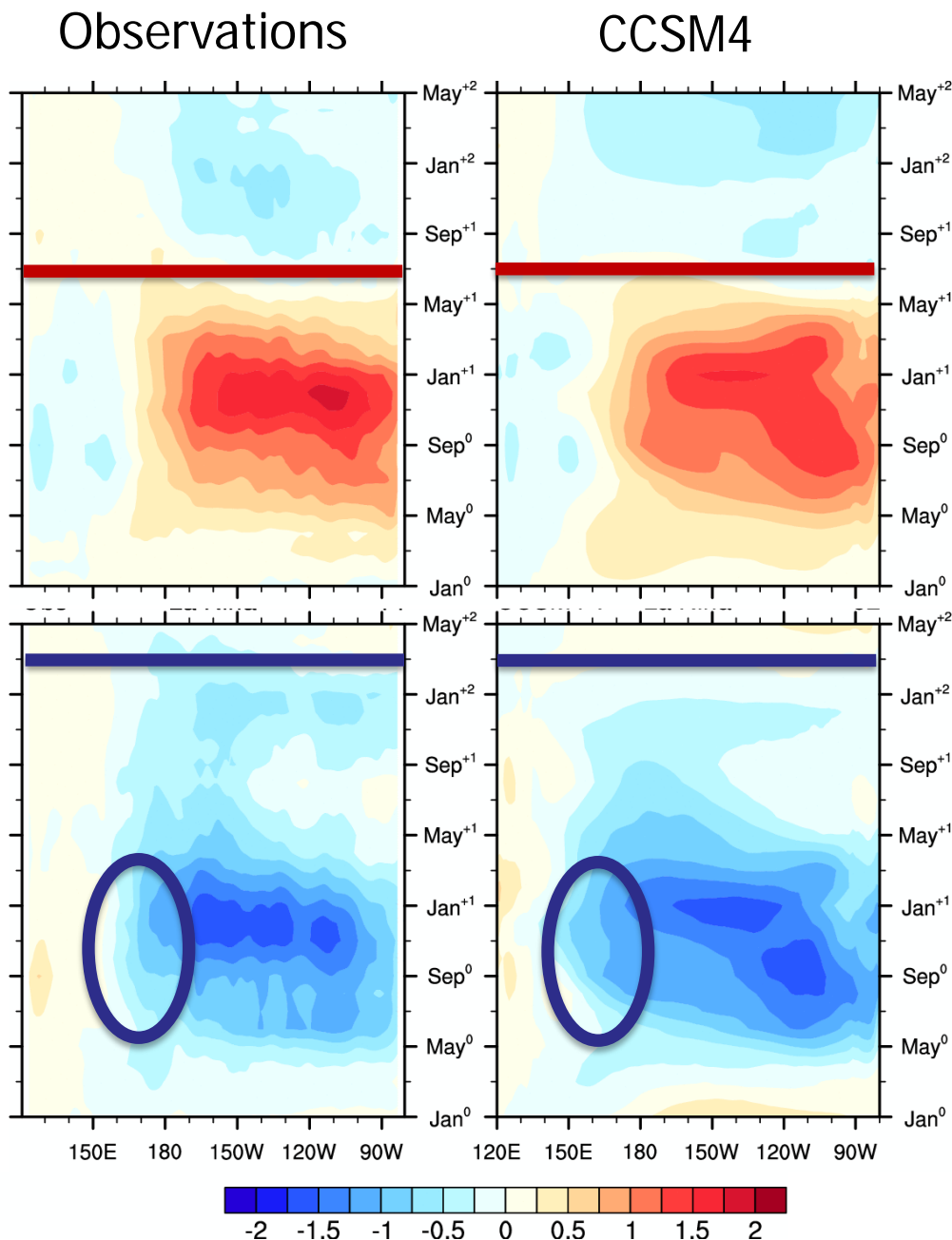
L_y \rightarrow width of zonal wind stress anomalies

Equatorial SST Composites

El Niño

Latitude/Time
cross-sections

La Niña



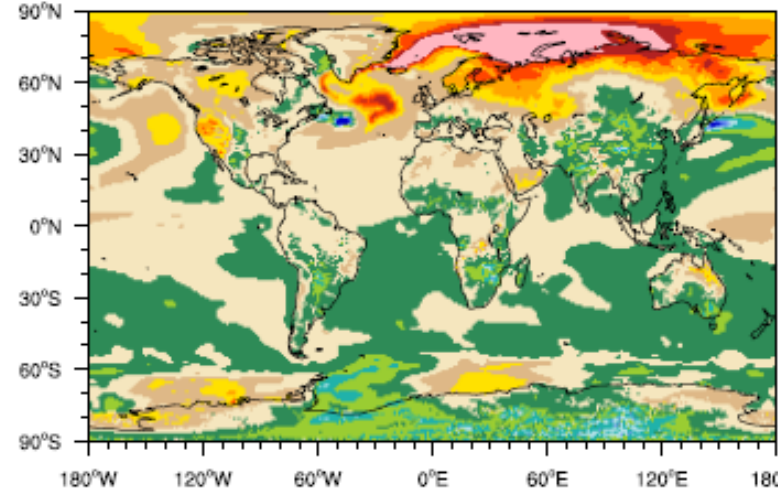
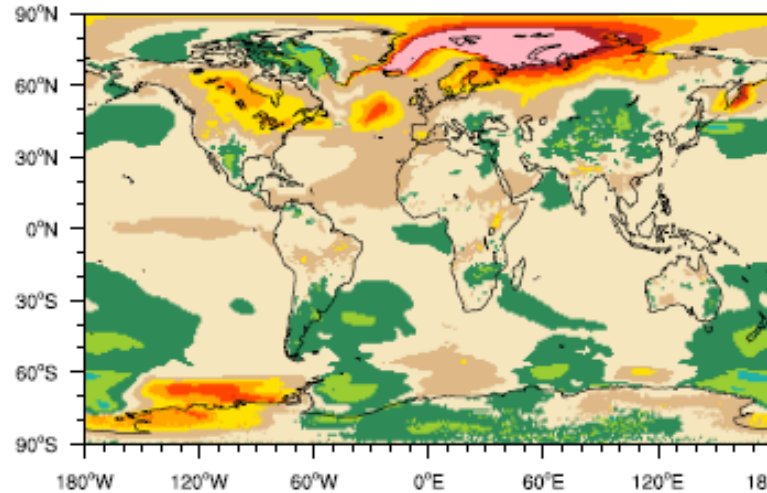
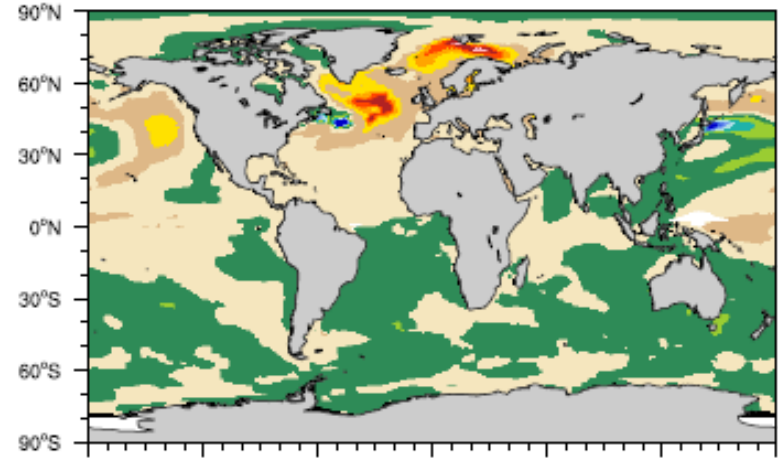
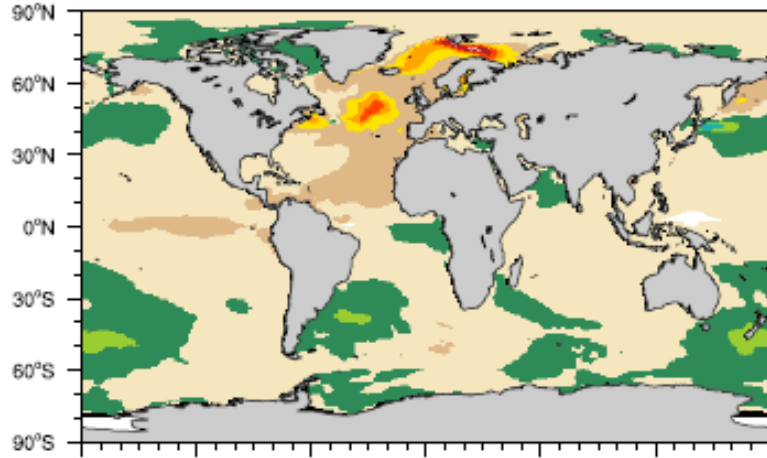
Deser et al. (2011)

Atlantic Multidecadal Variability

CCSM4 Annual Mean SST and Surface T regressed on:

AMV Index

AMOC Index (2 yr lead)



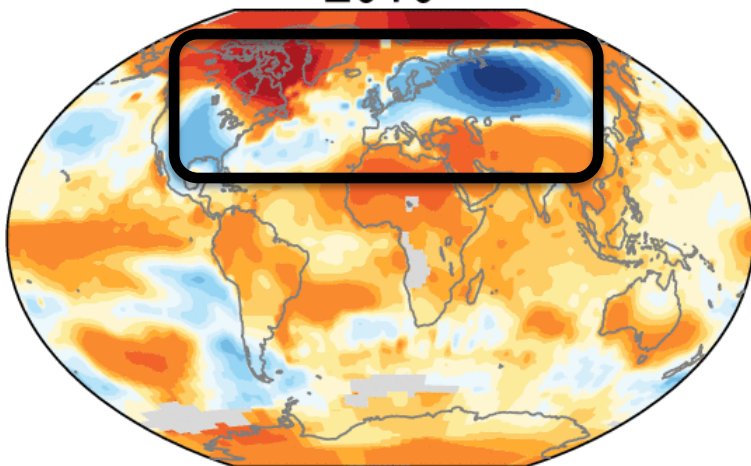
°C/s.d.

Danabasoglu et al. (2011)

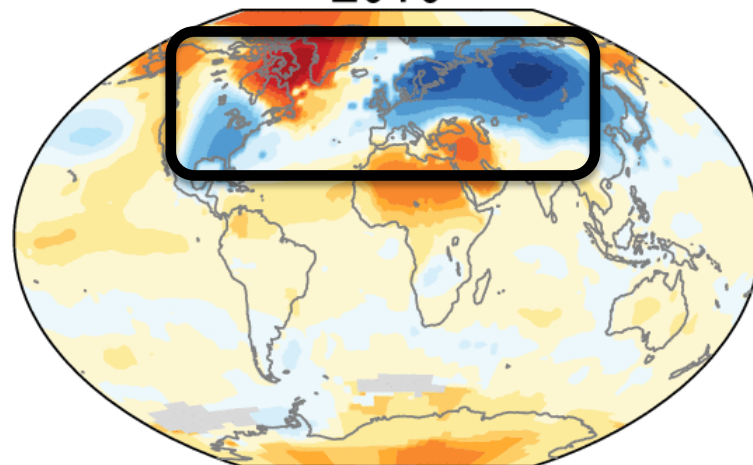
Anomalous Persistence of NAM

Winter Surface Temperature Anomalies

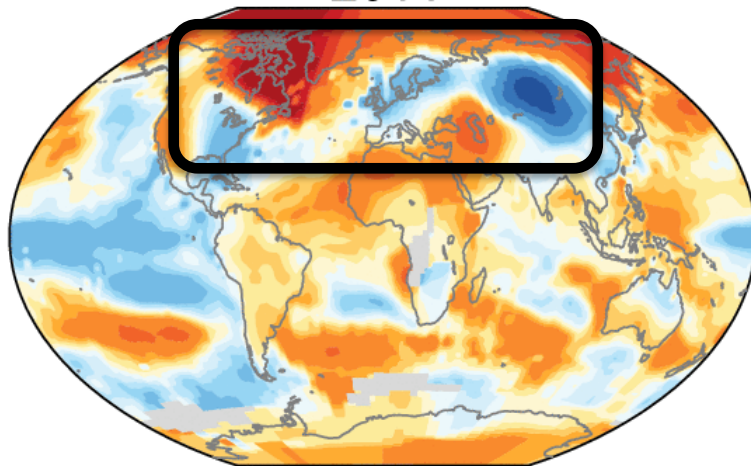
Total Observed
2010



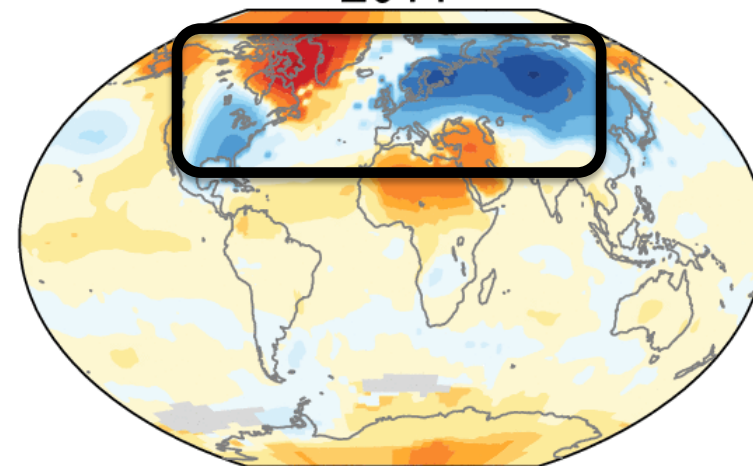
NAM Influence
2010



2011



2011

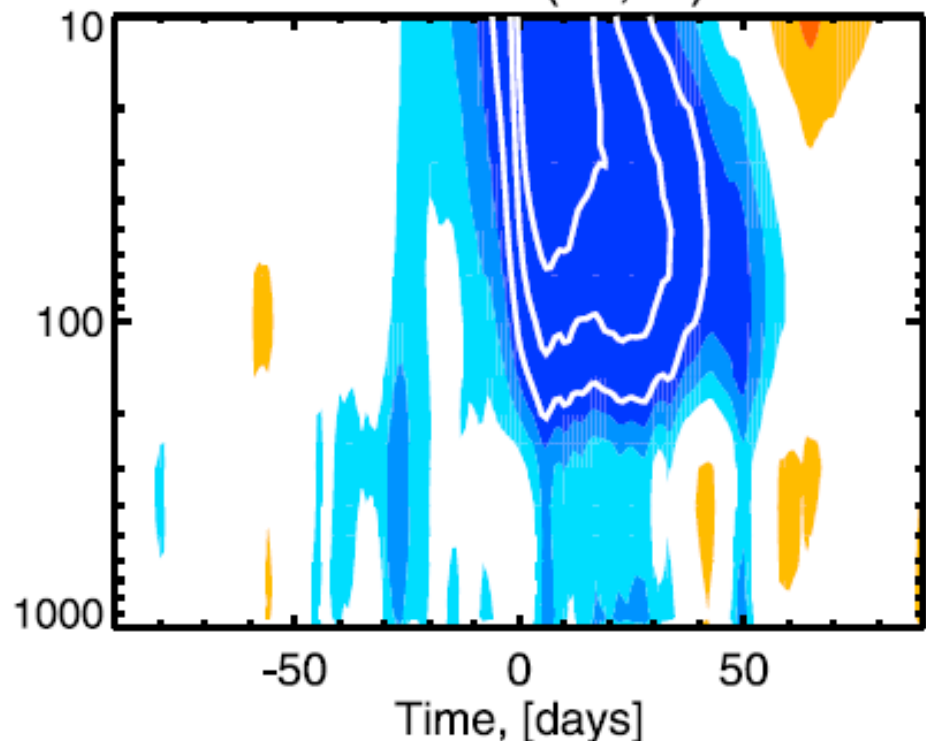
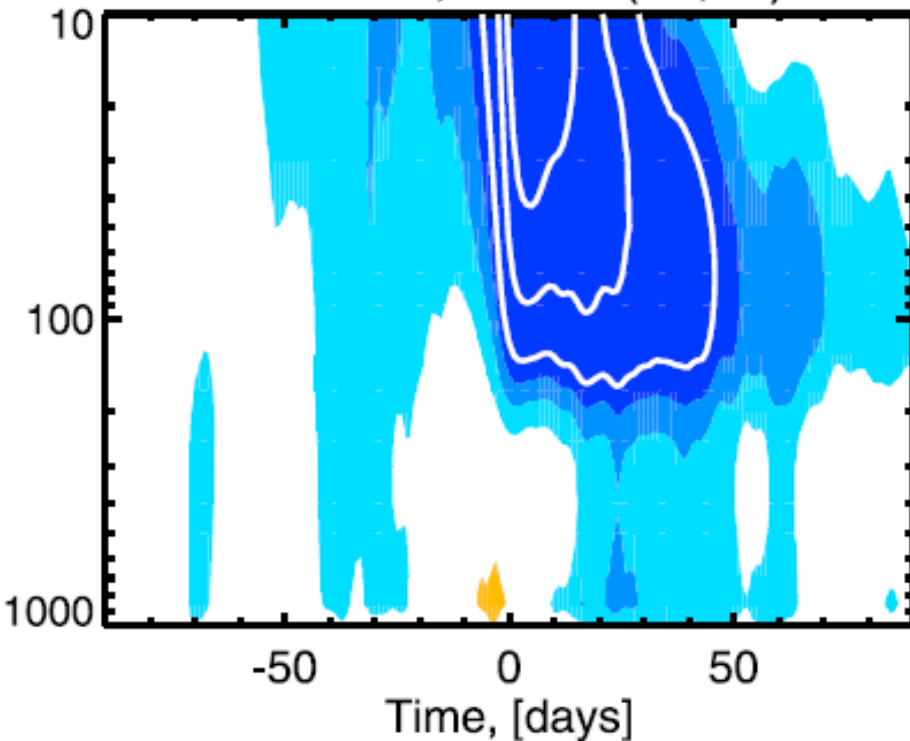


Composite Differences of NAM Index

Strong and Weak Stratospheric Events

WACCM (2 AMIP runs)

ECMWF Reanalyses



22 strong, 65 weak events

12 strong, 36 weak events

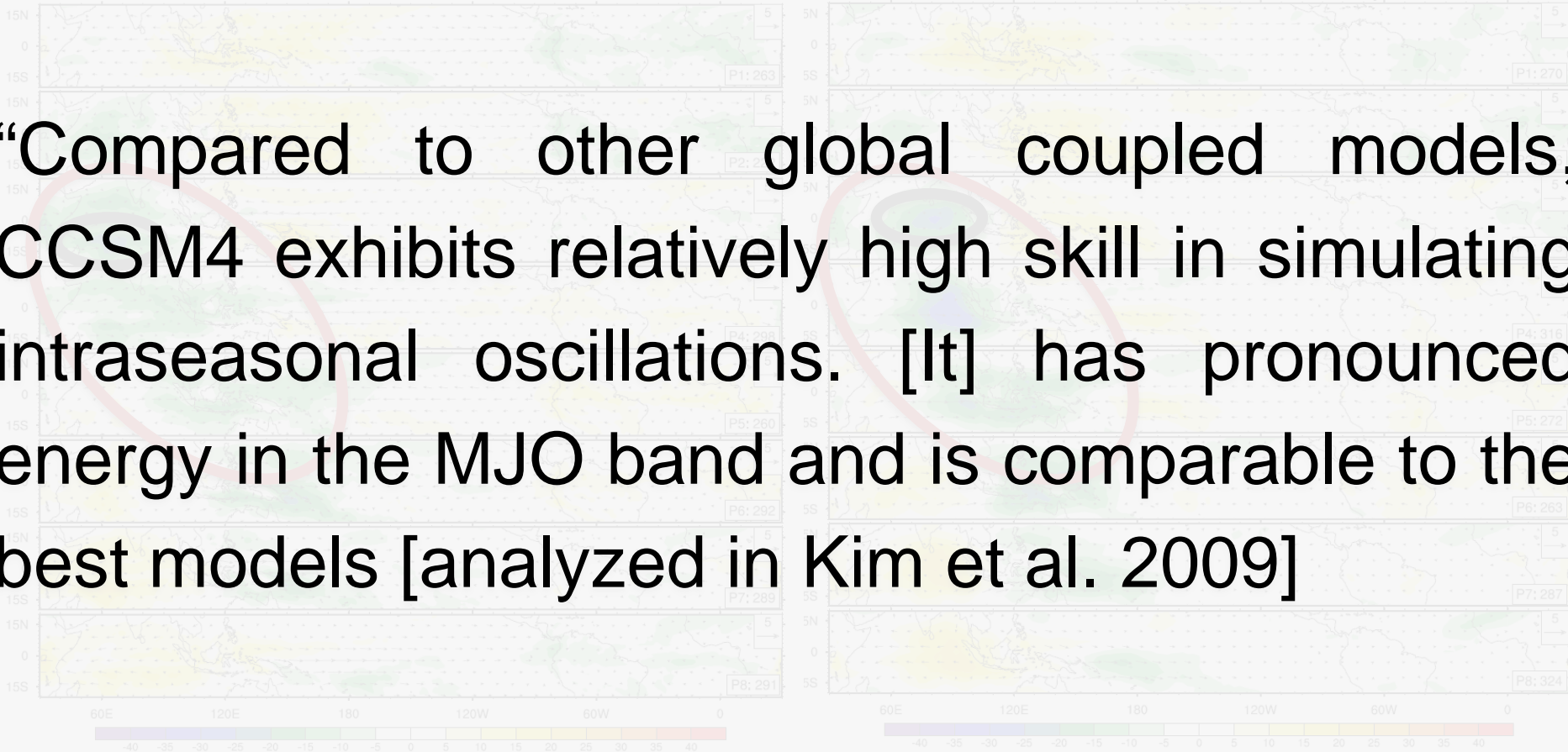
Gerber et al. (2010)

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



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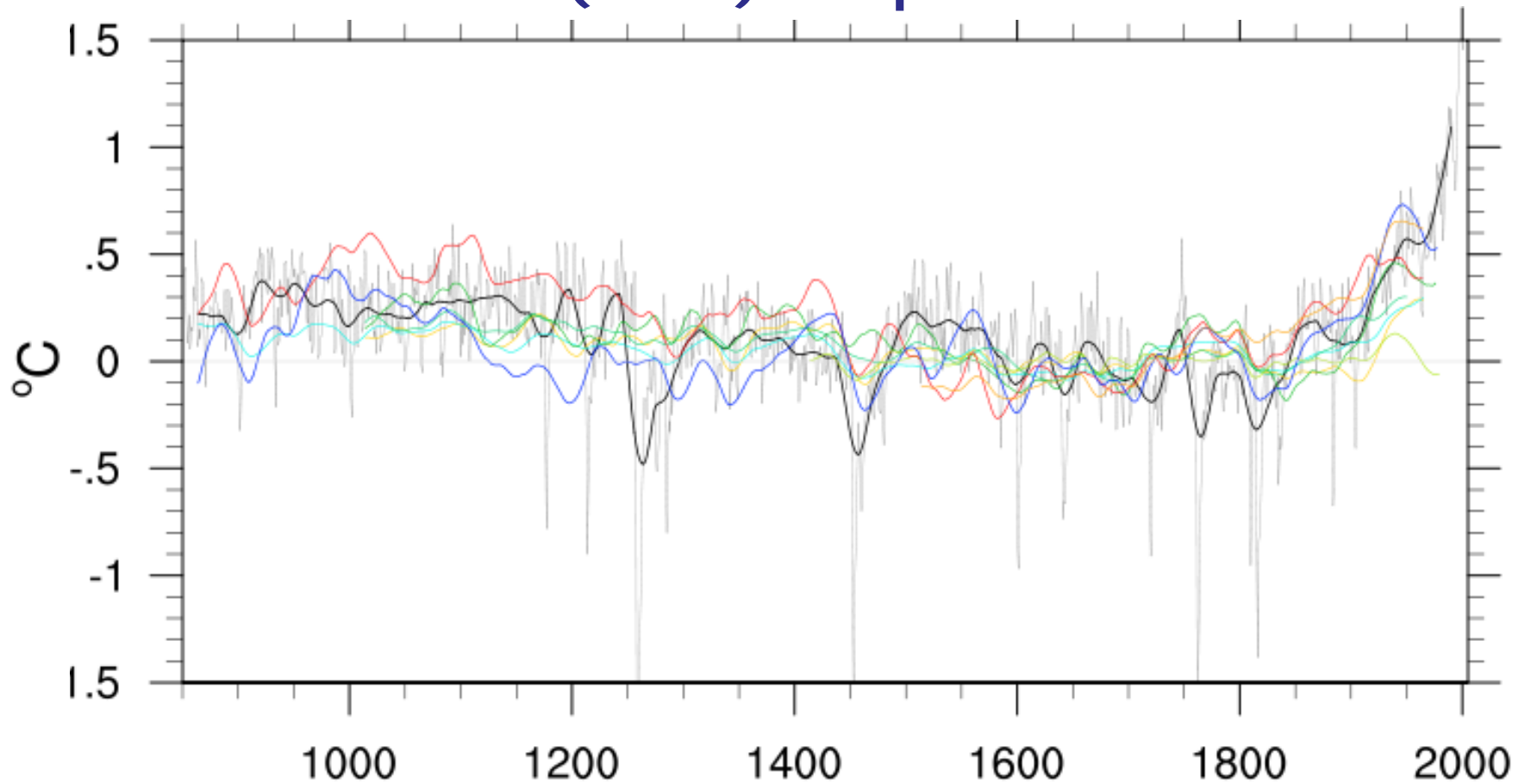
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Northern Hemisphere Temperature (Last Millennium 850-2005)

CCSM4 1° (black) compared to Proxies



Courtesy Bette Otto-Bliesner



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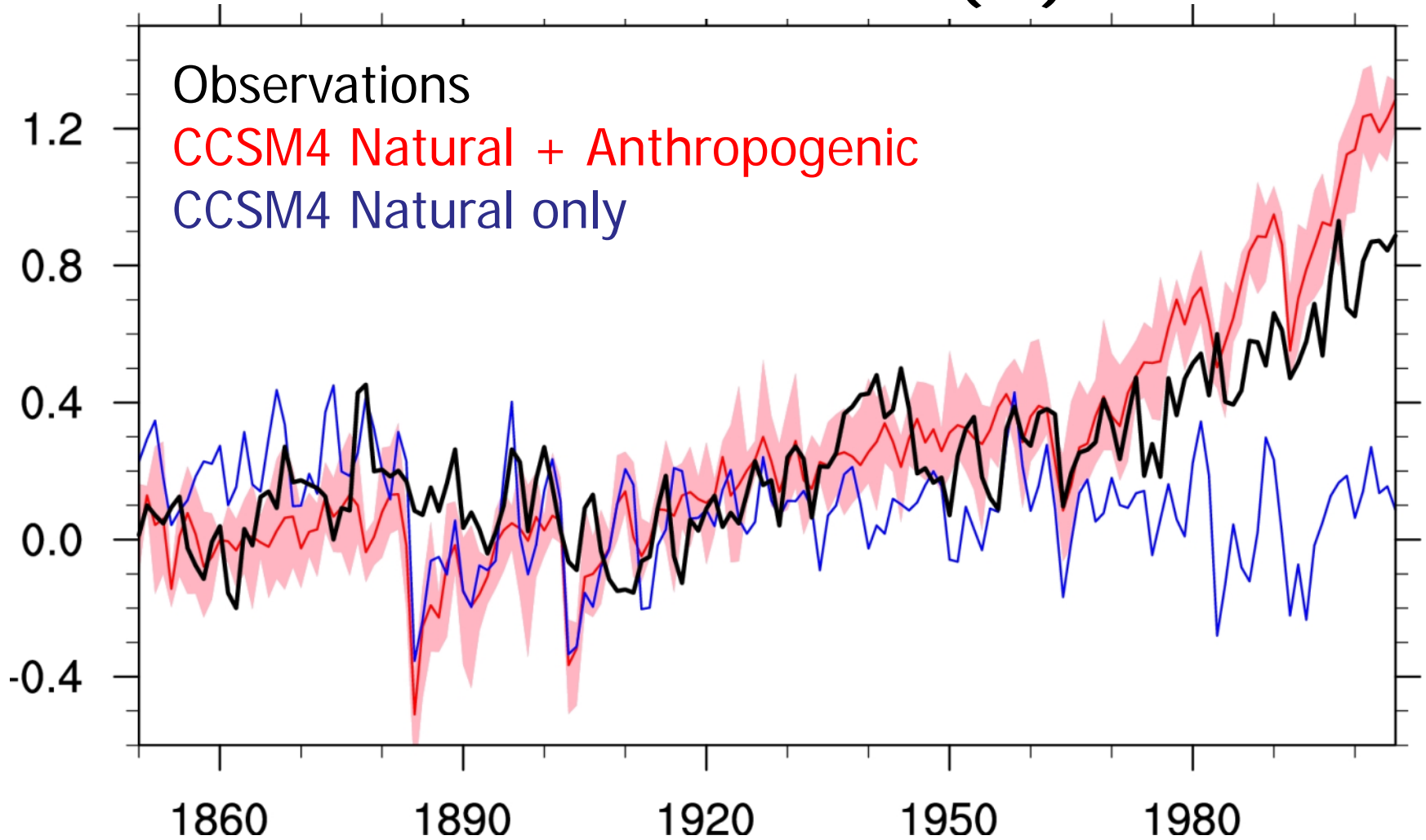
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Surface Temperature (1850-2005)

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



Meehl et al. 2011



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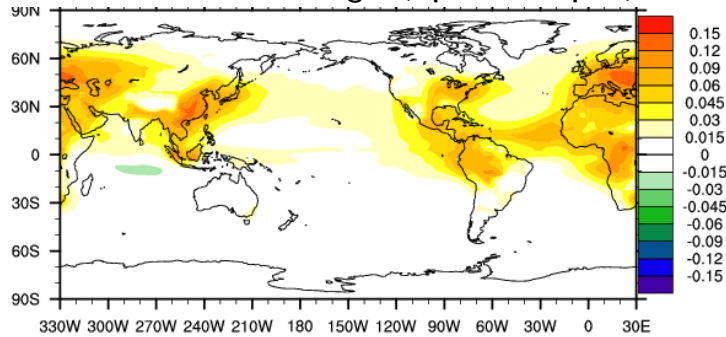
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Anthropogenic Aerosol Affects: CESM1 (CAM5)

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

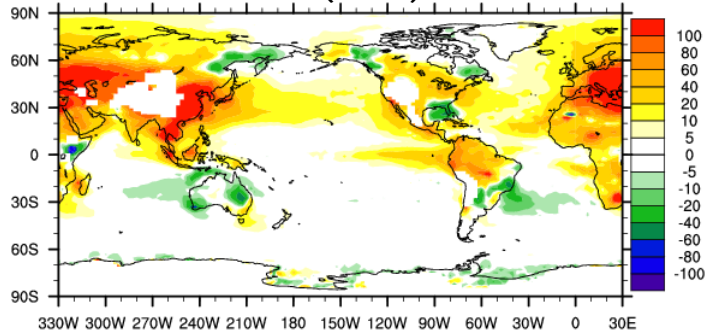
Total aerosol change (optical depth)



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

✓ Increased cloud droplet number concentration; strongest over land

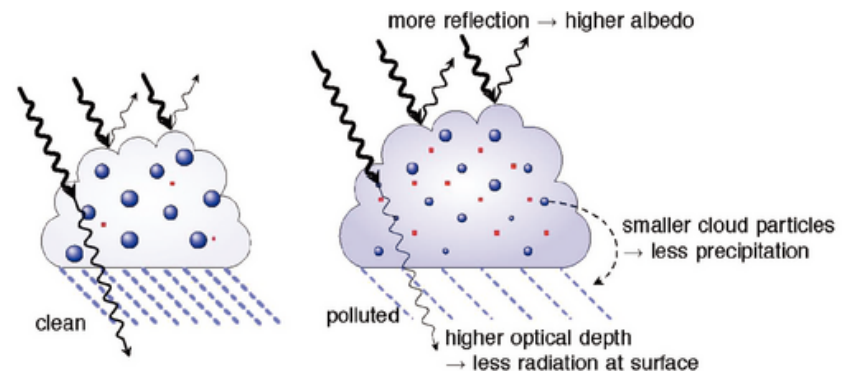
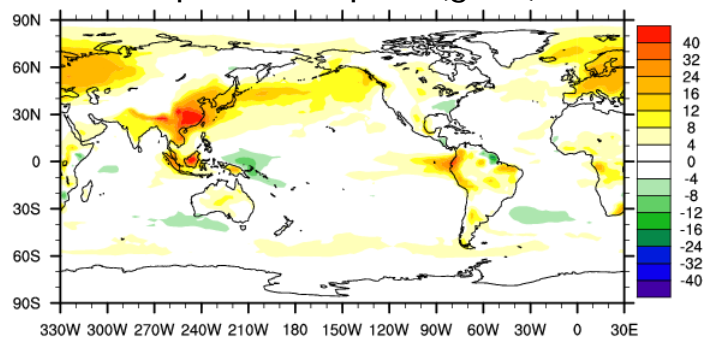
Cloud water droplet number concentration (#/cc) at 850 hPa



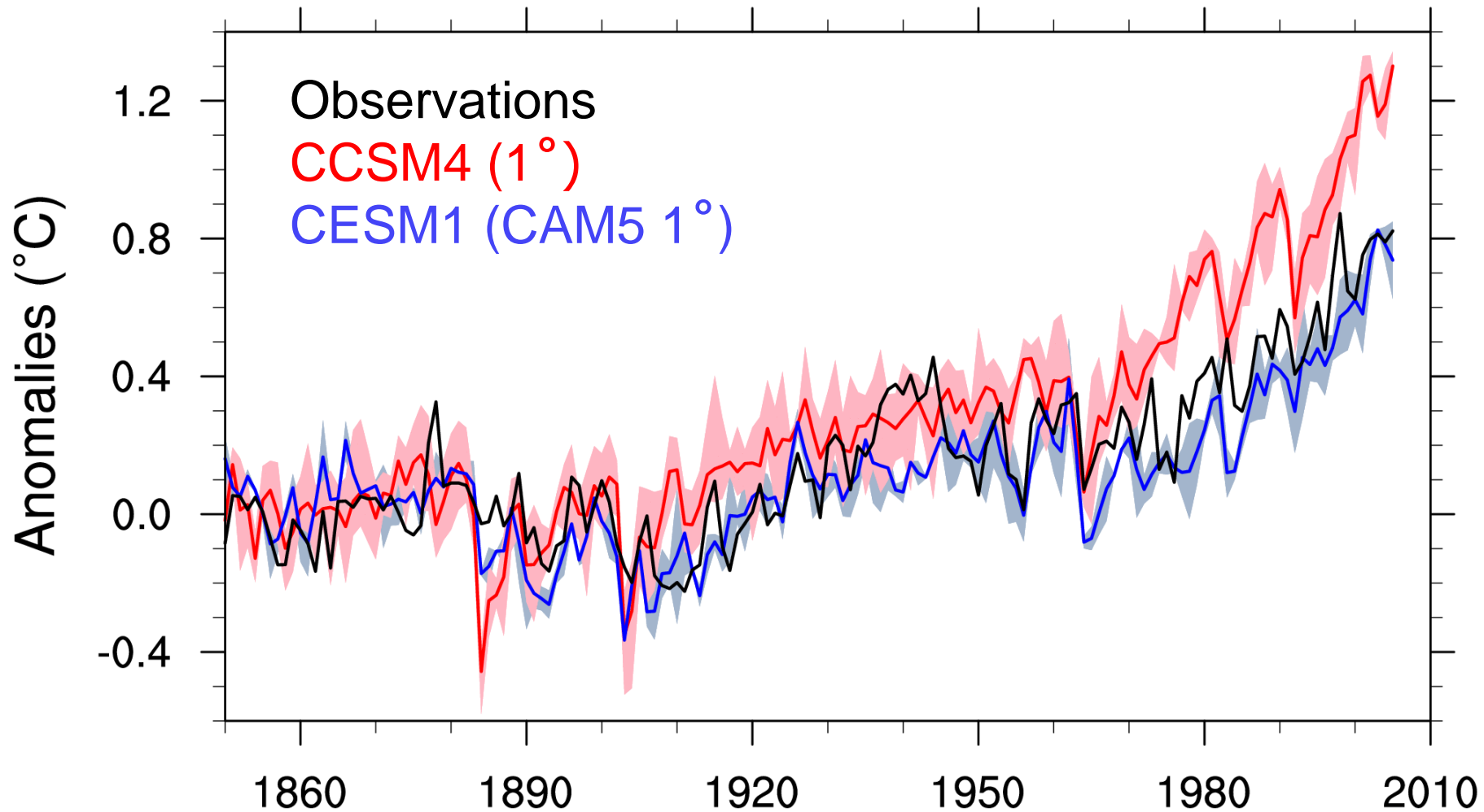
✓ Increased numbers of smaller drops; thus brighter low clouds with more liquid

Low cloud effects: net cooling over 20th century

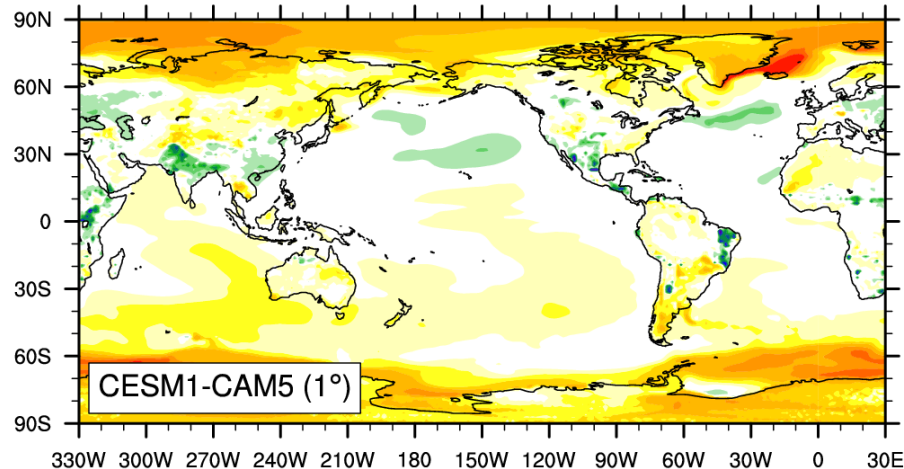
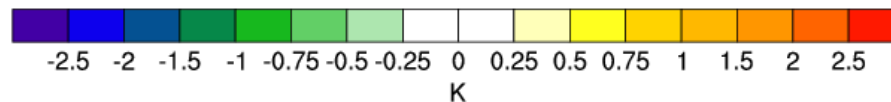
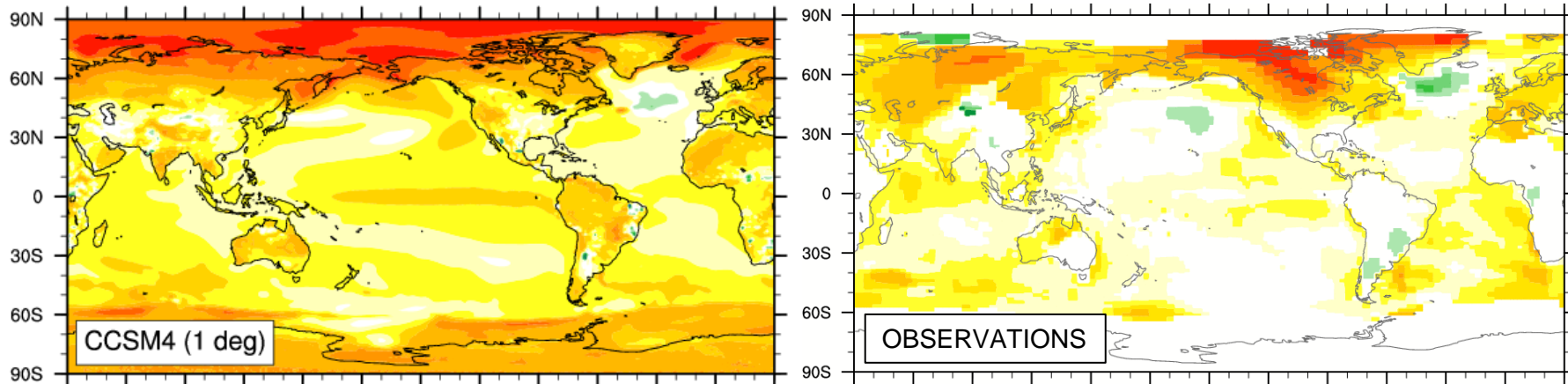
Liquid water path (g/m²)



Surface Temperature (1850-2005)



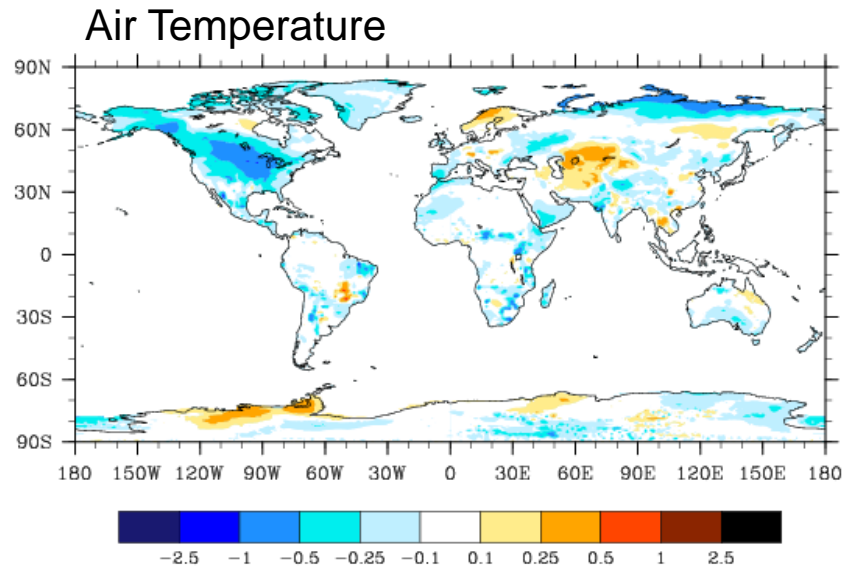
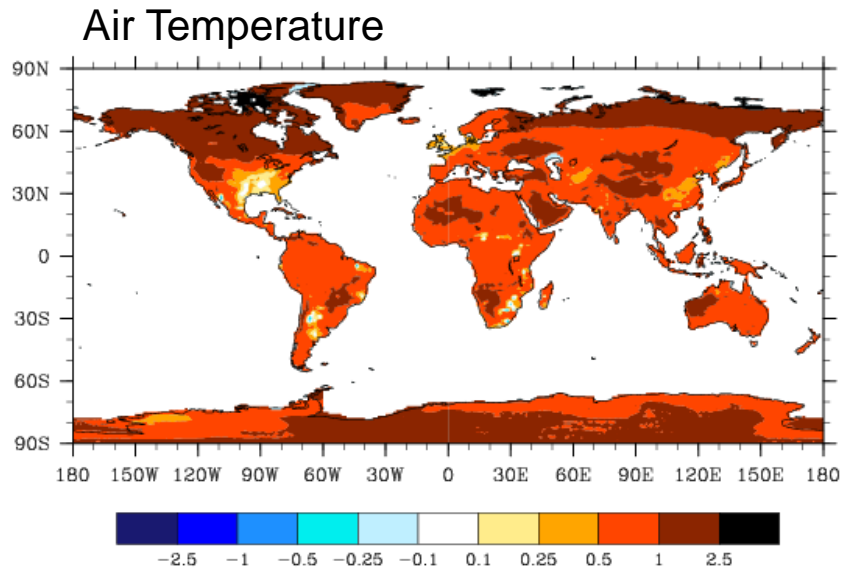
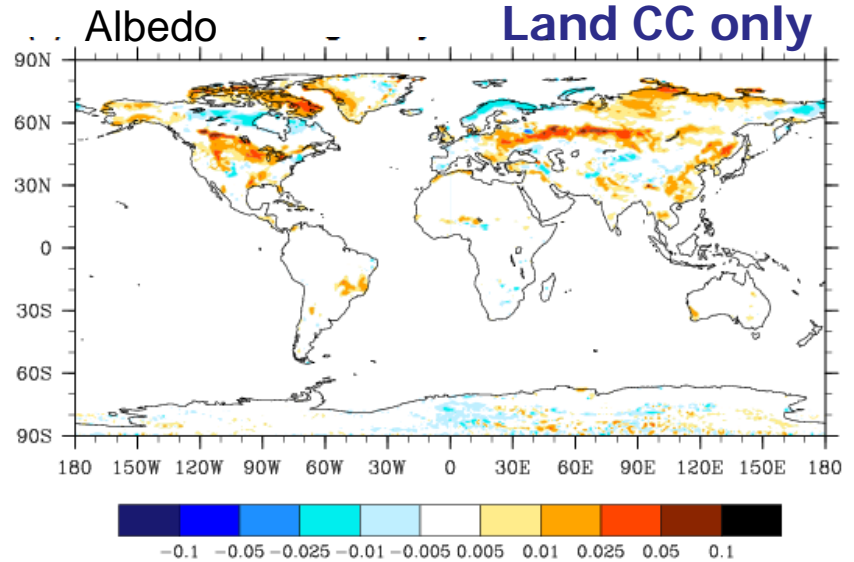
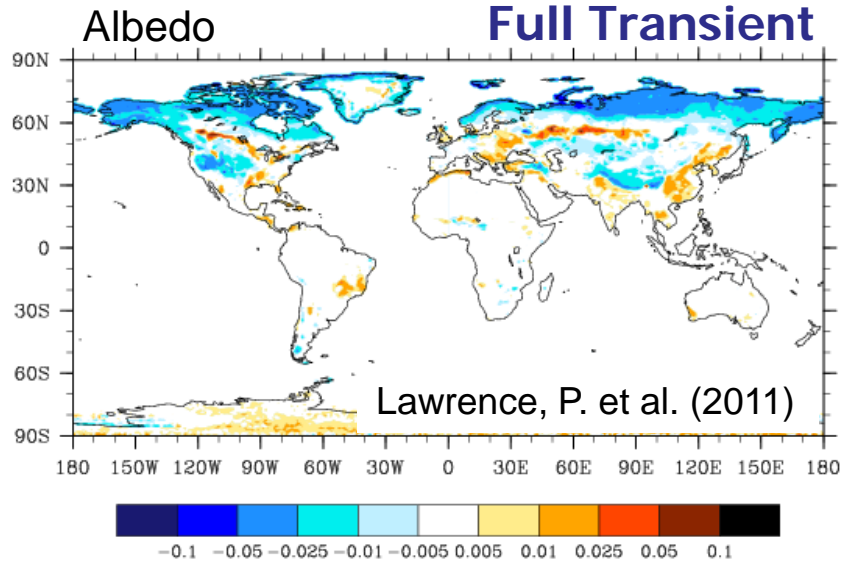
20th Century Surface Temperature Change



More realistic regional warming

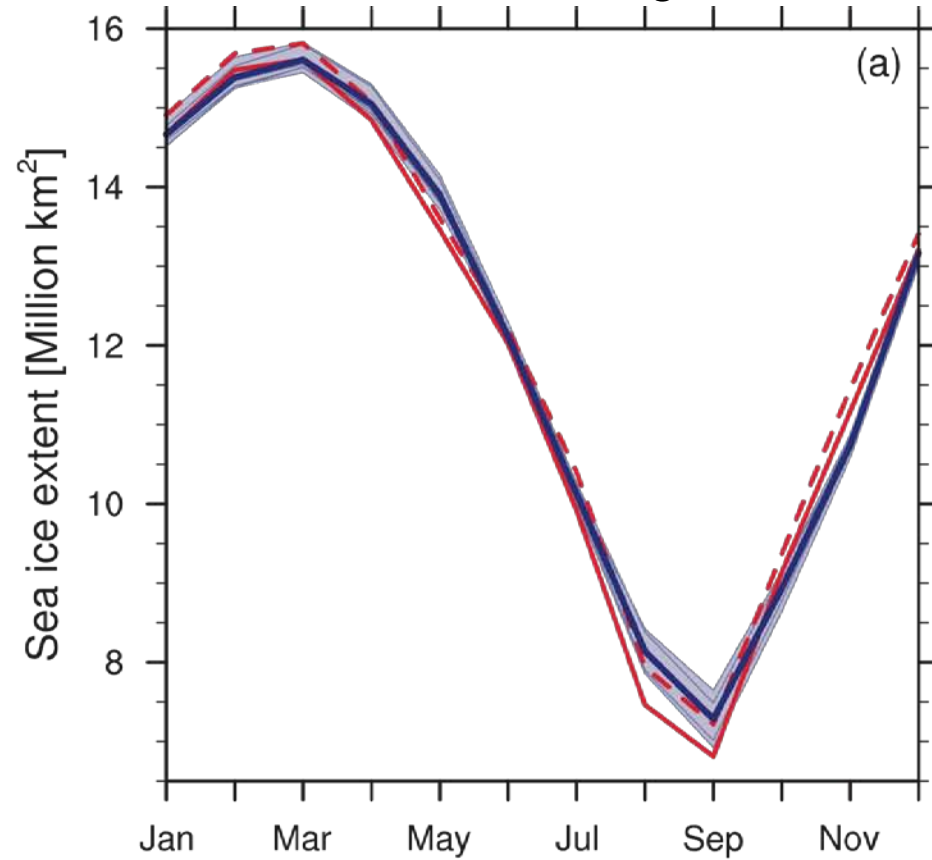
Impact of land cover change

(1976 to 2005 minus 1850-1879)



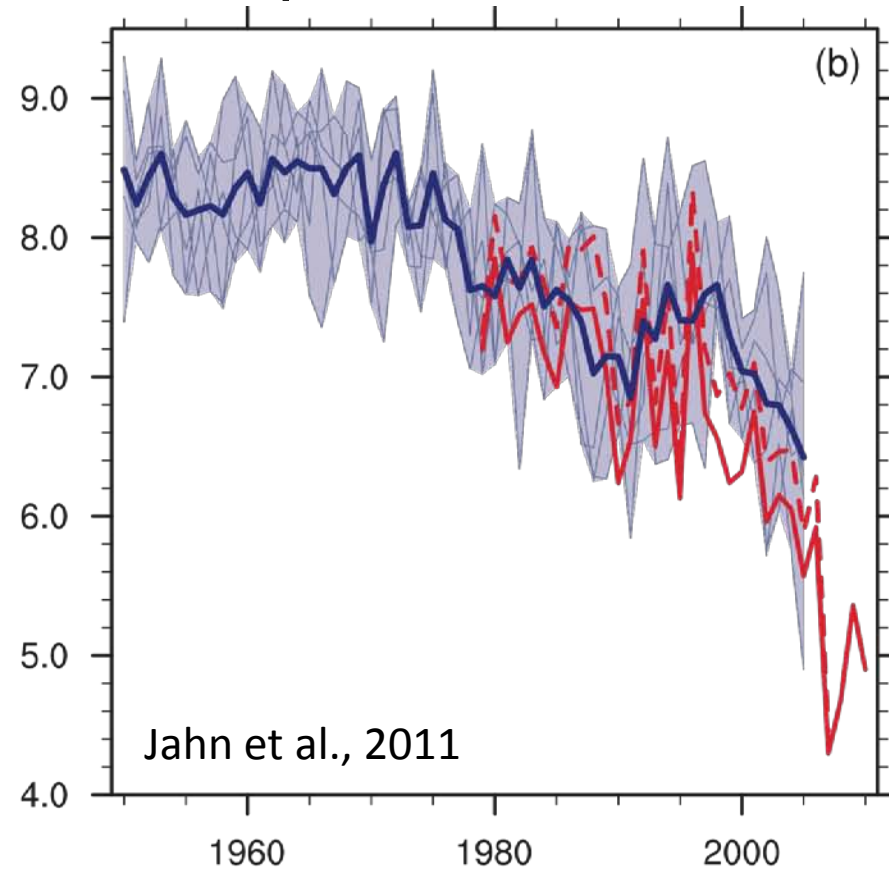
Arctic Sea Ice

Seasonal cycle



— CCSM4 ensemble mean
■ CCSM4 ensemble spread

September extent

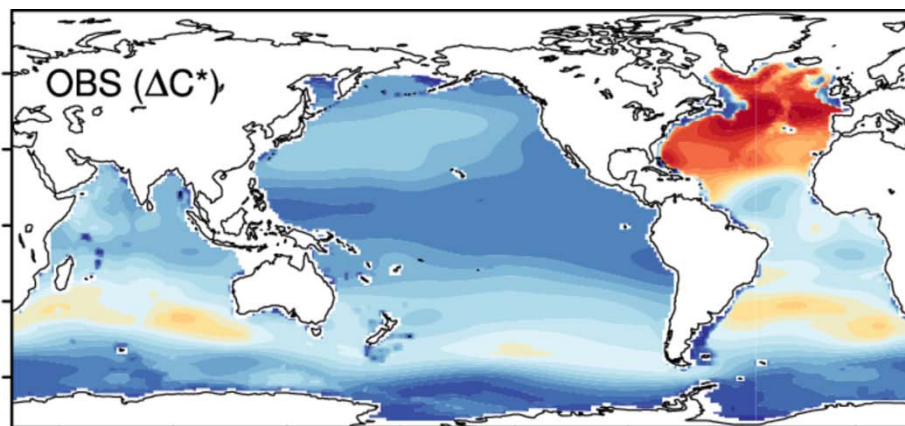


--- Bootstrap extent
— NSIDC extent (NASA)

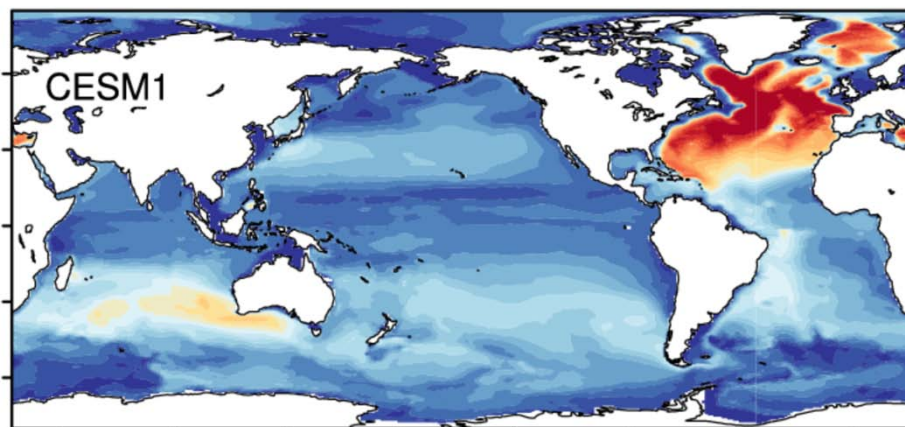
Jahn et al. (2011)

CESM1: Prognostic Ocean Carbon Cycle

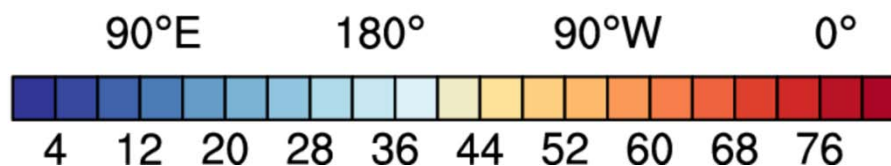
Ocean Inventory of Anthropogenic CO₂



Total
118 Pg C (±18)



90.3 Pg C



Courtesy Matt Long, ASP

Future Climate



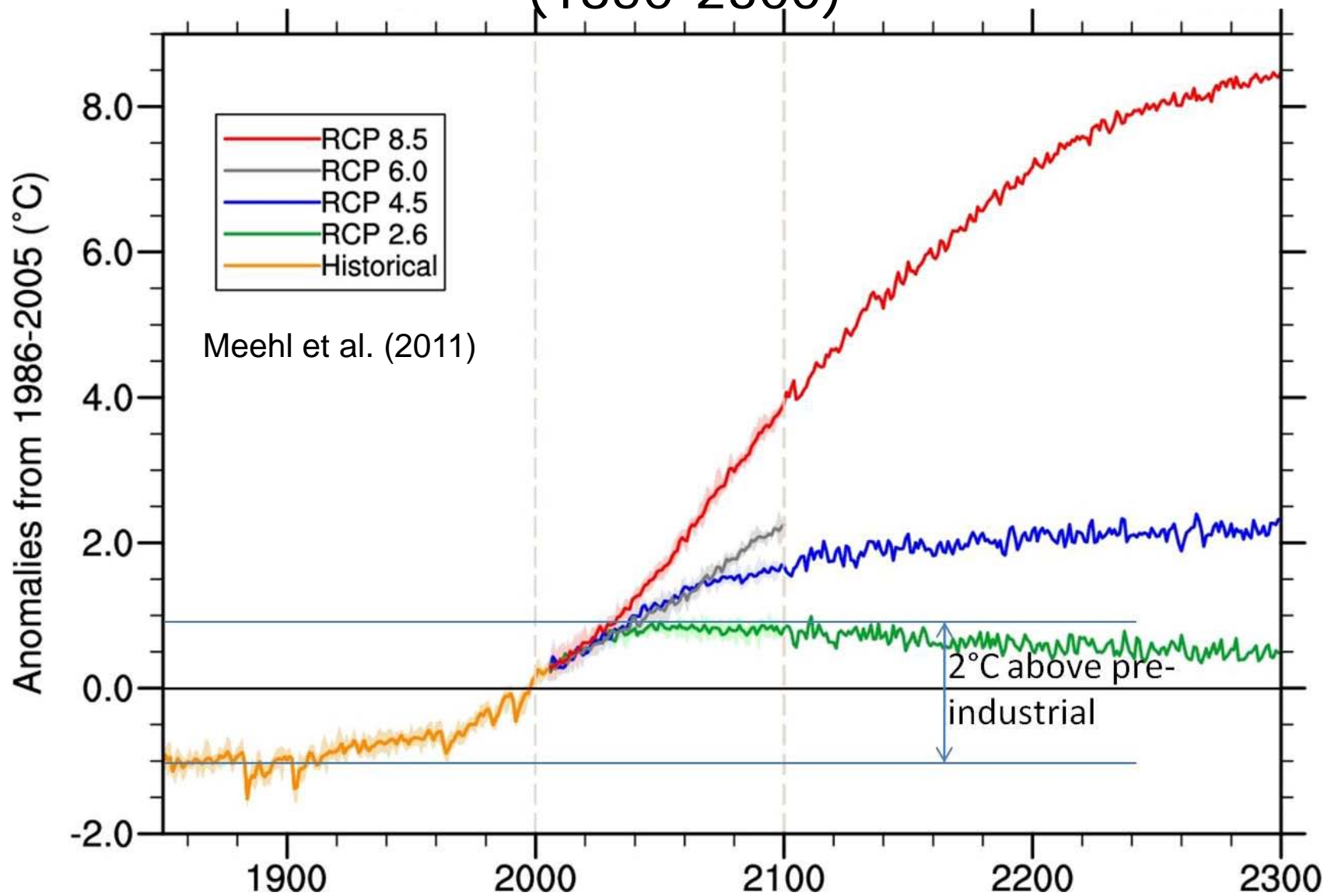
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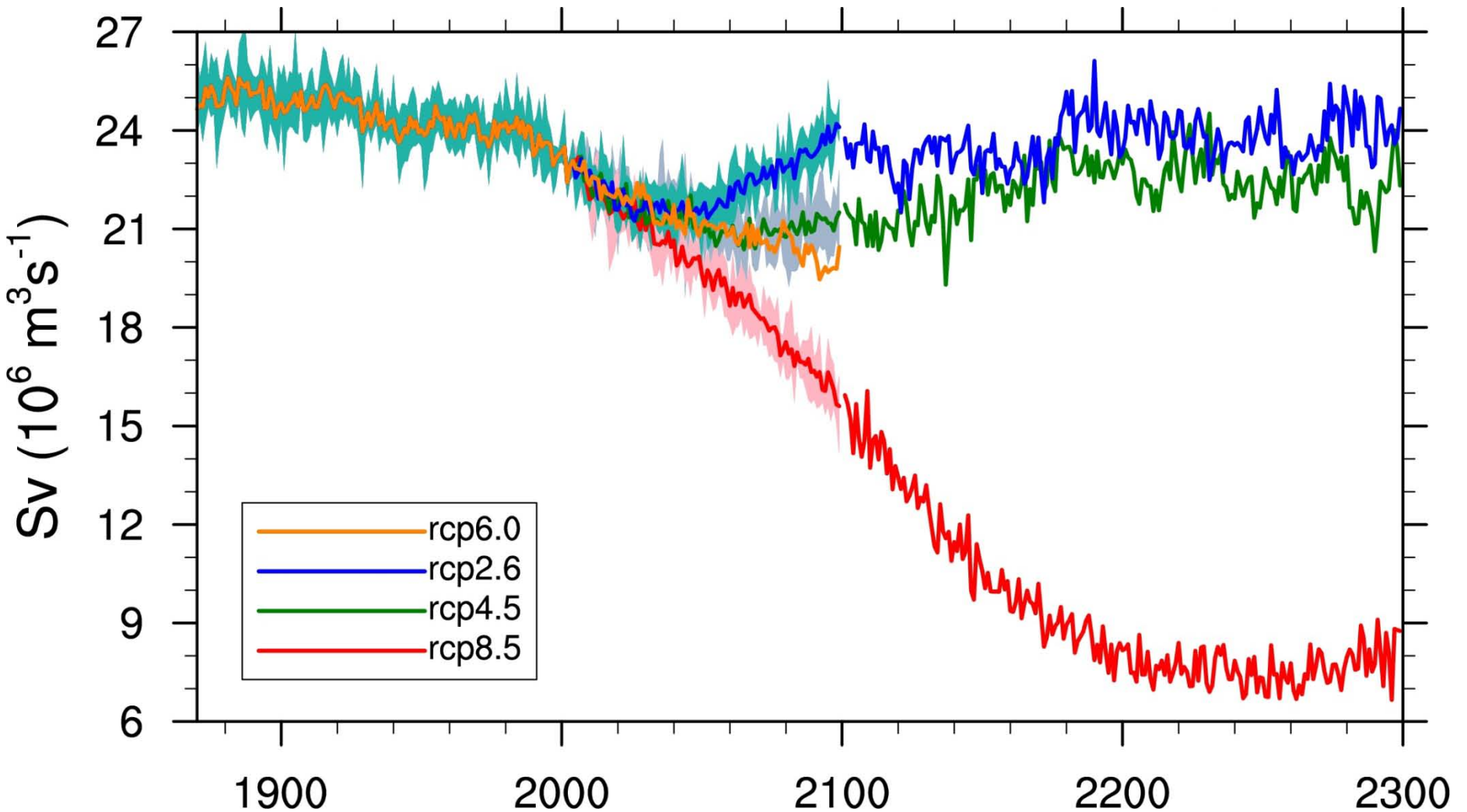
Jim Hurrell
jhurrell@ucar.edu



Global Surface Temperature (1850-2300)

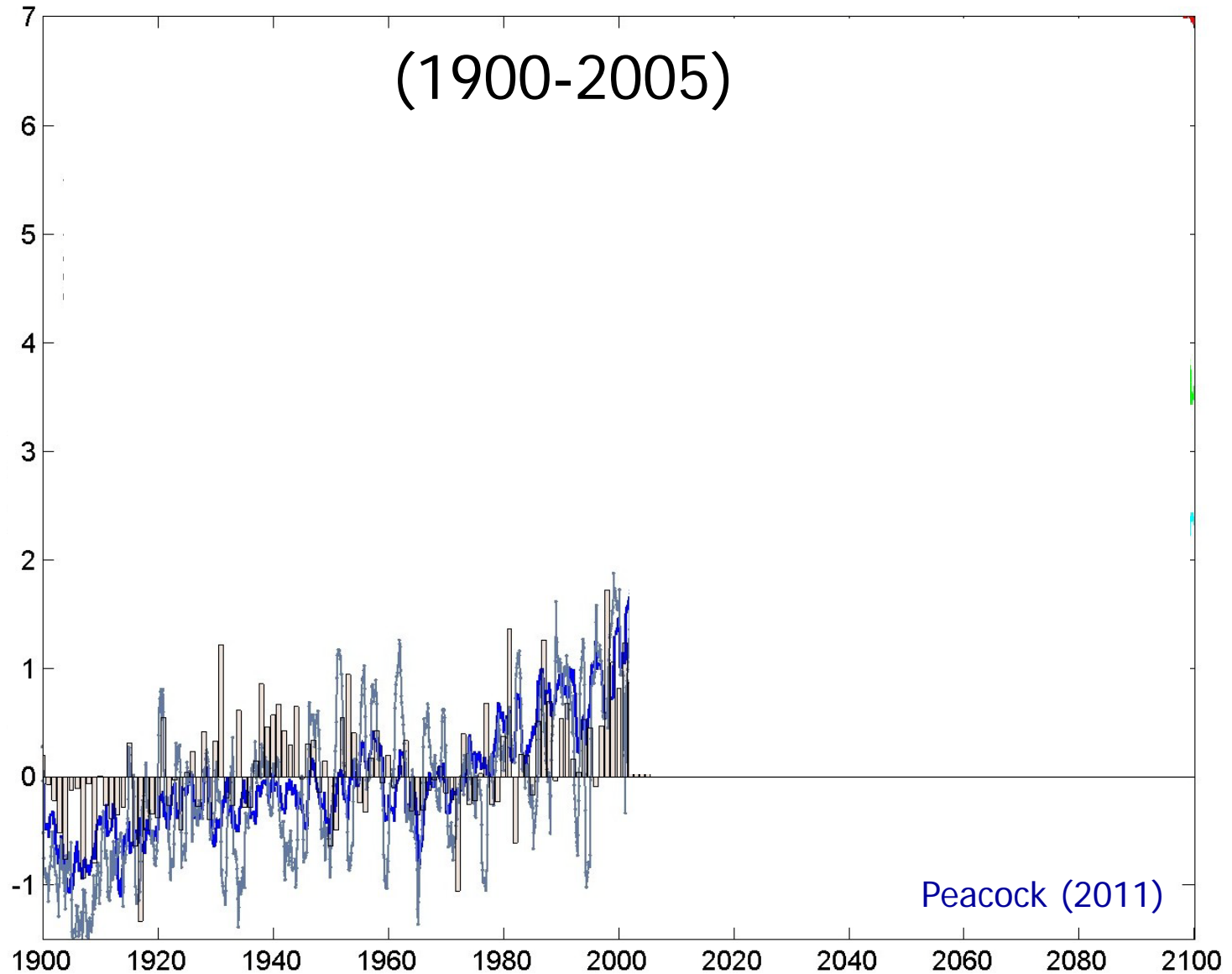


Atlantic Meridional Overturning

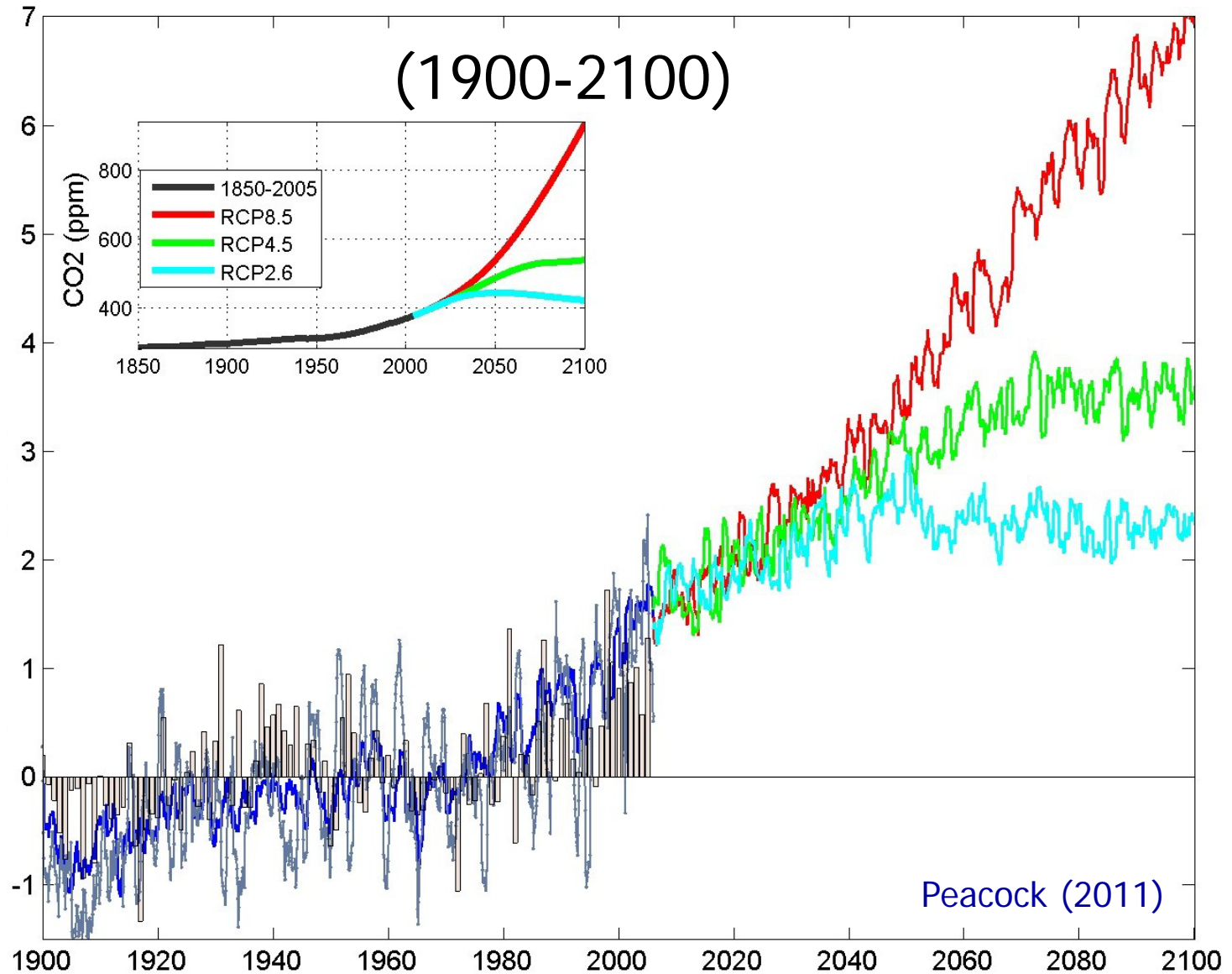


Meehl et al. (2011)

North American Annual Surface T (°C)



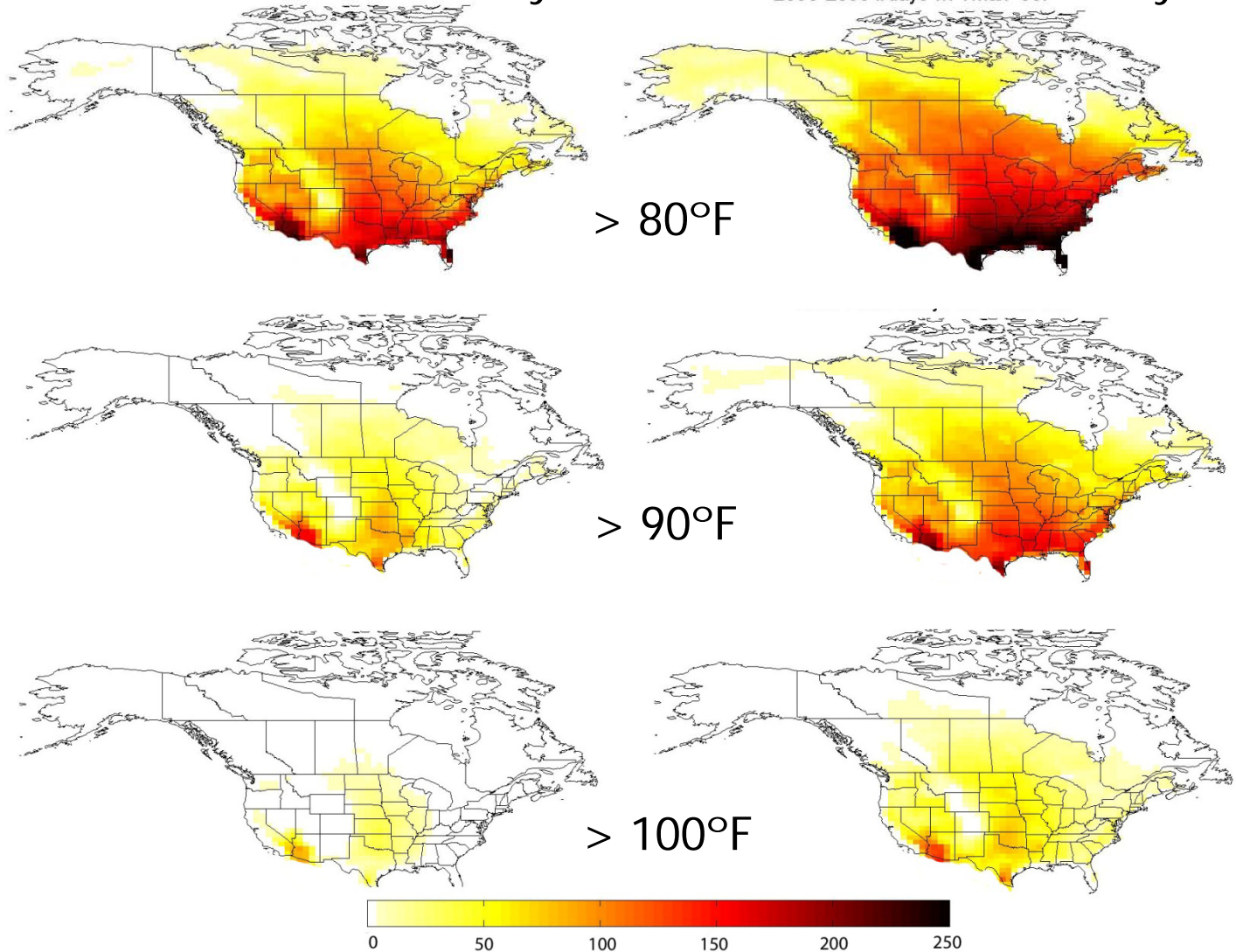
North American Annual Surface T (°C)



Extremes: Number of Warm Days

End of 20th Century

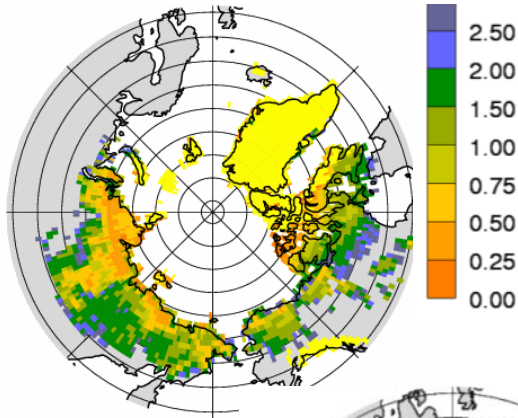
End of 21st Century



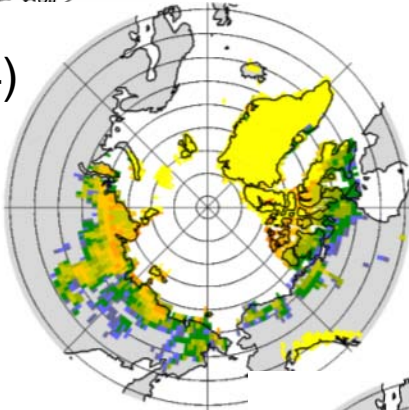
Peacock (2011)

Near-surface permafrost degradation

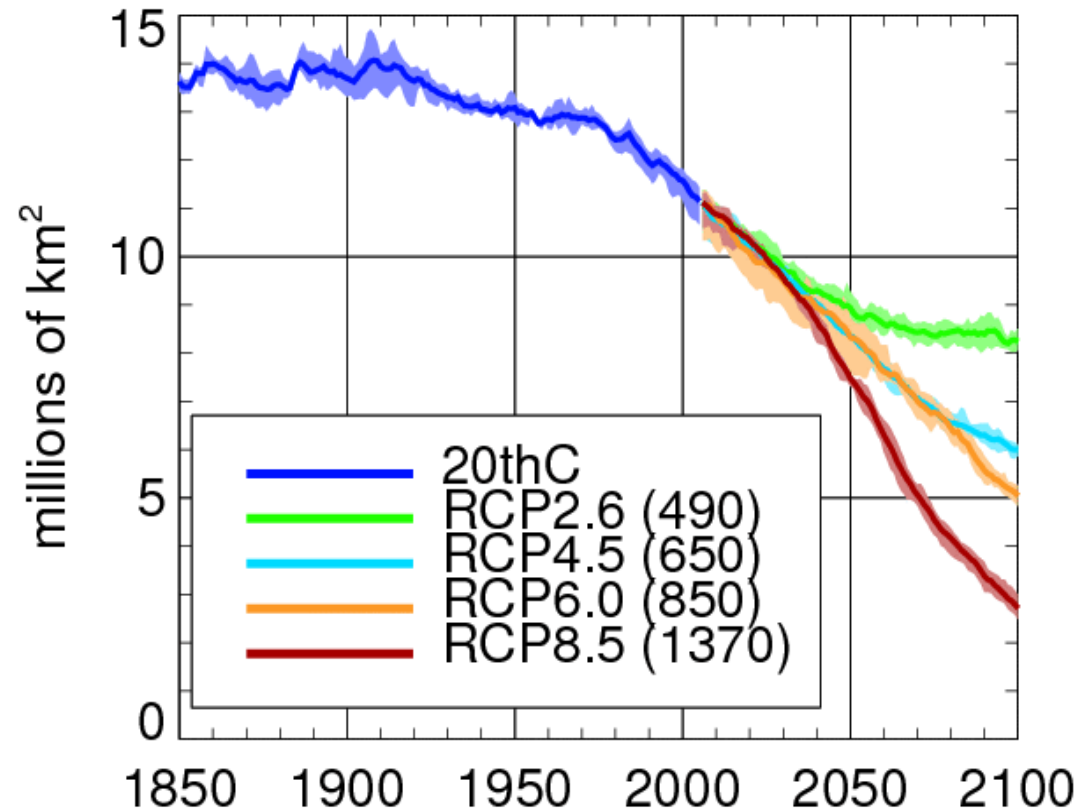
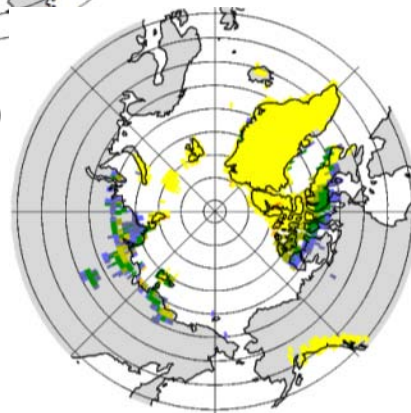
1970-1990 (12.5)



RCP2.6 (8.4)
2080-2100



RC8.5 (3.5)
2080-2100

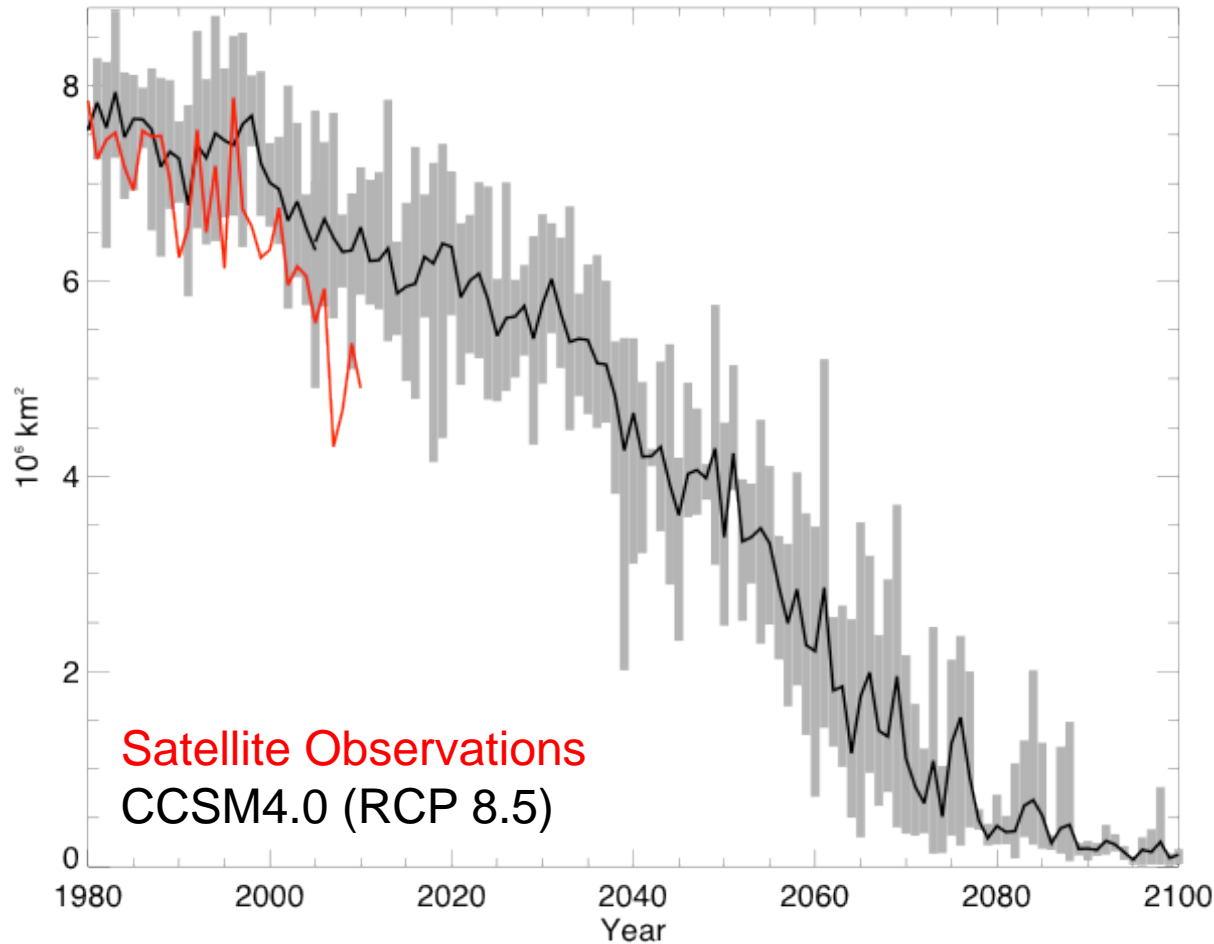


- Improved distribution and active layer thickness
- ~25% slower thaw rates compared to CCSM3 due to improved soil physics

Lawrence et al. (2011)

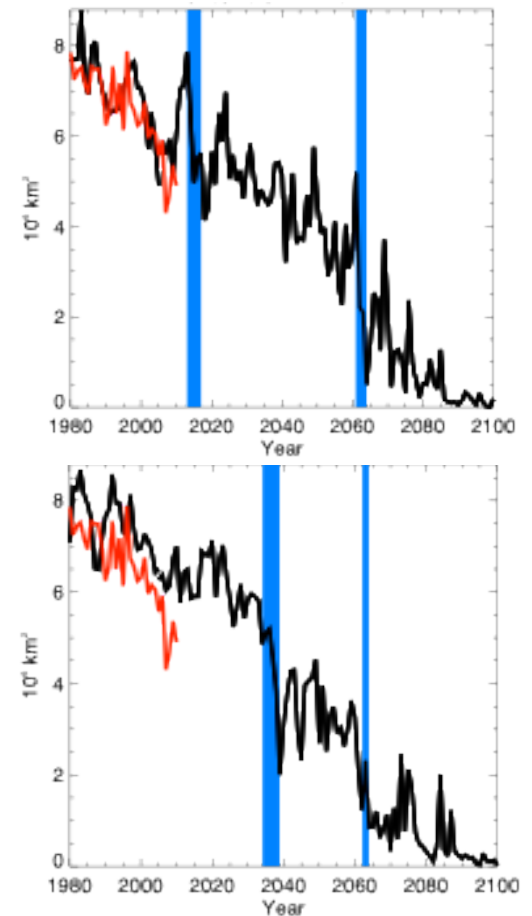
Simulation of the 21st Century

September Arctic Ice Extent



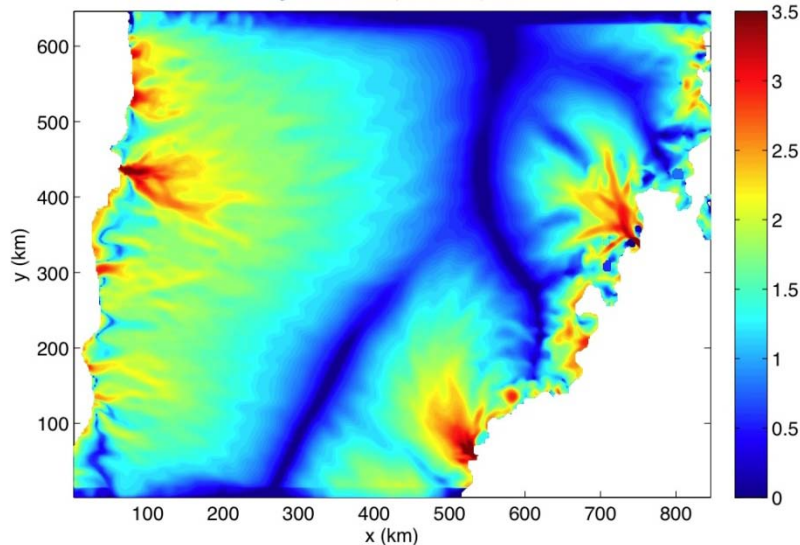
Vavrus et al. (2011)

Abrupt Changes



Land Ice in CESM

Goal: Physically based estimates of land-ice contribution to SLR



Depth-averaged ice speed

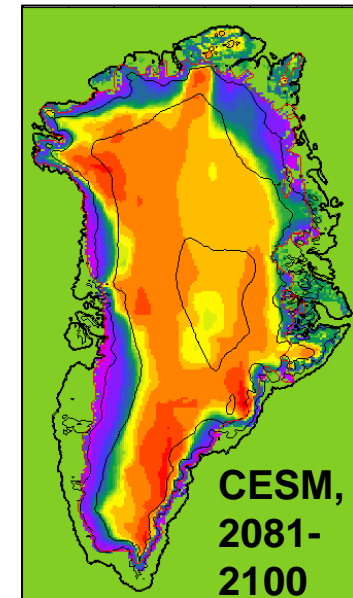
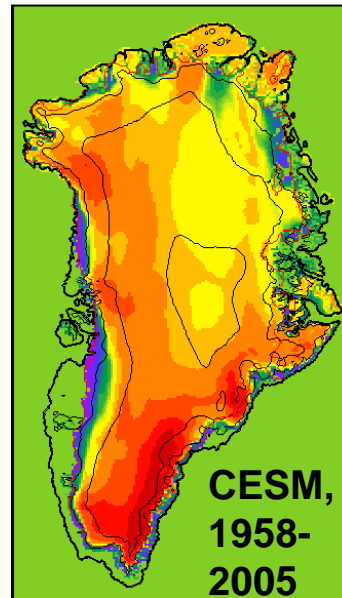
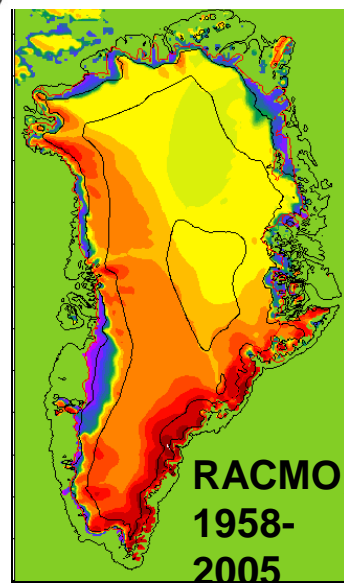
Red regions: large outlet glaciers

- Jakobshavn (center left)
- Kangerdlugssuaq (center right)
- Helheim (lower right)

Surface mass balance (mm/yr)

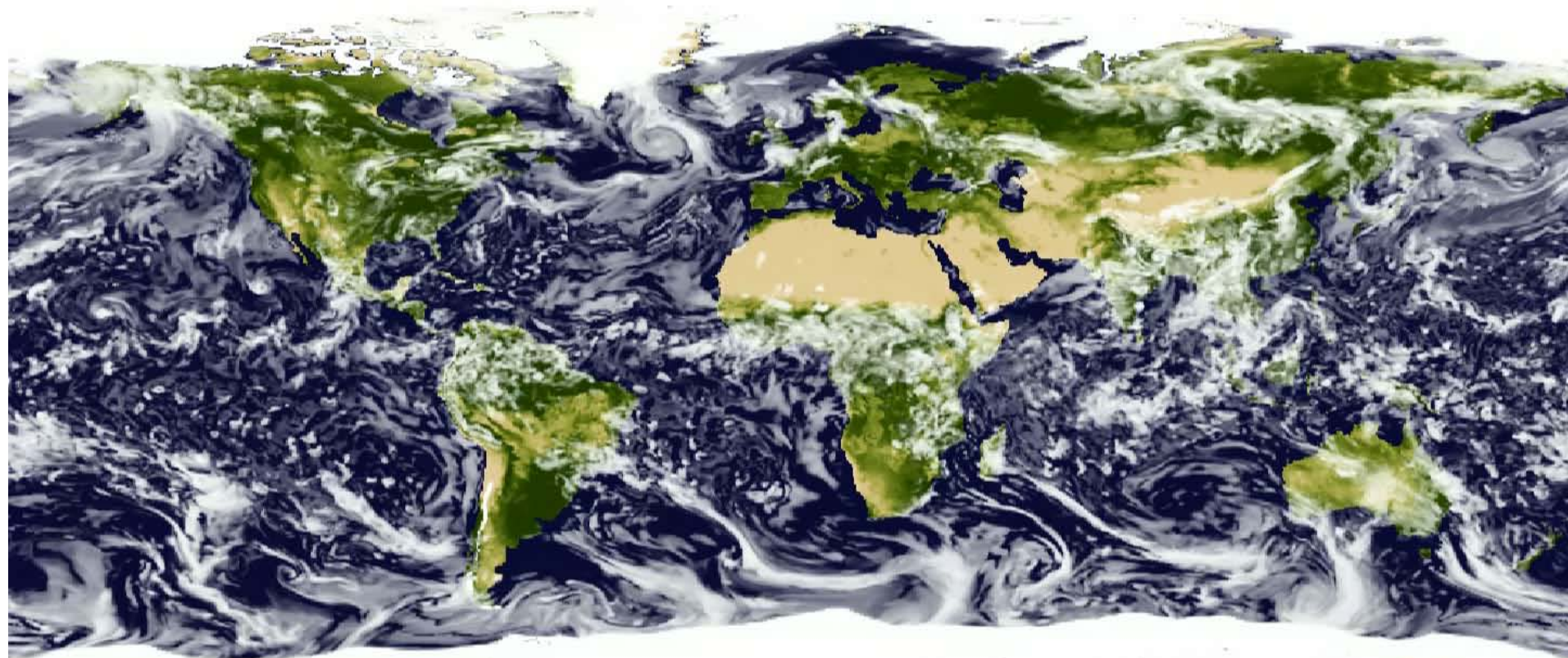
Net accumulation

Net ablation



Courtesy of M. Vizcaíno

High Resolution Global Climate Simulations



20 Jul 00 h



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Jim Hurrell
jhurrell@ucar.edu

