The IPCC Fourth Assessment Report (AR4) Process, and Climate Change Contributions from CCSM3

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Boulder, CO

The IPCC Fourth Assessment Report (AR4)

The Intergovernmental Panel on Climate Change (IPCC) consists of about 190 governments that commission assessments performed by the international climate science community on the state of human knowledge of climate and climate change

Working Group 1: Climate science

Working Group 2: Climate impacts and adaptation

Working Group 3: Mitigation

An assessment is different from a review!

A review compiles work in a certain area

An assessment compiles work in a certain area, evaluates that work, and comes to conclusions regarding our state of knowledge and understanding at that point in time. Subsequent assessments change with advances in our understanding

An IPCC assessment is policy relevant but not policy prescriptive

AR4 WG1 timetable

Apr 2003	1st Scoping meeting
Sep 2003	2nd Scoping meeting
Nov 2003	IPCC approval of outline
…….	Climate sensitivity workshop (July, 2004, Paris)
Sep 2004	1st LA meeting (Italy)
……	Zero order draft, internal review
Mar 2005 May 2005	Model analysis wkshp, IPRC, Hawaii 2nd LA meeting (Beijing)
……	1st draft due Aug. 12; expert review
Dec 2005	3rd LA meeting (New Zealand)
……	2nd draft due Mar. 3, Govt/expert rev
Jun 2006	4th LA meeting (Norway)
……	3rd draft due Sep 15; review of SPM
Jan 2007	IPCC WG1 approval

All new model runs needed for WGI

Documentation needed (papers submitted to journals) by May 31

All papers/documentation in press or appeared by December 15

Working Group I Contribution to the IPCC Fourth Assessment Report

Climate Change 2007: The Physical Science Basis

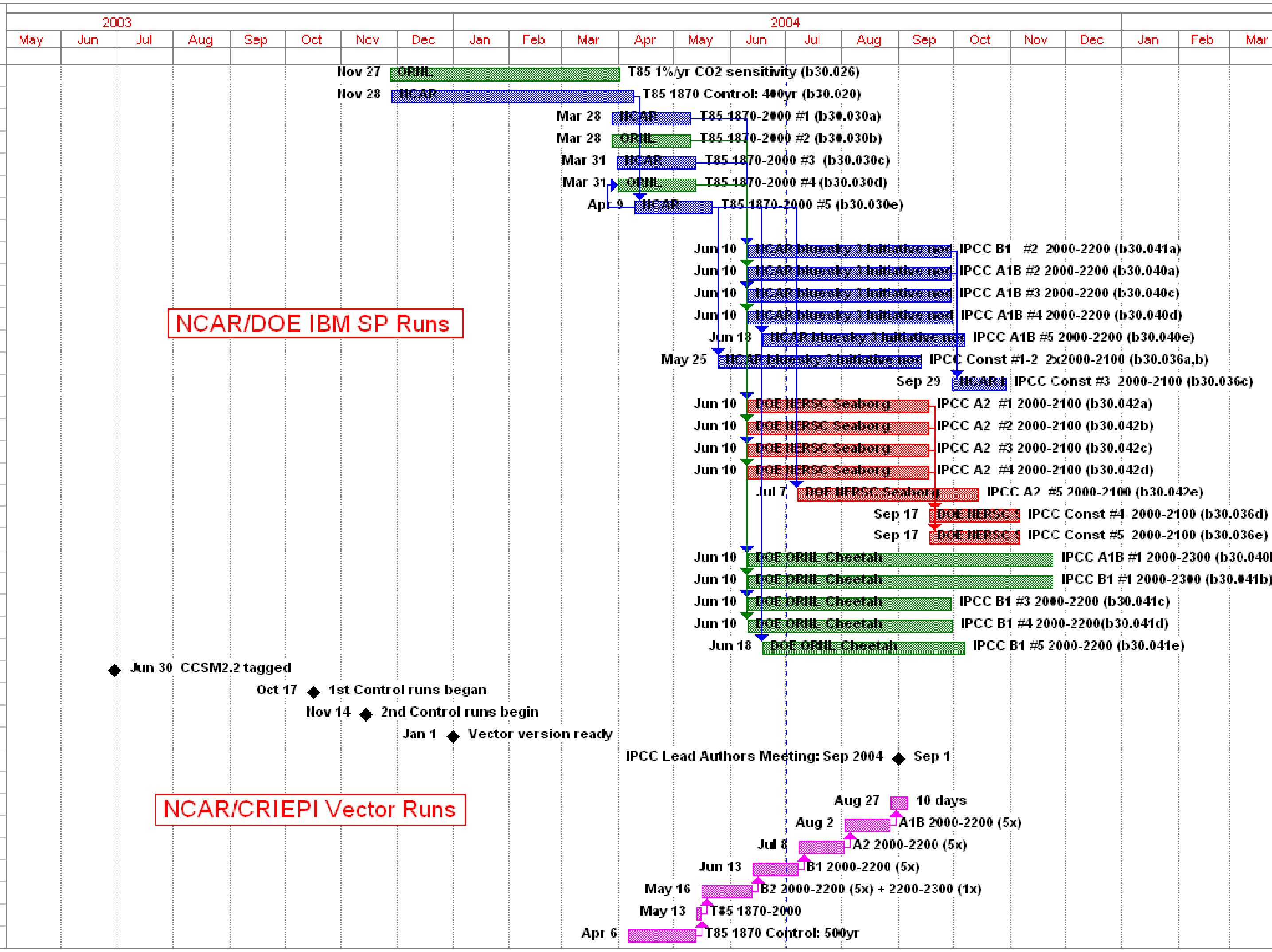
The IPCC AR4 has motivated the formulation of the largest international global coupled climate model experiment and multi-model analysis effort ever attempted, and is being coordinated by the WGCM Climate Simulation Panel

Fourteen modeling groups from around the world are participating with 21 models; considerable resources have been devoted to this project; PCMDI has archived ~27 TeraBytes of model data so far

From over 60 proposals submitted, funding for 18 analyses of the 20th century climate simulations was provided by NSF-NOAA-NASA-DOE under the Climate Model Evaluation Project (CMEP) and coordinated by U.S. CLIVAR

CCSM3 T85 IPCC Simulations

ID	Duration	Start	Finish	Predecessors
4	570 hrs	Thu 11/27/03	Thu 4/1/04	
5	466 hrs	Fri 11/28/03	Fri 4/9/04	2
6	130 hrs	Sun 3/28/04	Mon 5/10/04	
7	130 hrs	Sun 3/28/04	Mon 5/10/04	
8	130 hrs	Wed 3/31/04	Thu 5/13/04	
9	130 hrs	Wed 3/31/04	Thu 5/13/04	10SS-7 days
10	130 hrs	Fri 4/9/04	Sat 5/22/04	5
11				
12	200 hrs	Thu 6/10/04	Wed 9/29/04	6FS+24 days
13	200 hrs	Thu 6/10/04	Wed 9/29/04	7FS+24 days
14	200 hrs	Thu 6/10/04	Wed 9/29/04	8FS+21 days
15	200 hrs	Thu 6/10/04	Thu 9/30/04	9FS+21 days
16	200 hrs	Fri 6/18/04	Thu 10/7/04	10FS+20 days
17	200 hrs	Tue 5/25/04	Mon 9/13/04	10FS+2 hrs
18	100 hrs	Wed 9/29/04	Fri 10/29/04	12,13
19	100 hrs	Thu 6/10/04	Fri 9/17/04	6FS+23 days
20	100 hrs	Thu 6/10/04	Fri 9/17/04	7FS+23 days
21	100 hrs	Thu 6/10/04	Fri 9/17/04	8FS+20 days
22	100 hrs	Thu 6/10/04	Fri 9/17/04	9FS+20 days
23	100 hrs	Wed 7/7/04	Thu 10/14/04	10FS+33 days
24	100 hrs	Fri 9/17/04	Sat 11/6/04	19,20
25	100 hrs	Fri 9/17/04	Sat 11/6/04	21,22
26	300 hrs	Thu 6/10/04	Wed 11/24/04	6FS+24 days
27	300 hrs	Thu 6/10/04	Wed 11/24/04	7FS+24 days
28	200 hrs	Thu 6/10/04	Wed 9/29/04	8FS+21 days
29	200 hrs	Thu 6/10/04	Thu 9/30/04	9FS+21 days
30	200 hrs	Fri 6/18/04	Thu 10/7/04	10FS+20 days
31	0 days	Mon 6/30/03	Mon 6/30/03	
32	168 hrs?	Fri 10/17/03	Fri 11/14/03	
33	8 hrs?	Fri 11/14/03	Fri 11/14/03	
34	1 hr	Thu 1/1/04	Thu 1/1/04	
35	1 day	Wed 9/1/04	Wed 9/1/04	
36				
37	10 days	Fri 8/27/04	Sun 9/5/04	38
38	200 hrs	Mon 8/2/04	Fri 8/27/04	39
39	200 hrs	Thu 7/8/04	Mon 8/2/04	40
40	200 hrs	Sun 6/13/04	Thu 7/8/04	41
41	220 hrs	Sun 5/16/04	Sun 6/13/04	42
42	26 hrs	Thu 5/13/04	Sun 5/16/04	43
43	300 hrs	Tue 4/6/04	Thu 5/13/04	44



CCSM3 has made the largest contribution of any single model to the IPCC AR4 multi-model dataset with 8 ensemble members (5 for A2) at T85 for each experiment (about 30% of the PCMDI multi-model archive, or ~7.5 TeraBytes out of the total archive of ~27 TeraBytes)

Five members were run in the U.S. at NCAR, Oak Ridge National Laboratory (ORNL), and the National Energy Research Scientific Computing Center (NERSC);

Three members were run in Japan on the Earth Simulator, along with some unique “overshoot” scenarios (Tsutsui et al., 2005)

Results from analyses of the multi-model dataset were presented by 125 scientists at a workshop convened by US CLIVAR and hosted by IPRC (Univ. of Hawaii) March 1-4, 2005, and are feeding directly into the AR4 assessment process

To date, there are 306 analysis projects registered at PCMDI, and over 220 papers have been submitted to peer-reviewed journals with results from multi-model analyses for assessment in the IPCC AR4

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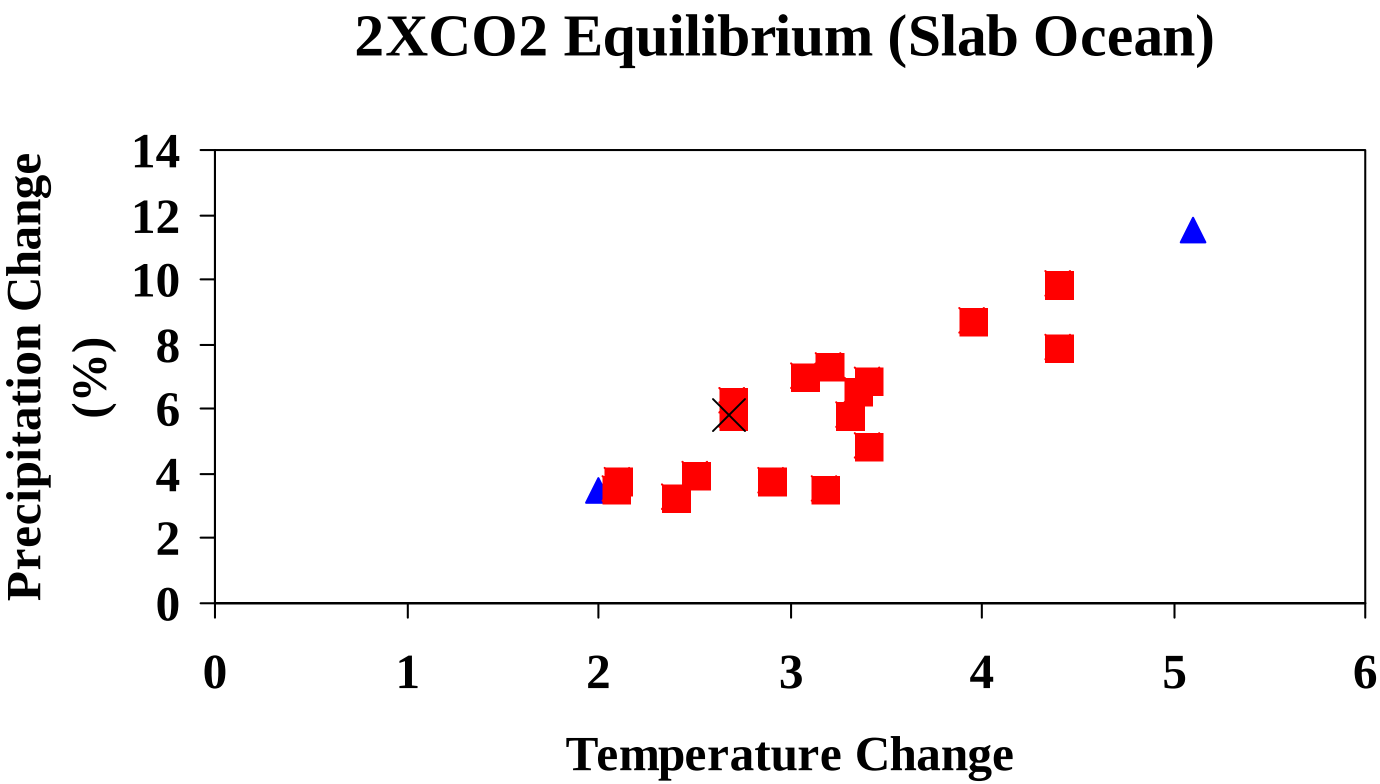
To date, there are 306 analysis projects registered at PCMDI, and over 220 papers have been submitted to peer-reviewed journals with results from multi-model analyses for assessment in the IPCC AR4

This is more than double our most optimistic estimate for participation

Equilibrium climate sensitivity from 17 models currently in use for the IPCC AR4 (CCSM3=X)

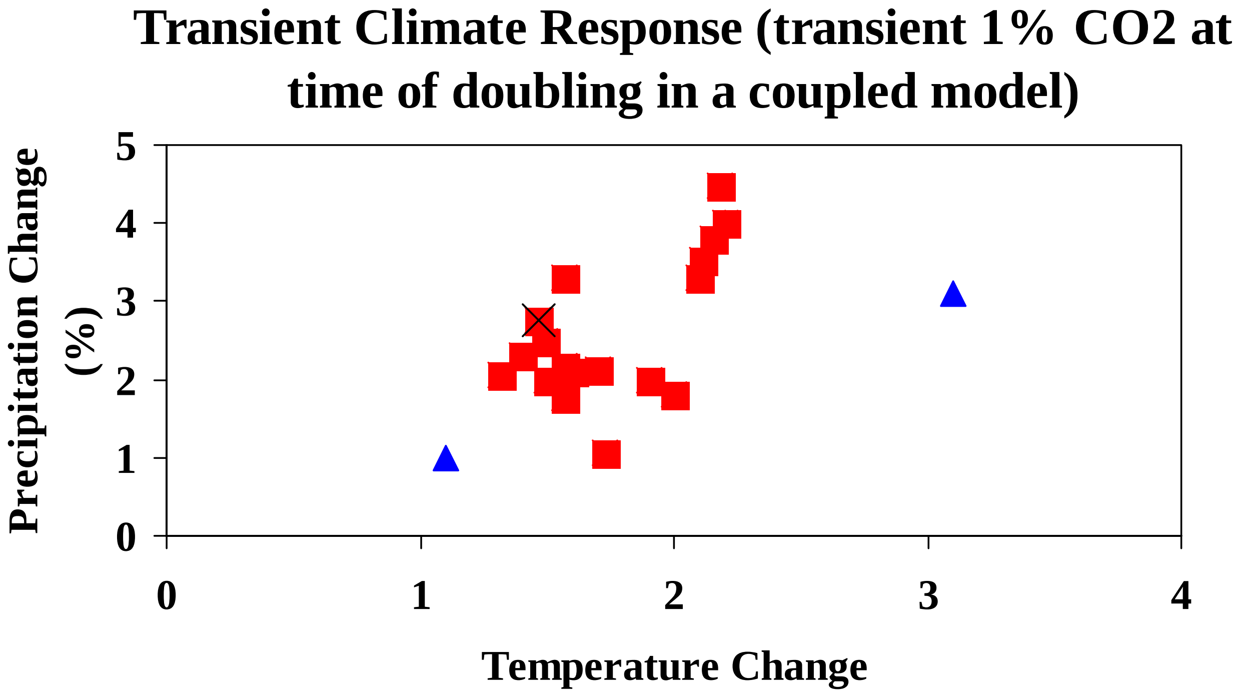
blue triangles = range of models in TAR (2.0-5.1C)

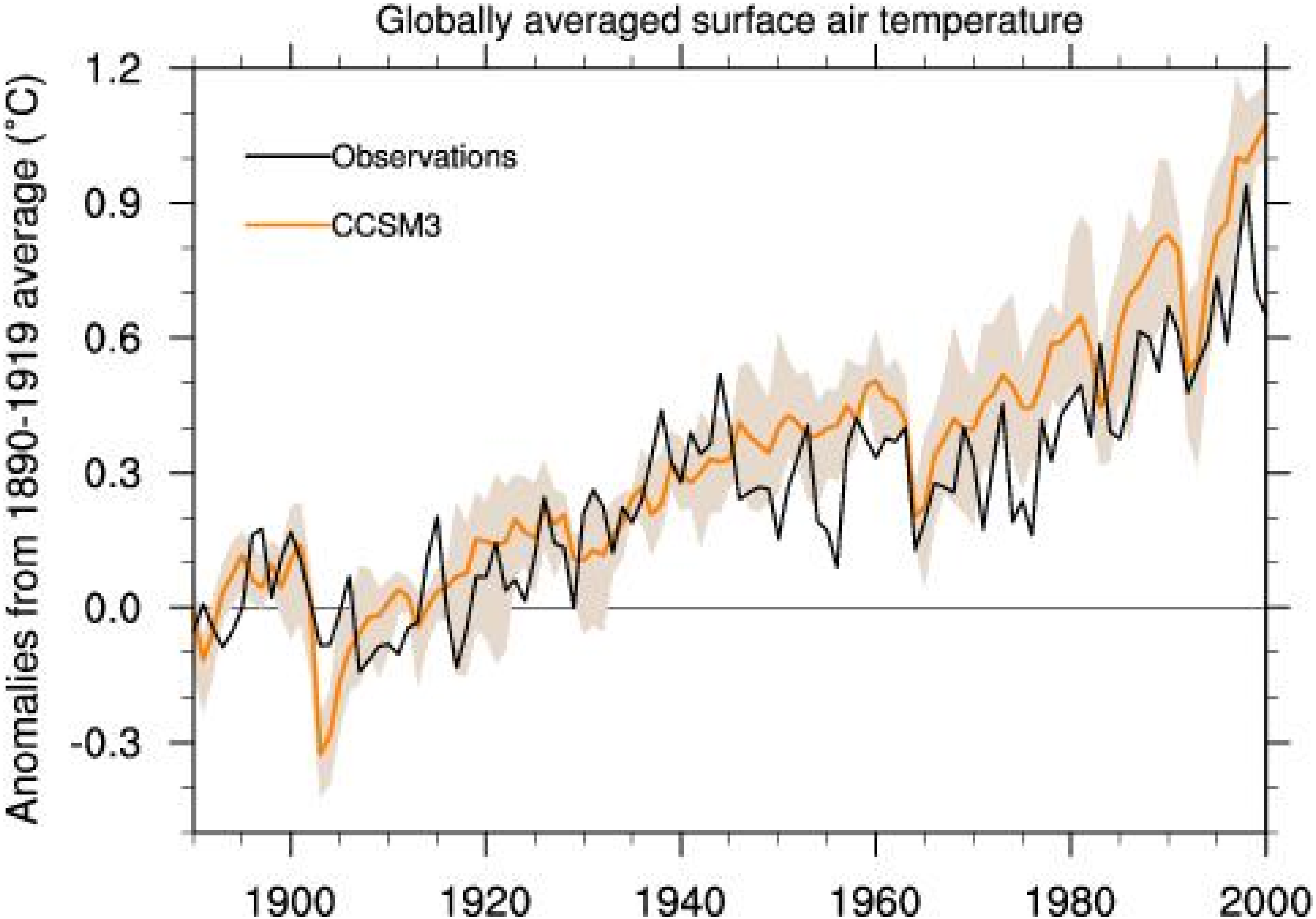
red squares = current models



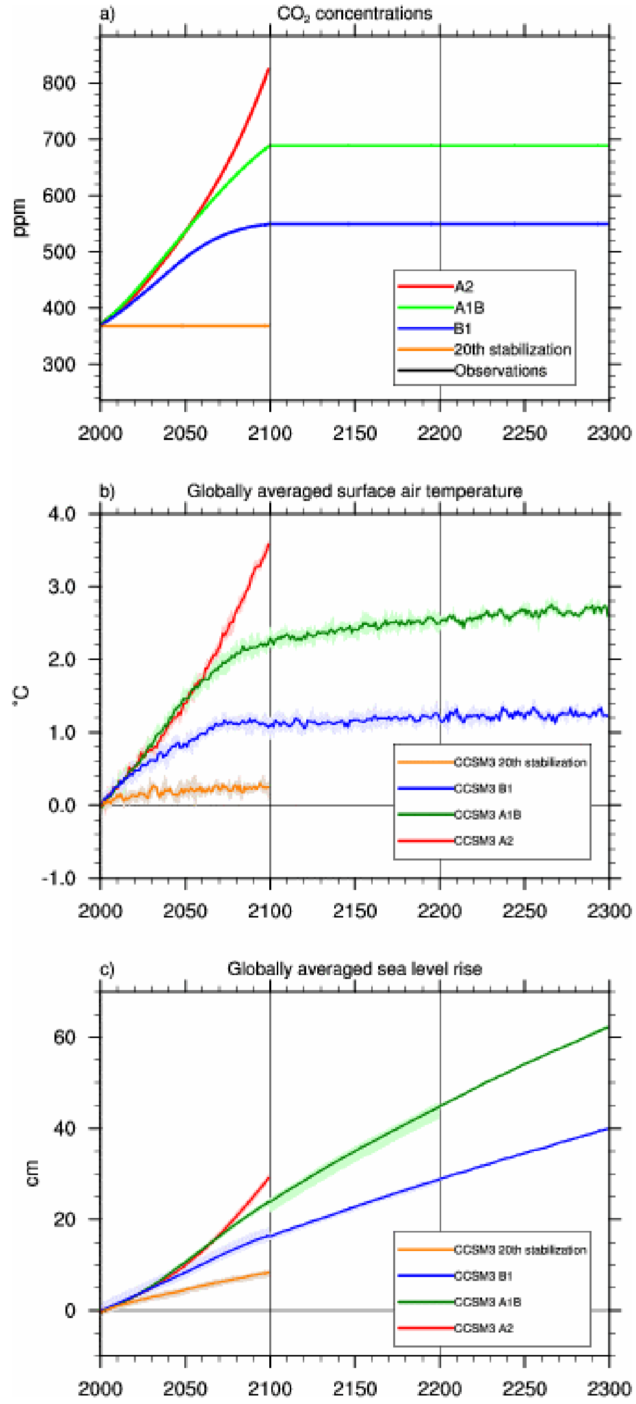
Transient climate response (TCR) from 17 models (CCSM3=X)

blue triangles = range of models in TAR (1.1-3.1C)
red squares = current models





(Meehl et al., 2005, J. Climate special issue paper)



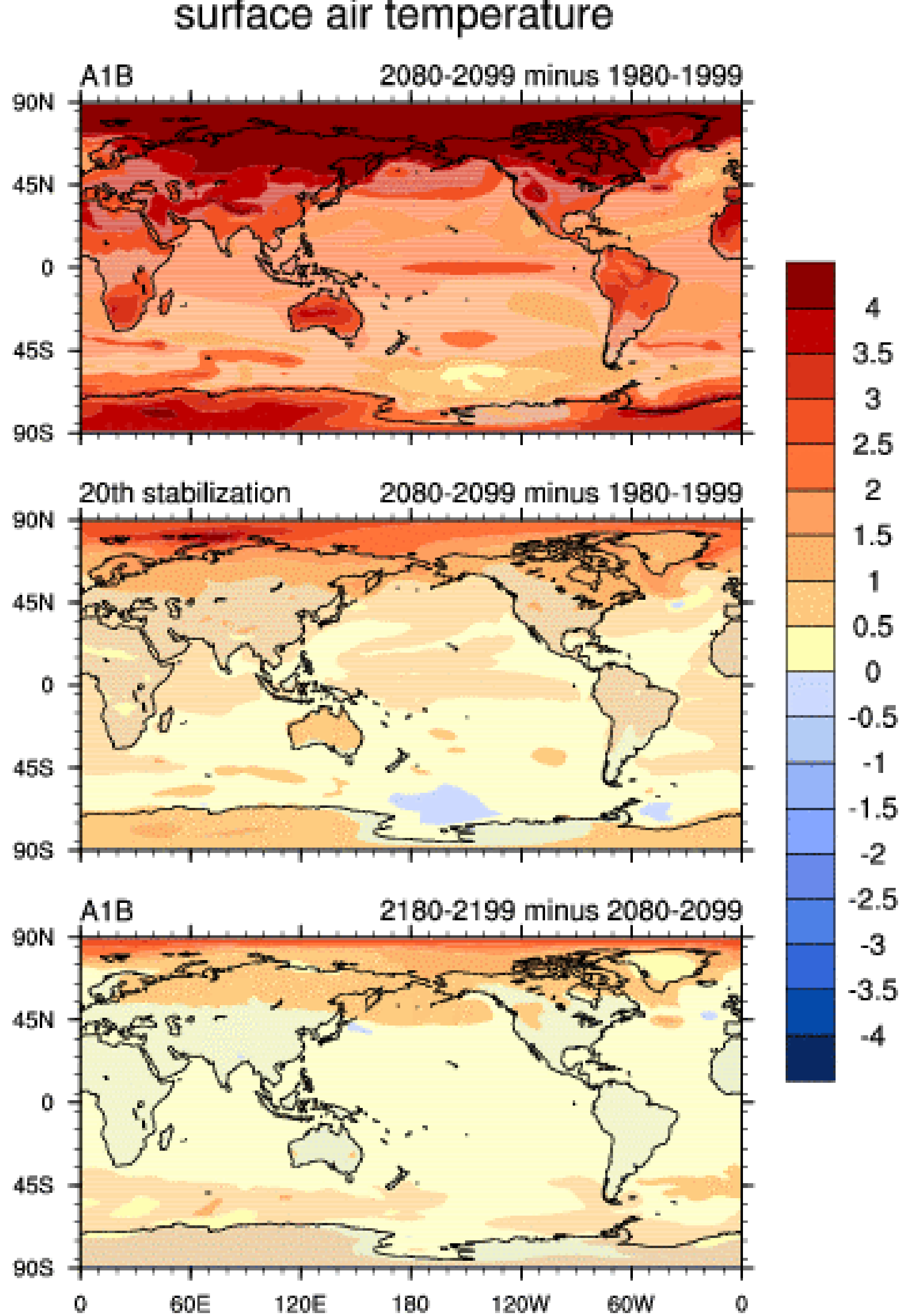
$A2 = 2.26XCO_2$

$A1B = 1.89XCO_2$

$B1 = 1.51XCO_2$

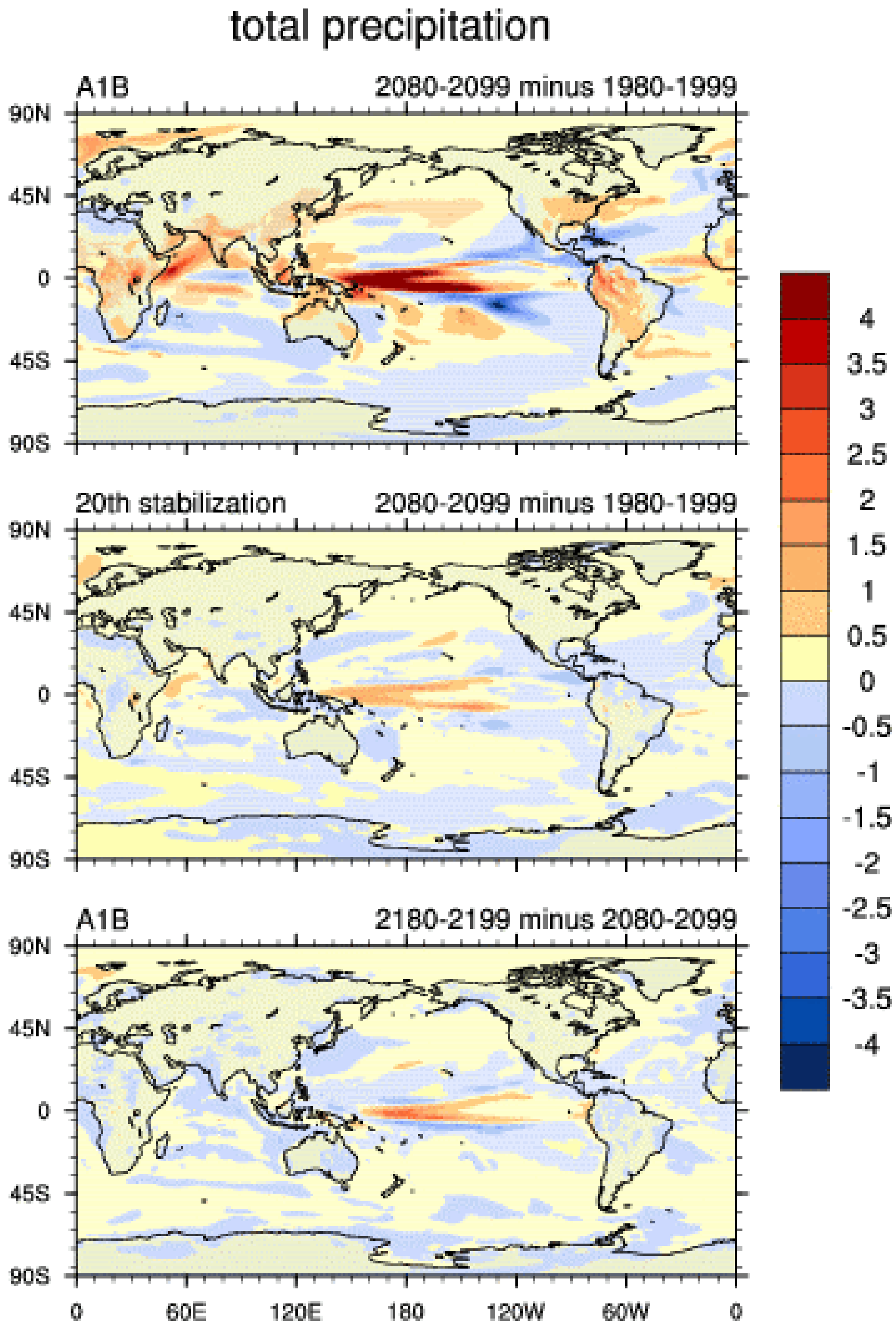
(Meehl et al., 2005, *J. Climate* special issue paper)

CCSM3



(Meehl et al., 2005, *J. Climate* special issue paper)

CCSM3

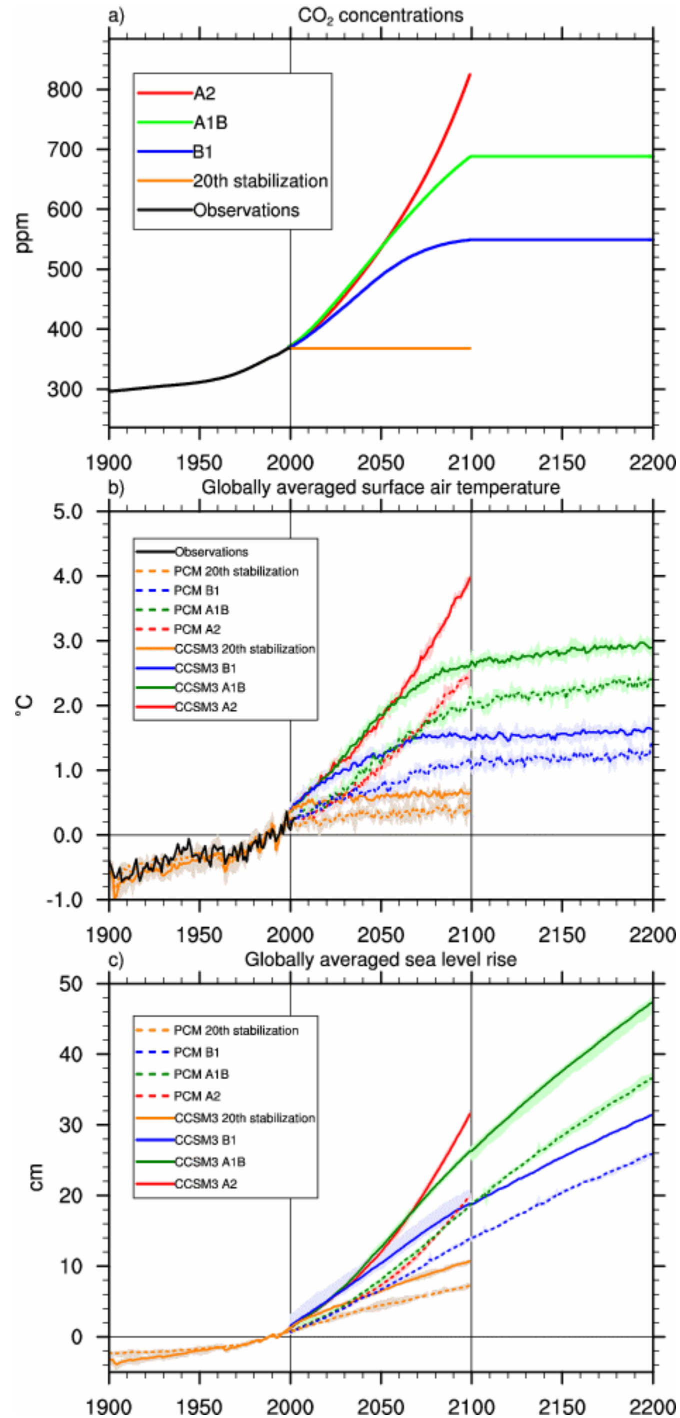


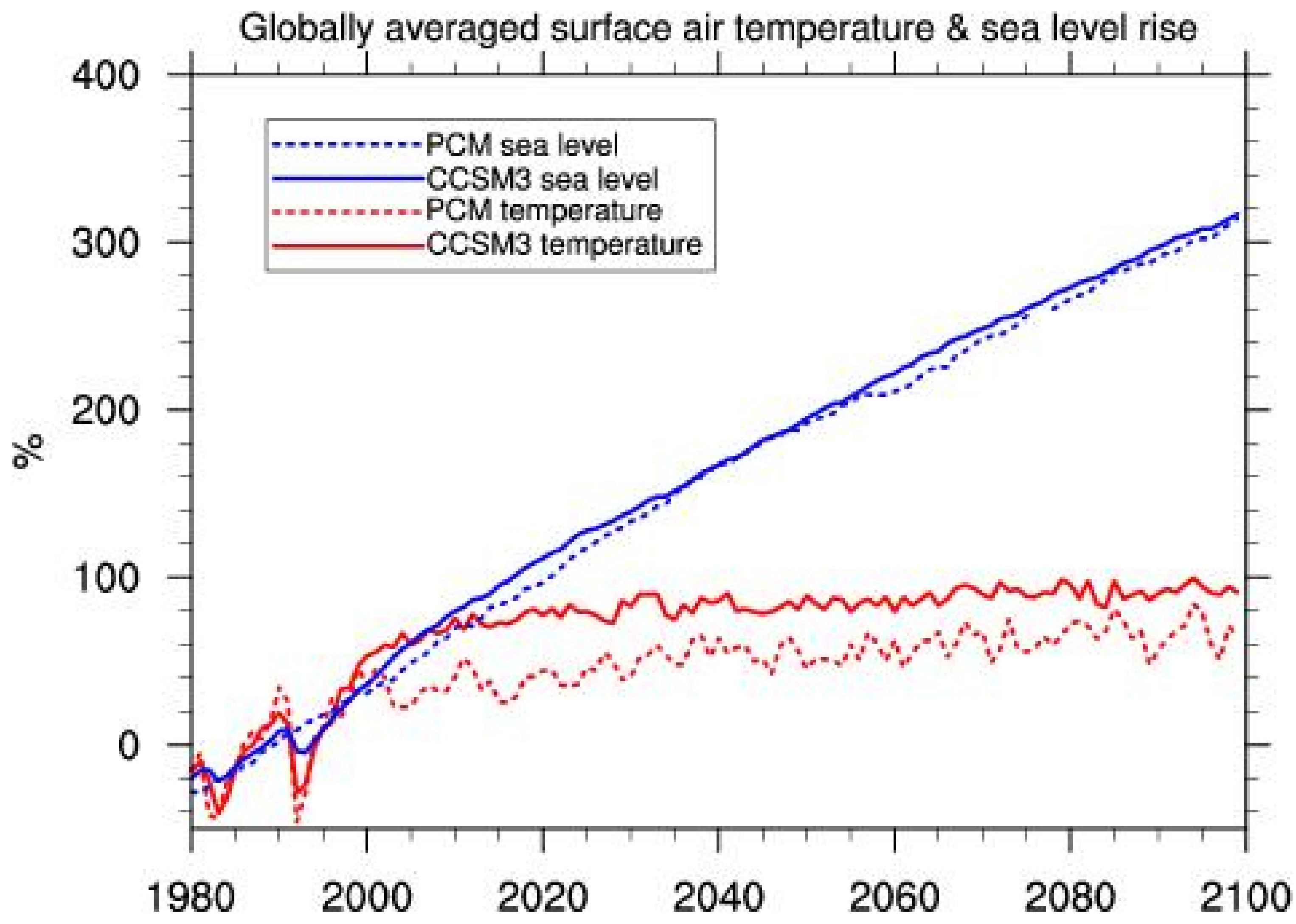
(Meehl et al., 2005, *J. Climate* special issue paper)

Climate change commitment: at any point in time, we are committed to additional warming and sea level rise from the radiative forcing already in the system.

Warming stabilizes after several decades, but sea level from thermal expansion continues to rise for centuries.

(Meehl et al., 2005: How much more warming and sea level rise? *Science*, **307**, 1769—1772)




Globally averaged surface air temperature & sea level rise
PCM sea level
CCSM3 sea level
PCM temperature
CCSM3 temperature
%
400
300
200
100
0
1980
2000
2020
2040
2060
2080
2100

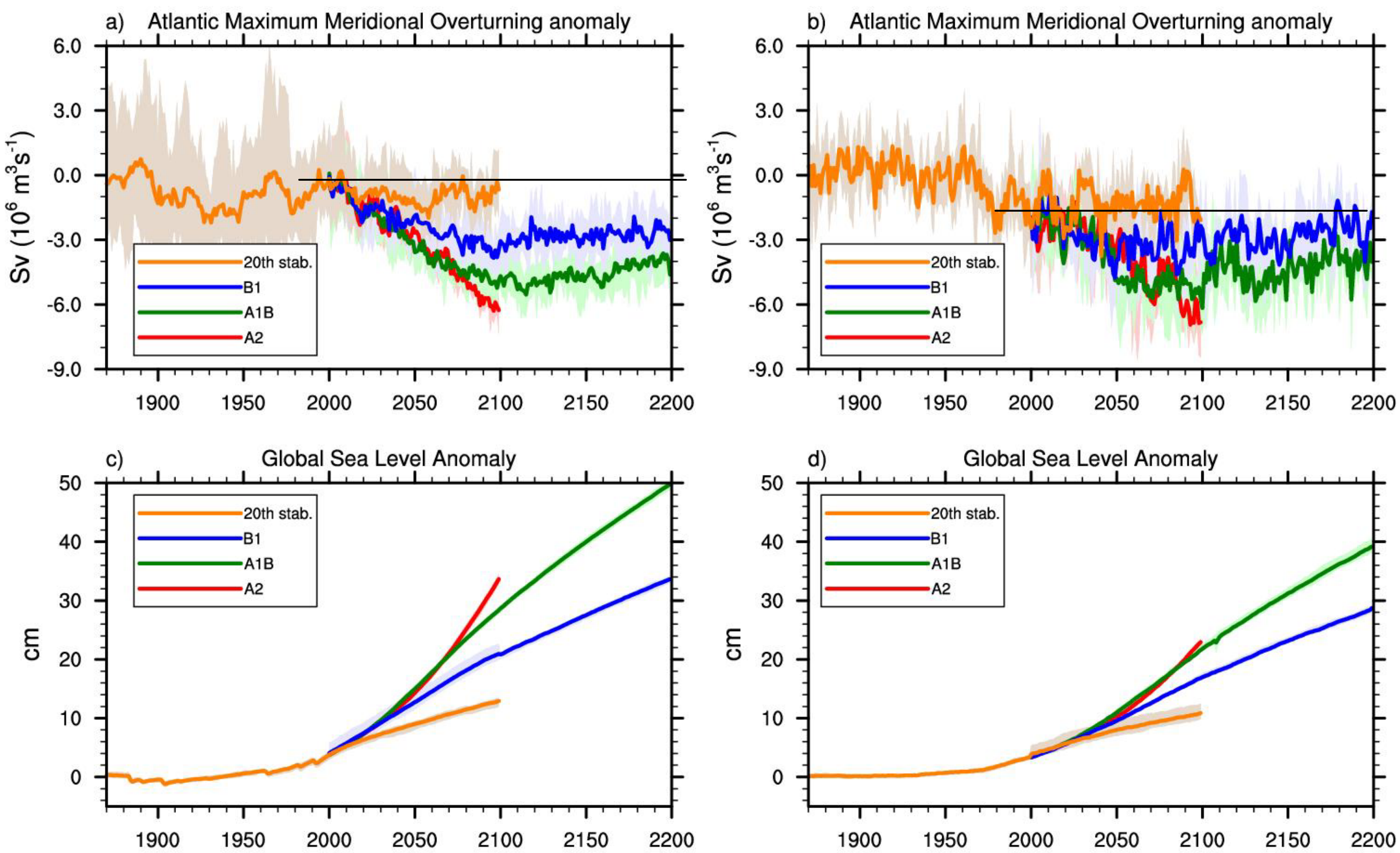
Higher climate sensitivity = greater response

Stronger mean MOC = greater ventilation and less commitment (CCSM3 = 22 Sv, PCM = 32 Sv)

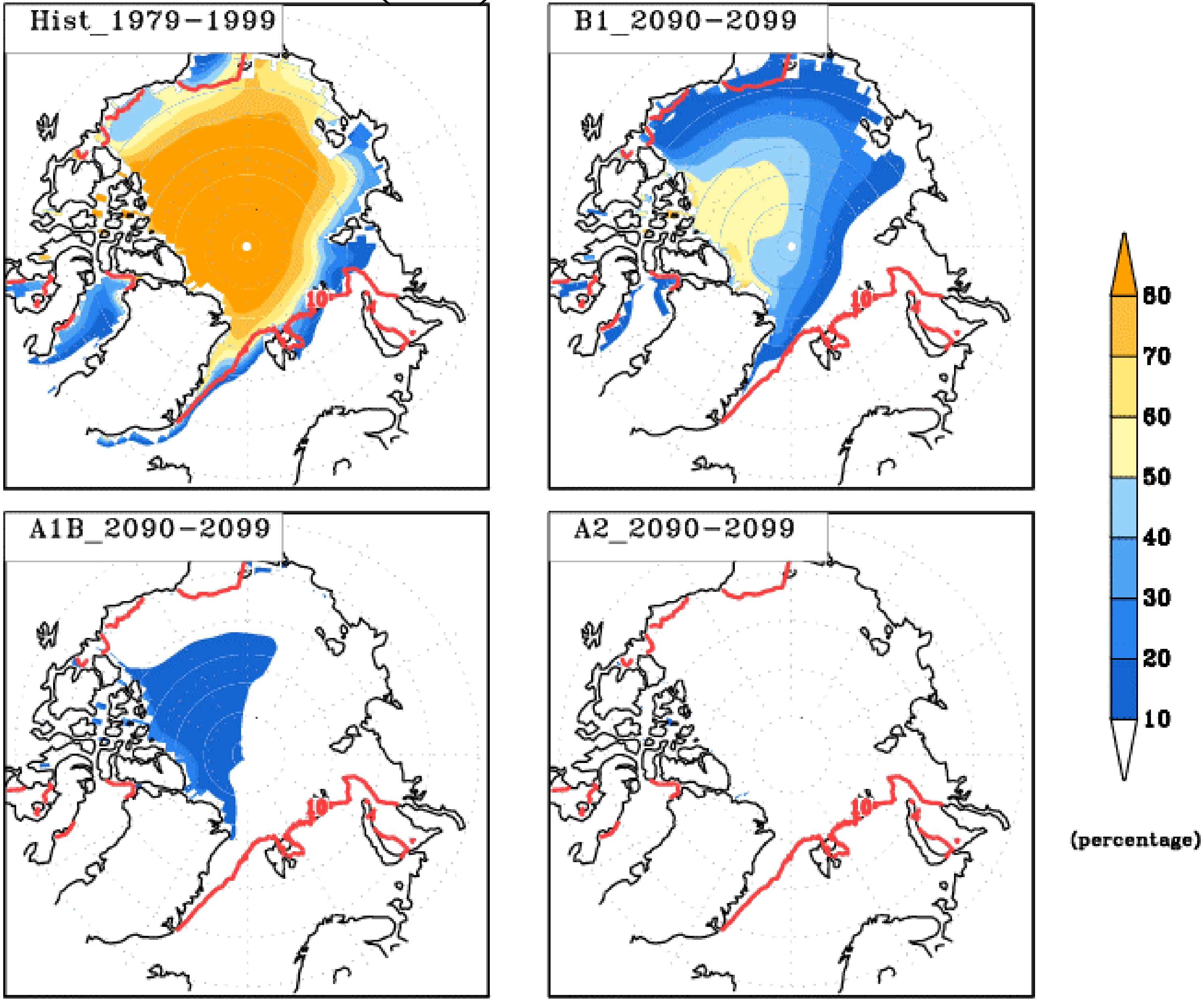
Greater percent decrease in MOC = less ventilation and longer timescales of MOC recovery and commitment

CCSM3: -18% to –28% PCM: -3% to –14%

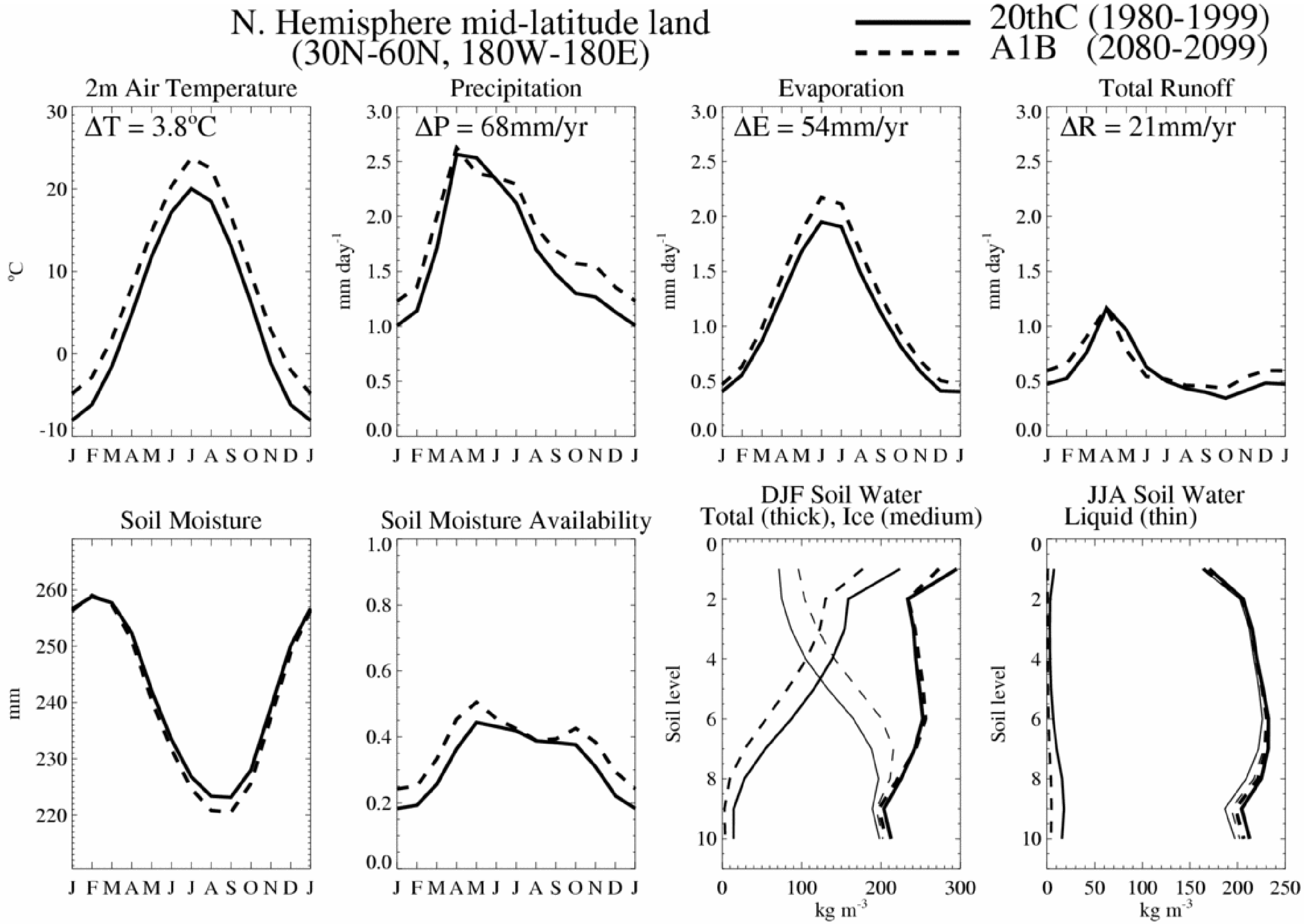
IPCC ensembles from CCSM (left) and PCM (right)



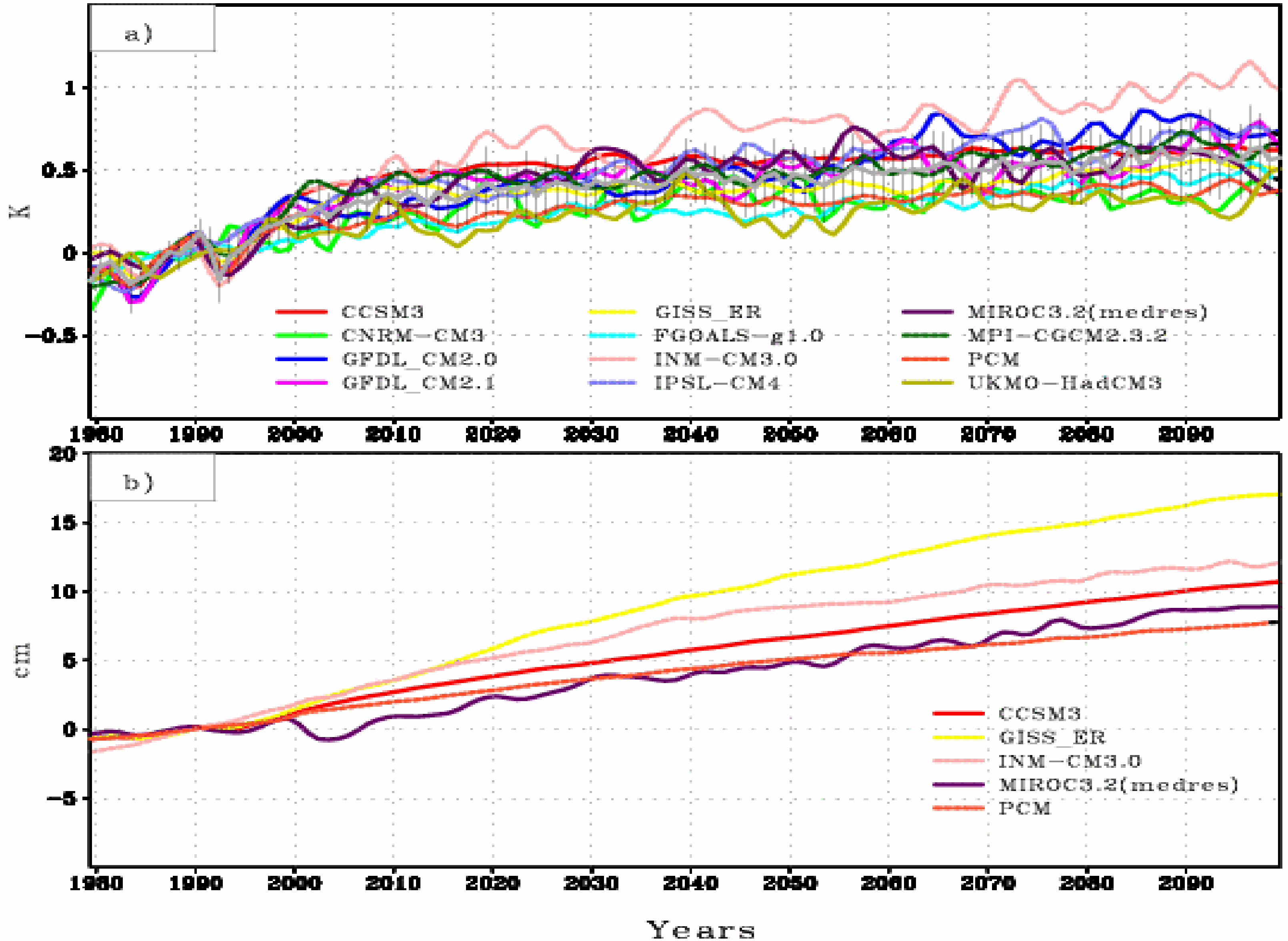
CCSM3 SUM(JAS) Sea Ice Concentration



(Teng et al., 2005, *Cli. Dyn.*, submitted)


N. Hemisphere mid-latitude land
(30N-60N, 180W-180E)
20thC (1980-1999)
A1B (2080-2099)
2m Air Temperature
ΔT = 3.8°C
°C
Precipitation
ΔP = 68mm/yr
mm day-1
Evaporation
ΔE = 54mm/yr
mm day-1
Total Runoff
ΔR = 21mm/yr
mm day-1
J F M A M J J A S O N D J
Soil Moisture
mm
Soil Moisture Availability
DJF Soil Water
Total (thick), Ice (medium)
Soil level
kg m-3
JJA Soil Water
Liquid (thin)
Soil level
kg m-3

Global avg TAS and Sea Level Change



(Teng et al., 2005, GRL, submitted)

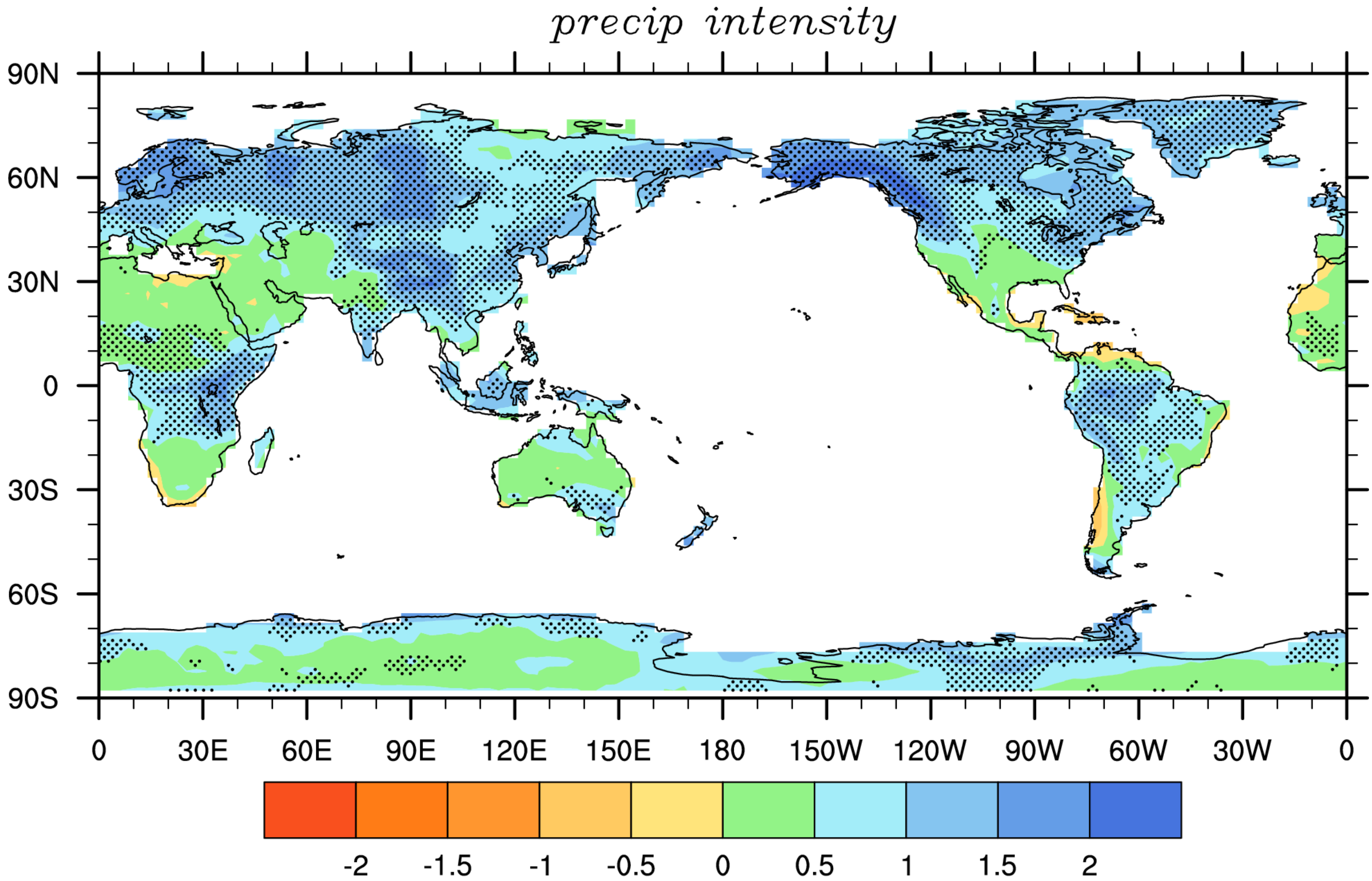


Fig. 1: The 8 member multi-model ensemble mean *precip intensity* difference from Tebaldi et al (2005) for A1B, 2080-2099 minus 1980-1999.

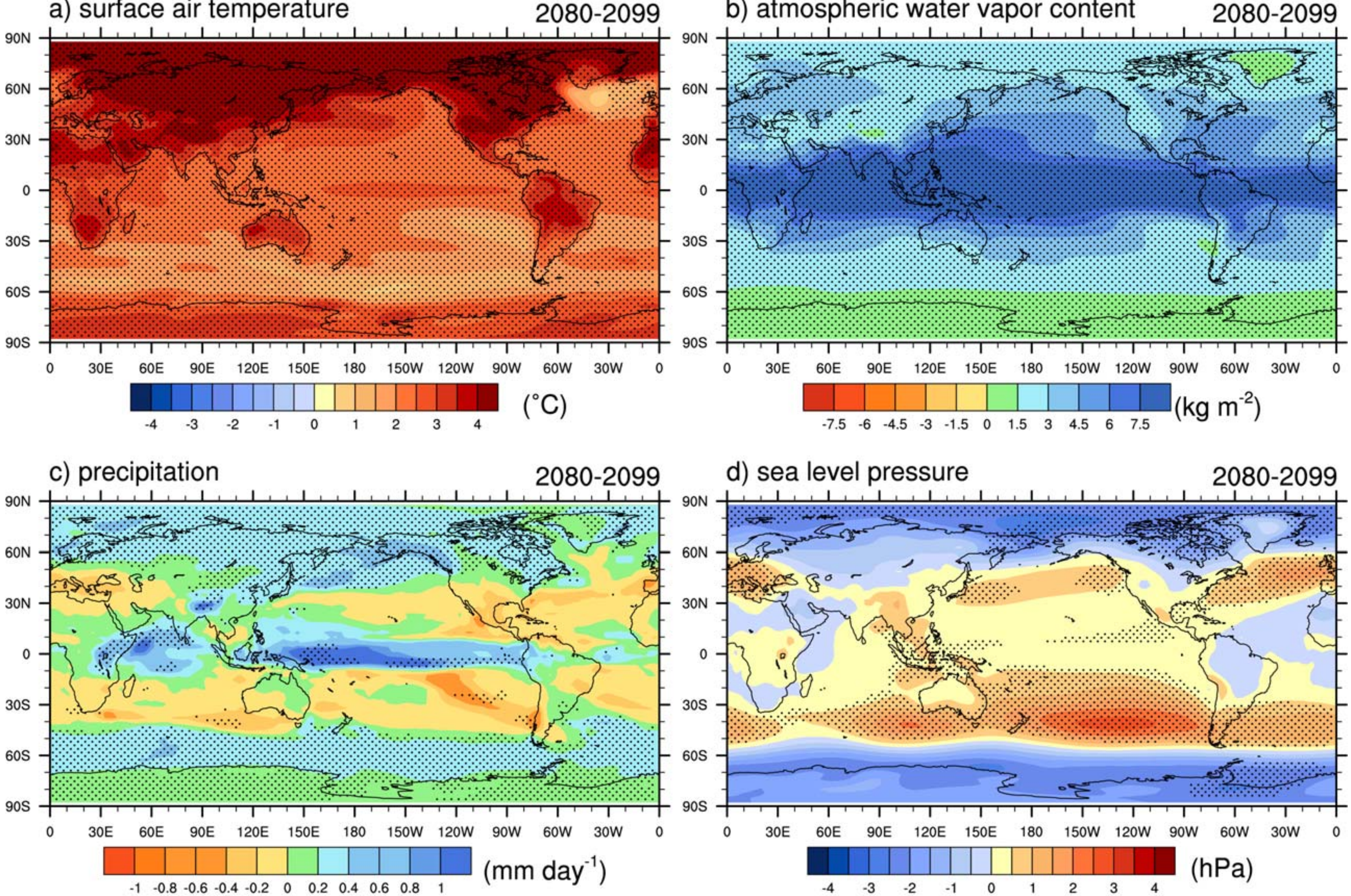


Fig. 2: a) annual mean surface temperature differences (°C), 2080-2099 minus 1980-1999, for A1B from the 8 member multi-model ensemble; b) same as (a) except for vertically integrated water vapor differences (kg m^{-2}); c) same as (a) except for precipitation differences (mm day^{-1}); d) same as (a) except for SLP differences (hPa). Dotted regions correspond to areas where the multi-model mean divided by the multi-model standard deviation is greater than 1

(Meehl et al., 2005, GRL, submitted)

Summary

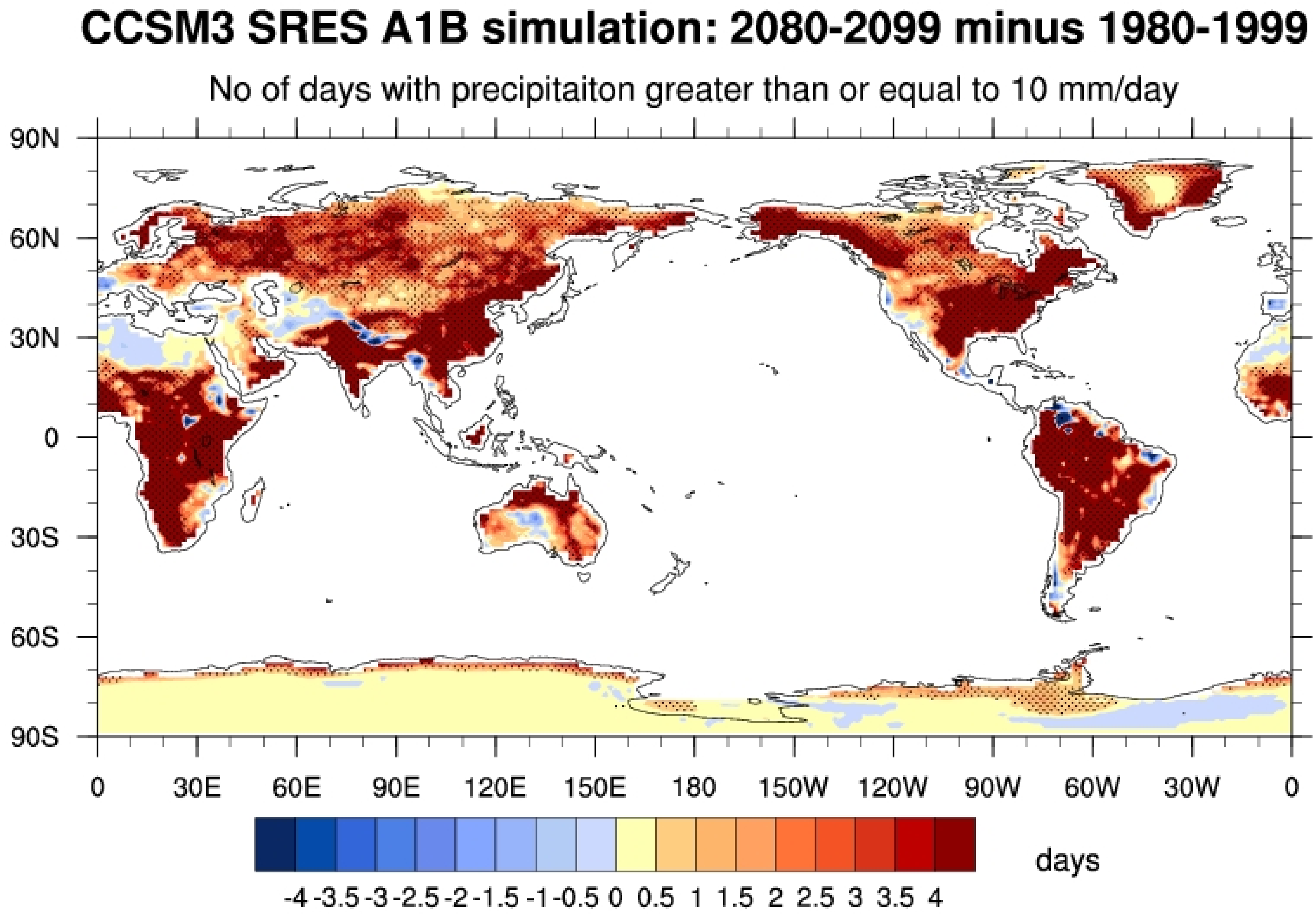
1. First drafts of IPCC AR4 chapters are being formulated, with eventual publication in spring, 2007

2. CCSM3 has made the largest contribution from any single model to the multi-model dataset being assessed for the AR4, with eight ensemble members of all experiments (five for A2), ~7.5 TeraBytes out of the total PCMDI multi-model archive of ~27 Terabytes (~30%)

Summary (continued):

3. A major international multi-model data collection and analysis effort has yielded over 220 papers now being assessed for the AR4

4. The large set of climate change experiments performed with the CCSM3 will continue to constitute a major resource for analysis of aspects of climate change for the next several years, as will the multi-model dataset of which CCSM3 is a part (maintained at PCMDI, and analysis projects will continue to be registered by the WGCM Climate Simulation Panel for the foreseeable future)


CCSM3 SRES A1B simulation: 2080-2099 minus 1980-1999
No of days with precipitaiton greater than or equal to 10 mm/day
90N
60N
30N
0
30S
60S
90S
0
30E
60E
90E
120E
150E
180
150W
120W
90W
60W
30W
0
-4 -3.5 -3 -2.5 -2 -1.5 -1 -0.5 0 0.5 1 1.5 2 2.5 3 3.5 4
days

Chapter 10: Global Climate Projections

Coordinating Lead Authors: Gerald Meehl (USA), Thomas Stocker (Switzerland)

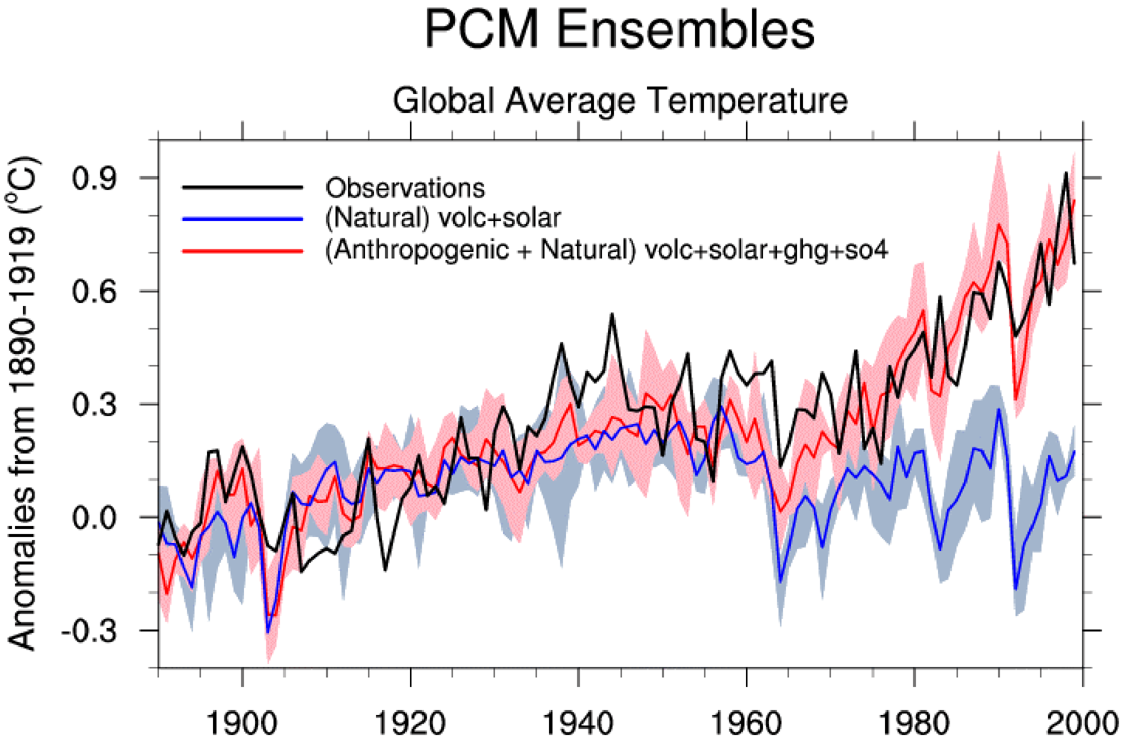
Lead Authors: William Collins (USA), Pierre Friedlingstein (France), Amadou Thierno Gaye (Senegal), Jonathan Gregory (United Kingdom), Akio Kitoh (Japan), Reto Knutti (Switzerland), James Murphy (United Kingdom), Akira Noda (Japan), Sarah Raper (Germany), Ian Watterson (Australia), Andrew Weaver (Canada), Zong-Ci Zhao (China)

Review Editors: Myles Allen (United Kingdom), Govind Ballabh Pant (India)

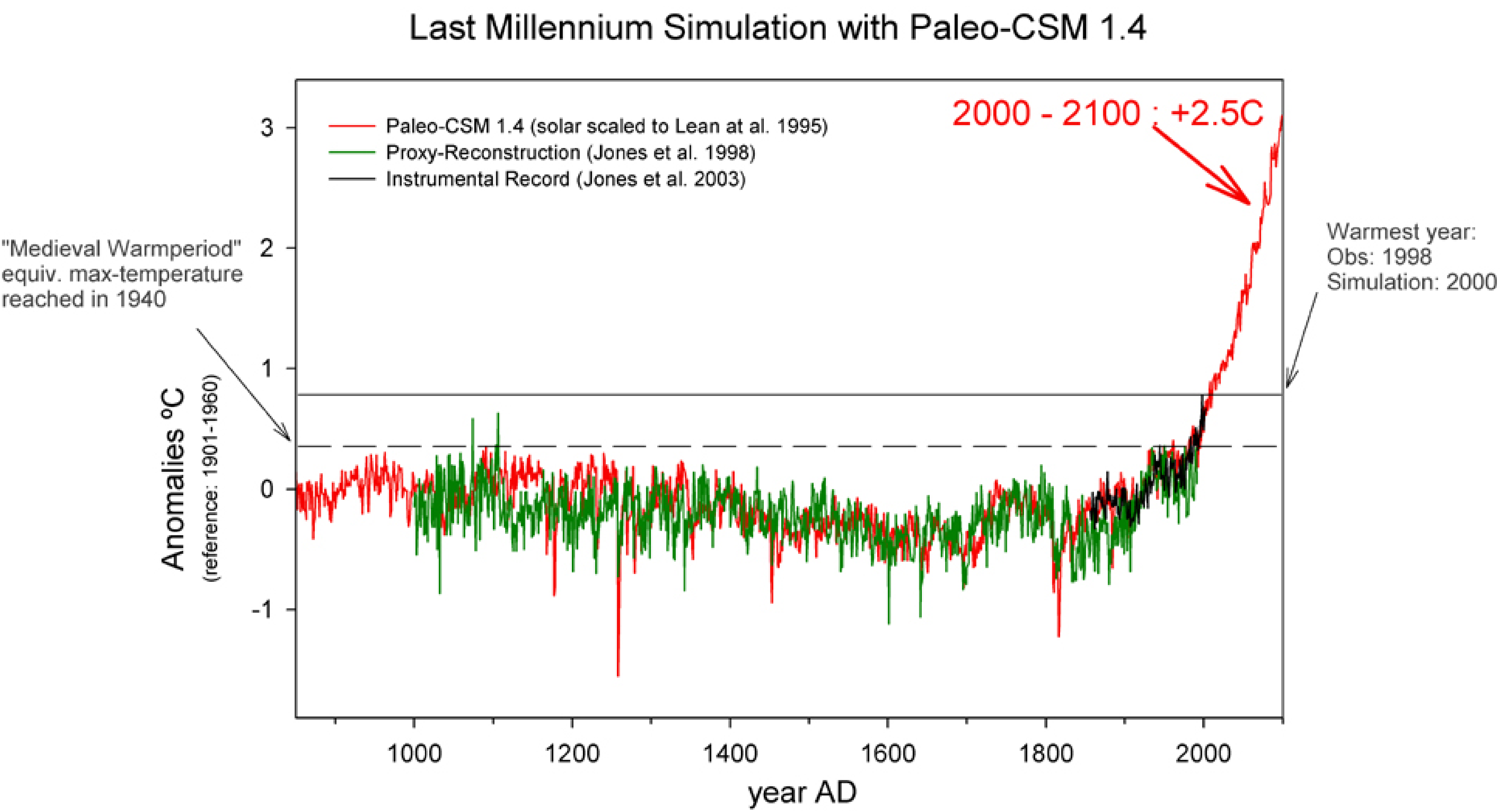
Natural forcings do not fully explain observed late 20th century warming

(uncertainty in climate model response is reduced by demonstrating that 20th century temperatures are directly related to the relevant forcings)

- Climate models with only “natural” forcings (volcanic and solar) do not reproduce observed late 20th century warming
- When increases in anthropogenic greenhouse gases and sulfate aerosols are included, models are able reproduce observed late 20th century warming



Meehl, G.A., W.M. Washington, C. Ammann, J.M. Arblaster, T.M.L. Wigley, and C. Tebaldi, 2004: Combinations of natural and anthropogenic forcings and 20th century climate. J. Climate, 17, 3721-3727.


Last Millennium Simulation with Paleo-CSM 1.4
Paleo-CSM 1.4 (solar scaled to Lean at al. 1995)
Proxy-Reconstruction (Jones et al. 1998)
Instrumental Record (Jones et al. 2003)
2000 - 2100 : +2.5C
"Medieval Warmperiod" equiv. max-temperature reached in 1940
Warmest year: Obs: 1998 Simulation: 2000
Anomalies °C
(reference: 1901-1960)
year AD
3
2
1
0
-1
1000
1200
1400
1600
1800
2000

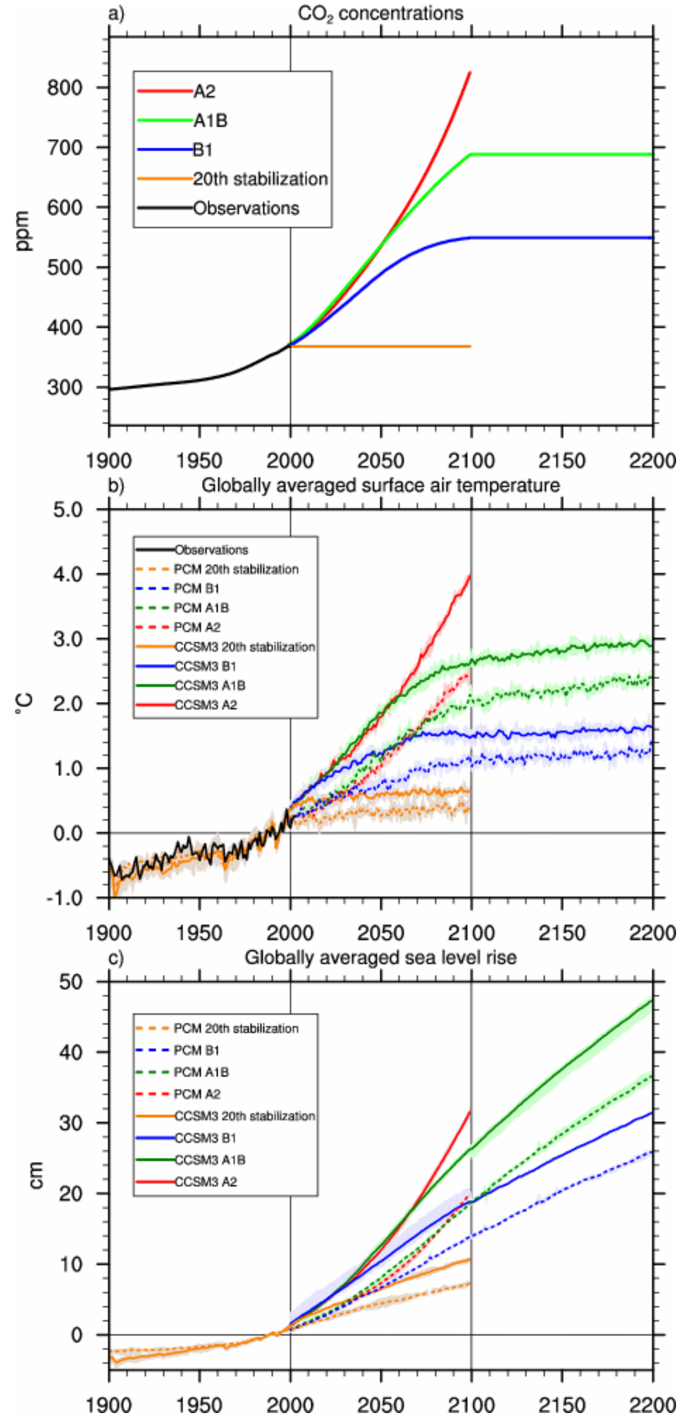
Ch. 10: Global Climate Projections

What's new?

1. Climate change commitment a major new theme in the multi-model experiments
2. Additional understanding and quantification of uncertainty — e.g. parameter uncertainty, forcing uncertainty
3. More quantitative estimates of climate sensitivity and TCR (range and probabilities)
4. More multi-model results and multi-member ensembles (probabilistic estimates of climate change)
5. More results on extremes

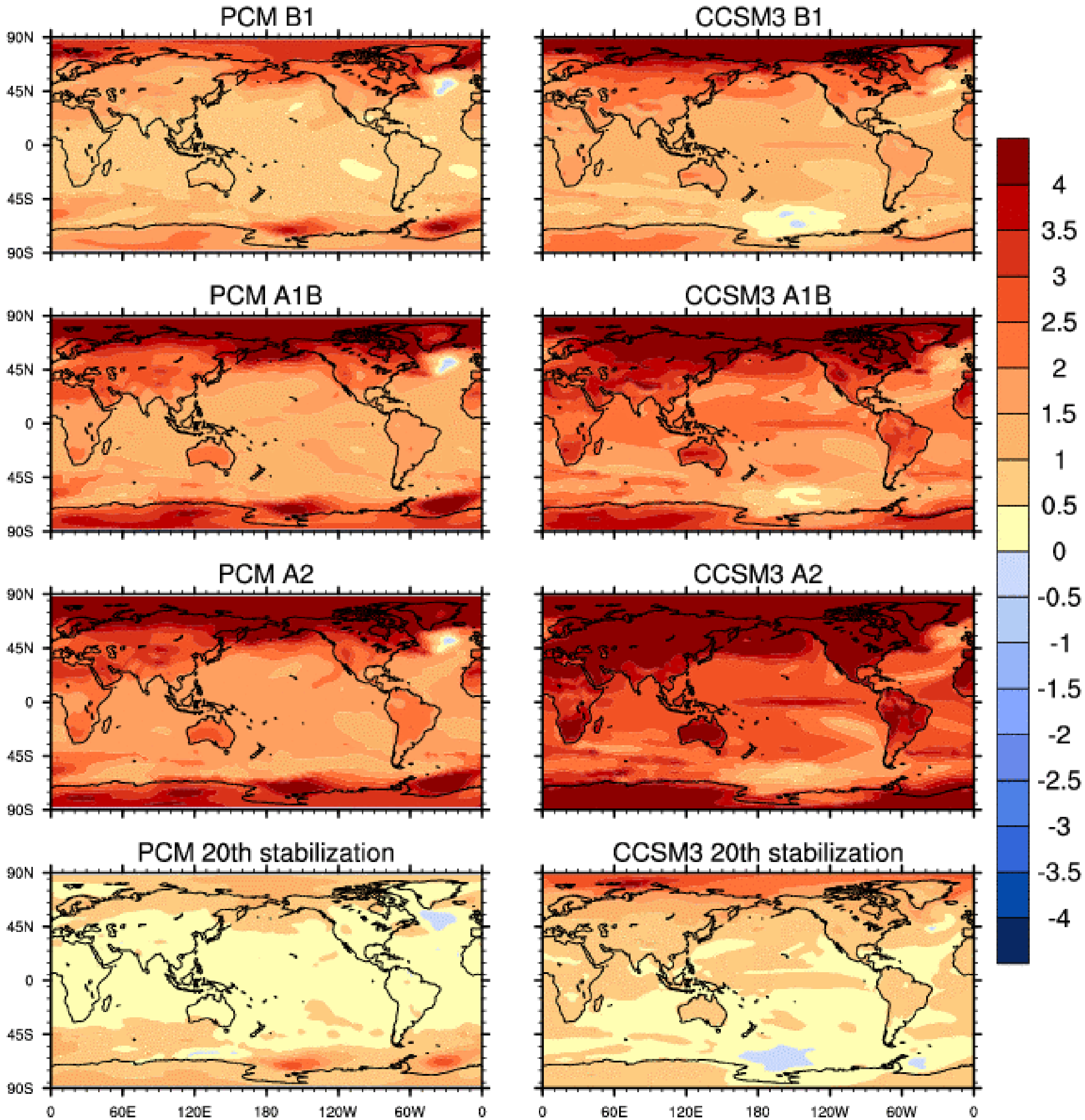
Climate change commitment: at any point in time, we are committed to additional warming and sea level rise from the radiative forcing already in the system

(Meehl et al., 2005: How much more warming and sea level rise? *Science*, **307**, 1769—1772)



2080-2099

difference in temperature



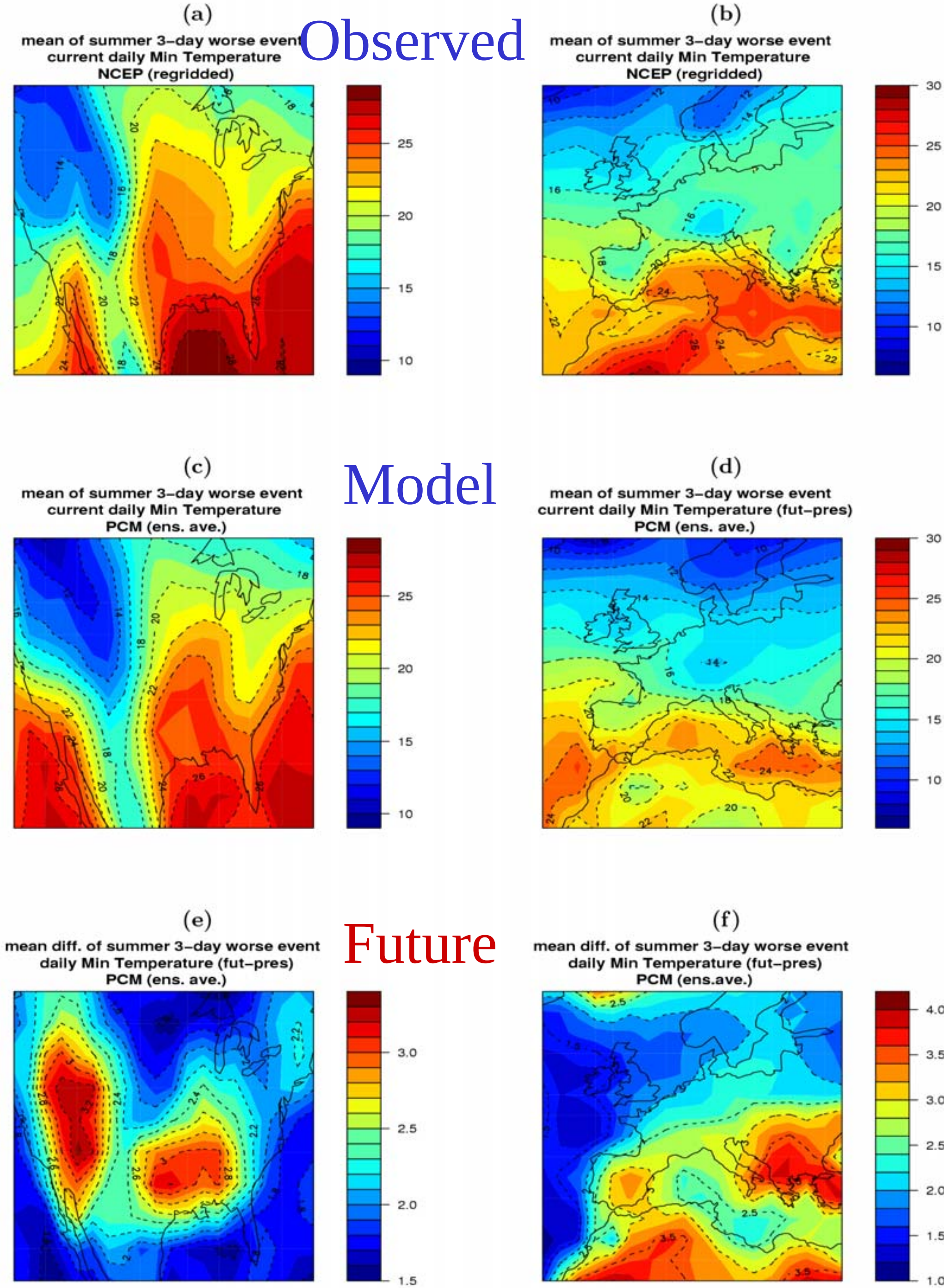
Climate models can be used to provide information on changes in extreme events such as heat waves

Heat wave severity defined as the mean annual 3-day warmest nighttime minima event

Model compares favorably with present-day heat wave severity

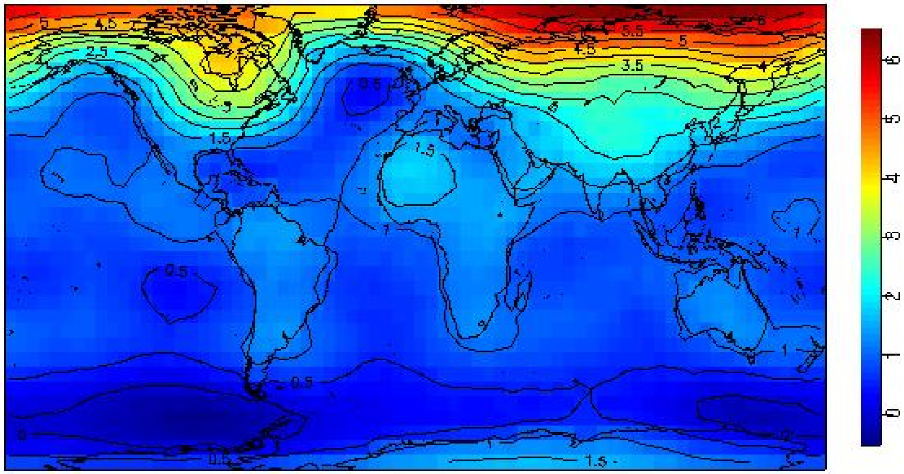
In a future warmer climate, heat waves become more severe in southern and western North America, and in the western European and Mediterranean region

Meehl, G.A., and C. Tebaldi, 2004: More intense, more frequent and longer lasting heat waves in the 21st century. *Science*, **305**, 994--997.

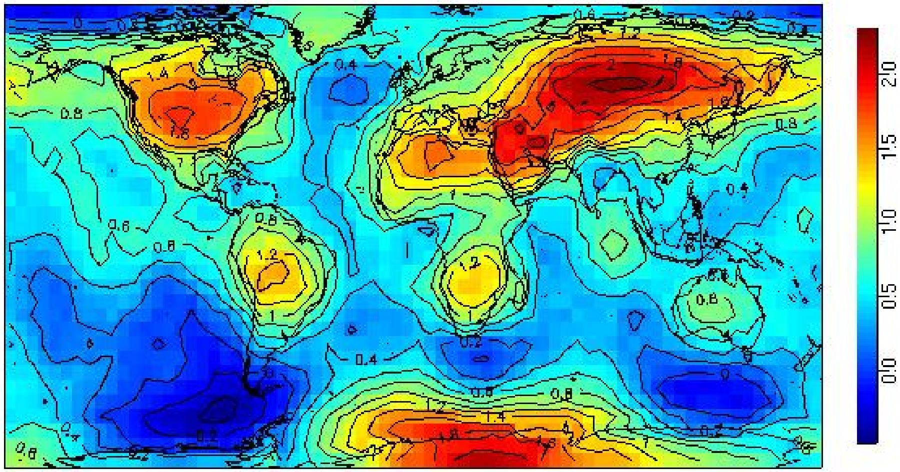


80% probability of at least this surface temperature change from 9 models for $2XCO_2$:

DJF Temperature change delta such that P{X>delta}=.8

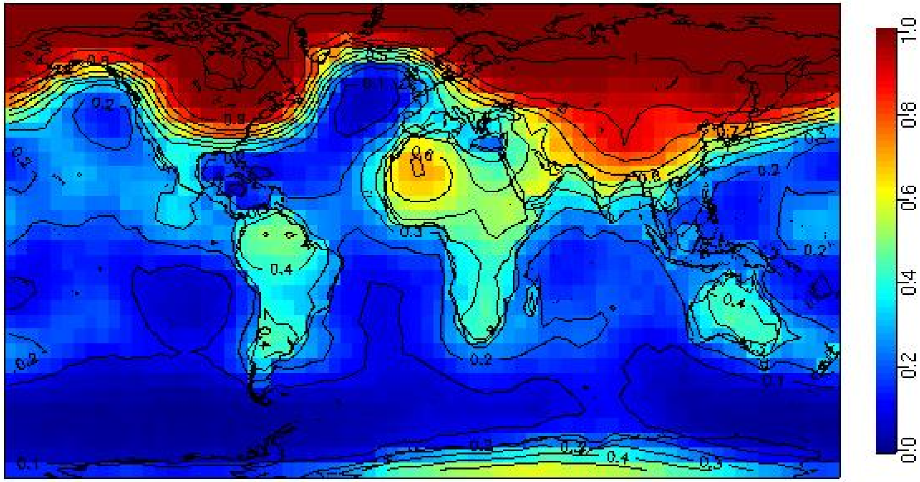


JJA Temperature change delta such that P{X>delta}=.8

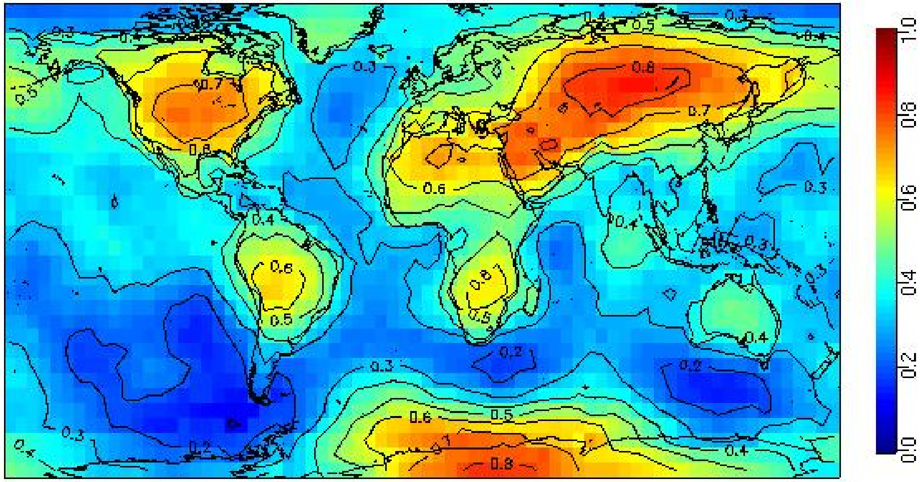


probability of temperature change exceeding 2°C from 9 models for $2XCO_2$:

Probability that DJF temperature exceeds 2 degrees C



Probability that JJA temperature exceeds 2 degrees C

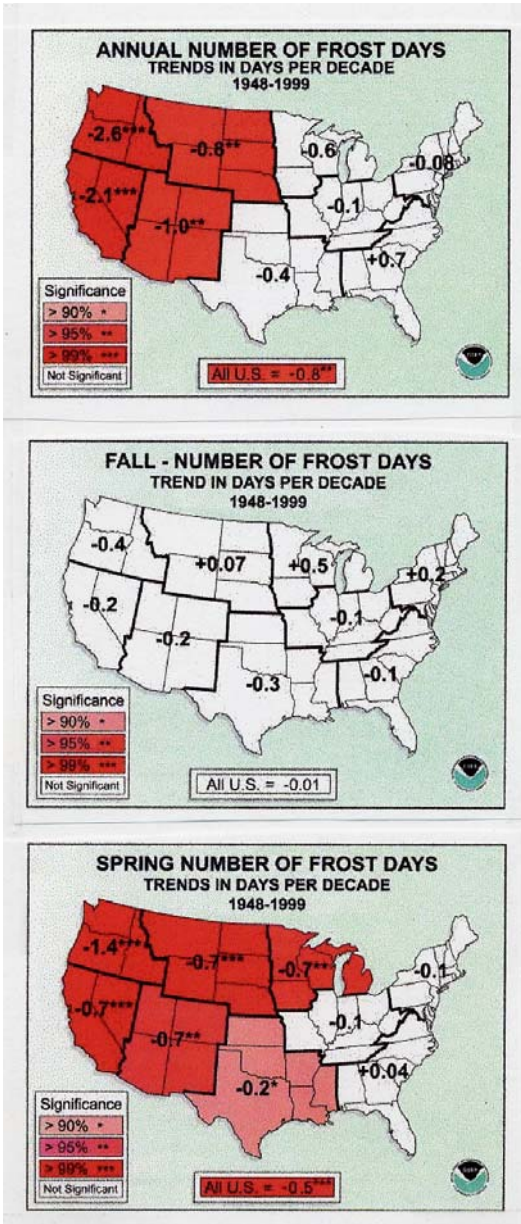


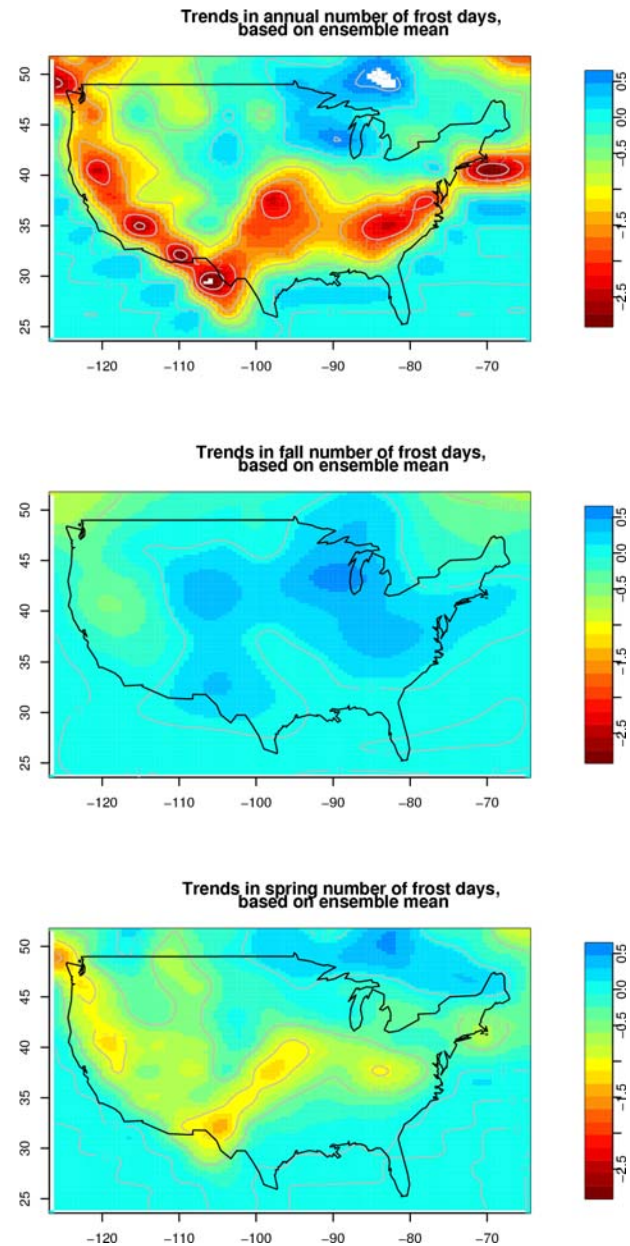
(from Furrer et al., 2005)

Summary

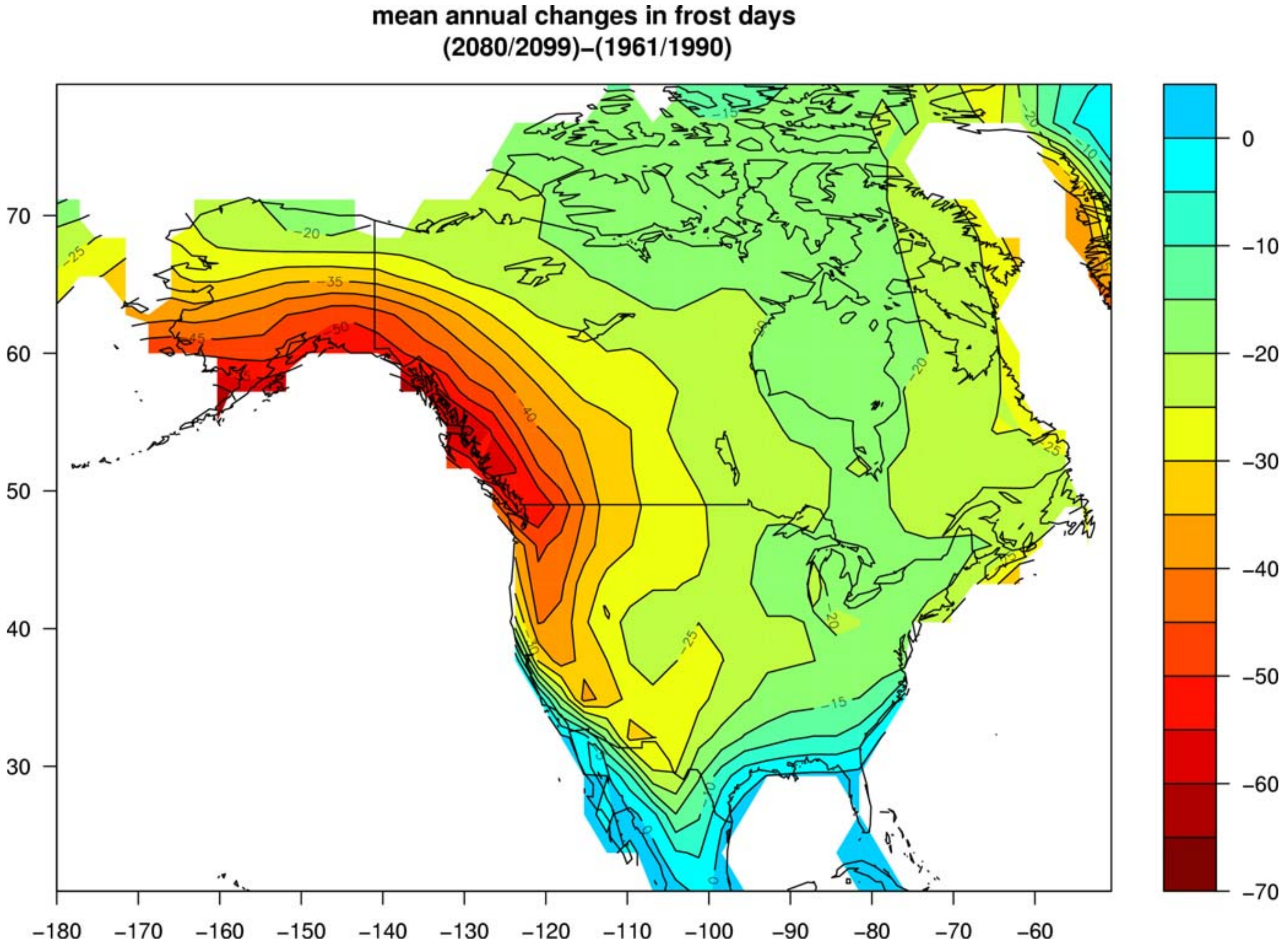
1. IPCC AR4 is underway, with eventual publication in spring, 2007
2. For Ch. 10 as an example, climate change commitment is a major new theme in multi-model experiments
3. Additional understanding and quantification of uncertainty —e.g. parameter uncertainty, forcing uncertainty
4. More quantitative estimates of climate sensitivity and TCR (range and probabilities)
5. More multi-model results and multi-member ensembles (probabilistic estimates of climate change)
6. More results on extremes

Changes in frost days in the late 20th century show biggest decreases over the western and southwestern U.S. in observations and the model



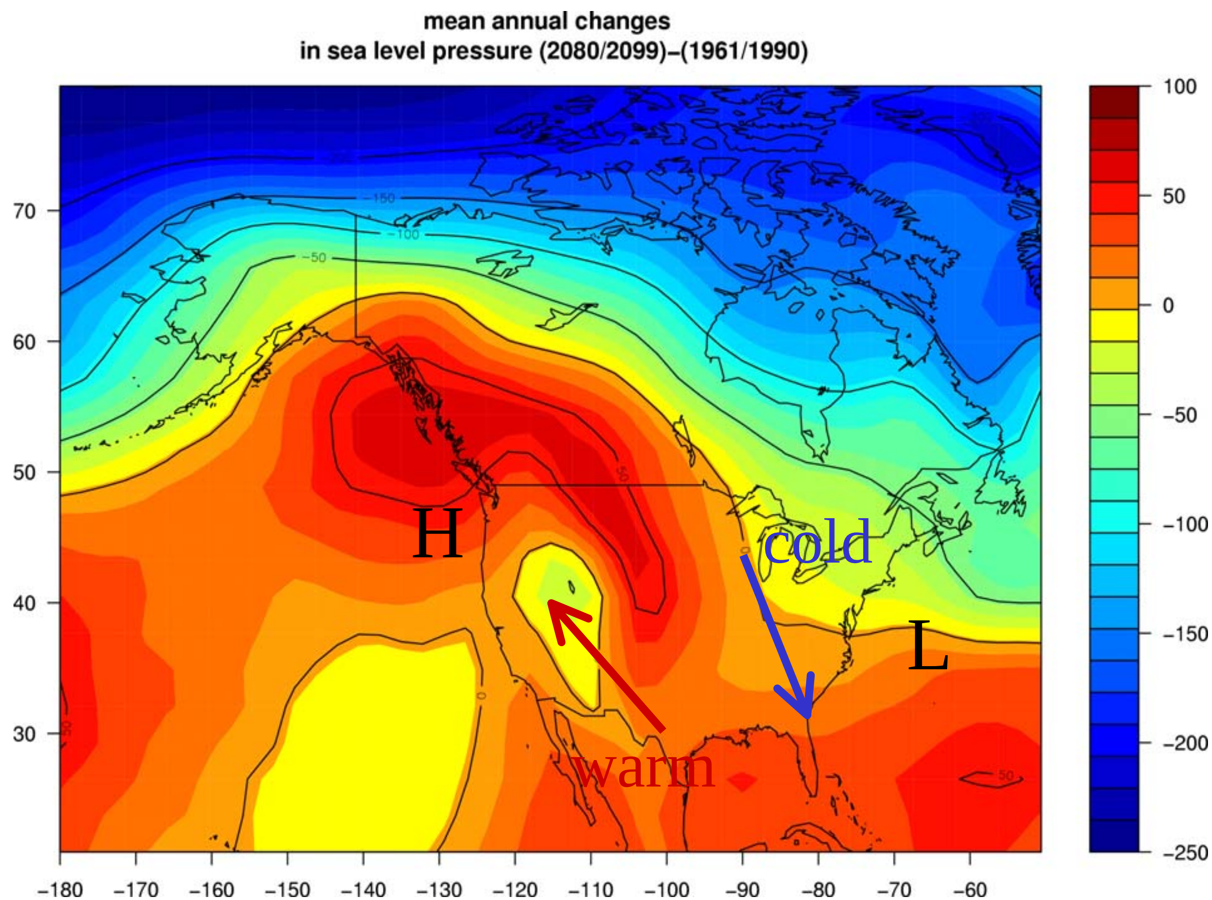


Future changes in frost days from the climate model show greatest decreases in the western and southwestern U.S., similar to late 20th century



Large-scale changes in atmospheric circulation affect regional pattern of changes in future frost days

Anomalous ridge of high pressure brings warmer air to northwestern U.S.causing relatively less frost days compared to the northeastern U.S. where an anomalous trough brings colder air from north



(Meehl, Tebaldi and Nychka, 2004: Changes in frost days in simulations of twentyfirst century climate, *Climate Dynamics*, 23, 495--511)

"…the previous estimated range for [equilibrium climate sensitivity], widely cited as +1.5 to +4.5°C, still encompasses the more recent model sensitivity estimates."

"The range of transient climate response for current AOGCMs is +1.1 to +3.1°C"

---IPCC Third Assessment Report, 2001

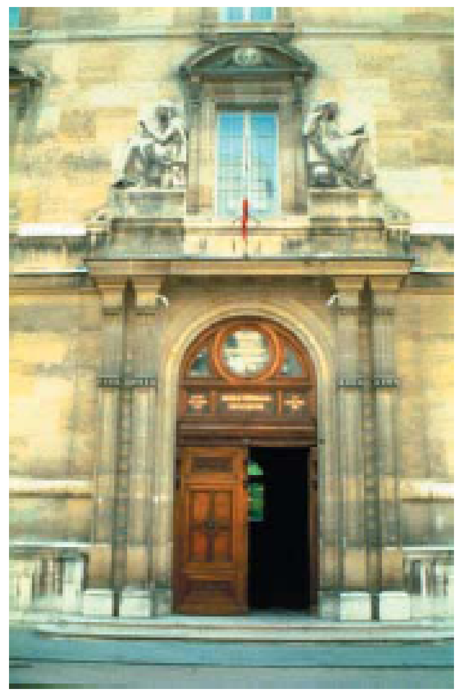
INTERGOVERNMENTAL PANEL ON CLIMATE CHANGE

WMO

UNEP

IPCC Working Group I

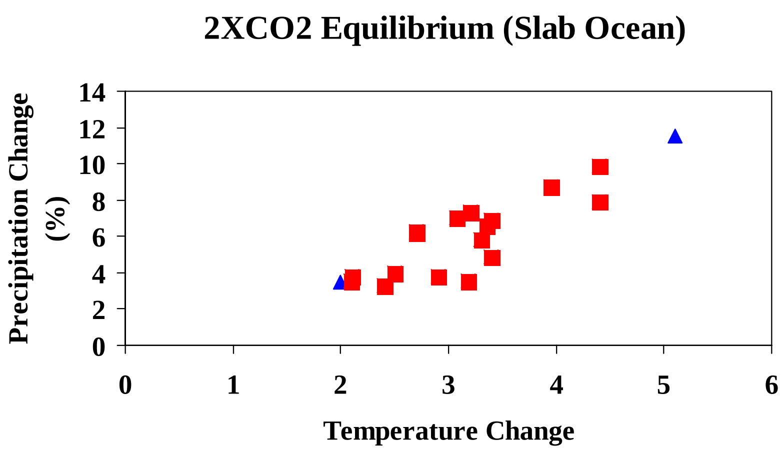
Workshop on Climate Sensitivity



École Normale Supérieure
Paris, France
26–29 July, 2004

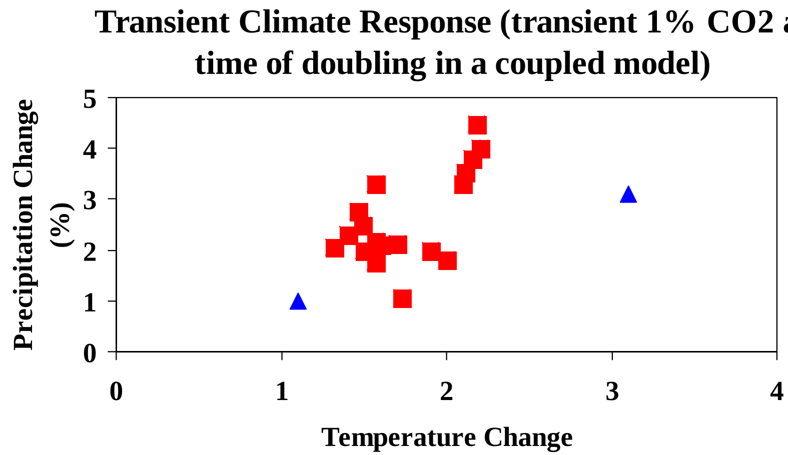
Equilibrium climate sensitivity from 17 models currently in use for the IPCC AR4

blue triangles = range of models in TAR (2.0-5.1C)
red squares = current models



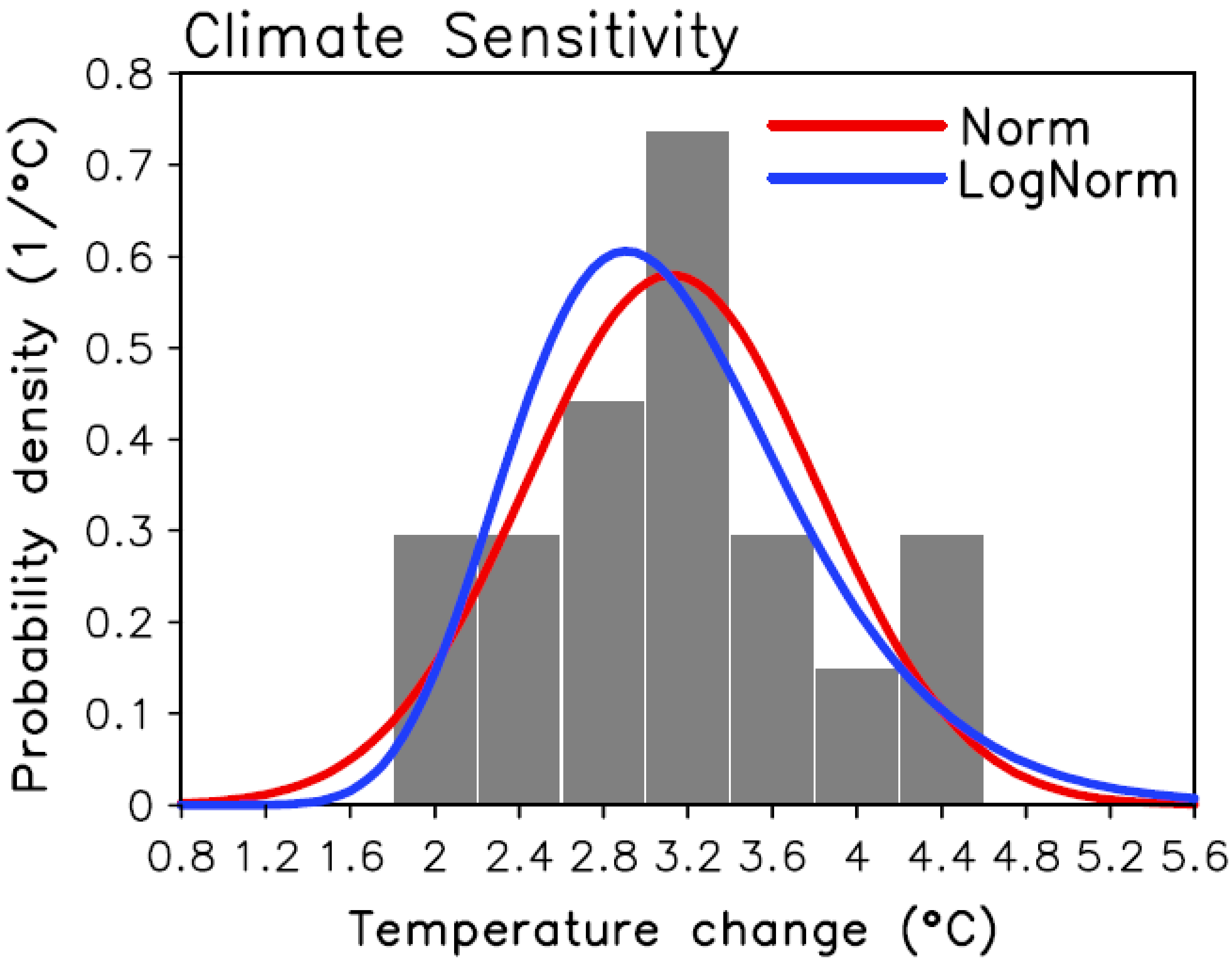
Transient climate response (TCR) from 17 models

blue triangles = range of models in TAR (1.1-3.1C)
red squares = current models

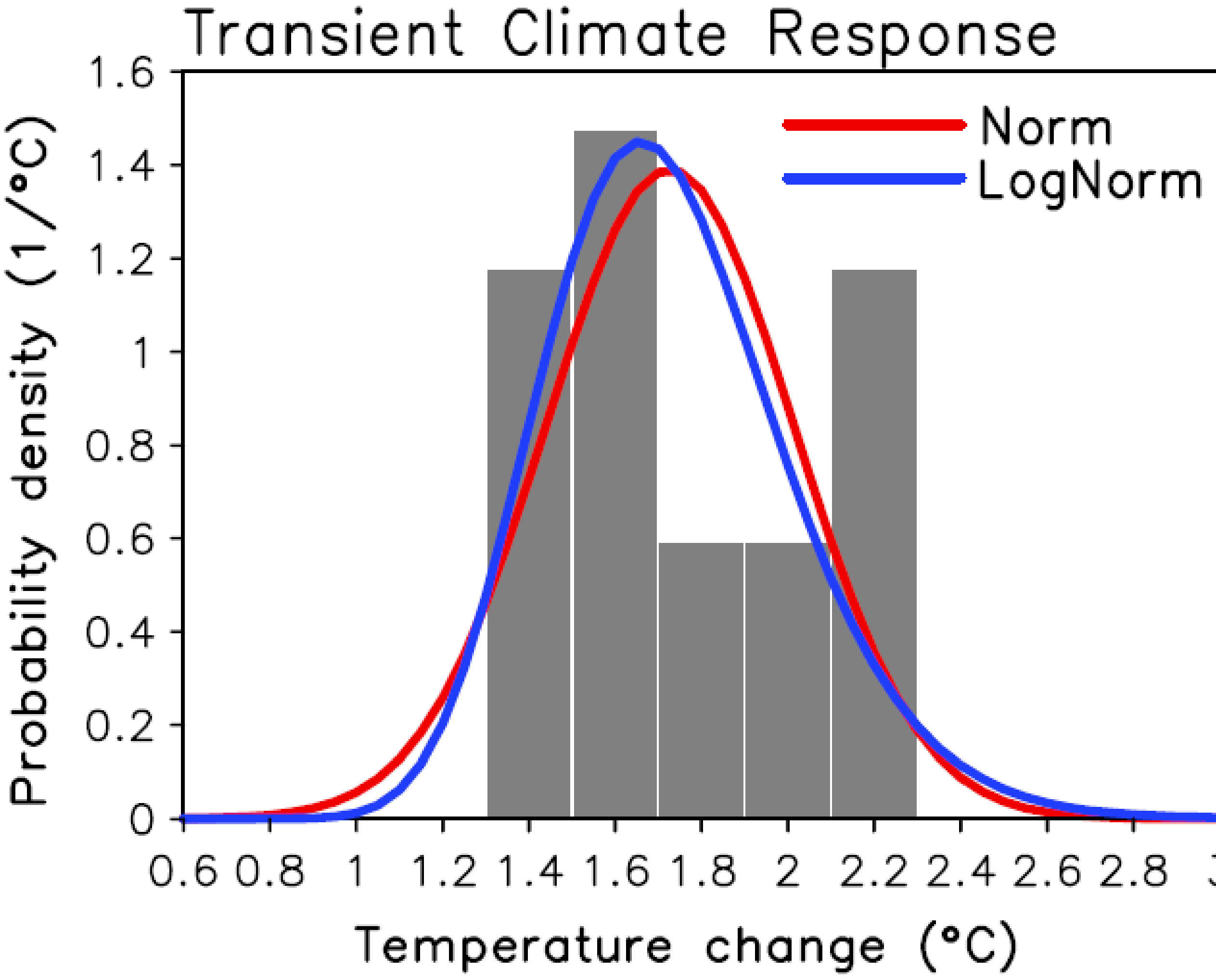


Based on 17 AOGCMs currently in use for the IPCC AR4:

The 5-95% uncertainty range for equilibrium climate sensitivity is 2.0-4.4ºC, with median value of 3.1ºC

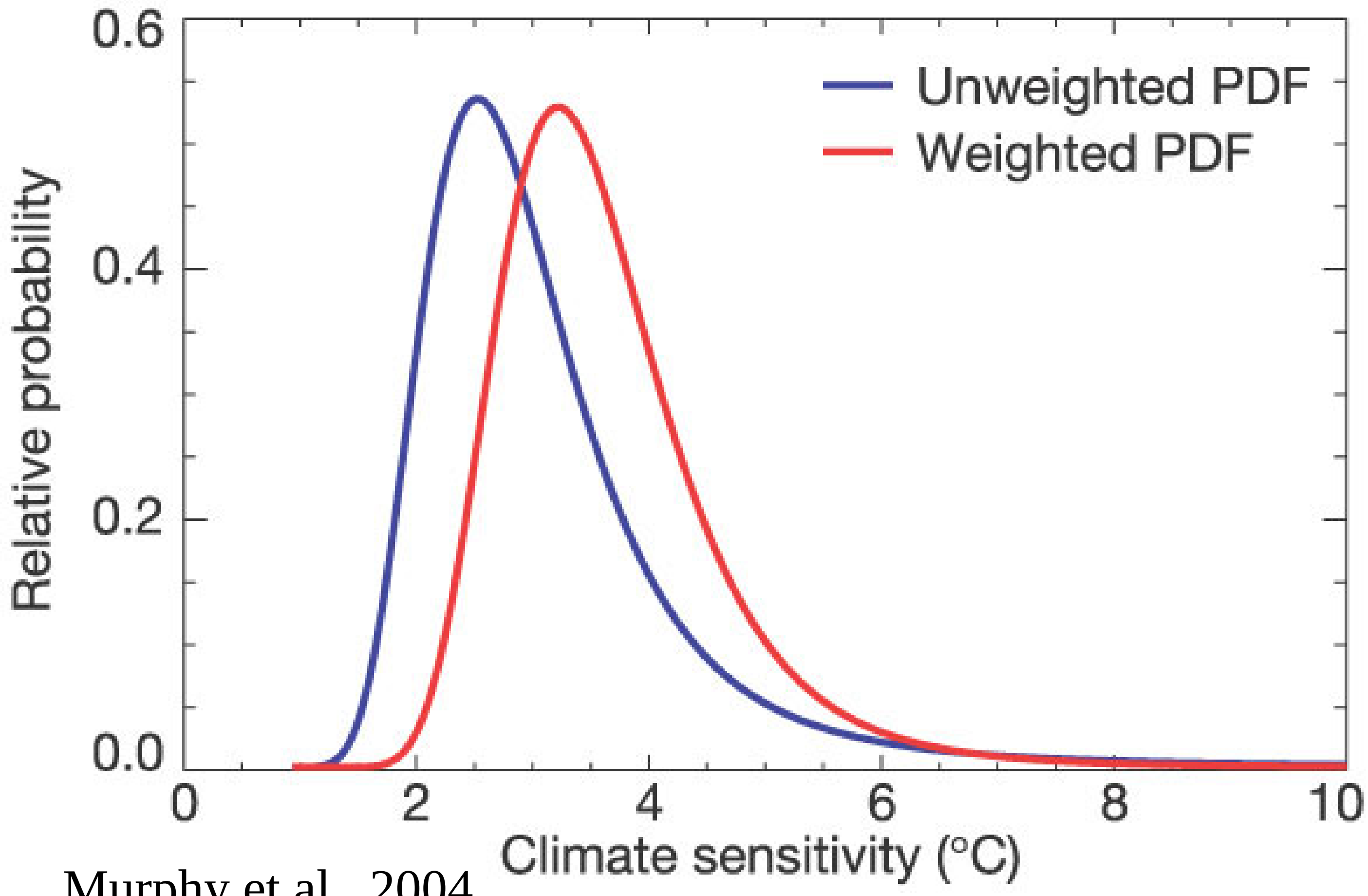


The 5-95% uncertainty range for TCR 1.3-2.2ºC, with a median value of 1.7ºC



Equilibrium climate sensitivity from a large number of perturbed parameter ensembles

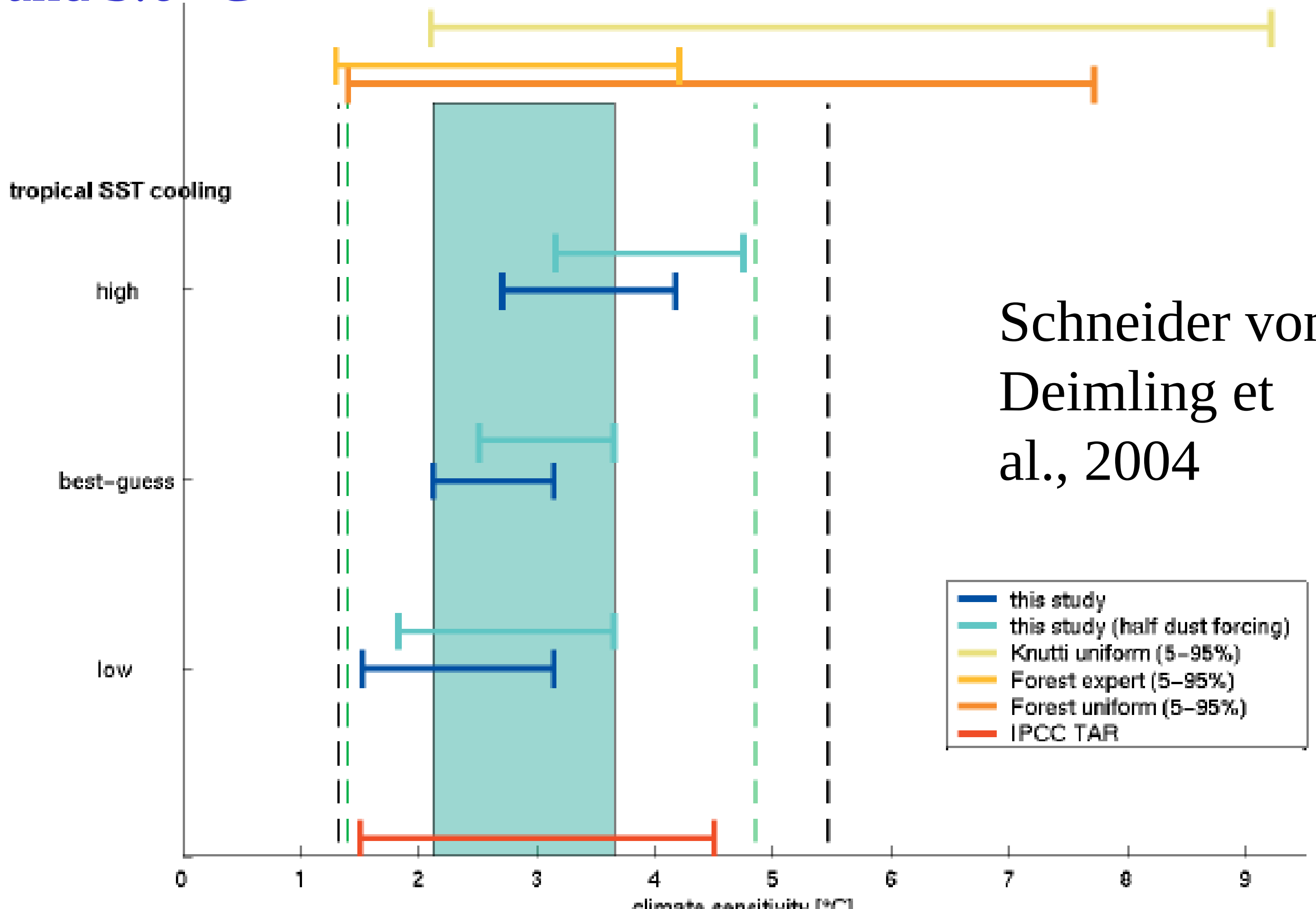
Weighted: 5% - 95% range: 2.4° - 5.4 °C, median: 3.5 °C



Murphy et al., 2004

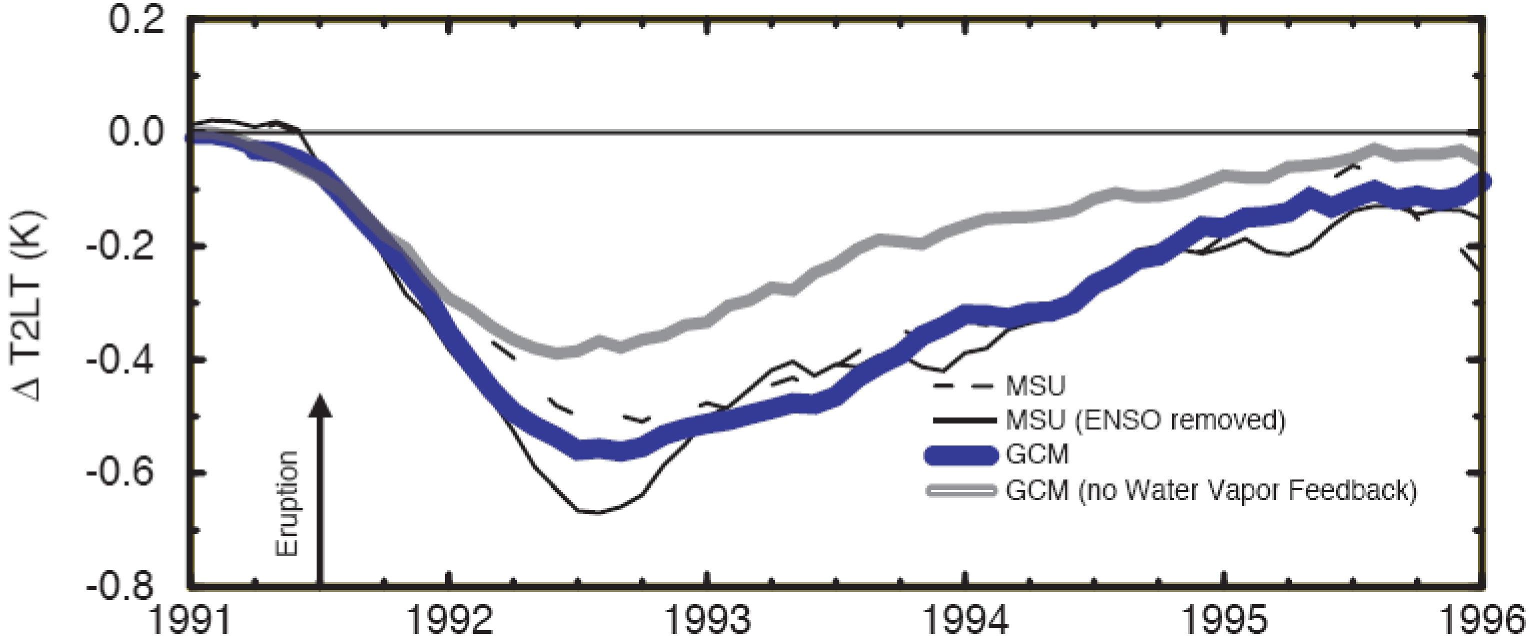
Climate sensitivity from LGM paleoclimate simulations

Using estimates of tropical cooling and multiple climate model simulations, estimate equilibrium climate sensitivity 5% to 95% range of 1.5 ° to 4.7 °C, with best guess between 2.1 ° and 3.6 °C



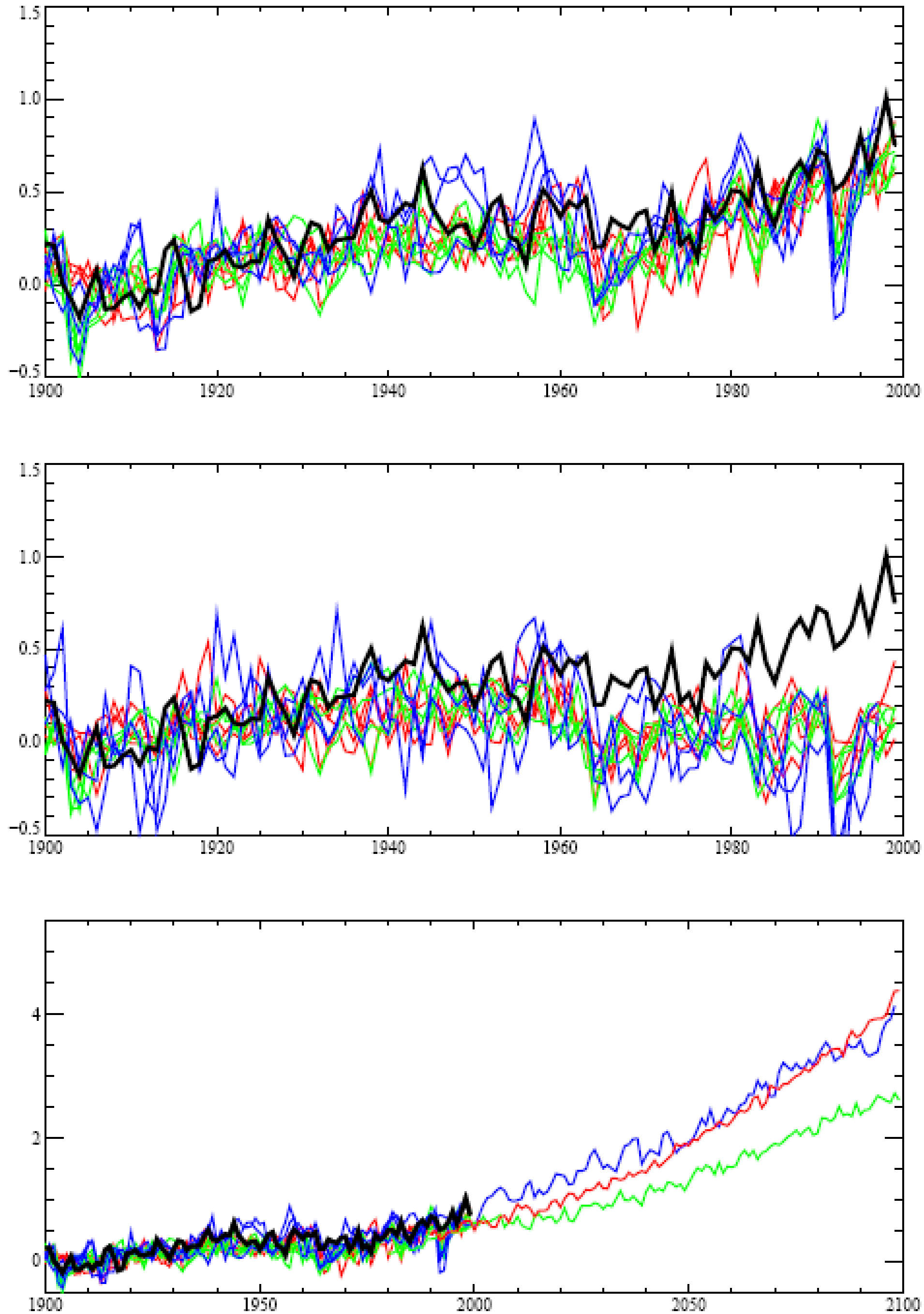
Schneider von Deimling et al., 2004

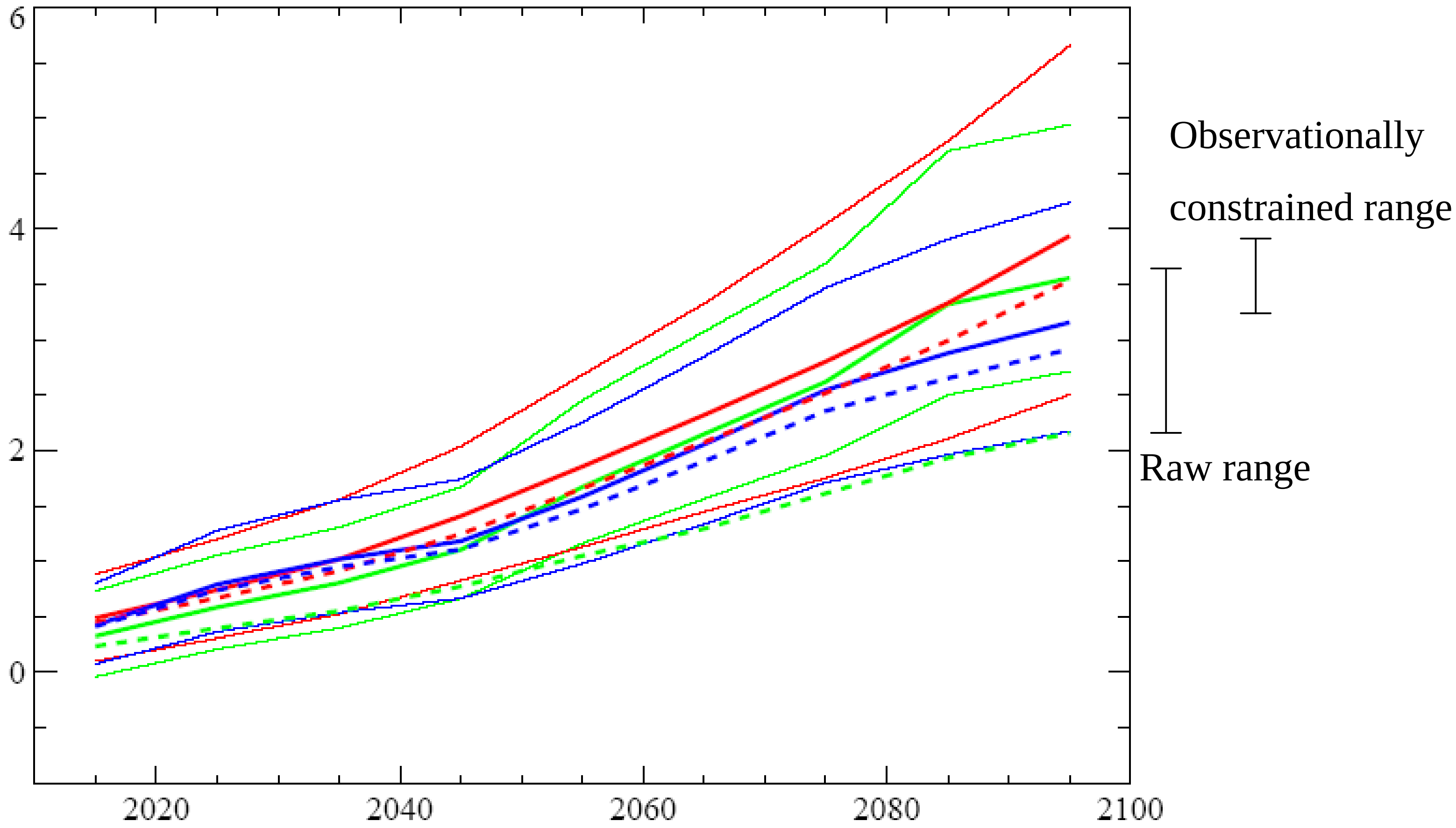
A climate model that can accurately simulate response to Pinatubo eruption has an equilibrium climate sensitivity of about 3.1ºC



Soden et al., 2002

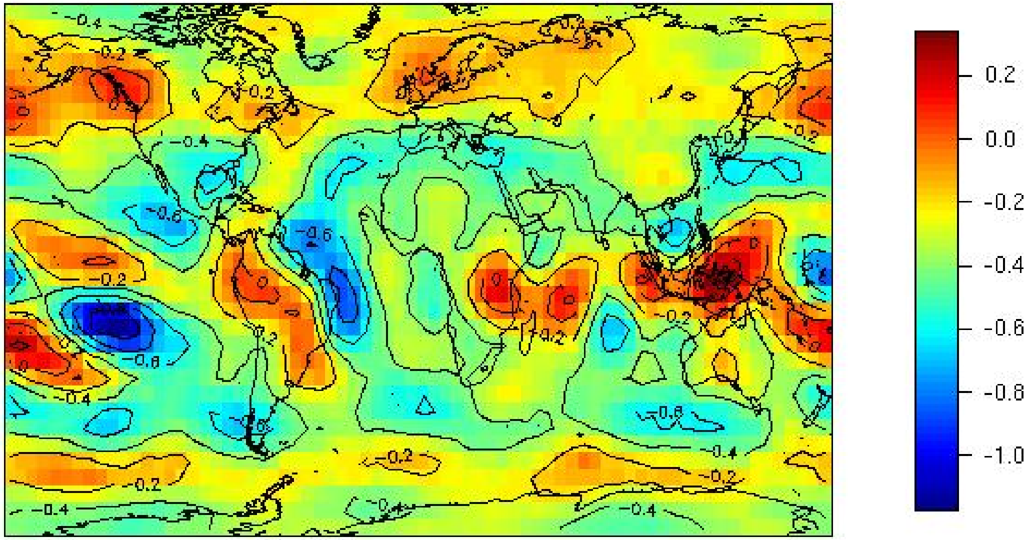
Globally averaged surface temperature time series from three models (PCM, GFDL, HadCM3) for multiple forcings (top), natural forcings only (middle), and simulations with A2 scenario to 2100 (from Stott et al., 2005)



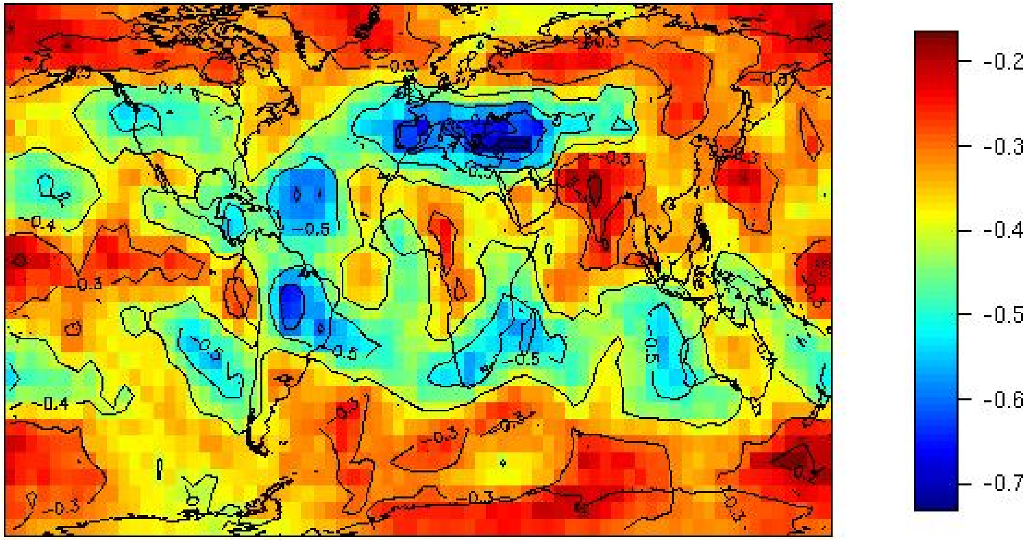


Globally averaged surface temperatures for A2 from three models for raw projections (dashed), best fit observationally constrained projections (thick solid), and 5 to 95 percentile uncertainty ranges (thin solid) from Stott et al. (2005)

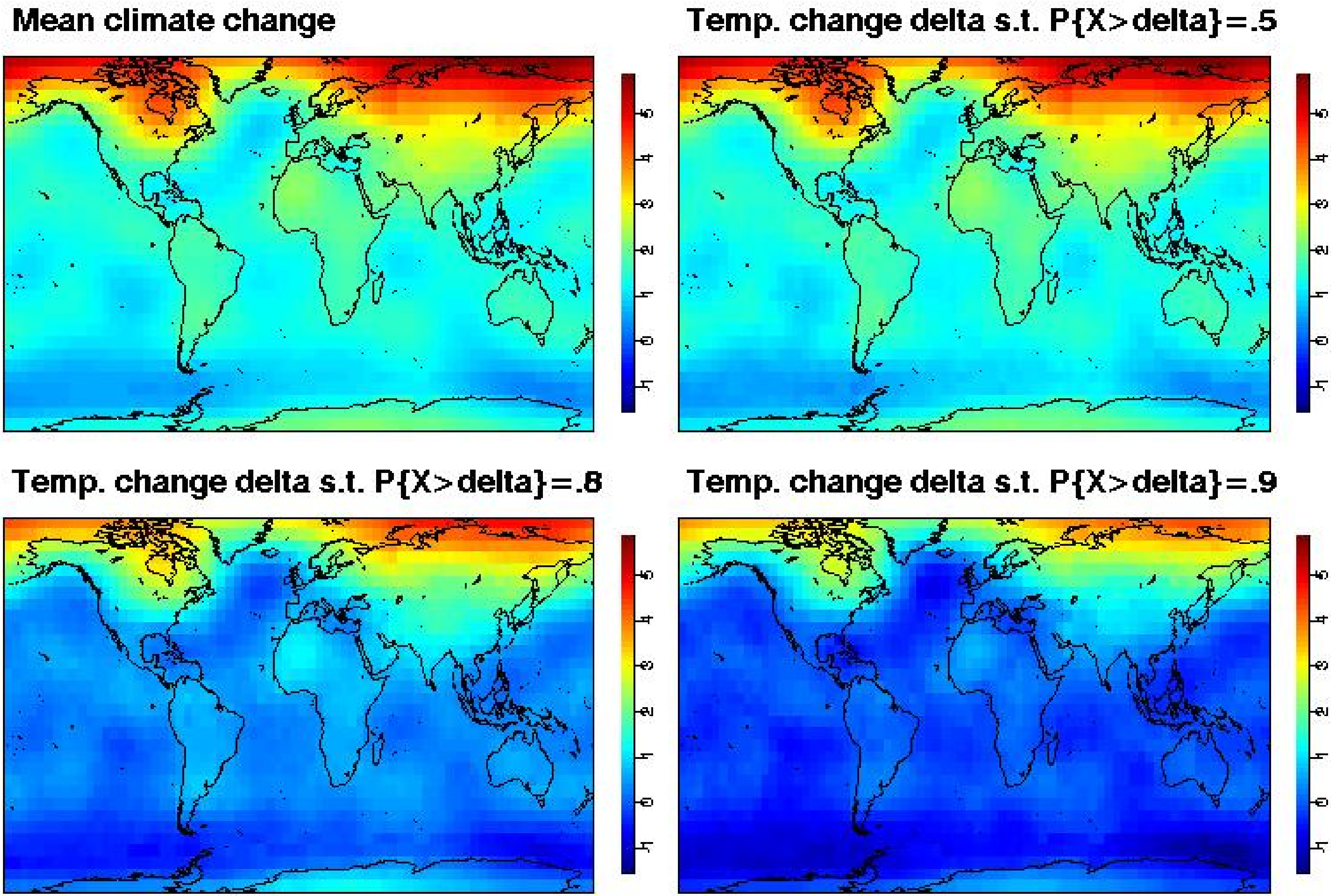
DJF precipitation change delta such that P{X>delta}=.8



JJA precipitation change delta such that P{X>delta}=.8



Probabilities of surface temperature change from 9 models for DJF



CCSP Synthesis and Assessment 3.1:

Climate models and their uses and limitations, including climate sensitivity, feedbacks, and uncertainty analysis

Lead and Supporting Agencies: DOE, NASA, NOAA, NSF

Agency Contacts:

Lead

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Focus on natural and human-caused factors influencing climate variability and change, ~1800 to 2000, and will characterize sources of uncertainties in comprehensive coupled climate models.

Audience: Climate model researchers, modelers from impacts community (prospectus up for public comment in next few days)

Specific questions to be addressed:

Q1: What are the major components and processes of the climate system that are included in present state-of-the-science climate models, and how do climate models represent these aspects of the climate system?

Q2: How are changes in the Earth's energy balance incorporated into climate models? How sensitive is the Earth's (modeled) climate to changes in the factors that affect the energy balance?

Q3: How uncertain are climate model results? In what ways has uncertainty in model-based simulation and prediction both increased and decreased over time with increased knowledge about the climate system?

Q4: How well do climate models simulate natural variability and how does variability change over time?

Q5: How well do climate models simulate regional climate variability and change?

Q6: What are the tradeoffs to be made in further climate model development (e.g., between increasing spatial/temporal resolution and representing additional physical/biological processes)?

Proposed Approach for Evaluation and Communication of Uncertainty and Confidence Levels of Climate Model Output

A central theme of this CCSP Product will be uncertainty and confidence levels of climate model output with respect to climate change and sea-level rise, caused by natural forces and human activities during the period 1800-2000.

Relationship to Other National and International Assessment Processes

This CCSP Product will build on previous IPCC assessments (e.g., First, Second, and Third Assessment Reports) and NRC reports (*e.g.*, Climate Change Science: an Analysis of Some Key Questions). It is expected that this CCSP Product will provide input to IPCC AR4 and to future NRC reports on climate models.

Summary

An IPCC workshop in Paris, 2004, was convened to address whether we could estimate climate sensitivity better than a simple range with all values having equal probability of occurrence

Compared to the TAR and previous IPCC assessments, in the AR4 there will be probabilistic estimates of equilibrium climate sensitivity and TCR with 5% to 95% uncertainty ranges and most probable values

These estimates will be based on current AOGCMs, large numbers of perturbed parameter ensembles, paleoclimate and observational (e.g. Pinatubo) analyses

In addition to IPCC, the CCSP reports will document various aspects of climate sensitivity and change. For example, CCSP Synthesis and Assessment 3.1 will address climate sensitivity, feedbacks and uncertainties (lead agency: DOE, supporting agencies: NASA, NOAA, NSF)

Based on 17 AOGCMs currently in use for the IPCC AR4:

The 5-95% uncertainty range for equilibrium climate sensitivity is 2.0-4.4ºC and that for TCR 1.3-2.2ºC.

The best (median) estimate for equilibrium climate sensitivity is 3.1ºC and that for TCR 1.7ºC.

Global Climate Sensitivity

Gerald A. Meehl

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