Image courtesy of NASA/GSFC

Current Efforts in Climate Forecasting and Modeling

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Greenhouse Gases, Carbon Taxes and Trading, and Carbon Sequestration

CHE 670 – Sustainability Seminar

Kansas State University

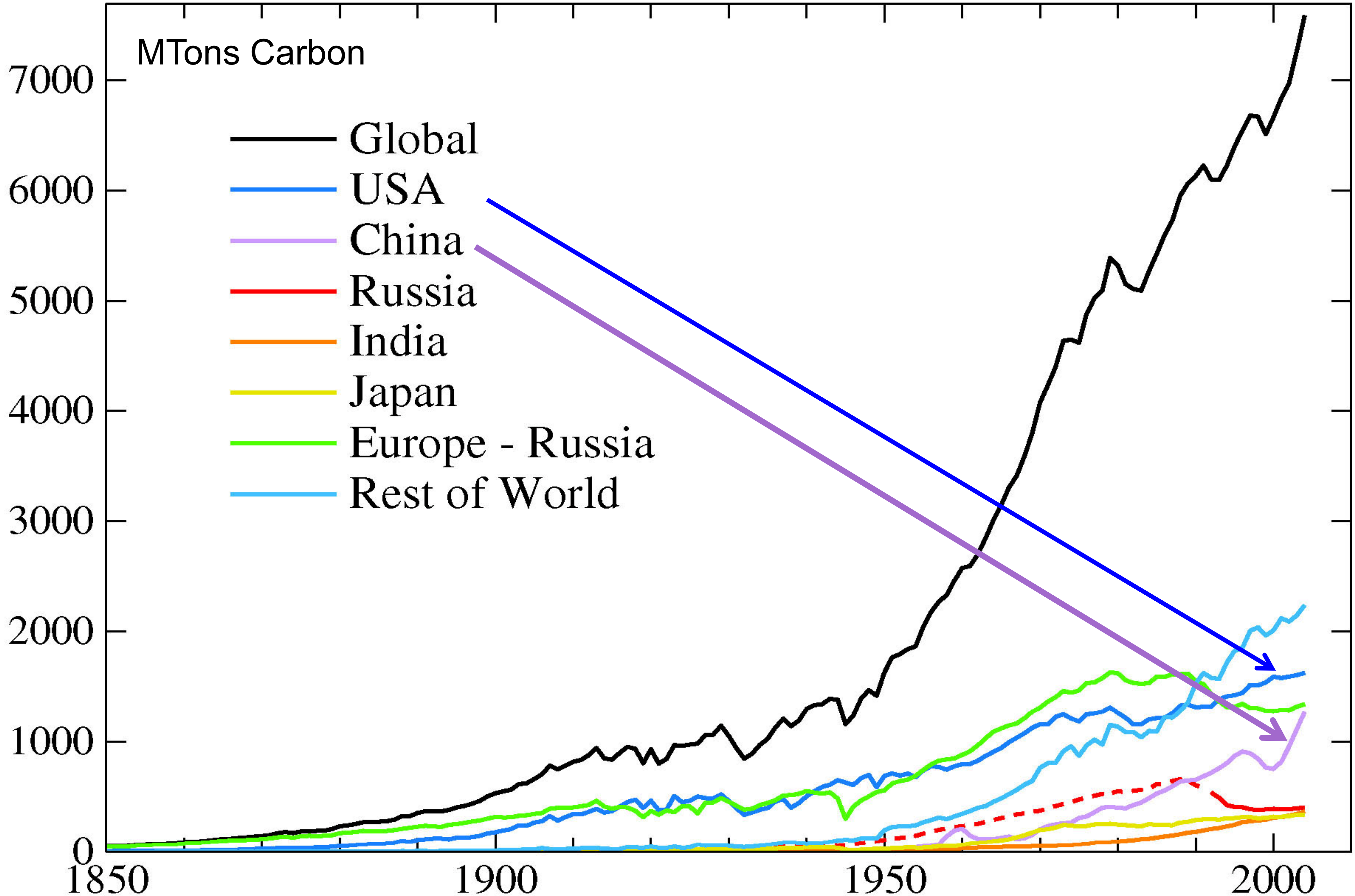
Manhattan, KS

6-8 Jan 2010

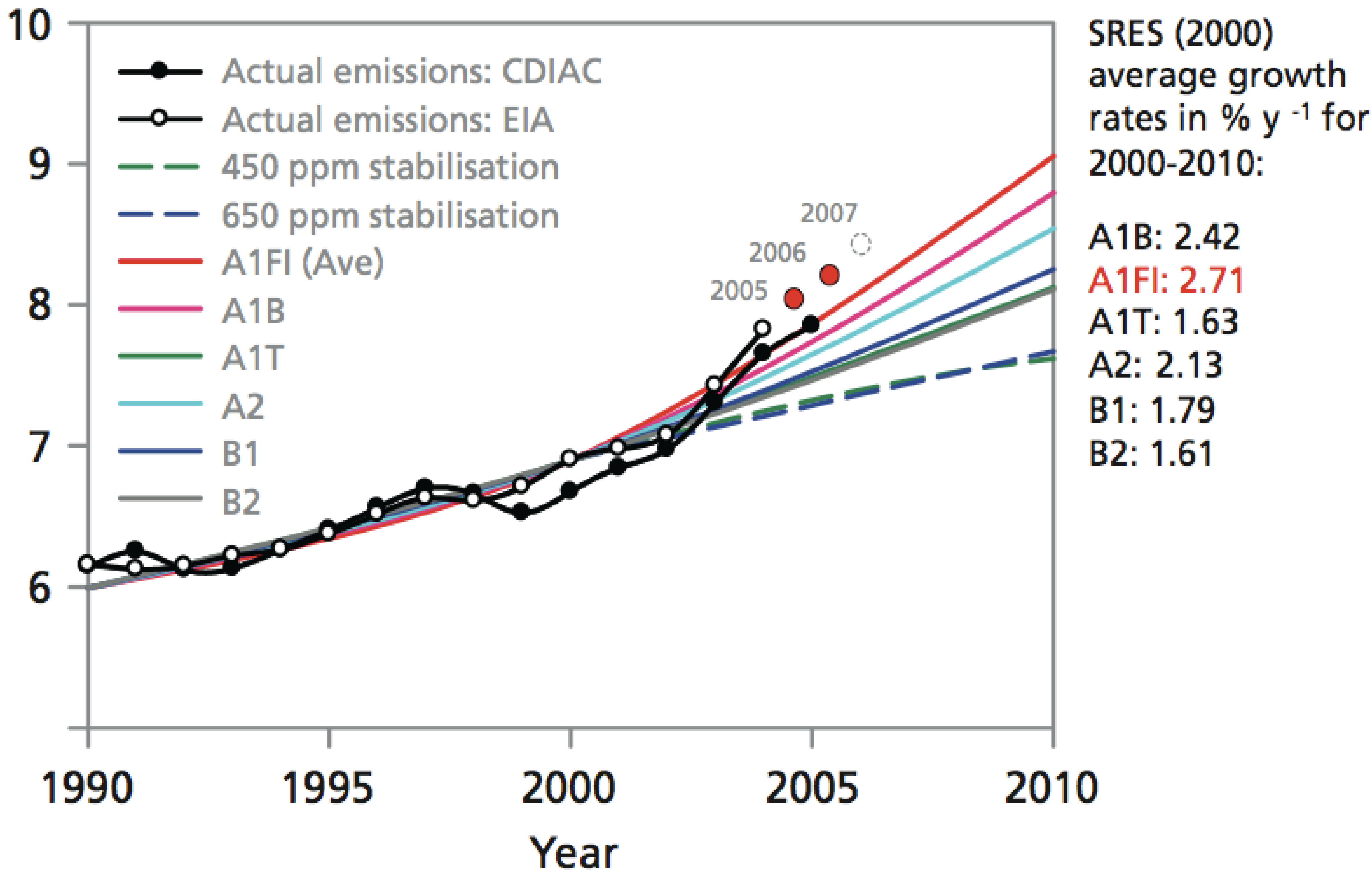
Outline

- Changes in atmospheric carbon dioxide
- Causes of climate change
- Changes in future climate around the globe
- Emission reductions to reach stabilization
- Climate change for the US Midwest

Country/Region Fossil Fuel CO_2 Annual Emissions

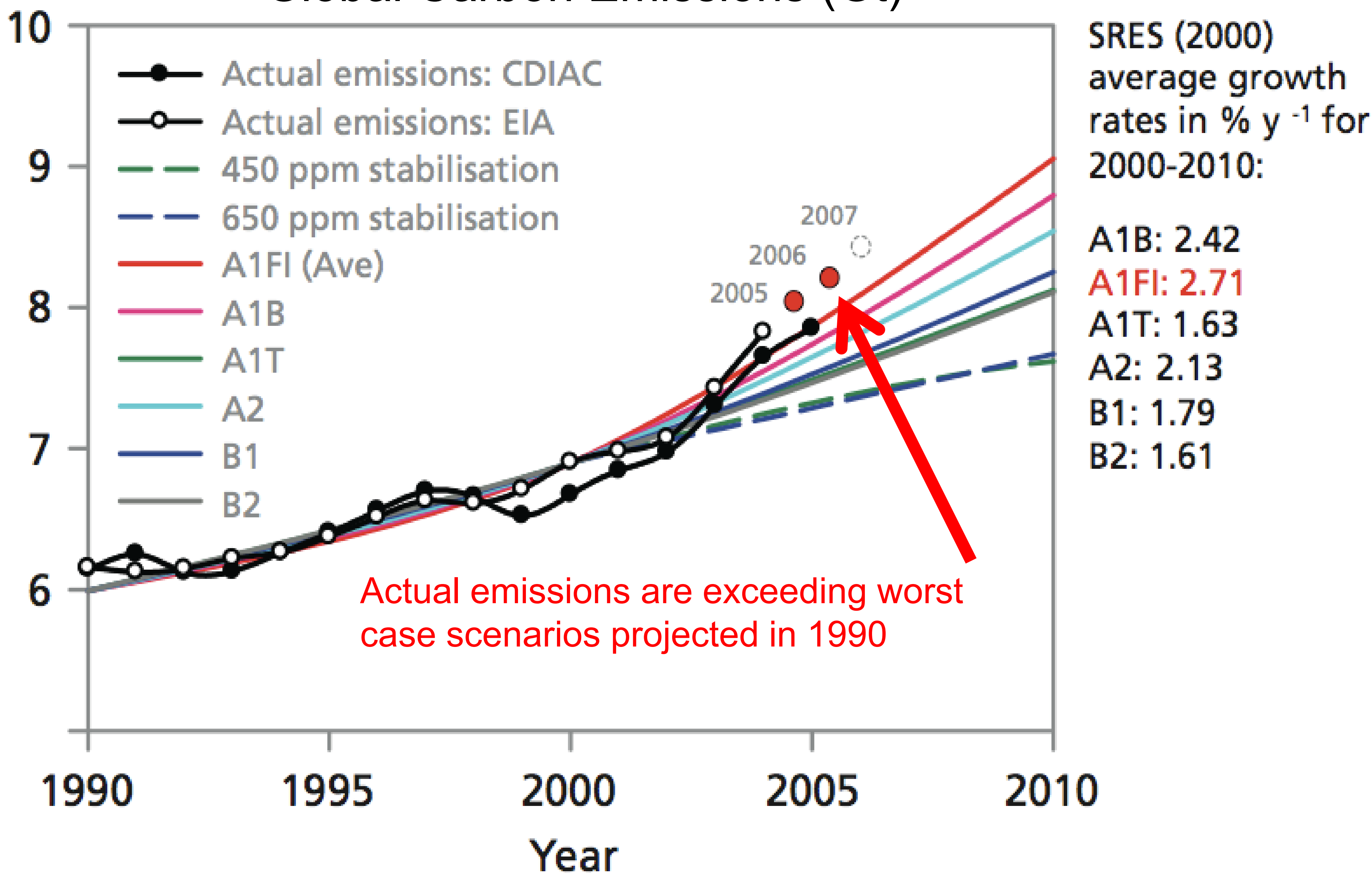


IPCC Third Assessment Report



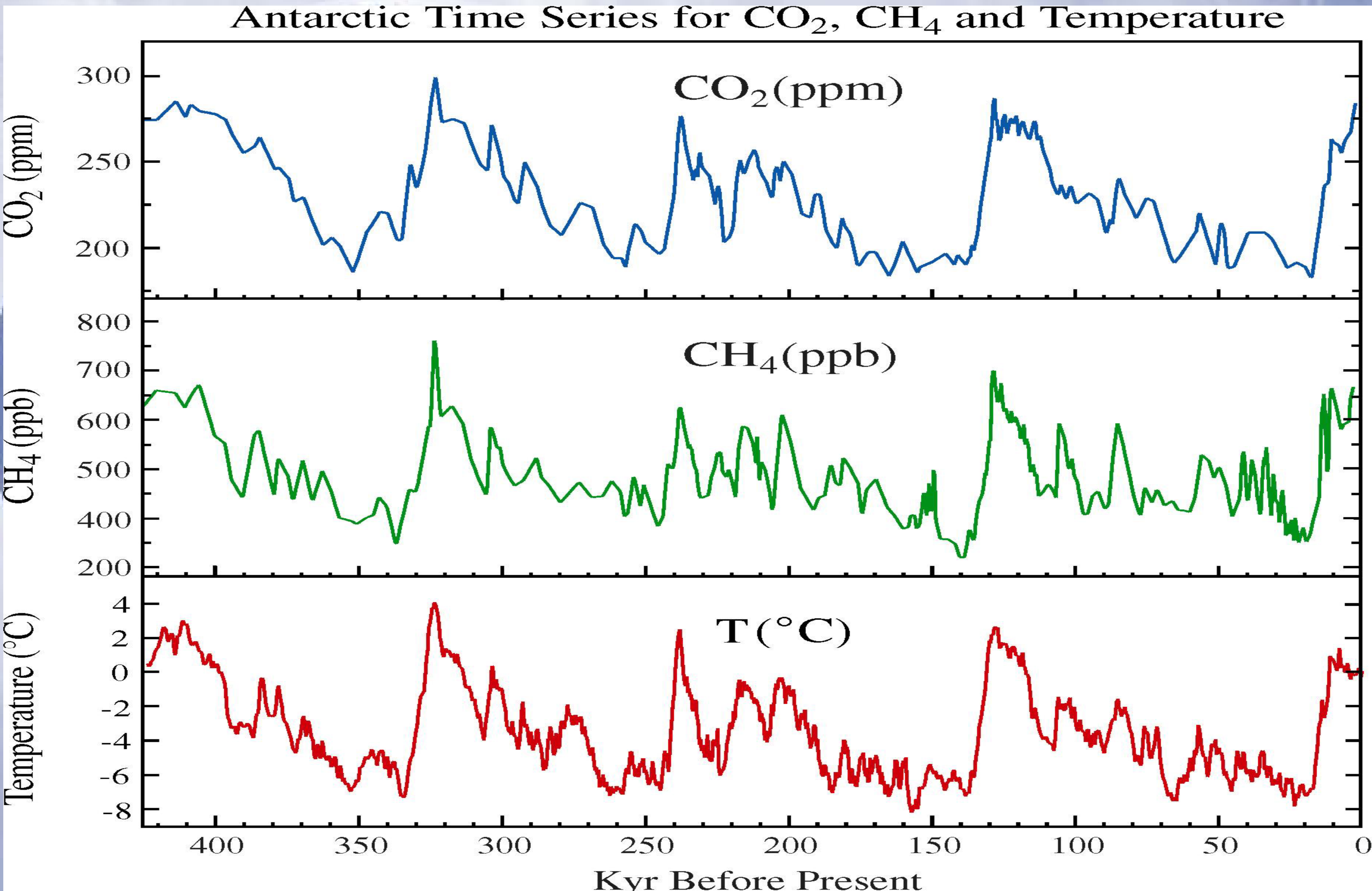
Observations of anthropogenic CO_2 emissions from 1990 to 2007. The envelope of IPCC projections are shown for comparison[12,18,34]. Coloured and stippled lines refer to different IPCC scenarios.

Global Carbon Emissions (Gt)

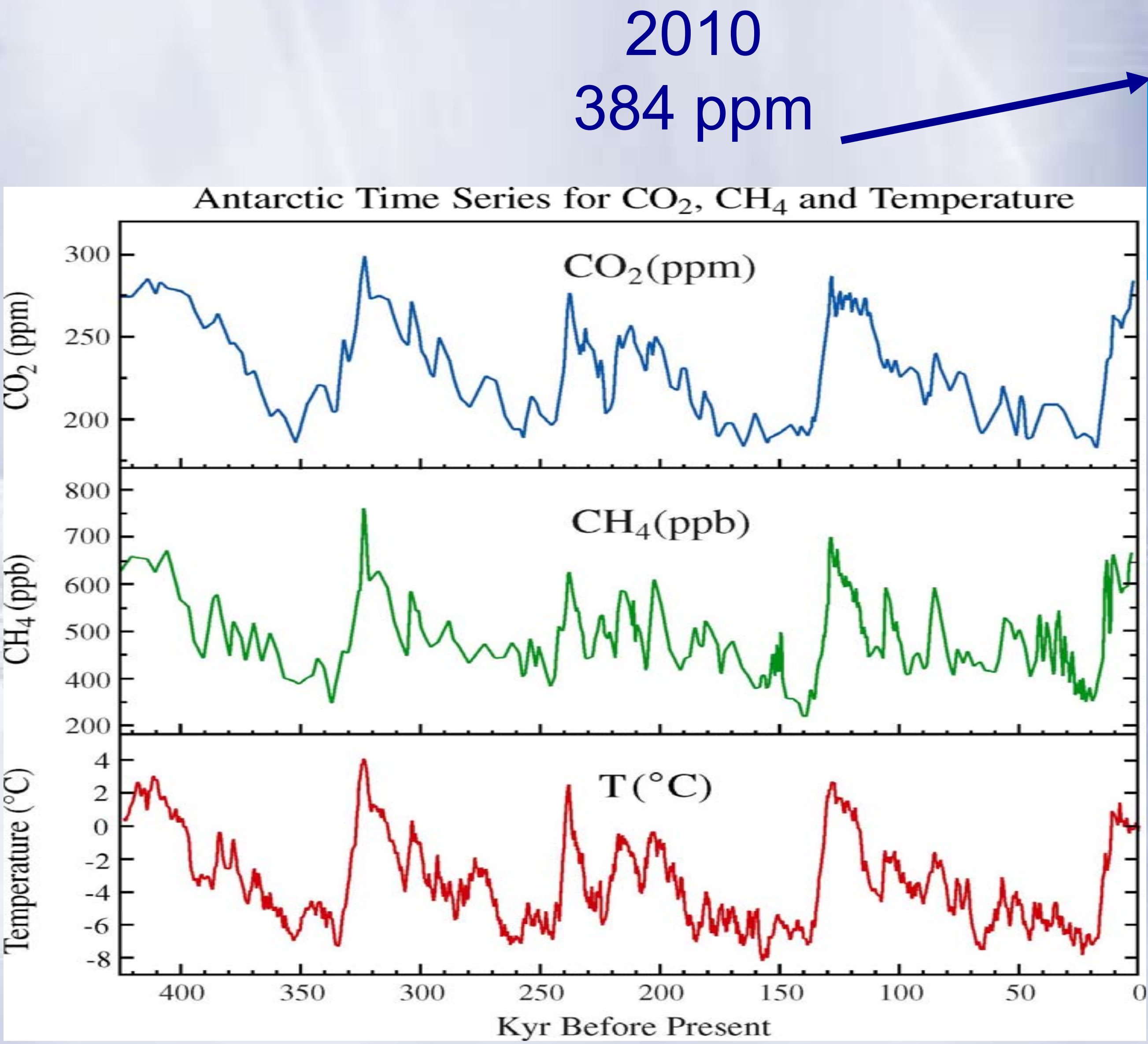


Observations of anthropogenic CO_2 emissions from 1990 to 2007. The envelope of IPCC projections are shown for comparison[12,18,34]. Coloured and stippled lines refer to different IPCC scenarios.

Carbon Dioxide and Temperature



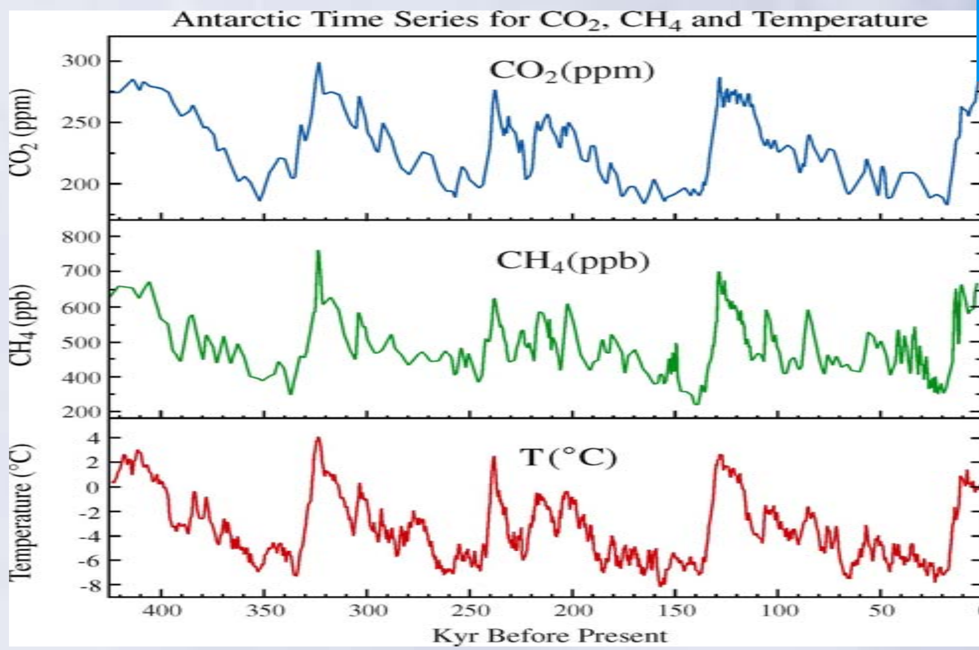
Carbon Dioxide and Temperature



Carbon Dioxide and Temperature

"Business as Usual"

950 ppm (2100)



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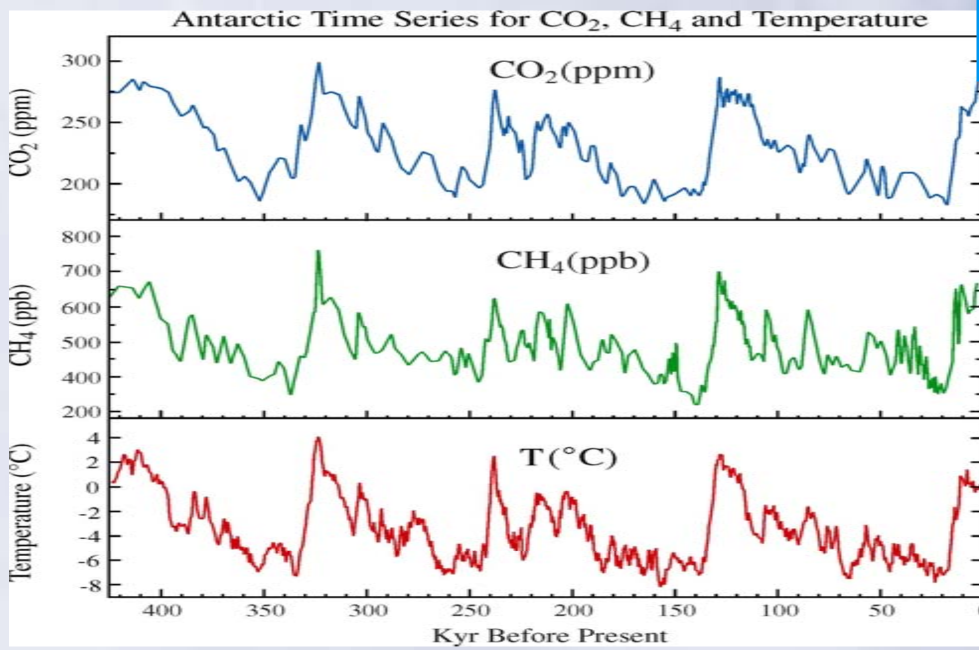
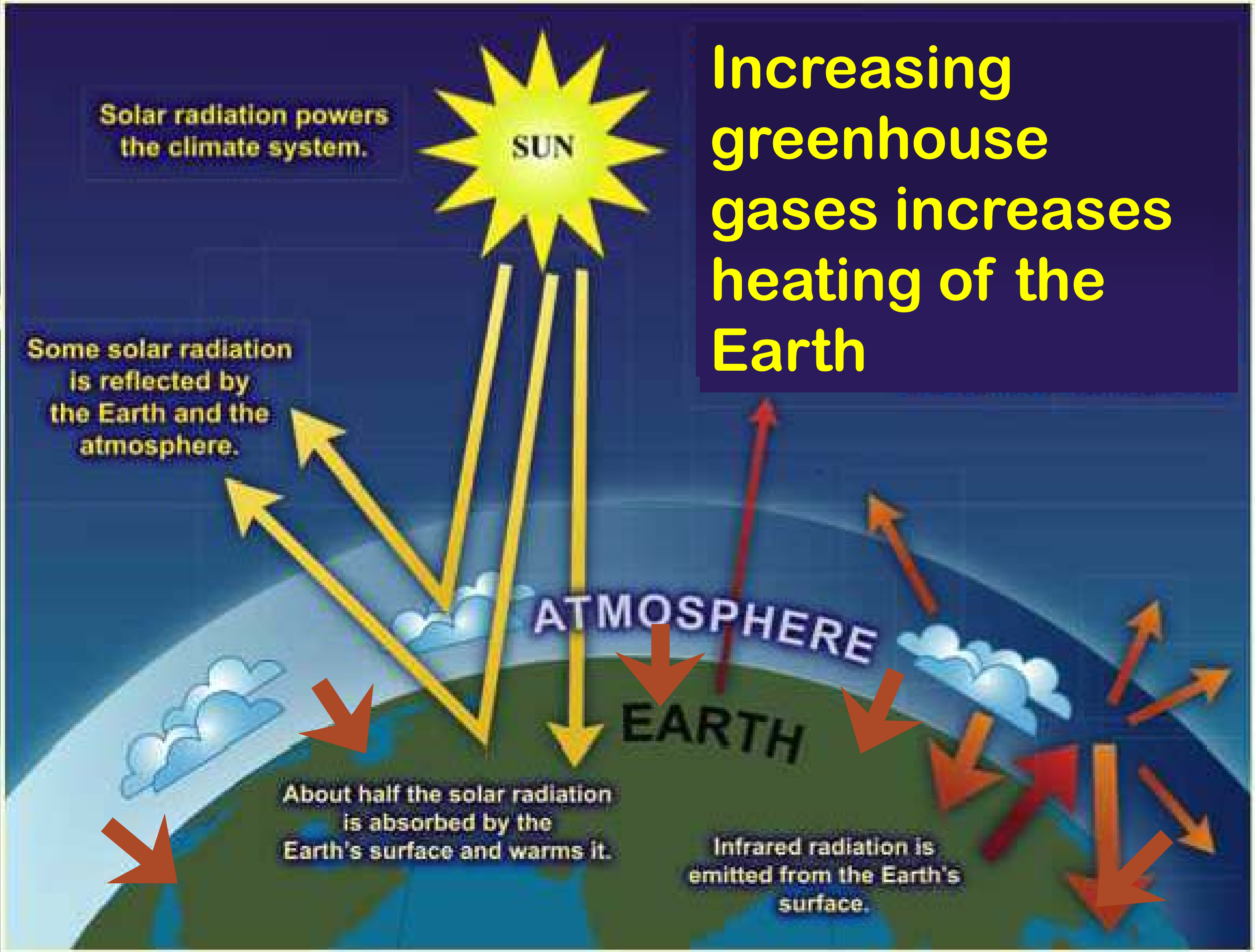
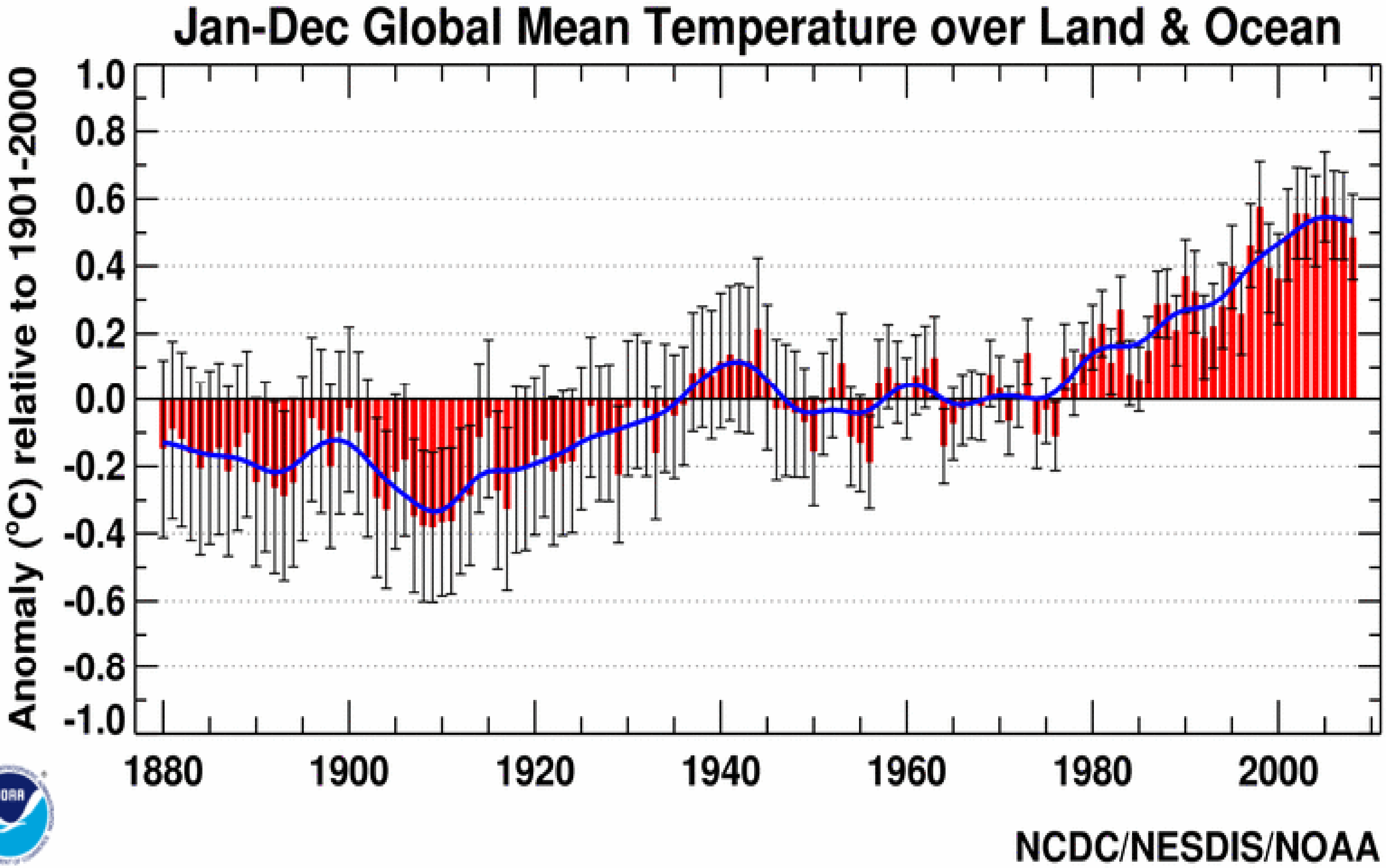


?

Increasing greenhouse gases increases heating of the Earth

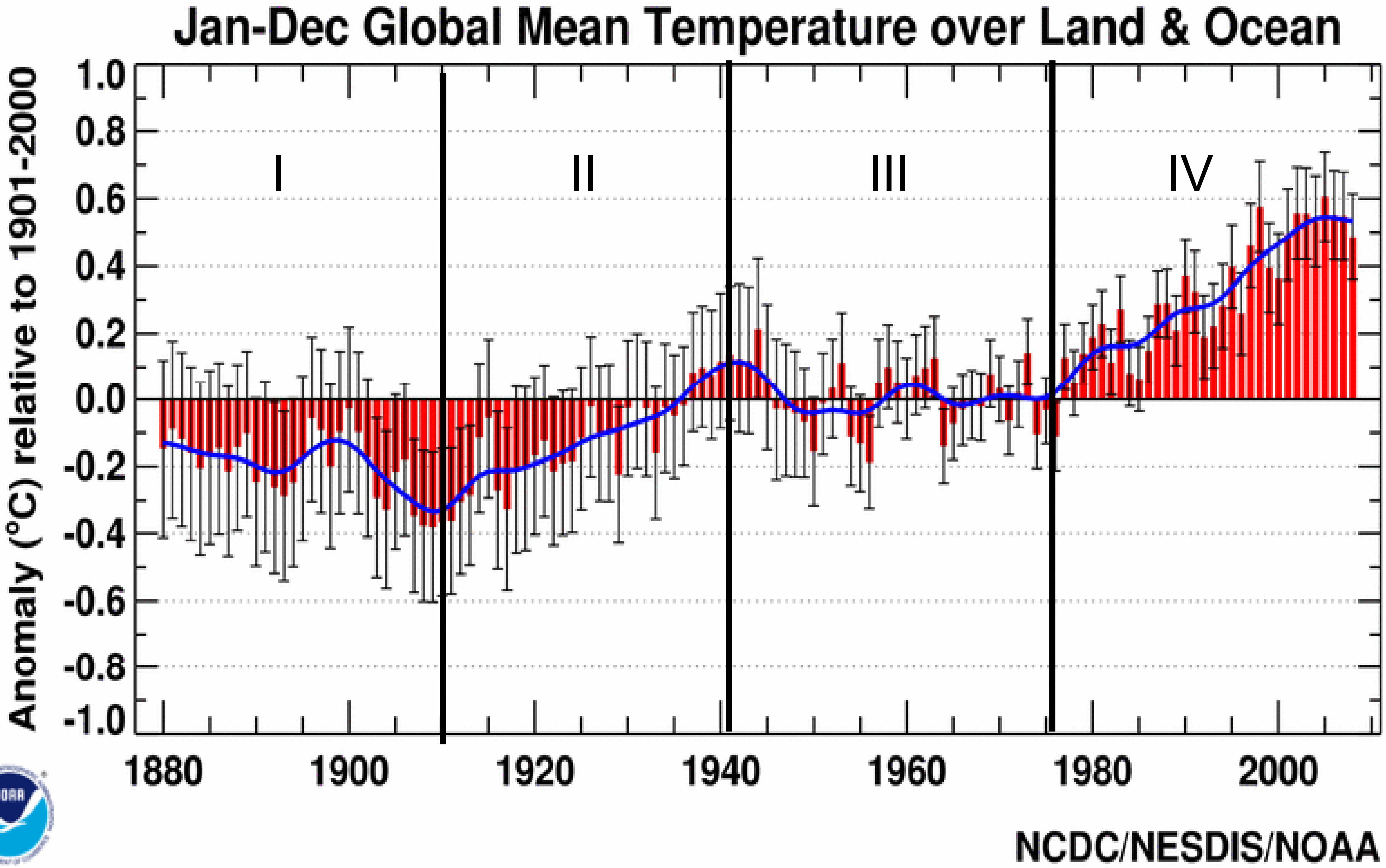


Global Mean Surface Temperature



http://www.ncdc.noaa.gov/img/climate/research/2008/ann/global-jan-dec-error-bar-pg.gif

Global Mean Surface Temperature



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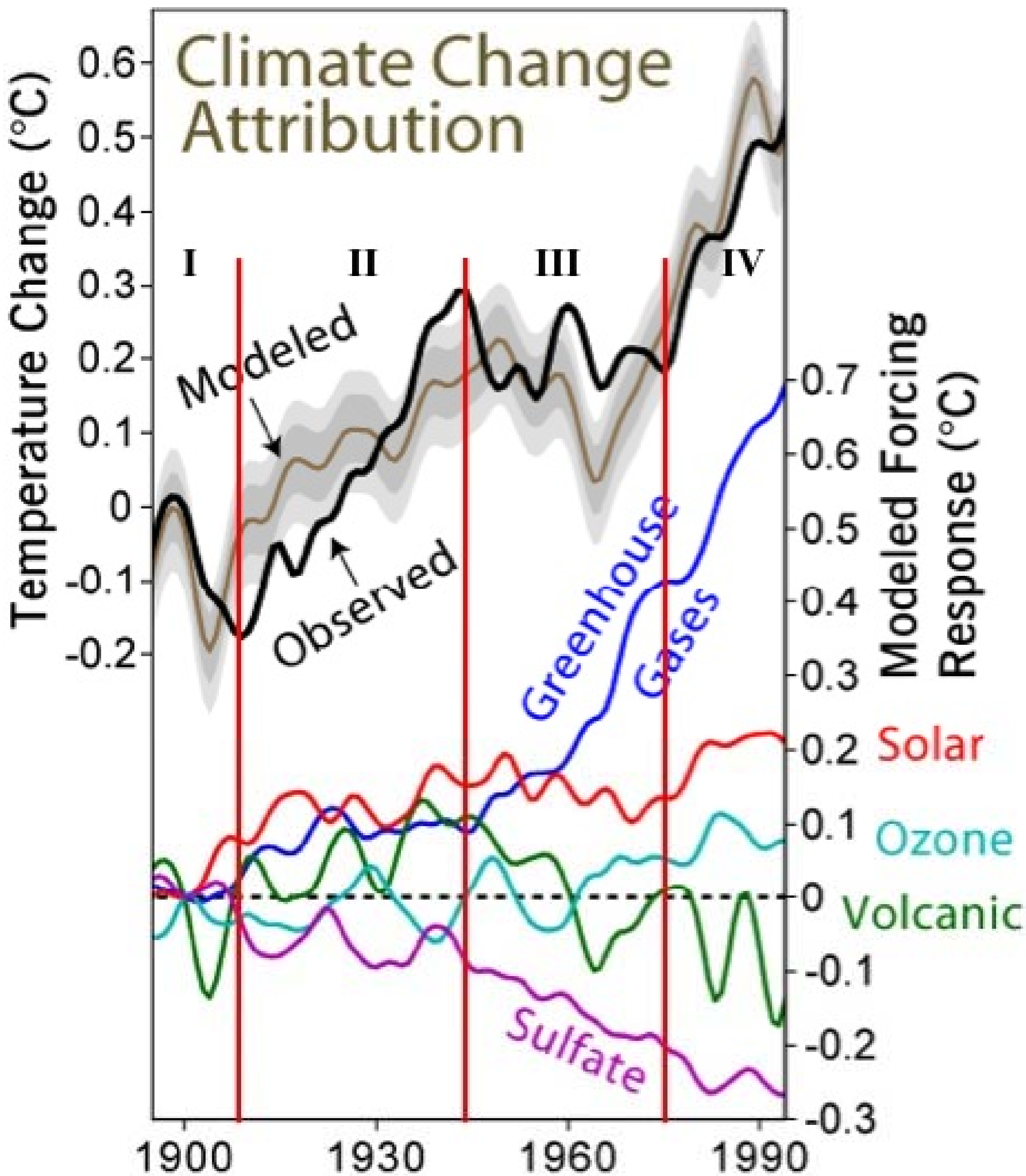
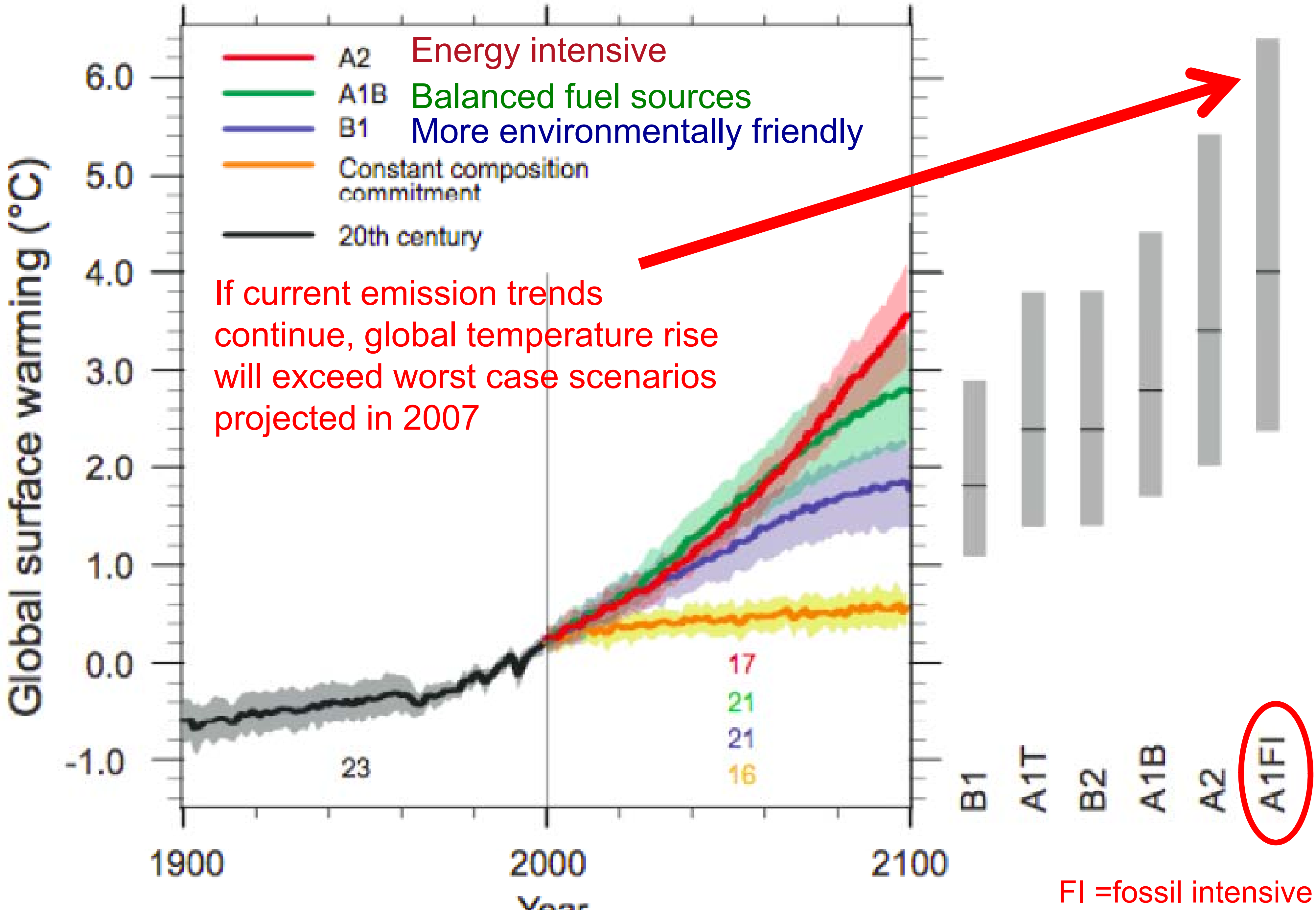
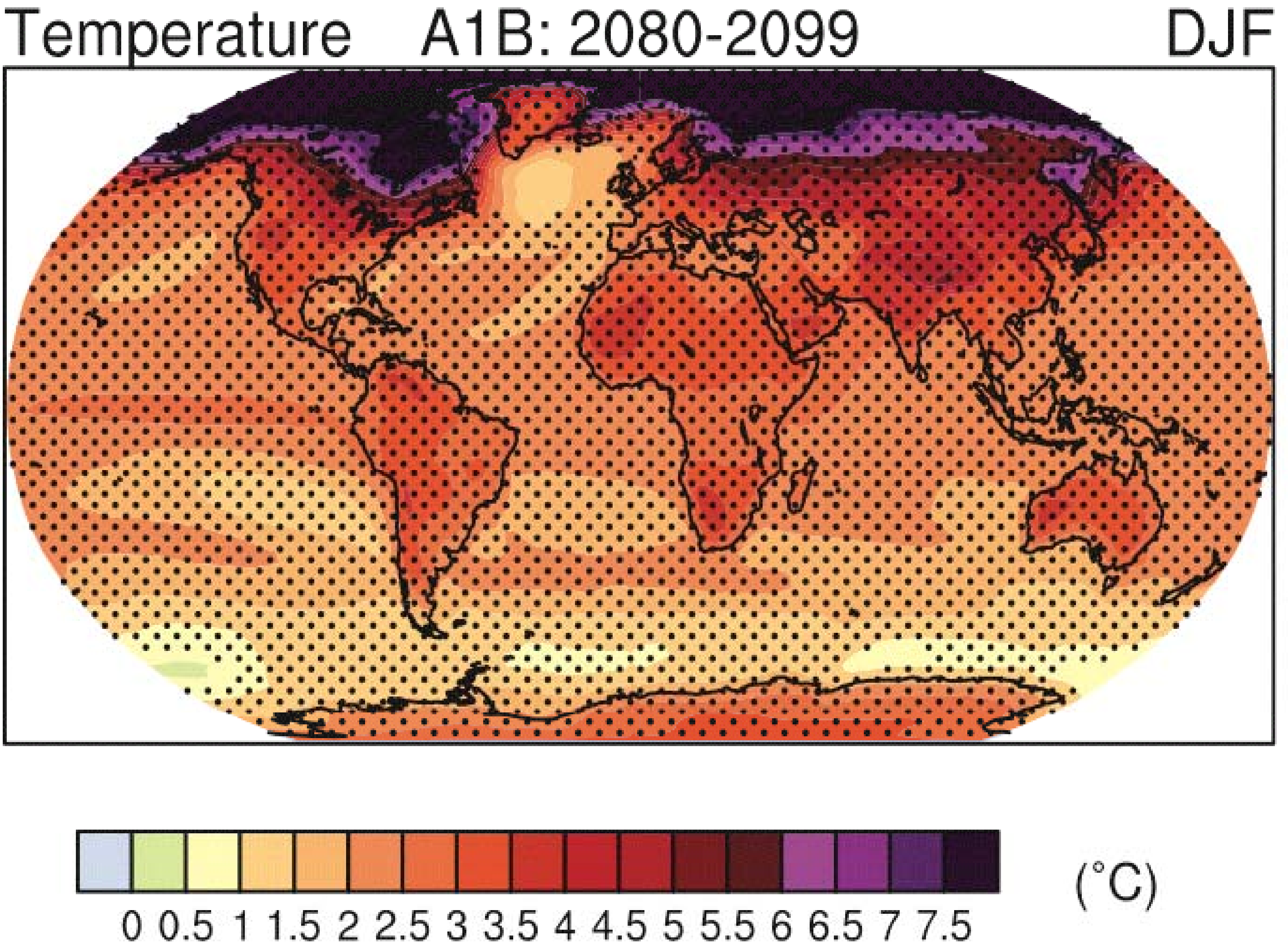
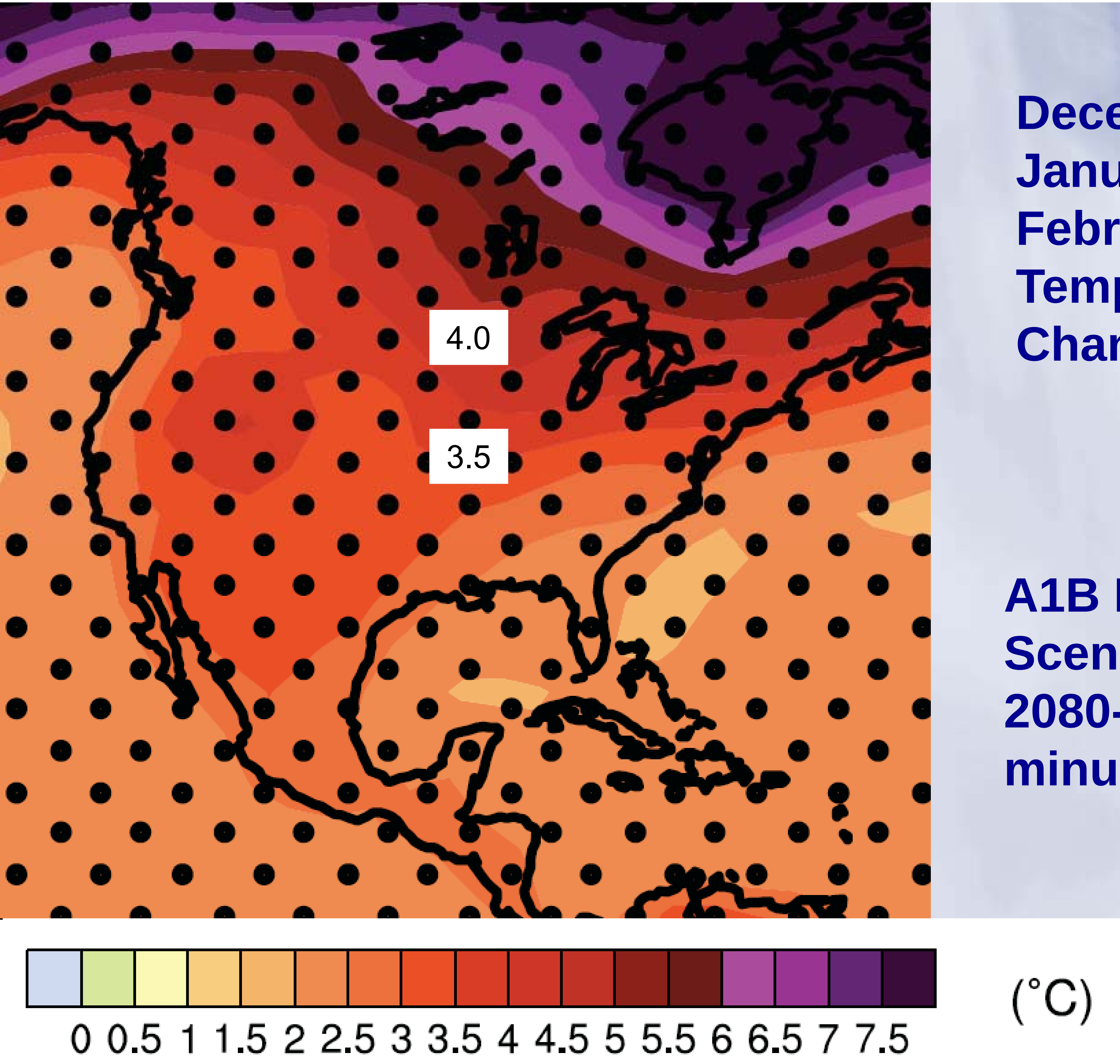


Natural and anthropogenic contributions to global temperature change (Meehl et al., 2004). Observed values from Jones and Moberg 2001. Grey bands indicate 68% and 95% range derived from multiple simulations.



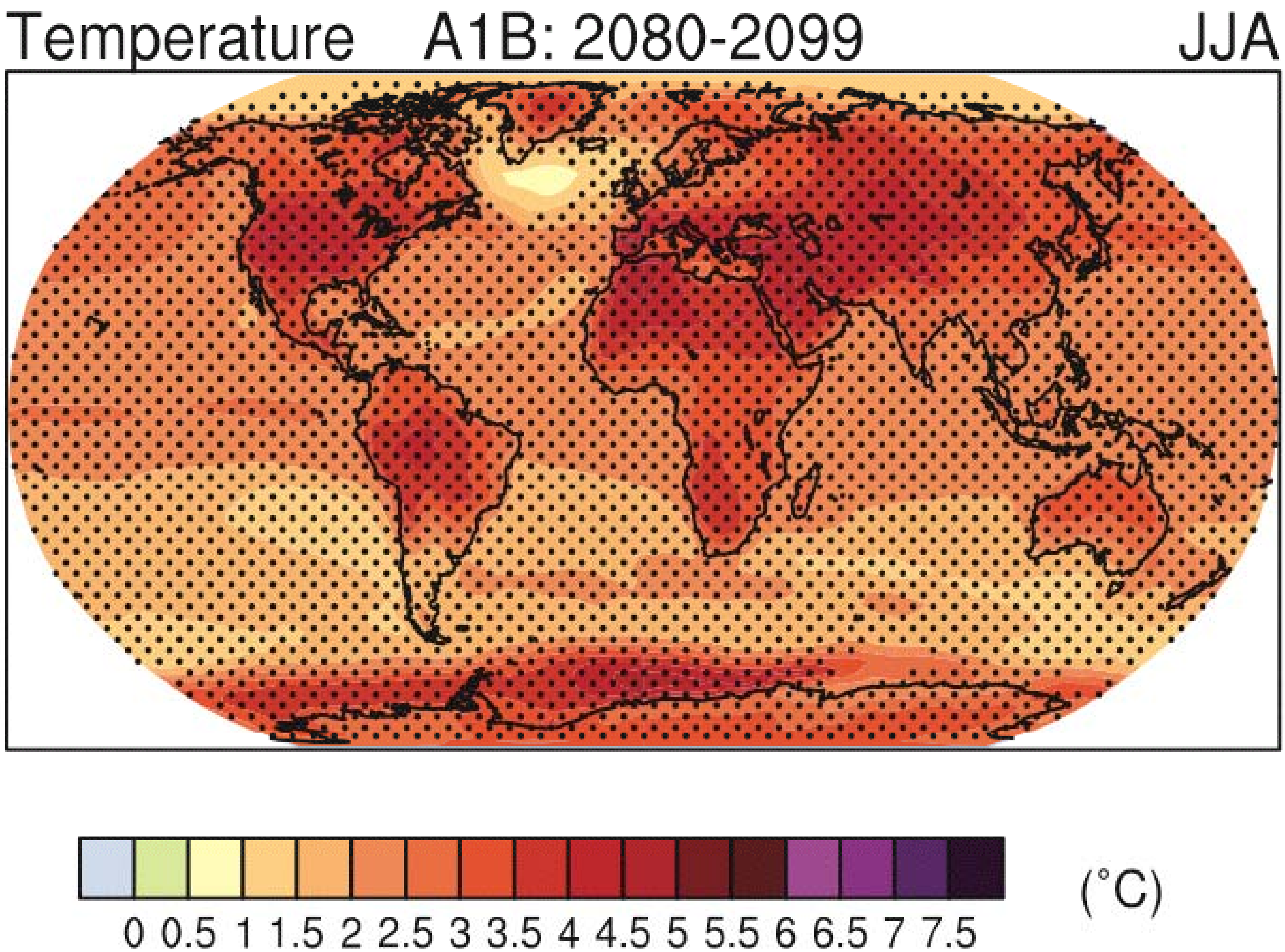
IPCC Fourth Assessment Report Summary for Policy Makers

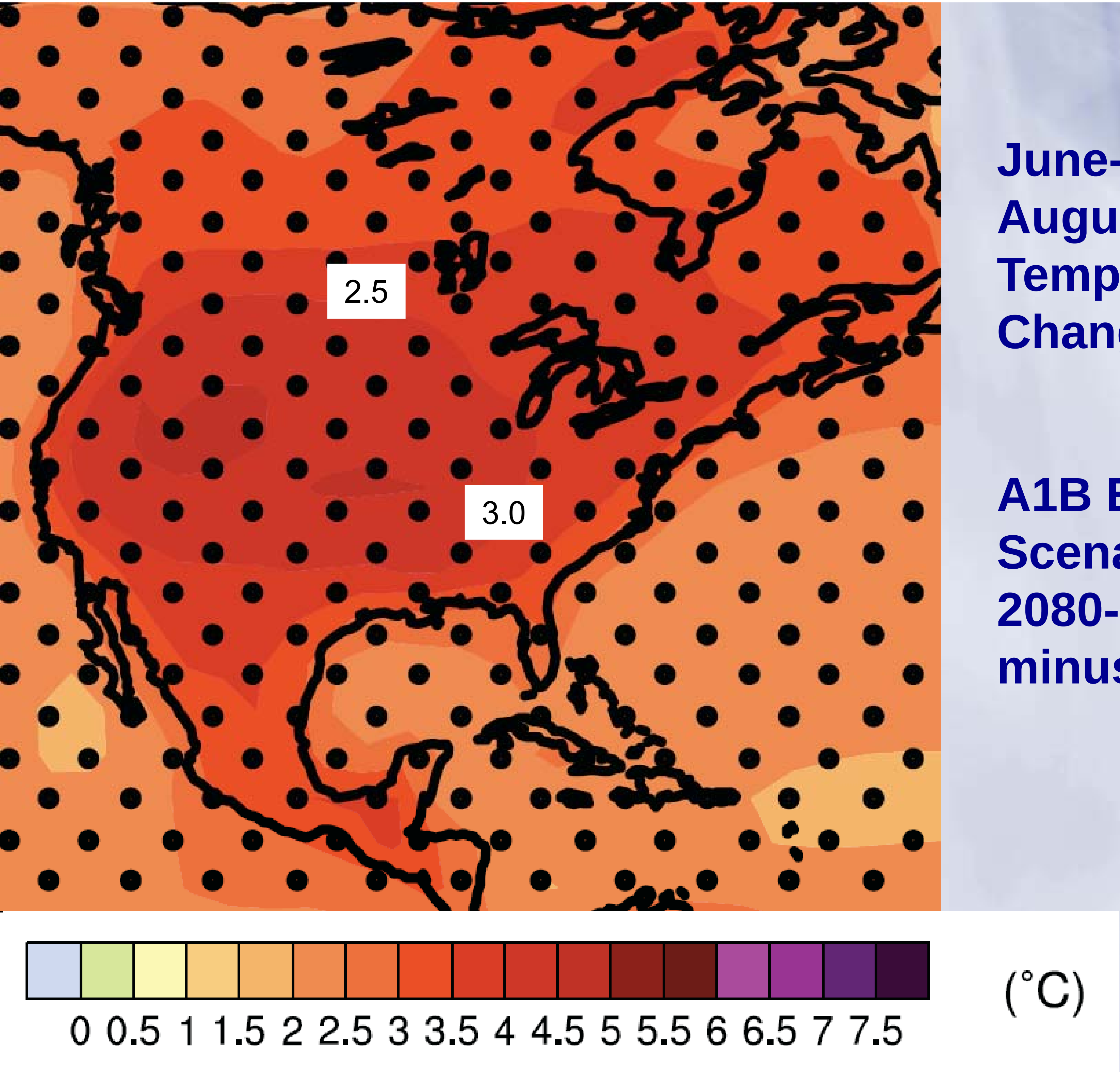

Temperature
A1B: 2080-2099
DJF
0 0.5 1 1.5 2 2.5 3 3.5 4 4.5 5 5.5 6 6.5 7 7.5
(°C)



December-January-February Temperature Change

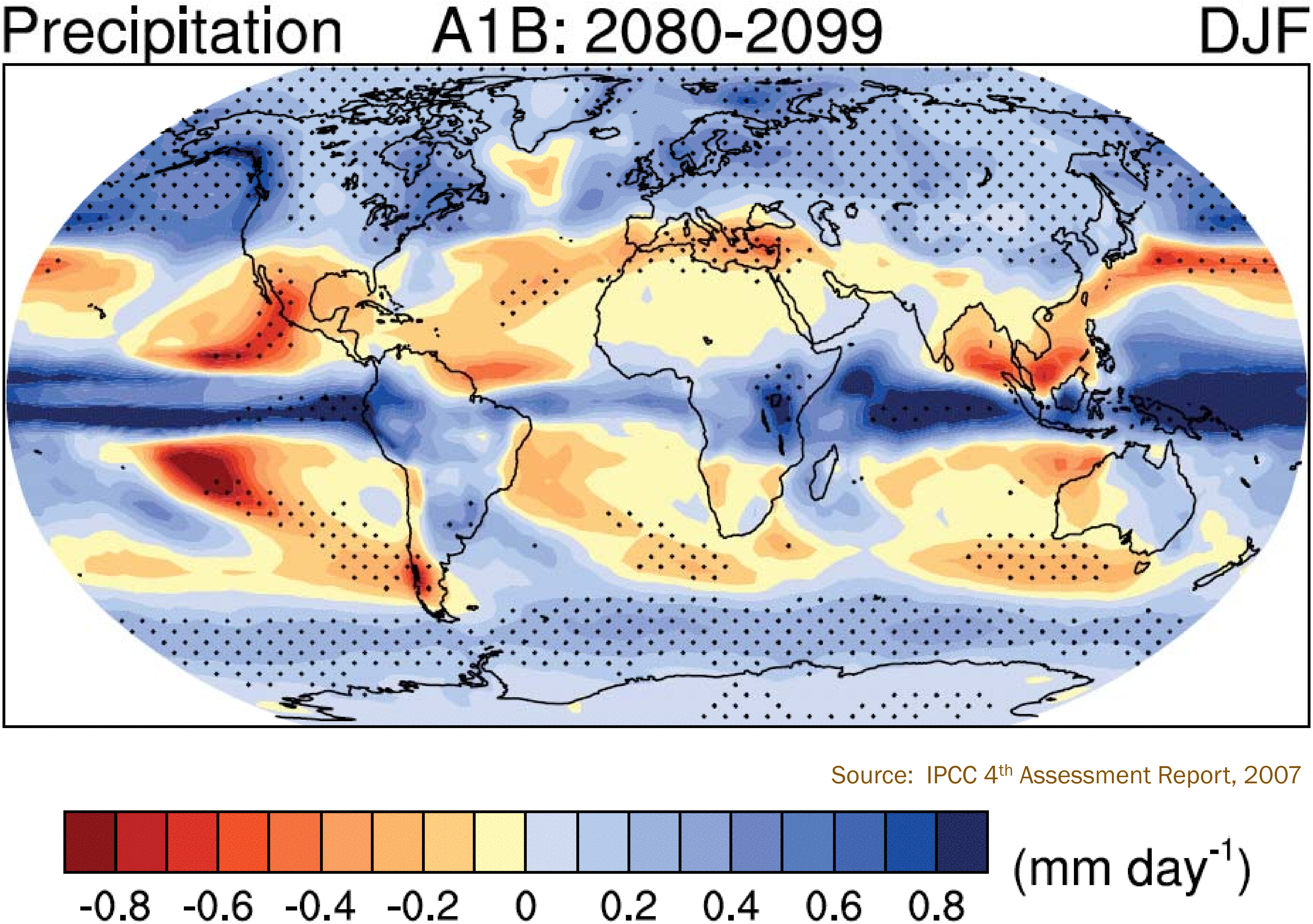
A1B Emission Scenario 2080-2099 minus1980-1999


Temperature A1B: 2080-2099 JJA
0 0.5 1 1.5 2 2.5 3 3.5 4 4.5 5 5.5 6 6.5 7 7.5
(°C)

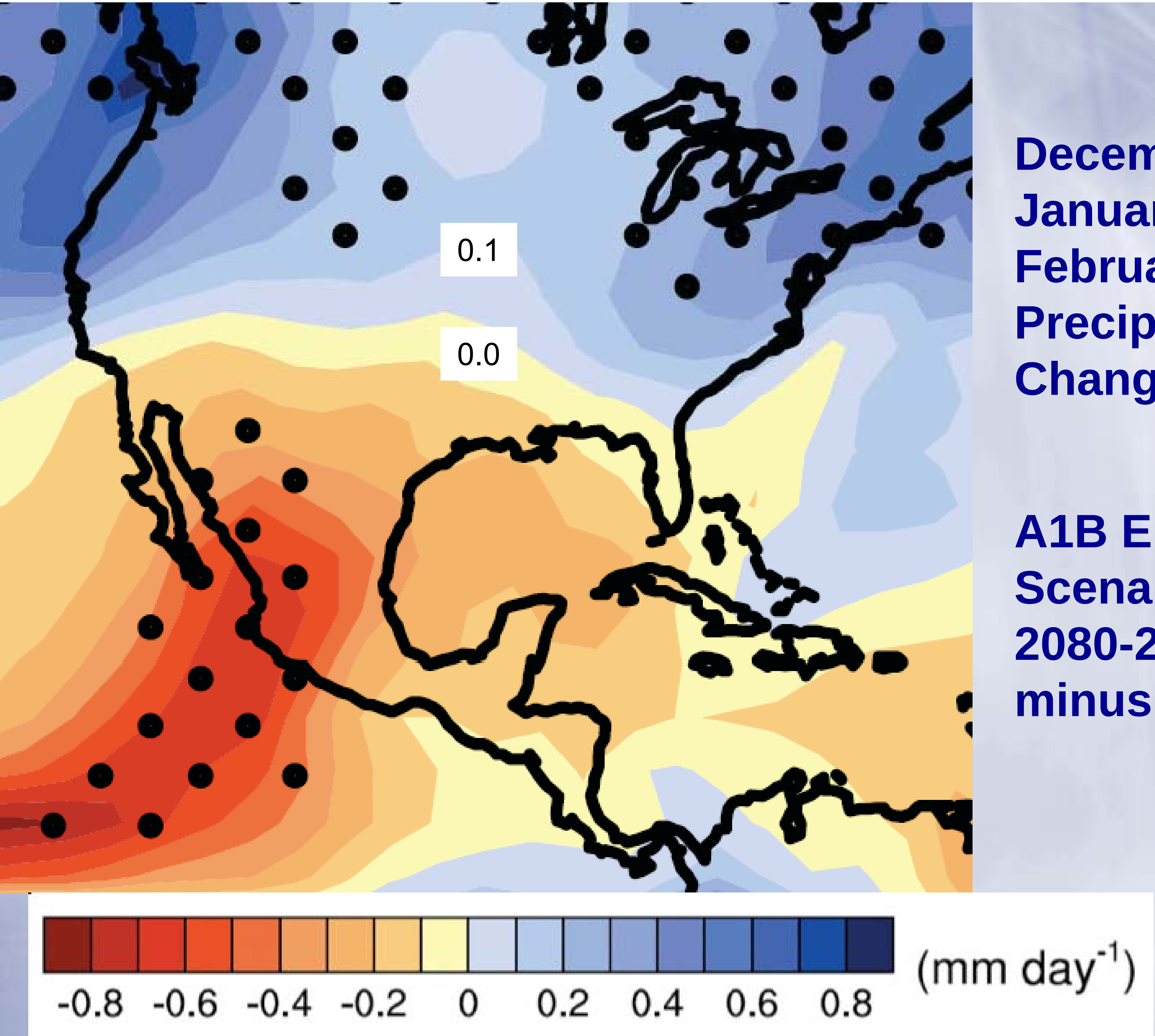


June-July-August Temperature Change

A1B Emission Scenario 2080-2099 minus1980-1999

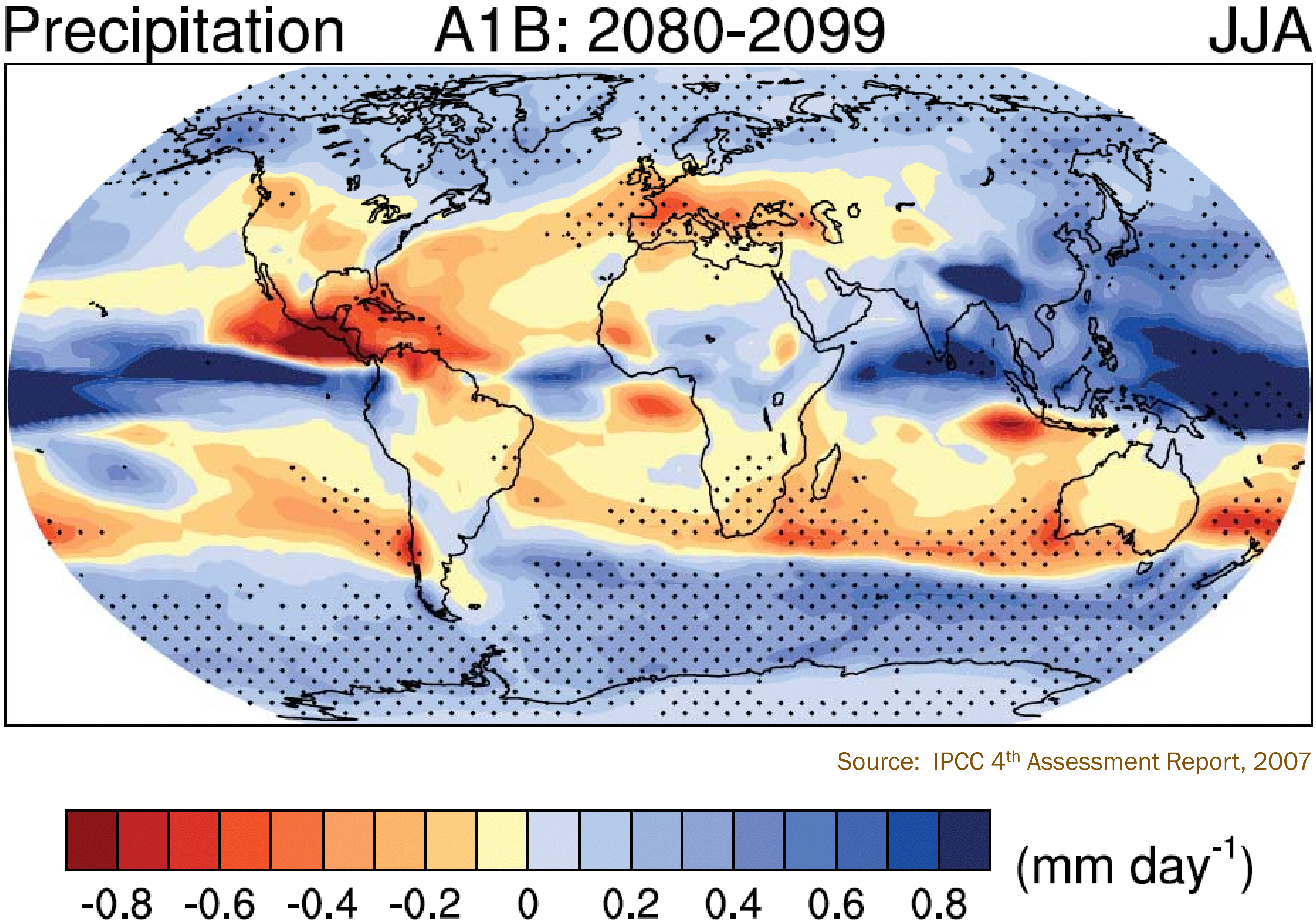


Source: IPCC 4th Assessment Report, 2007

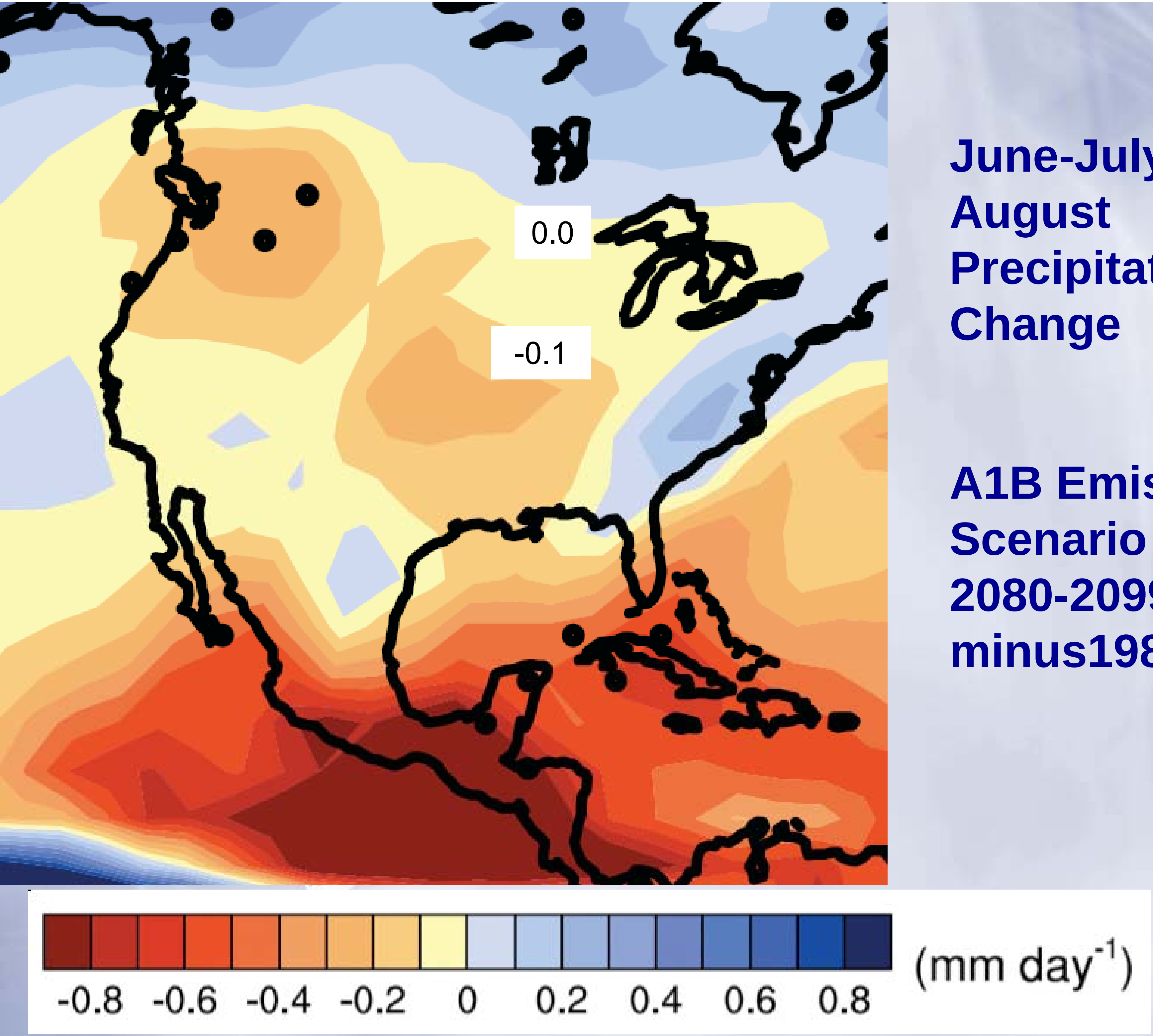


December-January-February Precipitation Change

A1B Emission Scenario 2080-2099 minus1980-1999



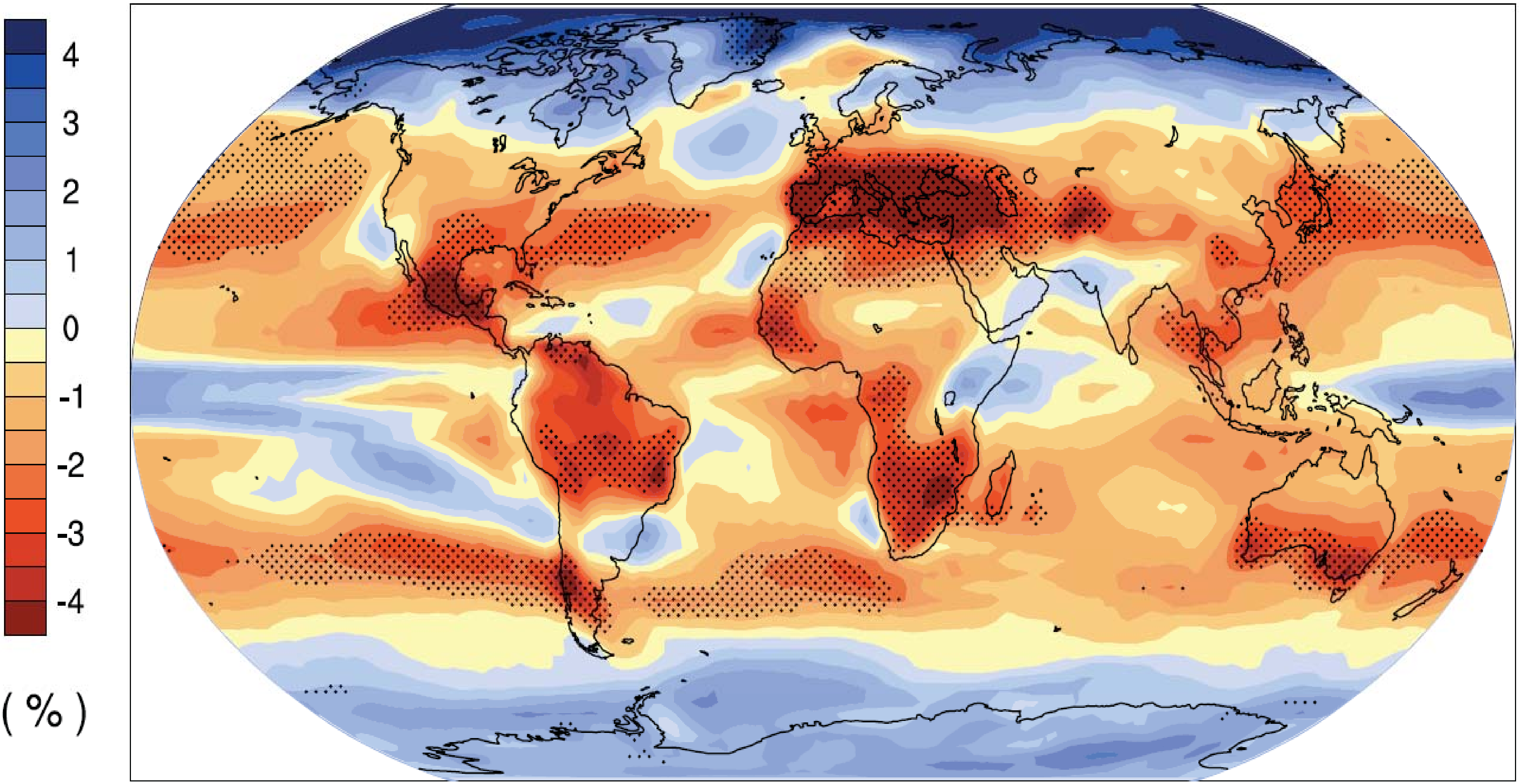
Source: IPCC 4th Assessment Report, 2007



June-July-August Precipitation Change

A1B Emission Scenario 2080-2099 minus1980-1999

Change in Annual Cloud Cover



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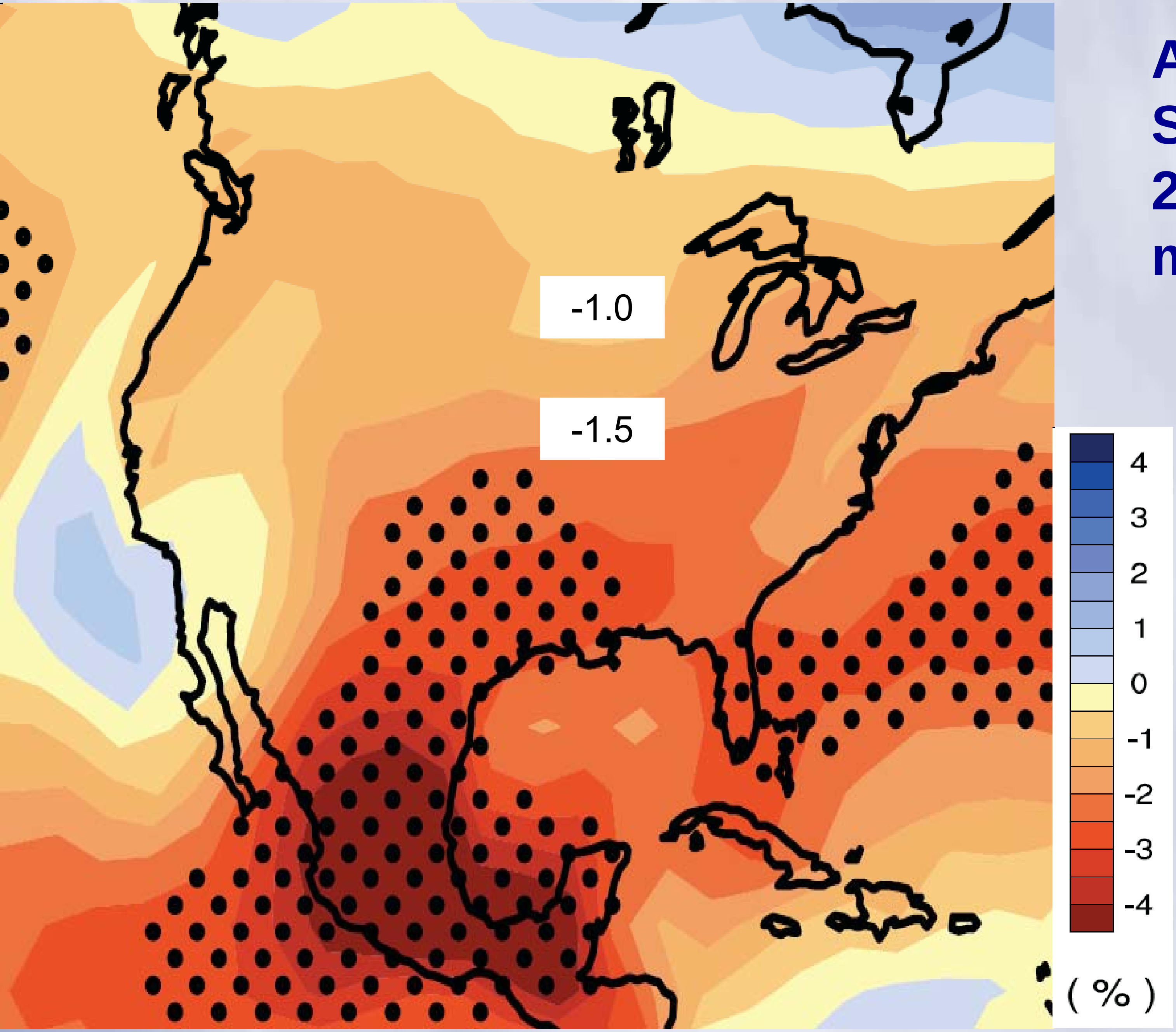
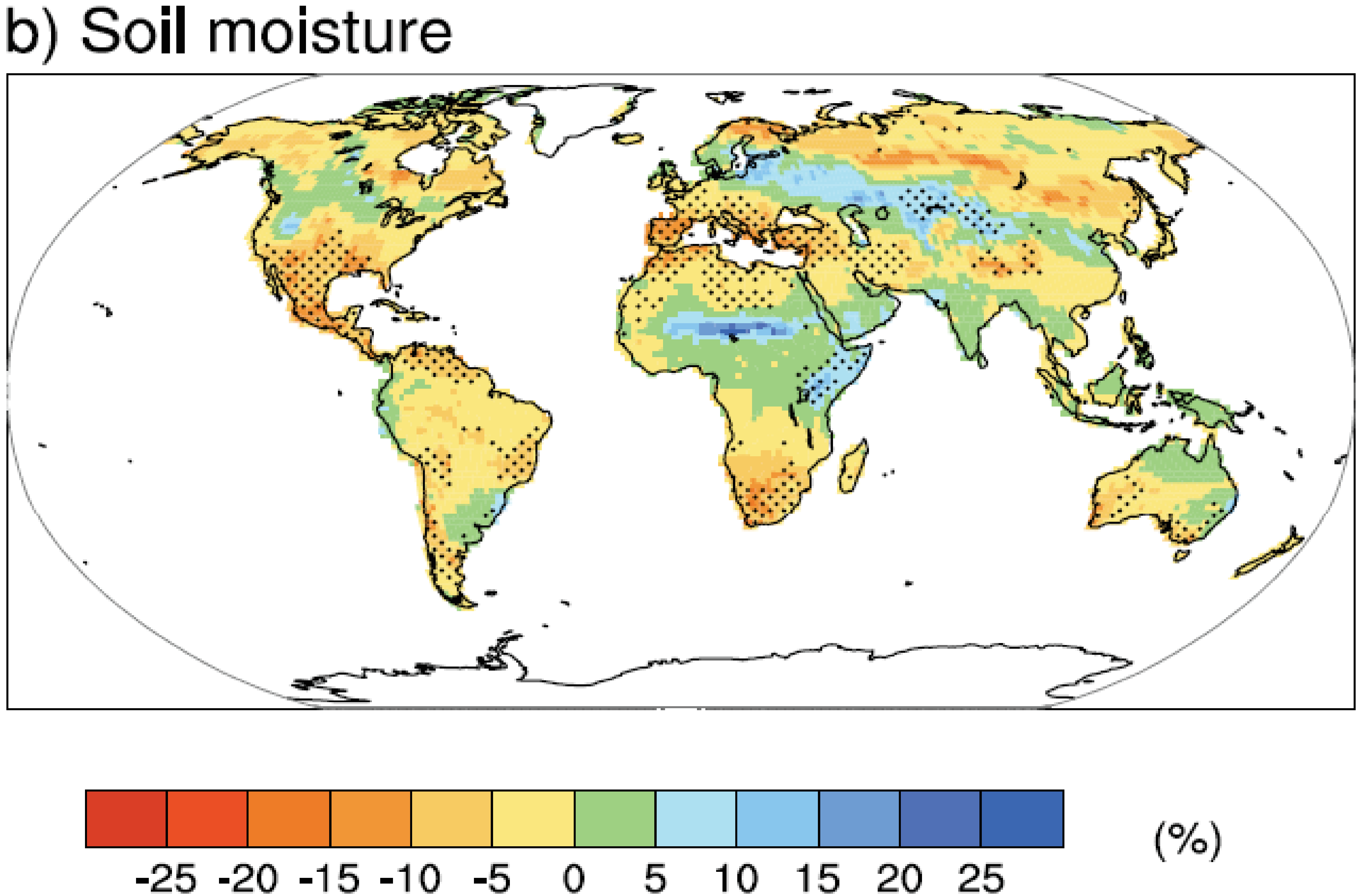


A1B Emission Scenario
2080-2099
minus1980-1999

Annual Change in Soil Moisture



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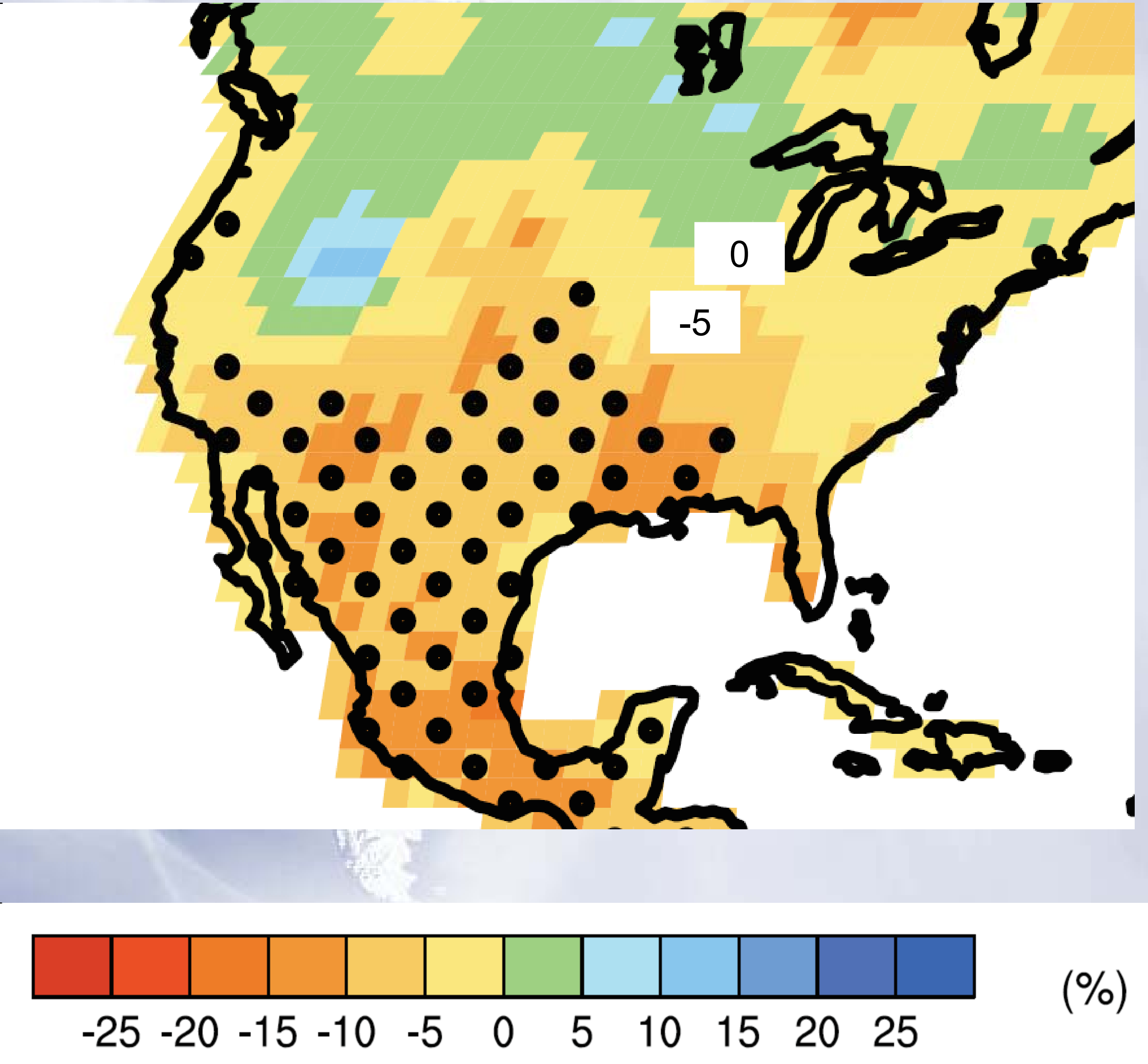

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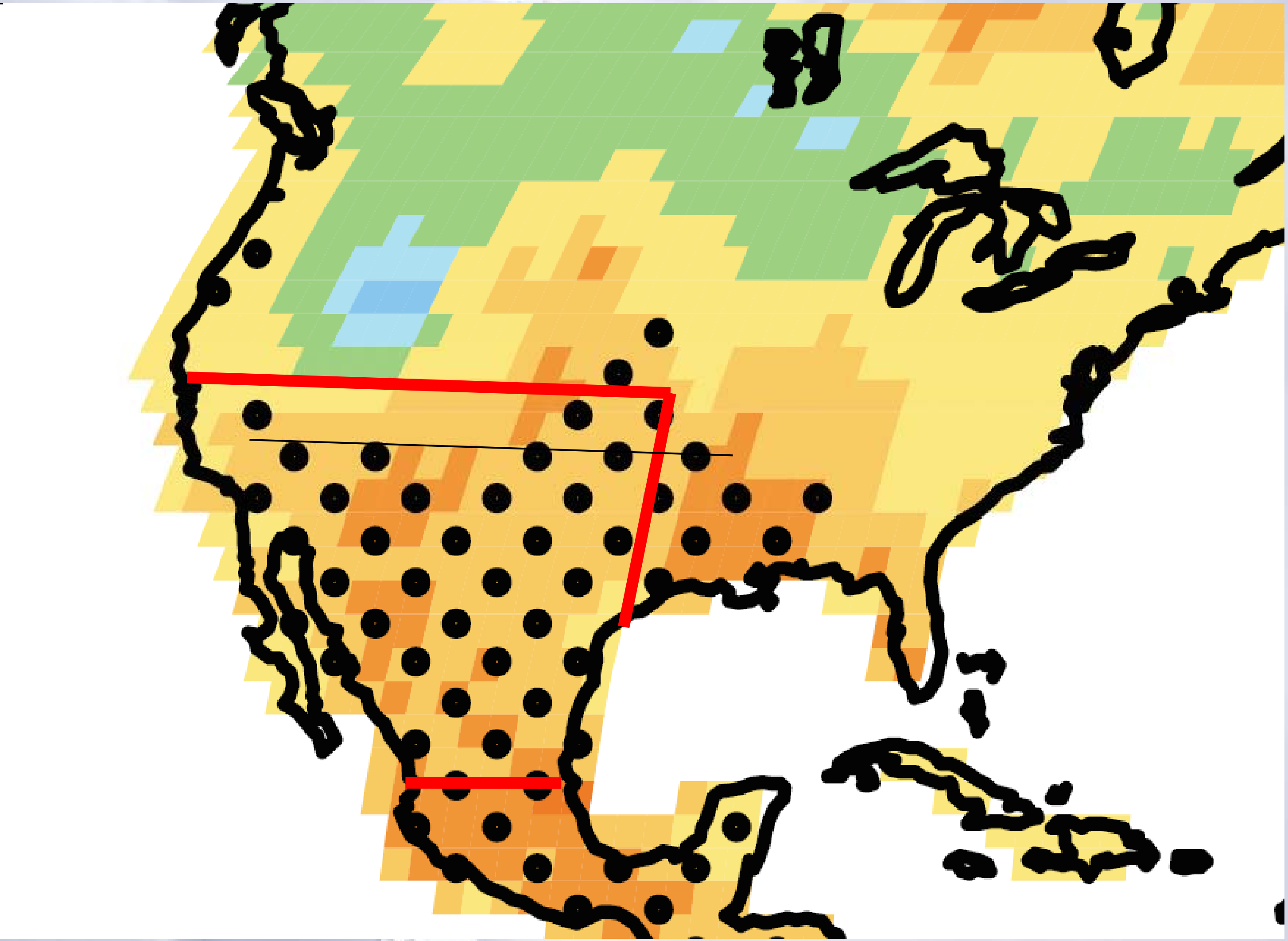
Imminent Transition to Arid Climate

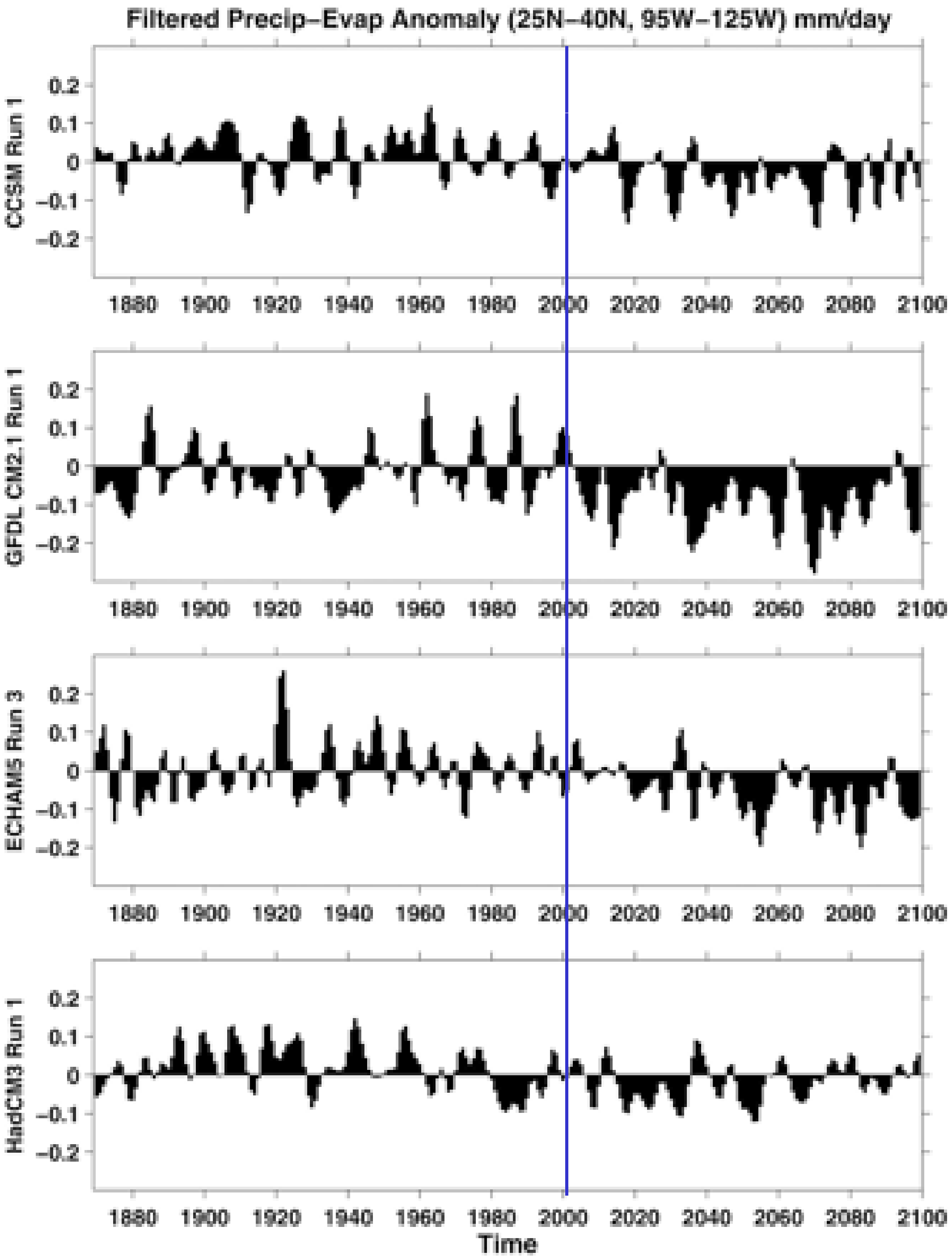


Precipitation minus Evaporation for Western US

25N-40N, 95W-125 W

(land areas only)

R. Seager, et al.,2007. Model Projections of an Imminent Transition to a More Arid Climate in Southwestern North America. **Science**, Vol. 316. no. 5828, pp. 1181 - 1184



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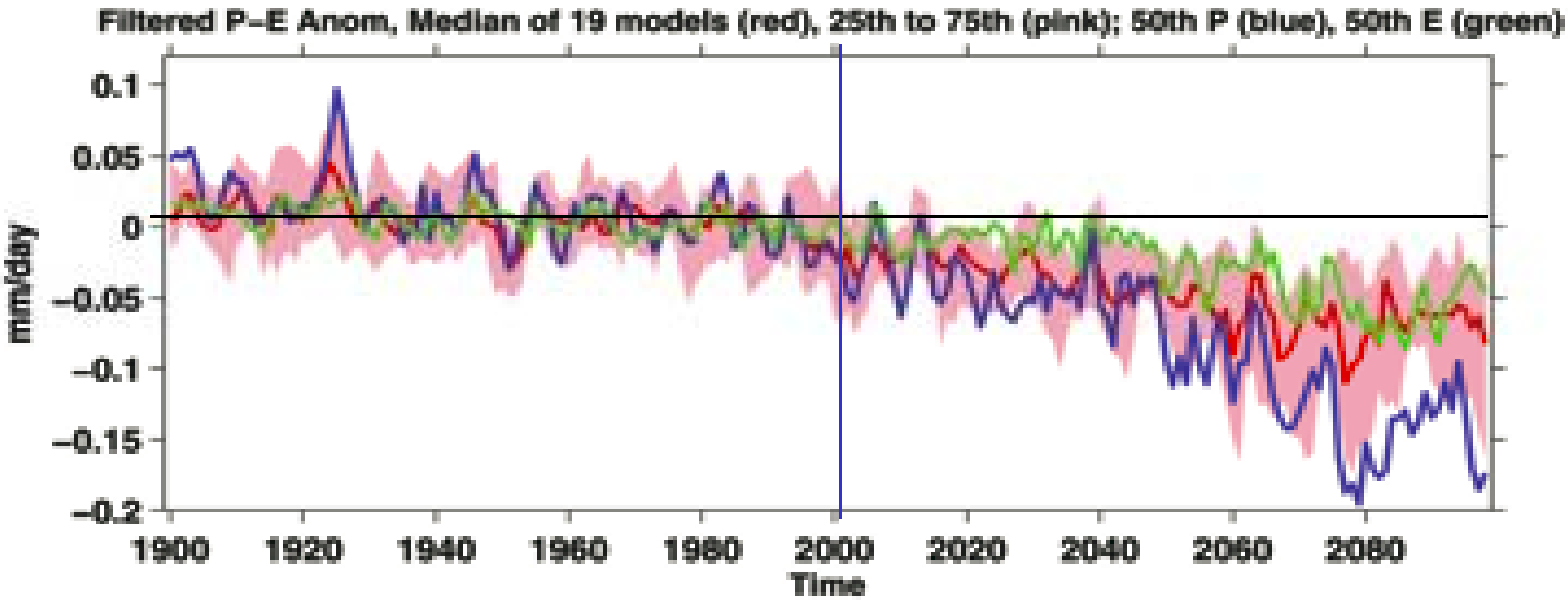

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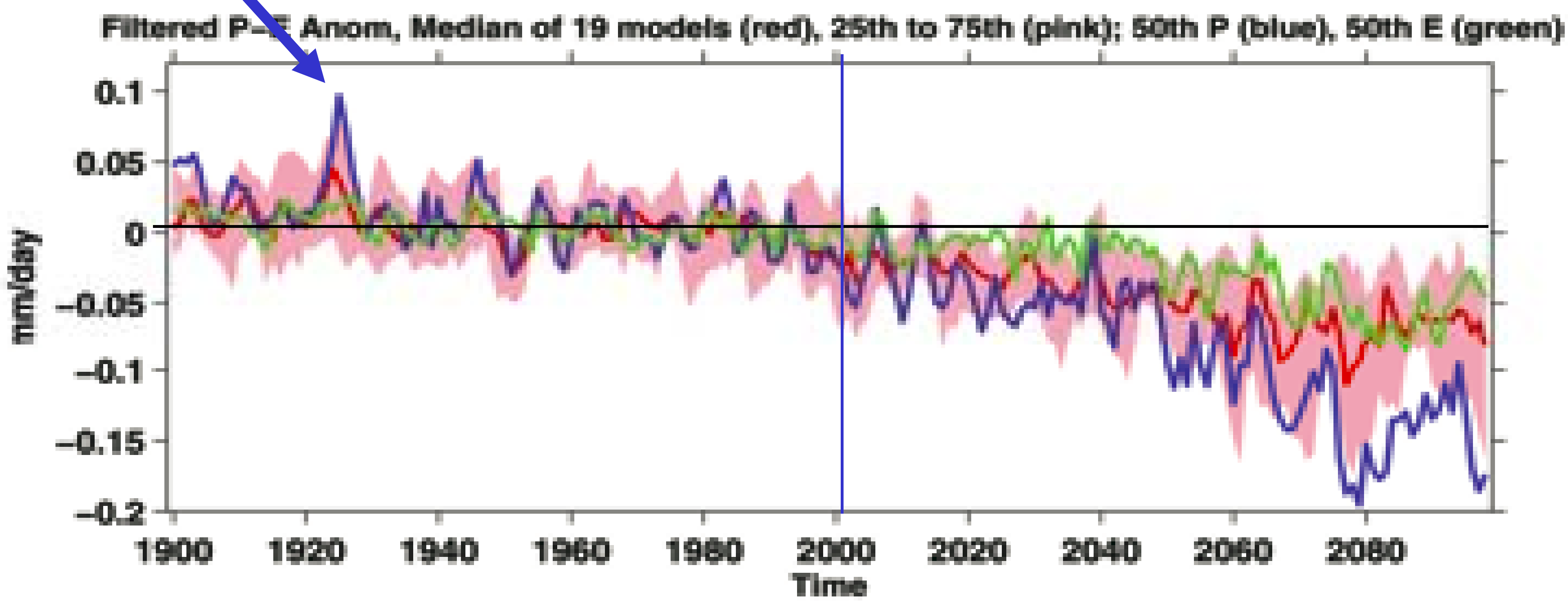
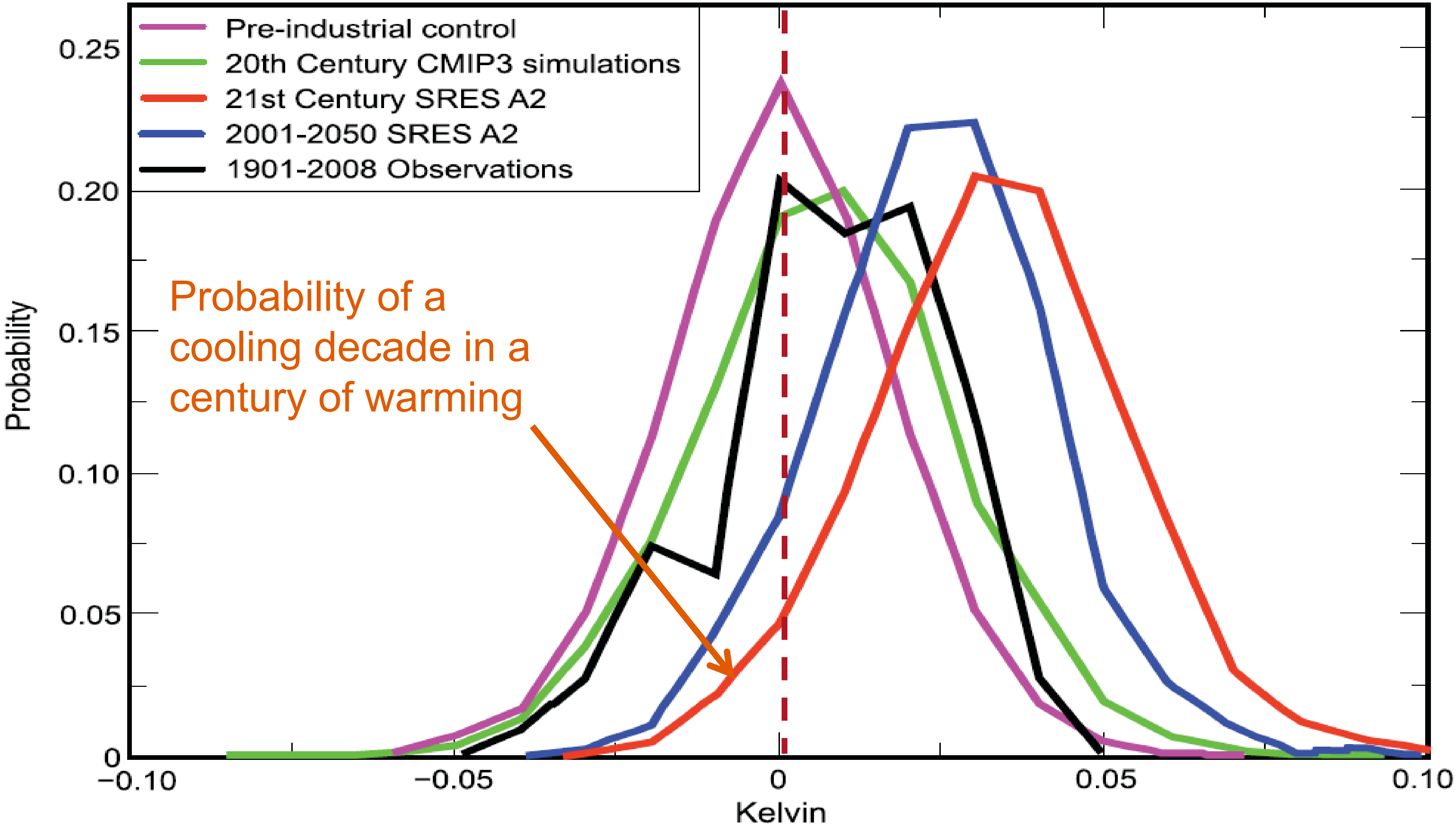
Colorado River Compact established, 1922



R. Seager, et al.,2007. Model Projections of an Imminent Transition to a More Arid Climate in Southwestern North America. **Science**, Vol. 316. no. 5828, pp. 1181 - 1184

Cooling Decade in a Century of Warming

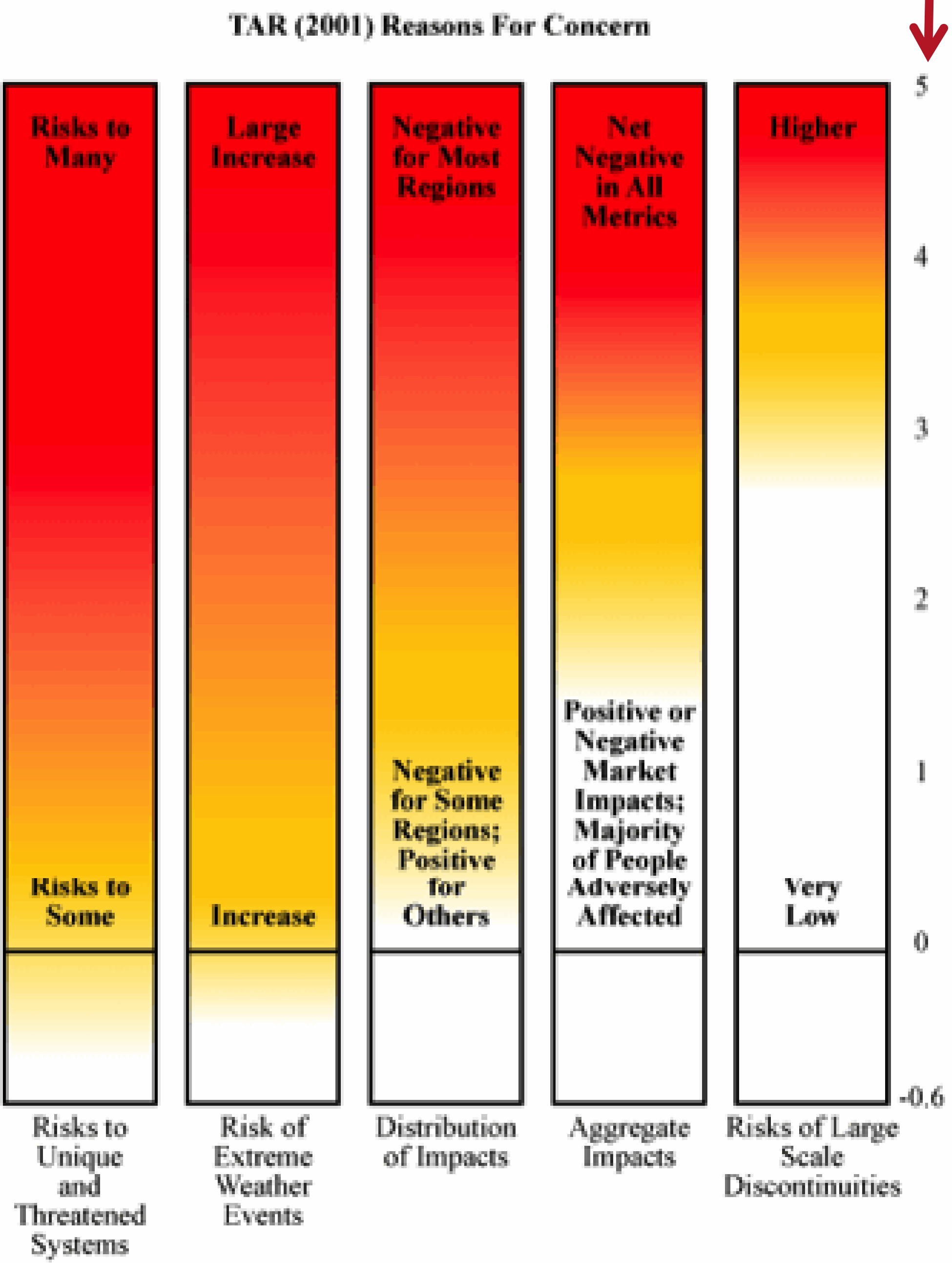


Probability distribution functions for decadal trends (kelvin/year) in globally averaged surface air temperature

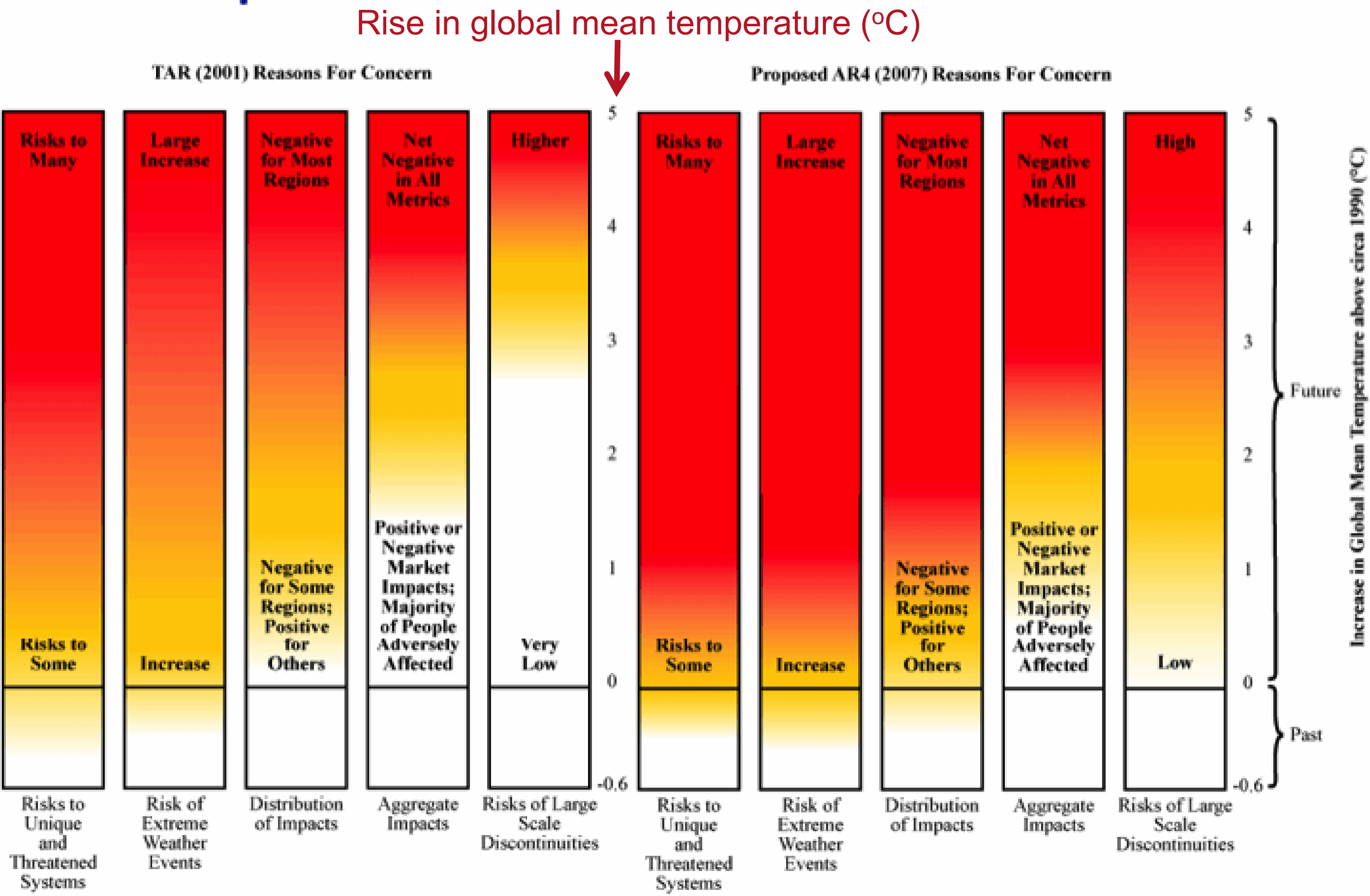
Easterling, D. R., and M. F. Wehner, 2009: Is the climate warming or cooling? *Geophys. Res. Lett.*, **36**, L08706, doi:10.1029/2009GL037810, 2009

Updated Reasons for Concern

Rise in global mean temperature (°C)



Updated Reasons for Concern



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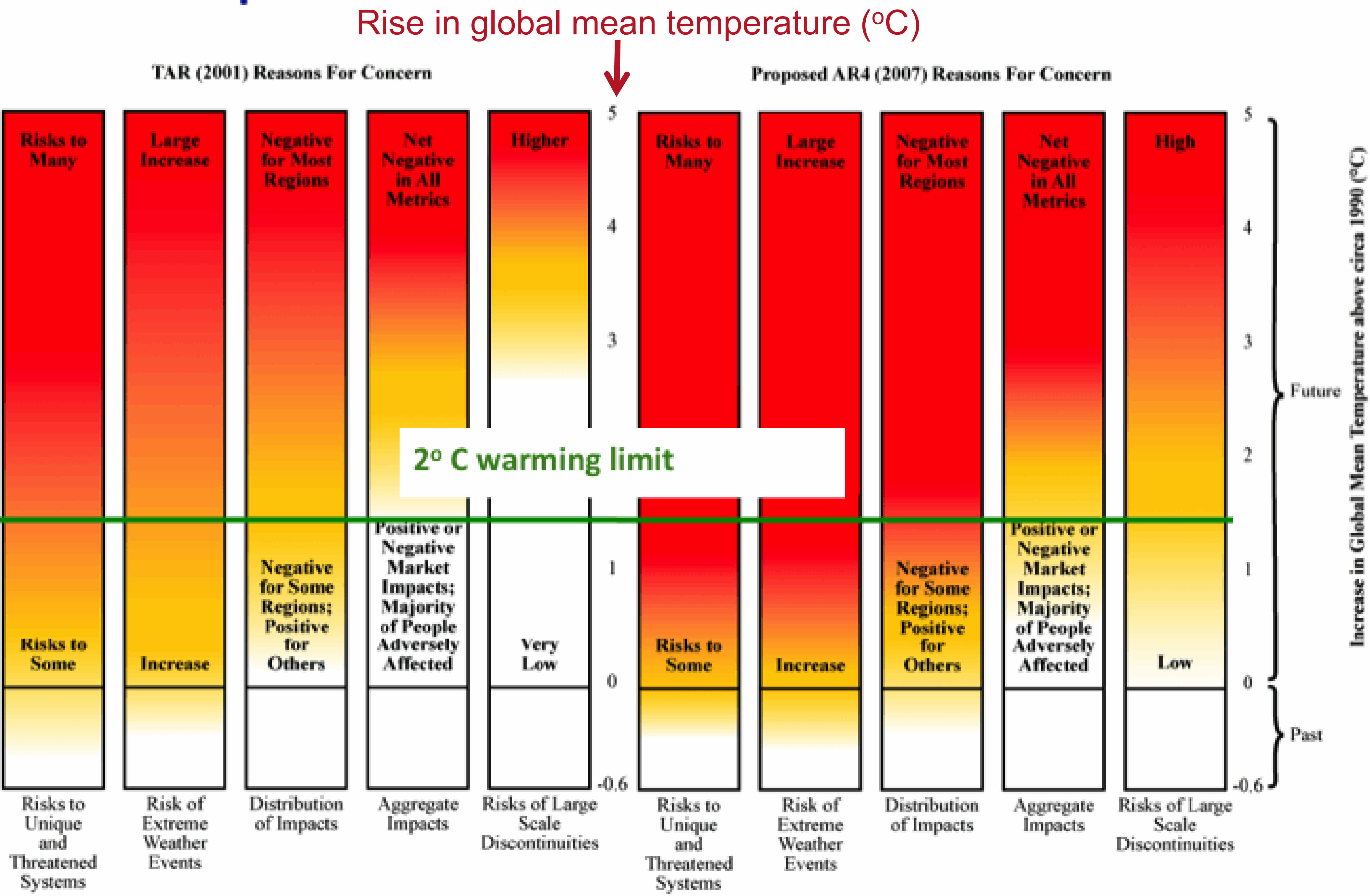
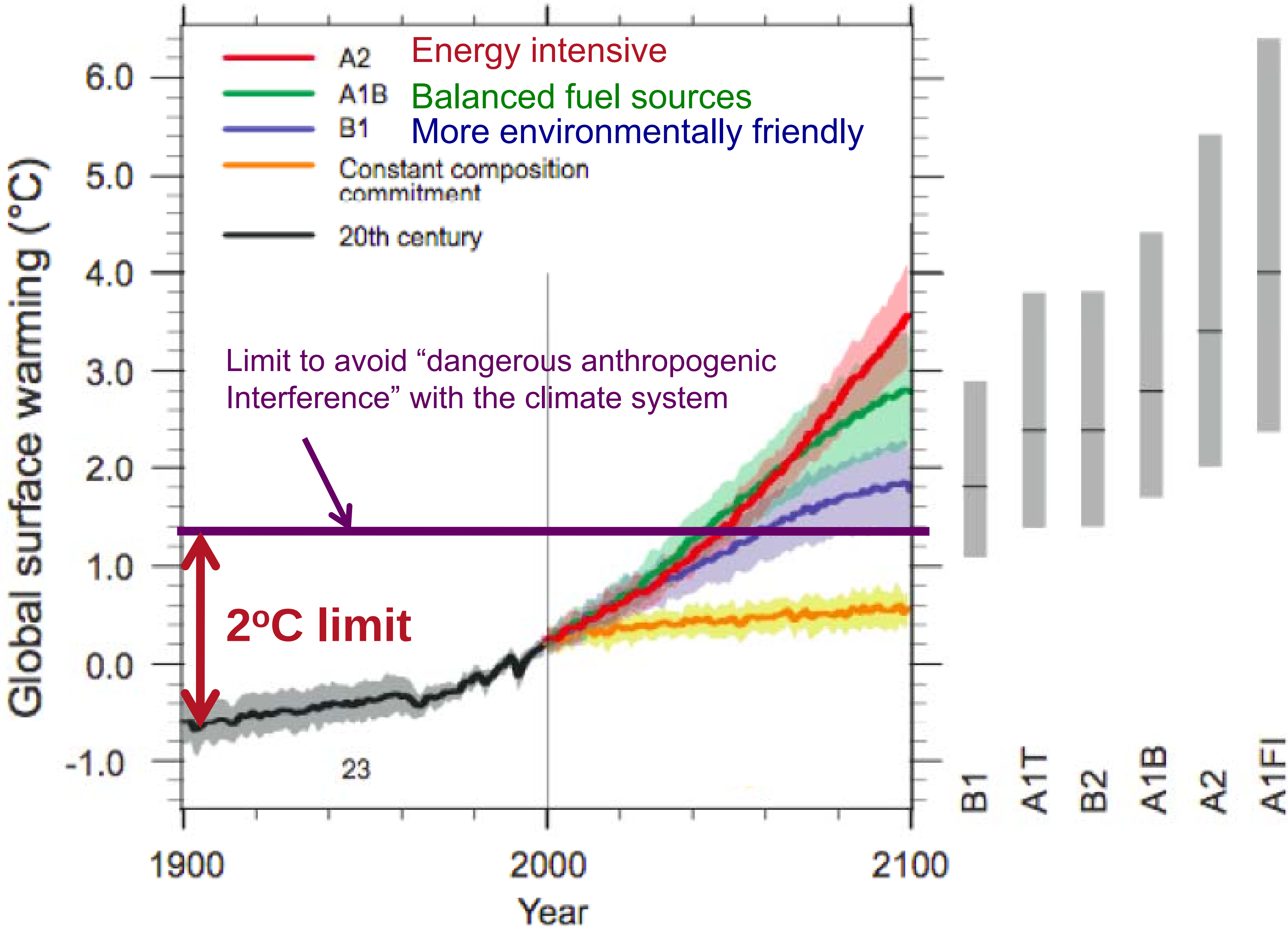
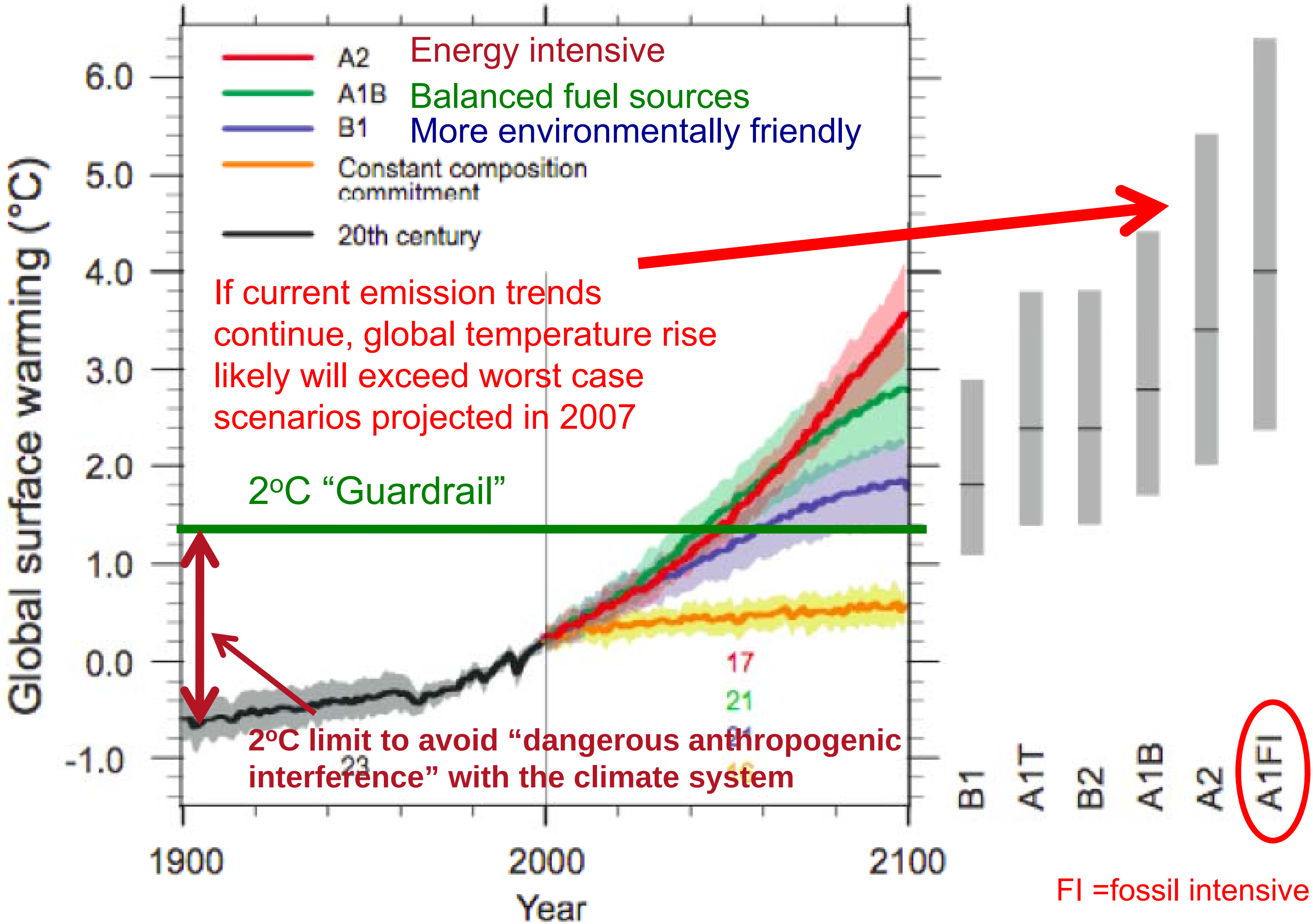


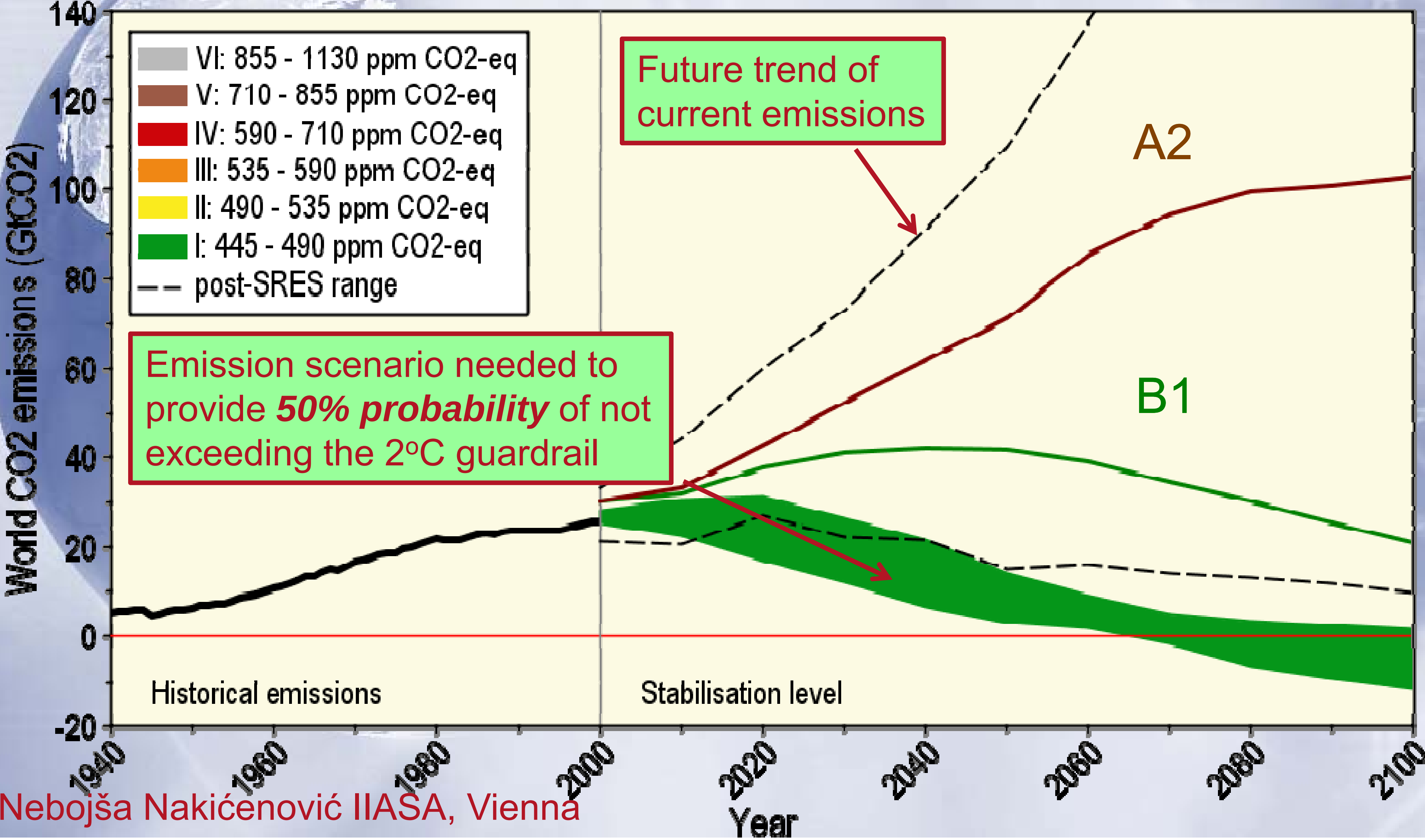


IPCC Fourth Assessment Report Summary for Policy Makers



IPCC Fourth Assessment Report Summary for Policy Makers

Long-Term Stabilization Profiles



Nebojša Nakićenović IIASA, Vienna

Options for Climate Stabilization

Temperature rise	CO_2	CO_2-eq.	Year of peak emissions	% change in global emissions
Global average temperature increase above pre-industrial at equilibrium, using "best estimate" climate sensitivity	CO_2 concentration at stabilisation (2005 = 379 ppm)	CO_2 -eq. concentration at stabilisation including GHGs and aerosols (2005 = 375 ppm)	Peaking year for CO_2 emissions	Change in CO_2 emissions in 2050 (percent of 2000 emissions)
°C	ppm	ppm	year	percent
2.0 - 2.4	350 - 400	445 - 490	2000 - 2015	-85 to -50
2.4 - 2.8	400 - 440	490 - 535	2000 - 2020	-60 to -30
2.8 - 3.2	440 - 485	535 - 590	2010 - 2030	-30 to +5
3.2 - 4.0	485 - 570	590 - 710	2020 - 2060	+10 to +60
4.0 - 4.9	570 - 660	710 - 855	2050 - 2080	+25 to +85
4.9 - 6.1	660 - 790	855 - 1130	2060 - 2090	+90 to +140

Table 1

Characteristics of various emission trajectories to achieve stabilisation of atmospheric greenhouse gas concentrations, in CO_2 and CO_2-eq. The equilibrium global average temperature increase above pre-industrial is given for each stabilisation target. Only the first scenario, shown in the first row, has a possibility to meet the 2°C guardrail. Note that current atmospheric greenhouse gas concentrations are about 385 ppm CO_2 and 396 ppm CO-eq (including the cooling effect of aerosols). Modified from[1] (table 5.1, p. 67).

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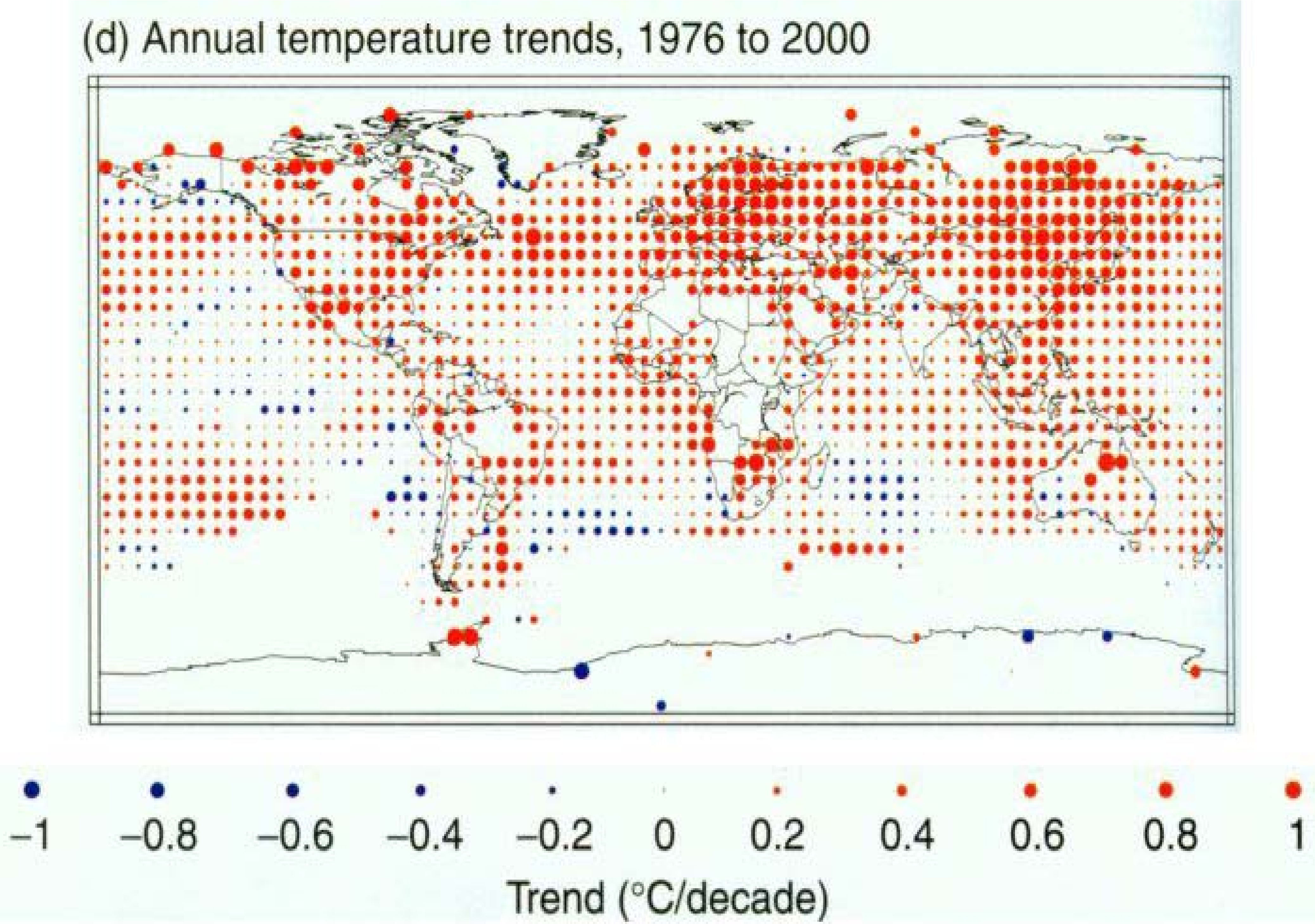
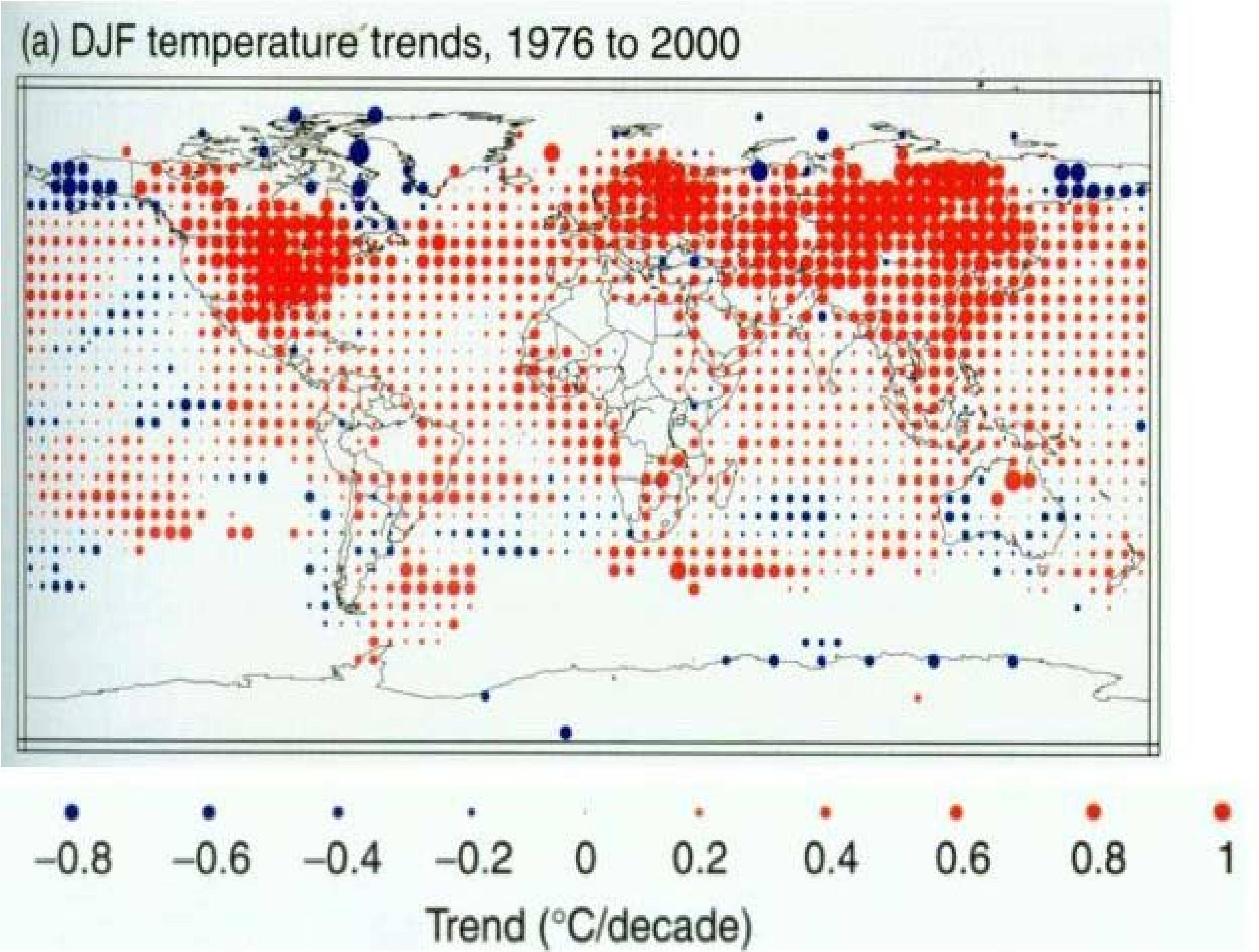
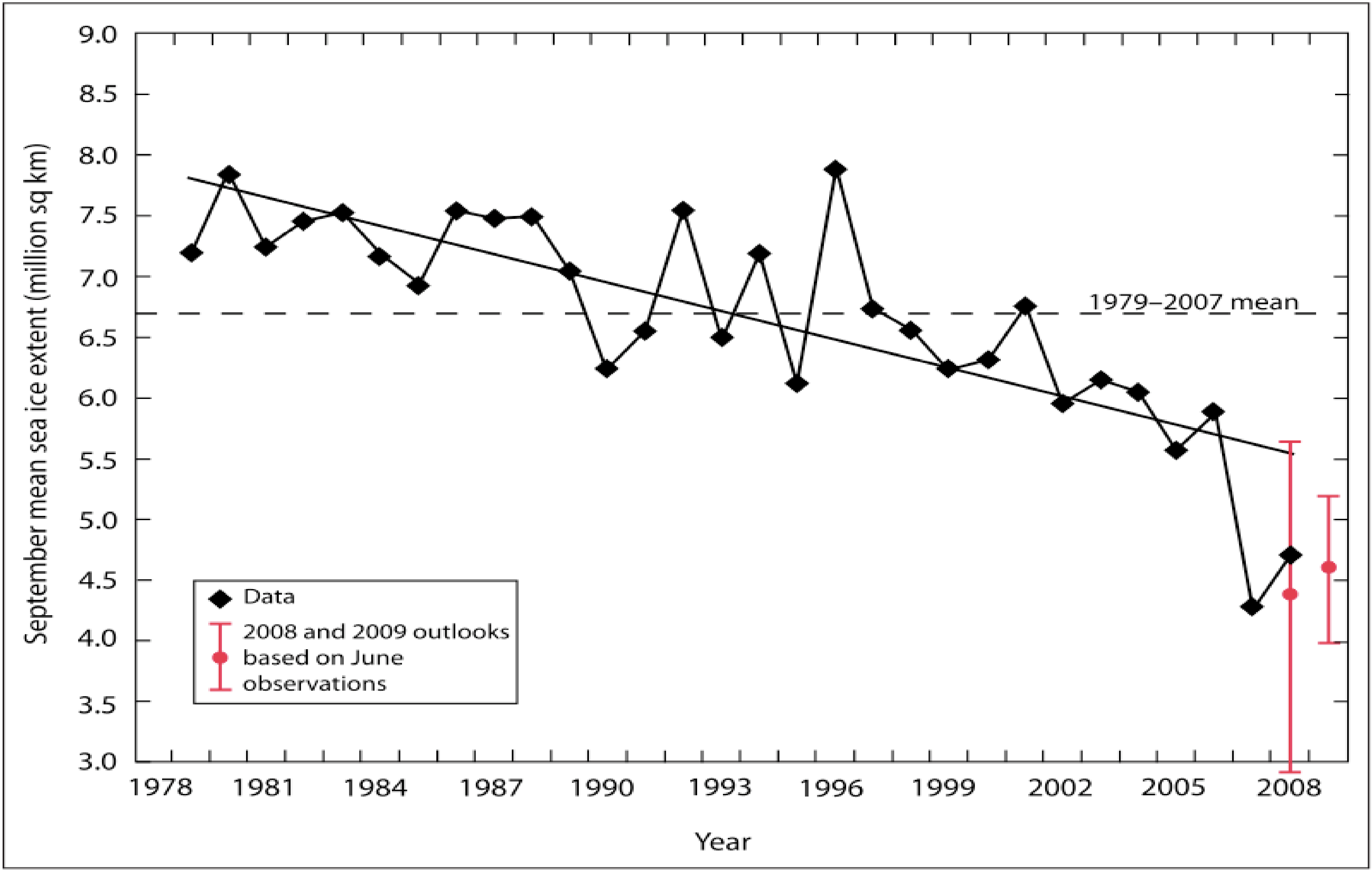


Source: IPCC, 2001: Climate Change 2001: The Scientific Basis

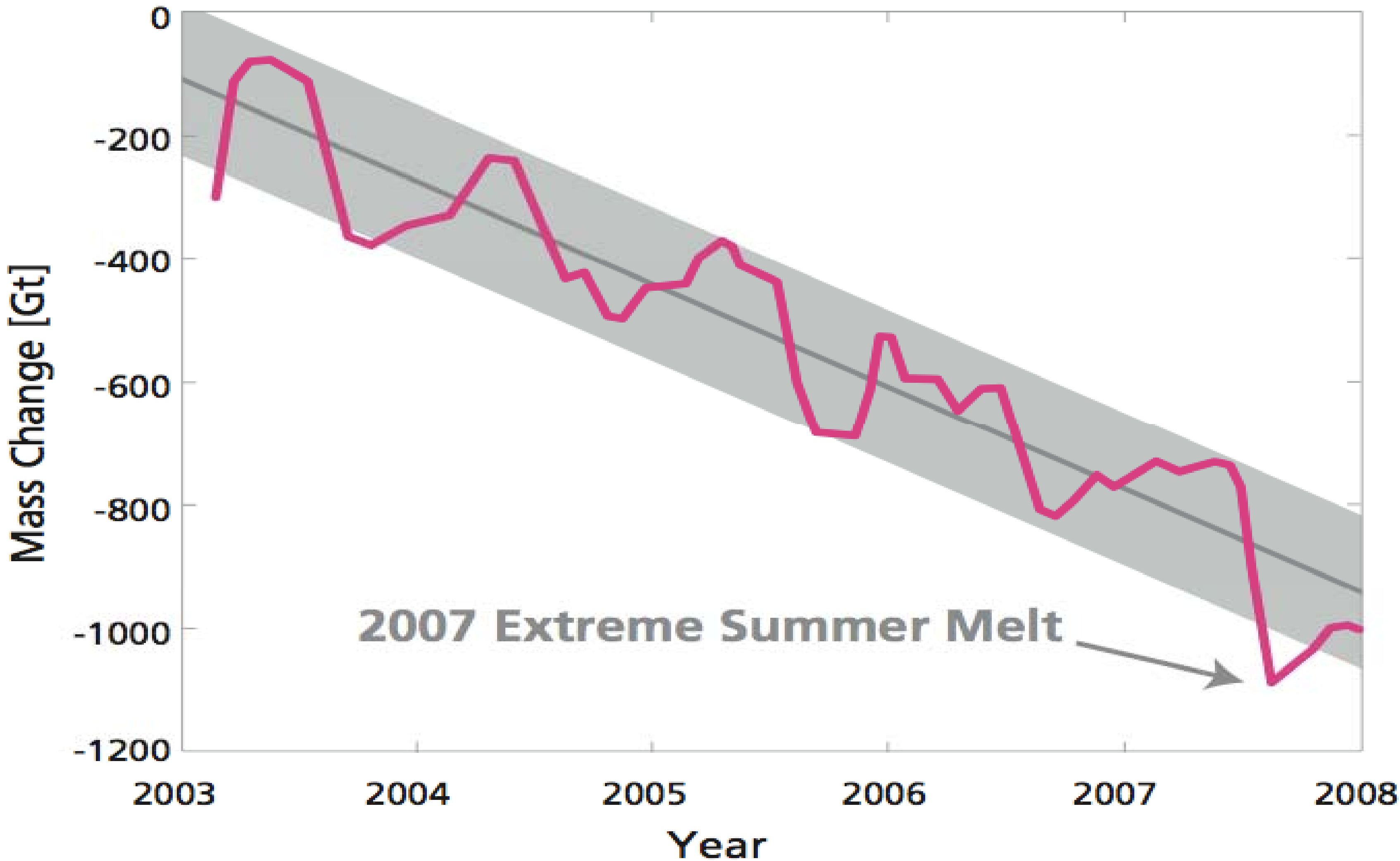


Source: IPCC, 2001: Climate Change 2001: The Scientific Basis

Arctic Sea-Ice Decline



Decline in Greenland Ice Mass



Change in the mass of the Greenland ice sheet from 2003 to 2008, as estimated from satellite measurements of changes in the gravitational field. The grey shaded area shows the 90% confidence level of the fitted straight line. The vertical axis is set to an arbitrary value of zero at the beginning of the observational period[8].

Increase in Hurricane Intensity

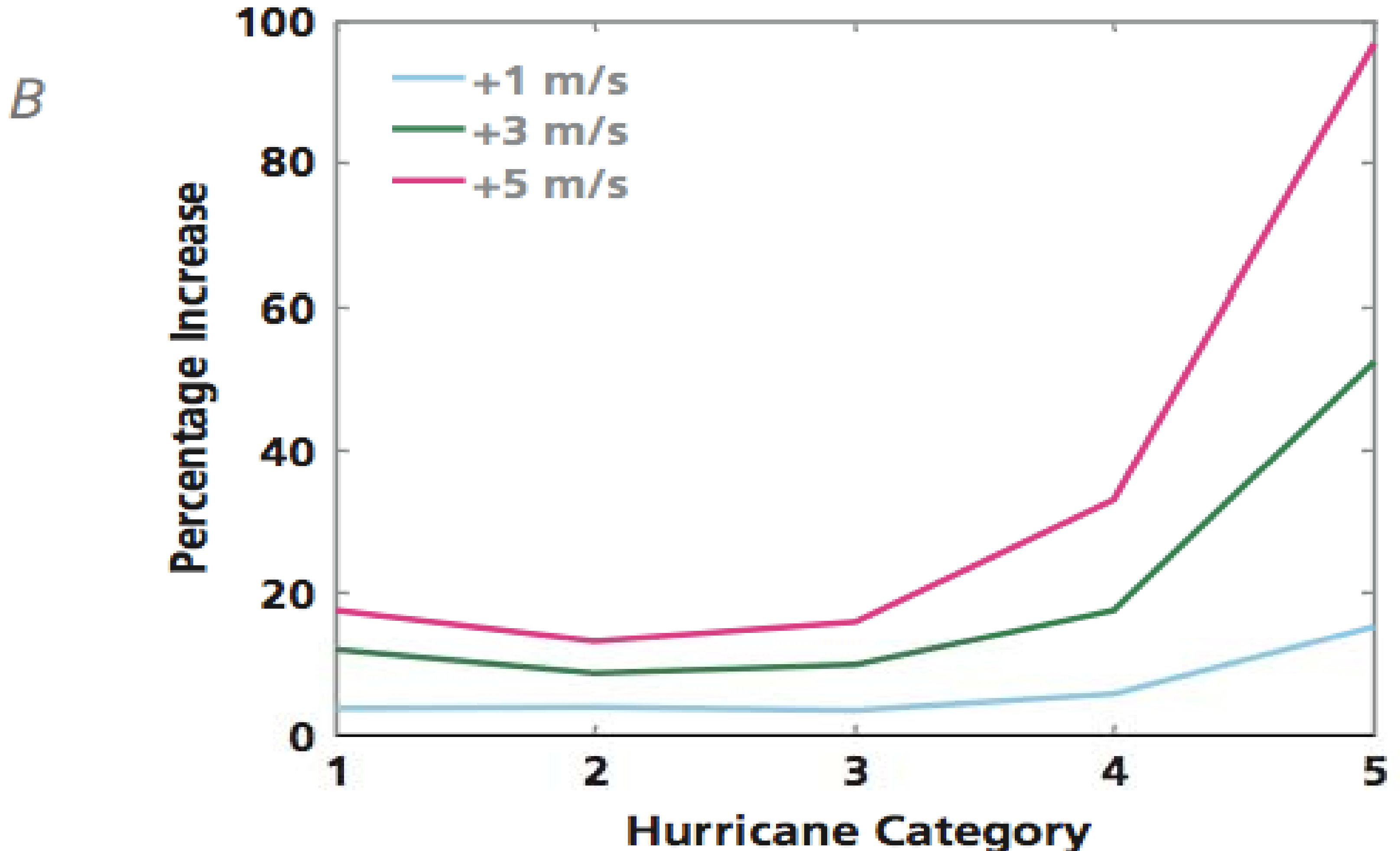
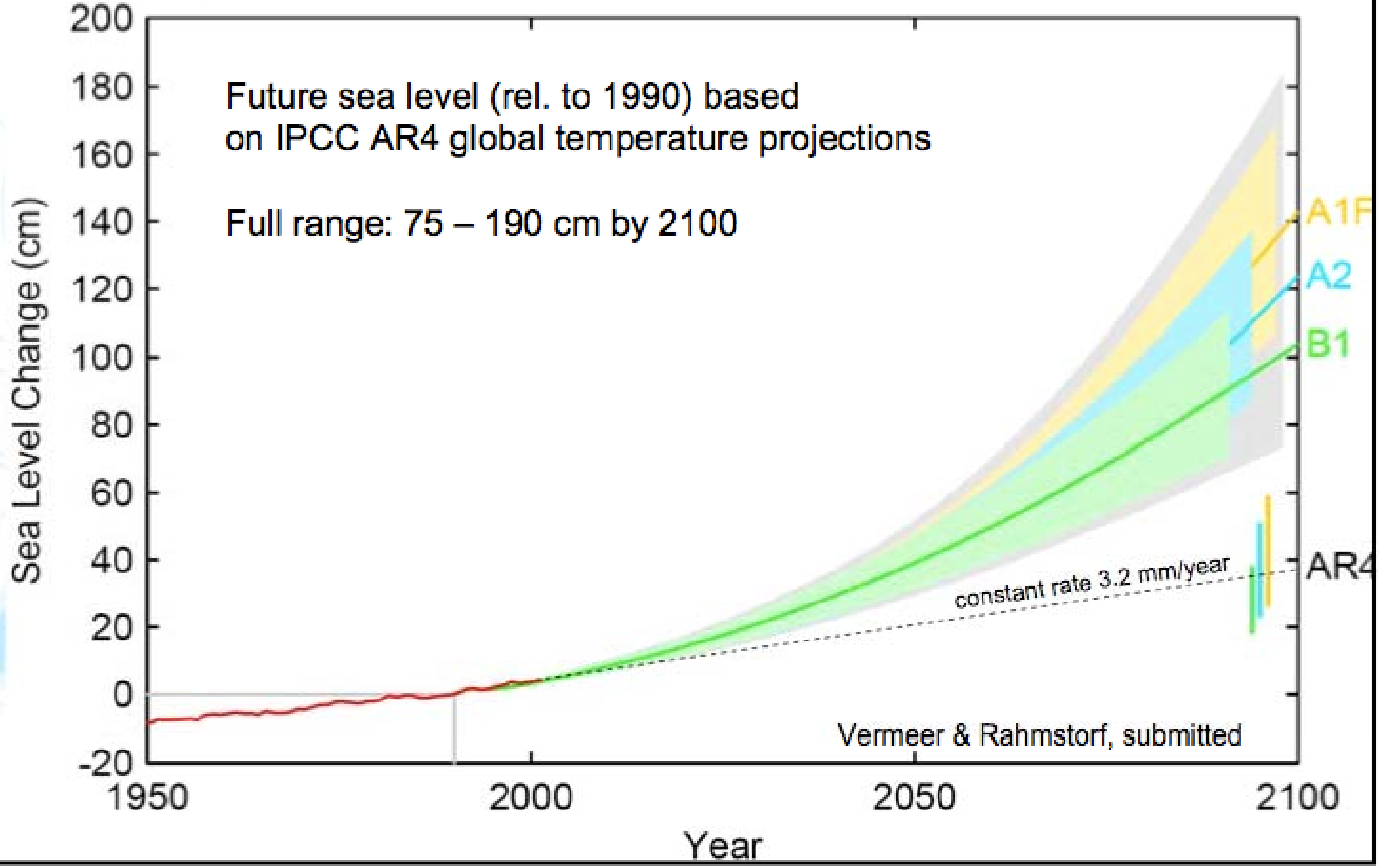


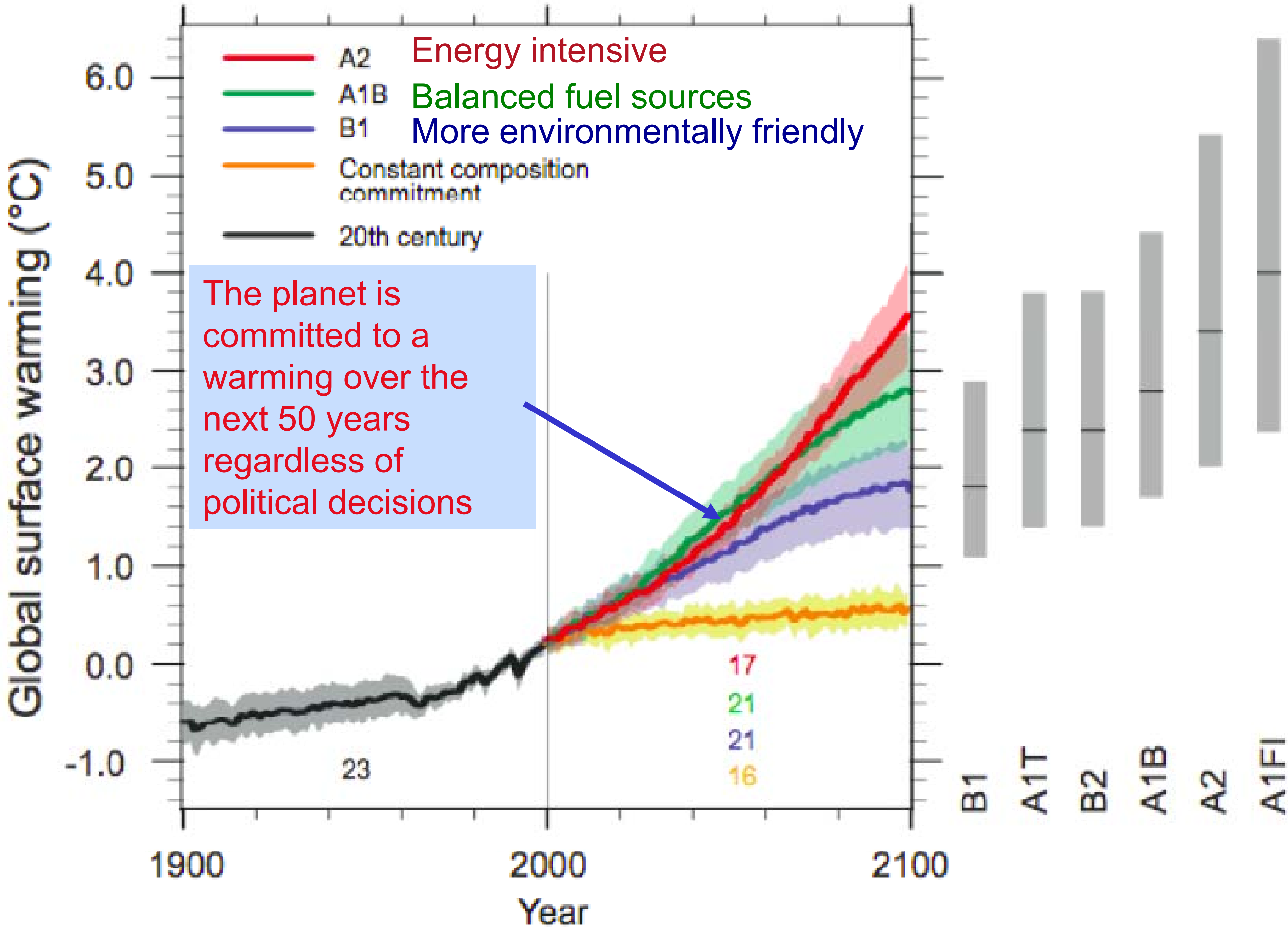
Figure 6

(A) The numbers of North Atlantic tropical cyclones for each maximum wind speed shown on the horizontal axis. The most intense (Category 5) tropical cyclones have maximum wind speeds of 70 m/s or greater. (B) The proportional increase by cyclone (hurricane) category (1 – least intense; 5 – most intense) arising from increases in maximum wind speeds of 1, 3 and 5 m/s. Note the disproportionately large increase in the most intense tropical cyclones with modest increases in maximum wind speed, compared to the increase in less intense cyclones[23].

WWW.OZEAN-KLIMA.DE

Future projections





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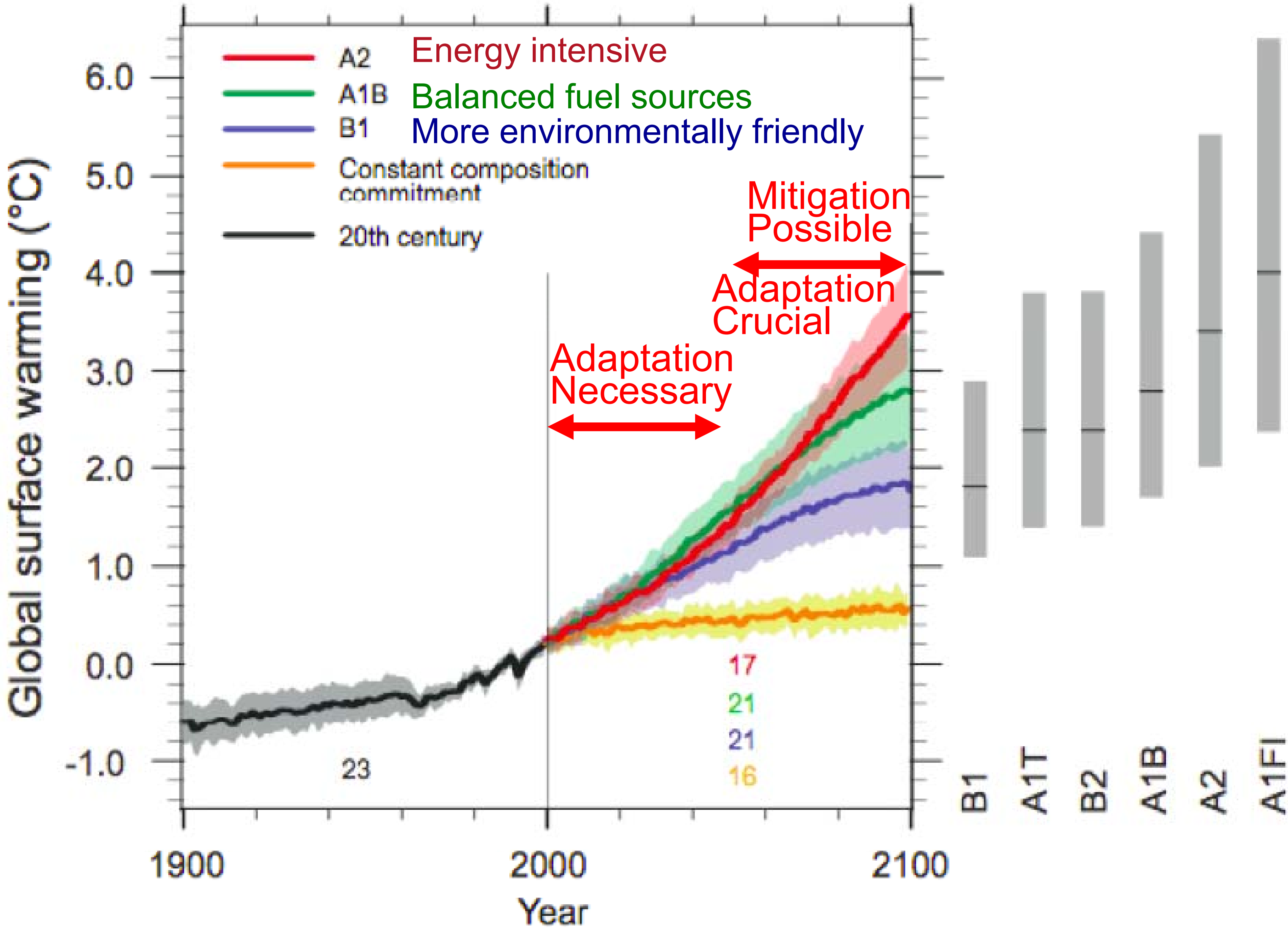
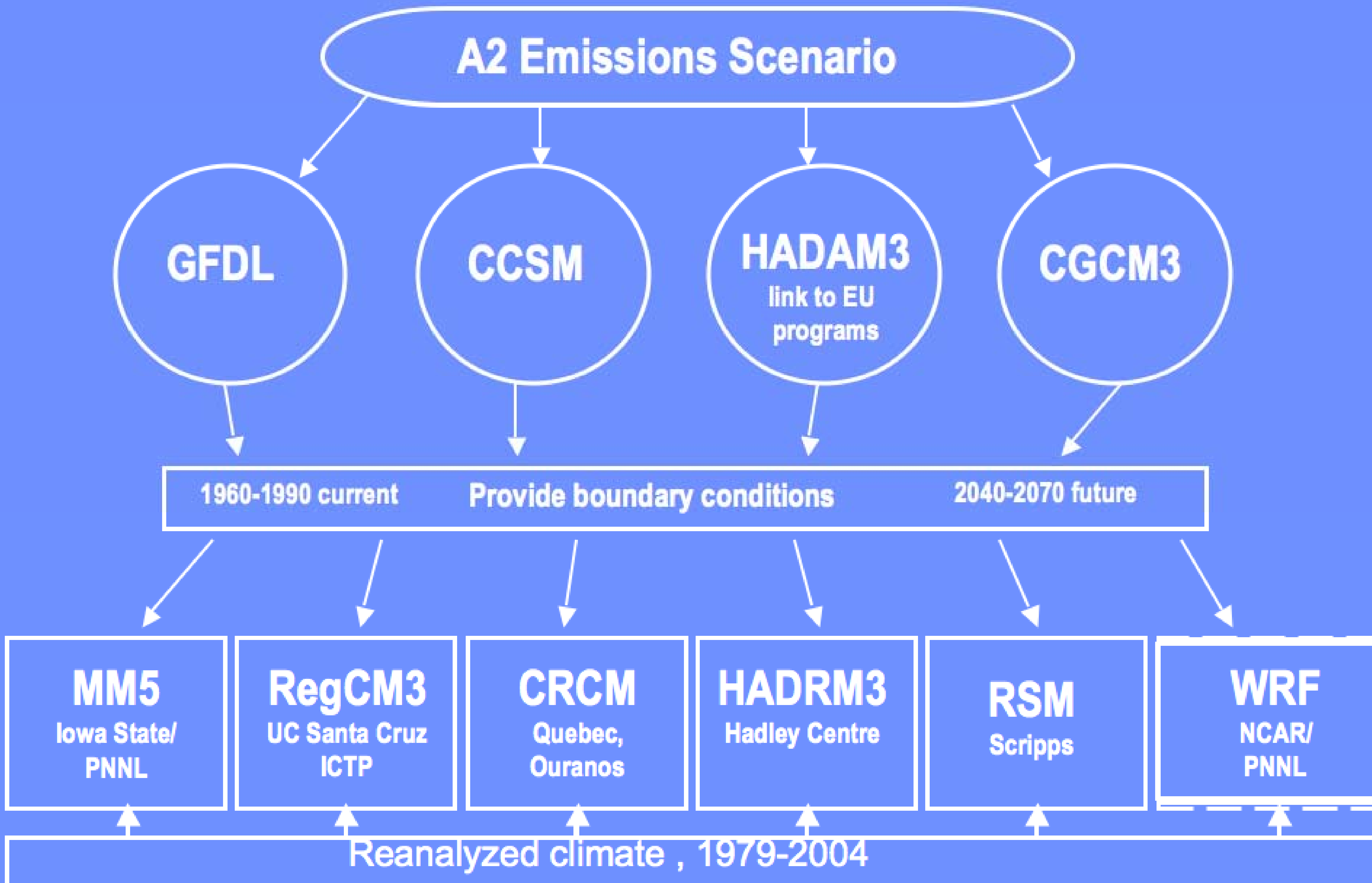
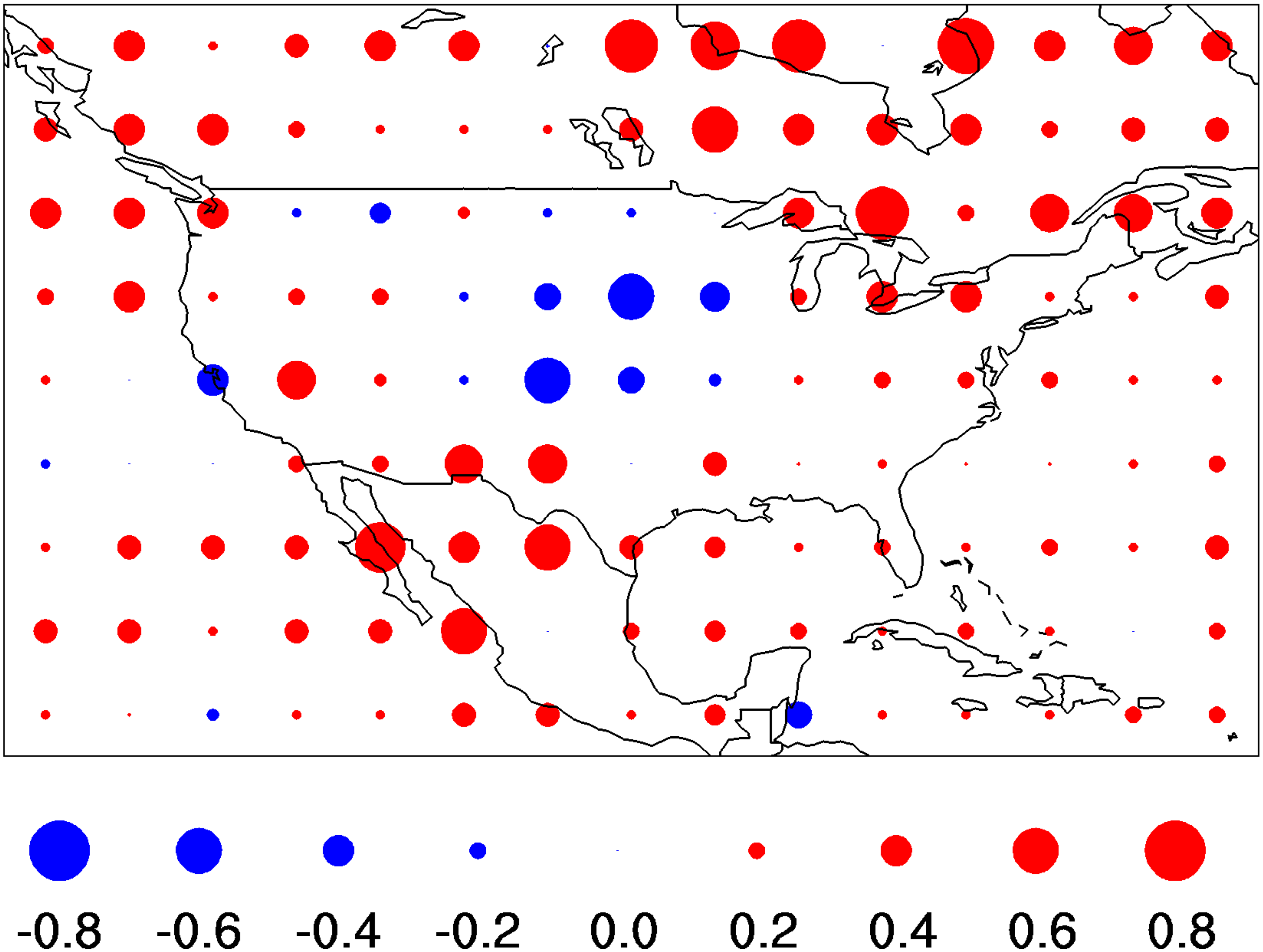


IPCC Fourth Assessment Report Summary for Policy Makers

NARCCAP Plan



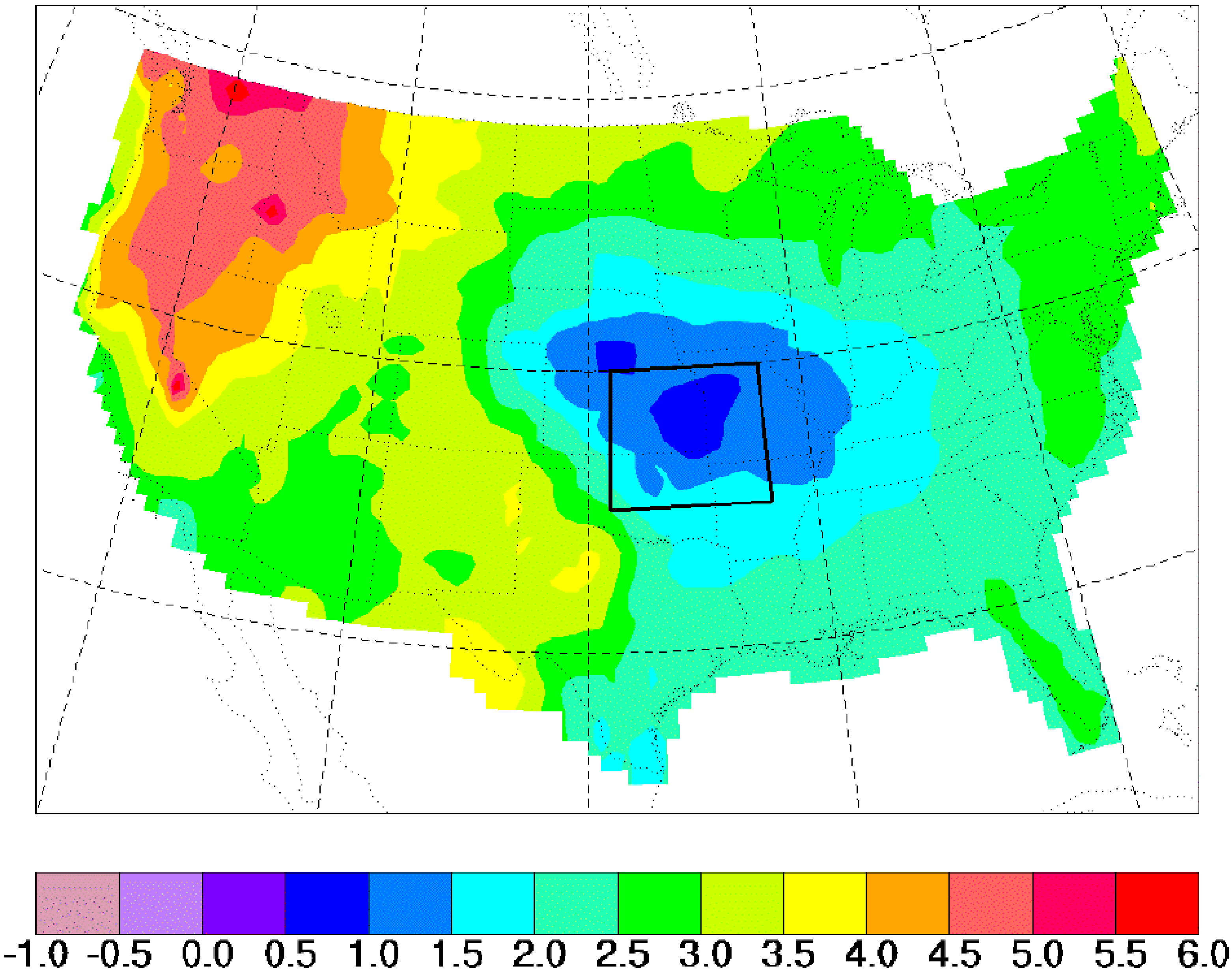
Observed Summer (JJA) Daily Maximum Temperature Changes (K), 1976-2000



Adapted from Folland et al. [2001]

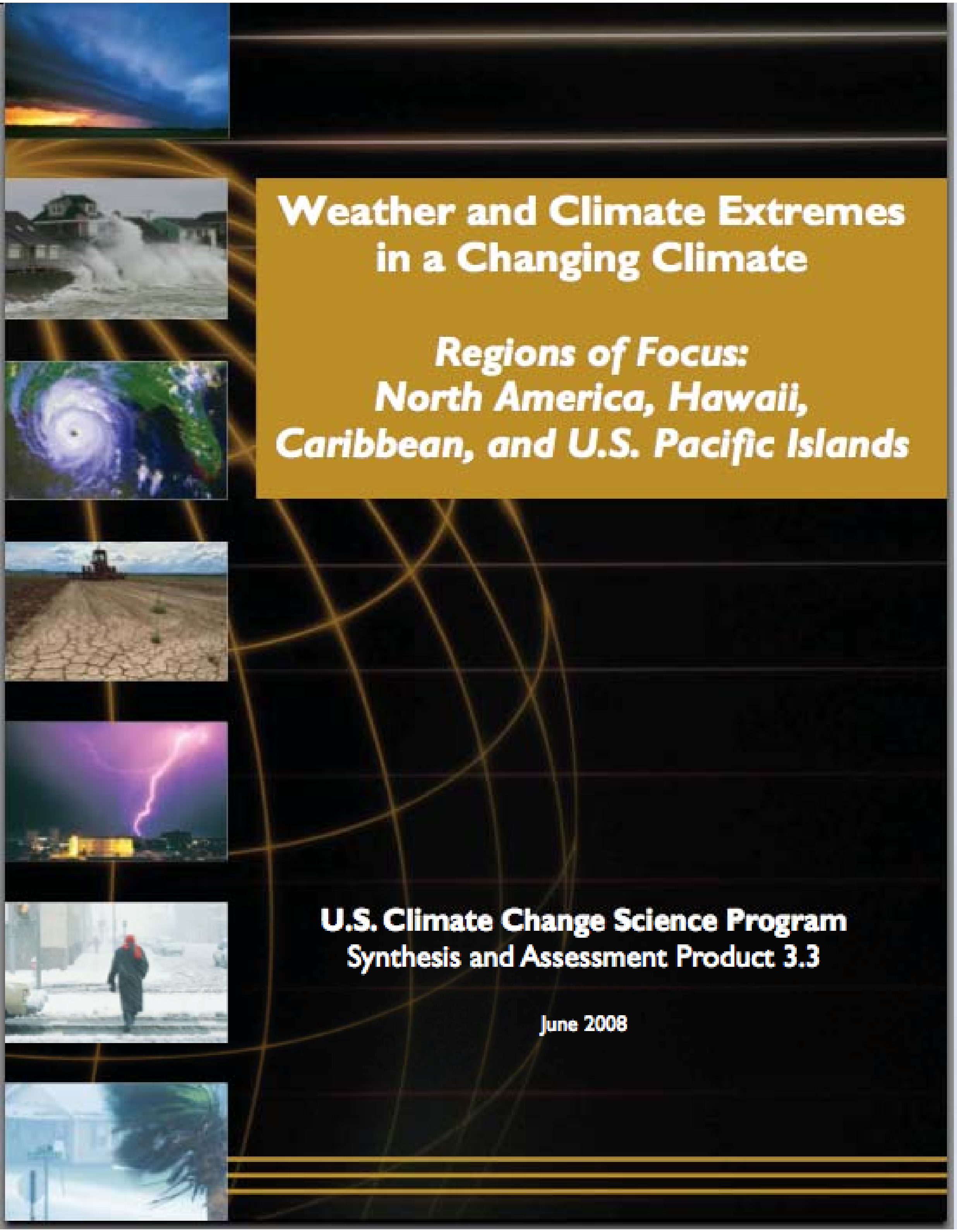
“Warming Hole”:

Simulations of changes in daily maximum summertime temperatures between 1990s and 2040s



ΔT_{max} (JJA) °C

Pan, Z., R. W. Arritt, E. S. Takle, W. J. Gutowski, Jr., C. J. Anderson, and M. Segal,2004: Altered hydrologic feedback in a warming climate introduces a “warming hole”. Geophys. Res. Lett.31, L17109, doi:10.1029/2004GL020528.



"One of the clearest trends in the United States observational record is an increasing frequency and intensity of heavy precipitation events… Over the last century there was a 50% increase in the frequency of days with precipitation over 101.6 mm (four inches) in the upper midwestern U.S.; this trend is statistically significant "

Projected Changes for the Climate of the Midwest*

Temperature

- Longer frost-free period (high)
- Higher average winter temperatures (high)
- Fewer extreme cold temperatures in winter (high)
- Fewer extreme high temperatures in summer in short term but more in long term (medium)
- Higher nighttime temperatures both summer and winter (high)
- More freeze-thaw cycles (high)
- Increased temperature variability (high)

Follows trend of last 25 years and projected by models
No current trend but model suggestion or current trend but model inconclusive

*Estimated from IPCC reports

Projected Changes for the Climate of the Midwest*

Precipitation

- More (~10%) precipitation annually (medium)
- Change in "seasonality": Most of the increase will come in the first half of the year (wetter springs, drier summers) (high)
- More water-logging of soils (medium)
- More variability of summer precipitation (high)
  - More intense rain events and hence more runoff (high)
  - Higher episodic streamflow (medium)
  - Longer periods without rain (medium)
- Higher absolute humidity (high)
- Stronger storm systems (medium)
- More winter soil moisture recharge (medium)
- Snowfall increases (late winter) in short term but decreases in the long run (medium)

Follows trend of last 25 years and projected by models

No current trend but model suggestion or current trend but model inconclusive

*Estimated from IPCC reports

Projected Changes for the Climate of the Midwest*

Other

- Reduced wind speeds (high)
- Reduced solar radiation (medium)
- Increased tropospheric ozone (high)
- Accelerated loss of soil carbon (high)
- Phenological stages are shortened (high)
- Weeds grow more rapidly under elevated atmospheric CO2 (high)
- Weeds migrate northward and are less sensitive to herbicides (high)
- Plants have increased water used efficiency (high)

Follows trend of last 25 years and projected by models
No current trend but model suggestion or current trend but model inconclusive

*Estimated from IPCC and CCSP reports

Summary

- Increases in CO_2 will create a wide variety of climate changes
- Some regions will experience changes favorable for local societal activities, but most will be unfavorable
- Stabilization to avoid passing the 2oC guardrail will require major decreases in global emissions
- Many, but not all, observed regional climate changes are consistent with global and regional climate model projections