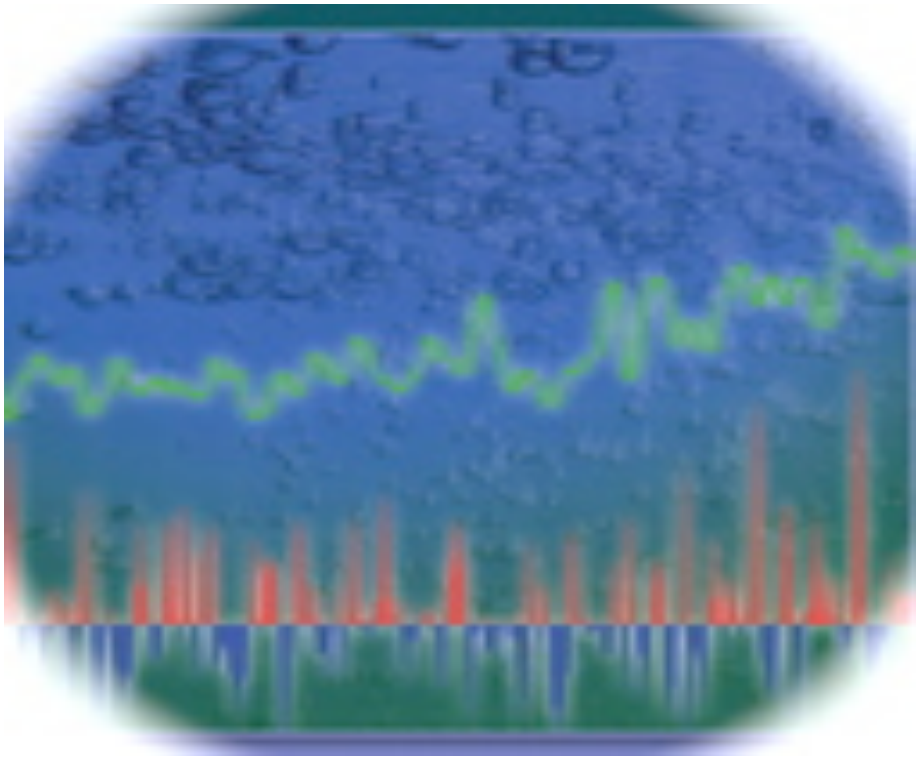
Climate Dynamics: Why Does Climate Vary?

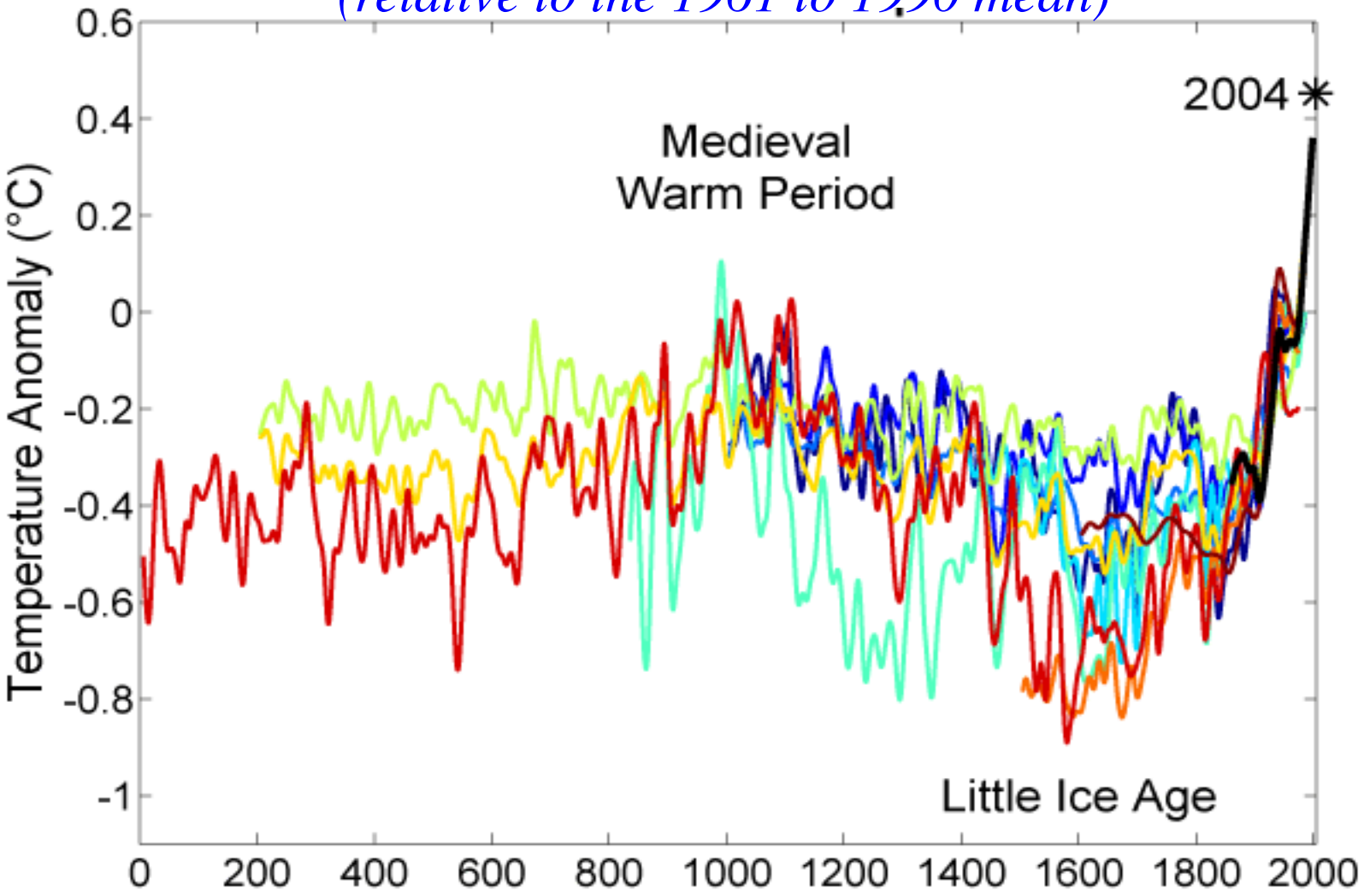


The Recent Global Warming: Observations, Theories, and the Science and Art of Modeling

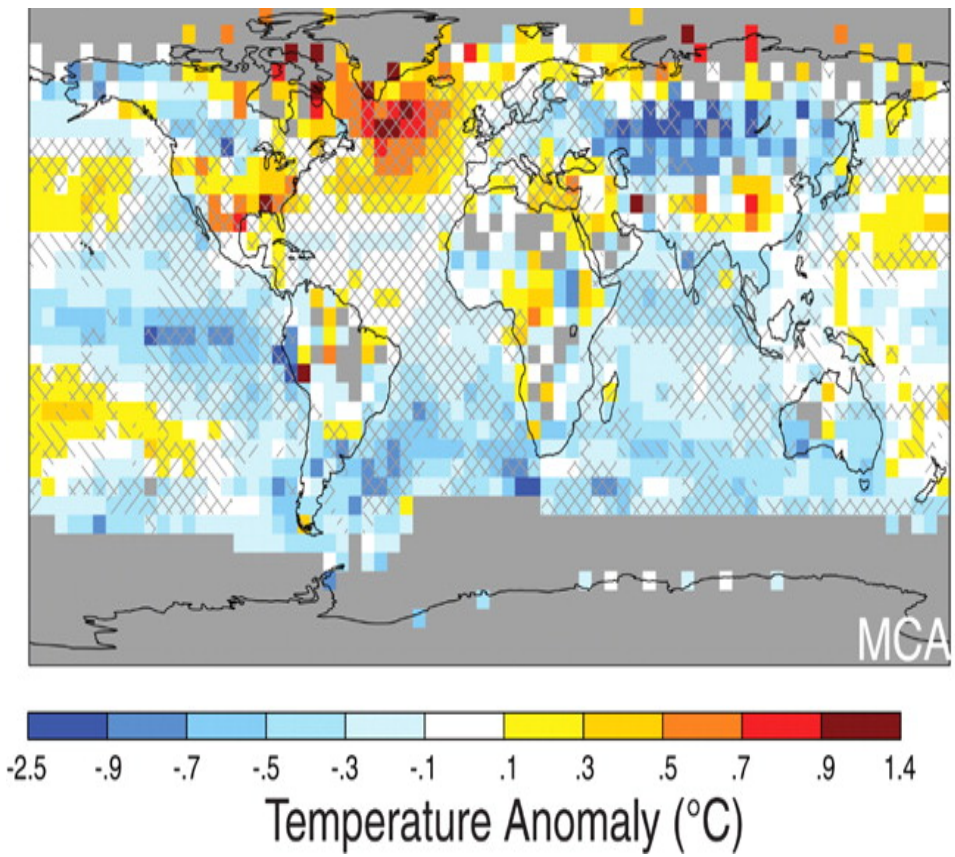
http://www.esrl.noaa.gov/psd/people/dezheng.sun/lectures/ATOC7500.html

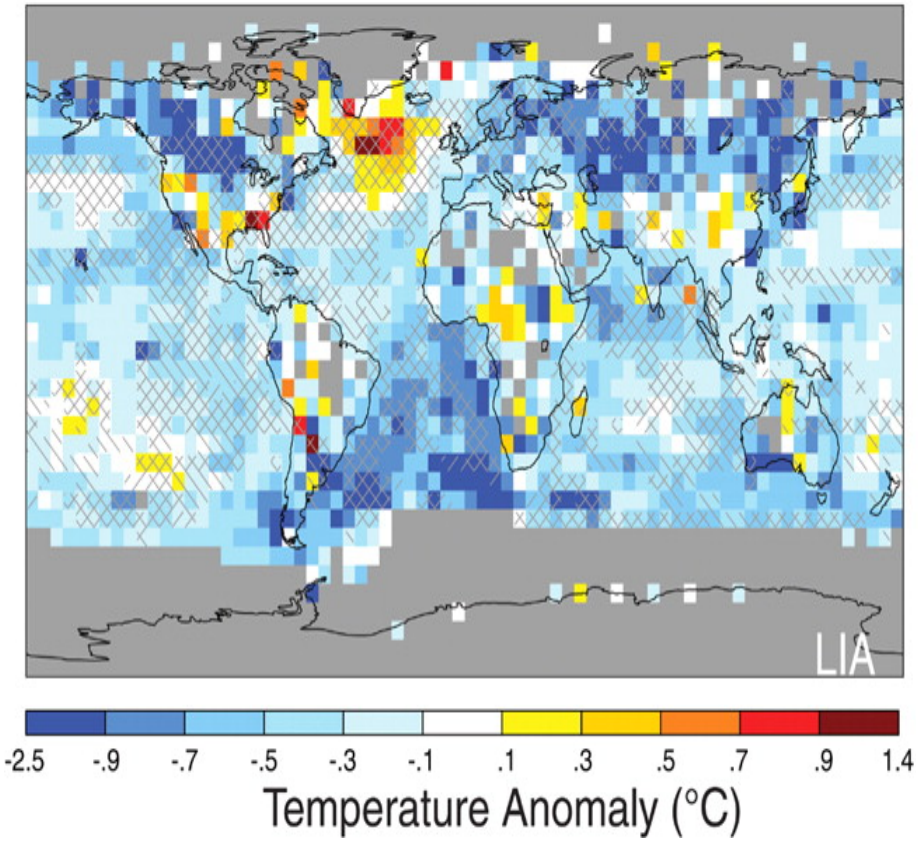
The MCA (MWP) & LIA

Global Surface Temperature over the last 2000 years
(relative to the 1961 to 1990 mean)



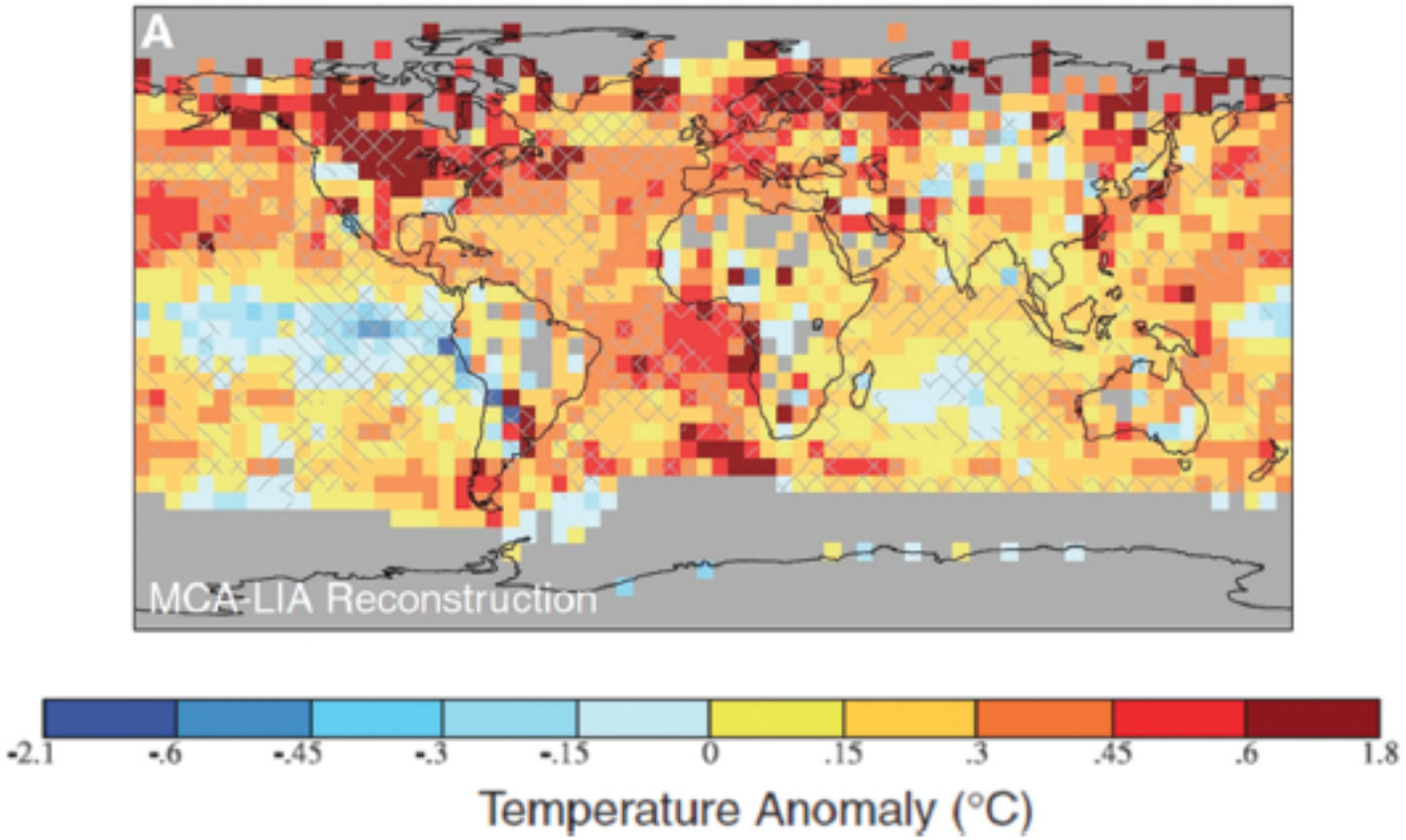
Temperature Anomalies of MCA (950-1250) & LIA (1400-1700) Relative to 1961-1990





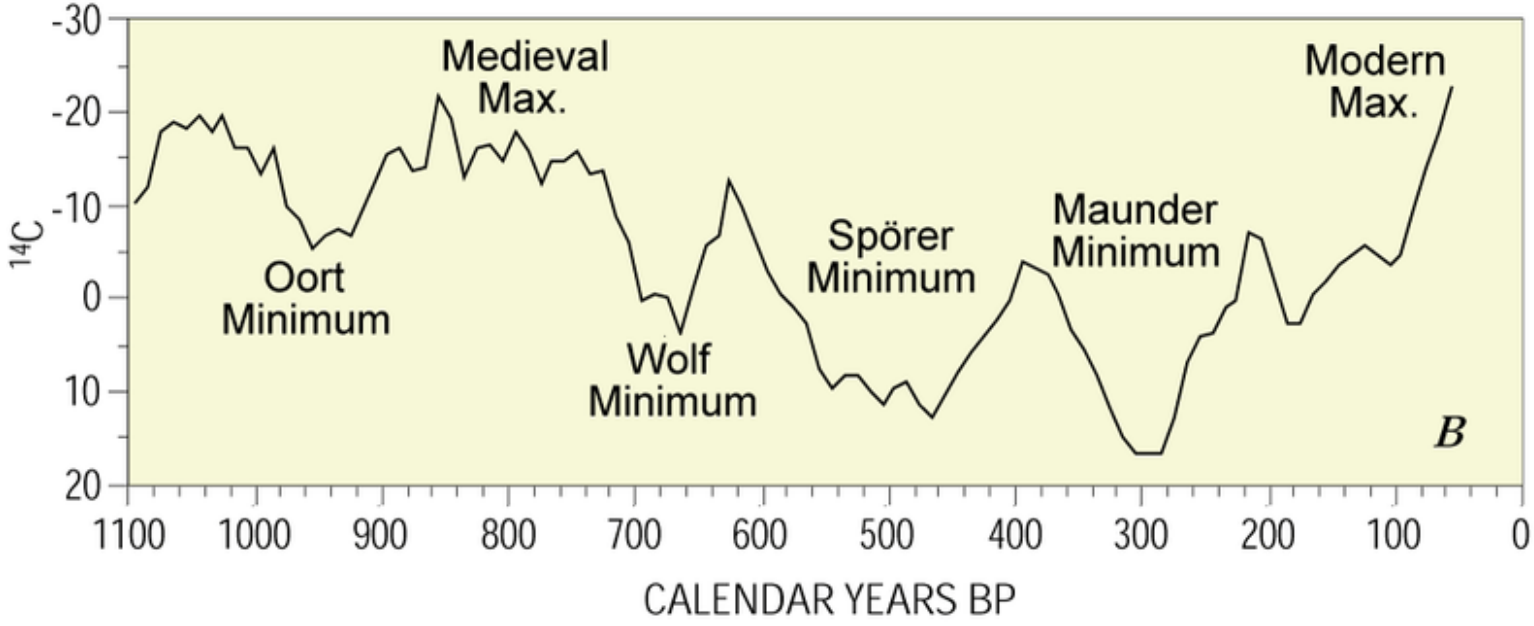
Mann et al. 2009

Temperature Difference Between MCA and LIA



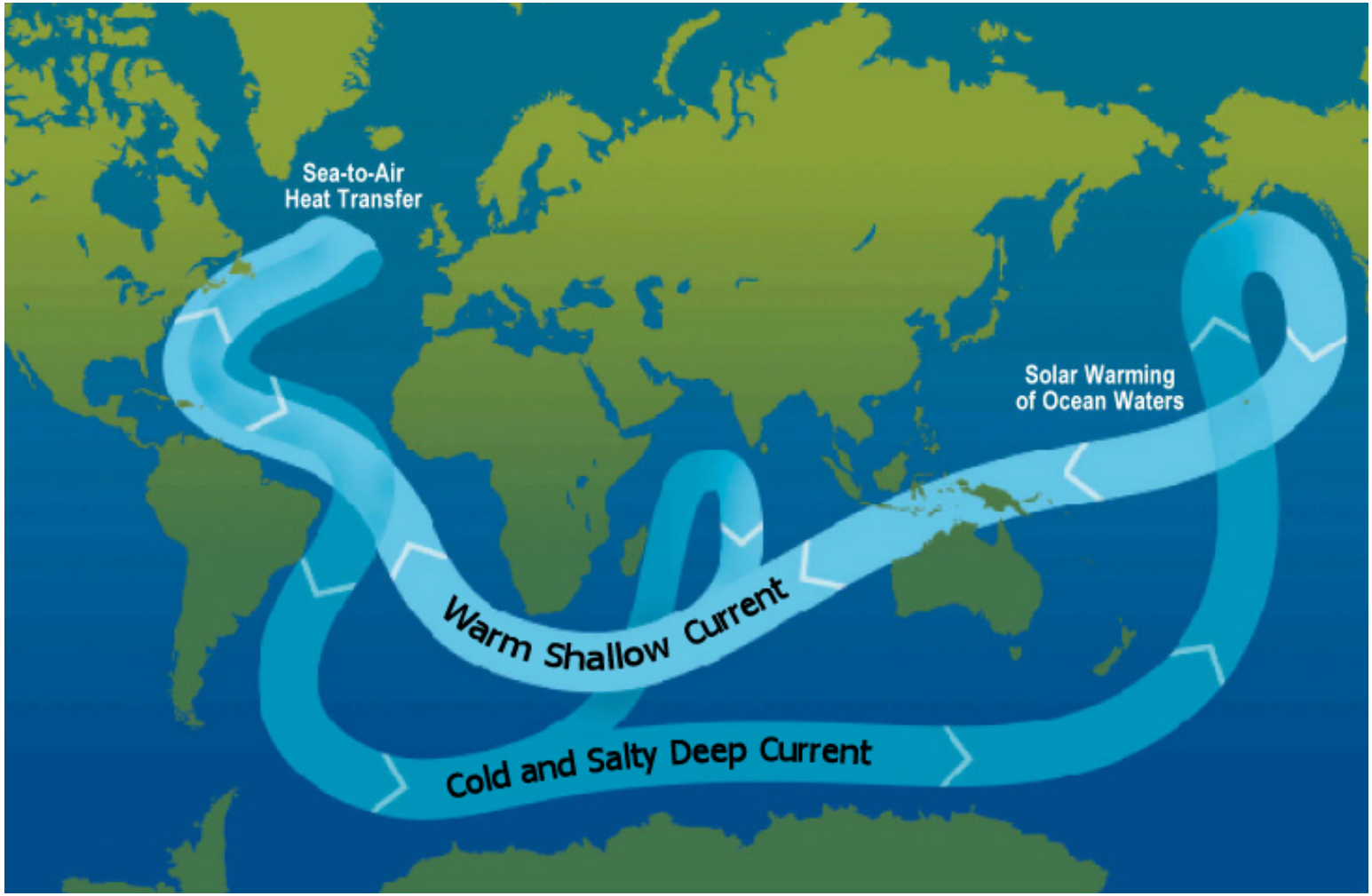
Trenberth (1990)

Mechanisms
Variability in Sunspot Activity



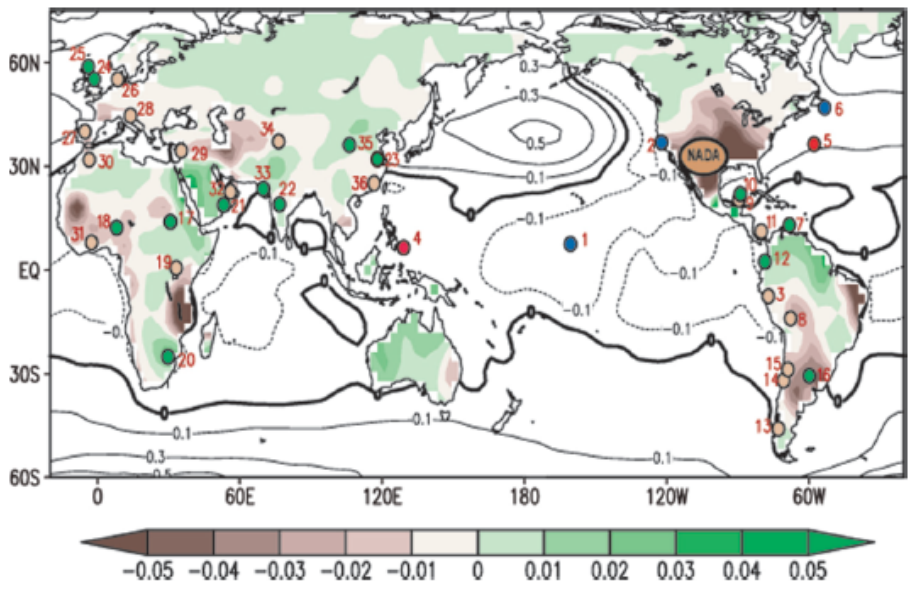
Mechanisms
Variability in Volcanic Activity

Mechanisms
Themohaline Circulation Variability

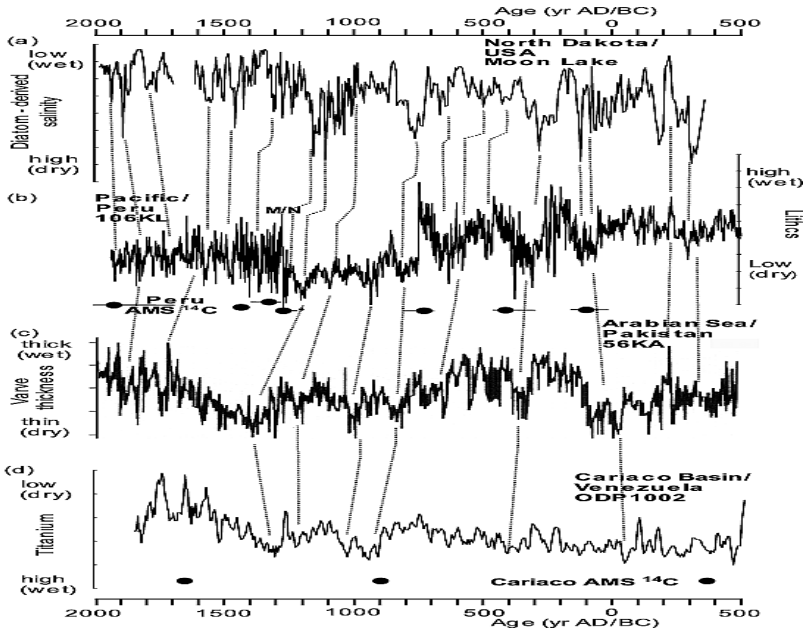


A Role for ENSO?

Coral Reconstructed MCA SST has a PDO-like Pattern

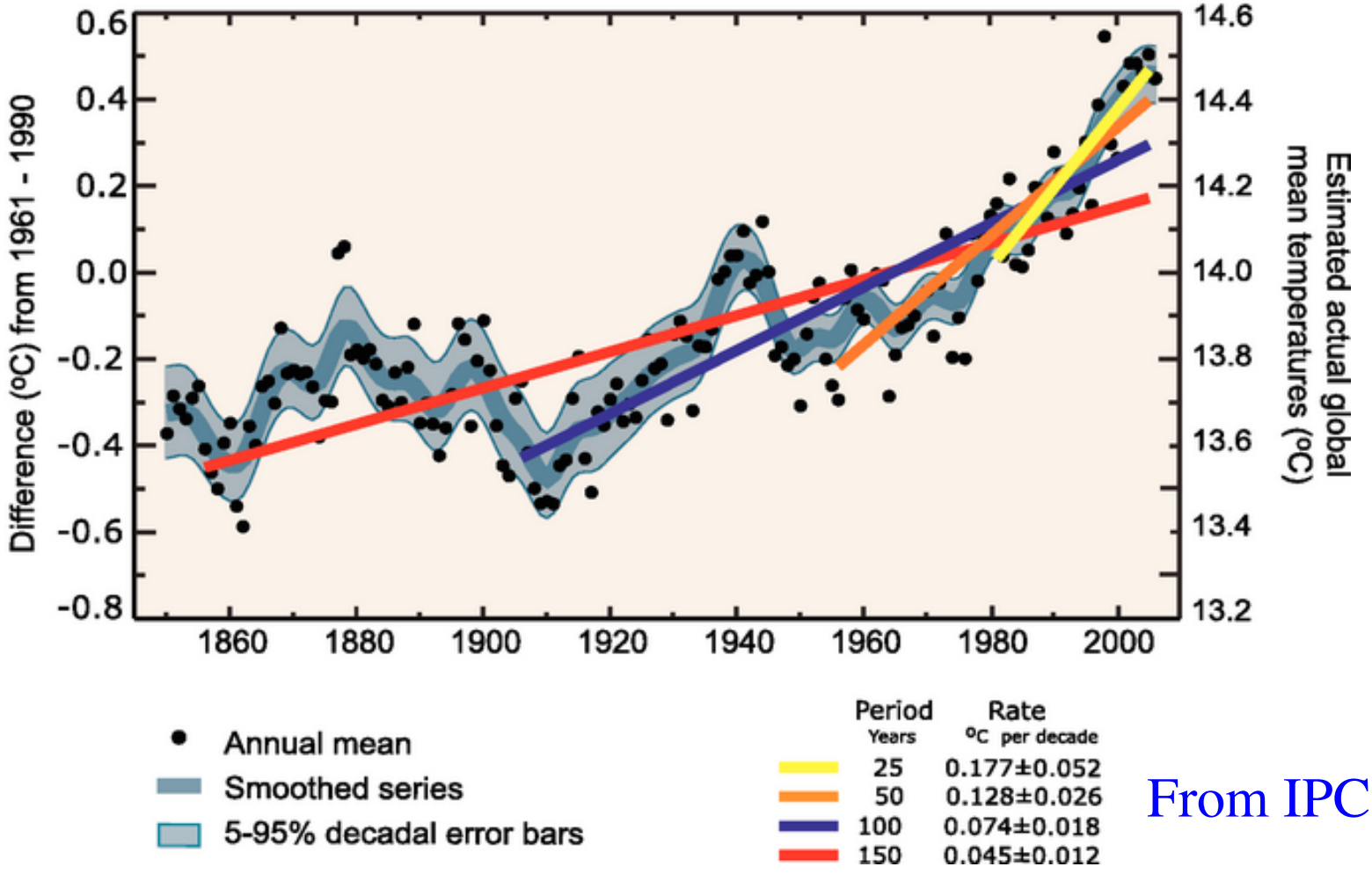


ENSO activity Was weak during MCA



The Recent Global Warming

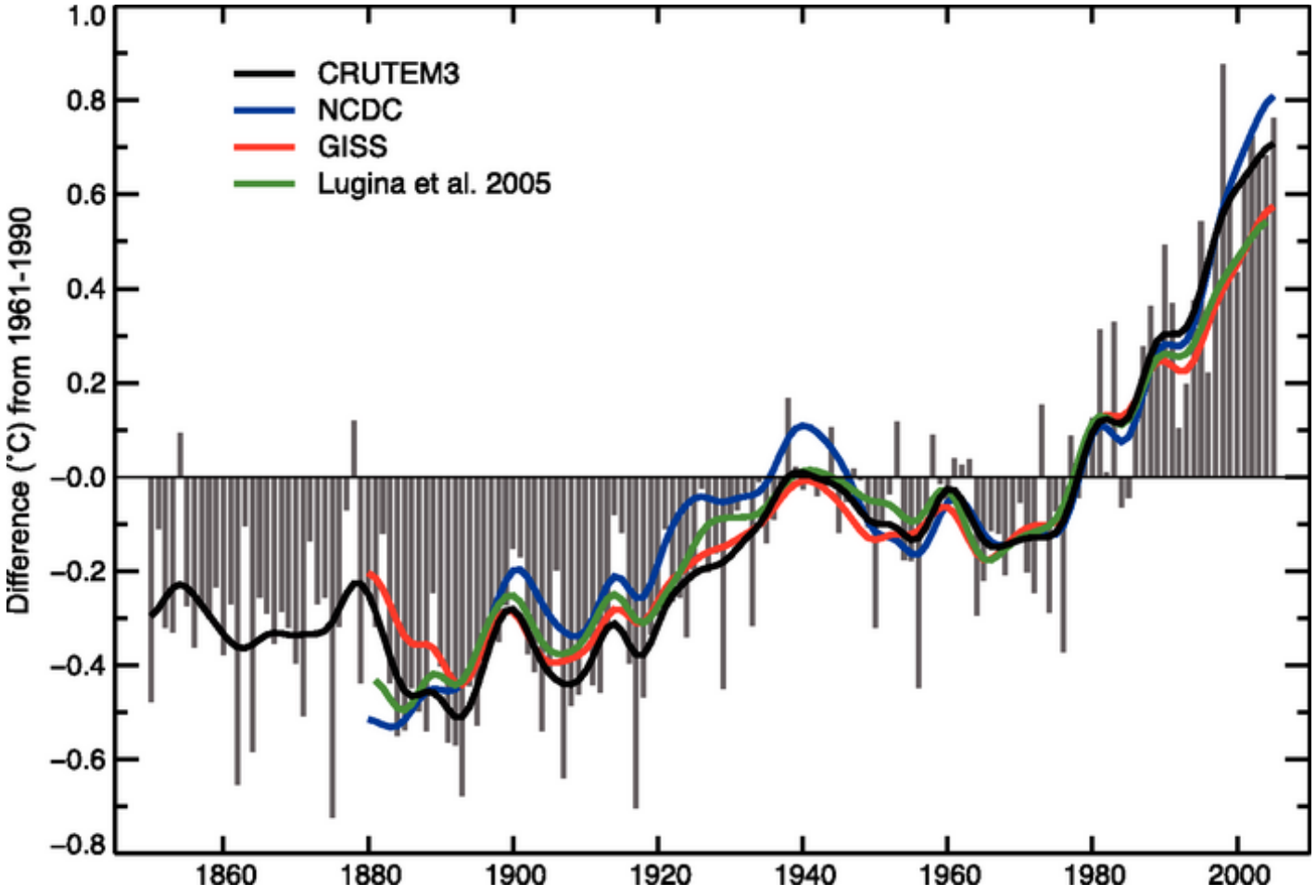
Annual anomalies of global surface air temperature (°C)
(relative to the 1961 to 1990 mean)



From IPCC

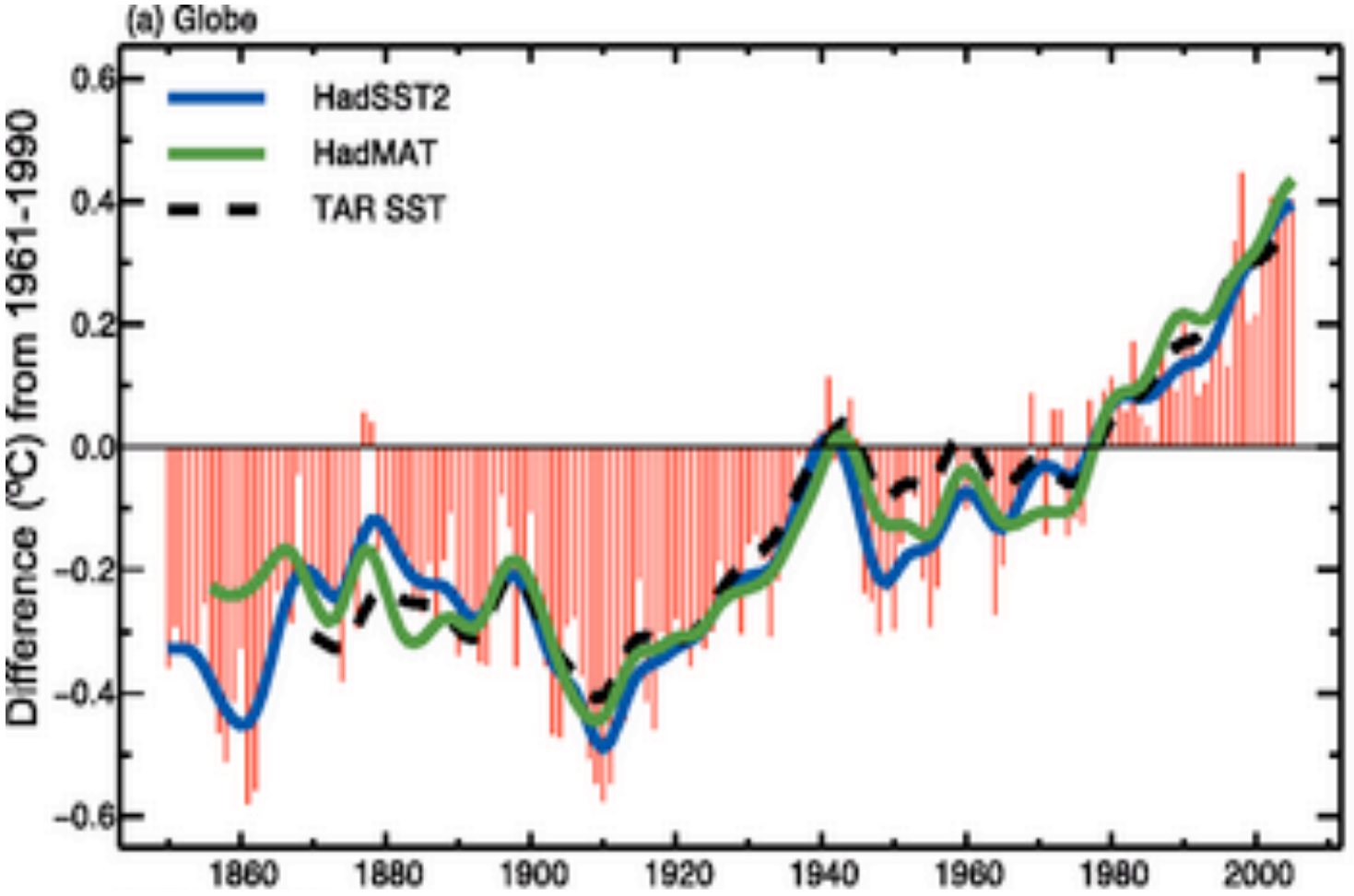
The Recent Global Warming

Annual anomalies of global surface air temperature over land (°C) (relative to the 1961 to 1990 mean)



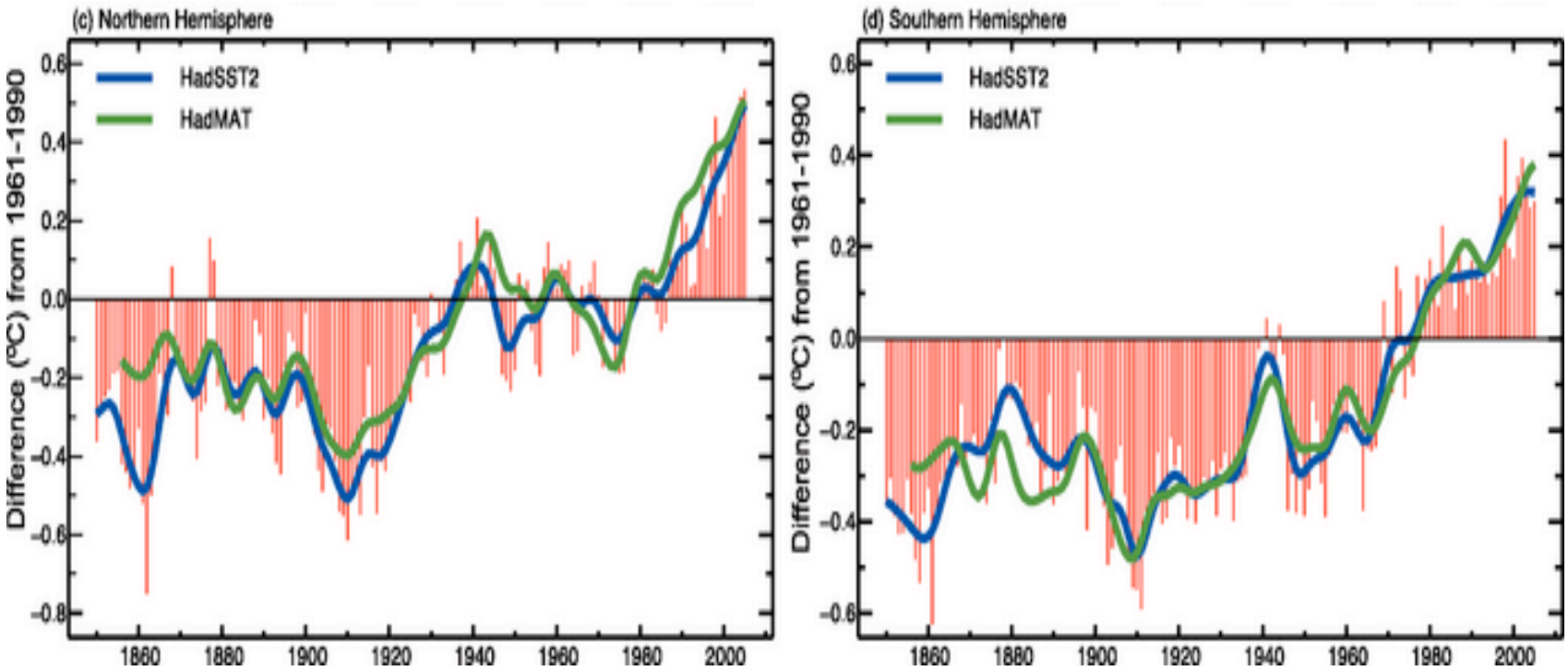
The Recent Global Warming

Annual anomalies of global Sea Surface Temperature (°C)
(relative to the 1961 to 1990 mean)



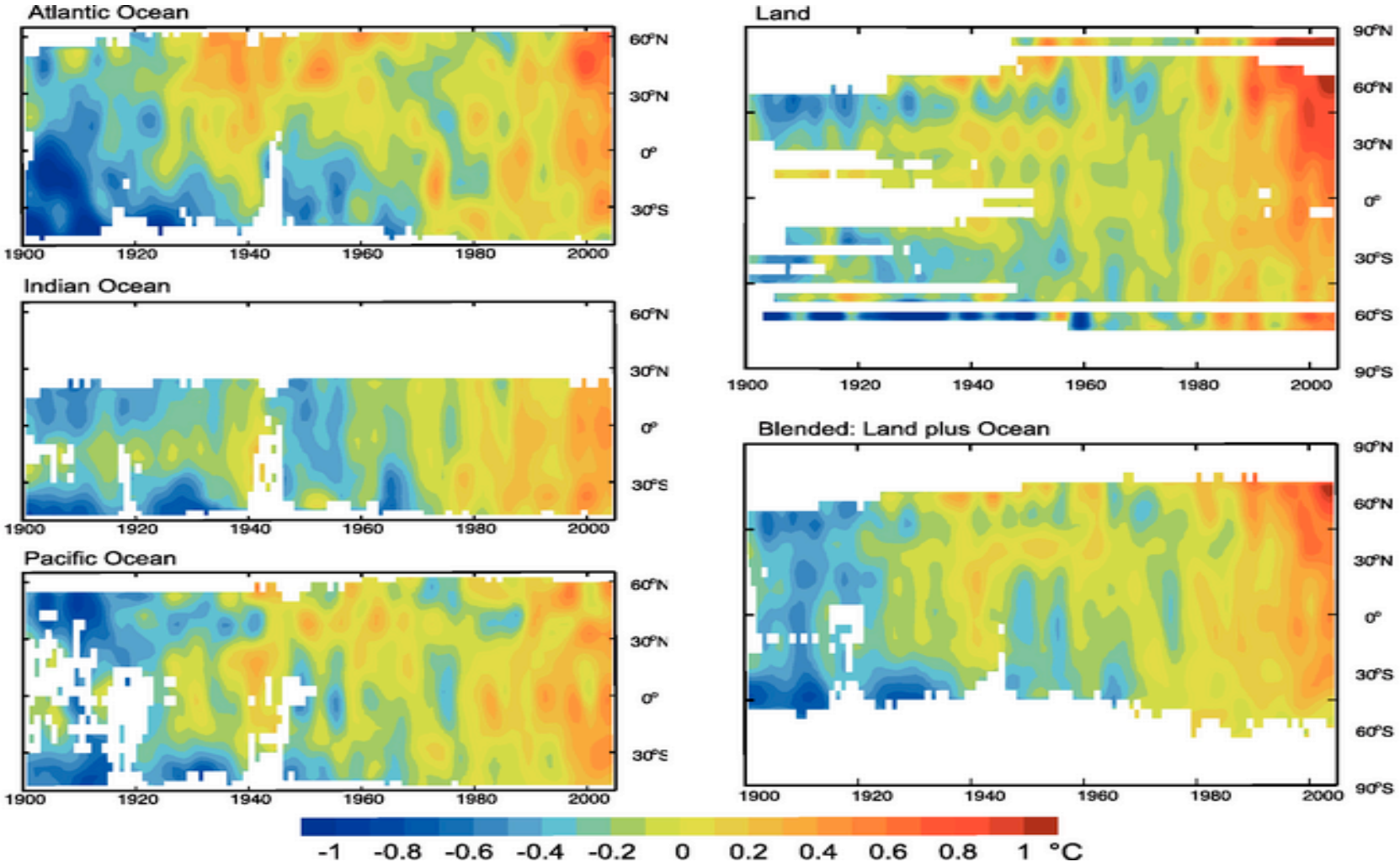
The Recent Global Warming

Annual anomalies of hemispheric Sea Surface Temperature (°C) (relative to the 1961 to 1990 mean)



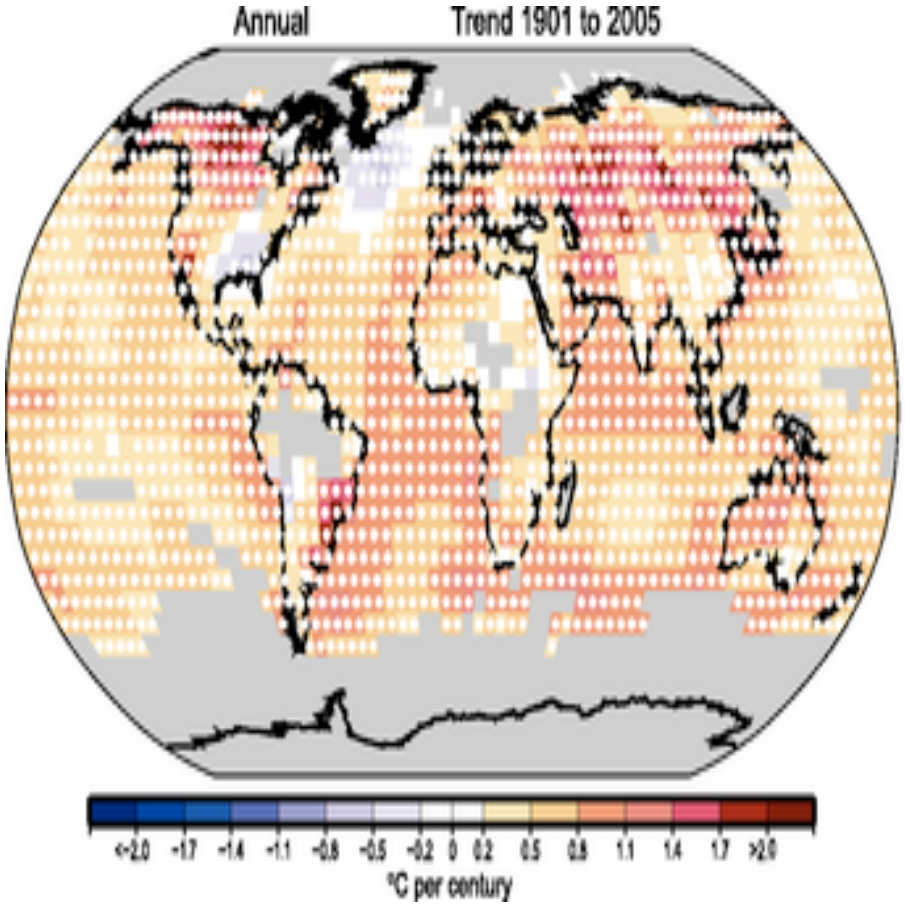
The Recent Global Warming

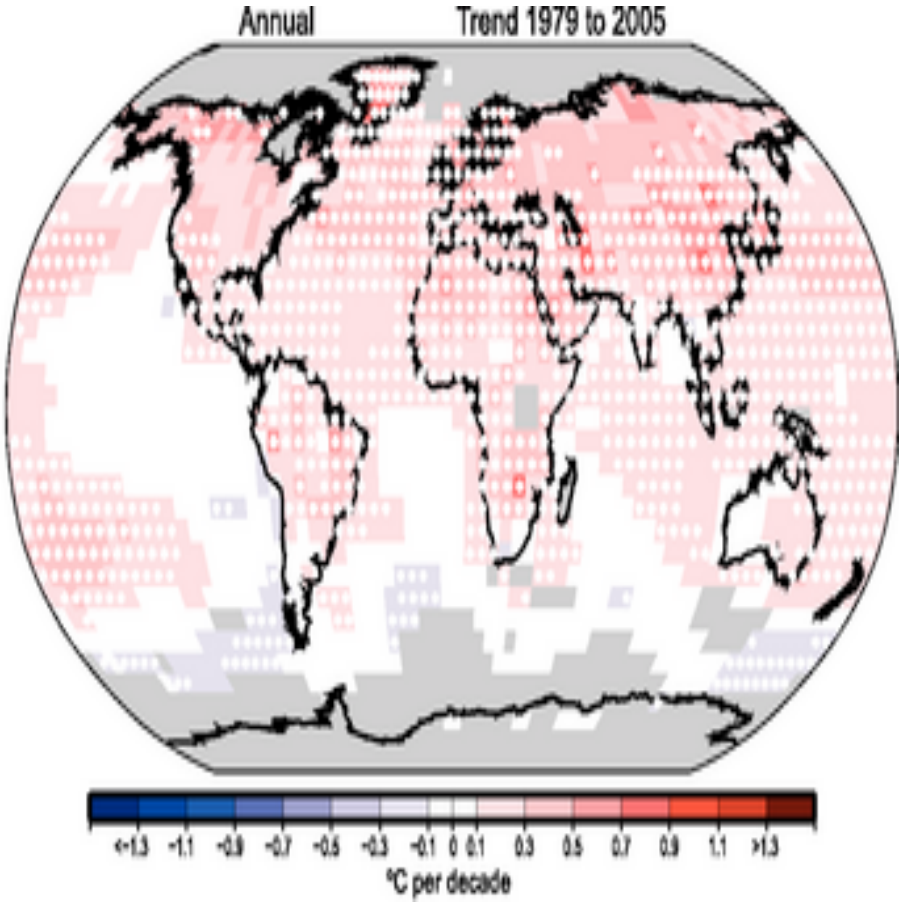
Zonal Mean Temperature Anomalies (°C)



The Recent Global Warming

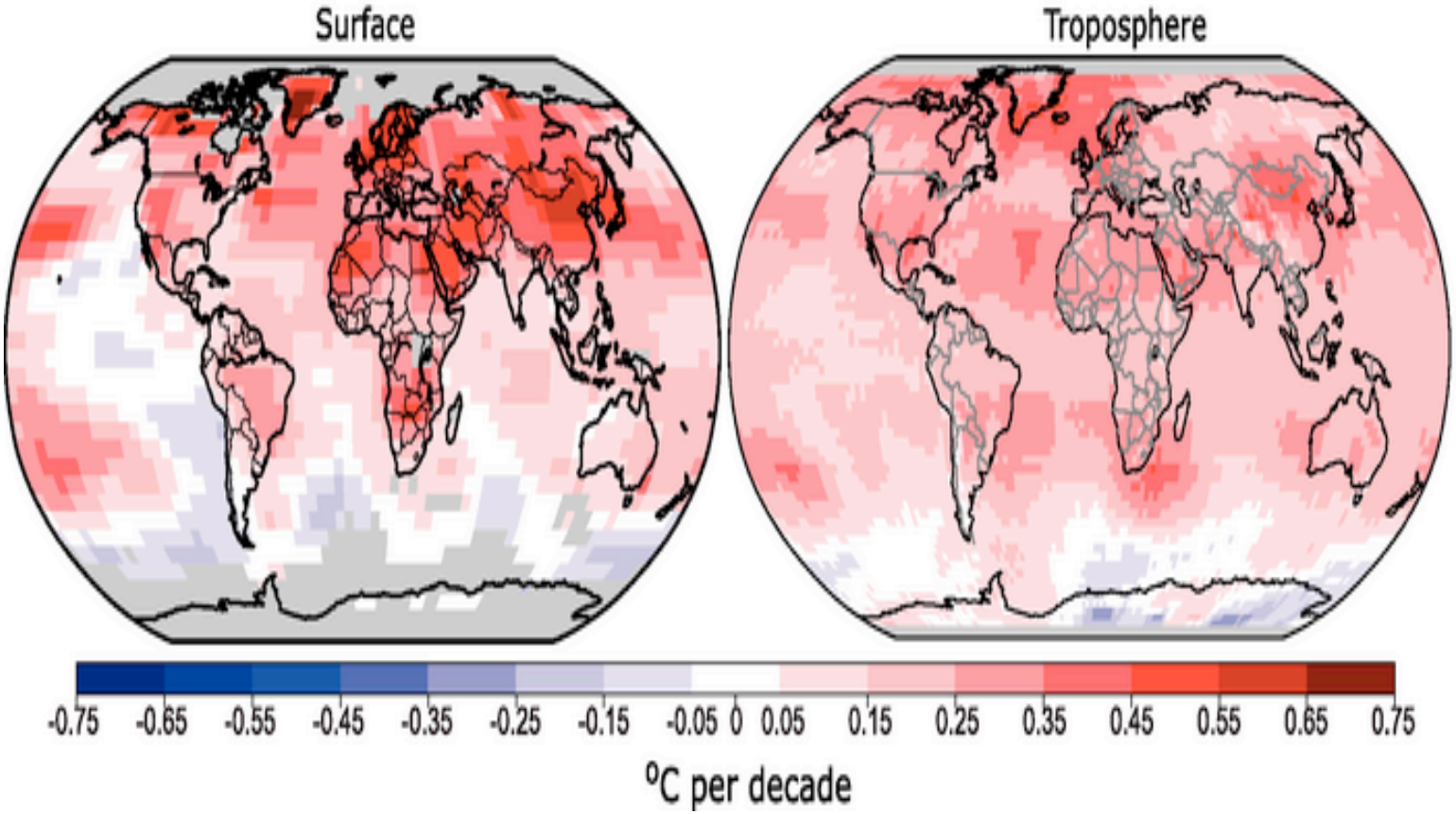
Surface air temperature trends over 1901—2005 and 1979-2005



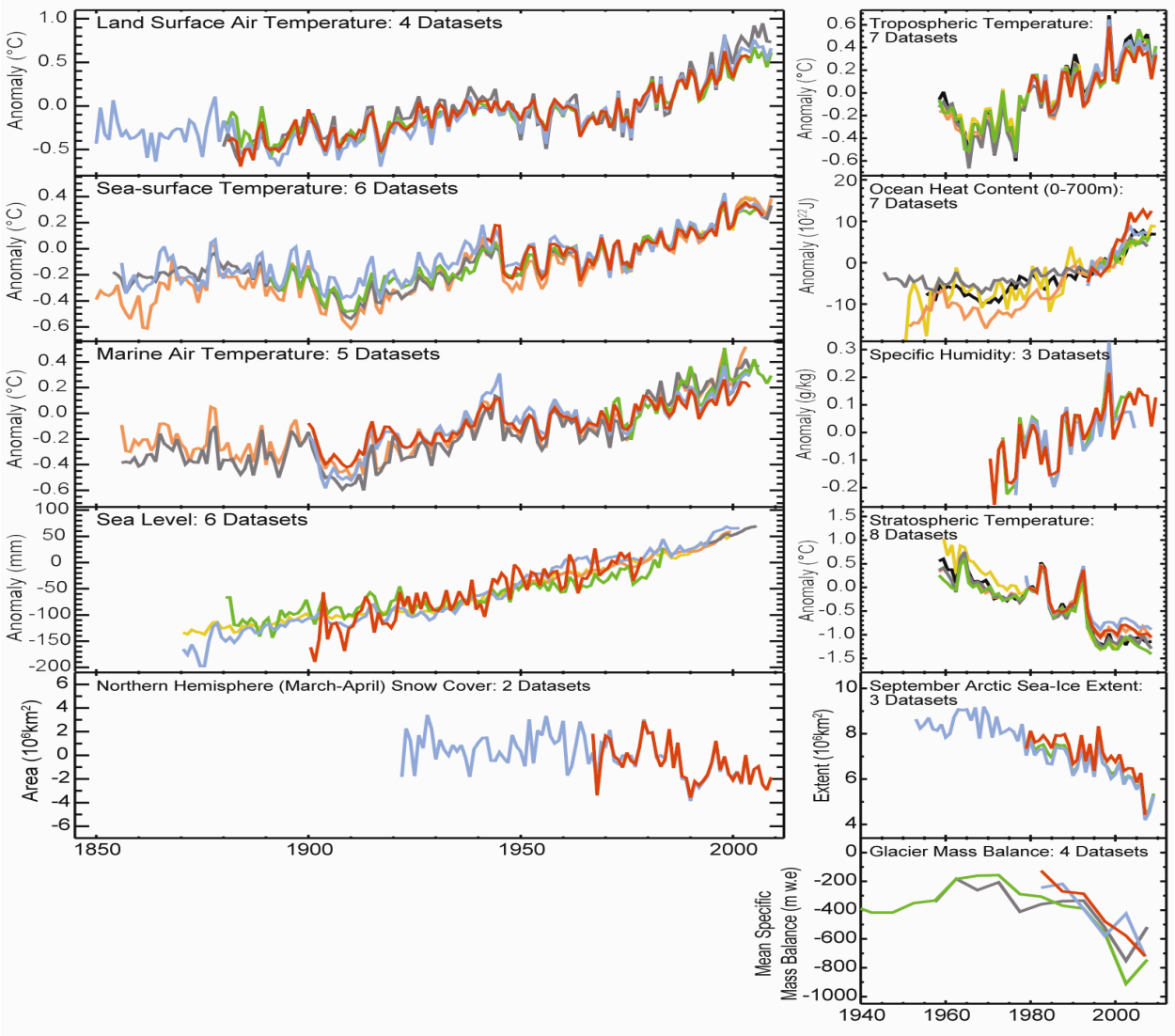


The Recent Global Warming

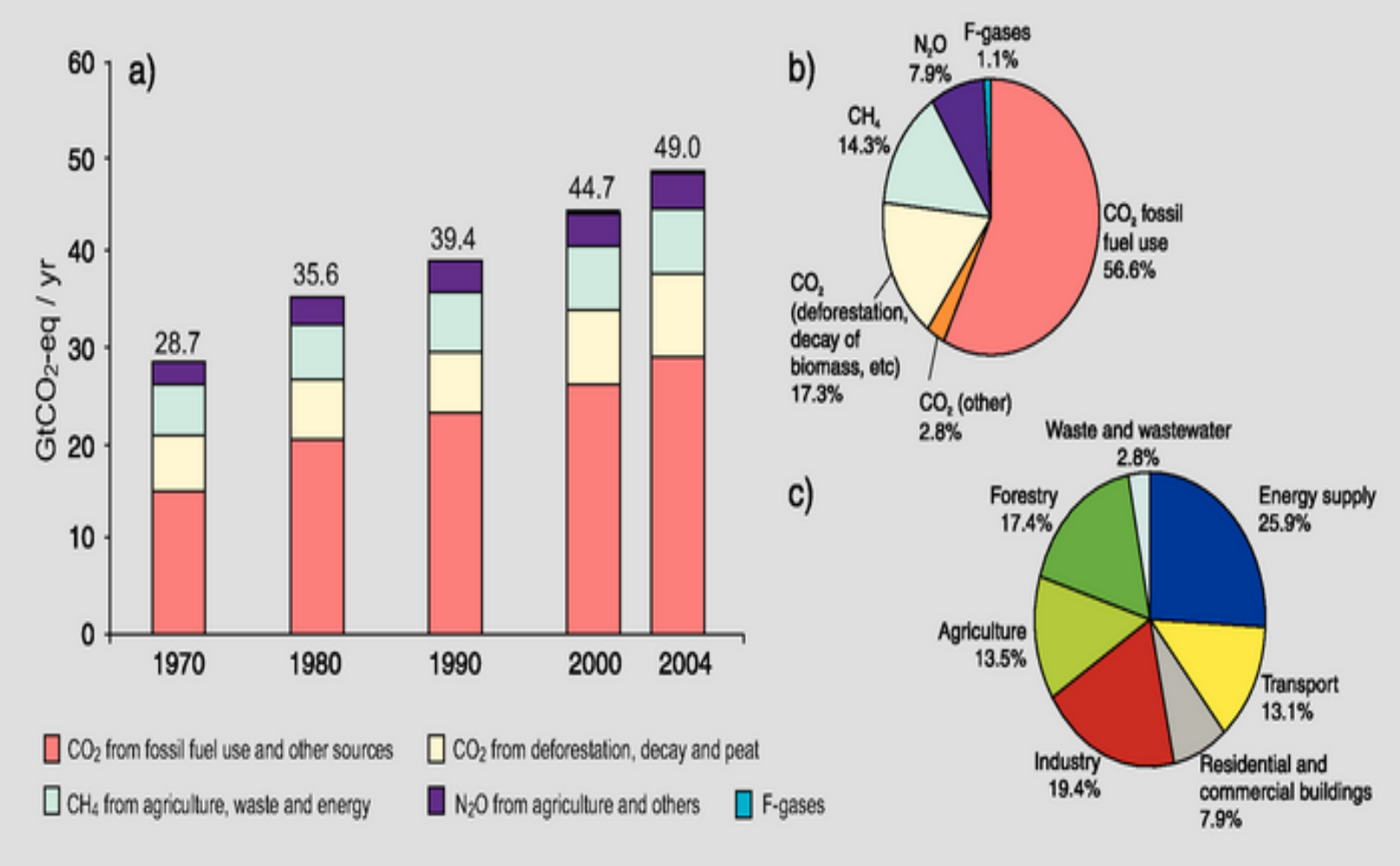
Surface and tropospheric temperature trends over 1979--2005



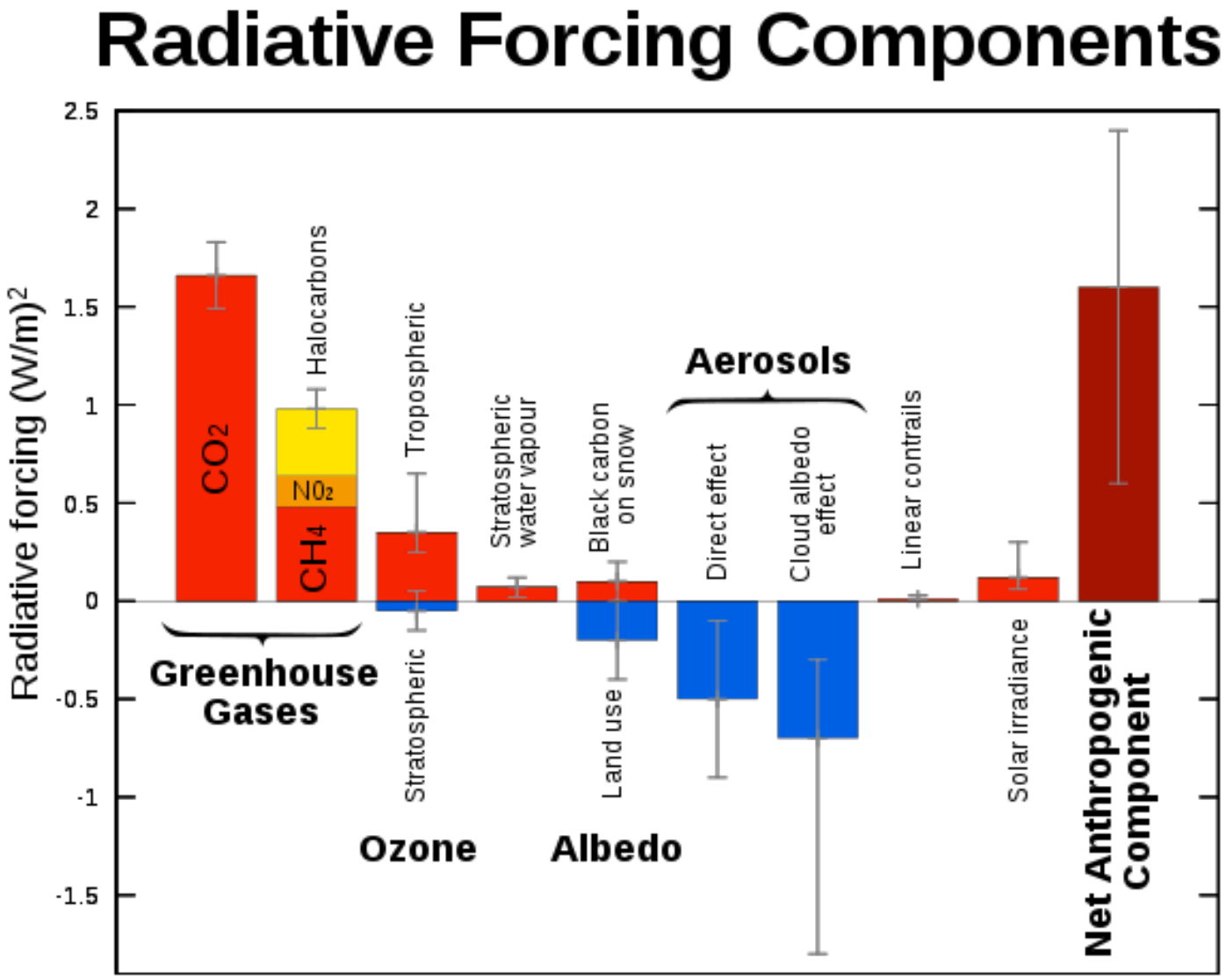
The 11 indicators of global warming



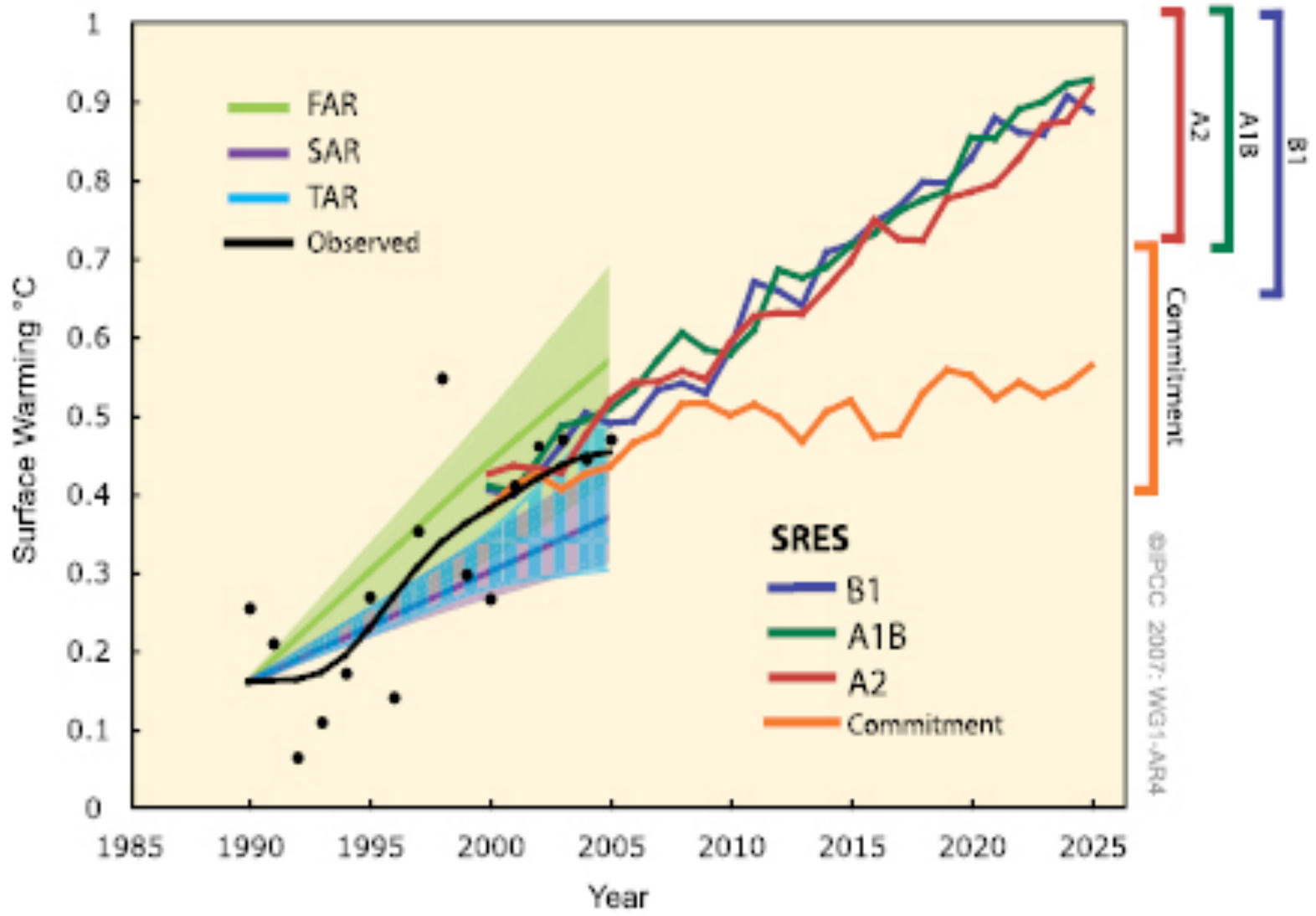
Increases in Greenhouse Gases in the Atmosphere



Added Radiative Forcing

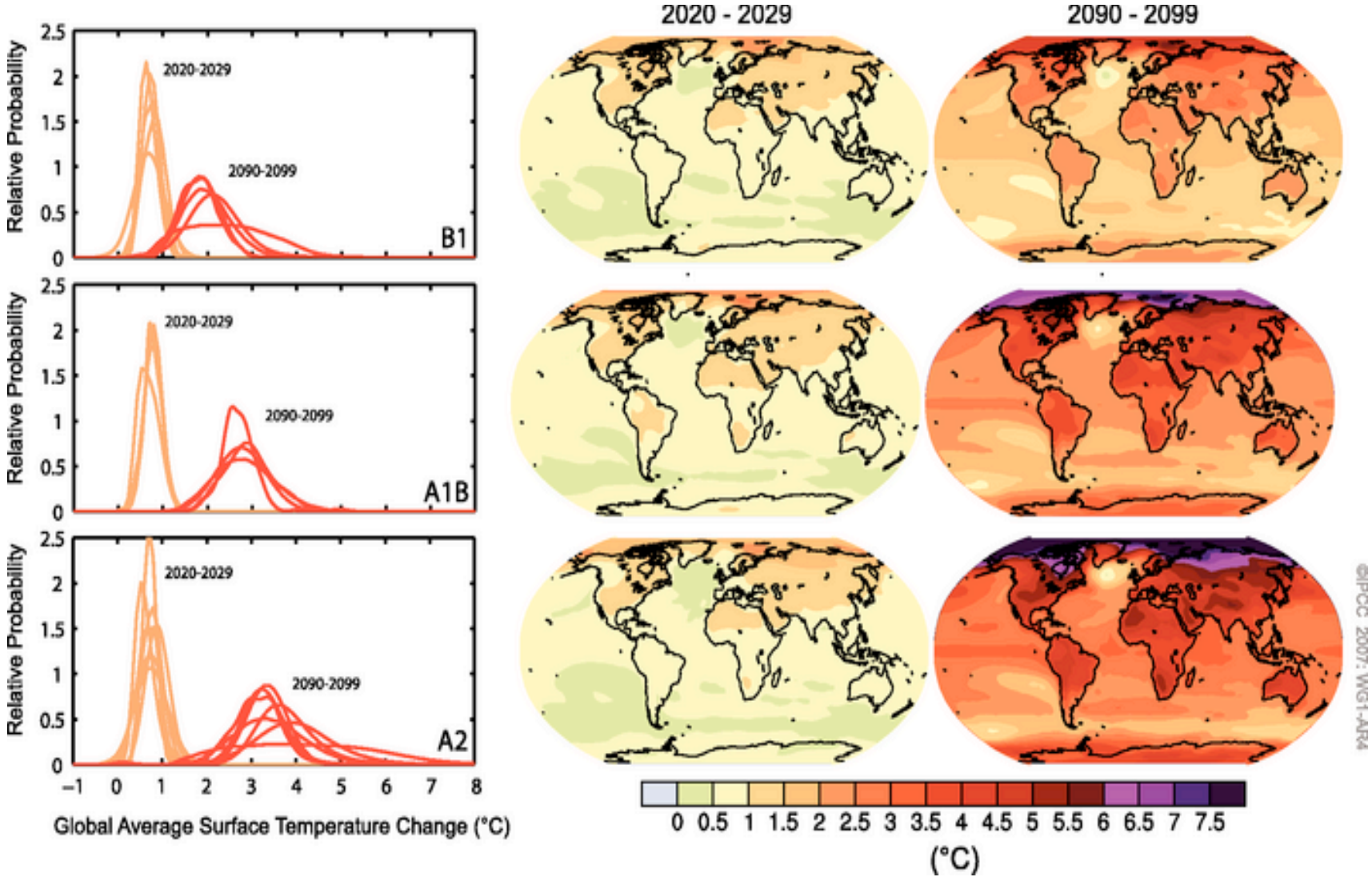


Projections of Future Climate Change

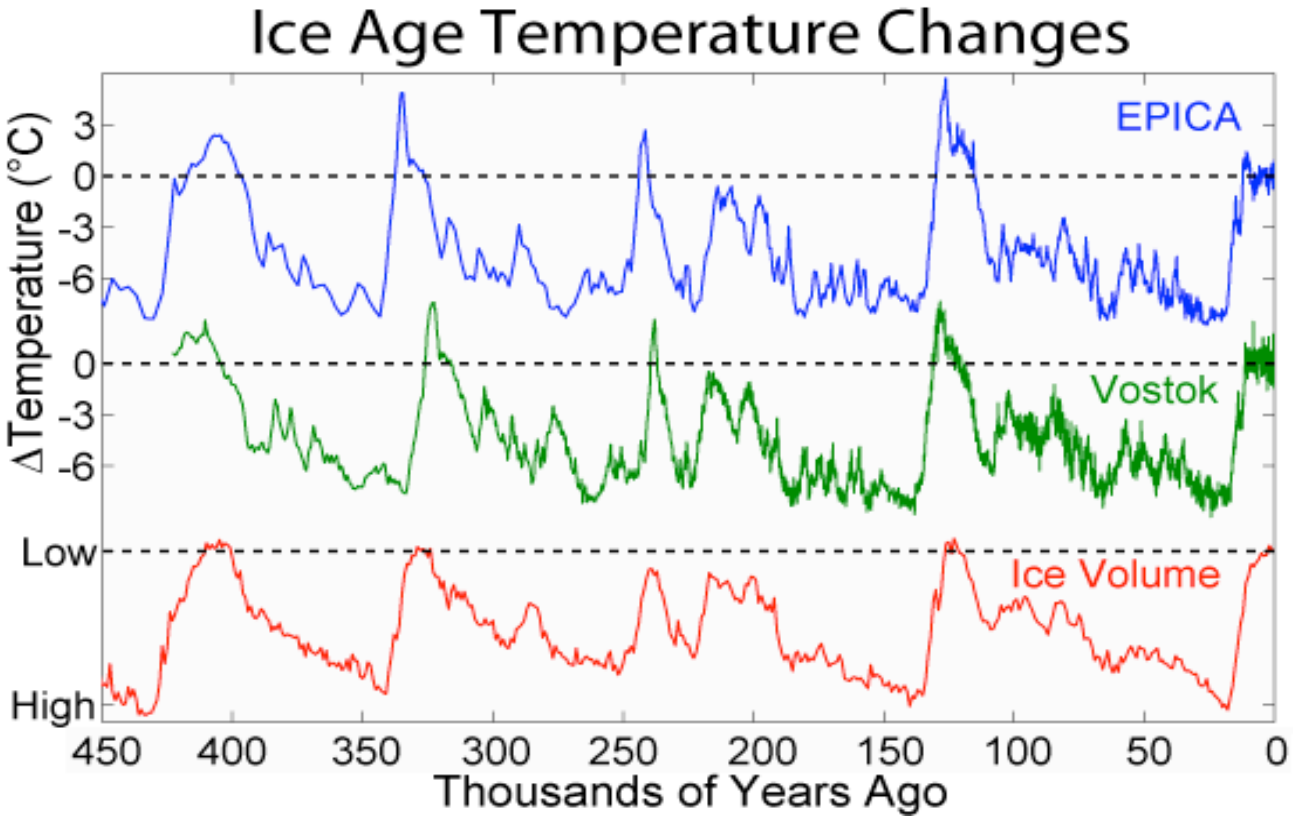


Projections of Future Climate Change

relative to the period 1980 to 1999



CO2: A Cause of the Ice Age?



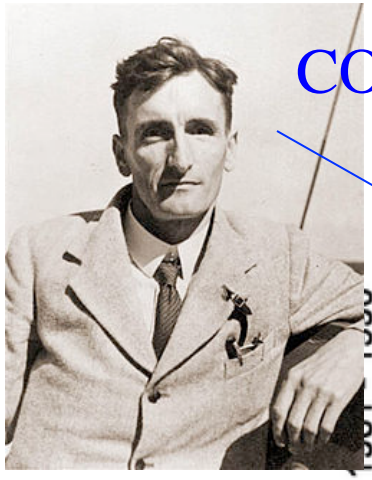
Svante Arrhenius

½ CO_2→-4 °C

2XCO_2→+4°C

From IPCC

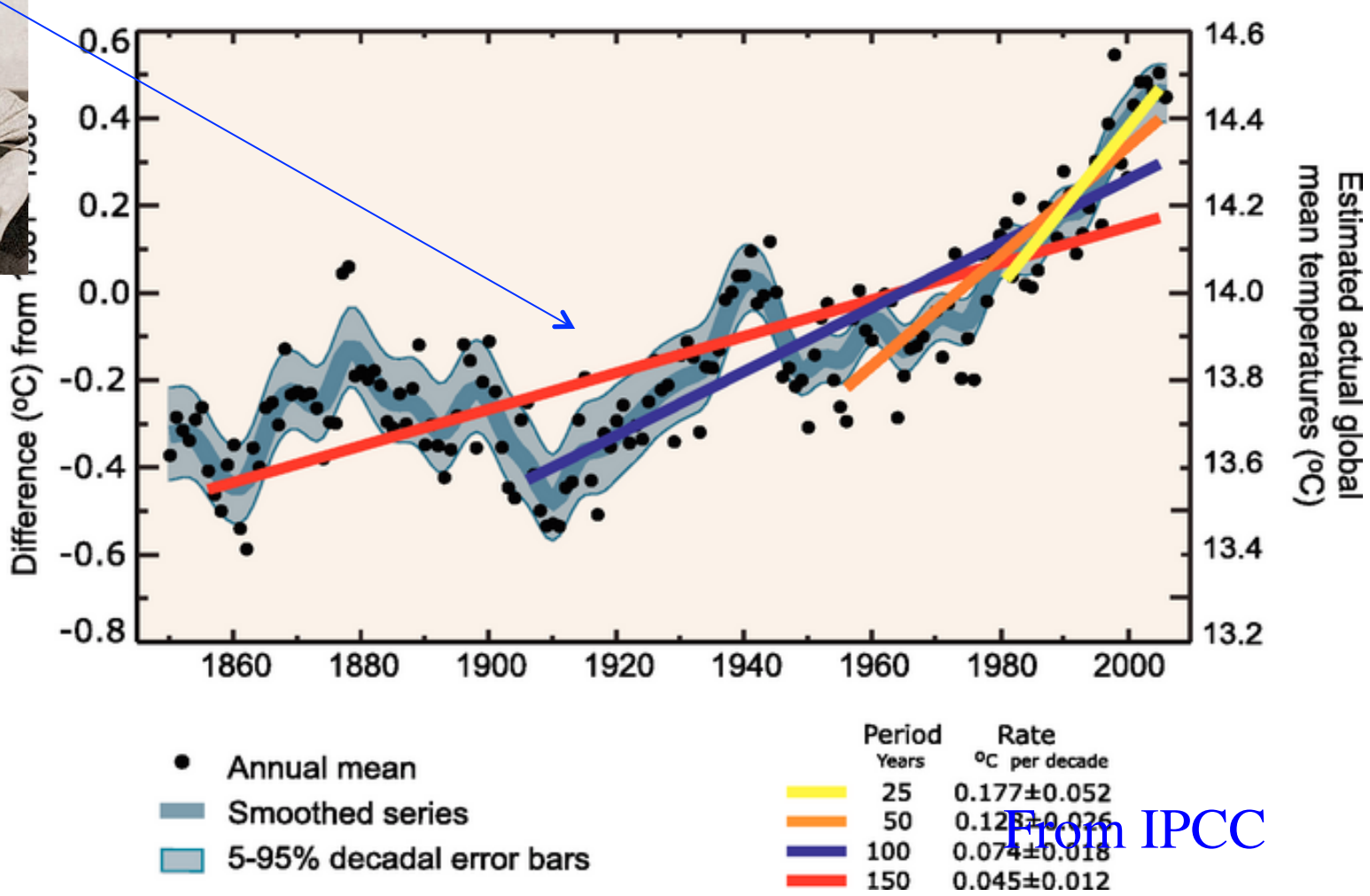
The Decadal Warming of 1930s



Guy Callendar

$2XCO_2 \rightarrow 2\ ^oC$

CO2?

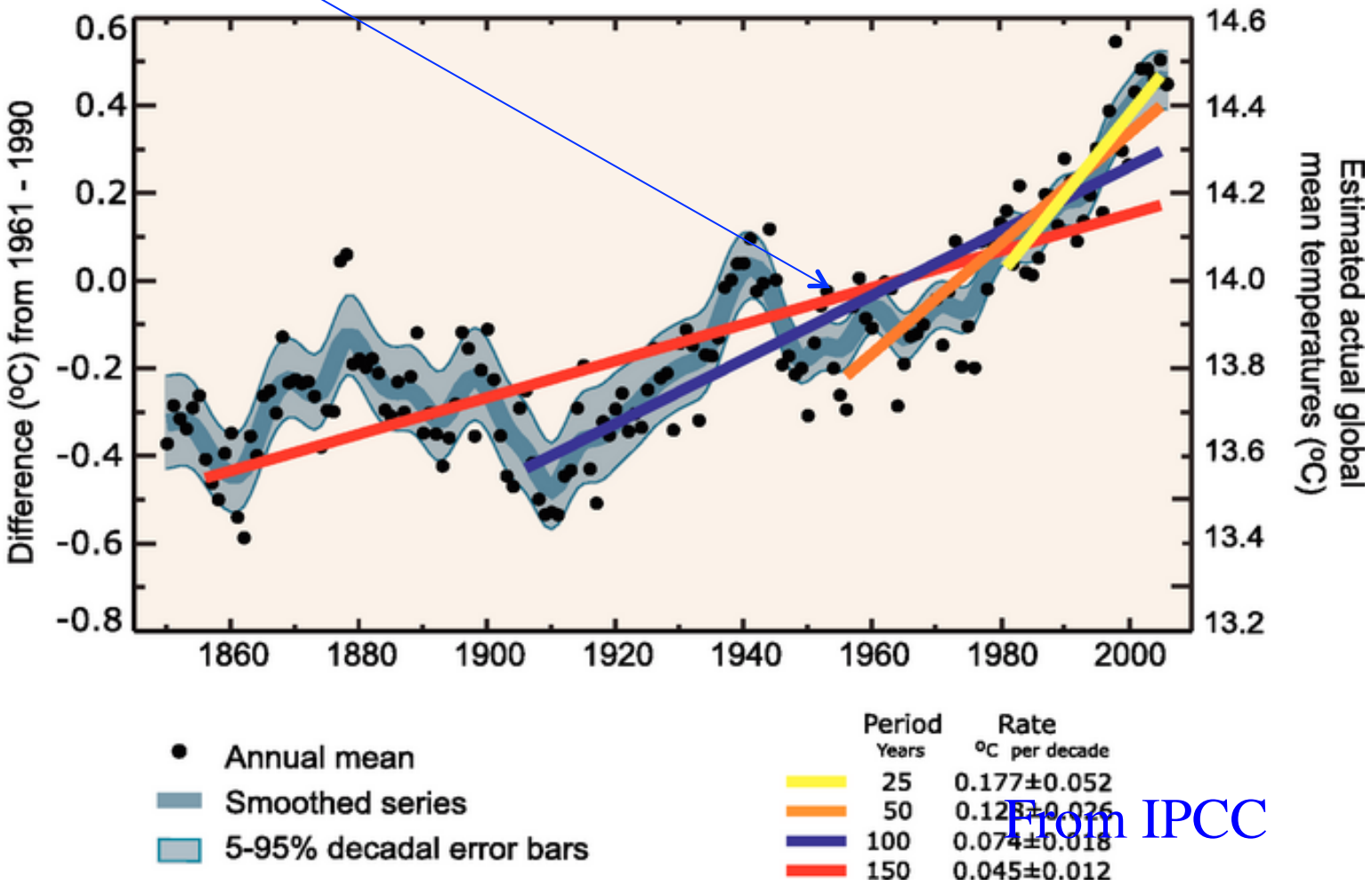


From IPCC

The Revival of CO2 Theory in 1950-60s

Bert Bolin

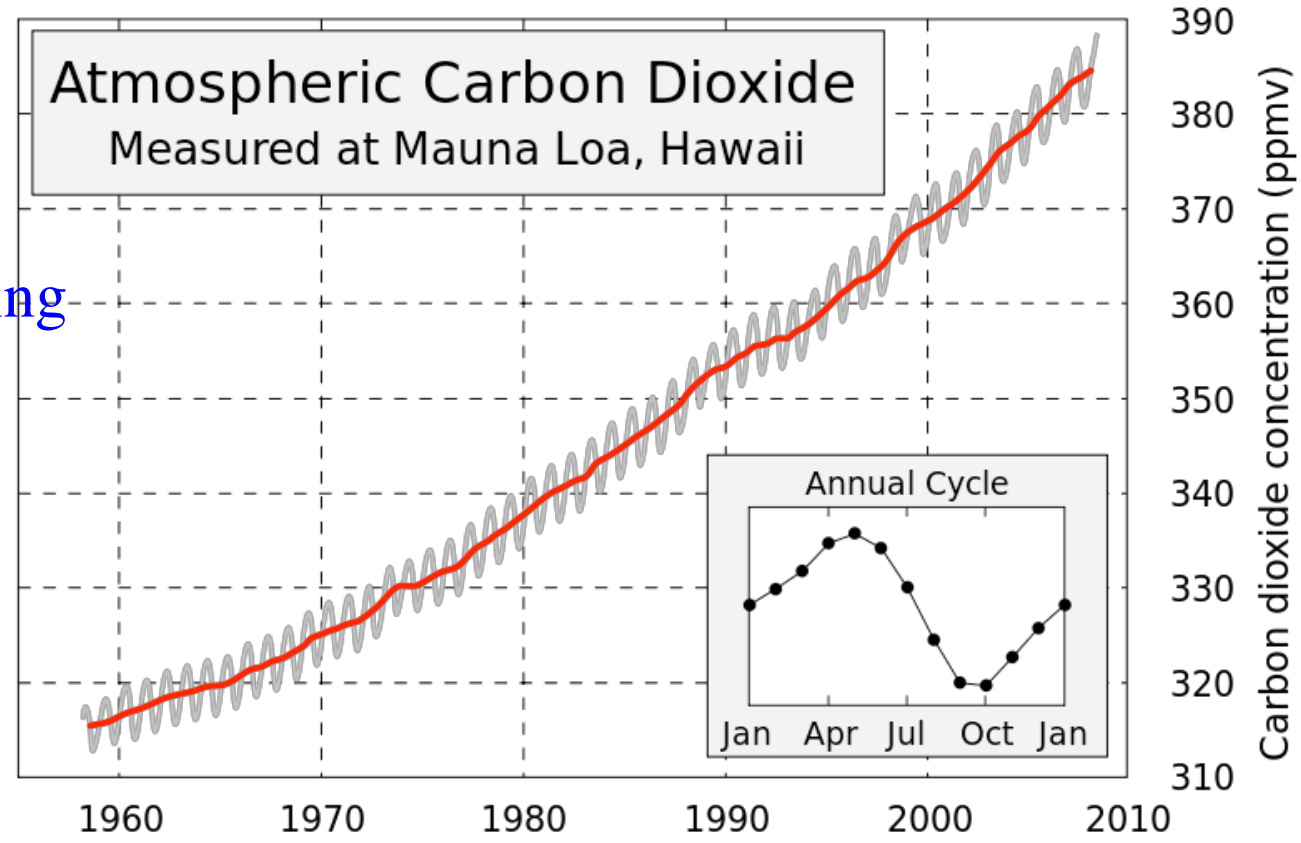
CO2?



From IPCC

The Revival of CO2 Theory in 1950-60s: The Keeling Measurements

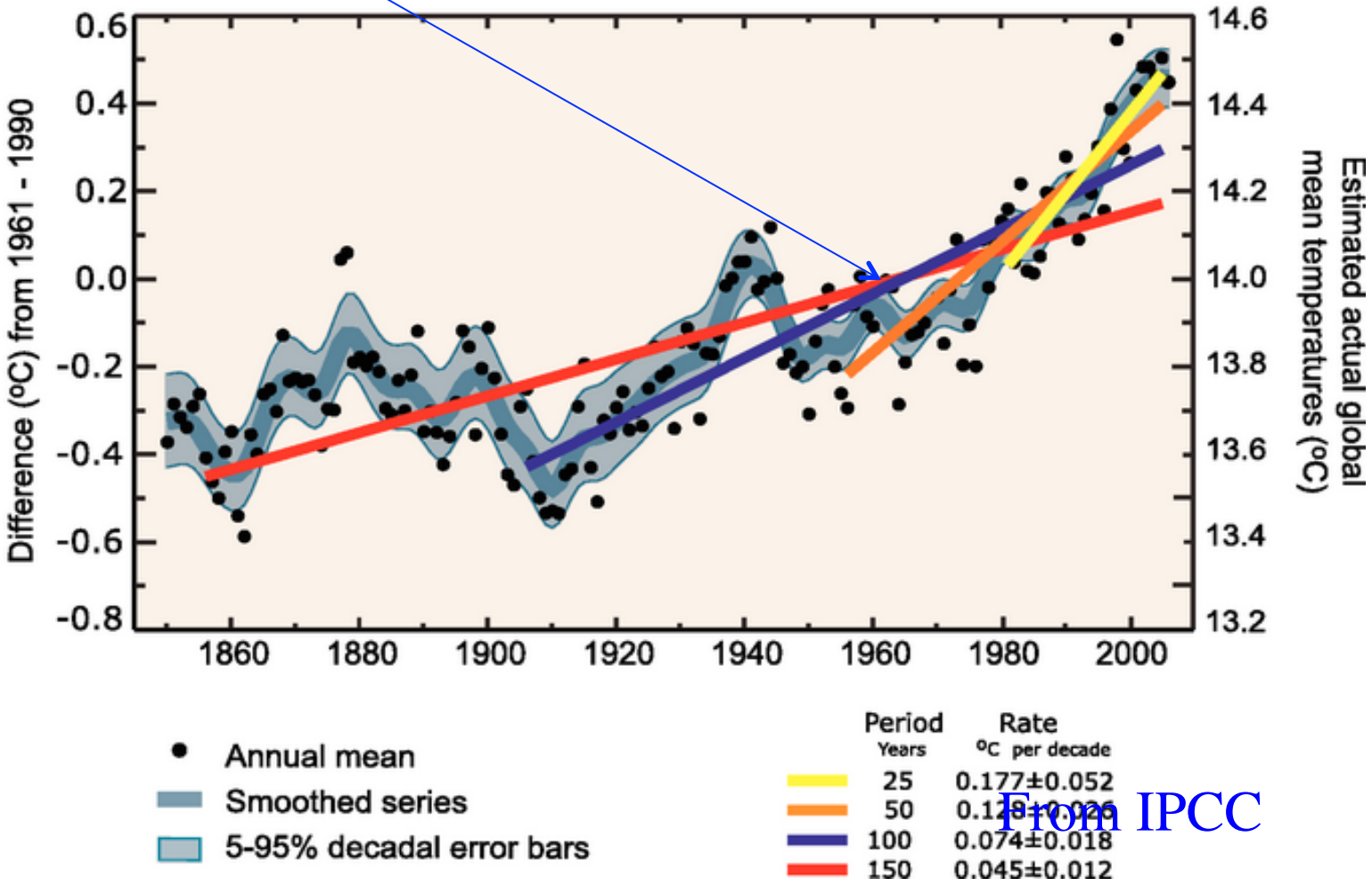
Charles Keeling



From IPCC

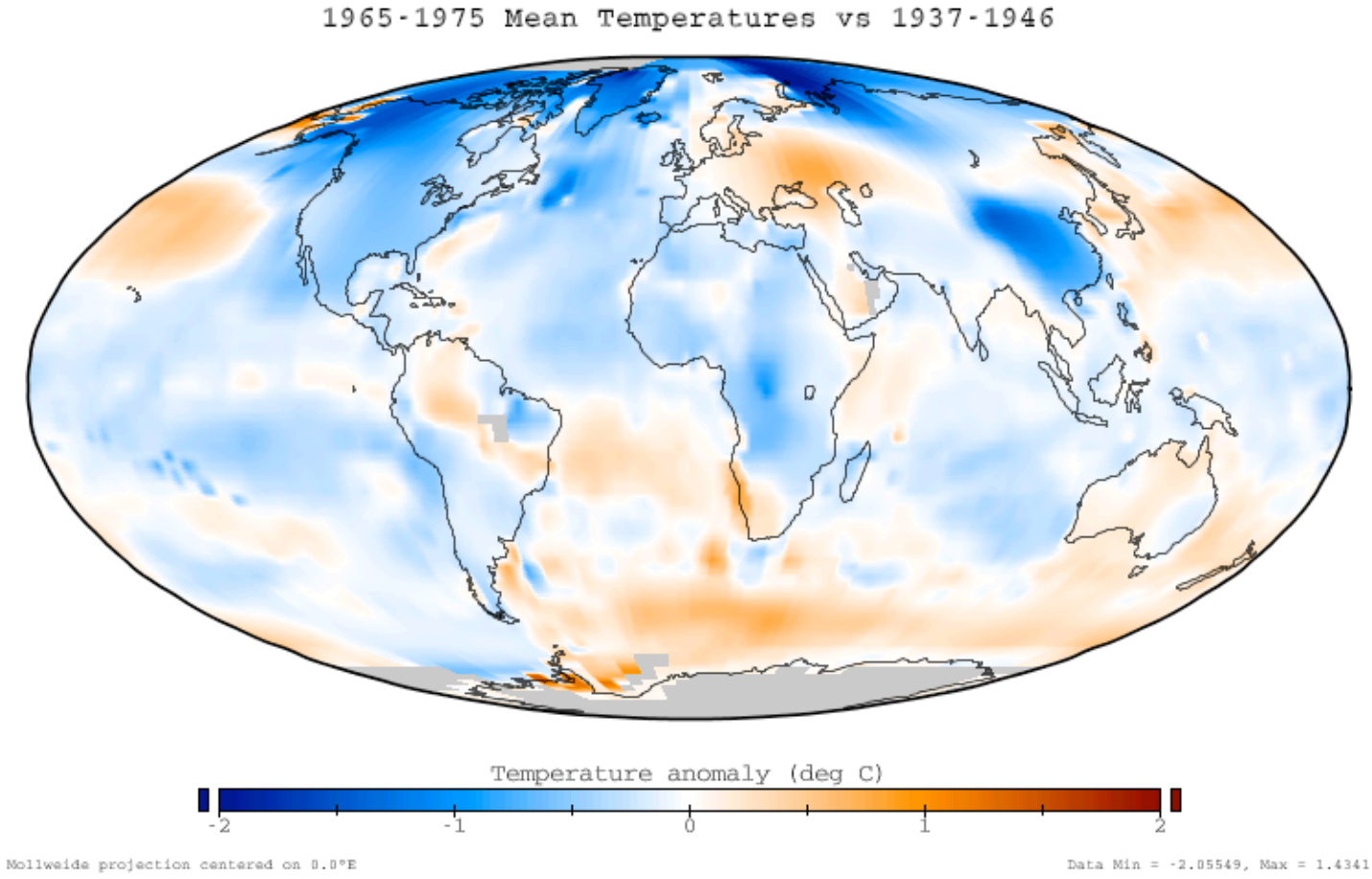
The Cooling in 40s and 60s

Ice Age Coming?

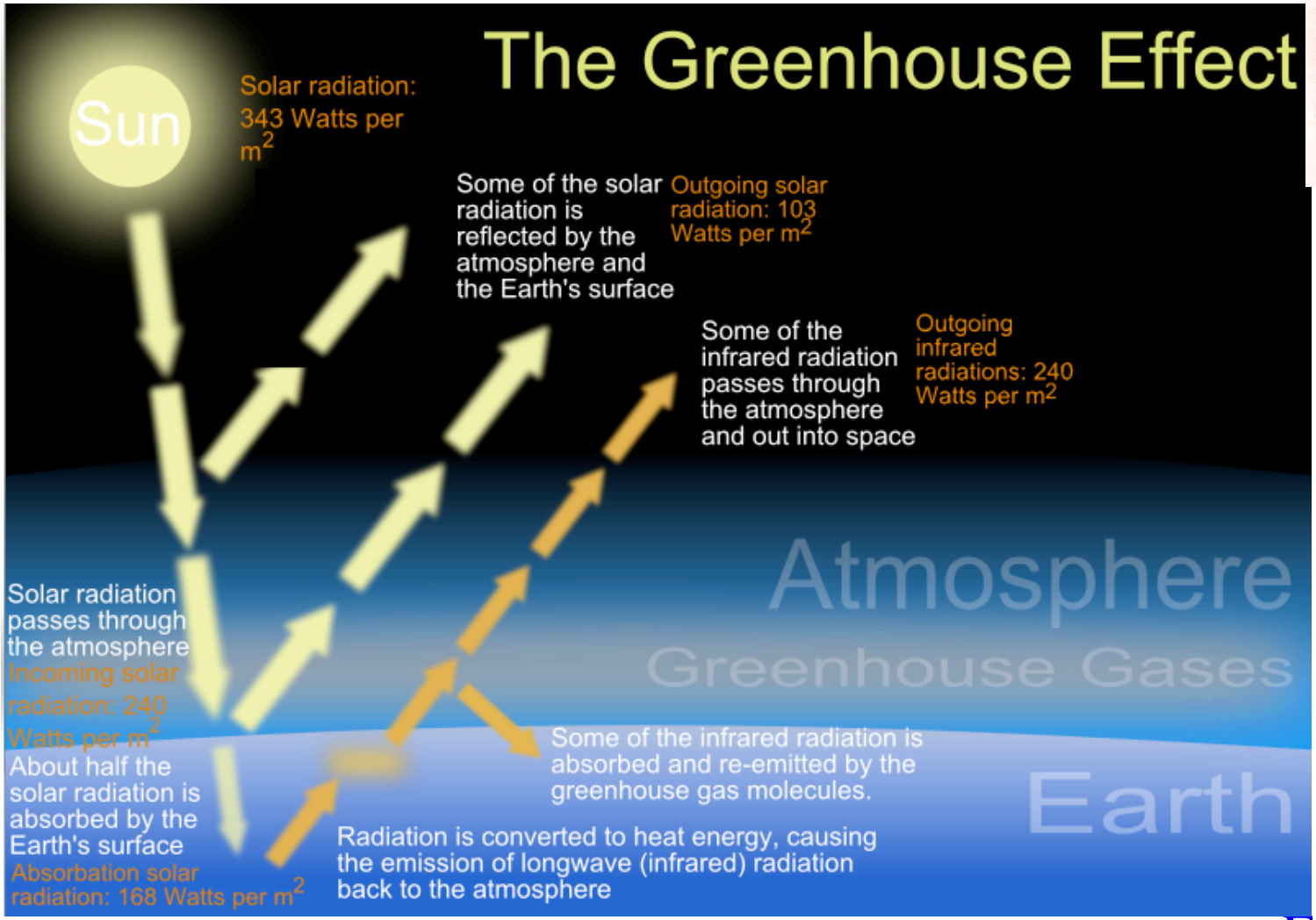


From IPCC

Future Climate Change Predicted in the 1970s: Returning to Ice Age



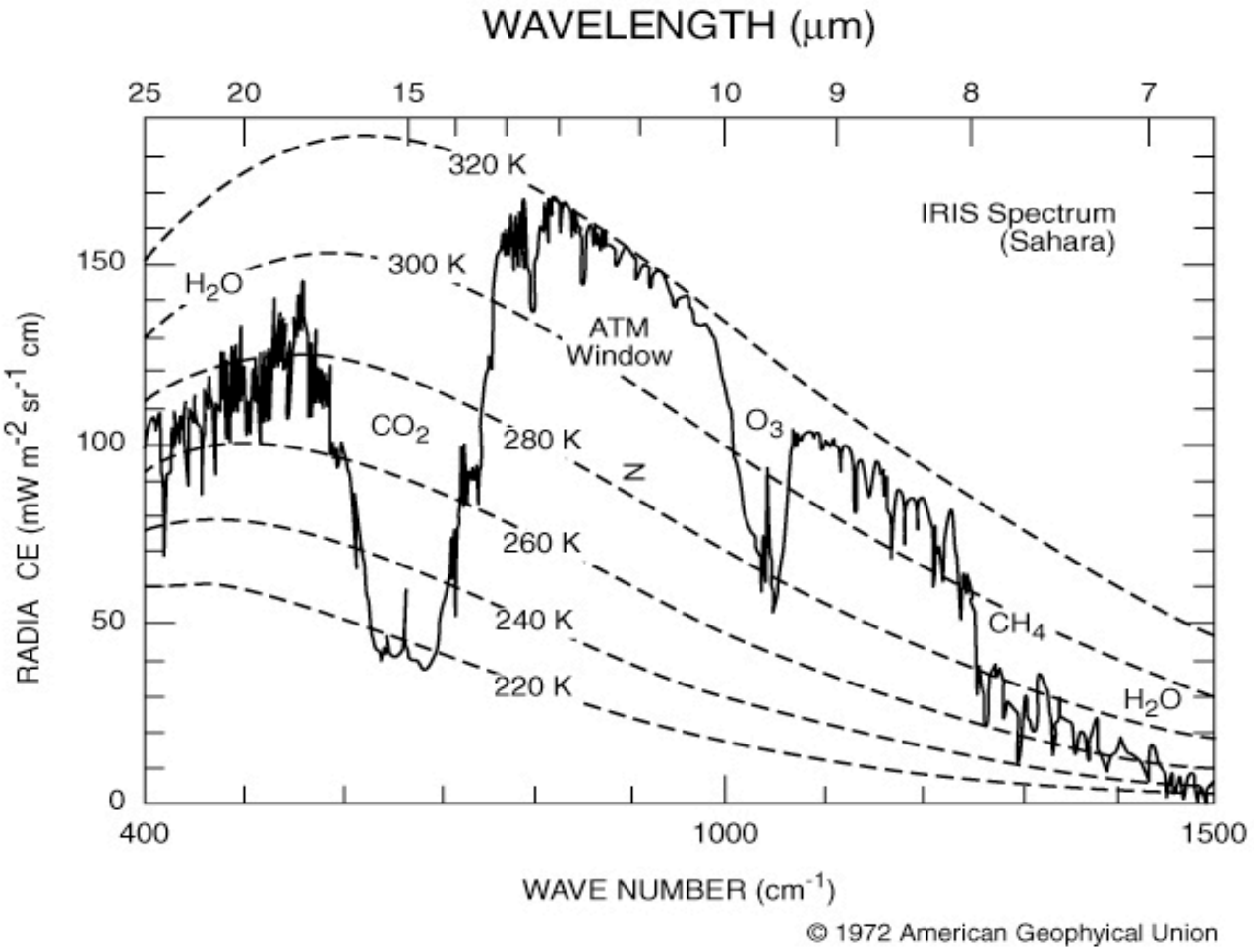
The Greenhouse Effect



Joseph Fourier

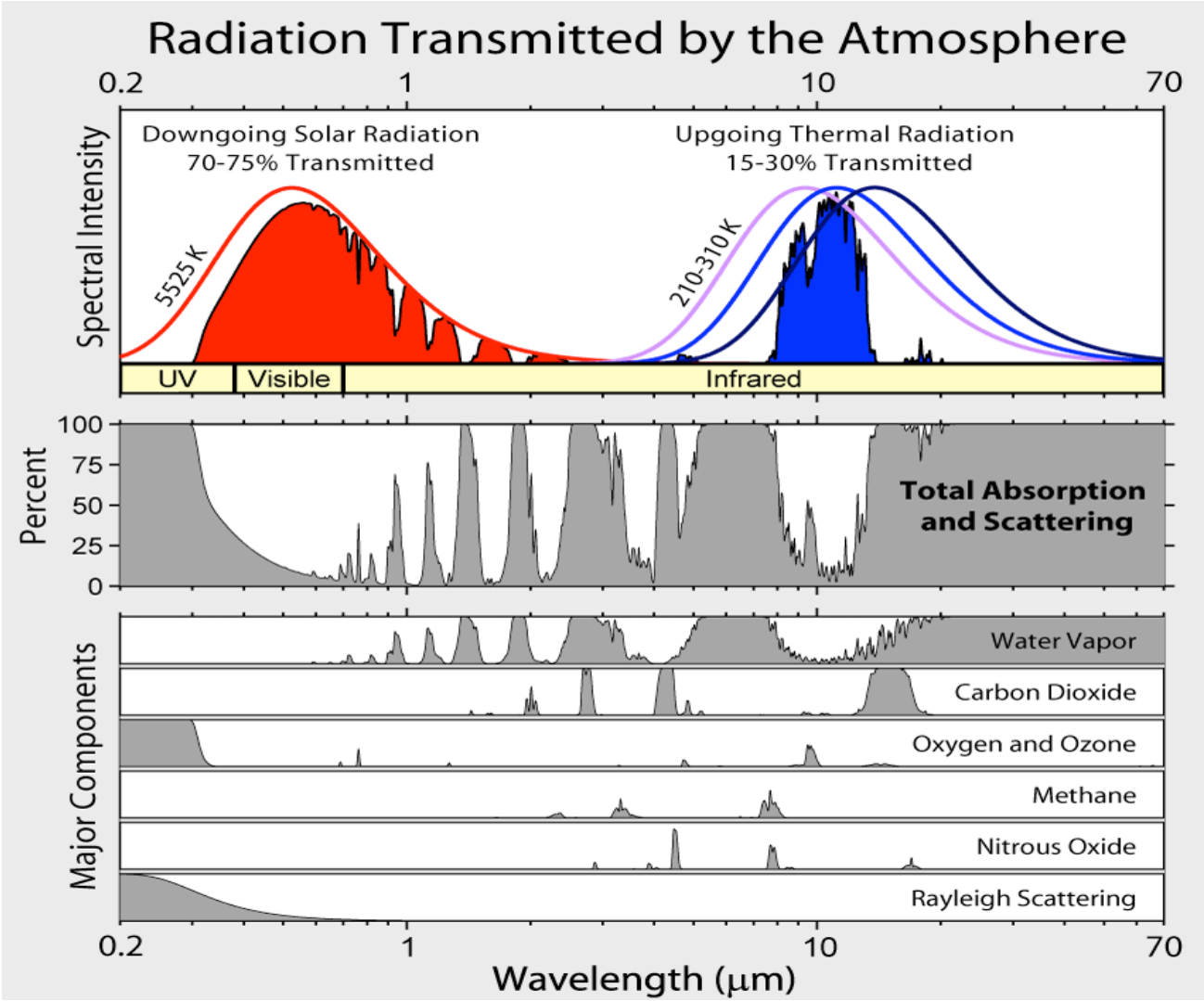
From IPCC

Major Greenhouse Gases In The Atmosphere



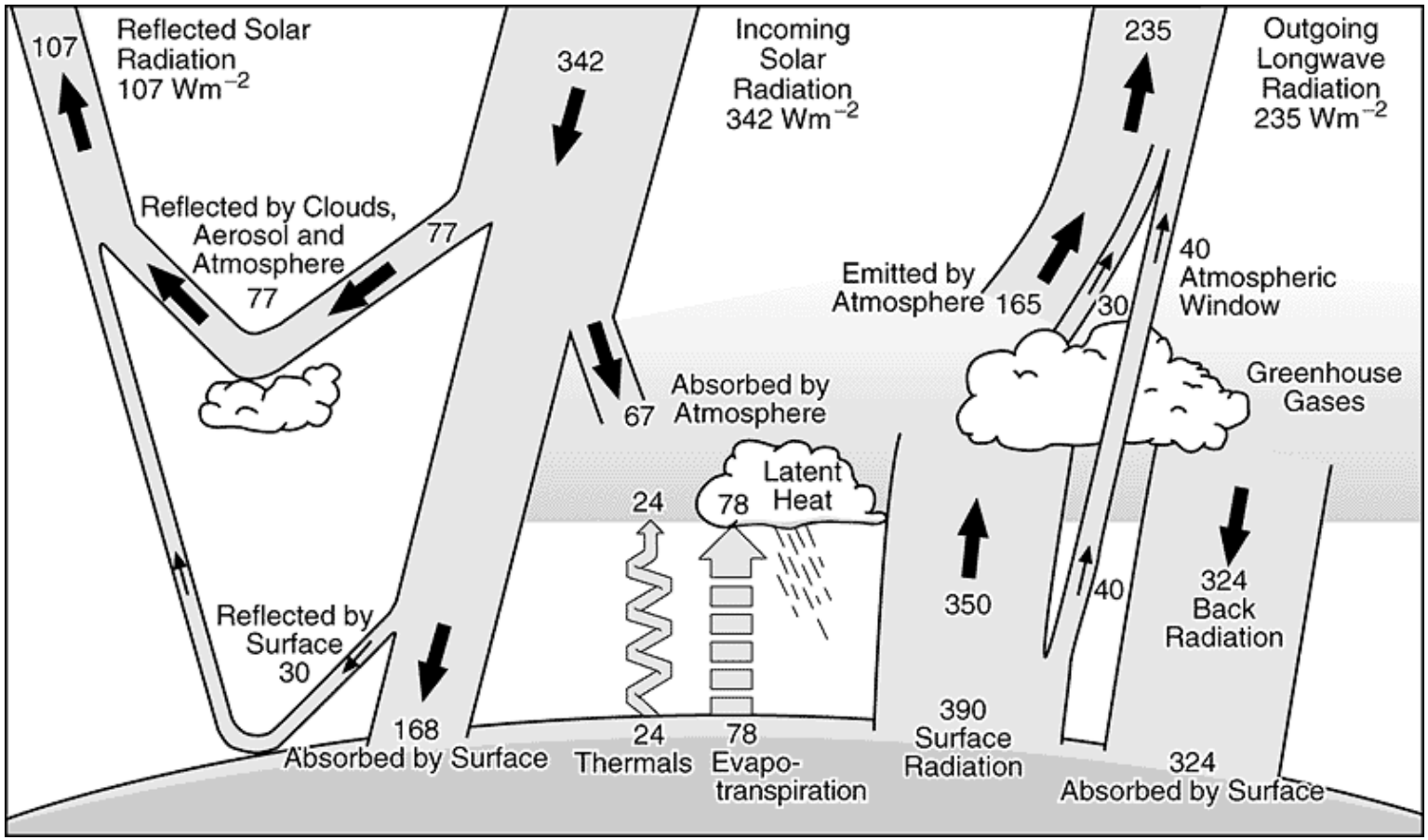
From IPCC

Major Greenhouse Gases In The Atmosphere



From MODTRAN

The Energy Balance of the Climate System



Homework

1) Calculate the rate of increase of temperature of a mixed layer ocean of a depth of 50 m when it is subjected to a net heating of 1.5 $W/m^{2.}$

2) Estimate the rate of increase of the mean temperature of a troposphere confined between 1000 mb and 200mb when it is subjected to a net heating of 1.5 W/m^2

3) Same as (1), except that the heating rate increases with the increase of the temperature at a rate of 1.5 $W/m^2/ {}^oC$. Assuming the initial temperature is 15 ^oC, what would be the temperature after 25 years, 50 years, and 100 years respectively?

4) (see next slide--)

Homework

4) ((bonus question)

The radiative forcing from a doubling of CO2 is about 4 W/m^2. Assuming that earth's surface radiates as a black body and there are no other processes in the climate system participating in the adjustment to new equilibrium in response to the radiative forcing from the doubling of CO2 (i.e, no feedbacks involved), what is the increase in the earth's surface temperature after the climate system re-equilibrates with the increased CO2 in the atmosphere?

Recommended Reading For the Next Lecture

- **Manabe, S., and R. T. Wetherald, 1967: Thermal equilibrium of the atmosphere with a given distribution of relative humidity. Journal of the Atmospheric Sciences, 24 (3), 241-259.**

- **Chapter 8, Climate Change 2007: Working Group I: The Physical Science Basis**