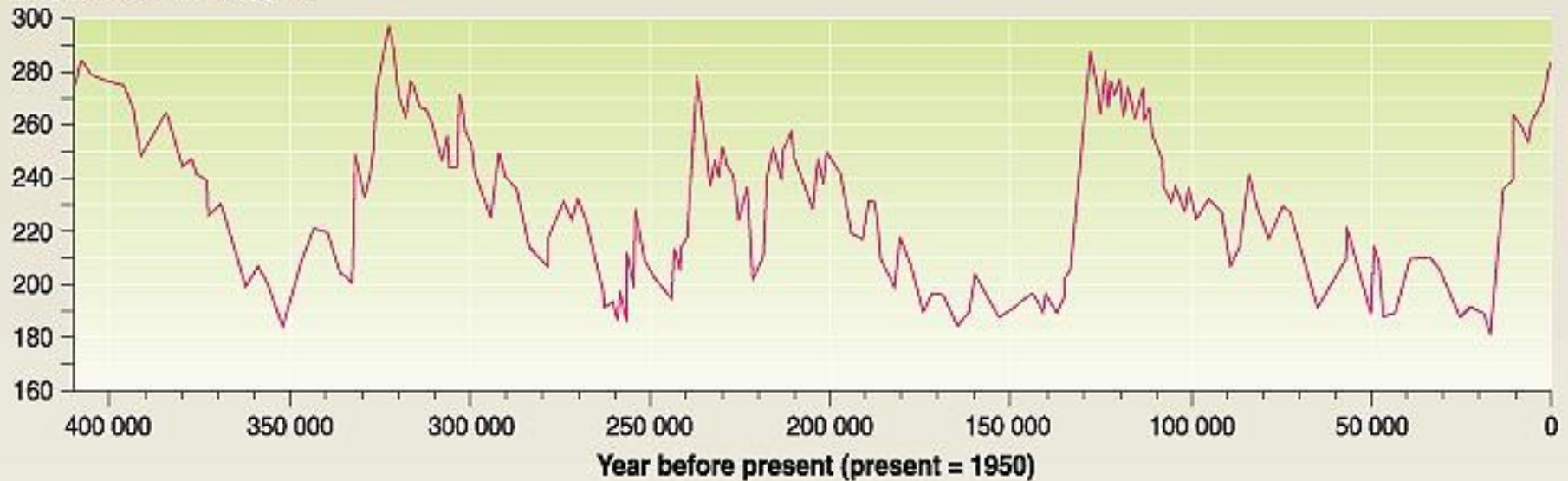


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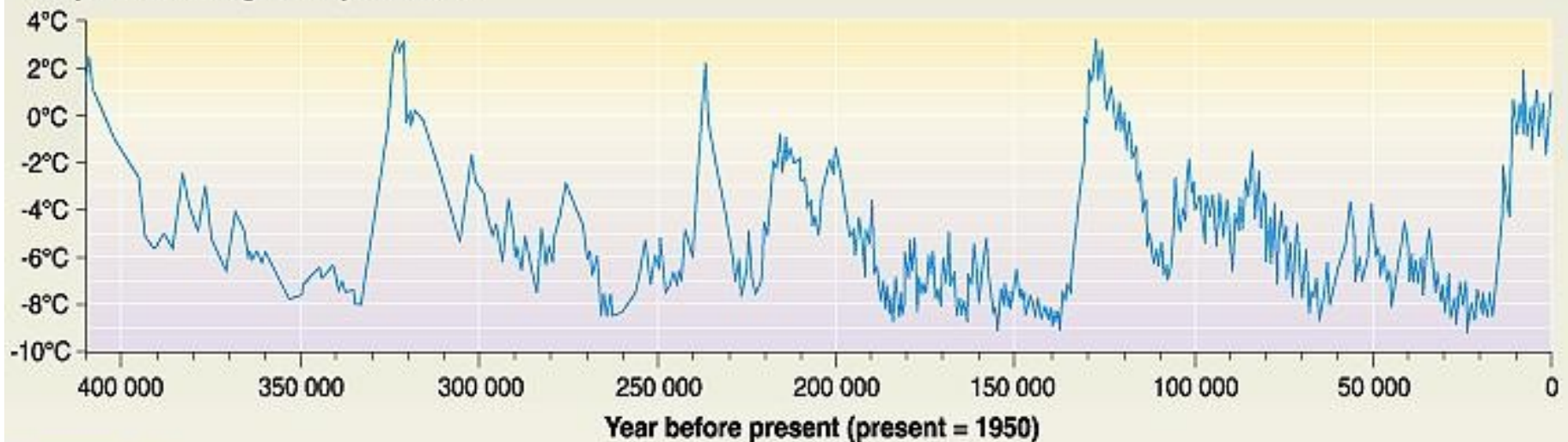
Global Climate Change II

# Temperature and CO<sub>2</sub> concentration in the atmosphere over the past 400 000 years (from the Vostok ice core)

CO<sub>2</sub> concentration, ppmv



Temperature change from present, °C



# Greenhouse Gases: CO<sub>2</sub>

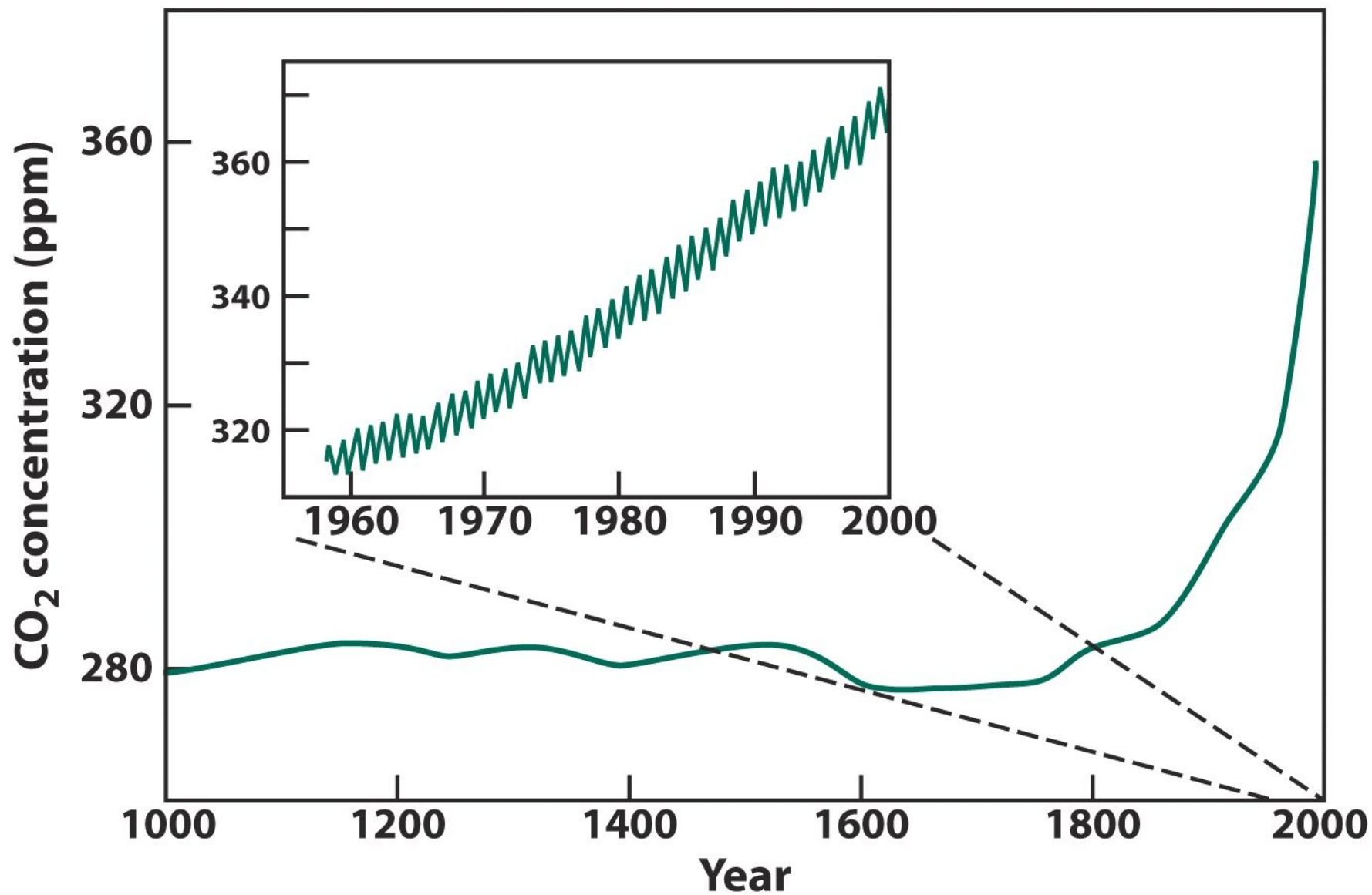
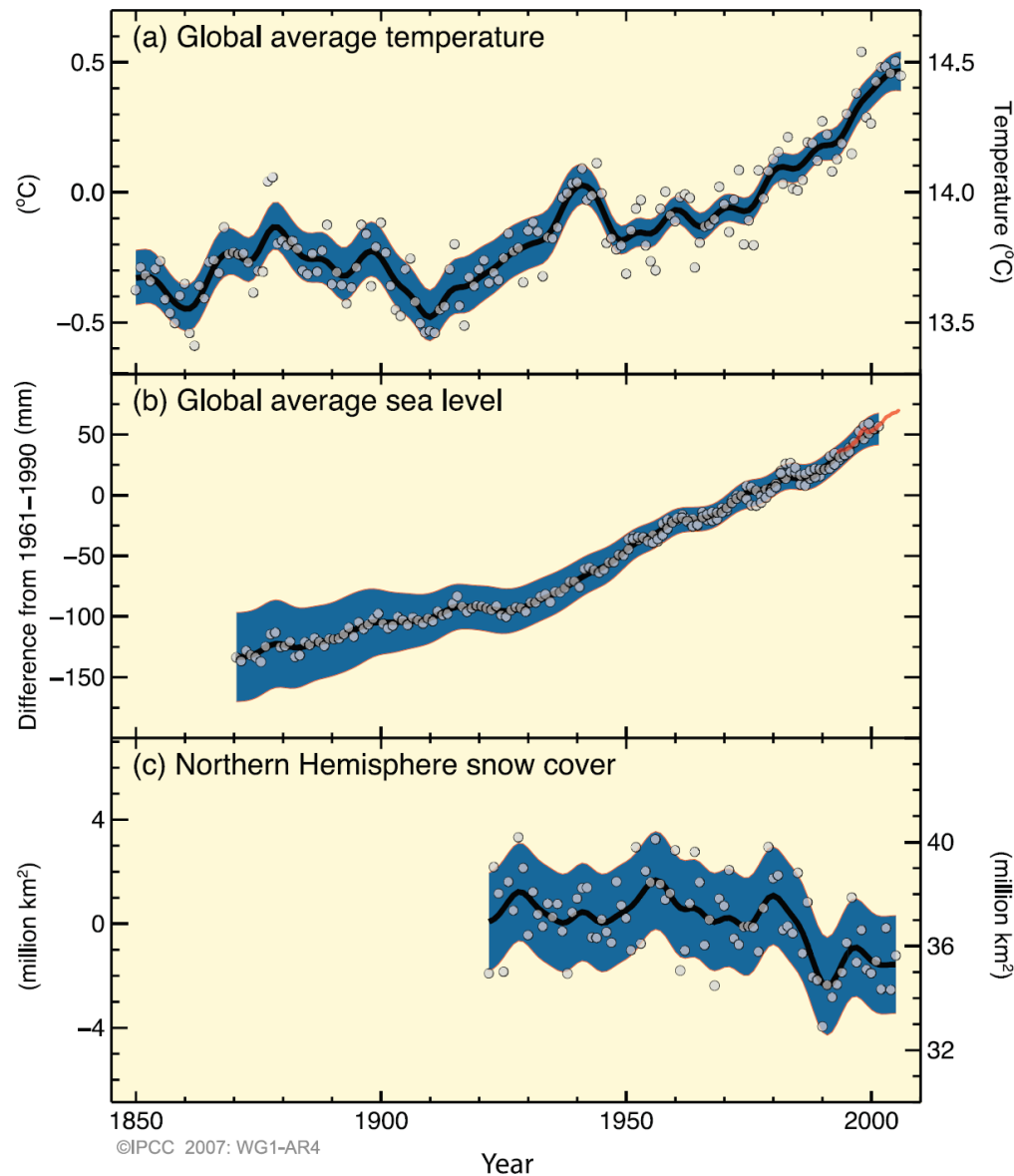


Figure 4-7  
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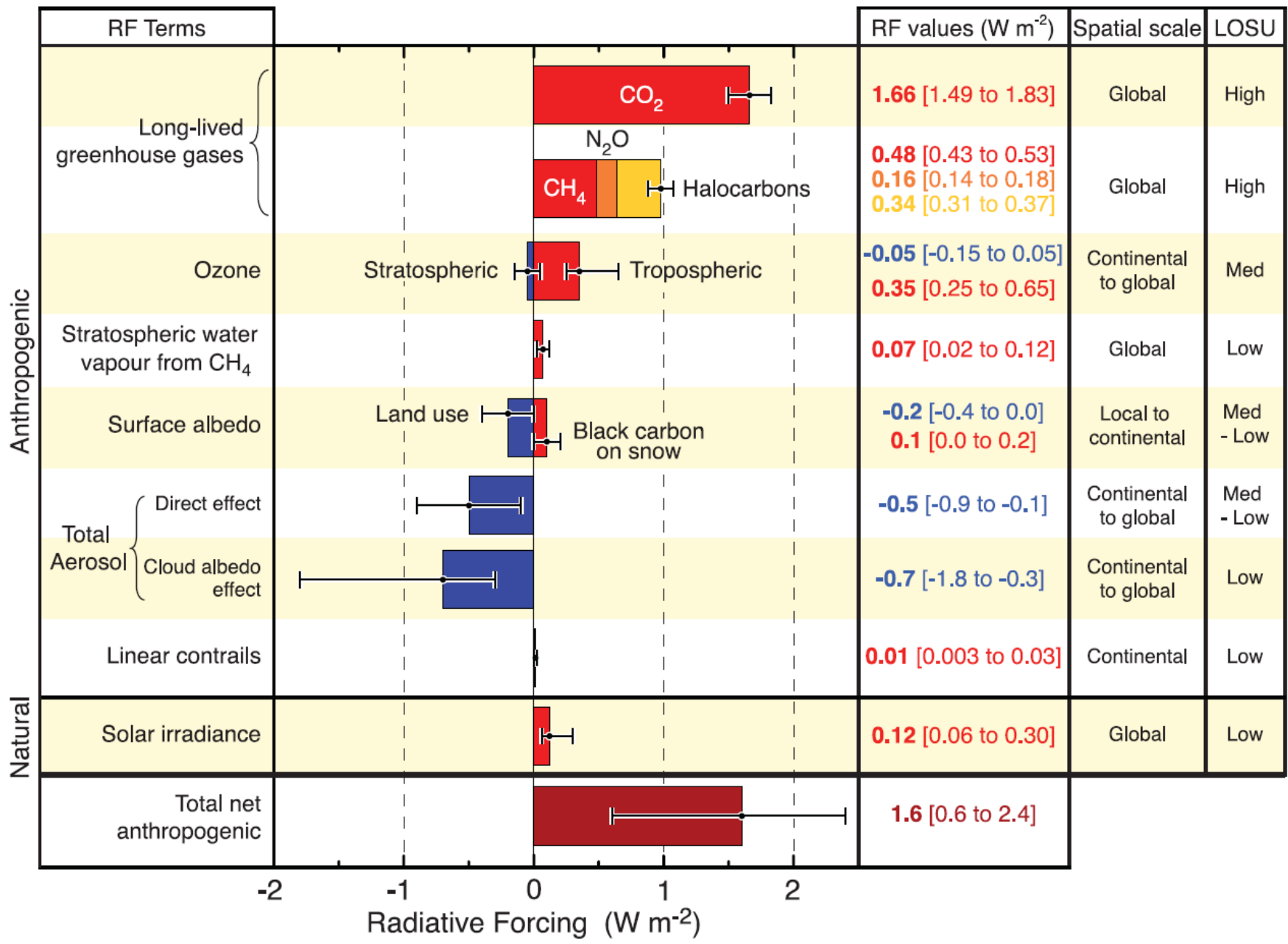


Among the explanations offered for this remarkable temperature increase is an *Enhanced Greenhouse Effect* due to an increase in the steady state concentration of Greenhouse Gases.

So, just how remarkable IS this temperature change?  
And what makes for an effective Greenhouse Gas?

Figure SPM.3. Observed changes in (a) global average surface temperature, (b) global average sea level from tide gauge (blue) and satellite (red) data and (c) Northern Hemisphere snow cover for March-April. All changes are relative to corresponding averages for the period 1961–1990. Smoothed curves represent decadal average values while circles show yearly values. The shaded areas are the uncertainty intervals estimated from a comprehensive analysis of known uncertainties (a and b) and from the time series (c). {FAQ 3.1, Figure 1, Figure 4.2, Figure 5.13}

# RADIATIVE FORCING COMPONENTS



©IPCC 2007: WG1-AR4

# Uncertainties in our understanding

The *existence* of global warming

Some skeptics argue that the changes are much smaller than those reported in the IPCC and similar reports

Even the IPCC scientists admit that the quality of our temperature data is unsatisfactory

But even if there is some uncertainty in the absolute amount, the trend is unmistakable

The debate really lies in the *causes* of global warming – can we explain the data using only natural variation?

# Alternative Explanations

## Variations in volcanic activity

It is certainly true that an increase in volcanic activity would lead to an increase in CO<sub>2</sub> and methane

... But also sulfate aerosol

The effect is transitory

There is little evidence of significantly increased activity

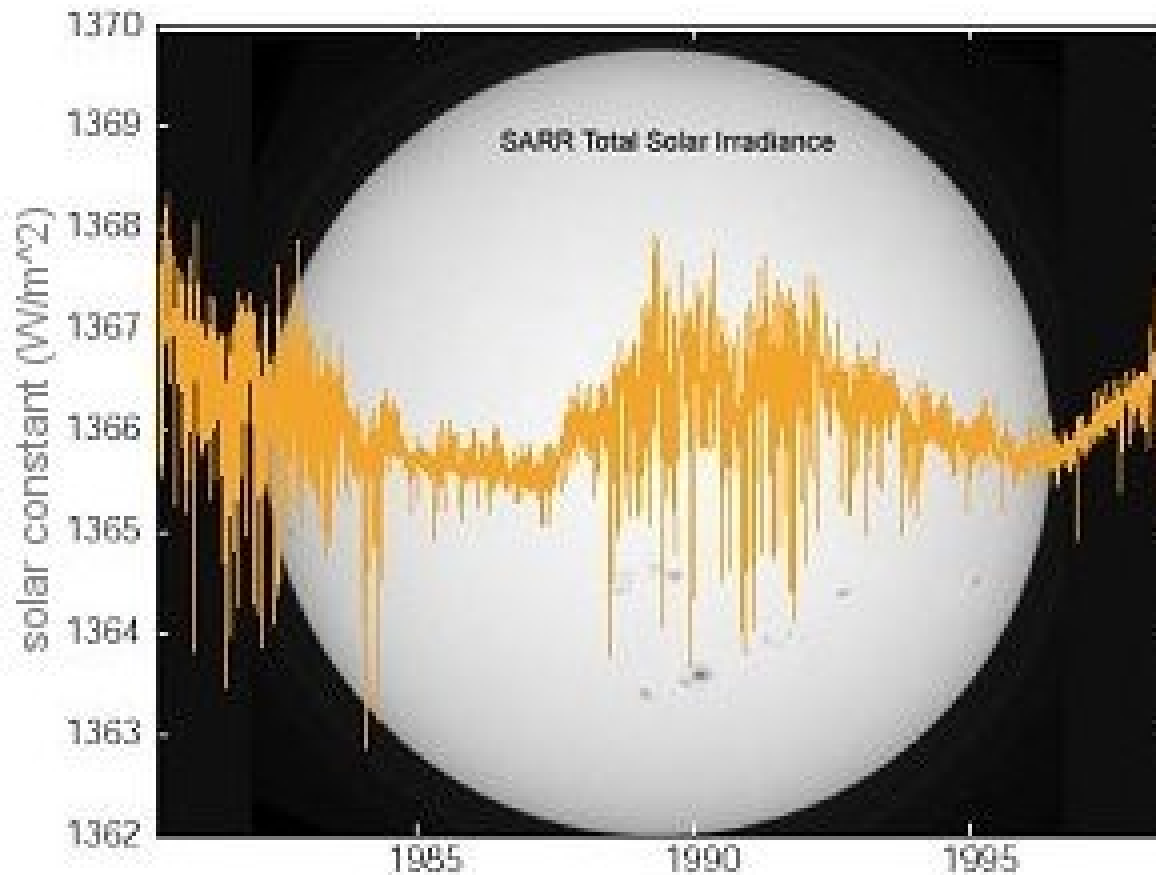
# Alternative Explanations

## Variations in solar irradiance

There are natural variations in solar activity

There is historical evidence that these fluctuations can effect climate!

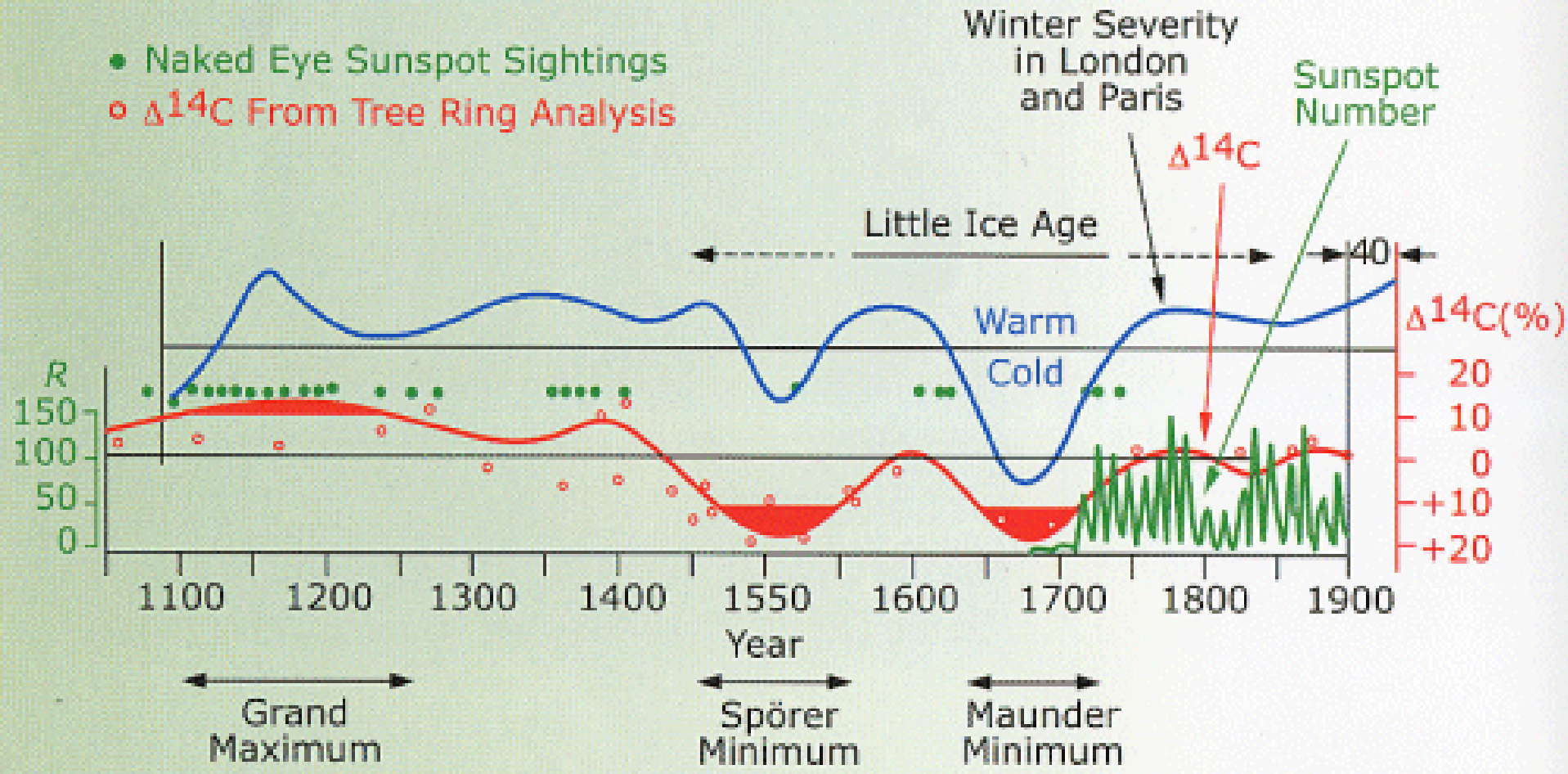




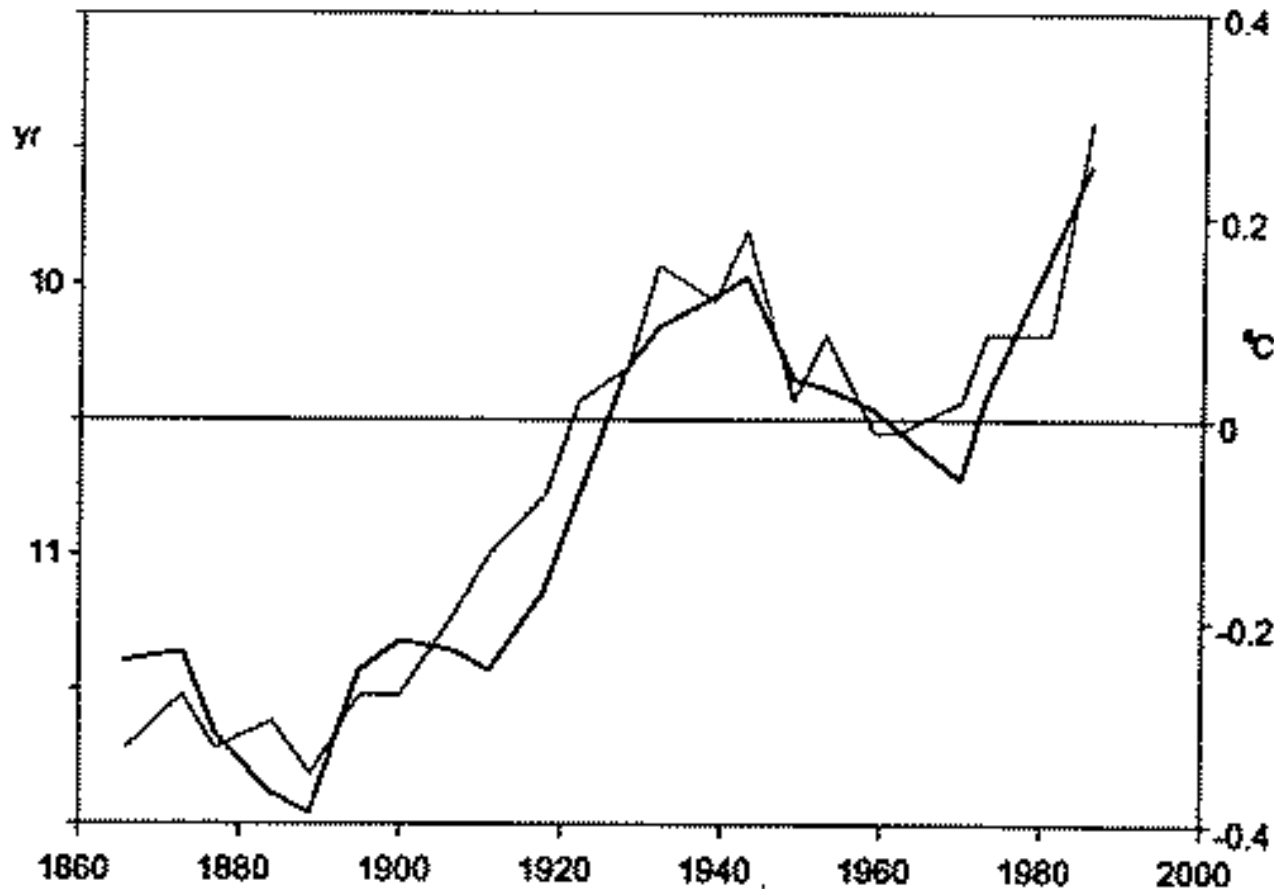
There is a repeating 11 year cycle of sunspot intensity that correlates with increased solar flux

There is also historical evidence of greater variations over short time scales

- Naked Eye Sunspot Sightings
- $\Delta^{14}\text{C}$  From Tree Ring Analysis

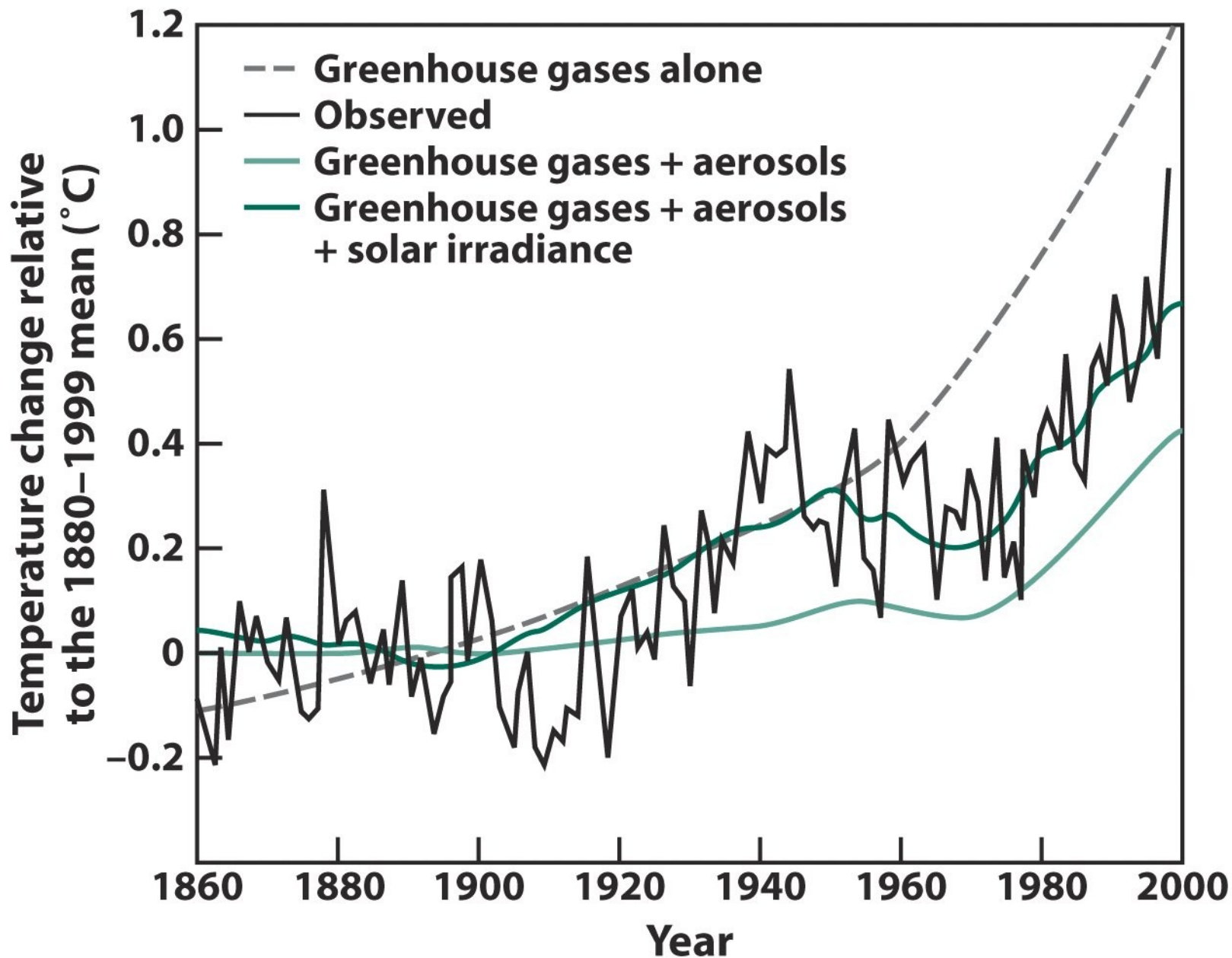


From [http://science.nasa.gov/headlines/y2003/17jan\\_solcon.htm](http://science.nasa.gov/headlines/y2003/17jan_solcon.htm), "The Inconstant Sun"



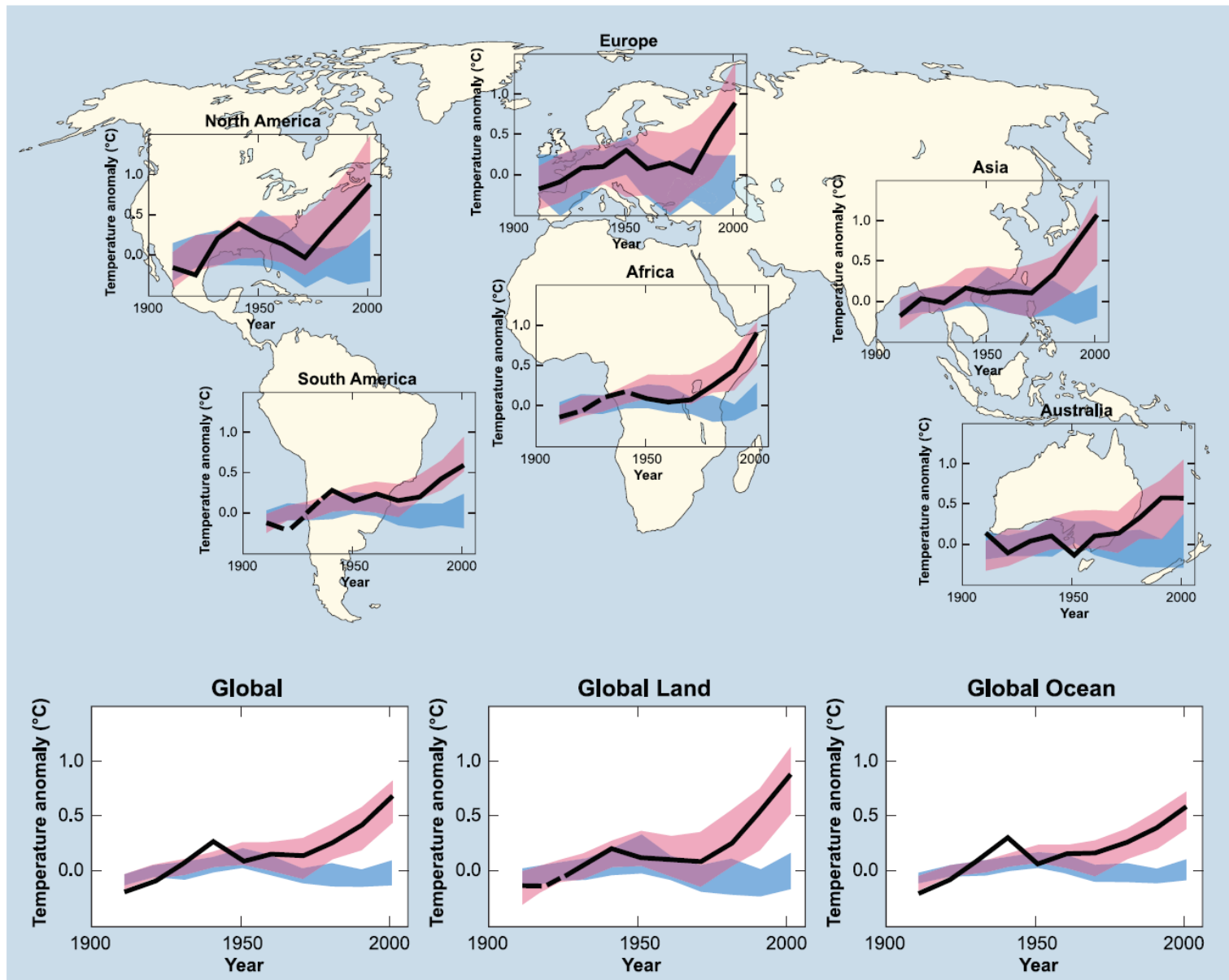
There is remarkable correlation between the sunspot cycle and observed temperature changes from 1860-1980.

But this correlation does not hold past 1980, and does not show the significant warming of the past 20 years



**Figure 4-22**  
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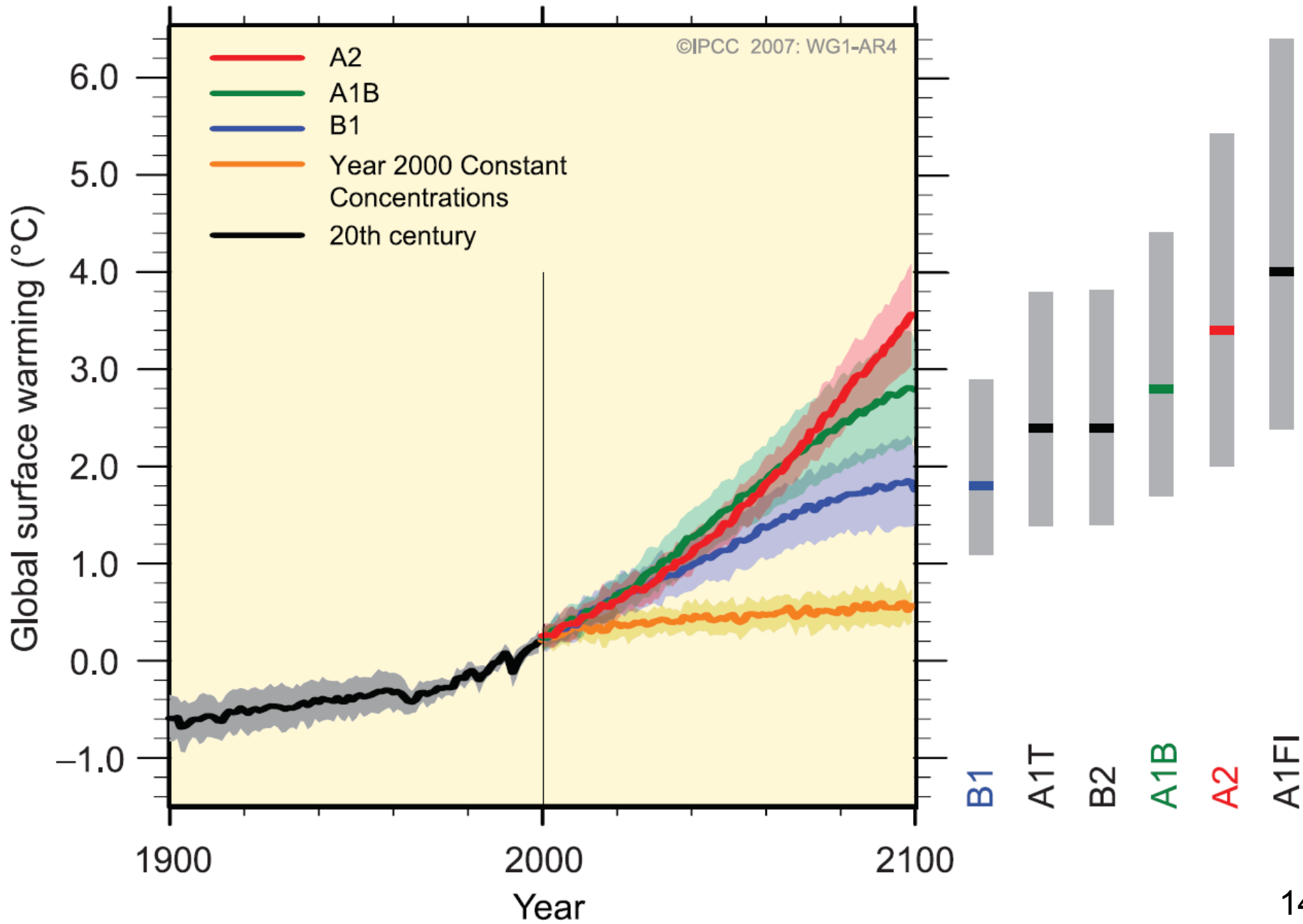
# GLOBAL AND CONTINENTAL TEMPERATURE CHANGE



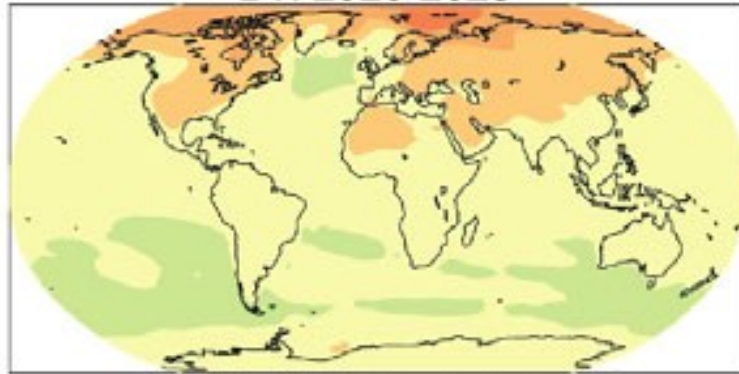
models using only natural forcings  
 models using both natural and anthropogenic forcings

observations

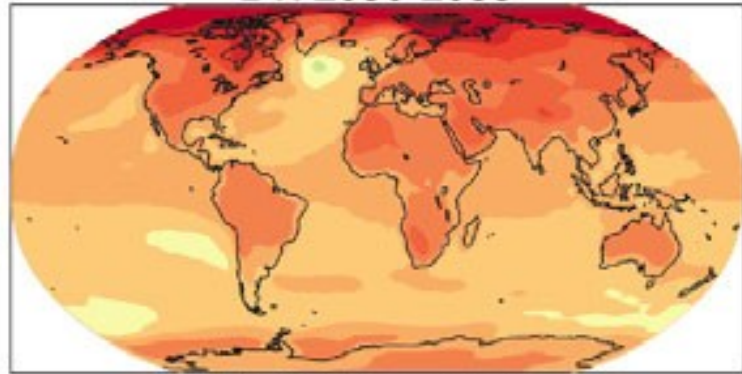
# MULTI-MODEL AVERAGES AND ASSESSED RANGES FOR SURFACE WARMING



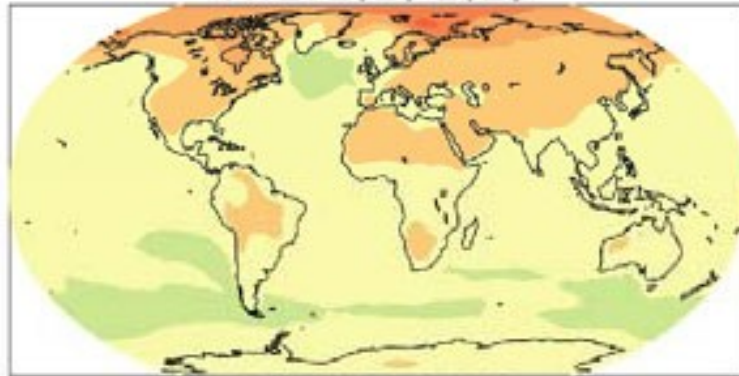
B1: 2020-2029



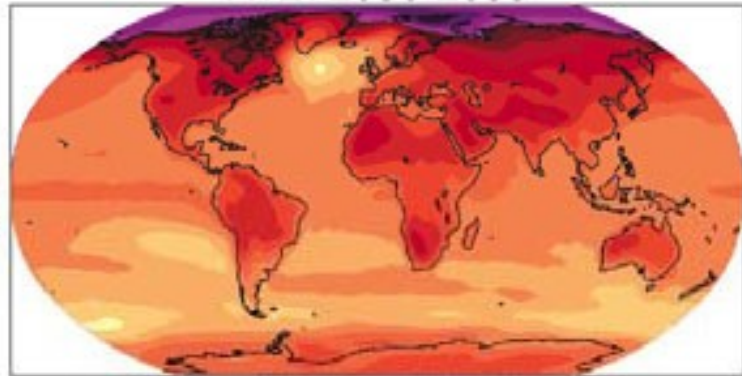
B1: 2090-2099



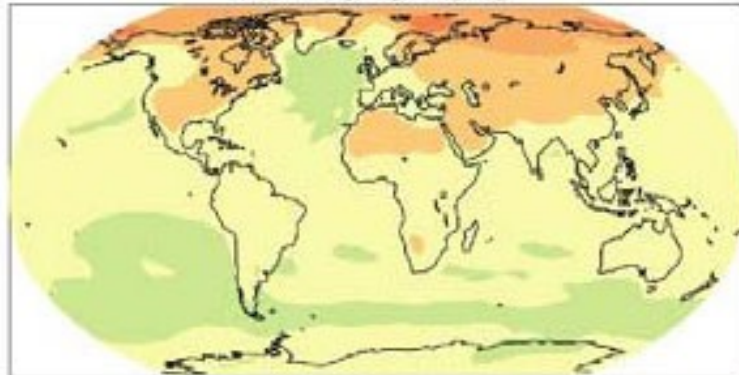
A1B: 2020-2029



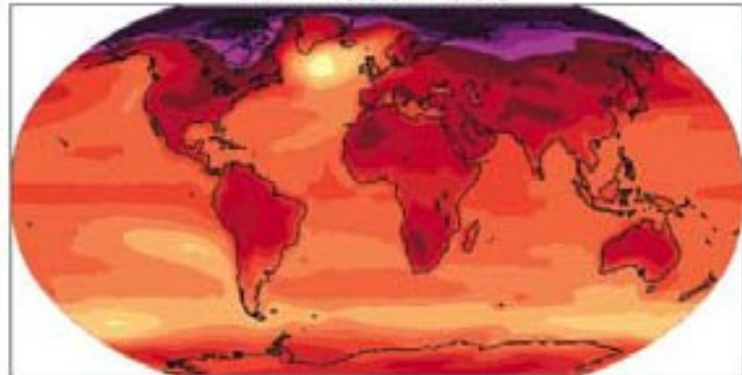
A1B: 2090-2099



A2: 2020-2029



A2: 2090-2099



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# Kyoto Protocol

- 1997
- 10,000 participants from 161 countries
- Goals to stabilize and reduce GHG concentrations in stratosphere
- Annex I nations (developed or industrialized countries) targeted for emission reduction: **by 2012**, the U.S. was expected to reduce its GHG emissions by 7% relative to 1990; Europe by 8%; Canada and Japan by 6%
- Annex II nations (3<sup>rd</sup> World or developing countries) NOT targeted for emission reduction



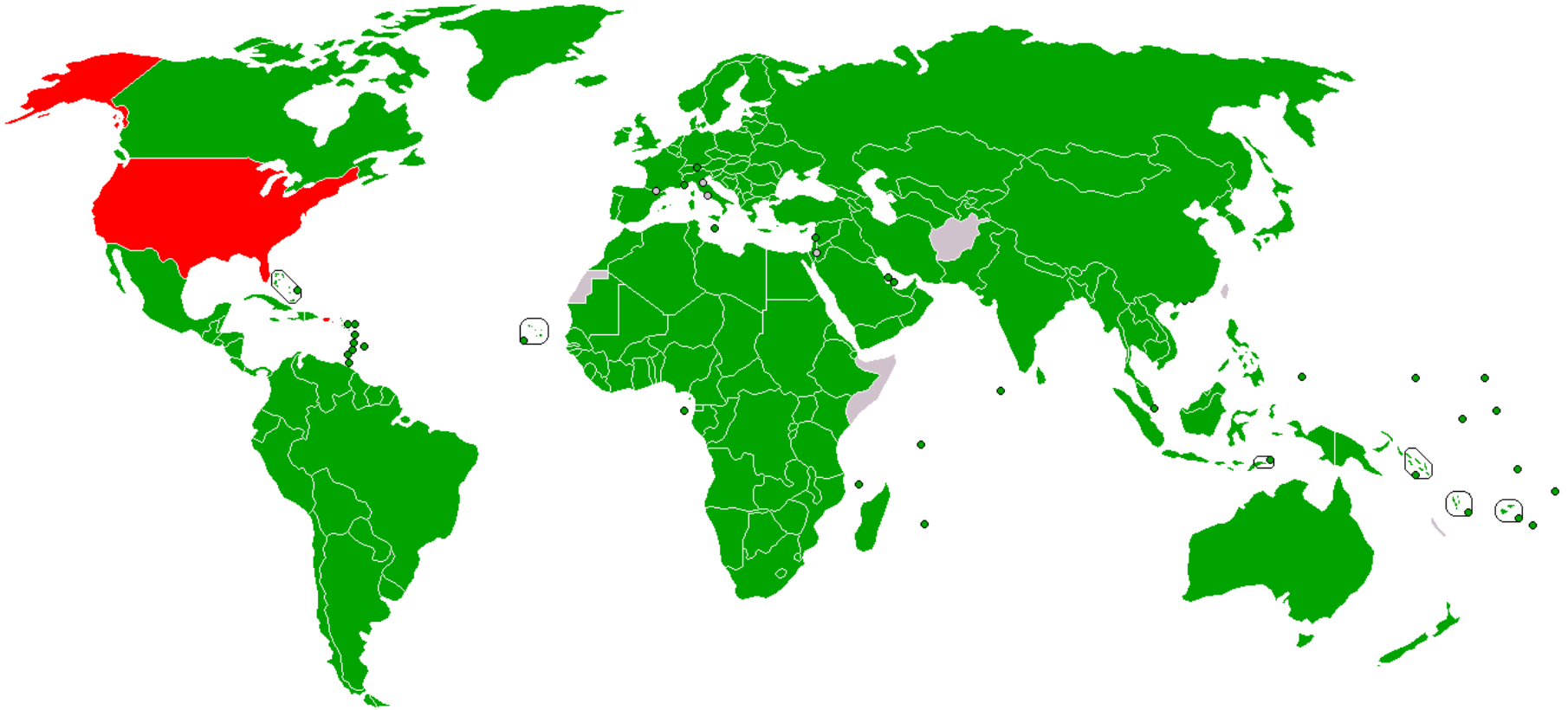
# Regulated Gases

- CO<sub>2</sub>
- CH<sub>4</sub>
- N<sub>2</sub>O
- HFCs
- SF<sub>6</sub>

# Kyoto Protocol

- Designed to go in to effect when two conditions have been met:
  - The governments of 55 countries have ratified the requirements
  - When Annex I nations responsible for 55% of the 1990 CO<sub>2</sub> emissions have ratified
- As of February 2005, when Russia passed its laws, those requirements are met
- As of February 2009, 183 countries are on board, and ~63 of 1990 CO<sub>2</sub> emissions are accounted for

# Participation in the Kyoto Protocol



Green: signed and ratified. Grey: Undecided. Red: Stated intention **not** to ratify.

Source: Wikimedia Commons

# U.S. Hasn't Ratified Kyoto

- Bill Clinton didn't sign
  - Annex II nations NOT targeted for emission reduction
  - The Senate voted 95-0 **opposing** any measure that did not bind developing nations
- George W. Bush didn't sign
  - China has an exemption but the U.S. does not
  - Economic concerns as well – enacting the requirements would have dramatic consequences for the U.S. economy
- When Obama was in Turkey in April 2009, he said that "it doesn't make sense for the United States to sign [the Kyoto Protocol] because [it] is about to end." At this time, two years and eleven months remained from the four-year commitment period.

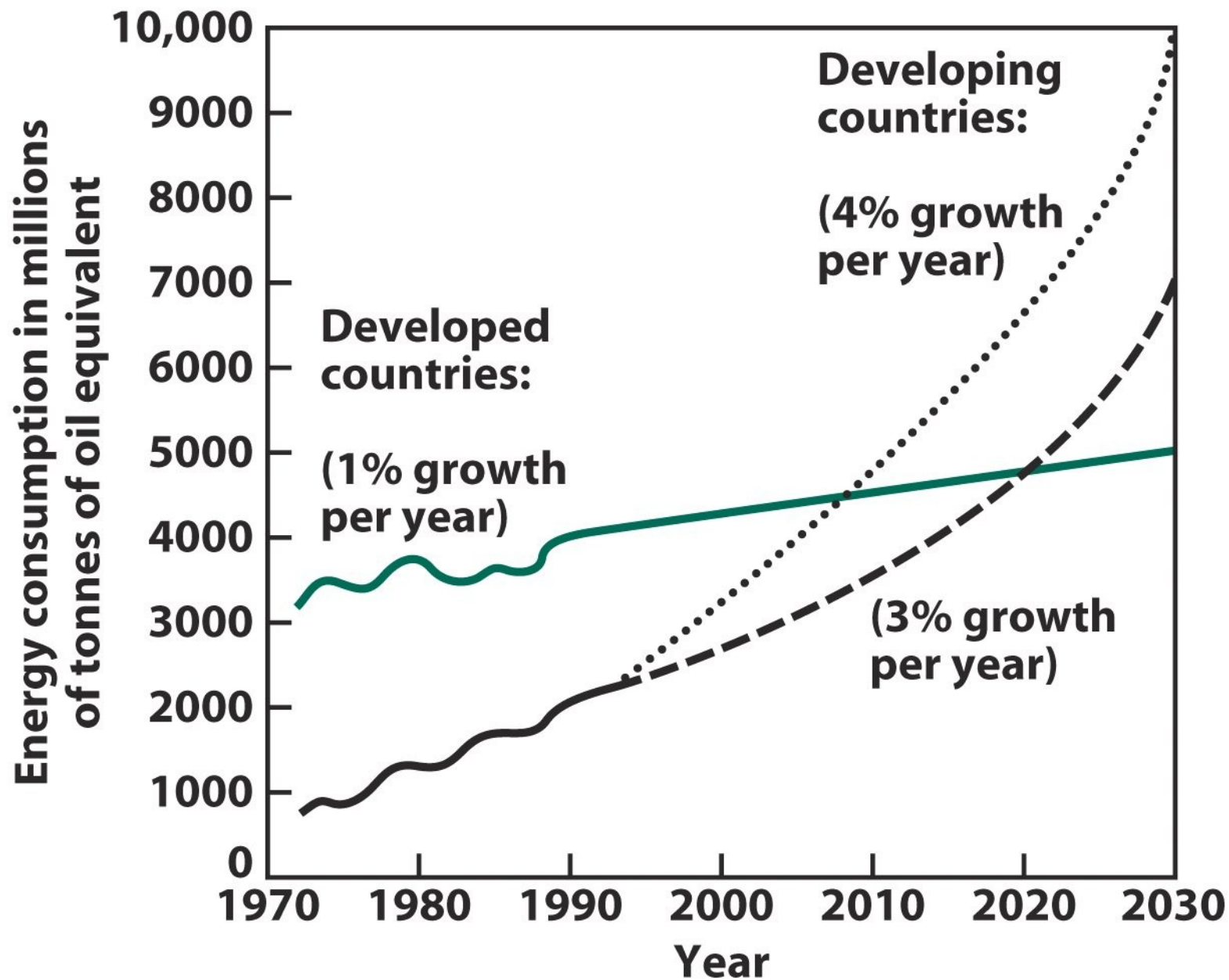
# Emissions in the Future

Most developed nations have pledged to reduce, or at least maintain, their emissions

Most developing nations have not

A 4% annual increase in usage leads to a doubling in 17 years

If we assume a 4% annual increase in developing nations, they will collectively be responsible for 2/3 of emissions by 2030



**Figure 5-3**  
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Where does that leave us?

There's a lot more to this story than CO<sub>2</sub> and methane concentrations

If you dig deeper, you'll learn a lot more about a "lag" between temperature rise and CO<sub>2</sub>

and about the role of the oceans

and about bias in the temperature records

and about water vapor

...

Where does that leave us?

But there is no doubt that anthropogenic greenhouse gases **should** increase tropospheric temperatures

The data is readily available

This is THE scientific debate of your lives.

You are scientists.

Don't let others decide for you.