Evidence and implications of anthropogenic climate change

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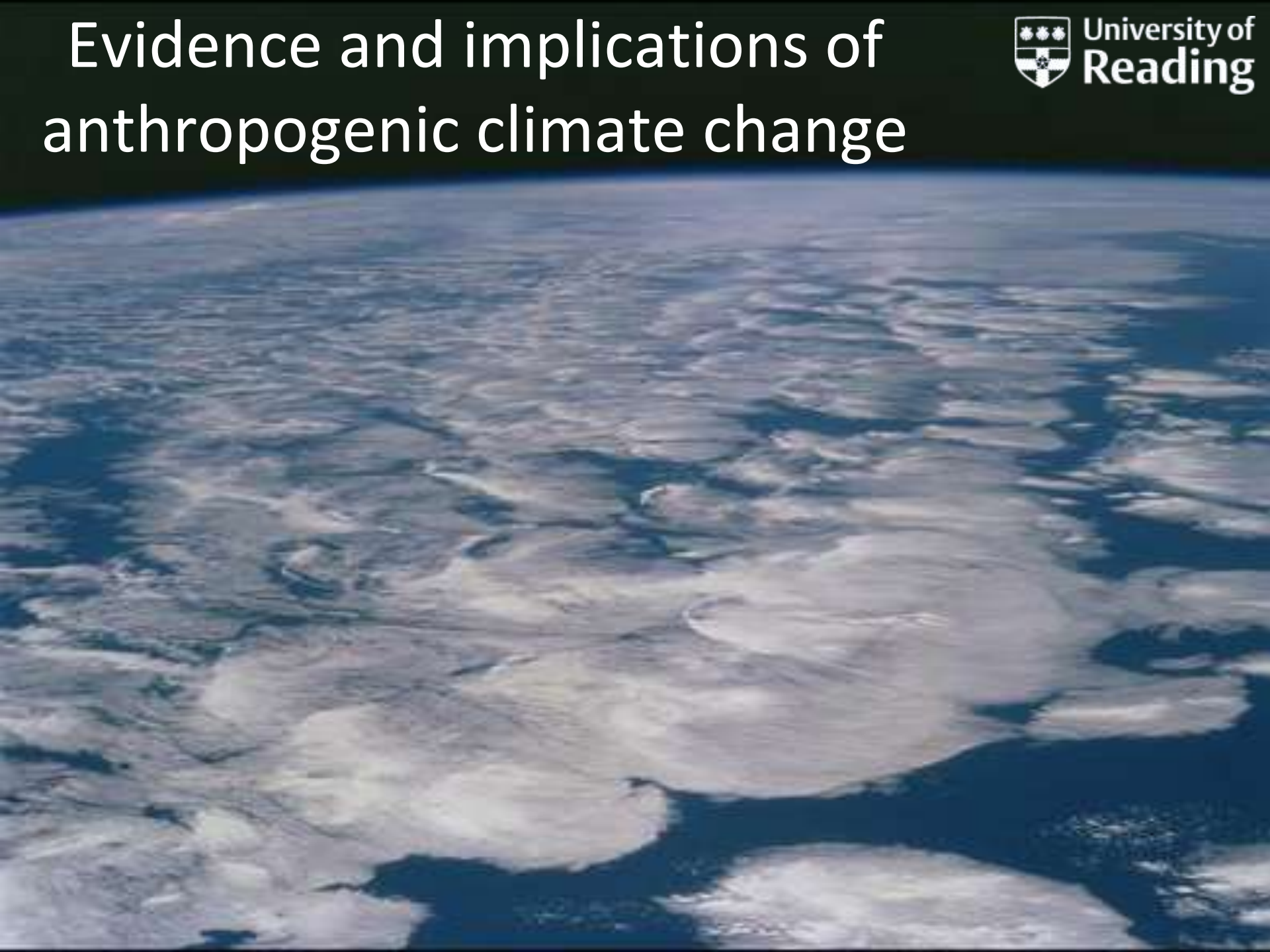
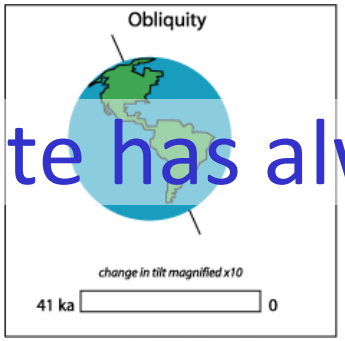
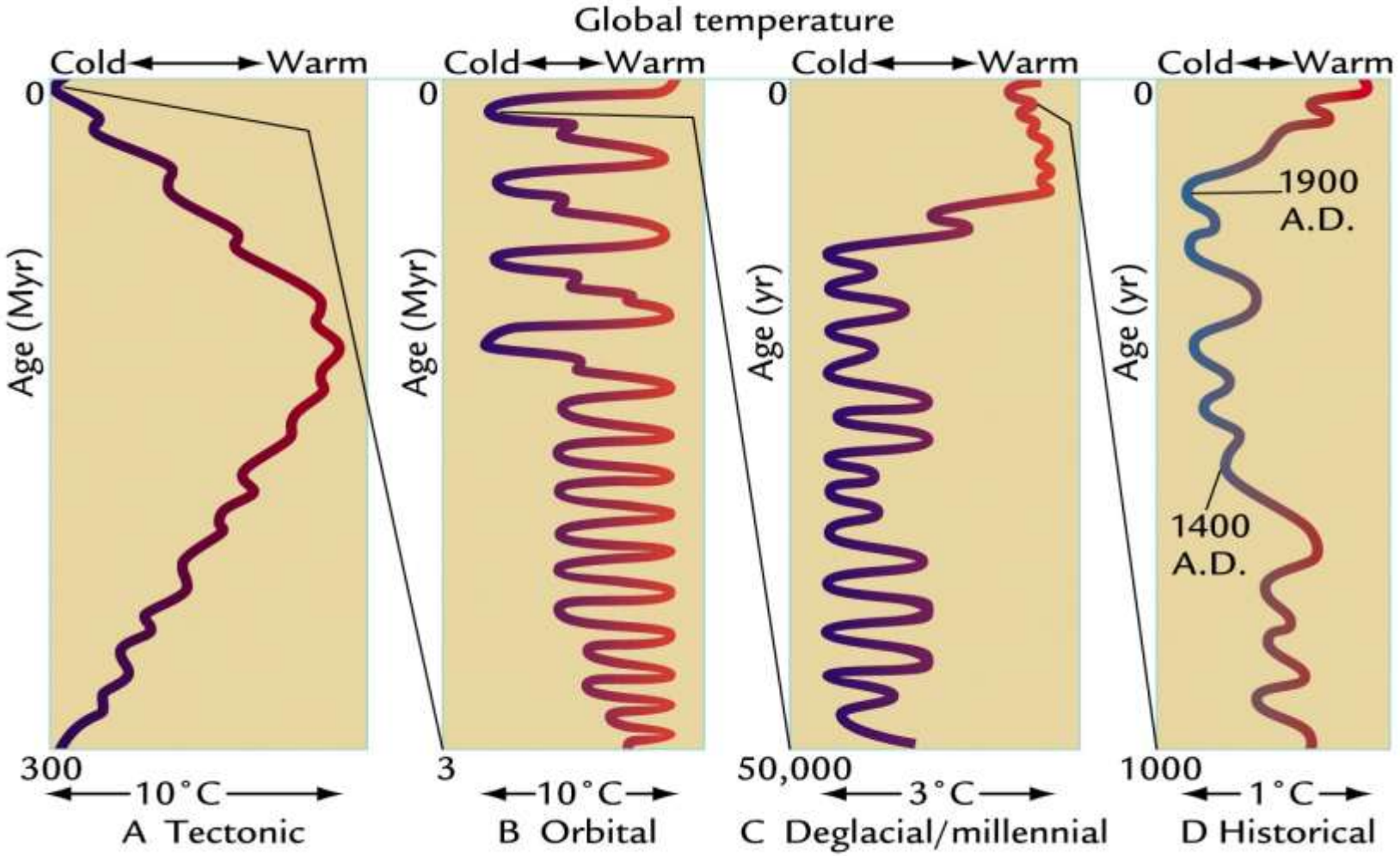


Earth's Climate has always been changing





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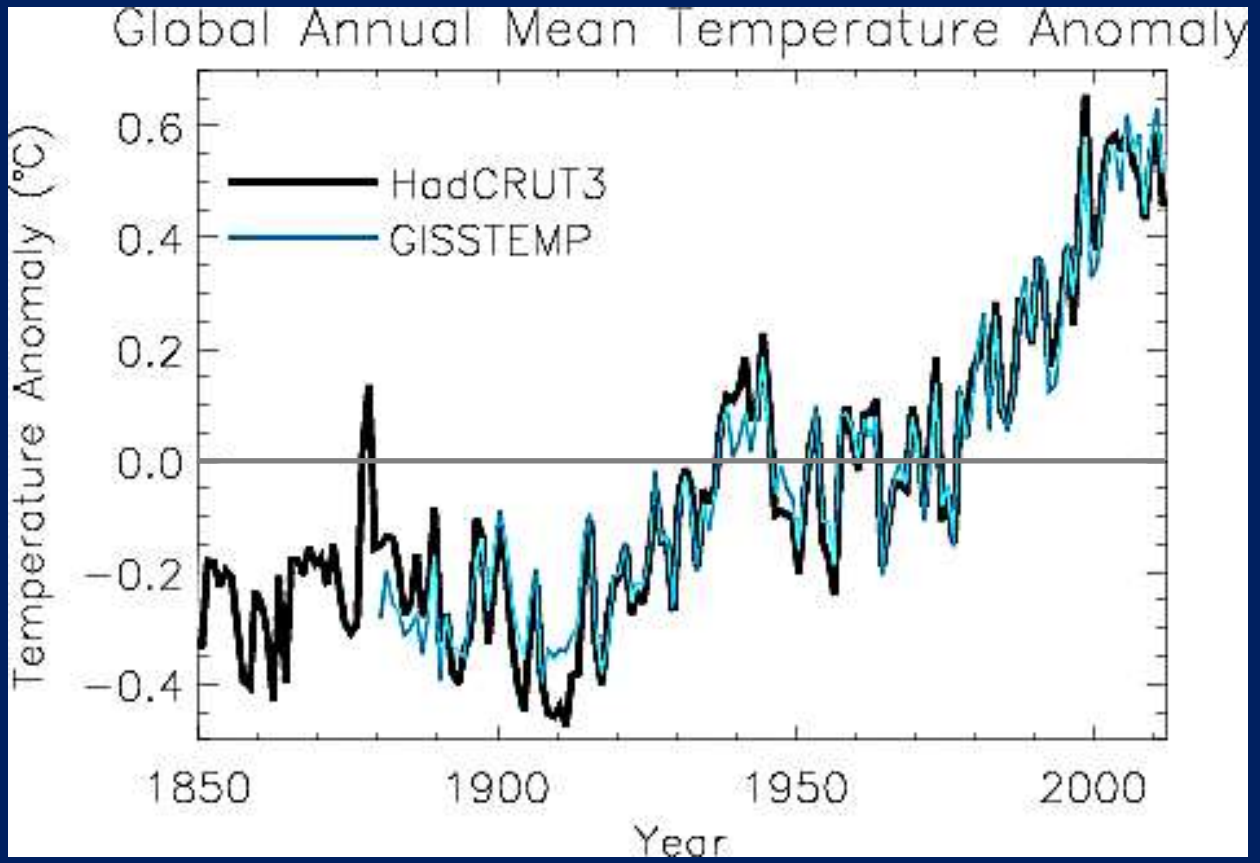
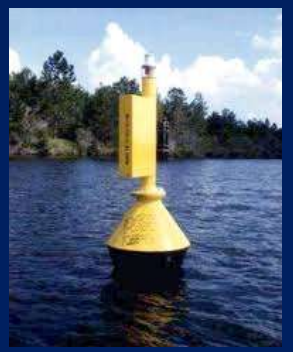
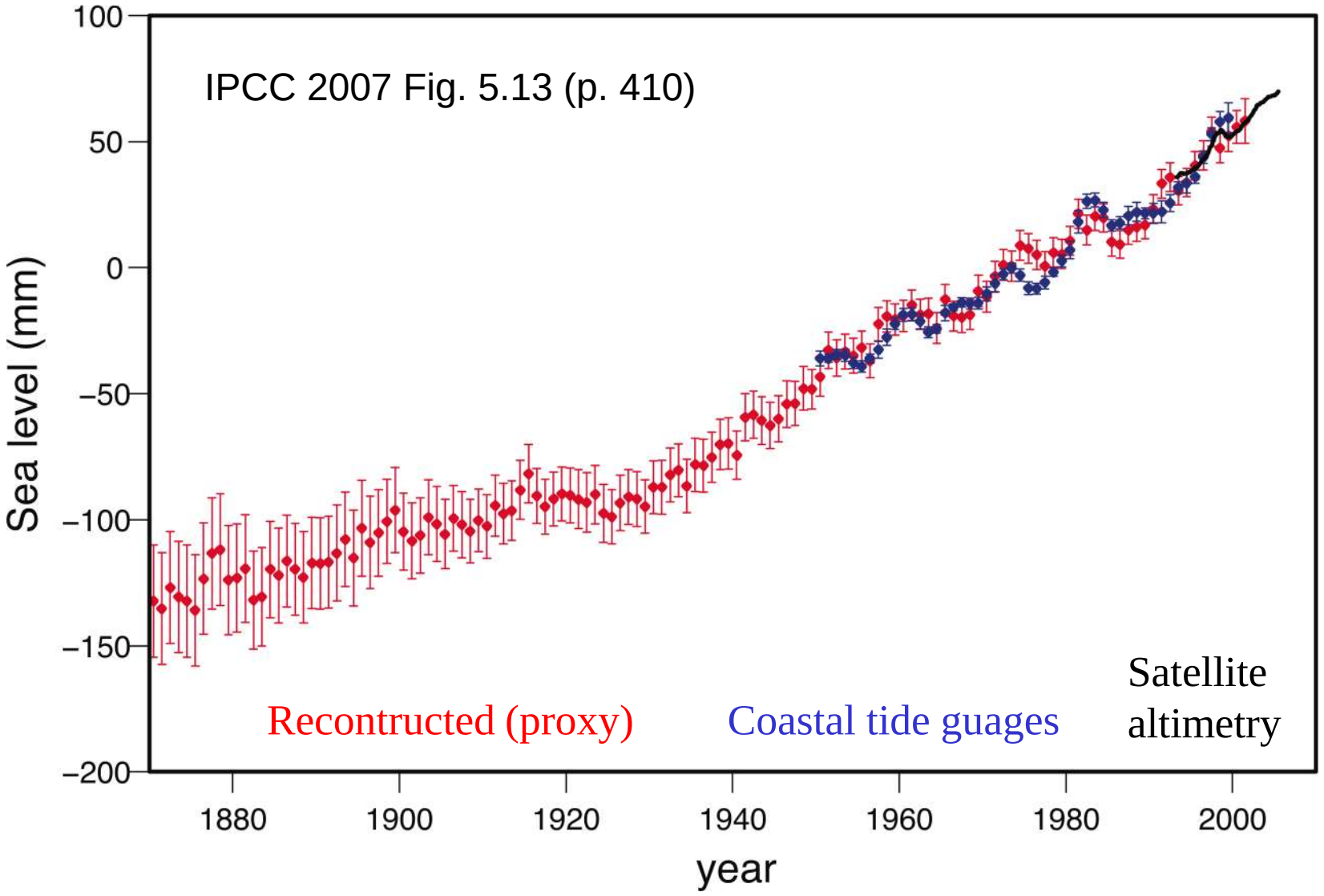
1) Is climate changing now?

Global Warming ?

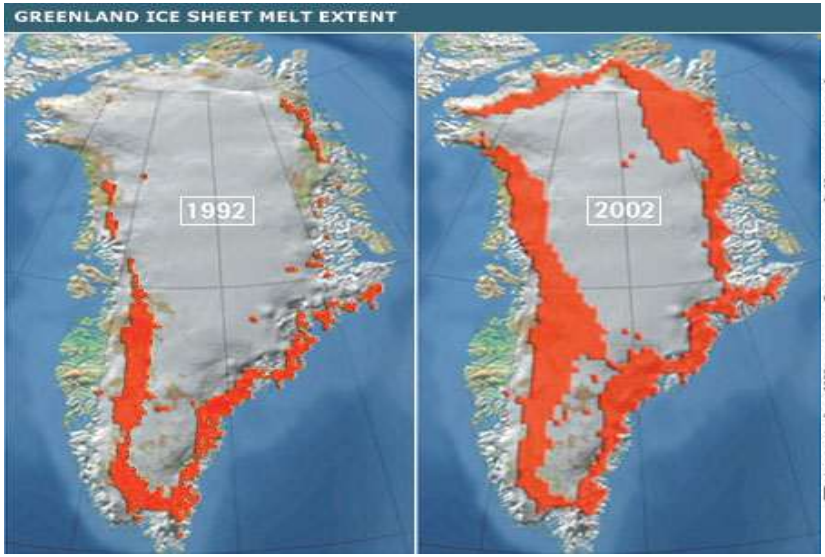


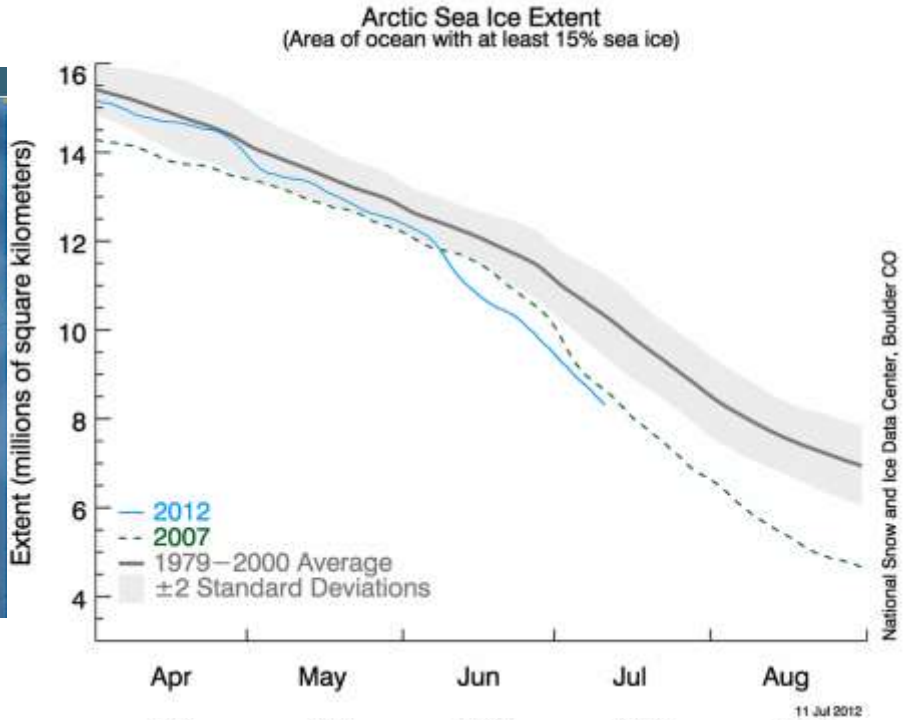


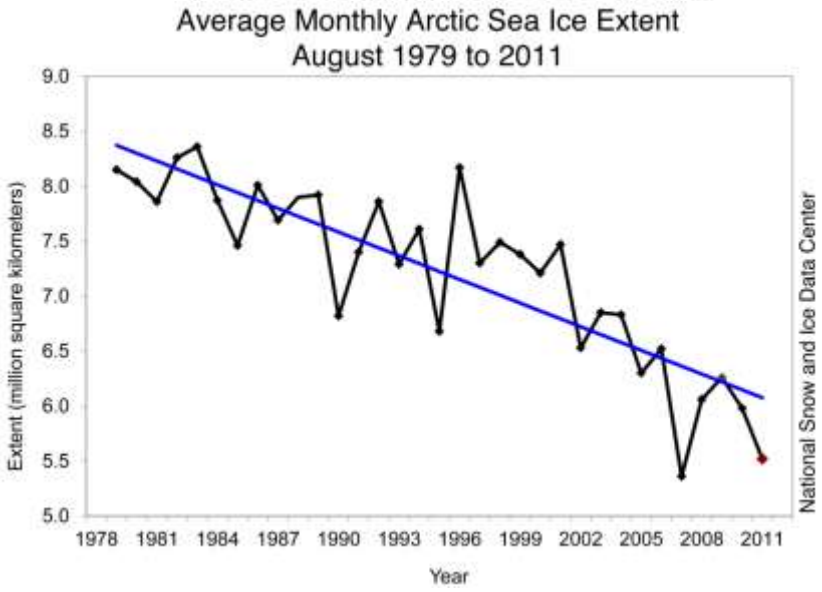
Sea level rising

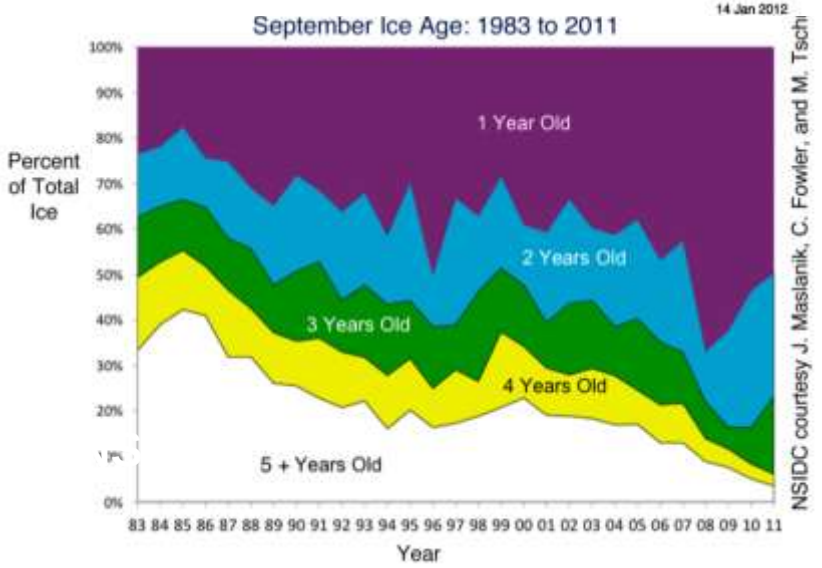


Melting of Arctic Ice

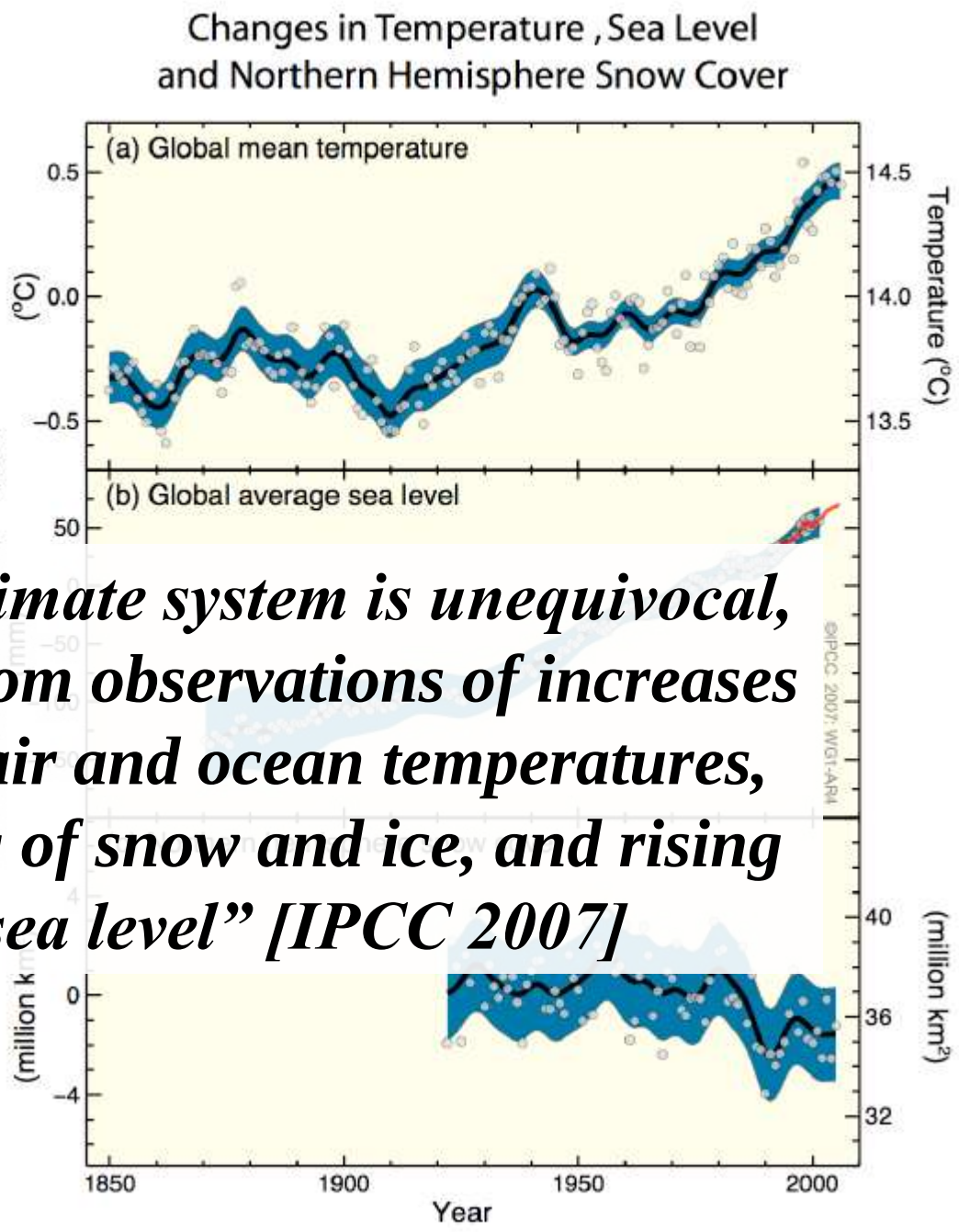








Is climate changing?



"Warming of the climate system is unequivocal, as is now evident from observations of increases in global average air and ocean temperatures, widespread melting of snow and ice, and rising global mean sea level" [IPCC 2007]

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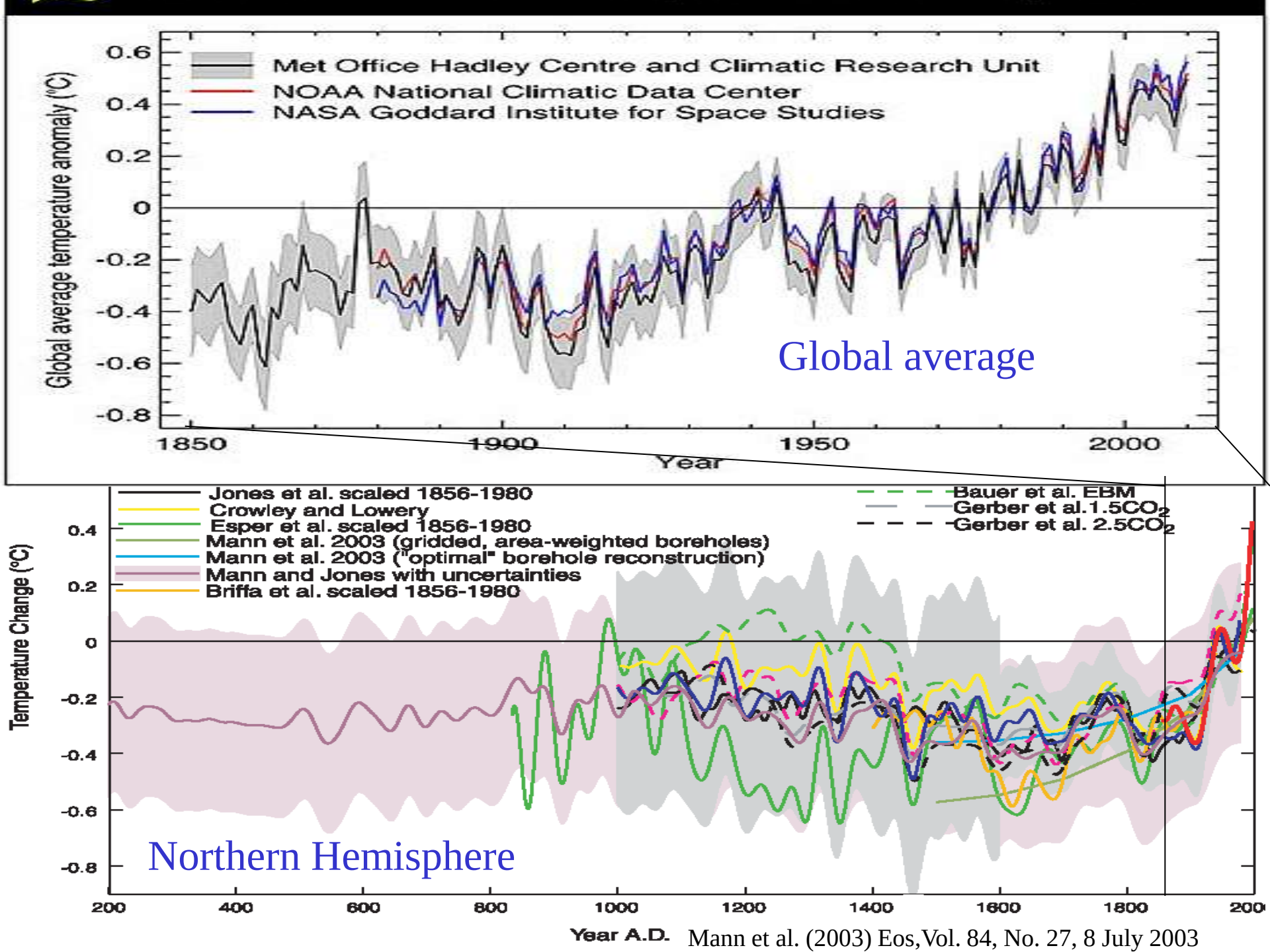
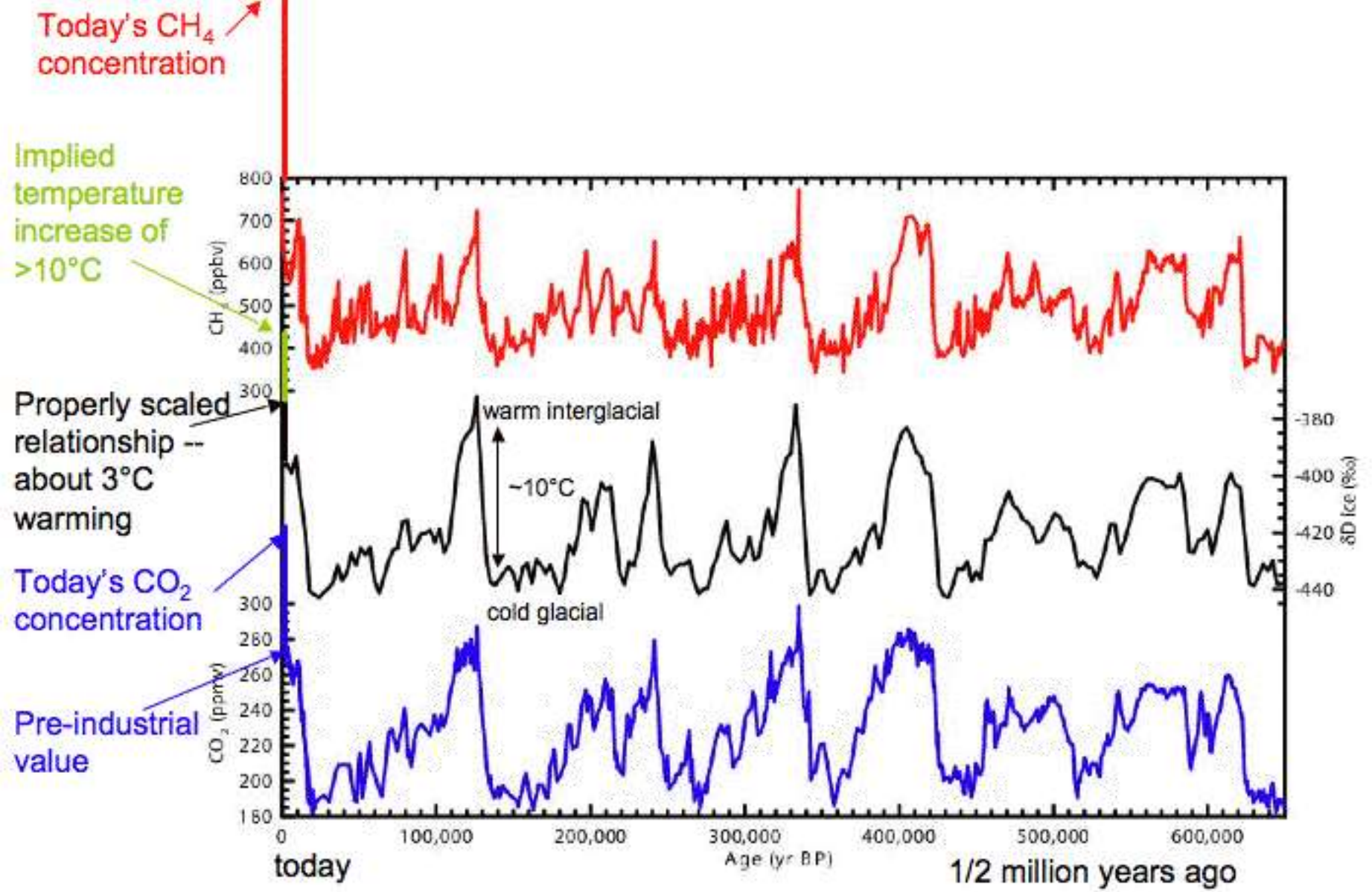
2) Is the warming unusual?



Mann et al. (2003) Eos,Vol. 84, No. 27, 8 July 2003



Methane, **temperature** (from hydrogen isotope ratios ("δD") and carbon dioxide from the Dome C Ice core. (EPICA Project members, 2006).

Is the warming unusual?

- Over the last 100 years the globe has warmed by about 0.8^{o}C
- The warming appears unprecedented in the last 1800 years
- The last time polar regions were warmer than today was more than 125 000 years ago
  - At that time sea level was 4-7m higher than today

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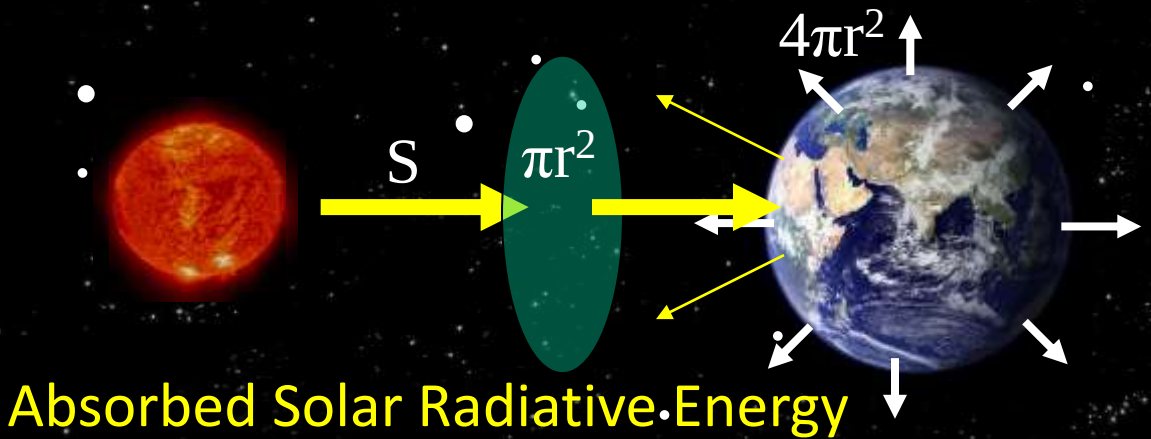
3) Why is it warming?

Earth's energy balance in space

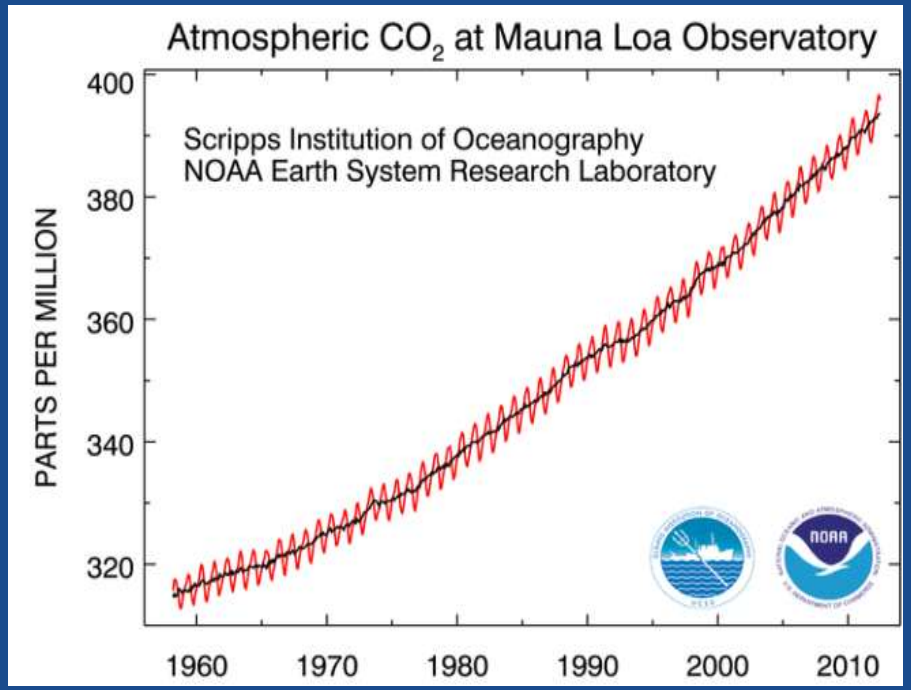


- There is a balance between the absorbed sunlight and the thermal radiative cooling of the planet
- Without the greenhouse effect, this balance would occur at a frigid global temperature of –18°C

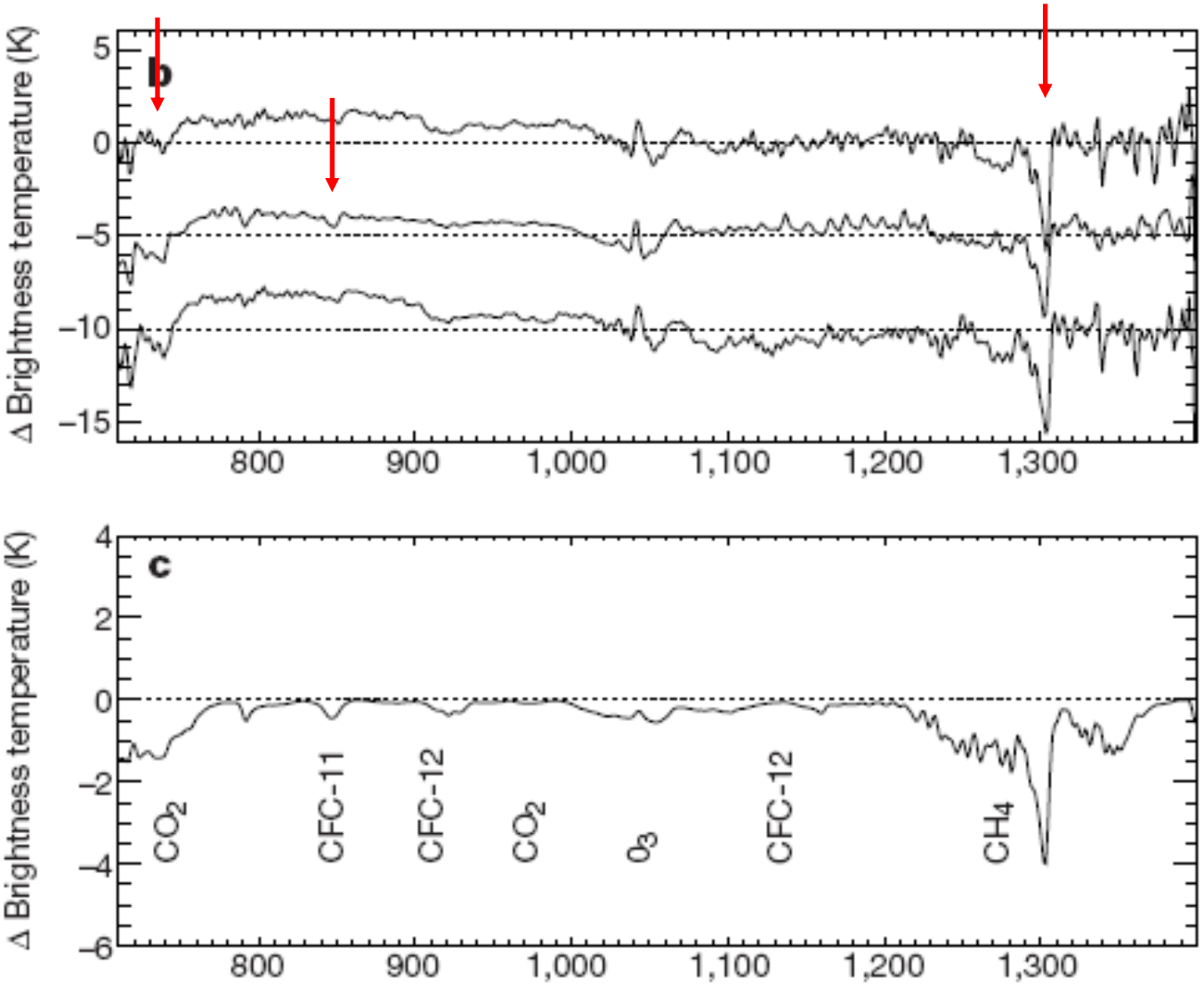
Fourier (1824); Tyndall (1858); Arhenius (1896); Lacis et al. (2011)

“Radiative forcing” of climate

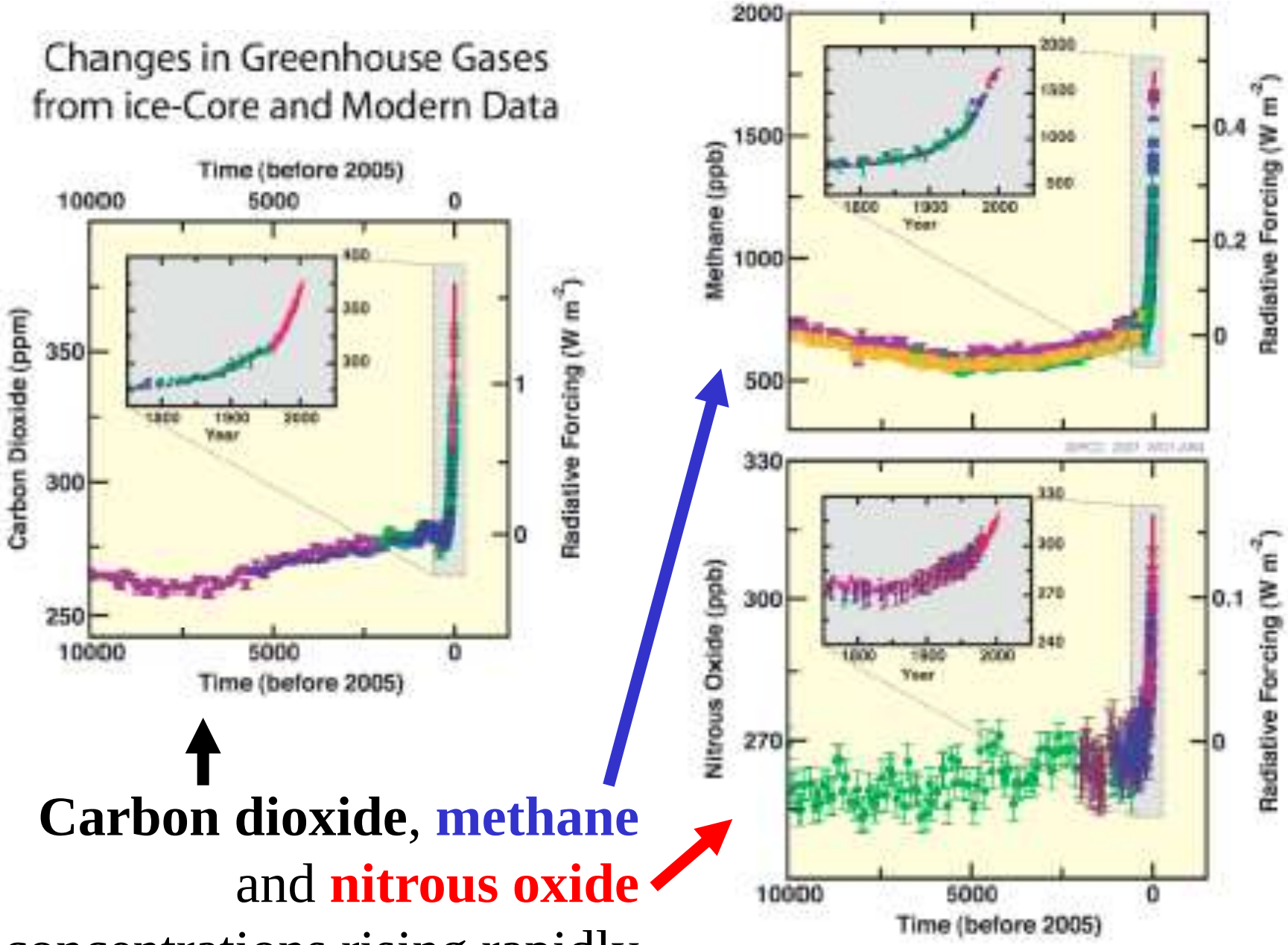
- Increases in greenhouse gases heat the planet by trapping heat
- Small pollutant particles (aerosols) cool the planet by reflecting sunlight
- If more energy is arriving than is leaving the planet, Earth should warm…



Satellite observations detect enhanced greenhouse effect: 1997-1970 Harries et al. 2001, Nature

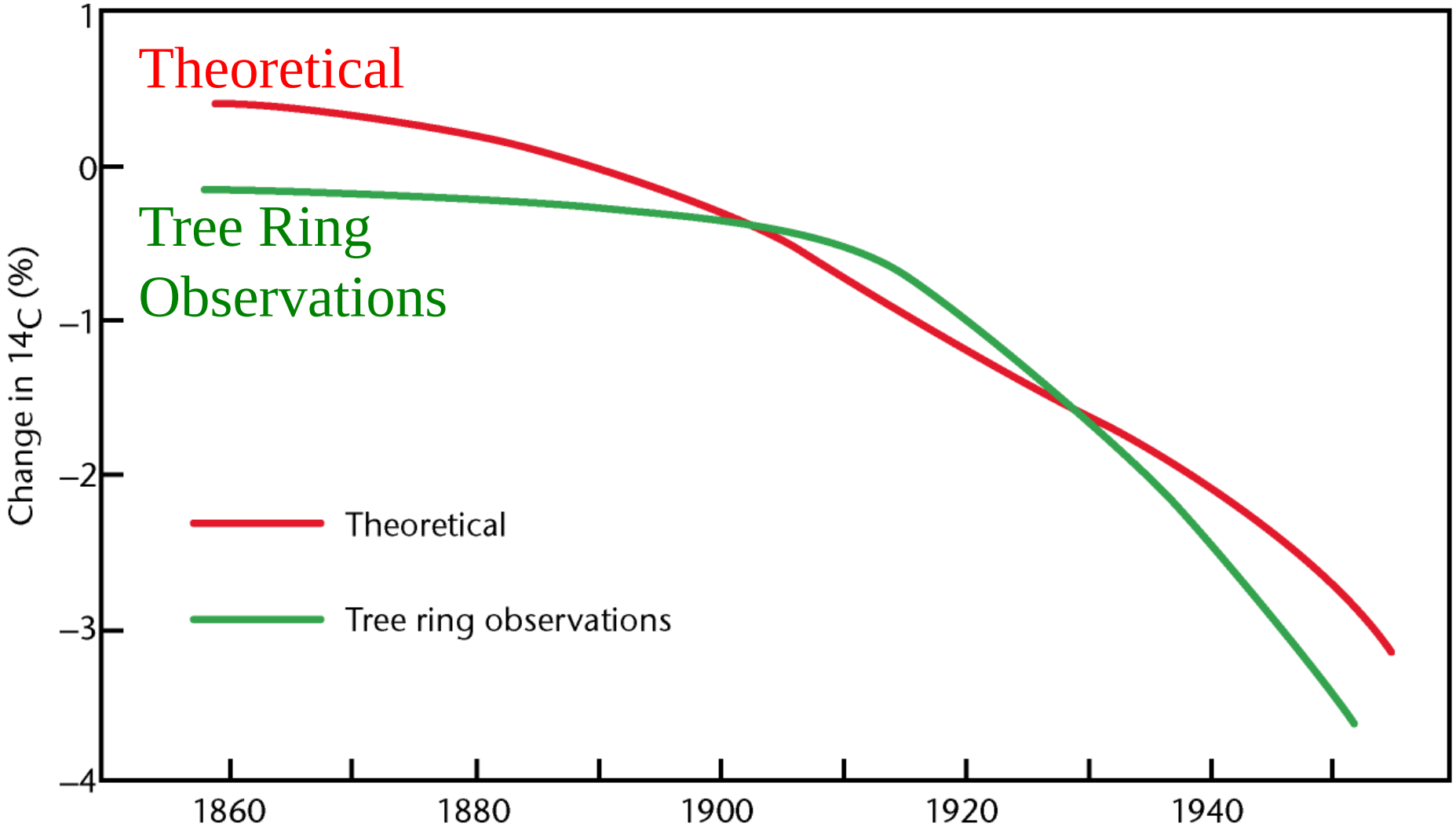


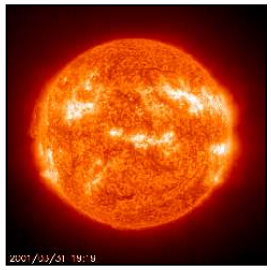
These results showed for the first time experimental confirmation of the significant increase in the greenhouse effect from trace gases such as carbon dioxide and methane



Carbon dioxide, **methane**
and **nitrous oxide**
concentrations rising rapidly

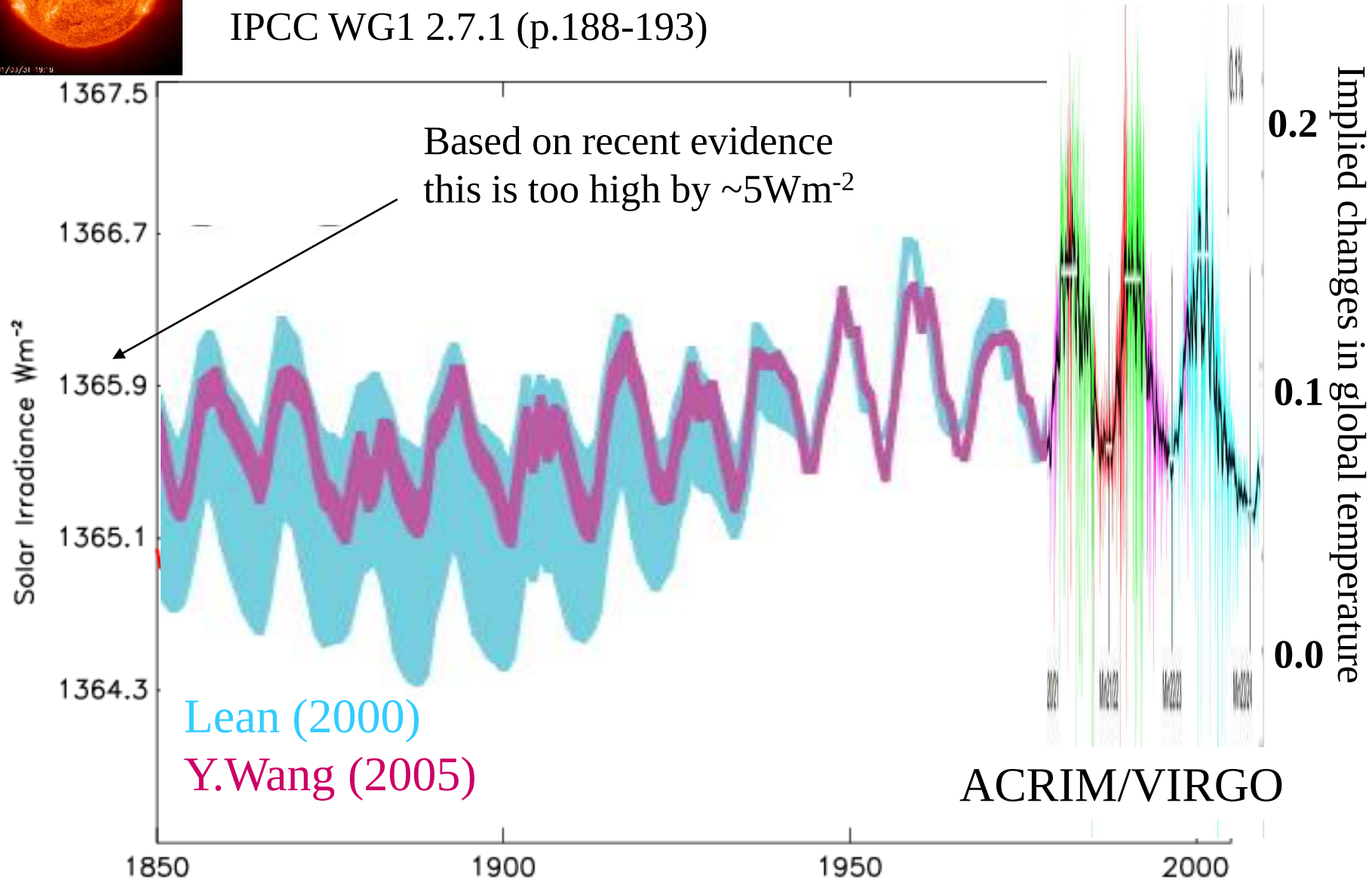
Fossil fuel CO_2 has diluted natural CO_2





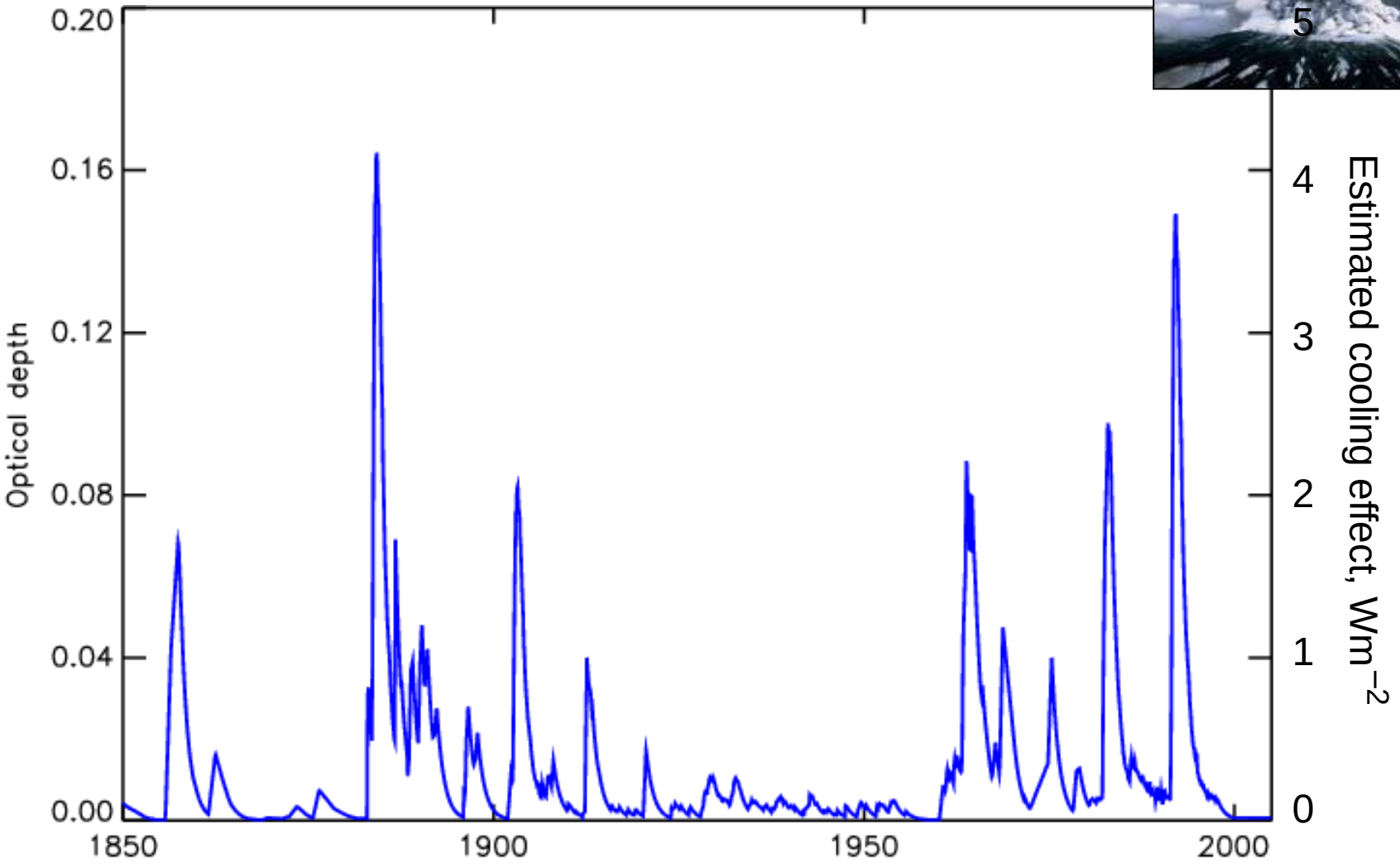
Solar output; stable over last 50 years

IPCC WG1 2.7.1 (p.188-193)



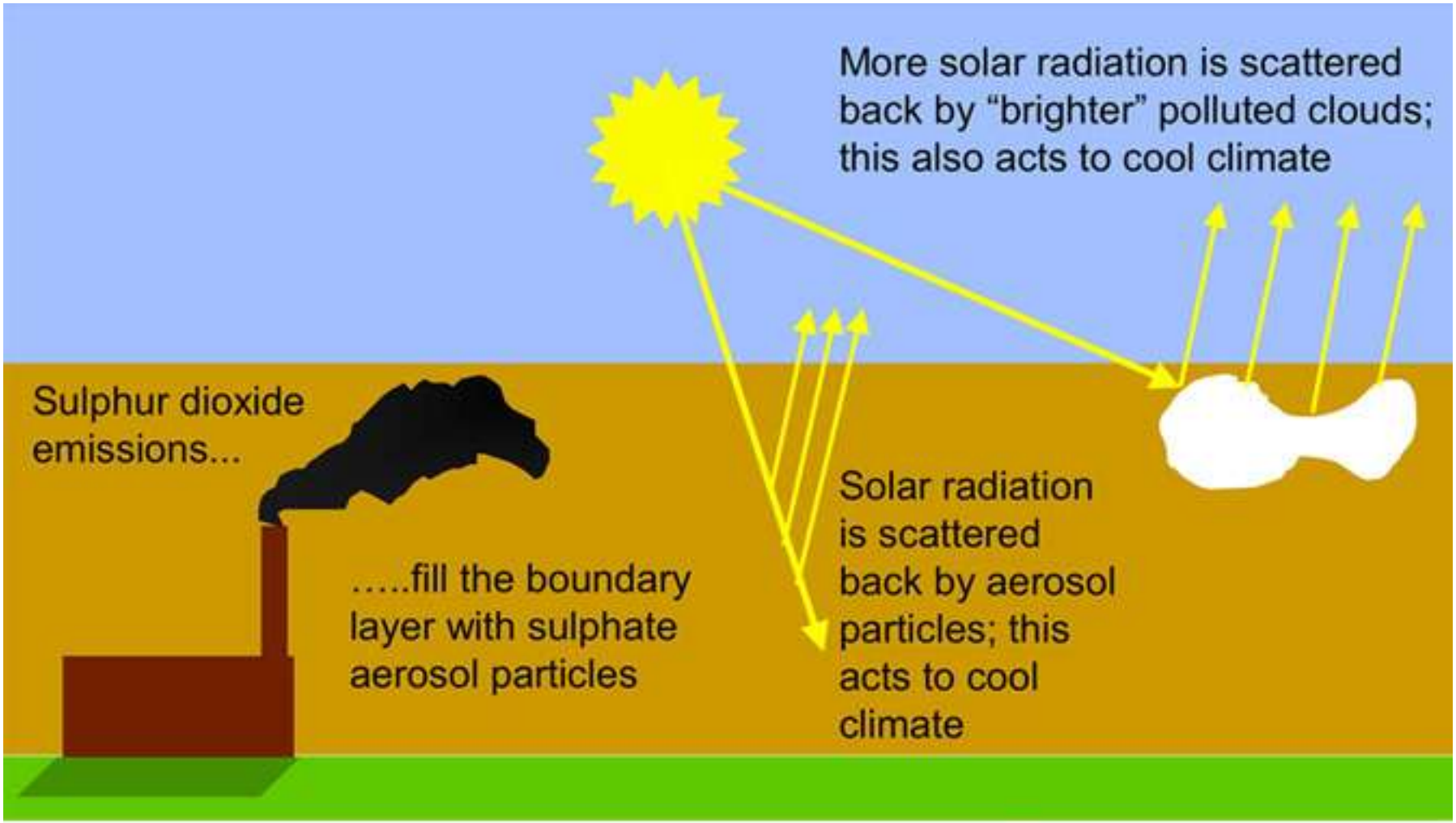
See also: http://www.pmodwrc.ch/pmod.php?topic=tsi/composite/SolarConstant

Change in volcanic aerosol

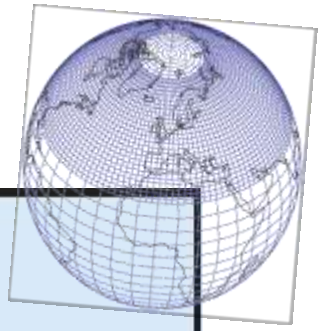


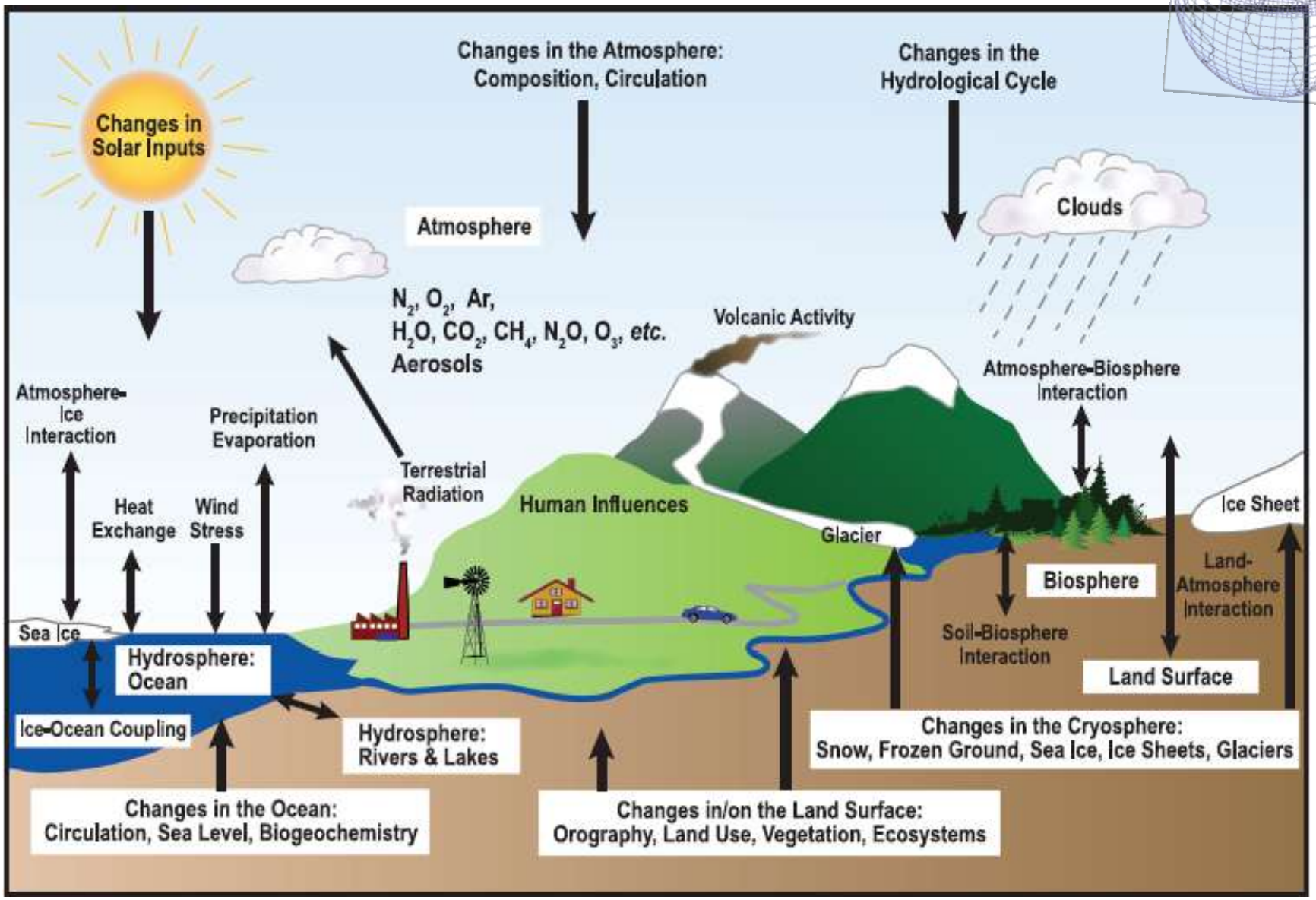
Source: Sato et al, GISS, NASA

Sulphur aerosols offset some of the heating from greenhouse gases



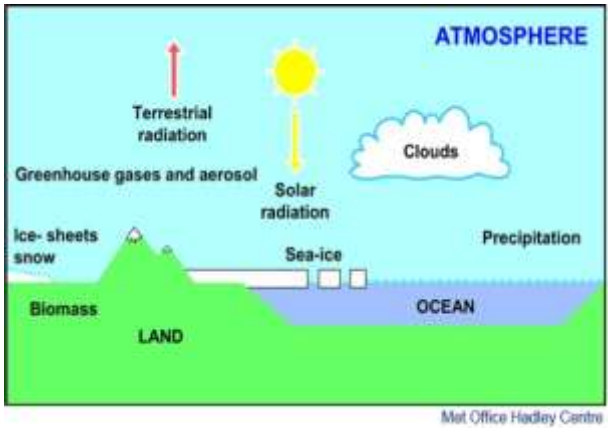
Computer Simulations of Climate

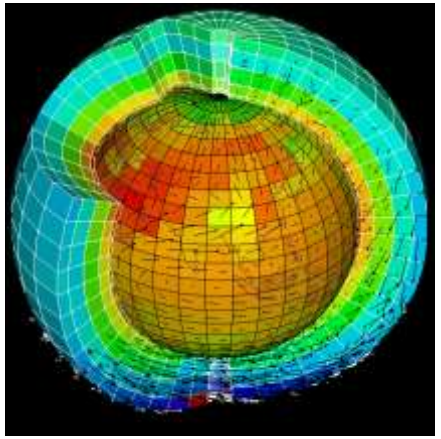




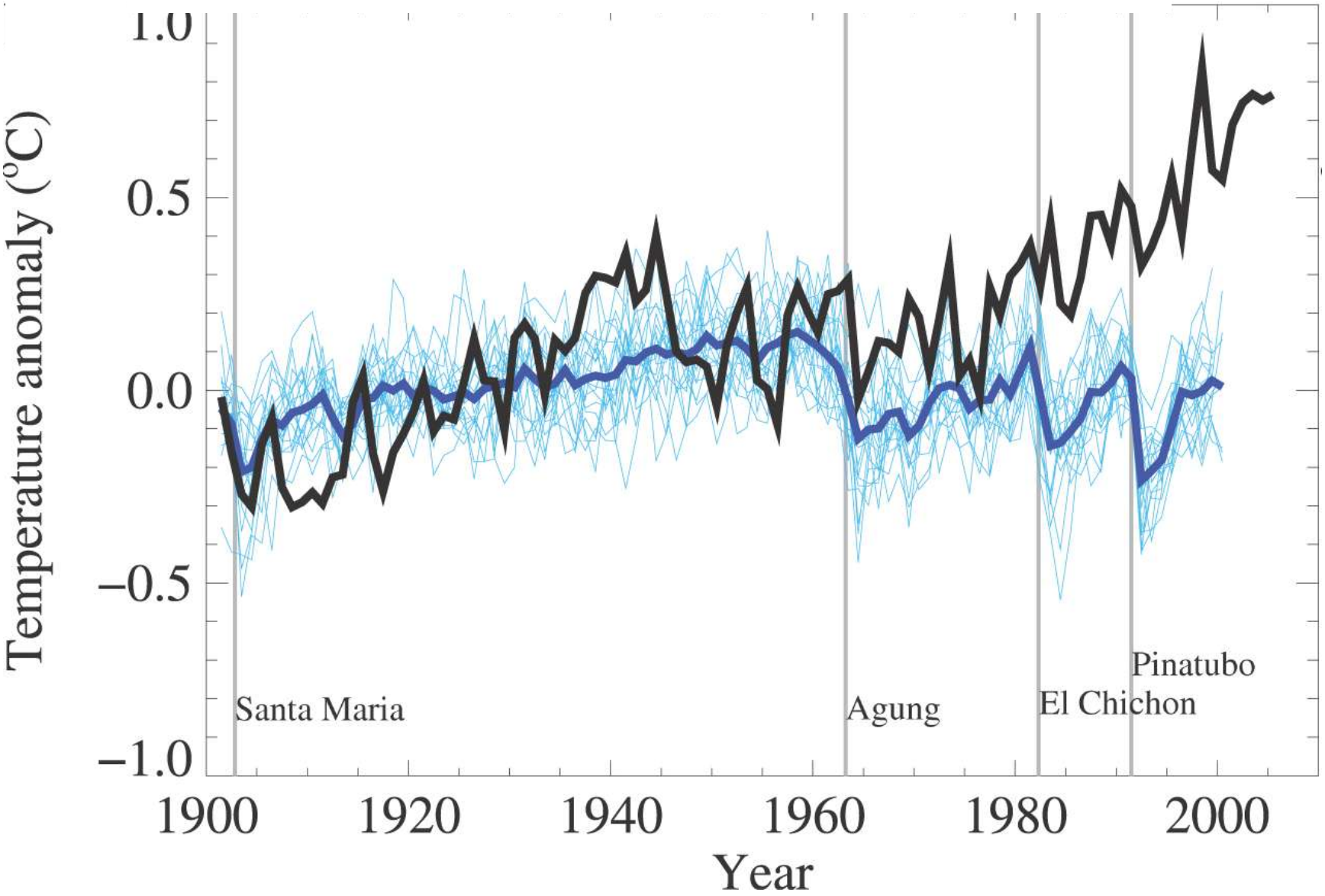
Experiments with computer simulations

- How much of the recent warming can be explained by natural effects?
- To answer such questions, experiments can be performed with detailed computer simulations

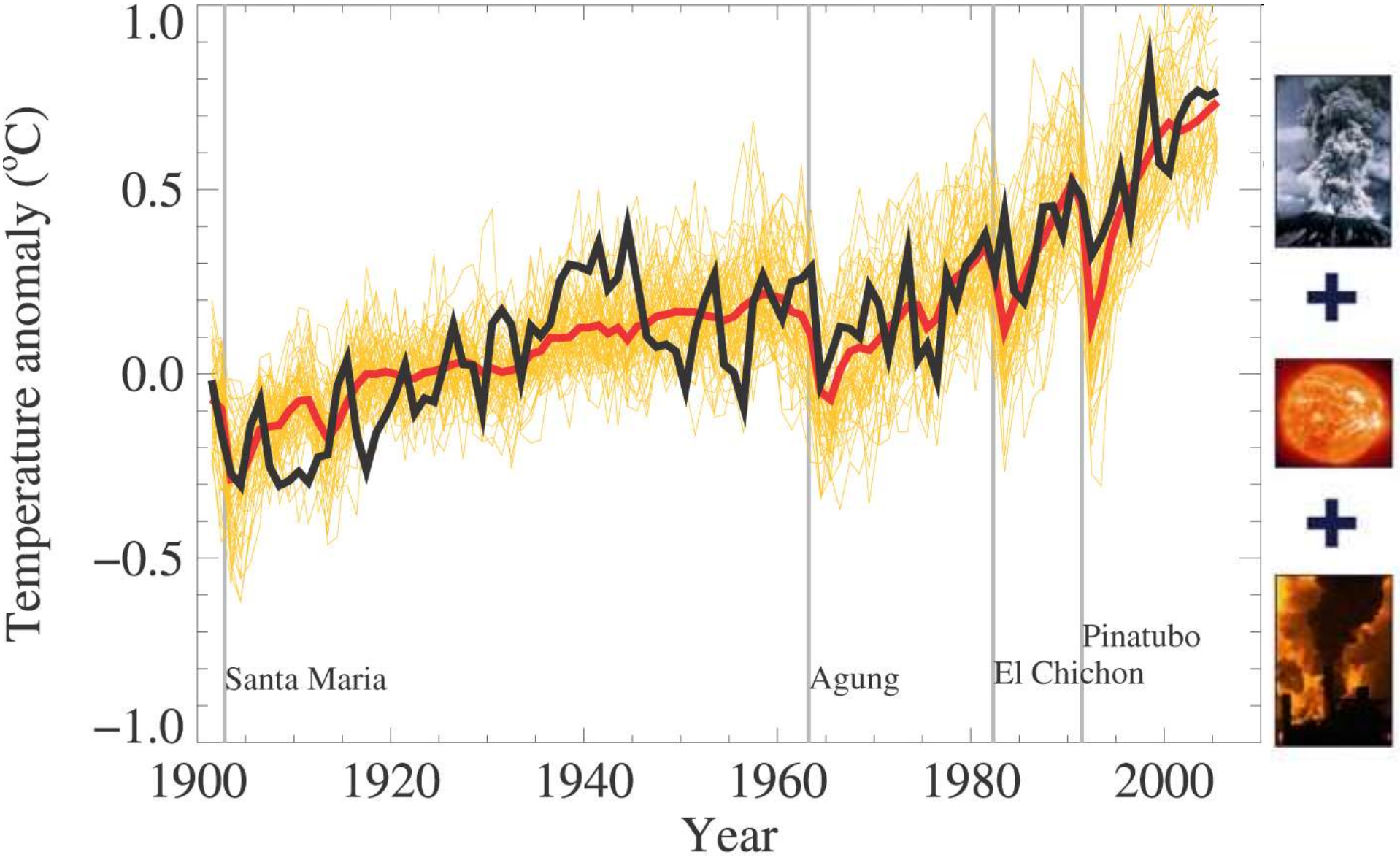




Natural factors cannot explain recent warming



Recent warming can be simulated when man-made factors are included



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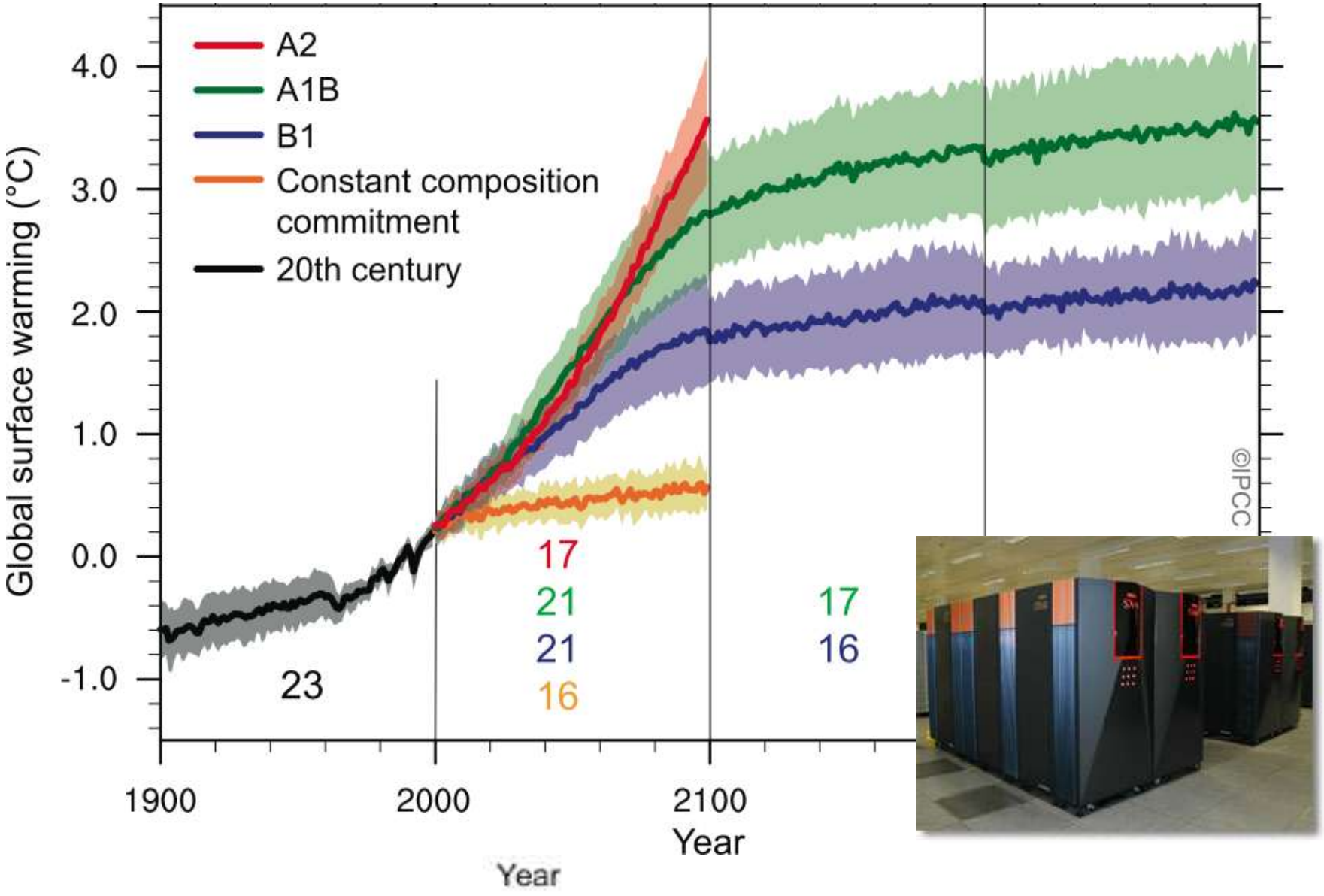
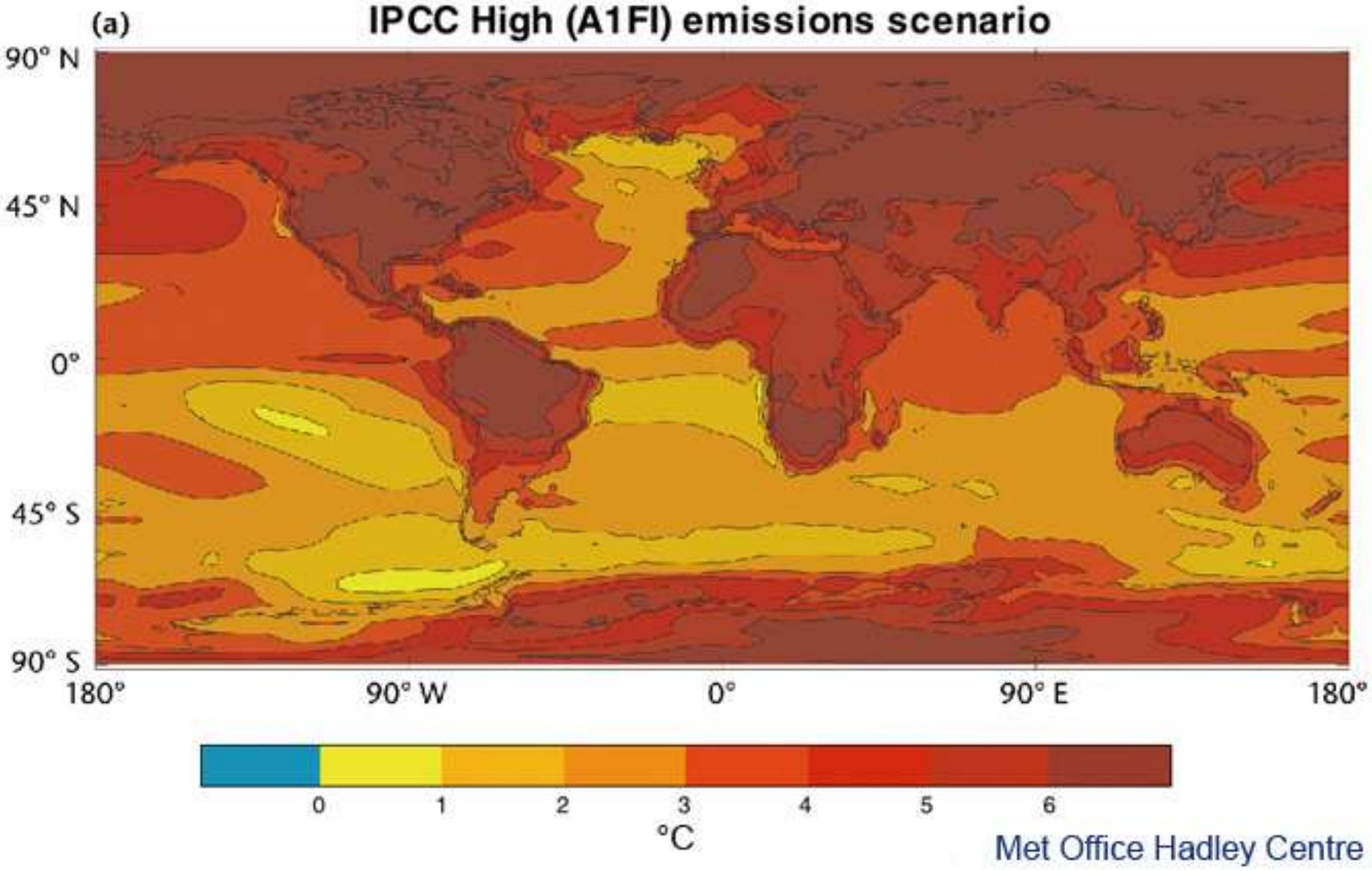
4) What are the predictions?

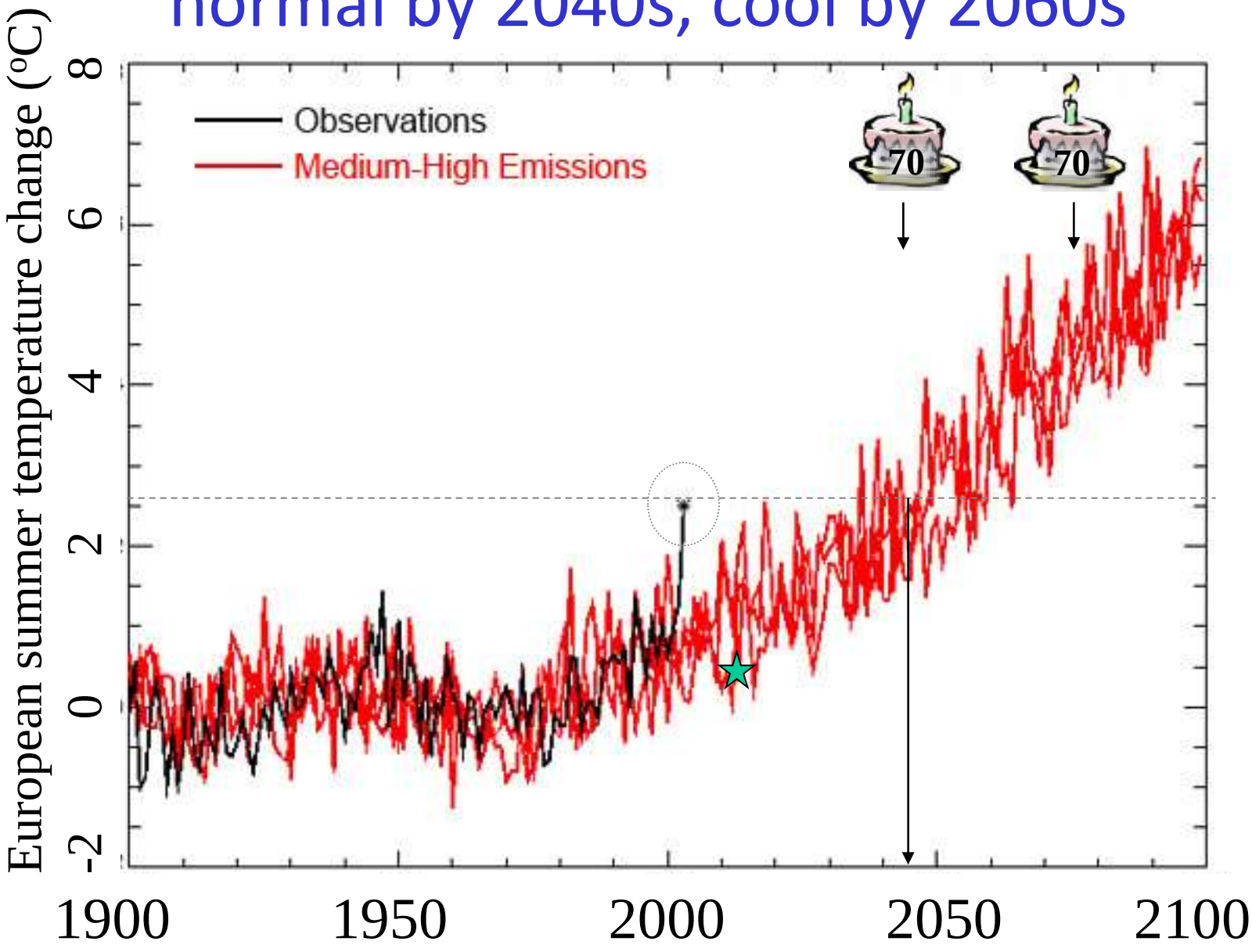
Global warming projections



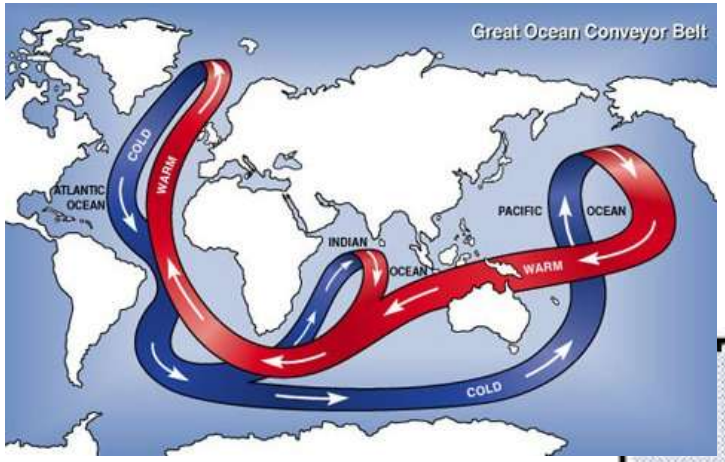
Land projected to warm more than oceans

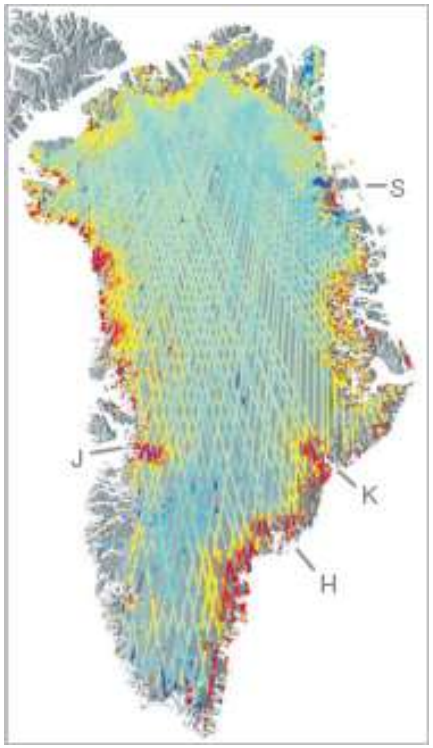


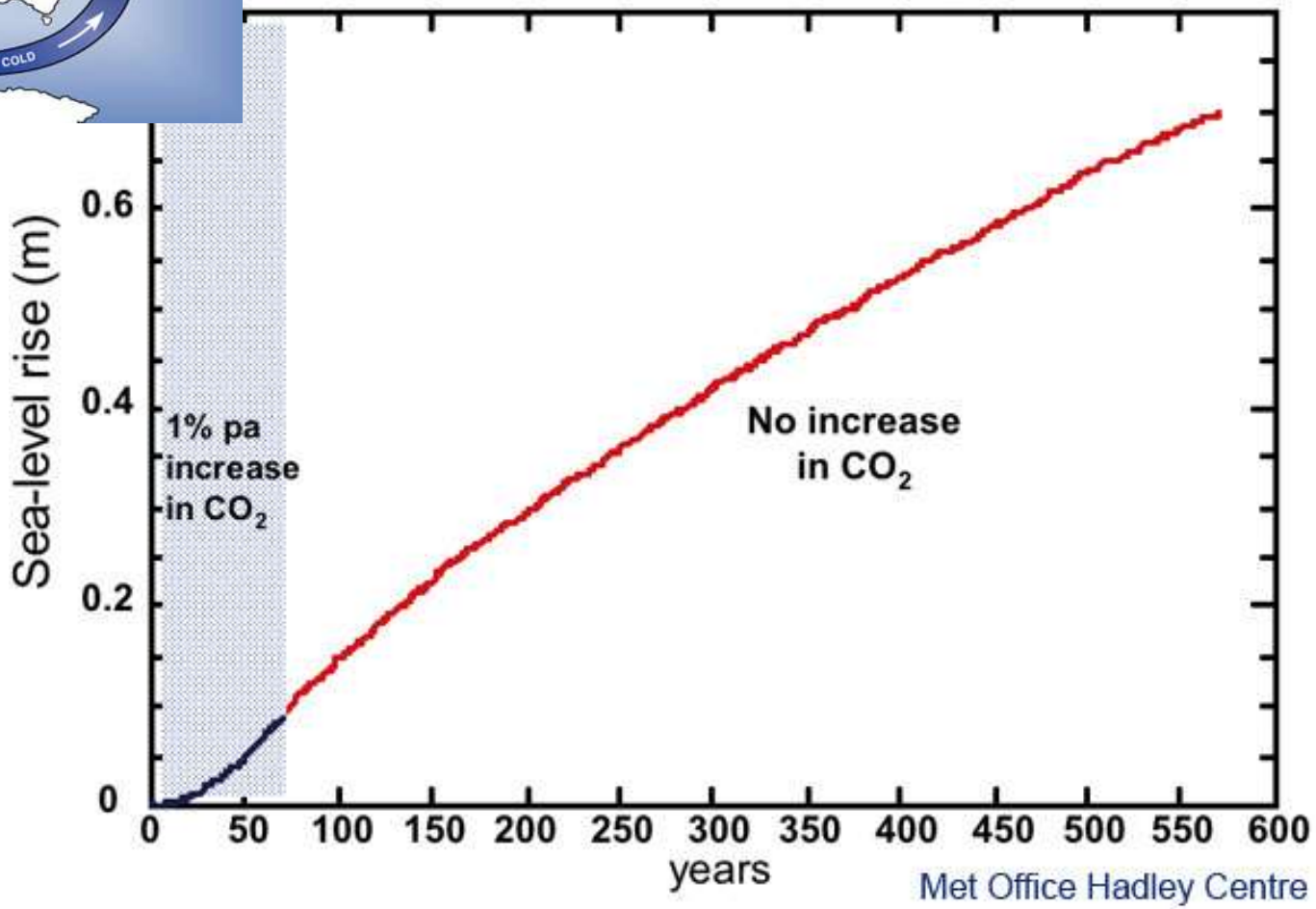
European 2003 summer temperatures could be normal by 2040s, cool by 2060s



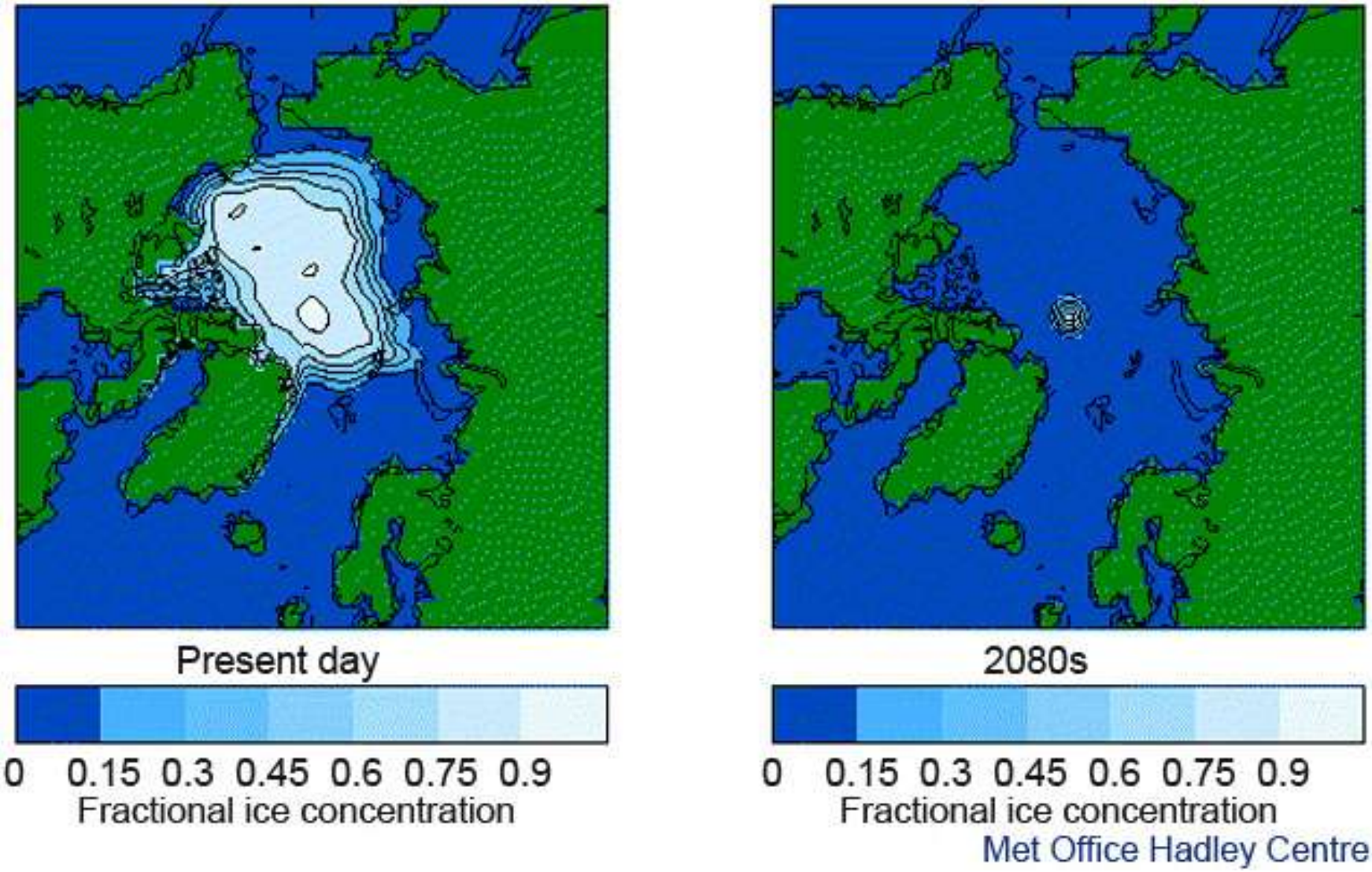
Long-term commitment to sea-level rise

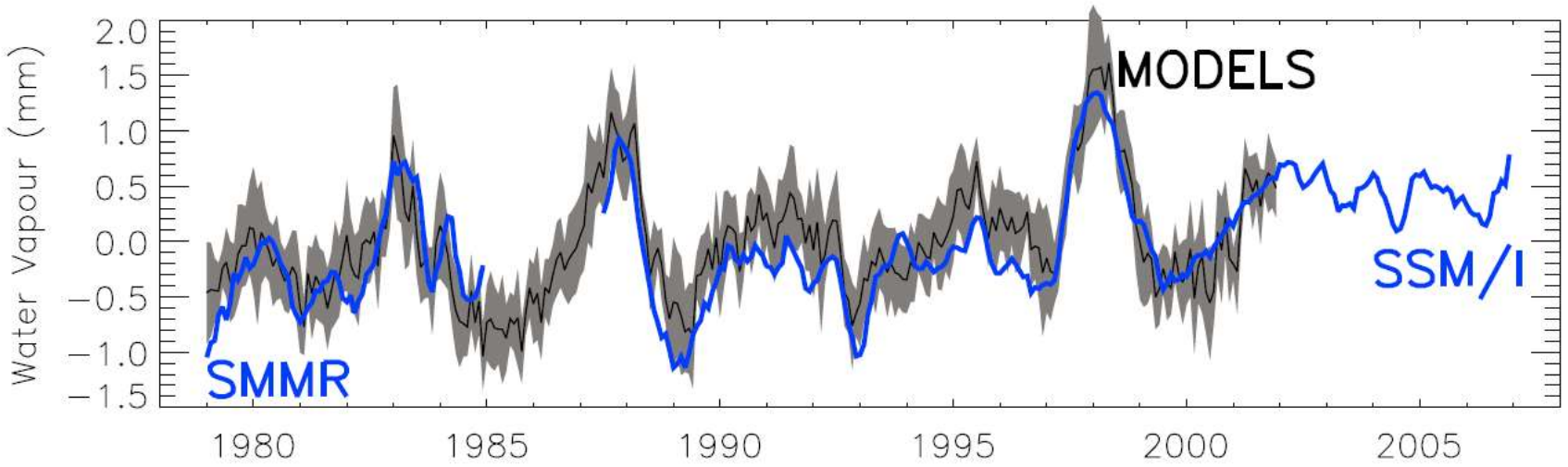




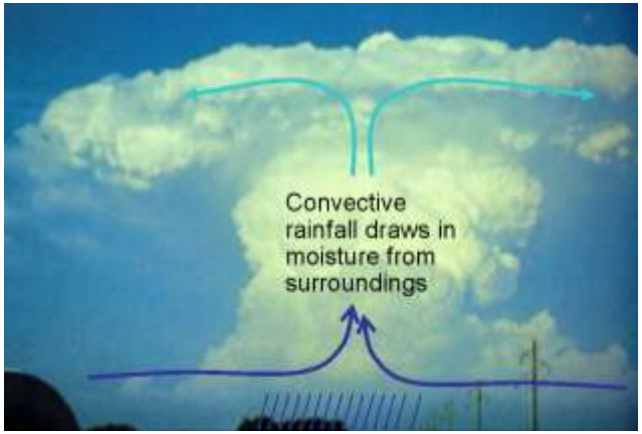


Arctic summer sea-ice could disappear by 2080s under IPCC High Emissions scenario





- Atmospheric moisture rises with warming in computer simulations and as detected by conventional and satellite observations

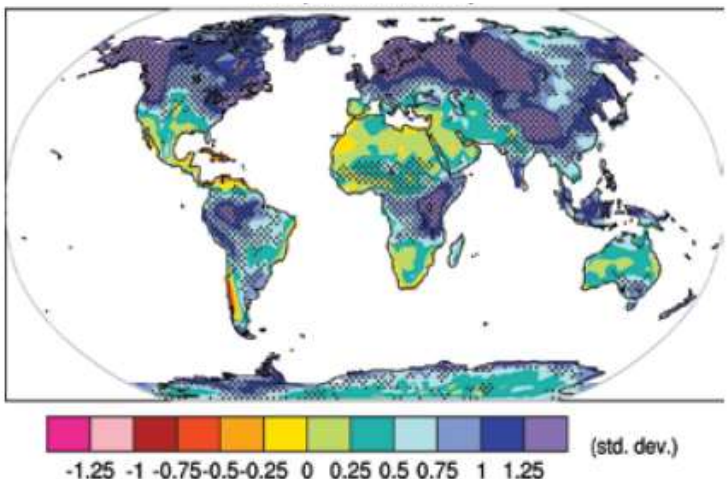


- The enhanced greenhouse effect amplifies initial warming: "feedback"

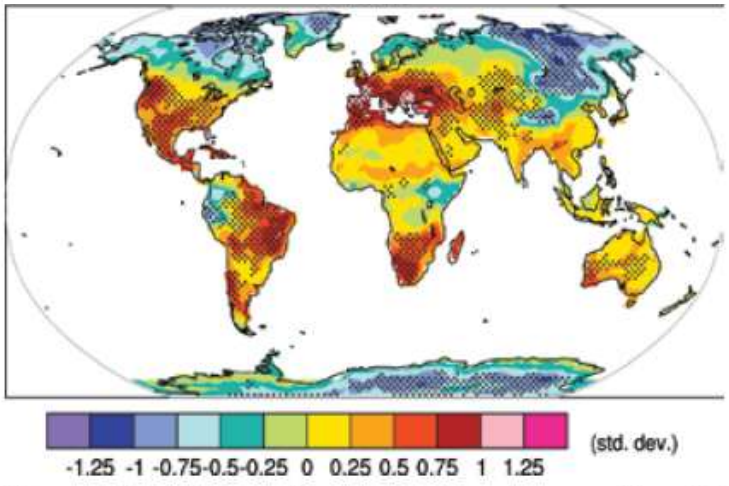
- Additional moisture fuels a greater intensity of rainfall

Projections of the global water cycle

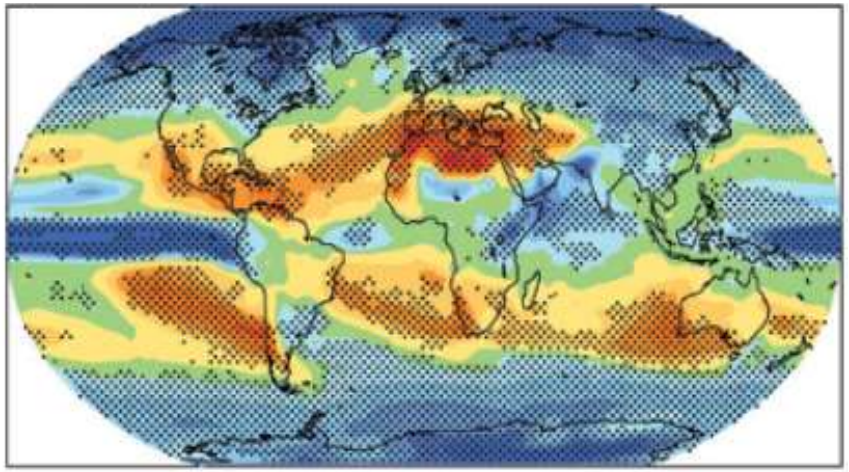
Precipitation Intensity



Dry Days



- More Global Precipitation
- More Intense Rainfall
- More Droughts
- Wet regions get Wetter, Dry regions get Drier?
- Regional projections??

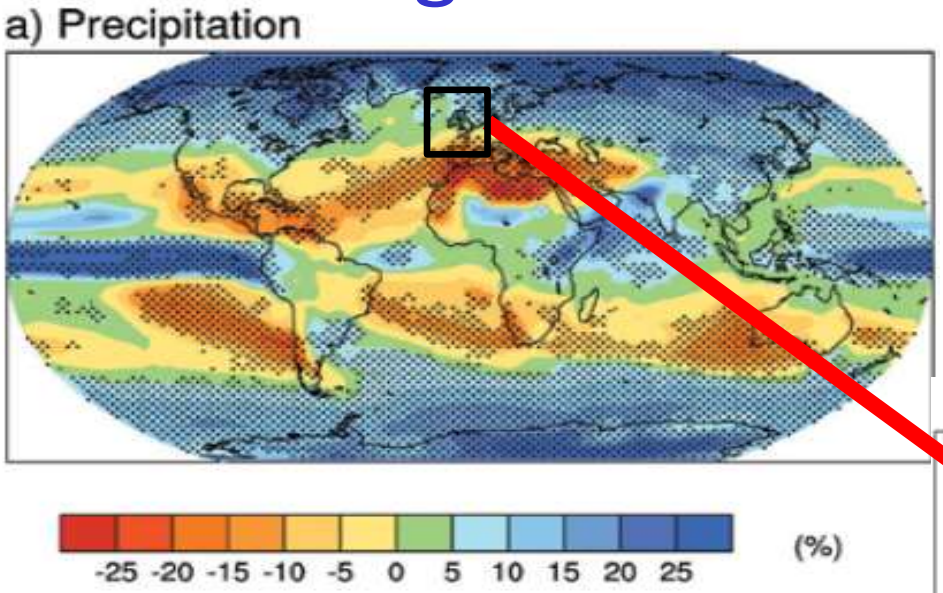


Precipitation Change (%)

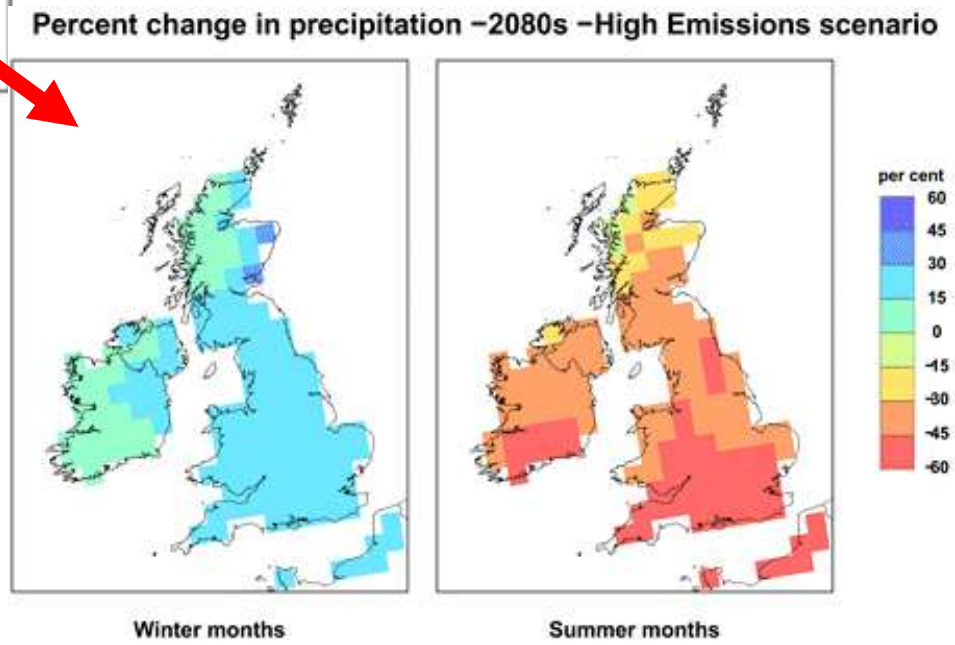
-25 -20 -15 -10 -5 0 5 10 15 20 25 (%)

IPCC WGI (2007)

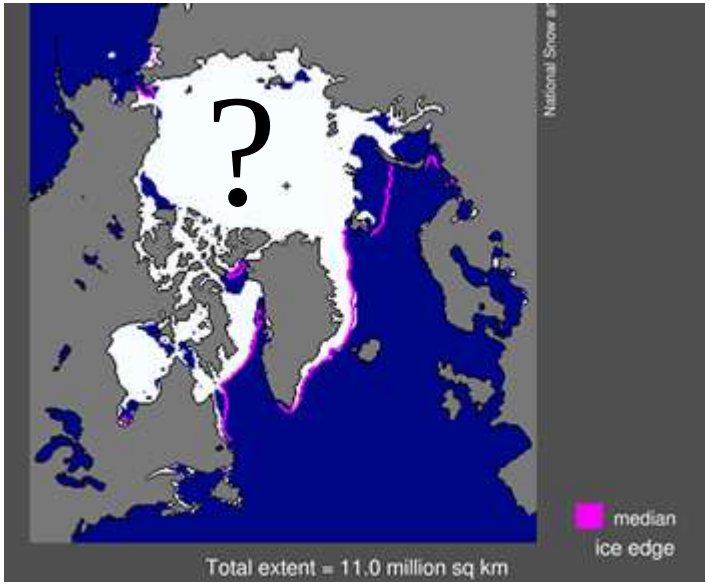
One of the largest challenges remains improving predictability of regional changes in the water cycle…

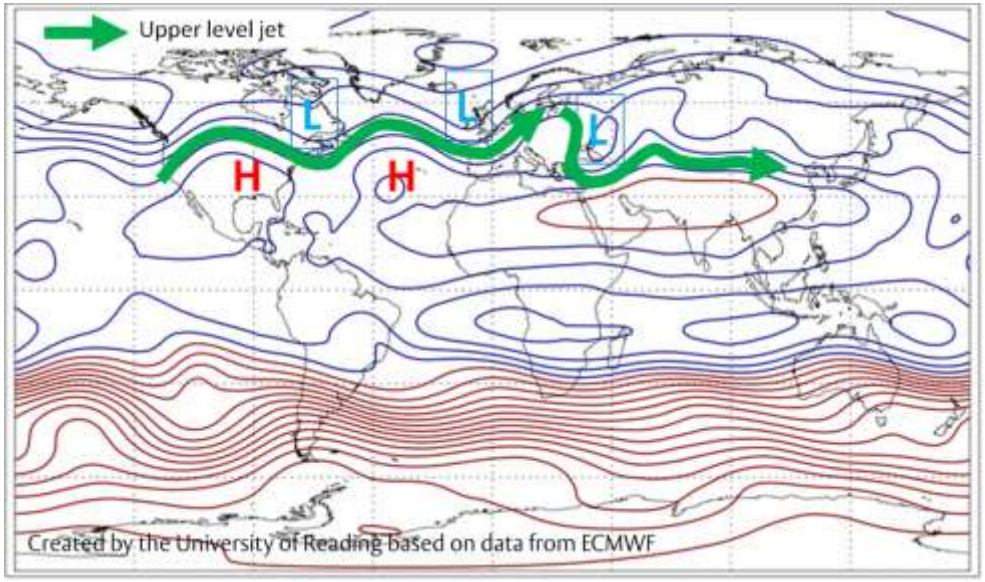


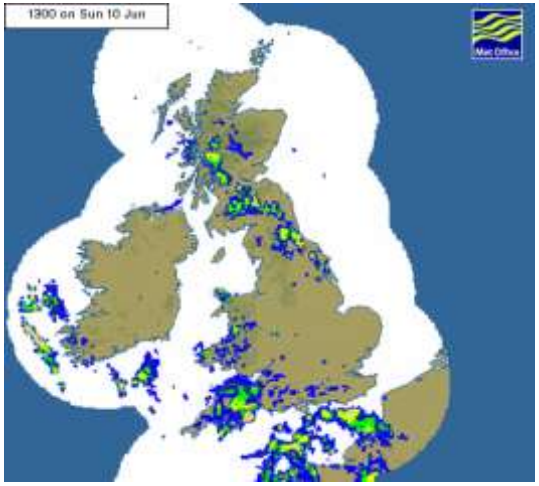
Changes in circulation systems are crucial to regional changes in water resources and risk yet predictability is poor.

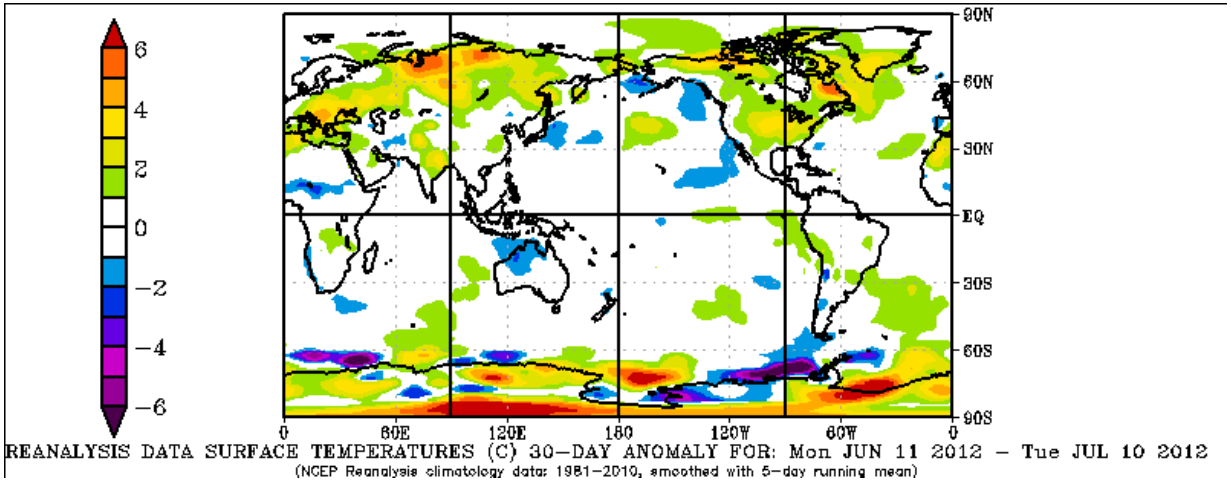


How will atmospheric and oceanic circulations change?









Summary

- The evidence for warming is unequivocal
- Warming is unusual in the context of last 1800 years globally and over last 100,000 years in the Arctic
- Greenhouse gases at highest levels for > 650,000 yrs
- Physics of greenhouse effect well understood
- Substantial changes in global temperature and rainfall patterns are projected using computer simulations
- Predicting regional climate change is a challenge…
  - How much more greenhouse gases will we emit?
  - Will changes in the land surface or clouds amplify warming?
  - How will atmospheric and oceanic circulations change?