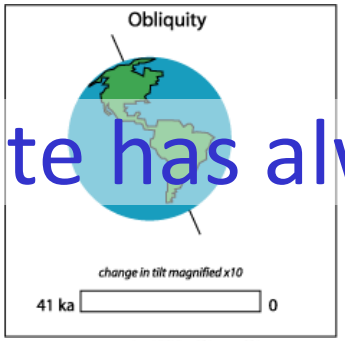
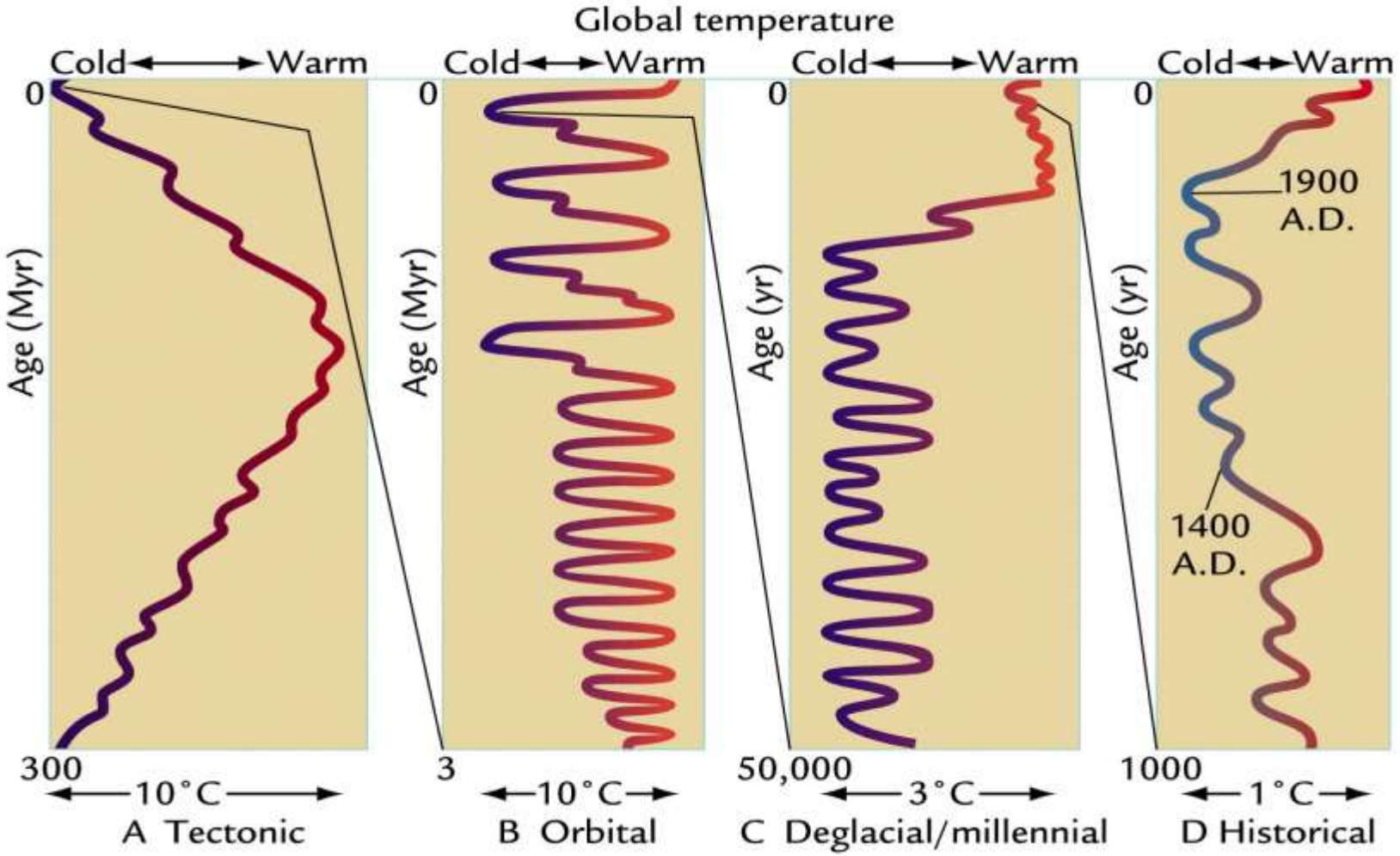
Climate Change - The Facts and Current Thinking

Dr Richard Allan,
Department of Meteorology
University of Reading

Earth's Climate has always been changing





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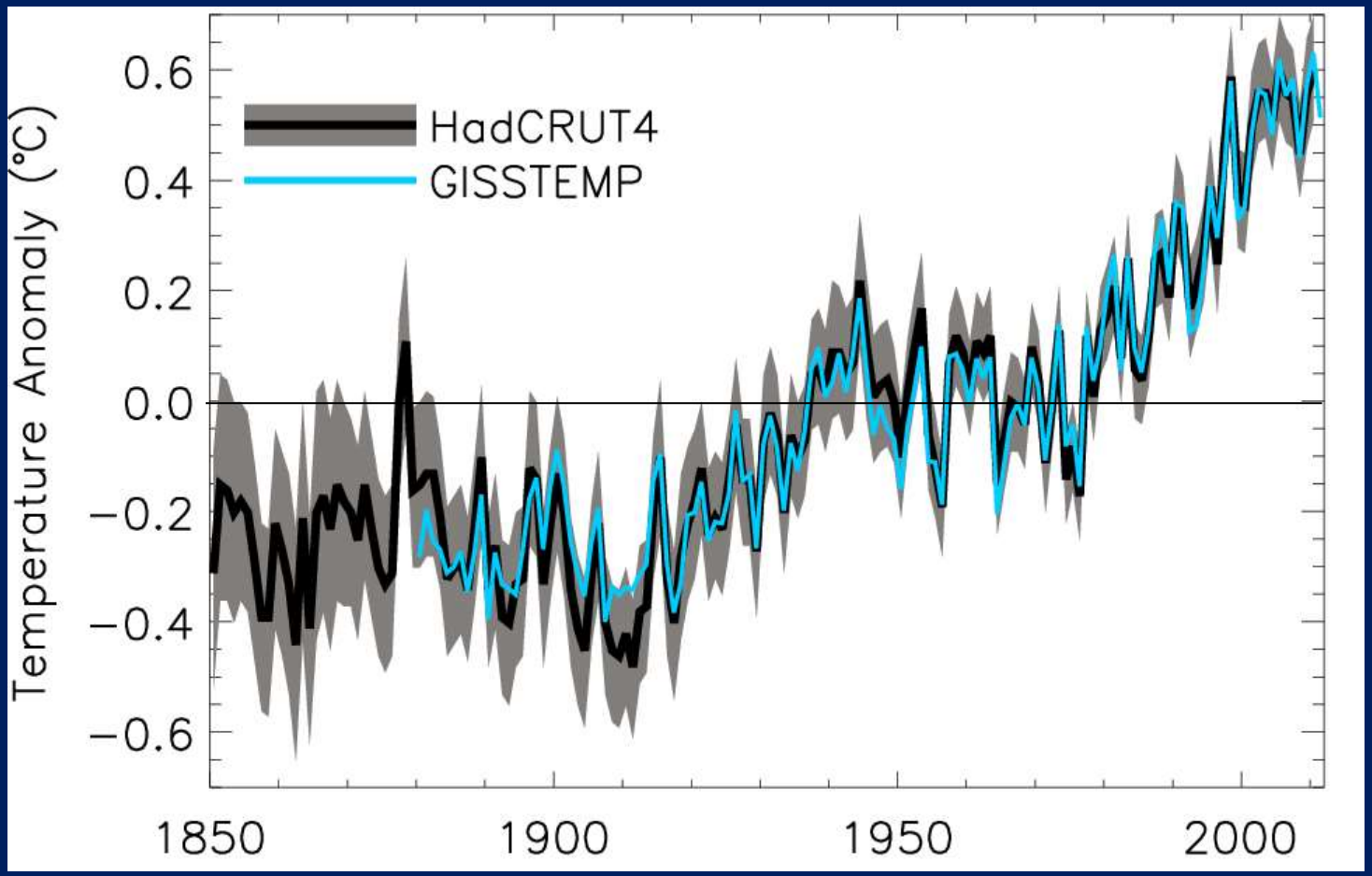
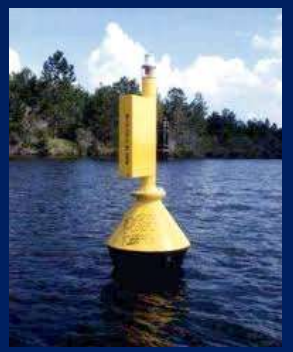
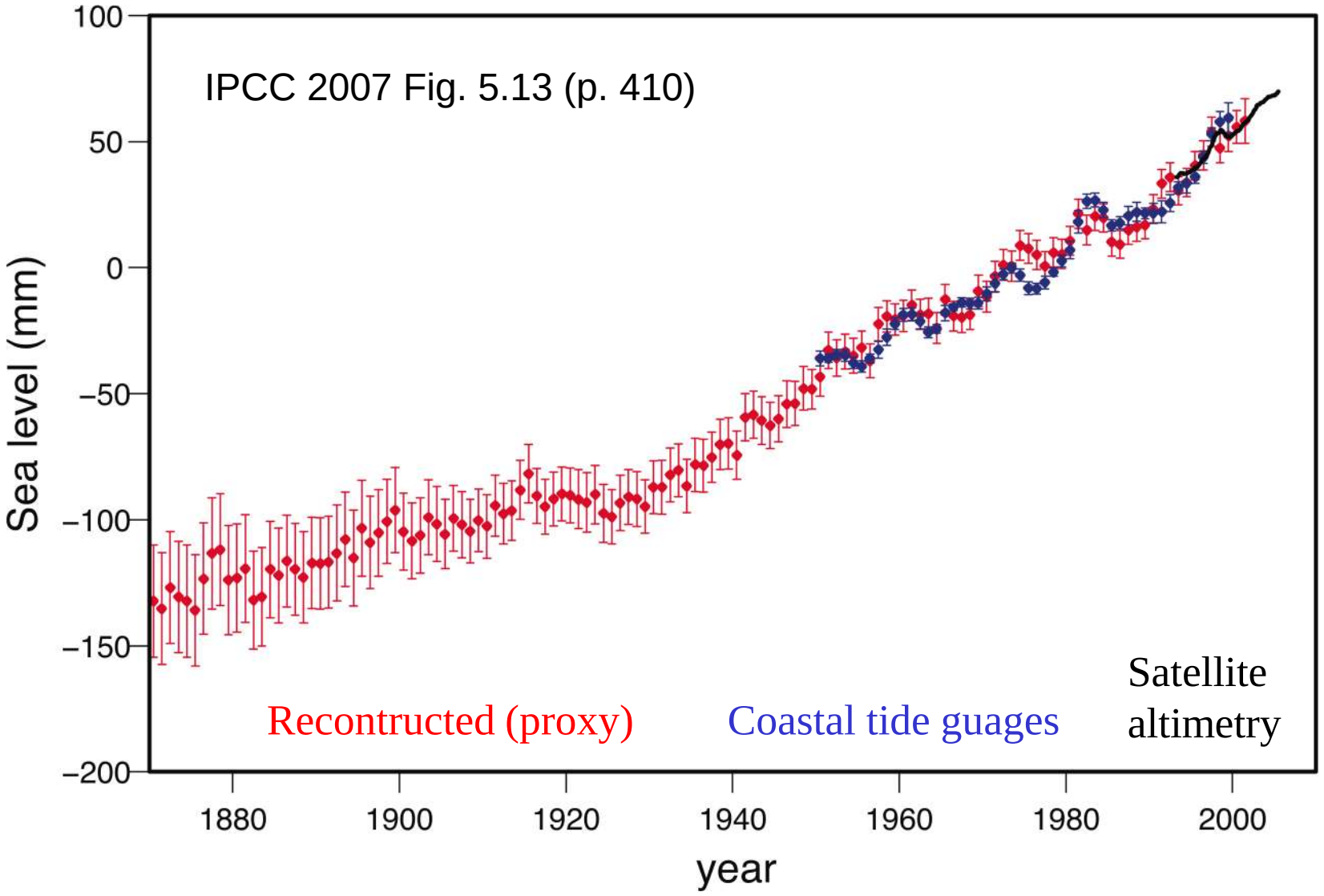
1) Is climate changing now?

Global Warming ?

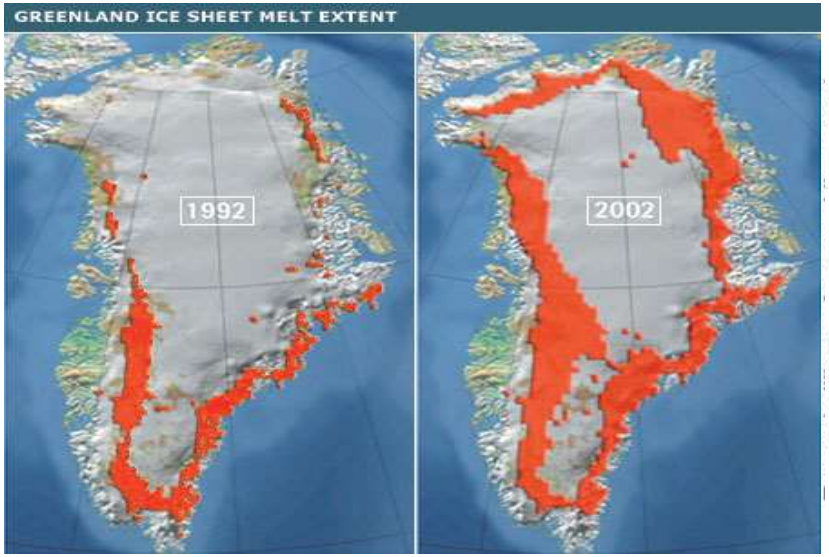


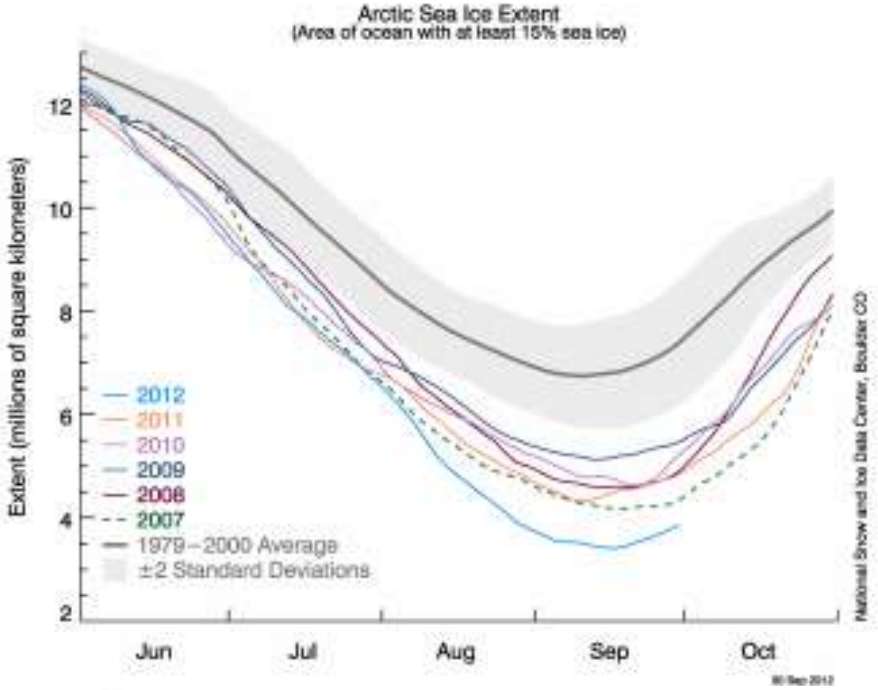


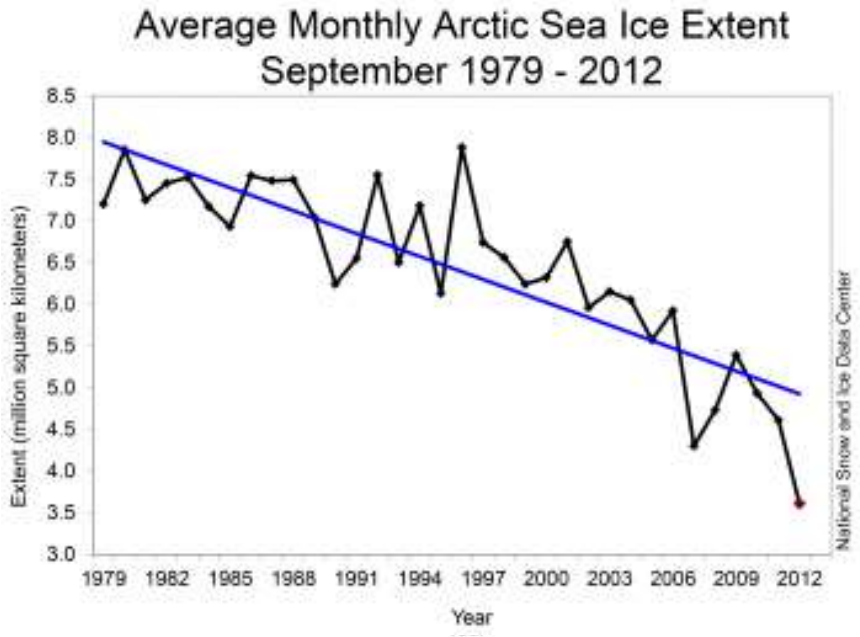
Sea level rising

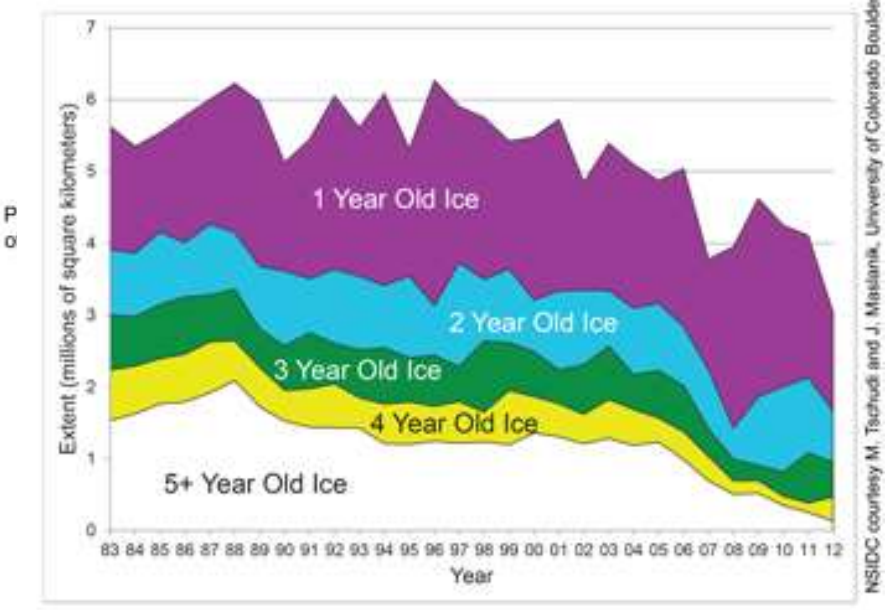


Melting of Arctic Ice

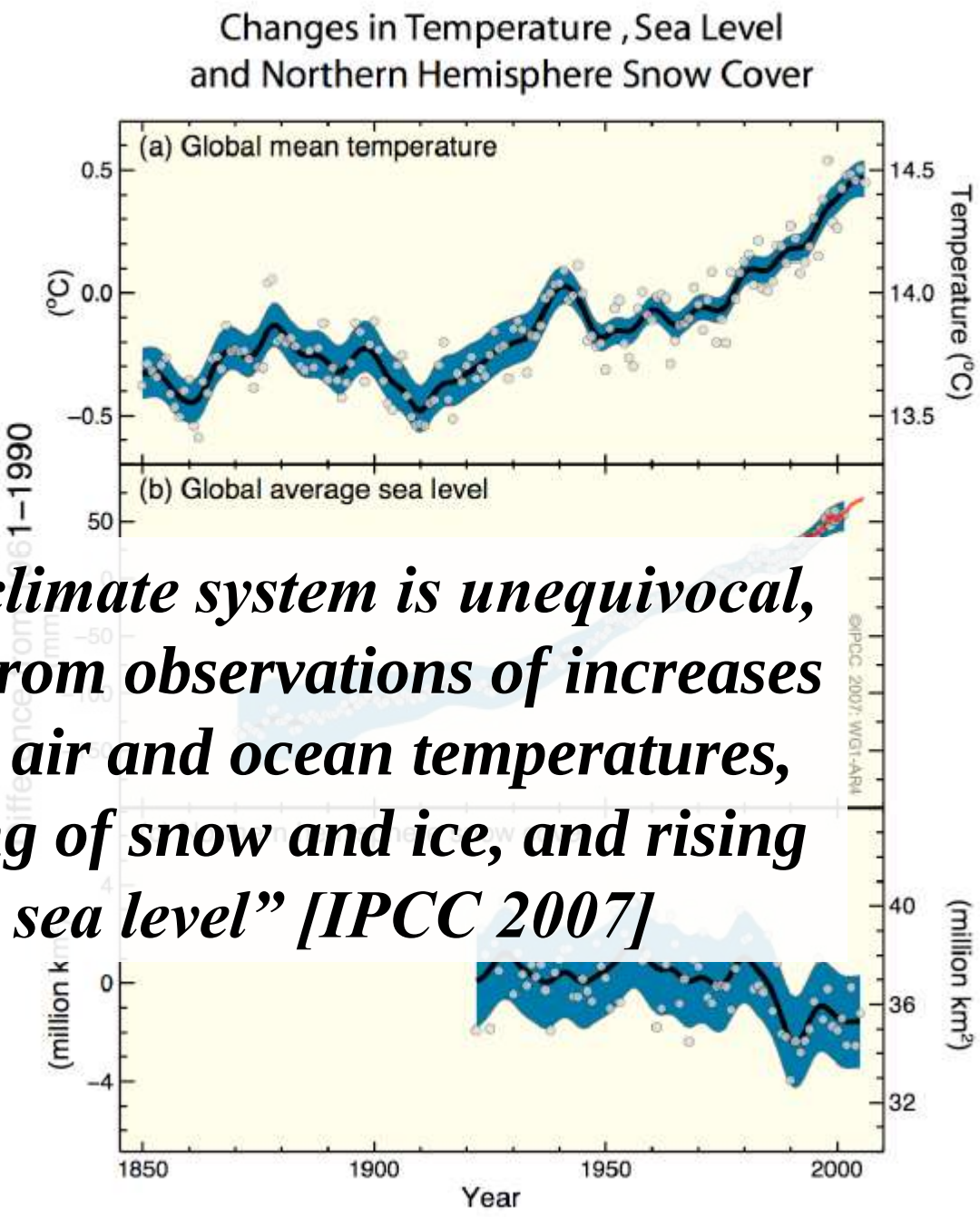








Is climate changing?



"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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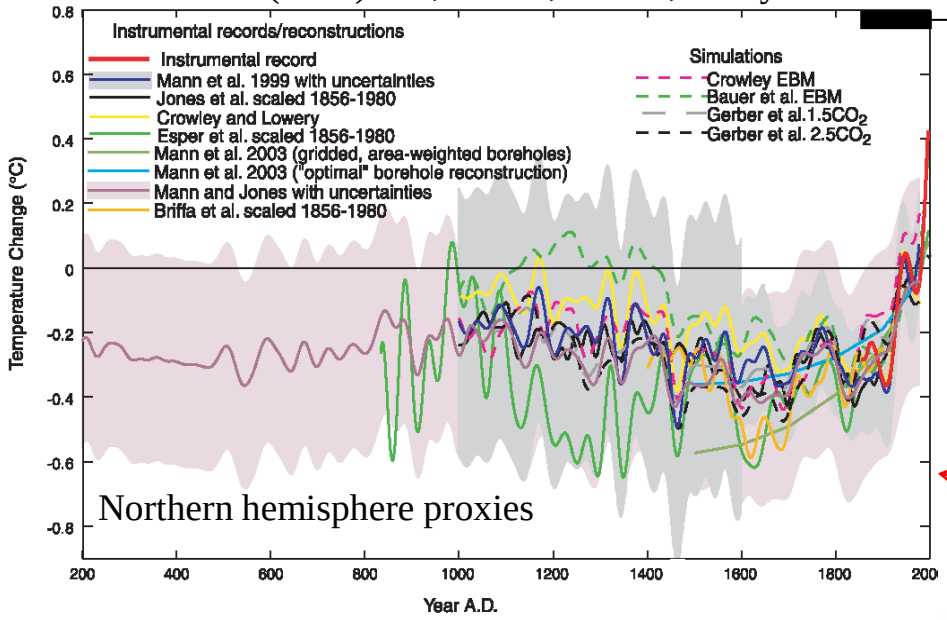
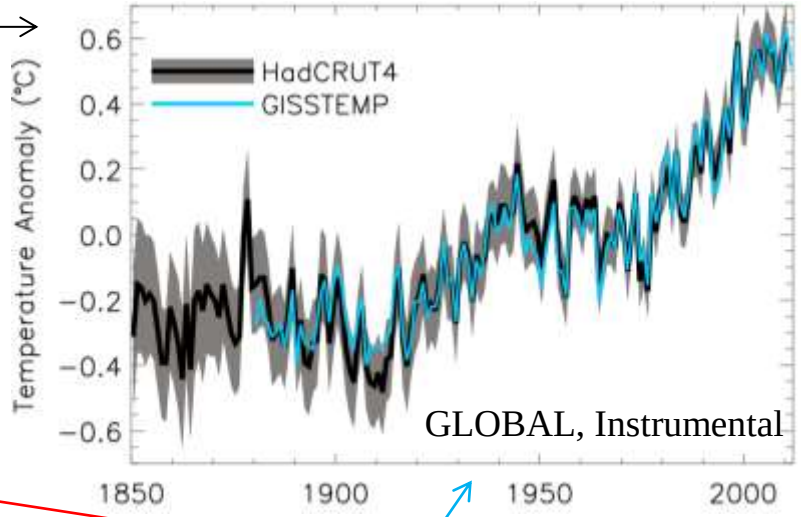
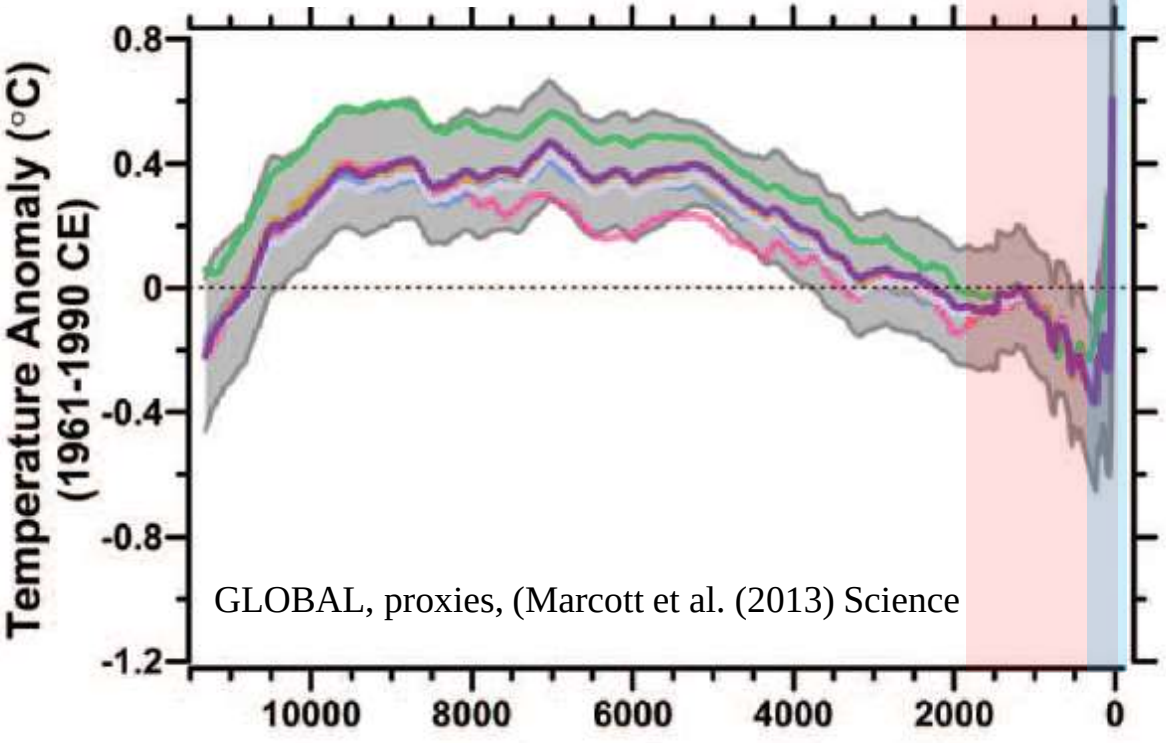
2) Is the warming unusual?

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



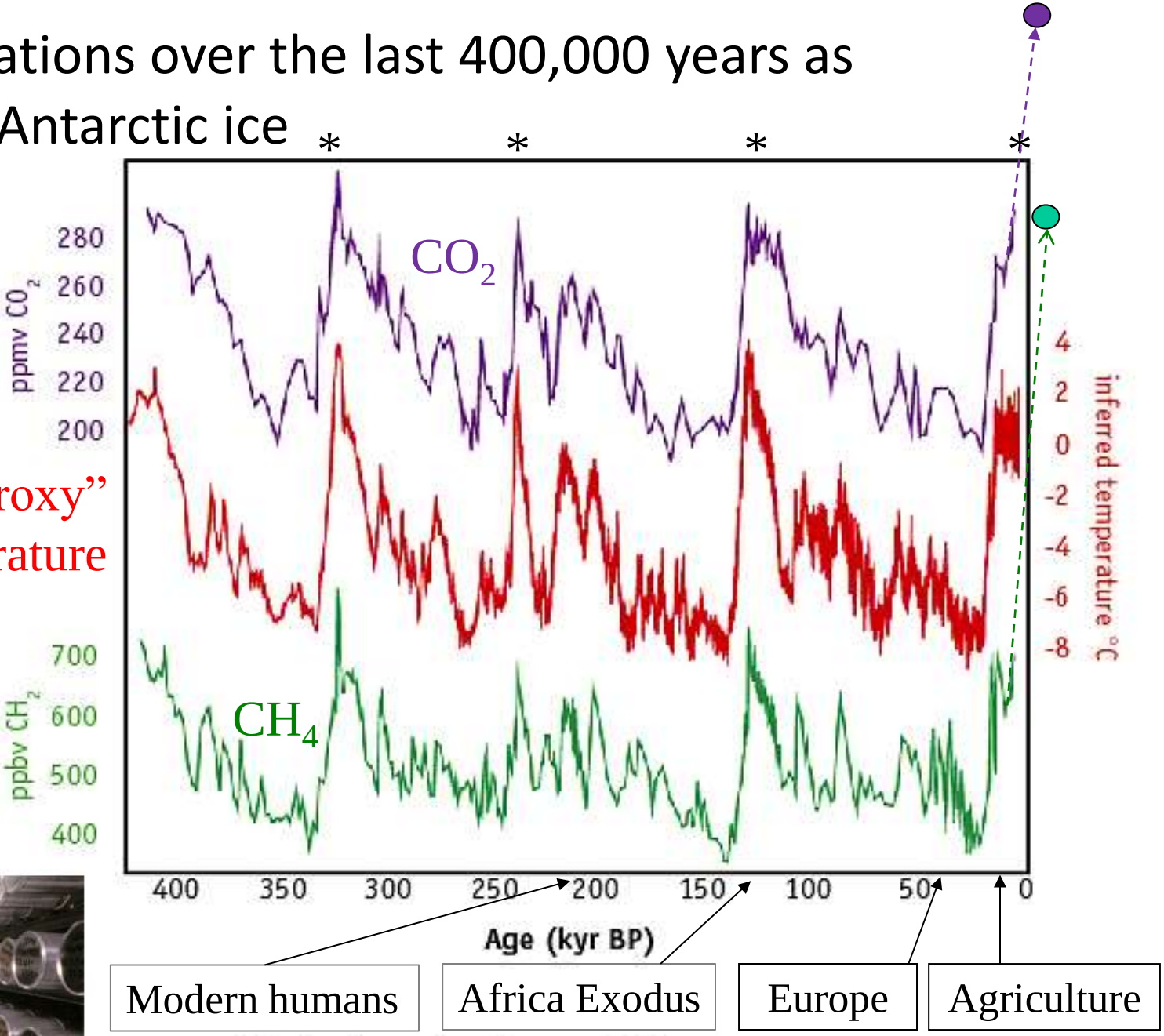




Climate variations over the last 400,000 years as recorded in Antarctic ice

* - indicates interglacial period

Inferred "proxy" Temperature



J.R. Petit et al., *Nature*, **399**, 429–36, 1999.

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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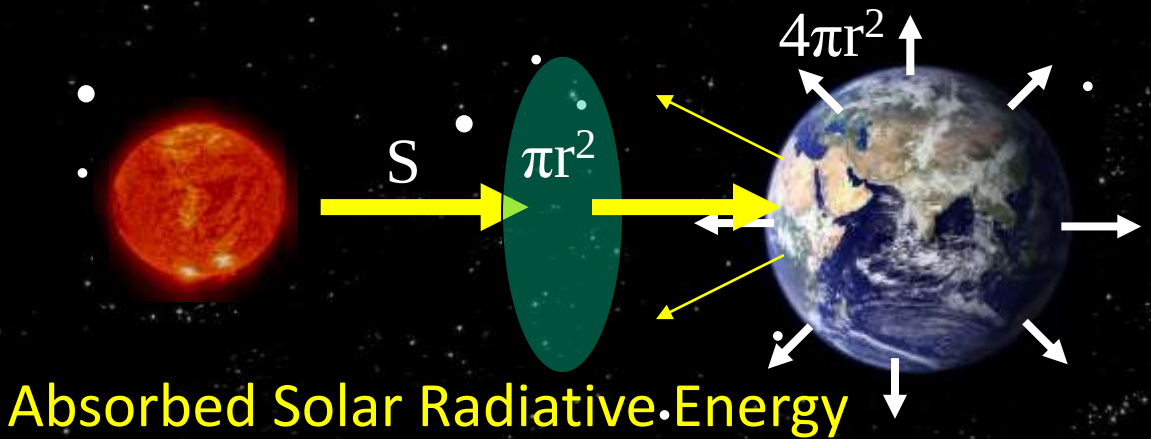
3) Why is it warming?

Earth's energy balance in space

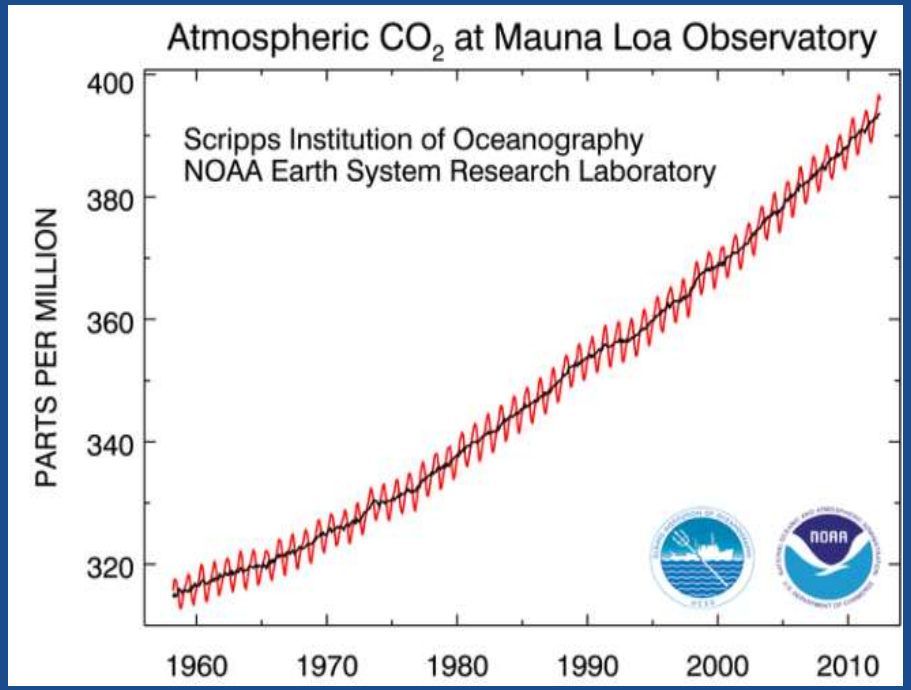


- There is a balance between the absorbed sunlight and the thermal radiative cooling of the planet
- Without the greenhouse effect, this balance would occur at a frigid global temperature of –18°C

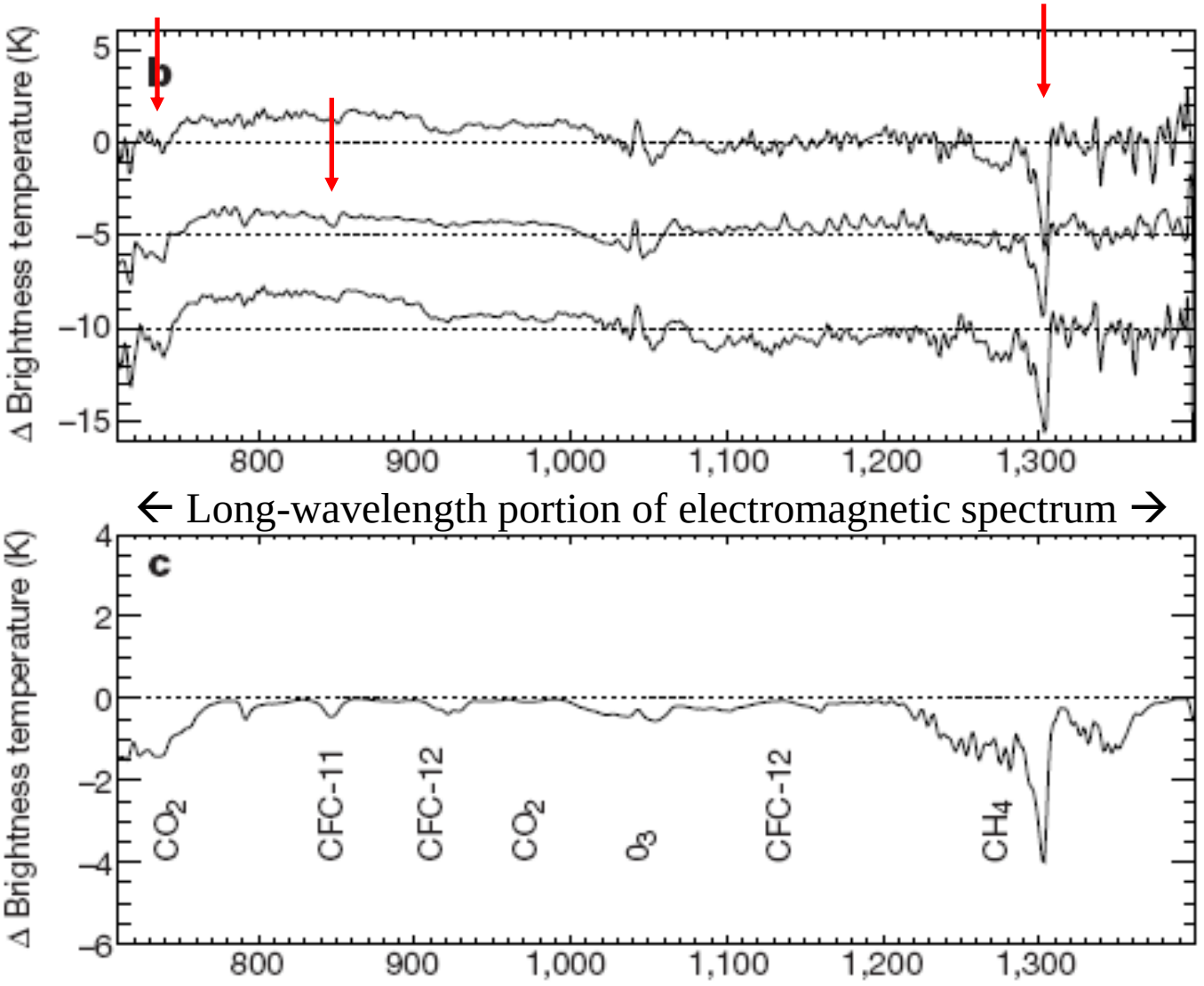
Fourier (1824); Tyndall (1858); Arhenius (1896); Lacis et al. (2011)

“Radiative forcing” of climate

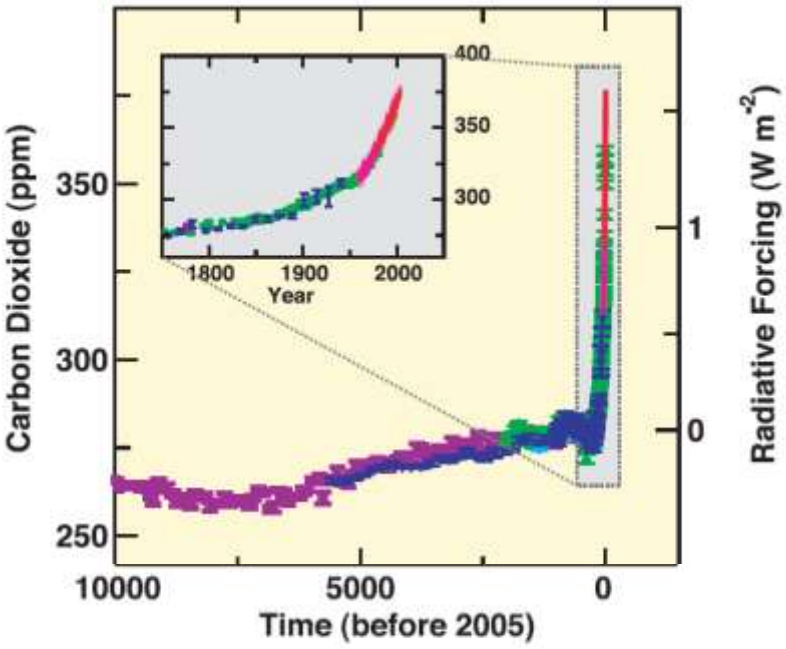
- Increases in greenhouse gases heat the planet by trapping heat
- Small pollutant particles (aerosols) cool the planet by reflecting sunlight
- If more energy is arriving than is leaving the planet, Earth should warm…
- Currently energy is accumulating at rate equivalent to 250 billion 1kW electric heaters over the globe

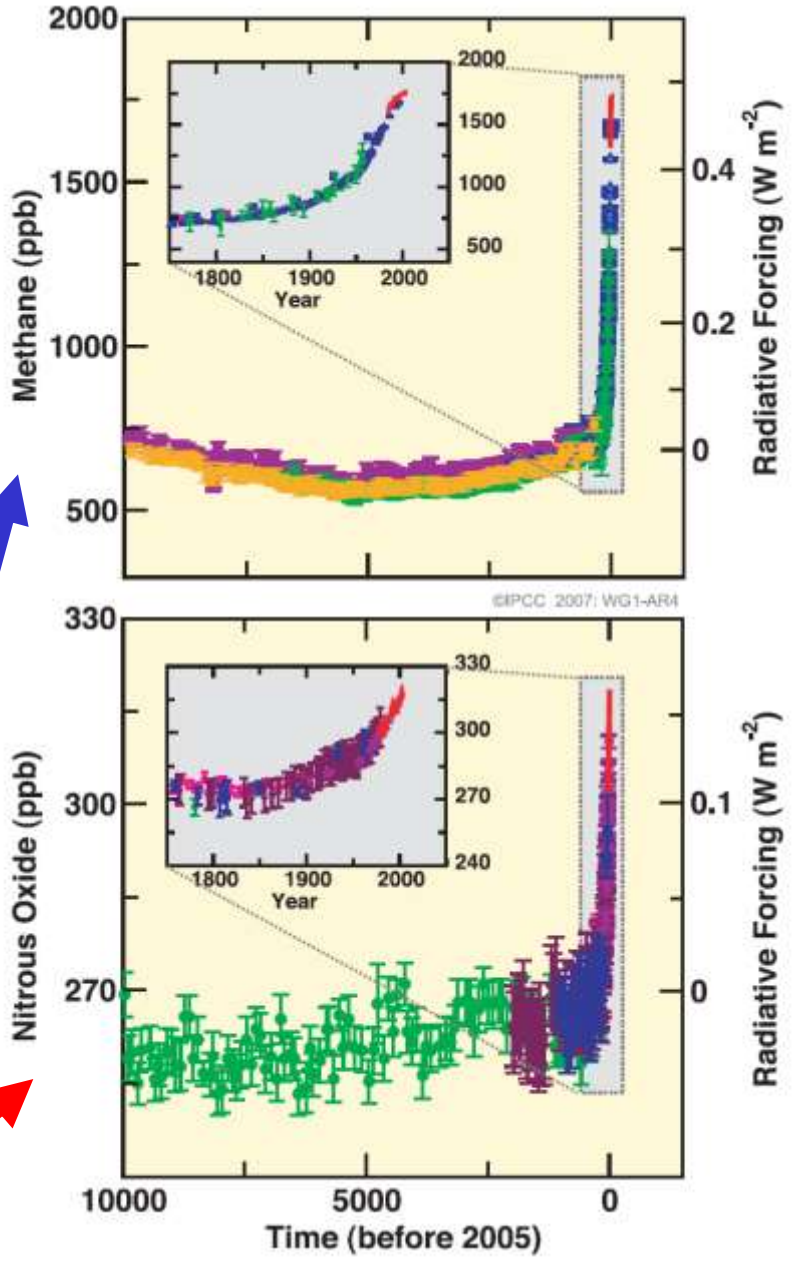


Satellite observations detect enhanced greenhouse effect: 1997-1970 Harries et al. 2001, Nature



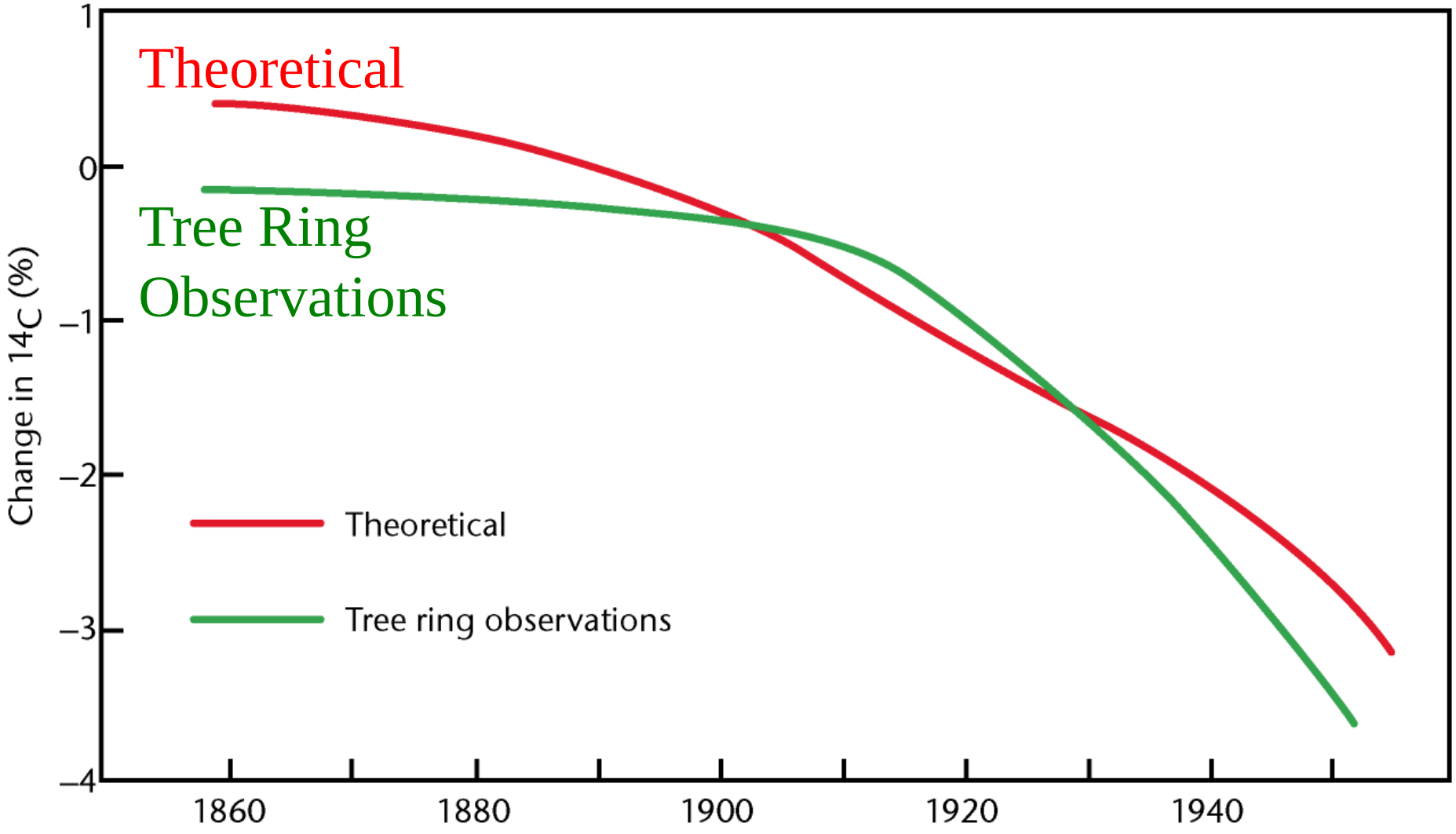
These results showed for the first time experimental confirmation of the significant increase in the greenhouse effect from trace gases such as carbon dioxide and methane

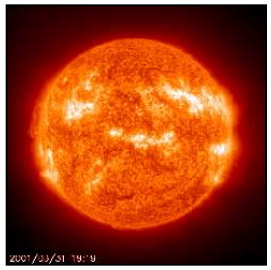




Carbon dioxide, **methane** and **nitrous oxide** concentrations rising rapidly

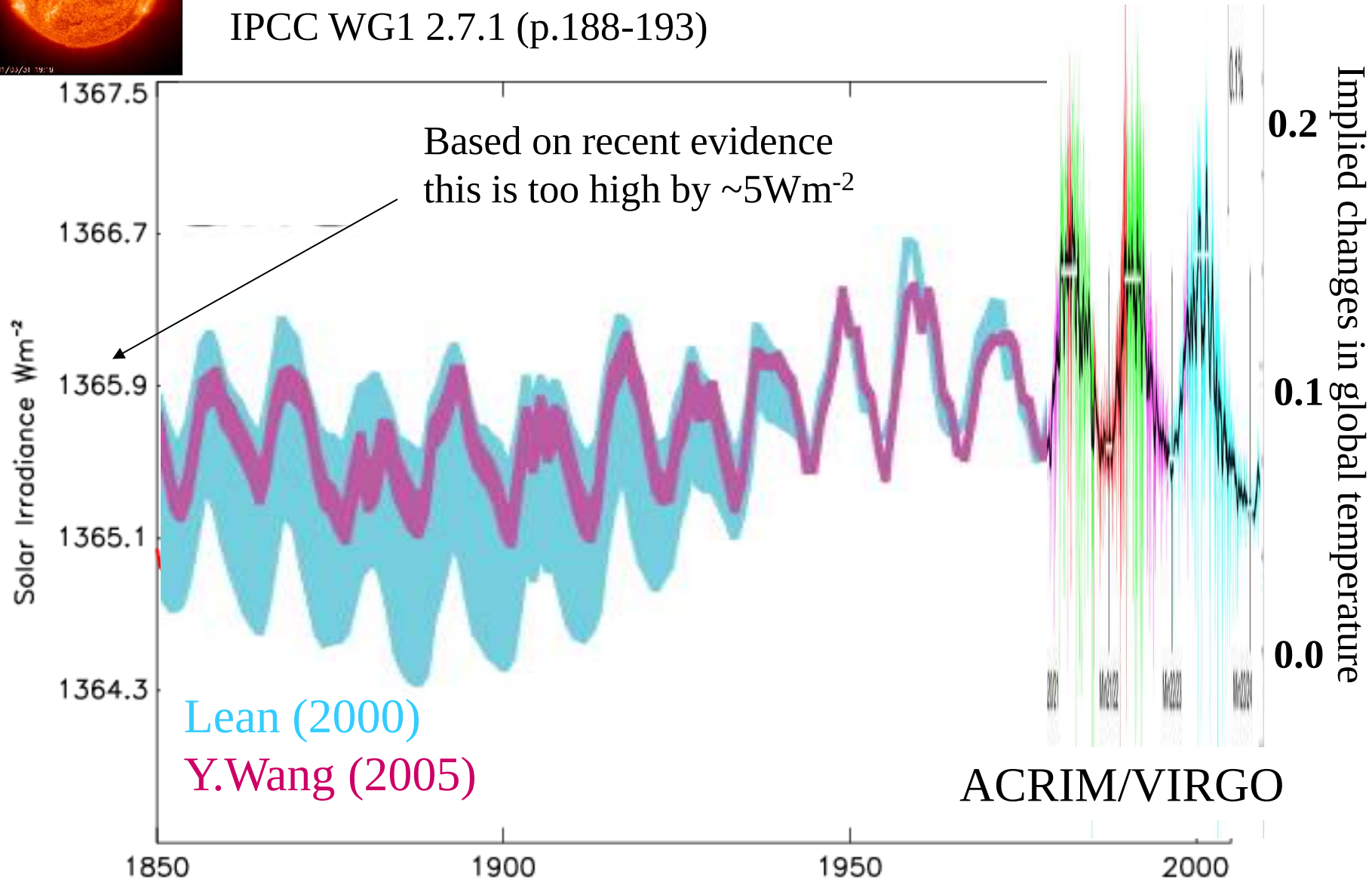
Fossil fuel CO_2 has diluted natural CO_2





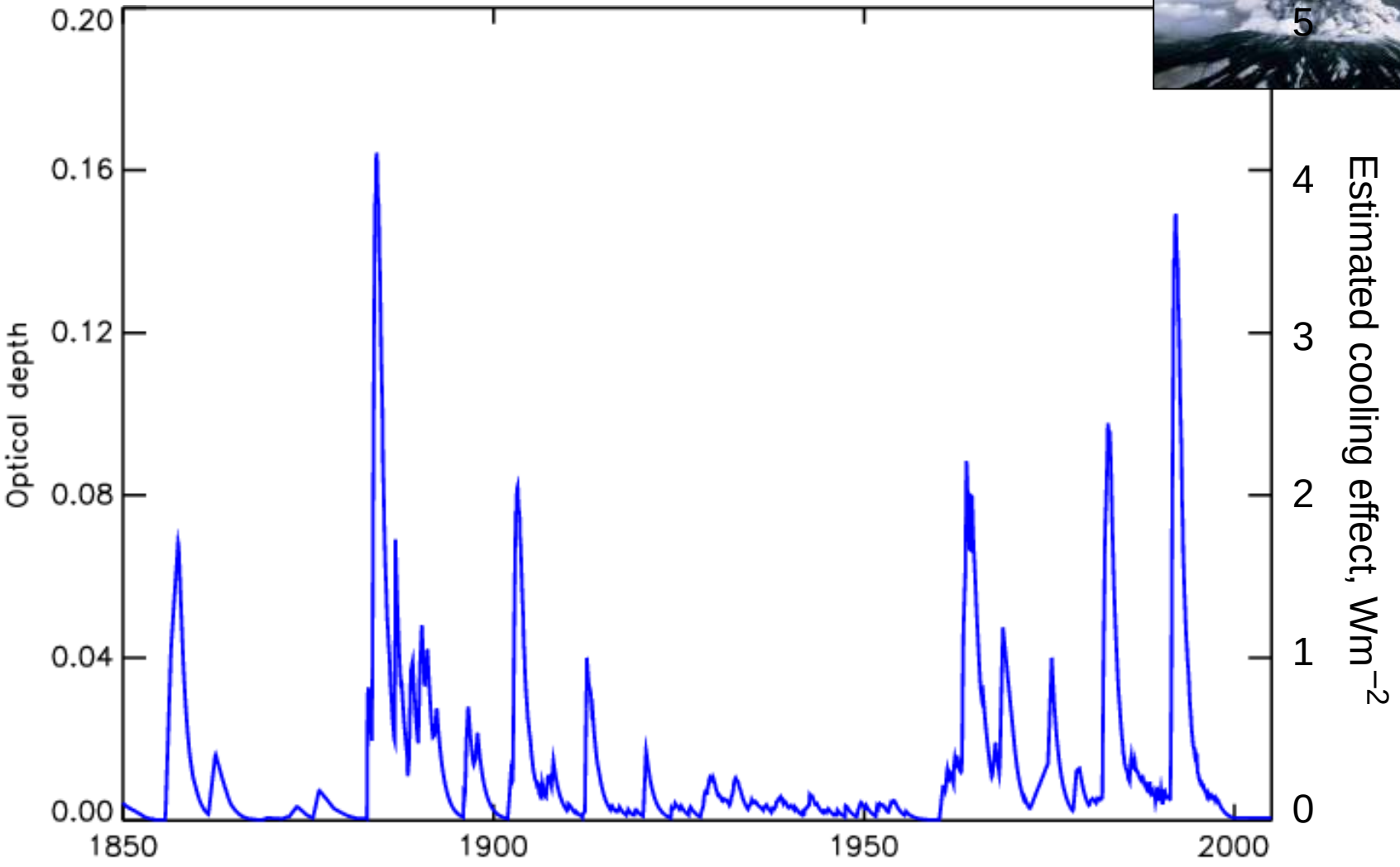
Solar output; stable over last 50 years

IPCC WG1 2.7.1 (p.188-193)



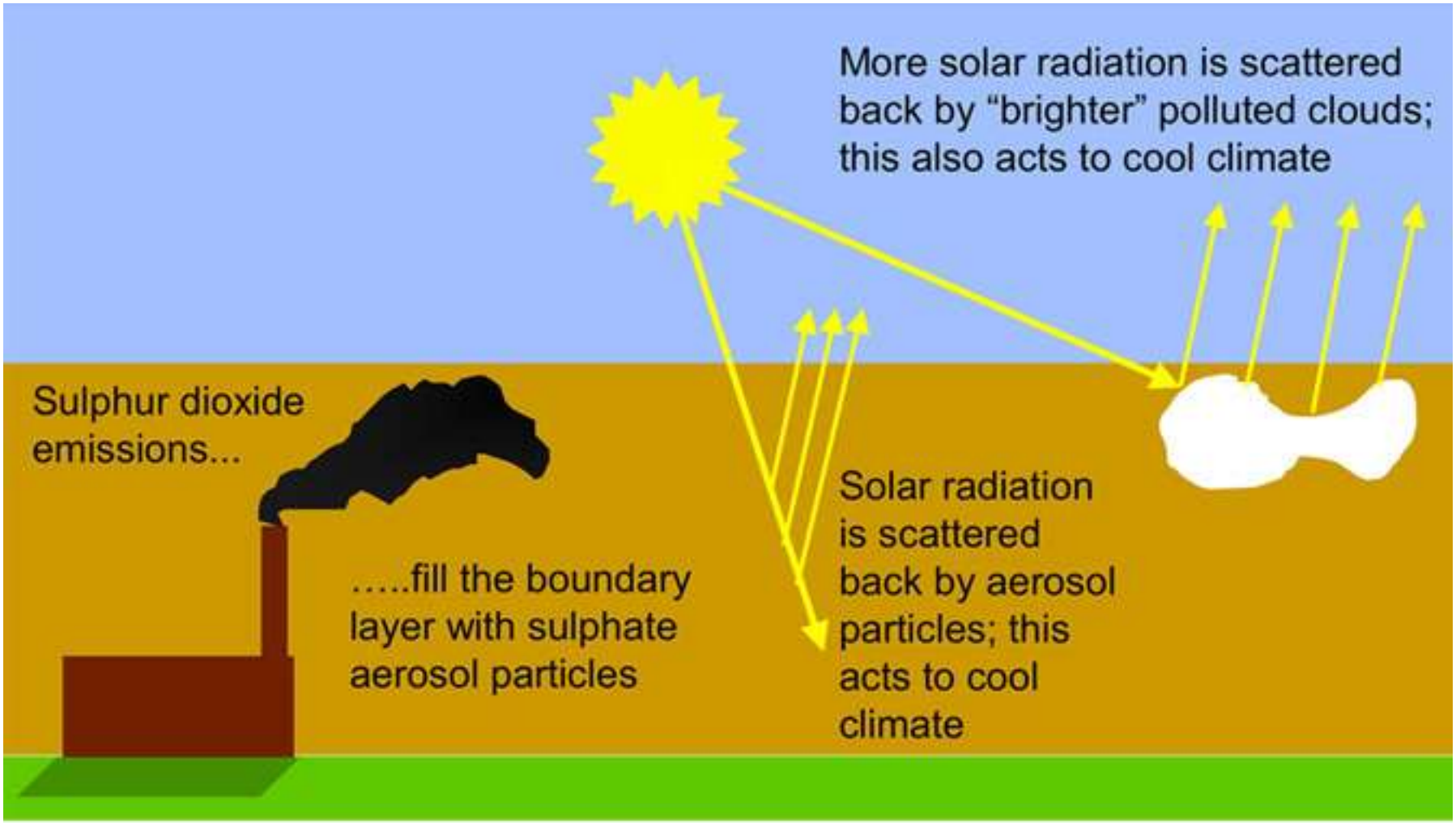
See also: http://www.pmodwrc.ch/pmod.php?topic=tsi/composite/SolarConstant

Change in volcanic aerosol

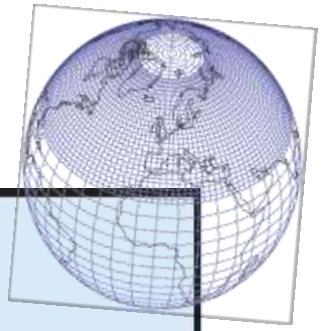


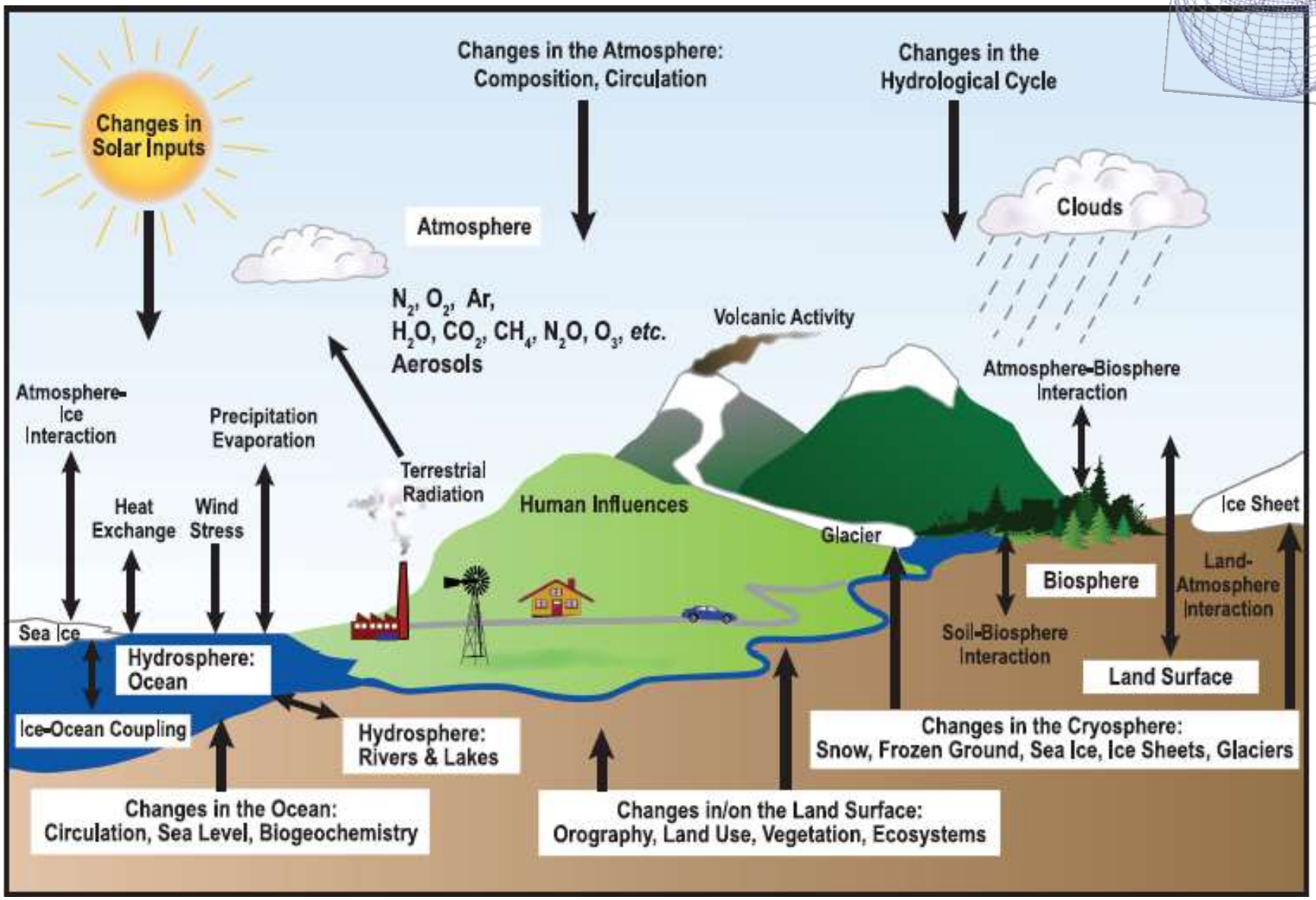
Source: Sato et al, GISS, NASA

Sulphur aerosols offset some of the heating from greenhouse gases



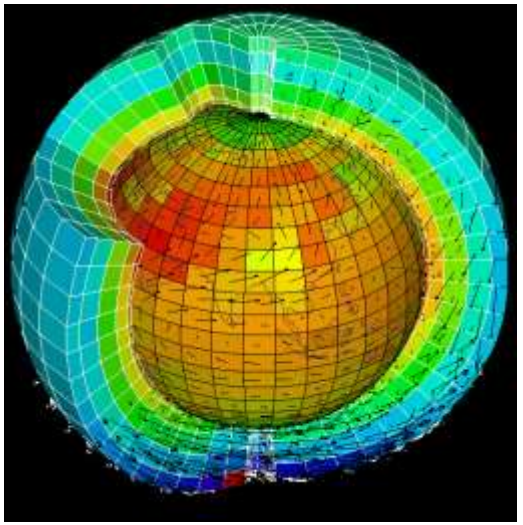
Computer Simulations of Climate

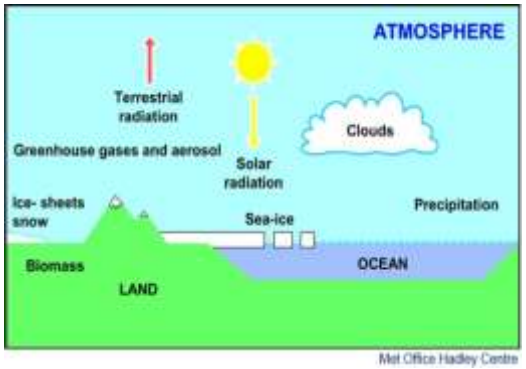




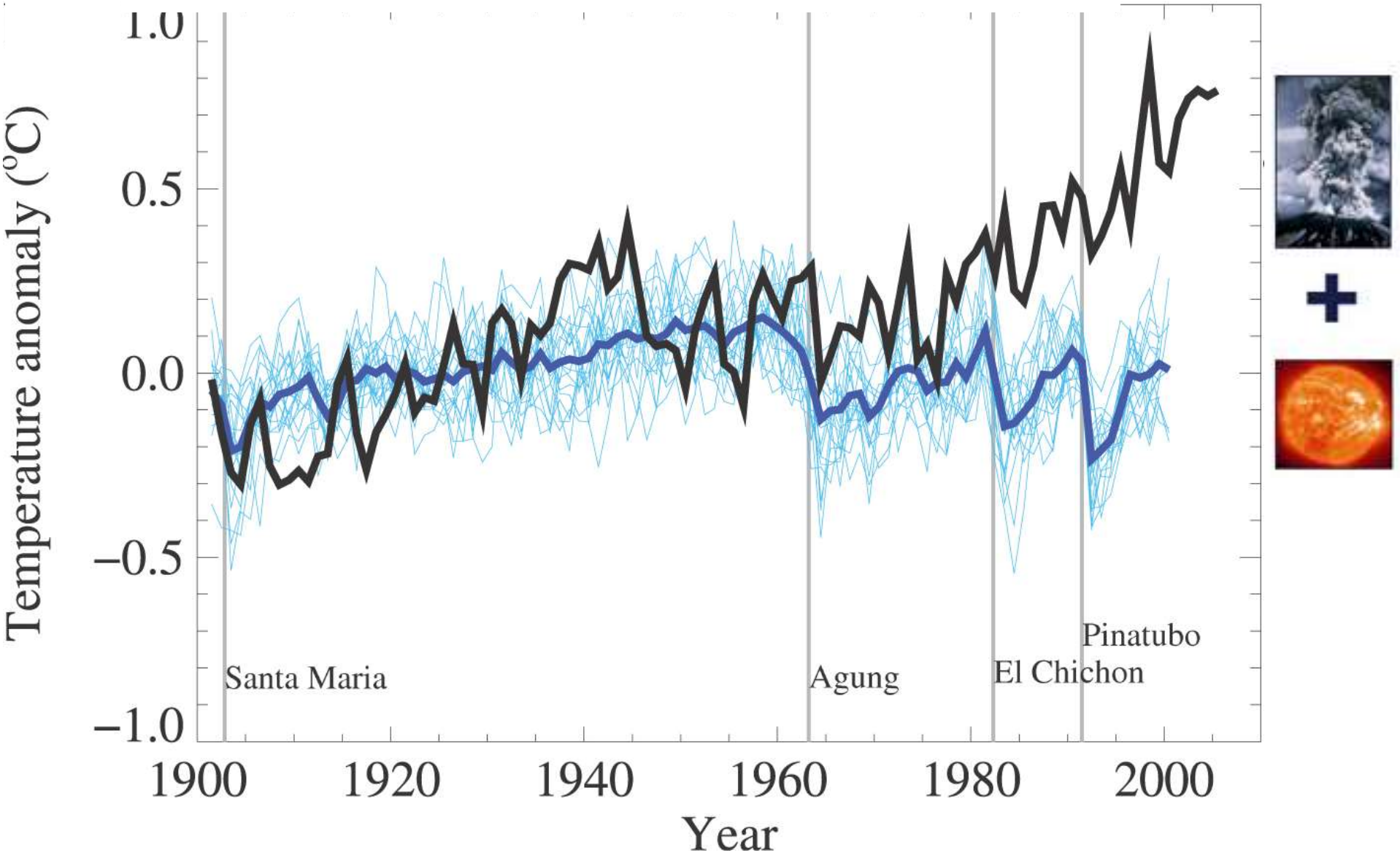
Experiments with computer simulations

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

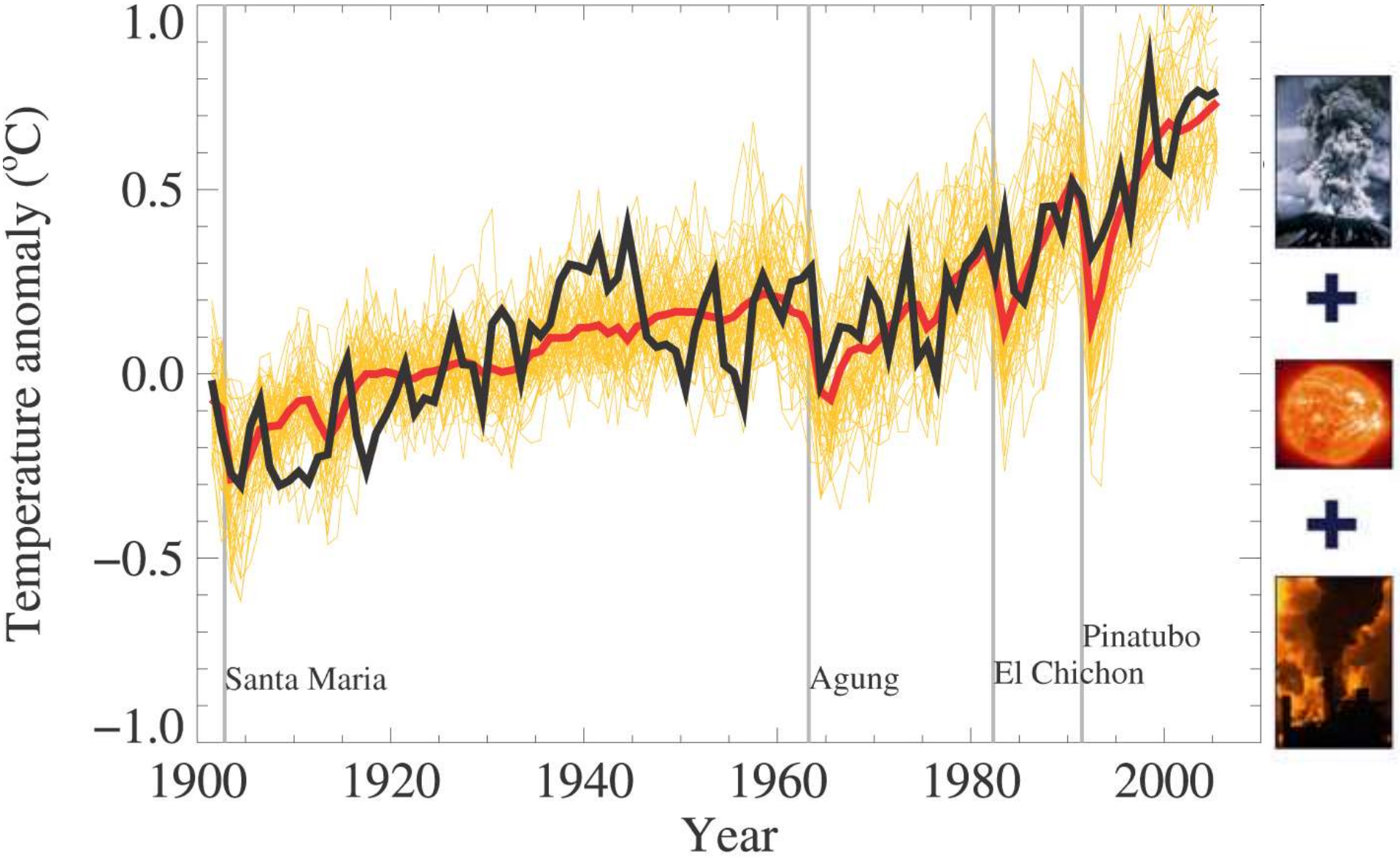




Natural factors cannot explain recent warming



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



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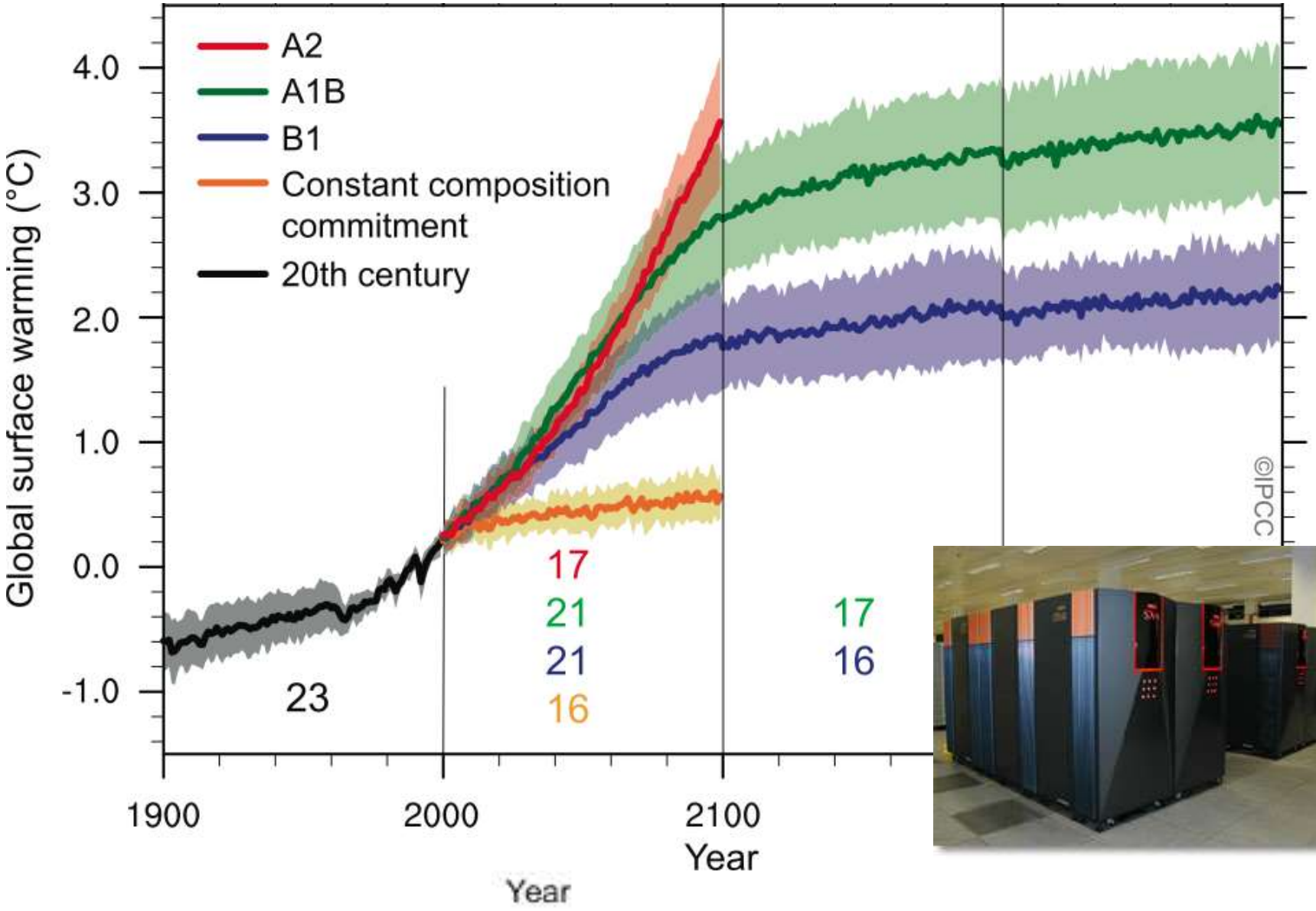
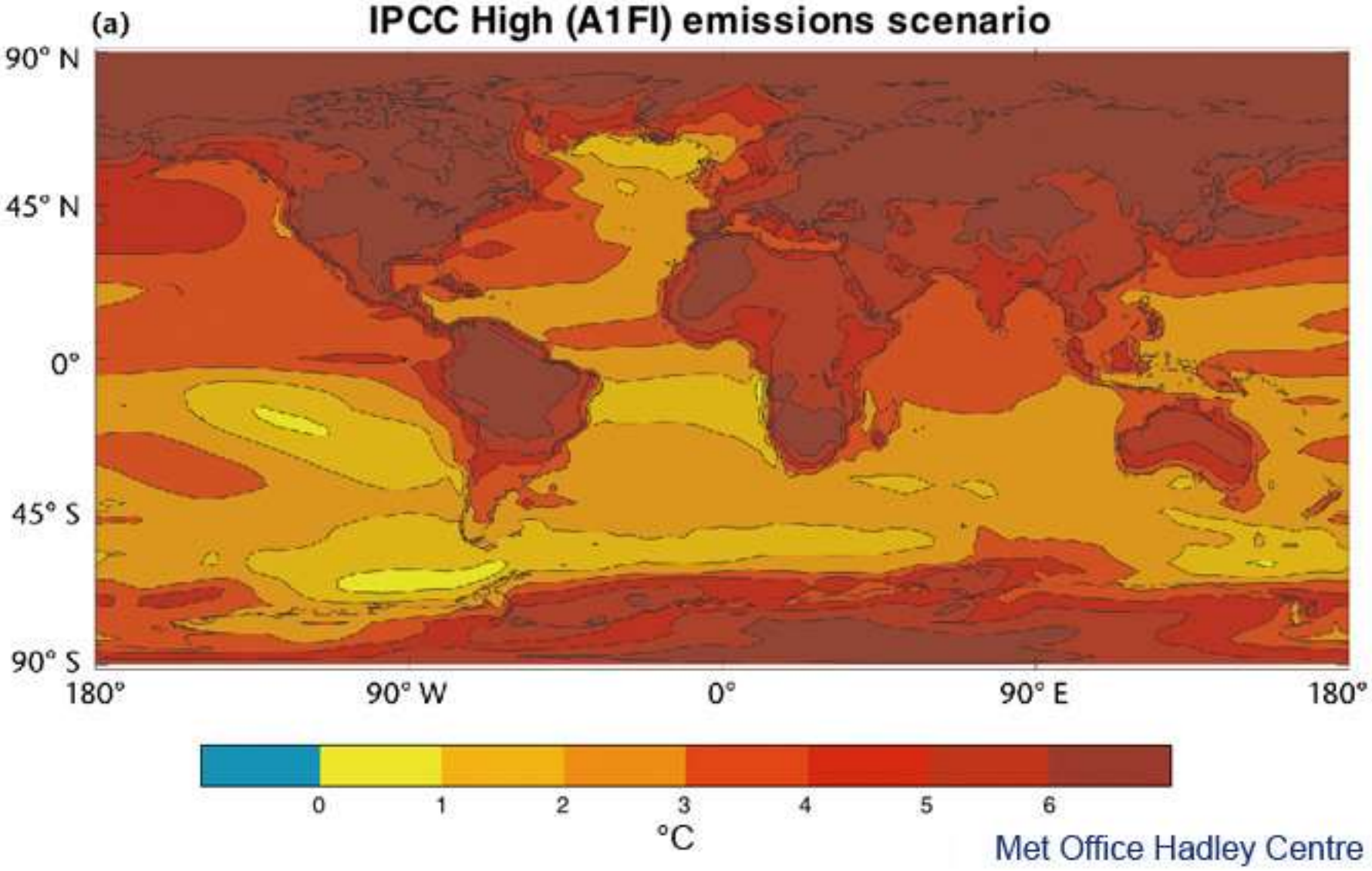
4) What are the predictions?

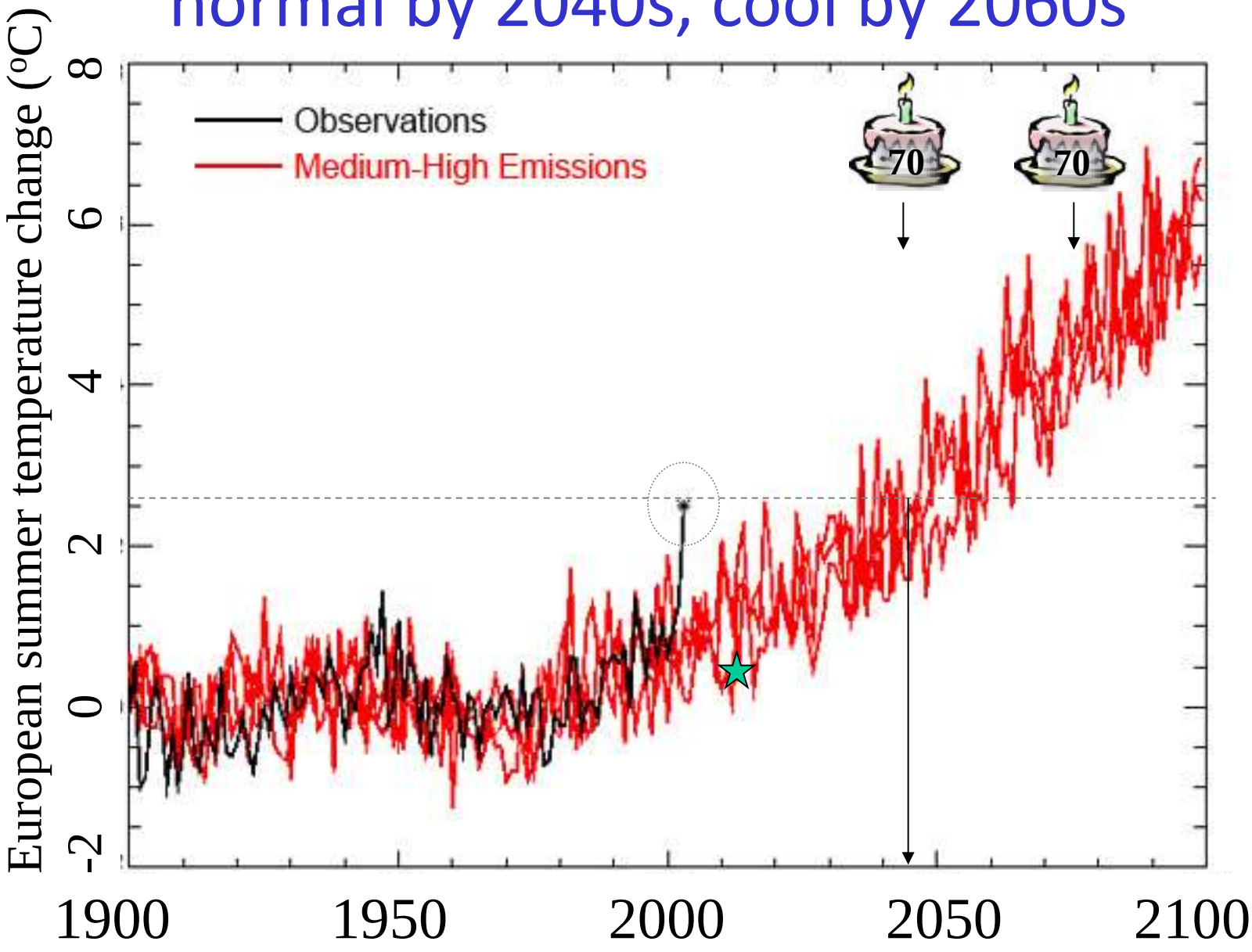
Global warming projections



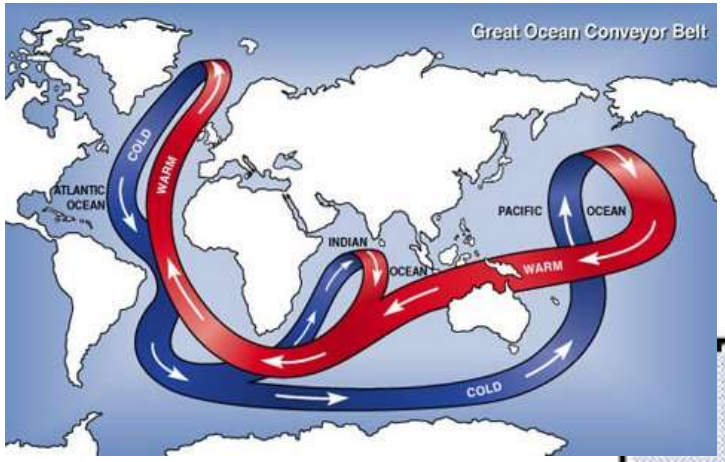
Land projected to warm more than oceans

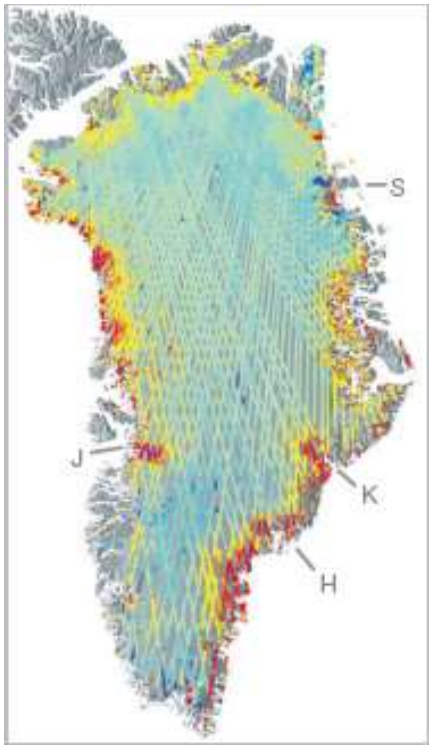


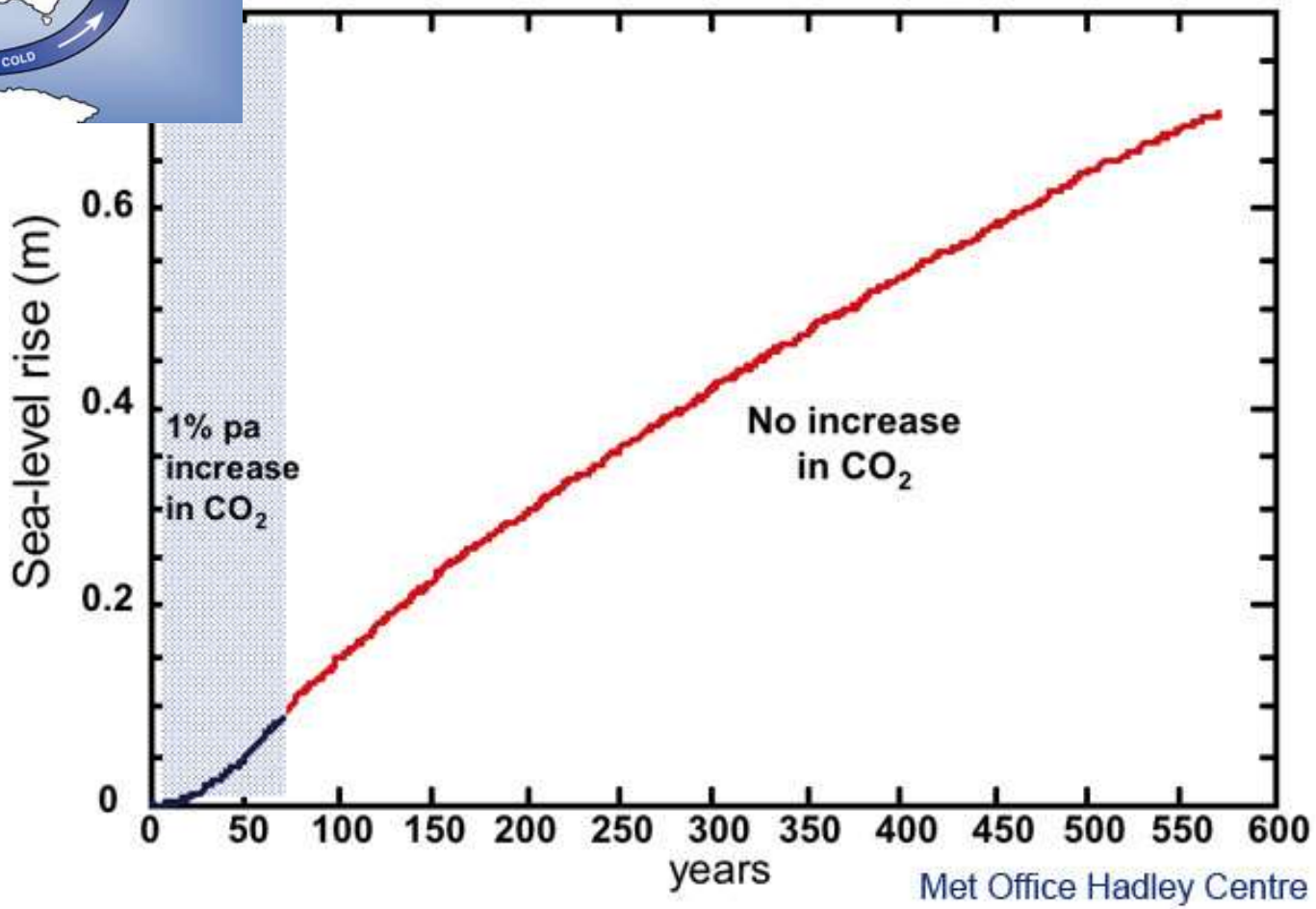
European 2003 summer temperatures could be normal by 2040s, cool by 2060s



Long-term commitment to sea-level rise

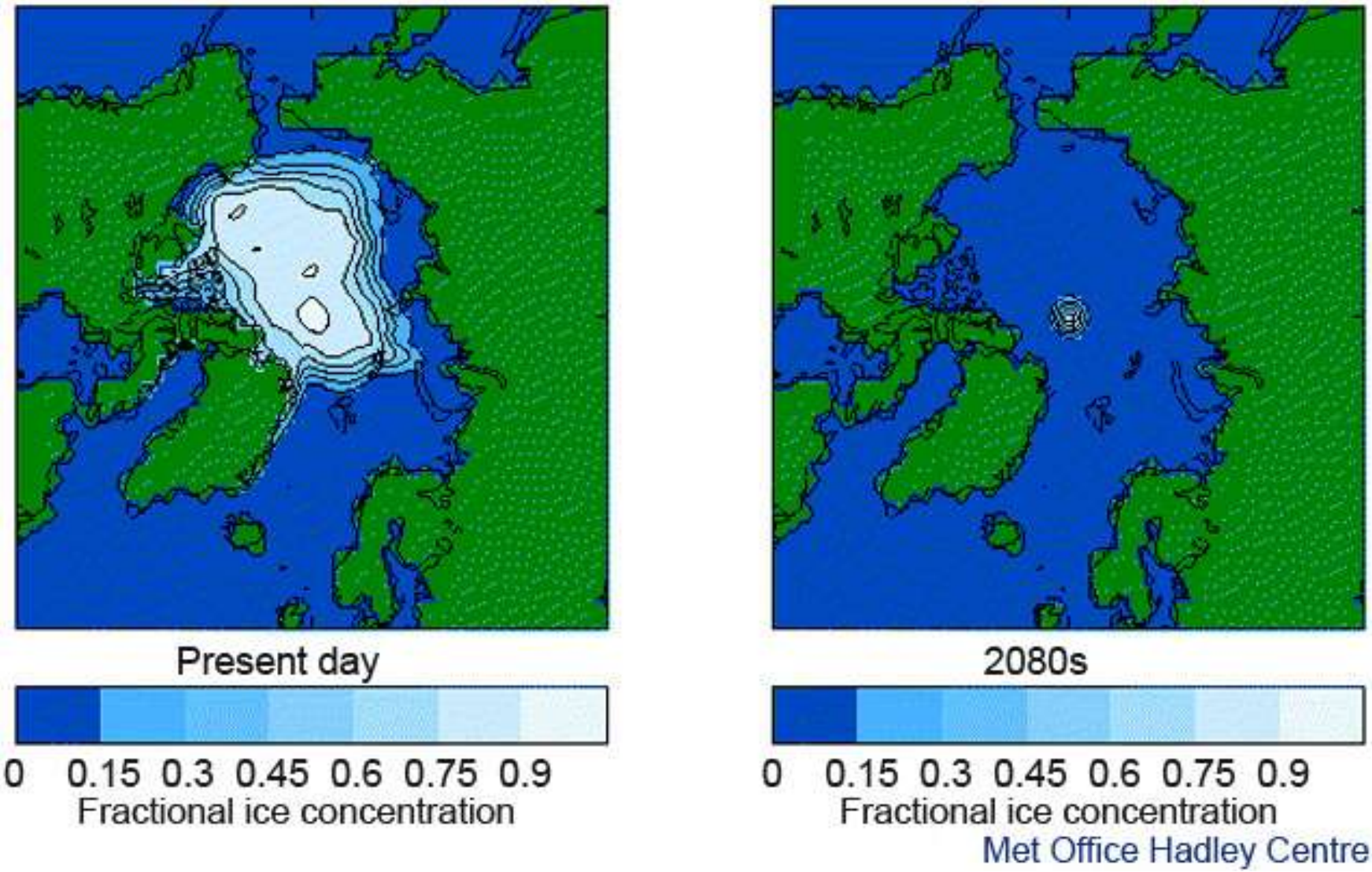


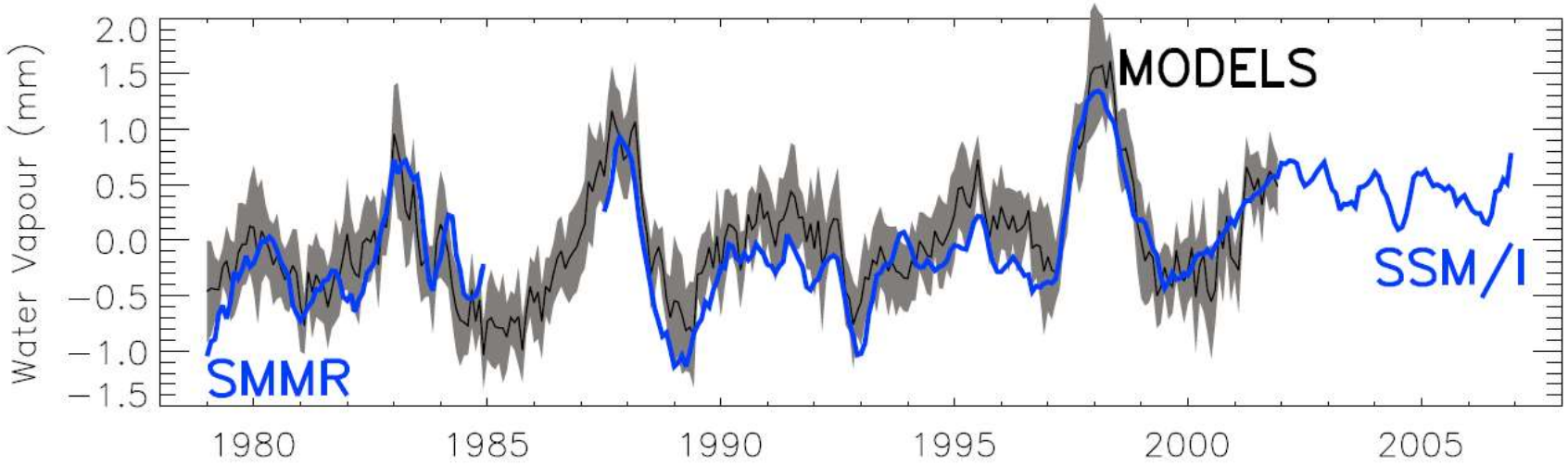




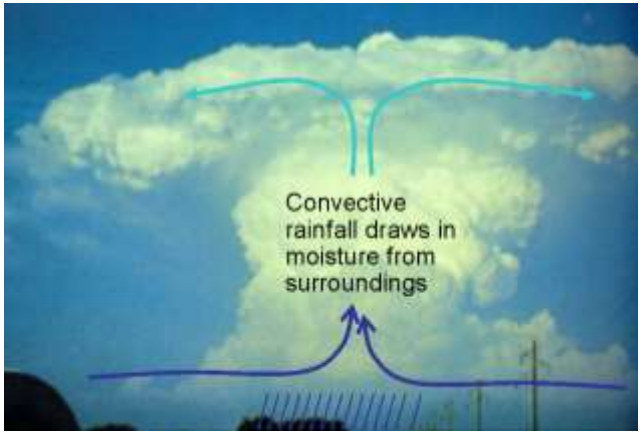
Arctic summer sea-ice could disappear by 2080s under IPCC High Emissions scenario

…but many simulations underestimate current ice loss?





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

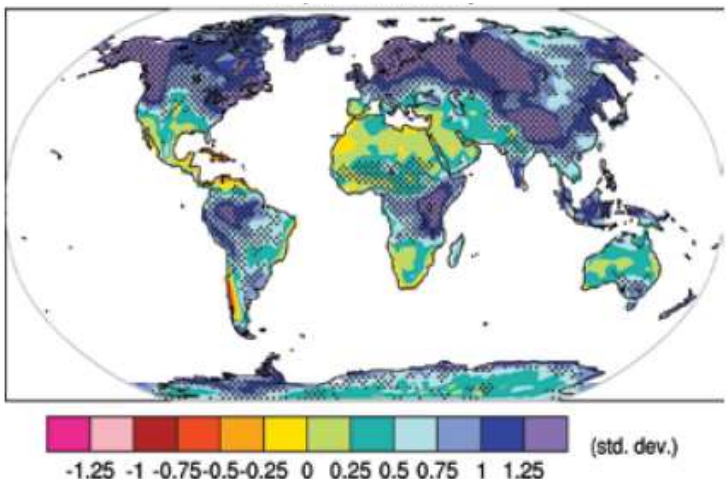


- The enhanced greenhouse effect amplifies initial warming: "feedback"

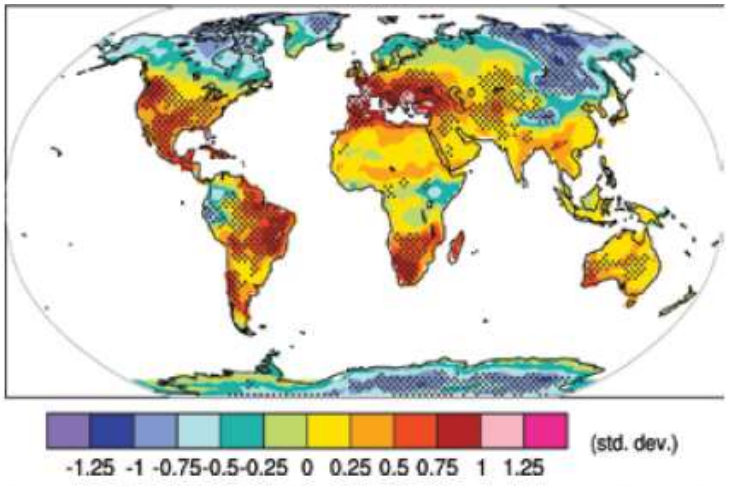
- Additional moisture fuels a greater intensity of rainfall

Projections of the global water cycle

Precipitation Intensity

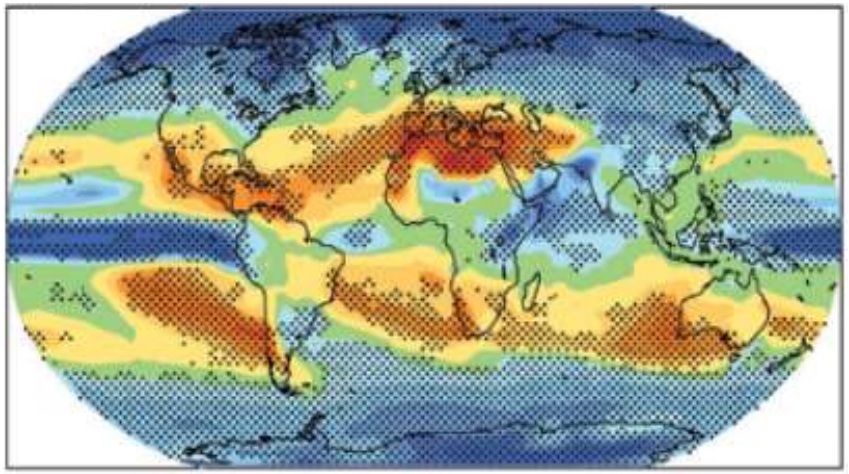


Dry Days



IPCC WGI (2007)

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

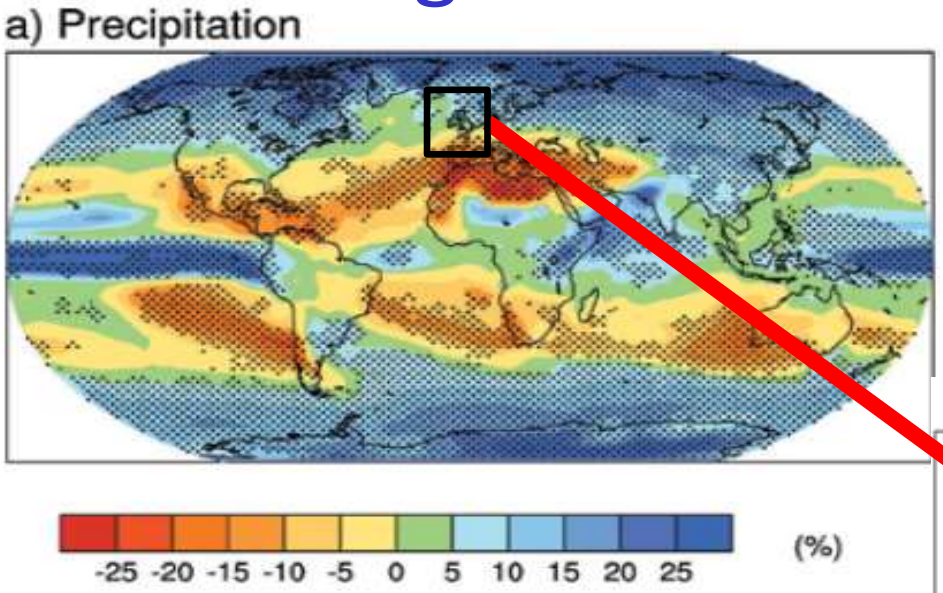


Precipitation Change (%)

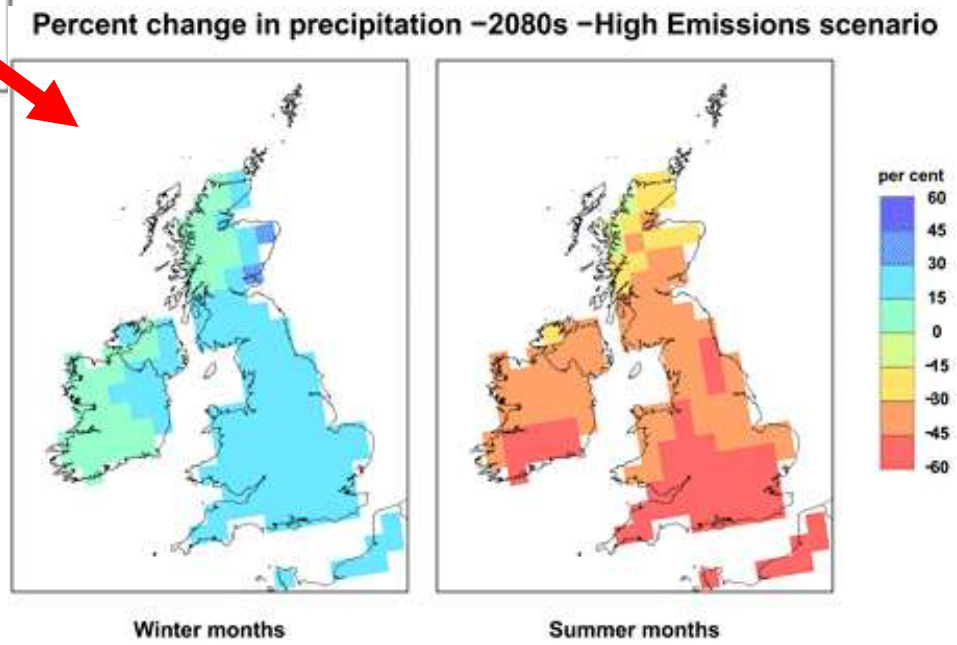
-25 -20 -15 -10 -5 0 5 10 15 20 25 (%)

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

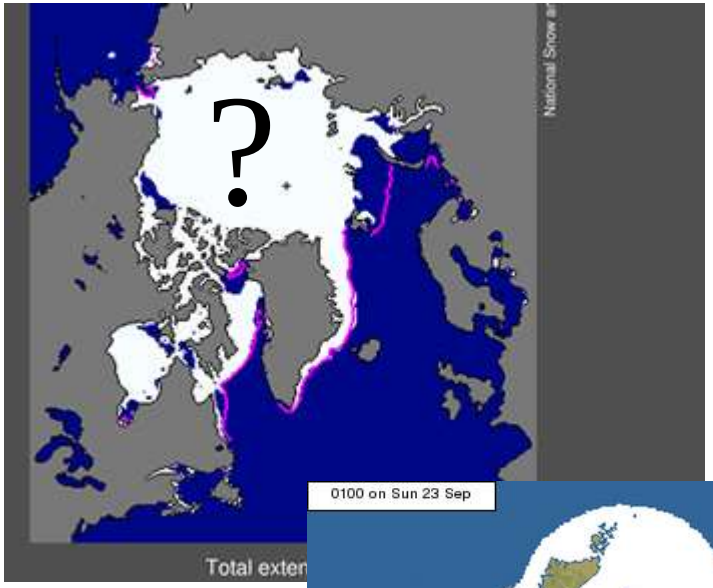
Changing water cycle

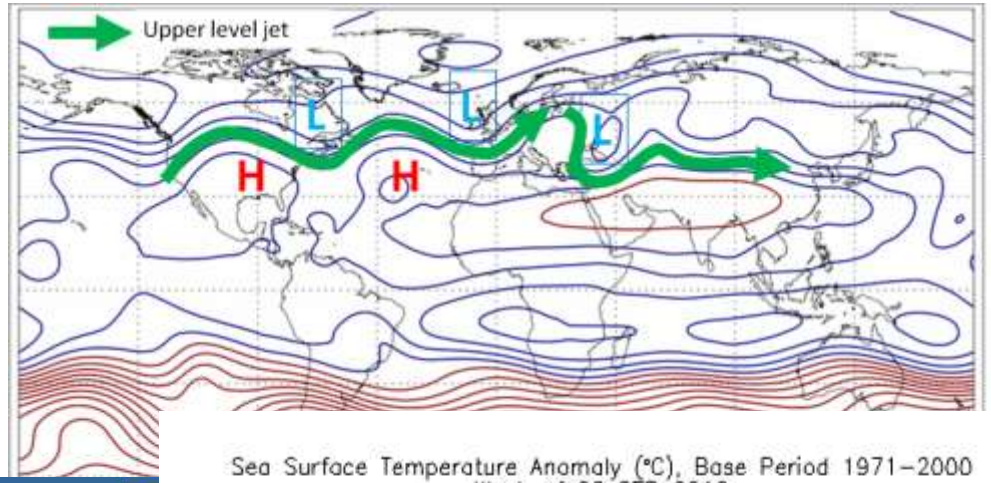


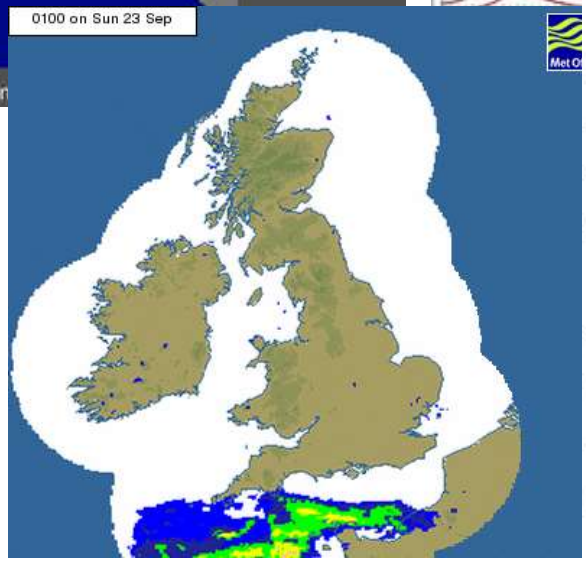
Changes in circulation systems are crucial to regional changes in water resources and risk yet predictability is poor.

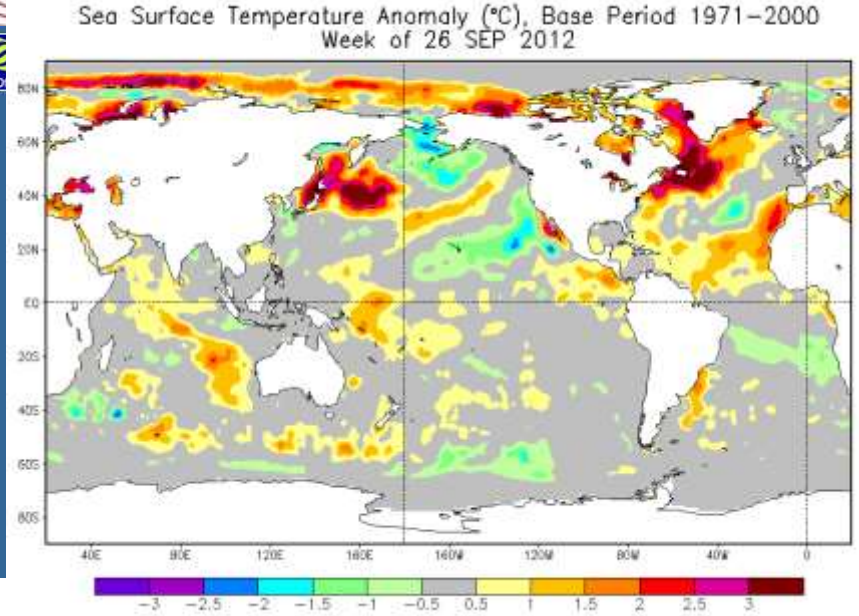


How will atmospheric and oceanic circulations change?

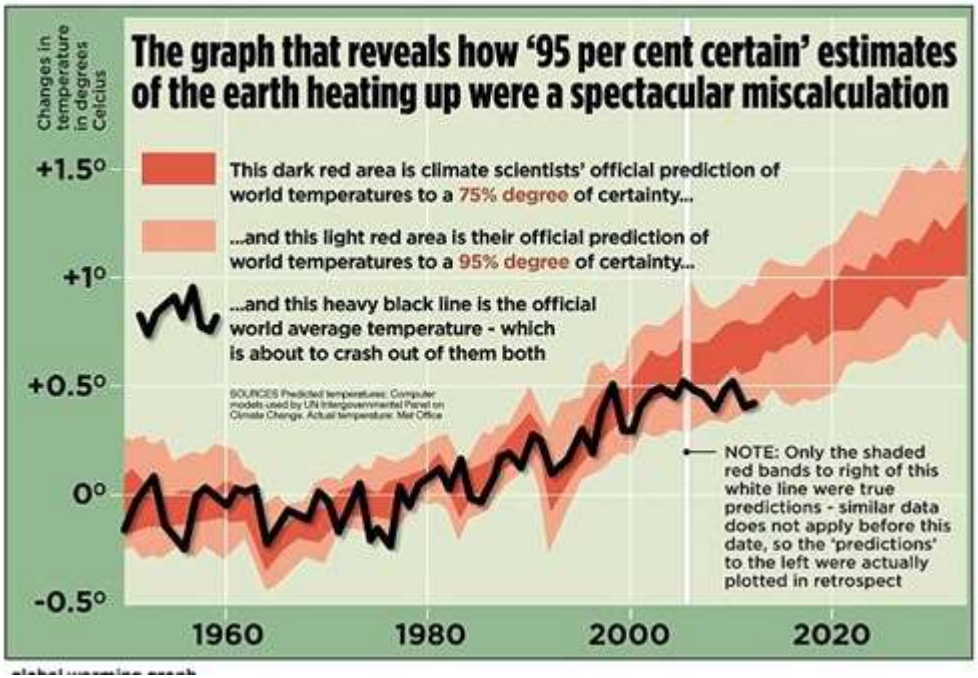








Outstanding questions



From the Mail on Sunday 16th March 2013

- Has global warming stopped (above)?
- Are computer predictions reliable?
- Why have we had such odd weather in recent years?

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 "knock on effects" of the warming involving the land surface or clouds to amplify or oppose the warming?
  - How will atmospheric and oceanic circulations change?

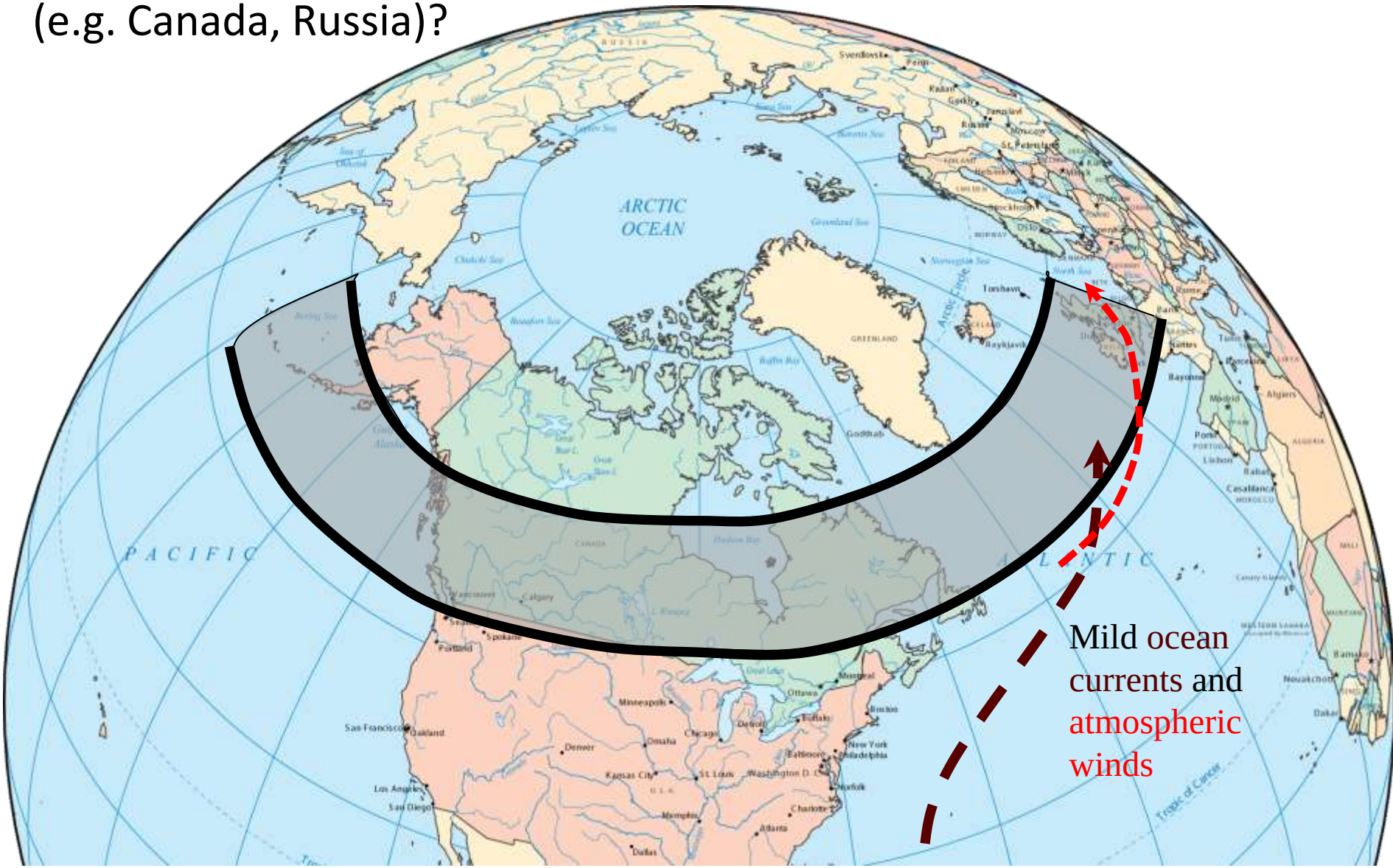
Extra Slides

(1) Jet Stream

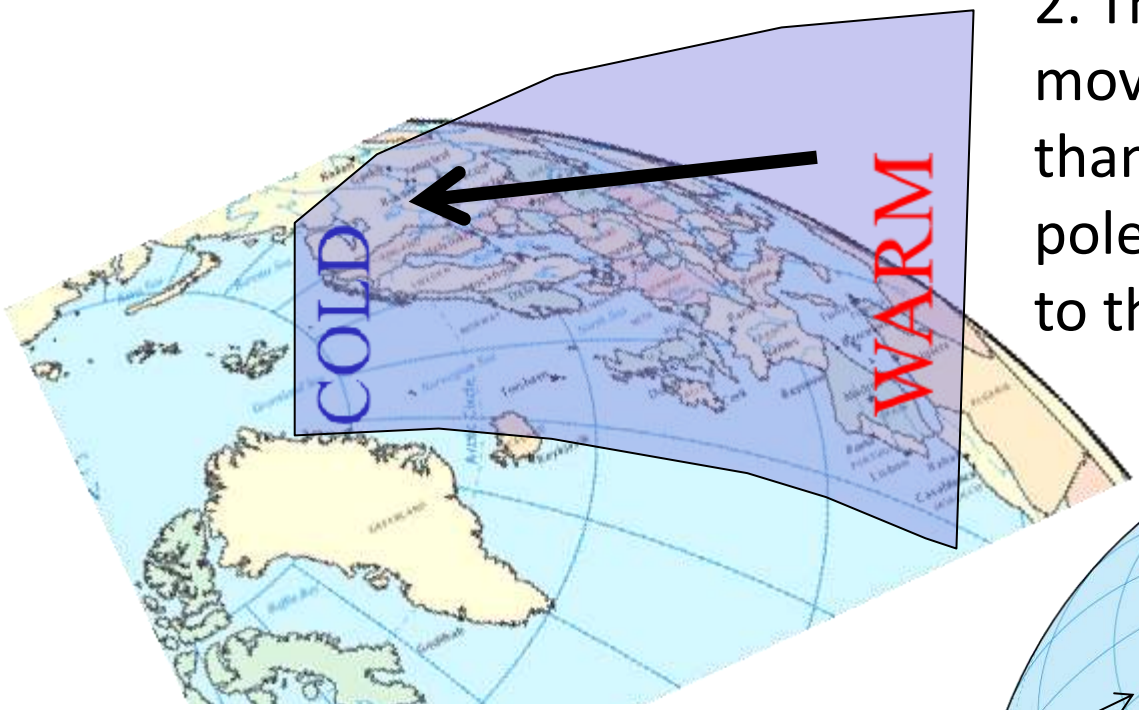
(2) Has Global Warming stopped?

(3) Cloud feedbacks and climate prediction uncertainty

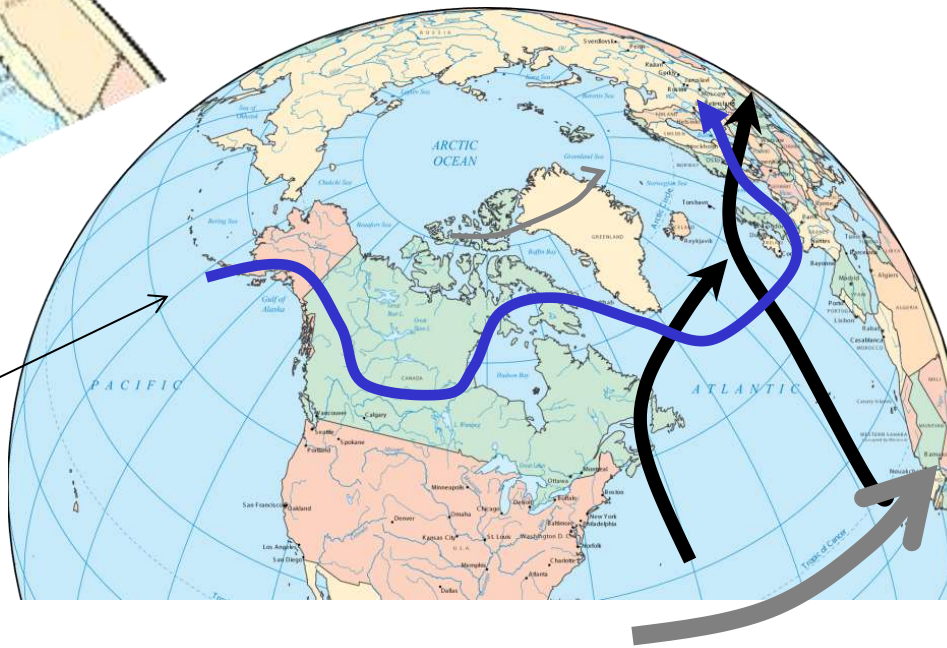
Why are our winters much milder than at similar latitudes (e.g. Canada, Russia)?



1. Air is warmer closer to the tropics (air expands) than at the poles (air contracts). This generates a **poleward flow of air** high up in the atmosphere

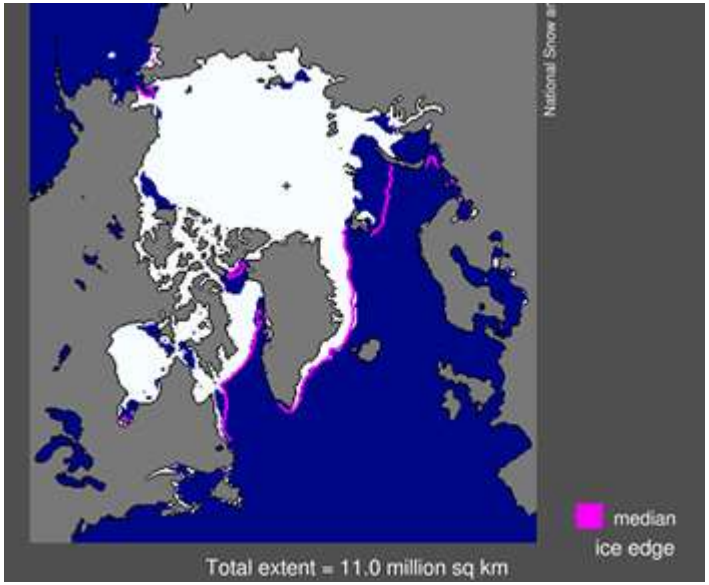


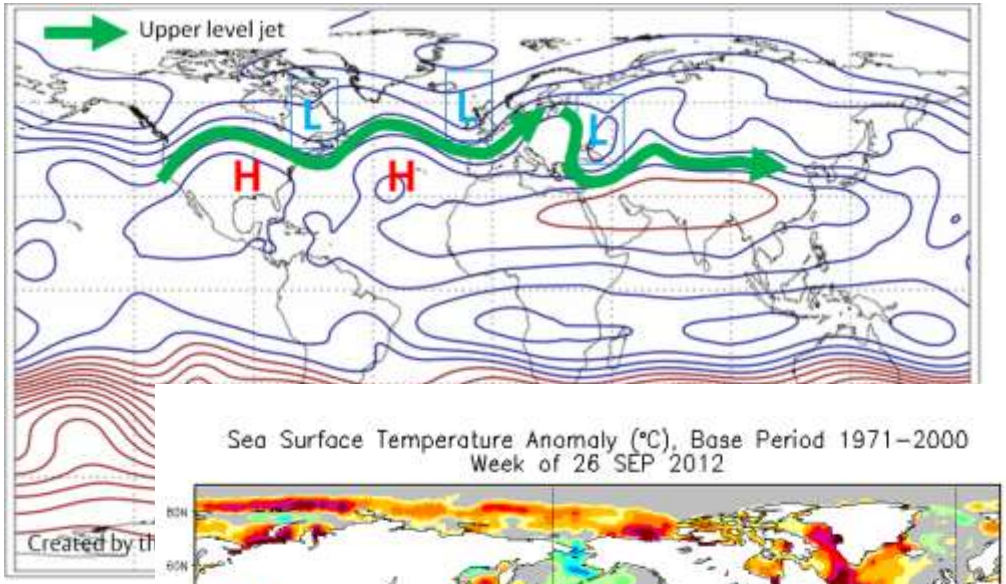
2. The Earth spins: the surface moves quicker near the equator than at higher latitudes. So poleward-flowing air is deflected to the **east** (direction of spin)

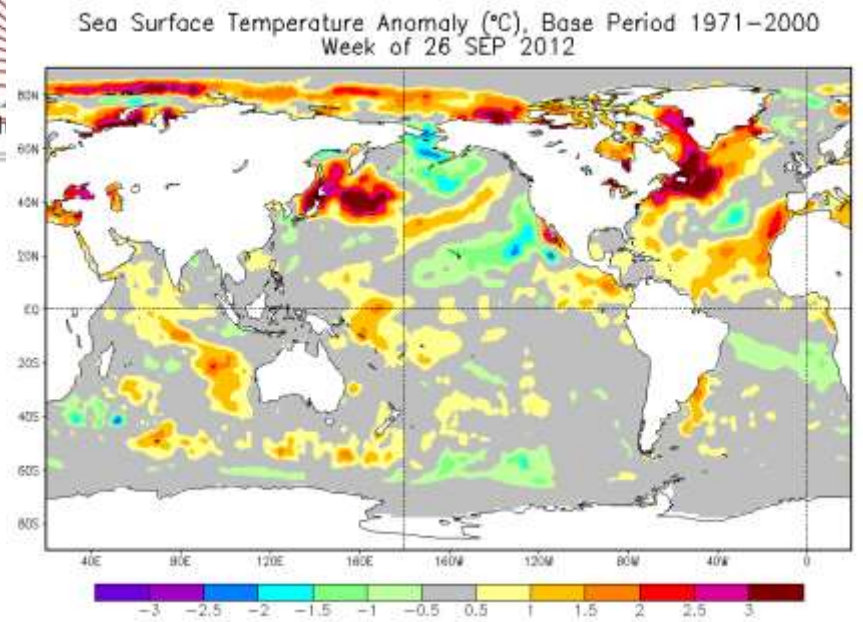


3. This high altitude (5-7km) fast moving ribbon of air is called the jet stream. It steers weather systems over or away from the UK.

Arctic Ice, ocean temperature and the jet stream



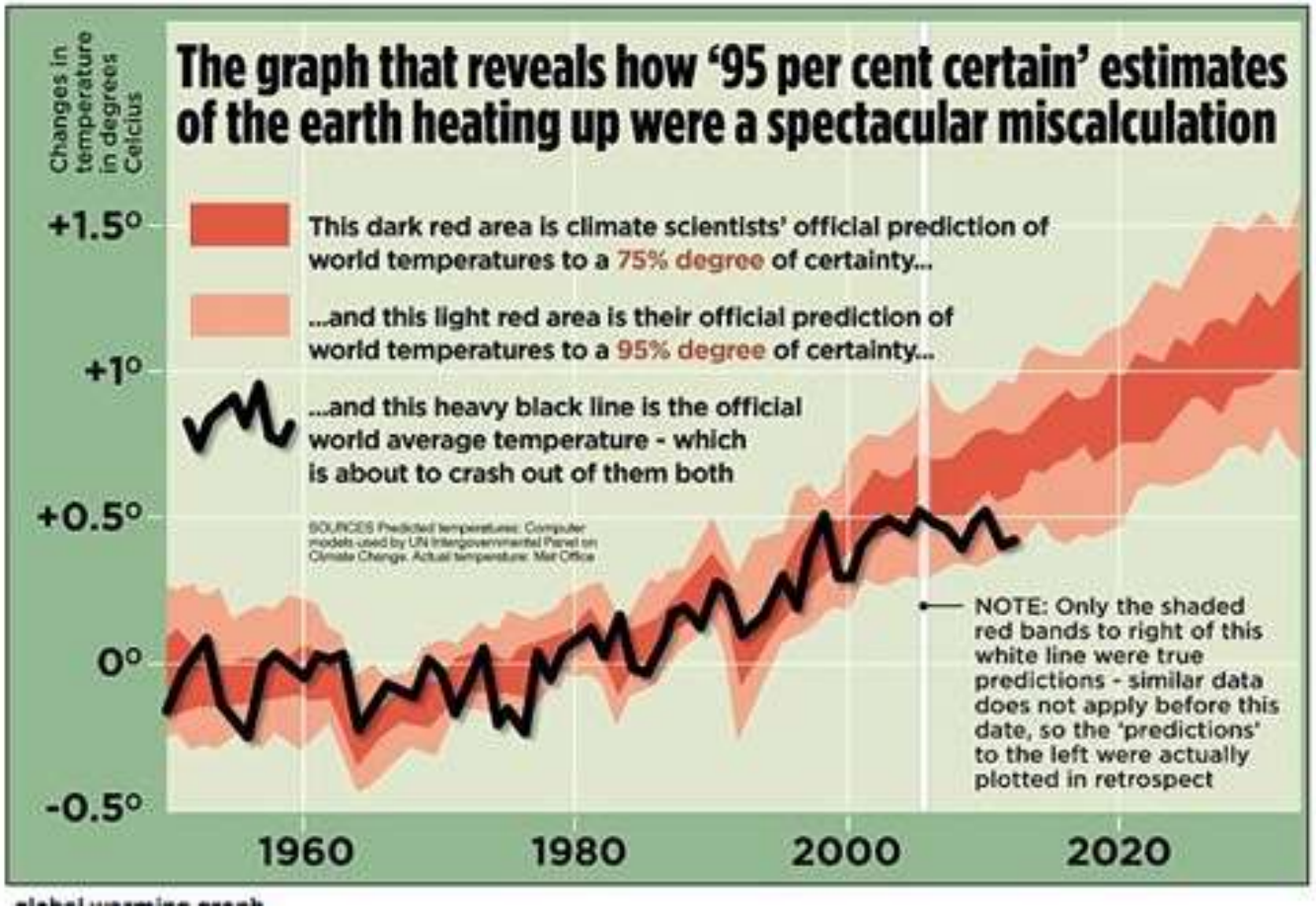




4. Changes in this temperature difference between equator and pole can alter the position and strength of the jet stream.

Both **natural** and **human-caused** effects influence our weather patterns

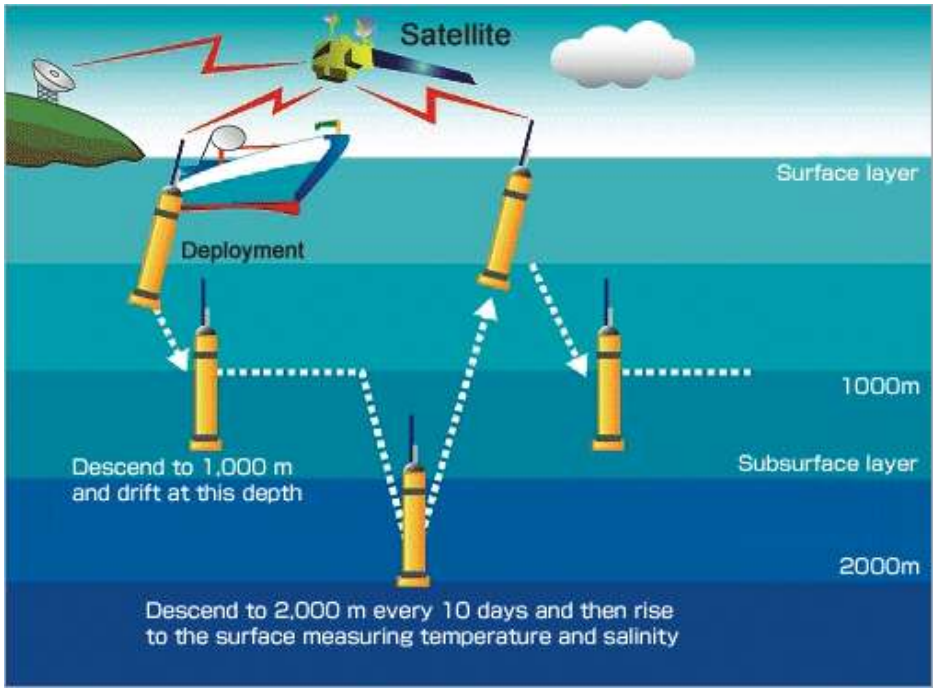
Has global warming stopped?



From the Mail on Sunday

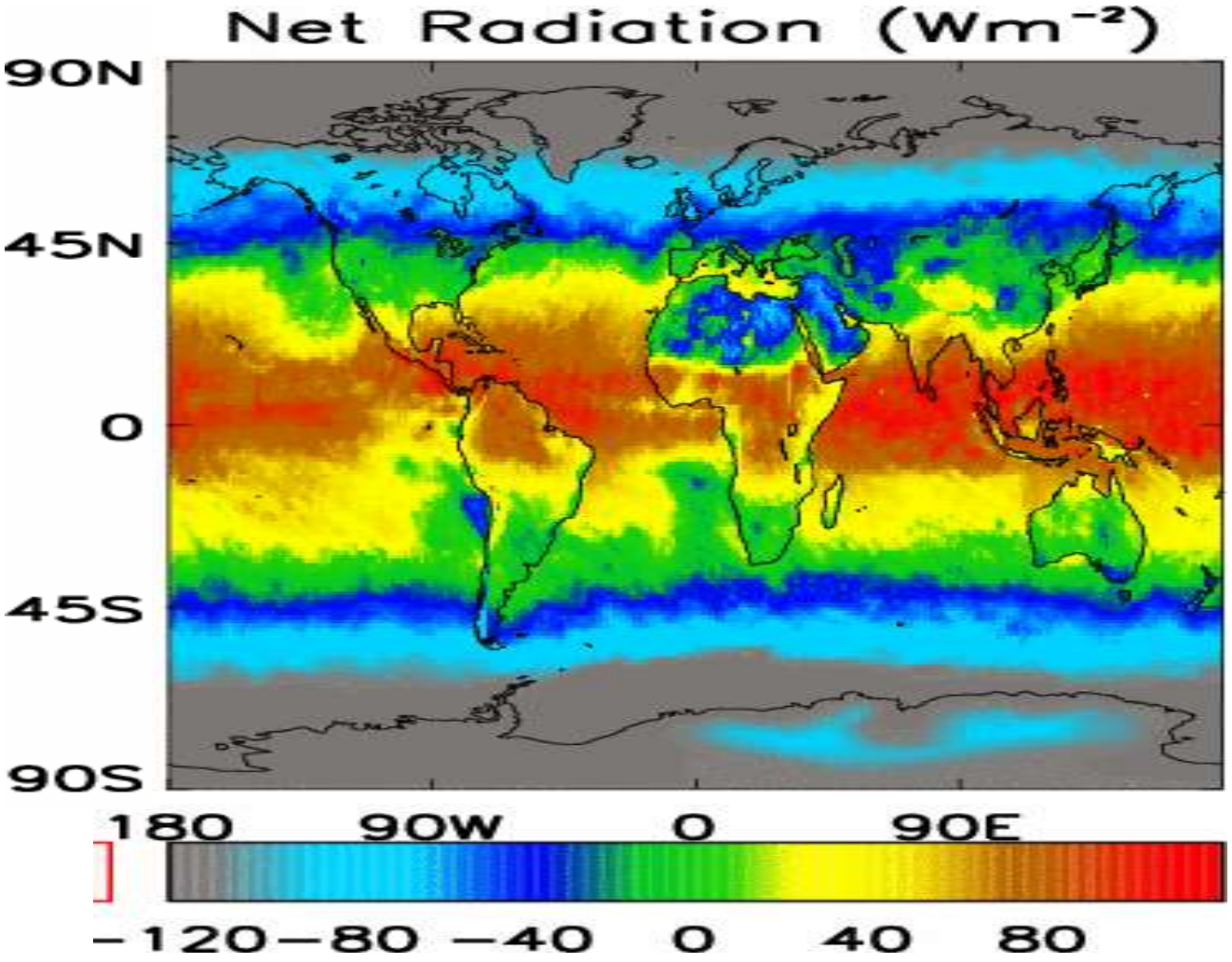
- Satellite instruments measure energy arriving and leaving our planet
  - Sunlight & thermal radiation
- Automated floats measure heating beneath the ocean surface

ARGO floats →



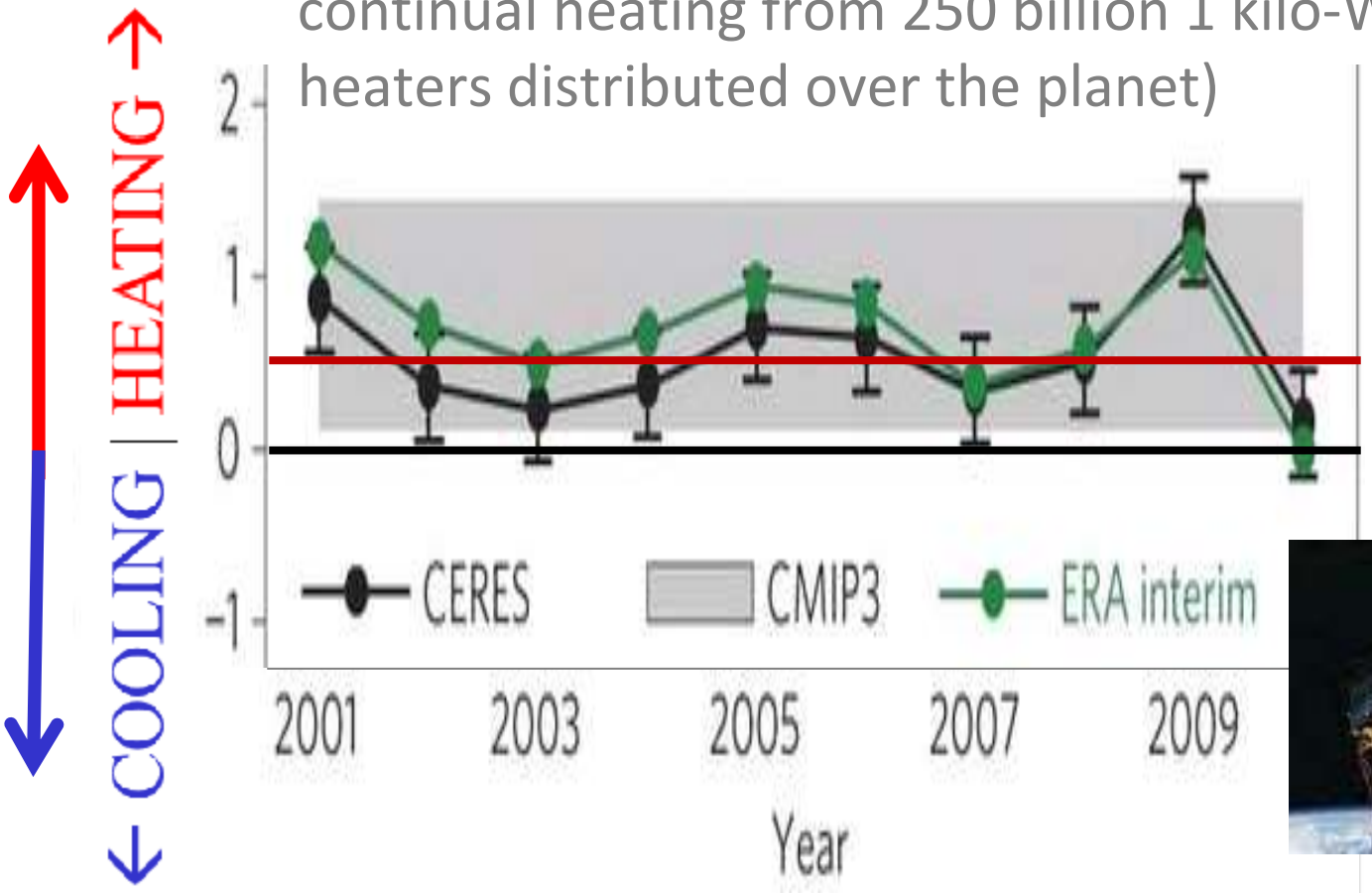
Top of Atmosphere Radiative Energy Fluxes

CERES/TERRA, September 2004

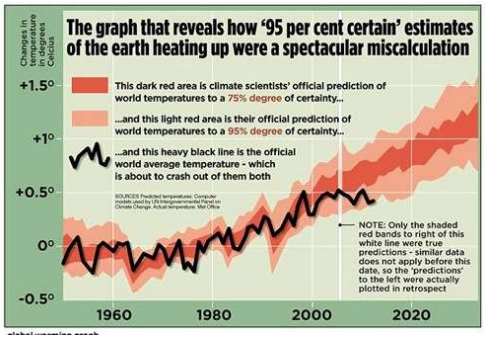


Combining satellite measurements with ocean observations

We found that heat is continuing to accumulate at the rate of 0.5 Watts per square metre (equivalent to continual heating from 250 billion 1 kilo-Watt electric heaters distributed over the planet)

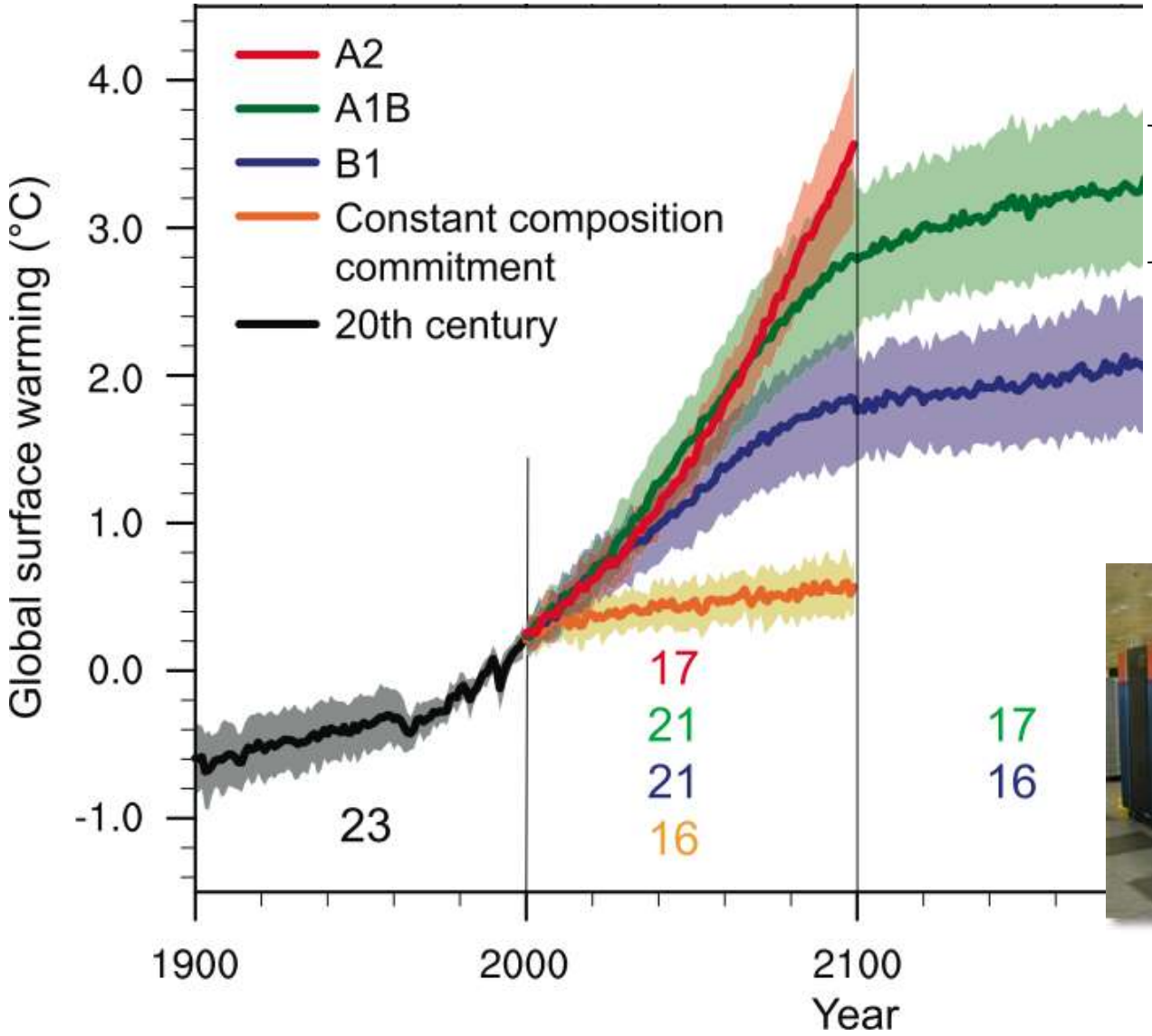


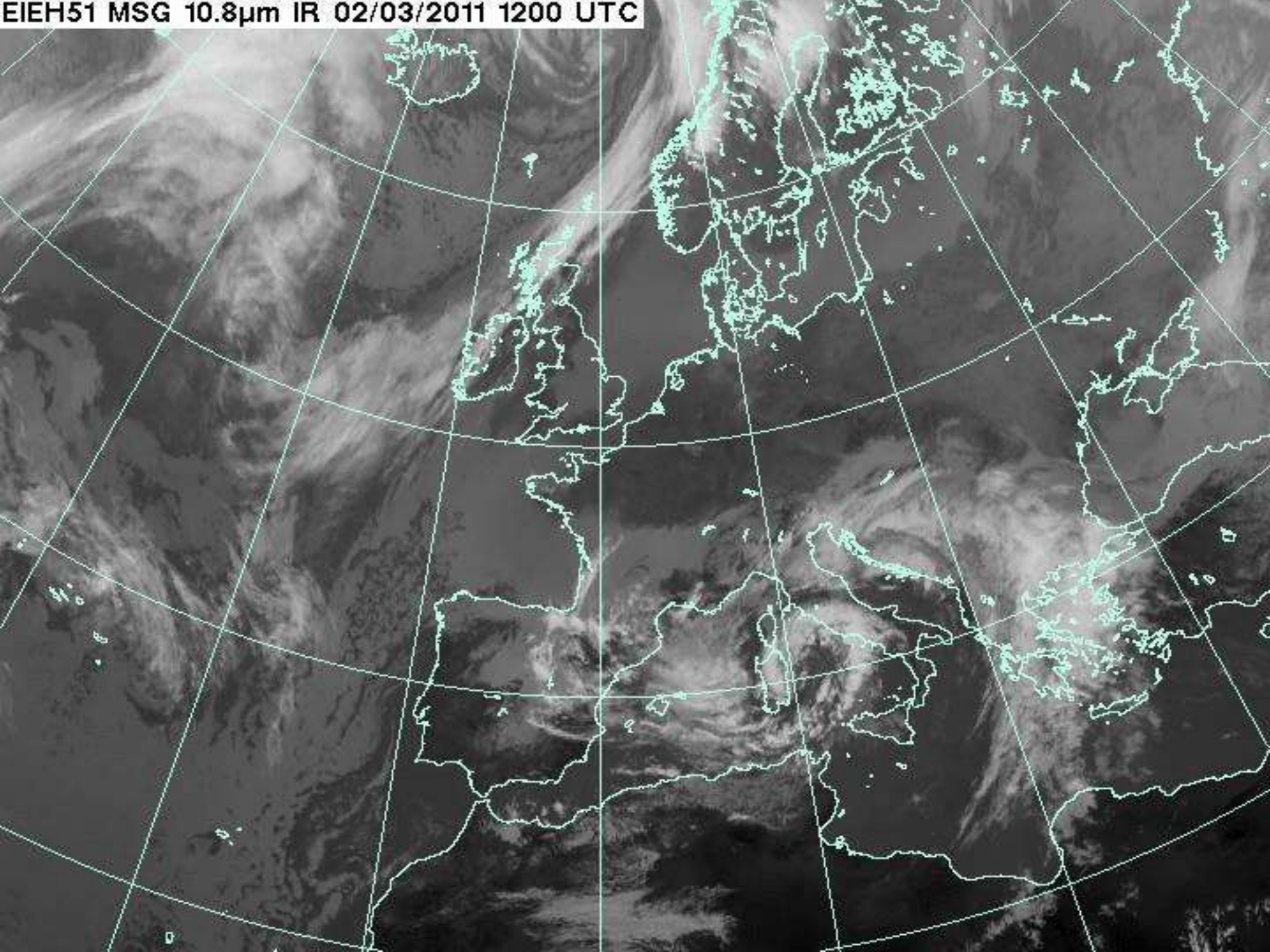
Has global warming stopped?

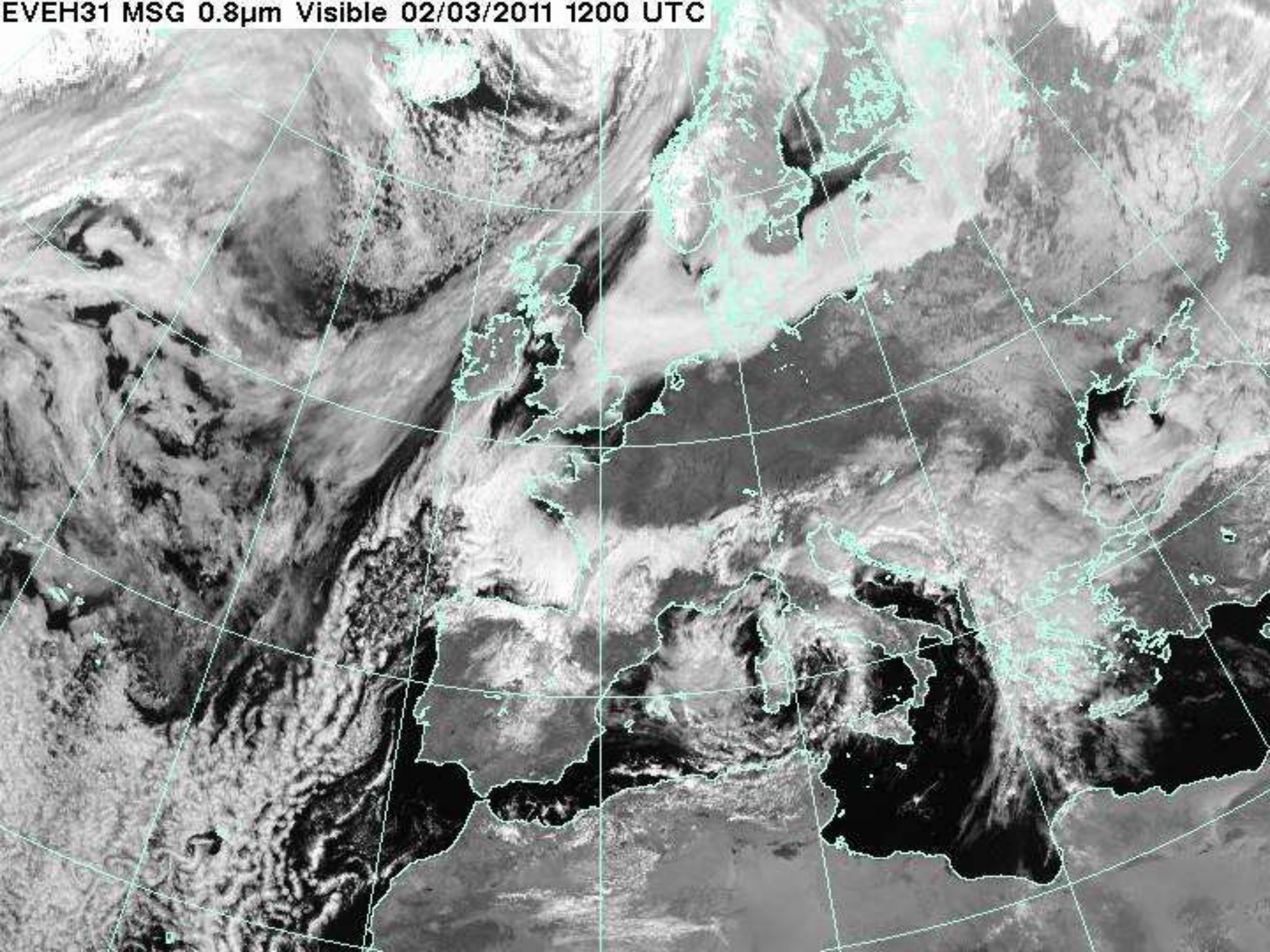


- No, the oceans are continuing to warm
- However, why has there been a hiatus in surface warming?
  - Cooling effects from a weaker sun or more aerosol pollution?
  - Natural fluctuations in the ocean
- We are currently researching these questions in a new Natural Environment Research Council project called DEEP-C.

Clouds and why global warming predictions are uncertain?




EIEH51 MSG 10.8µm IR 02/03/2011 1200 UTC


EVEH31 MSG 0.8µm Visible 02/03/2011 1200 UTC

Will clouds amplify or reduce the warming response to increases in greenhouse gases?

- Most of the water in the atmosphere is invisible, gaseous vapour
  - clouds are the tip of the iceberg
  - …water vapour with attitude
- Observations, simulations and basic physics show that water vapour provides an amplifying feedback on climate change
- Clouds affect both sunlight and infra-red radiation and are complex to simulate
- We currently don't know whether clouds amplify or reduce climate change