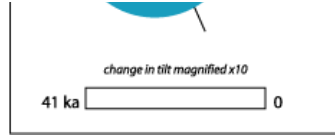
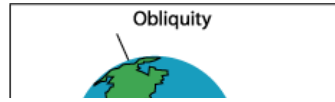


Global Climate Change

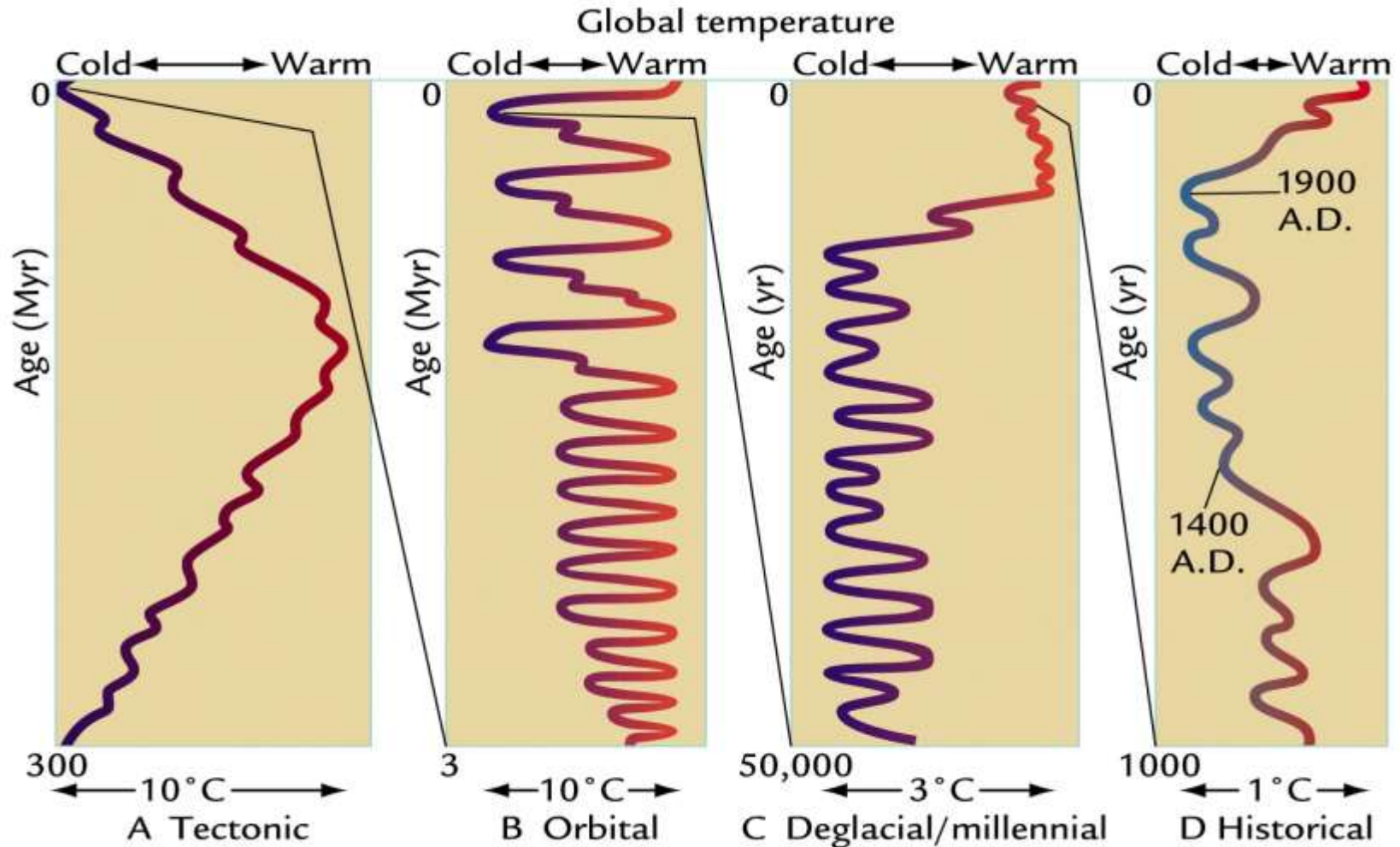
Reading International Festival, RISC 26th October 2015



Prof. Richard Allan,
Department of Meteorology
University of Reading



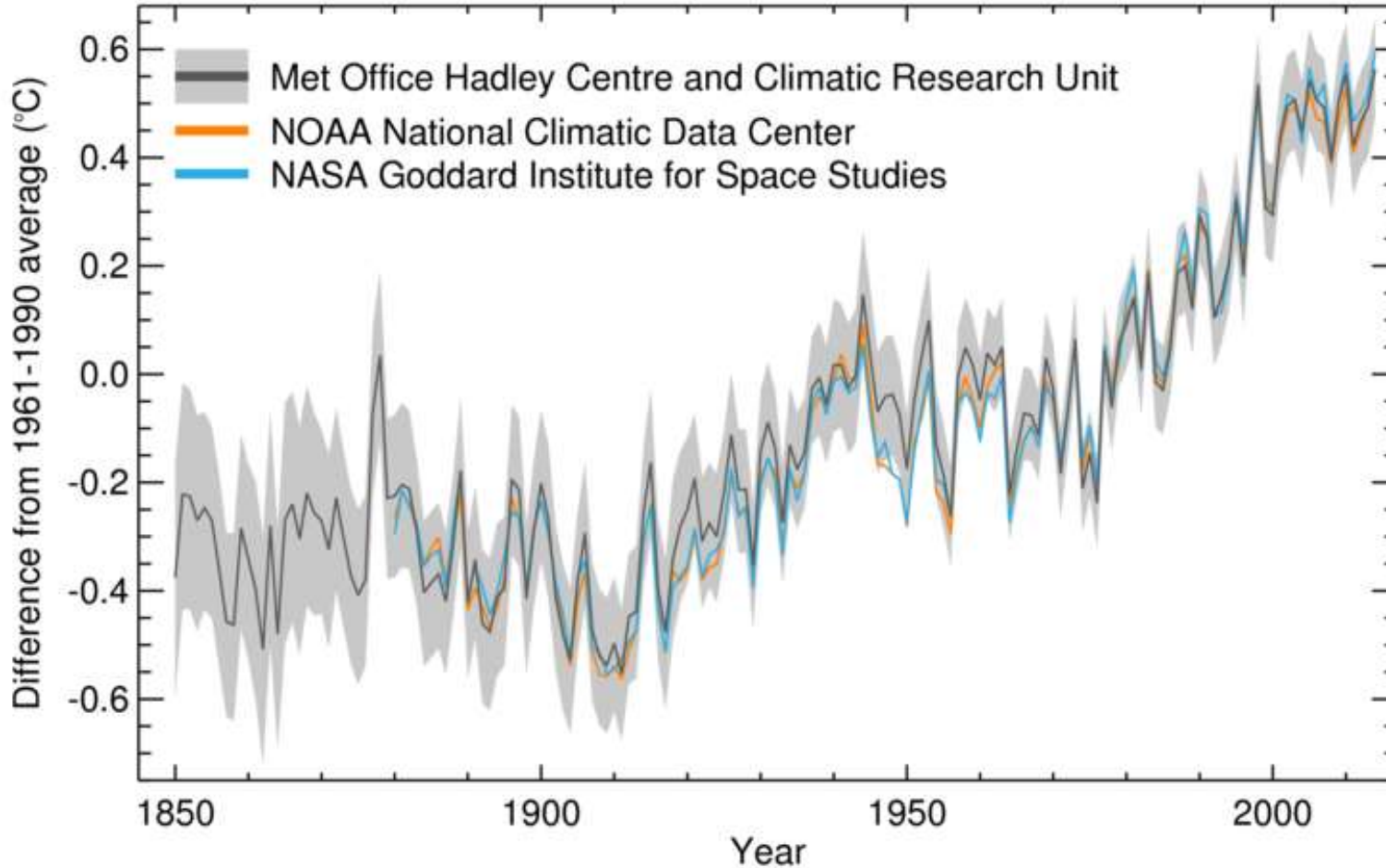
Earth's Climate has always been changing



The planet is warming

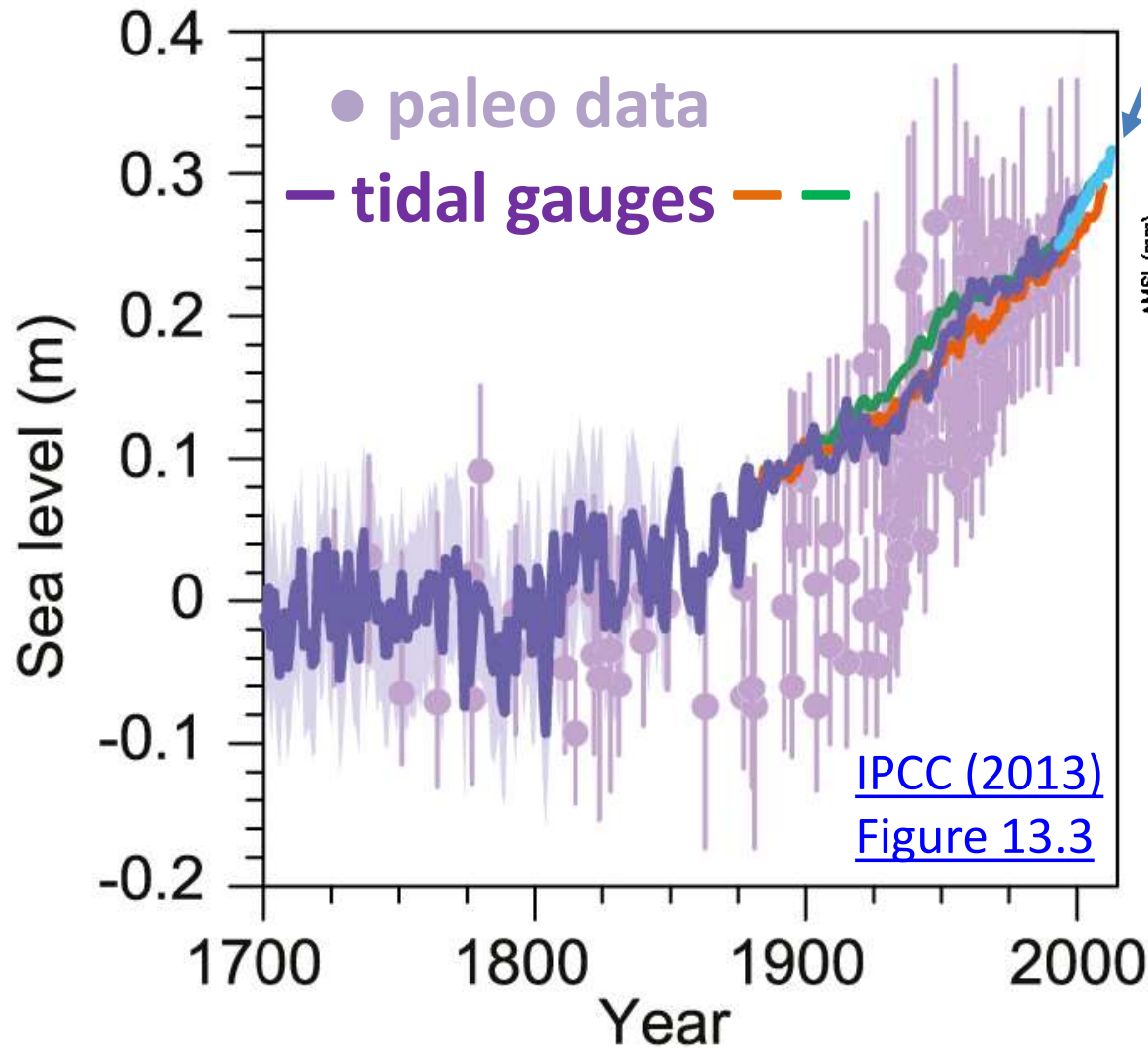


Global average temperature anomaly (1850-2014)

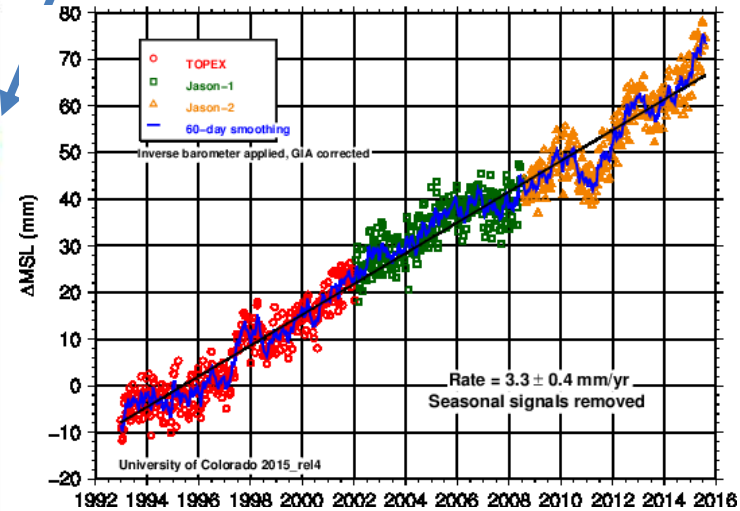


www.metoffice.gov.uk/research/monitoring/climate/surface-temperature

Global average sea level is rising...

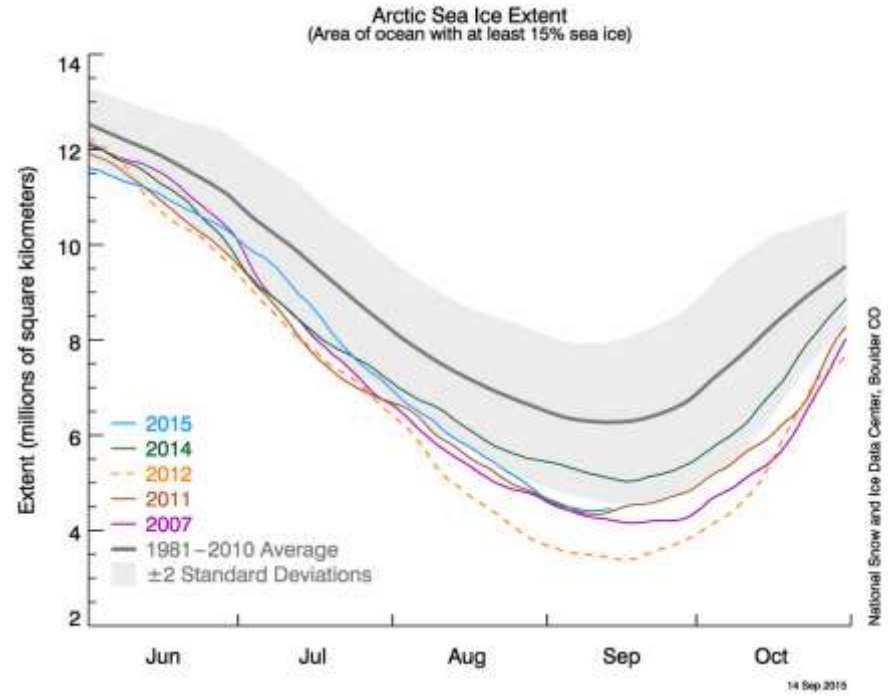
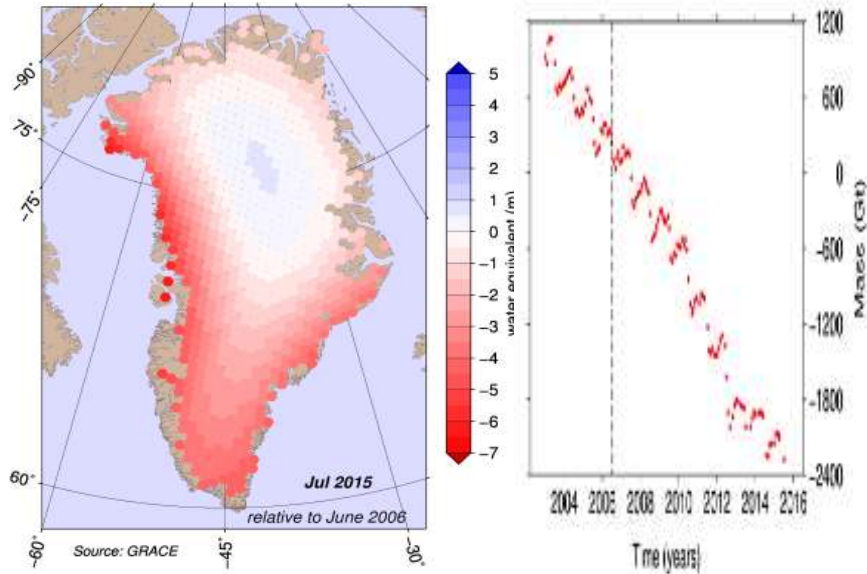


Satellite Altimeter data

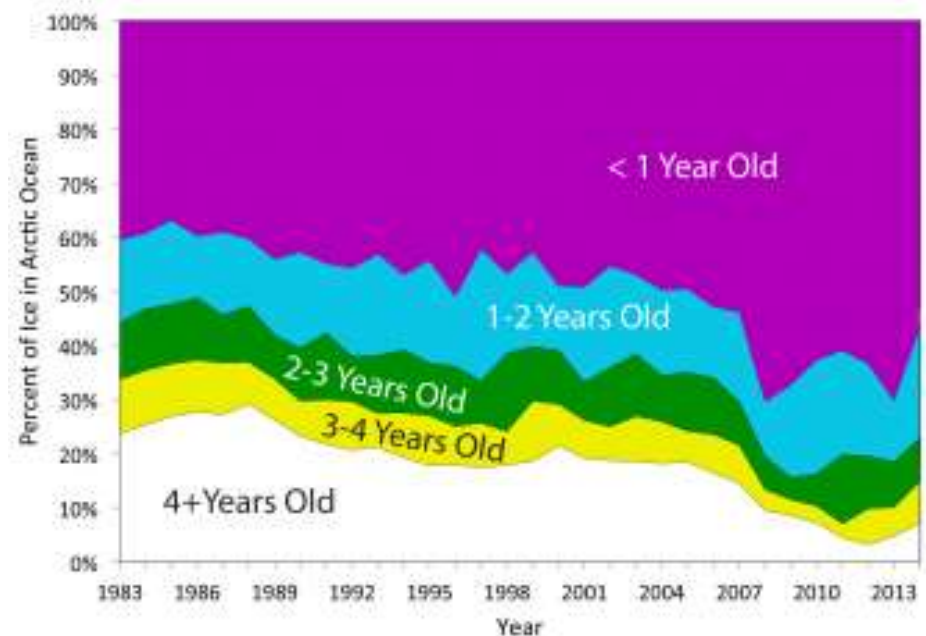
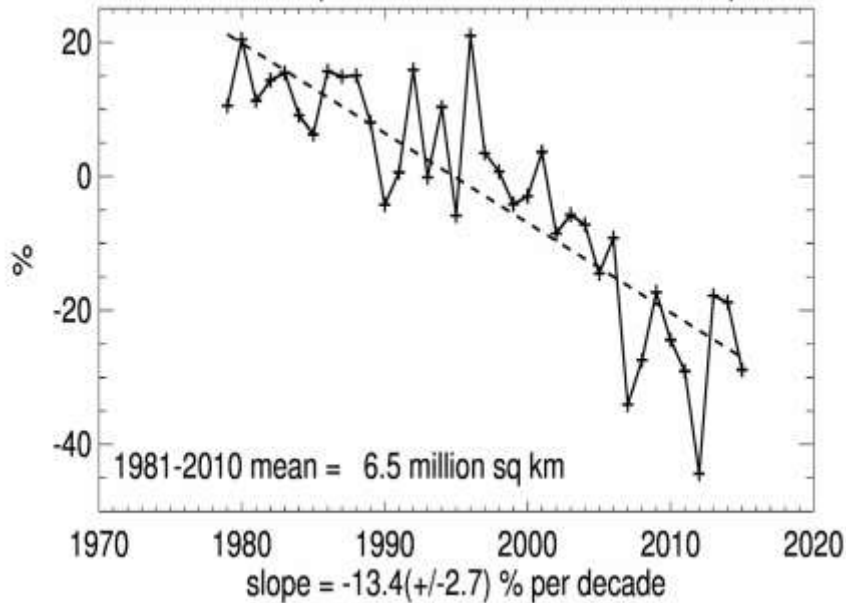


<http://sealevel.colorado.edu/>

Melting of Arctic Ice



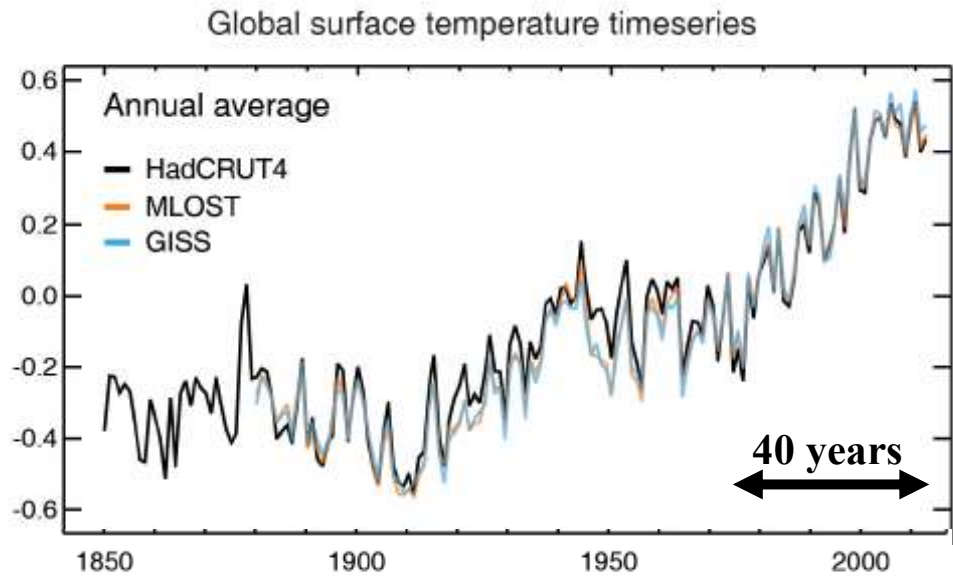
Northern Hemisphere Extent Anomalies Sep 2015



Evidence for current climate change

“Warming of the climate system is unequivocal, and since the 1950s, many of the observed changes are unprecedented over decades to millennia. The atmosphere and ocean have warmed, the amounts of snow and ice have diminished, sea level has risen, and the concentrations of greenhouse gases have increased.” IPCC (2013)

Temperature difference (°C) compared to 1961-1990 average

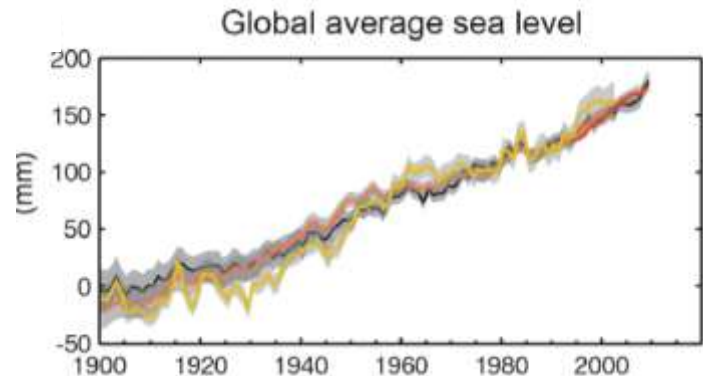
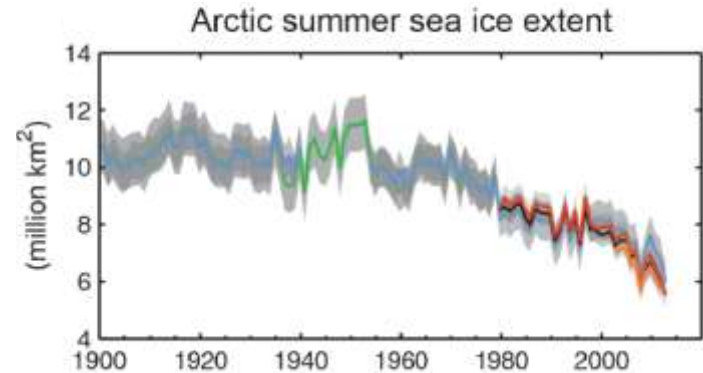


Differences in global average surface temperature compared to the 1961-1990 average

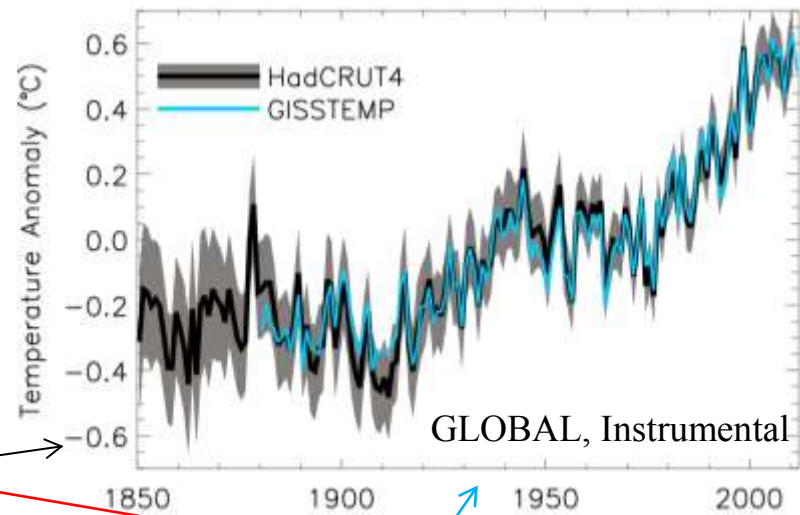
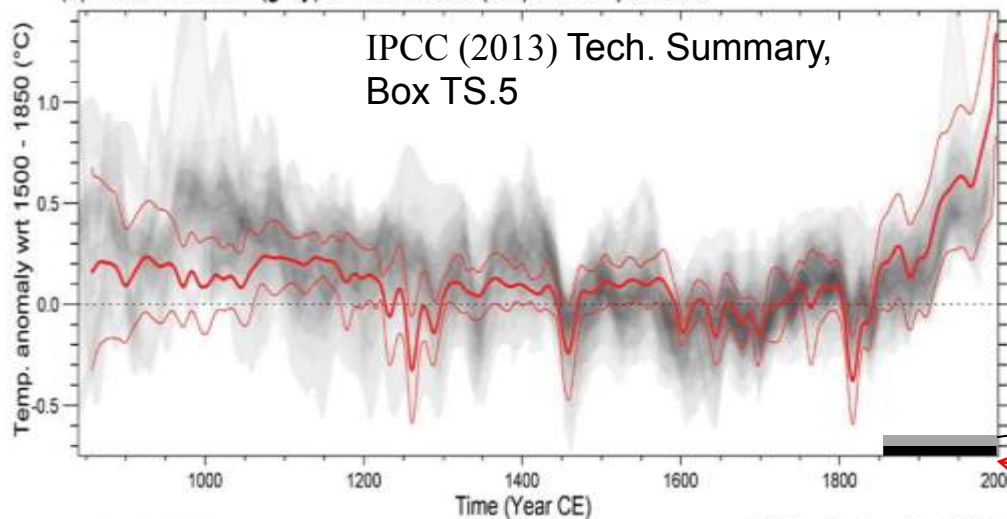
Middle: Changes in the July-September average summer Arctic sea ice extent

Bottom: Changes in global average sea level compared with 1900-1905 average

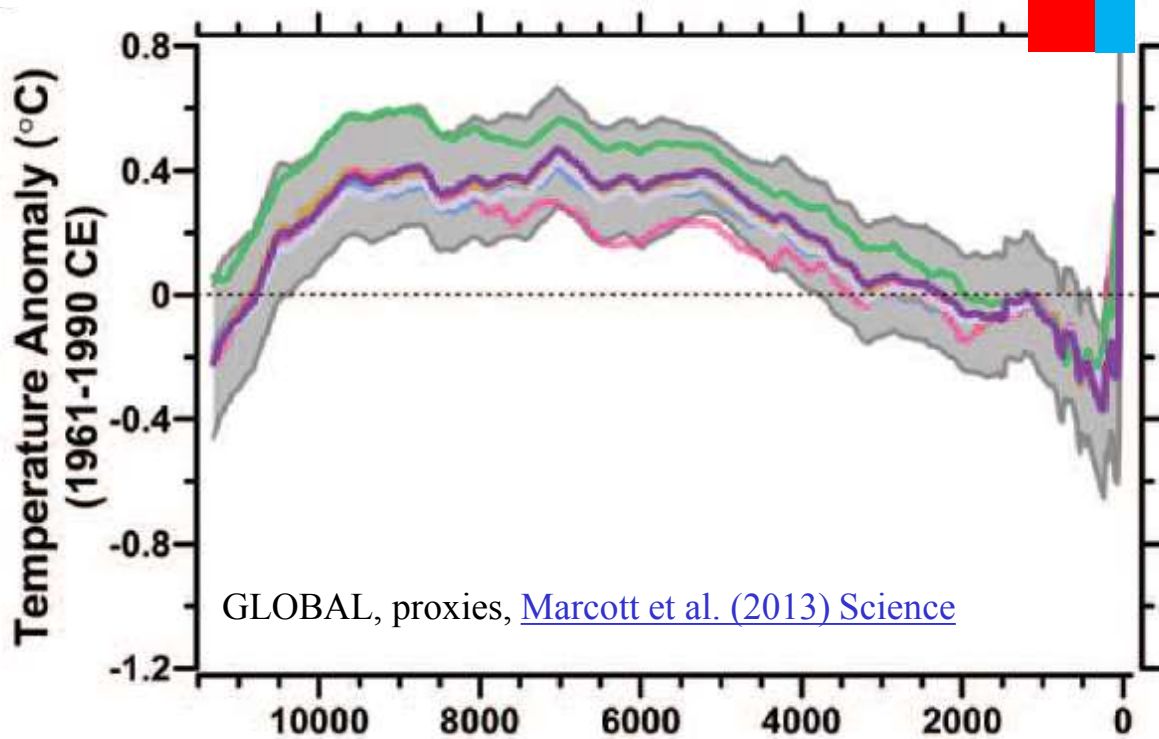
Source: IPCC WGI (2013) SPM



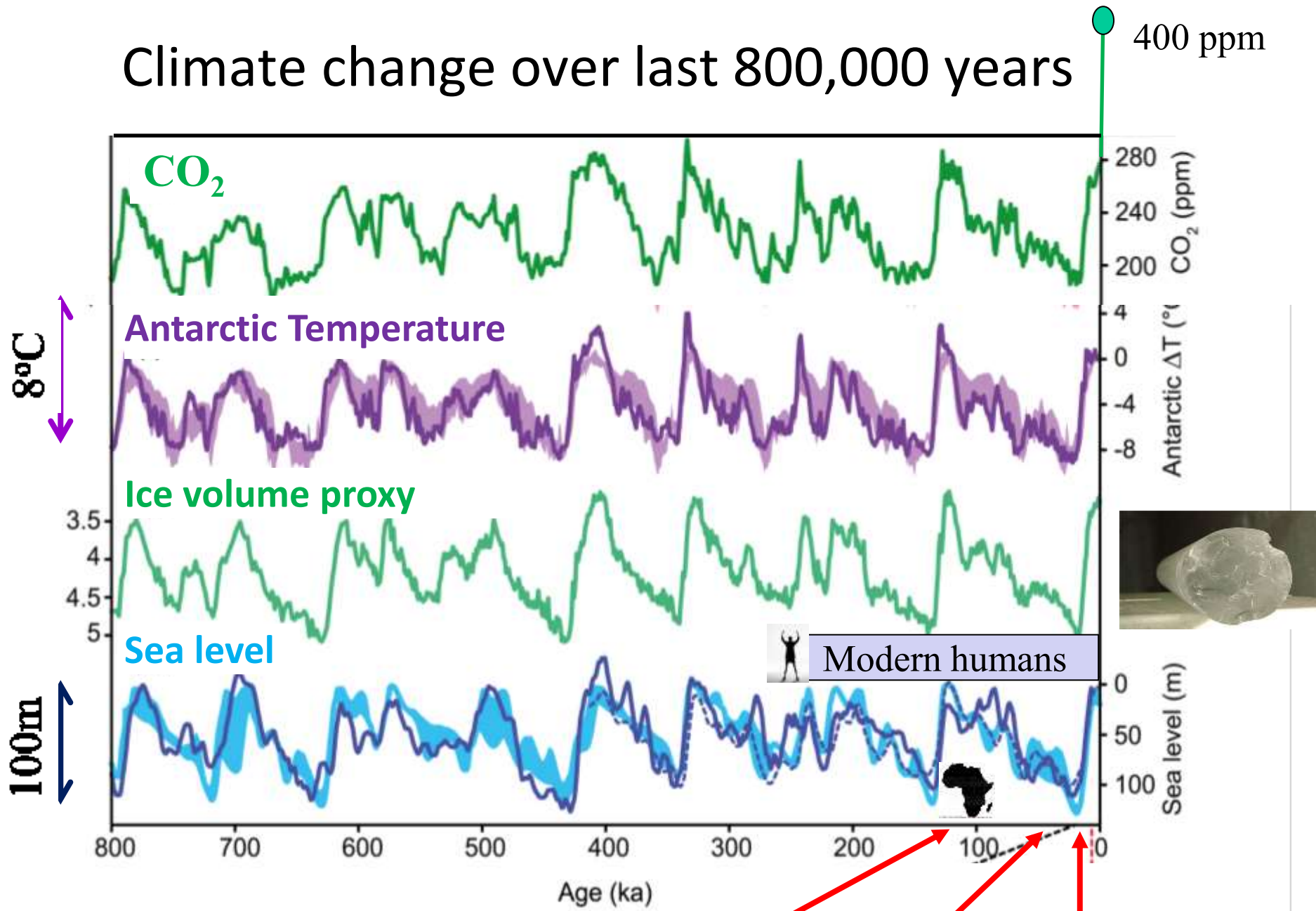
(b) Reconstructed (grey) and simulated (red) NH temperature



Northern hemisphere proxies



Climate change over last 800,000 years



[IPCC \(2013\) Chap. 5 Fig 5.3](#)

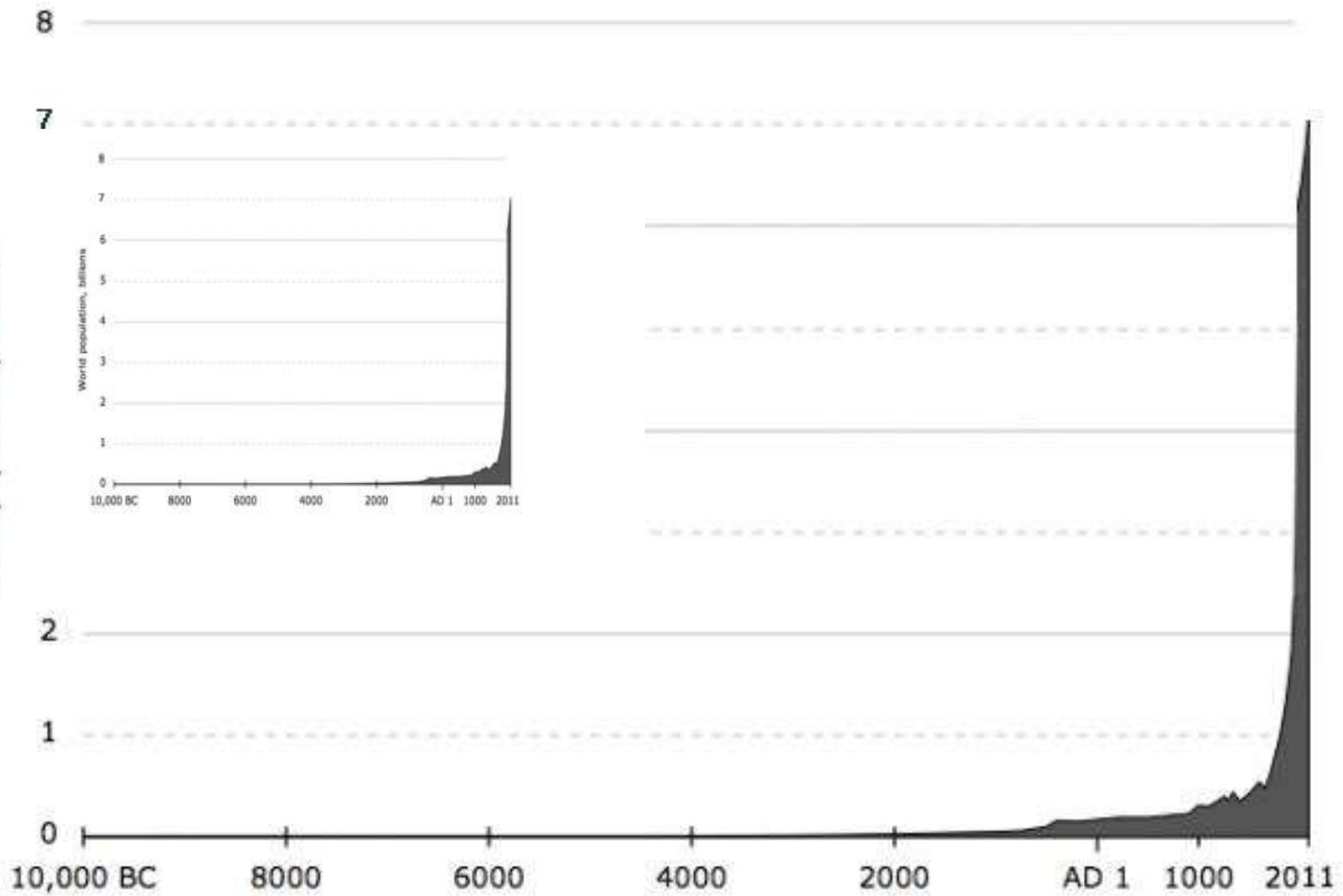
Africa Exodus Europe Agriculture

Is the warming unusual?

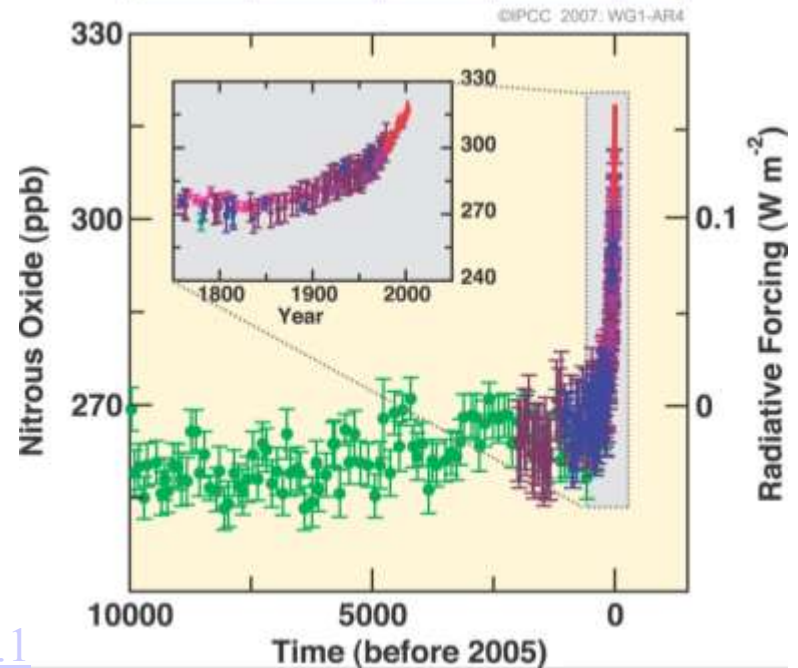
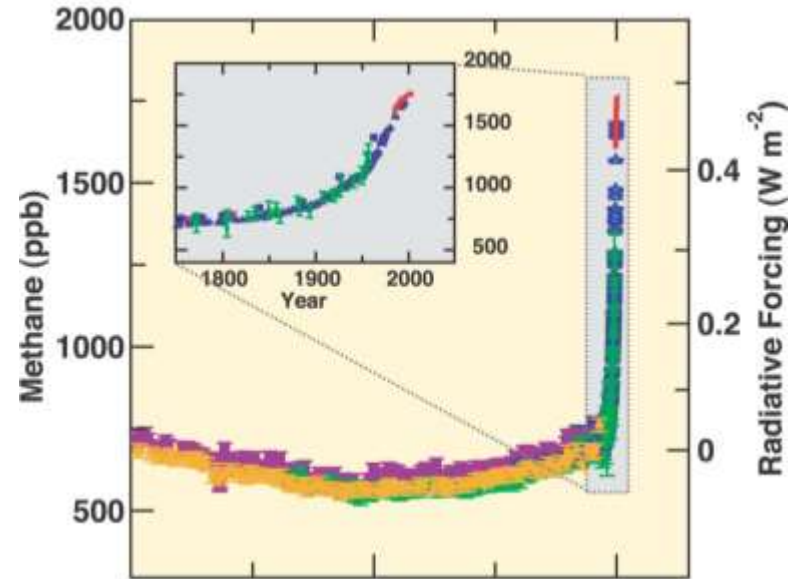
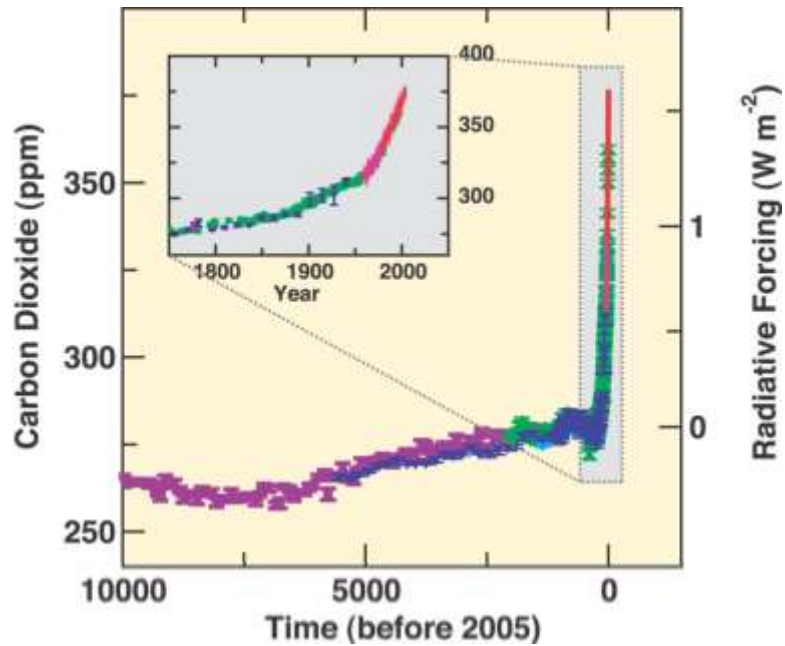
- Over the last 100 years the globe has warmed by around **0.8°C**
- 1983-2012 likely the **warmest 30 year** period in N. Hemisphere in past 1400 yrs
 - Comparably warmth in last 1400 years not as coherent in space or time as now
- Last time Arctic was warmer than today was probably **125,000 years ago**
 - Previous (very different) interglacial when sea level was 4-7m higher than today



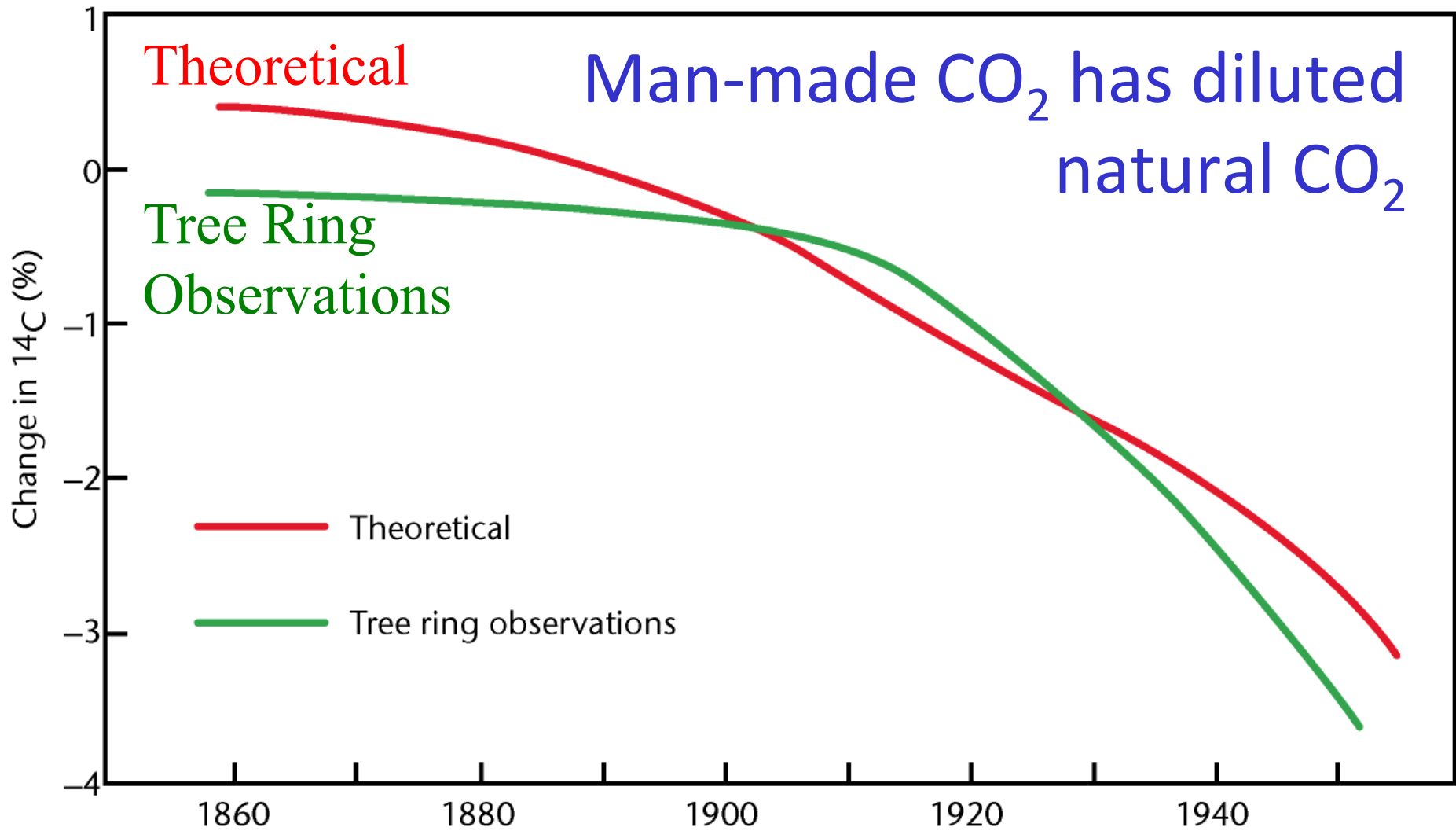
World population, billions



Changes in greenhouse gases from ice core and modern data

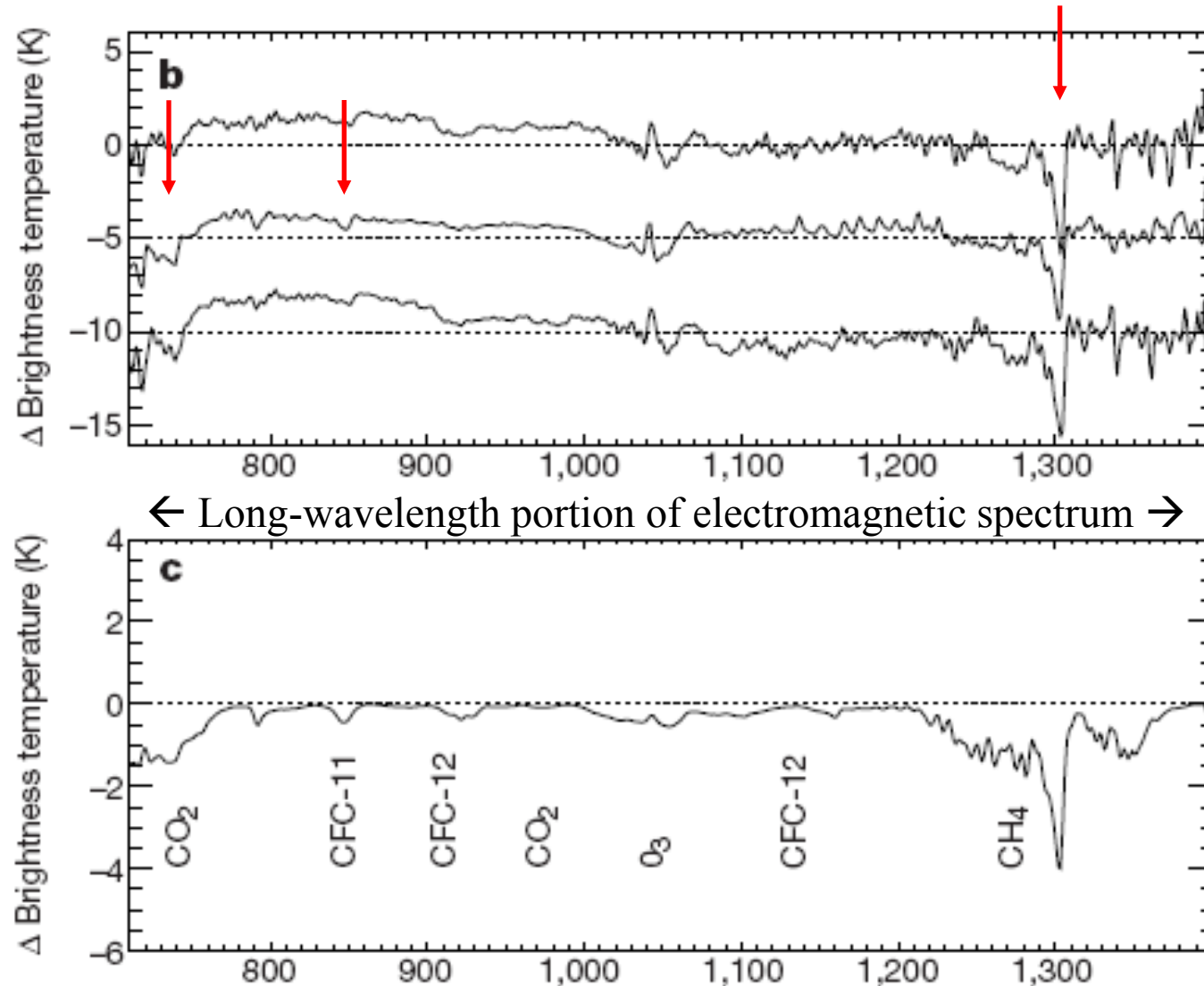


Carbon dioxide, methane
and nitrous oxide



Satellite observations detect enhanced greenhouse effect: 1997-1970

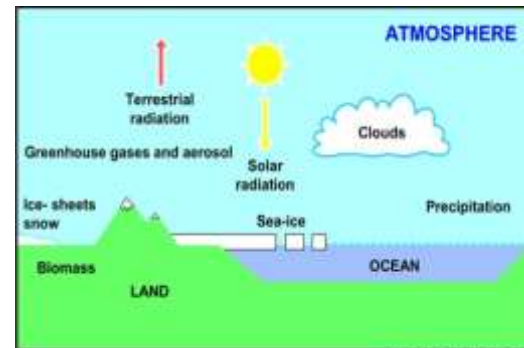
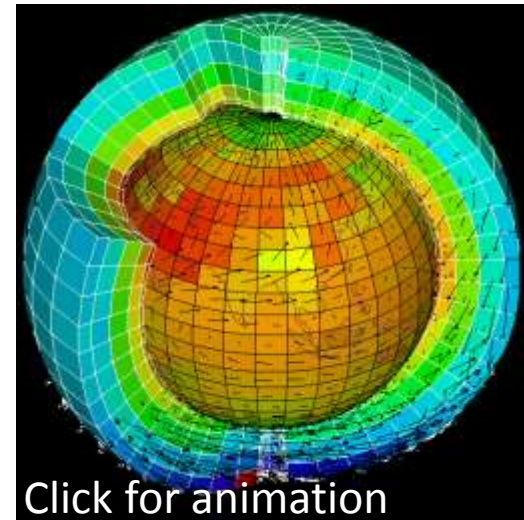
Harries et al. 2001, Nature



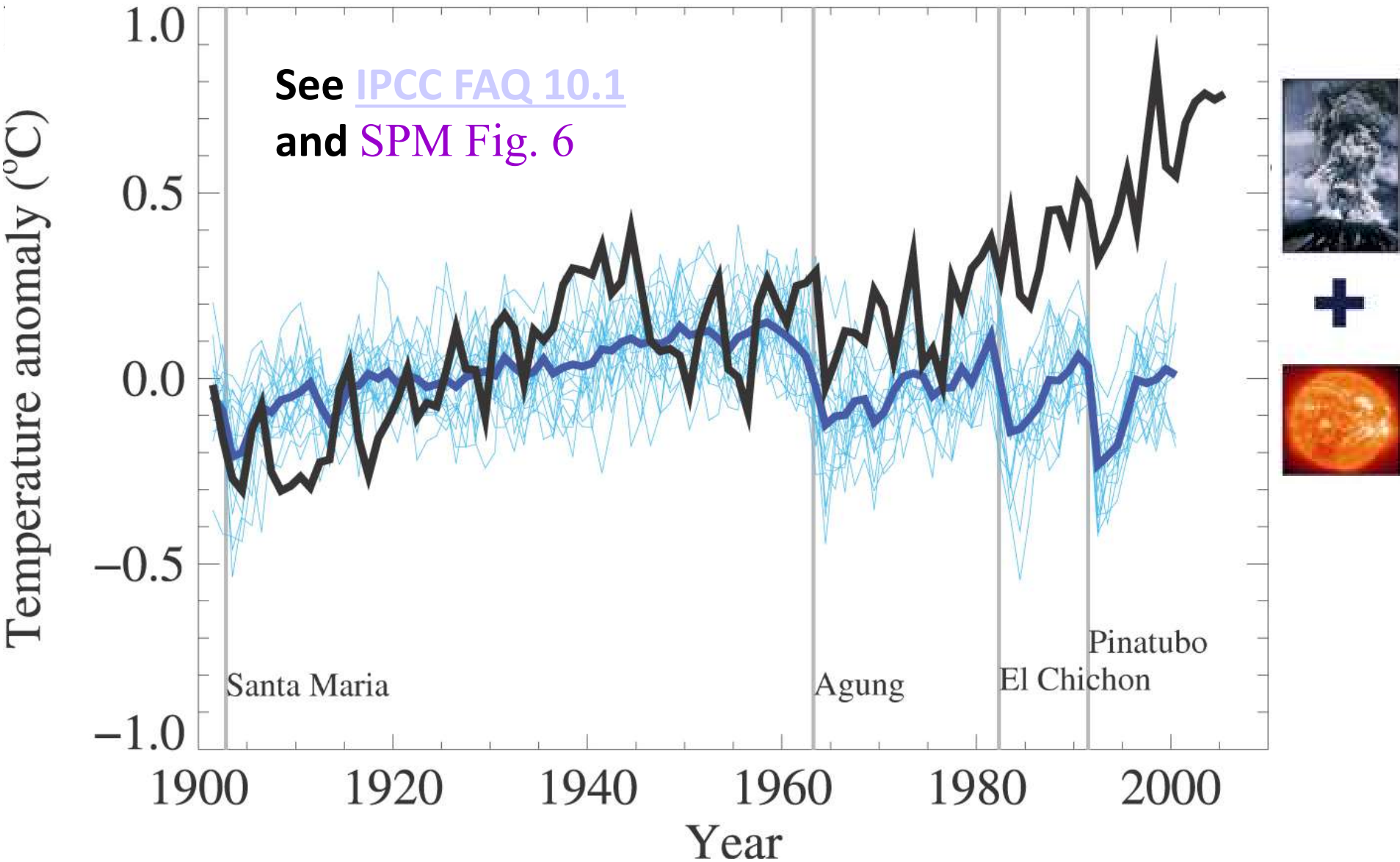
These results showed for the first time experimental confirmation of the significant increase in the greenhouse effect from trace gases such as carbon dioxide and methane

Attributing causes of climate change

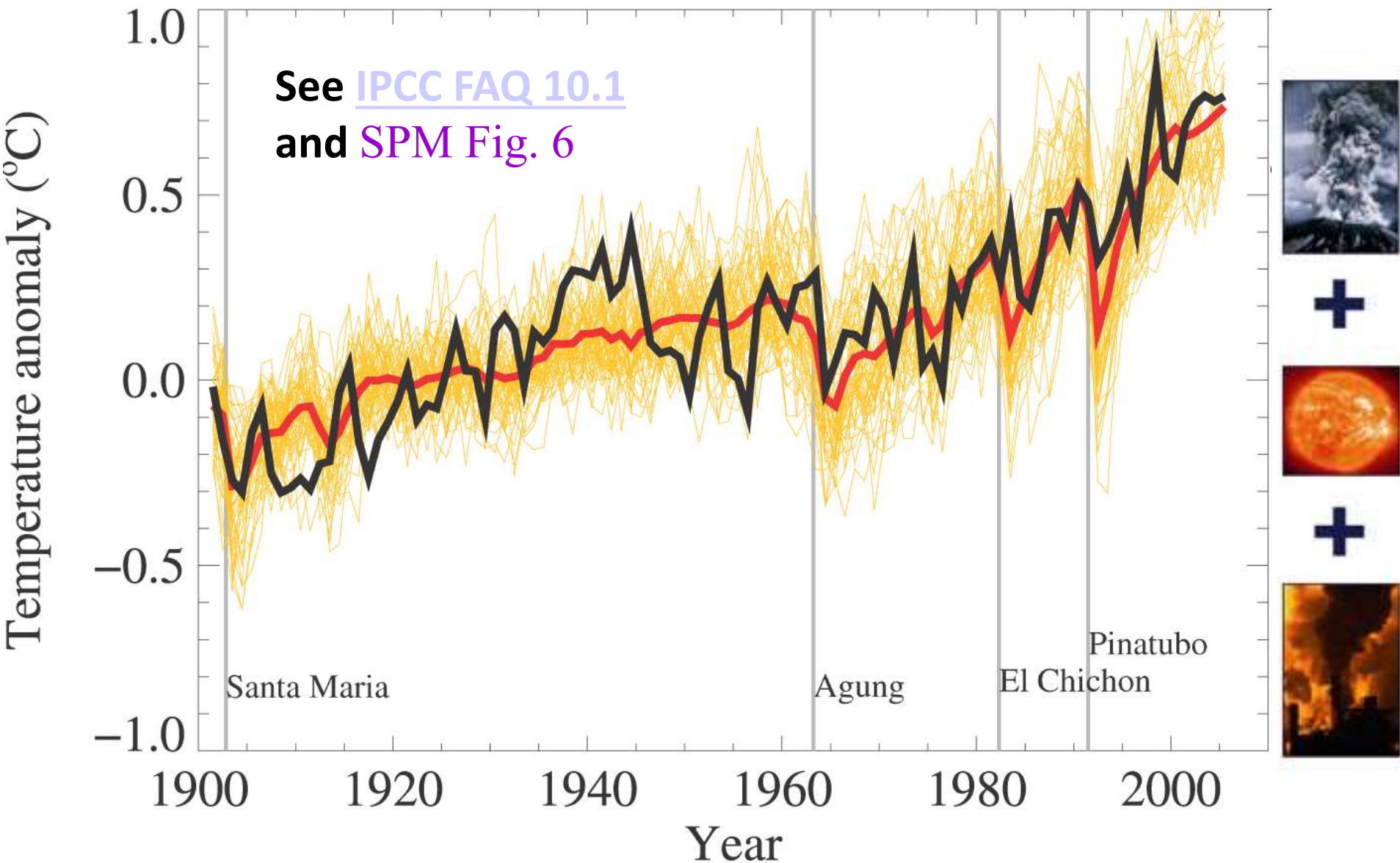
- How much of recent warming is explained by natural effects?
- To answer such questions, experiments can be performed with **climate simulations**
 - including just **natural factors** (ocean circulation, volcanic eruptions, changes in the sun, ...)
 - including **natural** and **anthropogenic factors** (e.g. greenhouse gas emissions which cause heating + sulphate aerosol pollutant particles which cause cooling)



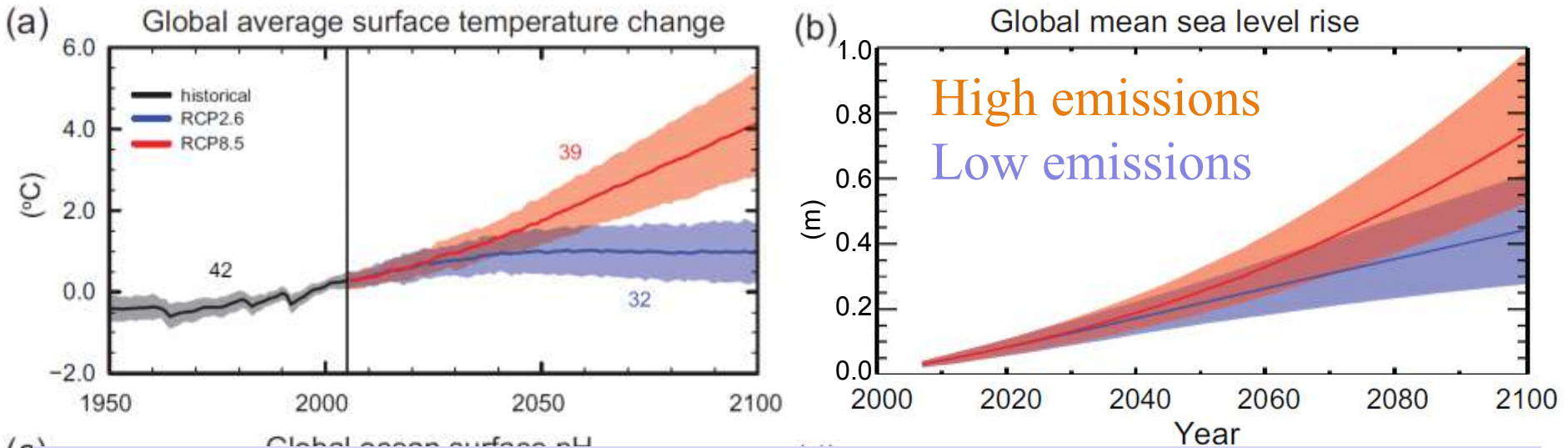
Natural factors cannot explain recent warming



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

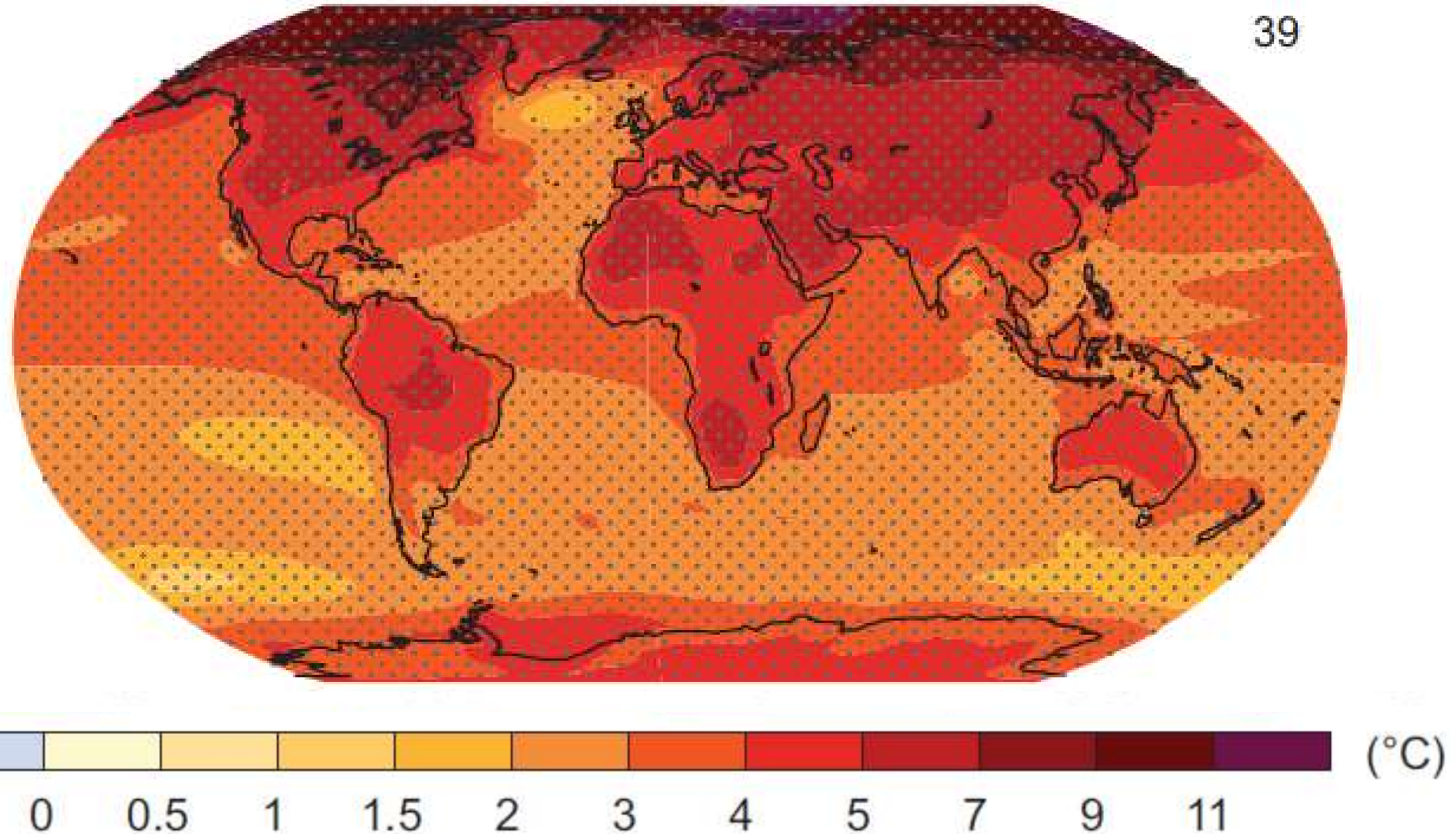


Future projections to 2100 from climate models

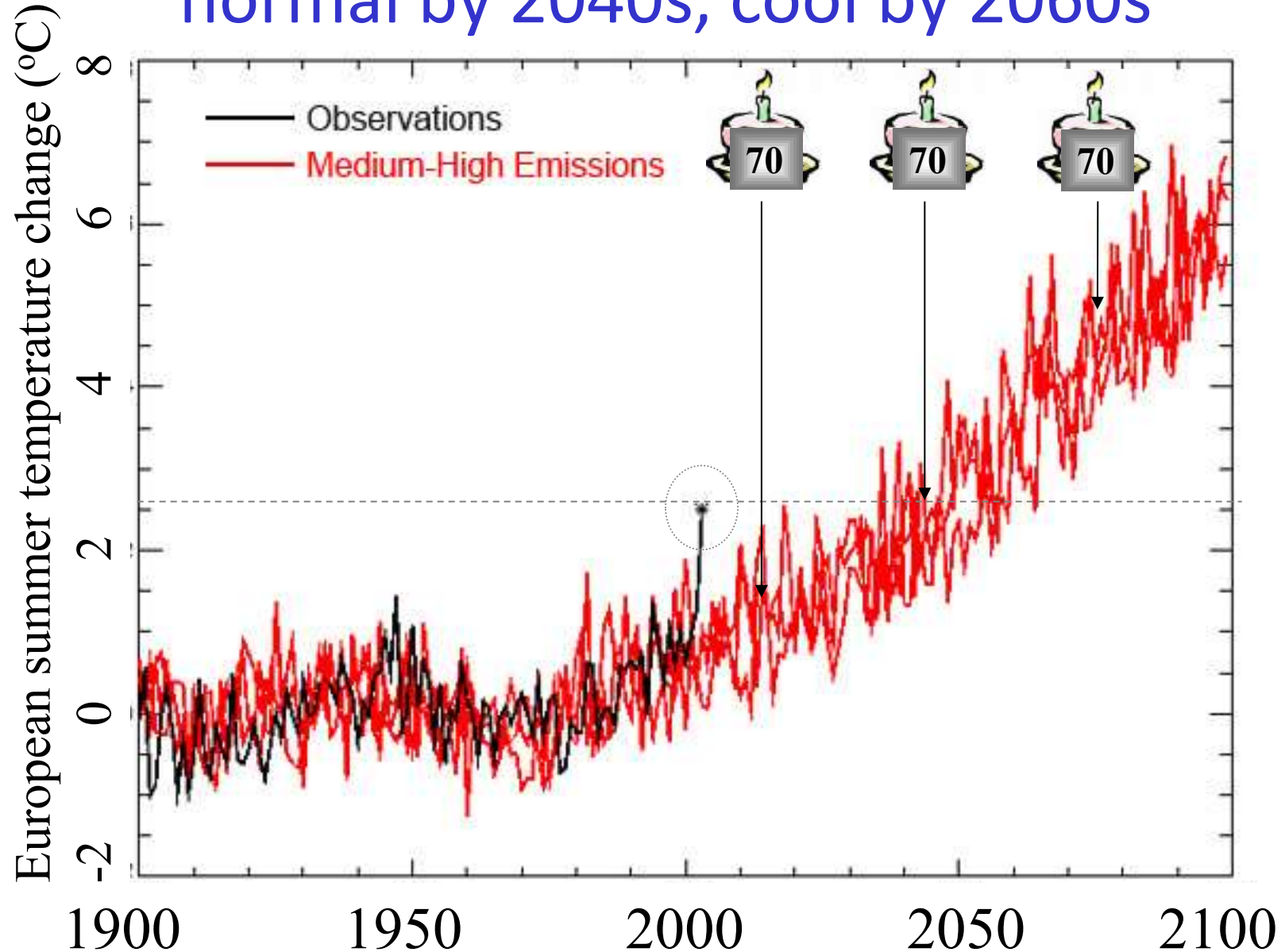


“Continued emissions of greenhouse gases will cause further warming and changes in all components of the climate system. Limiting climate change will require substantial and sustained reductions of greenhouse gas emissions.” [IPCC 2013 SPM]

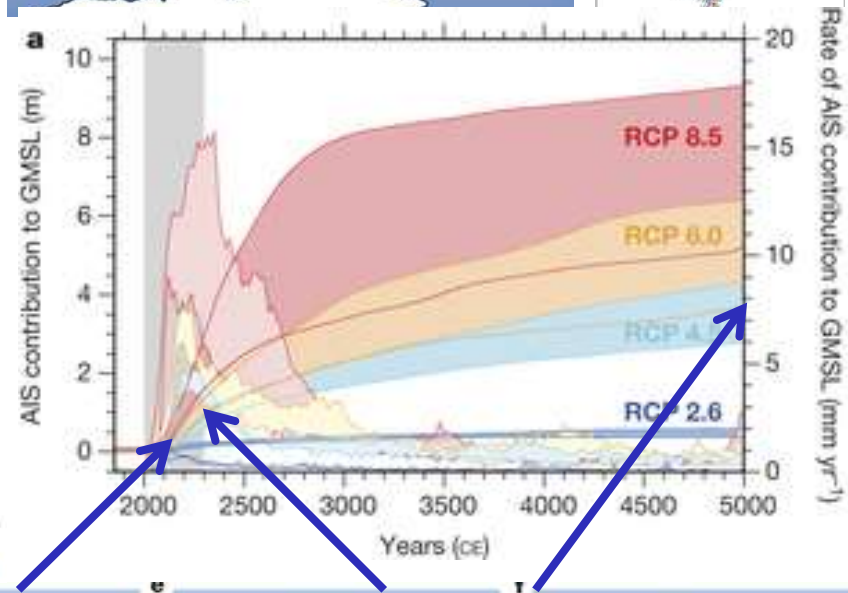
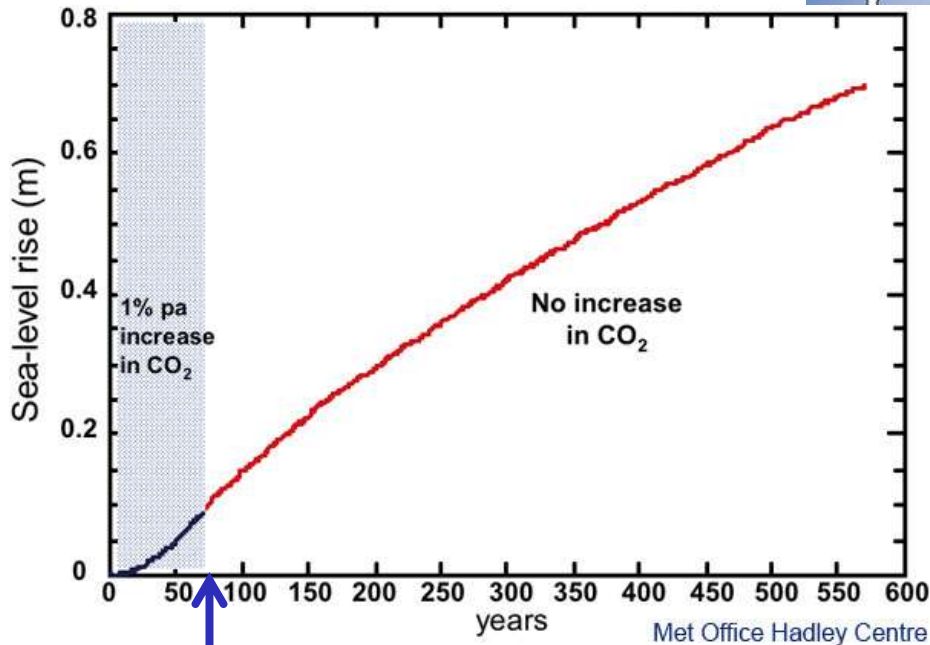
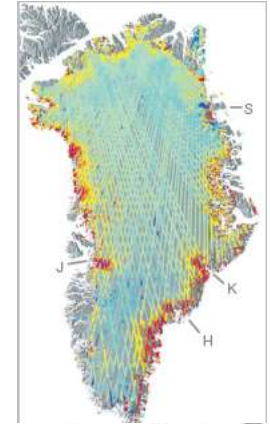
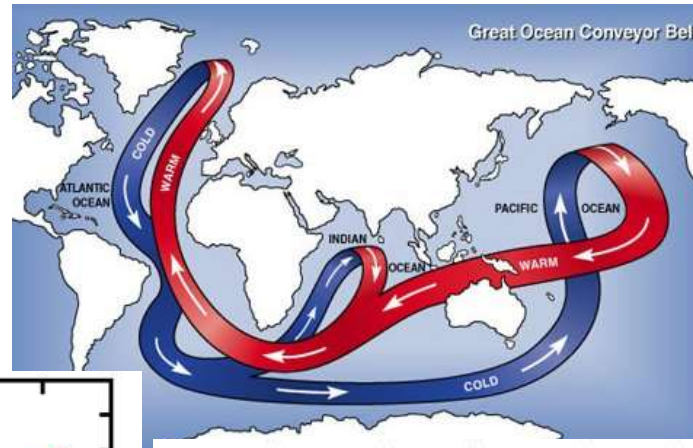
Change in average surface temperature (1986–2005 to 2081–2100) RCP 8.5 Scenario



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

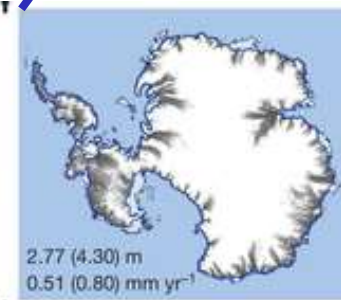
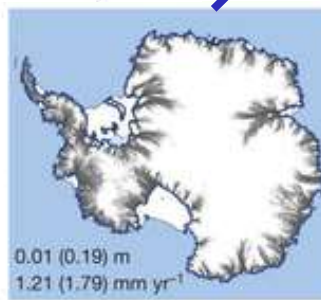


Long-term commitment to sea-level rise



CO₂ increases stops here

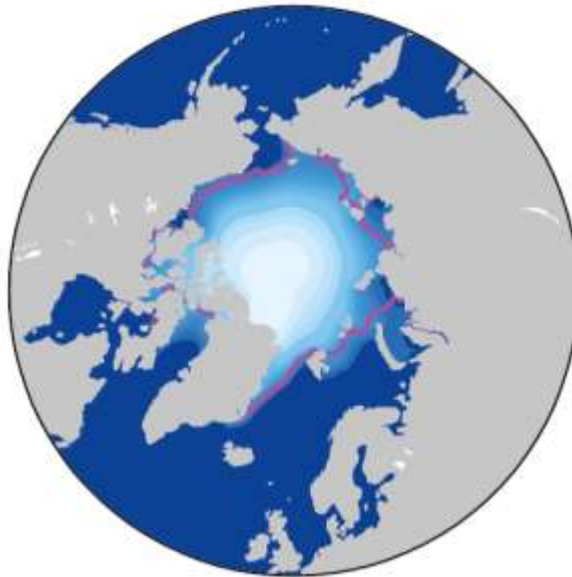
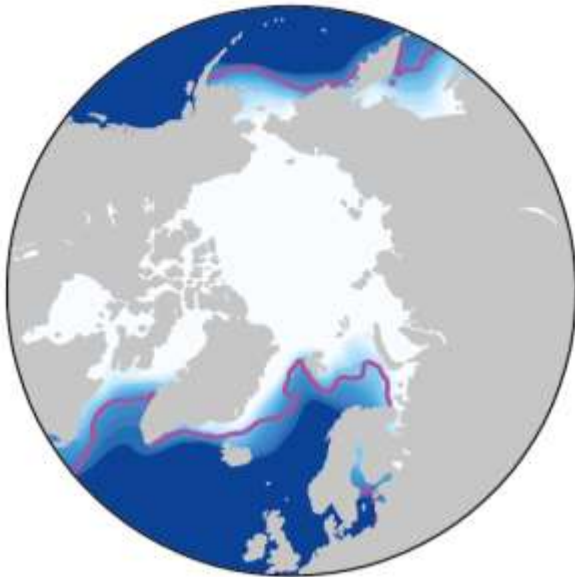
Mid/low emissions scenario: RCP4.5



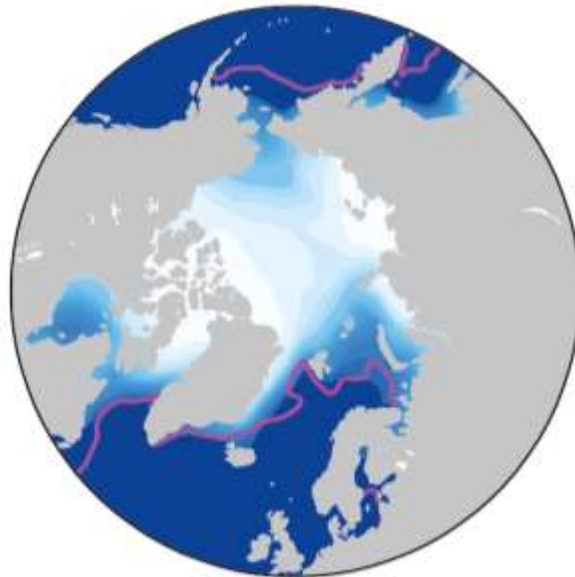
February

September

1986-2005

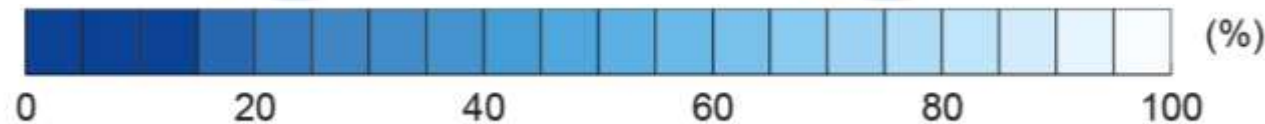


2081-2100 (RCP 8.5)



Arctic sea ice extent is projected to diminish over the 21st century

94% decrease in September and 34% decrease in February for the RCP8.5 scenario

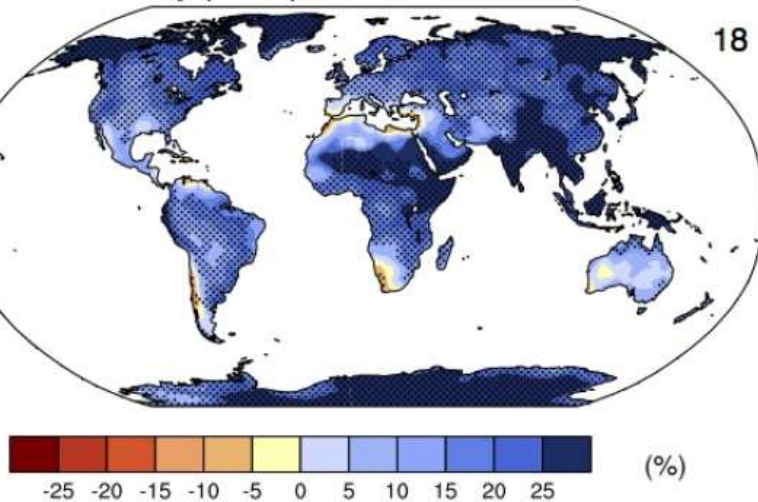


IPCC (2013)
WG1 Fig. 12.29

Projections of the water cycle

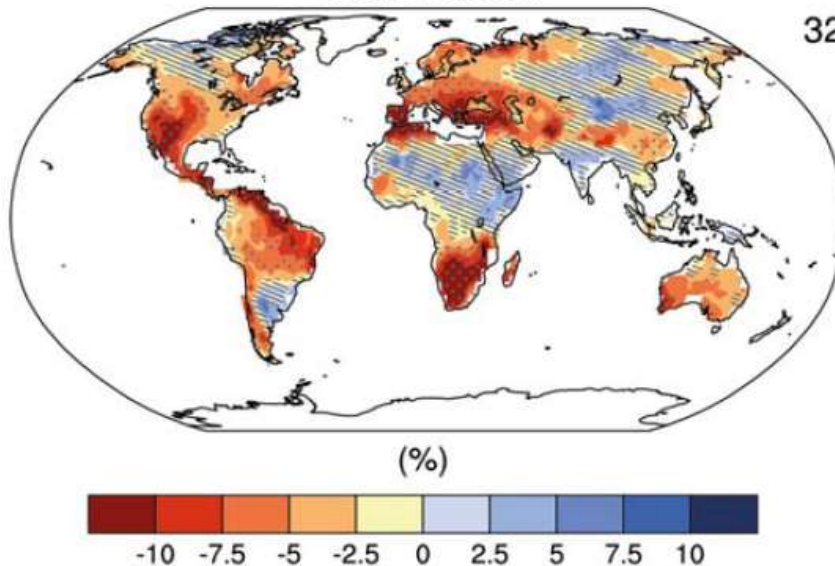
Precipitation intensity

18



Soil moisture

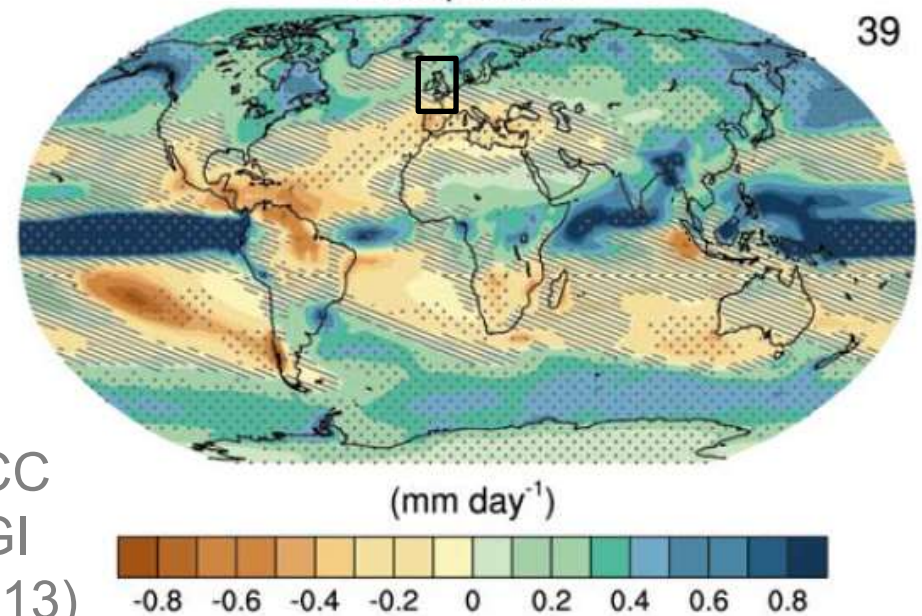
32



- Increased Precipitation
- More Intense Rainfall
- More droughts
- Wet regions get wetter, dry regions get drier?
- Regional projections??

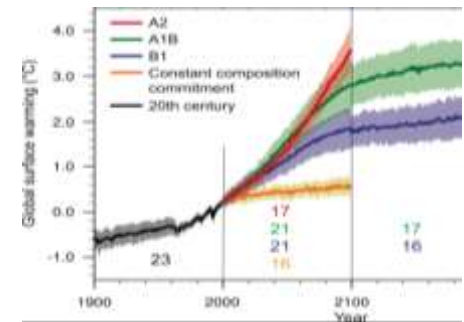
Precipitation

39



IPCC
WGI
(2013)

Summary

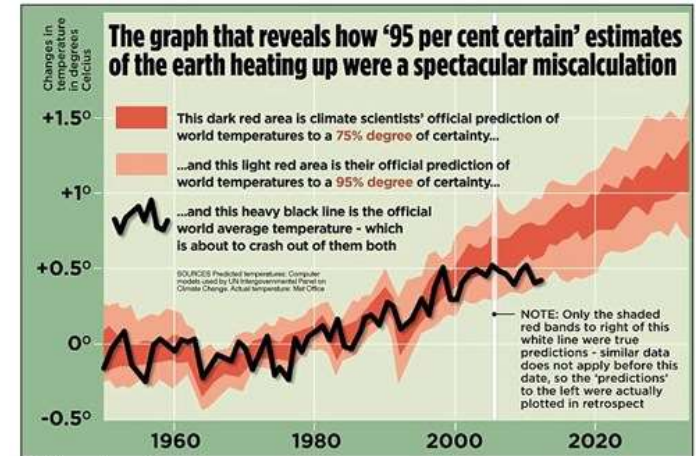


- The planet is warming and this is primarily attributable to rising greenhouse gas concentrations
- Greenhouse gases at highest levels for > 800,000 yrs
- Physics of greenhouse effect well understood
- Substantial changes in global temperature and rainfall patterns are projected using computer simulations
- Predicting regional climate change is a challenge...
 - Will substantial greenhouse gas emissions continue?
 - Are “knock on effects” of warming amplifying or reducing the magnitude of change (e.g. clouds, land surface, ...)?
 - Changes in atmospheric and oceanic circulations change are crucial for local impacts yet challenging to predict

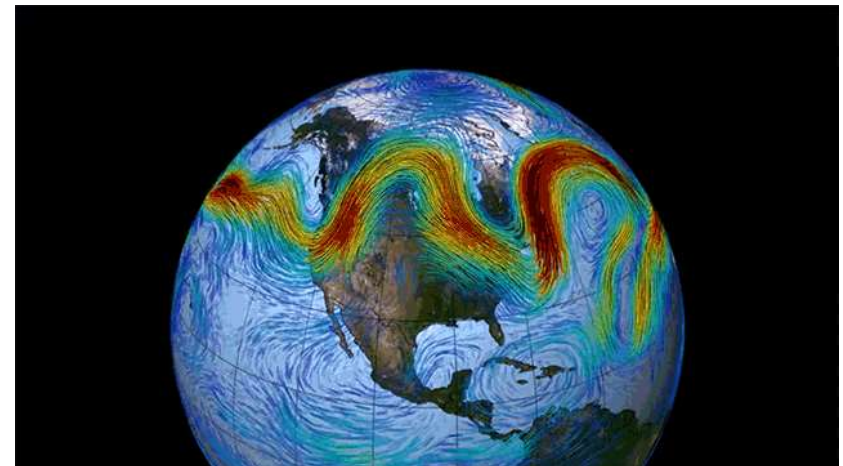
See Reading [MOOC on Our Changing Climate Change](#)

Outstanding questions

- Has there been a hiatus in global warming?
- Are clouds amplifying or reducing climate change?
- How will atmospheric and ocean circulations change?



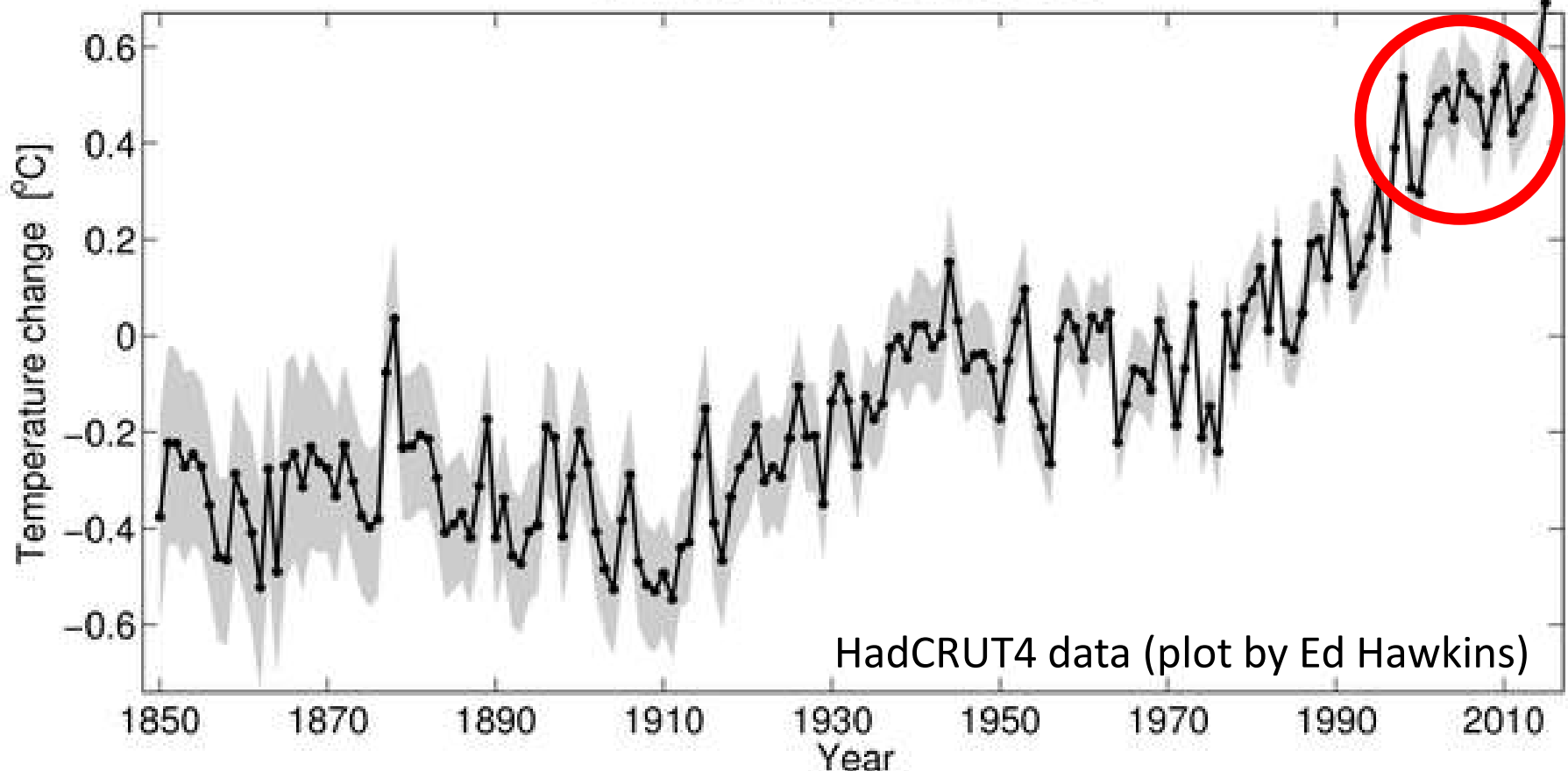
From the [Mail on Sunday 16th March 2013](#)



Has there been a hiatus in global warming?

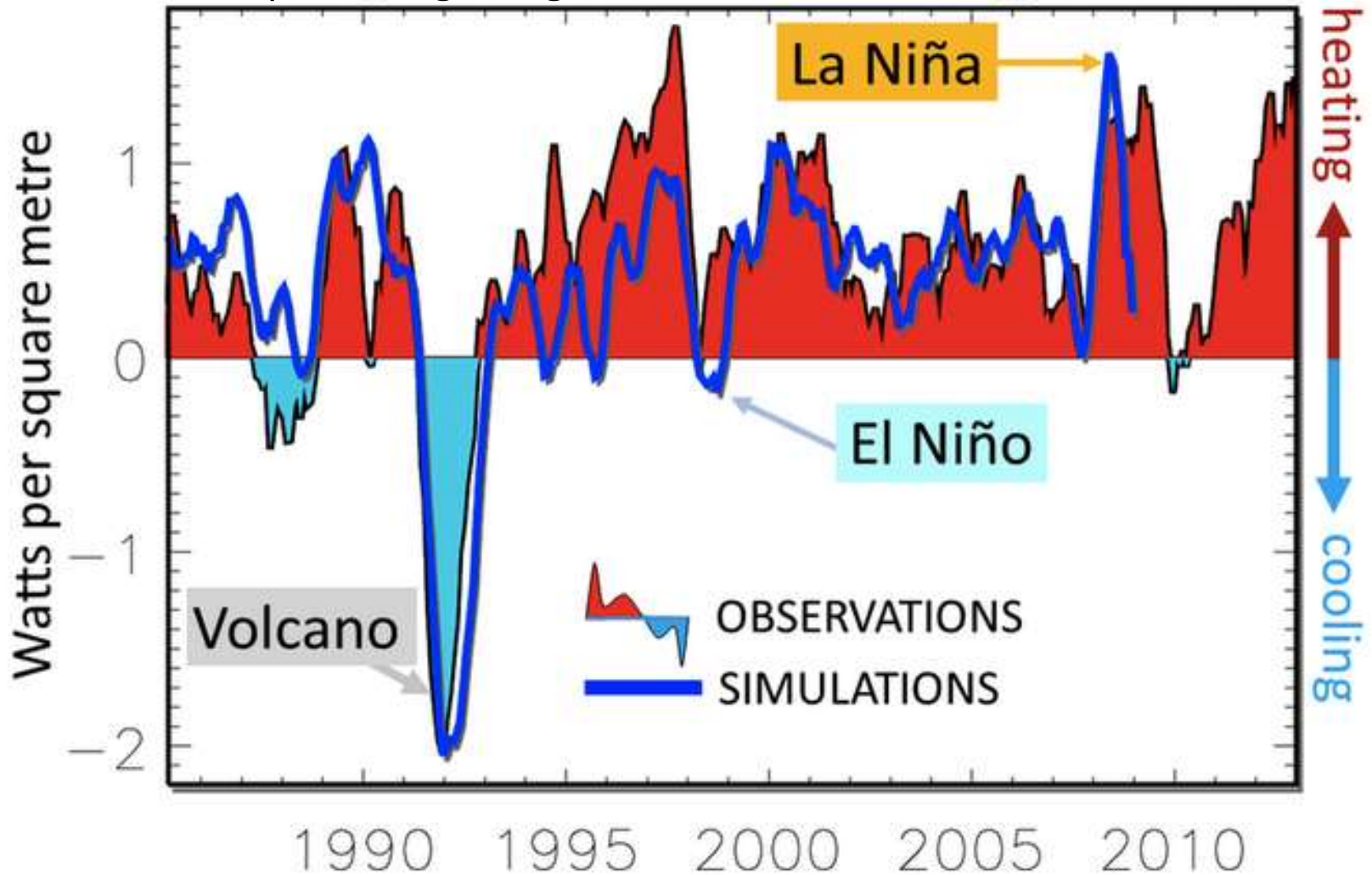


Global temperature since 1850



Planet Earth continues to heat up...

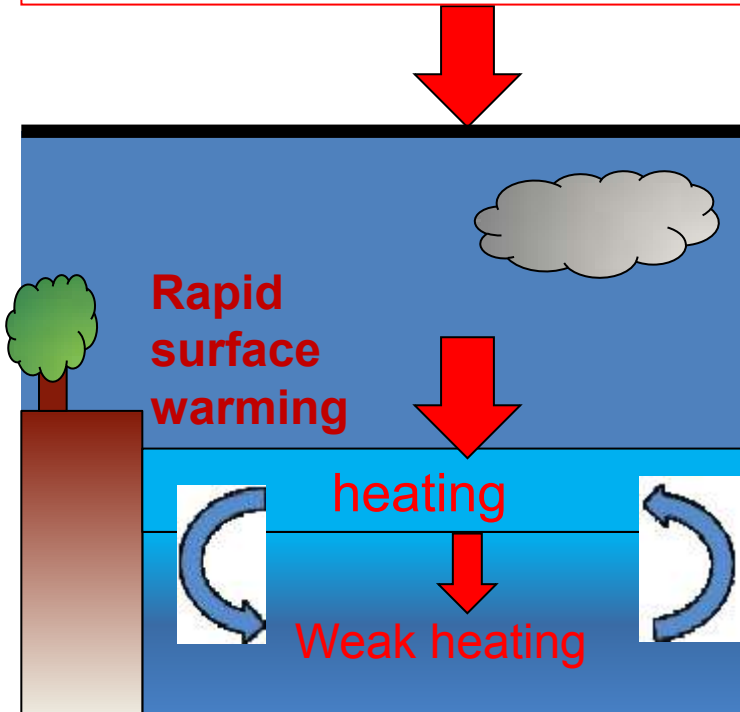
The planet is gaining heat at the rate of 300 trillion Watts...



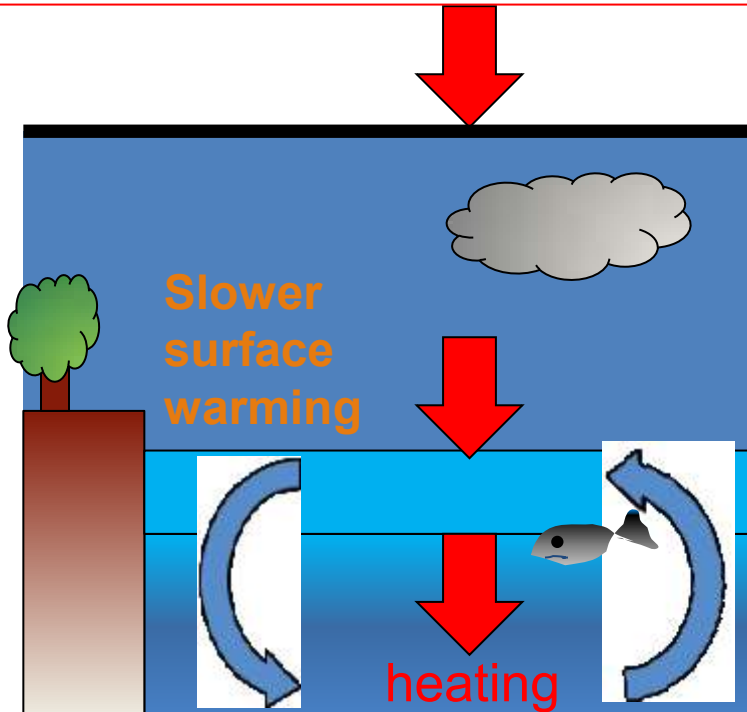
[Loeb et al. \(2012\) Nat. Geosci.](#) ; [Allan et al. \(2014\) GRL](#)

Decadal climate fluctuations expected

Heating due to rising greenhouse gas concentrations also influenced by aerosol pollution and natural factors e.g. volcanoes, the sun



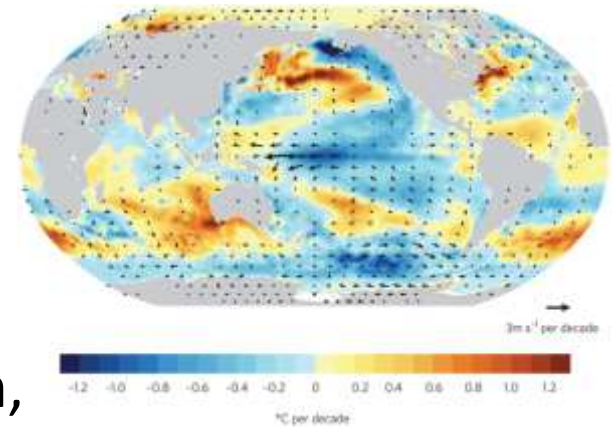
1980s-1990s: heating of upper layers of the ocean – rapidly rising surface temperature



2000s: heating of deeper layers of the ocean – slower rises in surface temperature

Large body of research – listed on [DEEP-C project website](#)

A hiatus in global warming?



- No: the oceans have continued to warm, sea levels have continued to rise and ice is melting...
- But...**natural factors have temporarily suppressed the rate of surface warming** slightly
 - A slight dimming of the sun and small volcanic eruptions offset some of the heating from rising greenhouse gases
 - Ocean fluctuations rearranged where heat has accumulated
 - Climate models can simulate ocean fluctuations but are not designed to capture timings of lumps and bumps in temperature record.
 - 2014 -2016 likely to be the warmest in the instrumental record
- How much the planet will warm in response to greenhouse gas emissions mostly depends on total emissions...

Implications for projections

