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Climate Science from a Climate Scientist

Professor Richard Allan,
Department of Meteorology, University of Reading

John Hall Venice Course, National Gallery, 25th January 2017

Walker INSTITUTE

National Centre for Atmospheric Science
NATURAL ENVIRONMENT RESEARCH COUNCIL

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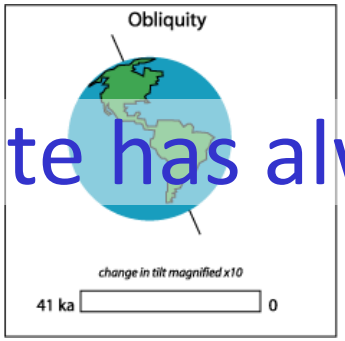
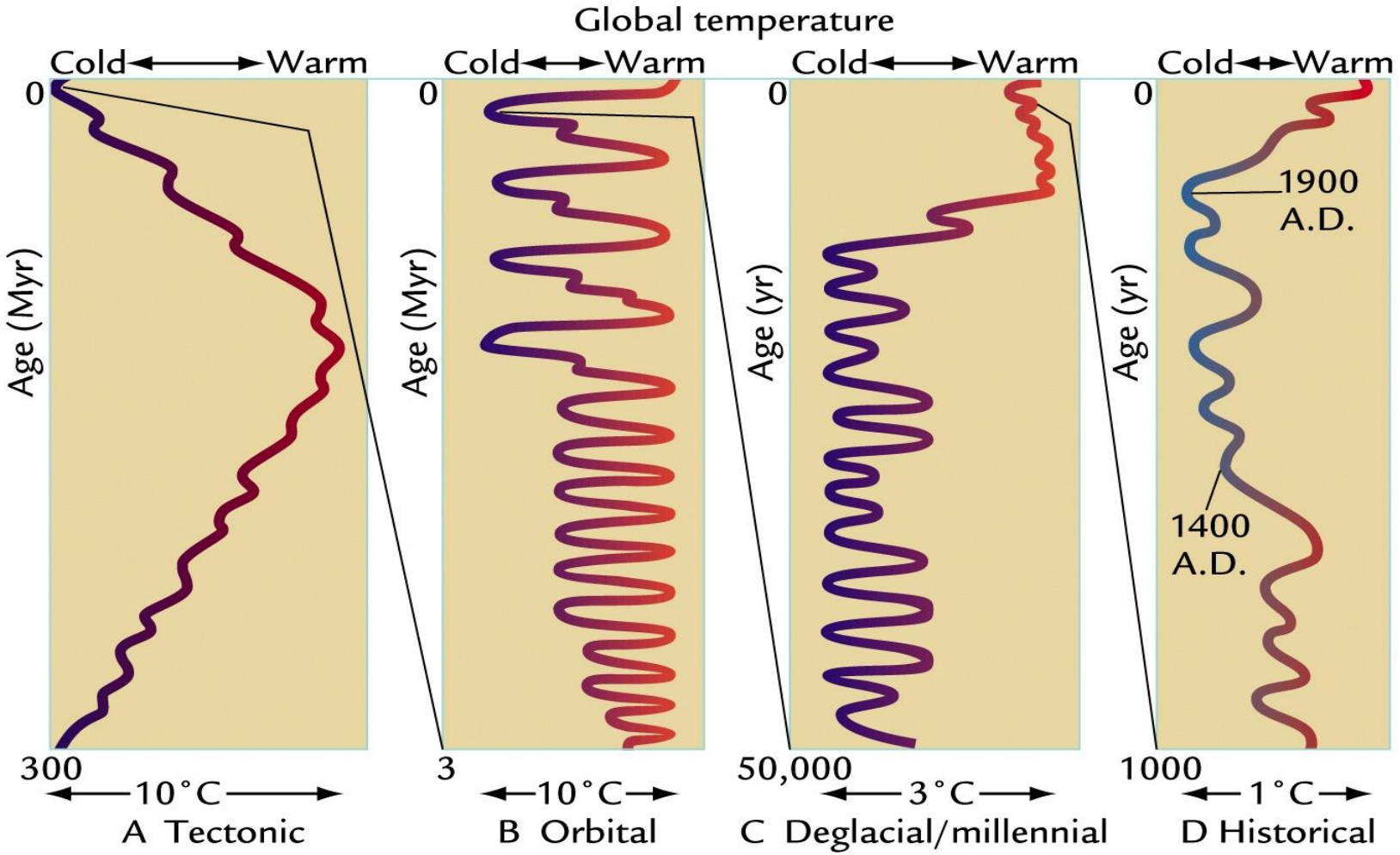
NERC SCIENCE OF THE ENVIRONMENT

Earth's Climate has always been changing





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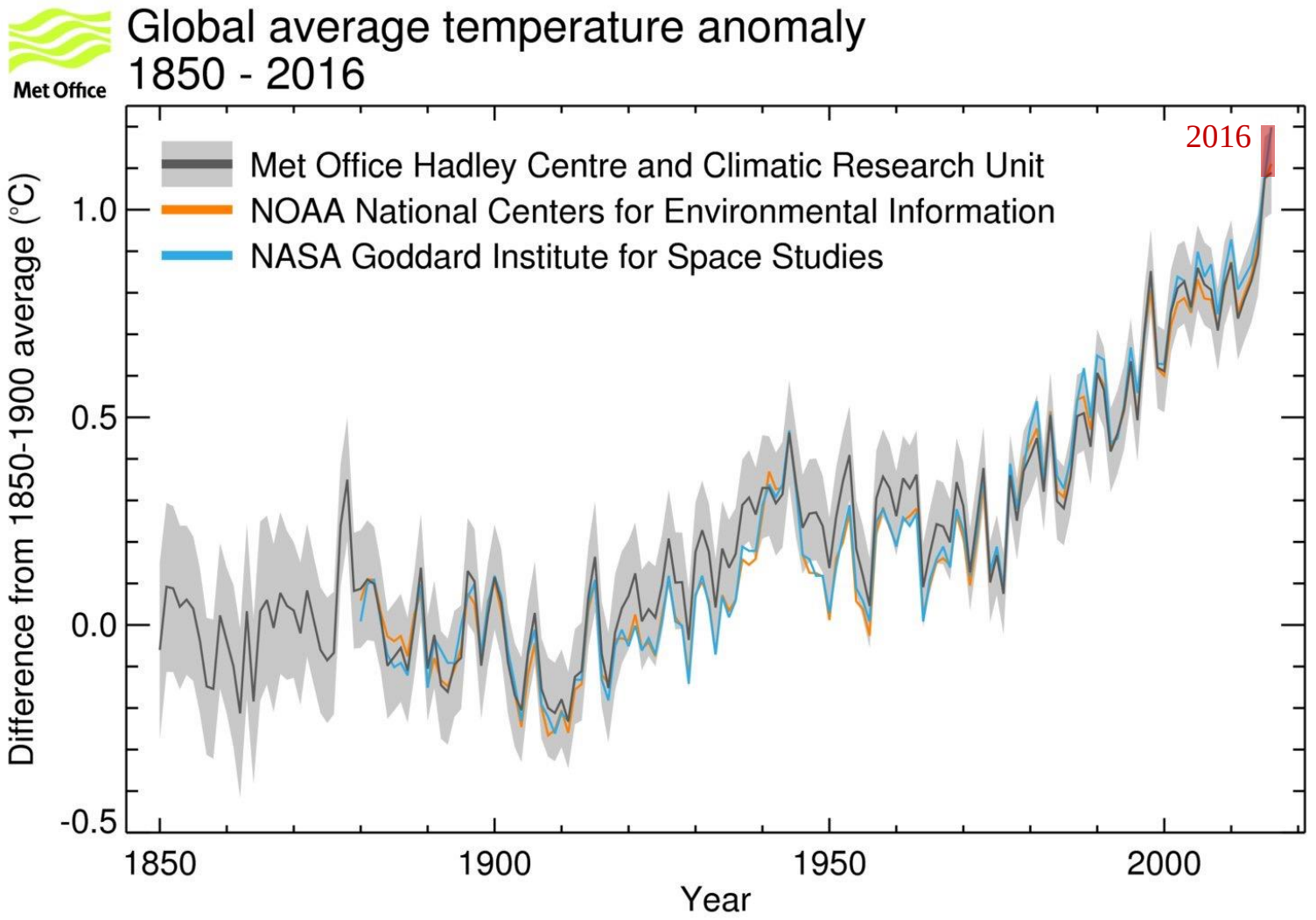
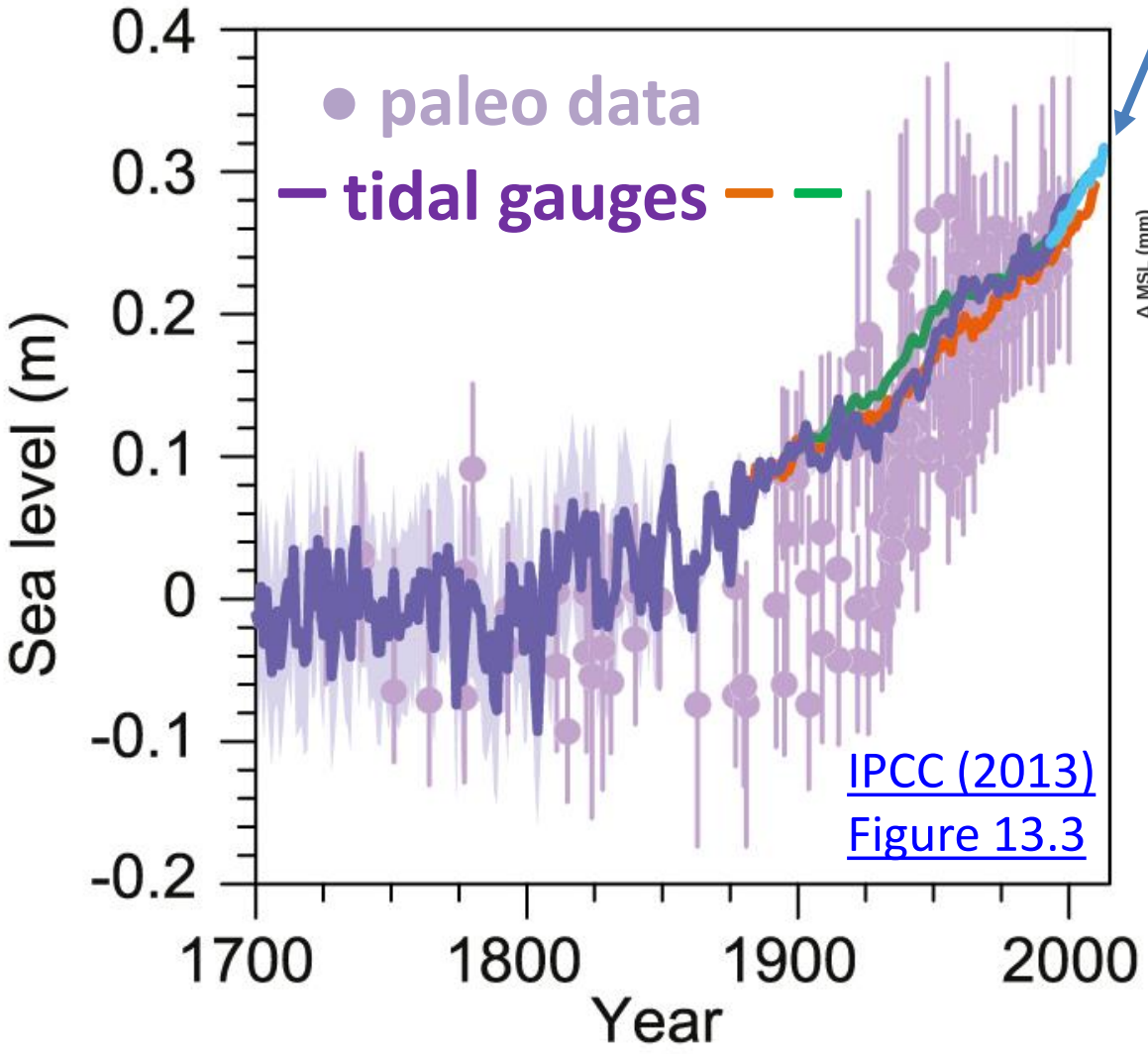
1) Is climate changing now?

The planet is warming



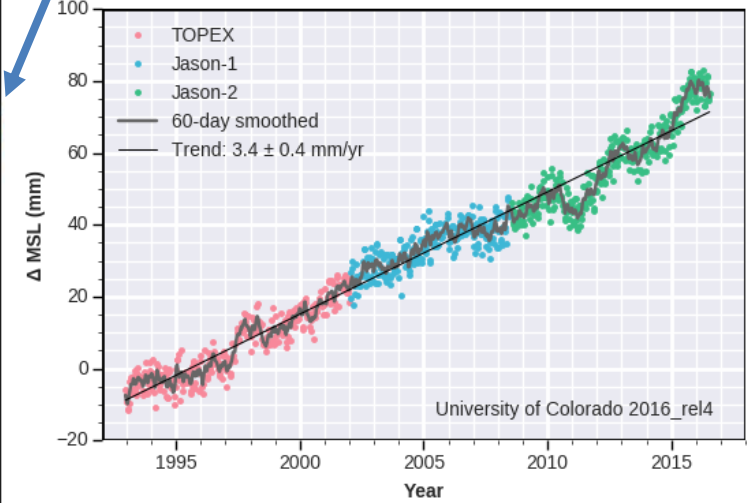
www.metoffice.gov.uk/research/monitoring/climate/surface-temperature

Global average sea level is rising…



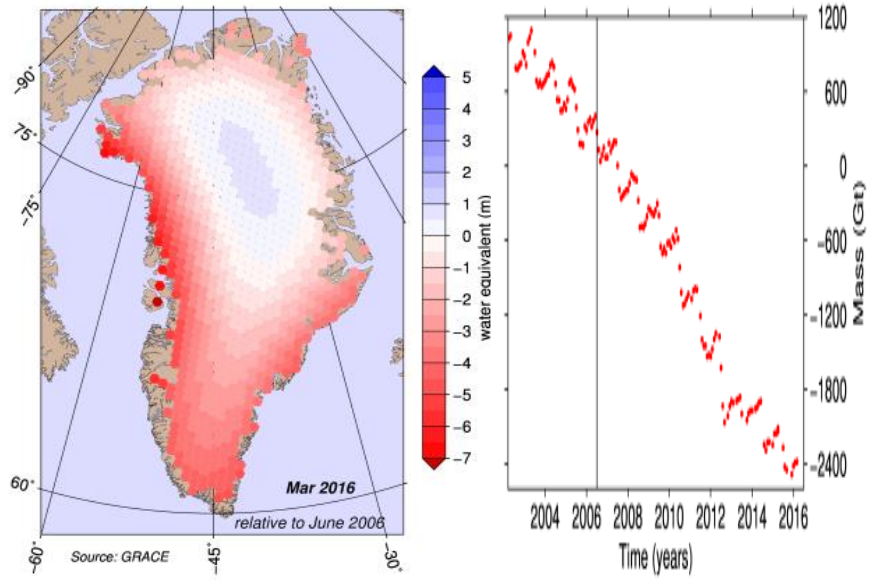
IPCC (2013)
Figure 13.3

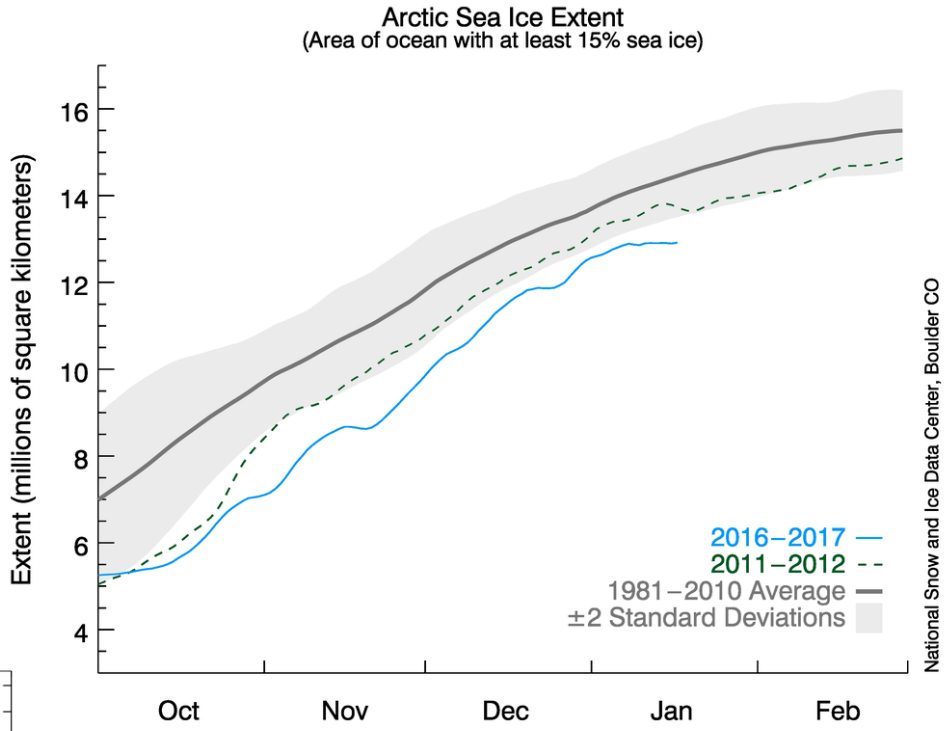
Satellite Altimeter data

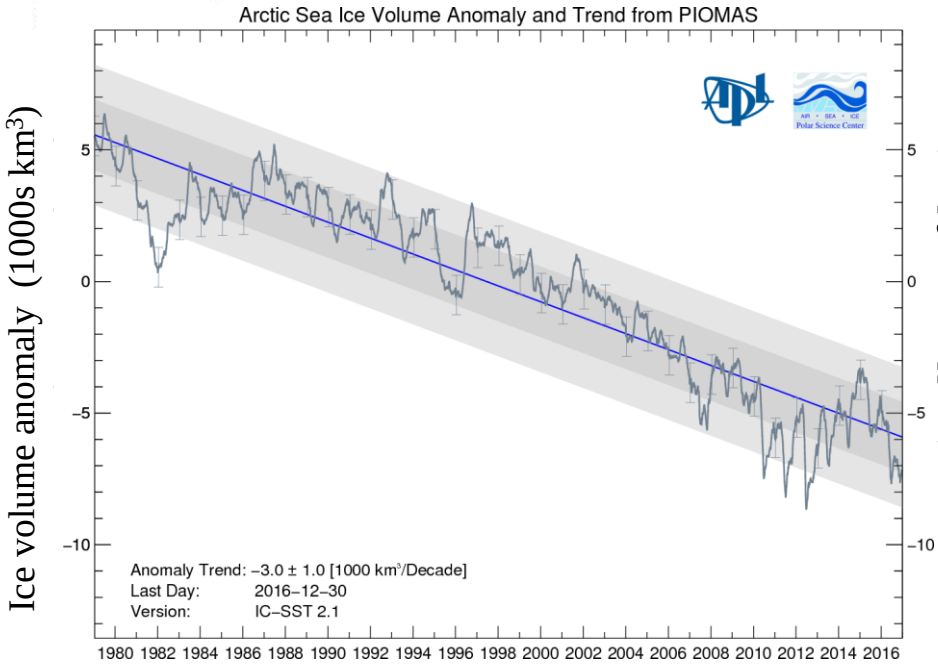


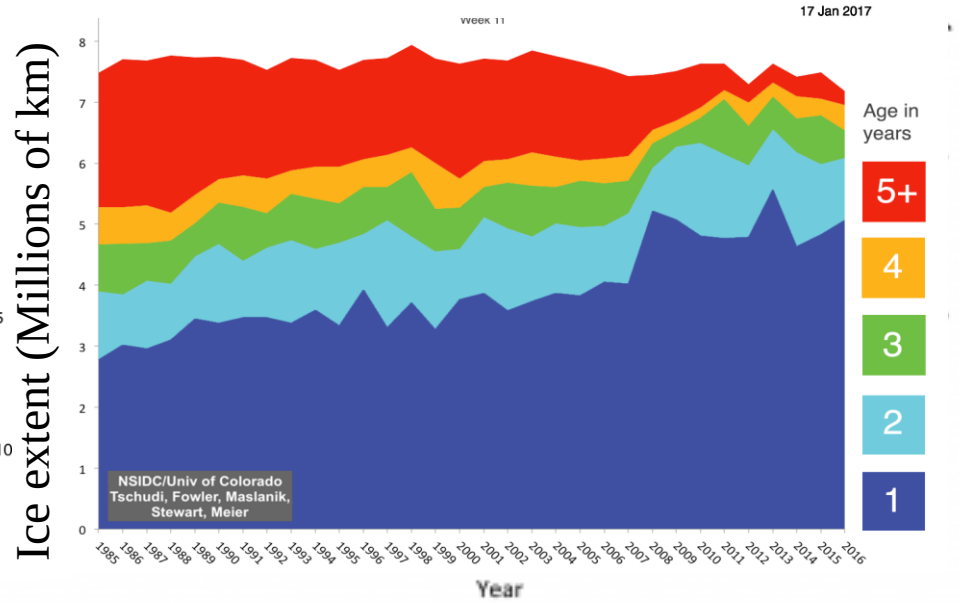
http://sealevel.colorado.edu/

Melting of Arctic Ice



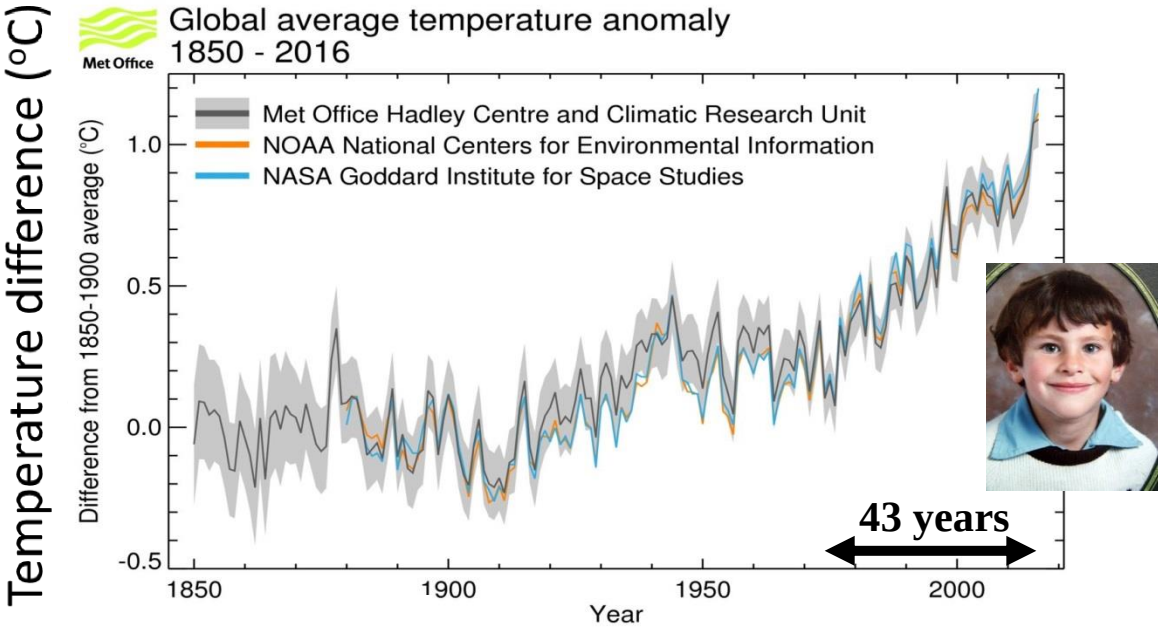




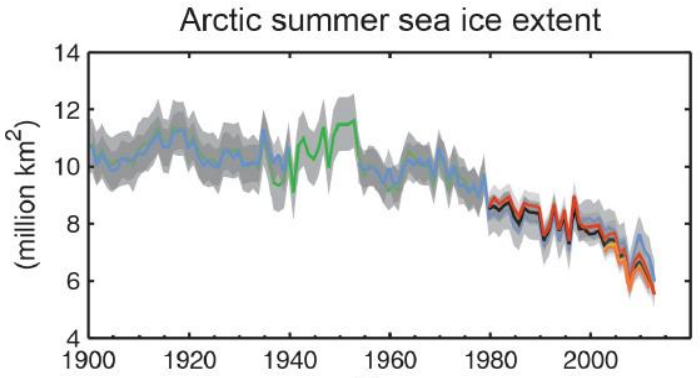


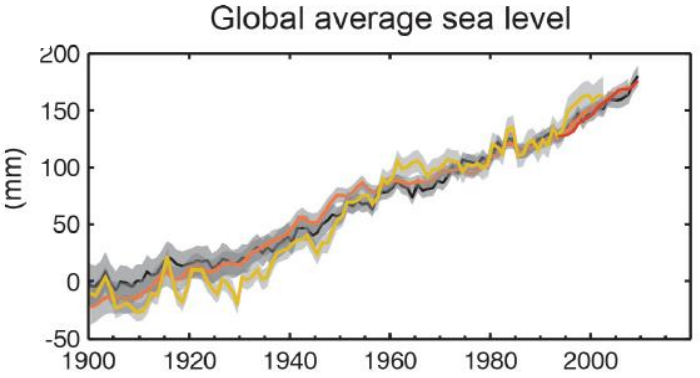
Evidence for current climate change

"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)



Top: 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





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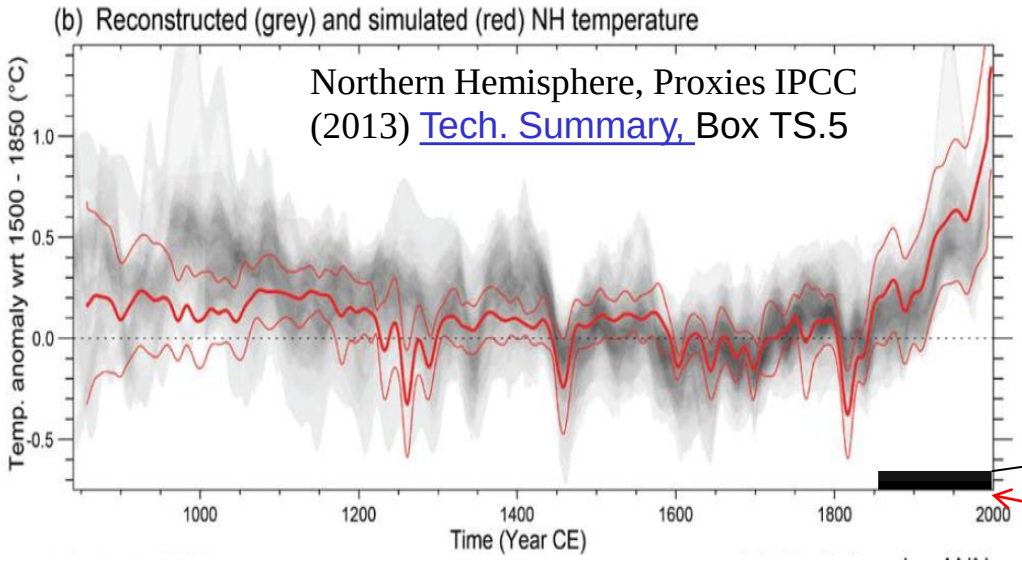
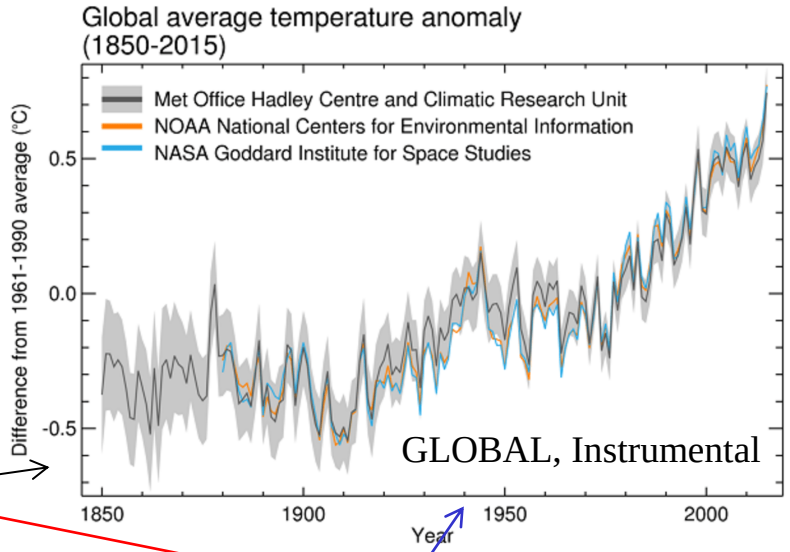
2) Is the warming unusual?

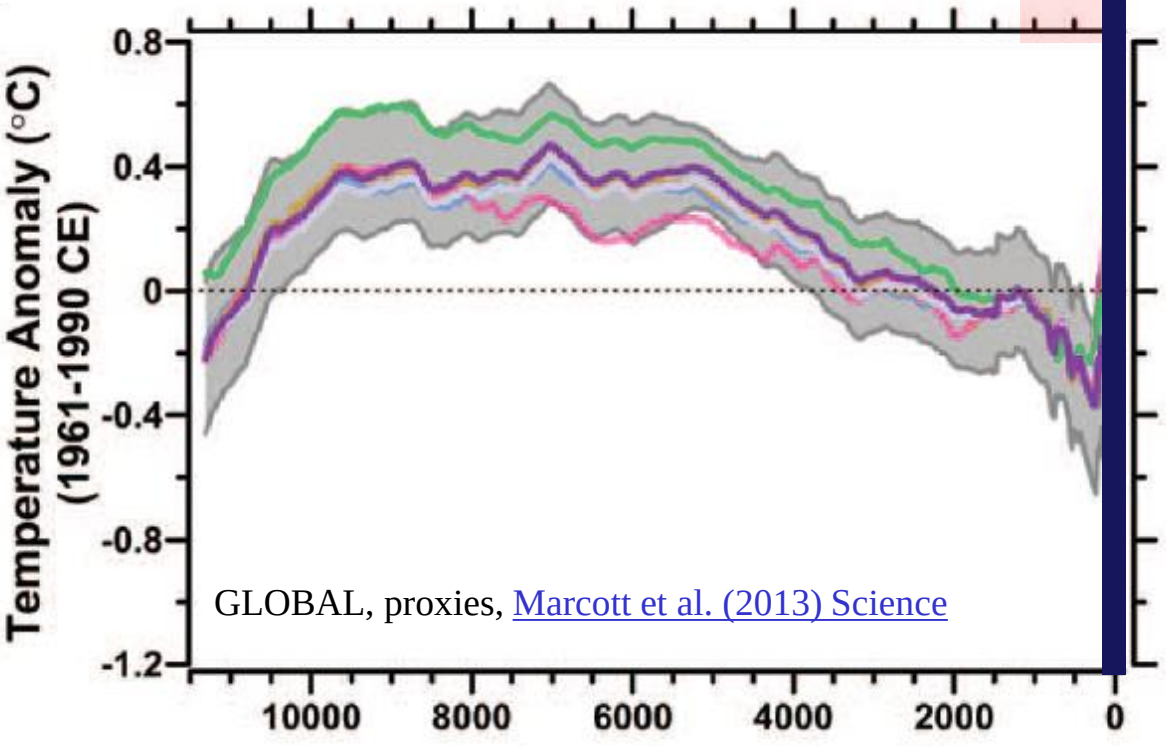


Northern Hemisphere, Proxies IPCC (2013) Tech. Summary, Box TS.5



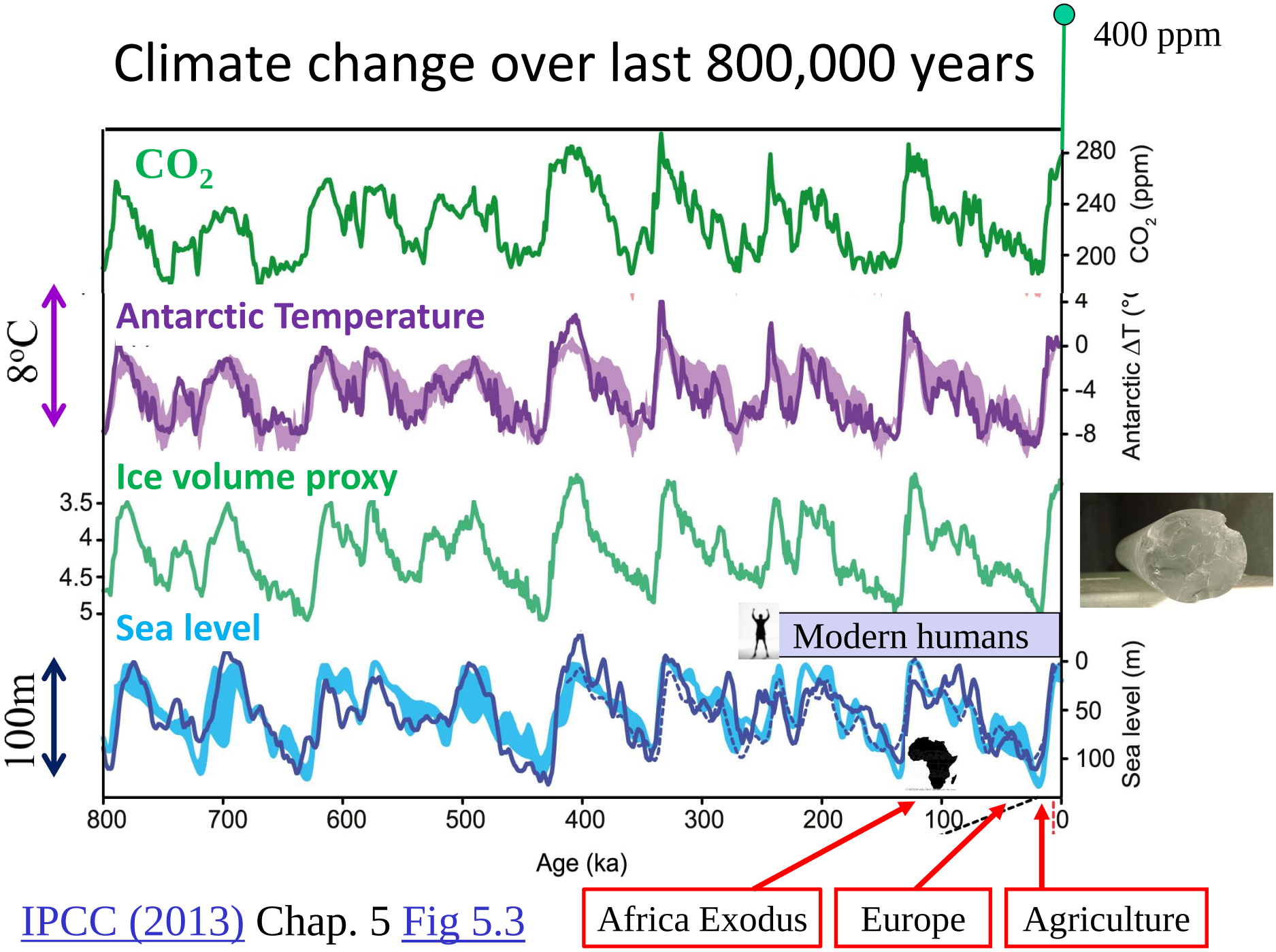
GLOBAL, Instrumental

Northern hemisphere proxies



GLOBAL, proxies, Marcott et al. (2013) Science

Climate change over last 800,000 years



IPCC (2013) Chap. 5 Fig 5.3

Is the warming unusual?

- Over the last 100 years the globe has warmed by around 1°C
- 1987-2016 likely the warmest 30 year period in N. Hemisphere in past 1400 yrs
  - Comparable warmth in last 1400 years not as coherent in space or time as present
- Last time Arctic was warmer than today was probably 125,000 years ago
  - Previous (very different) interglacial when sea level was 6-9m higher than today

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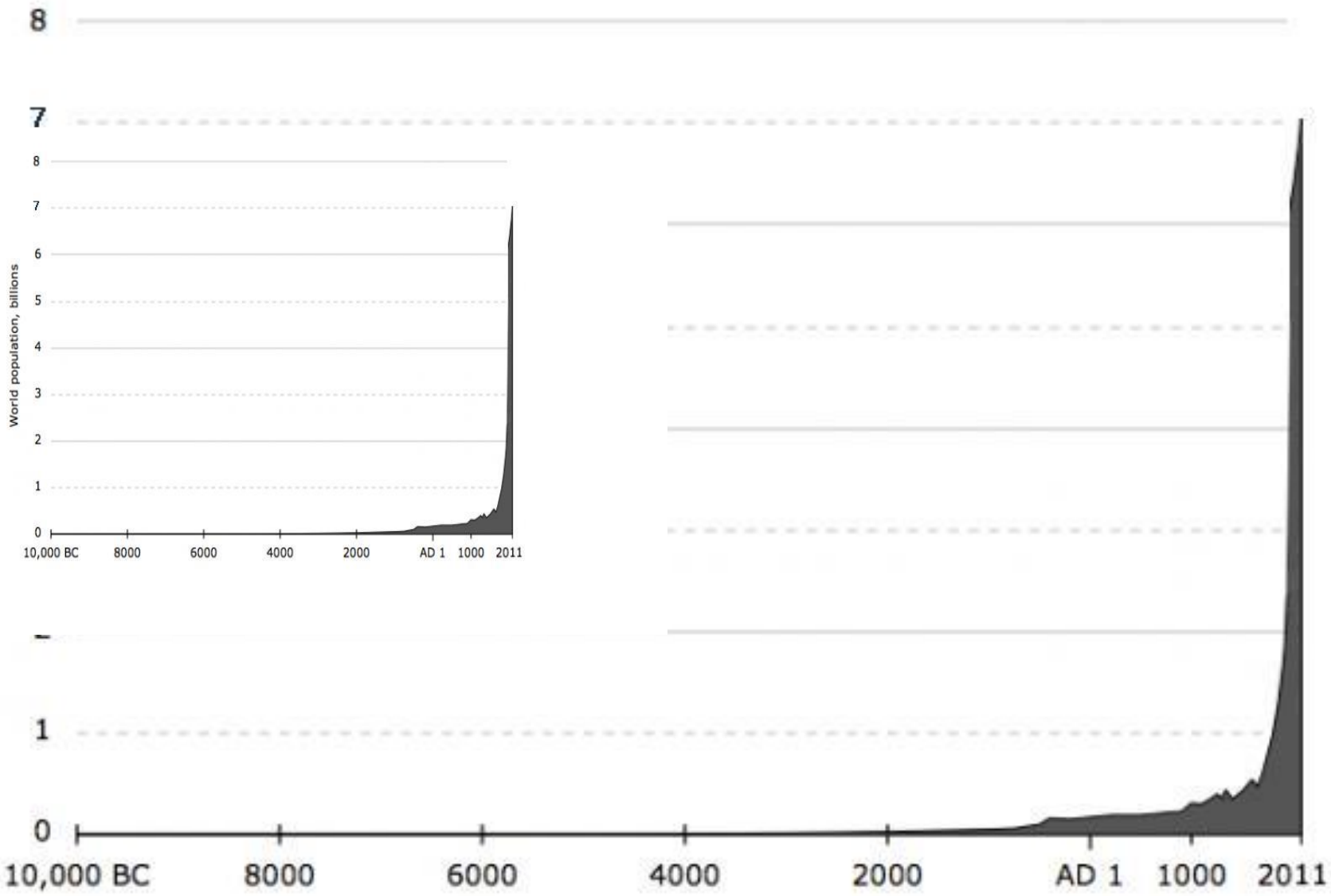
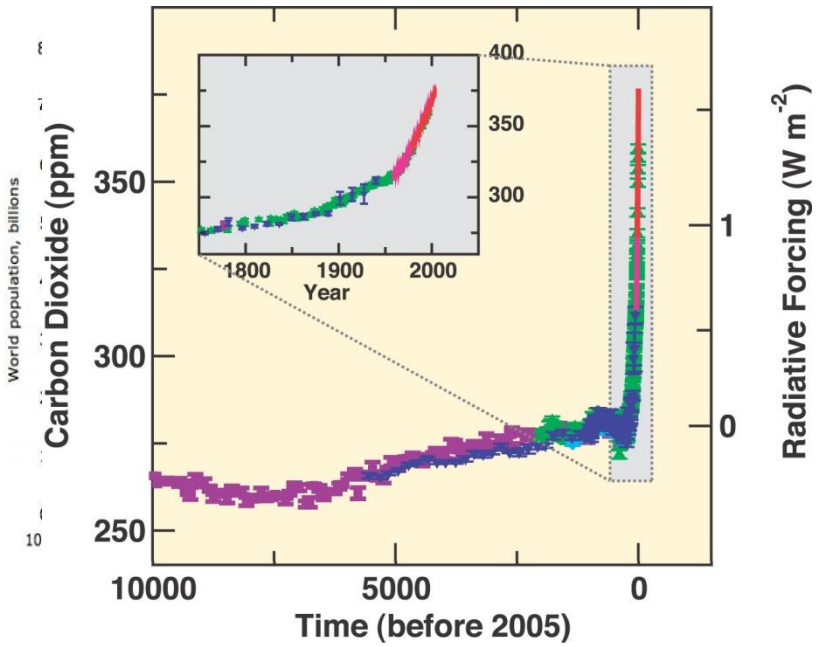
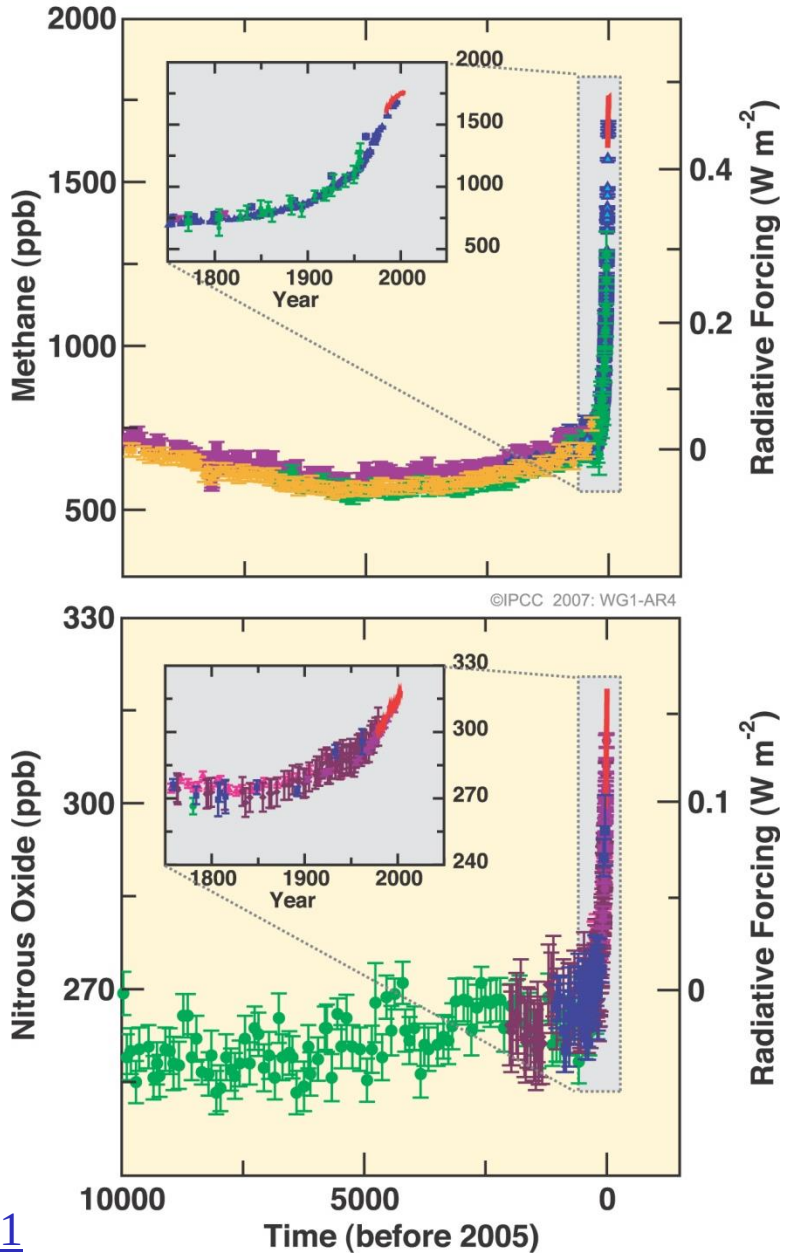
3) Why is it warming?


World population, billions
0
1
2
3
4
5
6
7
8
10,000 BC
8000
6000
4000
2000
AD 1
1000
2011

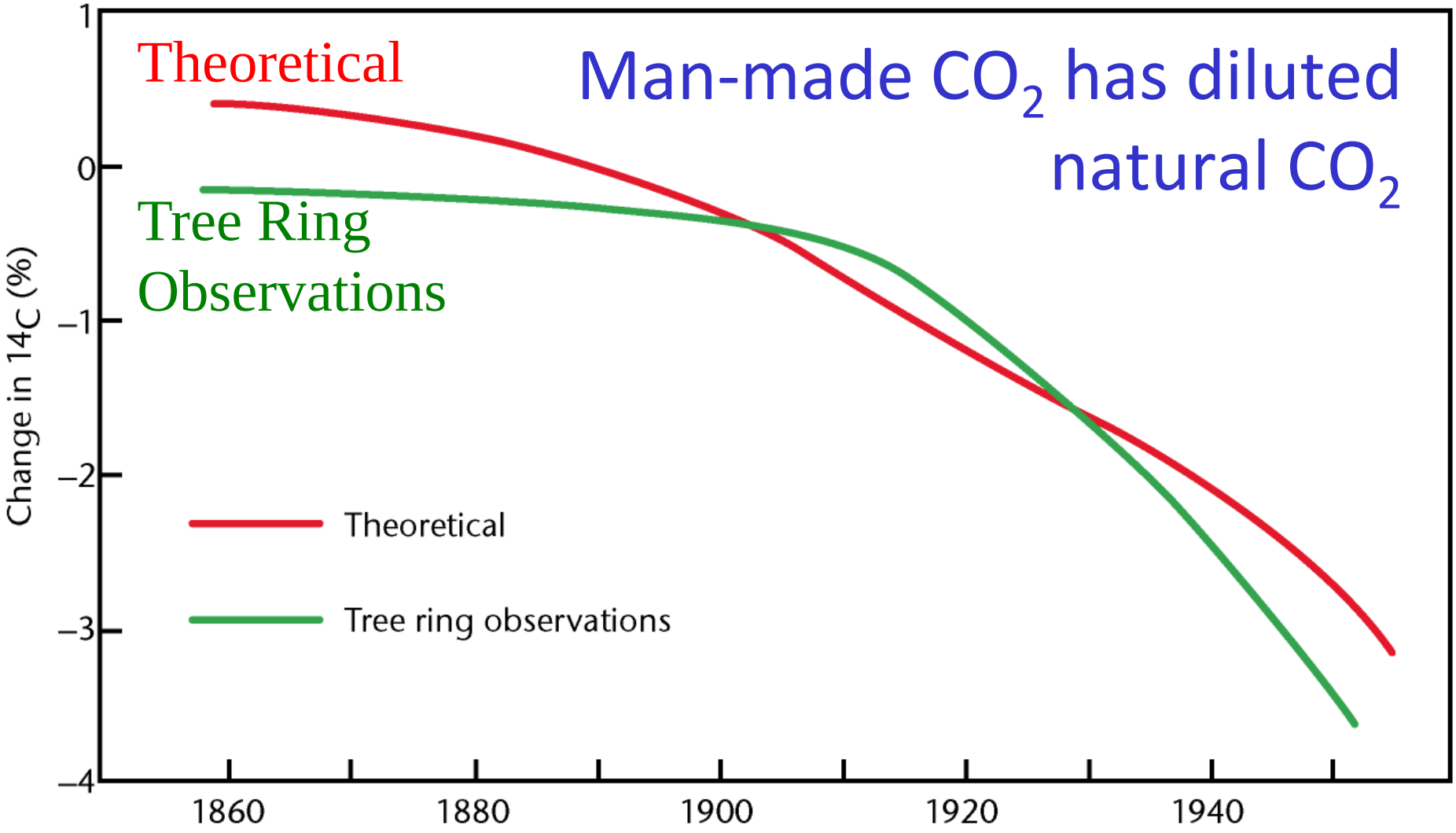
Changes in greenhouse gases from ice core and modern data



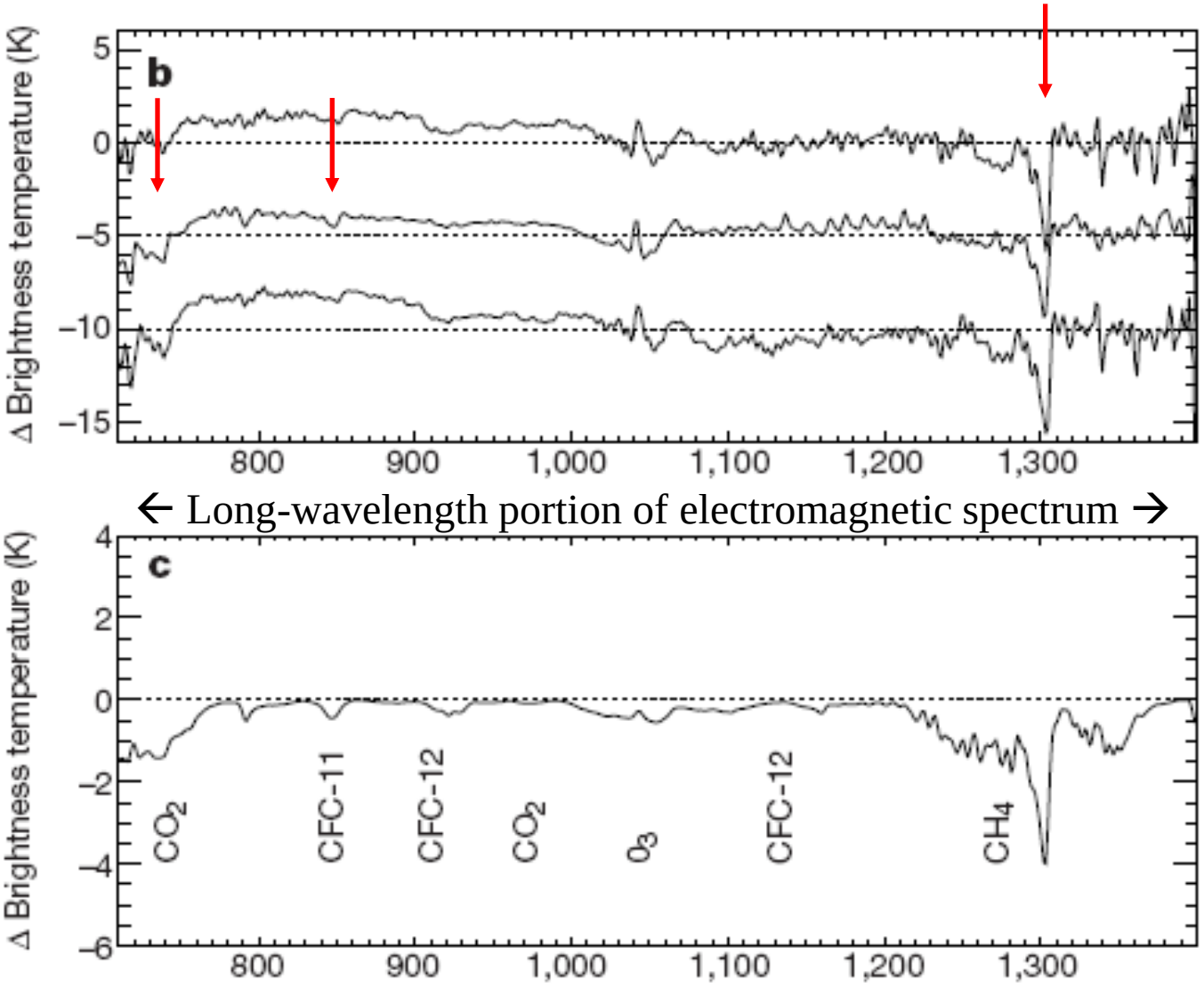


Carbon dioxide, **methane** and **nitrous oxide**

IPCC (2007) Summary for Policy Makers Fig. SPM.1


Theoretical
Man-made CO_2 has diluted natural CO_2
Tree Ring Observations
Change in ^{14}C (%)
1
0
−1
−2
−3
−4
1860
1880
1900
1920
1940
Theoretical
Tree ring observations

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

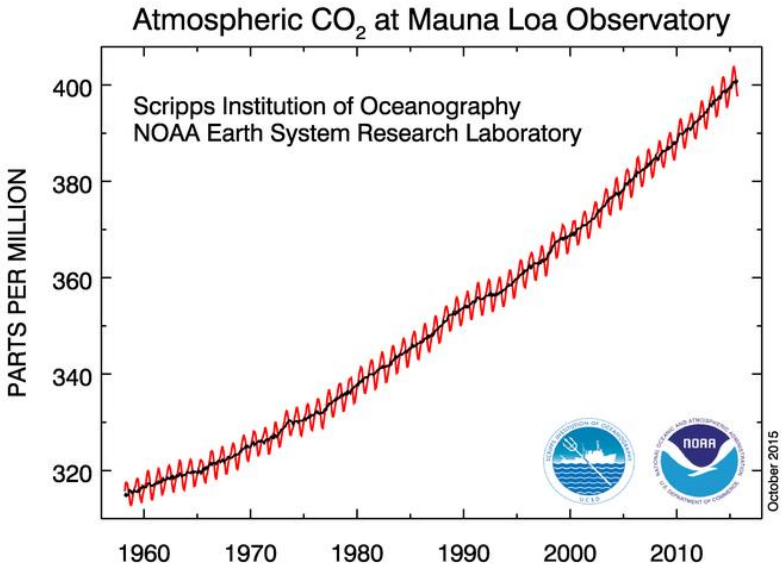


These results showed for the first time experimental confirmation of the significant increase in the greenhouse effect from trace gases such as carbon dioxide and methane

“Radiative forcing” of climate

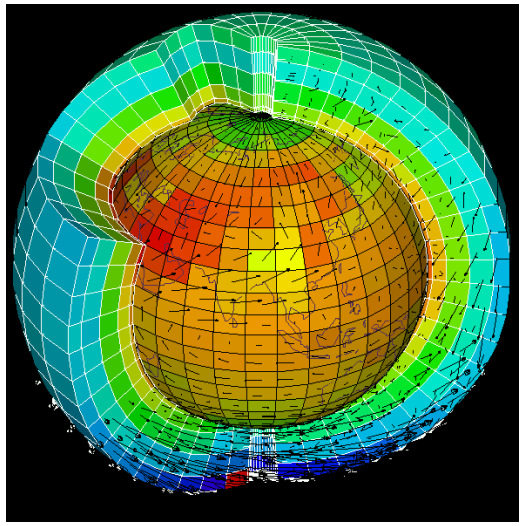
- Increases in greenhouse gases heat the planet by reducing how easily Earth can cool to space through infra-red emission
- More small pollutant “aerosol” particles cool the planet by reflecting sunlight
- If more energy is arriving than leaving, Earth should heat up…

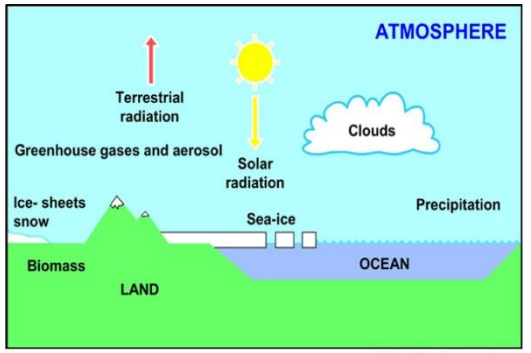
Currently energy is accumulating at rate equivalent to every person currently alive using 20 kettles (2kW) each to boil oceans (or about 300 trillion watts) [Allan et al. (2014)]



Attributing causes of climate change

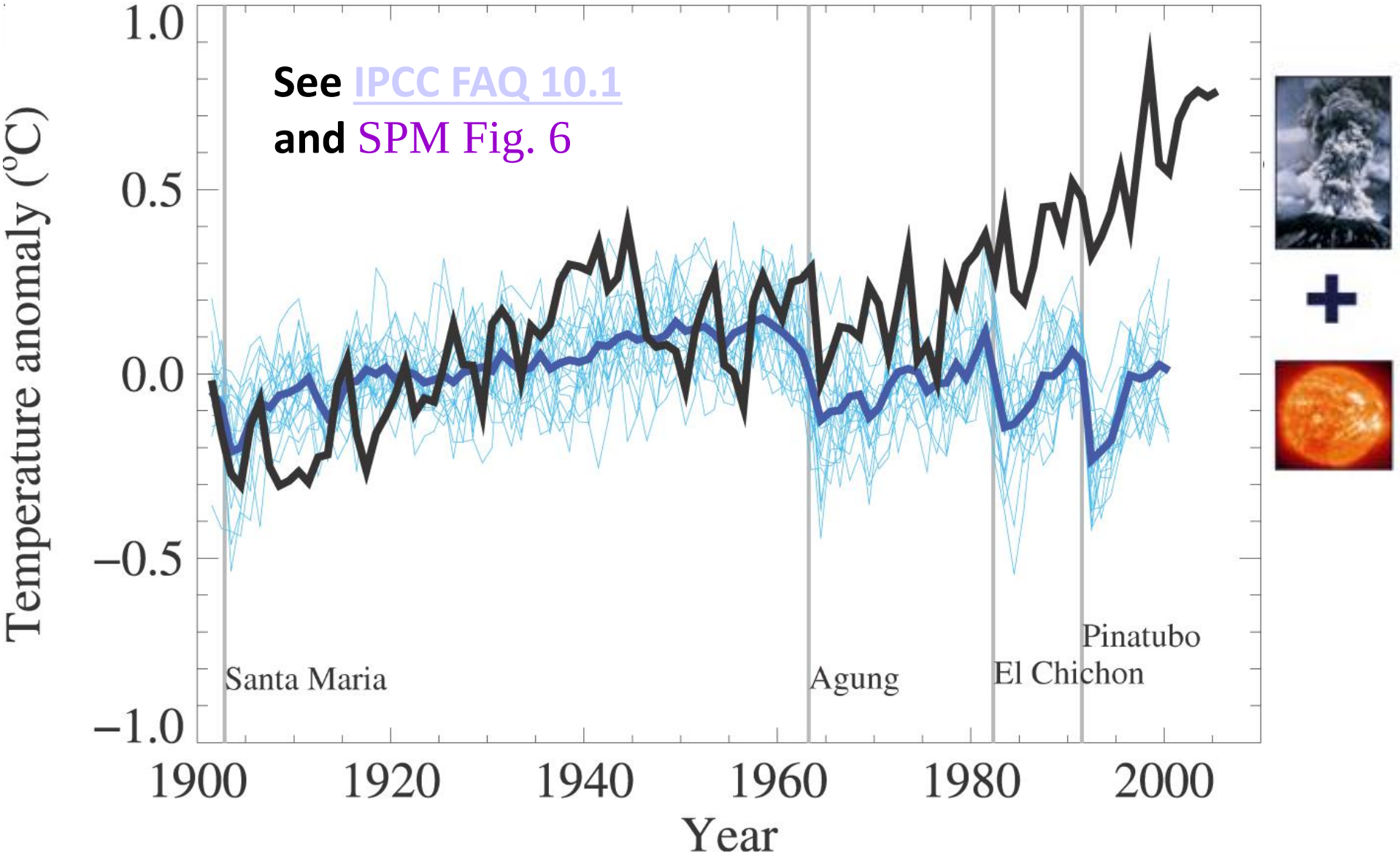
- How much of recent warming is explained by natural effects?
- To answer such questions, experiments can be performed with climate simulations
  - including just natural factors (ocean circulation, volcanic eruptions, changes in the sun, …)
  - including natural and anthropogenic factors (e.g. greenhouse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



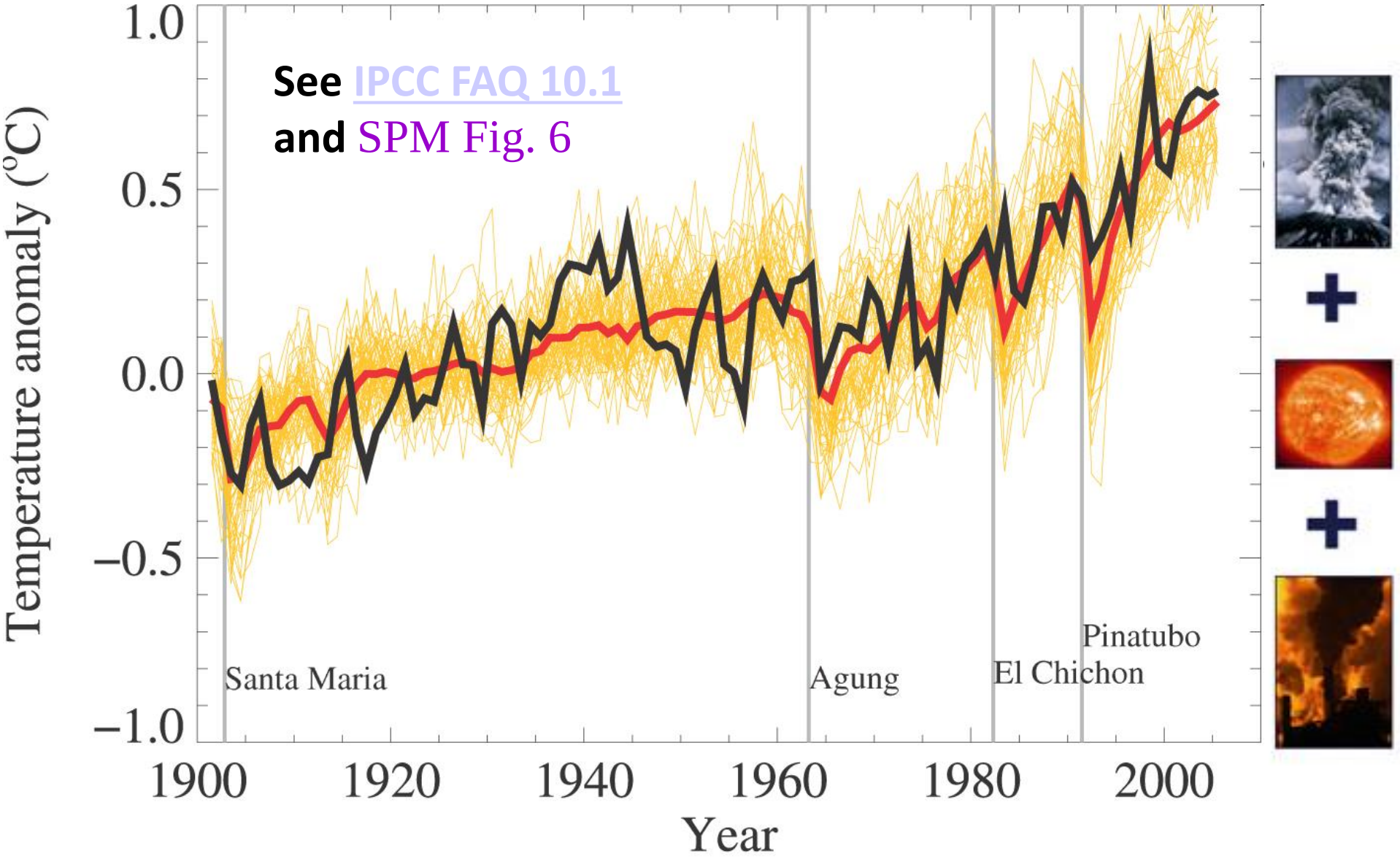


Met Office Hadley Centre

Natural factors cannot explain recent warming



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



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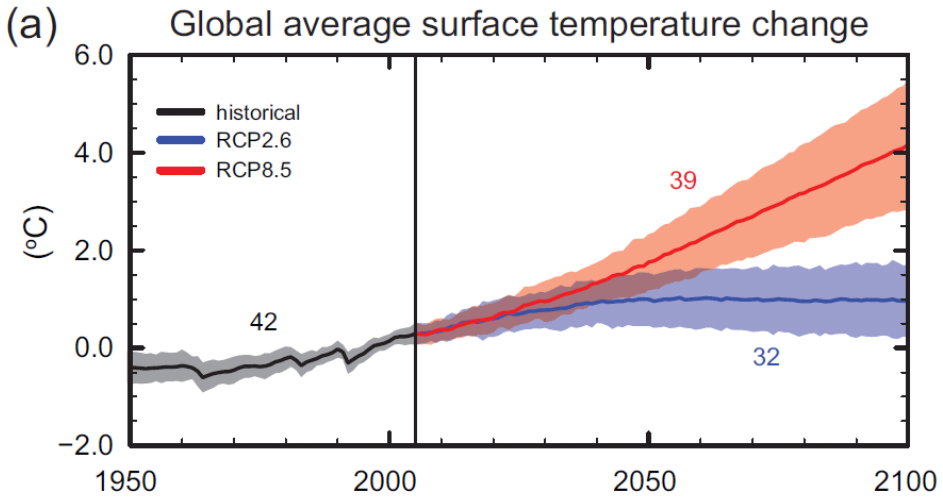
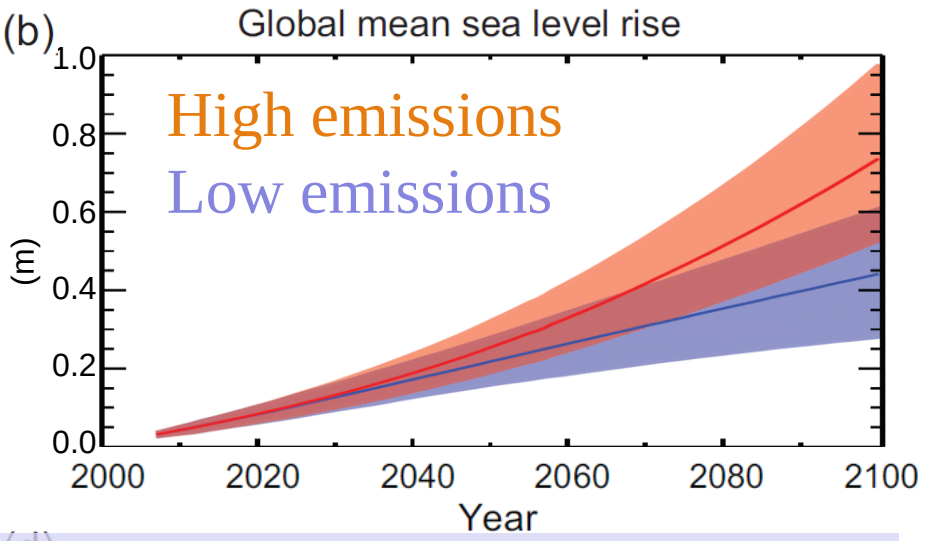
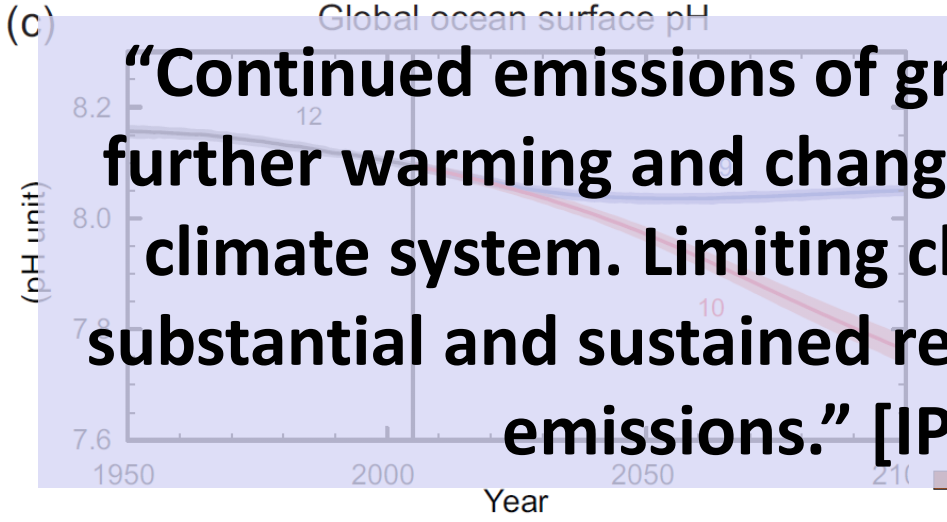
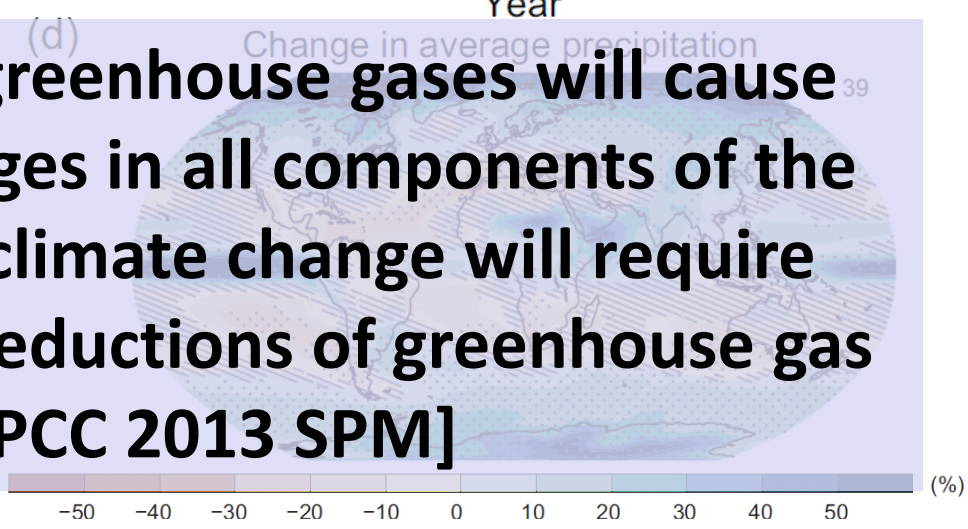
4) What are the predictions?

Future projections to 2100 from climate models





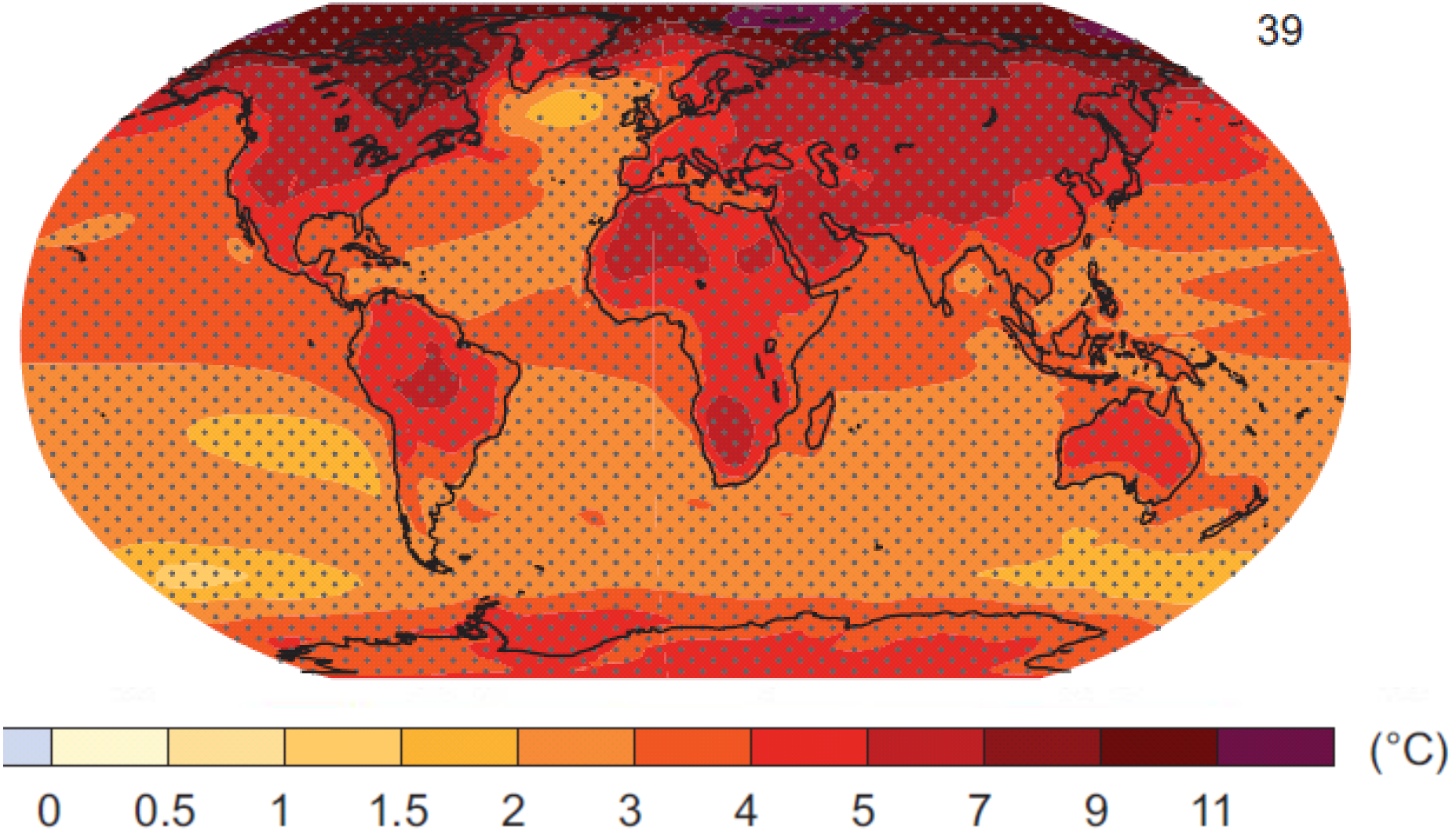




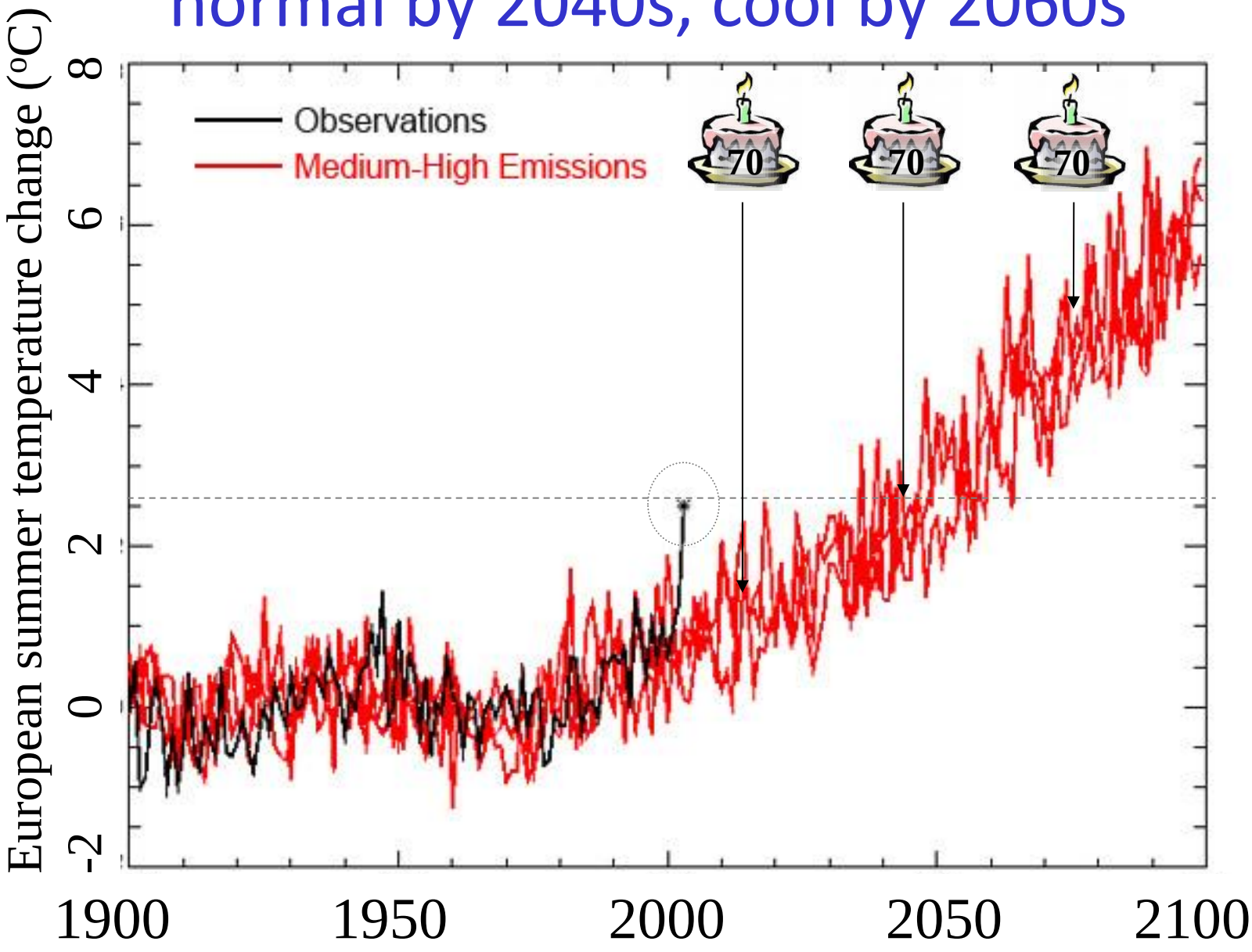
"Continued emissions of greenhouse gases will cause further warming and changes in all components of the climate system. Limiting climate change will require substantial and sustained reductions of greenhouse gas emissions." [IPCC 2013 SPM]

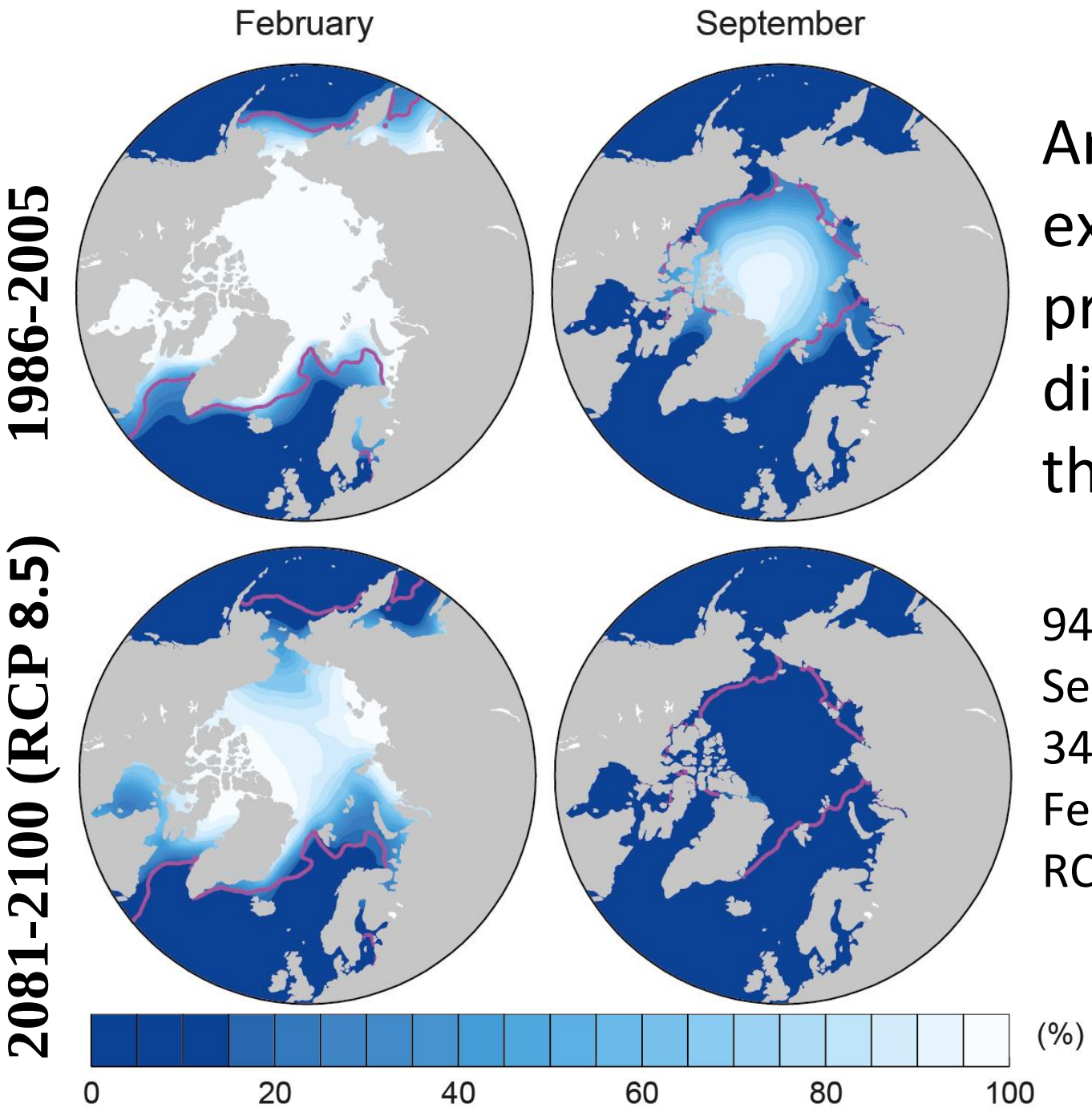
IPCC (2014) WG1 Summary for Policy Makers

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





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

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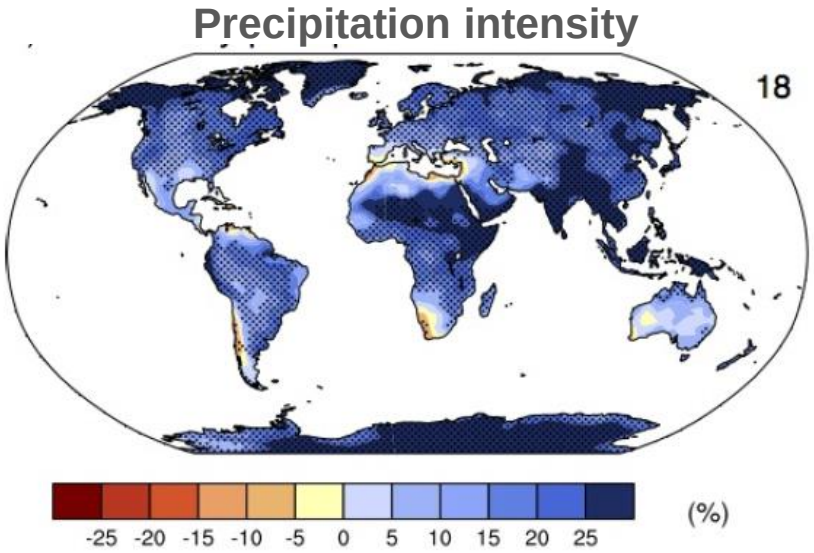
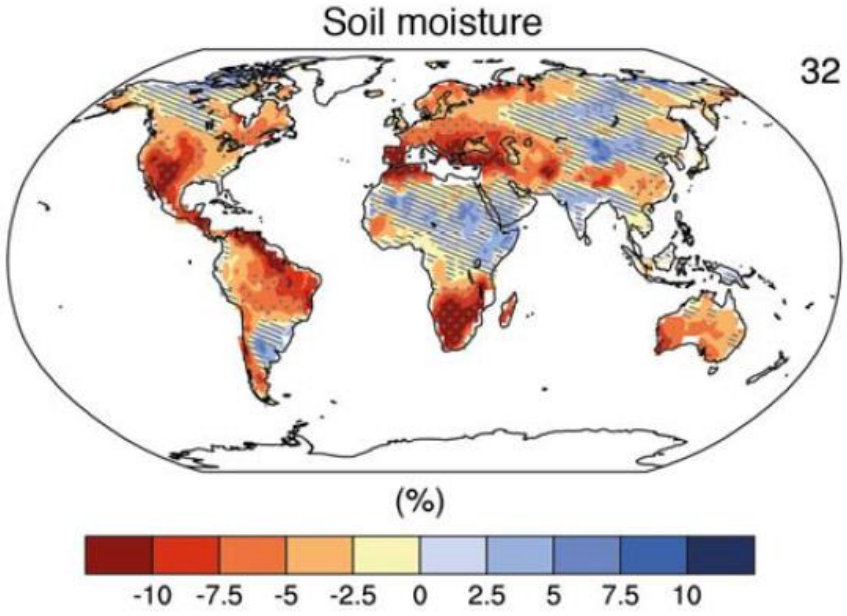
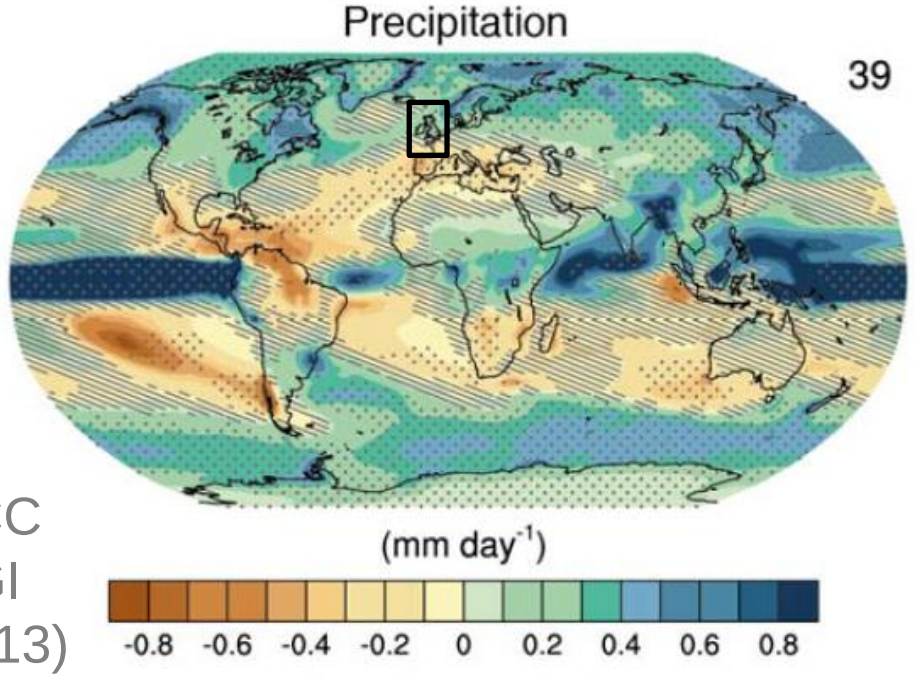
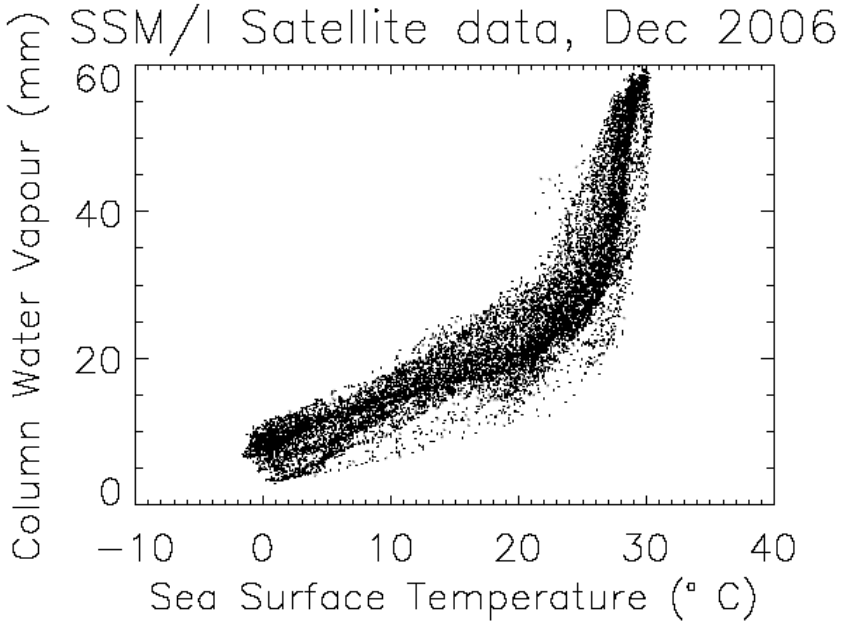


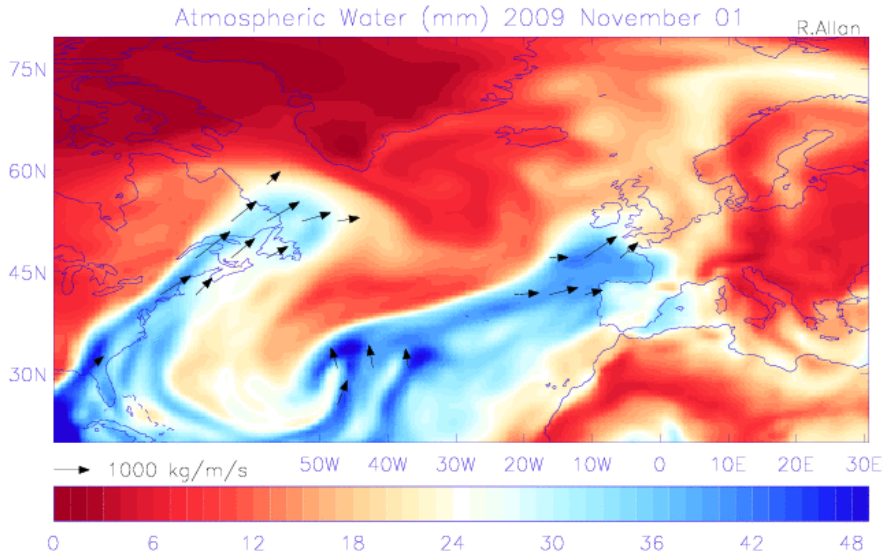


- Increased Precipitation
- More Intense Rainfall
- More droughts
- Intensification of wet and dry seasons?
- Regional projections??



IPCC WGI (2013)





Lavers et al. (2013) Environ. Res. Lett.

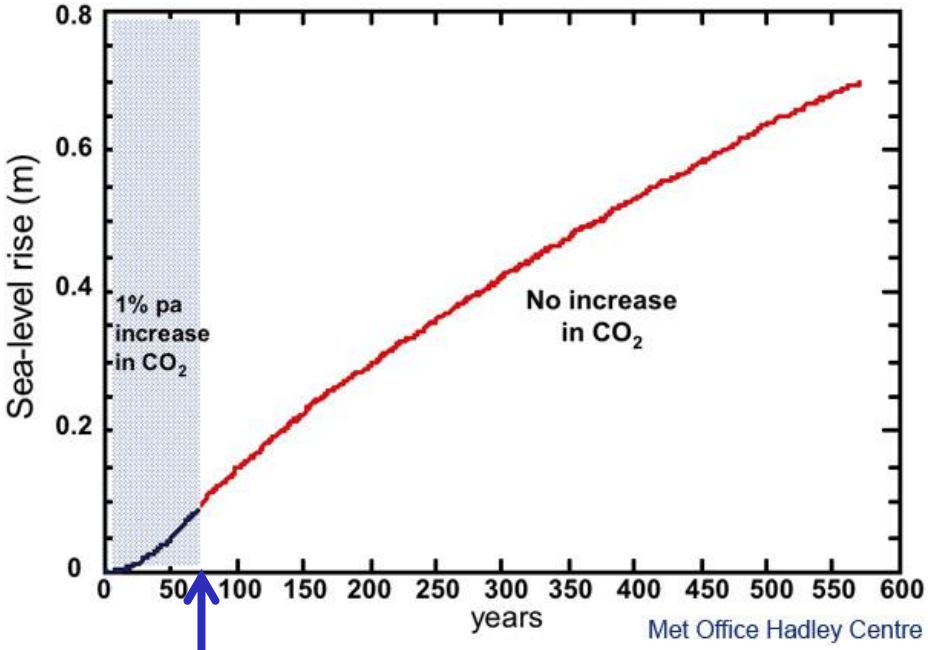
Water vapour & climate change

- Water vapour is a powerful greenhouse gas
- Water vapour in the air increases with warming
- This increases magnitude of climate change
- Also drives intensification of extreme rainfall events

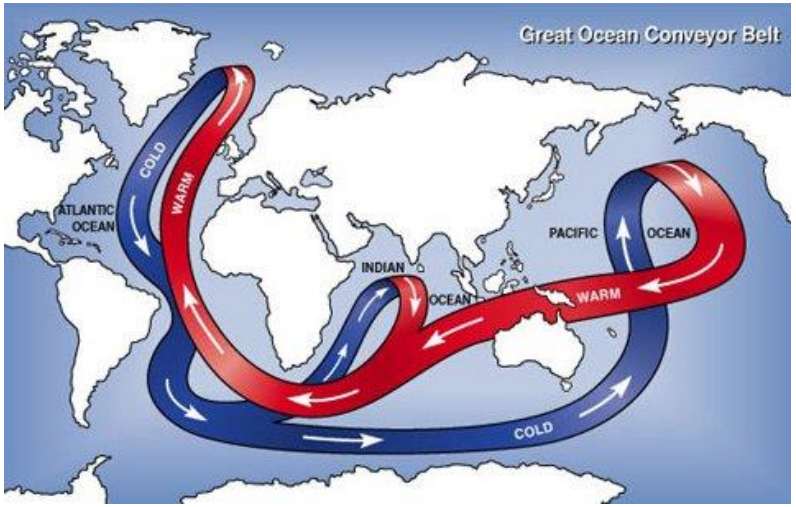
← Nov 2009 Cumbria flooding event

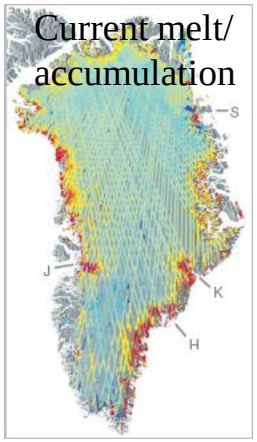
The weather will always generate extreme rainfall events but warming of climate will increase their severity

Long-term commitment to sea-level rise



CO_2 increase stops here

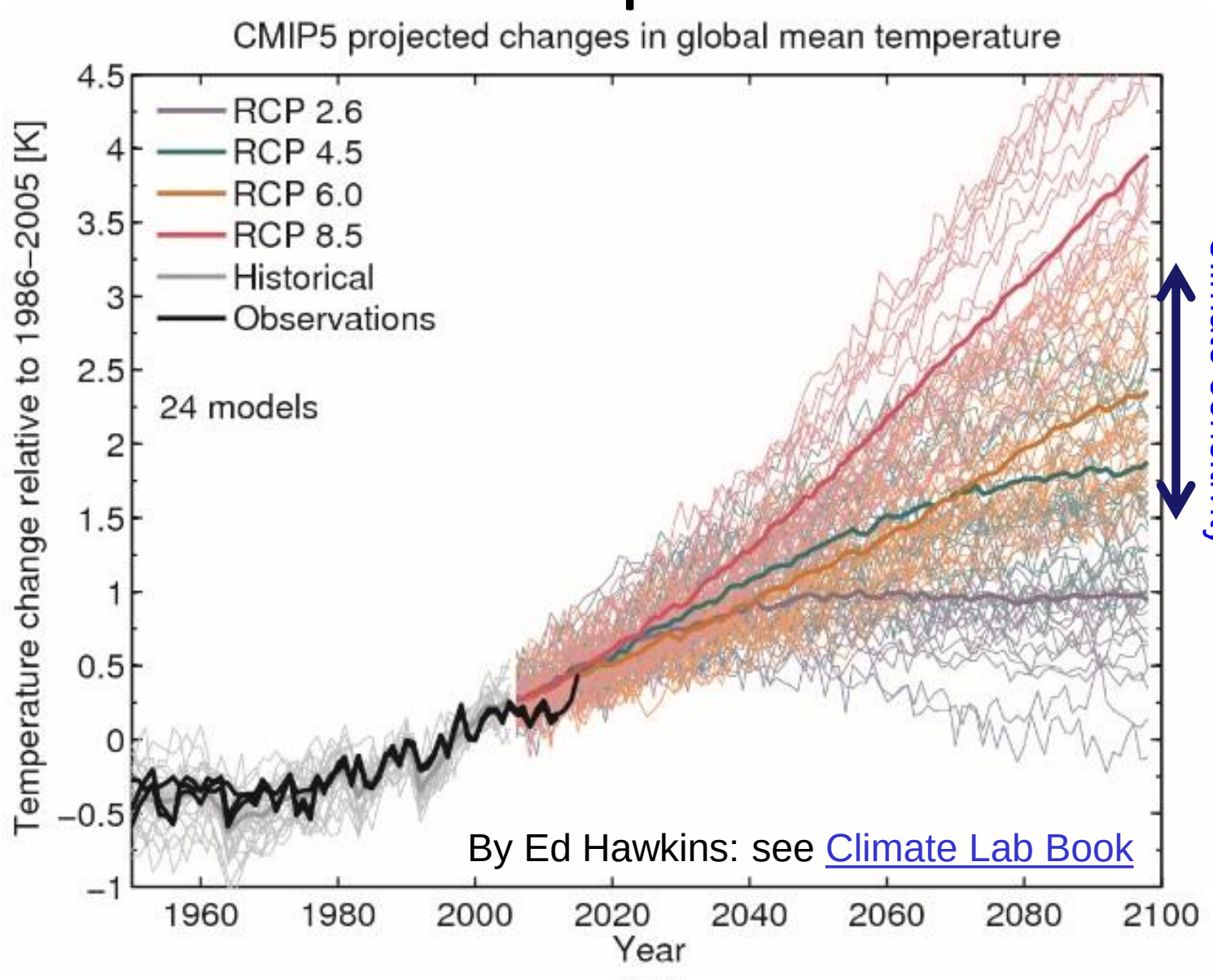




2.3m sea level rise per ^{o}C warming over long term (e.g. 2000 years) [IPCC Fig. 13.14]

Golledge et al. (2015) Nature

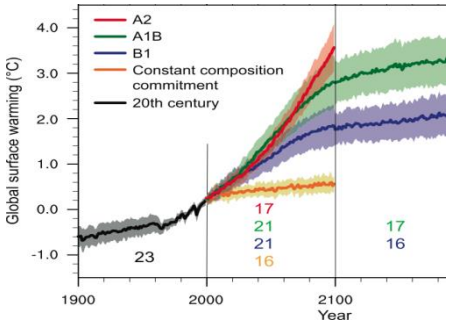
How much will planet warm?



Climate sensitivity

Climate sensitivity and socioeconomic scenario

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

COP21 Paris Climate Deal

source: http://www.carbonbrief.org/analysis-the-final-paris-climate-deal

- **Target**: global temperature well below 2°C; efforts to limit to 1.5°C
- **Mitigation**: pursue policies aiming to achieve INDC climate pledges; subsequent pledges progressively more ambitious; global stocktake 2018 & then every 5 years; peak global greenhouse gas emissions “as soon as possible”; “balance” between emissions & sinks 2050-2100
- **Adaptation**: $100bn/yr fund for developing countries: new collective quantified goal by 2025; periodic review of adaptive planning of Loss & damage has its own Article in the agreement — now on par with mitigation & adaptation; liability/compensation excluded.
- **Transparency:** "facilitative, non-intrusive, non-punitive” system of review will track countries’ progress; emissions trading allowed; aviation/shipping not included
- **Treaty:** deal enters force once 55+ parties, covering at least 55% of global emissions have signed up