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THE CAUSES AND CONSEQUENCES OF CLIMATE CHANGE

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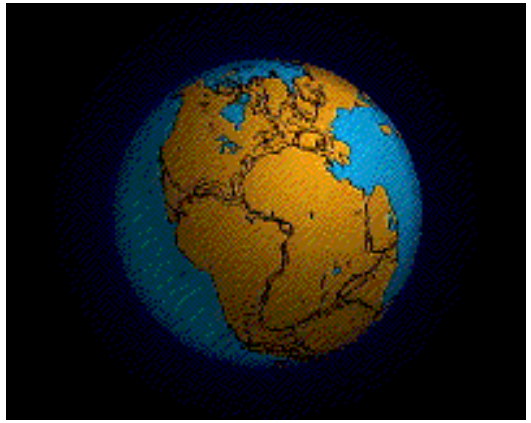
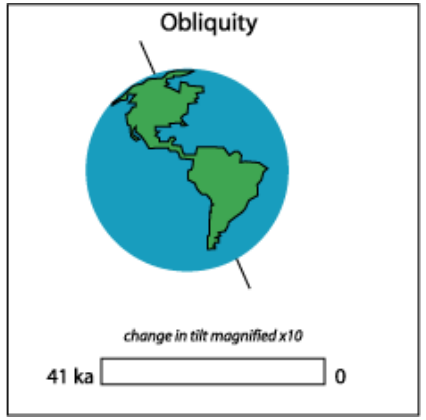
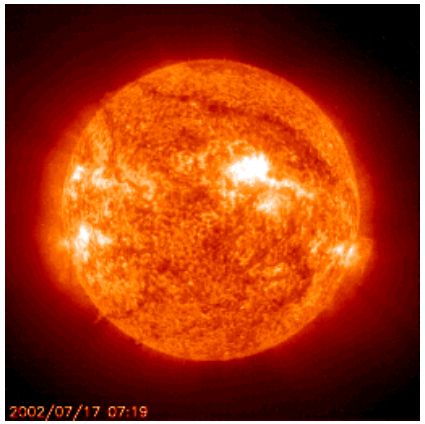
The Marist School, 28th April 2022







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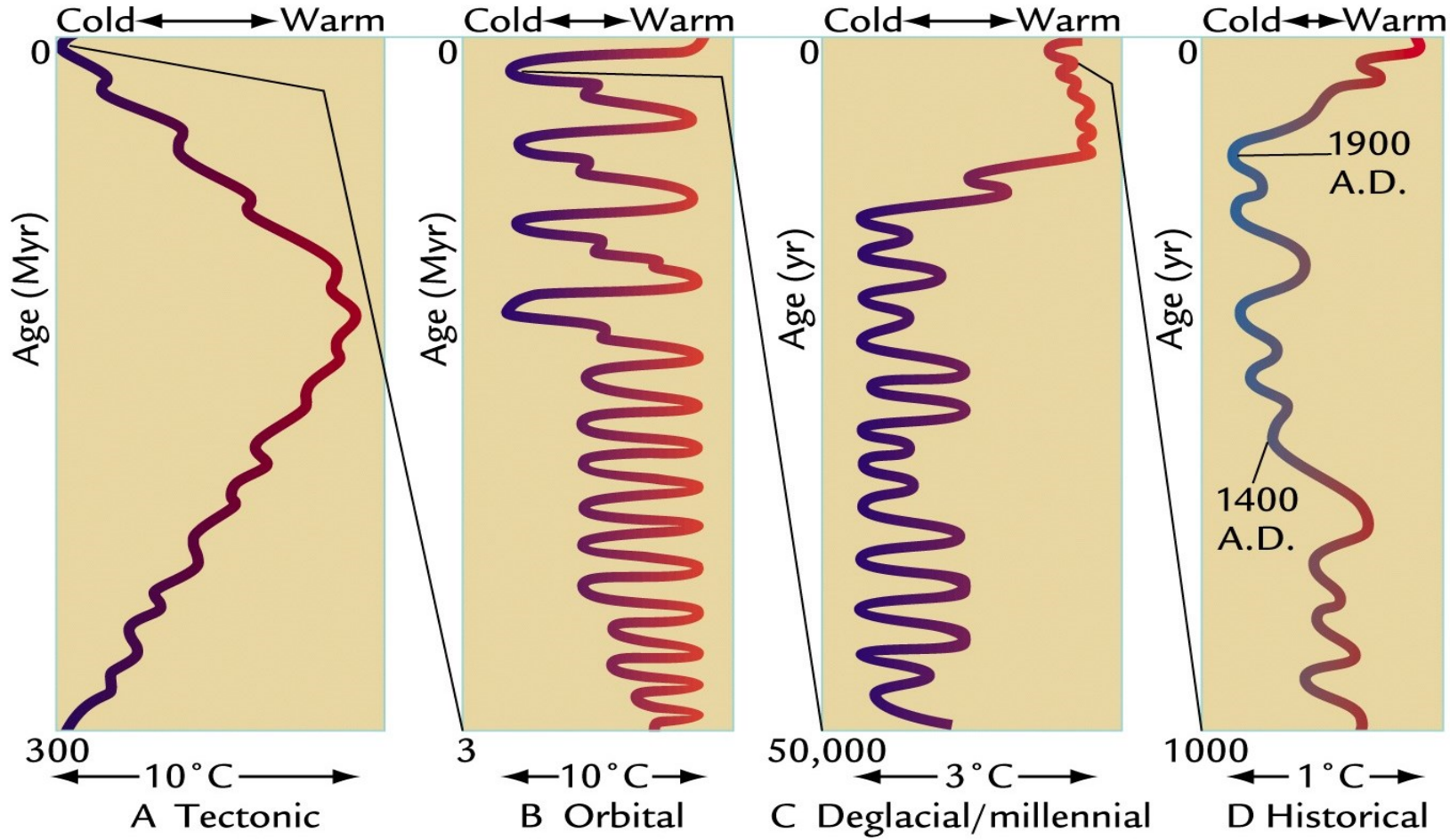


Earth's Climate has always been changing

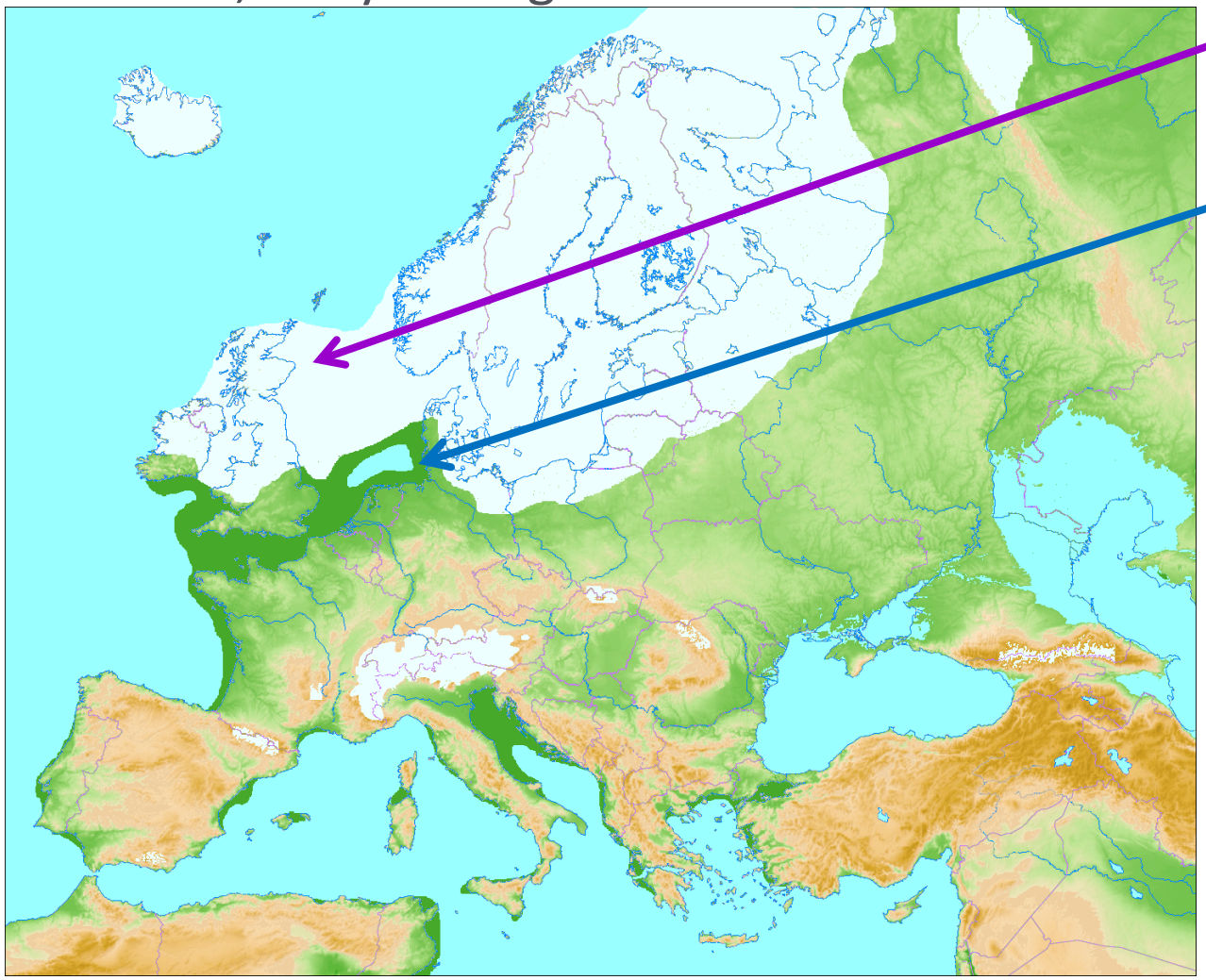
- Plate tectonics
- Orbital cycles
- The Sun
- Volcanoes

Ruddiman WF. 2001

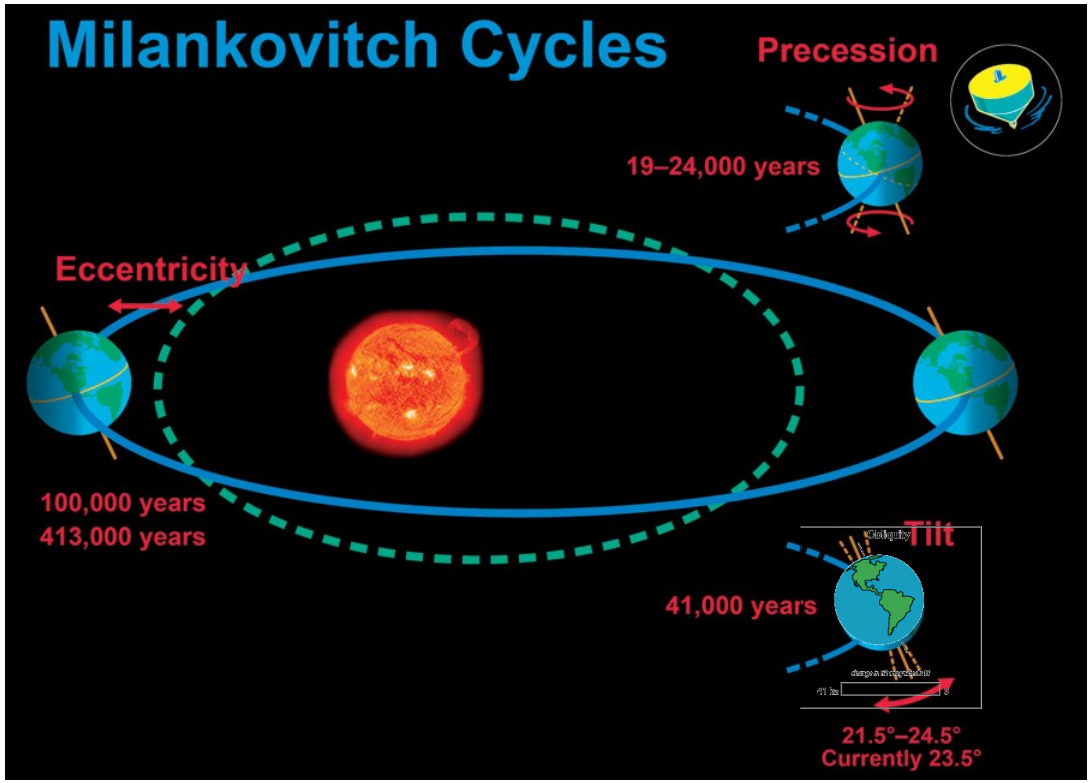
Earth's Climate, Past and Future

The last glacial maximum

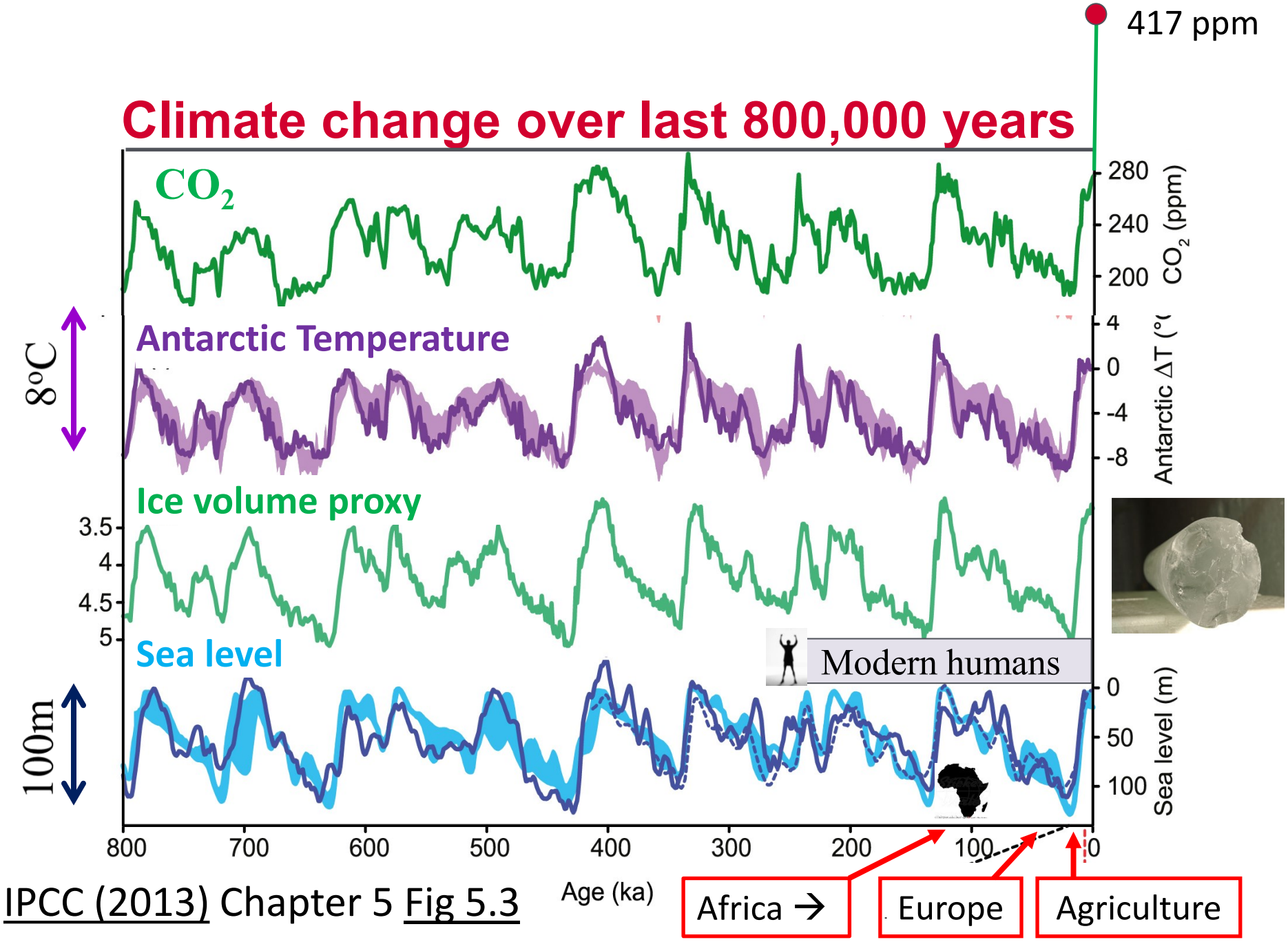
About 20,000 years ago…



- Northern Britain was covered by an ice sheet
- Sea level was 120 metres lower



Climate change over last 800,000 years



IPCC (2013) Chapter 5 Fig 5.3

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- Ice cores & ocean sediments show swings between inter-glacial and glacial climates
- Explained by known **cycles in Earth's orbit**
- 10 to 100 thousand year natural cycles in temperature & sea level - amplified by ice cover & CO_2 changes
- Natural swings in CO_2… until now

Natural & human-influenced carbon cycle

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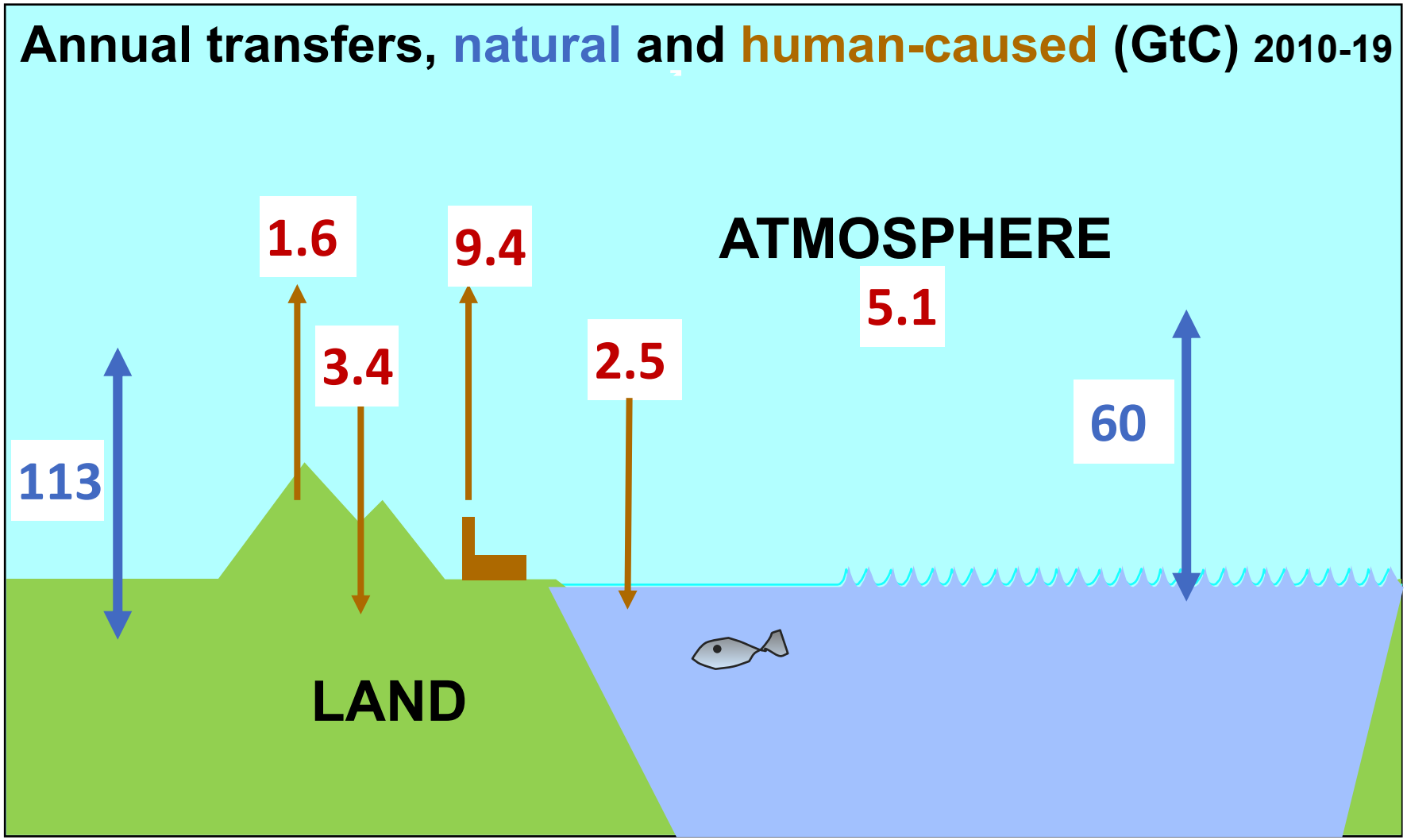


- Human activities have tipped the natural carbon cycle out of balance
- This is driving increases in atmospheric CO_2 concentrations
- CO_2 concentrations highest in at least 2 million years

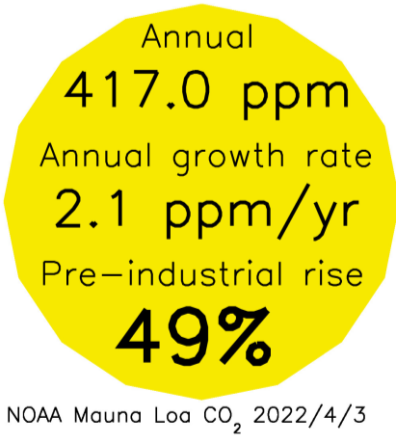
Values in billions of tonnes of Carbon per year from IPCC (2021) Ch5

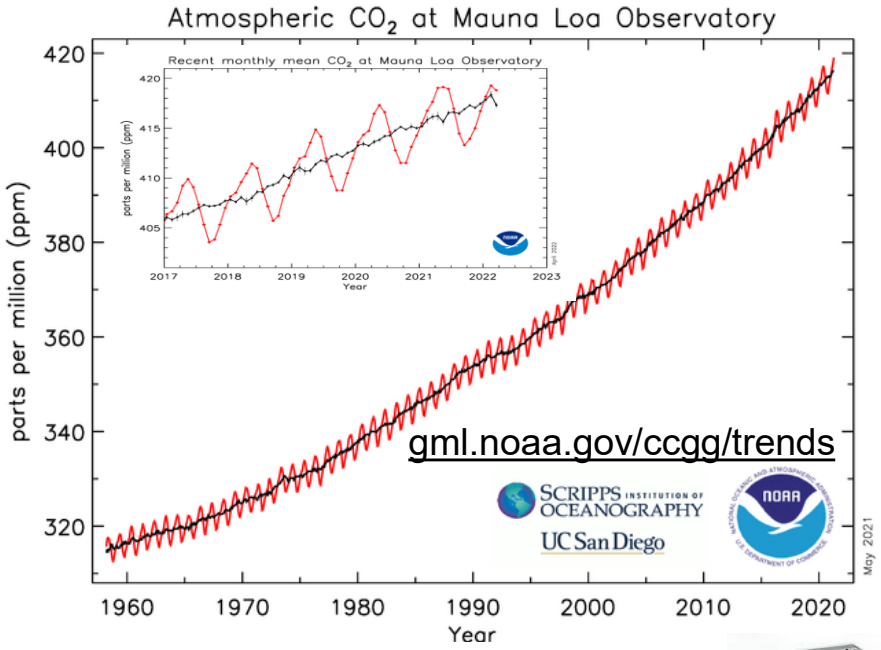
OUR CO_2 EMISSIONS ARE HEATING PLANET

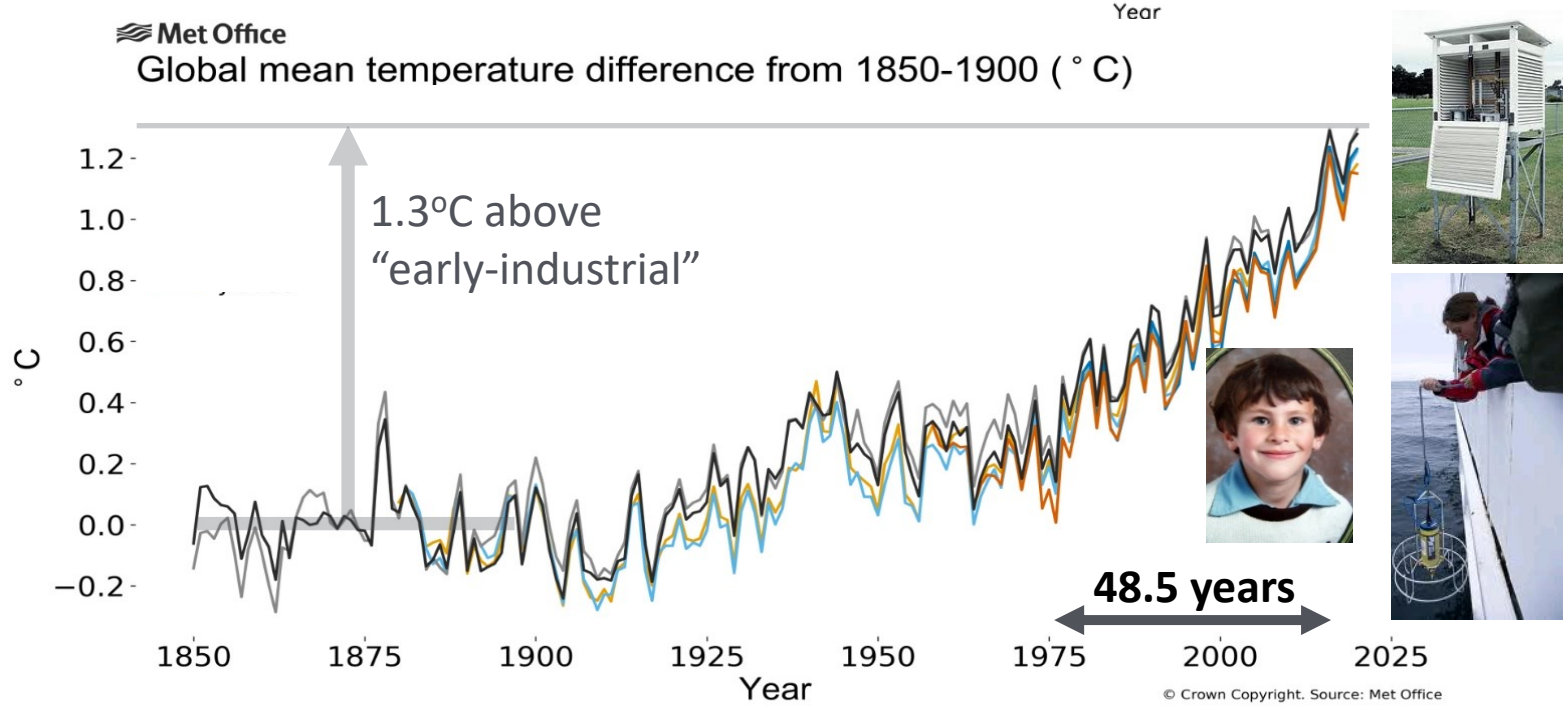
- Greenhouse gases reduce infrared heat loss to space
- Greenhouse gas increases intensify greenhouse effect and heat planet (more energy arriving than leaving)
- Pollutant "aerosol" particles reduce heating by reflecting sunlight

- Global mean warming
- Melting ice
- Rising sea level
- More intense rainfall, heatwaves & droughts

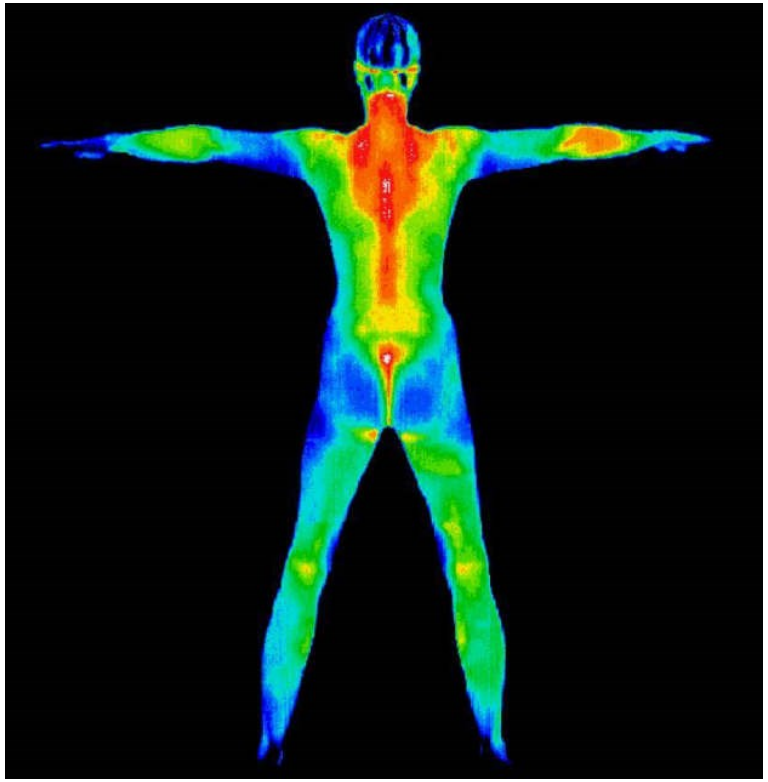
Evidence: www.ipcc.ch reports
Observations, physics, simulations
See also: climate.nasa.gov

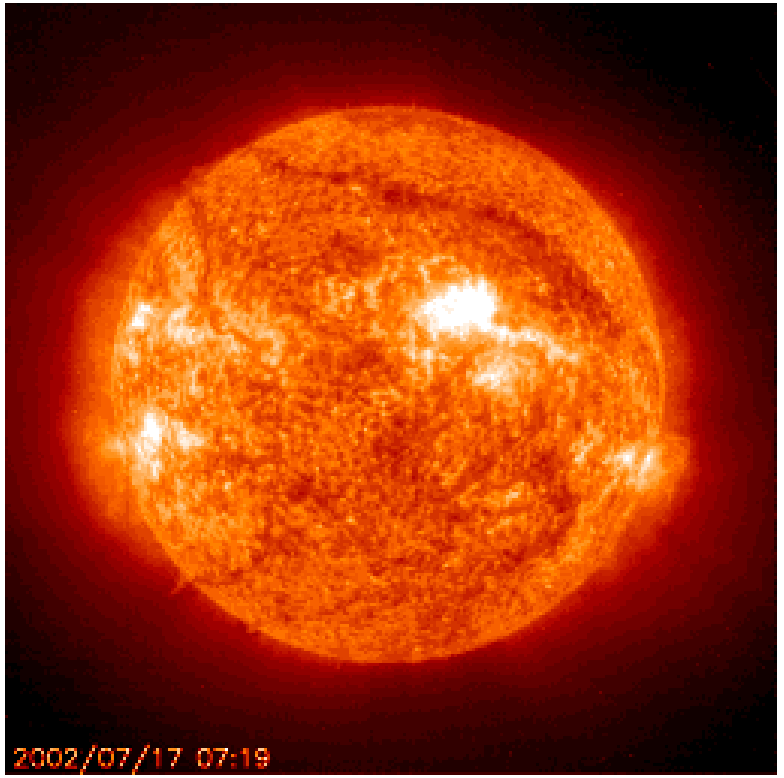






www.metoffice.gov.uk/hadobs/monitoring/dashboard.html





Everything emits radiation energy

units: Watt per square metre (Wm^{-2})

Cool things: long wave-length/thermal infrared radiation, e.g. us ~300 K

Hot things: short wave-length radiation, e.g. the sun ~6000 K

Temperature in Kelvin = Temperature in ^{o}C + 273.15

IR thermometer activity

EARTH'S RADIATIVE ENERGY BALANCE IN SPACE

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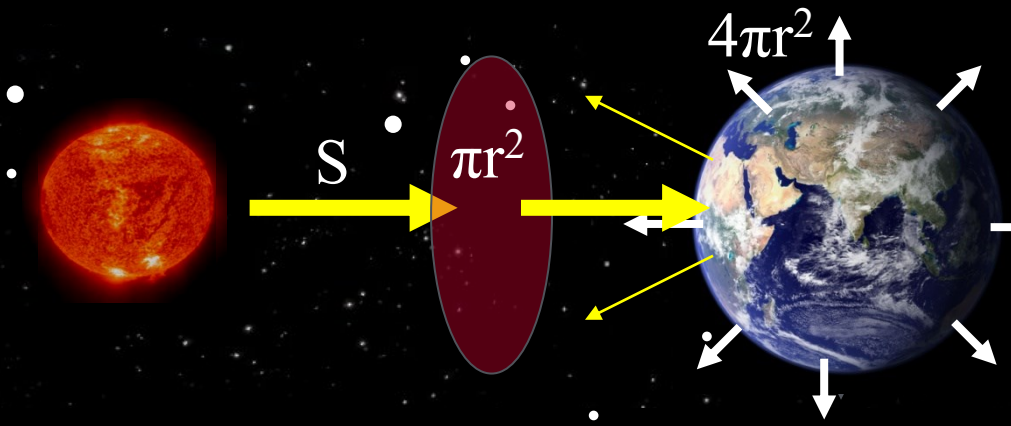

Thermal/Infra-red or Outgoing Longwave Radiation (OLR)

S is the solar constant (about 1361 Watts per square metre, W/m^2)

30% of incoming sunlight is reflected back to space by clouds, tiny aerosol particles and bright surfaces (e.g. deserts).

So absorbed sunlight is (S/4) x (1 - 0.3) = (1361/4)x0.7 = 238 W/m^2

This is balanced by infrared cooling to space to give us our planet's average temperature of around 15^{o}C. But rising concentrations of greenhouse gases such as carbon dioxide are reducing the infrared cooling so more energy is arriving than leaving and the planet is heating up.

Forcing and response: a natural experiment


29/3/06 11.05am


29/3/06 12.26pm

- Clouds affect radiation fluxes
- Radiation fluxes affect clouds

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Feedback demonstration

Water vapour & climate

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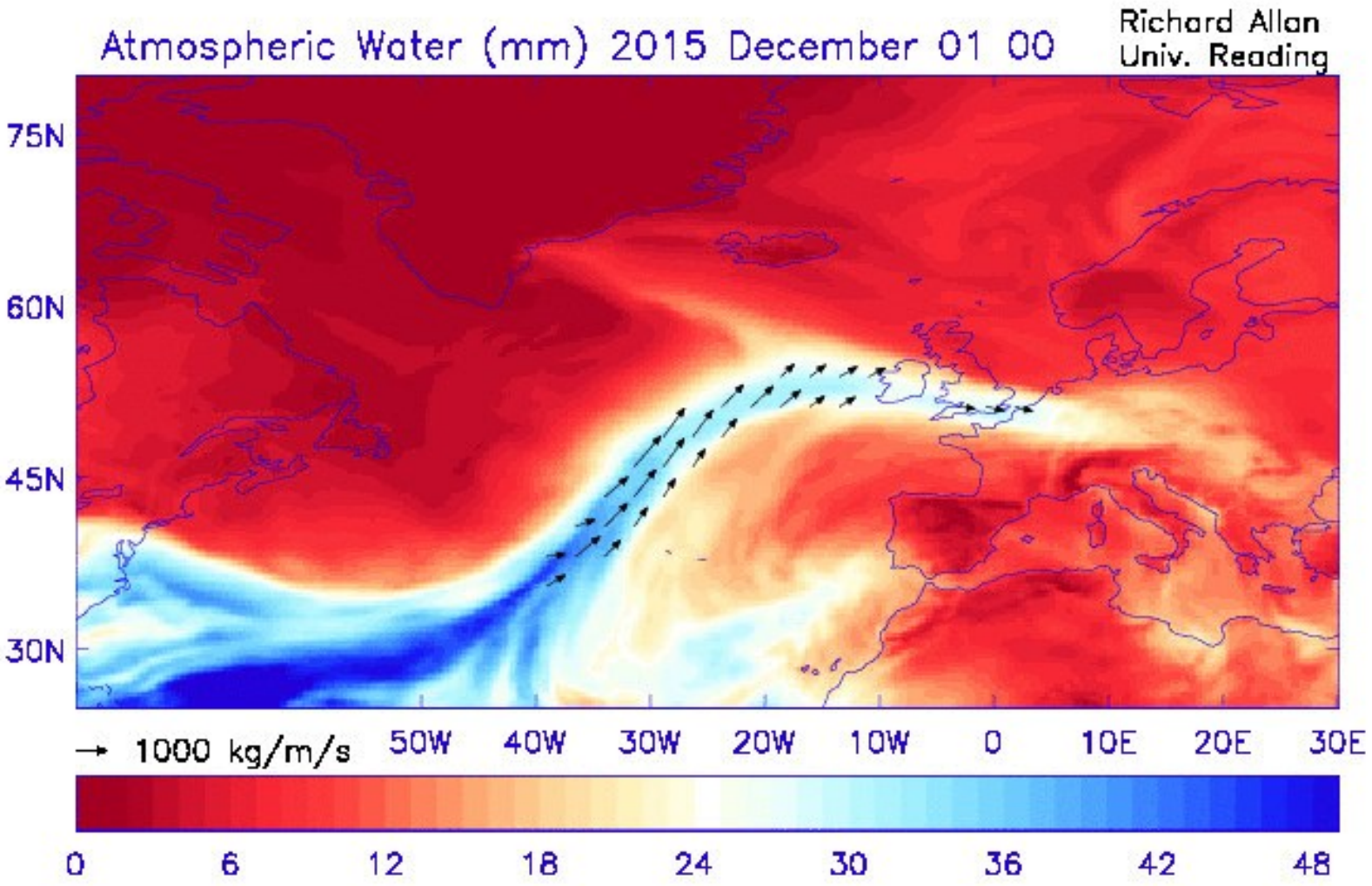

- Atmospheric rivers linked to UK flooding
- More atmospheric water:
  - ➢ increases intensity of rainfall & flooding
  - ➢ Amplifies climate change through a feedback loop

Feedback Loops Amplify Climate Change

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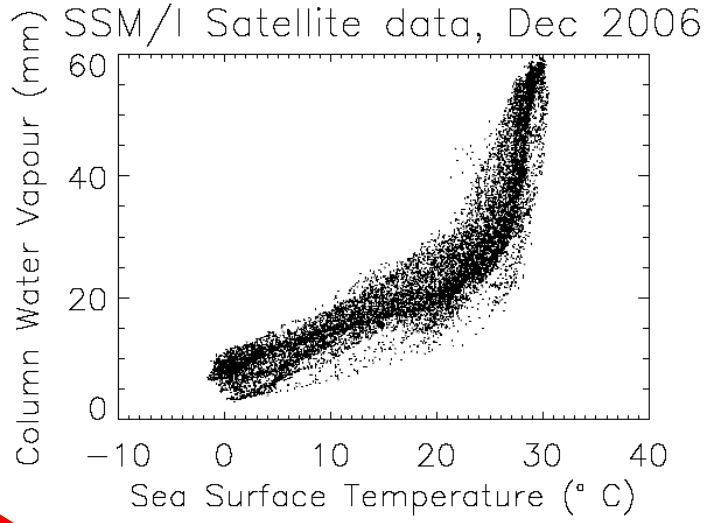
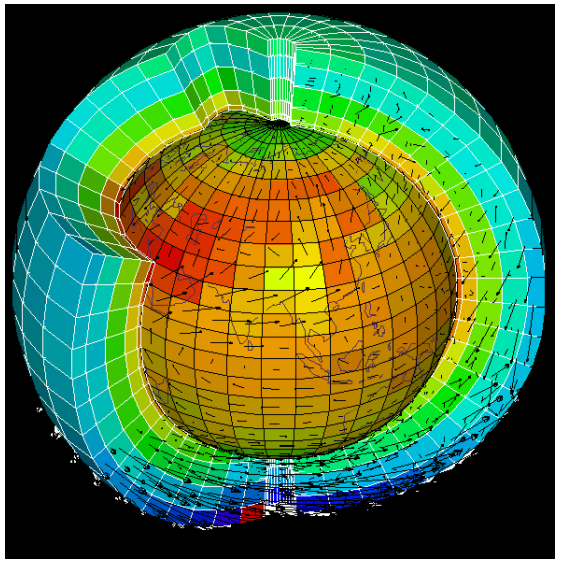


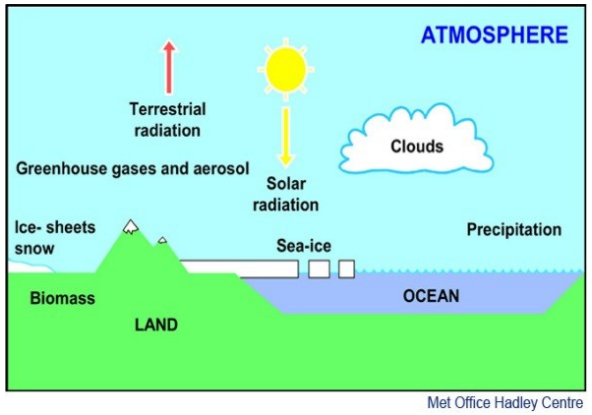
Feedbacks:

- ice/snow (+)
- water vapour (++)
- clouds (++/-)
- temperature profile (-)

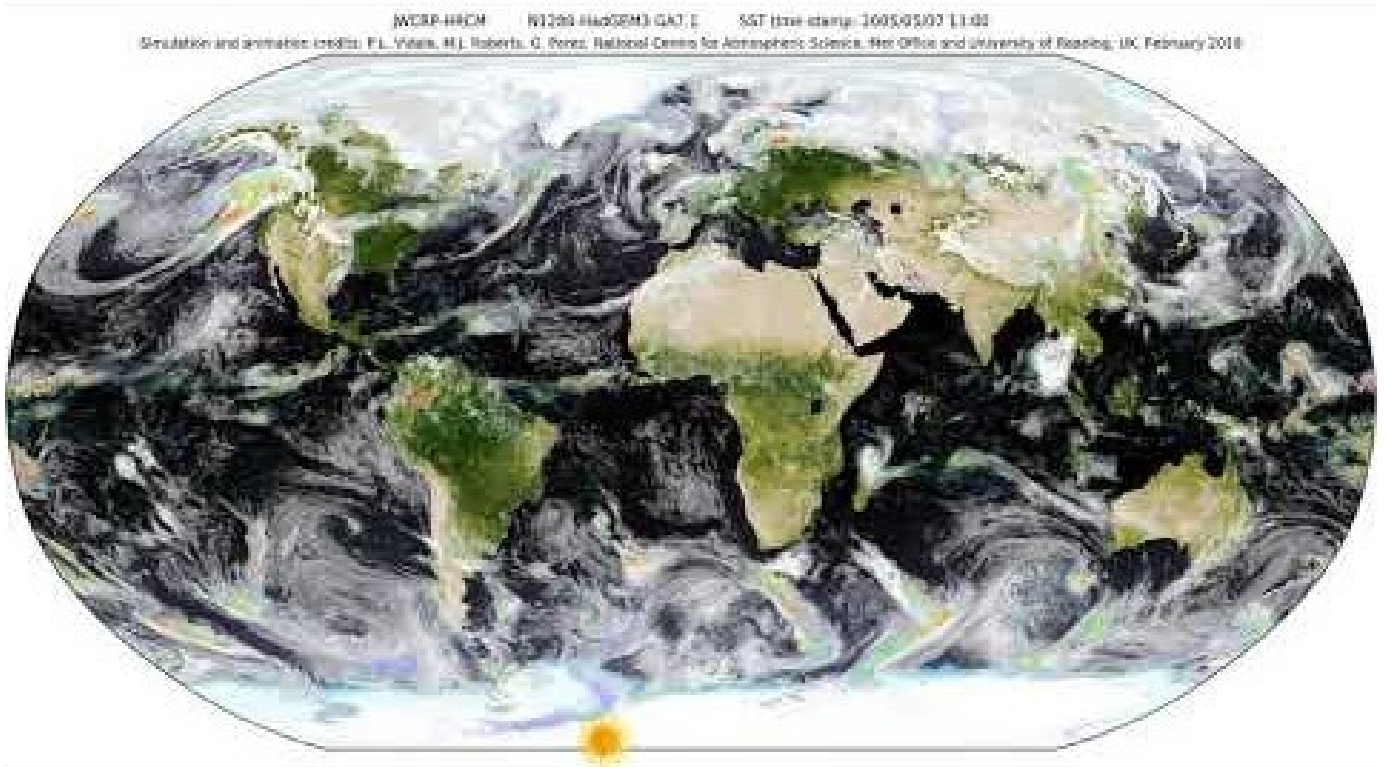
How do we make predictions?



- What's a prediction?
- Scientists use observations and experiments to understand the physics of the environment
- Physics of atmosphere, ocean & land encapsulated in millions of lines of computer code to construct climate simulations
- They are used to:
  - understand past climate change
  - project how climate will change over future decades and centuries



Met Office Hadley Centre



Simulation → Pier Luigi Vidale (University of Reading/NCAS)

It is indisputable that human activities are causing climate change

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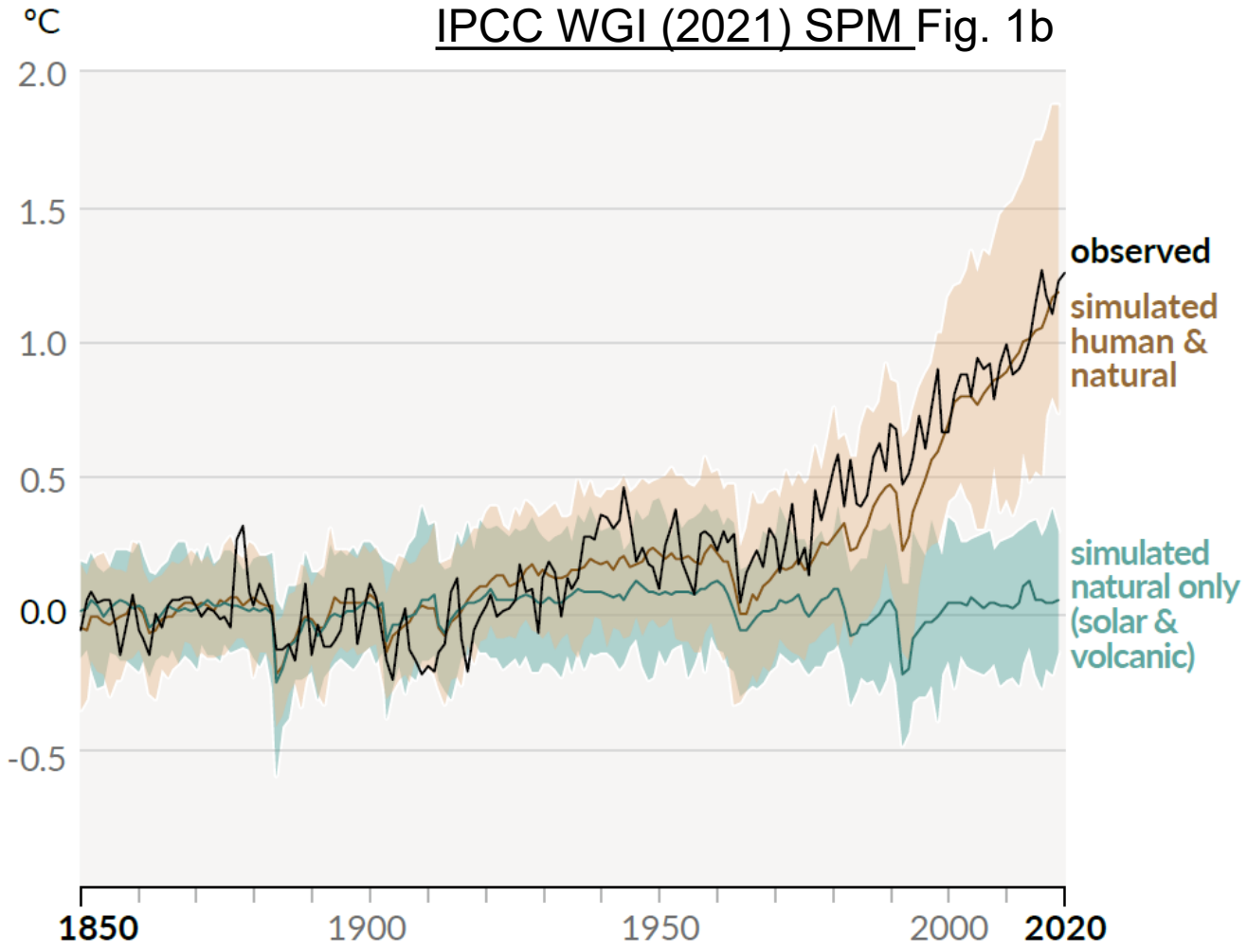
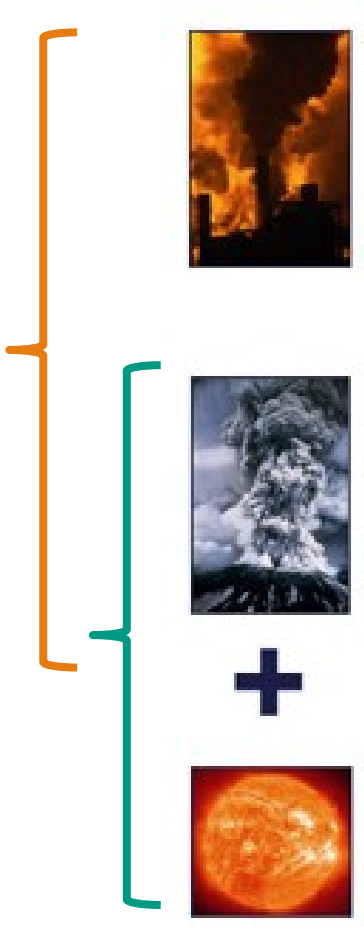
IPCC WGI (2021) SPM Fig. 1b





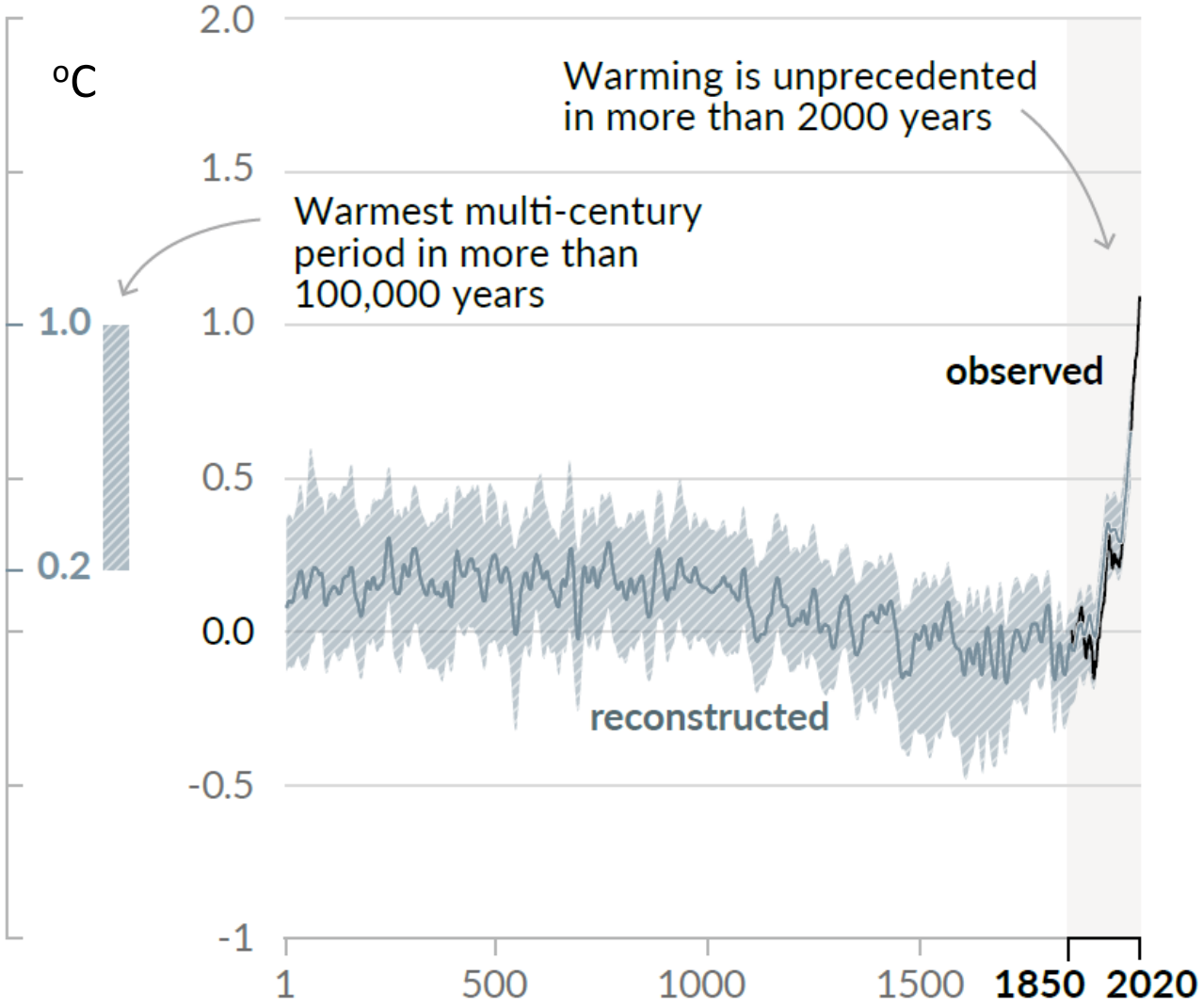
► Observed warming is driven by emissions from human activities

► Greenhouse gas warming has been partly masked by aerosol cooling

► Warming is amplified by feedback loops involving water vapour, ice & clouds

► Natural factors do not contribute to rapid warming over past 5 decades

Recent changes in the climate are widespread, rapid and unprecedented in thousands of years



- Global mean surface temperature increased faster since 1970 than in any other 50 year period over at least the last 2000 years
- Warmth of past decade comparable to last interglacial 125,000 years ago *[when peak sea level was 5-10m higher than today]*

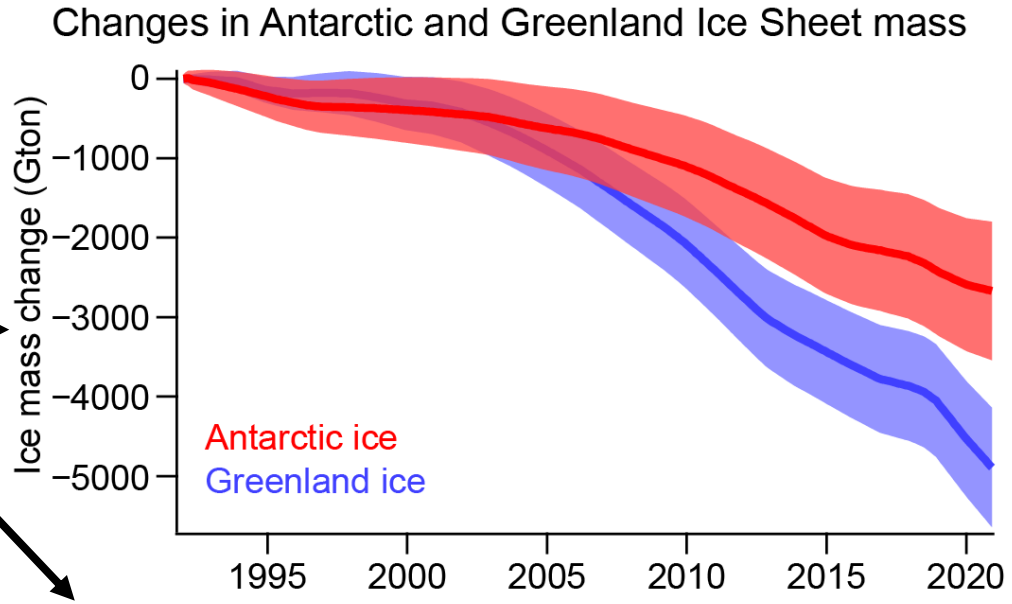
[IPCC WGI 2021 SPM]

ICE IS MELTING

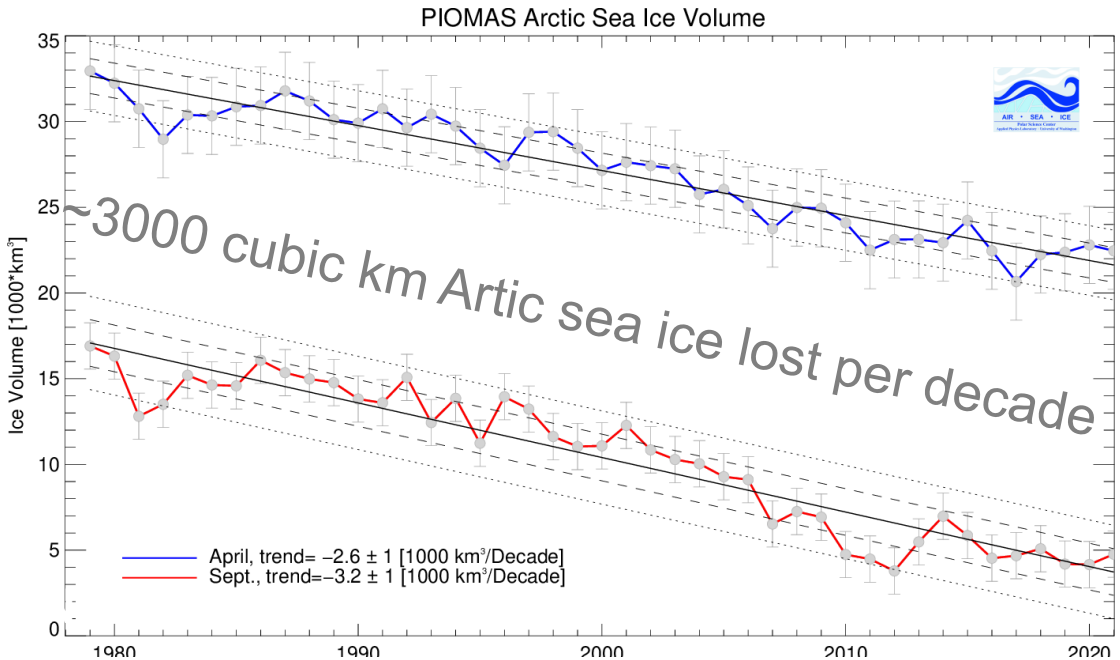
- Antarctica and Greenland are losing ice mass
- Arctic sea ice is melting

- Late summer Arctic sea ice area smaller than at any time in at least the past 1000 years
- glacier retreat since 1950s unprecedented in at least last 2000 years

[IPCC WGI 2021 SPM]

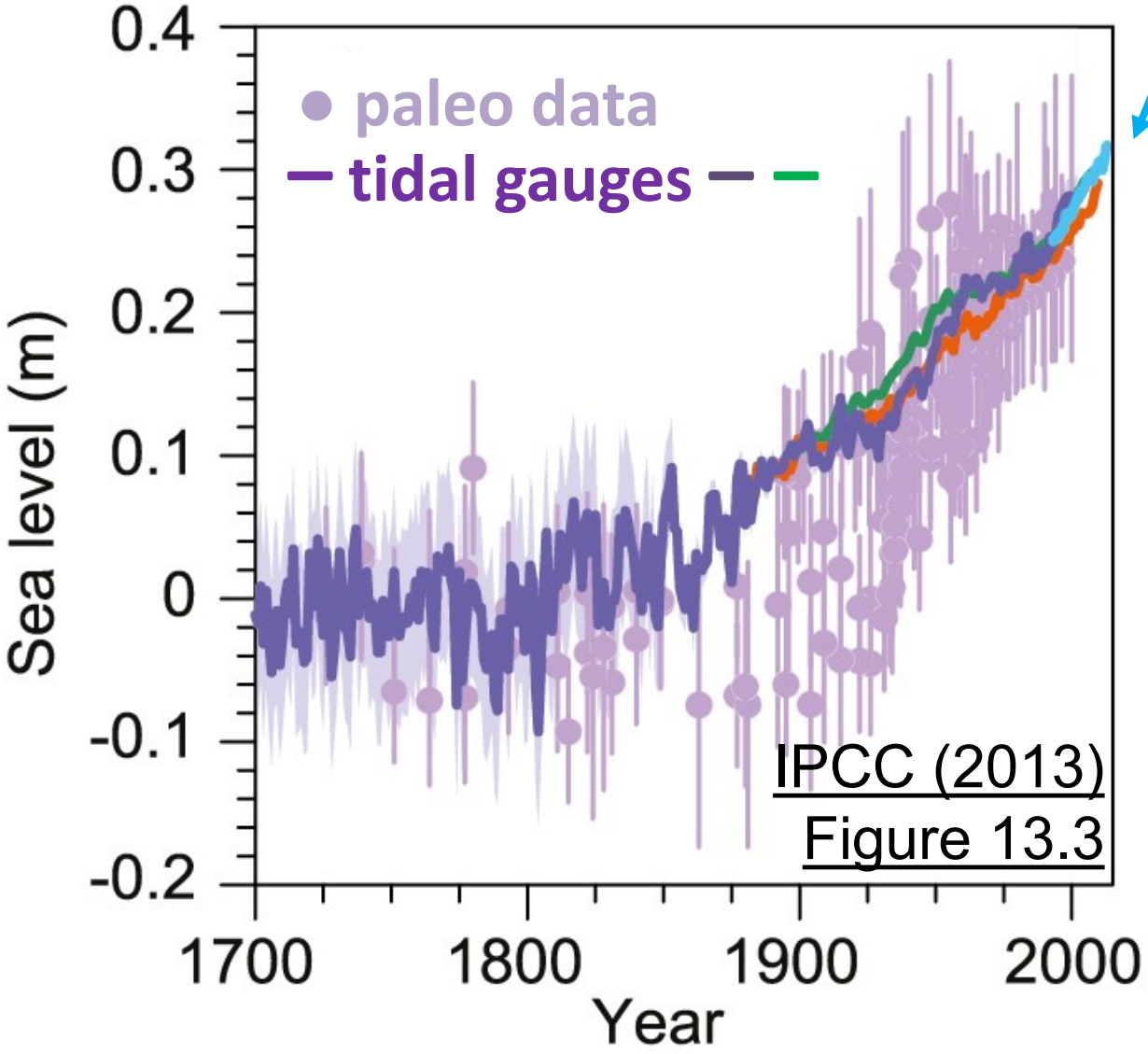


IPCC WG1 (2021)
Ch 2, Fig. 2.24

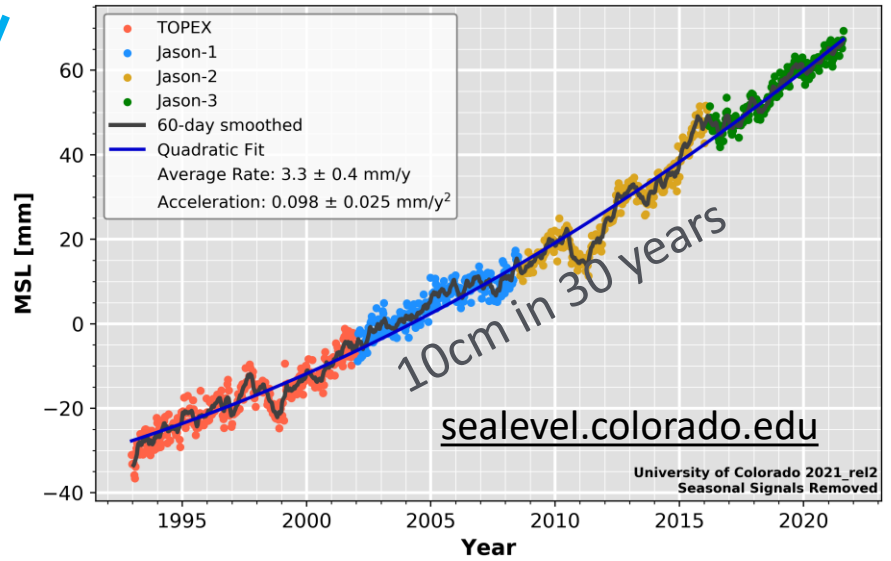


psc.apl.washington.edu/research/projects/arctic-sea-ice-volume-anomaly/

Global average sea level is rising…



Satellite Altimeter data



- 20cm increase in global mean sea level 1901-2018
- Rate of increase currently about 4cm per decade and accelerating

IPCC WG1 (2021) SPM; Ch. 2, Figure 2.28

HOW WILL CLIMATE CHANGE OVER OUR LIFETIMES?

EXAMPLE: HEATWAVES

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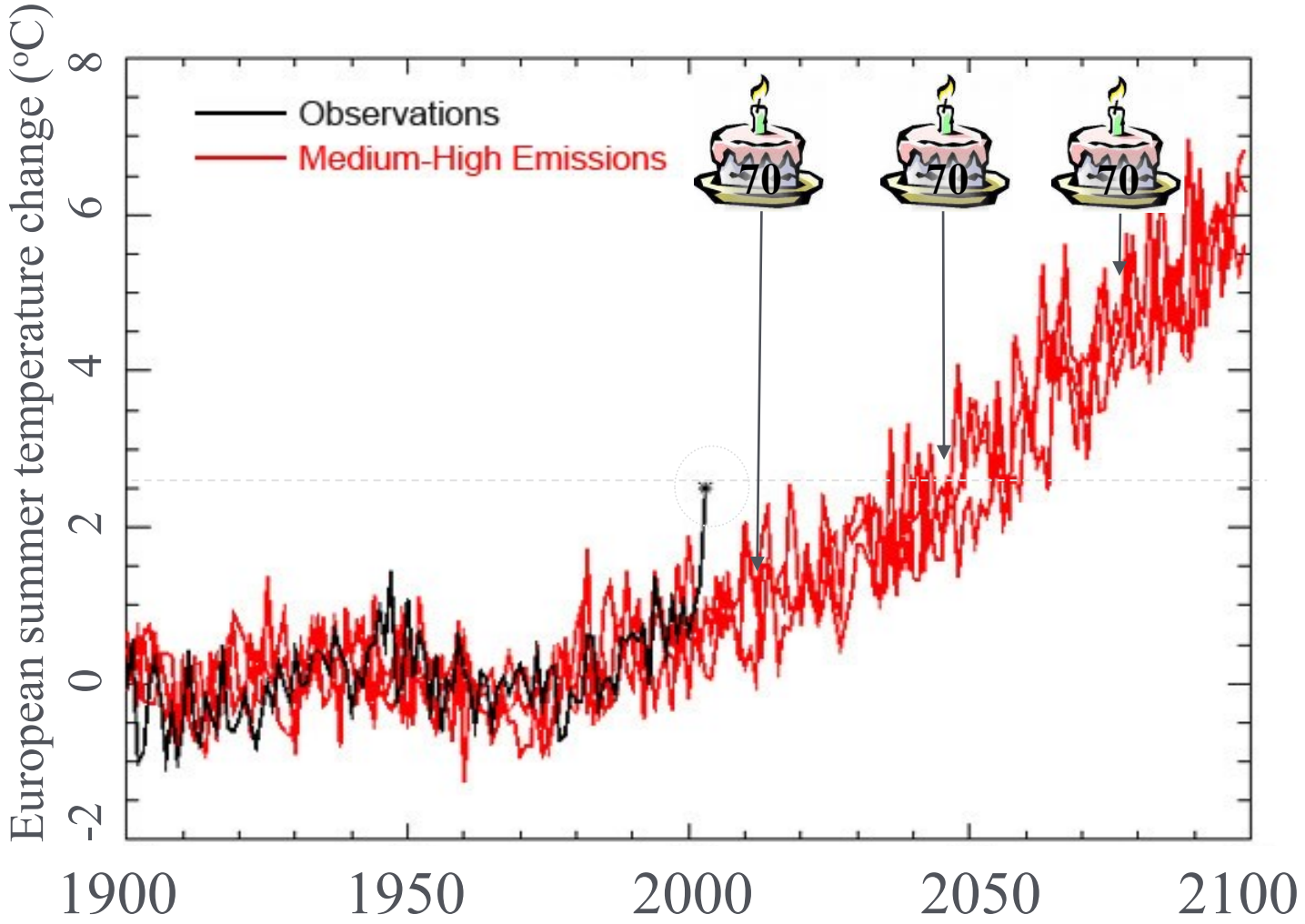

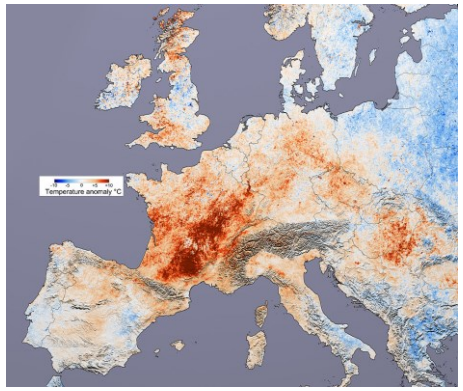

Continued global warming is projected to further intensify the global water cycle including the severity of wet and dry events

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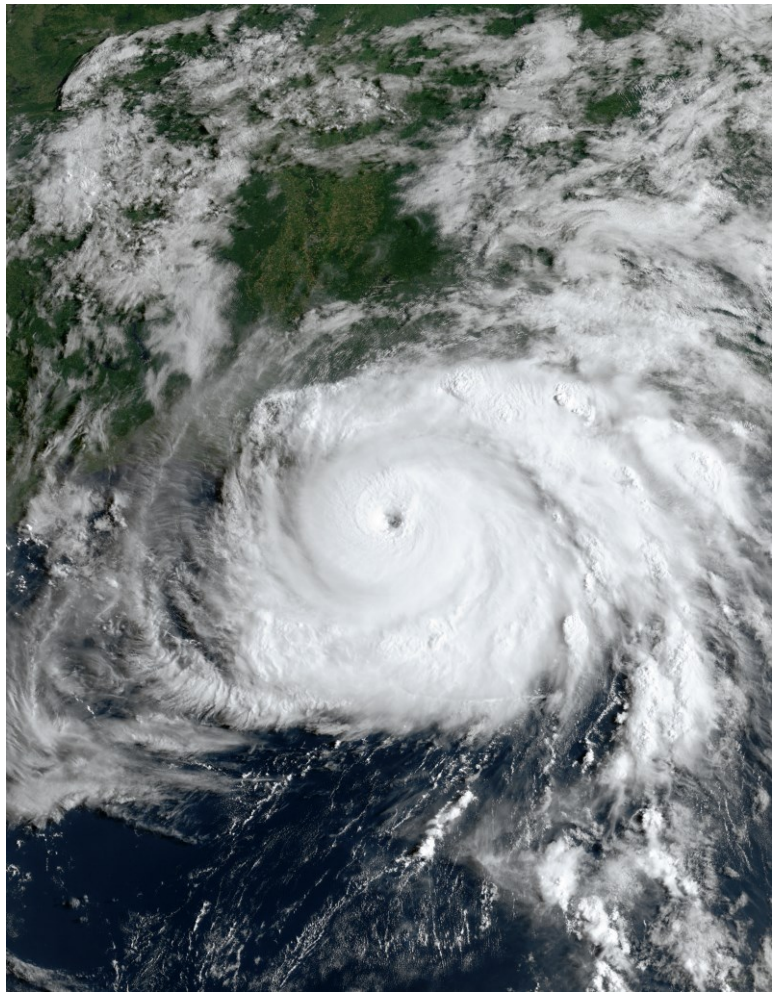
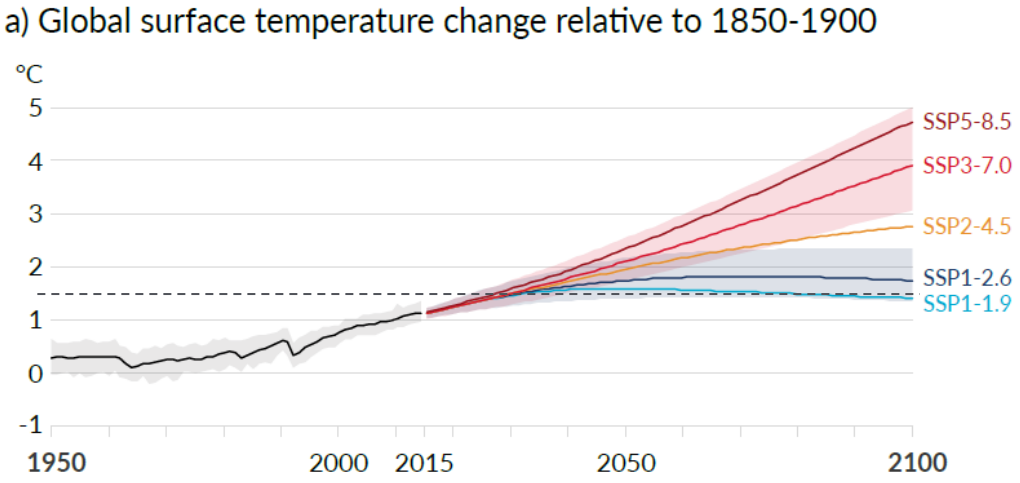
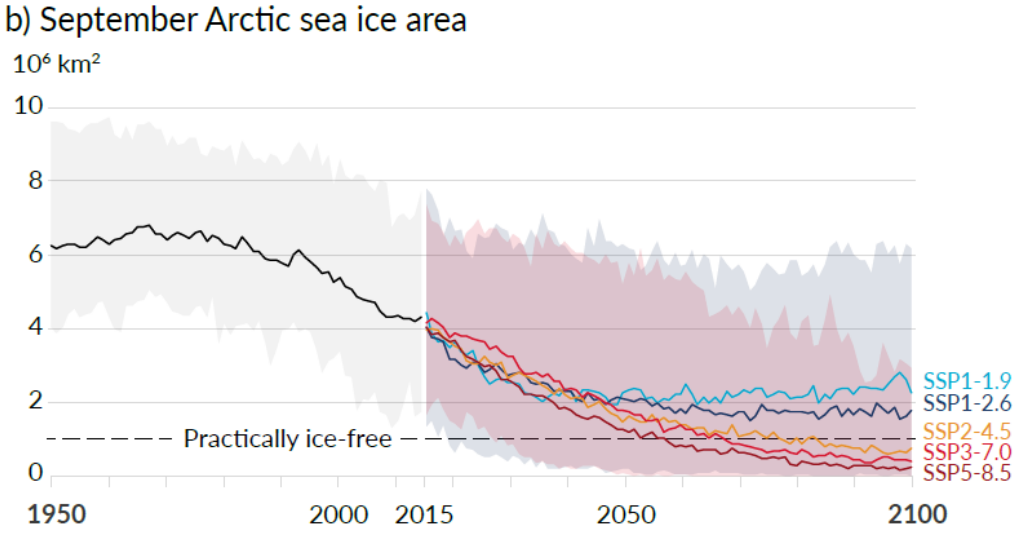


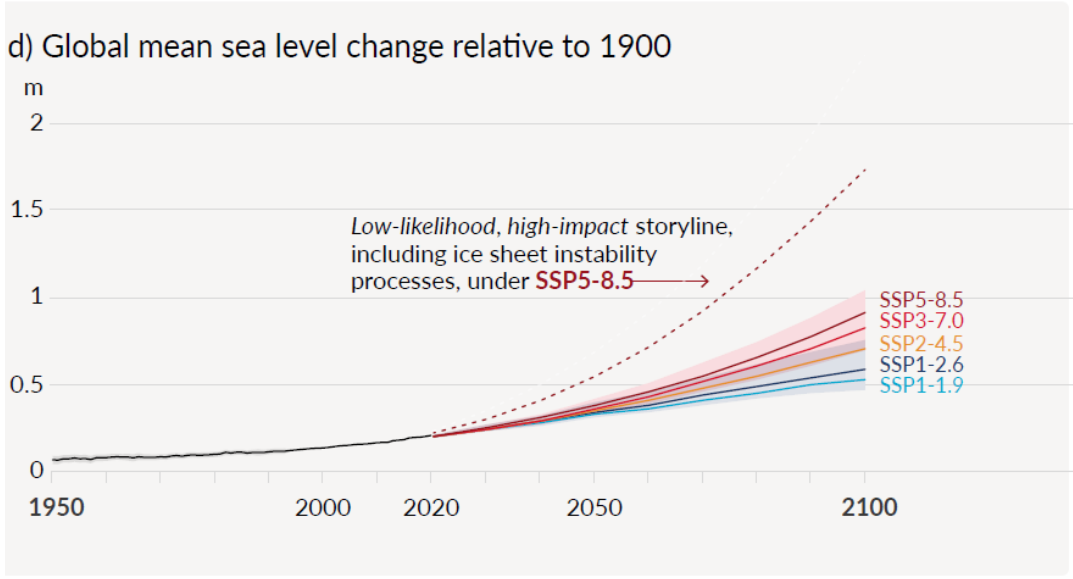
Some changes in the climate system are irreversible but many changes can be slowed or stopped by limiting warming

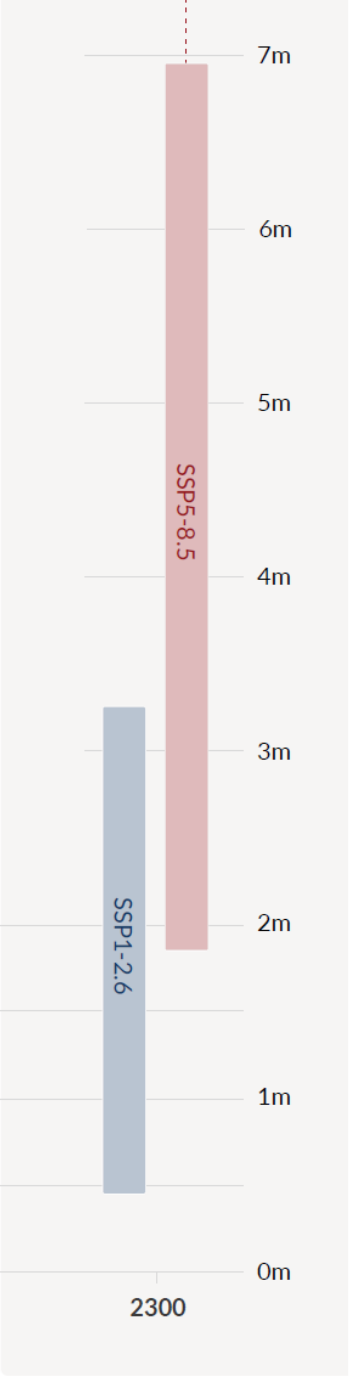


Global warming of 1.5°C and 2°C will be exceeded during the 21st century unless deep reductions in CO_2 and other greenhouse gas emissions occur in the coming decades
[IPCC (2021) WG1 SPM]

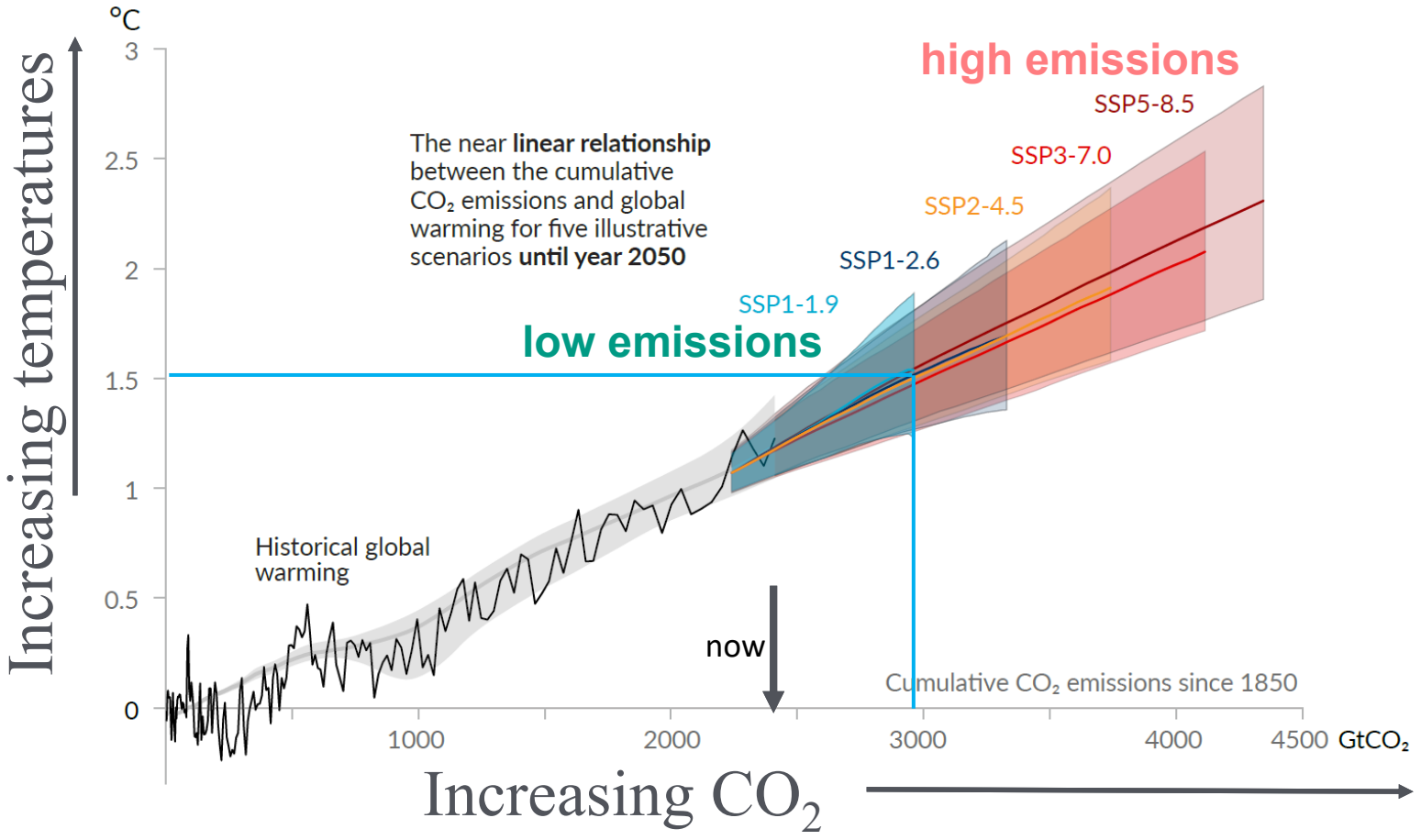
High emissions
Low emissions







Solution: Cut CO_2 Emissions to Net Zero



[IPCC WGI 2021 SPM]

- Each 1000 billion tonnes of CO_2 emission increases global temperature by ~0.5°C
- It is still physically possible to limit global warming to 1.5°C, but that requires deep reductions in CO_2 and other greenhouse gas emissions in the coming decades

Solutions: COP26 & beyond

- Greenhouse gas emission cuts across all sectors
- Capture and store CO_2
- Adapt to climate change

Summary

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- Earth's climate has always varied but it is an established fact that human activities are now driving climate change
- Recent changes in climate are widespread, rapid and unprecedented in thousands of years.
- Human activities are intensifying extreme climate events, including heat waves, heavy rainfall, and droughts
- Every bit of global warming increases the magnitude of regional climate change including the severity of extremes
- Limiting warming to 1.5°C requires immediate, rapid, and large-scale reductions in greenhouse gas emissions

IPCC report: www.ipcc.ch/report/ar6/wg1/