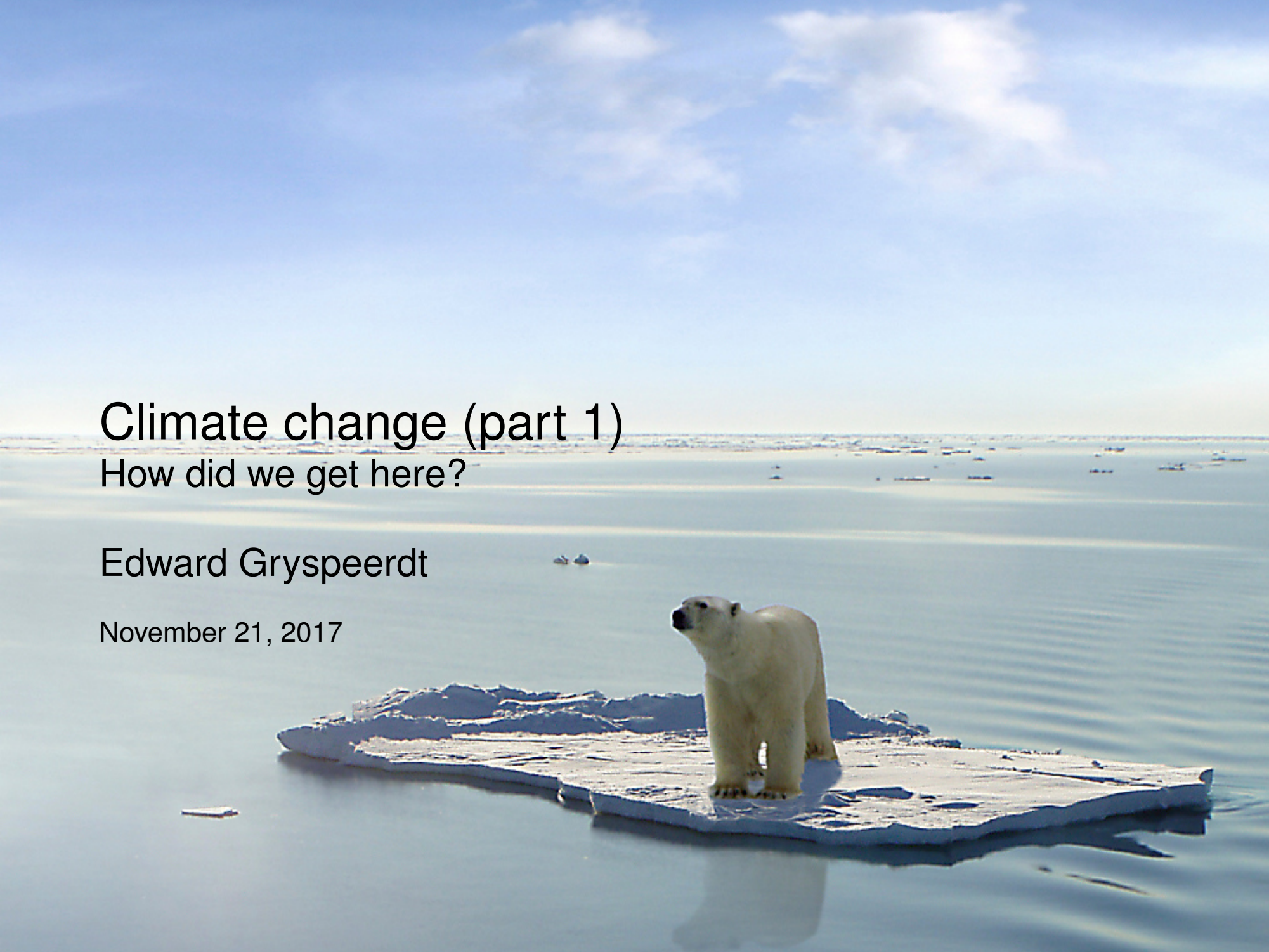
Climate change (part 1)

How did we get here?

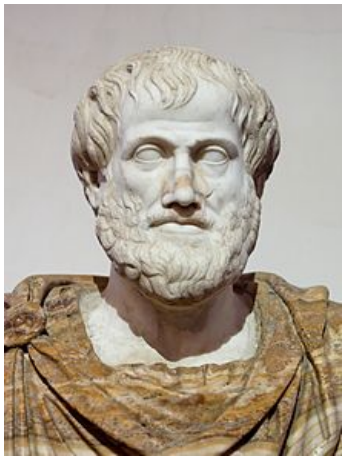
Edward Gryspeerdt

November 21, 2017



“Rain follows the plow”

The Greeks and Romans had ideas about climate change



“... places that formerly enjoyed a good climate deteriorate and grow dry. [...] In the time of the Trojan War, Argos was marshy [...], while Mycenae was good land [...]. Now the opposite is the case”

— Aristotle - Meteorologica ($\sim$350 BC)

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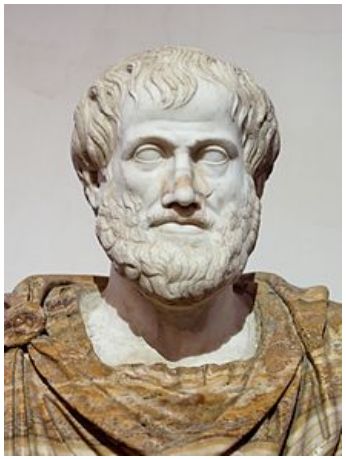

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Settlers in the new world had the theory that new settlements brought rain through agriculture

Image: Wikipedia-leaflet

The importance of an atmosphere

1820s: Fourier is credited with discovering the “greenhouse effect”

“The establishment and progress of human societies, the action of natural forces, can notably change, and in vast regions, the state of the surface, the distribution of water and the great movements of the air.”
“Such effects are able to make to vary, [...] the state of the surface and which greatly influence the temperature.”

Image: Wikipedia

Greenhouse gases

Carbonic Acid = 2·0.				
Dec.–Feb.	March–May.	June–Aug.	Sept.–Nov.	Mean of the year.
6·0	6·1	6·0	6·1	6·05
6·1	6·1	5·8	6·1	6·02
6·1	6·1	5·5	6·0	5·92
6·0	5·8	5·4	5·6	5·7
5·6	5·4	5·0	5·2	5·3
5·2	5·0	4·9	5·0	5·02
5·0	5·0	4·9	4·9	4·95
4·9	4·9	5·0	5·0	4·95
5·0	5·0	5·2	5·1	5·07
5·2	5·3	5·5	5·4	5·35
5·5	5·6	5·8	5·6	5·62
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  - Double the CO_2 gives a warming of 5-6°C

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  - Double the CO_2 gives a warming of 5-6°C
  - “This might be nice”...

Greenhouse gases (2)

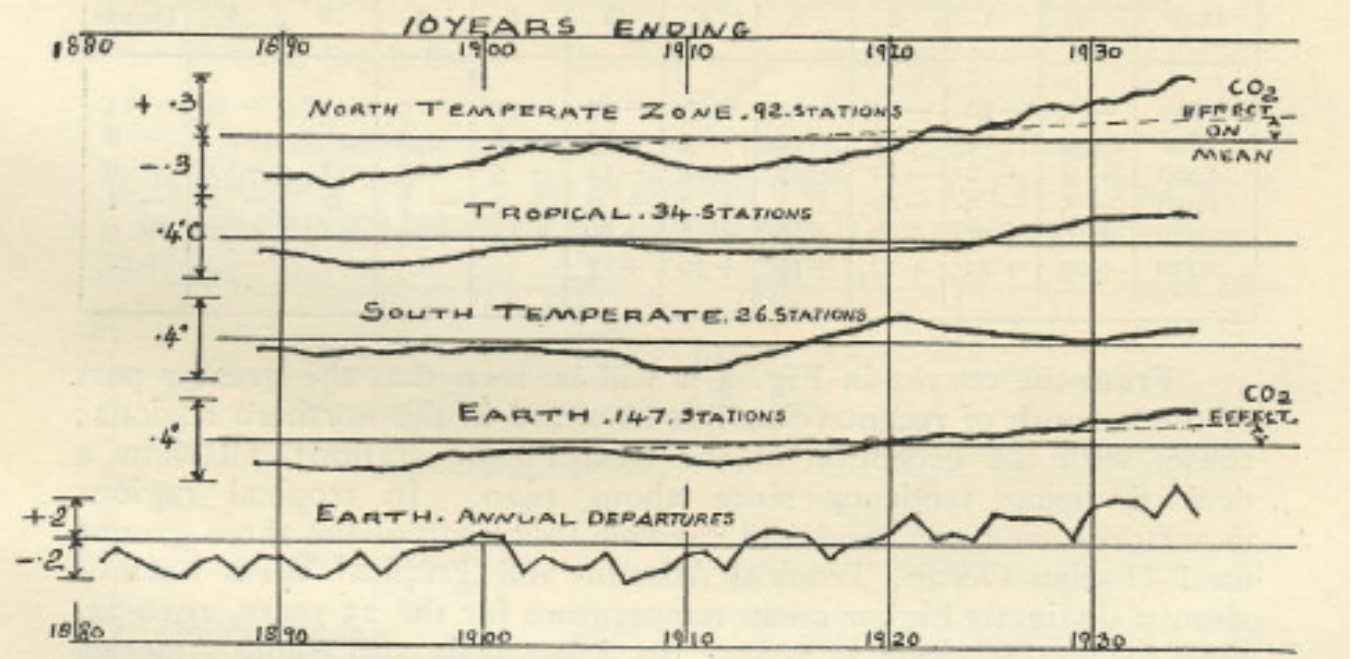

FIG. 4.—Temperature variations of the zones and of the earth. Ten-year moving departures from the mean, 1901-1930, °C.

- 1948: Guy Callender (a steam engineer) revived Arrhenius' work
- Suggested that a recent increase in temperature and CO_2 were linked
- The response from scientists at the time sounds familiar...

Greenhouse gases (3)

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"The Arctic is warming much faster. CO_2 would not produce such an effect so CO_2 cannot be responsible for any of the temperature change"

Scientific assessments

Evidence built further through the 60's and 70's

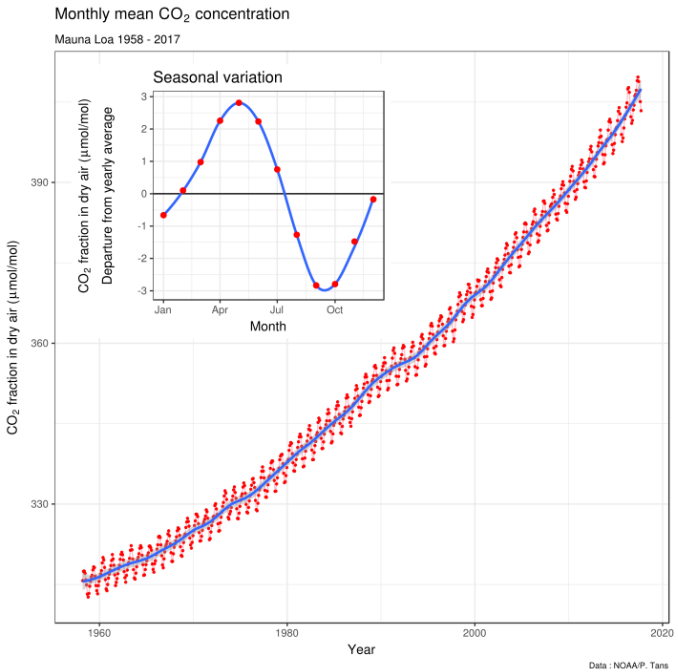

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Image: Wikipedia-delorme

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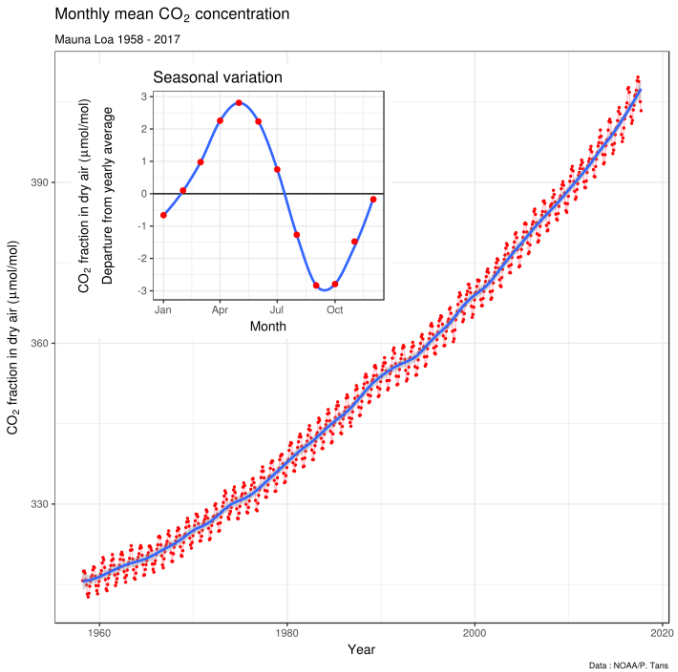

The Keeling Curve shows a strong increase in atmospheric CO_2 from the 1950s to the present

The increase of 25% CO2 expected by the end of the century therefore corresponds to an increase of 0.6°C in the world temperature, an amount somewhat greater than the climatic variation of recent centuries.

— John Sawyer (Director of Research, UK Met Office. 1972)

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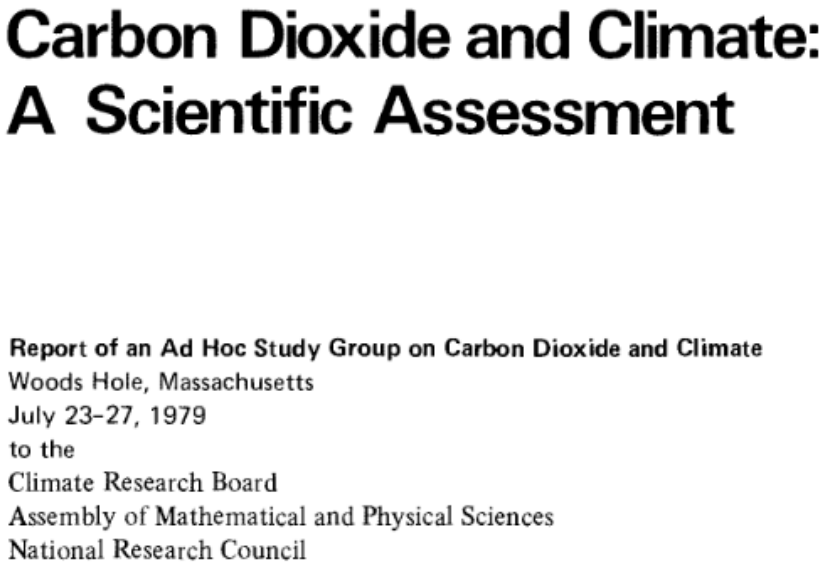
The “Charney report”

The “Charney report” by the US National Research Council, produced an estimate of the climate sensitivity (the warming due to the doubling of CO_2)



Carbon Dioxide and Climate: A Scientific Assessment

Report of an Ad Hoc Study Group on Carbon Dioxide and Climate
Woods Hole, Massachusetts
July 23–27, 1979
to the
Climate Research Board
Assembly of Mathematical and Physical Sciences
National Research Council

“When it is assumed that the CO_2 content of the atmosphere is doubled and statistical thermal equilibrium is achieved, the more realistic of the modeling efforts predict a global surface warming of between 2°C and 3.5°C, with greater increases at high latitudes.”

— J. Charney et al. (1979)

The IPCC

The World Meteorological Organisation (WMO) formed the Intergovernmental Panel on Climate Change (IPCC) in 1988.

The aim of the IPCC is to review and summarise current literature

- It does no research of it's own
- Produces reports every $\approx$6 years (1990, 1995, 2001, 2007, 2013)

The first (FAR) lead to the creation of the United Nations Framework Convention on Climate Change (UNFCCC)

The UNFCCC

Objective: “stabilize greenhouse gas concentrations in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate system”

It sets non binding limits on greenhouse gas emissions for developed (Annex I) countries and contains no enforcement mechanisms.

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- Kyoto (1997) - Set legally binding obligations to reduce GHG emissions
- Cancún (2010) - Agree warming should be limited to 2°C
- Paris (2015) - Aim to limit warming to less than 2°C, try for 1.5°C

IPCC Assessment reports

Currently three working groups

- WG1: Physical science basis
- WG2: Impacts and adaptation
- WG3: Mitigation of climate change
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Each report has a “summary for policymakers” (SPM), including the synthesis report

- The rest of the lecture is loosely based on the WG1 SPM


ipcc
ZWISCHENSTAATLICHER AUSSCHUSS FÜR Klimaänderung
KLIMAÄNDERUNG 2013
Wissenschaftliche Grundlagen
ZUSAMMENFASSUNG FÜR
POLITISCHE ENTSCHEIDUNGSTRÄGER

IPCC terminology

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 (see Figures SPM.1, SPM.2, SPM.3 and SPM.4). {2.2, 2.4, 3.2, 3.7, 4.2–4.7, 5.2, 5.3, 5.5–5.6, 6.2, 13.2}

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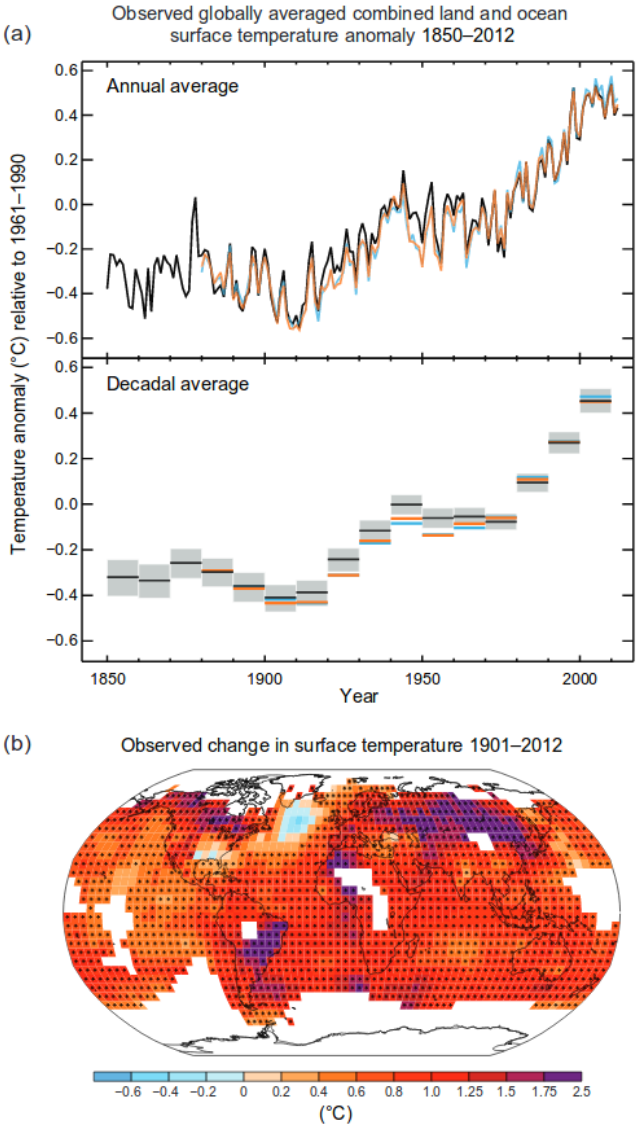
- High confidence
  - Robust evidence, agreement
- Medium confidence
  - Medium evidence, agreement
- Low confidence
  - Limited evidence, agreement

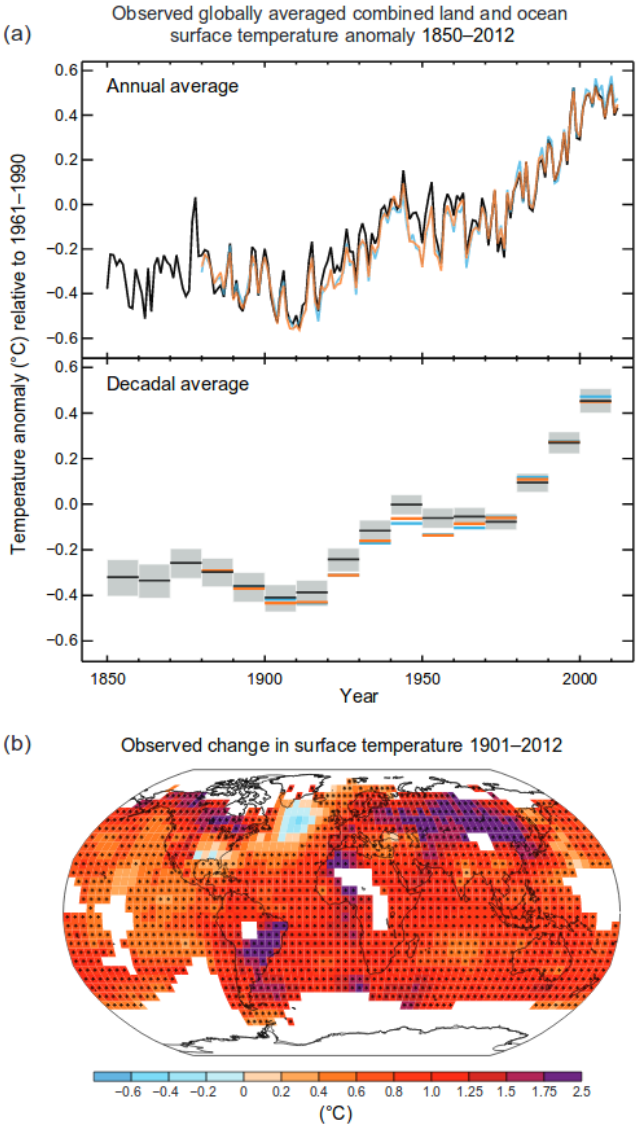
Term	Probability
Virtually Certain	99-100%
Extremely likely	95-100%
Very likely	90-100%
Likely	66-100%
About as likely as not	33-66%
Unlikely	0-33%
Very unlikely	0-10%
Exceptionally unlikely	0-1%

Atmosphere



- Total warming 1880-2012 is 0.85[0.65 to 1.06]°C

Atmosphere



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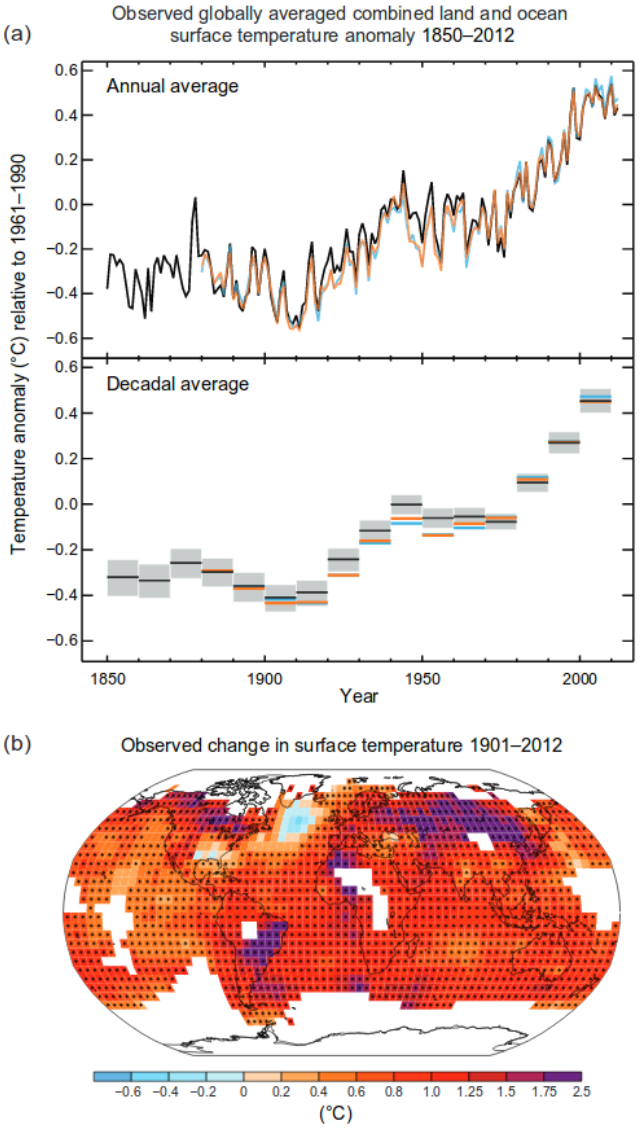

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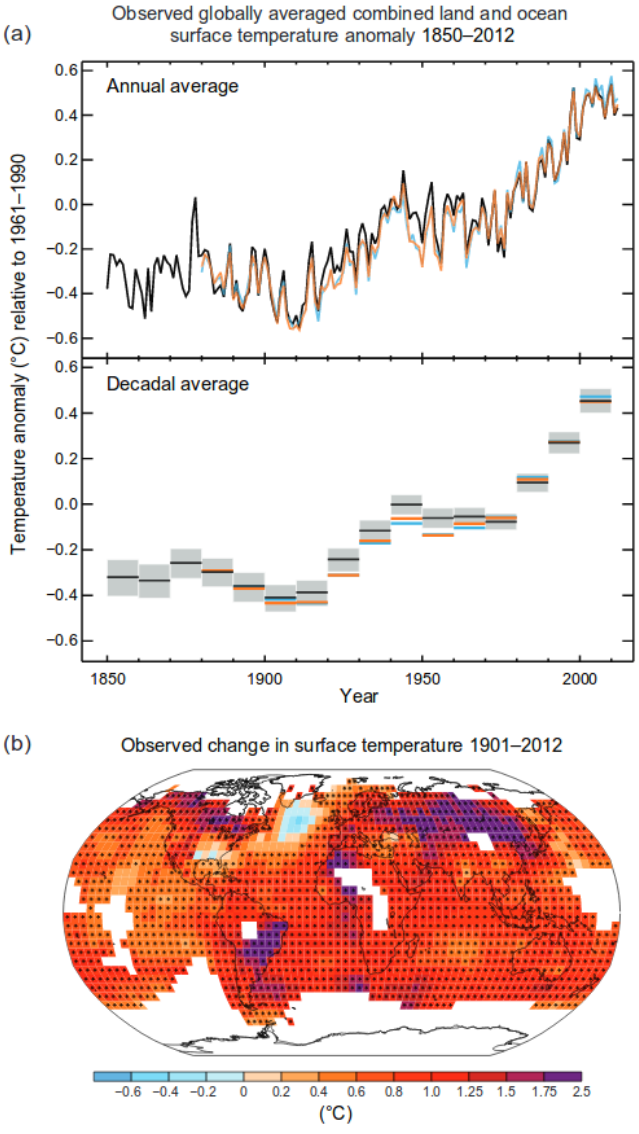

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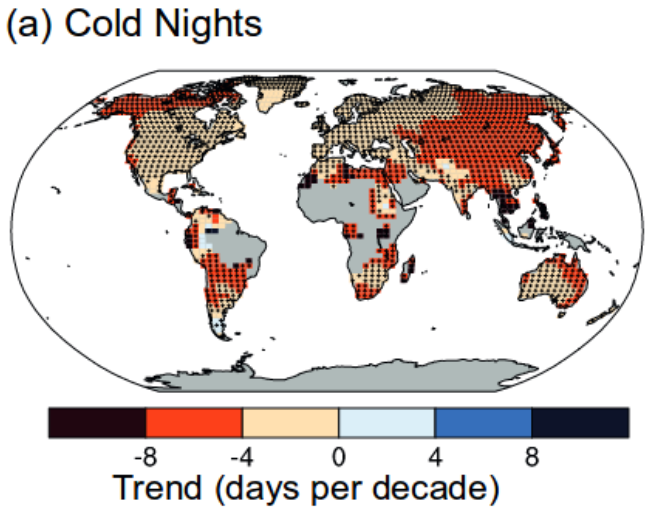

Trend in the number of cold nights

- Cold days and nights have decreased

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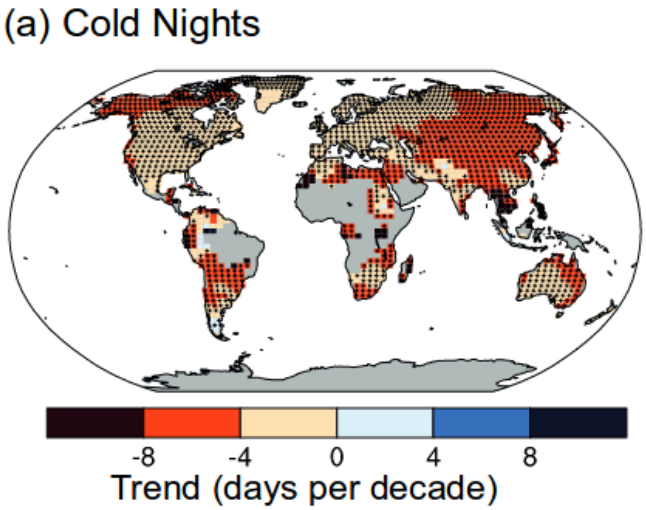

Trend in the number of cold nights

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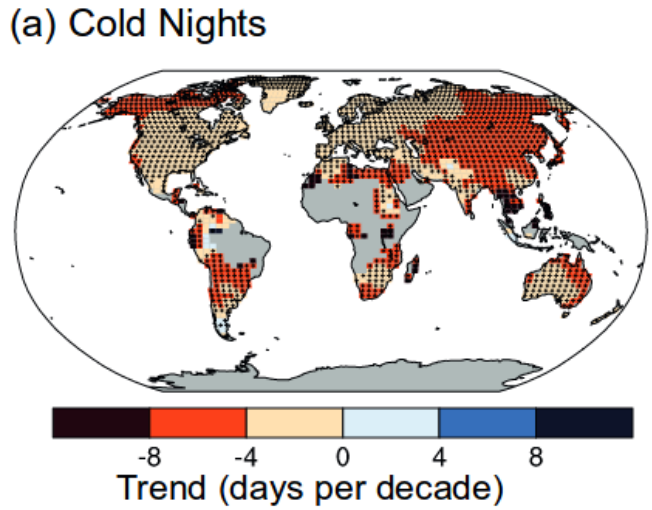

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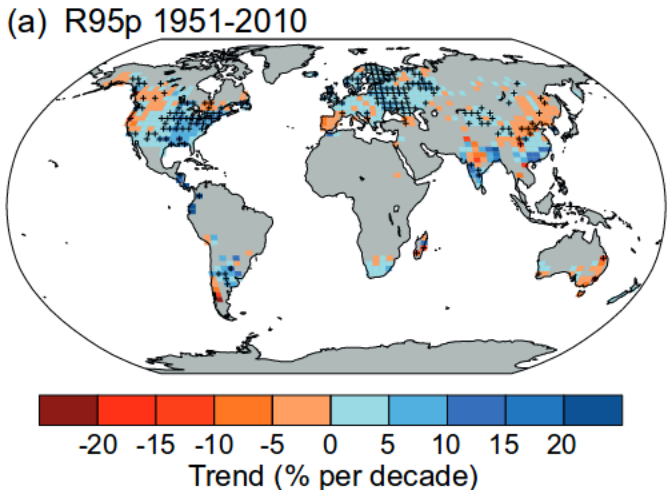

Trend in the amount of heavy precipitation events. Grey is missing data.

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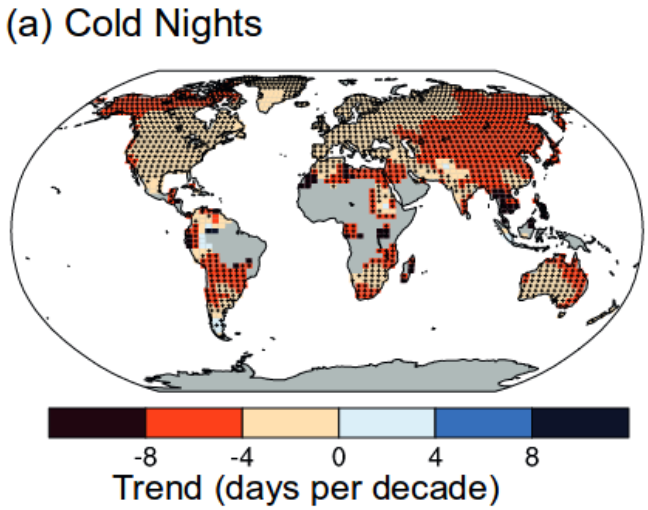

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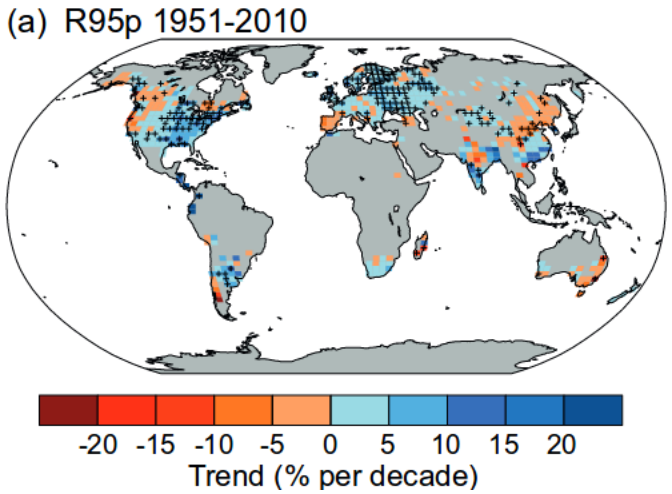

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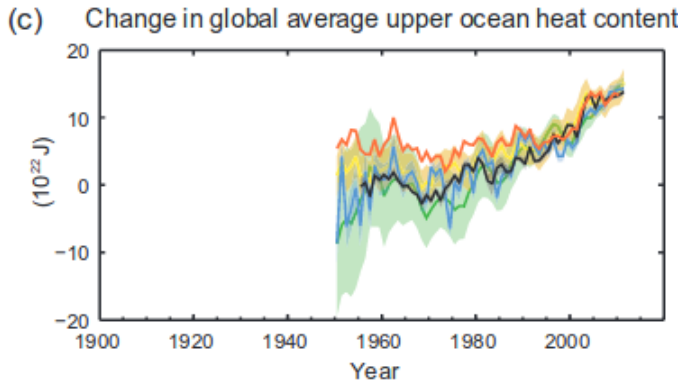

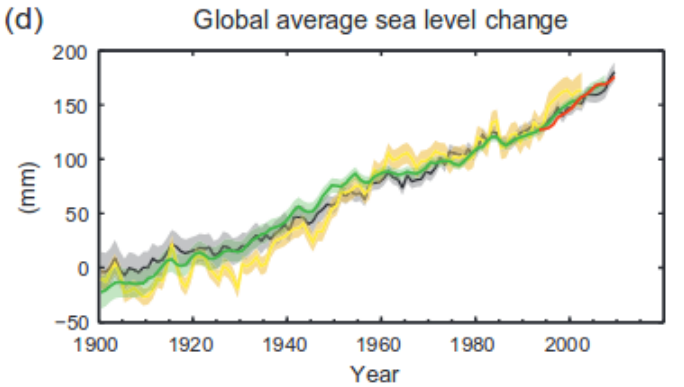

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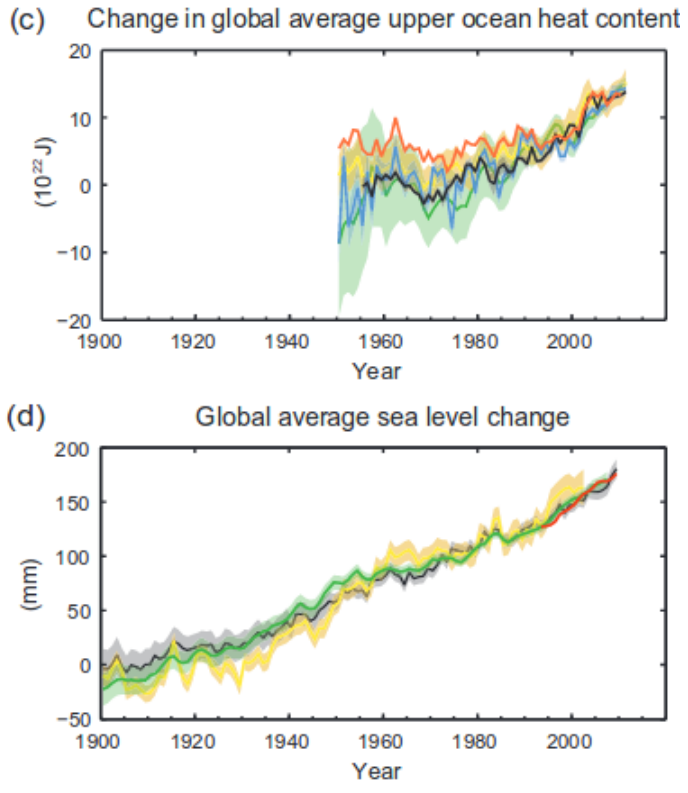

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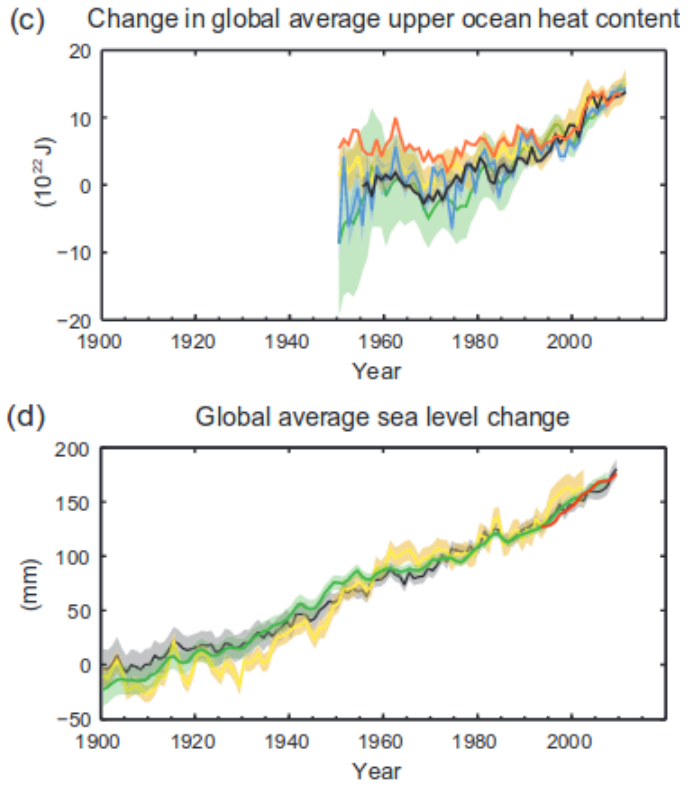

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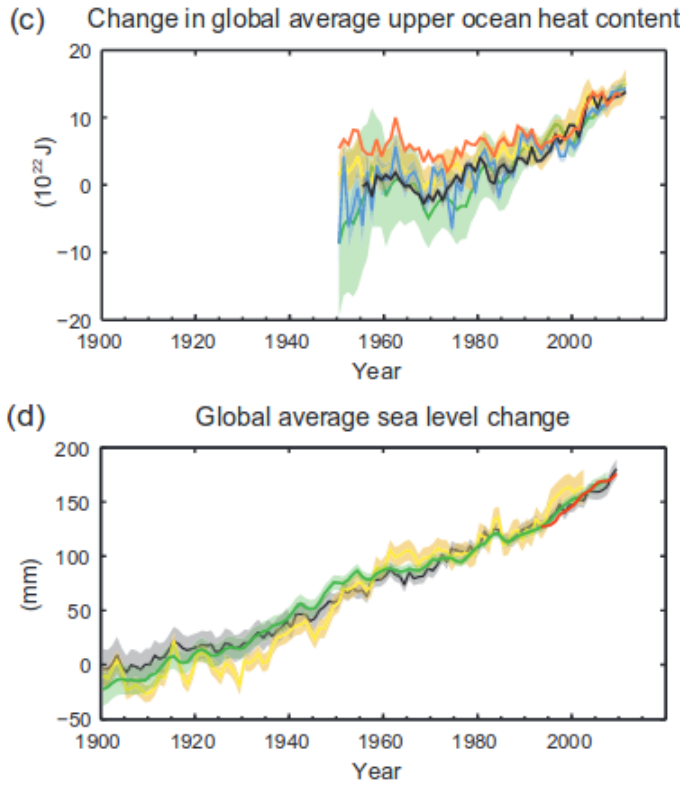

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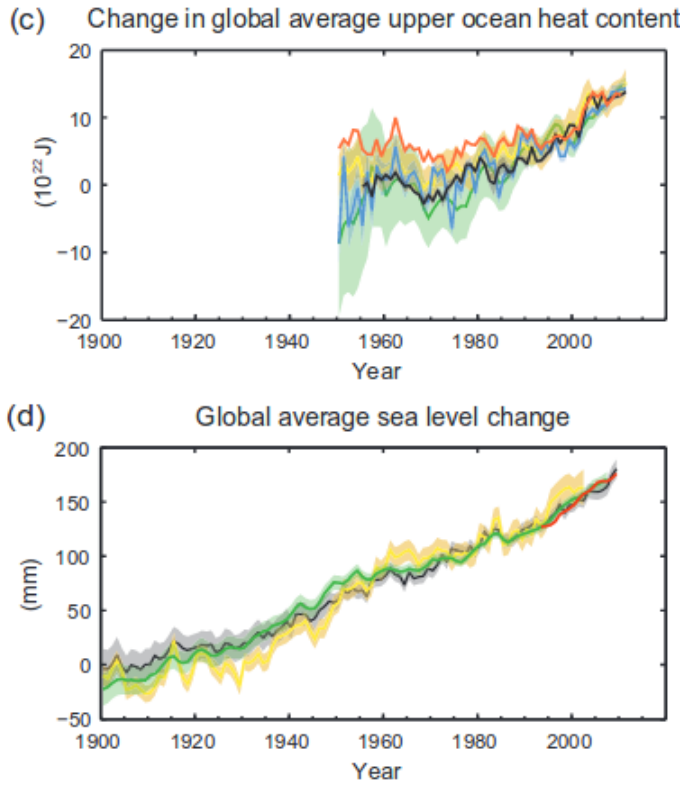

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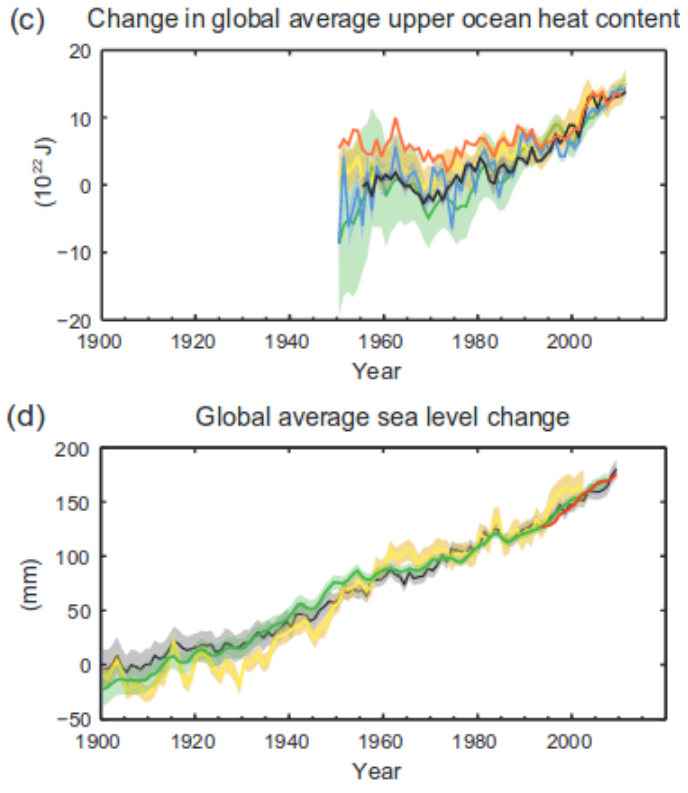

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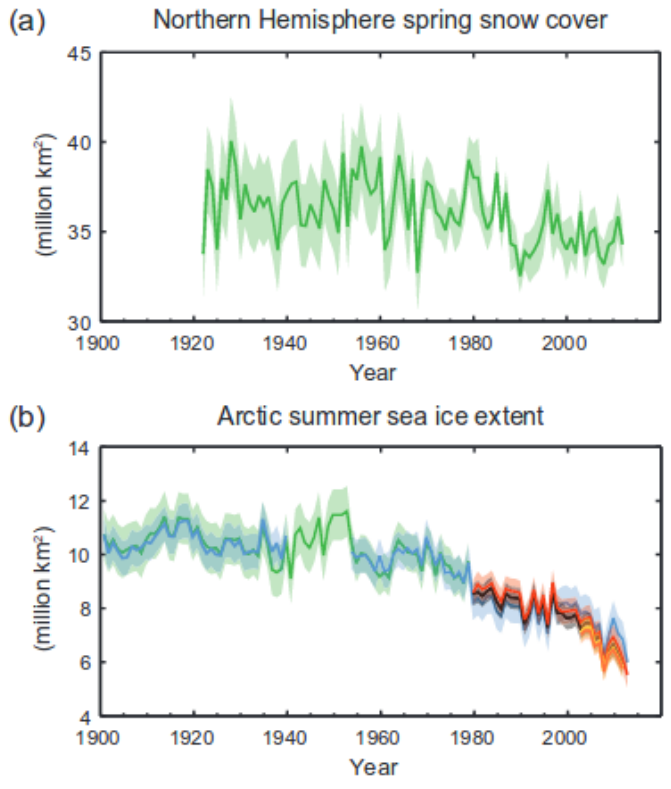
- Tide gauges and satellite altimetry

Cryosphere

- Greenland and Antarctic ice sheets have been losing mass



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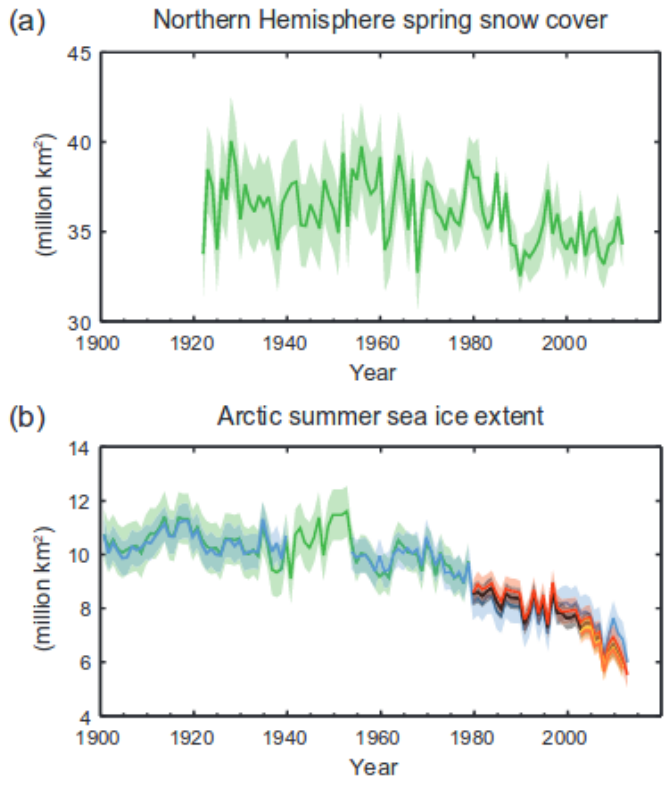
- Northern Hemisphere snow cover has decreased



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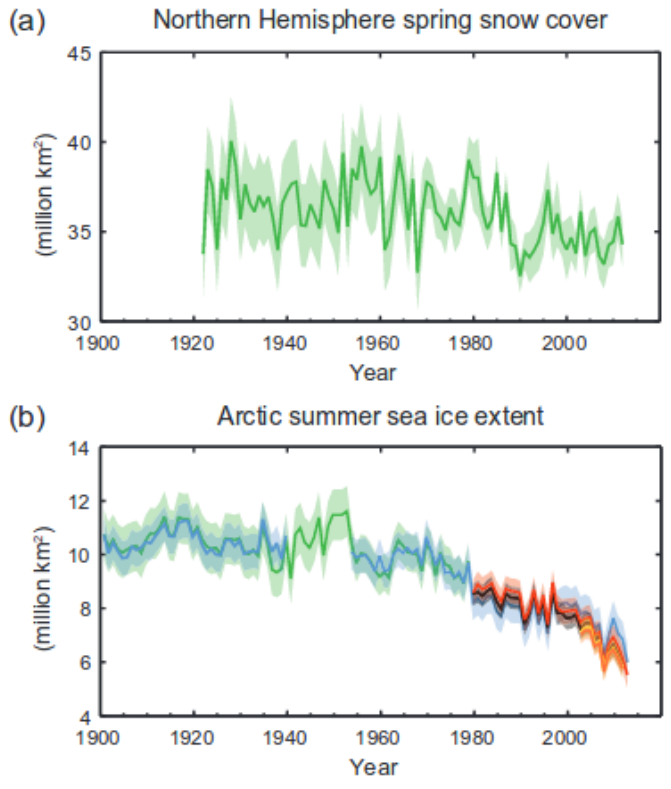
- Northern Hemisphere snow cover has decreased
- Permafrost area has decreased



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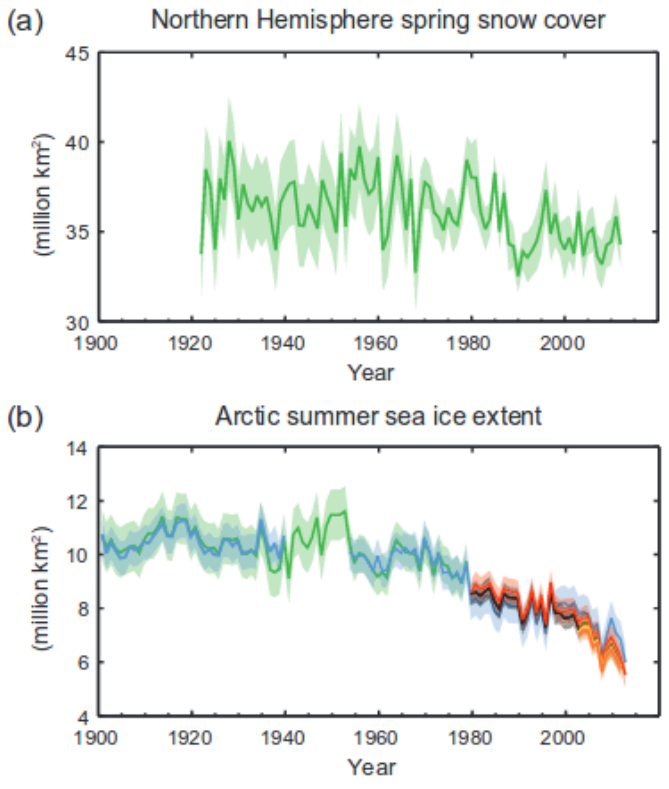

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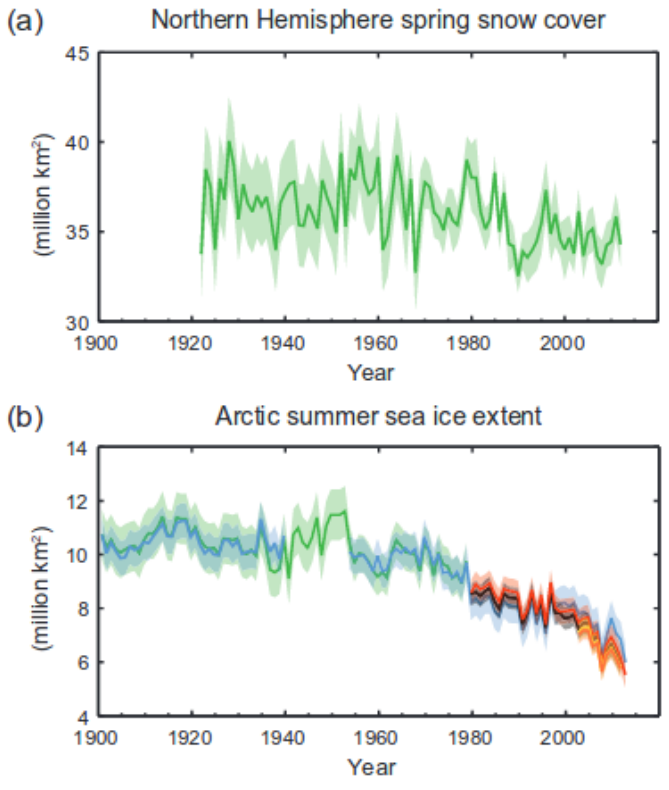
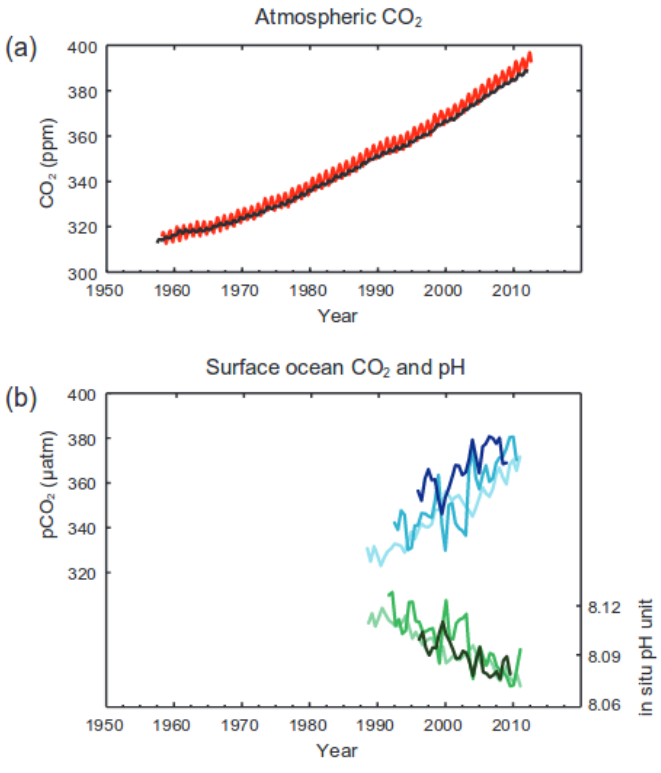
How do we know?

- Satellite and surface altimetry of ice sheets
- Satellite measurements of sea ice
- Surface observer reports



Carbon

- CO_2, CH_4, NO_x are at levels unprecedented in the last 800,000 years



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- CO_2, CH_4, NO_x are at levels unprecedented in the last 800,000 years
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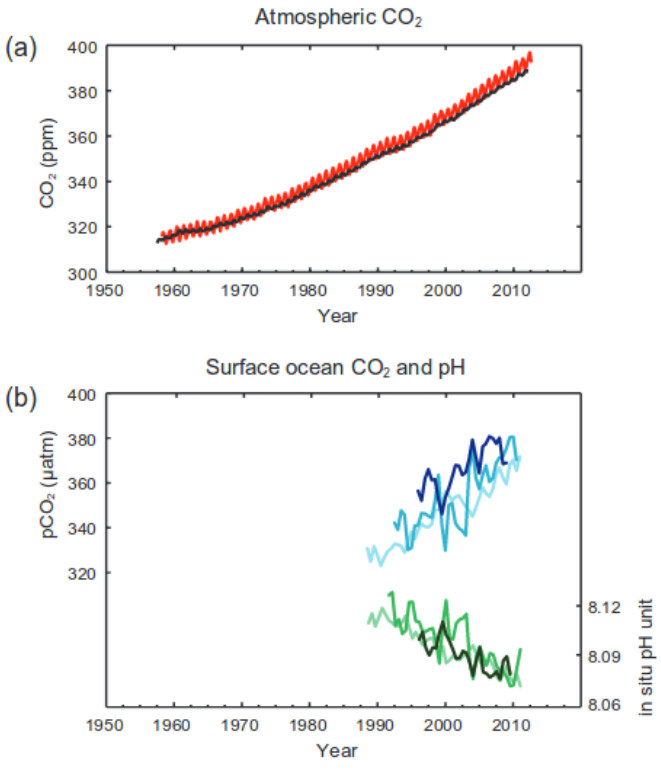

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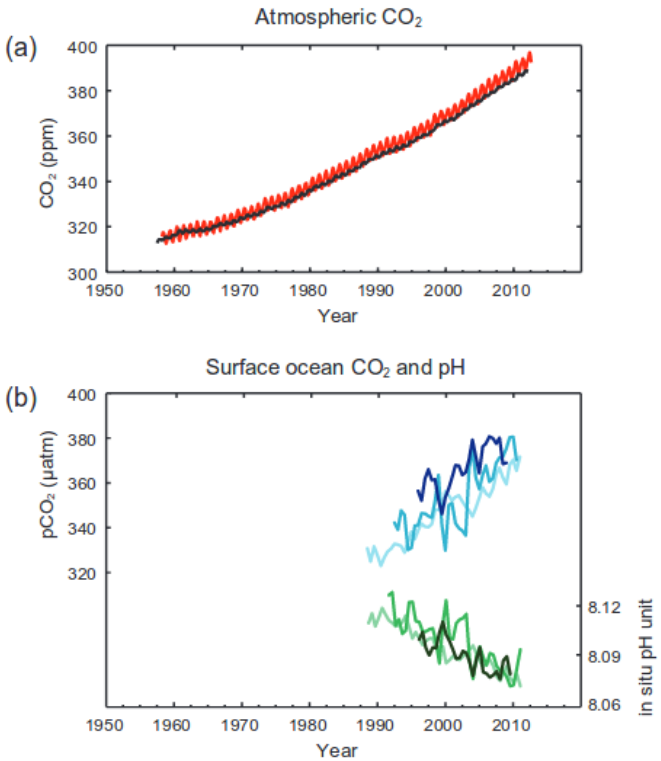

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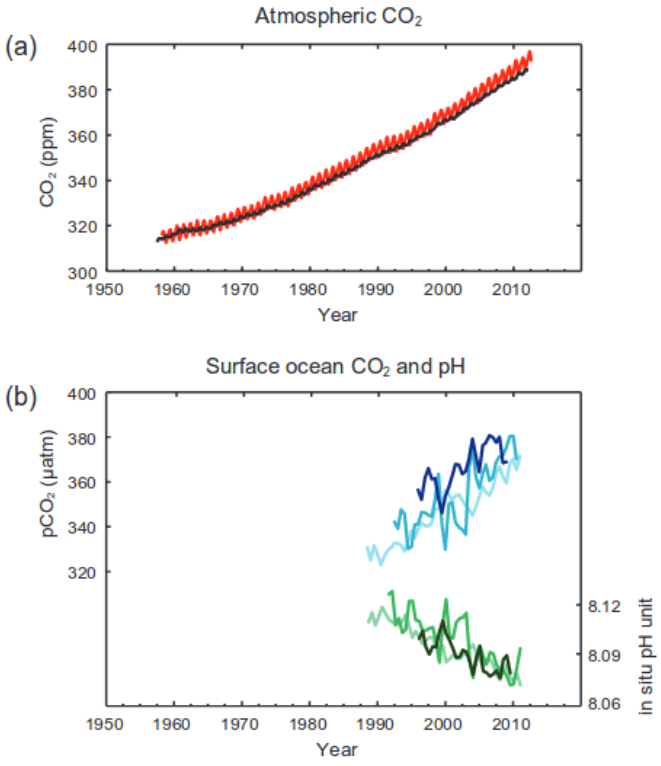
How do we know?

- In-situ gas concentration measurements
- Satellite remote sensing
- Ice core measurements/proxies

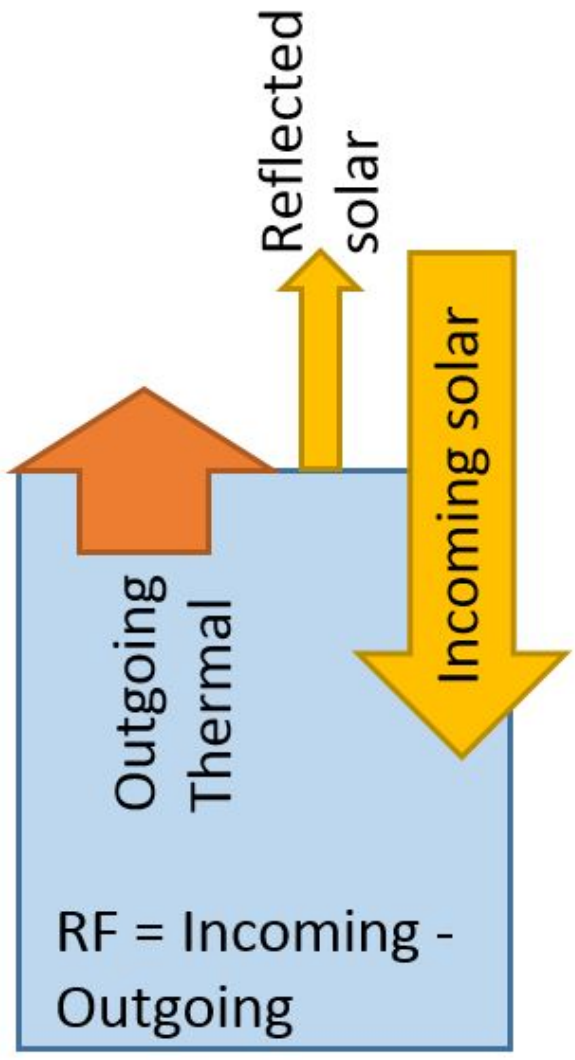


Radiative forcing

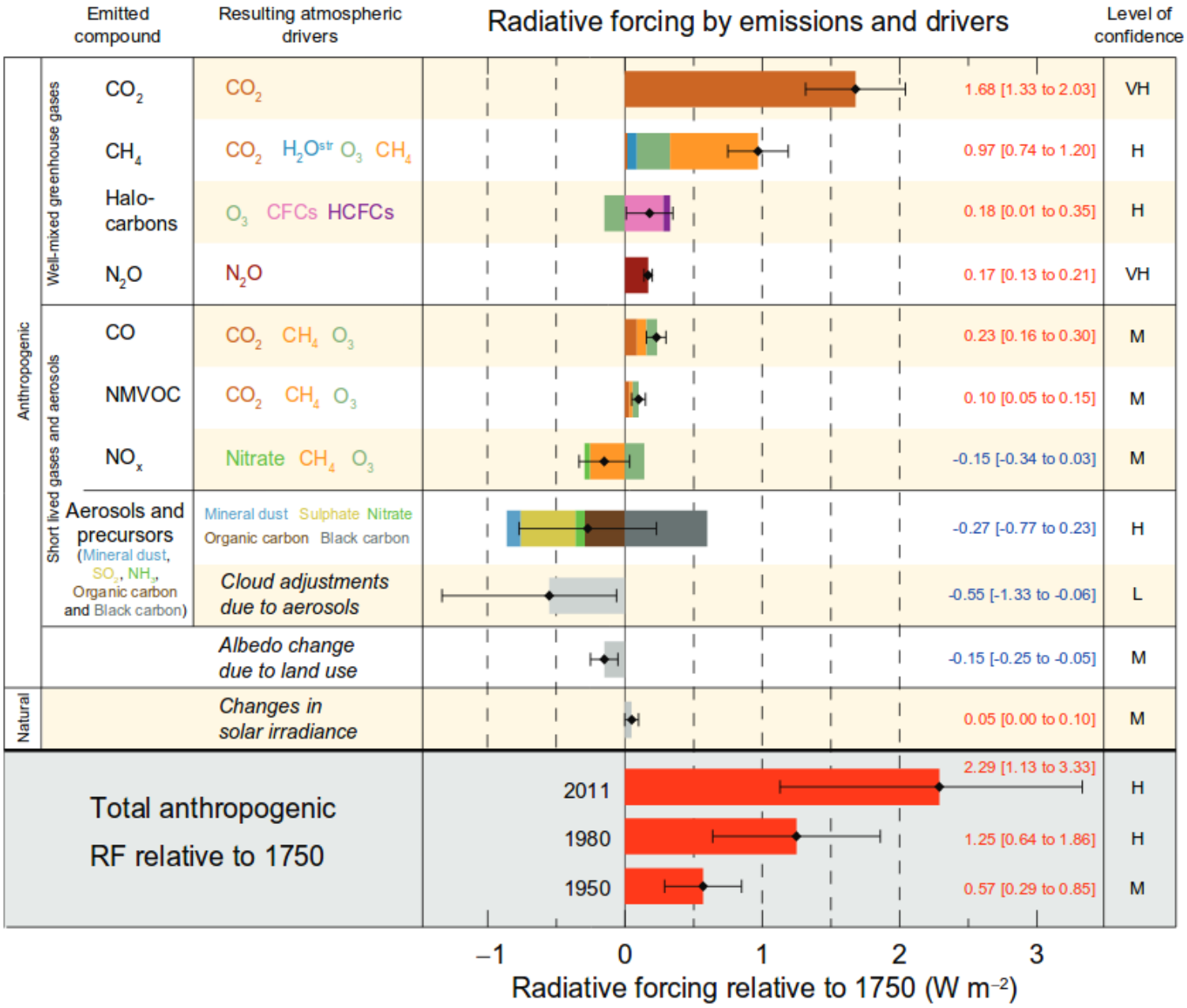
Radiative forcing (RF) quantifies the change in energy fluxes caused by a climate change driver.

- Positive RF - leads to surface warming
- Negative RF - leads to cooling

The total RF is positive, with the leading component being greenhouse gases



Radiative forcing by component



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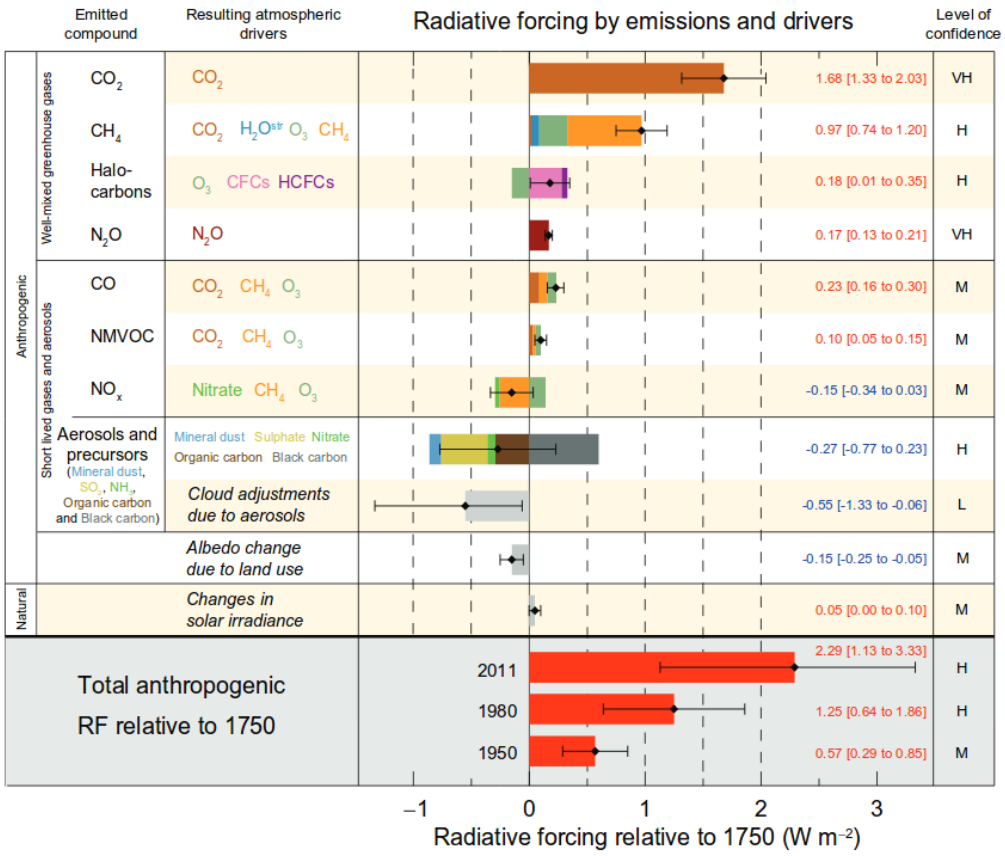

Key points:

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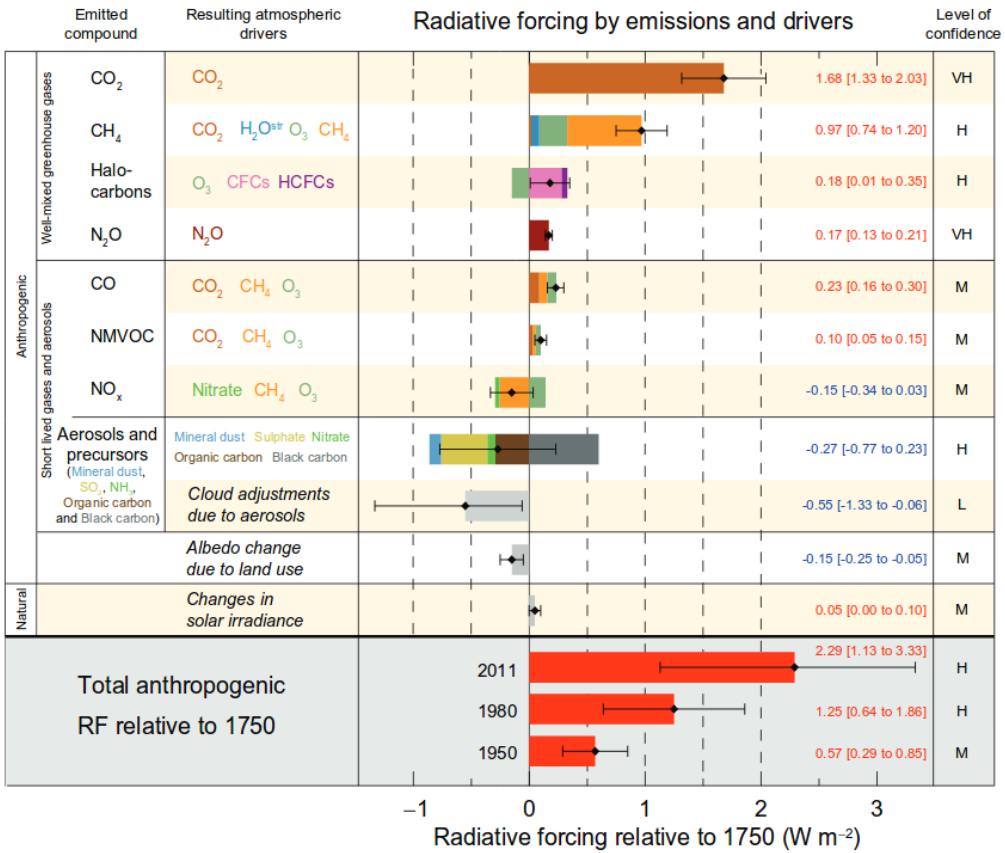

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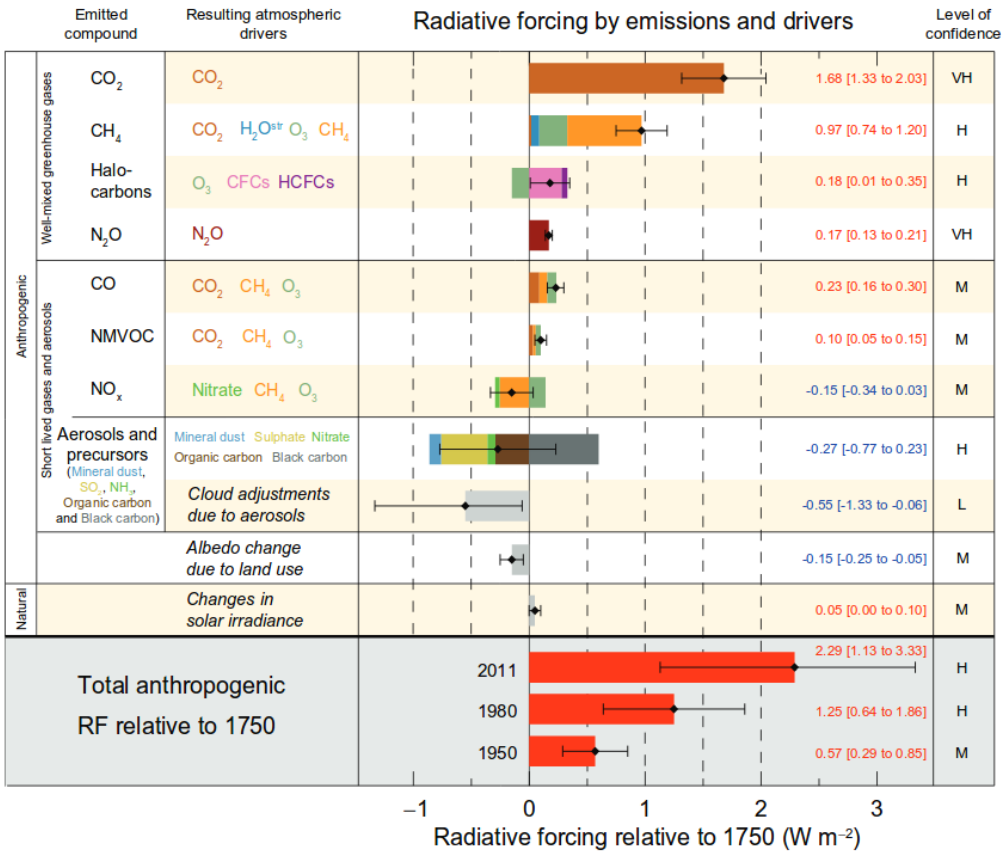

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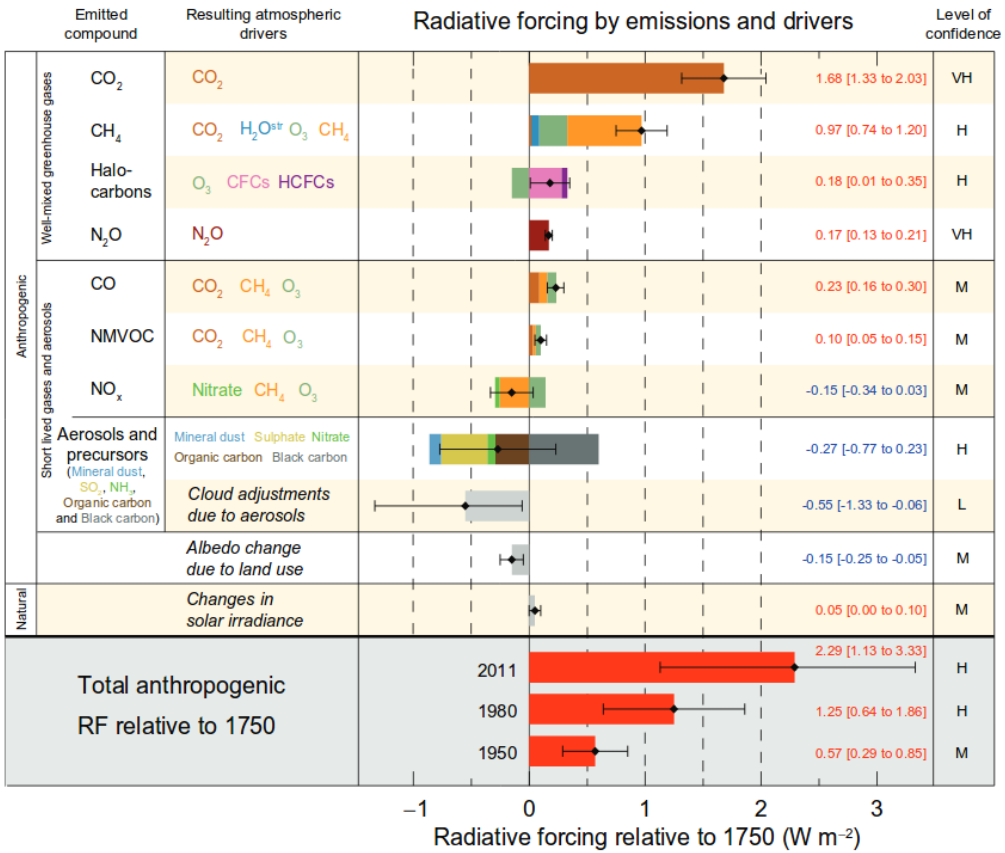

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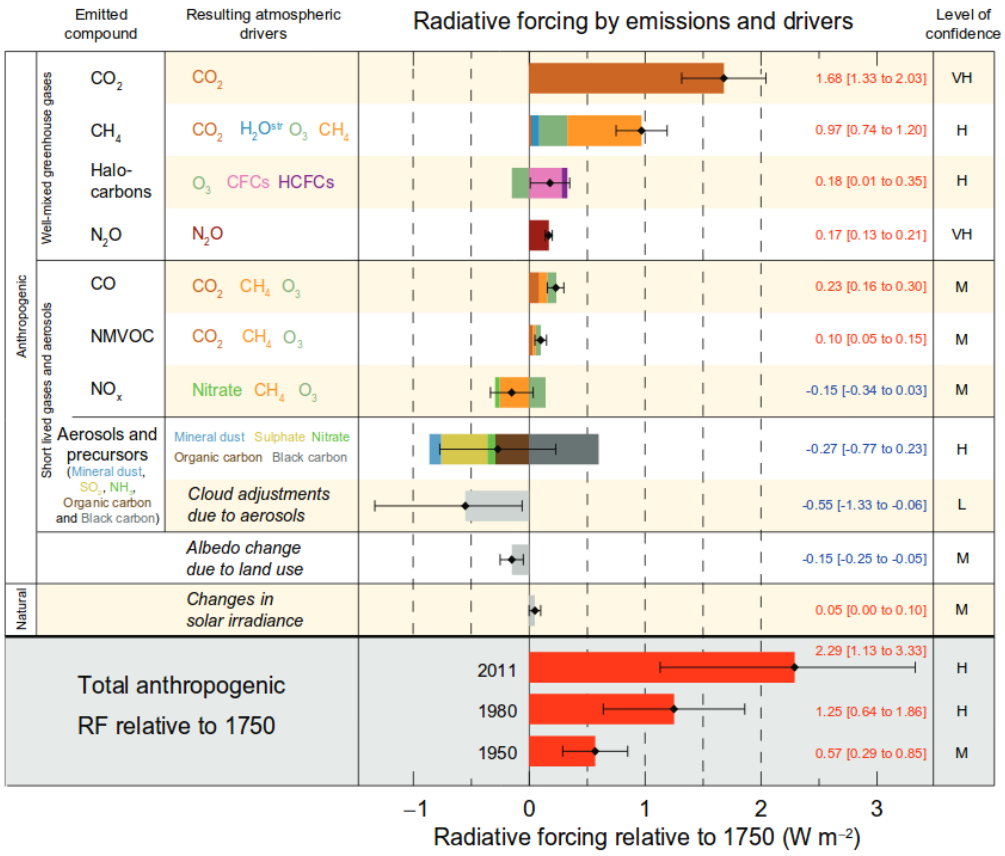

Key points:

- The total RF is positive
- GHGs drive the magnitude of the RF
- CO_2 is not the only GHG
- Much of the uncertainty comes from aerosols (and their interaction with clouds)
- The natural and solar components are small

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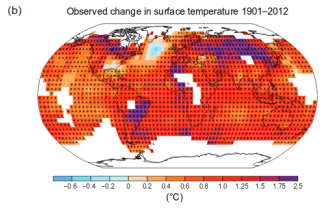
IPCC
INTERGOVERNMENTAL PANEL ON CLIMATE CHANGE

WMO UNEP



Summary (part 1)

- Our understanding of the climate system and climate change has accelerated in the last 30 years
  - The IPCC reviews current knowledge, providing a scientific consensus view on changes in the climate
- The Earth has warmed significantly
  - It is the warmest it has been for the last 1400 years
- The anthropogenic radiative forcing is positive
  - CO_2 is the largest forcer
  - Aerosol effects are the most uncertain

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