Global Climate Change

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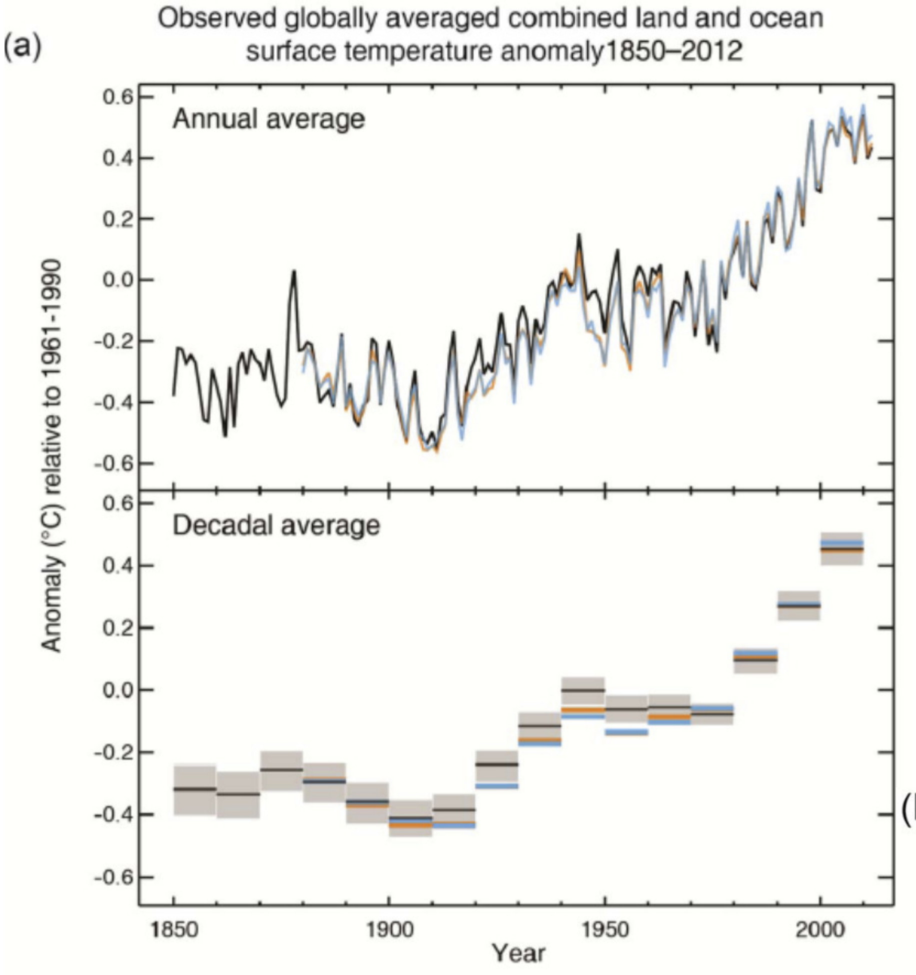
IPCC 5th Assessment Report for Climate Change 2013:

The Physical Basis

Observed Changes in the Climate System

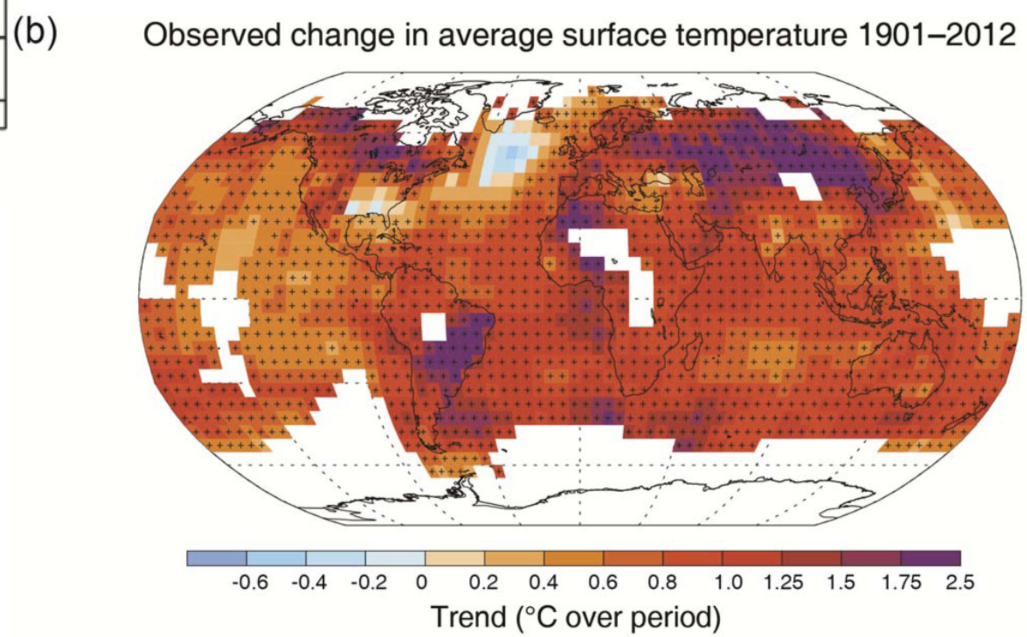
Warming of the climate system is unequivocal, and since the 1950s, many of the observed changes are unprecedented over decades to millennia.

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.



Each of the last three decades has been successively warmer at the Earth's surface than any receding decade since 1850.

In the Northern Hemisphere, 1983–2012 was likely the warmest 30-year period of the last 1400 years



Atmosphere Temperature

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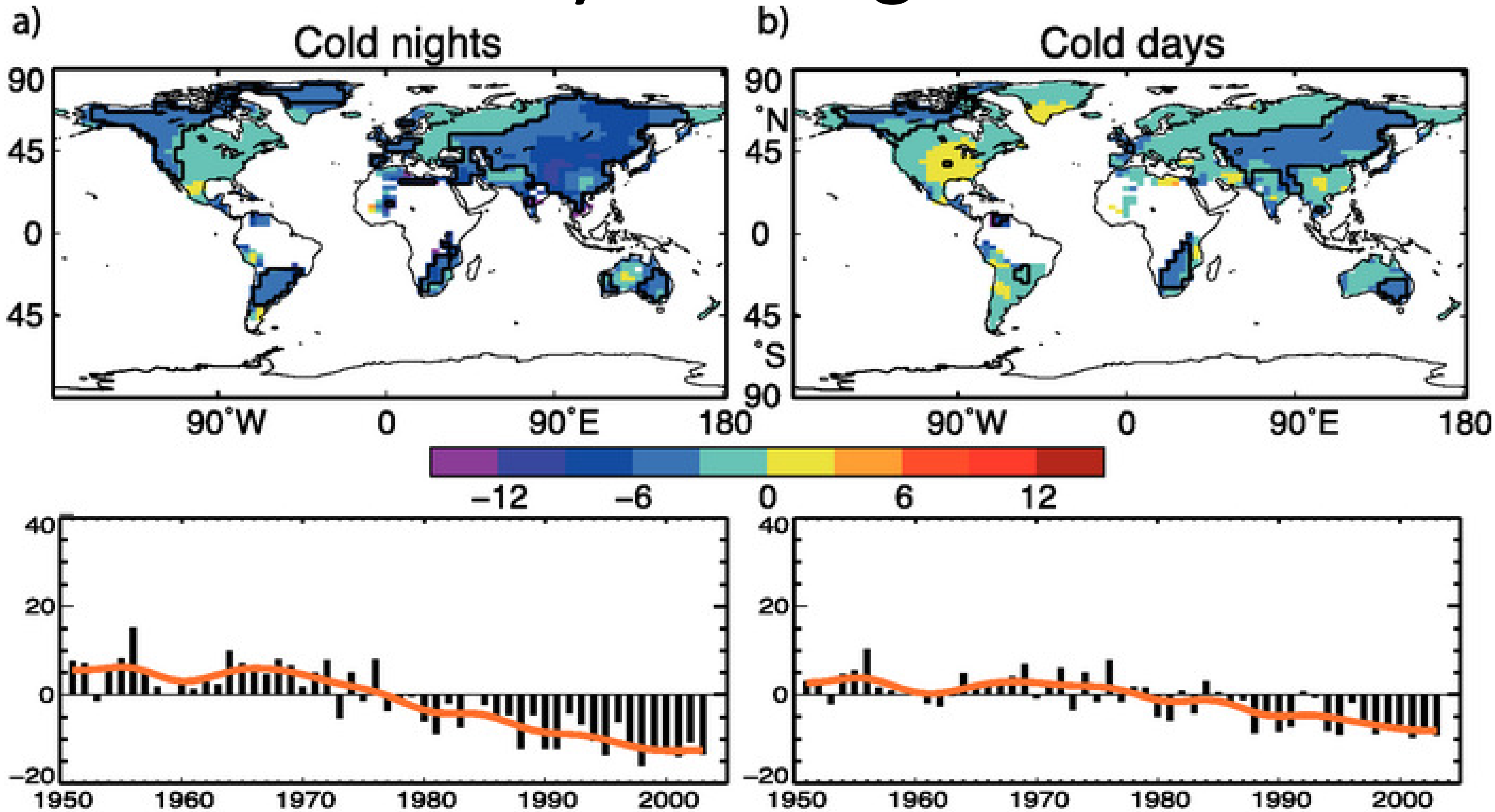
Days vs. Nights



Observed trends (days per decade) for 1951 to 2003 in the frequency of extreme temperatures (defined based on 1961 to 1990 values)

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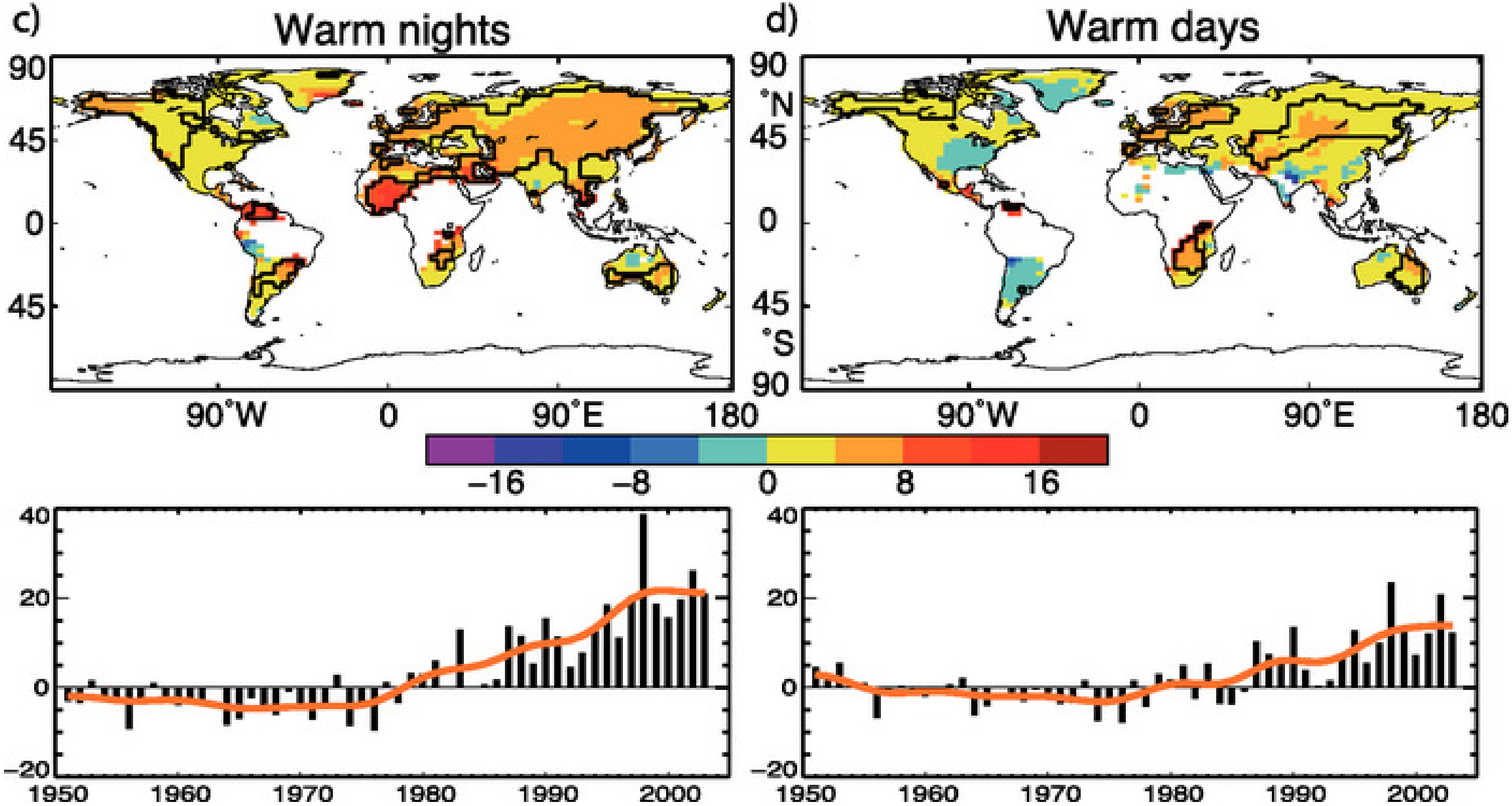
Days vs. Nights



The number of cold days and nights has decreased and the number of warm days and nights has increased on the global scale.

It is likely that the frequency of heat waves has increased in large parts of Europe, Asia and Australia.

Last 1300 yrs

anomalies (°C) from the 1961 to 1990 mean

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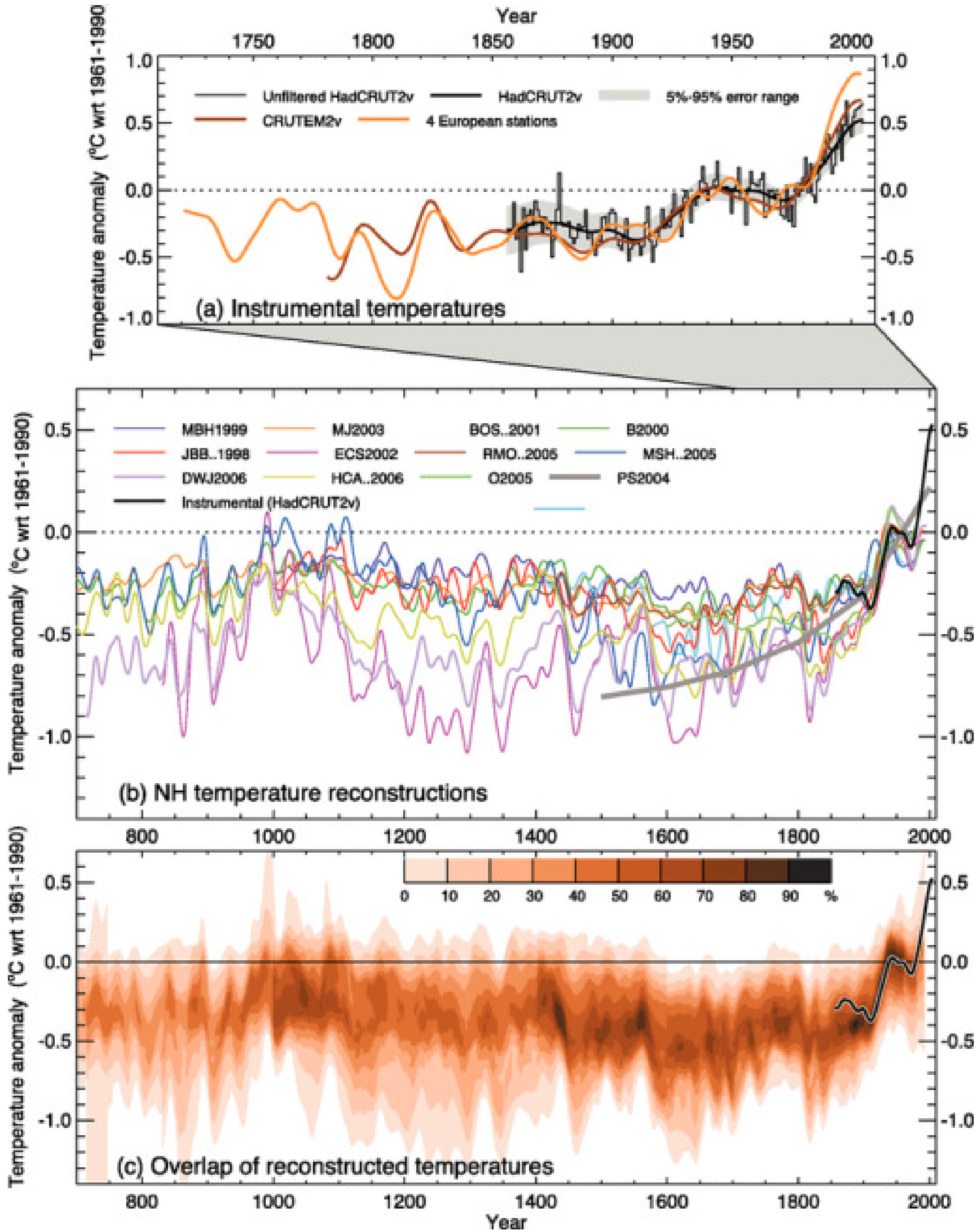
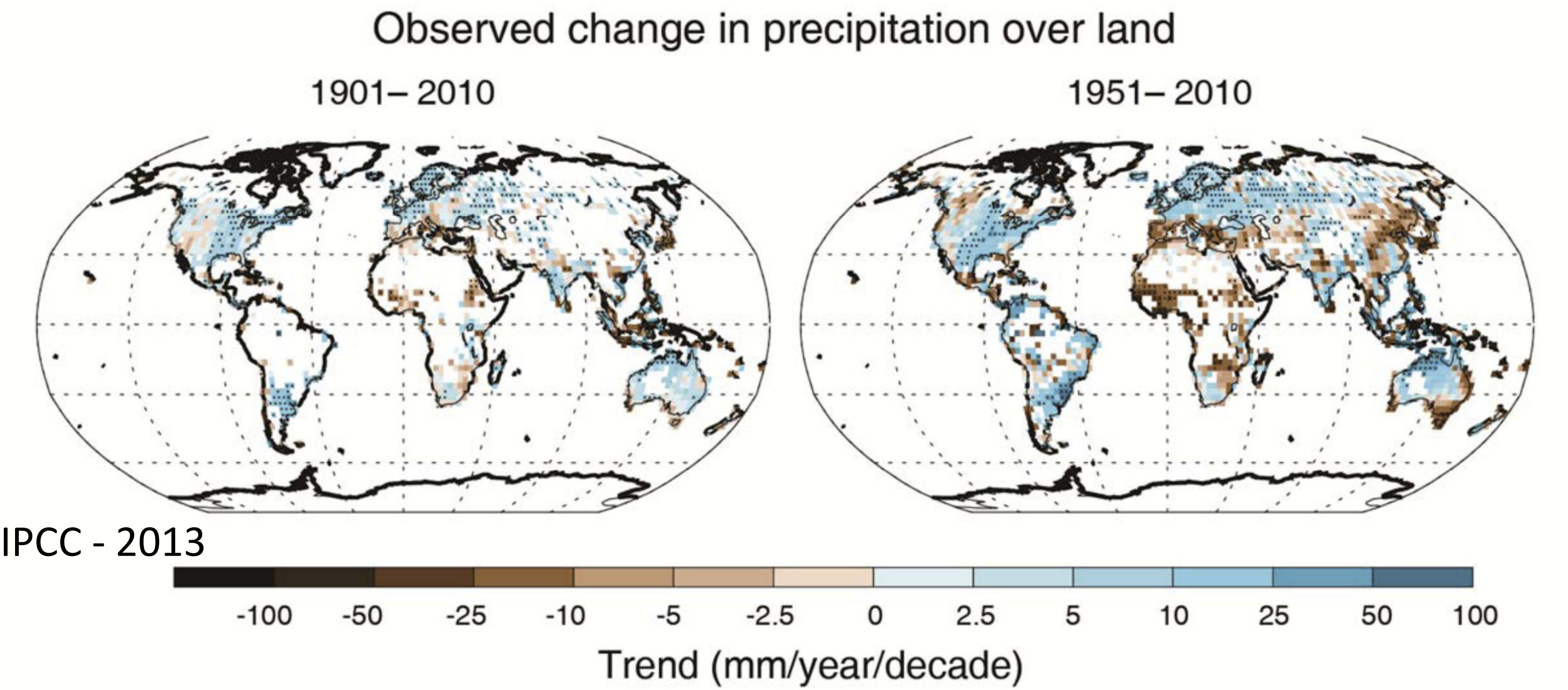


Atmosphere - Precipitation



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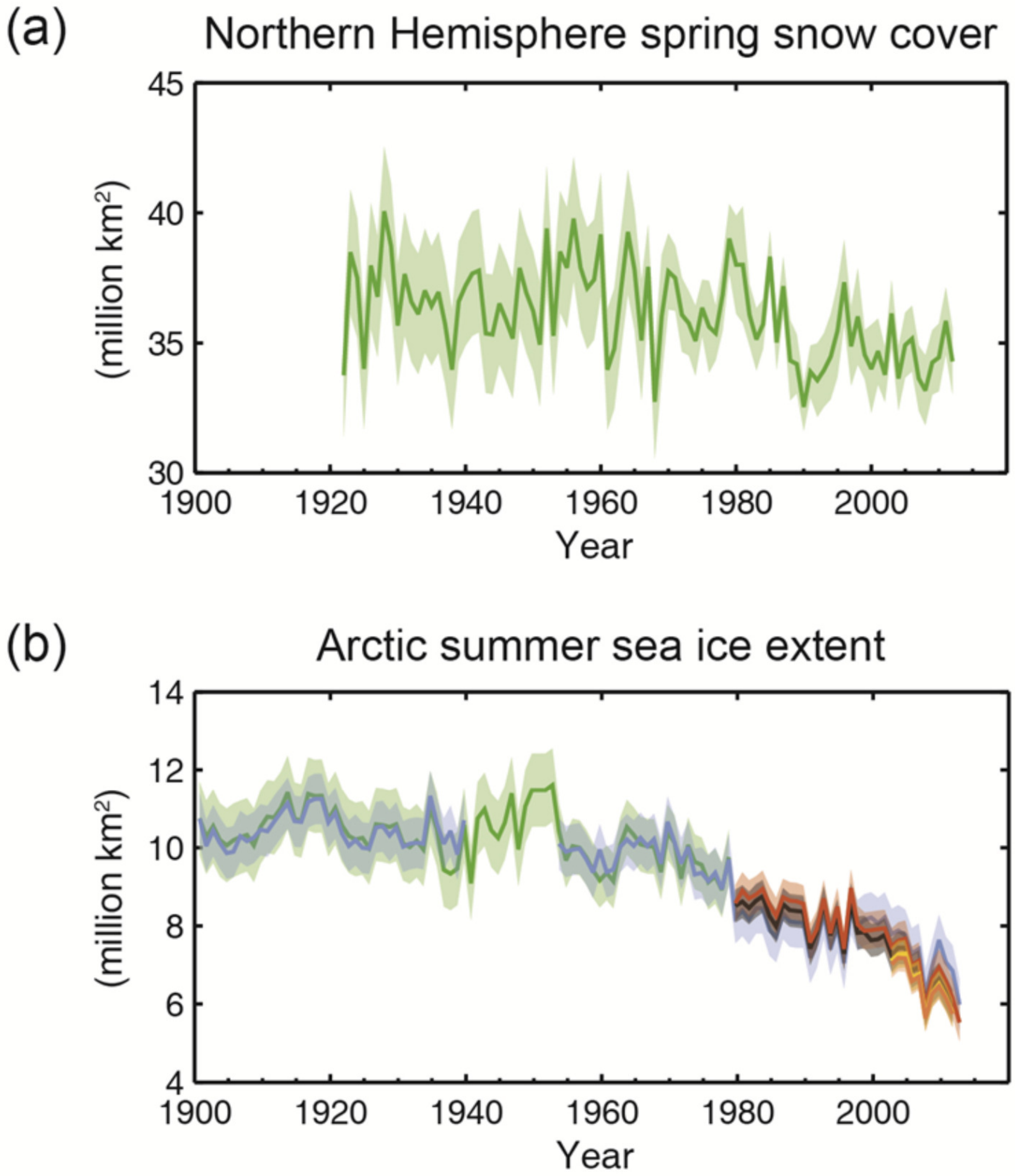
Extremes

More land regions where the number of heavy precipitation events has increased than where it has decreased.

The frequency or intensity of heavy precipitation events has likely increased in North America and Europe.

Cryosphere



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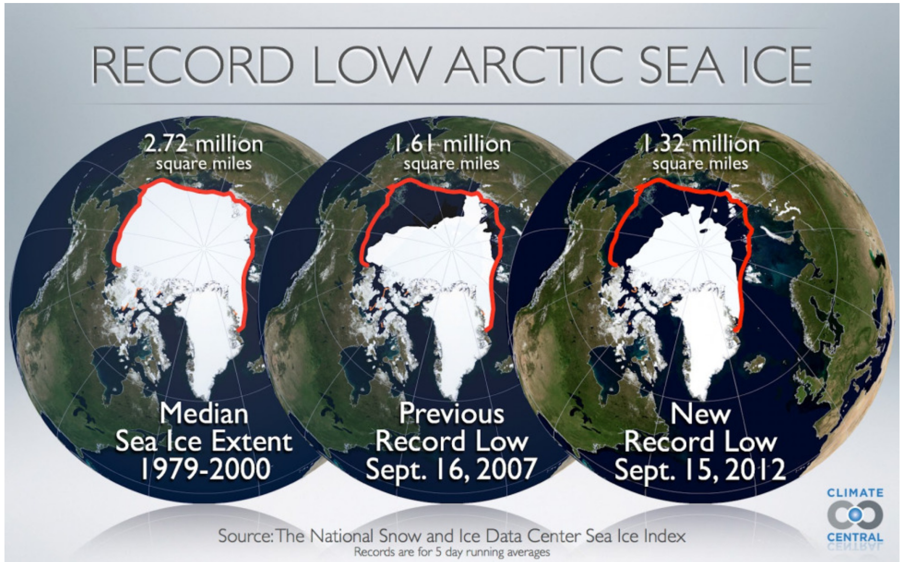
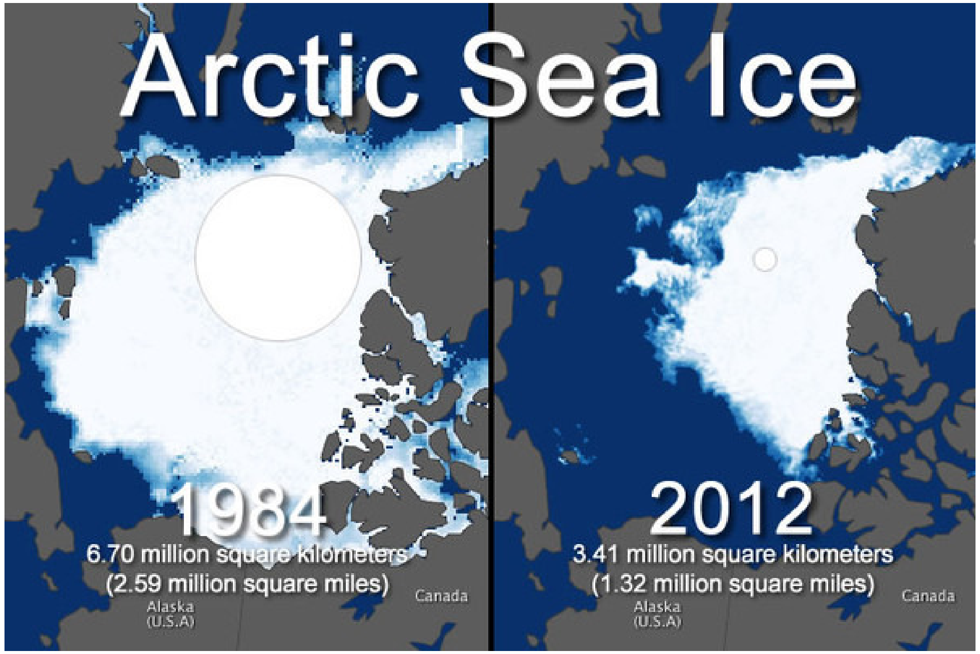
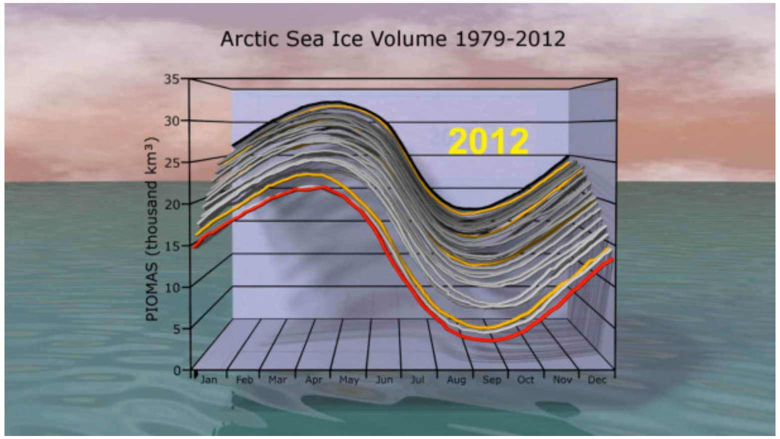
Melting Ice







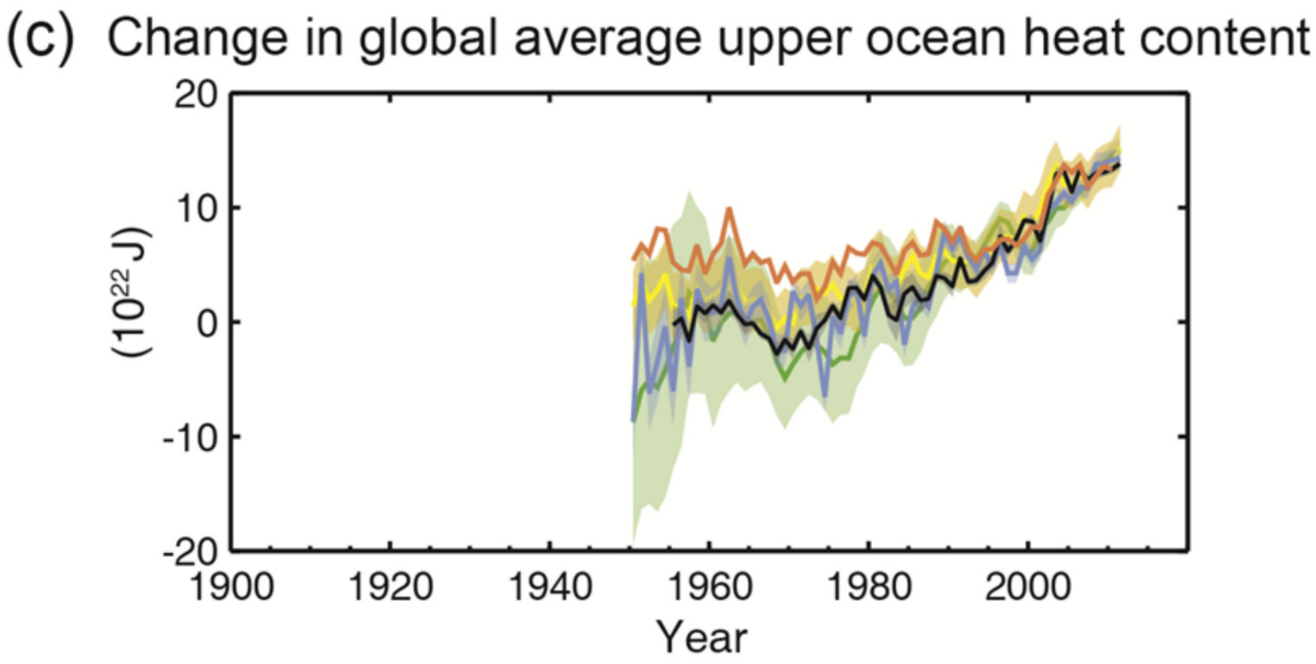
Since 1979, the volume of Summer Arctic Sea Ice has declined by 80% and is accelerating.

The first ice-free summer in the Arctic Ocean is expected to happen between 2016 and 2022.

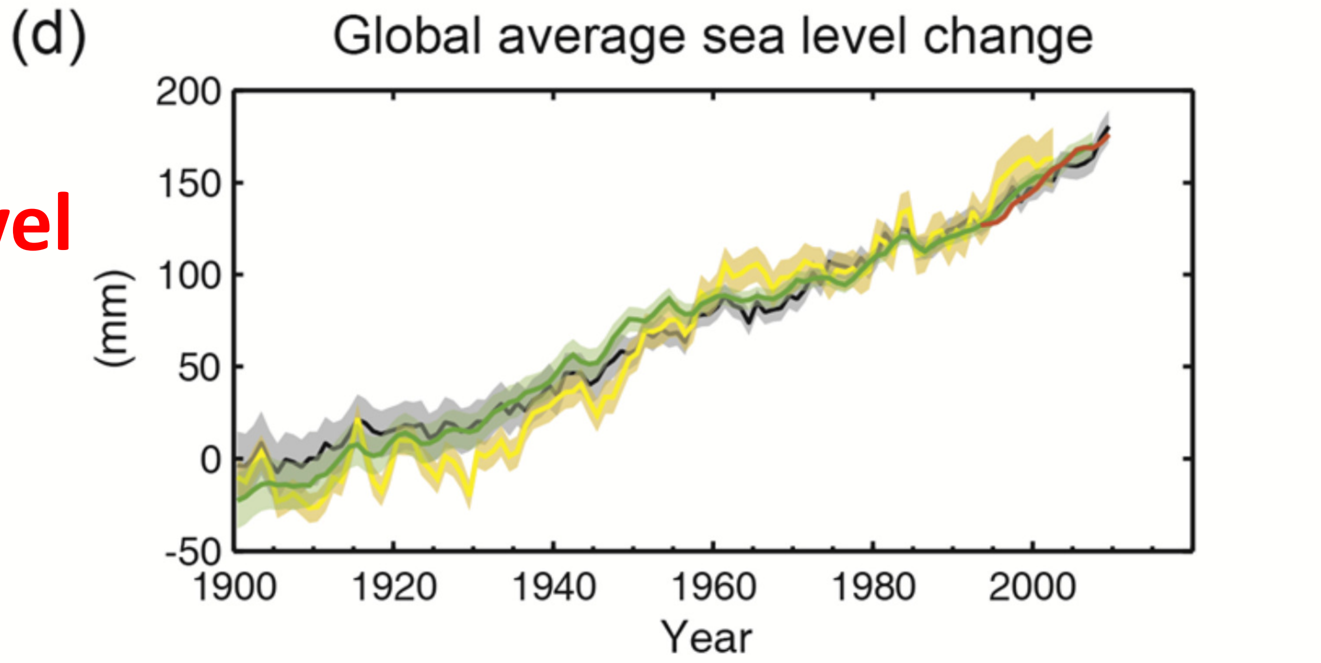
"The nine lowest maximum extents have occurred in the last nine years, since 2004," Meier says.

NASA 2013

Ocean



Sea Level



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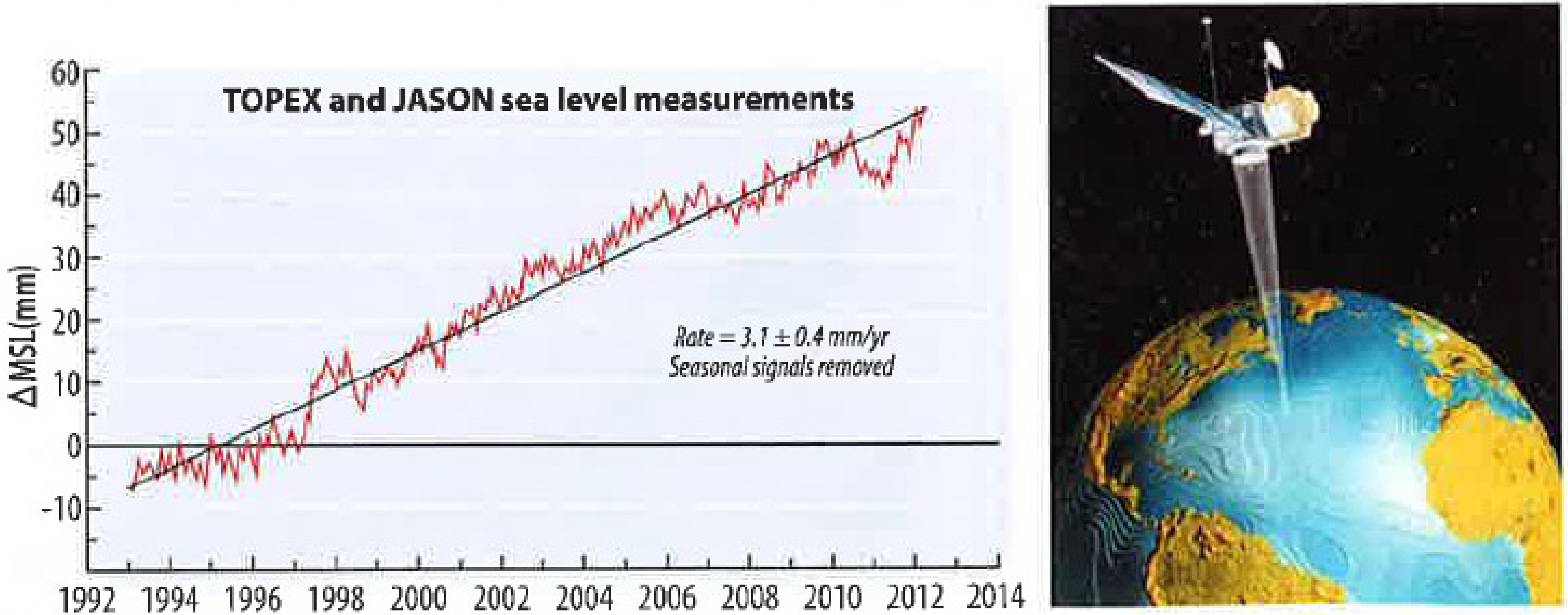
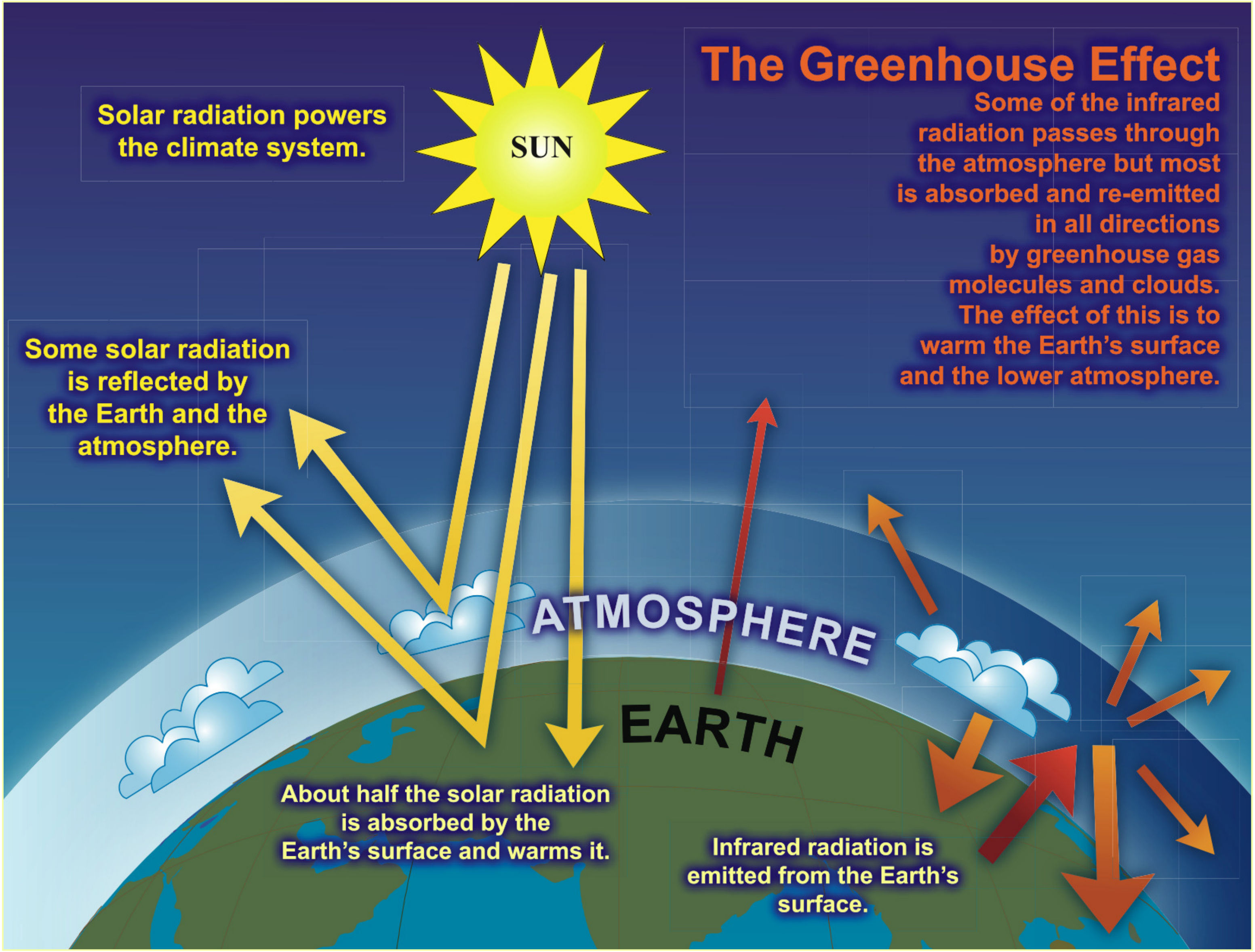
Warming + Melting = Sea Level Rise



(a) (b)

▲ **Figure 2.7:** (a) A graph of recent sea level rise, measured from NASA's TOPEX and JASON satellite instruments, showing changes in sea level averaged over a 60-day period (blue line) and the overall trend (black line) of 3.1 millimeters per year (0.12 inches). Note the small decrease in sea level between 2010 and 2012. This developed after unusually wet weather globally increased the amount of rainwater stored on land in rivers, lakes, reservoirs, and groundwater. This temporary decrease in sea level soon recovered as all the extra water made its way back slowly to the oceans. (b) Launched in 1992, the TOPEX/POSEIDON satellite was the first mission to analyze sea surface topography with precision. It has since been replaced by the JASON-2 satellite launched in 2008.

From: Kitchen (2014) – Global Climate Change


The Greenhouse Effect
Some of the infrared radiation passes through the atmosphere but most is absorbed and re-emitted in all directions by greenhouse gas molecules and clouds. The effect of this is to warm the Earth's surface and the lower atmosphere.
Solar radiation powers the climate system.
SUN
Some solar radiation is reflected by the Earth and the atmosphere.
ATMOSPHERE
EARTH
About half the solar radiation is absorbed by the Earth's surface and warms it.
Infrared radiation is emitted from the Earth's surface.

The greenhouse effect: early discoveries

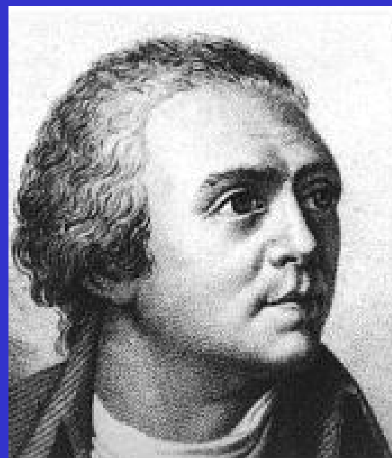

(www.nndb.com)

Edme Marriotte (1620-1684):

Sun's heat passes through glass, other heat does not (1681).

Horace Bénédict de Saussure (1740-1799):

Air in mountains does not trap heat as much as air in low-lying regions


(www.eoearth.org)

1824, Jean Baptiste Fourier

AMERICAN

JOURNAL OF SCIENCE, &c.

ART. I.—*General Remarks on the Temperature of the Terrestrial Globe and the Planetary Spaces;* by Baron FOURIER.*

Translated from the French, by Mr. EBENEZER BURGESS, of Amherst College.

THE question of terrestrial temperature, one of the most remarkable and difficult in natural philosophy, involves very different elements which require to be considered in a general light. I have

"greenhouse effect". He writes: "**The temperature [of the Earth] can be augmented by the interposition of the atmosphere**, because heat in the state of light finds less resistance in penetrating the air, than in re-passing into the air when converted into non-luminous heat."

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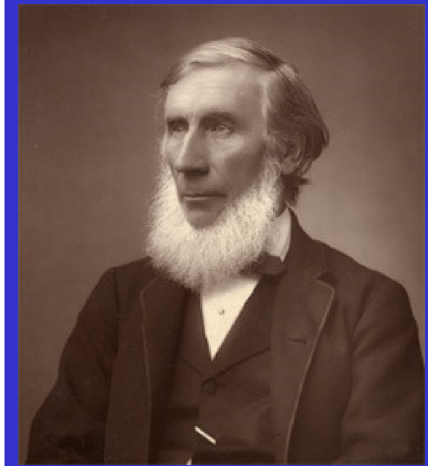
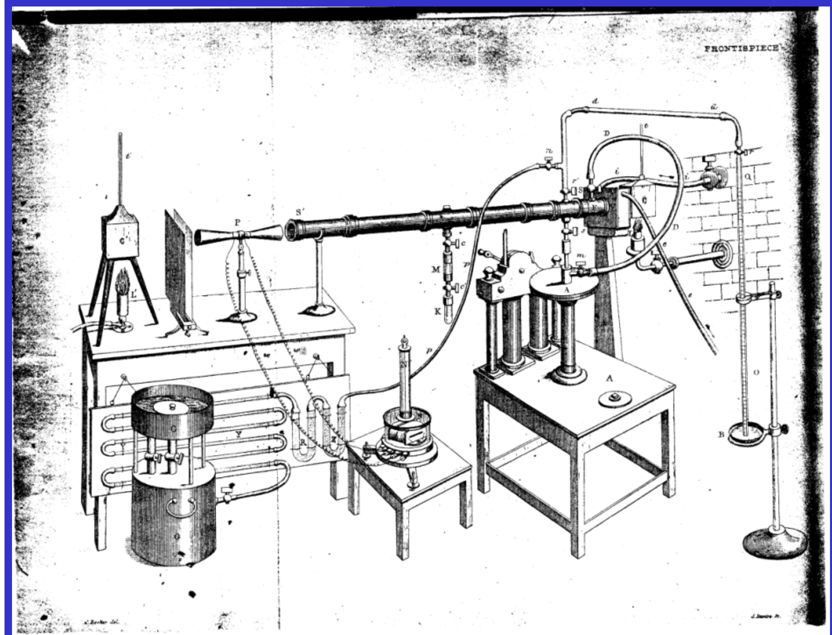
Optical properties of atmospheric gases

1861, John Tyndall

PHILOSOPHICAL MAGAZINE
AND
JOURNAL OF SCIENCE.

XXIII. *On the Absorption and Radiation of Heat by Gases and Vapours, and on the Physical Connexion of Radiation, Absorption, and Conduction.—The Bakerian Lecture.* By JOHN TYNDALL Esq., F.R.S. &c.*





Measured infrared radiation absorption properties of atmospheric molecules

Changing H_2O or CO_2 could cause "all the mutations of climate which the researches of geologists reveal"

Air	0
Oxygen	0
Nitrogen	0
Hydrogen	0
Carbonic oxide . . .	12
Carbonic acid . . .	18
Nitrous oxide . . .	29
Olefiant gas . . .	53

1896, Arrhenius
CO_2

PHILOSOPHICAL MAGAZINE

AND

JOURNAL OF SCIENCE.

[FIFTH SERIES.]

APRIL 1896.

XXXI. *On the Influence of Carbonic Acid in the Air upon the Temperature of the Ground.* *By* Prof. SVANTE ARRHENIUS *.

40% ⇑ or ⇓ in CO_2 could explain advance & retreat of glaciers. ($2xCO_2 \Rightarrow \Delta T \sim 4^{\circ}C$.) Human CO_2 emissions could prevent another ice age.

Nobel Prize - Chemistry (1903)

V. § 5. *Geological Consequences.*

I should certainly not have undertaken these tedious calculations if an extraordinary interest had not been connected with them. In the Physical Society of Stockholm there have been occasionally very lively discussions on the probable causes of the Ice Age; and these discussions have, in my opinion, led to the conclusion that there exists as yet no satisfactory hypothesis that could explain how the climatic conditions

CGUL/IDL

551.510.4 : 551.521.3 : 551.524.34

THE ARTIFICIAL PRODUCTION OF CARBON DIOXIDE AND ITS INFLUENCE ON TEMPERATURE

By G. S. CALLENDAR

(Steam technologist to the British Electrical and Allied Industries Research Association.)

(Communicated by Dr. G. M. B. Dobson, F.R.S.)

In conclusion it may be said that the combustion of fossil fuel, whether it be peat from the surface or oil from 10,000 feet below, is likely to prove beneficial to mankind in several ways, besides the provision of heat and power. For instance the above mentioned small increases of mean temperature would be important at the northern margin of cultivation, and the growth of favourably situated plants is directly proportional to the carbon dioxide pressure (Brown and Escombe, 1905). In any case the return of the deadly glaciers should be delayed indefinitely.

As regards the reserves of fuel these would be sufficient to give at least ten times as much carbon dioxide as there is in the air at present.

Guy Stuart Callendar (1897-1964)

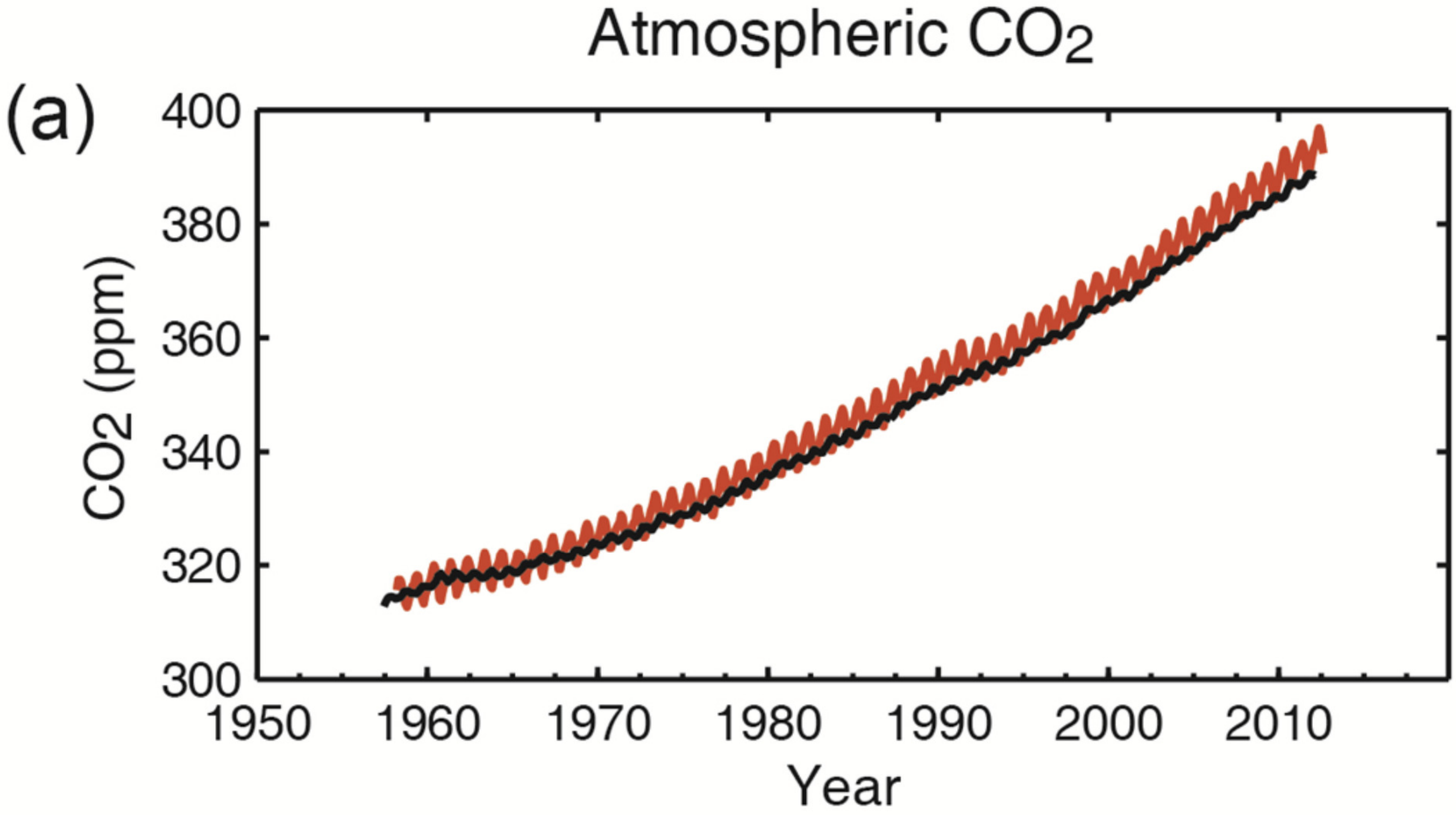
1938

$2xCO_2 \Rightarrow \Delta T \sim 2^{\circ}C$

Must treat atmosphere as set of interacting layers, not a single slab.

Speculated, with others, that ΔT over first part of 20th Century was anthropogenic.

Carbon and Other Biogeochemical Cycles



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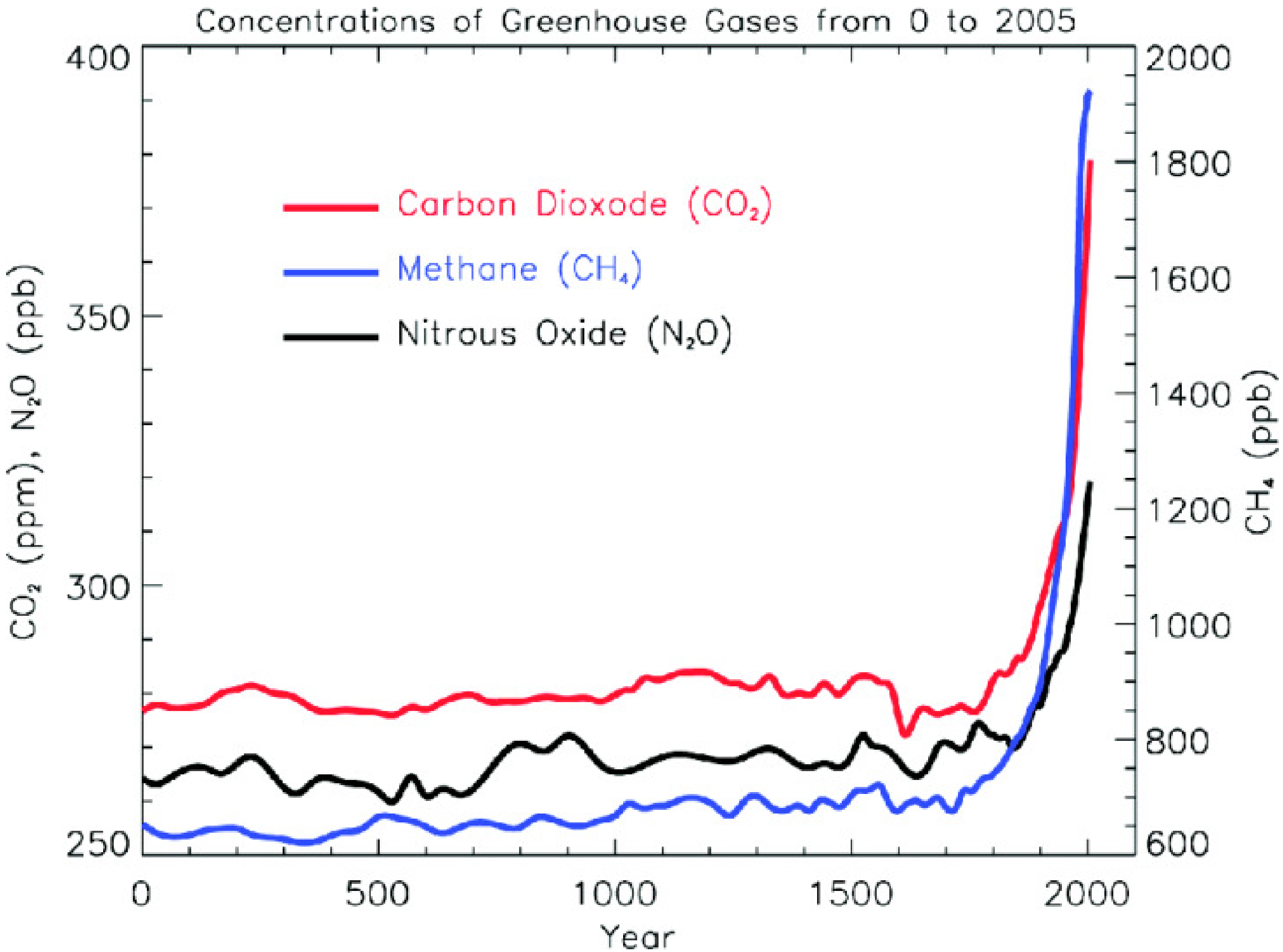
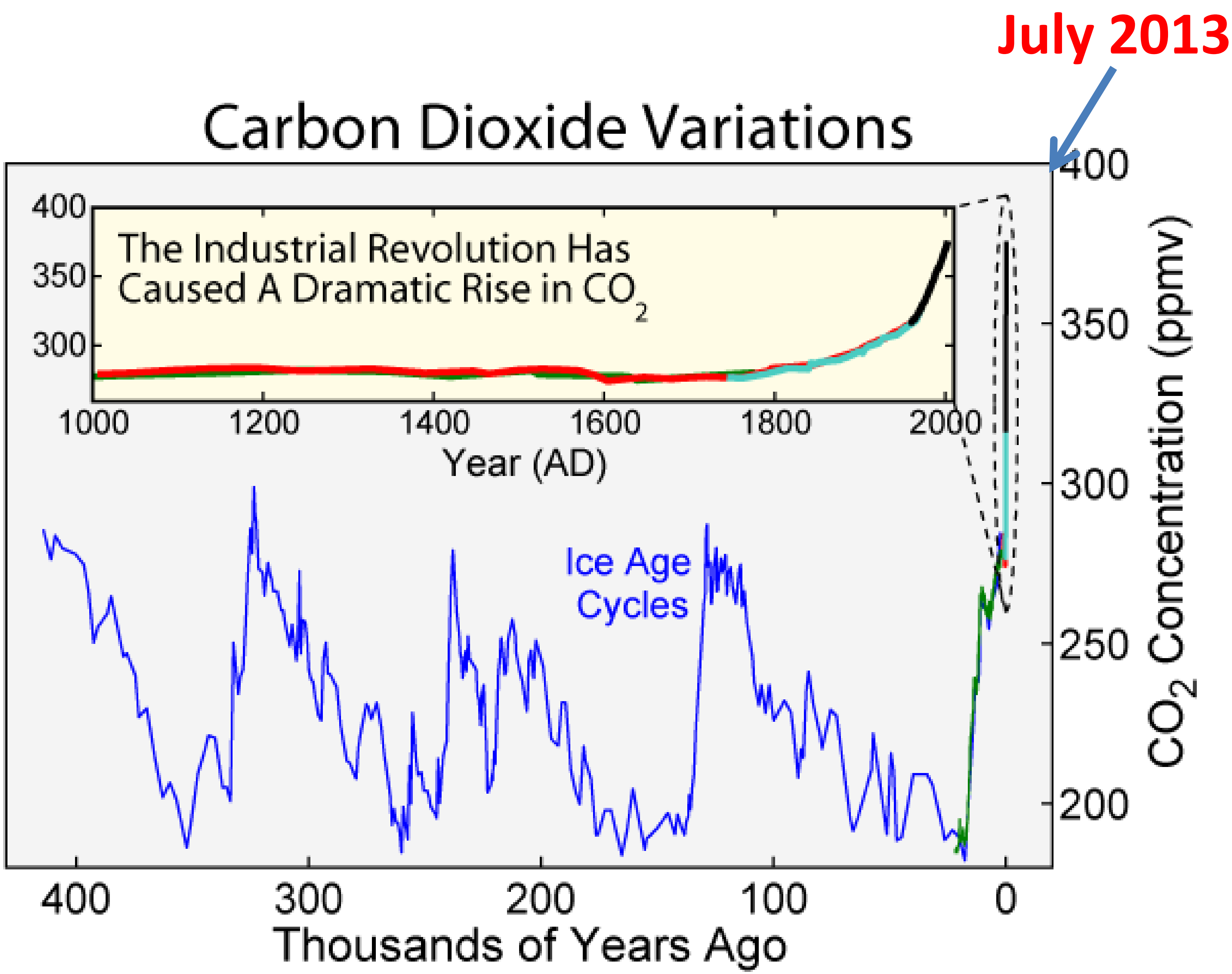
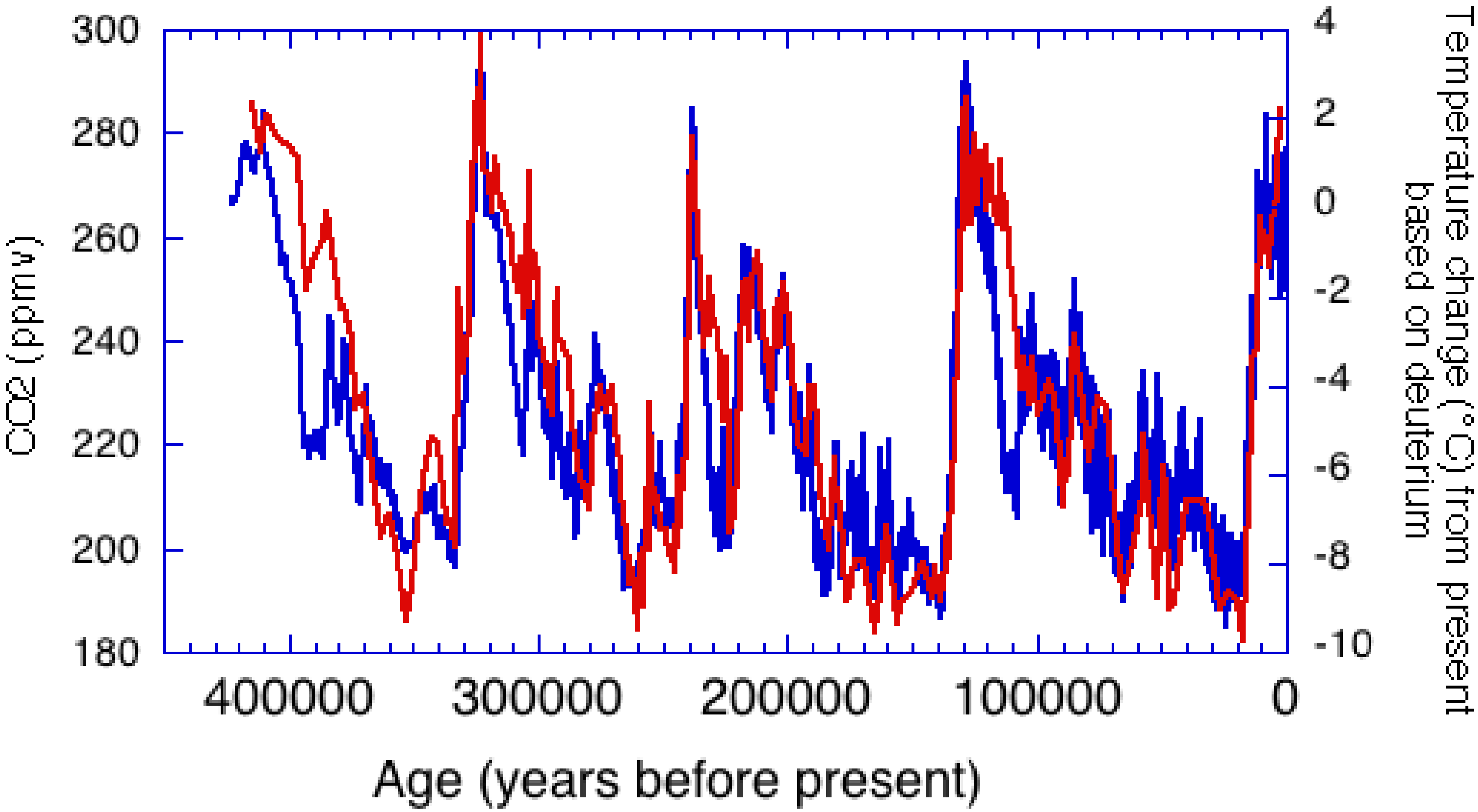
National Research Council - GHG



Analysis of air bubbles trapped in Antarctic ice cores show that, along with carbon dioxide, atmospheric concentrations of methane (CH4) and nitrous oxide (N2O) were relatively constant until they started to rise in the Industrial era. Atmospheric concentration units indicate the number of molecules of the greenhouse gas per million molecules of air for carbon dioxide and nitrous oxide, and per billion molecules of air for methane. **Source: U.S. Global Climate Research Prog.**

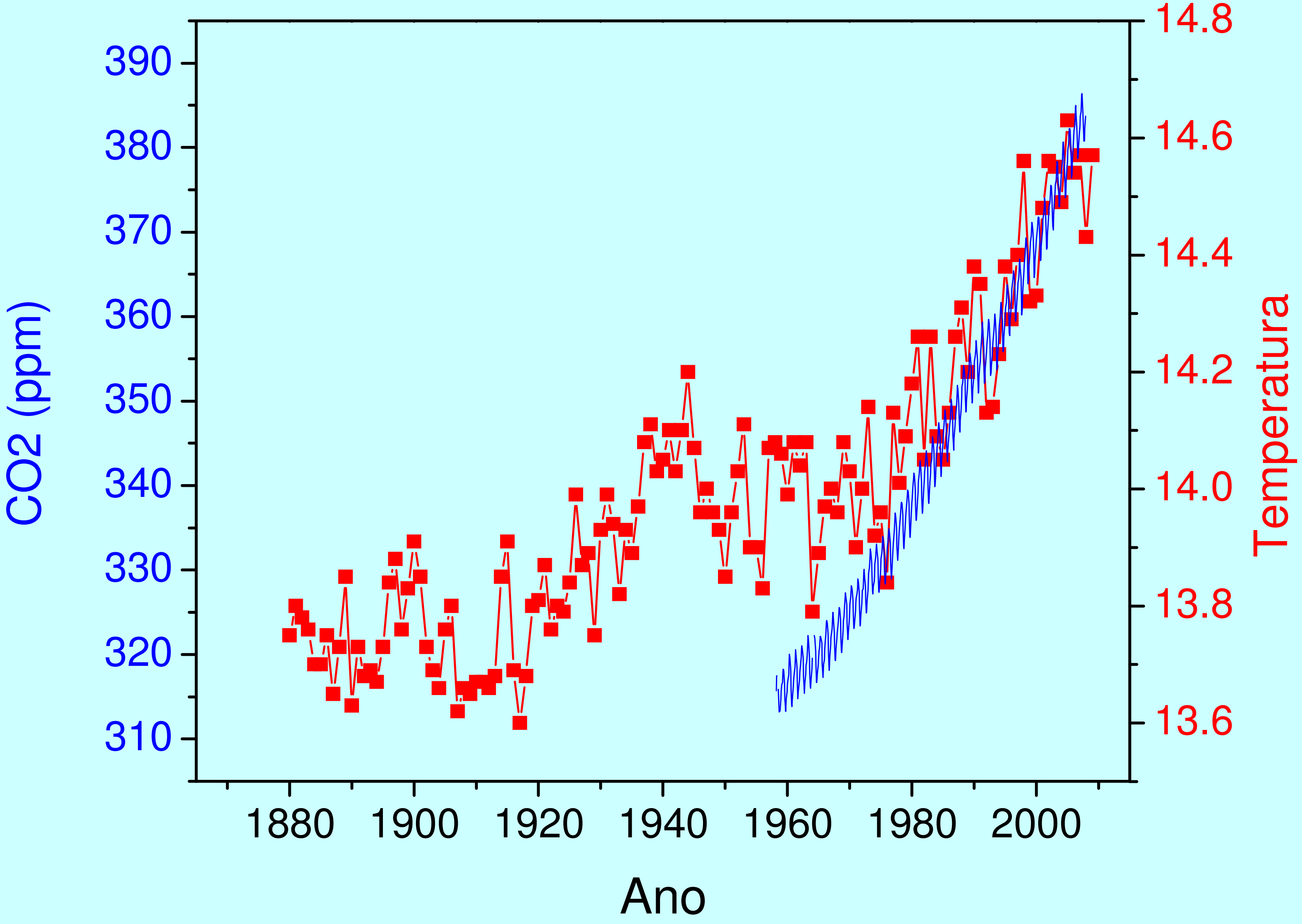

July 2013
Carbon Dioxide Variations
The Industrial Revolution Has
Caused A Dramatic Rise in CO2
400
350
300
1000
1200
1400
1600
1800
2000
Year (AD)
Ice Age
Cycles
400
350
300
250
200
CO2 Concentration (ppmv)
400
300
200
100
0
Thousands of Years Ago

Temperature and CO_2



Temperature change (blue) and
carbon dioxide change (red) observed in
[ice core records](#) [Many other records are available](#)

Temperature 1880-2009
CO2-1958-2009



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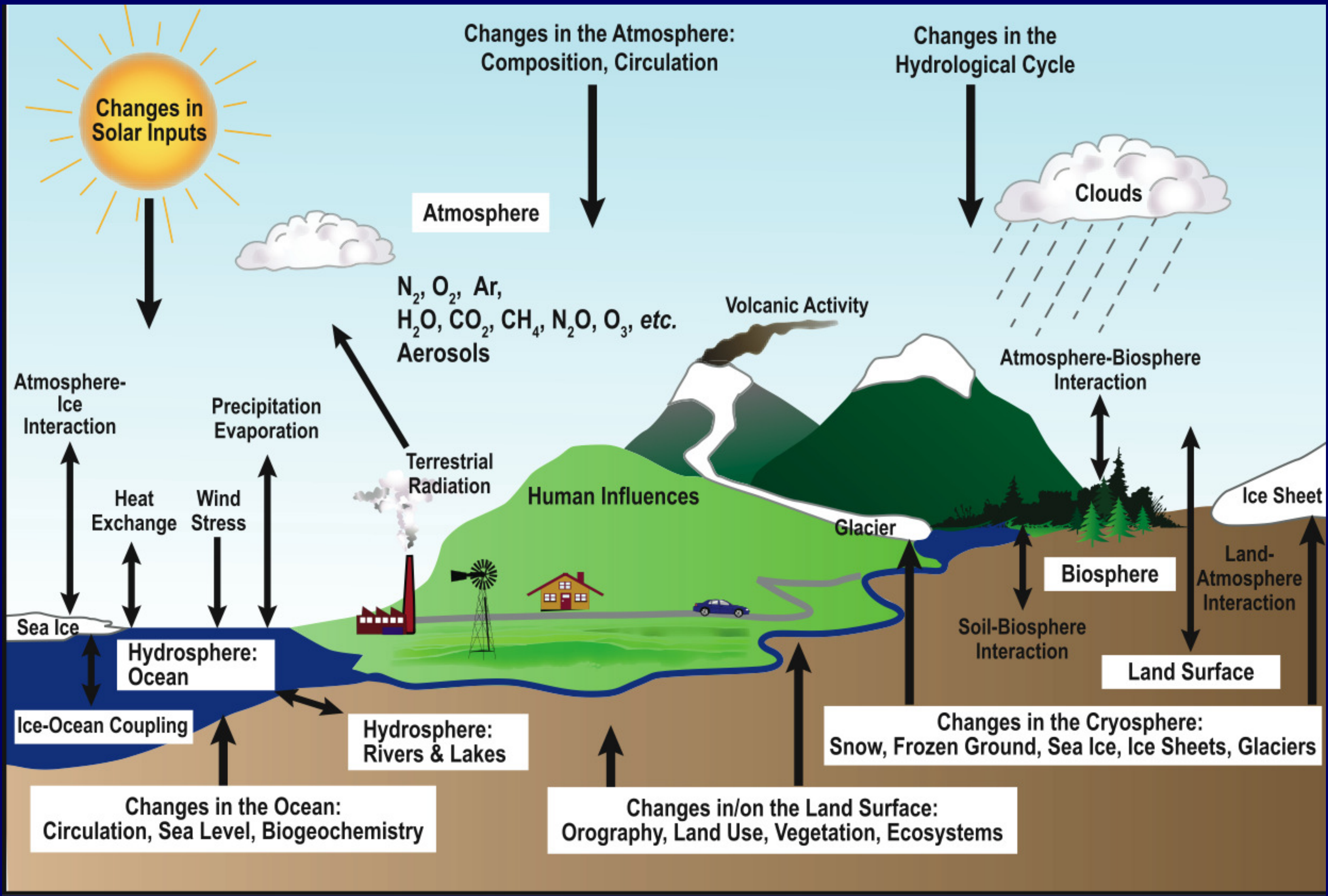
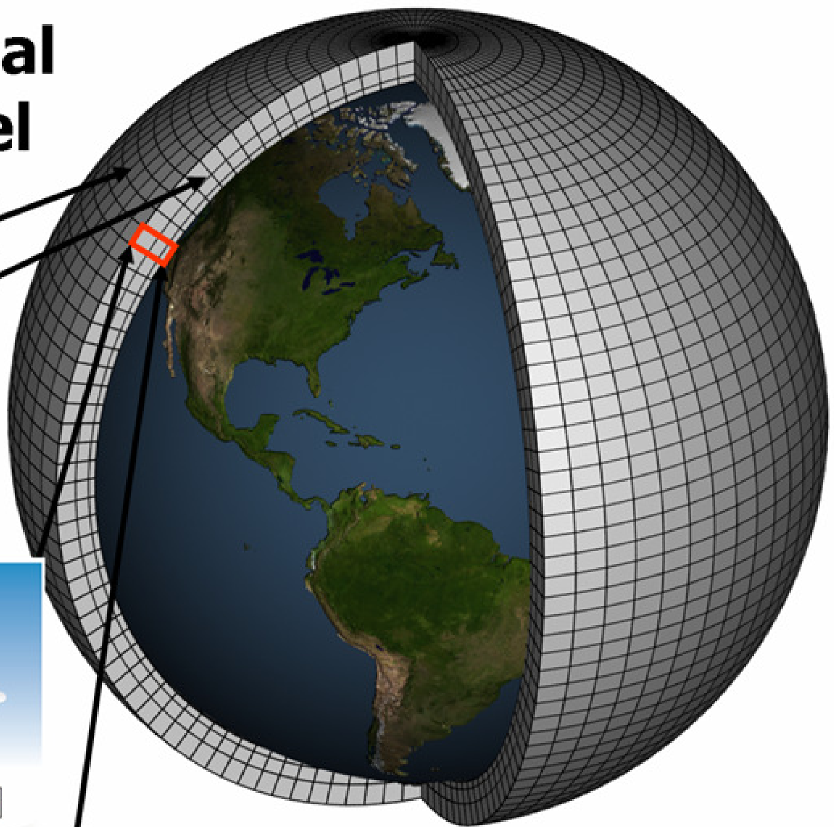
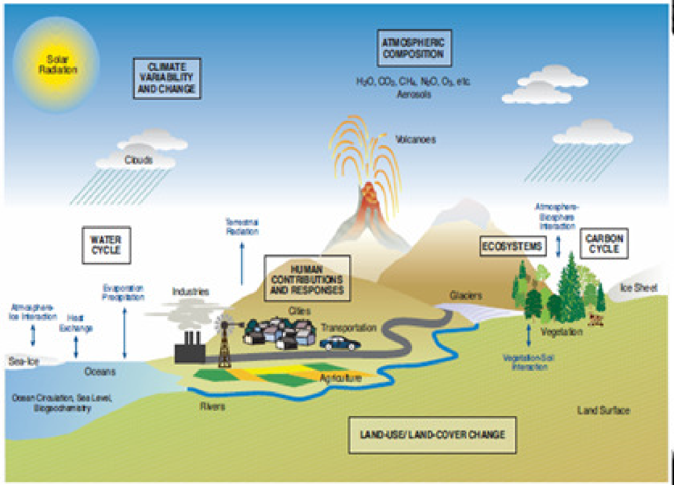
The Climate System

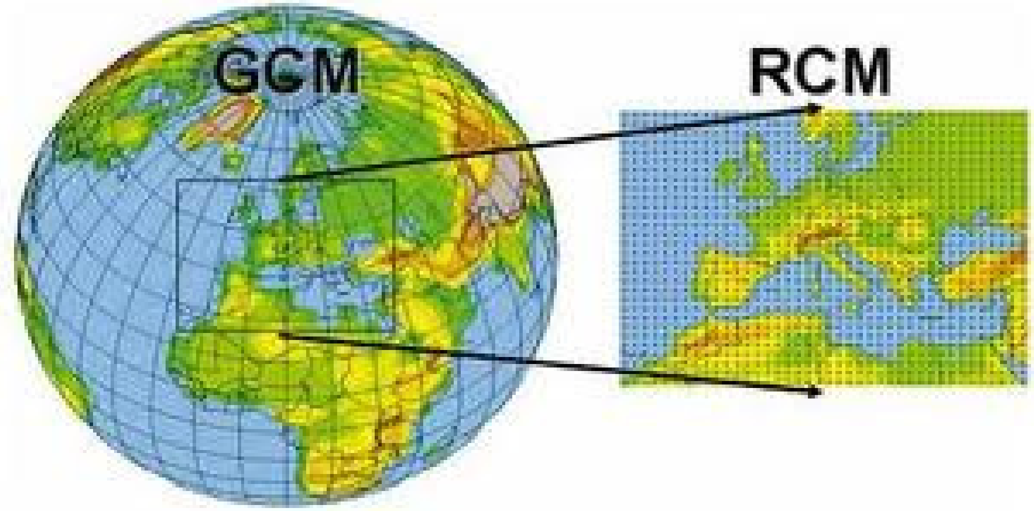


How do we simulate this?

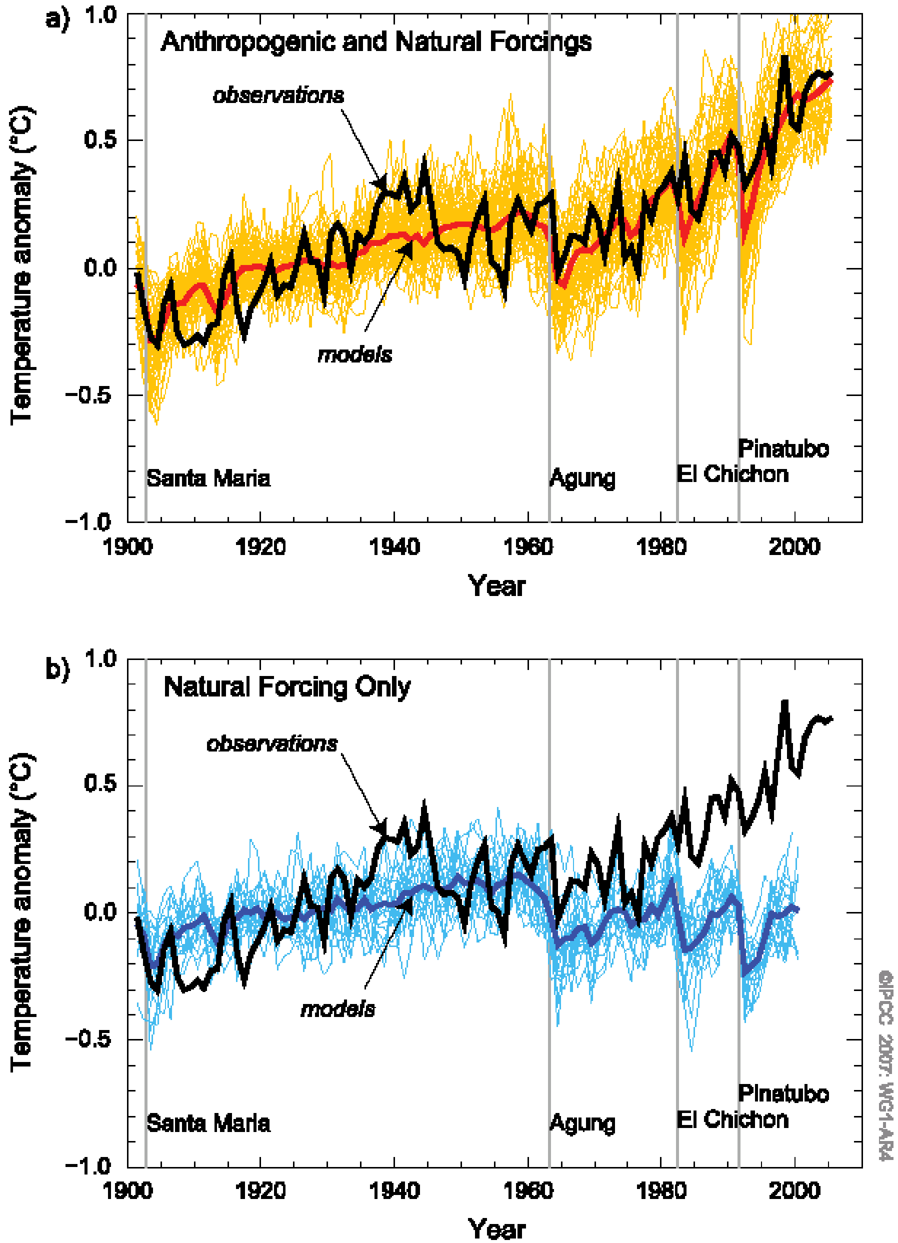
Schematic for Global Atmospheric Model







How Well Have GCMs performed?

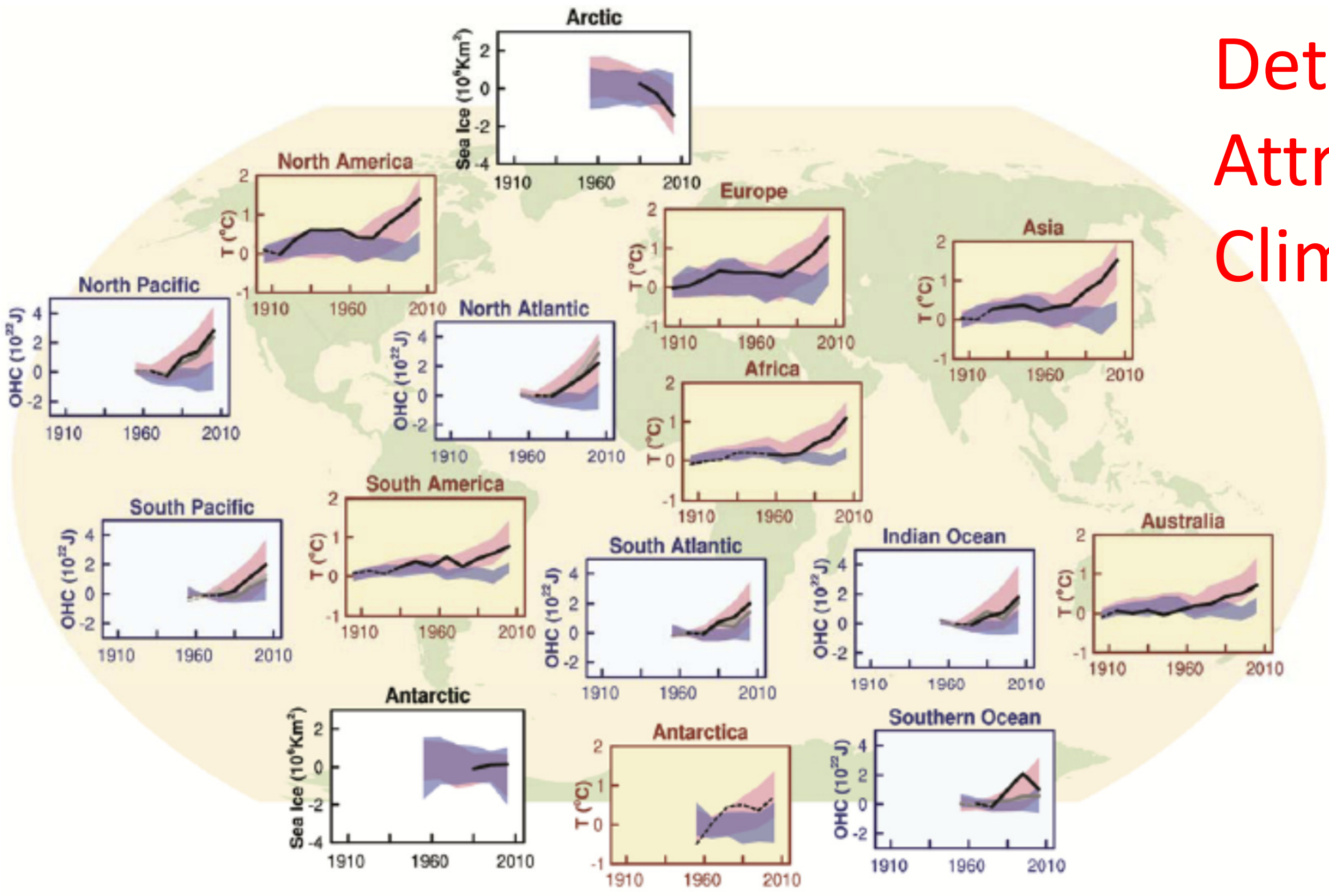


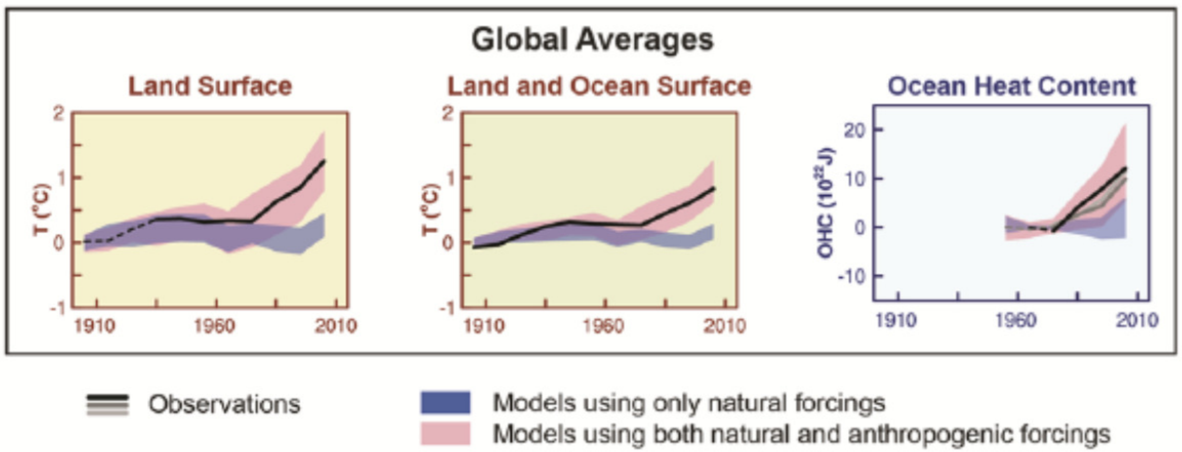
Anthropogenic and natural forcings

Figure TS.23. *(a) Global mean surface temperature anomalies relative to the period 1901 to 1950, as observed (black line) and as obtained from simulations with both anthropogenic and natural forcings. The thick red curve shows the multi-model ensemble mean and the thin lighter red curves show the individual simulations. Vertical grey lines indicate the timing of major volcanic events. (b) As in (a), except that the simulated global mean temperature anomalies are for natural forcings only. The thick blue curve shows the multi-model ensemble mean and the thin lighter blue curves show individual simulations. Each simulation was sampled so that coverage corresponds to that of the observations. {Figure 9.5}*

Source: IPCC 2007a (WG I TSp.62)

Detection and Attribution of Climate Change

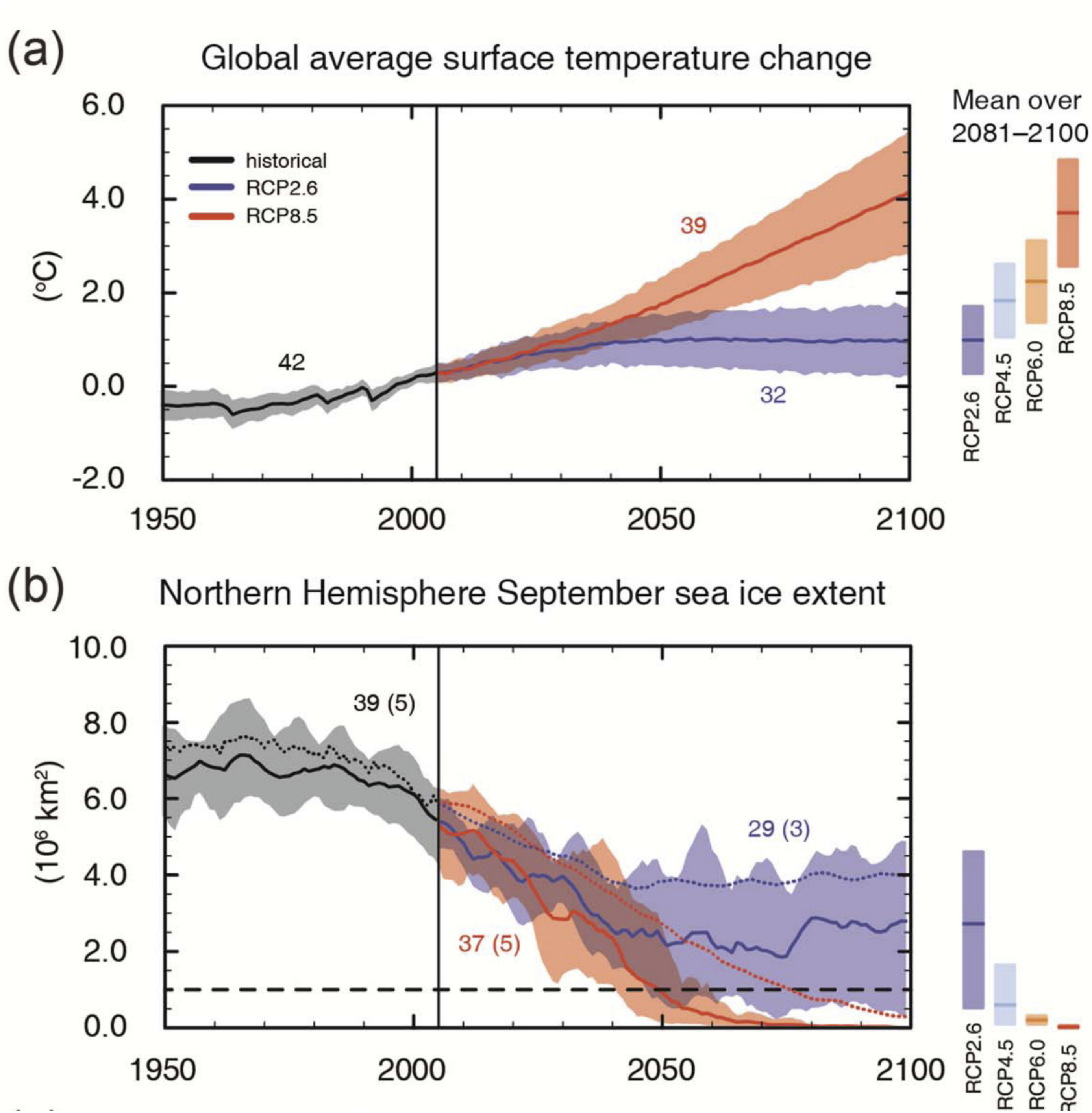




Human influence on the climate system is clear

Future Climate Change

CMIP5 multi-model simulated time series from 1950 to 2100



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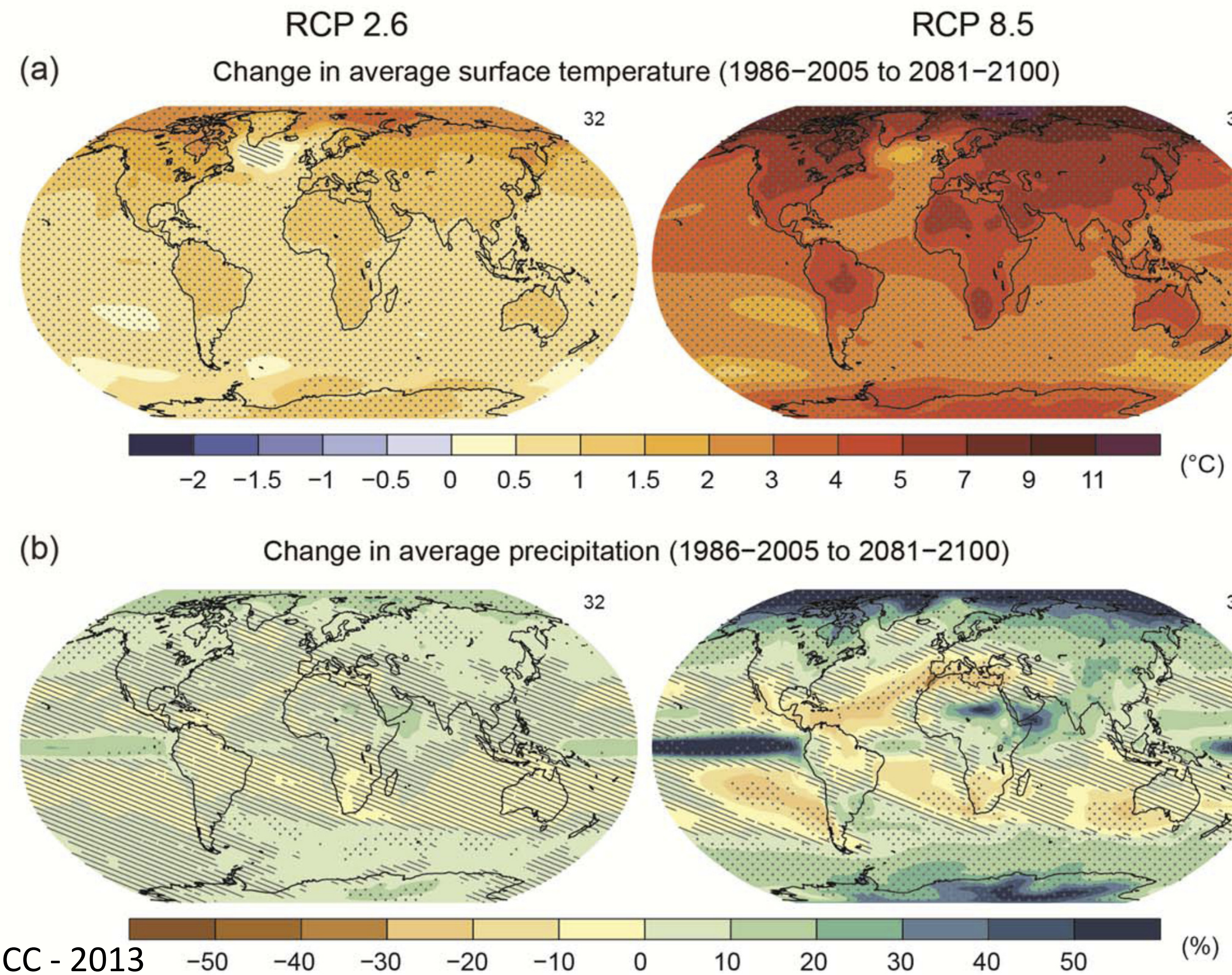
RCP 2.6
RCP 8.5
(a)
Change in average surface temperature (1986−2005 to 2081−2100)
32
39
−2 −1.5 −1 −0.5 0 0.5 1 1.5 2 3 4 5 7 9 11
(°C)
(b)
Change in average precipitation (1986−2005 to 2081−2100)
32
39
−50 −40 −30 −20 −10 0 10 20 30 40 50
(%)

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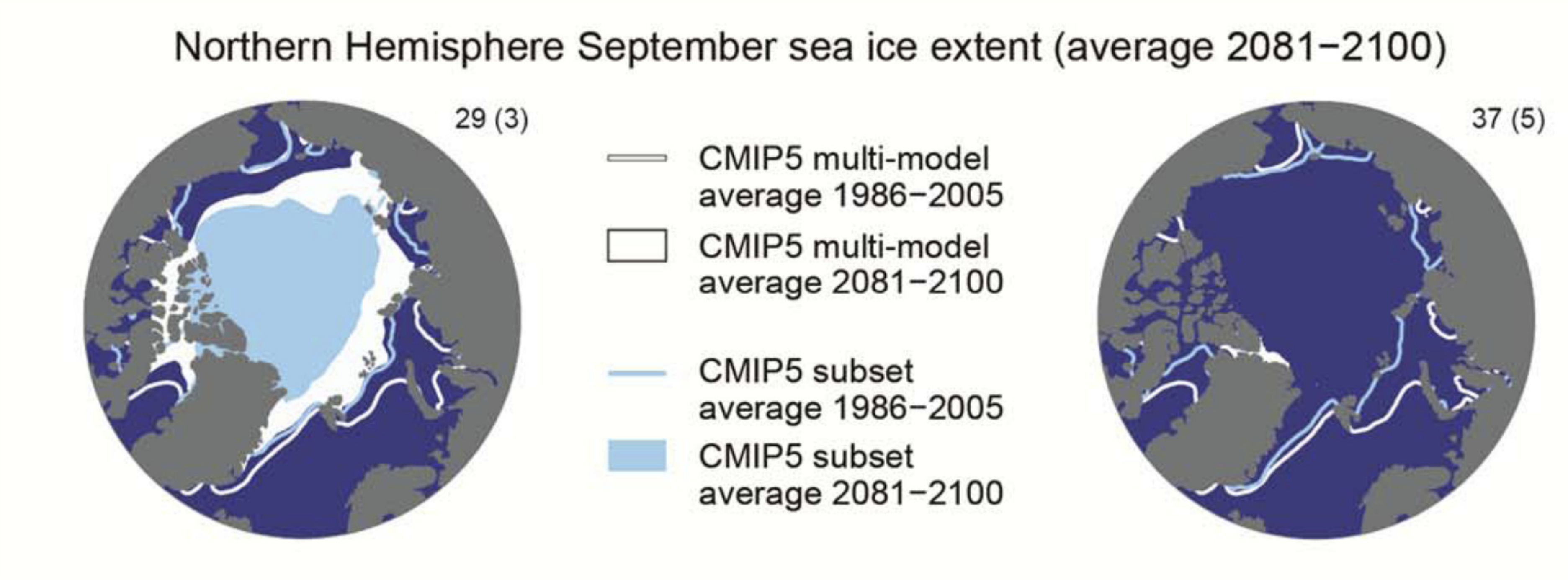
RCP2.6 **RCP8.5**



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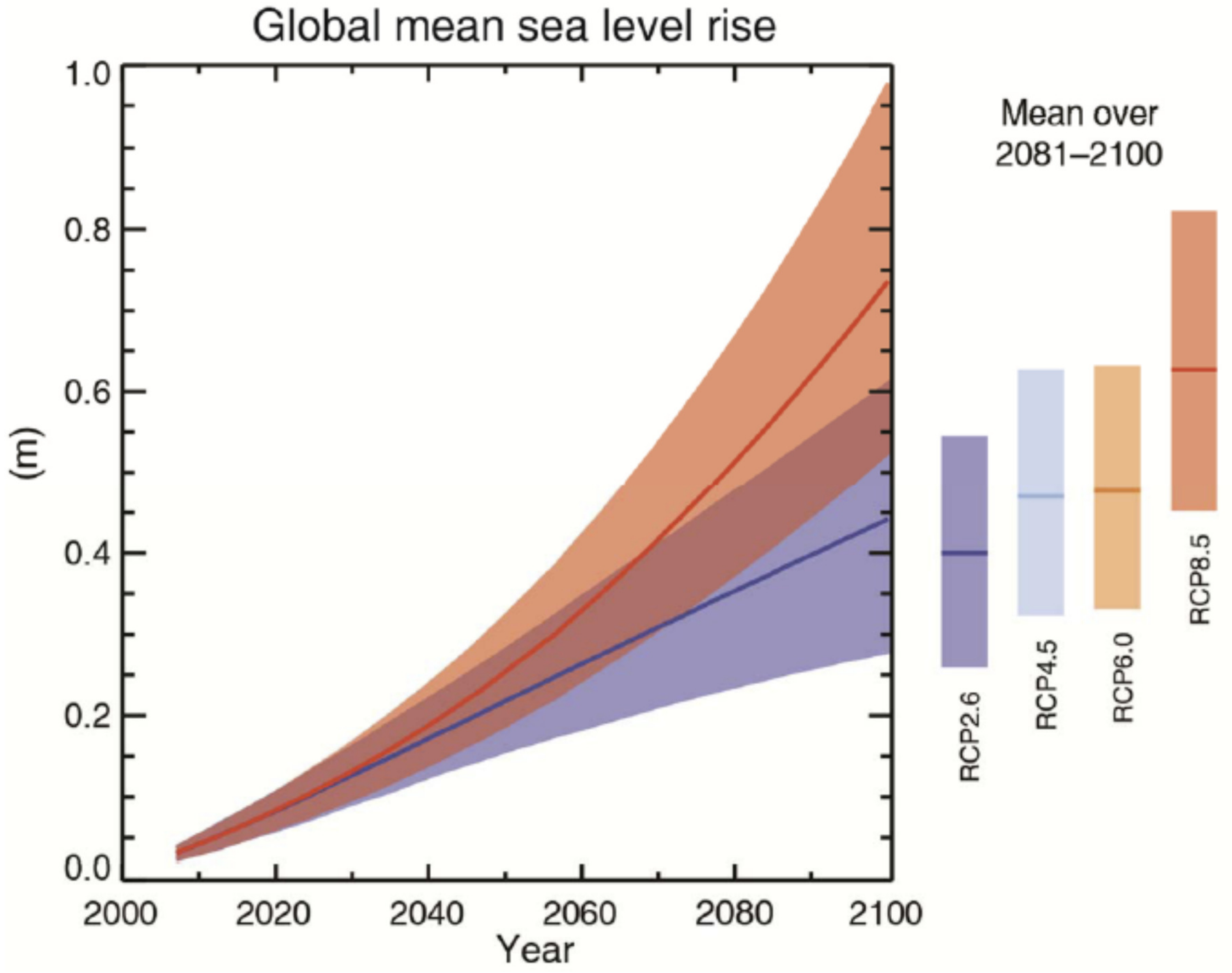
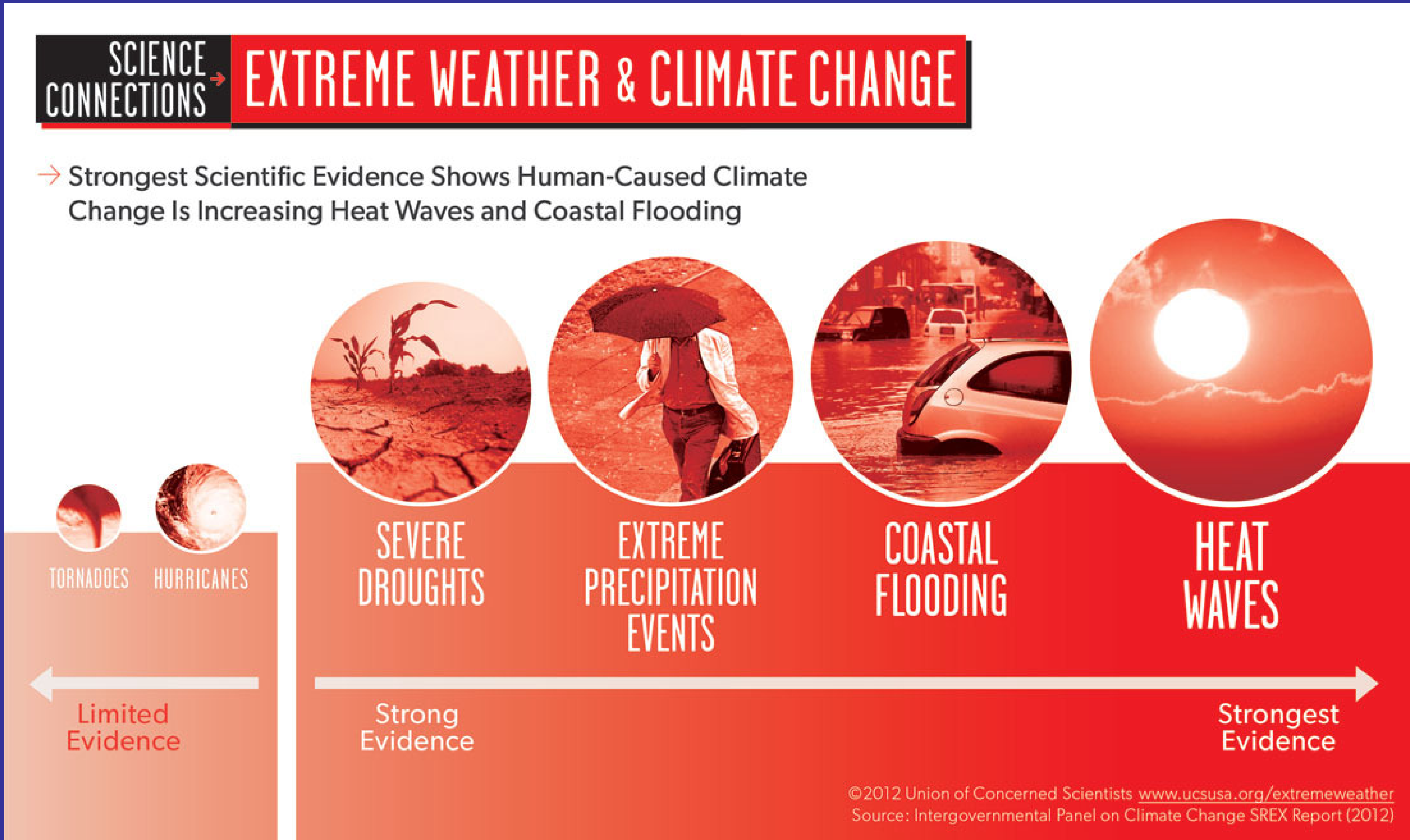


Global mean sea level rise
1.0
0.8
0.6
0.4
0.2
0.0
(m)
2000
2020
2040
2060
2080
2100
Year
Mean over
2081–2100
RCP2.6
RCP4.5
RCP6.0
RCP8.5

1853-2012

Instituto Dom Luiz

EXTREMES



young technicians
engineers of surveying and
geographical information technologies

play a major role

on monitoring and diagnosing the impacts of climate change and support decision makers to mitigate and adapt to climate change

Thank you!

		2046–2065		2081–2100	
Variable	**Scenario**	mean	*likely* range [c]	mean	*likely* range [c]
Global Mean Surface Temperature Change (°C) [a]	RCP2.6	1.0	0.4 to 1.6	1.0	0.3 to 1.7
	RCP4.5	1.4	0.9 to 2.0	1.8	1.1 to 2.6
	RCP6.0	1.3	0.8 to 1.8	2.2	1.4 to 3.1
	RCP8.5	2.0	1.4 to 2.6	3.7	2.6 to 4.8
		mean	*likely* range [d]	mean	*likely* range [d]
Global Mean Sea Level Rise (m) [b]	RCP2.6	0.24	0.17 to 0.32	0.40	0.26 to 0.55
	RCP4.5	0.26	0.19 to 0.33	0.47	0.32 to 0.63
	RCP6.0	0.25	0.18 to 0.32	0.48	0.33 to 0.63
	RCP8.5	0.30	0.22 to 0.38	0.63	0.45 to 0.82

Scenario	Cumulative CO_2 Emissions 2012–2100 (in GtC[a])	
	Mean	Range
RCP2.6	270	140 to 410
RCP4.5	780	595 to 1005
RCP6.0	1060	840 to 1250
RCP8.5	1685	1415 to 1910

Notes:
(a) 1 Gigatonne of carbon corresponds to 3.67 $GtCO_2$.

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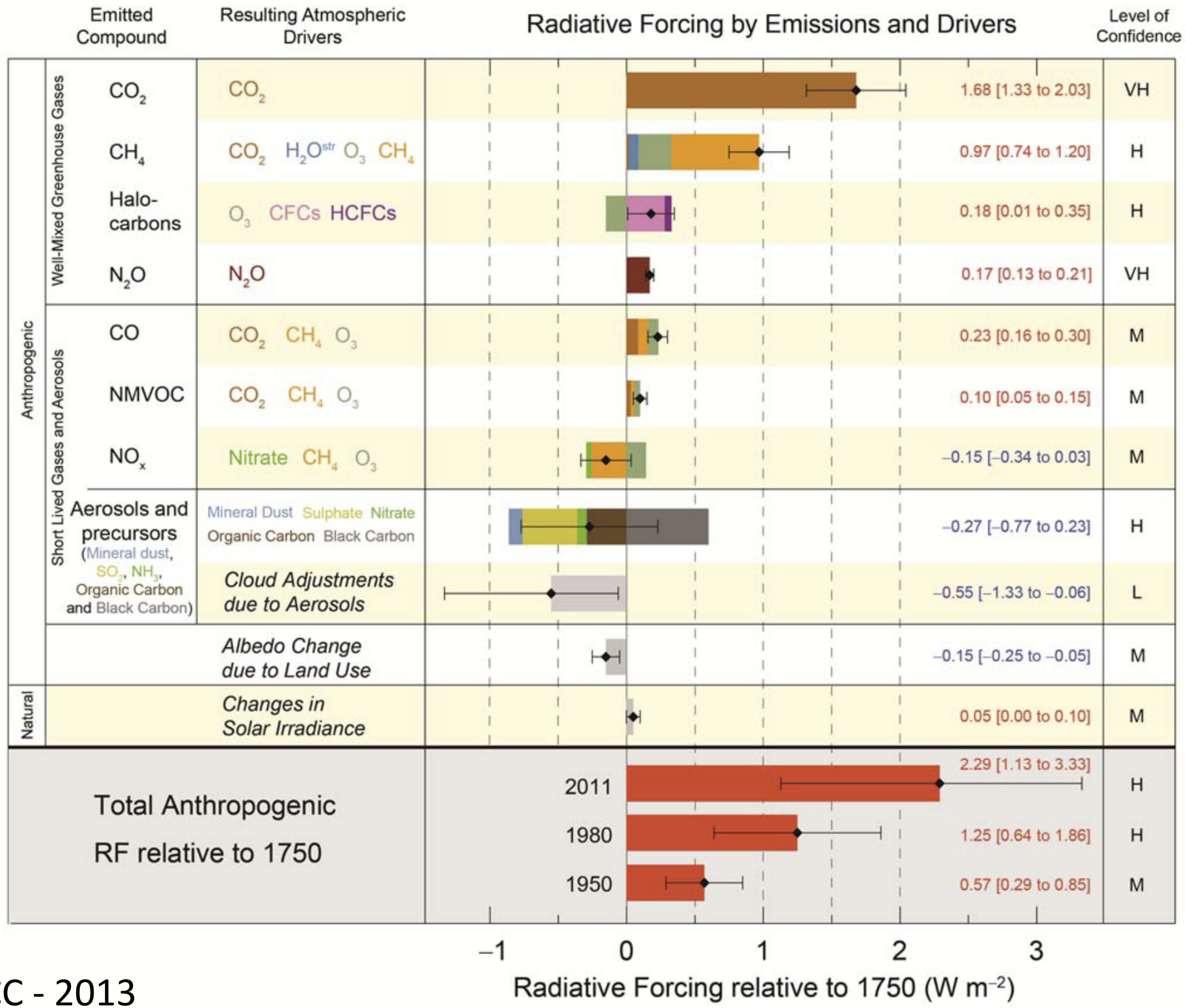
Drivers of Climate Change



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Evaluation of Climate Models

Climate models have improved since the AR4. Models reproduce observed continental-scale surface temperature patterns and trends over many decades, including the more rapid warming since the mid-20th century and the cooling immediately following large volcanic eruptions (very high confidence).

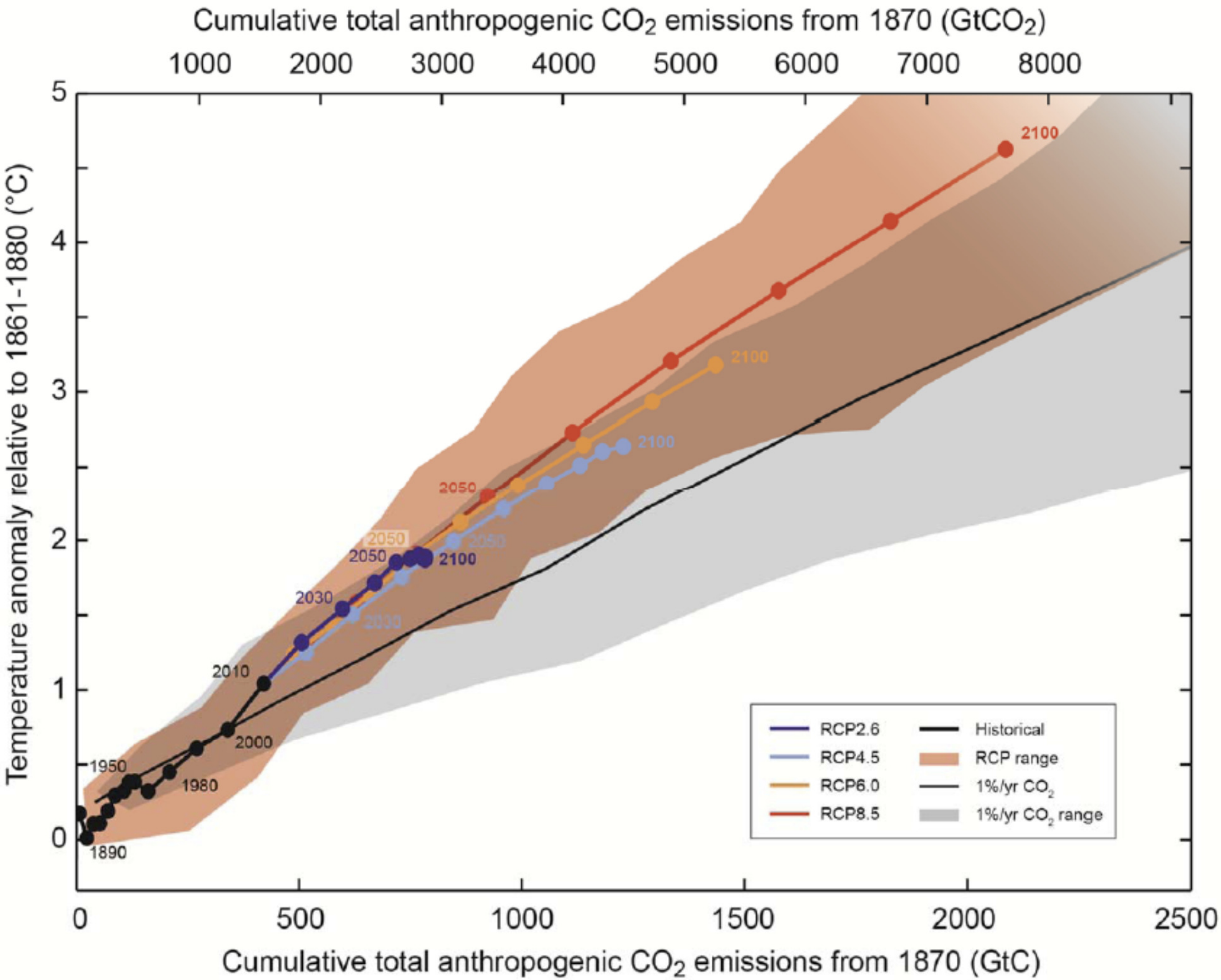
Mudança Climática Global

- A Terra está em aquecimento:
  - Como sabemos?
  - O que sabemos?

- **Razões e incertezas quanto às causas da MC:**
  - **O que é o sistema climático?**
  - **o efeito de estufa é um tema científico recente?**
  - **O que é o efeito de estufa?**
  - **Como simulamos o sistema climático?**
  - **Quais as projecções para o futuro?**
  - **Donde vêm os gases de estufa?**

Global Climate Change

- Earth is Warming
  - How do we know?
  - What do we know?
- How confident are hypotheses about causes?
  - What are greenhouse gases?
  - Where do they come from, and how do we know?
- Most common claims of the skeptics
  - T's are going down, not up
  - This warming is just part of a natural cycle
  - CO_2 is good for plants



Cumulative total anthropogenic CO2 emissions from 1870 (GtCO2)
1000
2000
3000
4000
5000
6000
7000
8000
Temperature anomaly relative to 1861-1880 (°C)
0
1
2
3
4
5
0
500
1000
1500
2000
2500
Cumulative total anthropogenic CO2 emissions from 1870 (GtC)
1890
1950
1980
2000
2010
2030
2050
2100
RCP2.6
RCP4.5
RCP6.0
RCP8.5
Historical
RCP range
1%/yr CO2
1%/yr CO2 range

What determines the Climate ?

Earth's Orbit