



SVENSKA ARALSJÖSÄLLSKAPET

Swedish Aral Sea Society



4. Climate Change

Lars Rydén
Professor Emeritus
Uppsala University

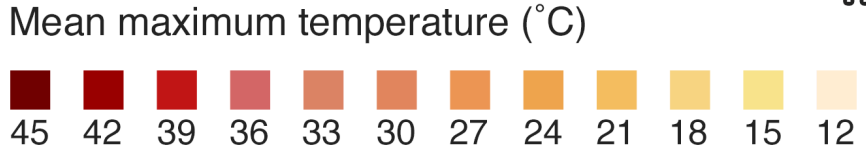
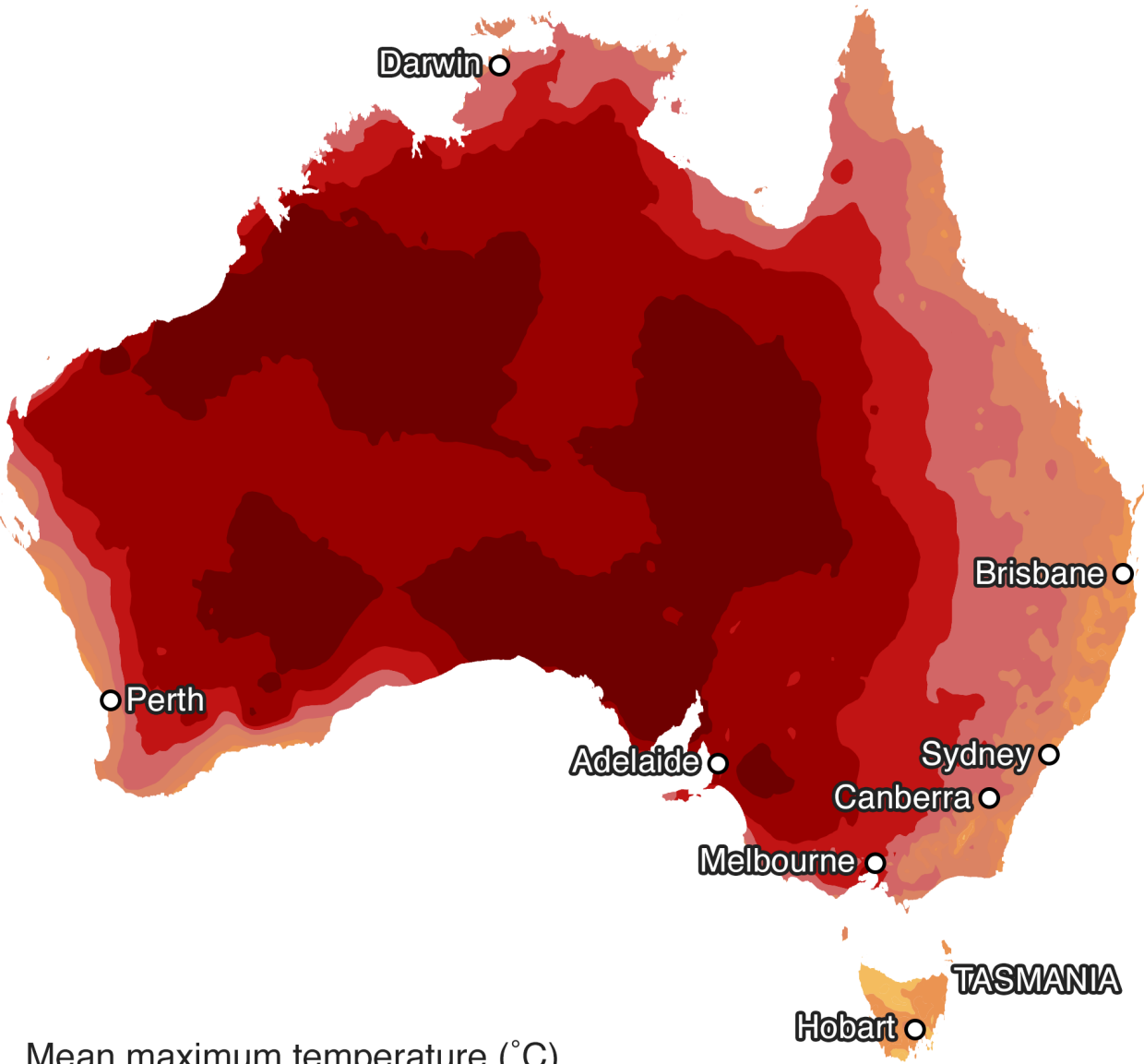
**Master Course on Sustainable Development and Sustainability Science
For Uzbekistan by SASS and Karakalpak State University Spring 2025**

I. Climate Change

Global warming is perceived in many ways

- Extreme hot weather – heat stress
- Melting glaciers
- Forest damages – increase forest fires, decreased biodiversity
- Water shortages in many countries
- Draught and desertification
- Extreme weather events and floods
- More often and more serious tornadoes and storms
- Tropical diseases come further north
- Sea level rise – coastal inundation
- Etc.....

Mean maximum temperature, 19 Dec



The heat wave in Australia 2019

<https://www.bbc.com/news/world-australia-50837025>



<https://www.bbc.com/news/world-australia-50837025>



<https://www.dw.com/en/deadly-heat-waves-set-to-surge-due-to-climate-change/a-39326267>



*Flooding in Jakarta, Indonesia, February 2017. Source: [World Meteorological Organization / Flickr](https://www.climatecentral.org/news/report-flooded-future-global-vulnerability-to-sea-level-rise-worse-than-previously-understood)
<https://www.climatecentral.org/news/report-flooded-future-global-vulnerability-to-sea-level-rise-worse-than-previously-understood>*



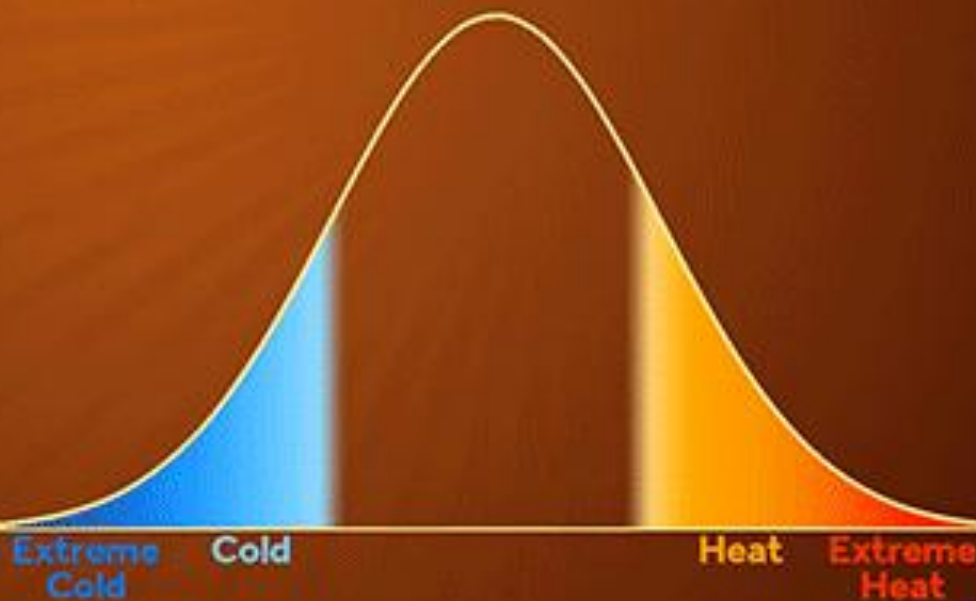
Pakistan 2022

<https://zeenews.india.com/video/world/pakistan-flood-2022-more-than-1000-people-died-in-the-devastating-floods-in-pakistan-2503959.html>



18 March 2019. The destruction unleashed by Cyclone Idai on Mozambique, Malawi and Zimbabwe, continues to claim lives and displace thousands. <https://news.un.org/en/story/2019/03/1034881>

SMALL CHANGE IN AVERAGE BIG CHANGE IN EXTREMES



CLIMATE  CENTRAL

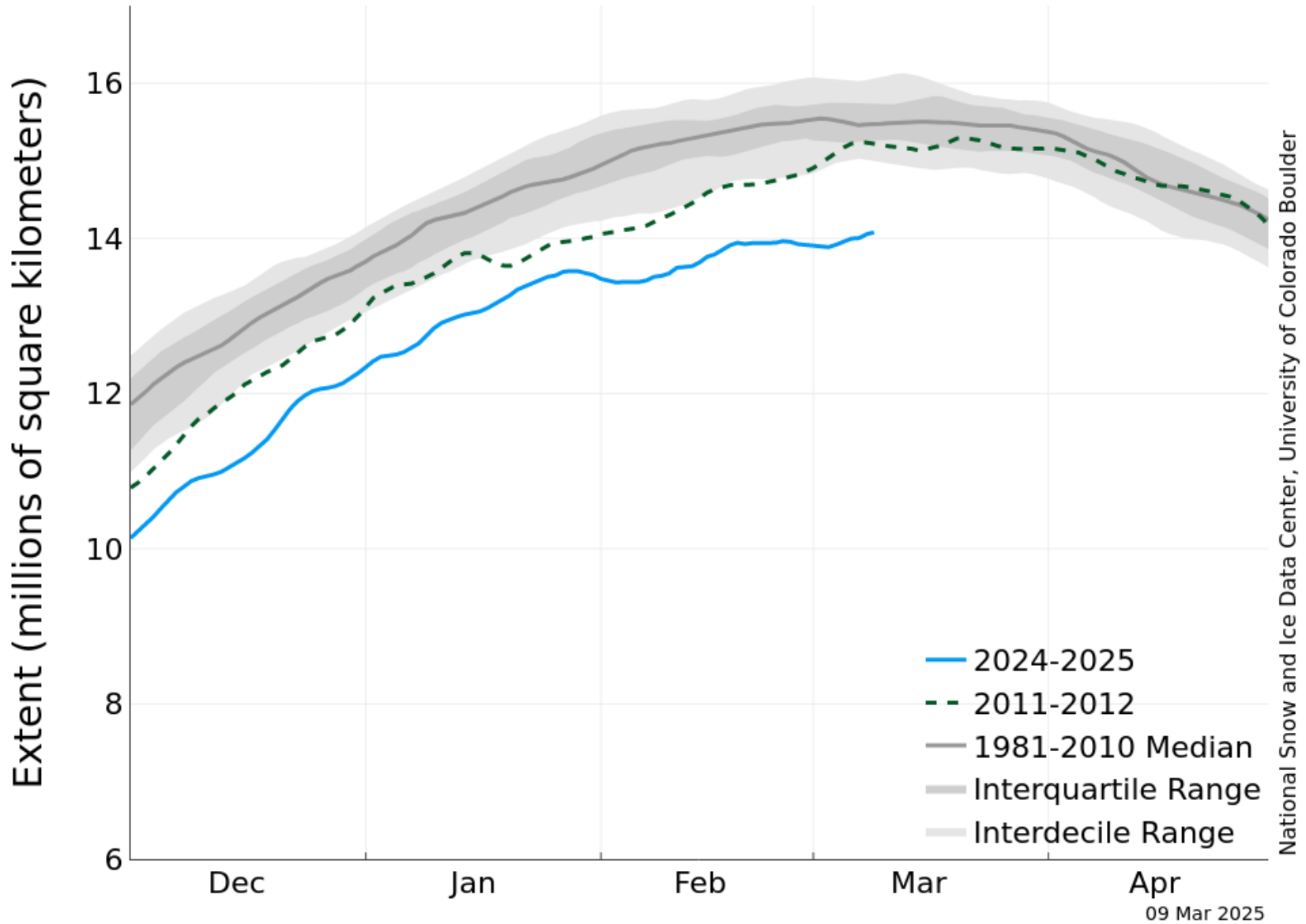
Sea Ice Extent, 09 Mar 2025

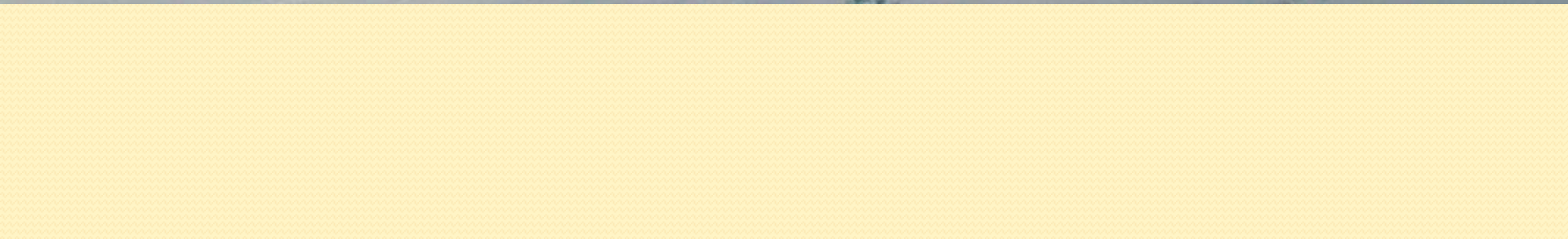


<https://nsidc.org/sea-ice-today>

The Arctic is warming faster than anywhere else on the planet, and as a result, sea ice in the Arctic Ocean is decreasing. Sea ice loss has far-reaching effects on the planet because the ice helps regulate Earth's climate, influences global weather patterns, and affects ocean circulations.

Arctic Sea Ice Extent (Area of ocean with at least 15% sea ice)





West Antarctic Ice Sheet Has Begun to Collapse

<http://news.discovery.com/earth/global-warming/west-antarctic-ice-sheet-has-begun-to-collapse-140514.htm>

On March 1, Antarctic sea ice likely reached its minimum extent of 1.98 million km², tying for second lowest extent with 2022 and 2024 in the 47-year satellite record.



SATELLITE DATA: 1993-PRESENT

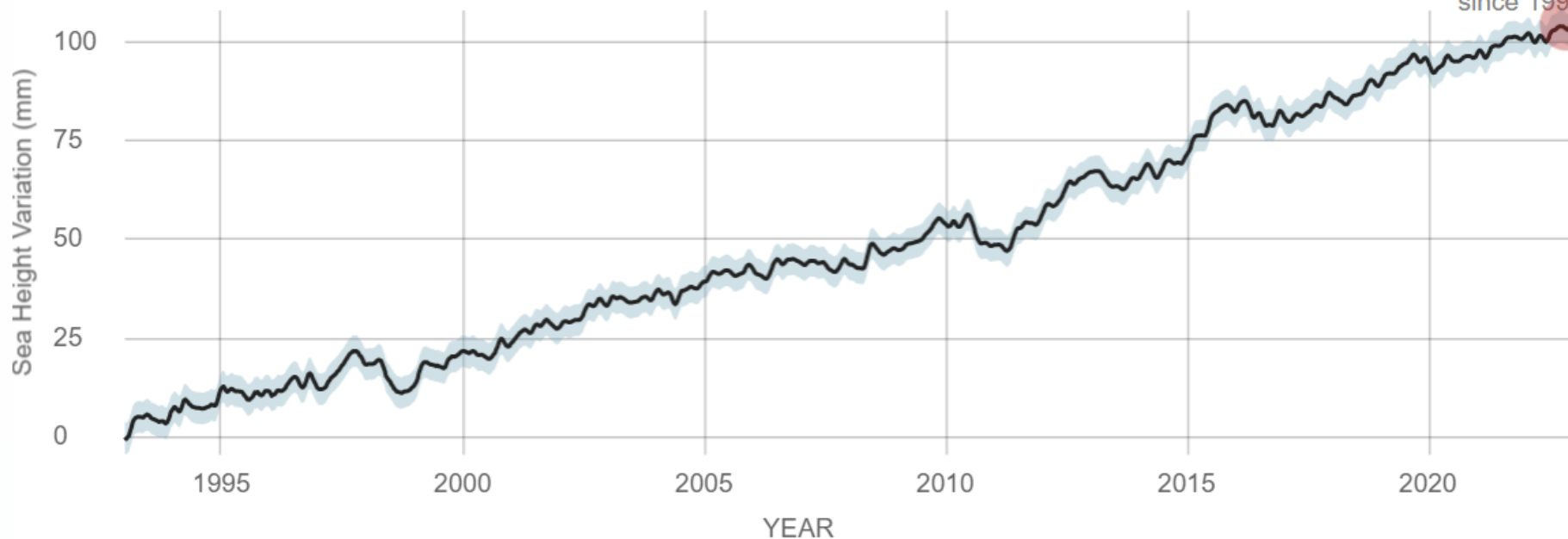
RISE SINCE 1993

Data source: Satellite sea level observations.

Credit: NASA's Goddard Space Flight Center

↑ 3.4

millimeters per year
since 1993



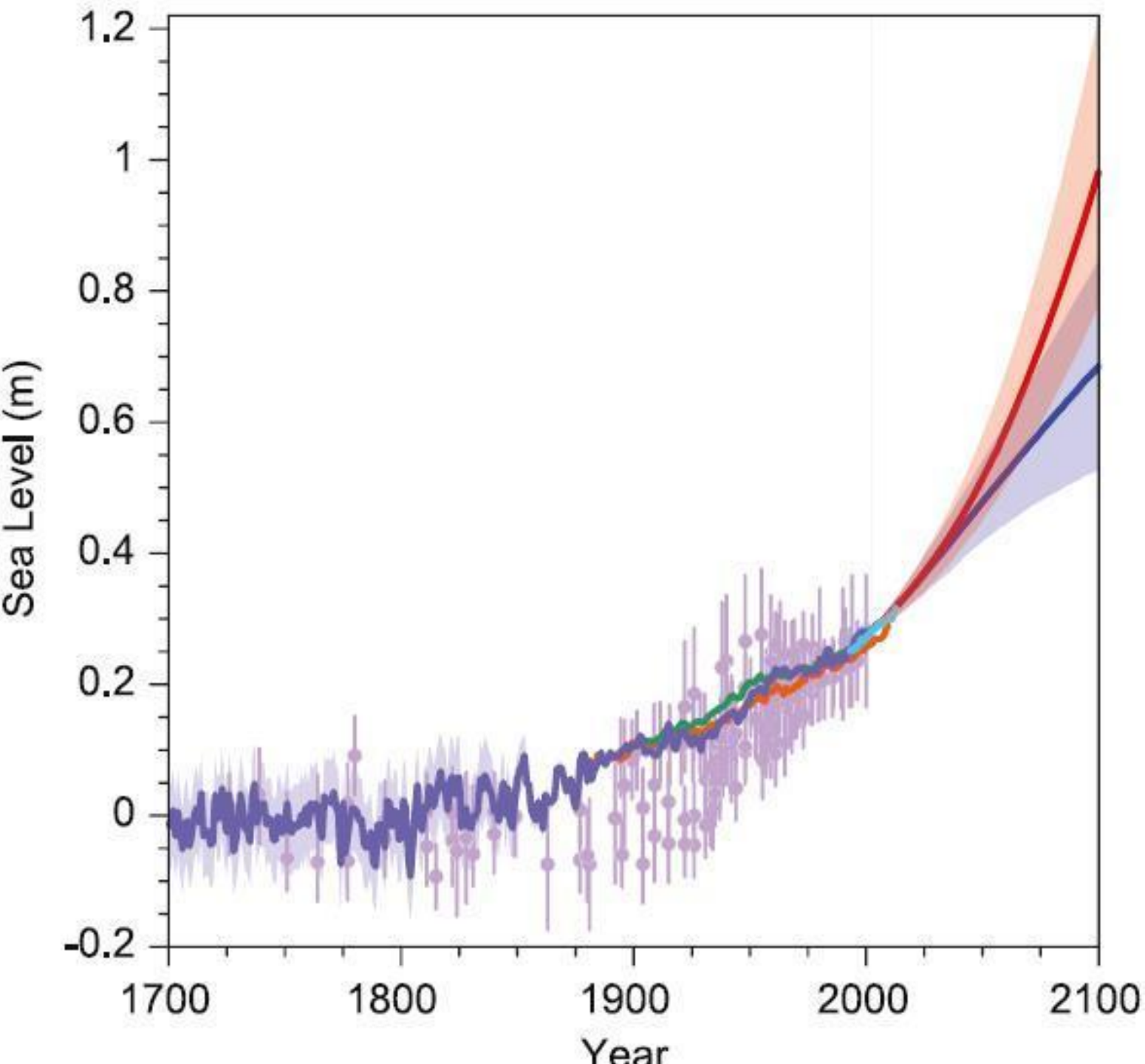
Click+drag to zoom

RESET

Get Data: [HTTP](#) | Snapshot: [PNG](#)

Sea Level Rise

<https://www.nasa.gov/specials/sea-level-rise-2020/>



<https://wordsinm-ocean.com/2016/01/06/how-far-will-sea-levels-rise-in-the-next-100-years/>

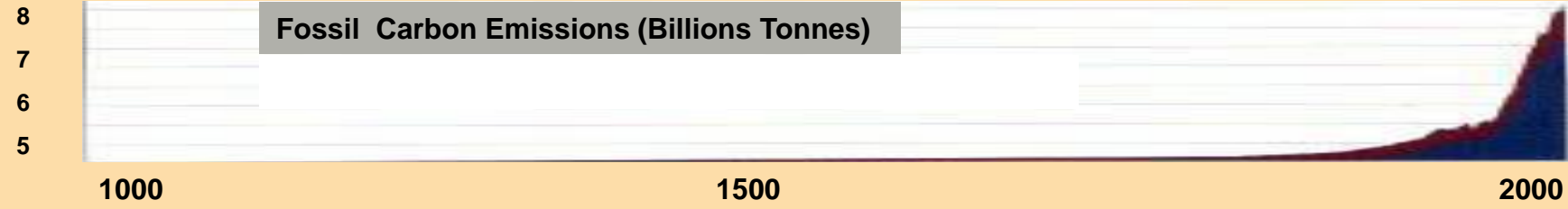
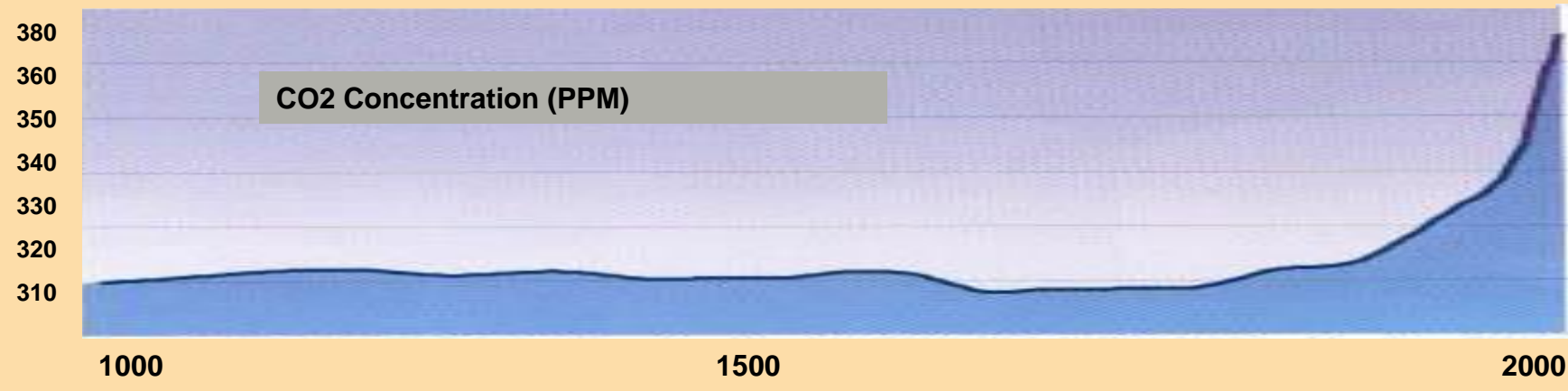
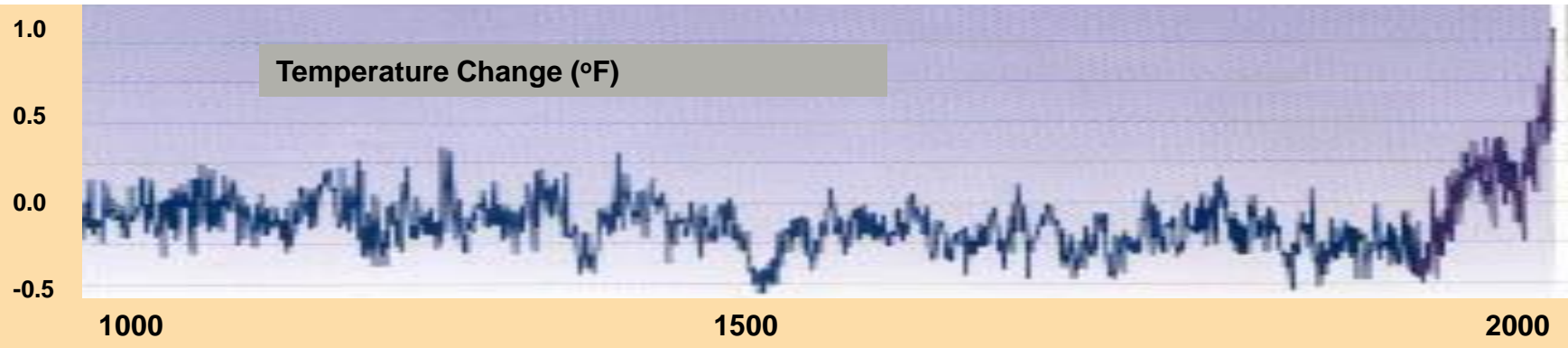


<https://www.amazon.com/Under-Sea-Great-Barrier-Reef/dp/B07F6VXJRC>





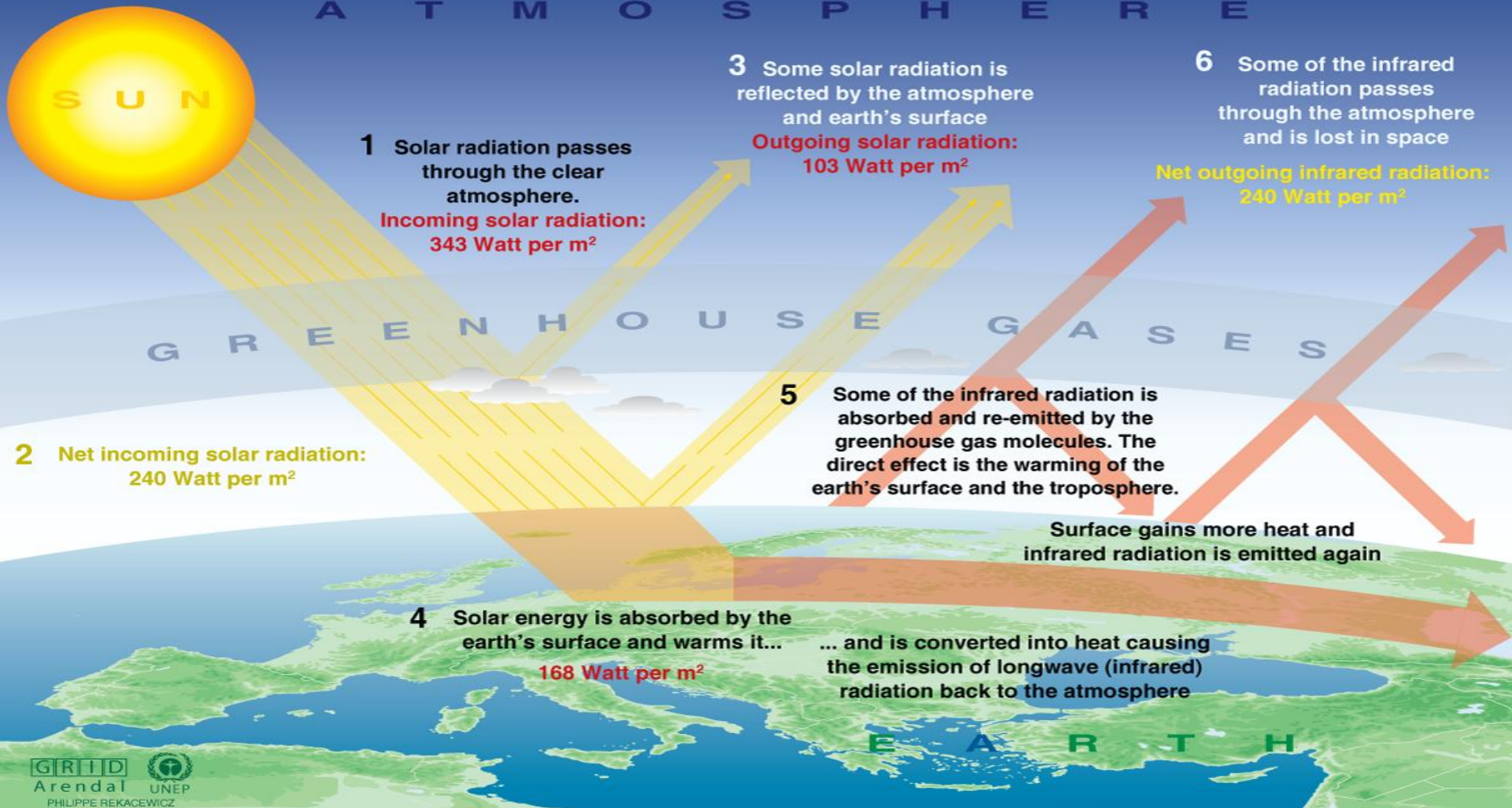
The causes of global warming



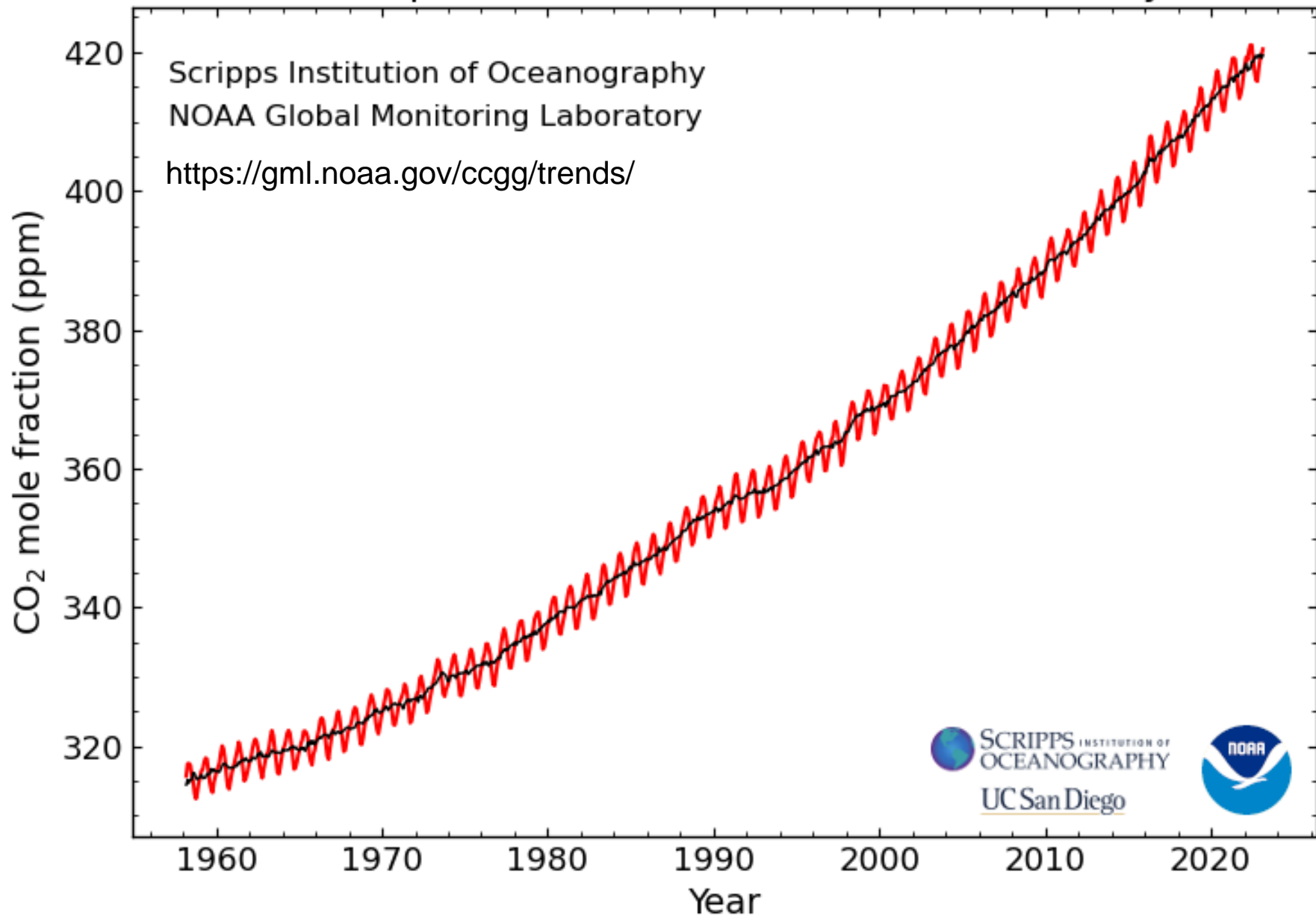


The greenhouse effect

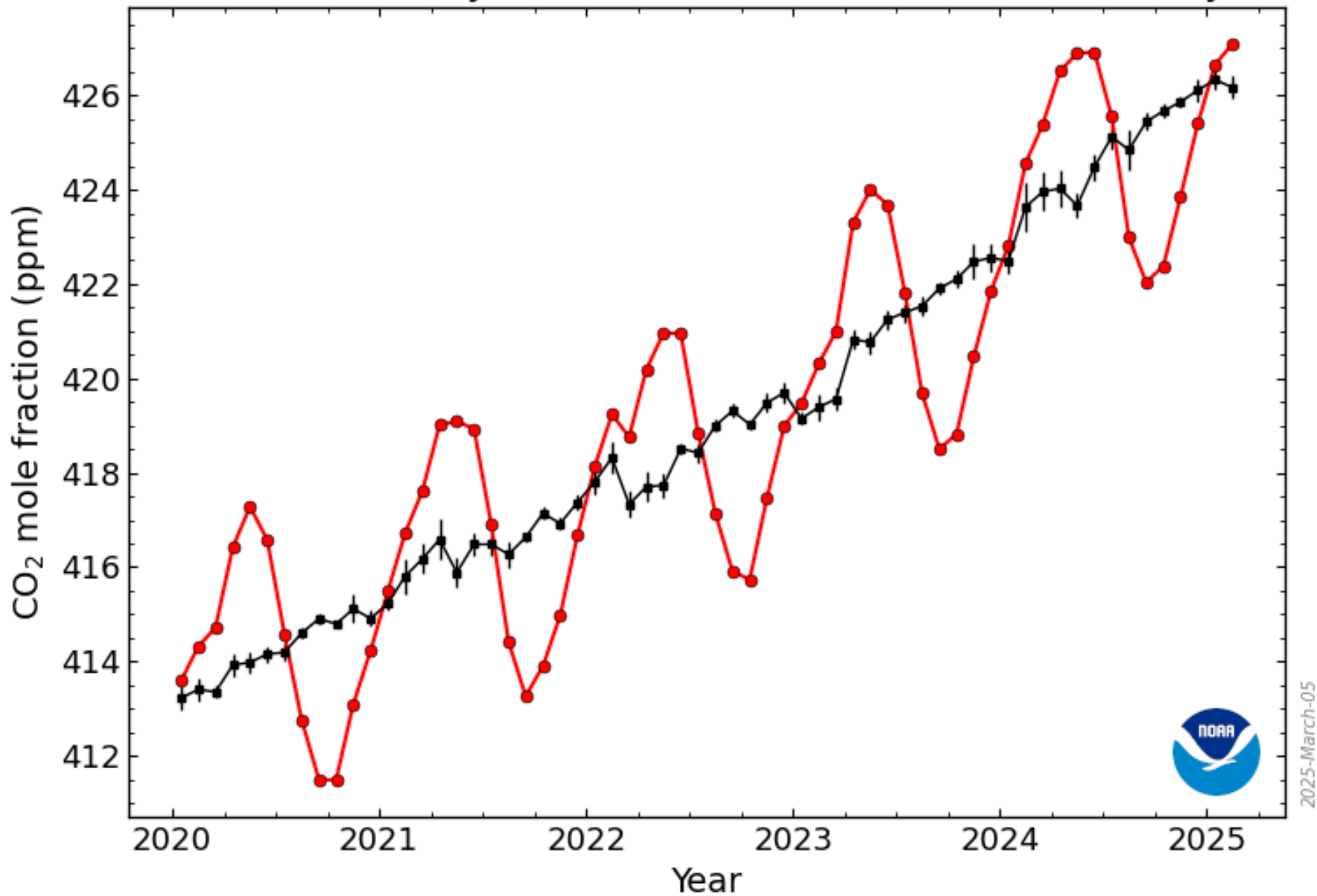
The Greenhouse effect



Atmospheric CO₂ at Mauna Loa Observatory

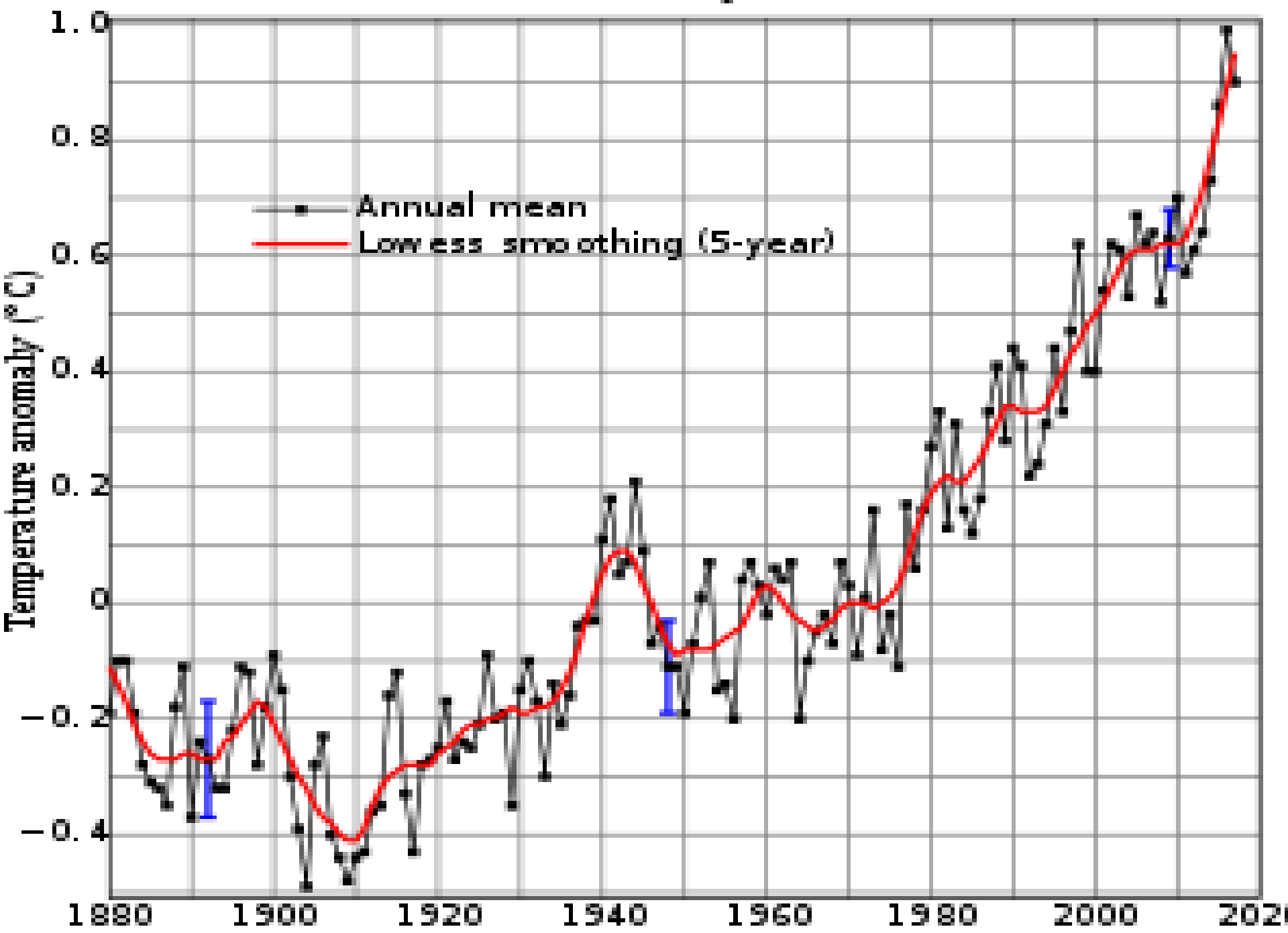


Recent Monthly Mean CO₂ at Mauna Loa Observatory



2025-March-05

Global land-ocean temperature index

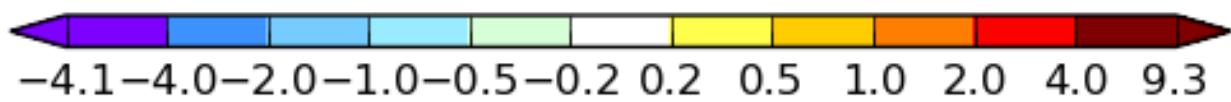
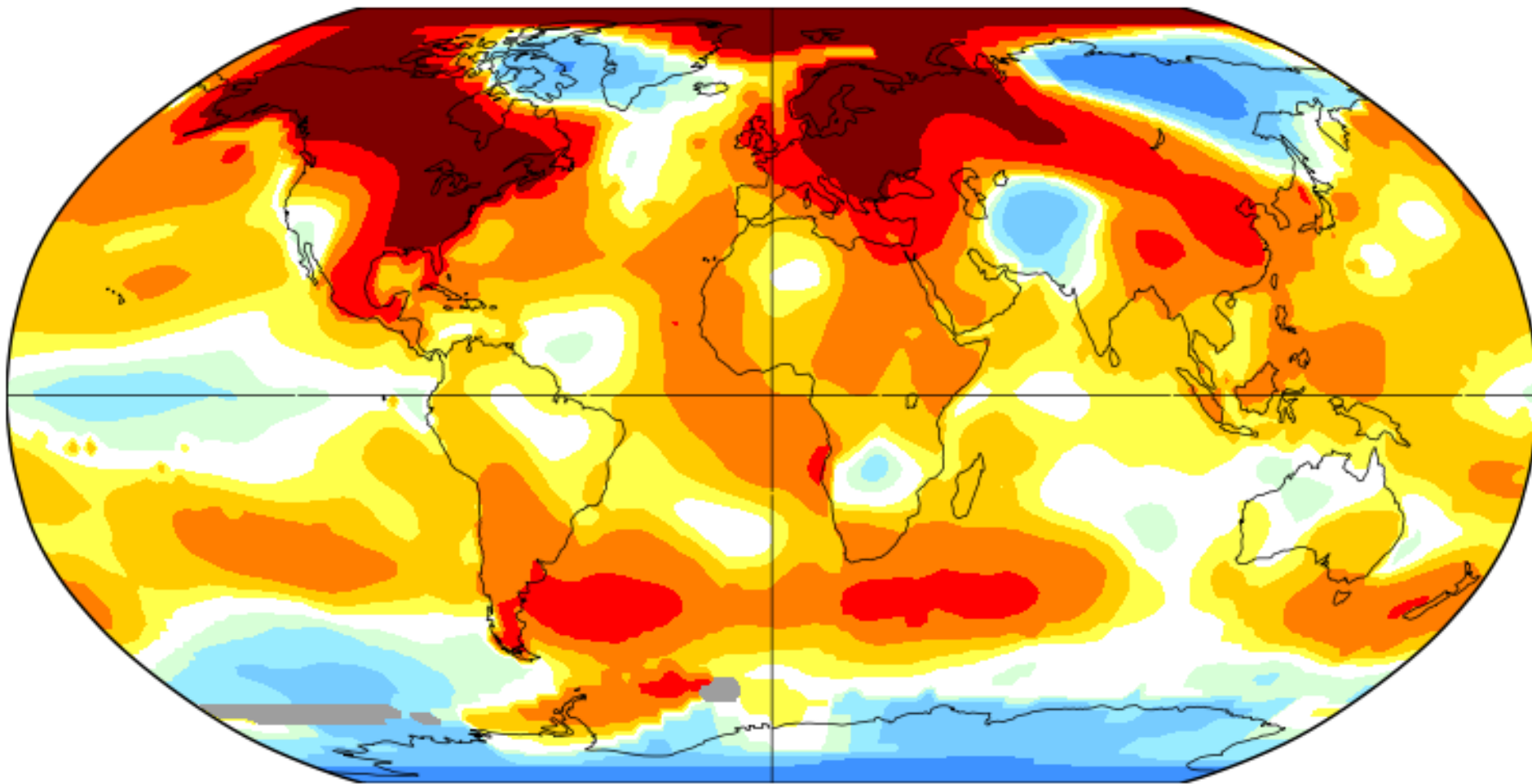


https://data.giss.nasa.gov/gistemp/animations/TEMPANOMALY_05_2024_pdiff.mp4

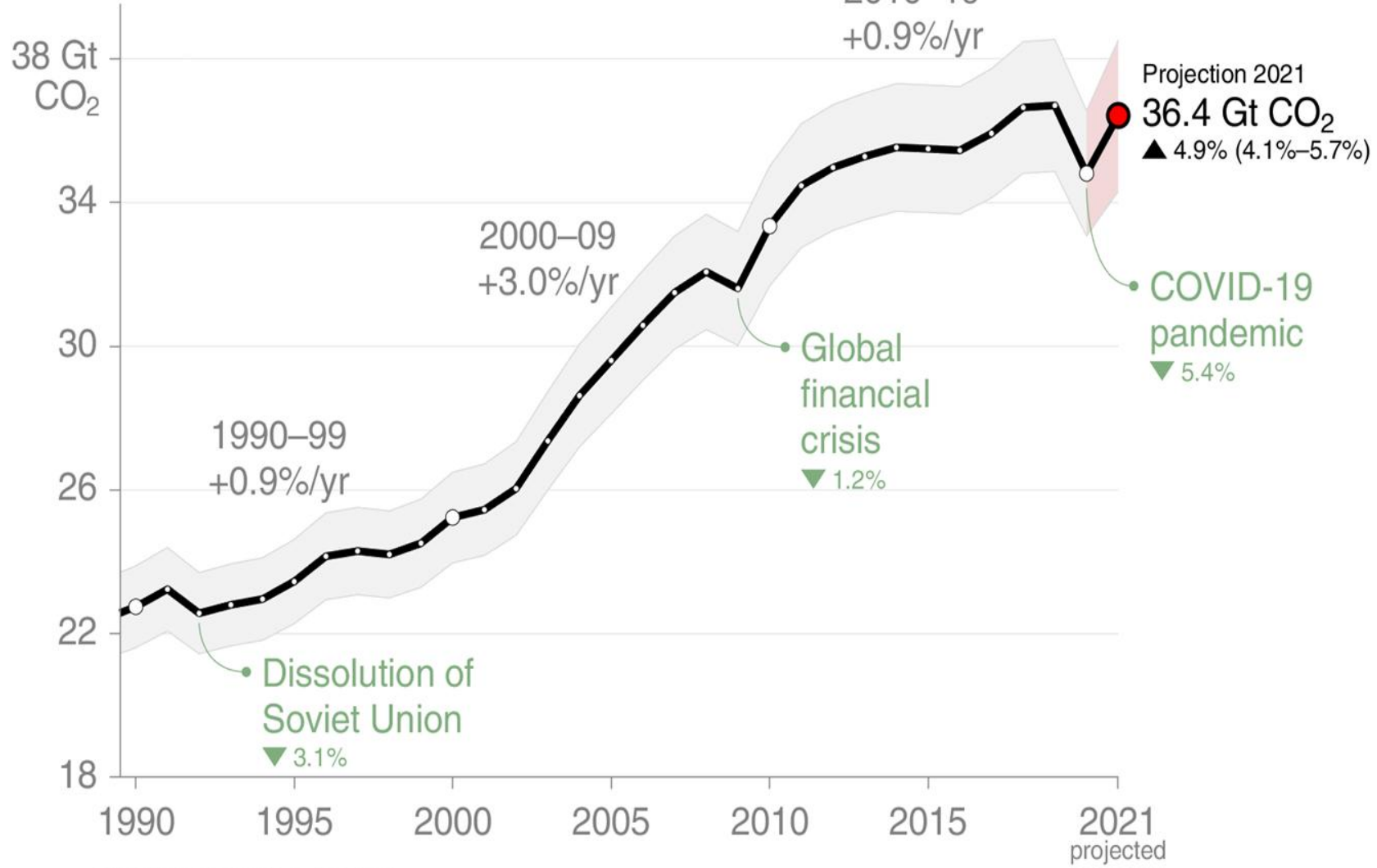
January 2023

L-OTI(°C) Anomaly vs 1951-1980

0.86

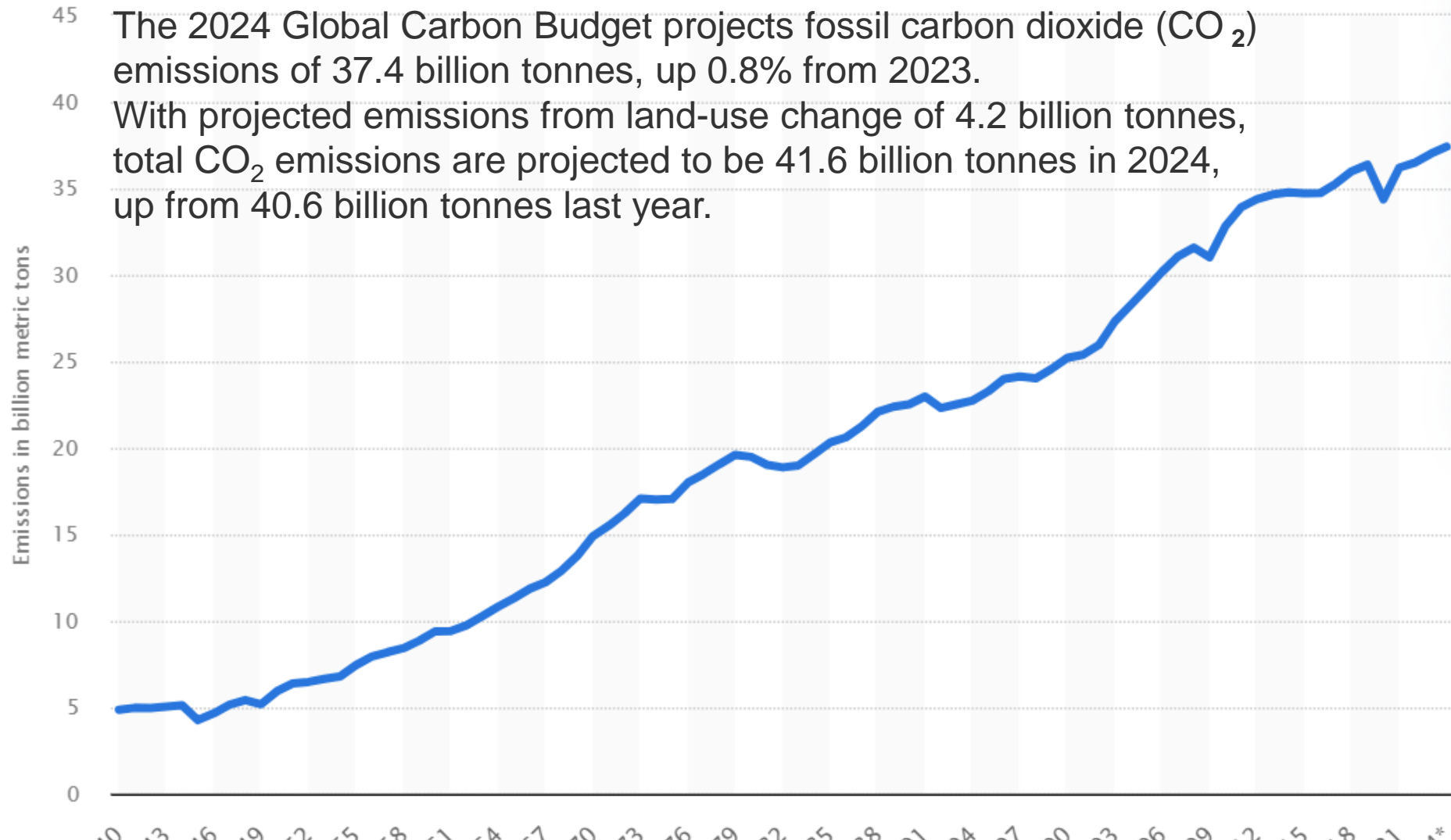


Global Fossil CO₂ Emissions



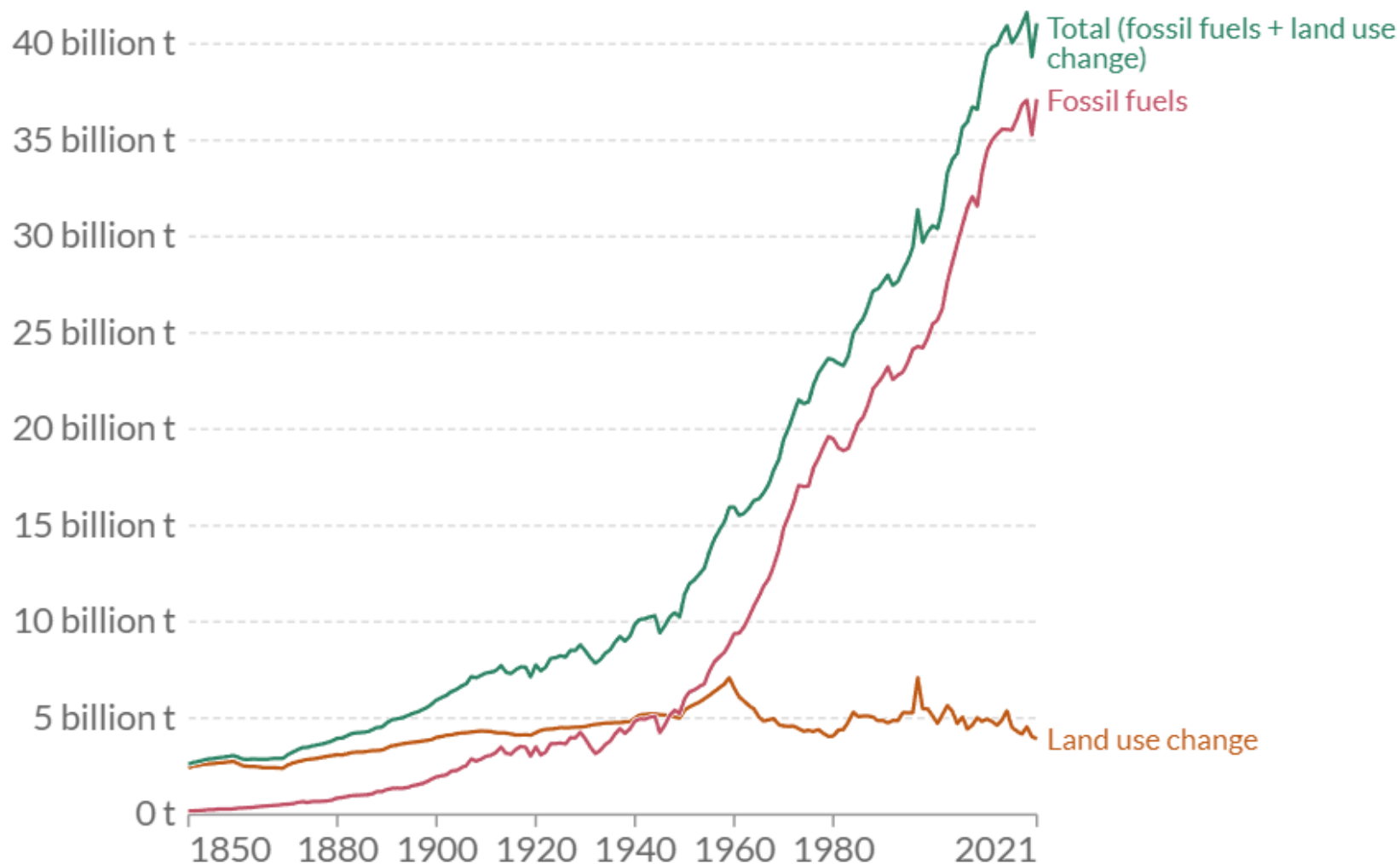
Annual carbon dioxide (CO₂) emissions worldwide from 1940 to 2024 *(in billion metric tons)*

<https://www.statista.com/statistics/276629/global-co2-emissions/>



Global CO₂ emissions from fossil fuels and land use change, World

[↔ Change country](#)



Annual Fossil CO₂ Emissions: Global

16 Gt
CO₂

Projected total emissions growth: +4.9% (+4.1% to +5.7%)

Projected Gt CO₂ in 2021

Coal 14.7

▲ 5.7% (+4.5% to +6.8%)

Oil 11.5

▲ 4.4% (+3.0% to +5.8%)

Gas 7.7

▲ 4.3% (+3.2% to +5.4%)

Cement 1.7

▲ 6.5% (+4.8% to +8.3%)

12

8

4

0

1960

1970

1980

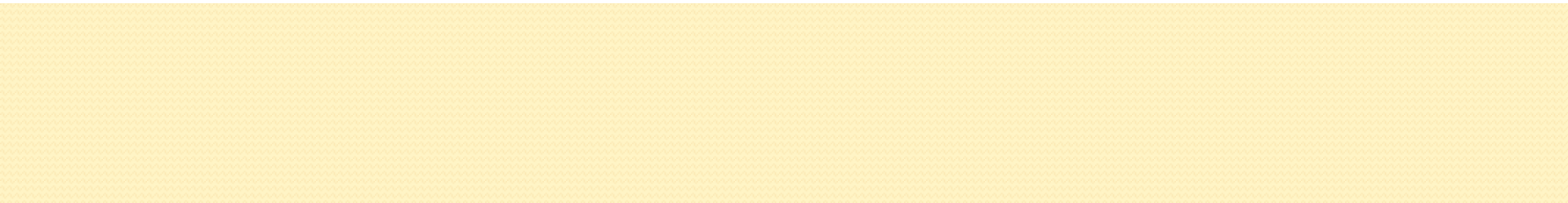
1990

2000

2010

2021
projected

© Global Carbon Project



Global GHG emissions for 2008 by type and source

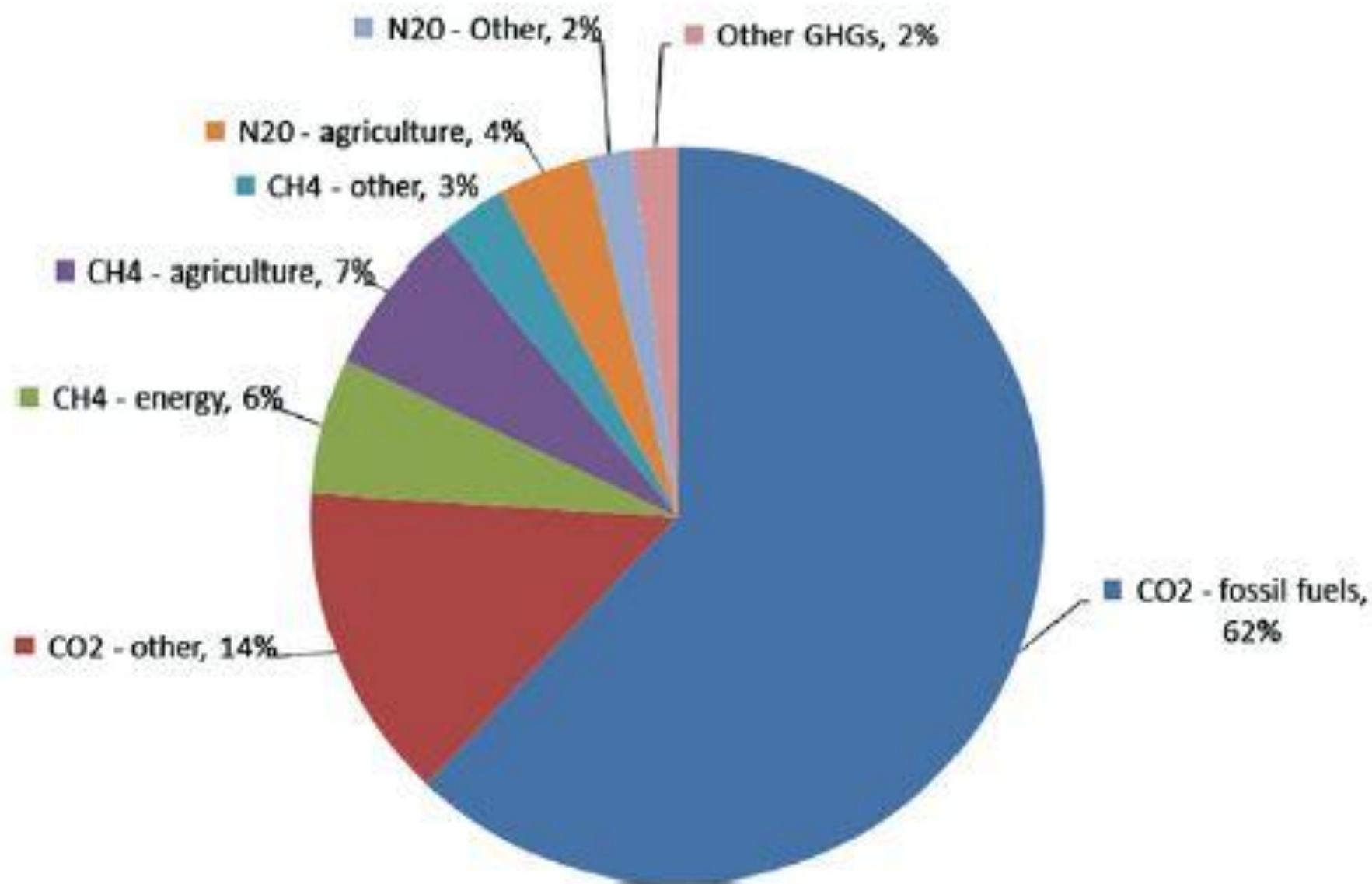


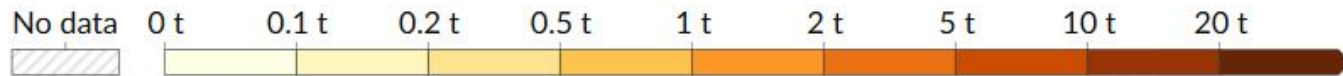
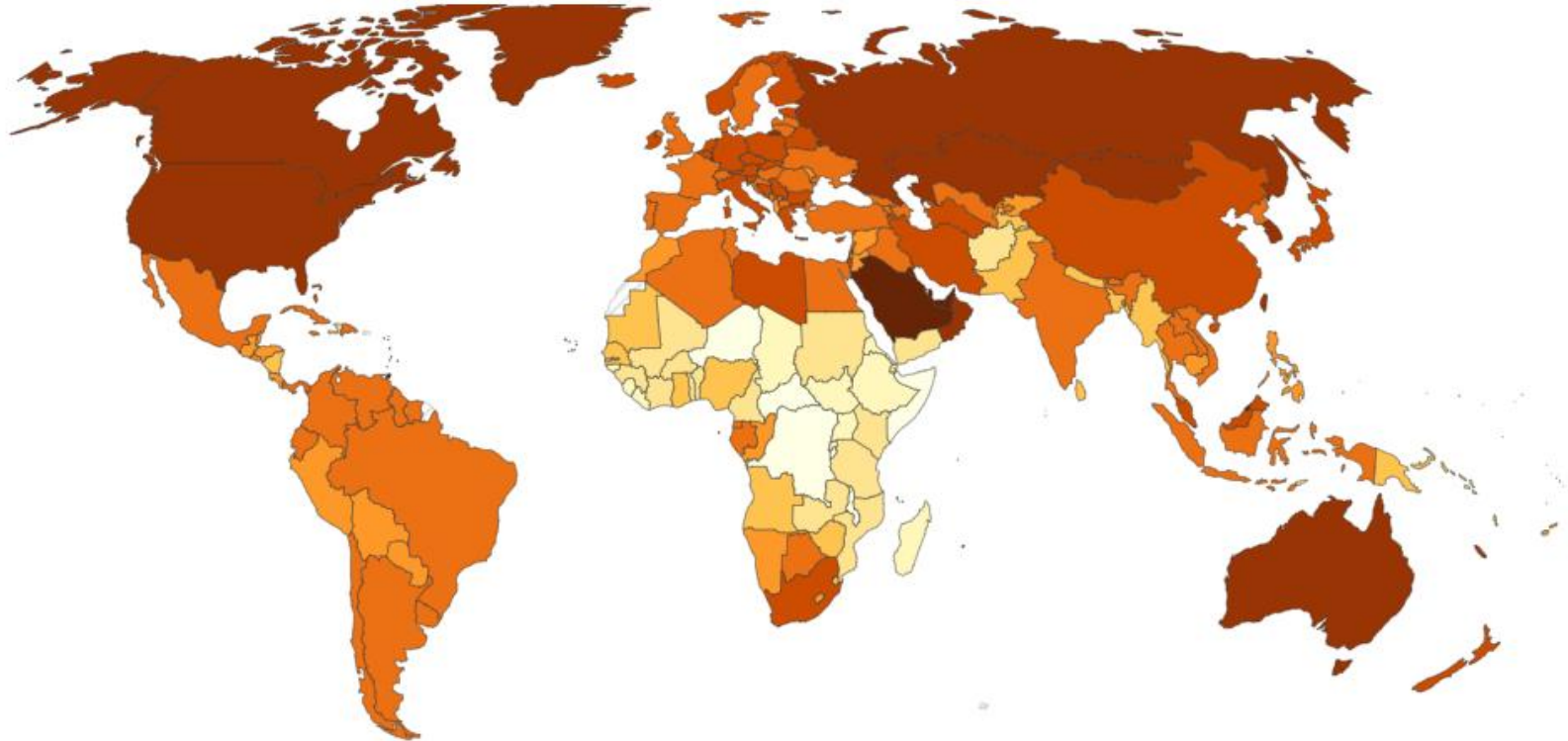
Fig. 3. Global anthropogenic GHG emissions by type and source. Data taken from IEA (2010).

Per capita CO₂ emissions, 2023

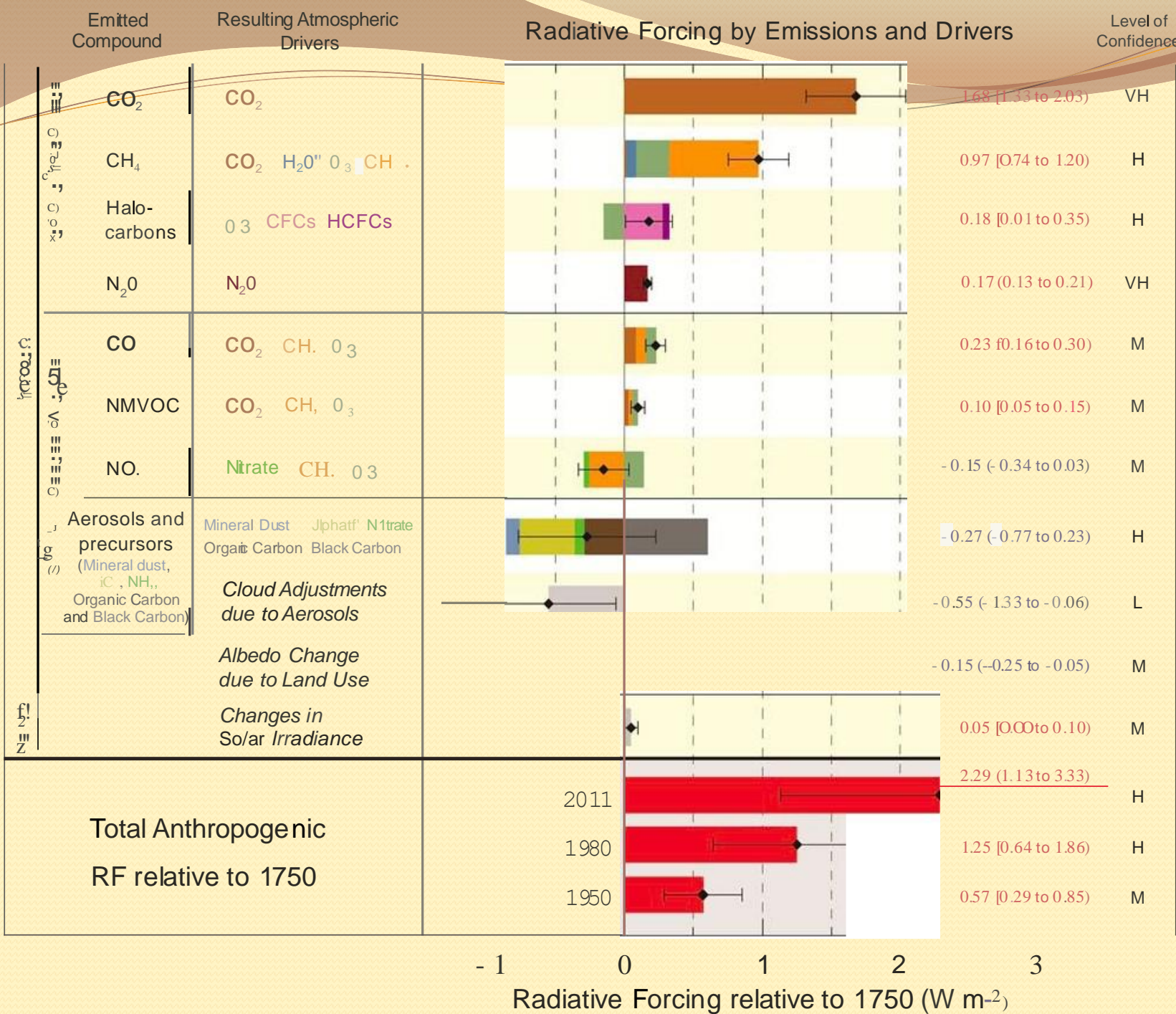
Carbon dioxide (CO₂) emissions from fossil fuels and industry. Land-use change is not included.

Table Map Line Slope

World



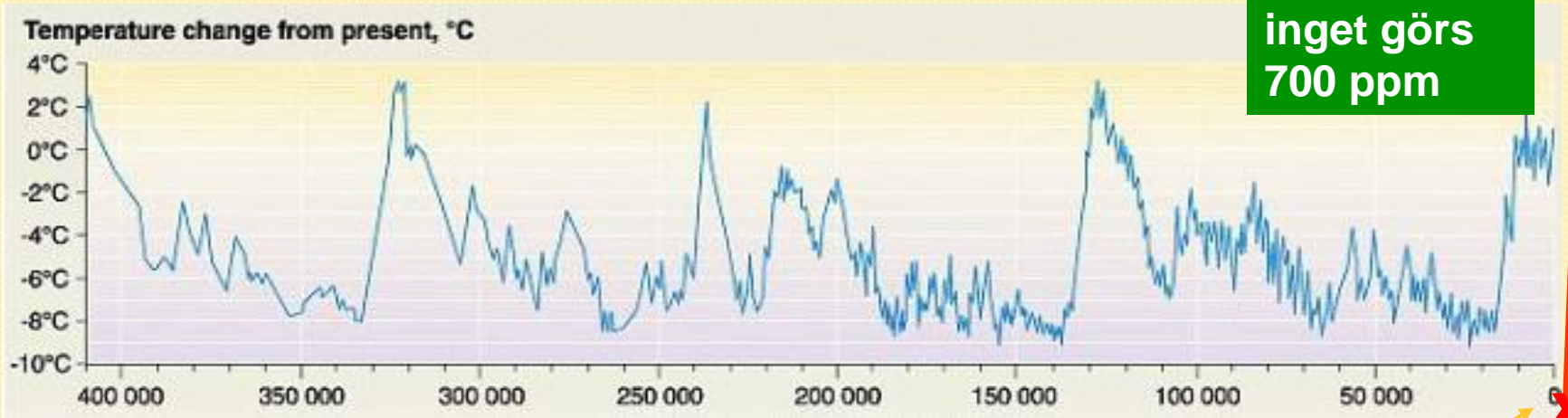
Radiative Forcing by Emissions and Drivers



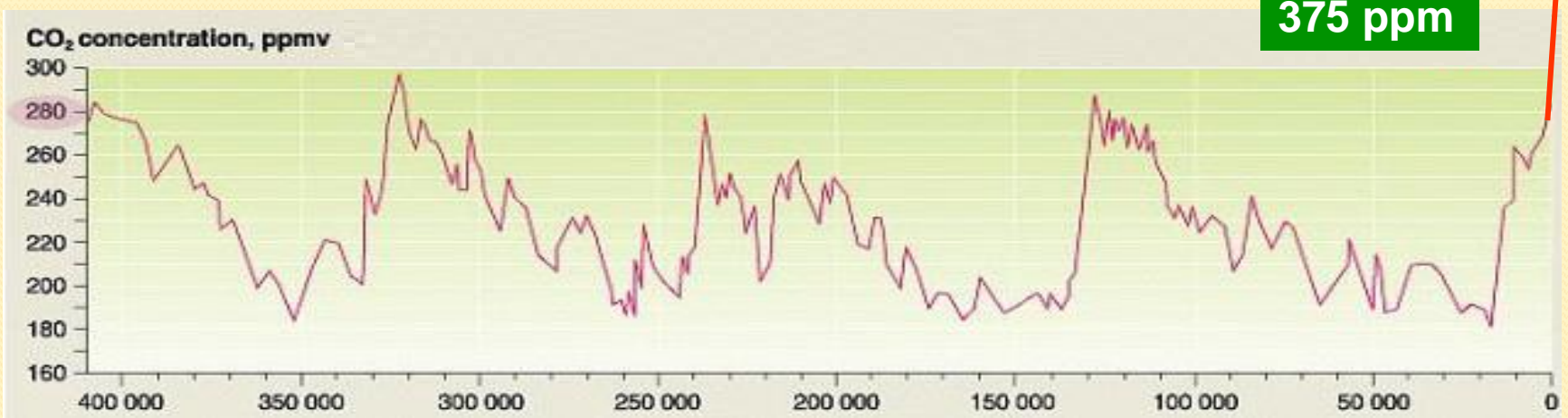
**The main cause of climate change
is the large use of fossil fuels -
*coal, oil and gas.***

Global temperatur och CO2 concentration

400 000 år data från " Vostok iskärnan"

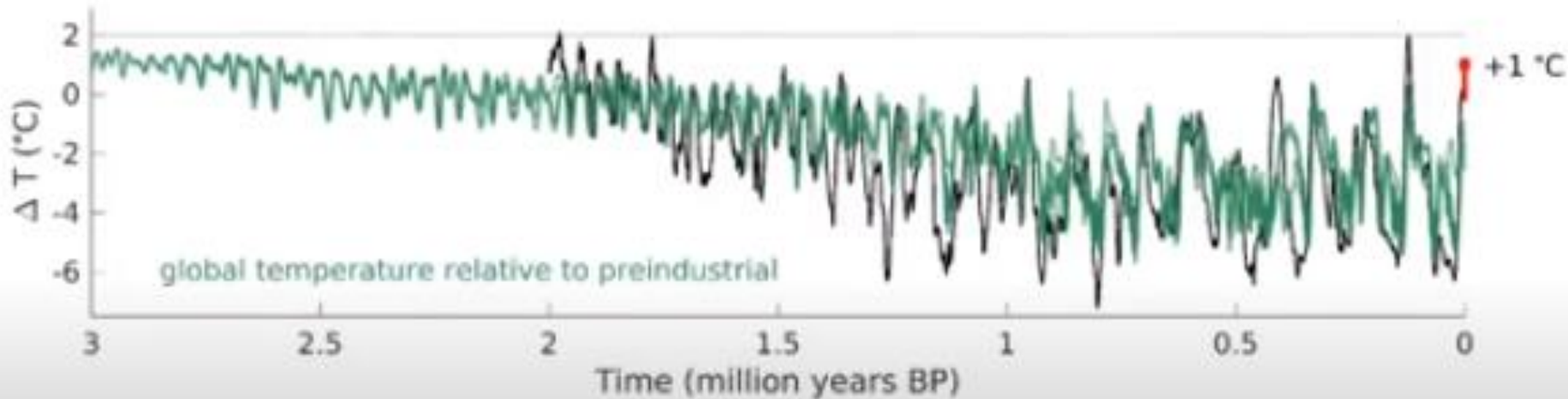


År 2100 om inget görs 700 ppm



2004 375 ppm

We have never exceeded 2 C in the last Three Million Years



Results of model simulations: Observations shown in black, model results in colour.

Climate variability is increasing. 2010 was warm in Russia, 2012 in North America; Winter was strong in Europe, etc

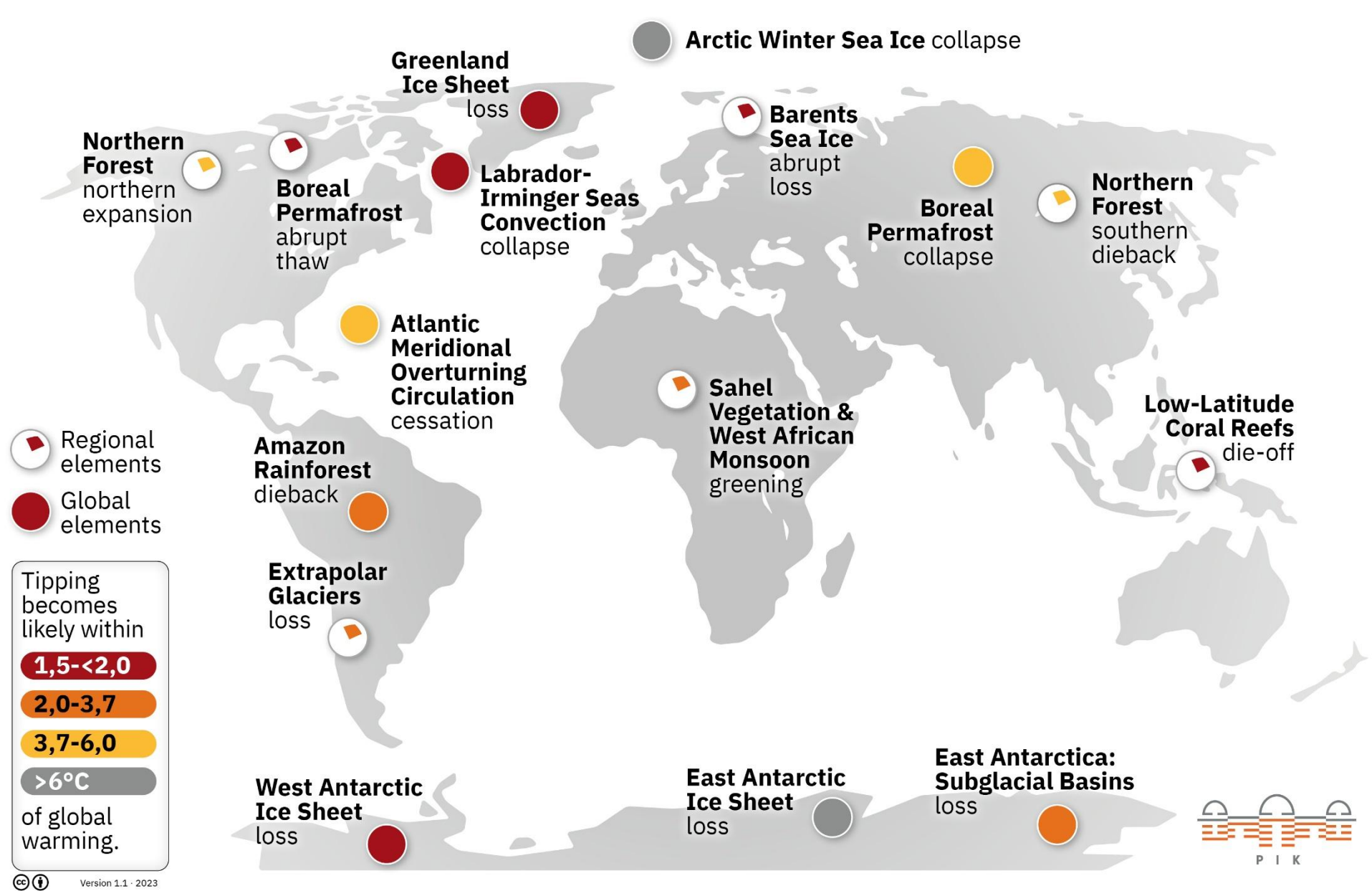
Present warming is very fast: 0.16 °C per decade. The warming after the last ice age was 0.1 C per century.

Climate sensitivity according to IPCC is around 3.7 watts per m². This leads to 3 °C increase for a doubling of CO₂ levels.

During previous warming events CO₂ levels started to increase followed by increased temperature. Now it is the opposite. We do not know what it will lead to.

Feedbacks and tipping points

- Arctic Sea summer ice melts –
feedback: decreased albedo
- Arctic permafrost is melting
feedback: increased methane emissions
- Amazon rainforest cut down and becomes savanna
feedback: decreased evapotranspiration
- Atlantic circulation decreases
feedback: ocean desalting



30 minutes

- 10 minutes to think on your comments;
- 20 minute discussion.

Discuss for example

- How much are you depending on fossil fuels today?
- Do you see ways to reduce this?

II. Climate practises and policies

Climate terminology

Carbon (as CO₂) flows between the atmosphere, the above ground biosphere, the ground and the sea.

All these flows have increased considerably since *coal, oil and gas*, stored as *fossil carbon*, has started to be used as a source of energy.

We talk about *carbon sinks* and *carbon sources*.

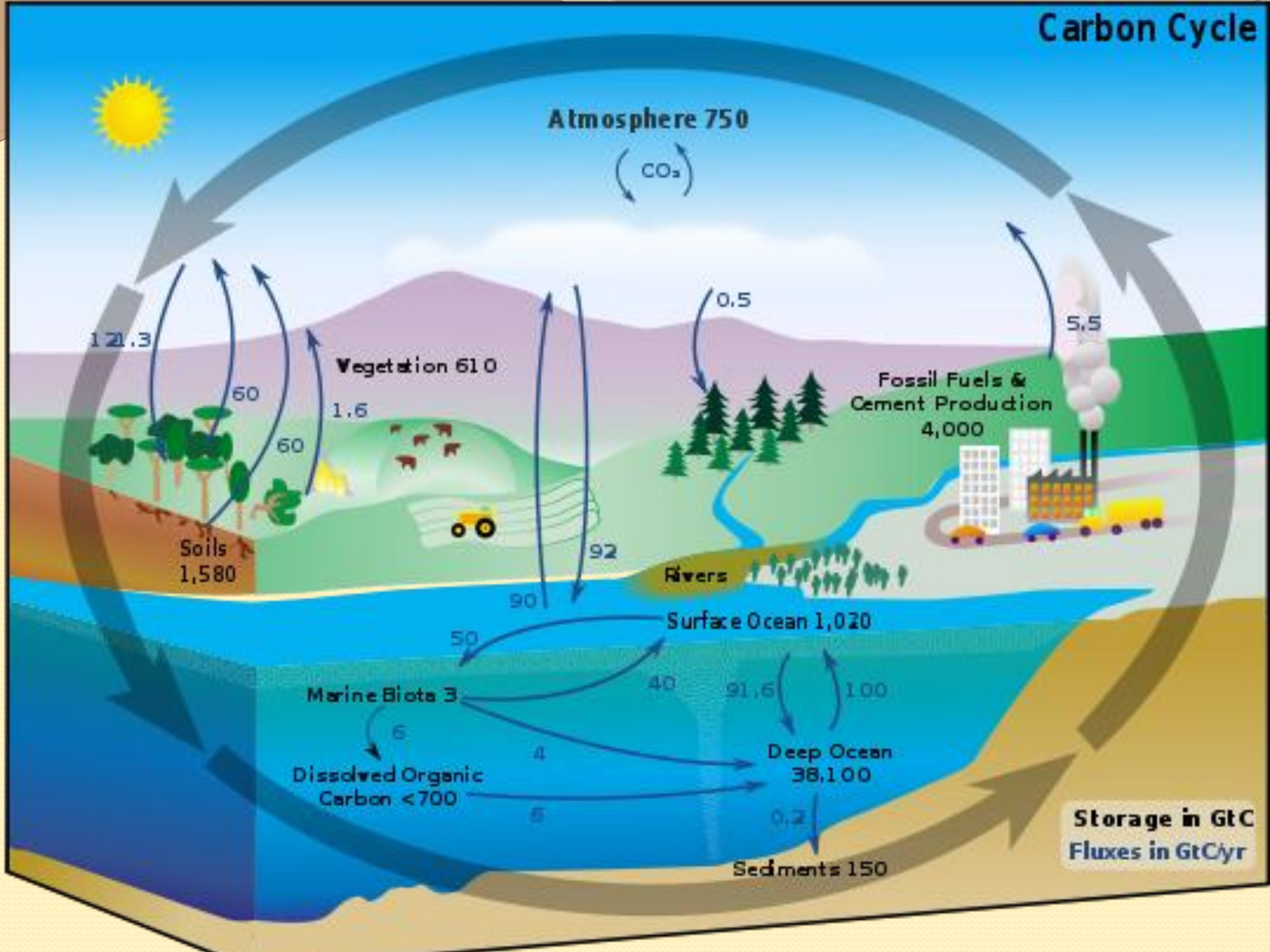
A growing forest is a carbon *sink*.

An overused soil is a carbon *source*.

When carbon is stored in a sink it is called *sequestration*.

When carbon is released from a source it is called *emission*.

Carbon Cycle



Adaptation

- Not building in coastal areas
- Building flood defences
- Protecting cities for extreme heat waves
- Develop crops which can grow in higher temperatures
- Switching to drought-resistant crops
- Etc

https://en.wikipedia.org/wiki/Green_roof#/media/File:20080708_Chicago_City_Hall_Green_Roof.JPG





<https://www.pri.org/stories/2016-06-20/sea-levels-rise-rotterdam-floats-top-example-how-live-water>

Mitigation

- Changing to renewable energy
- Stop using fossil fuels in power plants
- Stop using fossil fuels for heating
- Stop using fossils for driving cars, drive car less
- Reduce flying, take train for long distance travel
- Developing forestry
- Building in wood, not concrete
- And much more

Intergovernmental Panel on Climate Change (IPCC)

- In 1988 the **Intergovernmental Panel on Climate Change (IPCC)** was formed by the World Meteorological Association (WMO) and UN Environmental Programme (UNEP). IPCC is reporting research on climate change by thousands of scientists.
- **The assessment reports**, the most recent no 6 from 2021-2022, summarizes the collective understanding of climate change and its consequences as well as projections into the future.

United Nations Framework Convention on Climate Change (UNFCCC)

- The 1992 UN conference in Rio de Janeiro (UNCED) negotiated and signed a United Nations Framework Convention on Climate Change (UNFCCC).
- The convention went into force in 1994 when 50 states had ratified. Today 198 states are parties to the convention, that is, all states on Earth take part.
- The objective of the Convention is to stabilize greenhouse gas concentrations “at a level that would prevent dangerous anthropogenic (human induced) interference with the climate system.”
- The convention asks for mitigation (reduction) of climate change, but there is also adaptation to climate change mentioned.

Conferences of the Parties (COPs)

- The activities under the convention are negotiated at **Conferences of the Parties** (COPs), mostly organized yearly.
- At the 1997 COP₃ in Kyoto, Japan, a Protocol, a detailed plan of the actions required by each party of the convention, was signed. **The Kyoto Protocol** contains binding targets for 37 industrialized states and the European Community (so called Annex 1 countries) to reduce GHG emissions by 5% compared to the 1990 levels for the five-year commitment period 2008-2012. A second commitment period lasted 2012 to 2020. It is now replaced by the Paris Agreement
- The **Kyoto Protocol** entered into force in 2005 after Russia had signed. Of the major emitters USA and China have not entered the Protocol while Australia with a new government joined in 2008 and Canada left in 2012.



The 2009 COP15 in Copenhagen was set up to reach an agreement but failed. Instead the non-binding Copenhagen Accord was signed.

Nations Unies

Conférence sur les Changements Climatiques 2015

COP21/CMP11

Paris France



#ParisAgreement

“Long live the planet.

Long live Humanity. Long live life itself.”

The Paris Agreement states that the long-term temperature goal is to keep the rise in global surface temperature below 1.5 oC or well below 2 oC of pre-industrial levels.

Intended Nationally Determined Contributions (INDCs)

<http://www.c2es.org/international/2015-agreement/indcs>

<http://climateactiontracker.org/indcs.html>

123 INDCs from 150 countries, 87
% of global emissions

Nationally Determined Contributions
will give 3.6 °C.

To really stay below 2 °C we need
rapid decarbonisation of our
economies right now.



COP 26 in Glasgow 2021

- 153 countries new or updated emissions targets (NDCs) covering 80% of the world's greenhouse gas emissions.
- Status of NDCs shall be reported every year according to agreed rules.
- Financing poor countries shall reach \$100 billion/year by 2023 and increase to \$200 billion/year. It shall include mitigation, adaptation, loss and damage.
- The text includes “accelerating the phasedown of coal power and subsidies for fossil fuels”.

COP 26 in Glasgow 2021

- **Glasgow Leaders' Declaration on Forest and Land Use** halving and reversing forest loss and land degradation by 2030 signed by 133 nations covering over 90% of the world's forests.
- **Global Methane Pledge** limit methane emissions by 30% by 2030 compared to 2020 levels, signed by more than 100 nations.
- **Beyond Oil and Gas Alliance (BOGA)** to phase-out of oil and gas production signed by 11 National and Subnational Governments.

Commitments of the nations of the world 2021

- **USA** **Net Zero Emissions By 2050**
- **EU** **Carbon neutral by 2050**
- **China** **Carbon neutral by 2060**
- **Sweden** **Net Zero Emissions By 2045**
- **India** **Net Zero Emissions By 2070 (Glasgow)**

Uppsala City work for Net Zero Emissions By 2030
Some municipalities have net zero emission today

COP 28 in Dubai 2023

- Nearly every country in the world has agreed to “transition away from fossil fuels” – the main driver of climate change.
- Launching a fund to pay for “loss and damage” from climate change
- Global target to “triple installed capacity of renewables” to at least 11 terawatts (TW) by 2030.

COP 29 in Dubai 2024

- Reached a global agreement on carbon markets.

COP 30 in Belém, Brazil 2025

- Parties should submit new national climate plans.

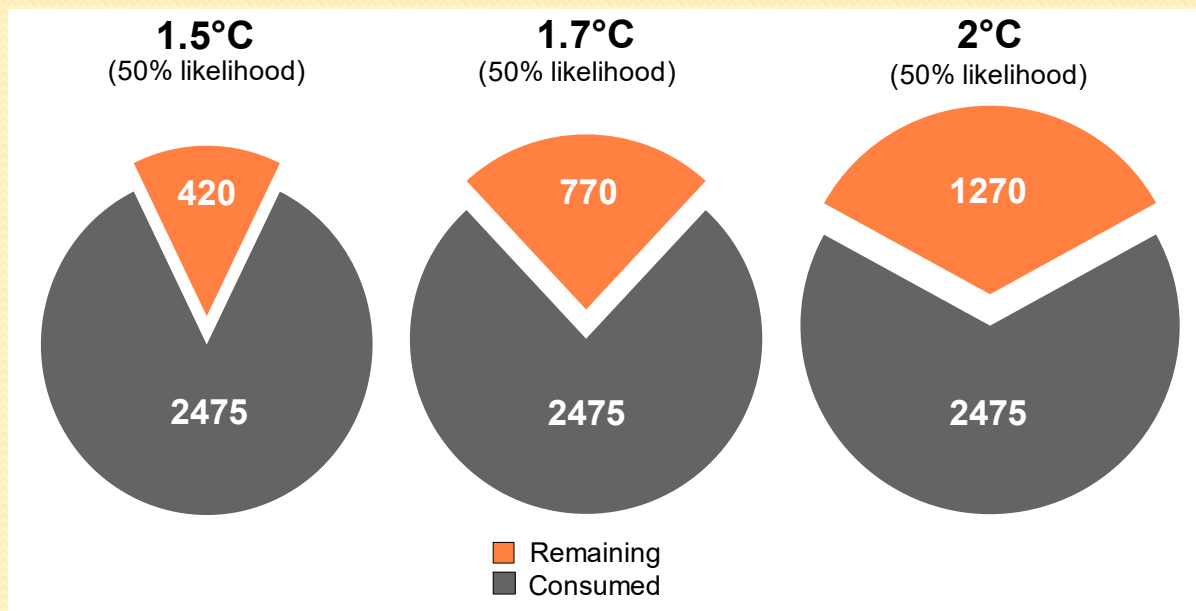
The CO₂ budget of the world in 2024

- The remaining budget for the world is about 400 billion tonnes of (400 Gtons) CO₂ for the 1.5 °C targets and 50 % likelihood.
- It can be divided between the countries. Then developing countries get more.
- Sweden gets 100-200 million tons.
- Today Sweden emits about 44 million tons per year (Uzbekistan 138 million tons per year).
- We thus need to be carbon free in 4 years, and reduce CO₂ emission by 25 % per year.

For global CO₂ budgets see <https://www.mcc-berlin.net/en/research/co2-budget.html>

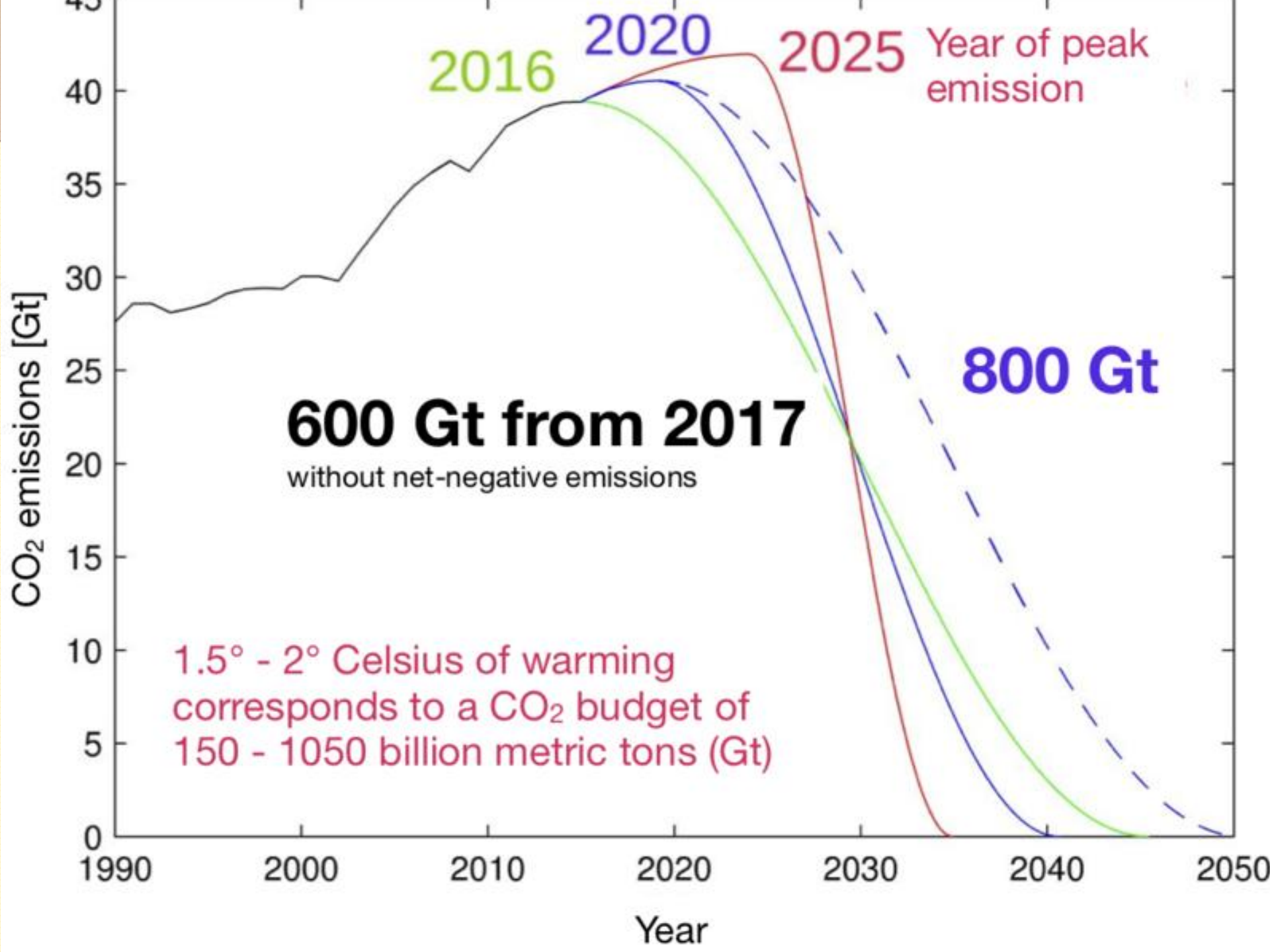
Remaining carbon budget

The remaining carbon budget to limit global warming to 1.5°C , 1.7°C and 2°C is 420 GtCO₂, 770 GtCO₂, and 1270 GtCO₂ respectively, equivalent to 11, 20 and 32 years from 2022. 2475 GtCO₂ have been emitted since 1750



Quantities are subject to [additional] uncertainties e.g., future mitigation choices of non-CO₂ emissions

Source: IPCC AR6 WG1; [Friedlingstein et al 2021](#); [Global Carbon Budget 2021](#)



The Carbon Law

- A “carbon law”, halving CO₂ emissions every decade would give the world a 75% chance of keeping Earth below 2 °C.
- Fossil-fuel emissions should peak by 2020 at the latest and fall to around zero by 2050.
- The “carbon law”, is based on Moore’s Law in the computer industry, which states that computer processors double in power about every two years. This rule of thumb has held for 50 years and still drives disruptive innovation

Proposed and researched by Potsdam Climate Institute

European Trading System, ETS

- Based on the COP₃ in Kyoto EU established a cap-and-trade system for CO₂, called European Trading System, ETS. In this system a number of major European industries, presently about 11 000, have been given allowances (rights) to emit specified amounts of CO₂. Those emitting more have to buy additional rights and those, which can reduce their emissions, may finance the costs of the investments needed by selling emission rights. The EU Allowances (EUAs) is reduced yearly in order for the EU to meet its target of a 55% reduction in GHG emissions by 2030 relative to 1990, and net zero by 2050. The annual decrease between 2021 and 2030 is 2.2 %.
- The third trading period, 2013-2020, include more GHGs, especially methane and nitrous oxide, more sectors especially air traffic, and reduced allowances of emission rights. Still emission rights are too cheap for ETS to be effective.
- Since 2020 the price has raised and is today 78 Euro/tonne and will increase systematically. The fourth trading period started. It is 2020-2030. (<https://www.statista.com/statistics/1322214/carbon-prices-european-union-emission-trading-scheme/>)

**Fossils should remain
in the ground!**

Actions from

- 1. States**
- 2. Municipalities**
- 3. Companies**
- 4. Civil Society Organisations (NGO)**
- 5. Individuals**

**People's Climate March New
York September 21, 2014**





**Greta Thunberg, 15 years of age,
in front of the Swedish Parliament 2018**



Wann werden die
et nicht
dein
fertigist

WE NEED A
GREEN
WORLD

GREEN

Climate NOW,
Homework later!

Zukunft
GRÜN
O DER
ARNICH

WAS DIT RUTE
KANNST BIS 2030
VORHER NICHT
AUF 2038!

THERE'S
NO PLANET
B

ZEL
KIM
ETH
VERAN

Das KLIMA
aussichtsloser,
als unsey
MATHE-ABI

What can you do yourself?

- **Transport:** Bike, (el bike) walk, public transport, carpool, go by car together, biogas, biodiesel, electric, etc. work from home, video conferencing.
- **Food:** avoid food waste, less meat or meat from free ranging, food from local producers, buy from nearby, eco-food.
- **Housing:** insulate your house, use green electricity, energy efficient equipment, turn off stand-by, sun heat, solar cells.

**The least you can do is as
much as possible**

There is much to read about Climate Change.

Climate change and climate science - A basic reader.

Chapter 1 *The Climate system* pp. 4-17.

Climate change and climate science - A basic reader.

Chapter 2 *Climate Change – causes and consequences* pp. 18-34 .

Climate change and climate science - A basic reader.

Chapter 4 *Mitigating and adaptation of climate change*. pp 45-48.