Swedish Aral Sea Society

Karakalpak State University

4. Climate Change

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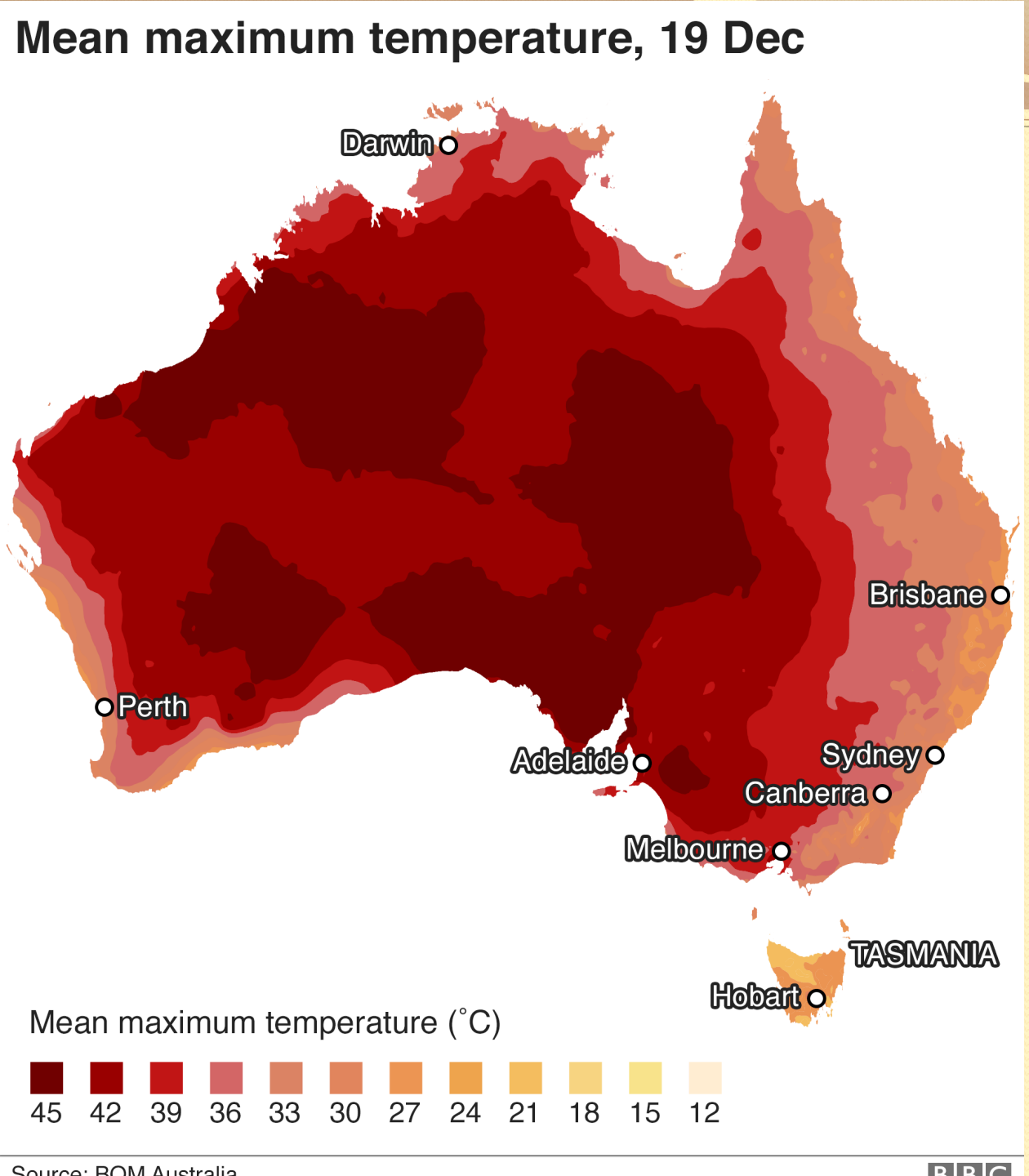
Uppsala University, Sweden

Master Course on Sustainable Development and Sustainability Science
For Uzbekistan by SASS and Karakalpak State University Spring 2026

Global warming

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……



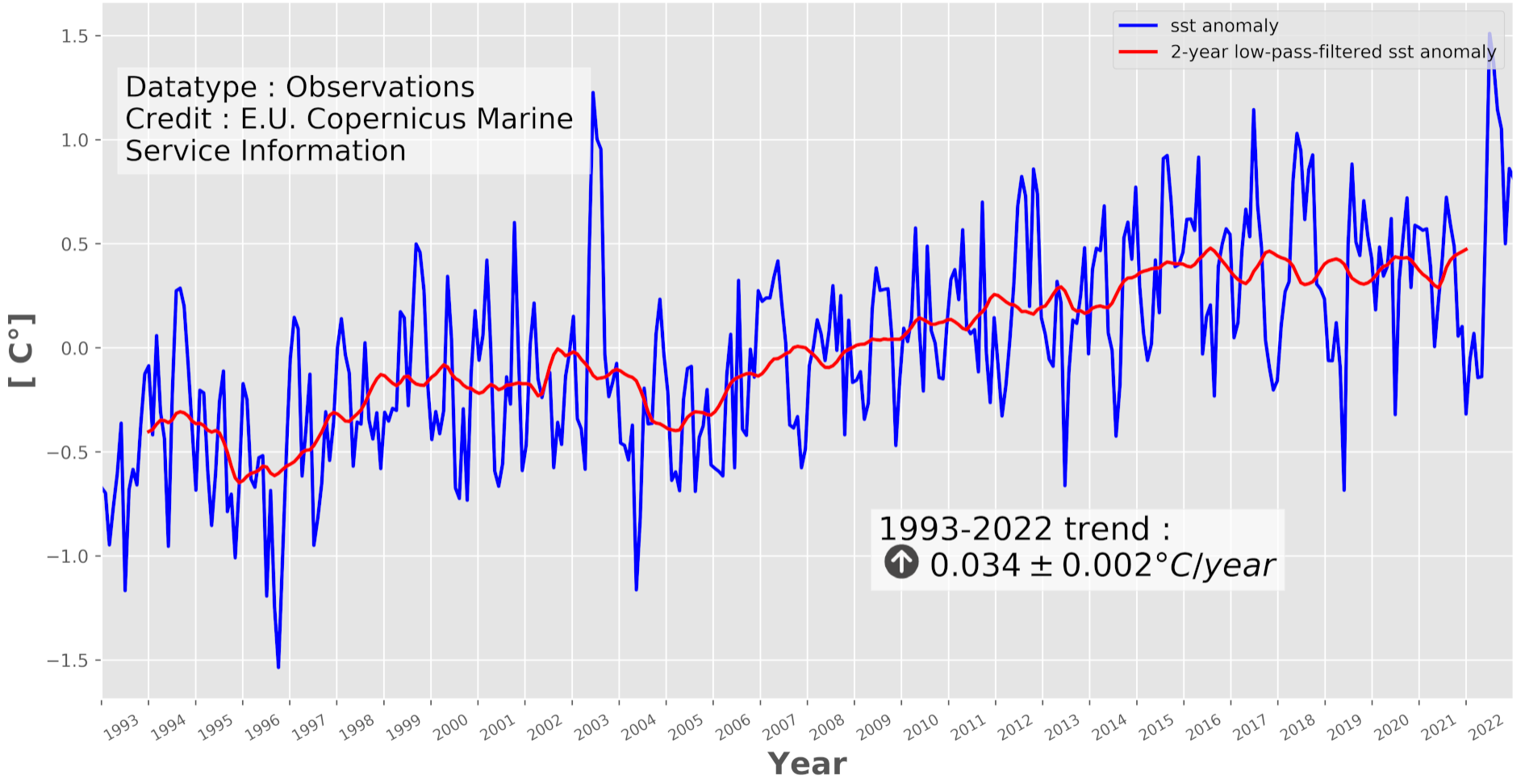
The heat wave in Australia 2019

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

Mediterranean Sea SST Anomaly (1993-2022)



Copernicus Marine Service

Copernicus

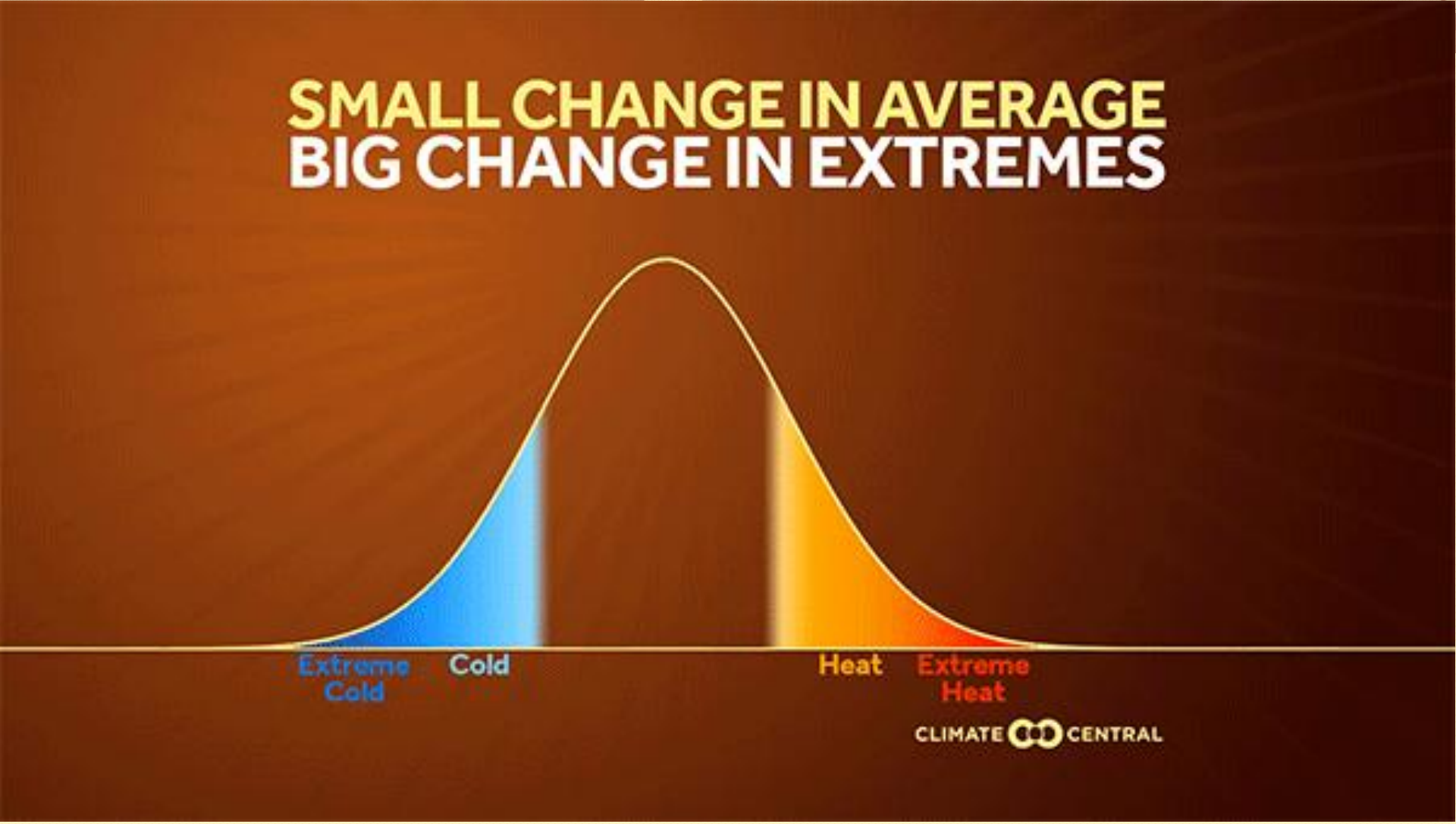
implemented by MERCATOR OCEAN INTERNATIONAL

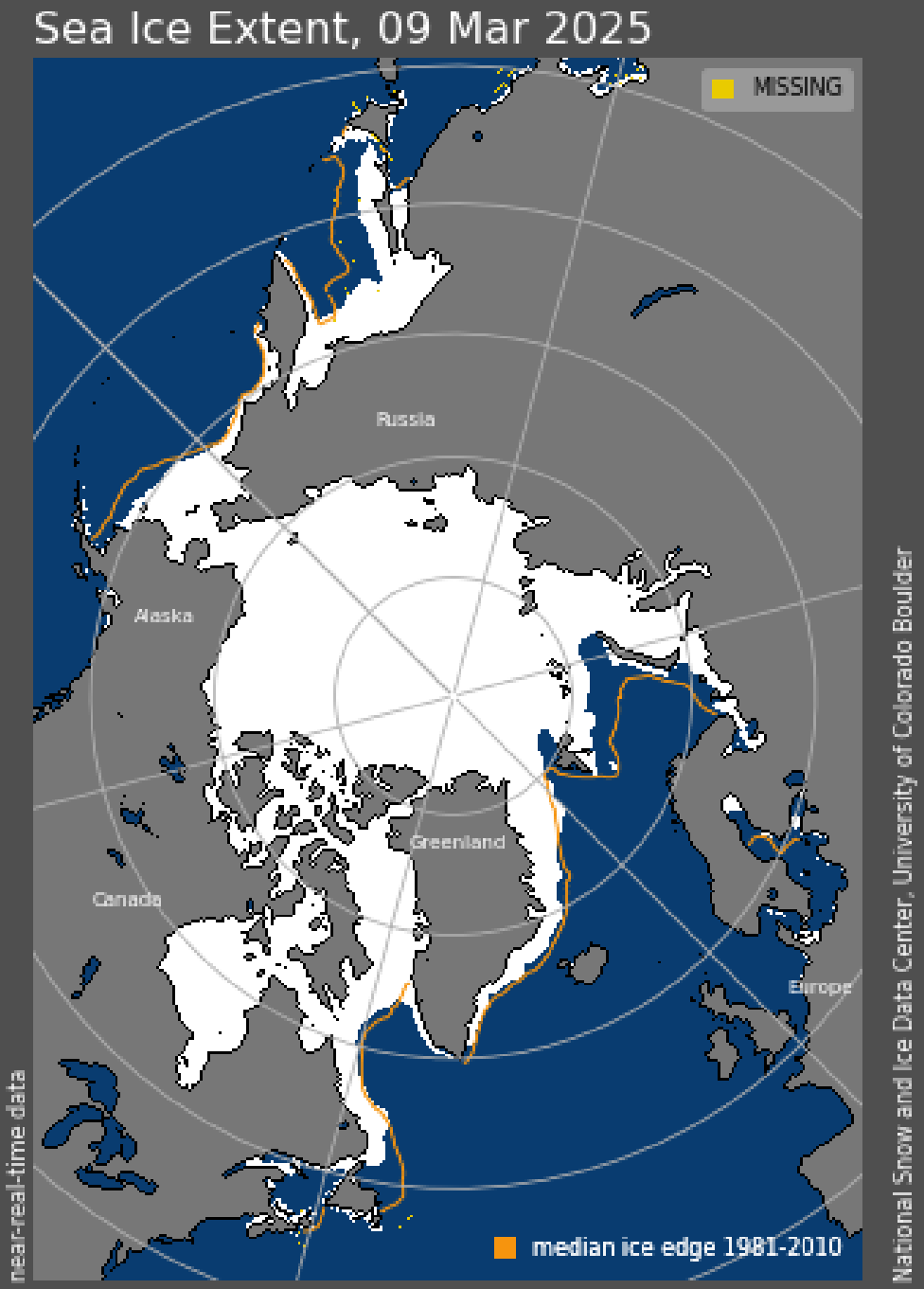
https://marine.copernicus.eu/access-data/ocean-monitoring-indicators/
mediterranean-sea-surface-temperature-time-series-and-trend

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

Flooding in Valencia Spain, 2024

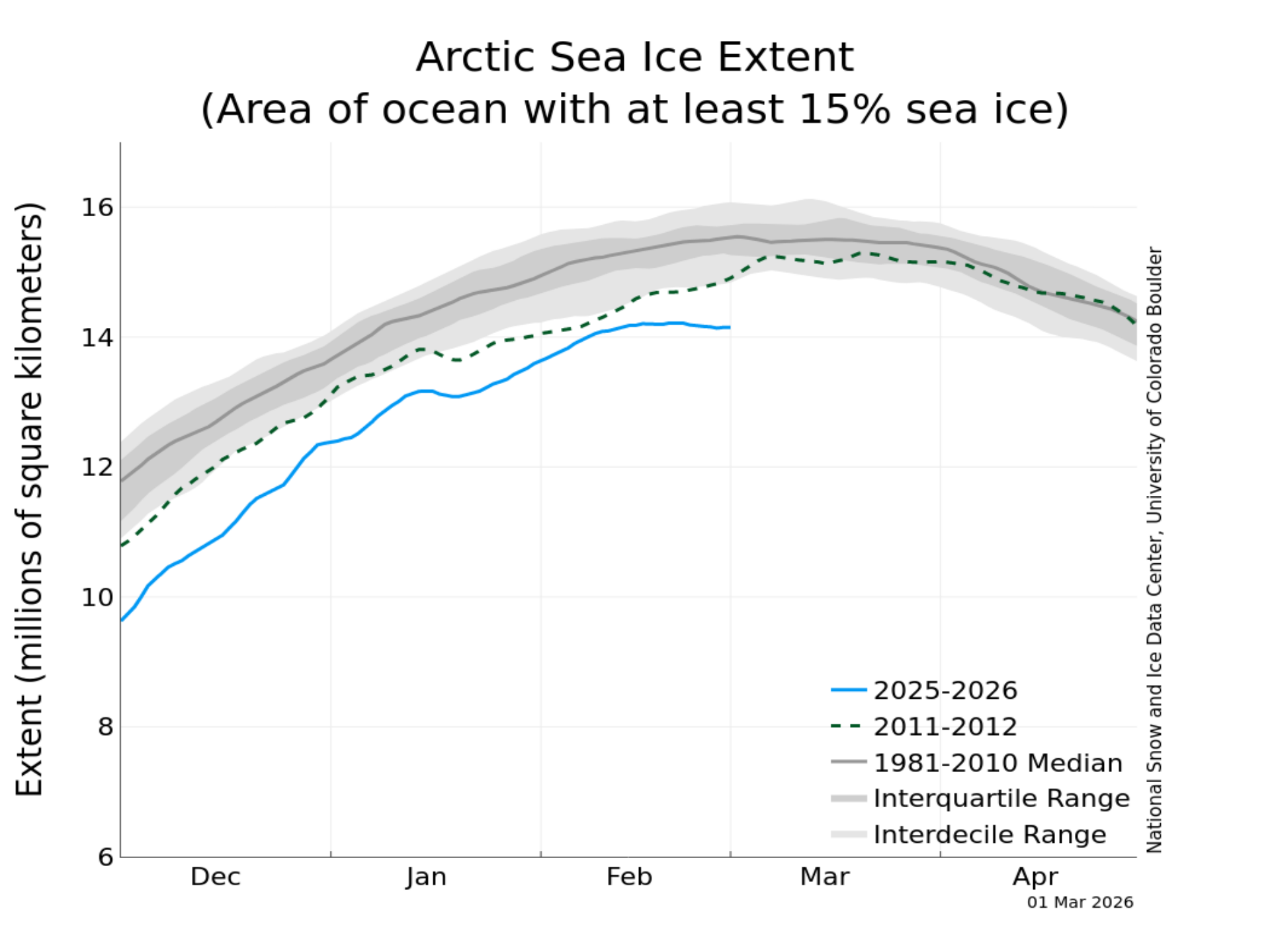
https://static01.nyt.com/images/2024/10/30/multimedia/Spain-flood-wwk-01-mpcq/Spain-flood-wwk-01-mpcq-videoSixteenByNine3000.jpg


SMALL CHANGE IN AVERAGE
BIG CHANGE IN EXTREMES
Extreme Cold
Cold
Heat
Extreme Heat
CLIMATE CENTRAL



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

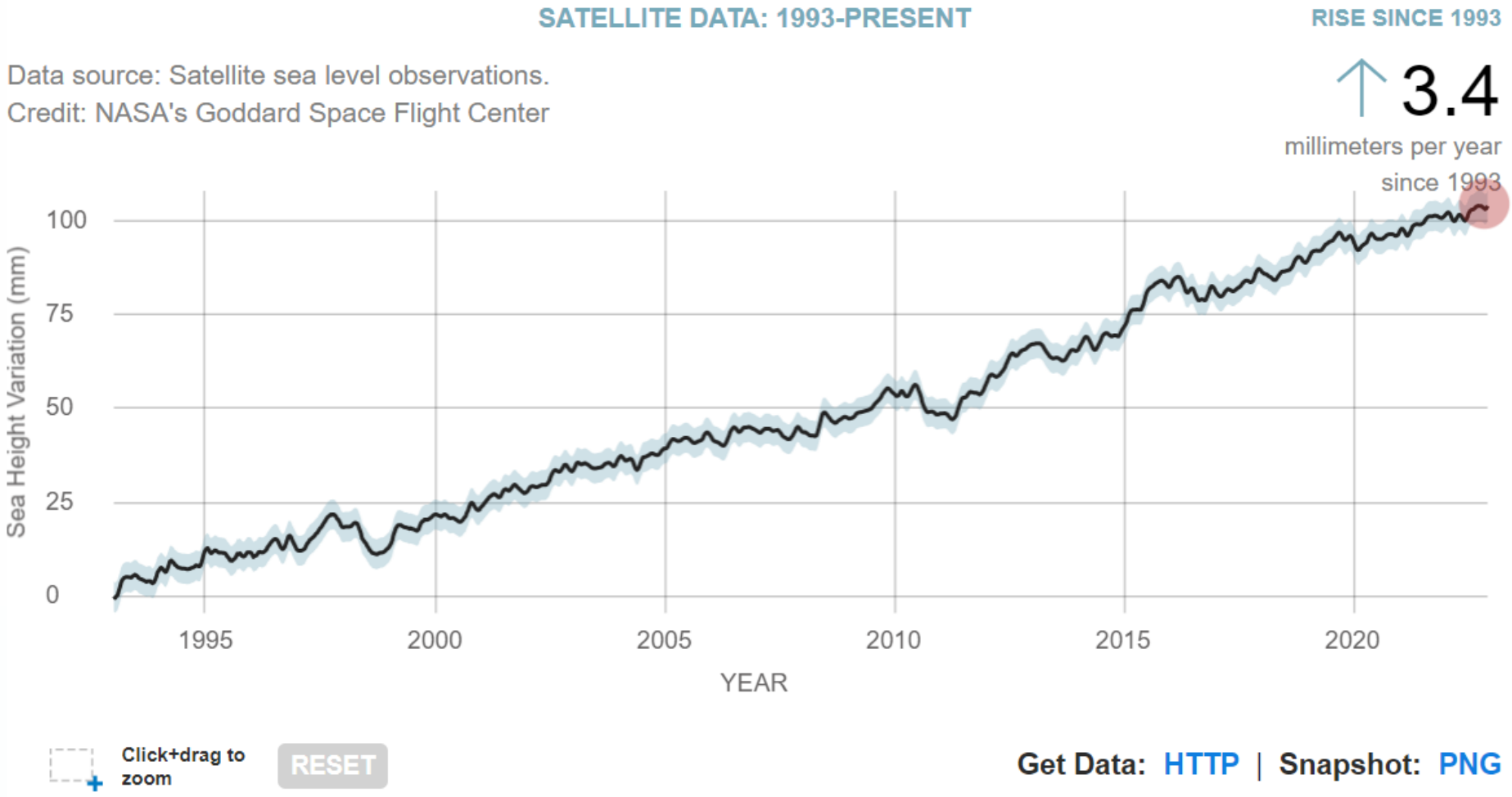
The Arctic is warming faster than anywhere else on the planet, and as a result, sea ice in the Arctic Ocean is decreasing. Sea ice loss has far-reaching effects on the planet because the ice helps regulate Earth's climate, influences global weather patterns, and affects ocean circulations.


Arctic Sea Ice Extent
(Area of ocean with at least 15% sea ice)
Extent (millions of square kilometers)
16
14
12
10
8
6
Dec
Jan
Feb
Mar
Apr
01 Mar 2026
2025-2026
2011-2012
1981-2010 Median
Interquartile Range
Interdecile Range
National Snow and Ice Data Center, University of Colorado Boulder

Ecosystems change dramaticallly

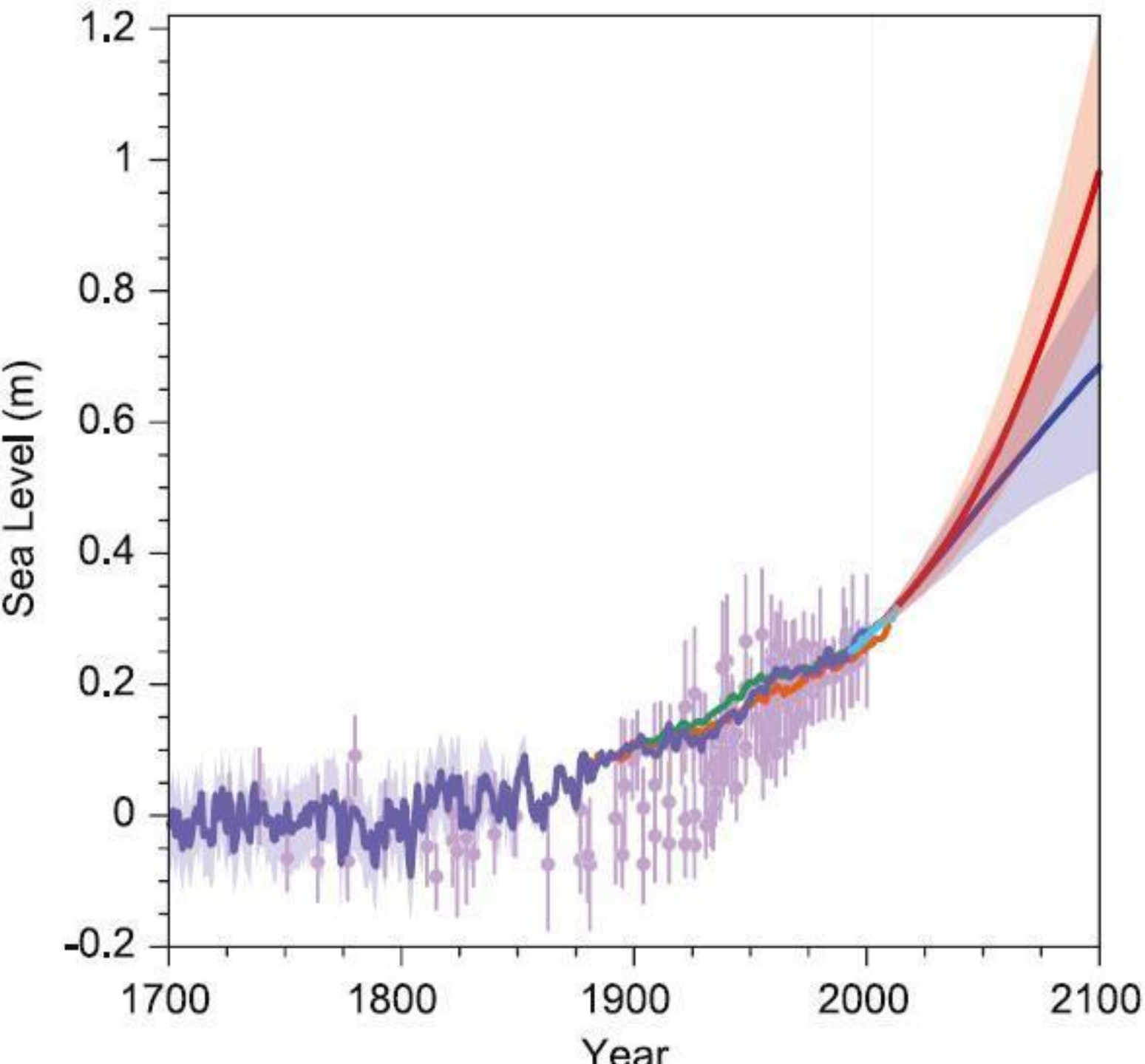
West Antarctic Ice Sheet Has Begun to Collapse
http://news.discovery.com/earth/global-warming/west-antarctic-ice-sheet-has-begun-to-collapse-140514.htm

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



Sea Level Rise

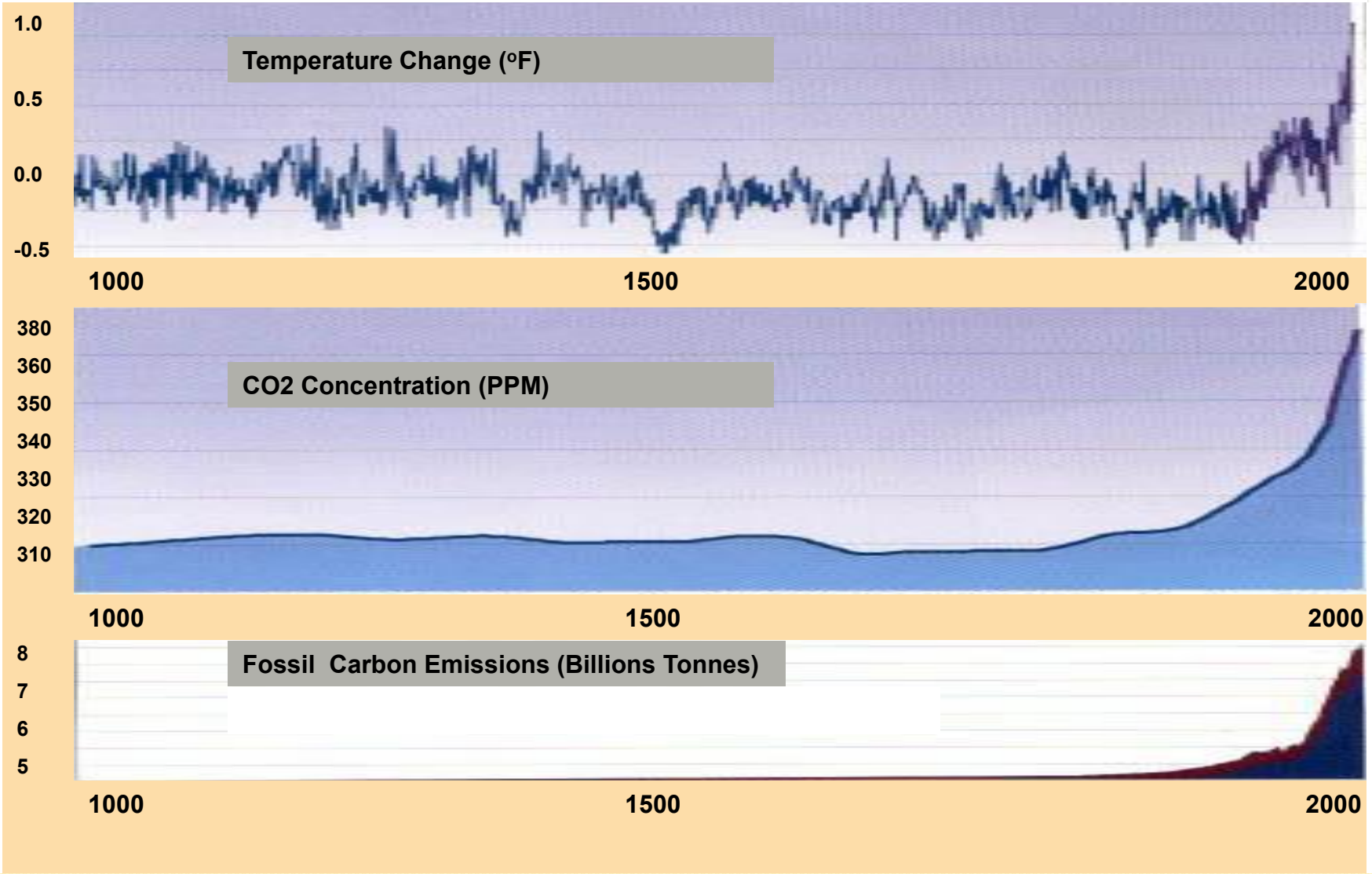
https://www.nasa.gov/specials/sea-level-rise-2020/



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

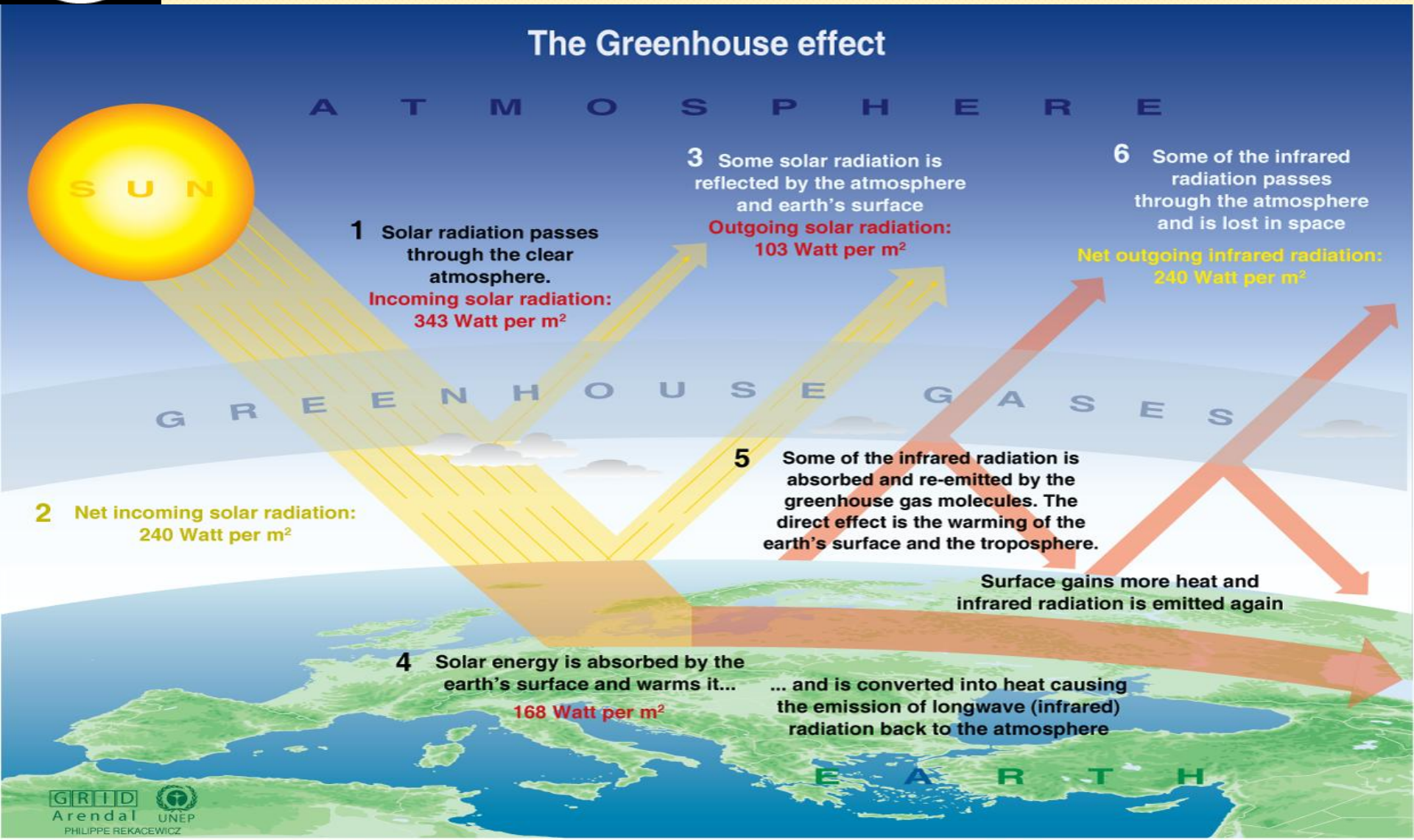
https://www.amazon.com/Under-Sea-Great-Barrier-Reef/dp/B07F6VXJRC

The causes of global warming

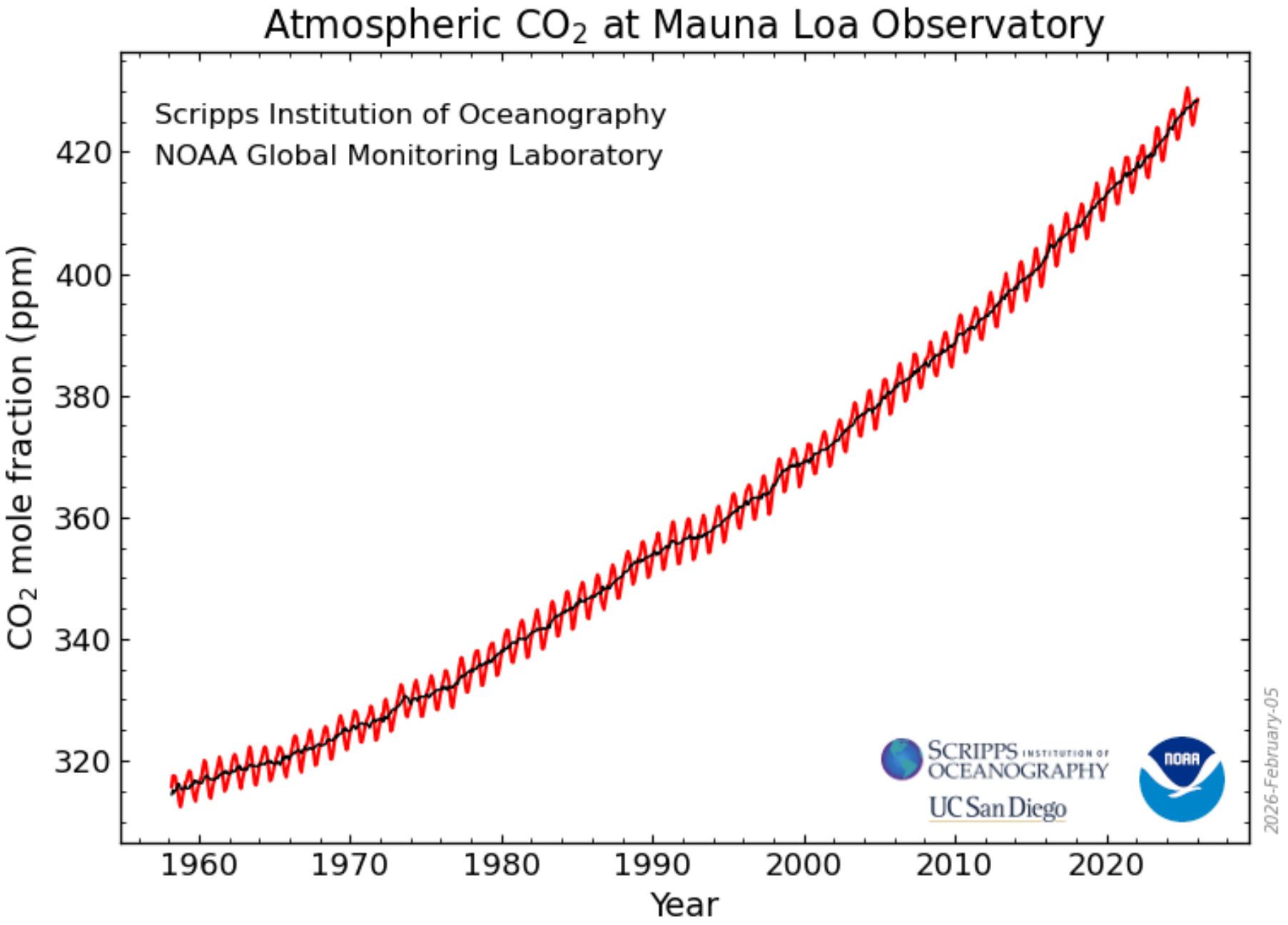

1.0
0.5
0.0
-0.5
Temperature Change (°F)
1000
1500
2000
380
360
350
340
330
320
310
CO2 Concentration (PPM)
1000
1500
2000
8
7
6
5
Fossil Carbon Emissions (Billions Tonnes)
1000
1500
2000

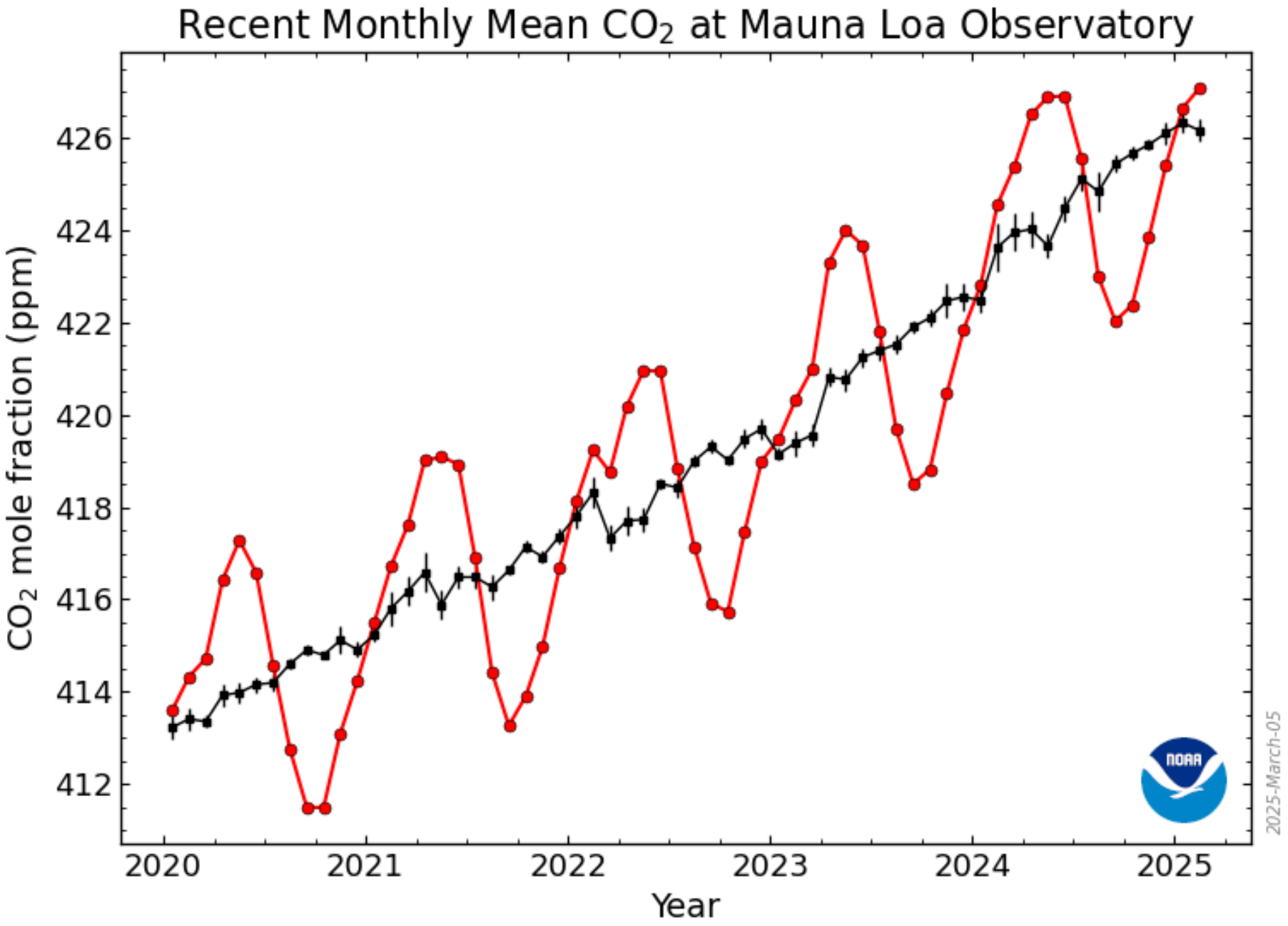
SVEBIO

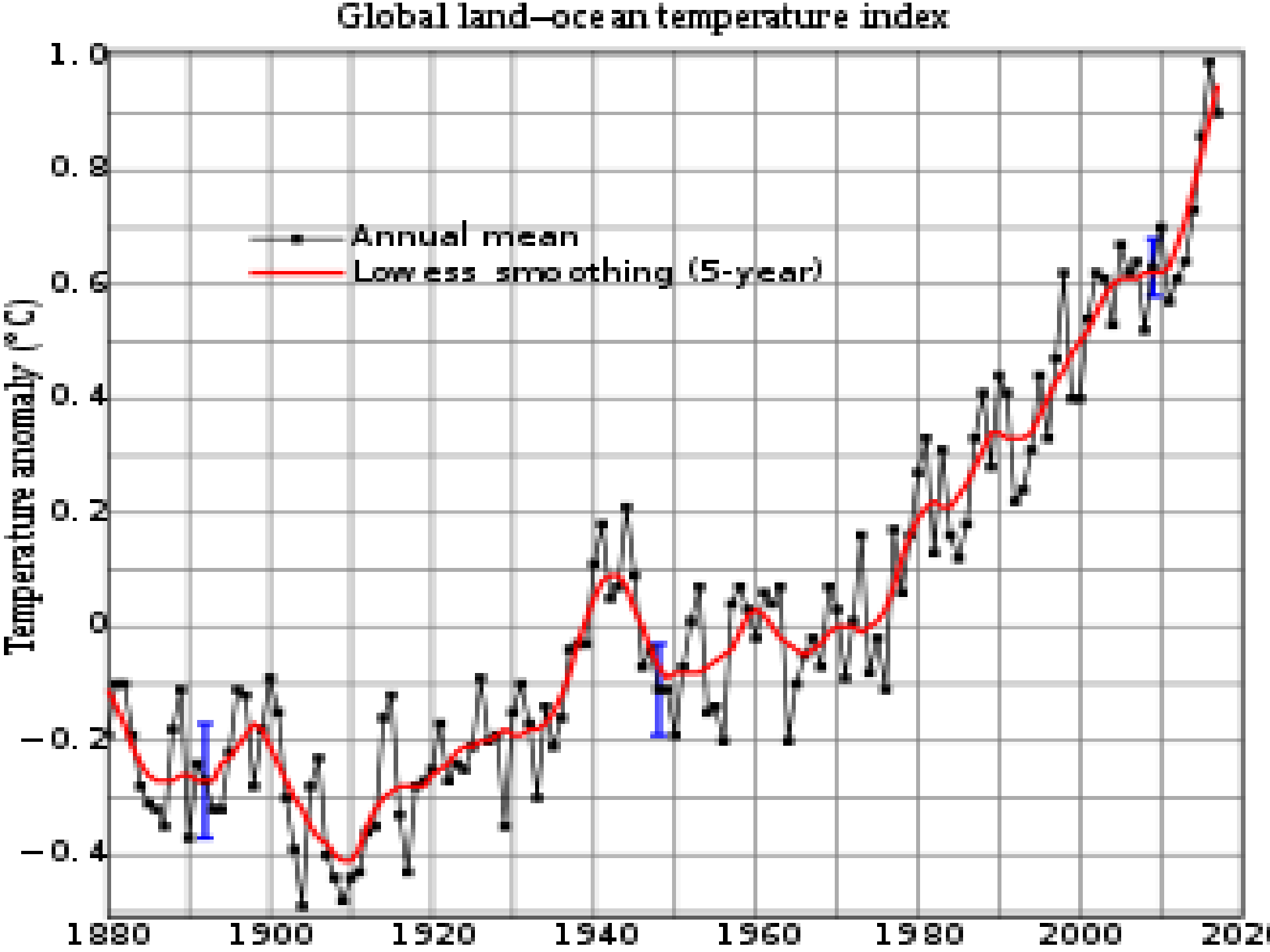
The greenhouse effect



Sources: Okanagan university college in Canada, Department of geography, University of Oxford, school of geography; United States Environmental Protection Agency (EPA), Washington; Climate change 1995, The science of climate change, contribution of working group 1 to the second assessment report of the intergovernmental panel on climate change, UNEP and WMO, Cambridge university press, 1996.


Atmospheric CO_2 at Mauna Loa Observatory
Scripps Institution of Oceanography
NOAA Global Monitoring Laboratory
CO_2 mole fraction (ppm)
420
400
380
360
340
320
1960
1970
1980
1990
2000
2010
2020
Year
SCRIPPS INSTITUTION OF OCEANOGRAPHY
UC San Diego
NOAA
2026-February-05

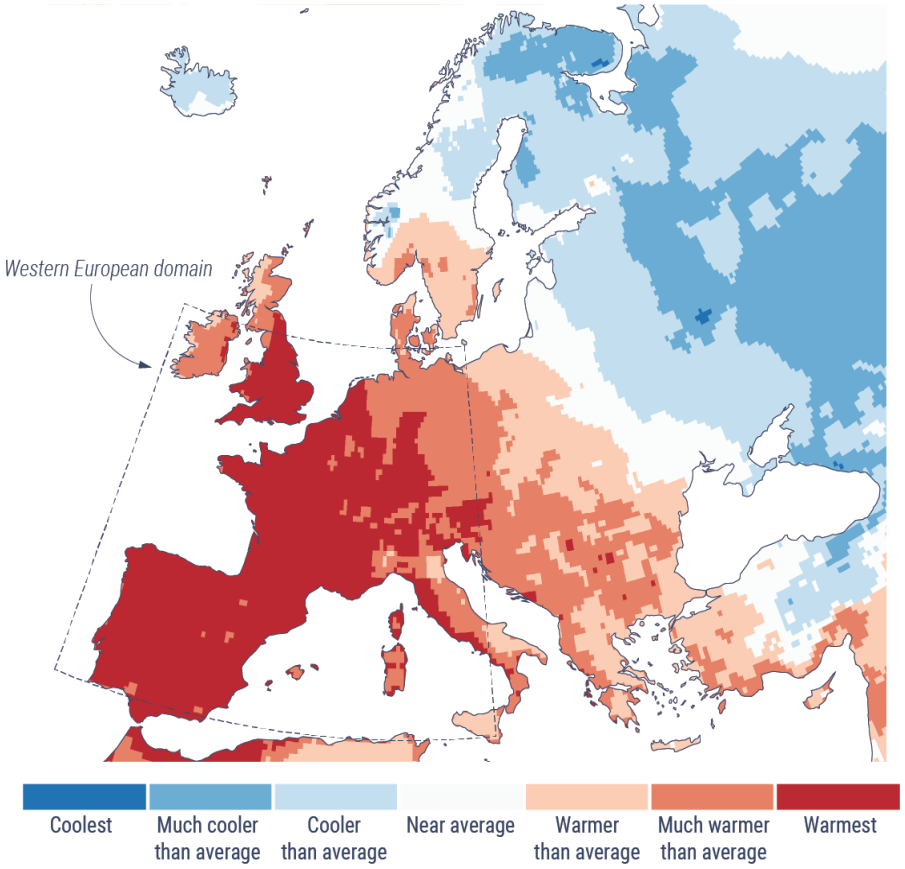

Recent Monthly Mean CO_2 at Mauna Loa Observatory
CO_2 mole fraction (ppm)
426
424
422
420
418
416
414
412
2020
2021
2022
2023
2024
2025
Year
NOAA
2025-March-05


Global land–ocean temperature index
Annual mean
Lowess smoothing (5-year)
Temperature anomaly (°C)
1.0
0.8
0.6
0.4
0.2
0
−0.2
−0.4
1880
1900
1920
1940
1960
1980
2000

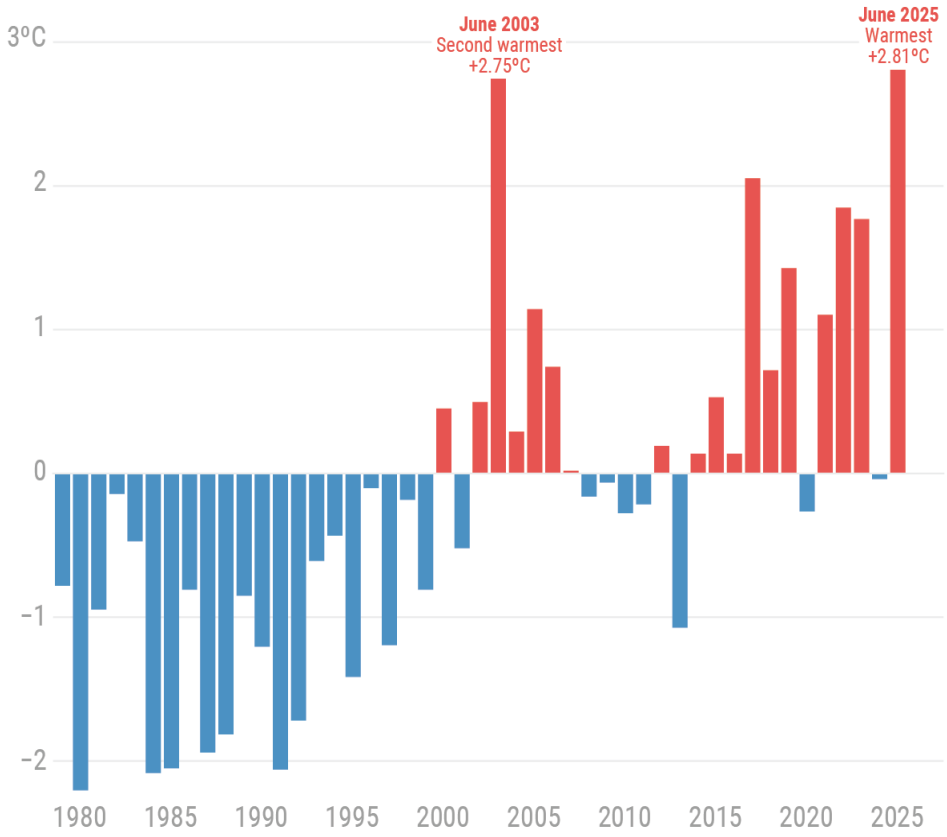
Surface air temperature anomalies

Data: ERA5 • Reference period: 1991–2020 • Credit: C3S/ECMWF

Average anomalies from 17 June to 2 July 2025



Anomalies in June in western Europe



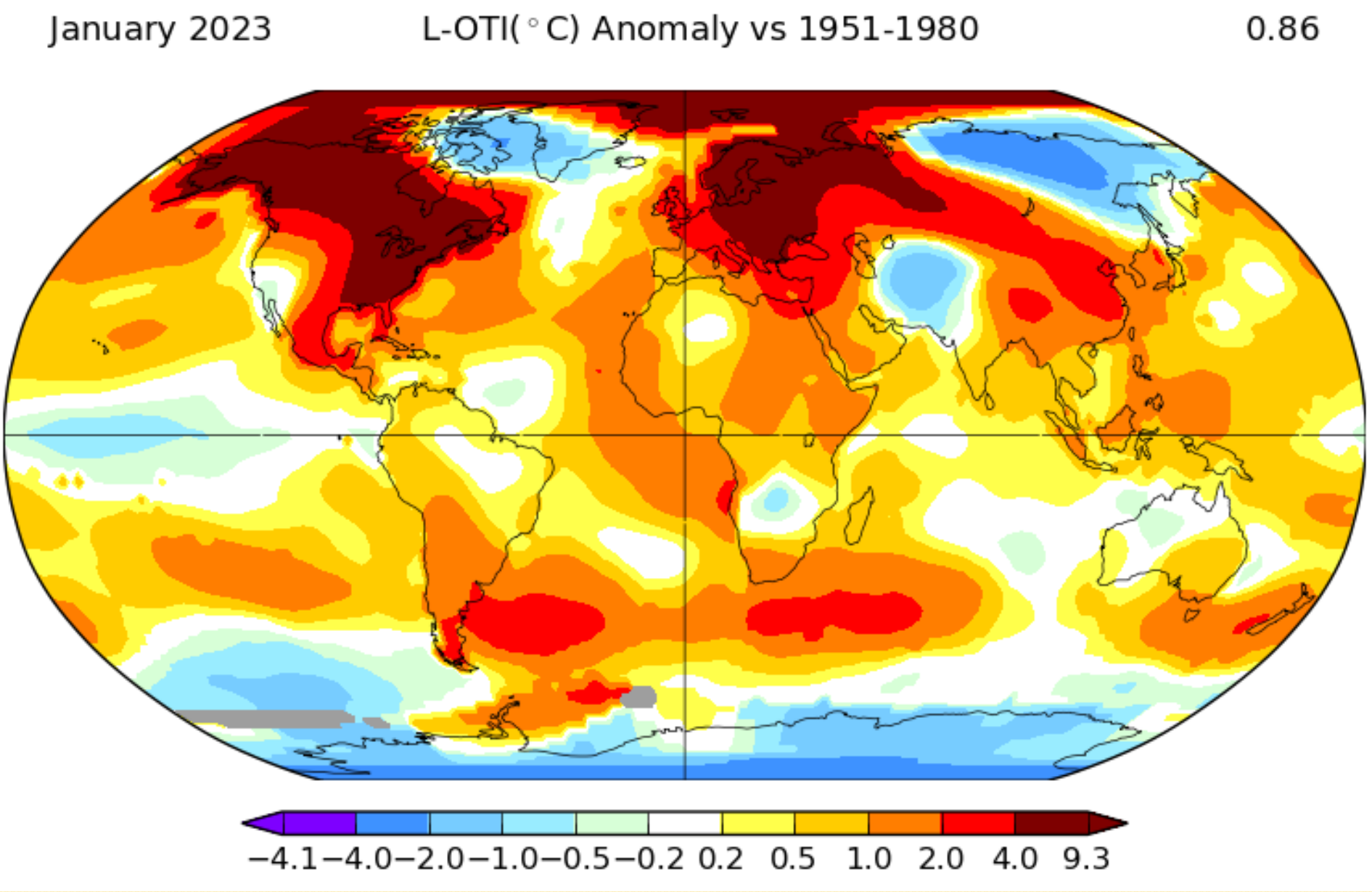
PROGRAMME OF THE EUROPEAN UNION

Copernicus Europe's eyes on Earth

Climate Change Service

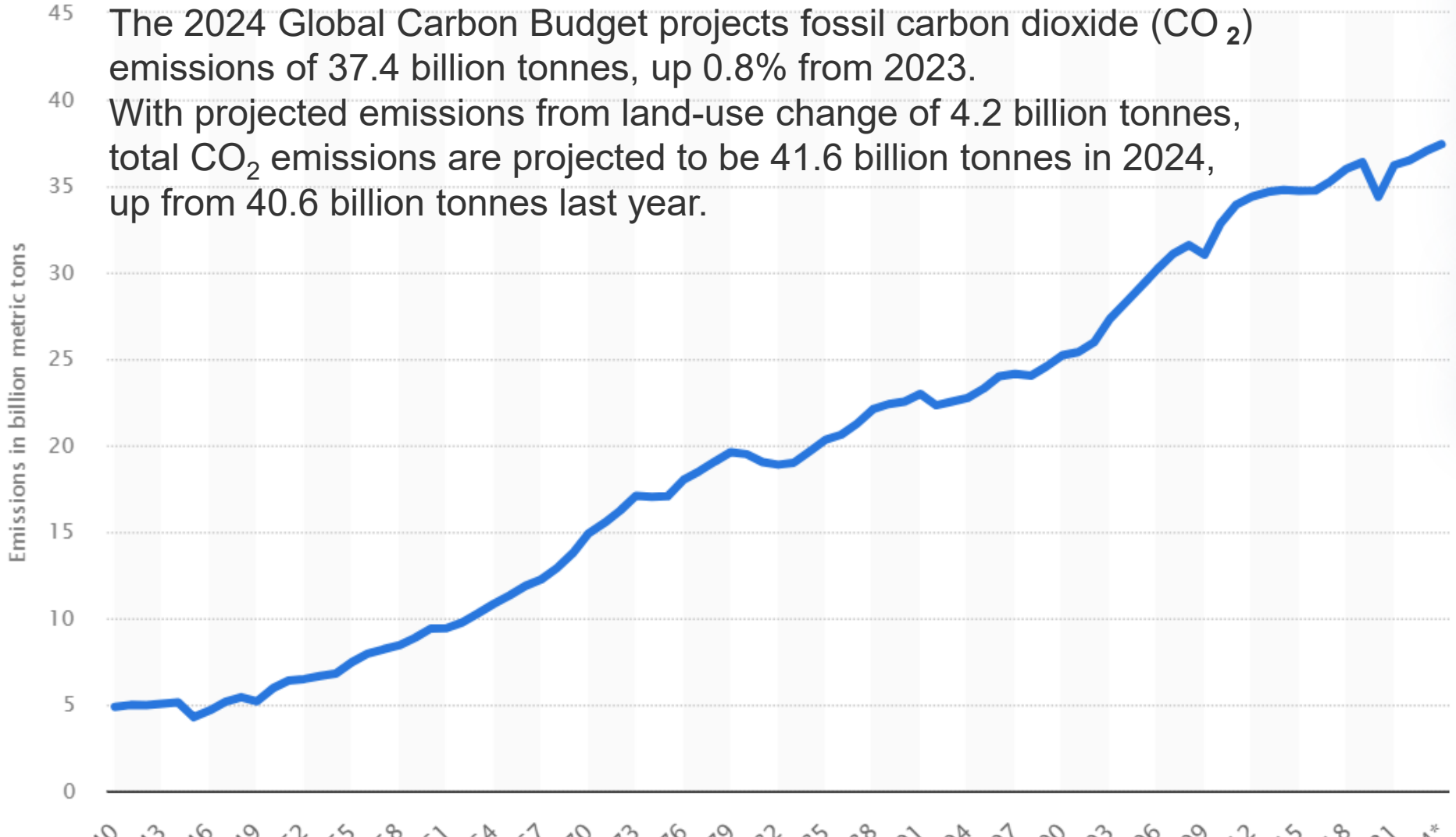
IMPLEMENTED BY ECMWF

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


January 2023
L-OTI(°C) Anomaly vs 1951-1980
0.86
−4.1 −4.0 −2.0 −1.0 −0.5 −0.2 0.2 0.5 1.0 2.0 4.0 9.3

Annual carbon dioxide (CO_2) emissions worldwide from 1940 to 2024 *(in billion metric tons)*

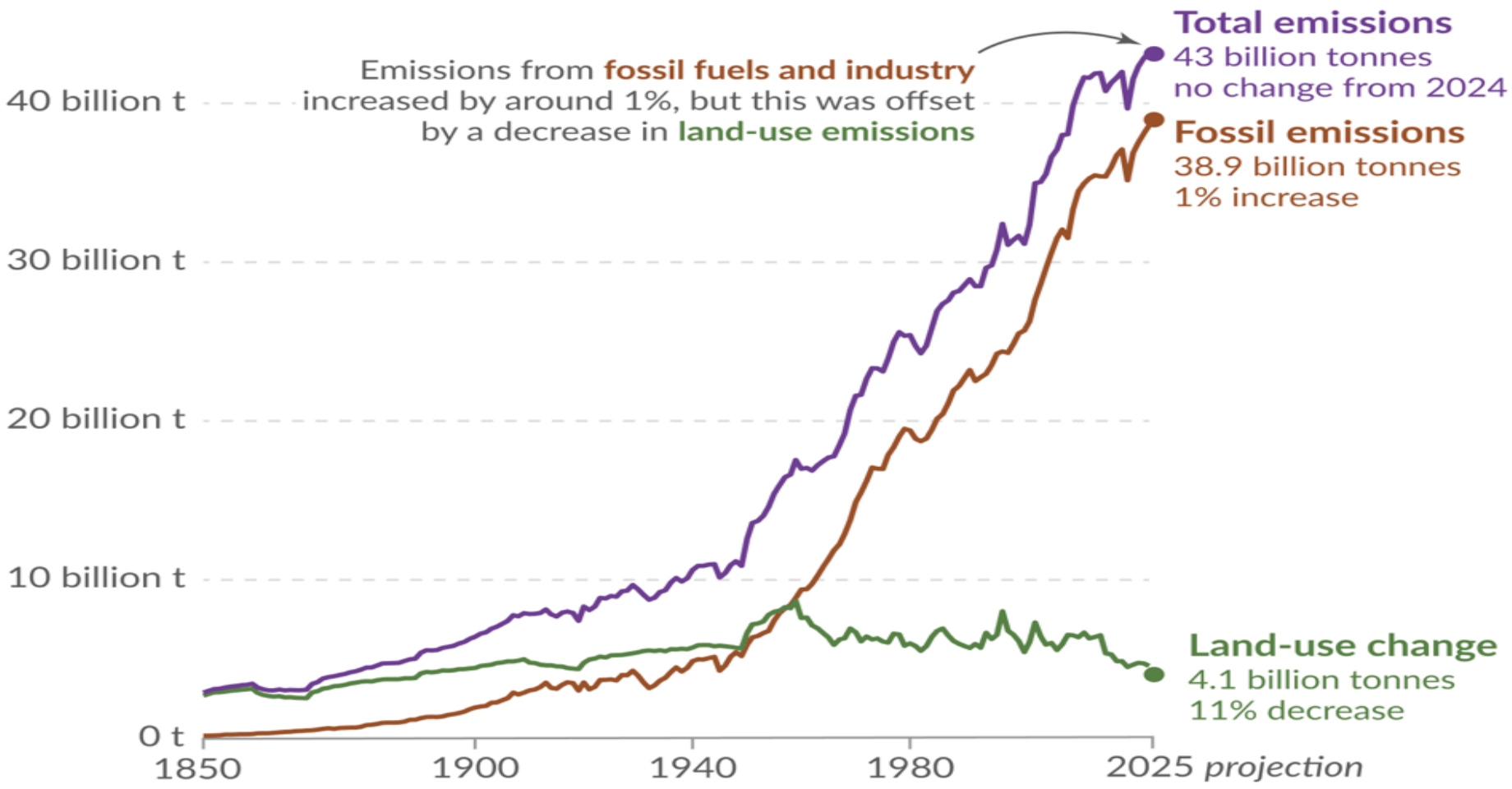
https://www.statista.com/statistics/276629/global-co2-emissions/



Global CO_2 emissions, with projections for 2025

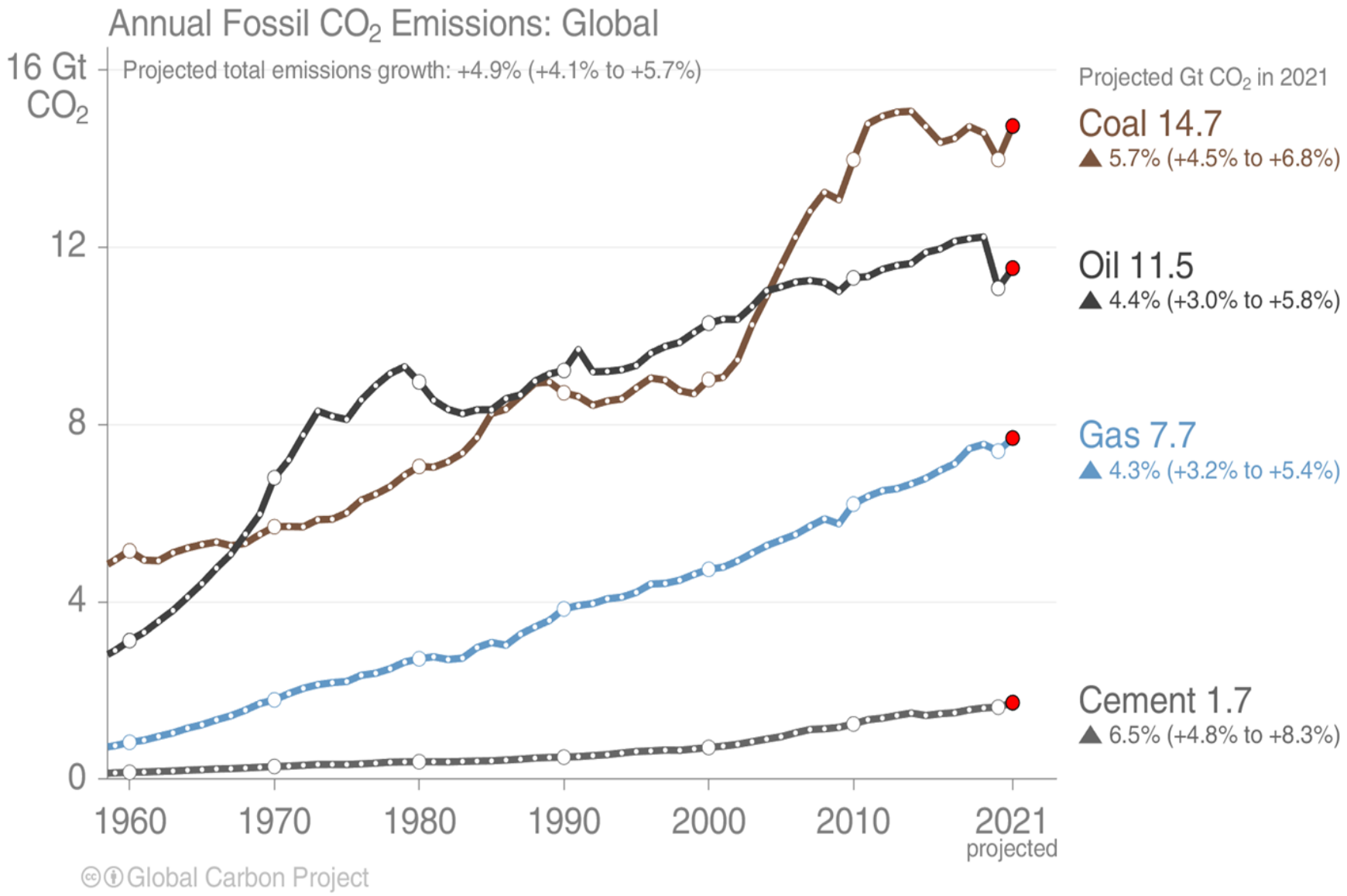
Our World in Data

Historical estimates of global carbon dioxide emissions (CO_2), with projections for 2025 (●) based on energy and land-use activity so far.

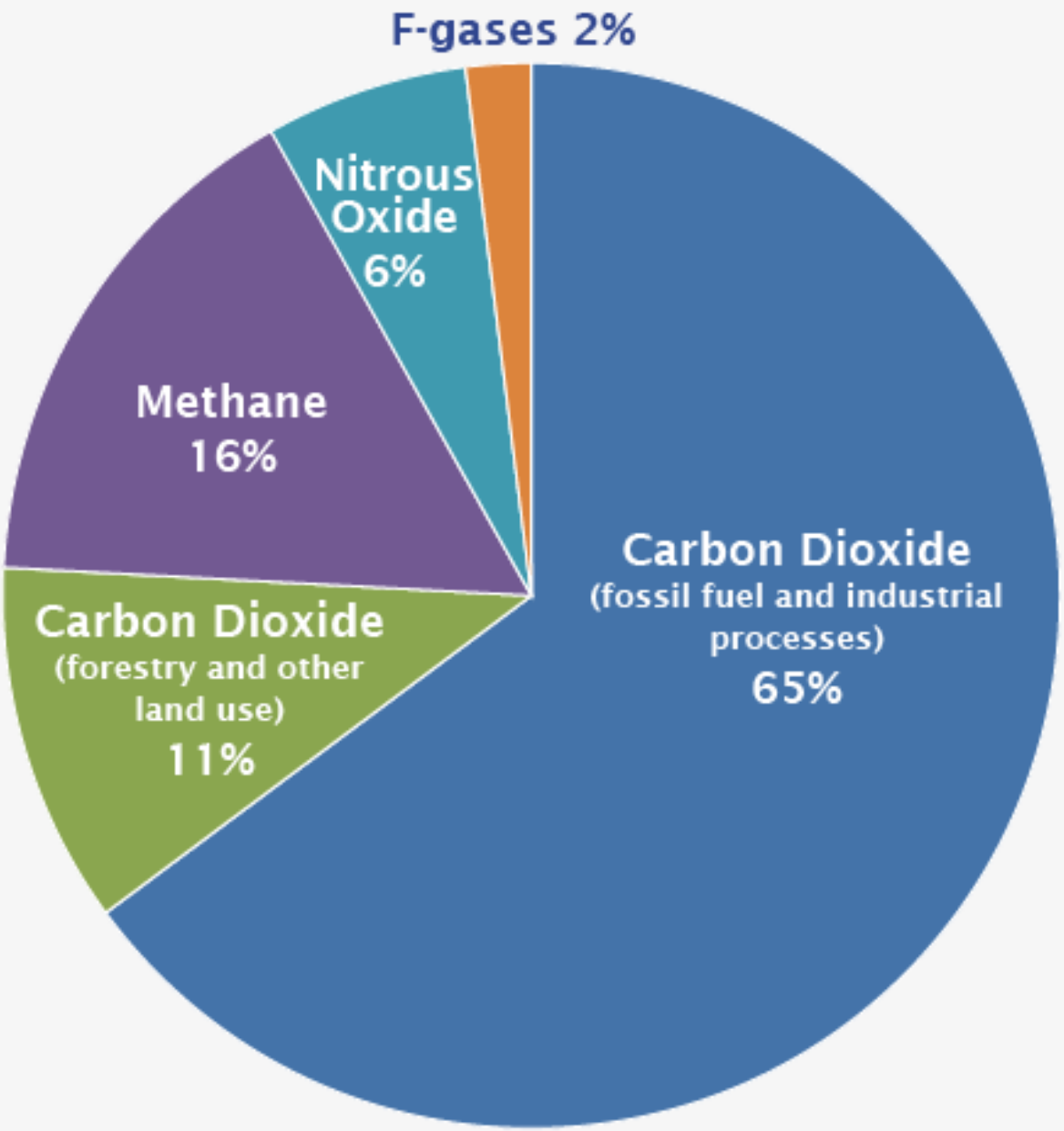


Note: Projections come with uncertainty, and are based on incomplete data for this year. Fossil emissions do not include cement carbonation.

Data source: Global Carbon Project (2025)


Annual Fossil CO_2 Emissions: Global
Projected total emissions growth: +4.9% (+4.1% to +5.7%)
16 Gt CO_2
12
8
4
0
1960
1970
1980
1990
2000
2010
2021
projected
Projected Gt CO_2 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%)
Global Carbon Project

Global Greenhouse Gas Emissions by Gas



https://19january2021snapshot.epa.gov/sites/static/files/2016-05/global_emissions_gas_2015.png

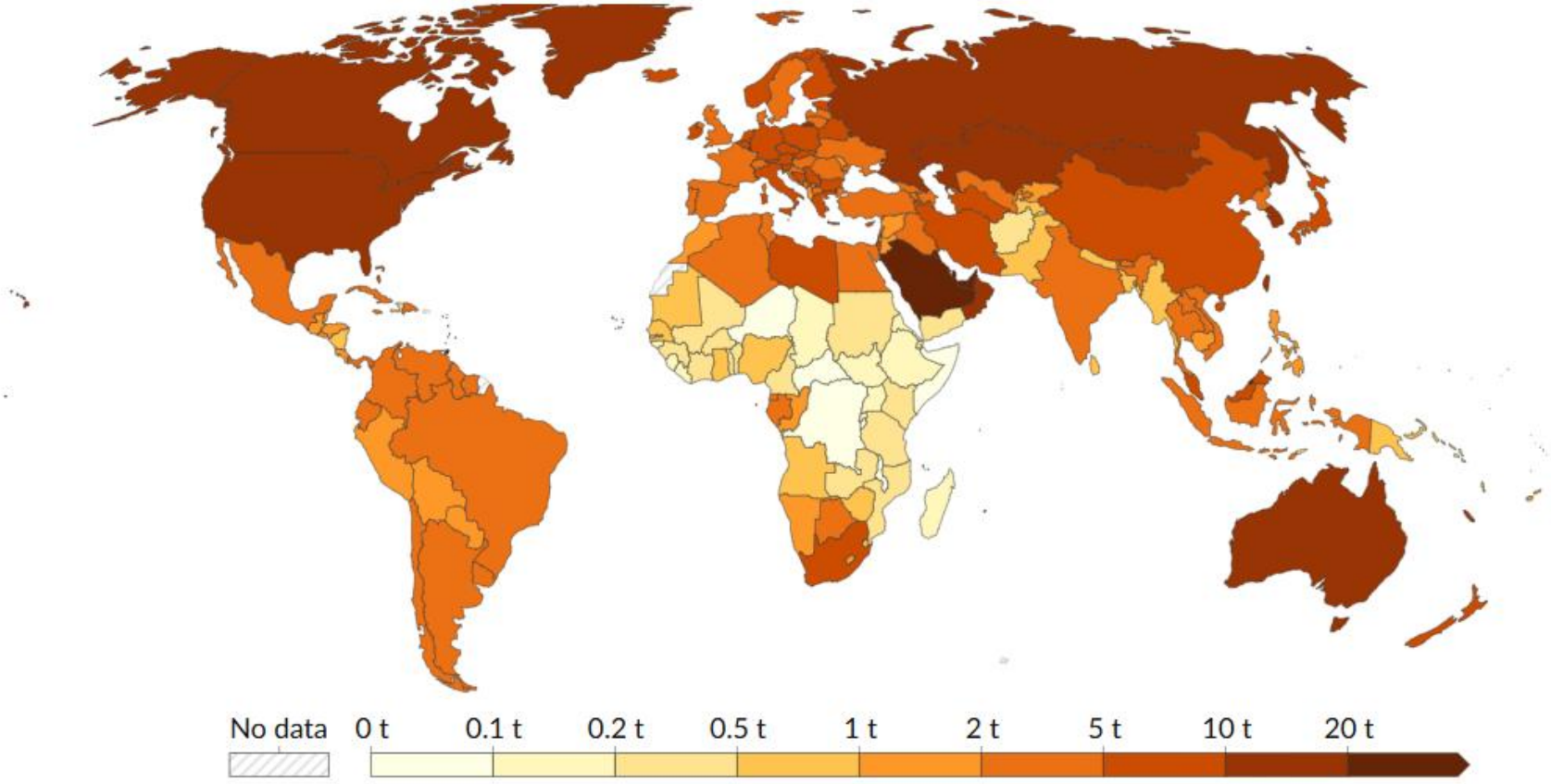
Per capita CO_2 emissions, 2023

Carbon dioxide (CO_2) emissions from fossil fuels and industry. Land-use change is not included.

Our World in Data

Table | Map | Line | Slope

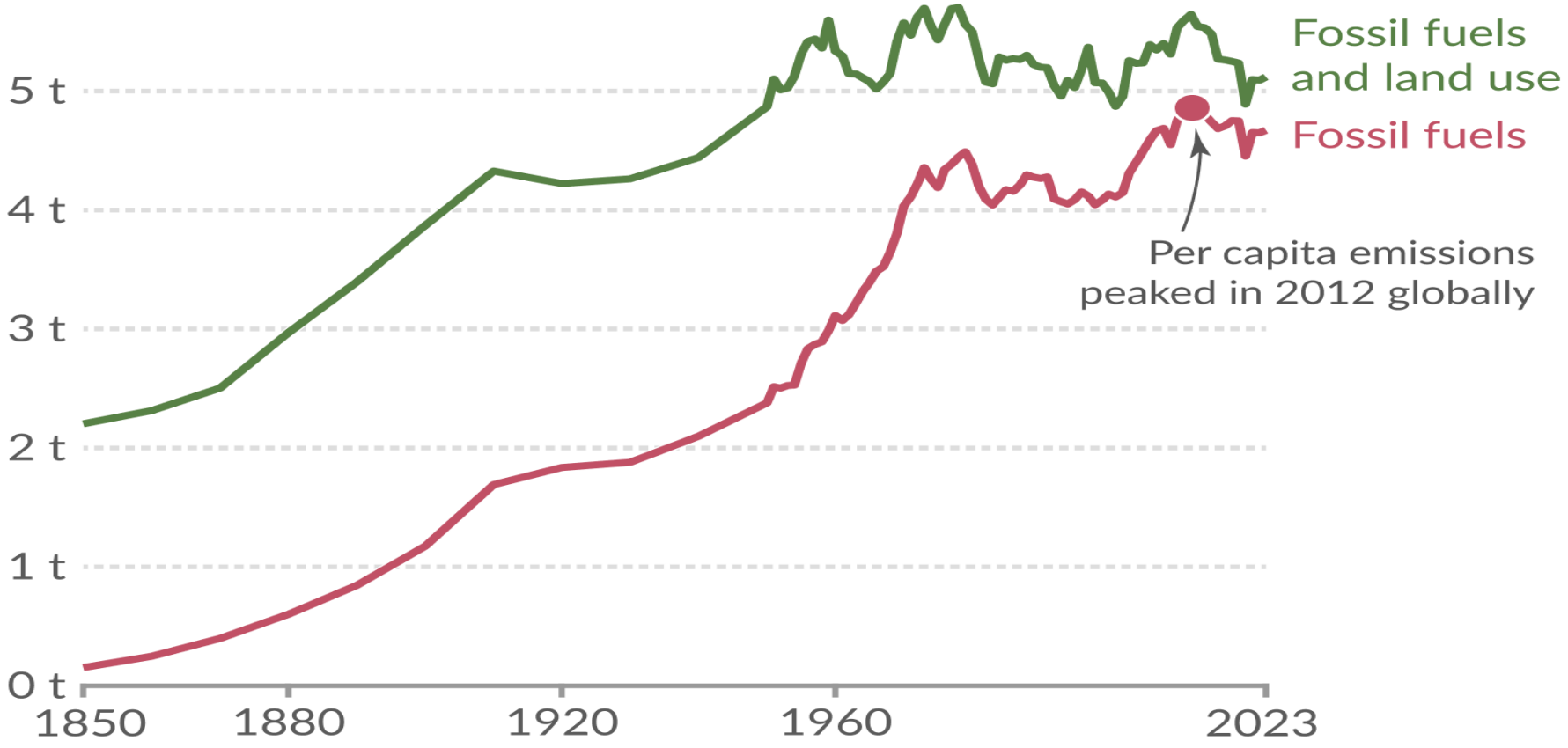
World



The world has passed peak per capita CO_2 emissions

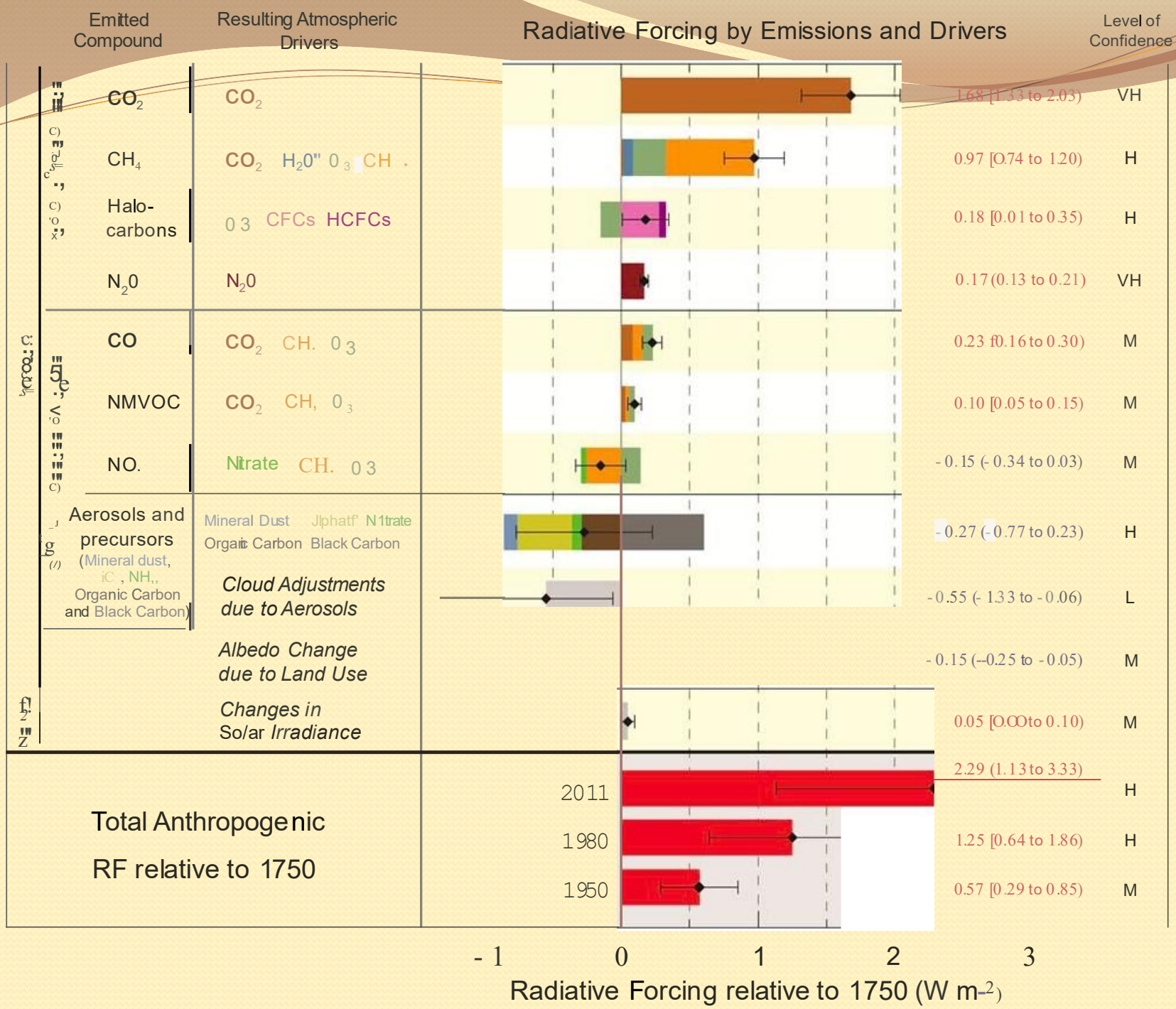
Our World in Data

Fossil fuel emissions also include direct emissions from industrial processes such as cement production.



Data source: Global Carbon Budget (2024)

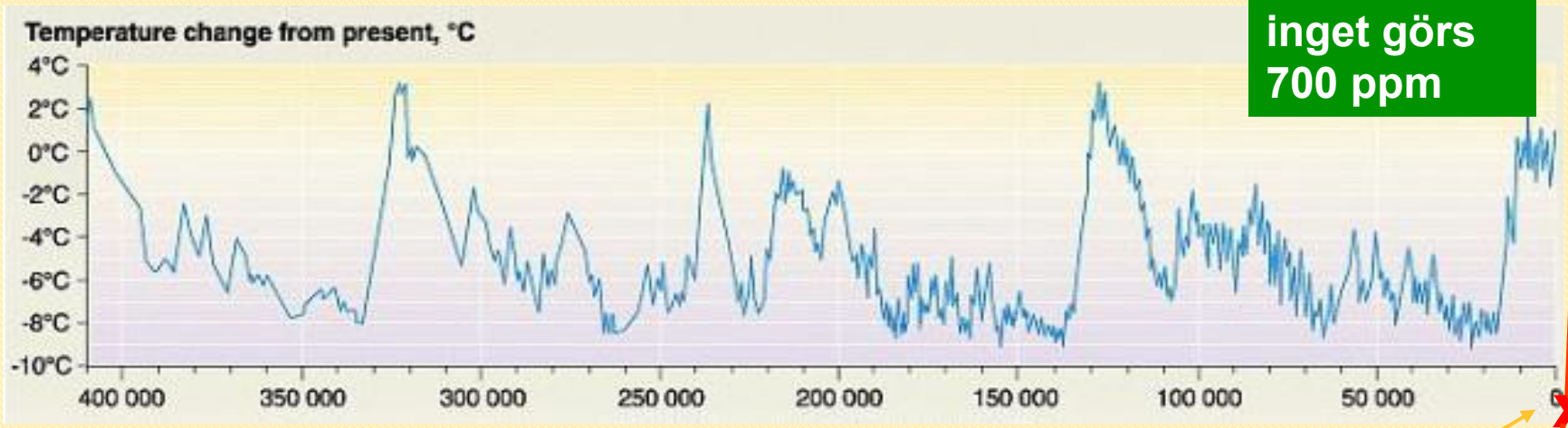
OurWorldinData.org/co2-and-other-greenhouse-gas-emissions | CC BY


Emitted Compound
Resulting Atmospheric Drivers
Radiative Forcing by Emissions and Drivers
Level of Confidence
CO2
CO2
1.68 [1.33 to 2.03)
VH
CH4
CO2 H20" 03 CH .
0.97 [0.74 to 1.20)
H
Halo-carbons
03 CFCs HCFCs
0.18 [0.01 to 0.35)
H
N20
N20
0.17 (0.13 to 0.21)
VH
CO
CO2 CH. 03
0.23 f0.16 to 0.30)
M
NMVOC
CO2 CH, 03
0.10 [0.05 to 0.15)
M
NO.
Nitrate CH. 03
- 0.15 (- 0.34 to 0.03)
M
Aerosols and precursors (Mineral dust, iC , NH,, Organic Carbon and Black Carbon)
Mineral Dust Jlphatf' N1trate
Organic Carbon Black Carbon
- 0.27 (- 0.77 to 0.23)
H
Cloud Adjustments due to Aerosols
- 0.55 (- 1.33 to - 0.06)
L
Albedo Change due to Land Use
- 0.15 (--0.25 to - 0.05)
M
Changes in Solar Irradiance
0.05 [0.00 to 0.10)
M
Total Anthropogenic RF relative to 1750
2011
2.29 (1.13 to 3.33)
H
1980
1.25 [0.64 to 1.86)
H
1950
0.57 [0.29 to 0.85)
M
- 1
0
1
2
3
Radiative Forcing relative to 1750 (W m-2)

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

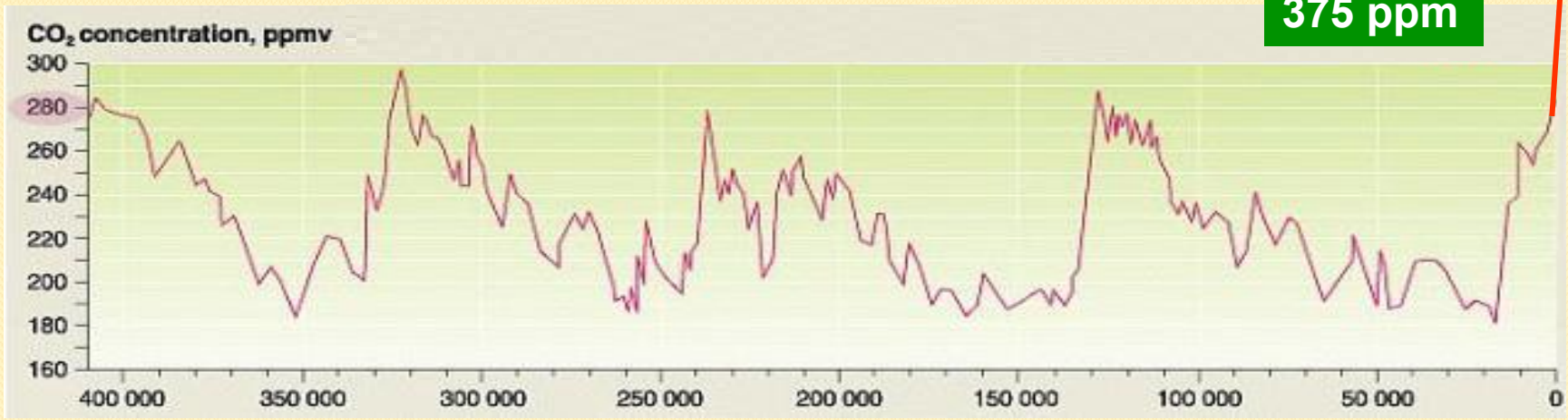
Global temperatur och CO2 concentration

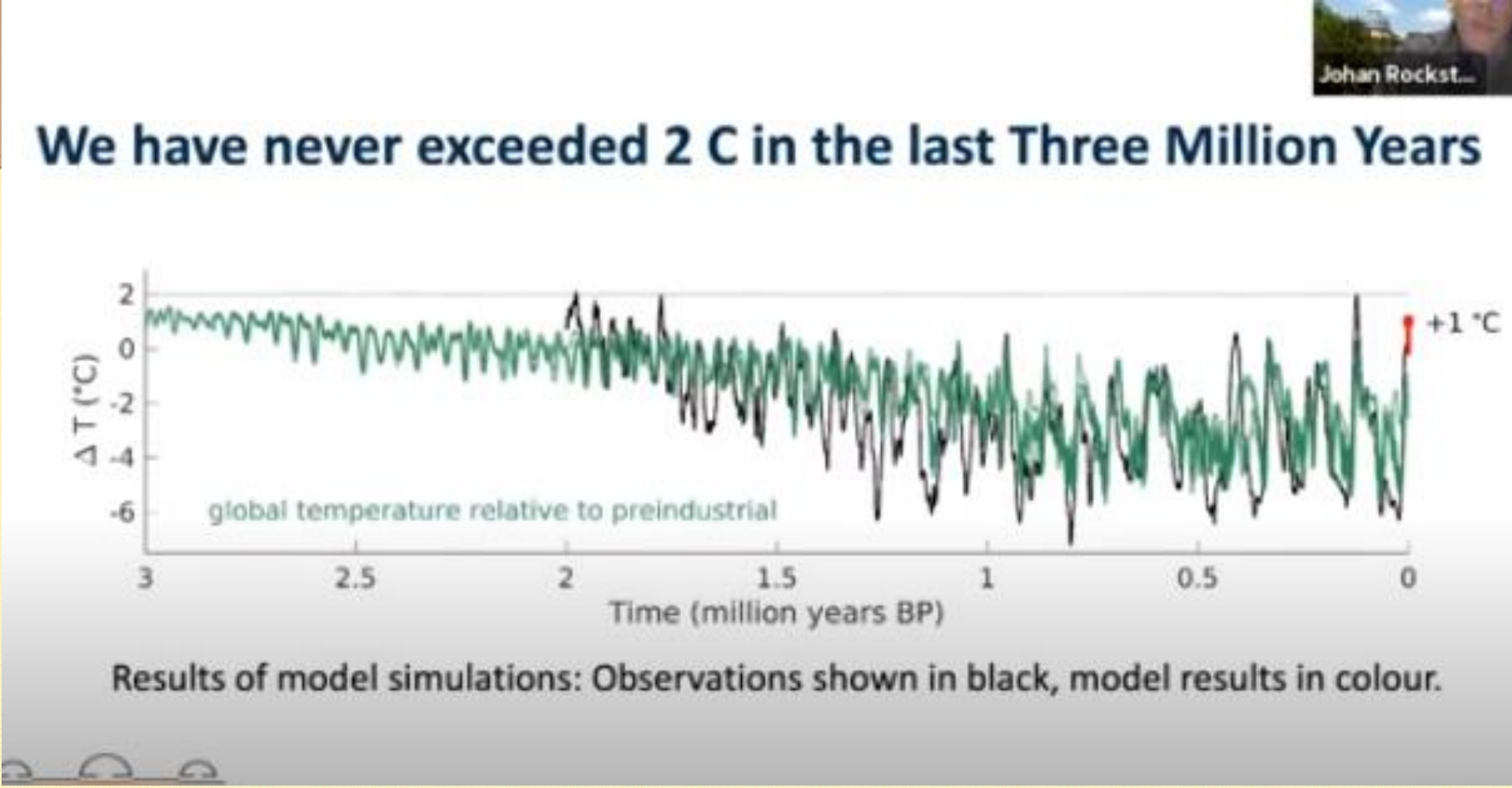
400 000 år data från ” Vostok iskärnan”



År 2100 om inget görs 700 ppm

2004 375 ppm





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

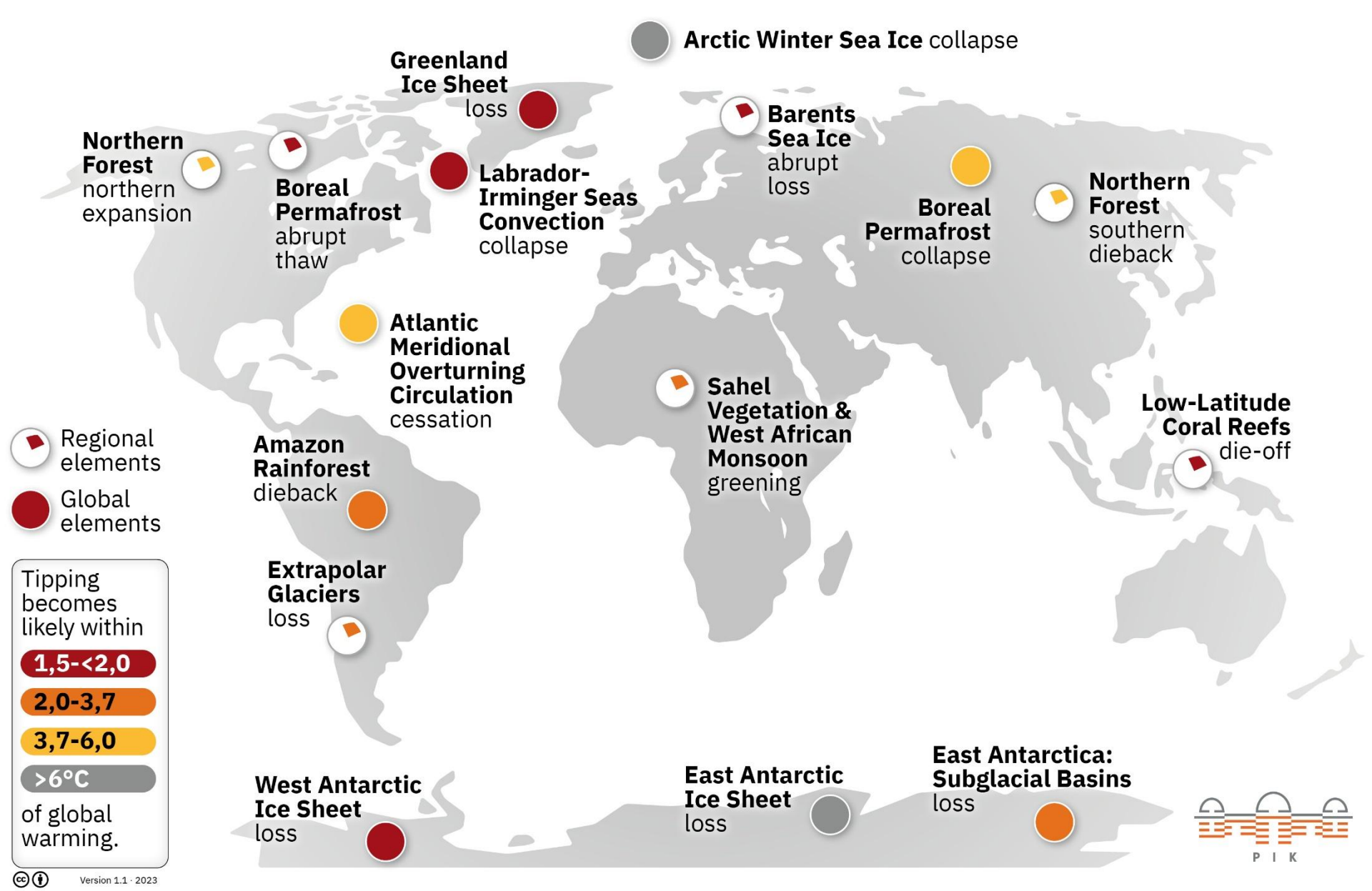
Present warming is very fast: 0.16 ^{o}C per decade. The warming after the last ice age was 0.1 C per century.

Climate sensitivity according to IPCC is around 3.7 watts per m^2. This leads to 3 ^{o}C increase for a doubling of CO_2 levels.

During previous warming events CO_2 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
- Artic permafrost is melting
  feedback: increased methane emissions
- Amazone rainforest cut down and becomes savanna
  feedback: decreased evapotranspiration
- Atlantic circulation decreases
  feedback: ocean desalting



Climate practises and policies

Climate terminology

Carbon (as CO_2) flows between the atmosphere, the above ground biosphere, the ground and the sea.

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

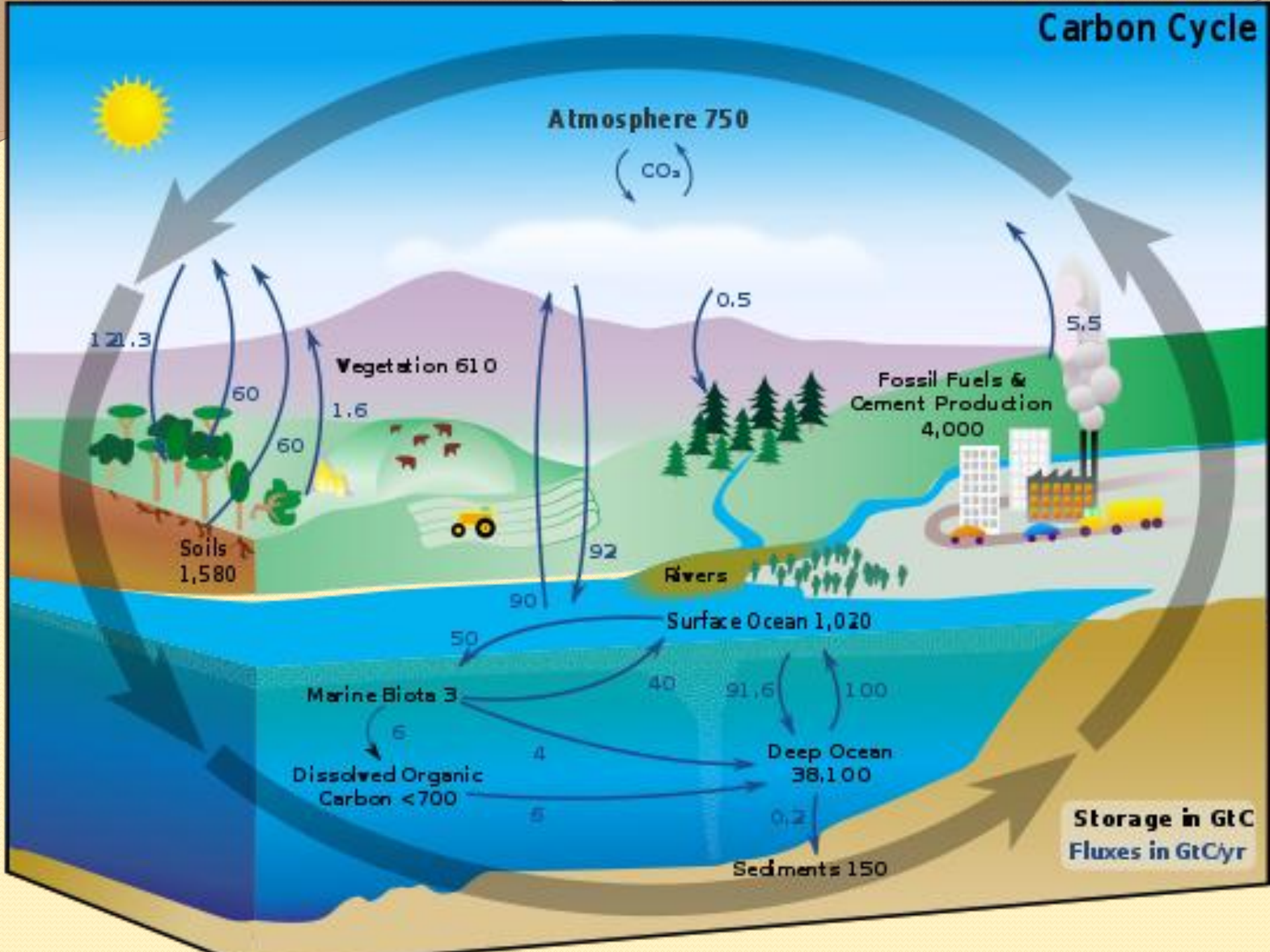
We talk about *carbon sinks* and *carbon sources*.

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
Atmosphere 750
CO_2
121.3
60
60
Vegetation 610
1.6
0.5
5.5
Fossil Fuels &
Cement Production
4,000
Soils
1,580
92
90
Rivers
Surface Ocean 1,020
50
40
91.6
100
Marine Biota 3
6
4
Dissolved Organic
Carbon <700
Deep Ocean
38,100
0.2
Sediments 150
Storage in GtC
Fluxes in GtC/yr

Adaptation

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

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 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 ^{o}C.

To really stay below 2 ^{o}C we need rapid decarbonisation of our economies right now.

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, the United Arab Emirates 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 Baku, Azerbaijan 2024

- Reached a global agreement on carbon markets.

COP 30 in Belém, Brazil 2025

- Parties should submit new national climate plans.

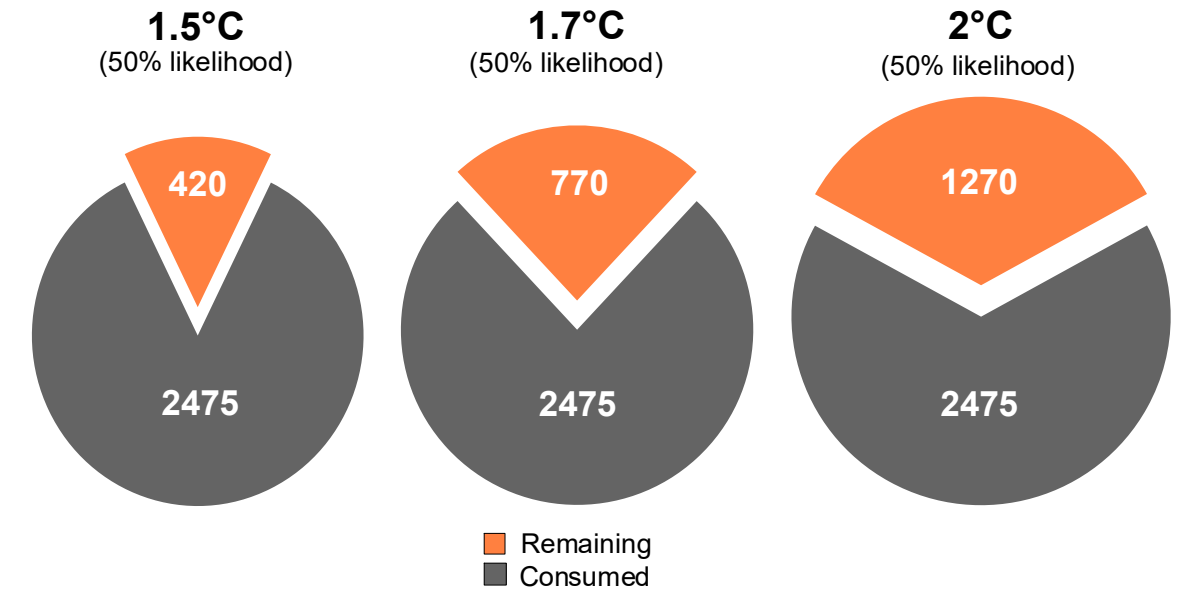
The CO2 budget of the world in 2024

- The remaining budget for the world is about 400 billion tonnes of (400 Gtons) CO2 for the 1.5 oC 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

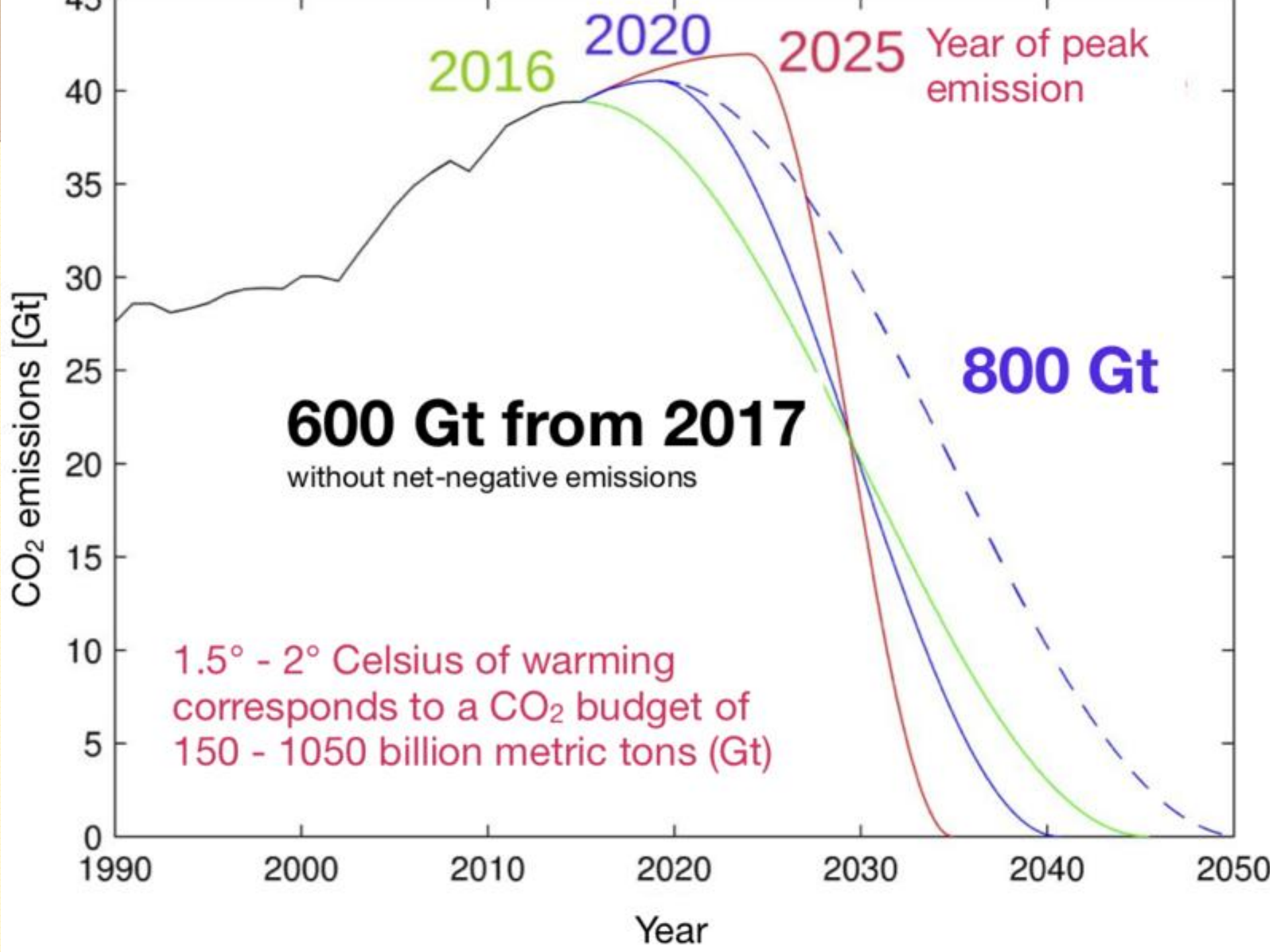
Remaining carbon budget

The remaining carbon budget to limit global warming to 1.5°C , 1.7°C and 2°C is 420 $GtCO_2$, 770 $GtCO_2$, and 1270 $GtCO_2$ respectively, equivalent to 11, 20 and 32 years from 2022. 2475 $GtCO_2$ have been emitted since 1750



Quantities are subject to [additional] uncertainties e.g., future mitigation choices of non-CO_2 emissions

Source: IPCC AR6 WG1; Friedlingstein et al 2021; Global Carbon Budget 2021


2016
2020
2025
Year of peak emission
800 Gt
600 Gt from 2017
without net-negative emissions
1.5° - 2° Celsius of warming
corresponds to a CO_2 budget of
150 - 1050 billion metric tons (Gt)
CO_2 emissions [Gt]
Year
0
5
10
15
20
25
30
35
40
1990
2000
2010
2020
2030
2040
2050

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 CO_2, 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 CO_2. 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 sections 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 increases 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

Fridays for future

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 near-by, 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.