



The Basics of Climate Change

WHAT IS CLIMATE CHANGE?

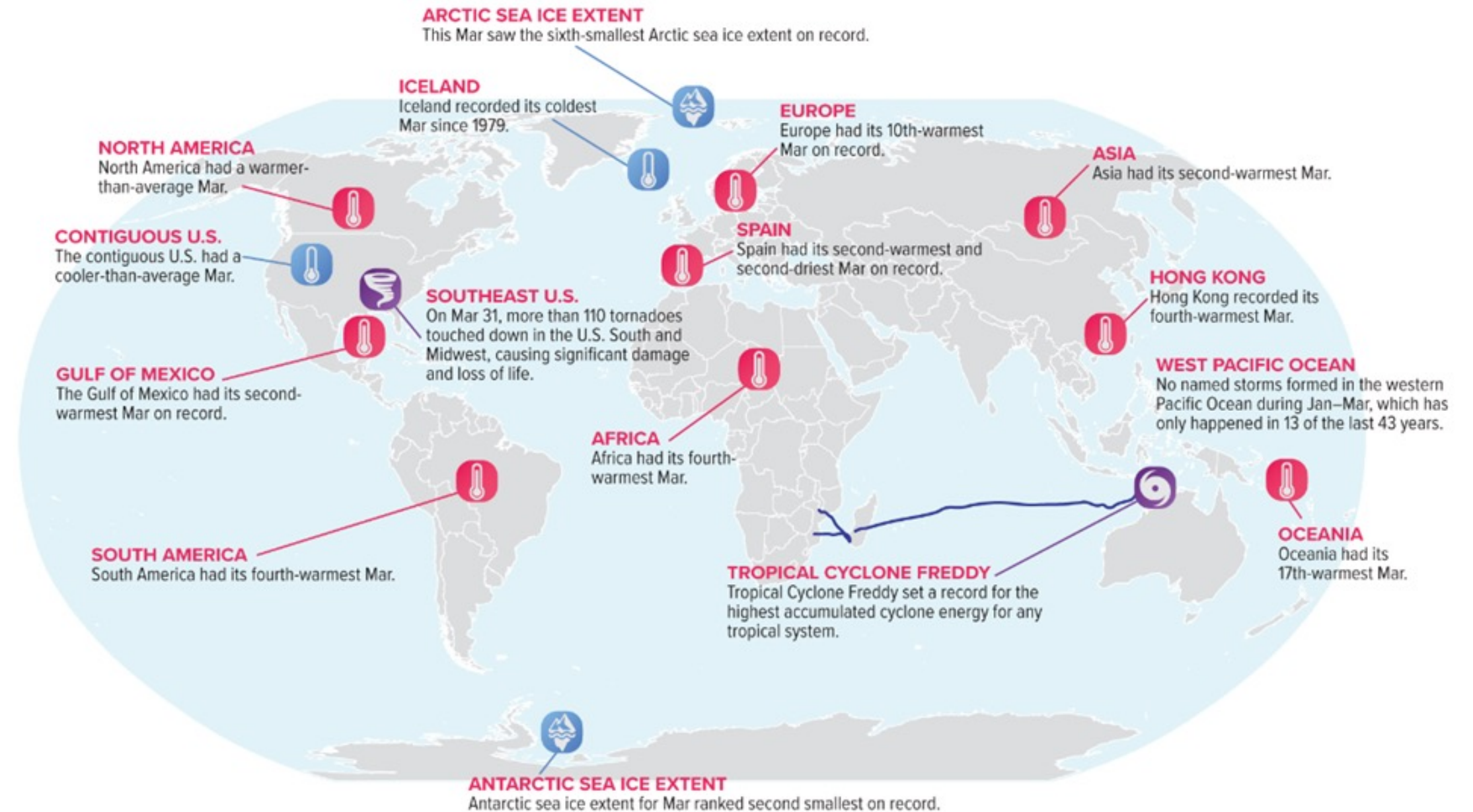
TEMPERATURE and CO₂ LEVELS

GLOBAL AVERAGE TEMPERATURE

Selected significant events and anomalies: March 2023



GLOBAL AVERAGE TEMPERATURE
Mar 2023 average global surface temperature was the second highest for Mar since global records began in 1850.



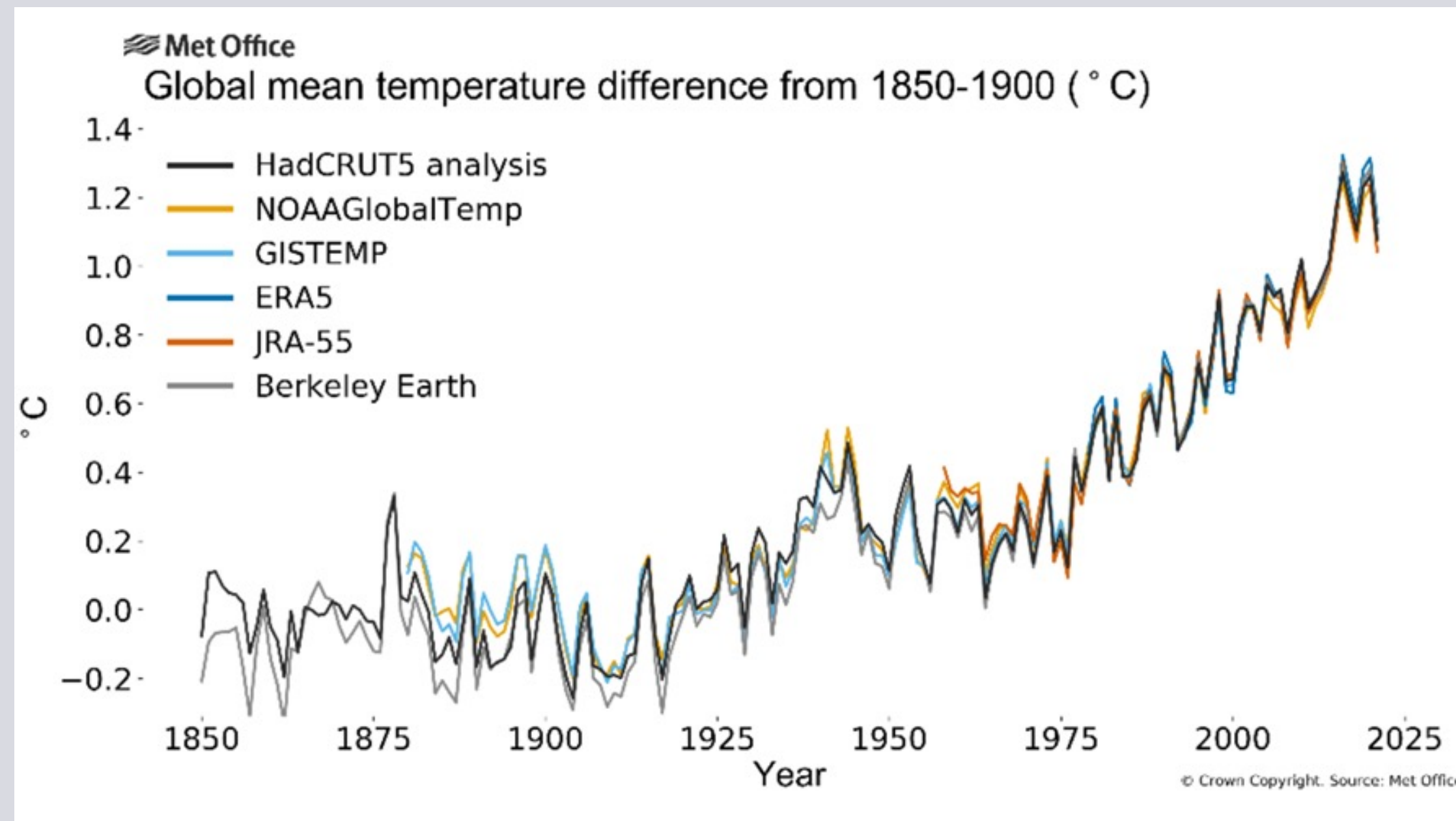
MARCH 2023 average global surface temperature was the second highest for March since global records began 1850

GLOBAL WARMING

WHERE ARE WE NOW?

WHERE ARE WE GOING?

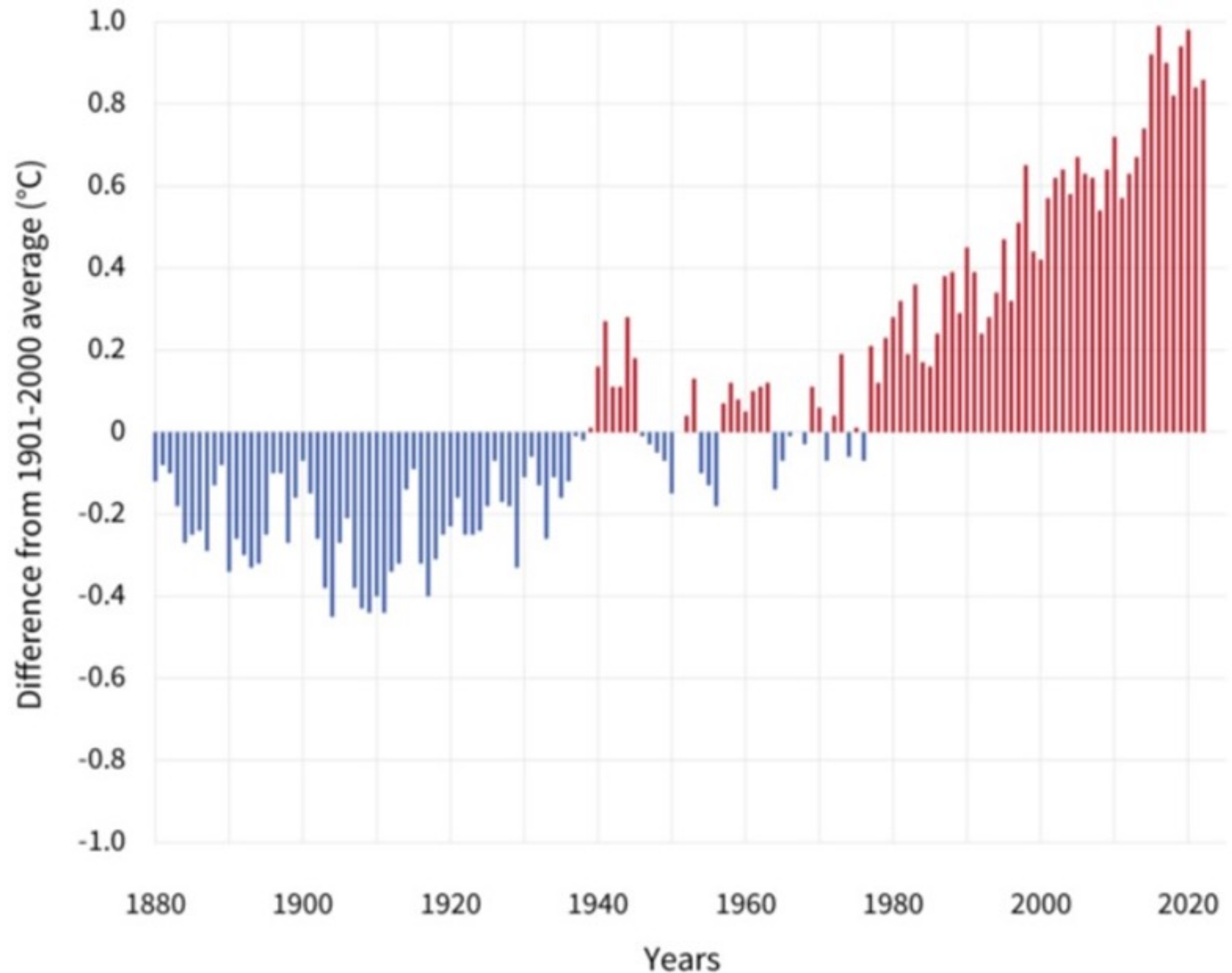
The rankings of individual years should be considered in the long-term context, especially since the differences between individual years are sometimes marginal. Since the 1980s, each decade has been warmer than the previous one. This is expected to continue. (public.wmo.int)



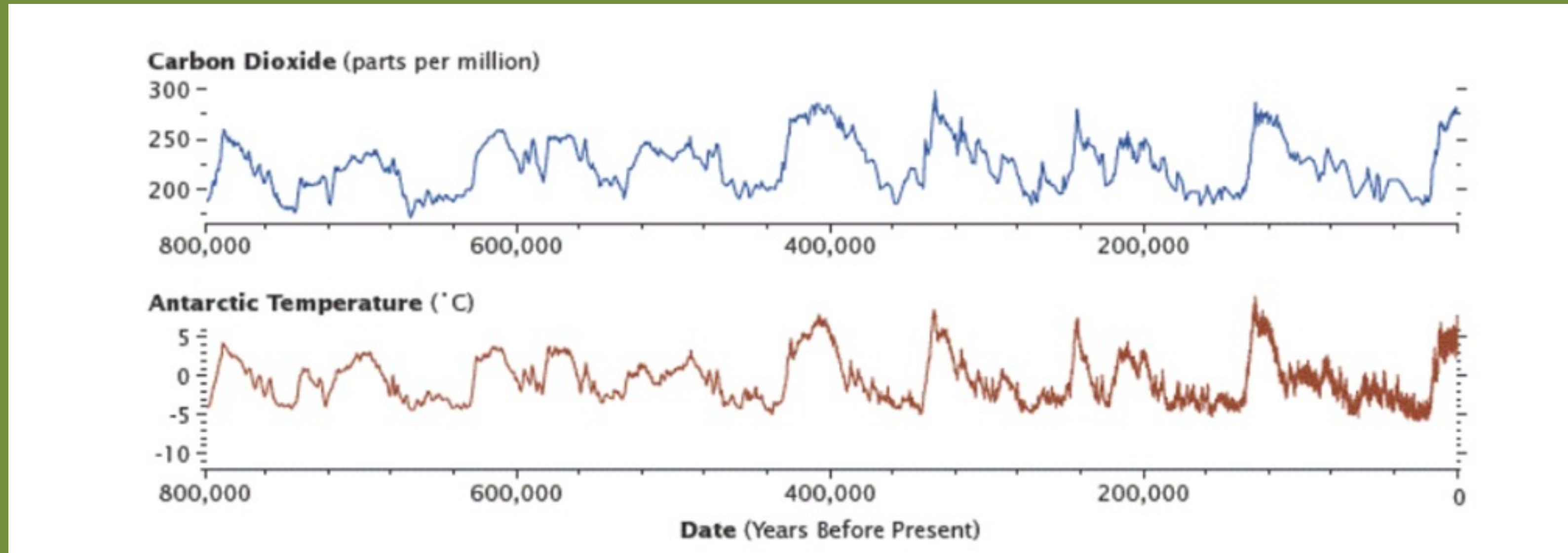
Data source: World Meteorological Organization (WMO), 2023

Yearly surface temperature compared to the 20th-century average from 1880–2022. Blue bars indicate cooler-than-average years; red bars show warmer-than-average years.

NOAA Climate.gov graph, based on data from the National Centers for Environmental Information. (climate.gov, 2023)



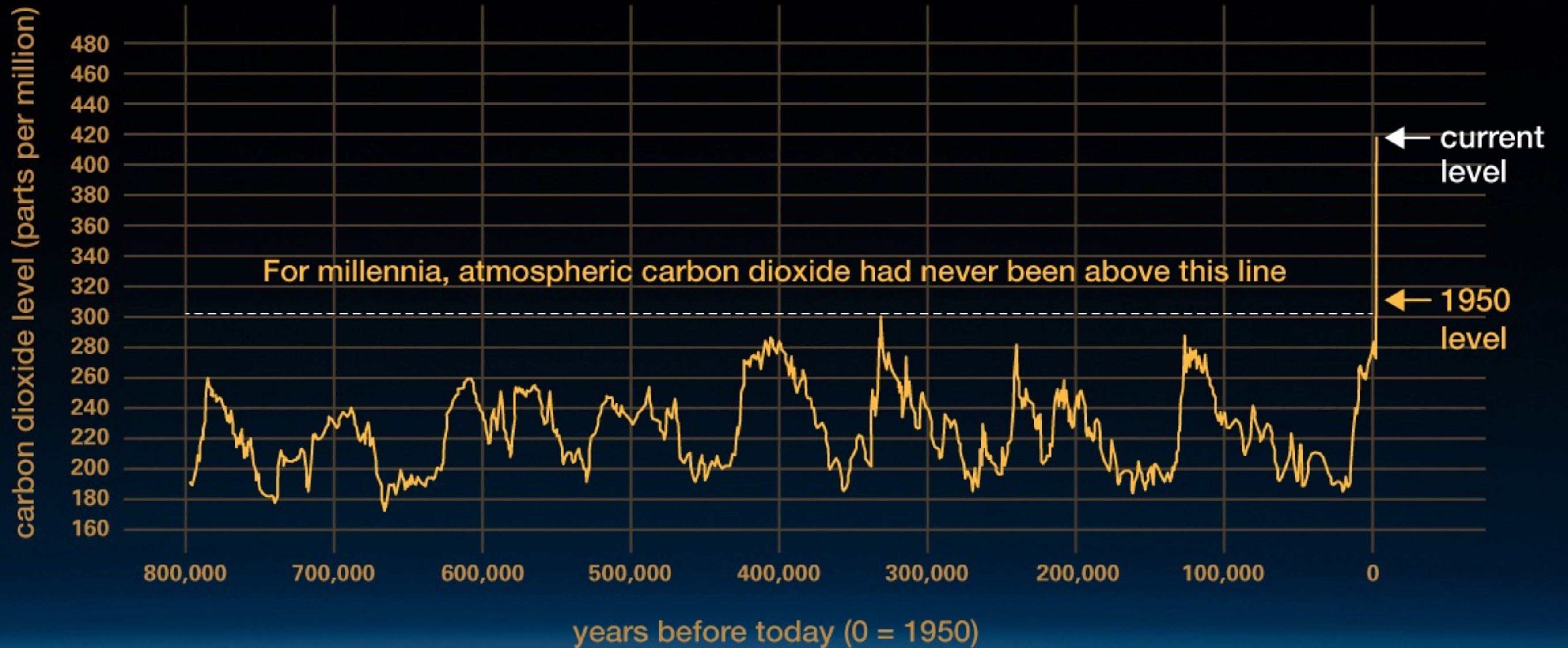
The temperature of the Earth's atmosphere and the carbon dioxide level in the atmosphere have moved together for at least 800,000 years: NASA Earth Observatory
<https://www.feedbackreigns.net/evidence/temperature-co2/>



'The blue line shows the "carbon dioxide level in the atmosphere" over the 800,000 years before 1950. (It does not show the rapid rise in CO2 levels, since 1950, to over 400 parts per million (ppm)).

The red line shows the "Antarctic air temperature" over this same period.'

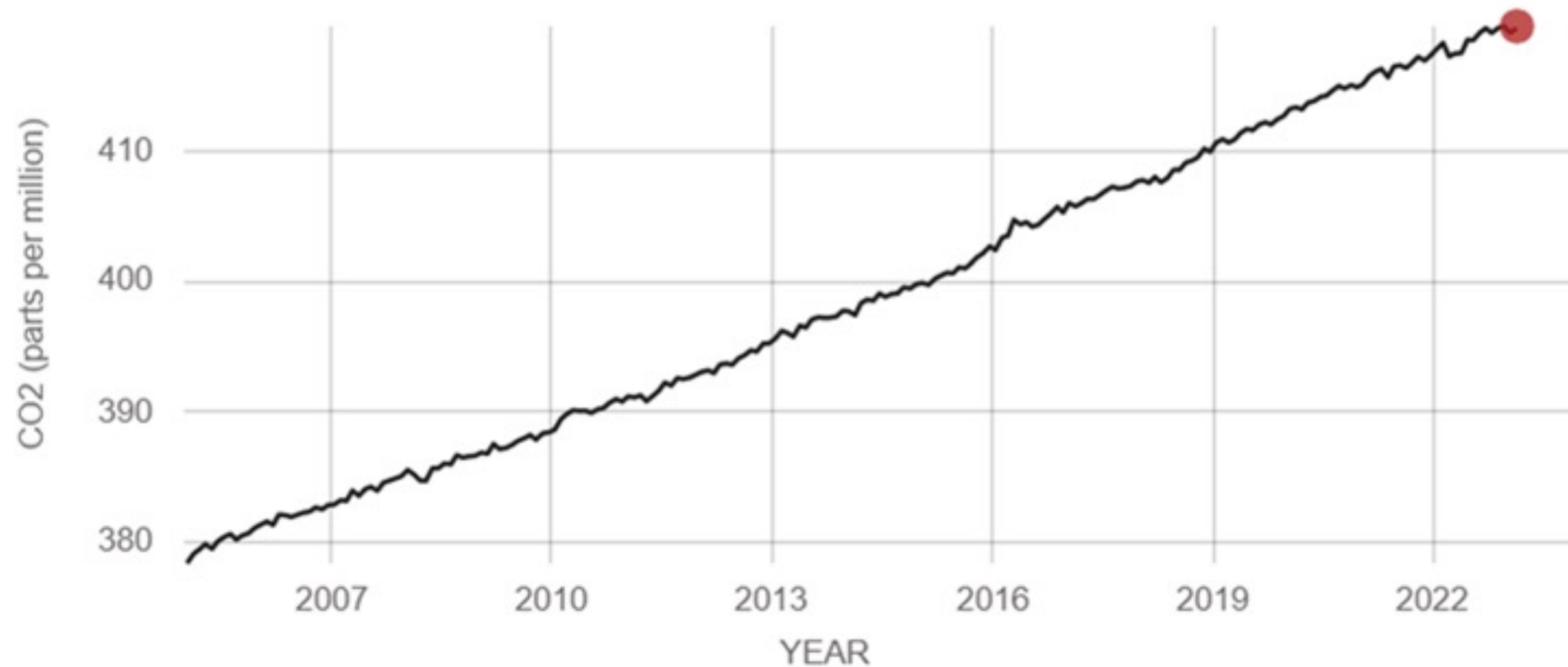
(<https://www.feedbackreigns.net/evidence/temperature-co2/>)



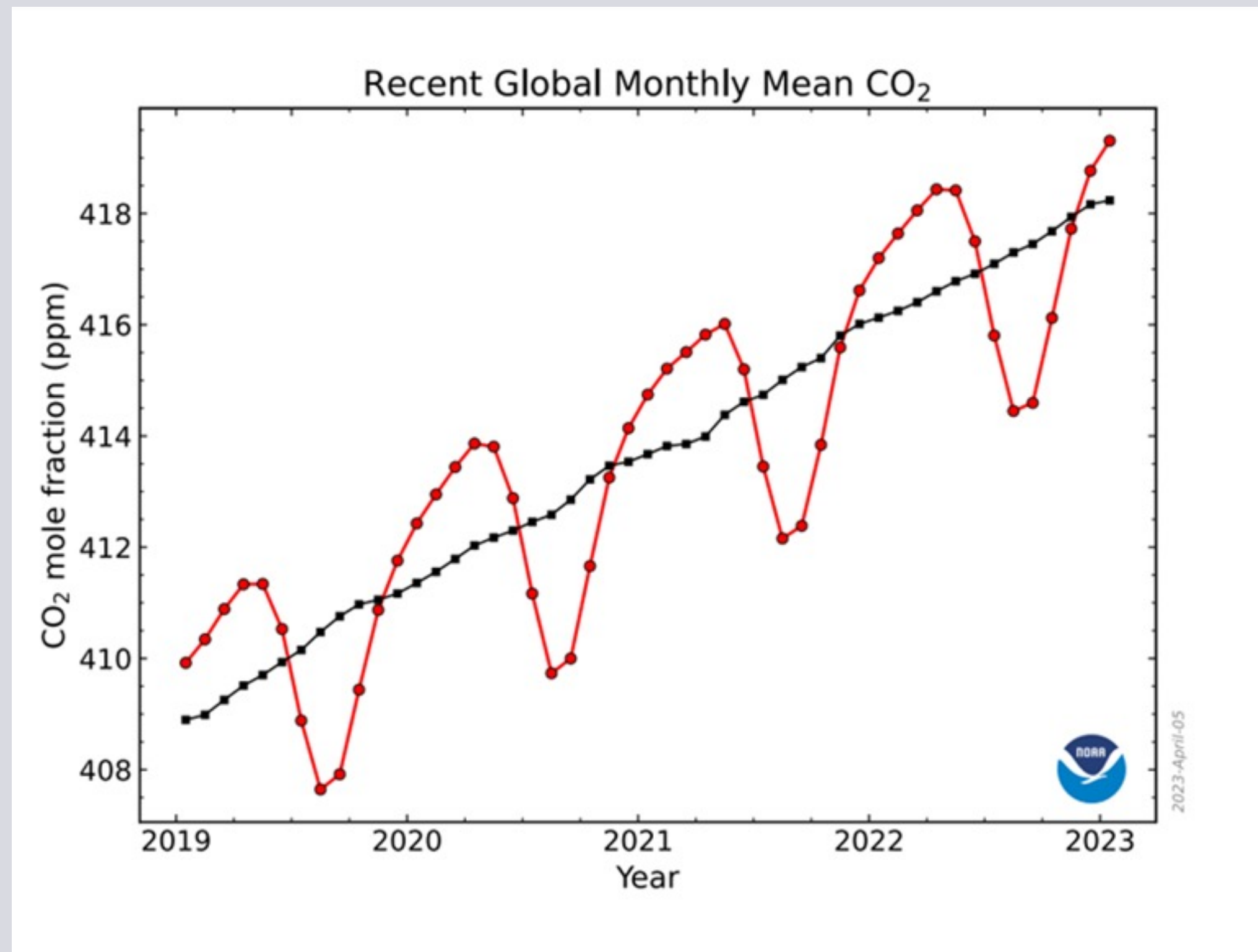
During ice ages, CO₂ levels were around 200 parts per million (ppm), and during the warmer interglacial periods, they hovered around 280 ppm (see fluctuations in the graph). In 2013, CO₂ levels surpassed 400 ppm for the first time in recorded history. (climate.nasa.gov)

DIRECT MEASUREMENTS: 2005-PRESENT

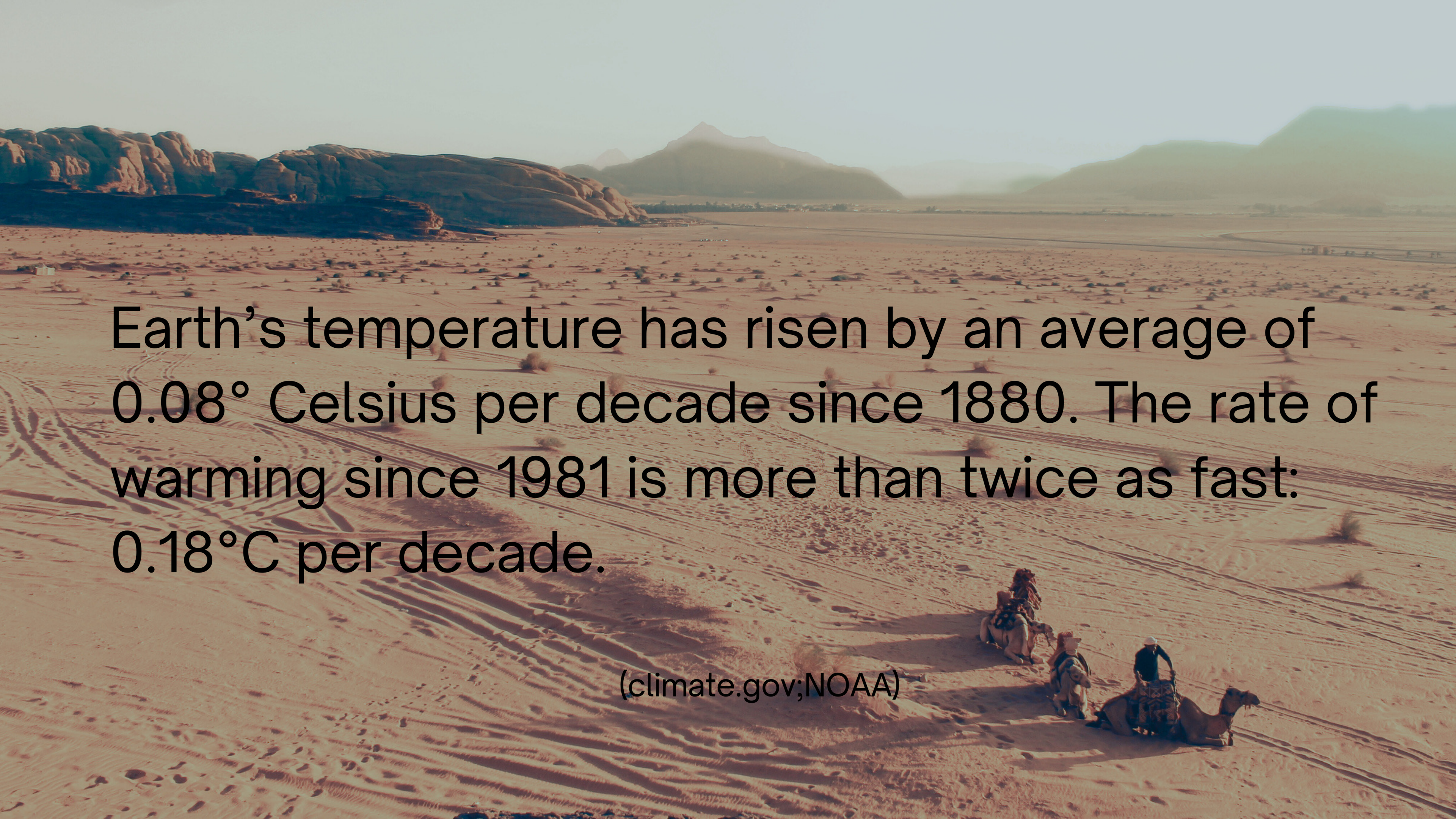
Data source: Monthly measurements (average seasonal cycle removed). Credit: [NOAA](#)



Since the beginning of industrial times (in the 18th century), human activities have raised atmospheric CO2 by 50% – meaning the amount of CO2 is now 150% of its value in 1750. This is greater than what naturally happened at the end of the last ice age 20,000 years ago. Carbon Dioxide, Latest measurement: February 2023, 419 ppm ([nasa.gov](#))

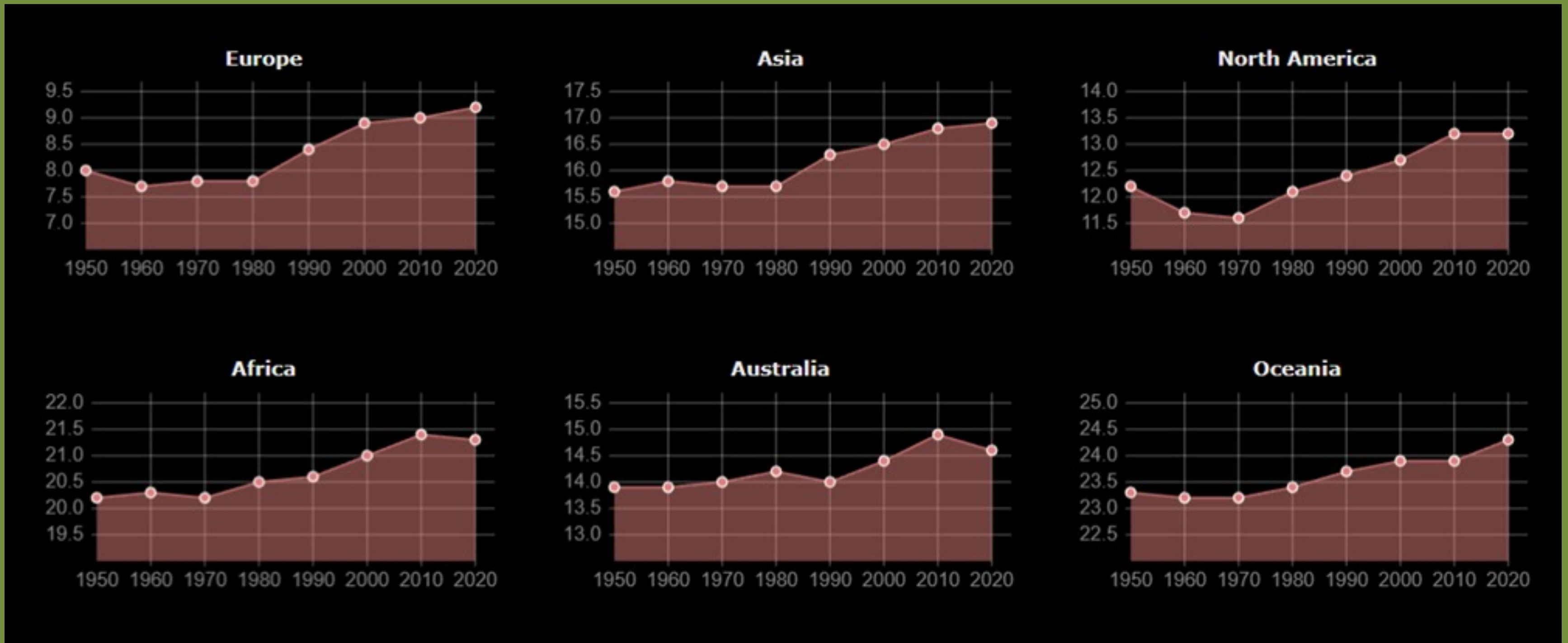


Global Monthly Mean CO₂, the graphs show monthly mean carbon dioxide globally averaged over marine surface sites. January 2023: 419.31 ppm, January 2022: 417.20 ppm Last updated: Apr 05, 2023 (gml.noaa.gov)



Earth's temperature has risen by an average of 0.08° Celsius per decade since 1880. The rate of warming since 1981 is more than twice as fast: 0.18°C per decade.

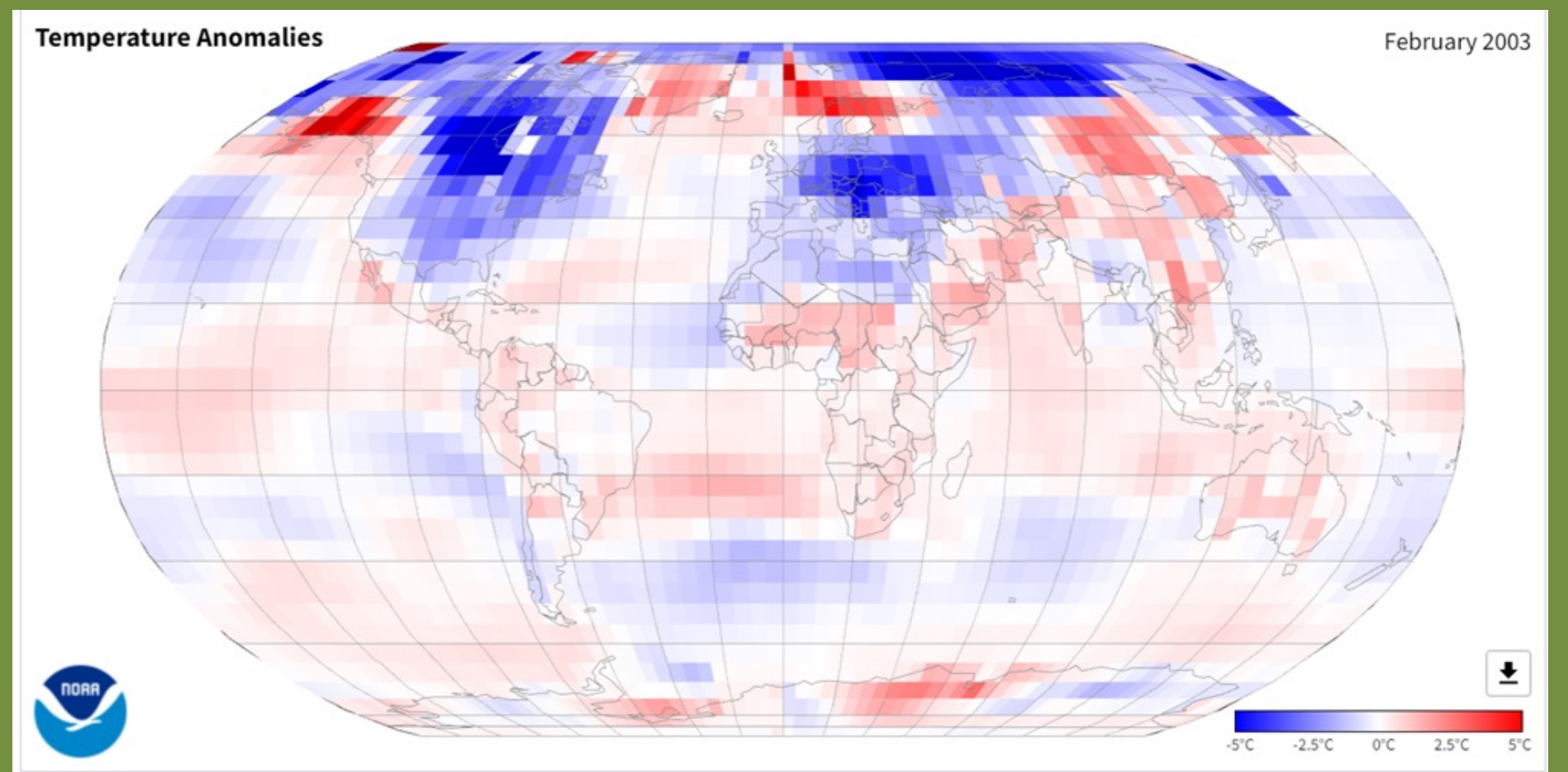
(climate.gov;NOAA)



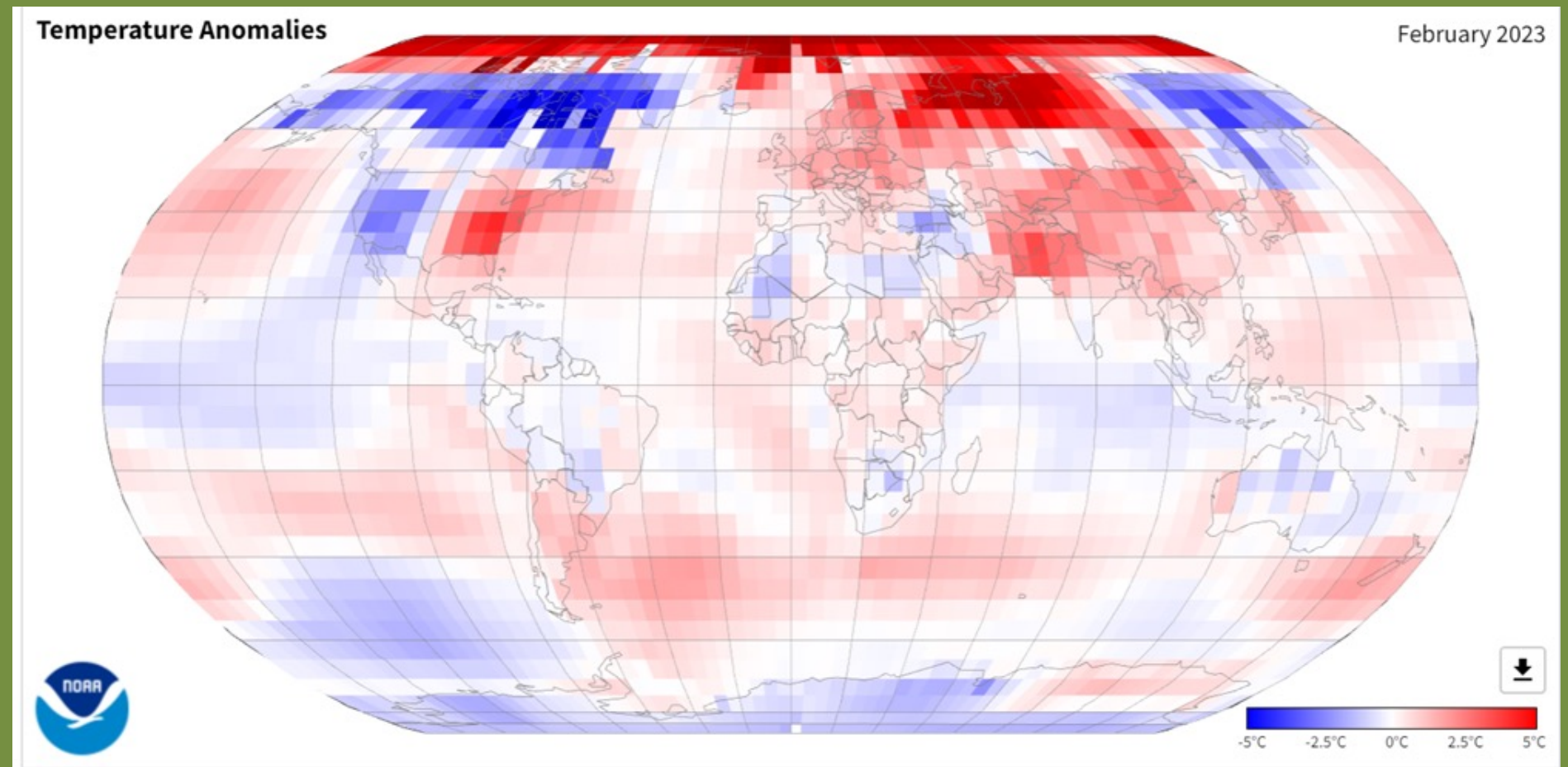
The graphs show the average daily temperatures. It can be seen quite clearly that there has been a sharp increase in temperatures worldwide since the 1980s. Particularly noticeable are the developments in Europe, North America and Asia, where there are considerable temperature increases. (worlddata.info)

The warmest eight years have all been since 2015, with 2016, 2019 and 2020 constituting the top three. An exceptionally strong El Niño event occurred in 2016, which contributed to record global temperatures.

(public.wmo.int)



Temperature anomalies are based on the 1991-2020 mean (NOAA, 2023)



2022 was the sixth-warmest year on record based on NOAA's temperature data.

The 2022 surface temperature was 0.86 °Celsius warmer than the 20th-century average of 13.9 °C and 1.06 °C warmer than the pre-industrial period (1880-1900).

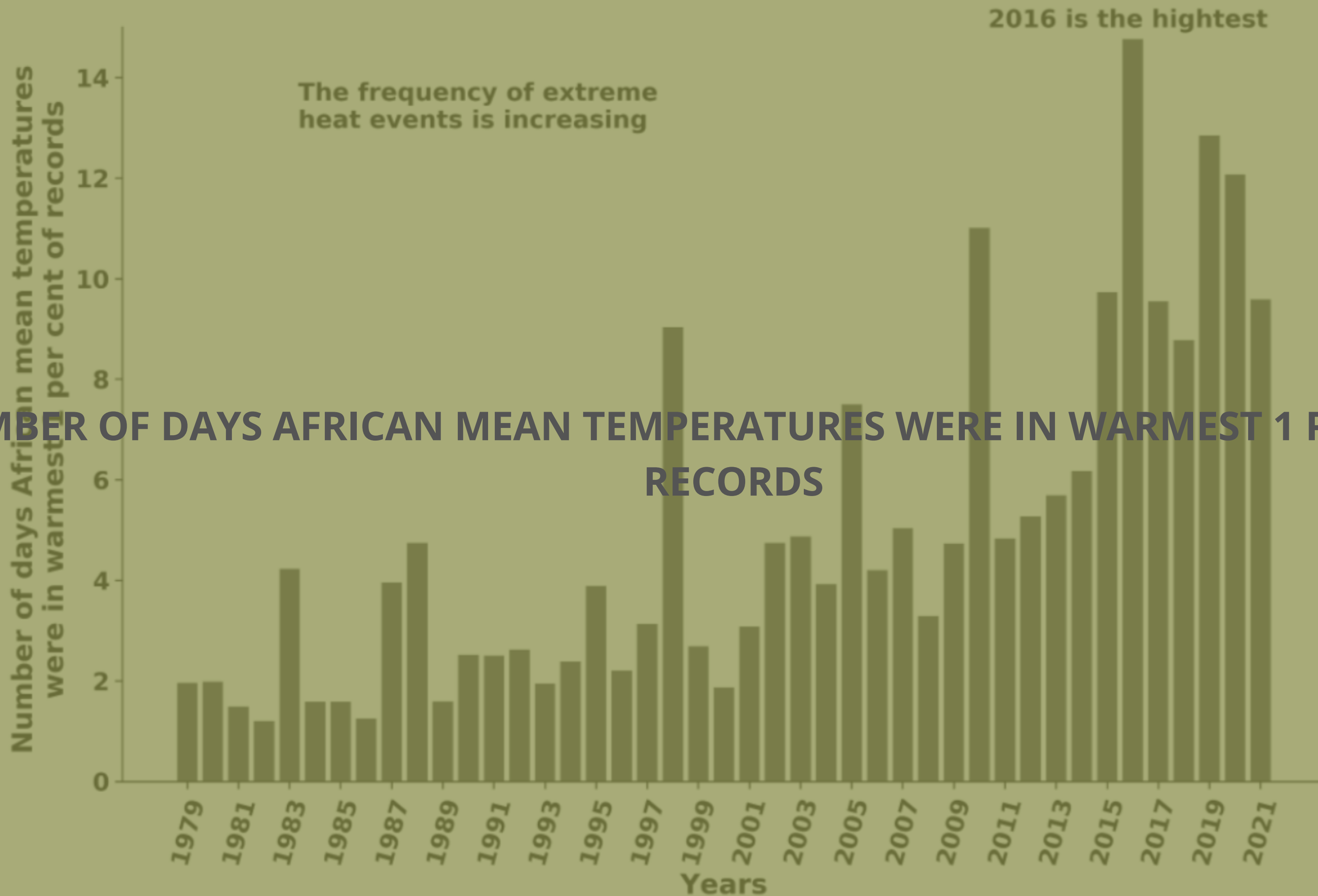
The 10 warmest years in the historical record have all occurred since 2010.
(climate.gov)



The average global temperature in 2022

The average global temperature in 2022 was about 1.15 [1.02 to 1.27] °C above the pre-industrial (1850-1900) levels. 2022 is the 8th consecutive year (2015-2022) that annual global temperatures have reached at least 1°C above pre-industrial levels, according to all datasets compiled by WMO. 2015 to 2022 are the eight warmest years on record. Long-term warming continues. (IPCC)

NUMBER OF DAYS AFRICAN MEAN TEMPERATURES WERE IN WARMEST 1 PER CENT OF RECORDS





2021 ranked between the third and the fourth warmest year on record for Africa. (wmo.int)

Without immediate and deep emissions reductions across all sectors and regions, it will be impossible to keep warming below 1.5° C. (IPCC)

In 2020, the COVID-19 pandemic lockdowns led to the single biggest drop in CO₂ emissions on record. Since then, however, CO₂ emissions have exceeded pre-pandemic levels recorded in early 2019. (wmo.int)

Climate

Climate, sometimes understood as the "average weather," is defined as the measurement of the mean and variability of relevant quantities of certain variables (such as temperature, precipitation or wind) over a period of time, ranging from months to thousands or millions of years. The classical period is 30 years, as defined by the World Meteorological Organization. Climate in a wider sense is the state, including a statistical description, of the climate system. (WMO)

Climate is the long-term average of the weather in a given place. (EPA)

Weather Versus Climate

Weather is a specific event or condition that happens over a period of hours or days. For example, a thunderstorm, a snowstorm, and today's temperature all describe the weather. Climate refers to the average weather conditions in a place over many years (usually at least 30 years). (epa.gov)

Climate system

The global system consisting of five major components: the atmosphere, the hydrosphere, the cryosphere, the lithosphere and the biosphere and the interactions between them. The climate system changes in time under the influence of its own internal dynamics and because of external forcings such as volcanic eruptions, solar variations, orbital forcing, and anthropogenic forcings such as the changing composition of the atmosphere and land-use change.

(IPCC)

Global mean surface temperature (GMST) and Sea surface temperature (SST)

Global mean surface temperature (GMST)

Estimated global average of near-surface air temperatures over land and sea-ice, and sea surface temperatures over ice-free ocean regions, with changes normally expressed as departures from a value over a specified reference period. When estimating changes in GMST, near-surface air temperature over both land and oceans are also used.

Sea surface temperature (SST)

The sea surface temperature is the subsurface bulk temperature in the top few meters of the ocean, measured by ships, buoys, and drifters. From ships, measurements of water samples in buckets were mostly switched in the 1940s to samples from engine intake water. Satellite measurements of skin temperature (uppermost layer; a fraction of a millimeter thick) in the infrared or the top centimeter or so in the microwave are also used, but must be adjusted to be compatible with the bulk temperature.

Land surface air temperature LST and Global mean surface air temperature GSAT

Land surface air temperature (LST)

The near-surface air temperature over land, typically measured at 1.25–2 m above the ground using standard meteorological equipment.

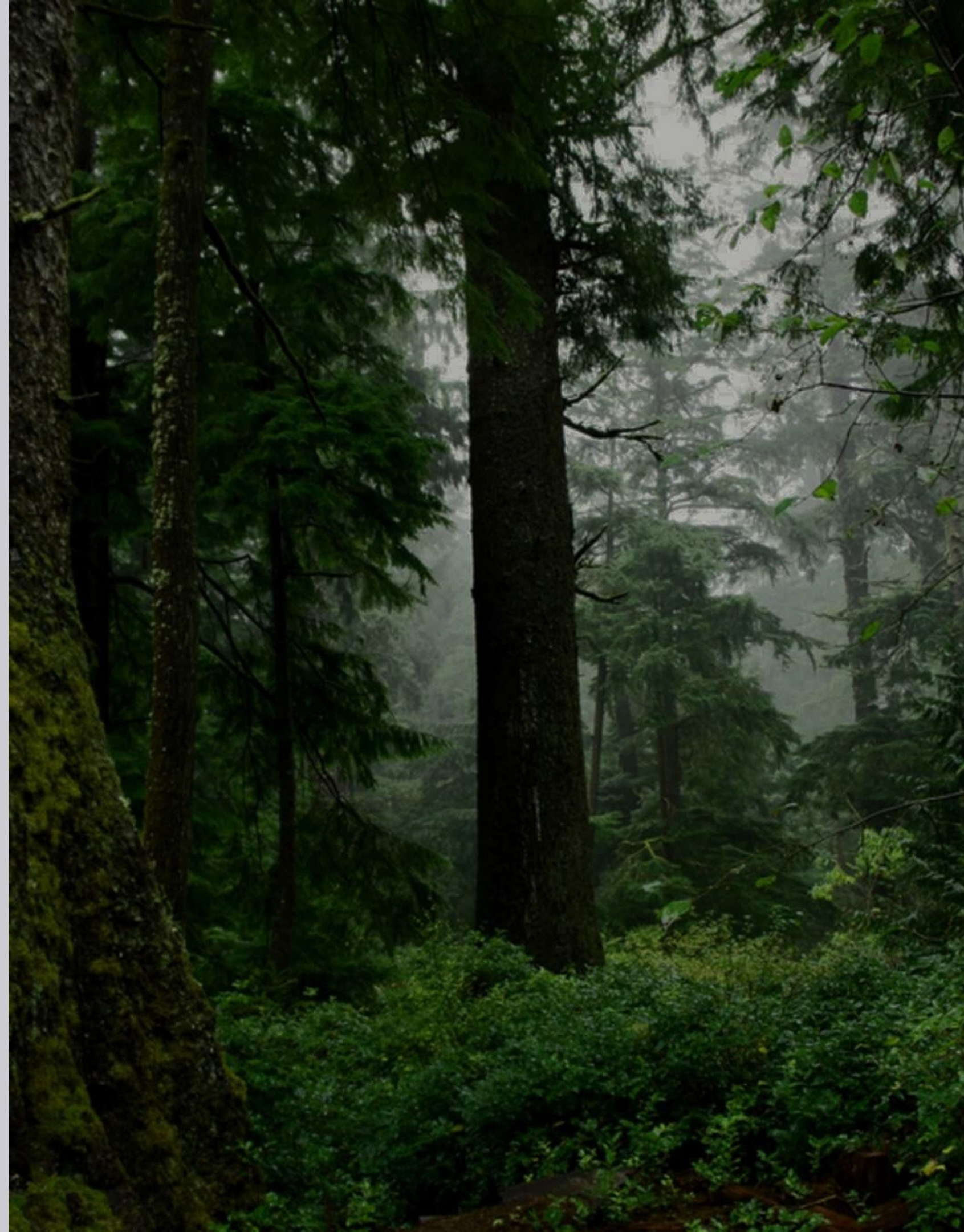
Global mean surface air temperature (GSAT)

Global average of near-surface air temperatures over land and oceans. Changes in GSAT are often used as a measure of global temperature change in climate models but are not observed directly.



Carbon dioxide emissions

Carbon dioxide (CO₂) is a colourless, odourless and non-poisonous gas formed by combustion of carbon and in the respiration of living organisms and is considered a greenhouse gas. Emissions means the release of greenhouse gases and/or their precursors into the atmosphere over a specified area and period of time. Carbon dioxide emissions or CO₂ emissions are emissions stemming from the burning of fossil fuels and the manufacture of cement; they include carbon dioxide produced during consumption of solid, liquid, and gas fuels as well as gas flaring. (ec.europa.eu)



A tropical beach scene with palm trees and waves crashing on the shore. The text is overlaid on this background.

CO2 emissions

...until well into the 20th century, global emissions were dominated by Europe and the United States. In 1900, more than 90% of emissions were produced in Europe or the US; even by 1950, they accounted for more than 85% of emissions each year.

But in recent decades this has changed significantly. In the second half of the 20th century we see a significant rise in emissions in the rest of the world, particularly across Asia, and most notably, China.

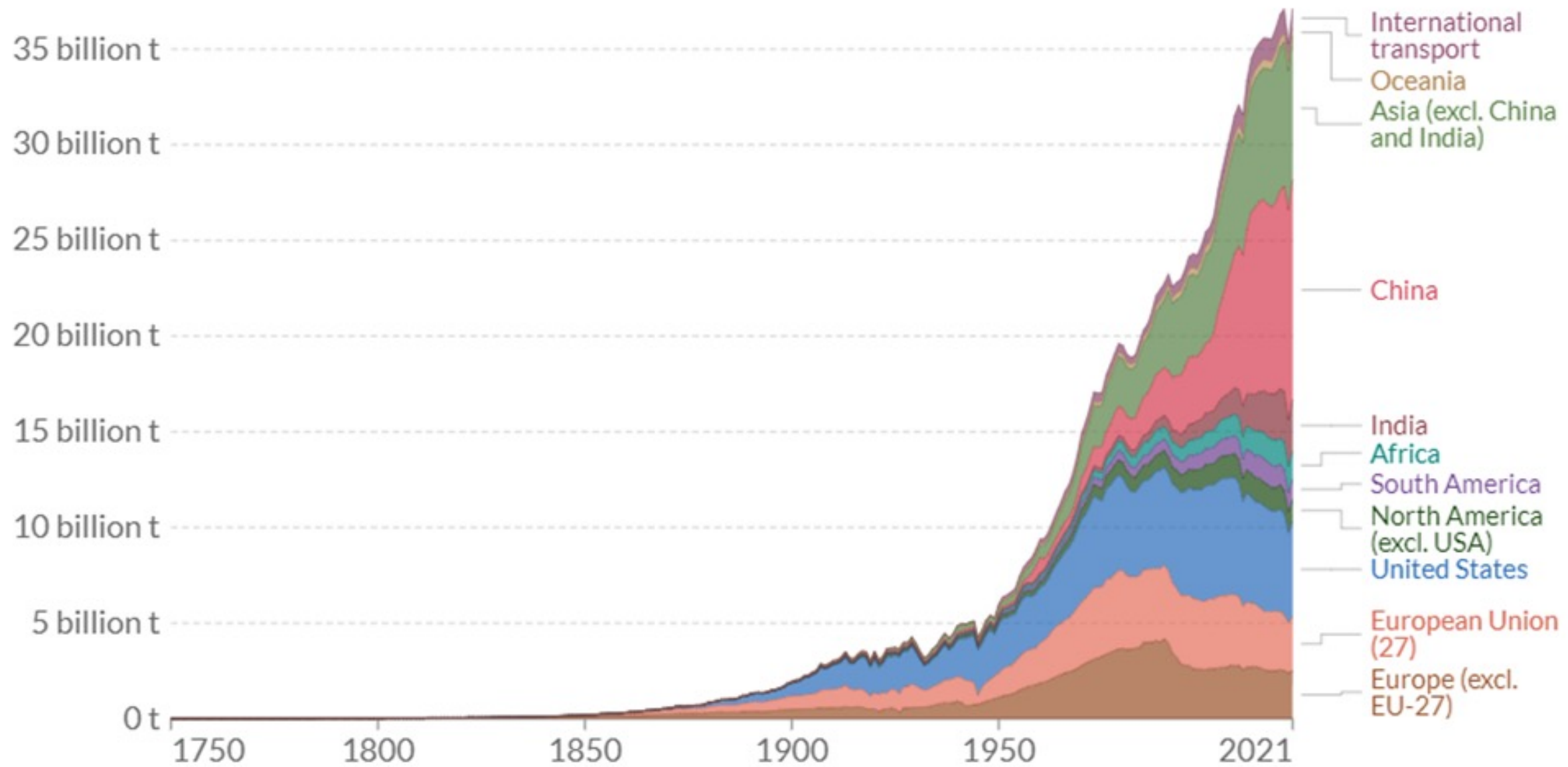
**The US and Europe now account for just under one-third of emissions.
(ourworldindata.com)**

Annual CO₂ emissions by world region

Our World
in Data

This measures fossil fuel and industry emissions. Land use change is not included.

□ Relative



Source: Our World in Data based on the Global Carbon Project (2022)

OurWorldInData.org/co2-and-greenhouse-gas-emissions • CC BY

▶ 1750 ○ 2021

Data source: ourworldindata.org

Carbon dioxide equivalent

A carbon dioxide equivalent or CO₂ equivalent, abbreviated as CO₂-eq is a metric measure used to compare the emissions from various greenhouse gases on the basis of their global-warming potential (GWP), by converting amounts of other gases to the equivalent amount of carbon dioxide with the same global warming potential.

Carbon dioxide equivalents are commonly expressed as million metric tonnes of carbon dioxide equivalents, abbreviated as MMTCDE.

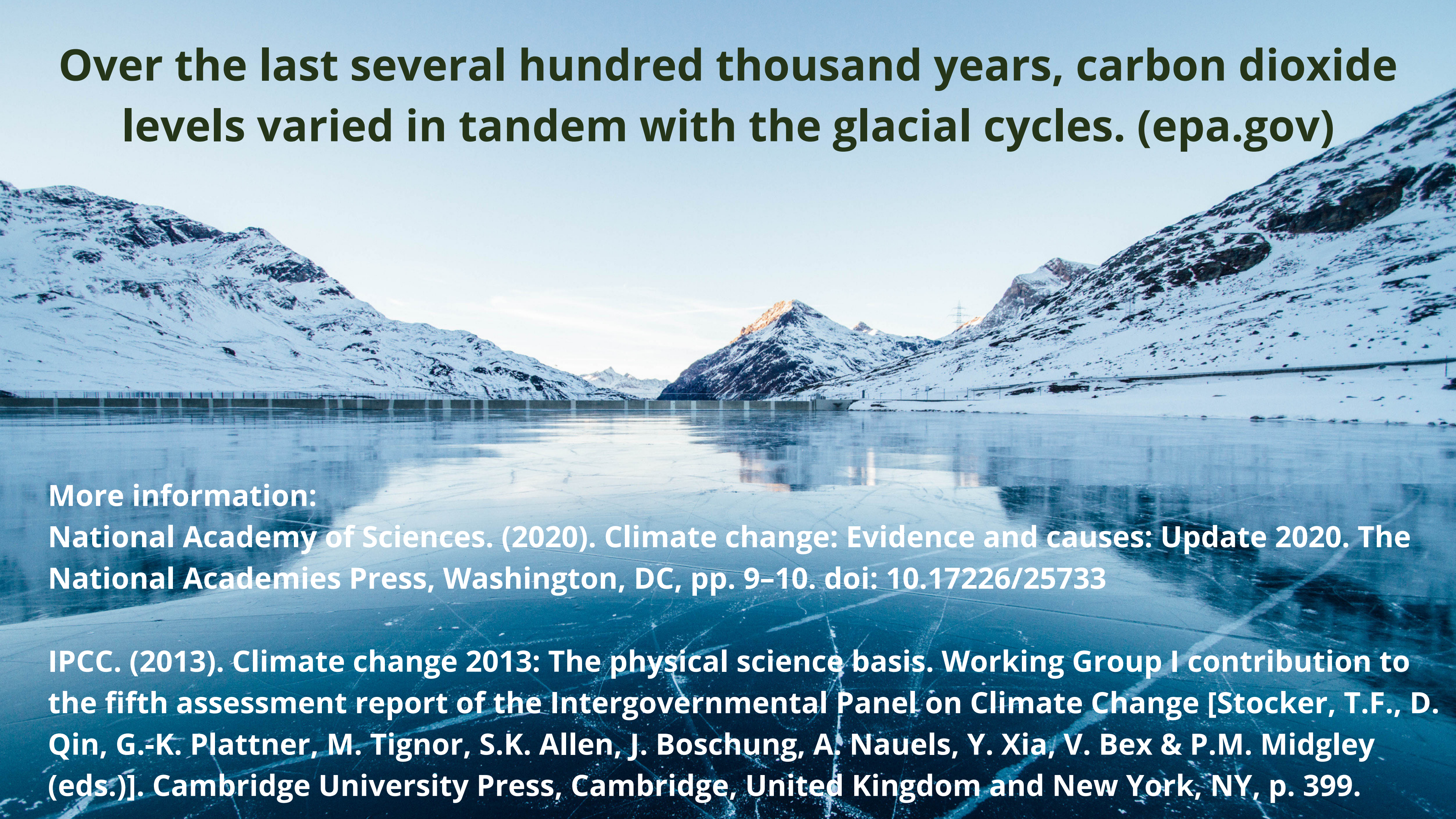
The carbon dioxide equivalent for a gas is derived by multiplying the tonnes of the gas by the associated GWP: $\text{MMTCDE} = (\text{million metric tonnes of a gas}) * (\text{GWP of the gas})$.

For example, the GWP for methane is 25 and for nitrous oxide 298. This means that emissions of 1 million metric tonnes of methane and nitrous oxide respectively is equivalent to emissions of 25 and 298 million metric tonnes of carbon dioxide. (ec.europa.eu)

Carbon cycle

In Earth's past, the carbon cycle has changed in response to climate change. Variations in Earth's orbit alter the amount of energy Earth receives from the Sun and leads to a cycle of ice ages and warm periods like Earth's current climate. (See Milutin Milankovitch.) Ice ages developed when Northern Hemisphere summers cooled and ice built up on land, which in turn slowed the carbon cycle. Meanwhile, a number of factors including cooler temperatures and increased phytoplankton growth may have increased the amount of carbon the ocean took out of the atmosphere. The drop in atmospheric carbon caused additional cooling. Similarly, at the end of the last Ice Age, 10,000 years ago, carbon dioxide in the atmosphere rose dramatically as temperatures warmed (earthobservatory.nasa.gov).

Read more about Milutin Milankovitch: <https://climate.nasa.gov/news/2948/milankovitch-orbital-cycles-and-their-role-in-earths-climate/> and Carbon cycle: <https://earthobservatory.nasa.gov/features/CarbonCycle/page4.php>



Over the last several hundred thousand years, carbon dioxide levels varied in tandem with the glacial cycles. (epa.gov)

More information:

National Academy of Sciences. (2020). Climate change: Evidence and causes: Update 2020. The National Academies Press, Washington, DC, pp. 9–10. doi: 10.17226/25733

IPCC. (2013). Climate change 2013: The physical science basis. Working Group I contribution to the fifth assessment report of the Intergovernmental Panel on Climate Change [Stocker, T.F., D. Qin, G.-K. Plattner, M. Tignor, S.K. Allen, J. Boschung, A. Nauels, Y. Xia, V. Bex & P.M. Midgley (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, p. 399.

Global Warming Potential

GWP

The Global Warming Potential (GWP) was developed to allow comparisons of the global warming impacts of different gases. Specifically, it is a measure of how much energy the emissions of 1 ton of a gas will absorb over a given period of time, relative to the emissions of 1 ton of carbon dioxide (CO₂).
(epa.gov)

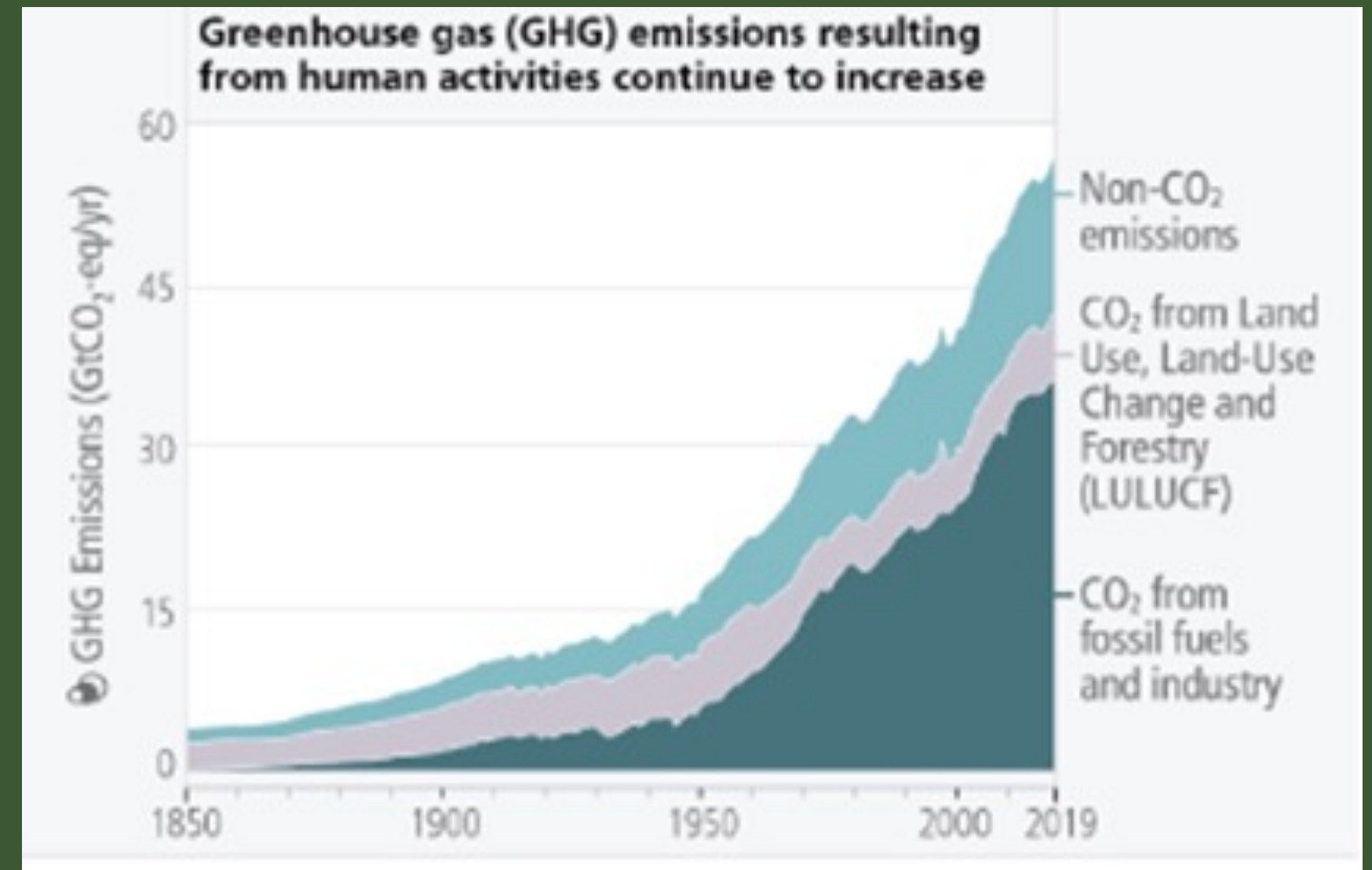


The larger the GWP, the more that a given gas warms the Earth compared to CO₂ over that time period. The time period usually used for GWPs is 100 years. GWPs provide a common unit of measure, which allows analysts to add up emissions estimates of different gases (e.g., to compile a national GHG inventory), and allows policymakers to compare emissions reduction opportunities across sectors and gases.

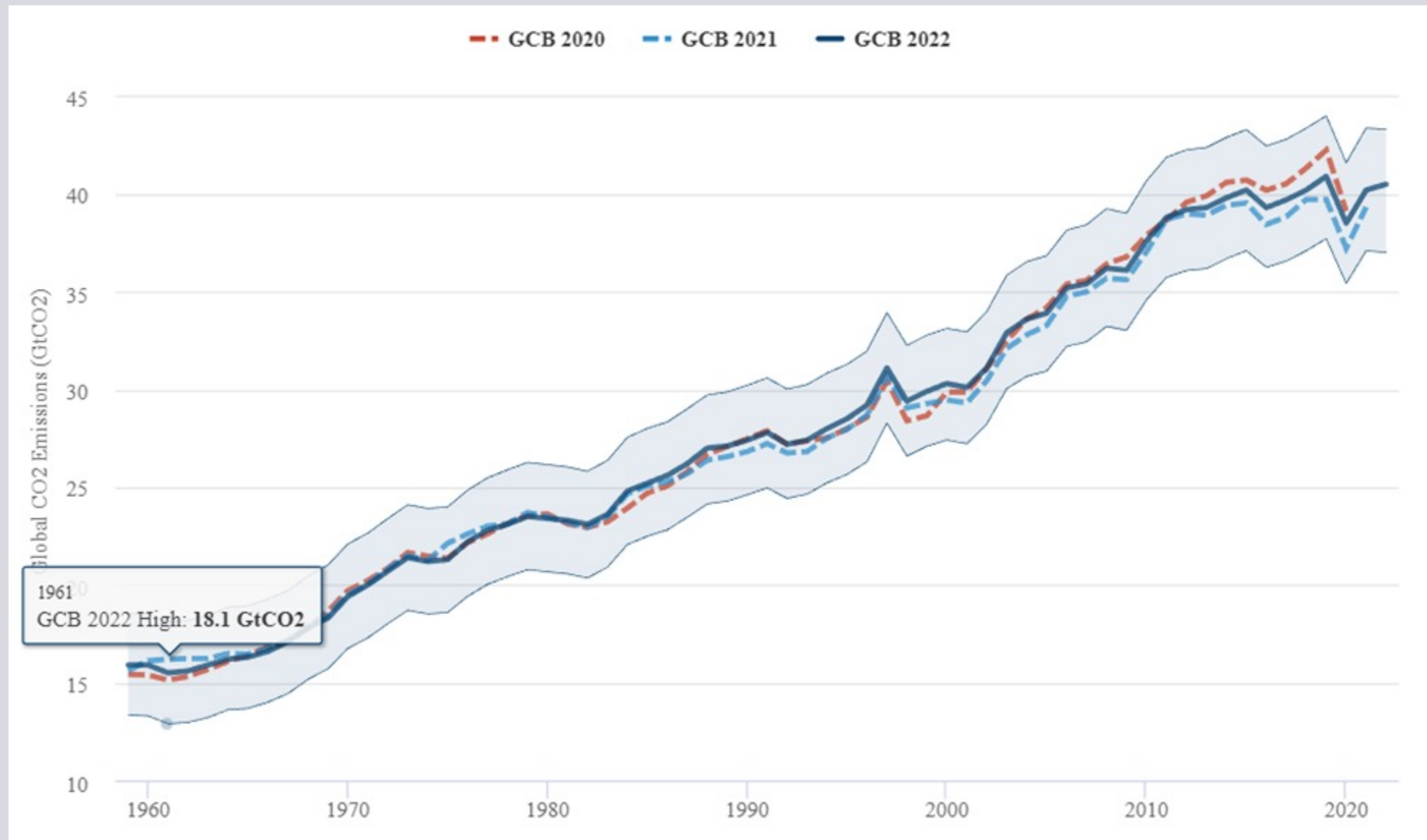
(epa.gov)

Global greenhouse gas emissions have continued to increase, with unequal historical and ongoing contributions arising from unsustainable energy use, land use and land-use change, lifestyles and patterns of consumption and production across regions, between and within countries, and among individuals (high confidence). (IPCC, 2023)

Emissions of GHG have increased rapidly over recent decades. Global net anthropogenic GHG emissions include CO₂ from fossil fuel combustion and industrial processes (CO₂-FFI) (dark green); net CO₂ from land use, land-use change and forestry (CO₂-LULUCF) (green); CH₄; N₂O; and fluorinated gases (HFCs, PFCs, SF₆, NF₃) (light blue). These emissions have led to increases in the atmospheric concentrations of several GHGs including the three major well-mixed GHGs CO₂, CH₄ and N₂O (IPCC, 2023).

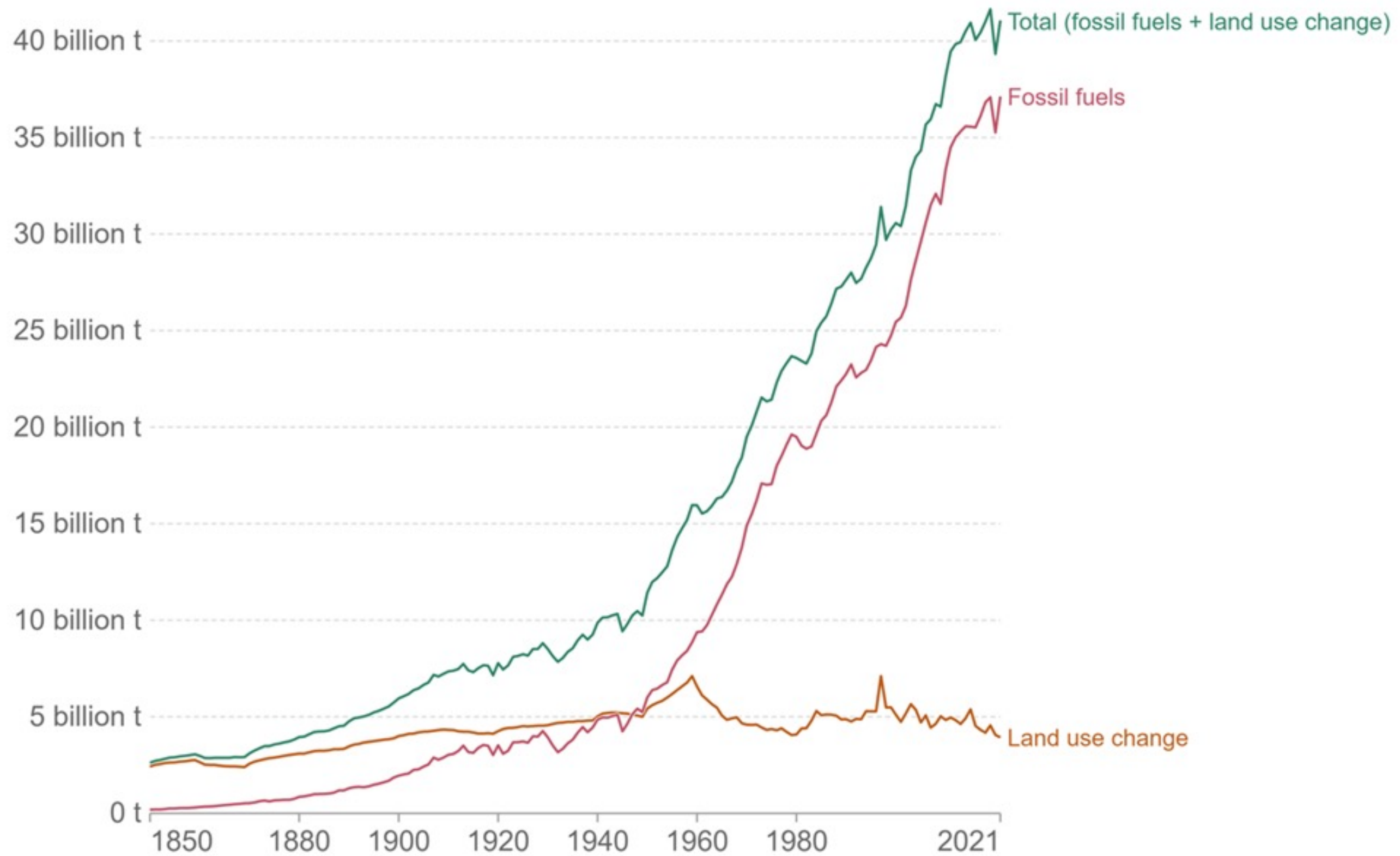


IPCC, 2023



Annual total global CO2 emissions – from fossil and land-use change – between 1959 and 2022 for the 2020, 2021 and 2022 versions of the Global Carbon Project’s Global Carbon Budget, in billions of tonnes of CO2 per year (GtCO2). Shaded area shows the estimated one-sigma uncertainty for the 2022 budget. Data from the Global Carbon Project . (carbonbrief.org)

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



Global carbon dioxide emissions from fossil fuels and cement have increased by 1.0% in 2022, new estimates suggest, hitting a new record high of 36.6bn tonnes of CO₂ (GtCO₂).

The increase in fossil emissions in 2022 has been primarily driven by a strong increase in oil emissions as global travel continues to recover from the Covid-19 pandemic. Coal and gas emissions grew more slowly, though both had record emissions in 2022.

Total global CO₂ emissions – including land use and fossil CO₂ – increased by approximately 0.8% in 2022, driven by a combination of steady land-use emissions between 2021 and 2022 and increasing fossil CO₂ emissions.

(carbonbrief.org)

What is climate change?

Climate change refers to a change in the state of the climate that can be identified (e.g., by using statistical tests) by changes in the mean and/or the variability of its properties, and that persists for an extended period, typically decades or longer.

Climate change may be due to natural internal processes or external forcings such as modulations of the solar cycles, volcanic eruptions and persistent anthropogenic changes in the composition of the atmosphere or in land use (IPCC).

"Climate change" means a change of climate which is attributed directly or indirectly to human activity that alters the composition of the global atmosphere and which is in addition to natural climate variability observed over comparable time periods ([UNFCCC, 1992 Article 1\(2\)](#)).



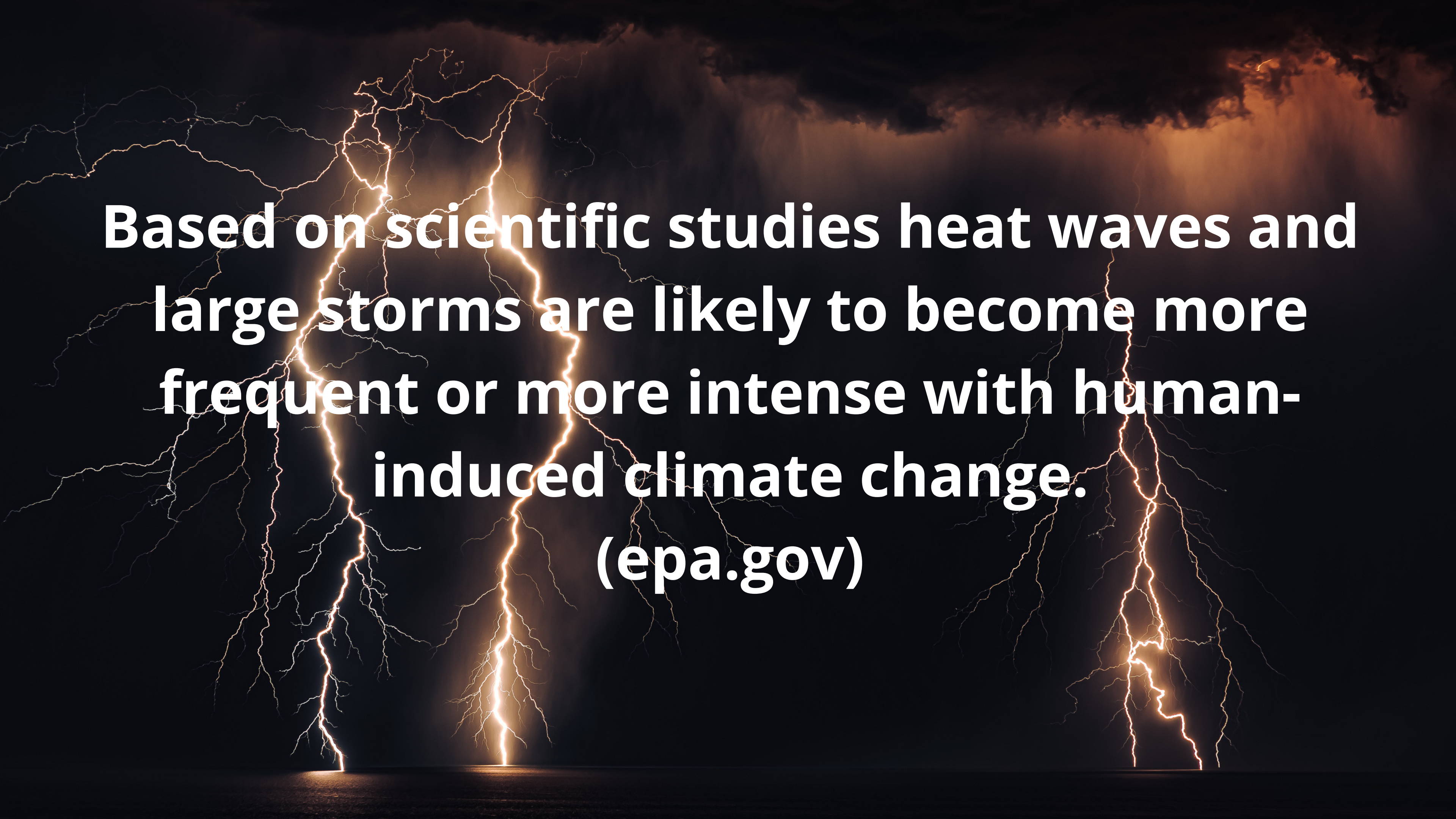
Widespread and rapid changes in the atmosphere, ocean, cryosphere and biosphere have occurred. Human-caused climate change is already affecting many weather and climate extremes in every region across the globe. This has led to widespread adverse impacts and related losses and damages to nature and people (high confidence). Vulnerable communities who have historically contributed the least to current climate change are disproportionately affected (high confidence).

(IPCC, 2023)



**Rising global average temperature is associated
with widespread changes in weather patterns.
(epa.gov)**


**Some of this warming will occur even if future
greenhouse gas emissions are reduced, because the
Earth system has not yet fully adjusted to
environmental changes we have already made.
(nasa.gov)**



Based on scientific studies heat waves and large storms are likely to become more frequent or more intense with human-induced climate change.

([epa.gov](https://www.epa.gov))

Africa had an annual temperature of $+1.01^{\circ}\text{C}$ ($+1.82^{\circ}\text{F}$), which is the 10th highest in the continent's 113-year record. Despite being above-average, this value was the smallest annual temperature for Africa since 2014. The year 2022 marked Africa's 46th consecutive year with temperatures above average. Africa's 10 warmest years have occurred since 2005. Africa's annual temperature has increased at an average rate of 0.13°C (0.23°F) per decade since 1910; however, it has more than doubled to 0.28°C (0.50°F) since 1981. (ncei.noaa.gov 2023)



Scientists have delivered a “final warning” on the climate crisis, as rising greenhouse gas emissions push the world to the brink of irrevocable damage that only swift and drastic action can avert. ([theguardian.com](https://www.theguardian.com))