Climate is long-term weather.

The term “Climate Change” tries to capture the many large-scale chemical and physical changes that we are making to Earth's atmosphere, oceans, soils and species distribution – in addition to altering Earth’s weather.

- The atmospheric concentration of CO_2 is the highest in at least 2 million years.
- The atmospheric concentration of CH_4 and N_2O are the highest in at least 800,000 years.
- Since 1950, increases in CO_2 and CH_4 far exceed the natural multi-millennial cycles of the past 800,000 years.

https://www.ipcc.ch/report/ar6/wg1/downloads/report/IPCC_AR6_WGI_SPM.pdf

Climate status update

- 2023 was the warmest year ever recorded
- 77 countries set record high annual average temperatures, including China, Brazil, Japan, Germany and Mexico
- Both land and ocean individually also set new records for the warmest year

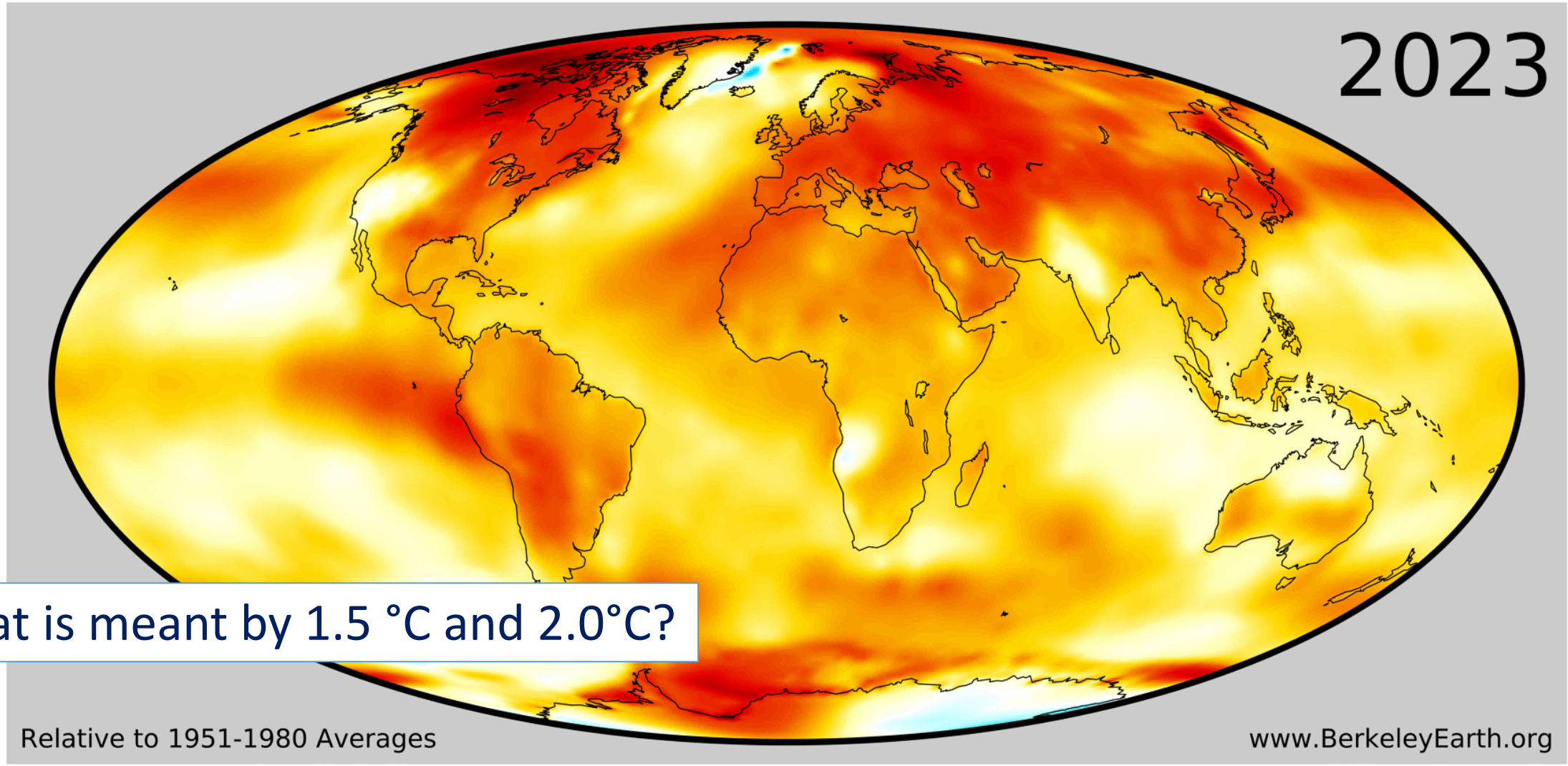
https://berkeleyearth.org/global-temperature-report-for-2023/

Climate status update

- 2023 was the first time that any year has exceeded the key 1.5 °C threshold (1.54 °C)

- The last nine years have included all nine of the warmest years observed in the instrumental record

https://berkeleyearth.org/global-temperature-report-for-2023/



What is meant by 1.5 °C and 2.0°C?

https://berkeleyearth.org/global-temperature-report-for-2023/

Monday, August 9, 2021
Today's Paper

The New York Times

A Hotter Future Is Certain, Climate Panel Warns. But How Hot Is Up to Us.

- Nations have delayed curbing emissions for so long that global warming will inevitably intensify over the next 30 years, a major U.N. report found.
- There is a short window to avoid the most harrowing future, the report said. Doing so would require a coordinated international effort starting immediately.

The Dixie Fire destroyed one town and forced thousands to flee their homes in Northern California. David Swanson/Reuters

Greenhouse gasses from Fourier to Keeling to Vostok

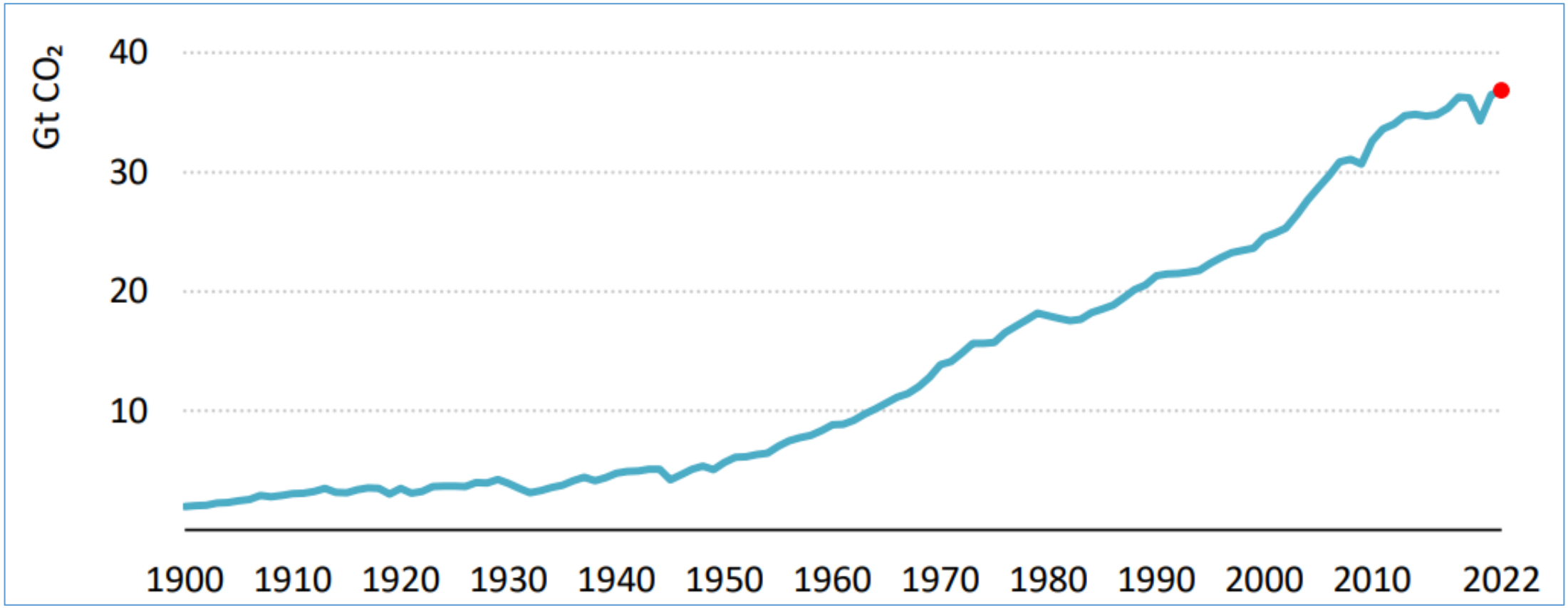
Ivanka Trump
@IvankaTrump

FACT: Greenhouse gases generated by the U.S. will slide 9.2% this year, tumbling to the lowest level in at least three decades. @EPA

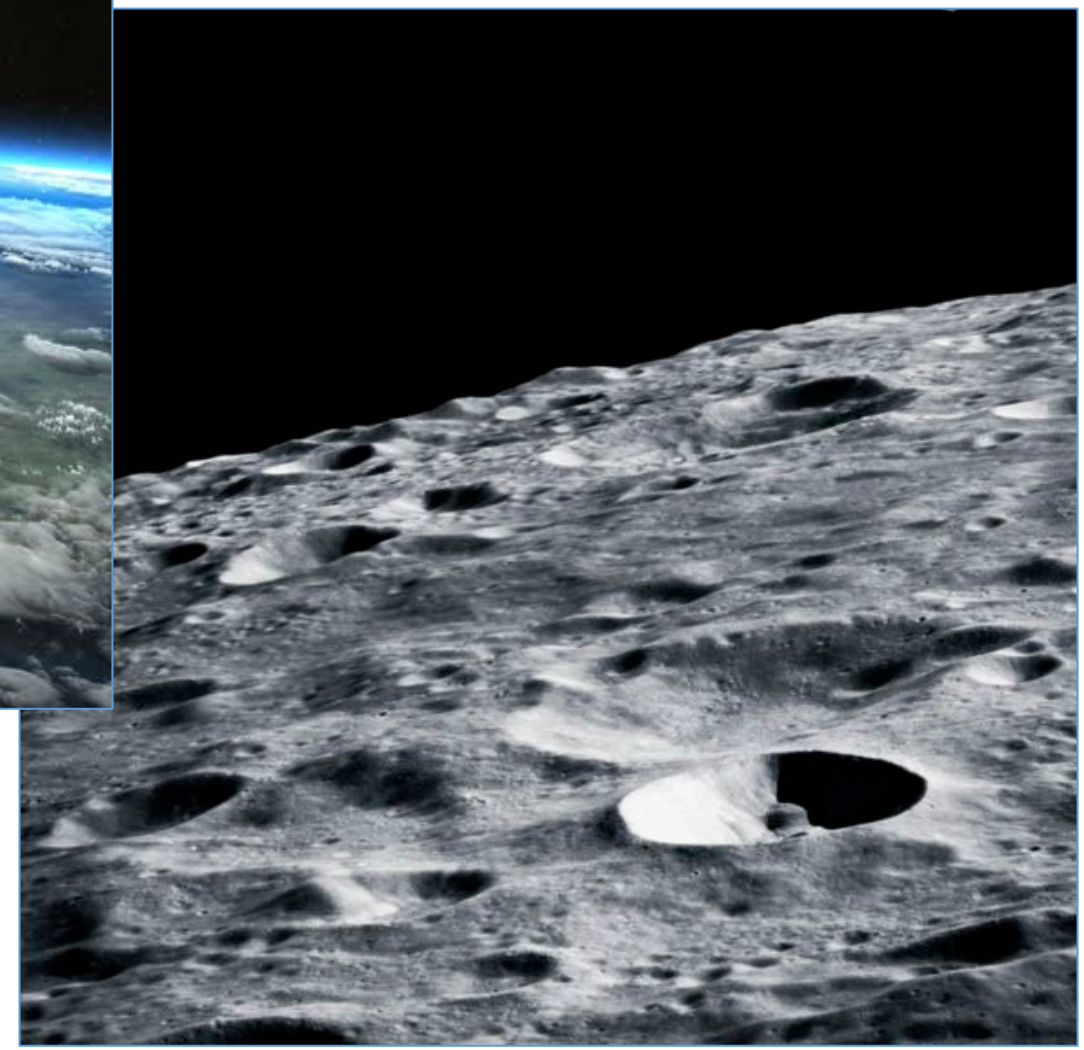
7:40 AM · Nov 24, 2020

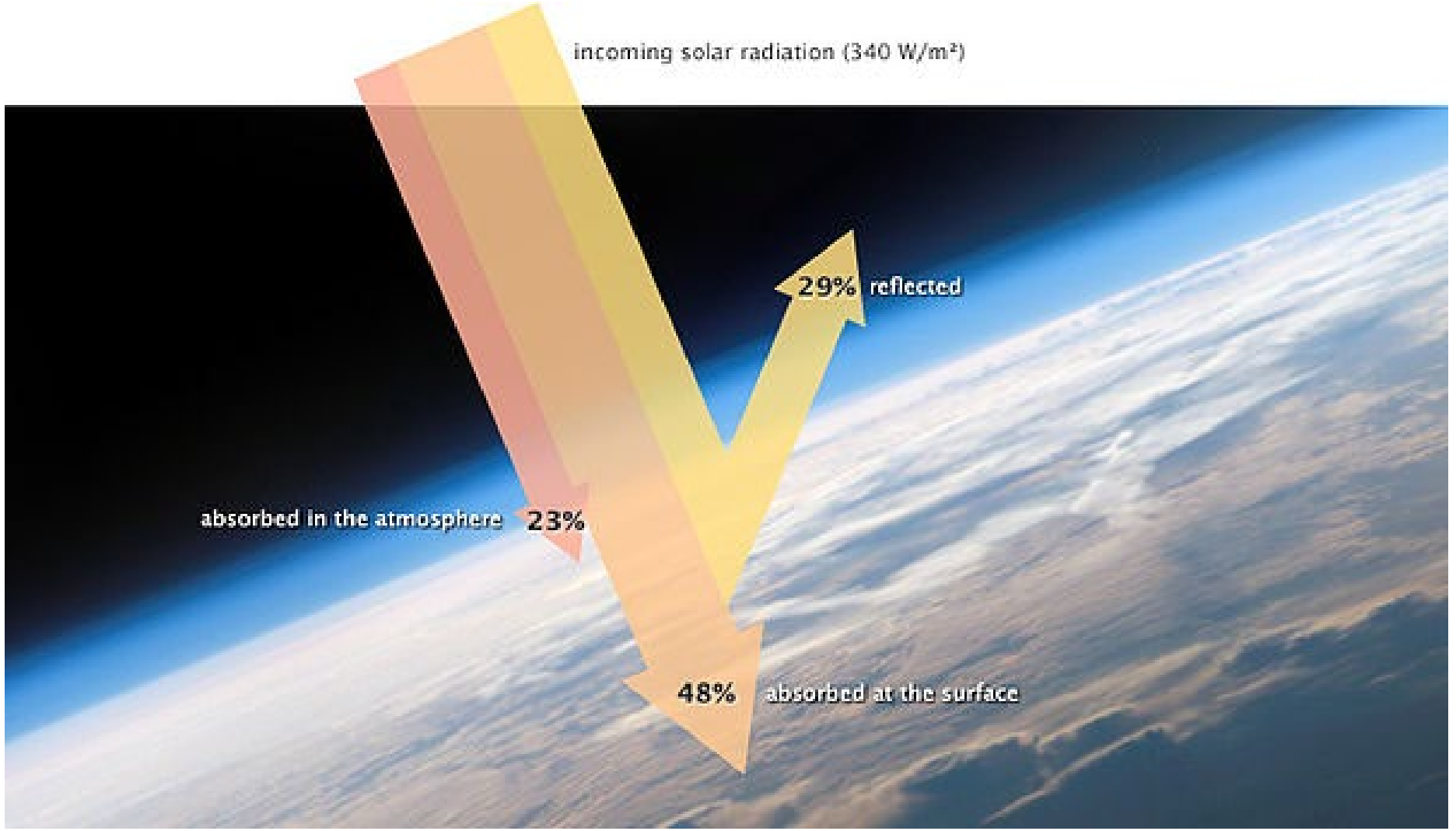
60.6K 33.3K people are Tweeting about this

Global CO_2 emissions from fossil fuel combustion

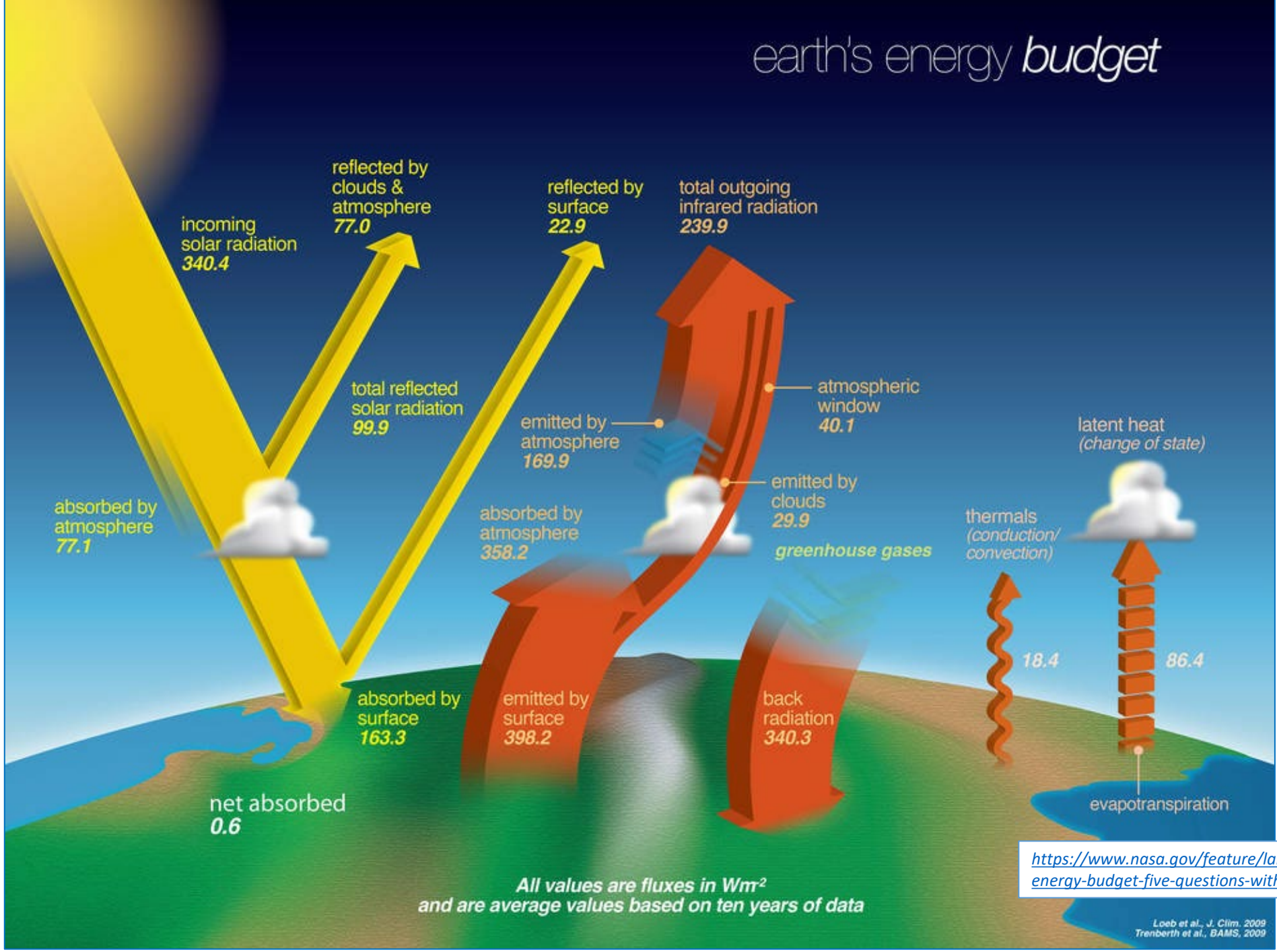


IEA - Global Energy Review – March 2, 2023 - https://www.iea.org/reports/co2-emissions-in-2022





https://www.nasa.gov/feature/langley/what-is-earth-s-energy-budget-five-questions-with-a-guy-who-knows



https://www.nasa.gov/feature/langley/what-is-earth-s-energy-budget-five-questions-with-a-guy-who-knows

99% =

$N_2 + O_2 + Ar$

Greenhouse Gas	Formula	100-year GWP (AR4)
Carbon dioxide	CO_2	1
Methane	CH_4	25
Nitrous oxide	N_2O	298
Sulphur hexafluoride	SF_6	22,800
Hydrofluorocarbon-23	CHF_3	14,800
Hydrofluorocarbon-32	CH_2F_2	675
Perfluoromethane	CF_4	7,390
Perfluoroethane	C_2F_6	12,200
Perfluoropropane	C_3F_8	8,830
Perfluorobutane	C_4F_{10}	8,860
Perfluorocyclobutane	c-C_4F_8	10,300
Perfluoropentane	C_5F_{12}	13,300
Perfluorohexane	C_6F_{14}	9,300

https://www.theconsciouschallenge.org/ecologicalfootprintbibleoverview/climate-change-global-overview

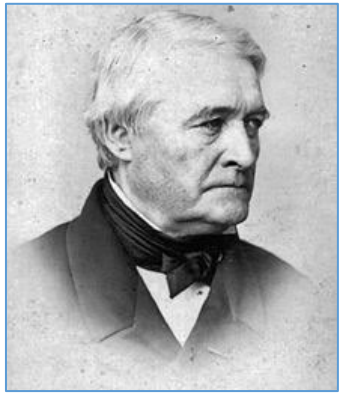
The greenhouse effect is the process by which radiation from a planet's atmosphere warms the planet's surface to a temperature above what it would be without the presence of “Greenhouse” heat-trapping gasses in its atmosphere.

Greenhouse gases add to the warmth of a planet’s surface by trapping heat emitted from the surface and re-radiating it back to the surface.

Who figured this out?

1824: Joseph Fourier

- Proposed that Earth's atmosphere retains heat that would otherwise be emitted back into space

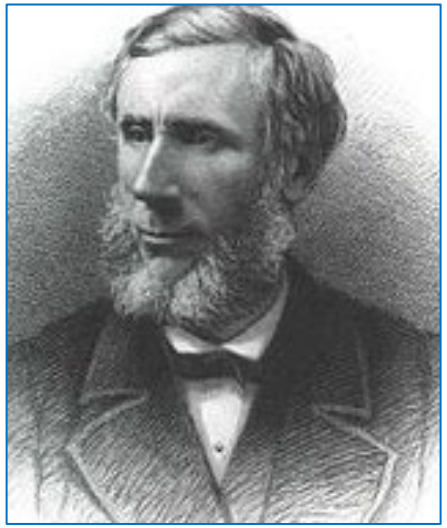


1827: Claude Pouillet

- Developed the first mathematical treatment of the greenhouse effect
- Speculated that water vapor and carbon dioxide might trap heat in the atmosphere

1856: Eunice Newton Foote

- First to show in experiments and put in print that if carbon dioxide levels were higher, the planet would be warmer

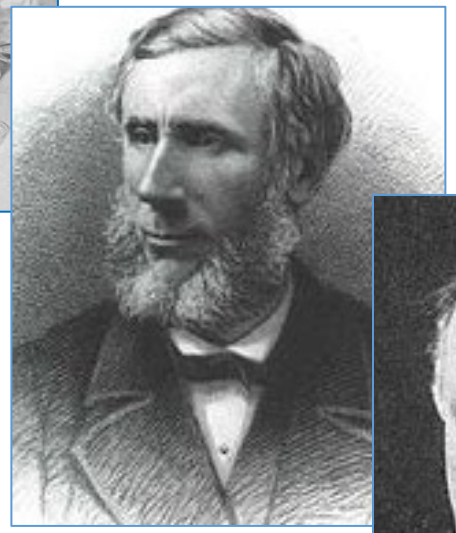


1859: John Tyndall

- Showed the ability of gases like water vapor, carbon dioxide, ozone and hydrocarbons to absorb and re-emit heat

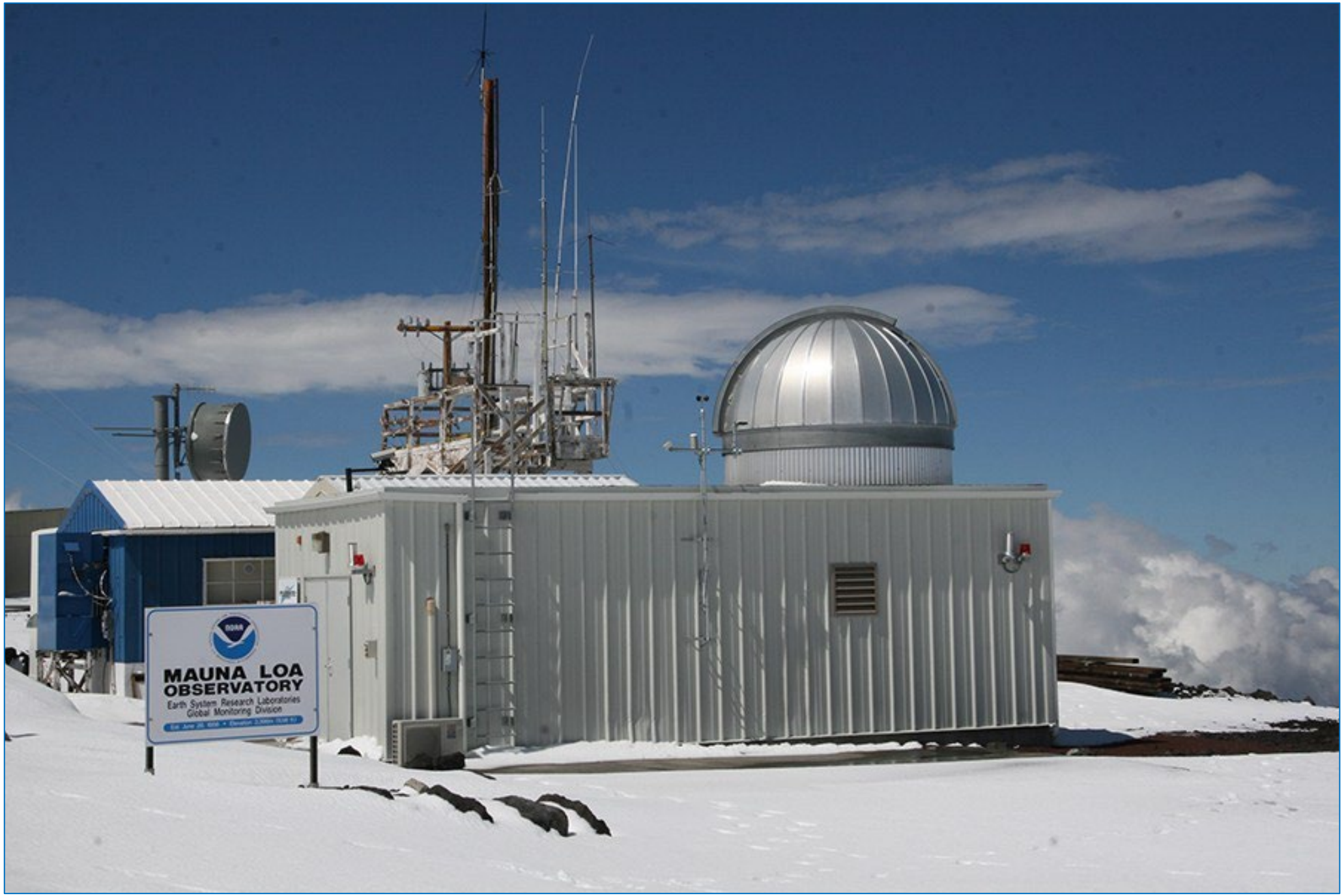
1896: Svante Arrhenius

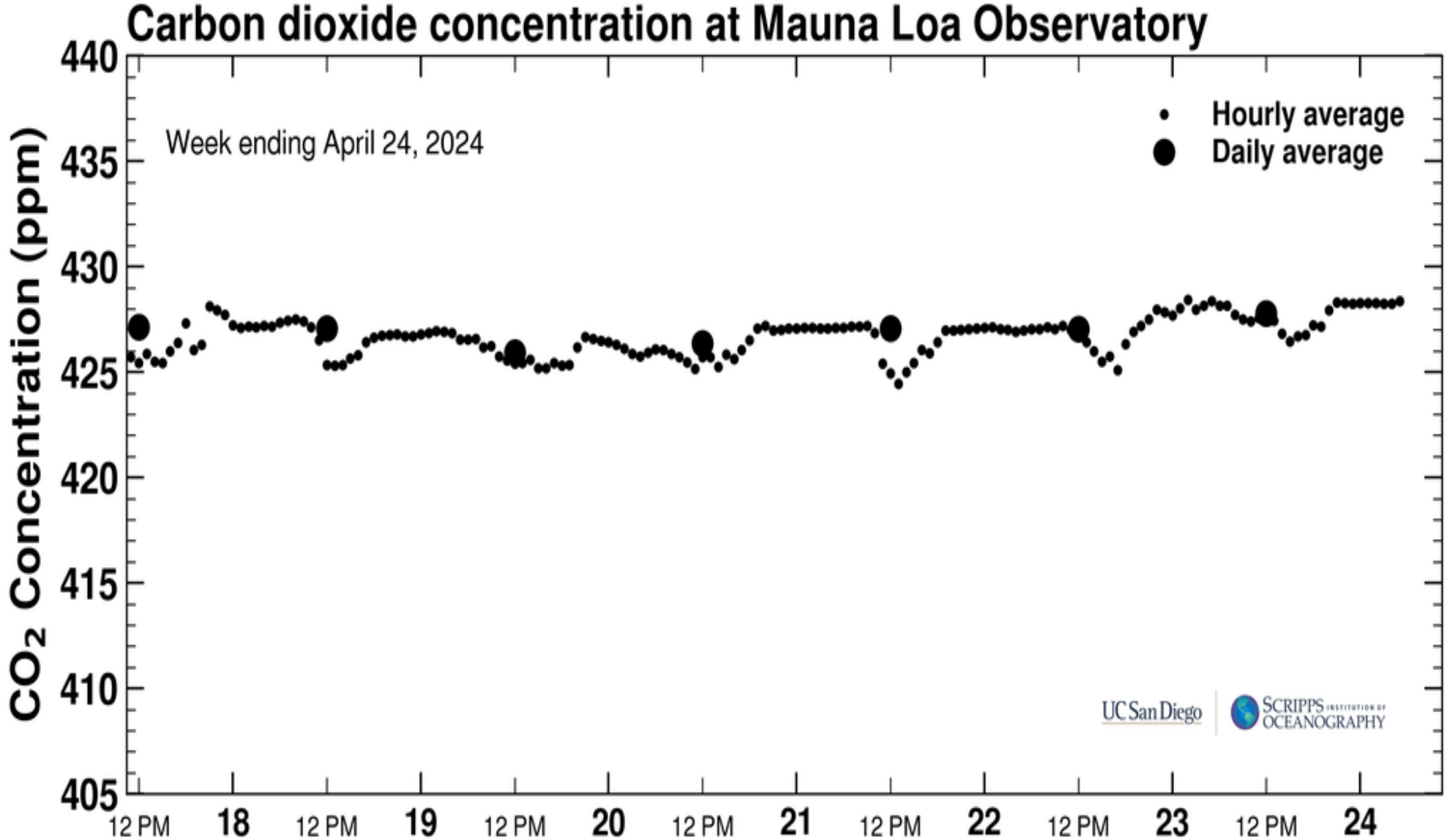
- First to use modern principles of physical chemistry to calculate how increases in CO_2 will increase Earth's surface temperature
- Concluded that human-caused CO_2 emissions, from fossil-fuel burning and other combustion processes, are large enough to cause global warming



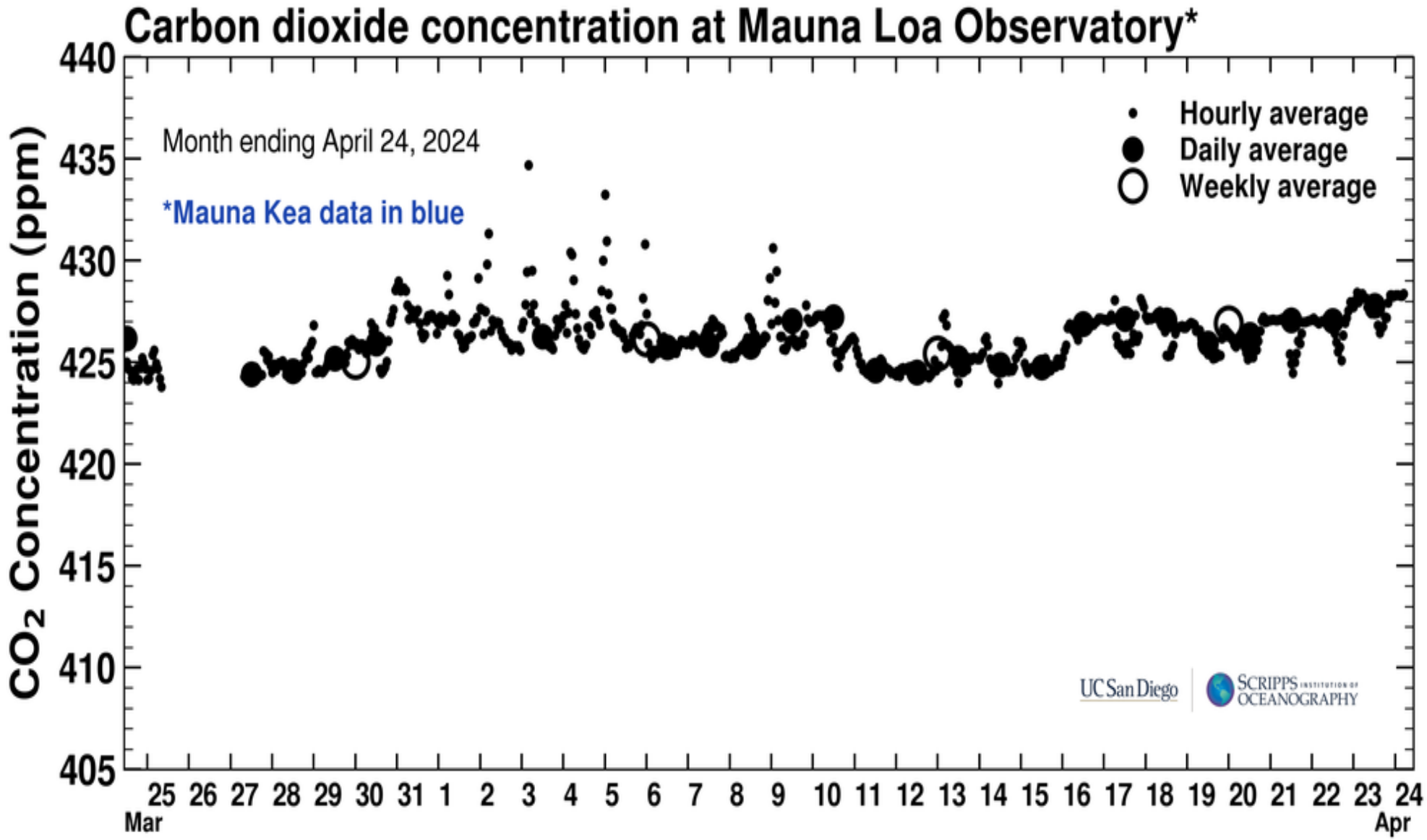
1824 ~ 1896

1958: Keeling

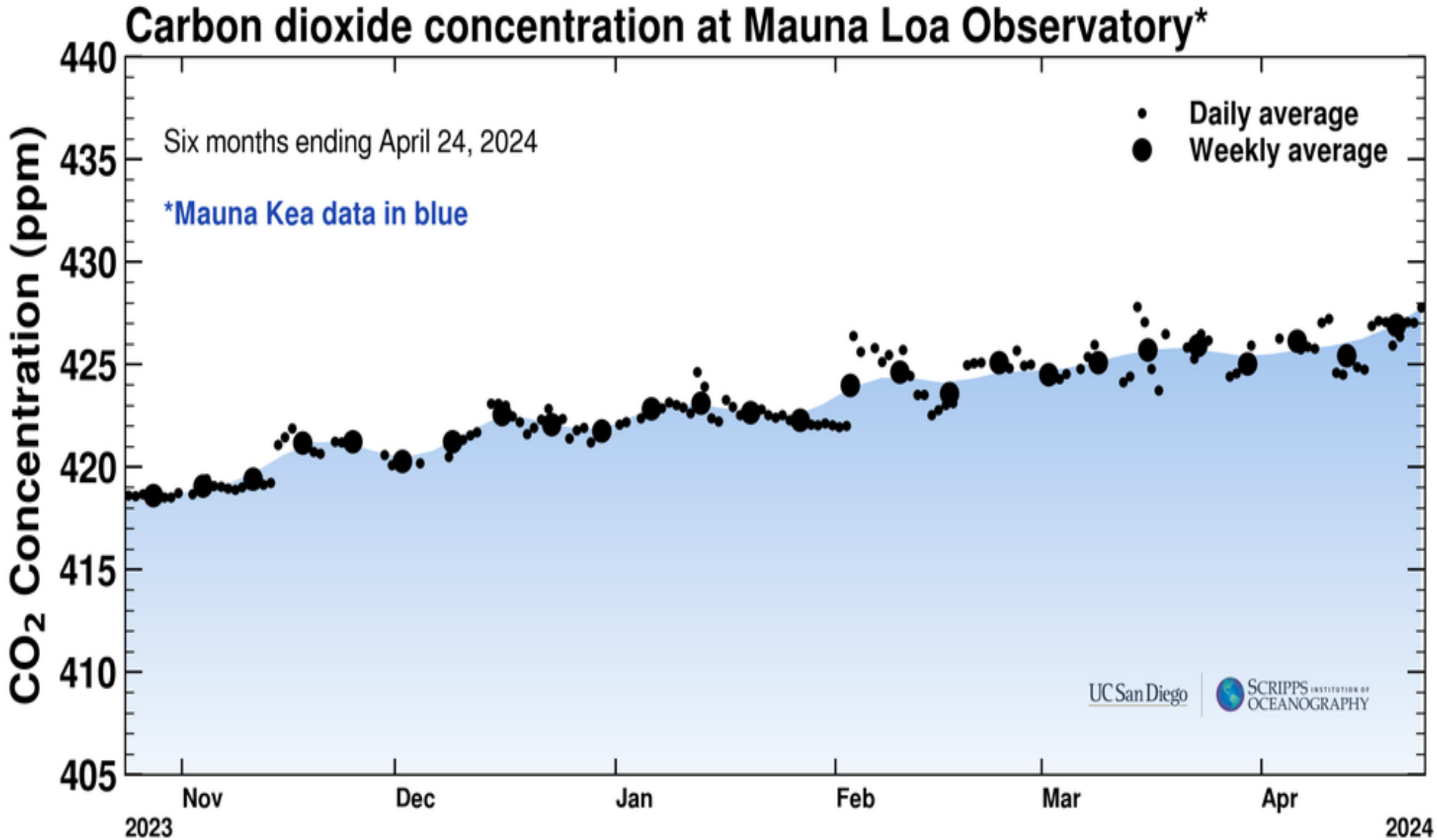

MAUNA LOA
OBSERVATORY
Earth System Research Laboratories
Global Monitoring Division



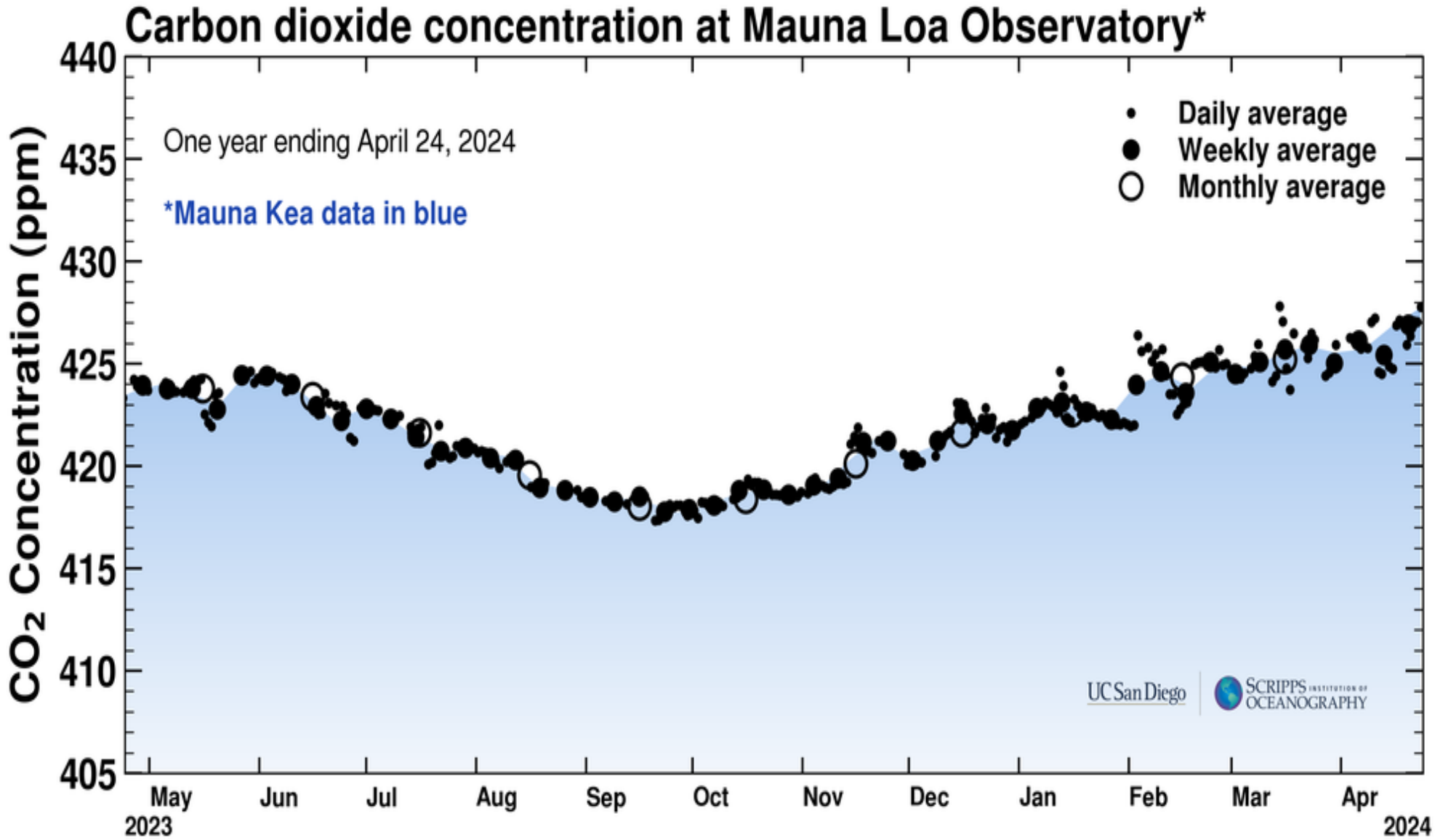
https://keelingcurve.ucsd.edu/



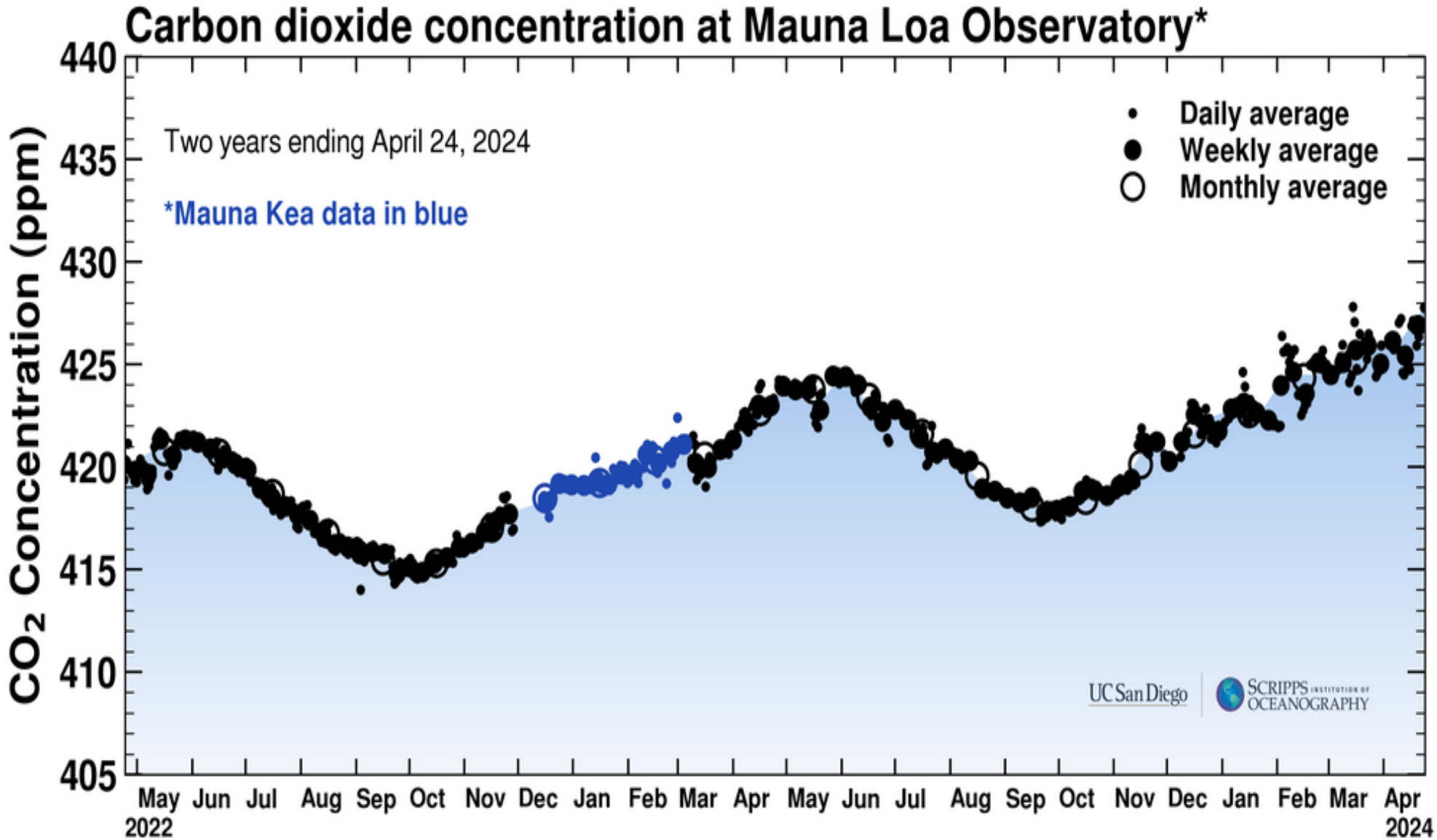
https://keelingcurve.ucsd.edu/



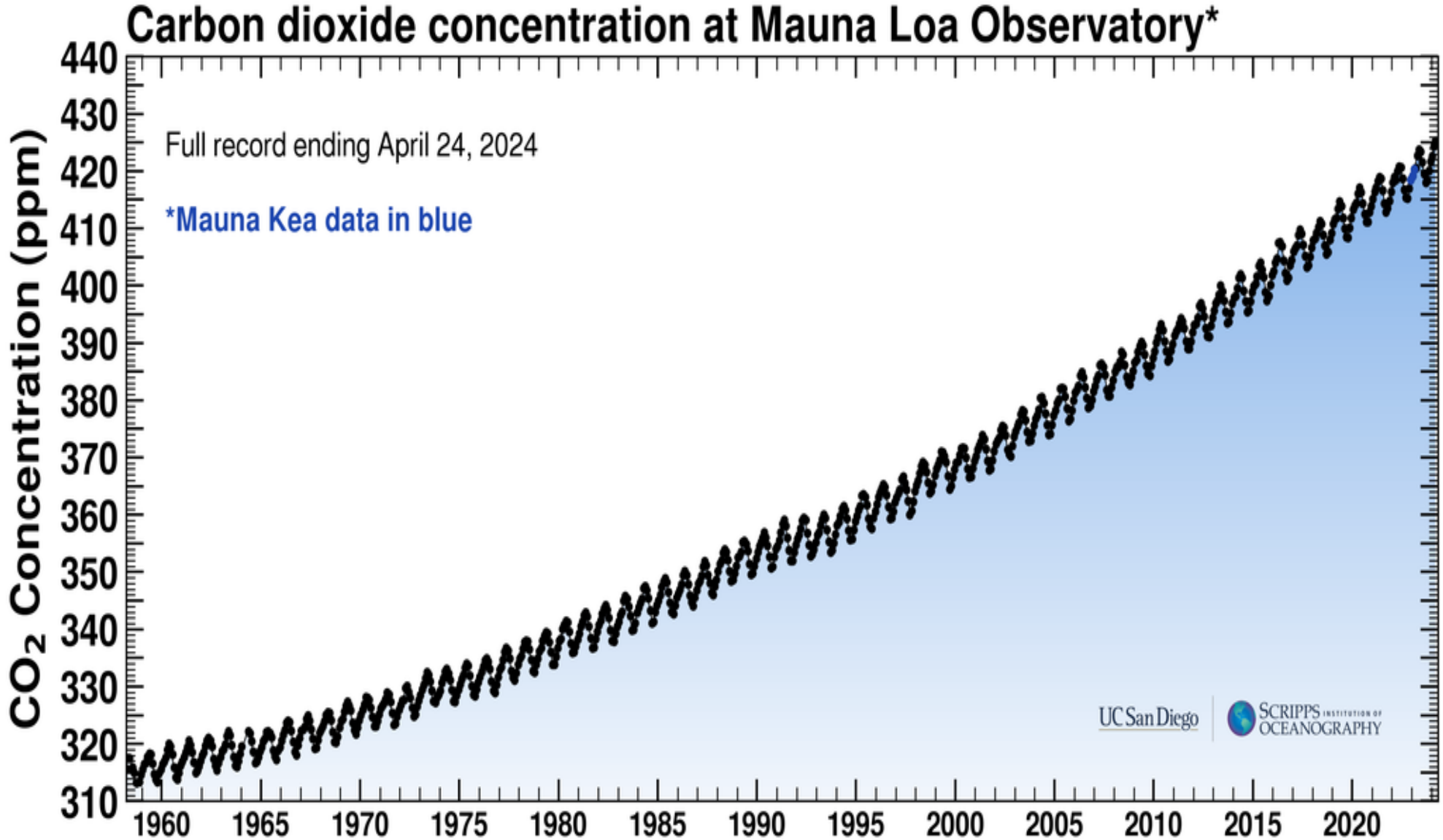
https://keelingcurve.ucsd.edu/



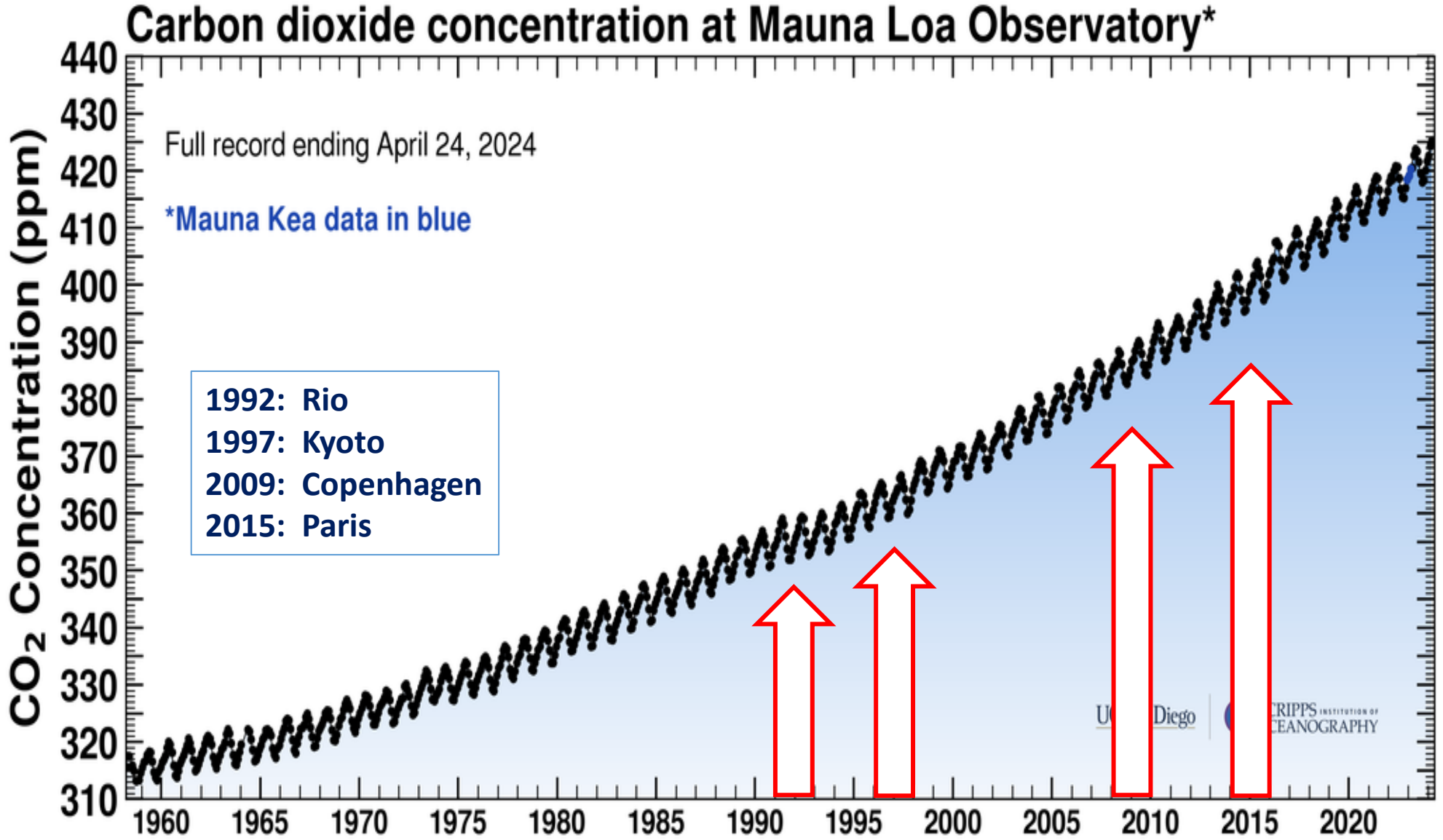
https://keelingcurve.ucsd.edu/



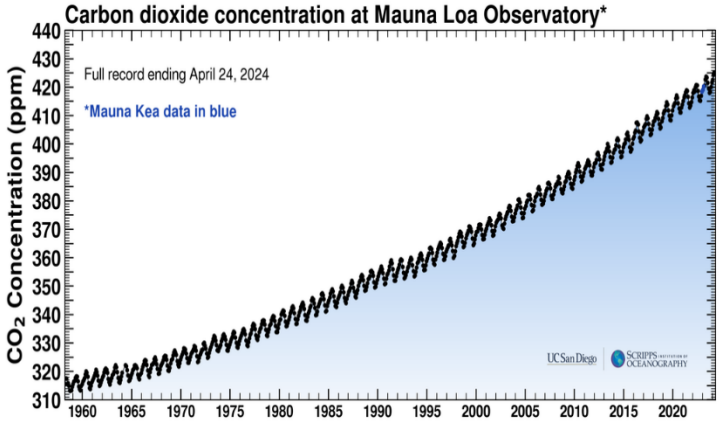
https://keelingcurve.ucsd.edu/



https://keelingcurve.ucsd.edu/

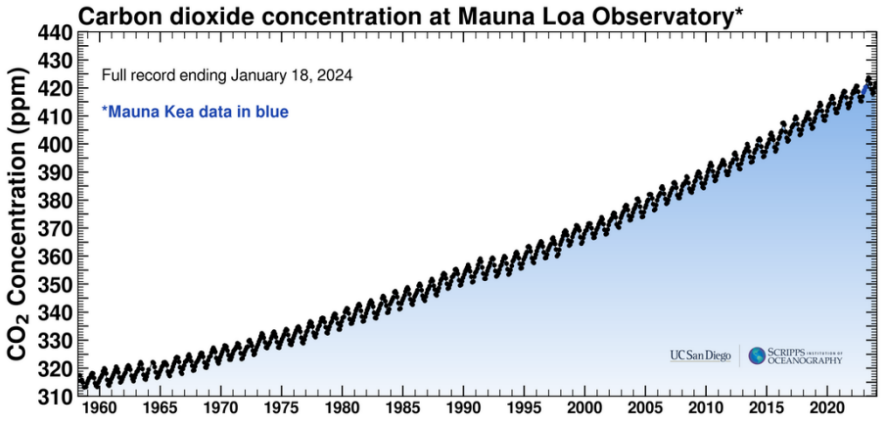


https://keelingcurve.ucsd.edu/



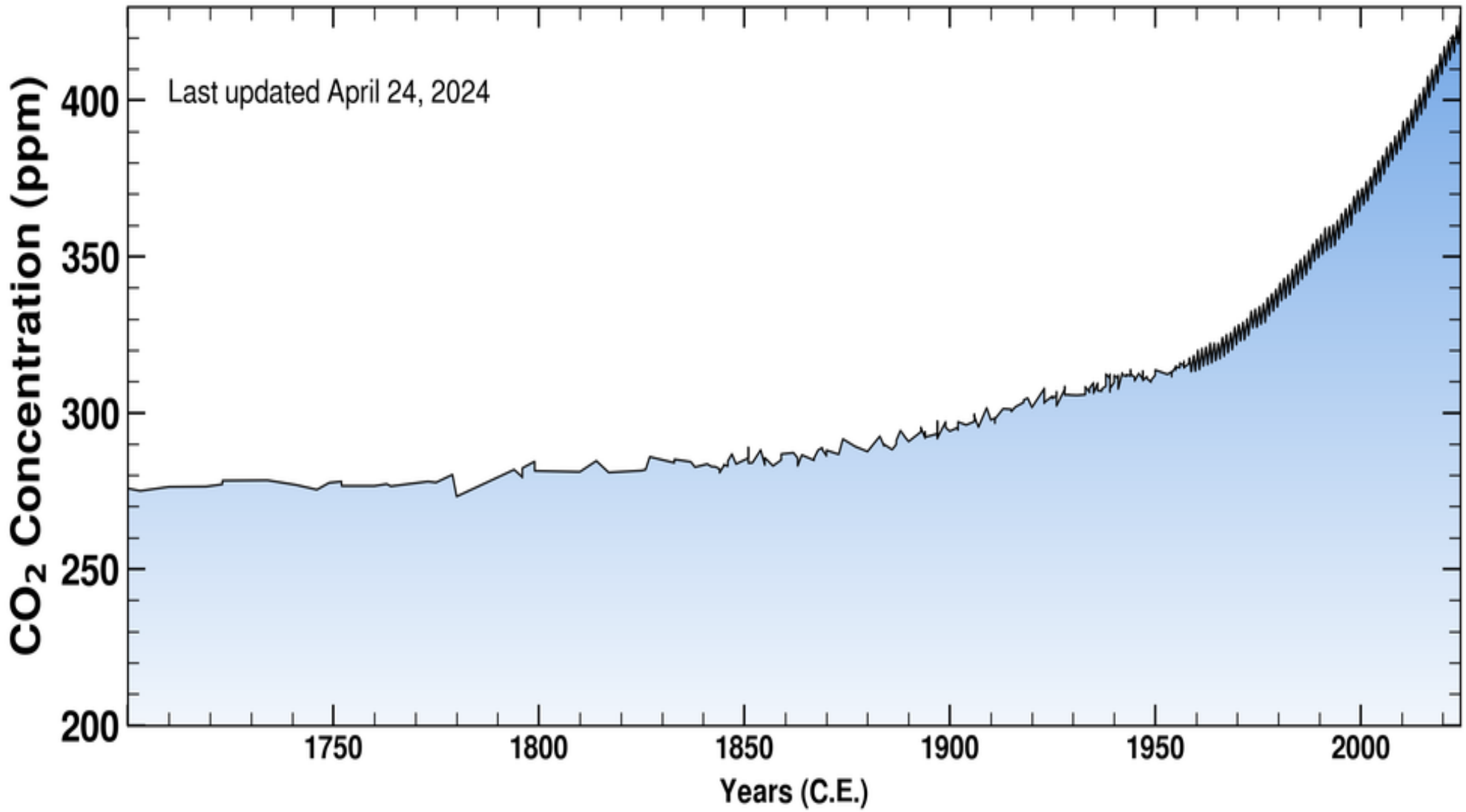
Take-aways regarding the Keeling Curve – the basics:

1. We know the concentration of CO_2 in the atmosphere.
2. We have an accurate, continuous record of CO_2 in the atmosphere.
3. We know the rate of change of CO_2 in the atmosphere.
4. We can observe that the rate of change is increasing.
5. We can observe that about half of emissions stay in the atmosphere.

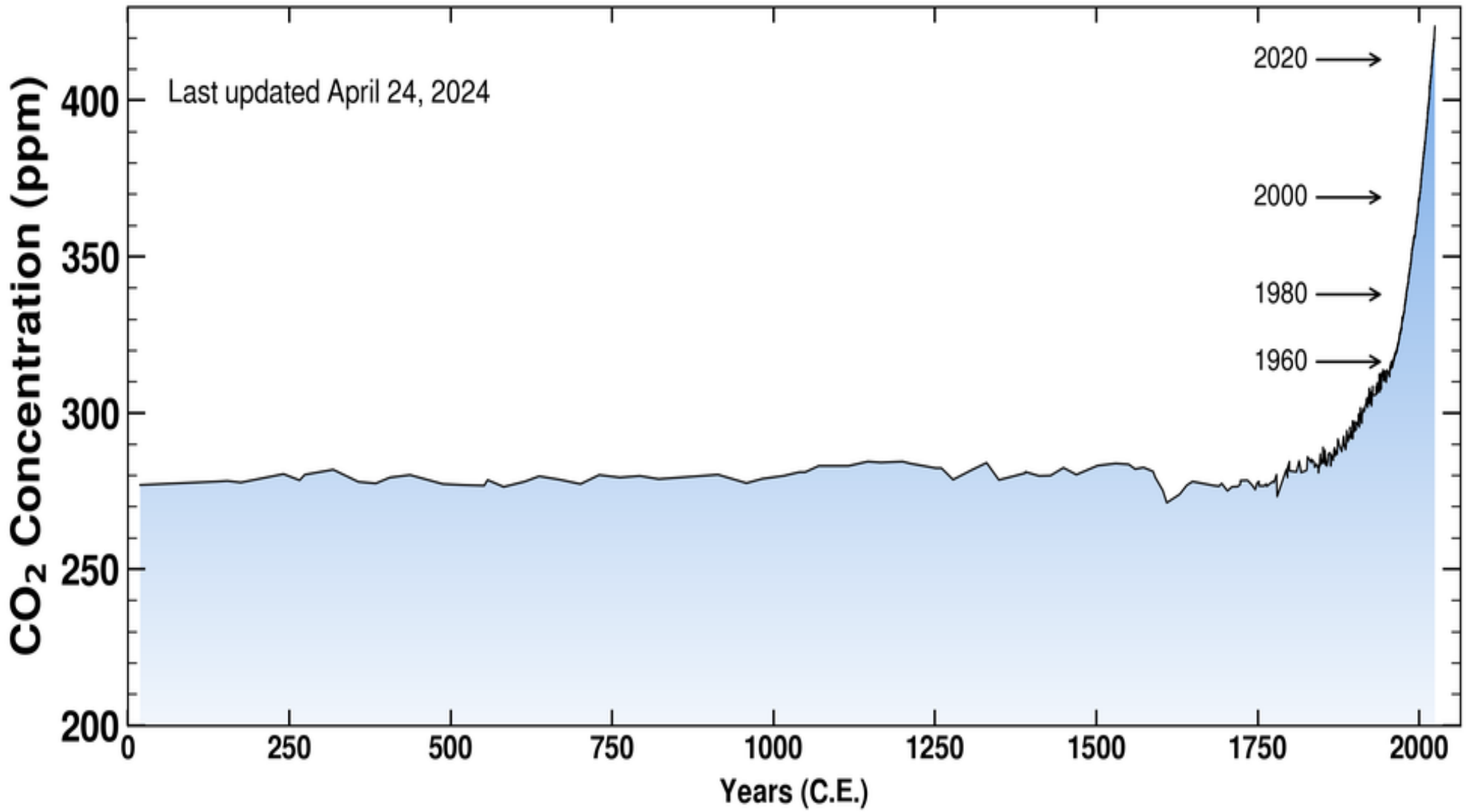


Take-aways regarding the Keeling Curve – the biggest points:

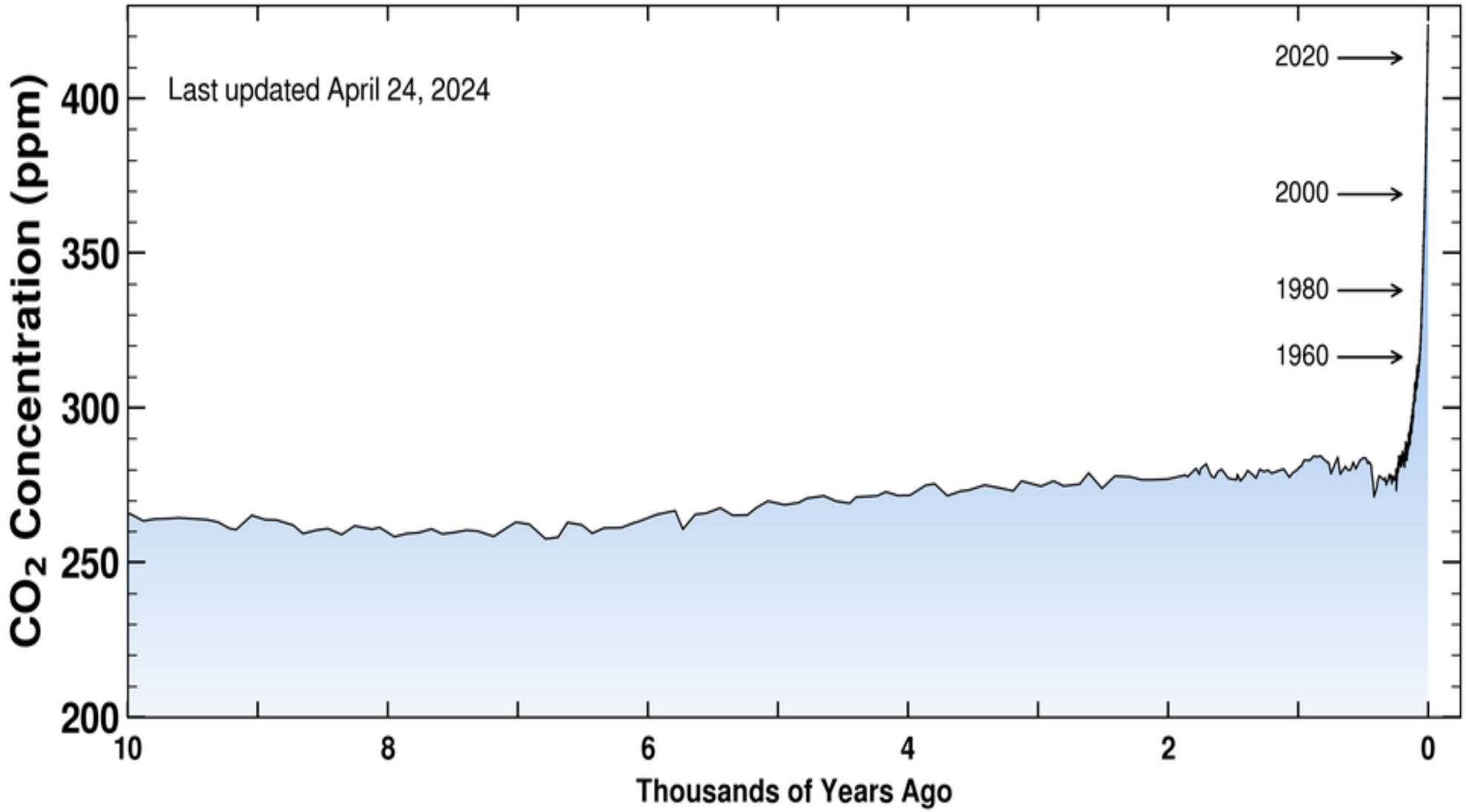
6. The vertical axis is global temperature a few decades out.
7. We have understood the significance of this for decades.
8. The Keeling Curve is a *leading* indicator of climate change.



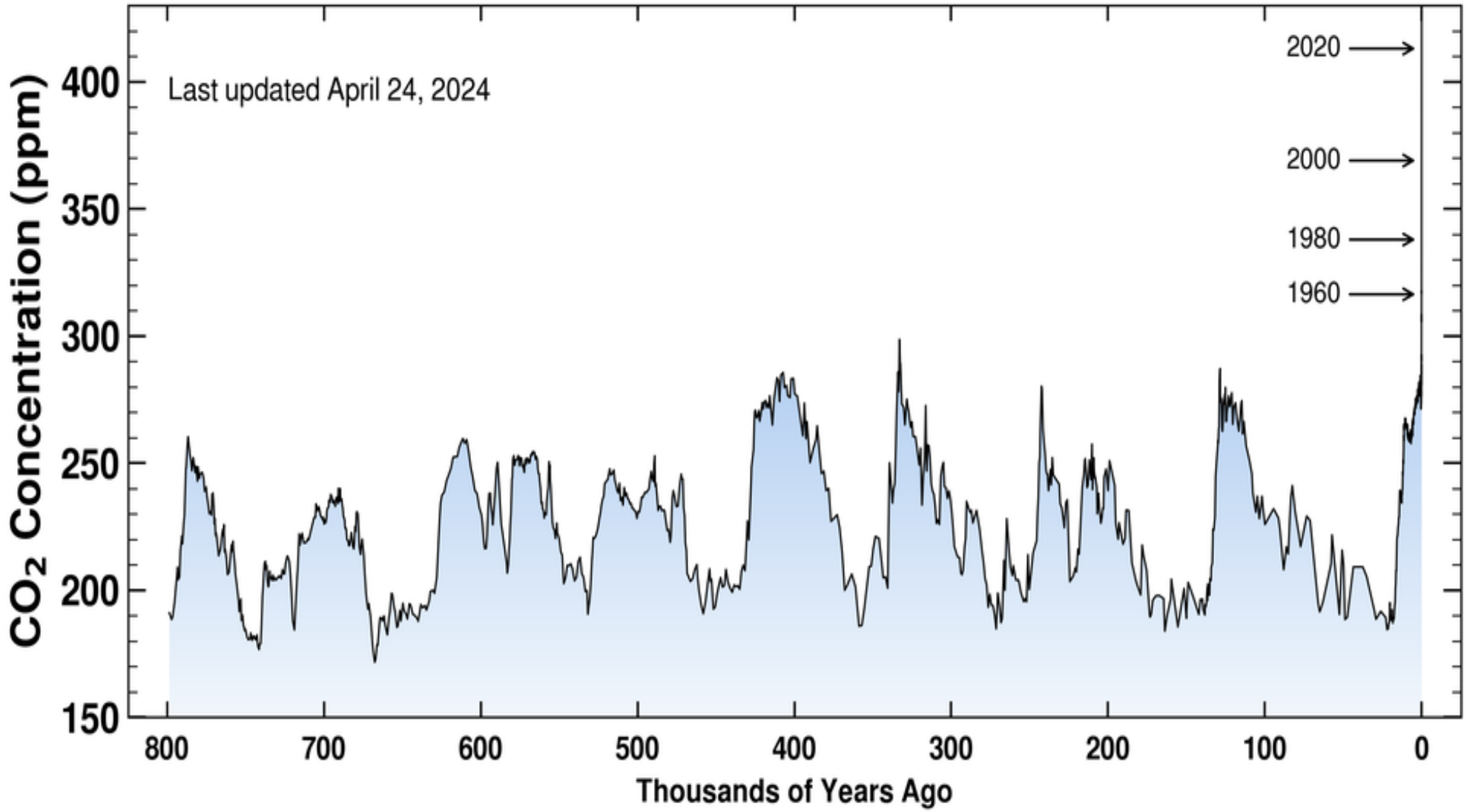
https://keelingcurve.ucsd.edu/



https://keelingcurve.ucsd.edu/



https://keelingcurve.ucsd.edu/



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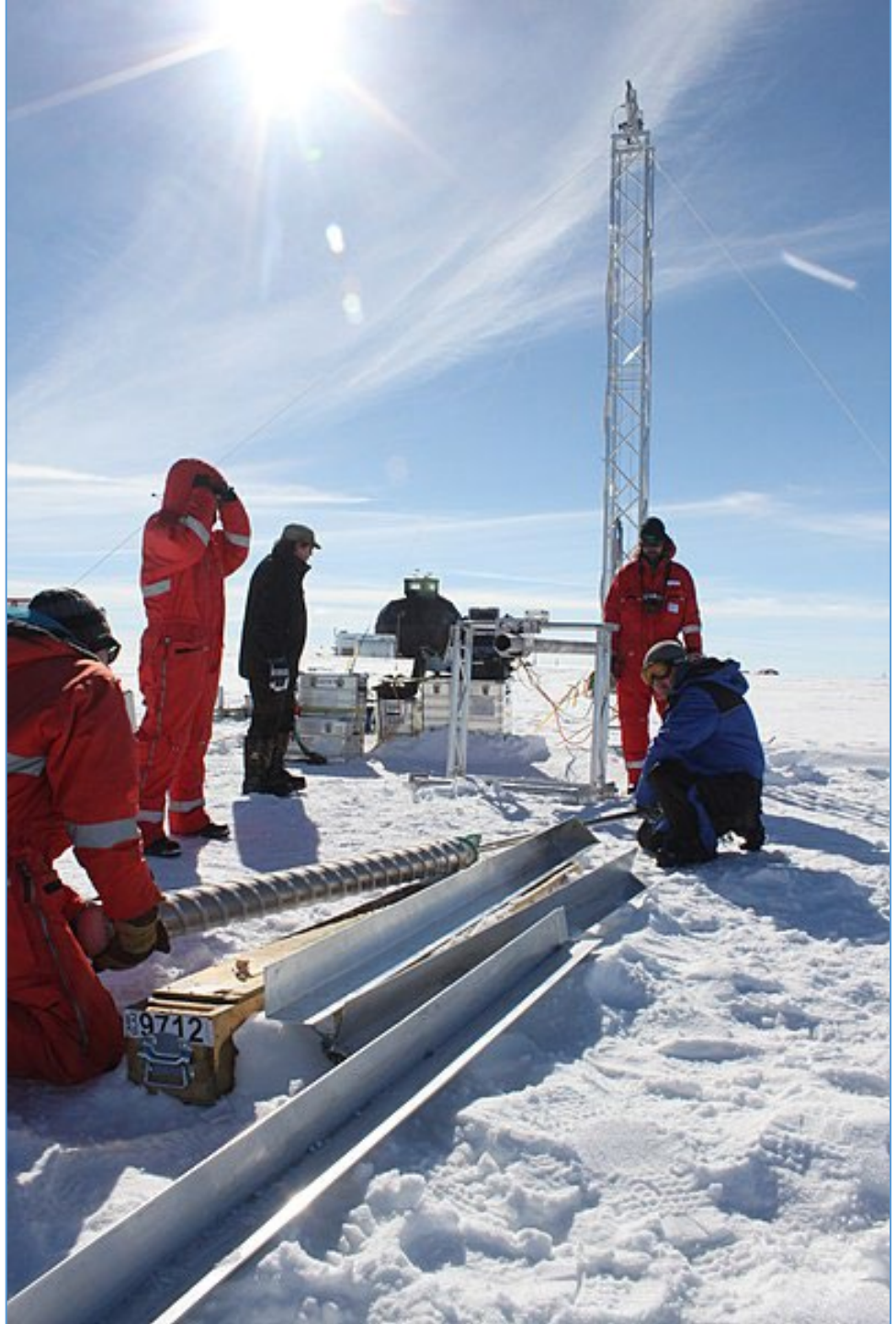
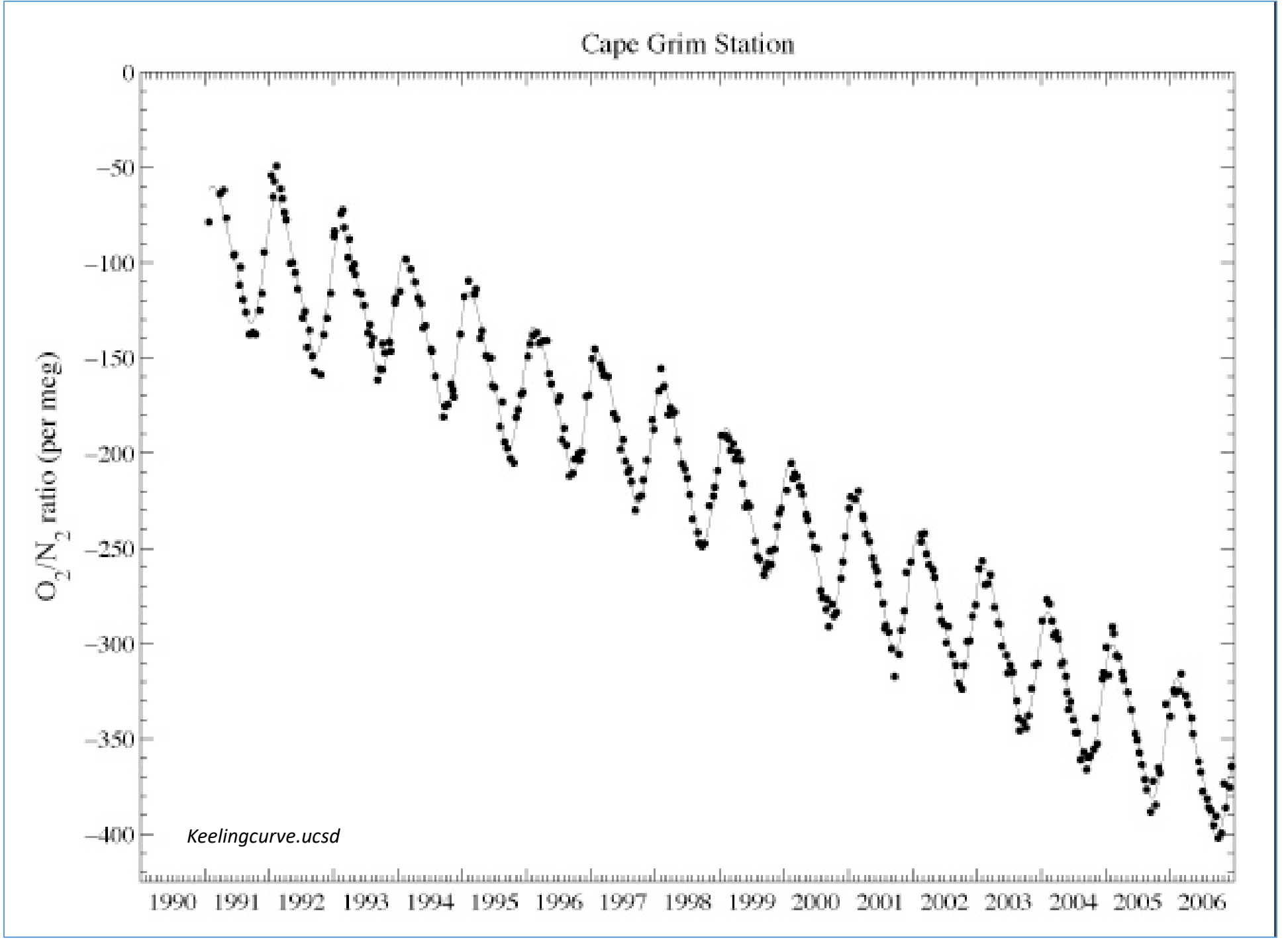


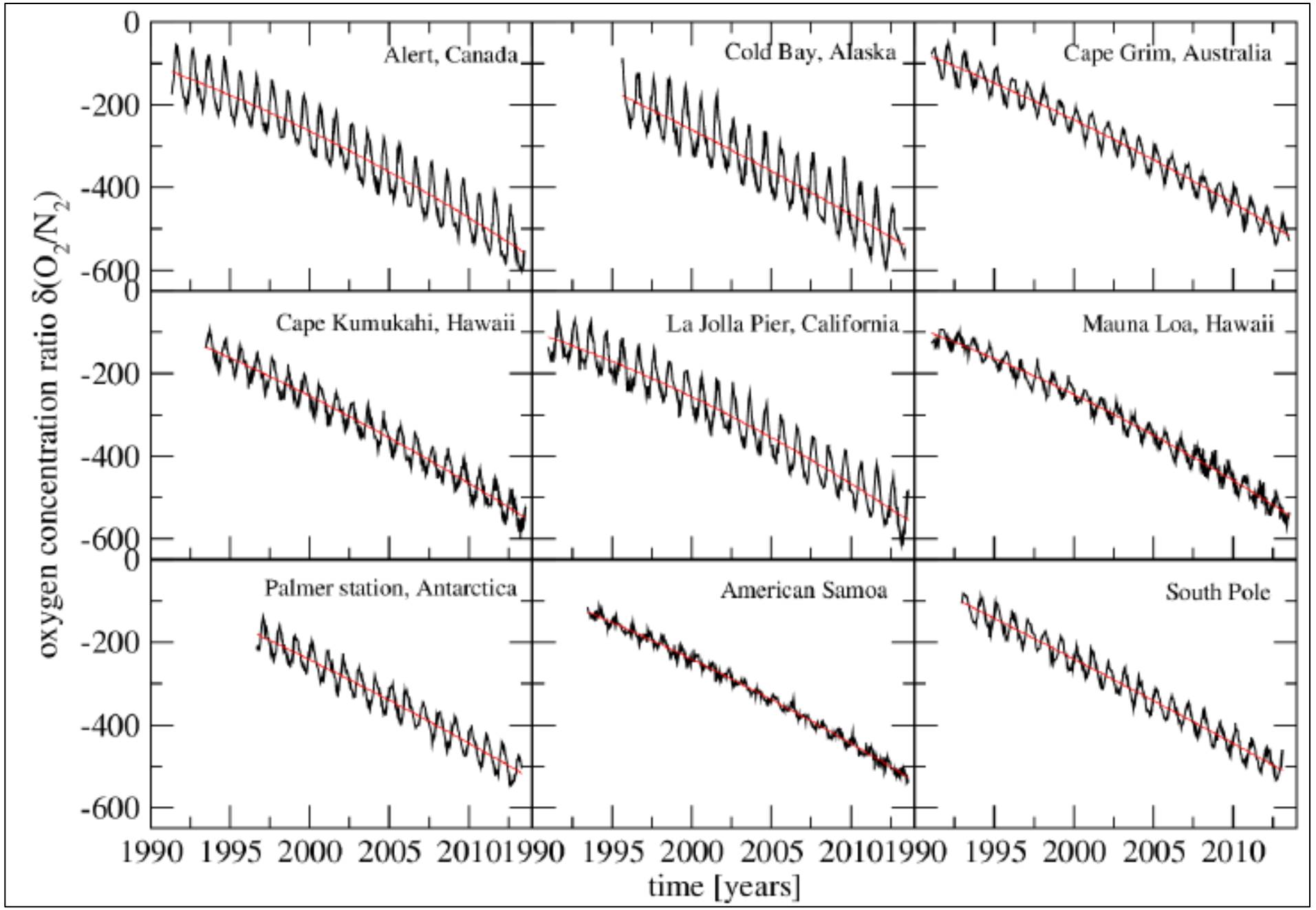
Paleoclimatology in Antarctica and on Greenland

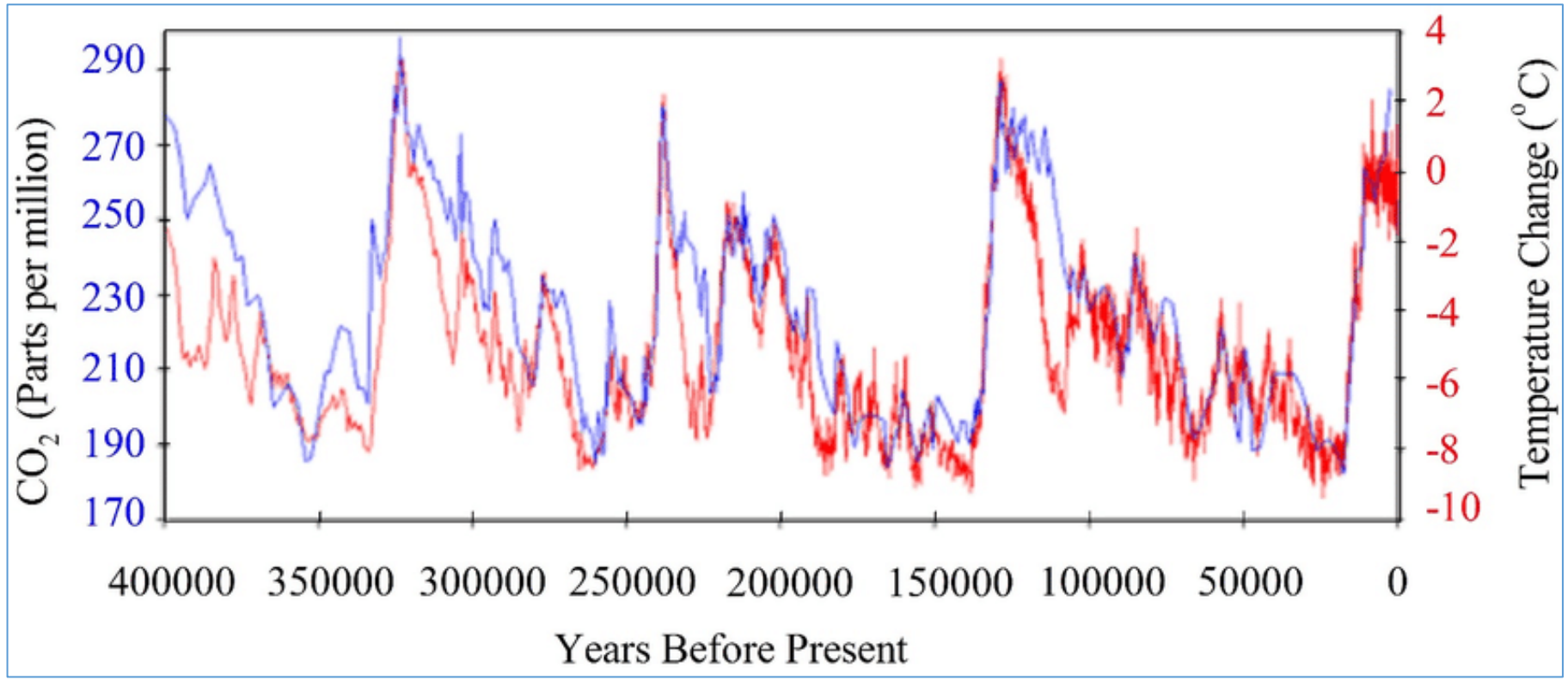
Where is all the CO_2 coming from?

$$CH_4 + 2O_2 \rightarrow 2H_2O + CO_2$$

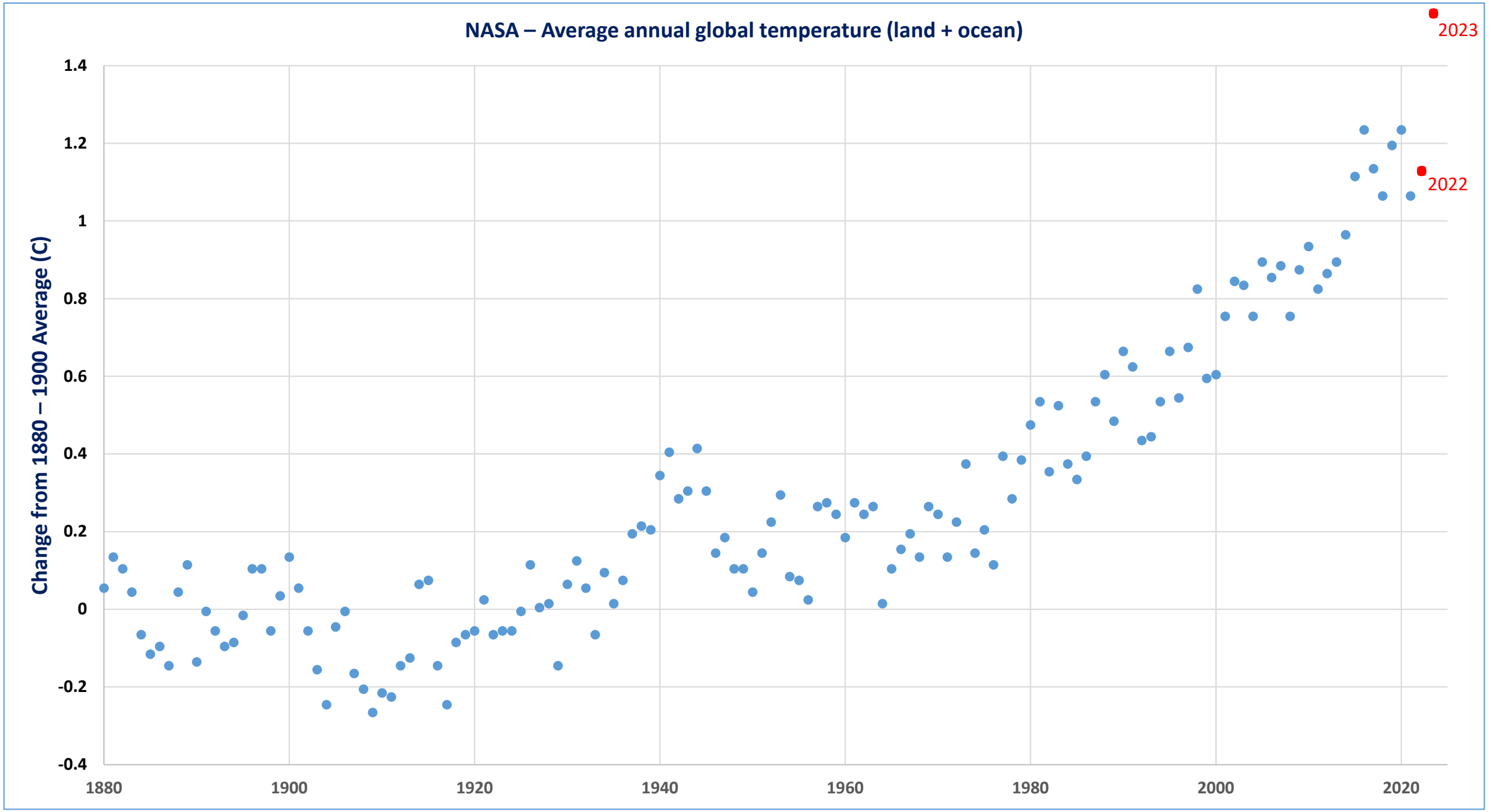
$$C_8H_{18} + 12.5O_2 \rightarrow 9H_2O + 8CO_2$$


Cape Grim Station
0
−50
−100
−150
−200
−250
−300
−350
−400
O_2/N_2 ratio (per meg)
1990
1991
1992
1993
1994
1995
1996
1997
1998
1999
2000
2001
2002
2003
2004
2005
2006
Keelingcurve.ucsd


Alert, Canada
Cold Bay, Alaska
Cape Grim, Australia
Cape Kumukahi, Hawaii
La Jolla Pier, California
Mauna Loa, Hawaii
Palmer station, Antarctica
American Samoa
South Pole
oxygen concentration ratio δ(O2/N2)
0
-200
-400
-600
1990
1995
2000
2005
2010
time [years]

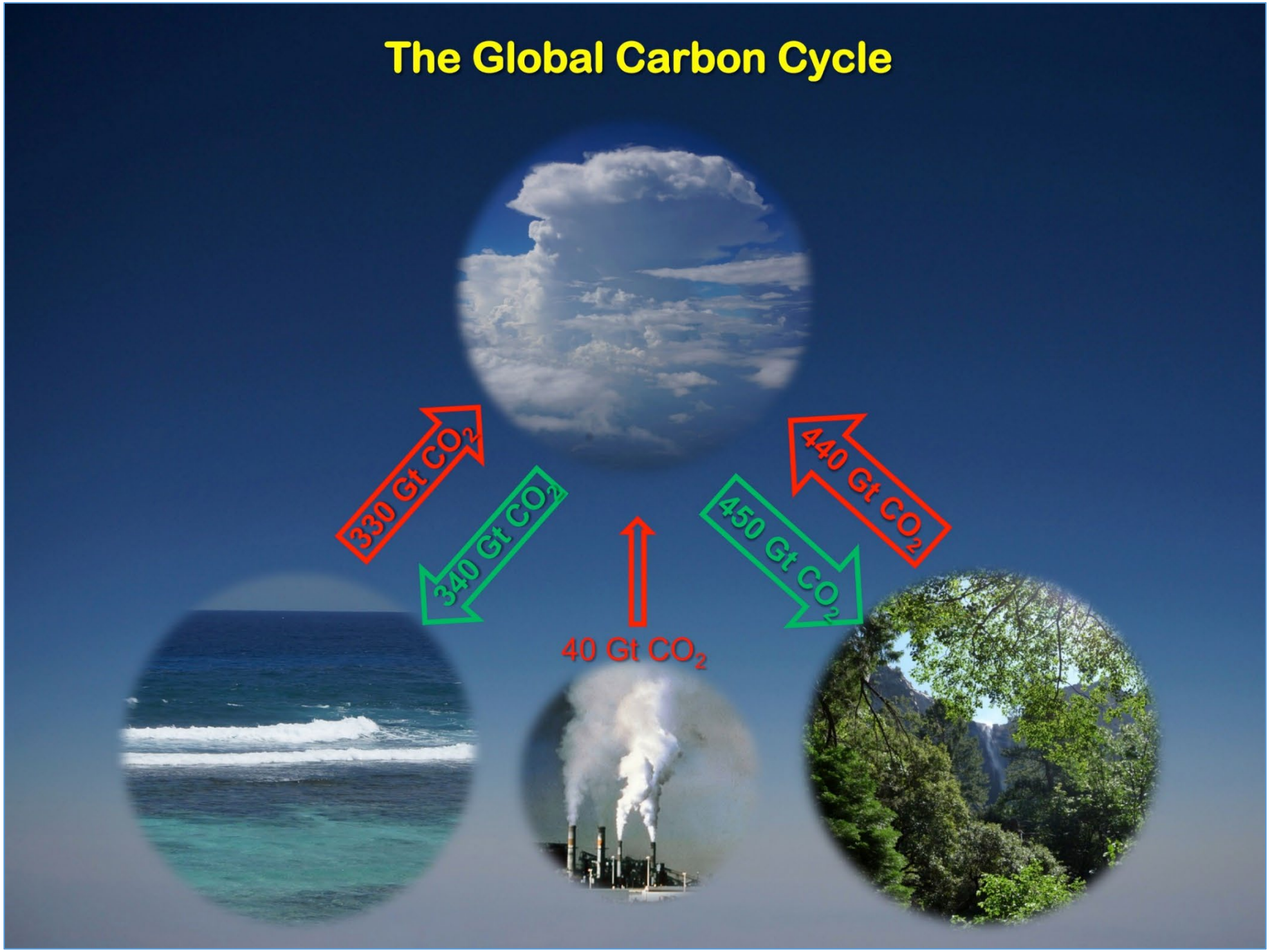


https://www.researchgate.net/figure/Vostok-ice-core-records-for-carbon-dioxide-concentration-and-temperature-change-CO2-lags_fig2_340835138

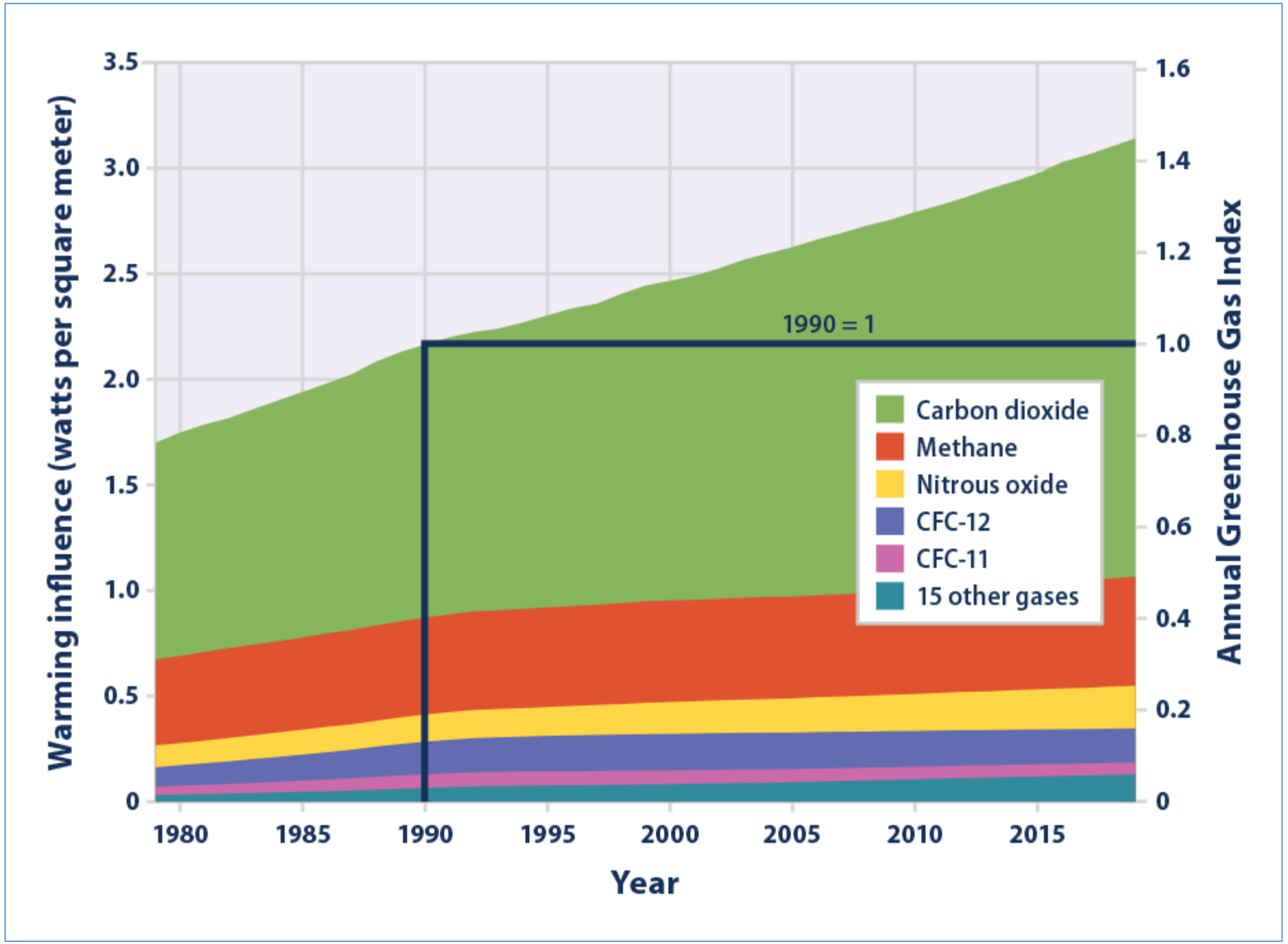


1.54 ± 0.06 °C above the 1850 – 1900 average - *https://berkeleyearth.org/global-temperature-report-for-2023/*

https://climate.nasa.gov/vital-signs/global-temperature/

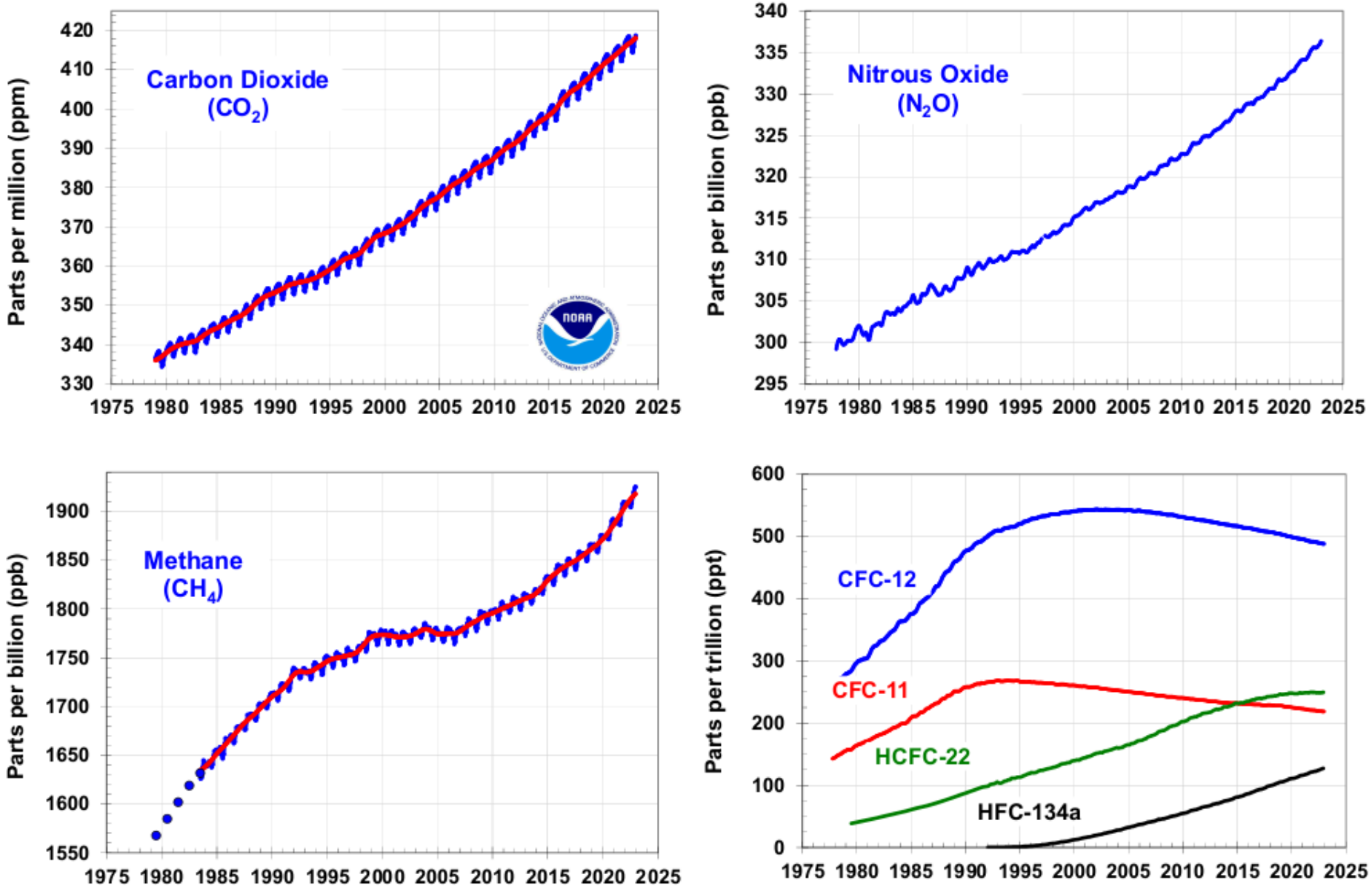


https://svs.gsfc.nasa.gov/12044

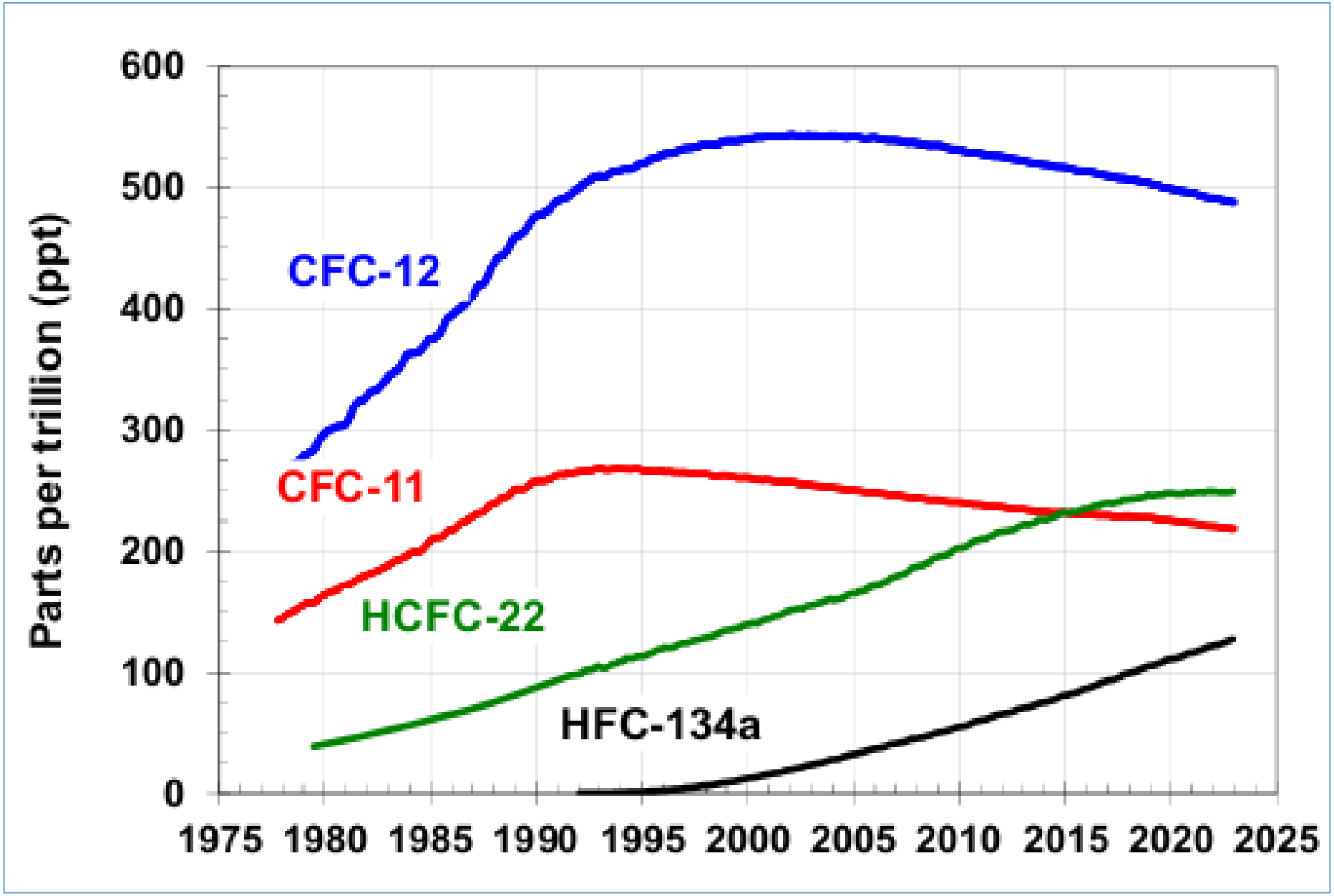


https://www.epa.gov/climate-indicators/climate-change-indicators-climate-forcing

About those other GHGs…



https://www.esrl.noaa.gov/gmd/aggi/aggi.html



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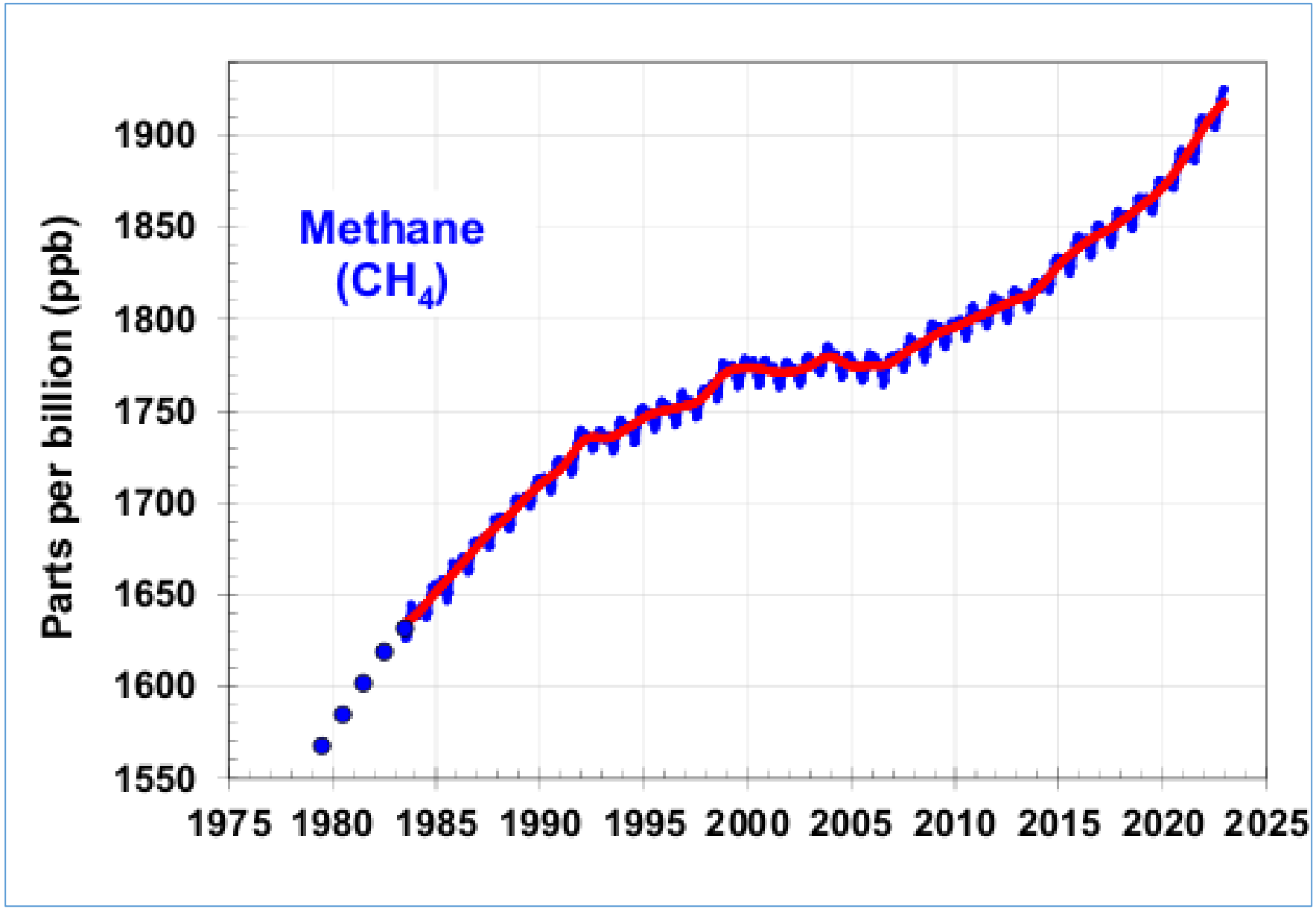
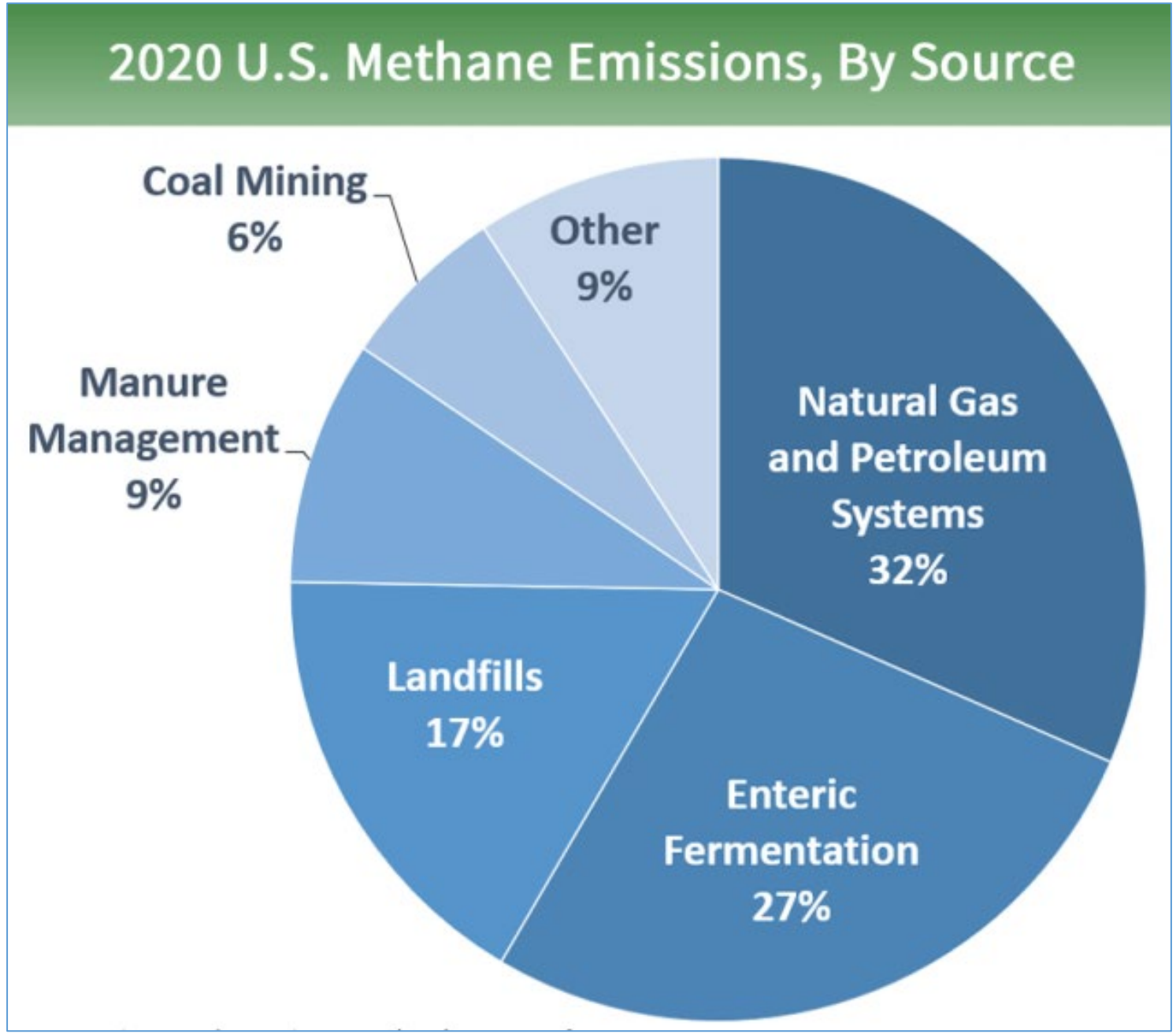


https://www.esrl.noaa.gov/gmd/aggi/aggi.html



https://www.epa.gov/ghgemissions/overview-greenhouse-gases

"To give you a sense of scale, all the cows on the planet are generating emissions roughly on par with the United States."

-- Kimberly Henderson, McKinsey

https://www.mckinsey.com/capabilities/sustainability/our-insights/climate-math-what-it-takes-to-limit-warming-to-1-point-5-degrees-c

BEEF

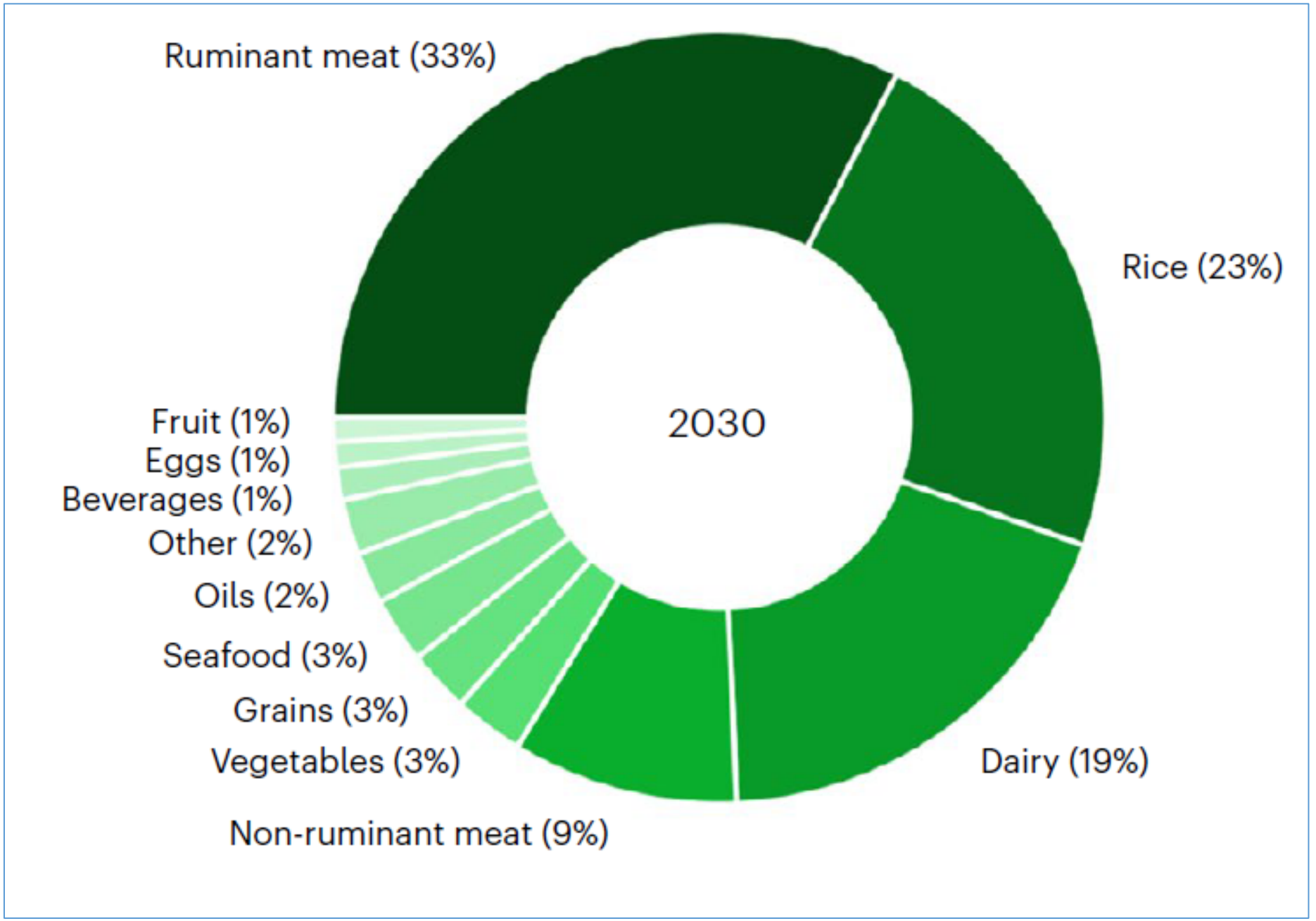
THE CHECKOFF BEEF BOARD QUALIFIED STATE BEEF COUNCILS

Is Beef to Blame for Climate Change?

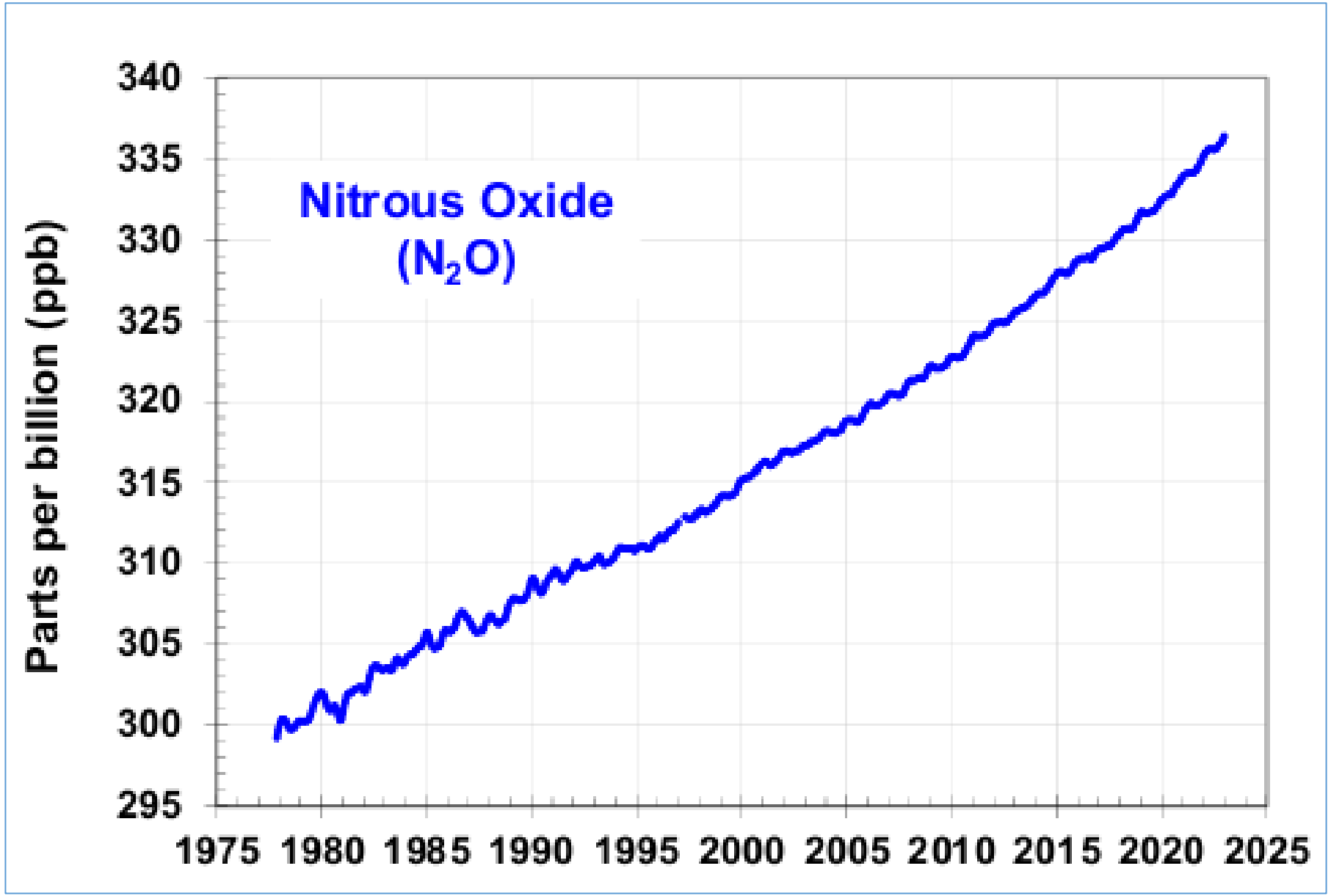
September 19, 2019

From Meatless Mondays to the EAT-Lancet initiative, the beef industry has seen the call for consumers to eat less beef many times over. A recent **EAT-Lancet report** PDF out of the United Kingdom suggests that the only way to save the planet is to eat less meat—and more nuts and beans. Reports such as these influence dietary guidelines around the world, so it is imperative the beef industry both understands and shares the true facts about beef's environmental footprint.

https://www.beefboard.org/2019/09/19/is-beef-to-blame-for-climate-change/



Future warming from Global Food Consumption – Nature Climate Change – March 6, 2023 - https://www.nature.com/articles/s41558-023-01605-8



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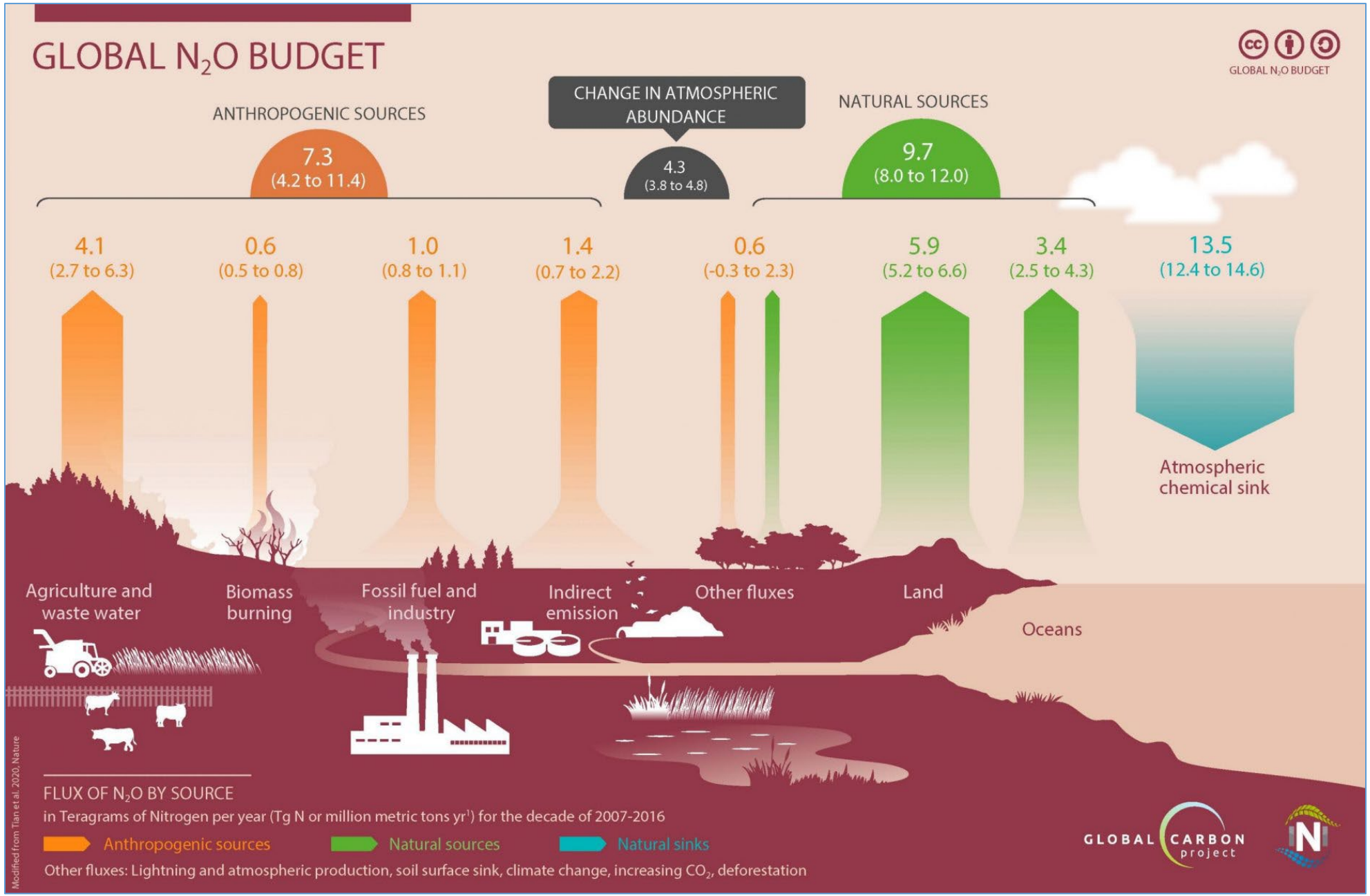
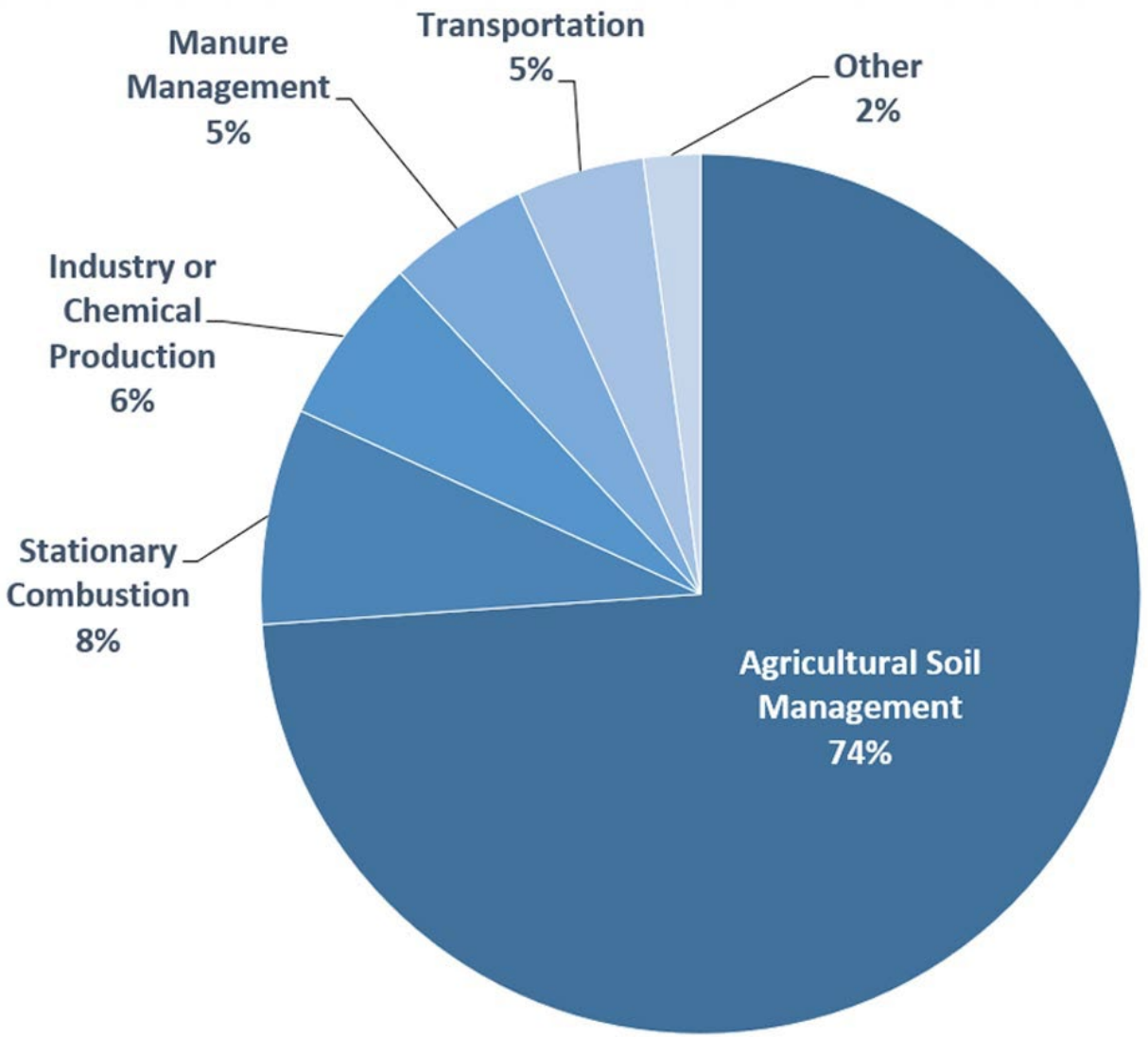


https://www.globalcarbonproject.org/nitrousoxidebudget/

2017 U.S. Nitrous Oxide Emissions, By Source

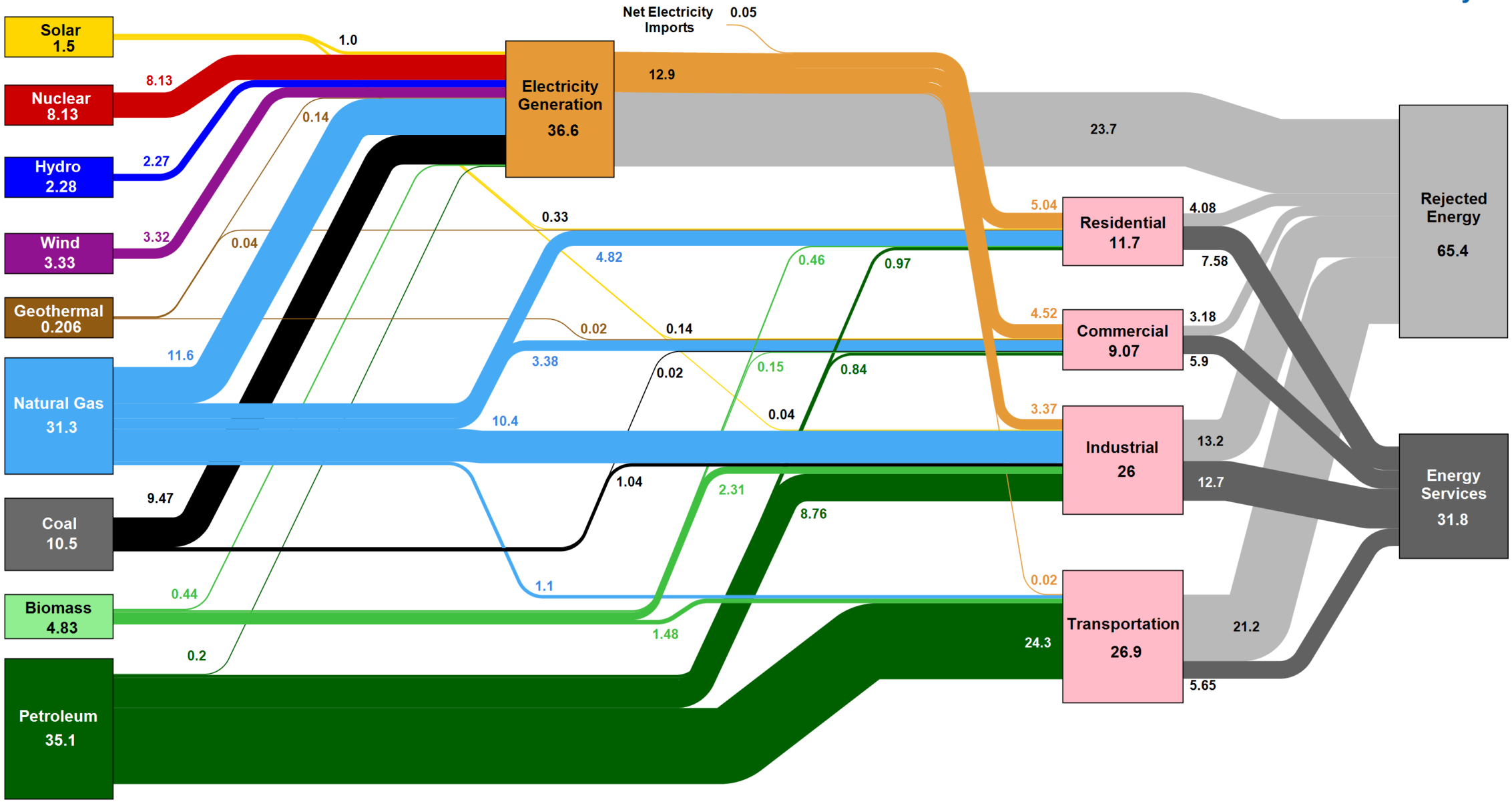


U.S. Environmental Protection Agency (2019). Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2017

https://www.epa.gov/ghgemissions/overview-greenhouse-gases#nitrous-oxide

Estimated U.S. Energy Consumption in 2021: 97.3 Quads

Lawrence Livermore National Laboratory



Source: LLNL March, 2022. Data is based on DOE/EIA MER (2021). If this information or a reproduction of it is used, credit must be given to the Lawrence Livermore National Laboratory and the Department of Energy, under whose auspices the work was performed. Distributed electricity represents only retail electricity sales and does not include self-generation. EIA reports consumption of renewable resources (i.e., hydro, wind, geothermal and solar) for electricity in BTU-equivalent values by assuming a typical fossil fuel plant heat rate. The efficiency of electricity production is calculated as the total retail electricity delivered divided by the primary energy input into electricity generation. End use efficiency is estimated as 65% for the residential sector, 65% for the commercial sector, 21% for the transportation sector and 49% for the industrial sector, which was updated in 2017 to reflect DOE's analysis of manufacturing. Totals may not equal sum of components due to independent rounding. LLNL-MI-410527