

04 Greenhouse effect of the atmosphere

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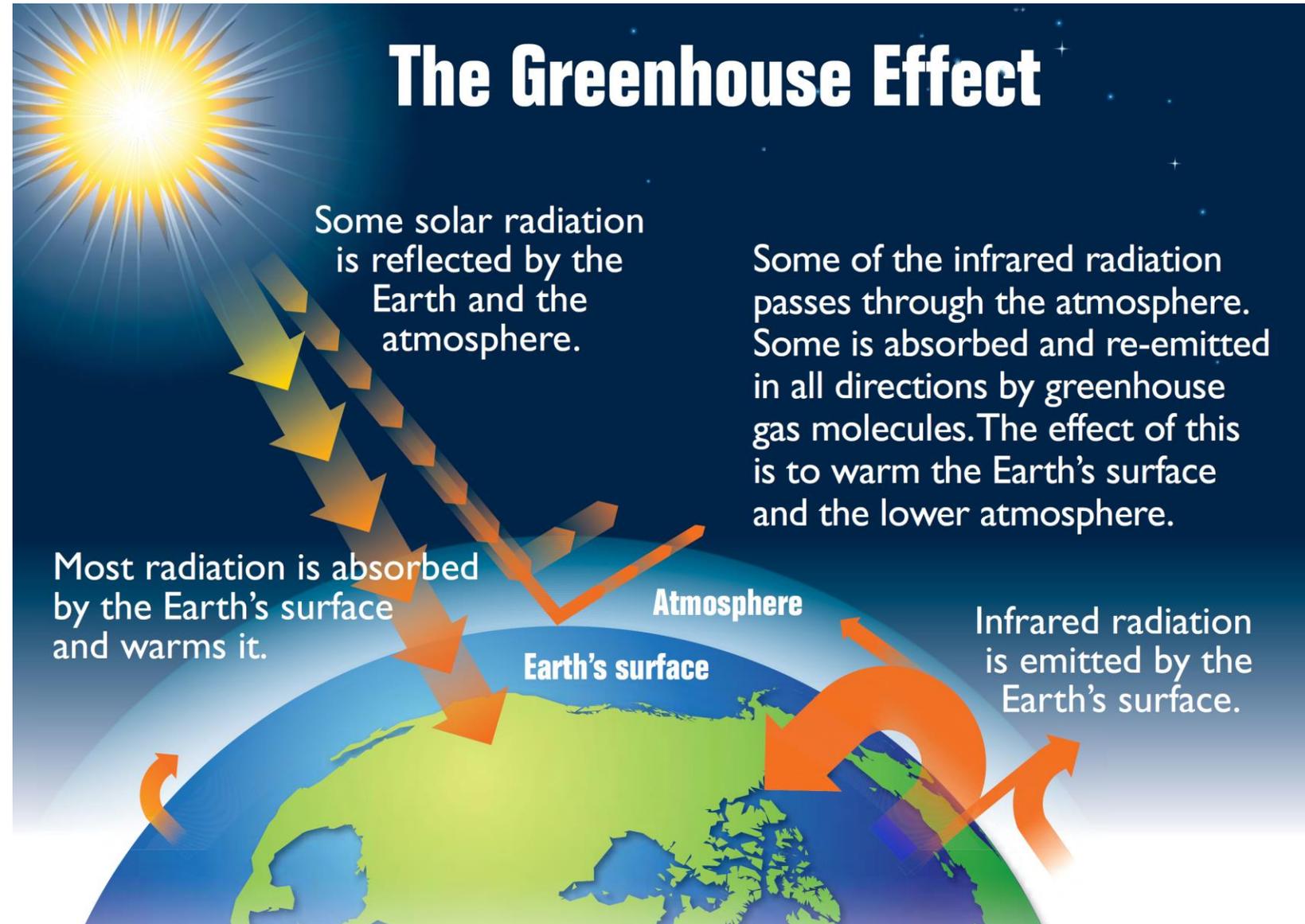
Content

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2. Greenhouse gases (GHGs)
3. Absorption of infrared radiation by GHGs in the atmosphere
4. Radiative forcing of GHGs
5. Human and natural influences on global temperature

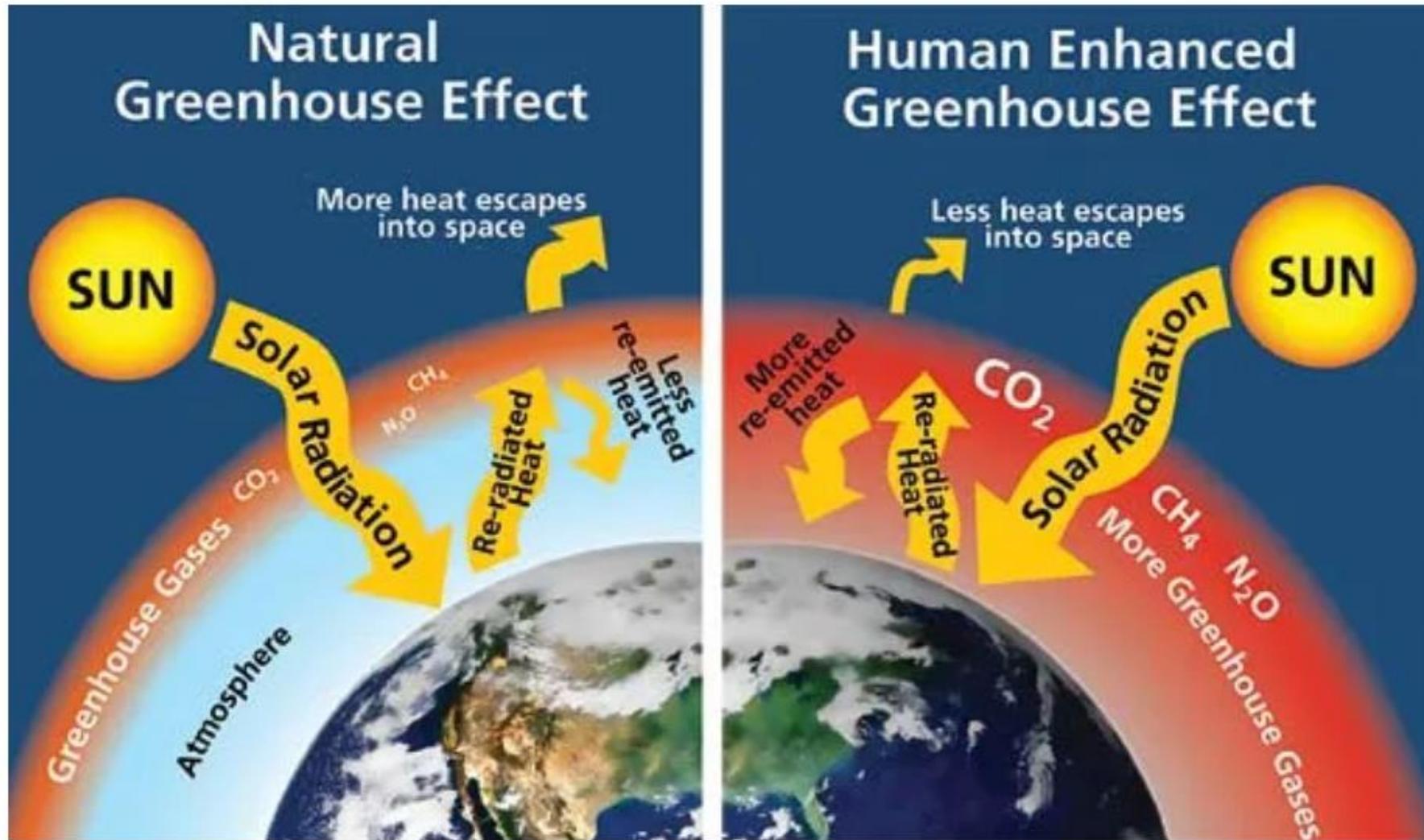
Greenhouse effect

- **natural process** that increases the temperature of the Earth's lower atmosphere by **~33°C** (beneficial)

... makes the Earth liveable for humans



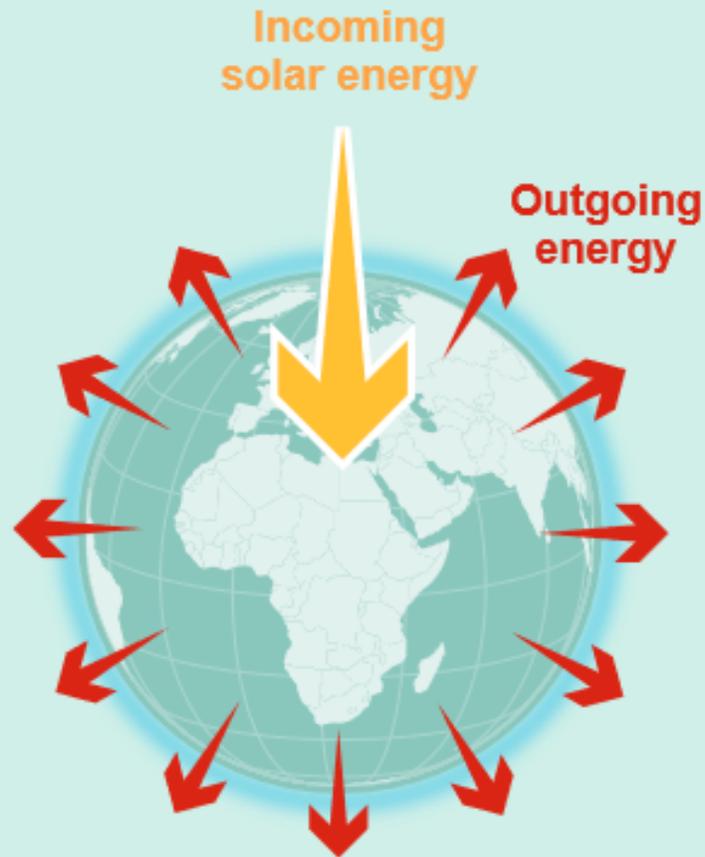
Greenhouse effect



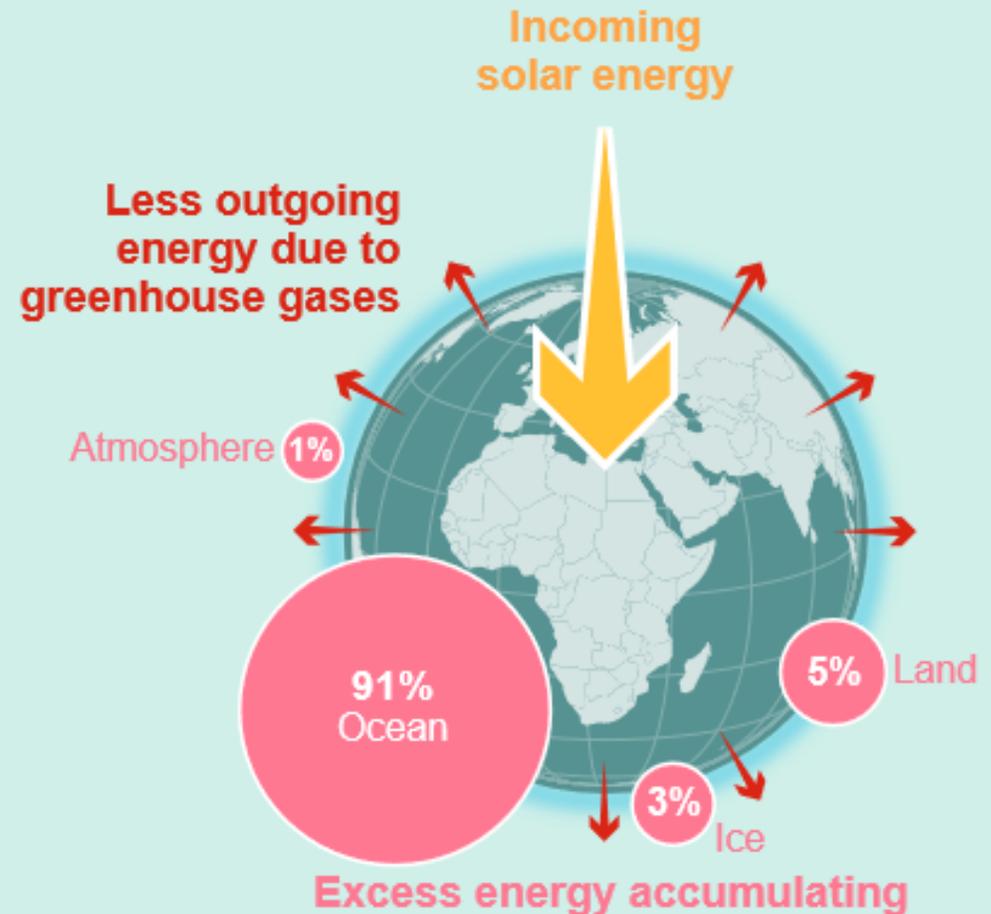
The Earth's energy budget and climate change

Since at least 1970, there has been a persistent imbalance in the energy flows that has led to **excess energy being absorbed by different components of the climate system.**

Stable climate: in balance



Today: imbalanced



Who discovered the greenhouse effect?

1824: Joseph Fourier



Earth's atmosphere functions similarly to a „*hotbox*“

https://cs.wikipedia.org/wiki/Joseph_Fourier

1896: Svante Arrhenius

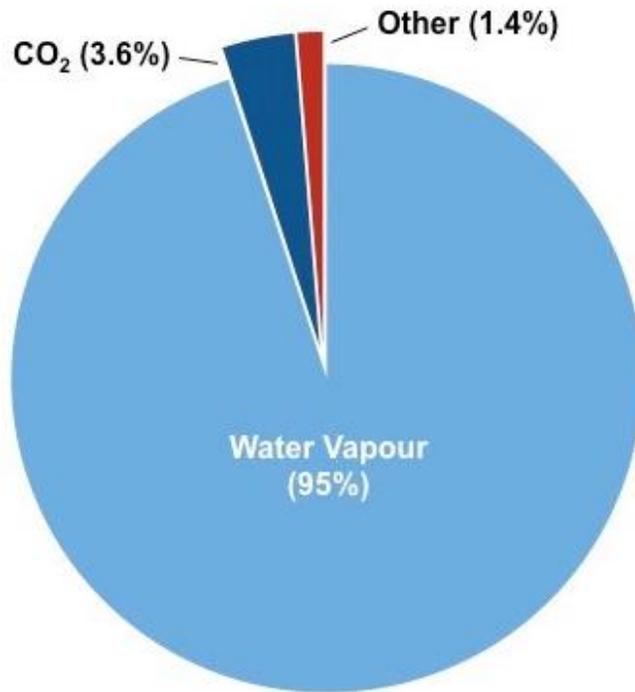


„*Hot-house theory*“ of the atmosphere

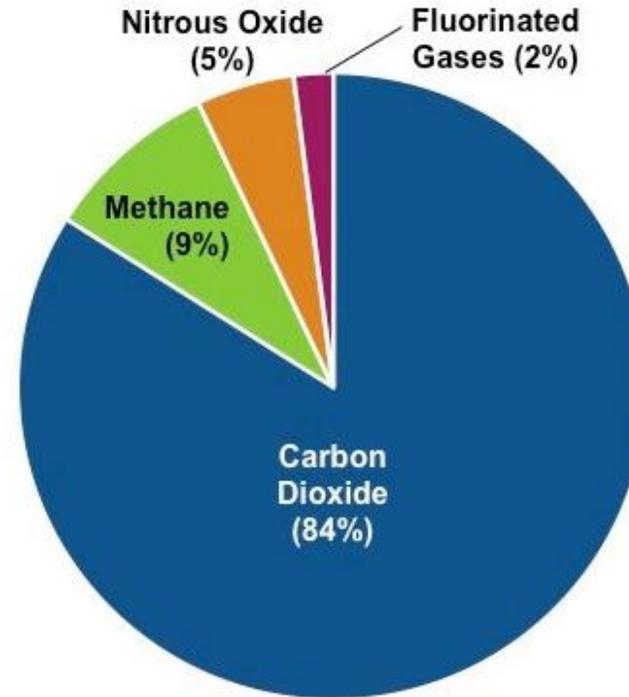
https://en.wikipedia.org/wiki/Svante_Arrhenius

Greenhouse gasses

Proportion of Greenhouse Gases (Natural vs Anthropomorphic)



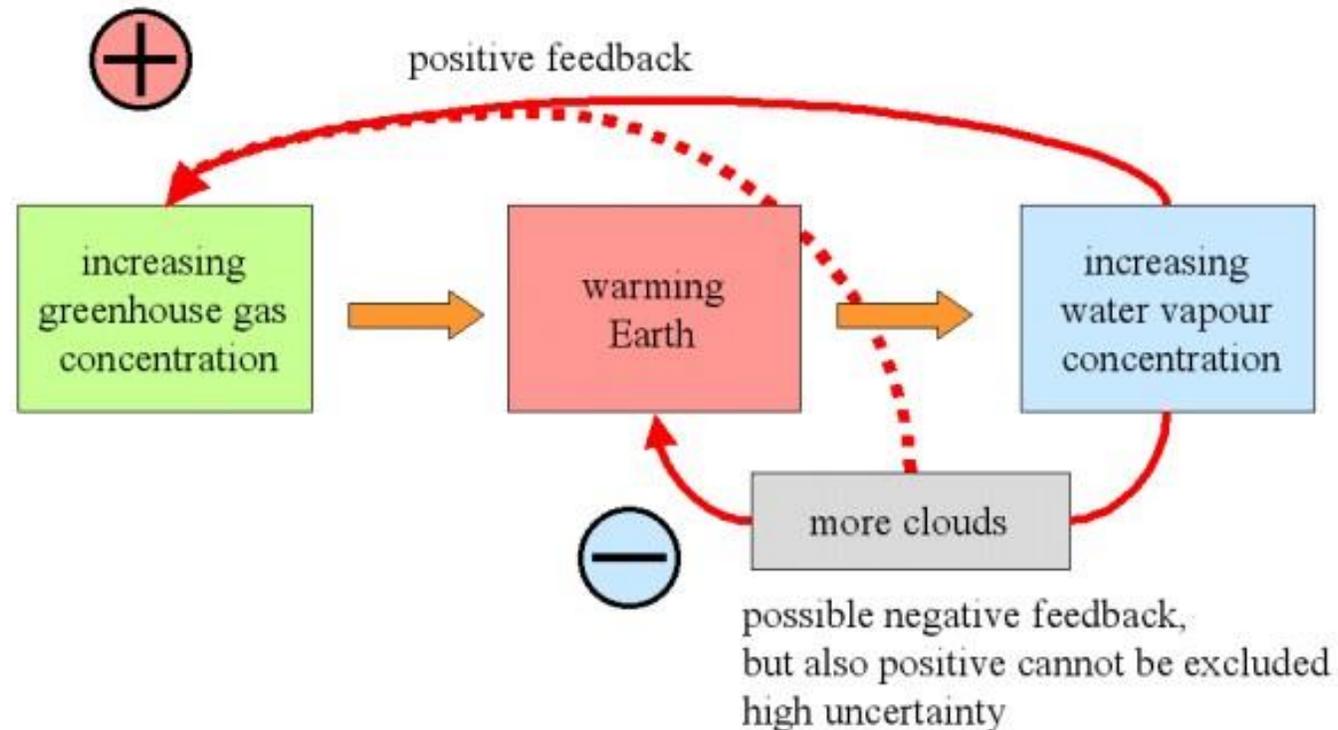
**Greenhouse Gases
in Atmosphere**



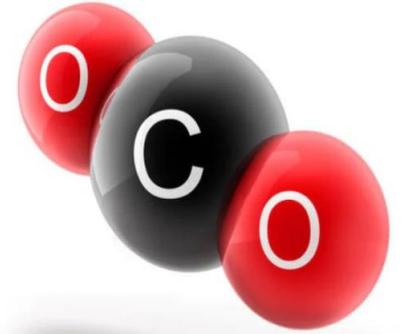
**Anthropomorphic (Man-Made)
Greenhouse Gases**

Water vapor

- the most abundant GHG overall
- the reason or the consequence of global warming?

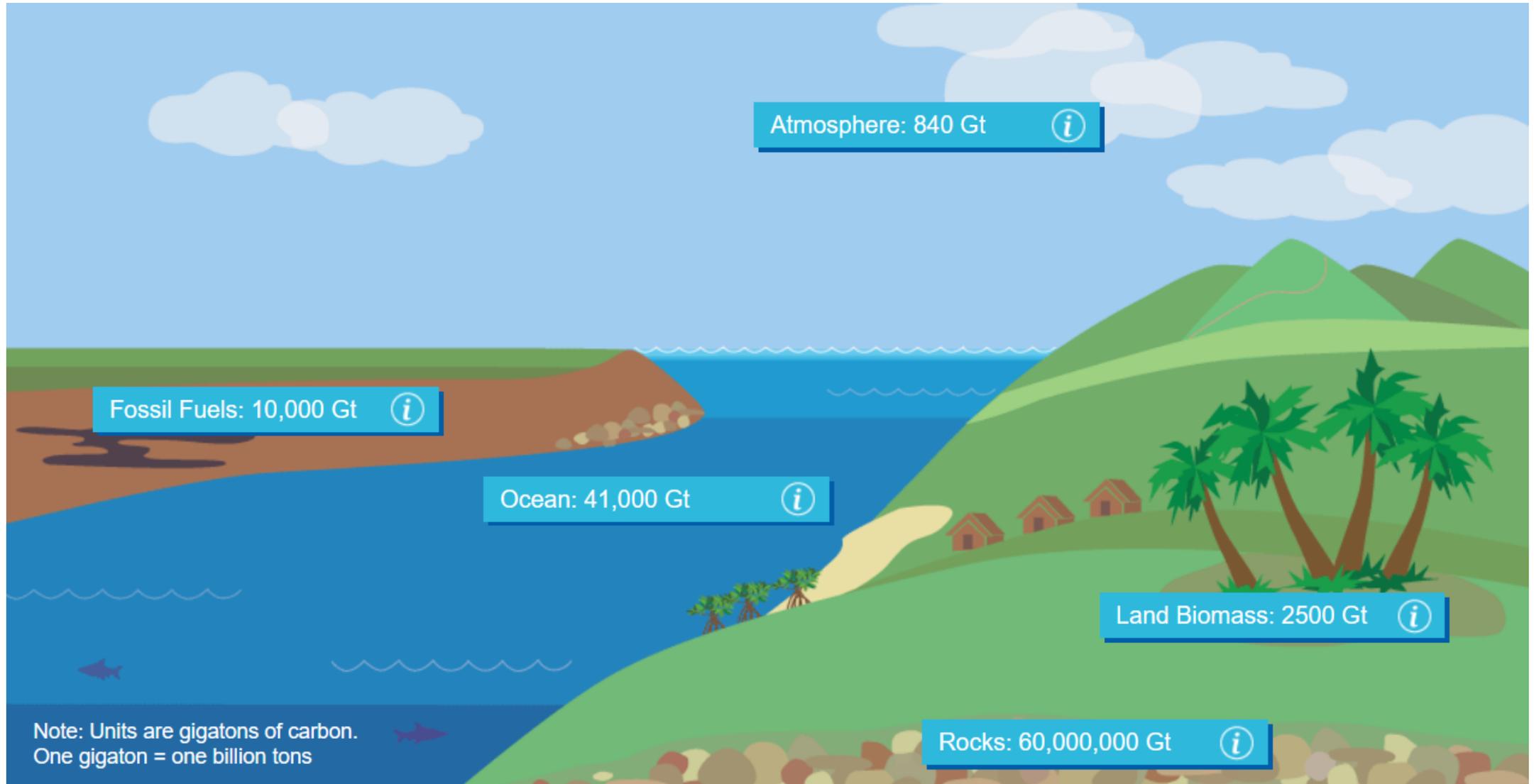


Carbon dioxide (CO₂)

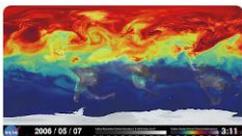
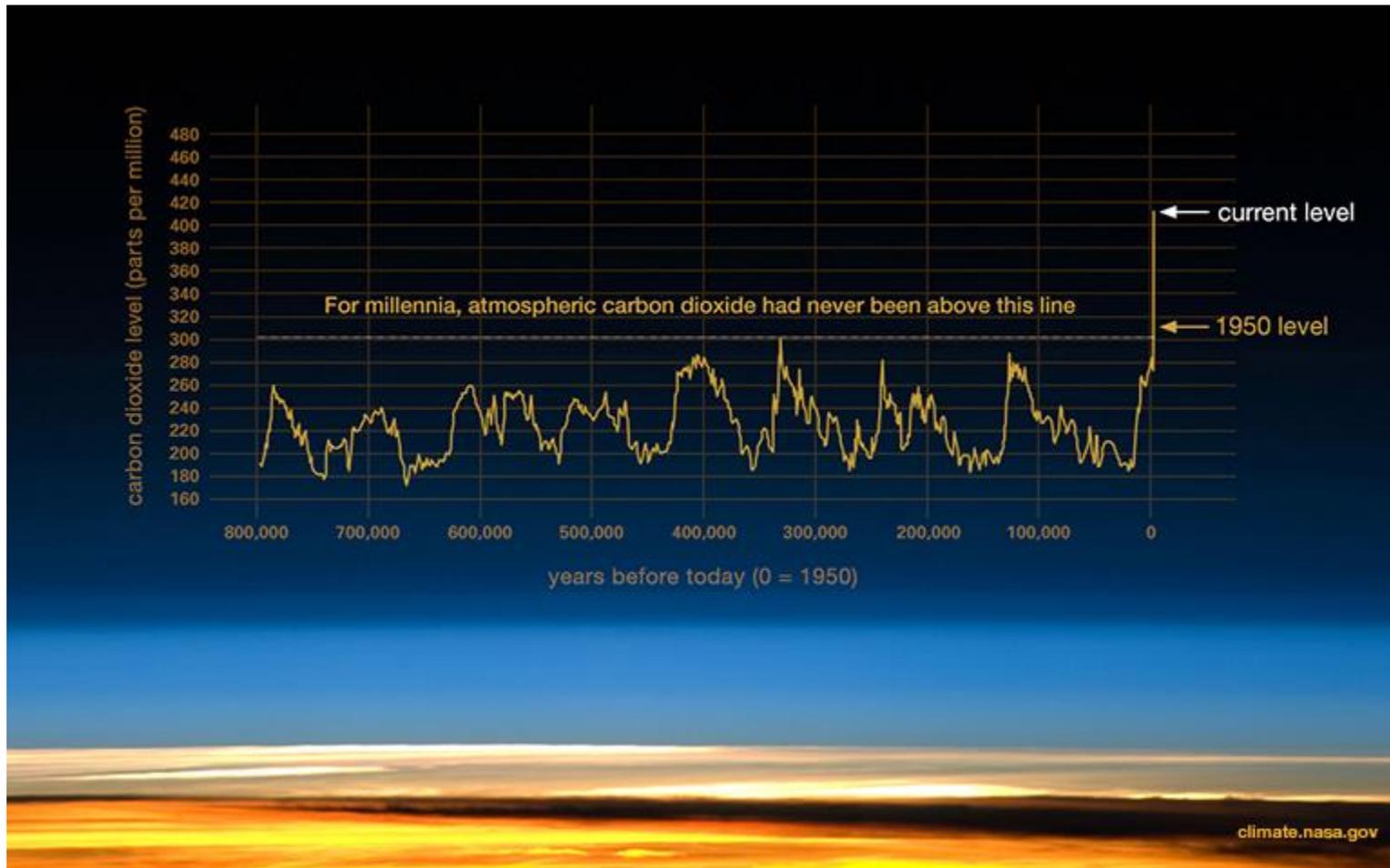


- 2/3 of the total heating influence of all human-produced GHGs
- concentration of 422 ppm (January 2024)
<https://gml.noaa.gov/ccgg/trends/global.html>
- **burning of fossil fuels, soil waste, trees and wood products, land use changes**
- CO₂ dissolves well into the water – **ocean acidification** (pH dropped from 8.21 to 8.11 since the start of the Industrial Revolution)
- **warmer oceans** dissolve less CO₂ – higher concentration of CO₂ in the atmosphere

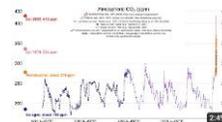
Carbon Cycle Reservoirs



How much CO2 is in the atmosphere?



<https://www.youtube.com/watch?v=x1SgmFa0r04>



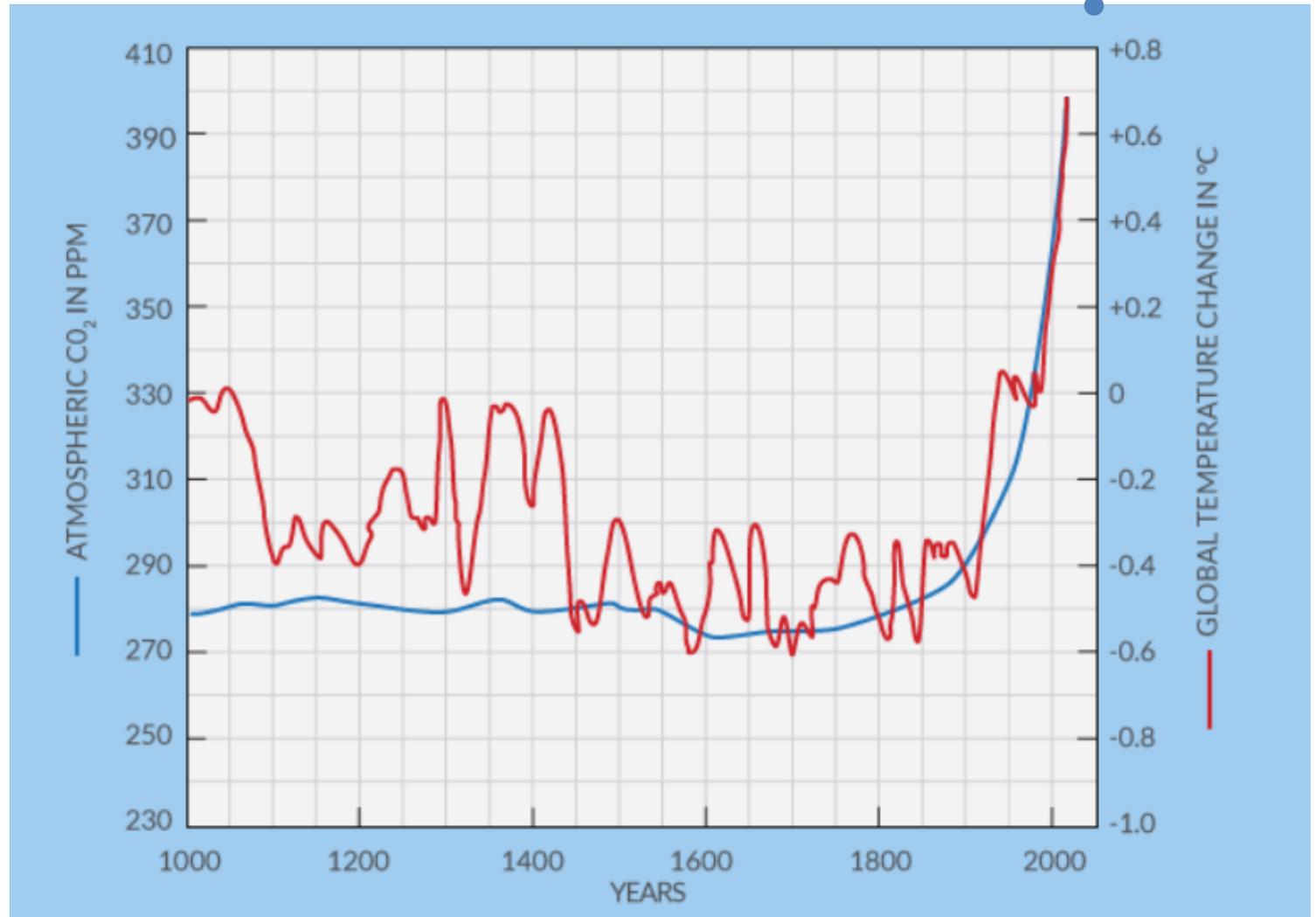
<https://www.youtube.com/watch?v=gbxEsG8g6BA>

<https://www.bbc.com/news/science-environment-41604760>

Temperature and CO2

https://contrib.pbslearningmedia.org/WGBH/pcep14/pcep14_int_co2cycle/index.html#img2_toggle

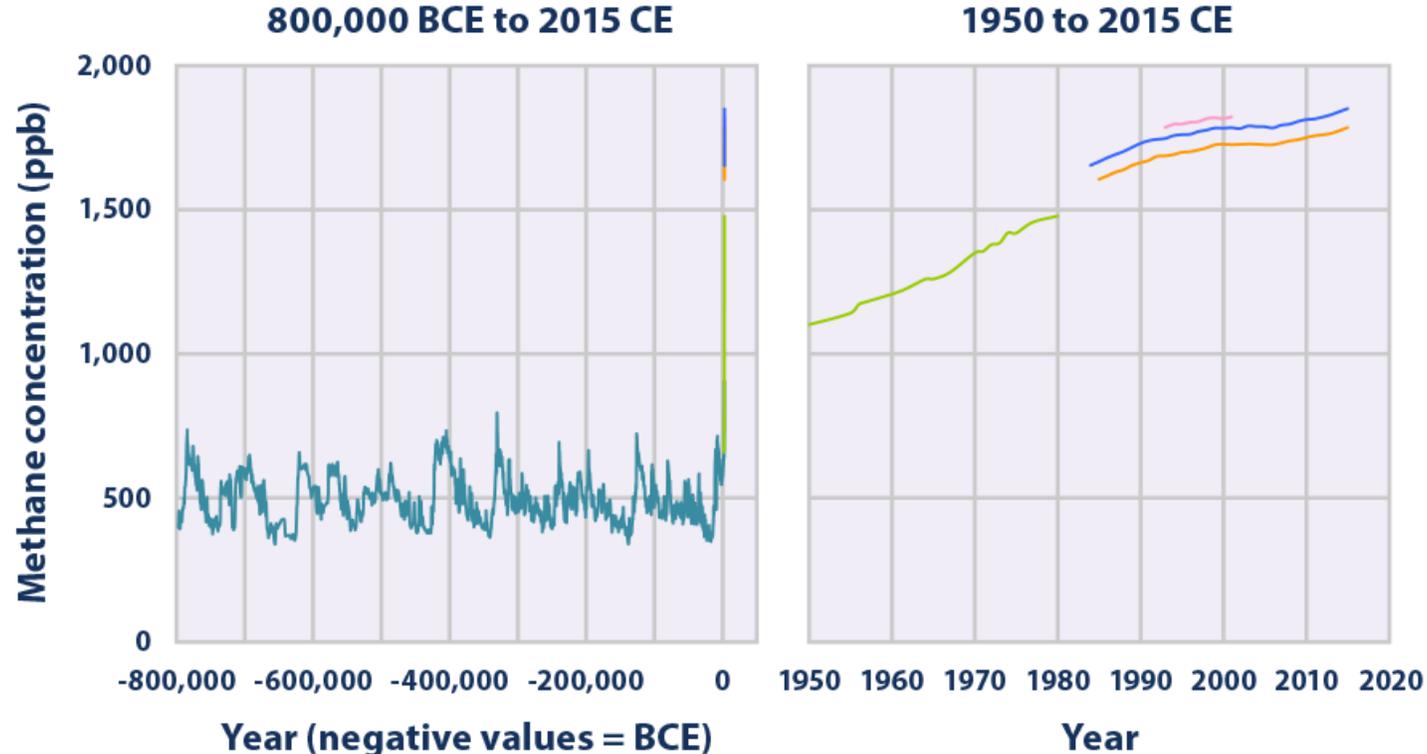
422 ppm in 2024



<https://contrib.pbslearningmedia.org>

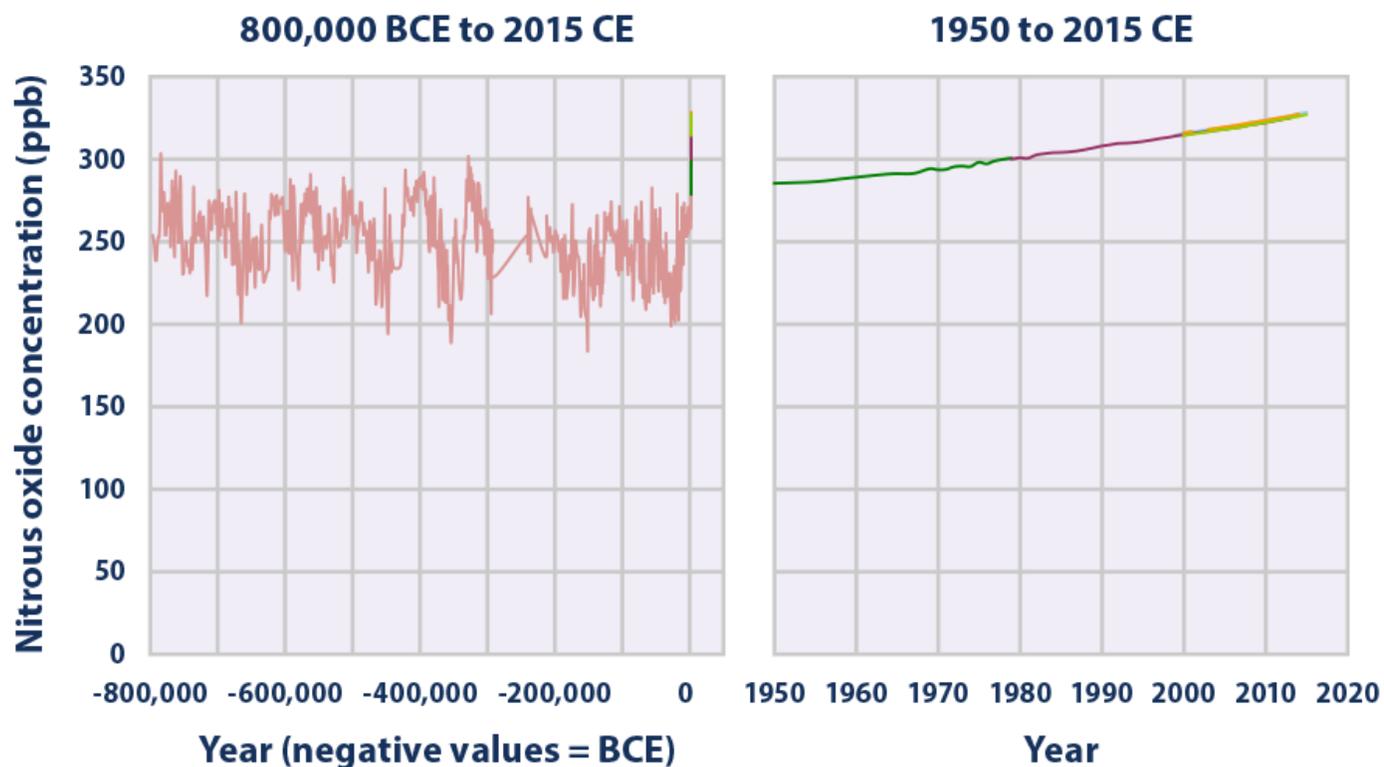
Methane

- emitted during the production and transport of coal, natural gas, and oil; from livestock and other agricultural practices, land use, decay of organic waste in municipal solid waste landfills



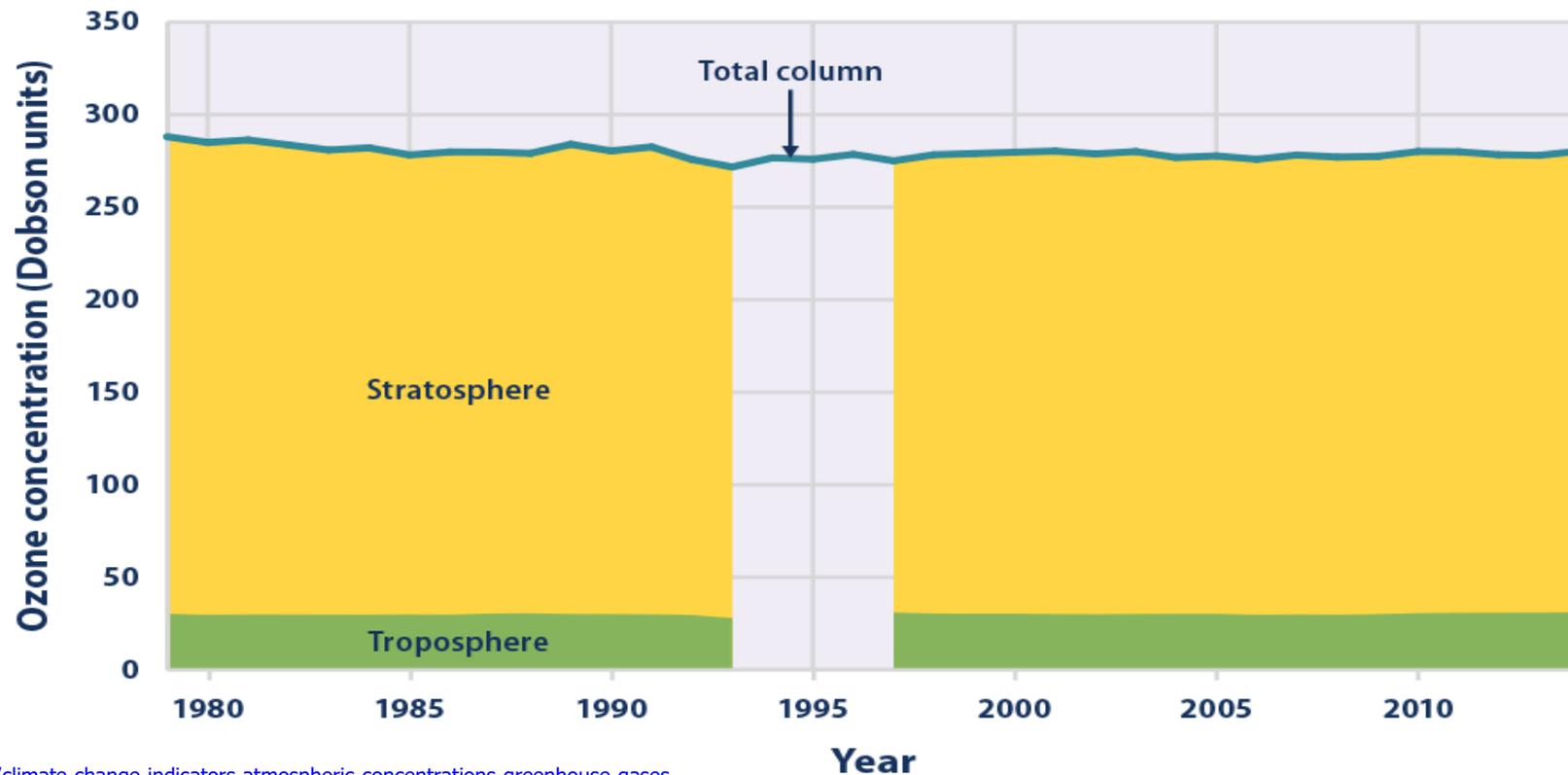
Nitrous oxide N₂O

- emitted during agricultural, land use, and industrial activities; combustion of fossil fuels and solid waste; during treatment of wastewater



Ozone

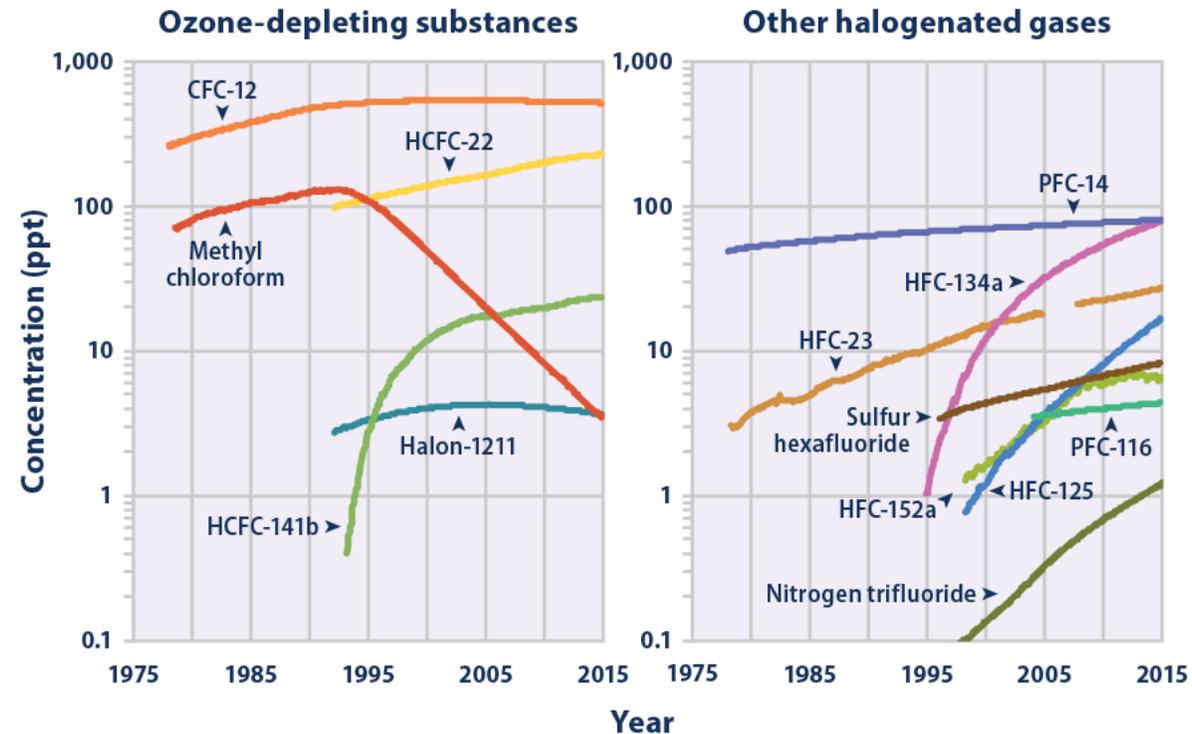
- **In the stratosphere** - blocks ultraviolet radiation which is harmful to plant and animal life
- **In the troposphere** - harmful to human health, the major component of photochemical smog



Fluorinated gases

hydrofluorocarbons (HFCs), perfluorocarbons (PFCs), sulfur hexafluoride (SF6), and nitrogen trifluoride (NF3)

- synthetic, powerful GHGs that are emitted from a variety of **household, commercial, and industrial** sources (aerosols, refrigerators, plastic foam, solvents, pharmaceutical industry)
- **ozone-depleting** substances in the stratosphere
- small quantities X strong GHE in the atmosphere



GLOBAL WARMING

WHAT IS GLOBAL WARMING?

- Global warming is one aspect of climate change. It refers to the long-term increase in Earth's average air/surface temperature
- It is caused by increased concentrations of greenhouse gases in the atmosphere, driven primarily by human activities such as burning fossil fuels and farming

WHICH ARE THE MAJOR GREENHOUSE GASES?

- **Carbon dioxide (CO₂)** represents ~76% of greenhouse gas emissions
62% of total CO₂ emission comes from burning fossil fuels (oil, coal, and natural gas)
- **Methane (CH₄)** (from - livestock rearing, poor waste management)
- **Nitrous oxide (N₂O)** (from - fertiliser use, burning fossil fuels)
- **Fluorinated gases** - hydrofluorocarbons, chlorofluorocarbons, and other F-gases. (From - industrial processes, refrigeration).
- **Water vapour (H₂O)**
 - » Different from other greenhouse gases.
 - » Increased water vapour not linked to human activity directly.
 - » Air is warmer because of other greenhouse gases, causing more water to evaporate.
 - » The air then holds more water, which absorbs more heat.
 - » More heat is trapped in the atmosphere and contributes to overall warming across the globe.



WHAT IS THE GREENHOUSE EFFECT?

- Gases in Earth's atmosphere trap the sun's heat and keep the planet warm. This natural process protects the Earth from freezing
- Human activities are disrupting this balance by releasing excessive greenhouse gases into the air. These absorb more sunlight and solar radiation reflected off Earth's surface
- These gases trap more heat, causing the planet to warm up unnaturally—this is called the greenhouse effect



IMPACTS OF GLOBAL WARMING

- Longer and hotter heatwaves
- Wildfires
- Heavier rainfall and storms
- Erratic weather patterns
- Sea levels rise, causing coastal flooding
- Glaciers disappear
- Snow melts earlier
- Water shortages
- New pests in forests, farms, and cities damaging agriculture and fisheries
- Coral reefs are destroyed
- Habitat loss for plants and animals
- Increase in allergies, asthma, and infectious disease outbreaks (with higher pollen/pollution, and conditions favouring pathogens/mosquitoes)

Radiative forcing of GHGs

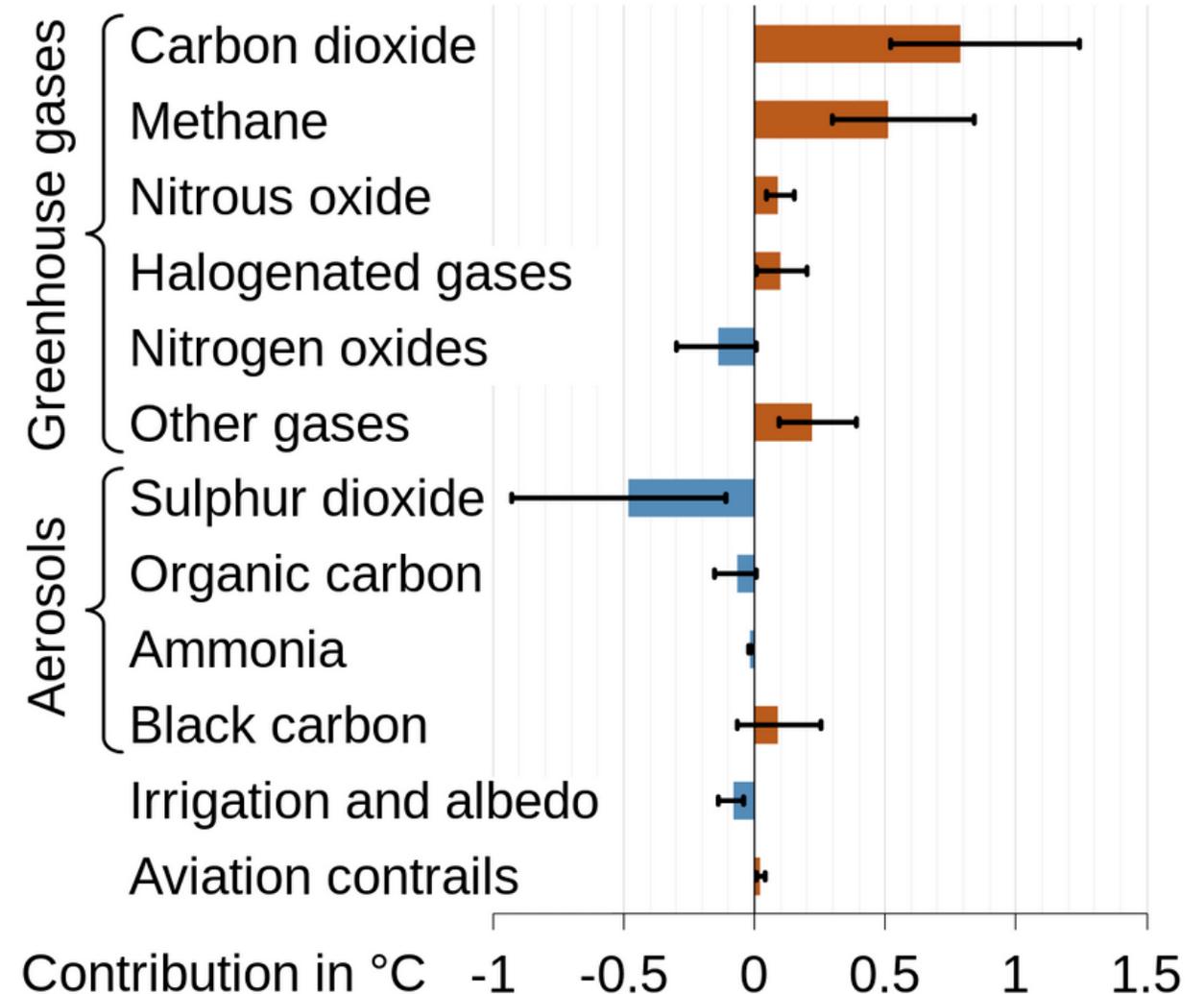
- predictor of globally-averaged temperature change
- **the more radiative force** a gas is (ie, the more it affects the energy balance of the atmosphere per unit mass), **the smaller the amount** is sufficient to affect processes in the atmosphere.
- an increase in the radiation effect by **1 W/m²** will **increase** the surface temperature **by 0.5°C**.

Radiative forcing of GHGs

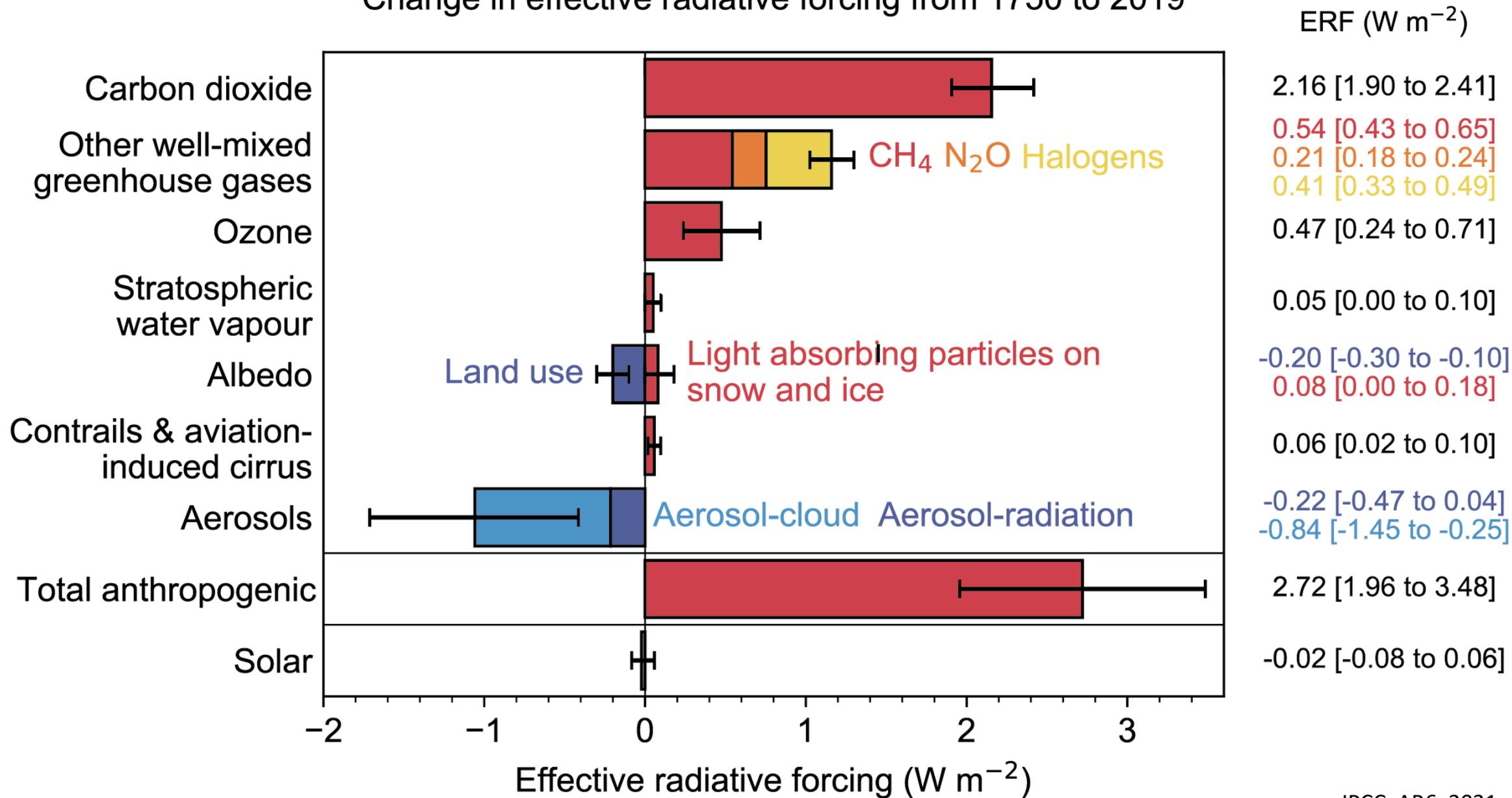
contributions to temperature changes:

- **positive** radiative forcings = temperature increase
- **negative** radiative forcing = temperature decrease

Physical drivers of climate change



Change in effective radiative forcing from 1750 to 2019



Global warming potential (GWP) and CO2 equivalents

- comparisons of the global warming impacts of different gases

GWP - 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 CO₂

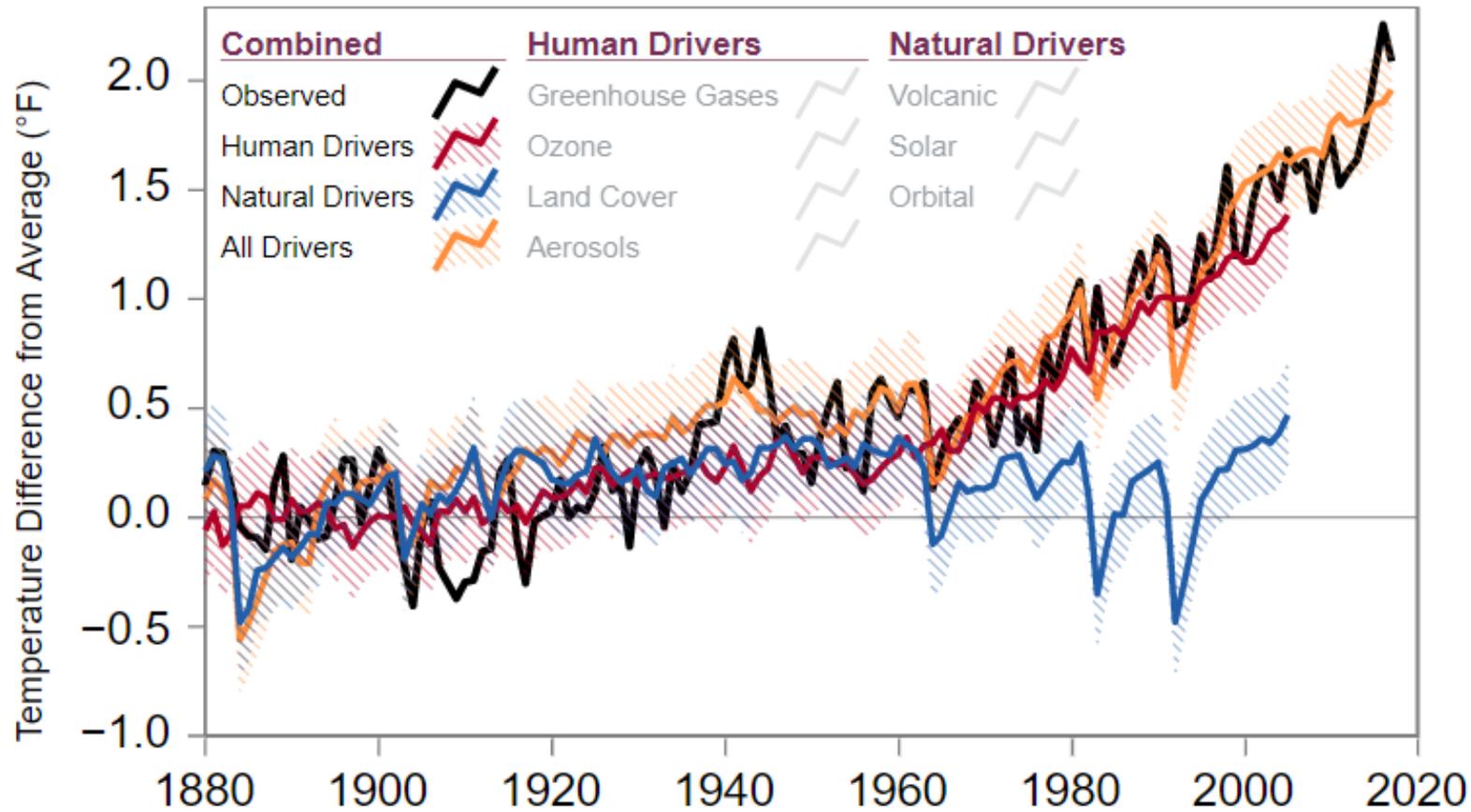
CO₂ equivalent - is the amount of CO₂ that has the same equivalent contribution to the greenhouse effect of the atmosphere as the given amount of certain gas

Global warming potential (GWP) and CO2 equivalents

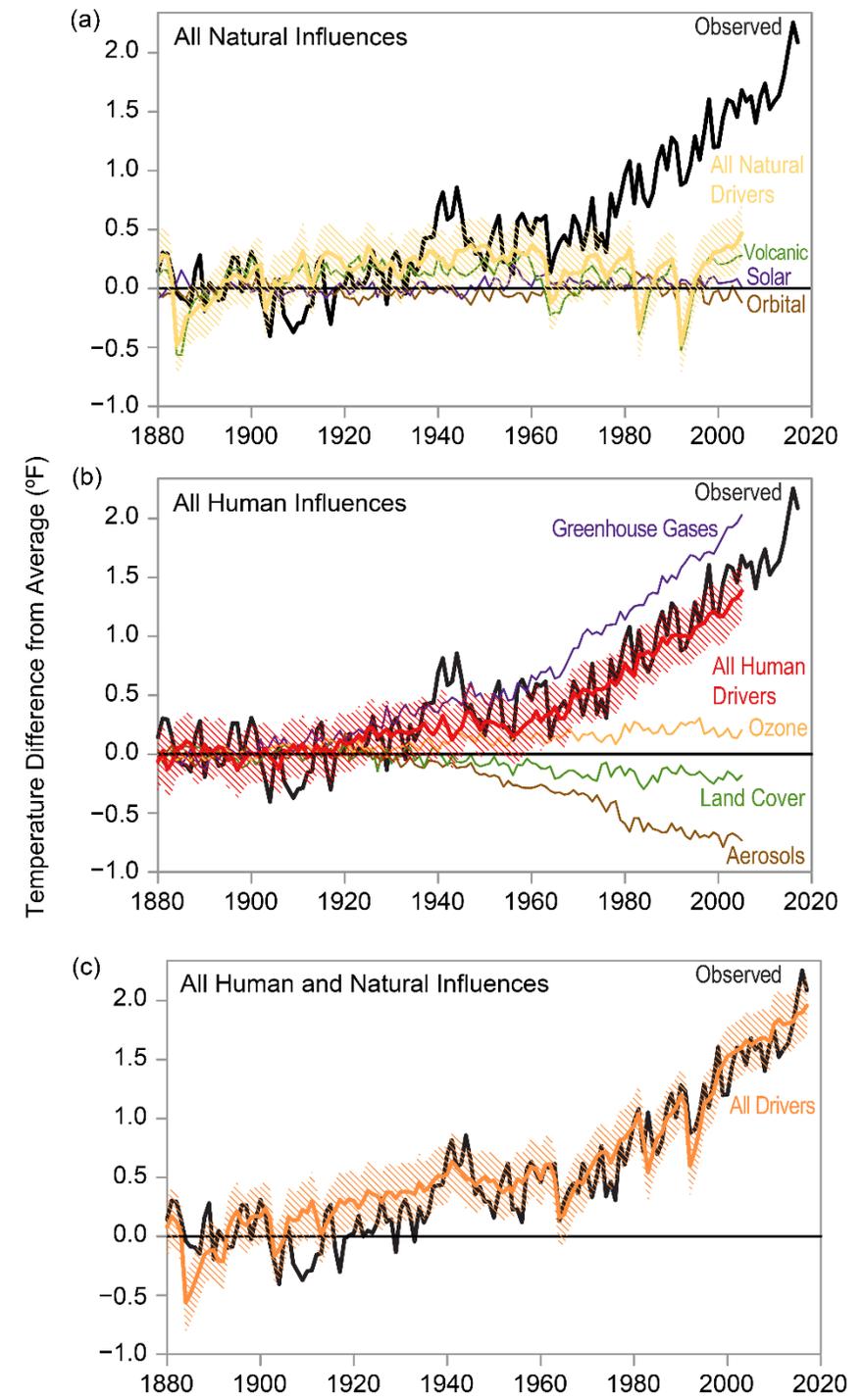
Atmospheric lifetime and **GWP** relative to CO₂ at different time horizon for various greenhouse gases

Gas name	Chemical formula	Lifetime (years) ^[22]	Global warming potential (GWP) for given time horizon		
			20-yr ^[22]	100-yr ^[22]	500-yr ^[39]
Carbon dioxide	CO ₂	30–95	1	1	1
Methane	CH ₄	12	84	28	7.6
Nitrous oxide	N ₂ O	121	264	265	153
CFC-12	CCl ₂ F ₂	100	10 800	10 200	5 200
HCFC-22	CHClF ₂	12	5 280	1 760	549
Tetrafluoromethane	CF ₄	50 000	4 880	6 630	11 200
Hexafluoroethane	C ₂ F ₆	10 000	8 210	11 100	18 200
Sulfur hexafluoride	SF ₆	3 200	17 500	23 500	32 600
Nitrogen trifluoride	NF ₃	500	12 800	16 100	20 700

Human and natural influences on global temperature



<https://www.epa.gov/climatechange-science/causes-climate-change>



Human-induced warming – actual value

globalwarmingindex.org

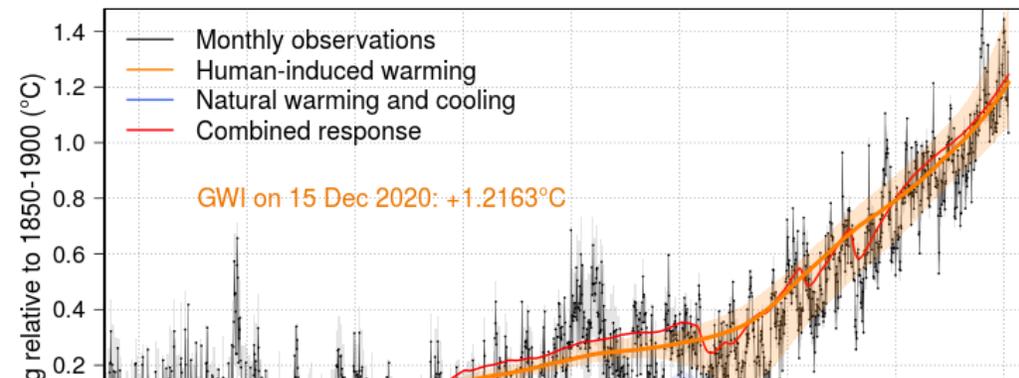
Tracking progress to a safe climate

Human-induced warming: $+1.293157477$ °C

on Thu, 07 Mar 2024 11:20:07 GMT

This number shows an up-to-the-second assessment of human-induced global warming since the second half of the 19th century. In the 2015 Paris Agreement countries around the world agreed to work towards keeping global warming below 2 degrees – and ideally at 1.5 degrees – in order to avoid the worst impacts of climate change.

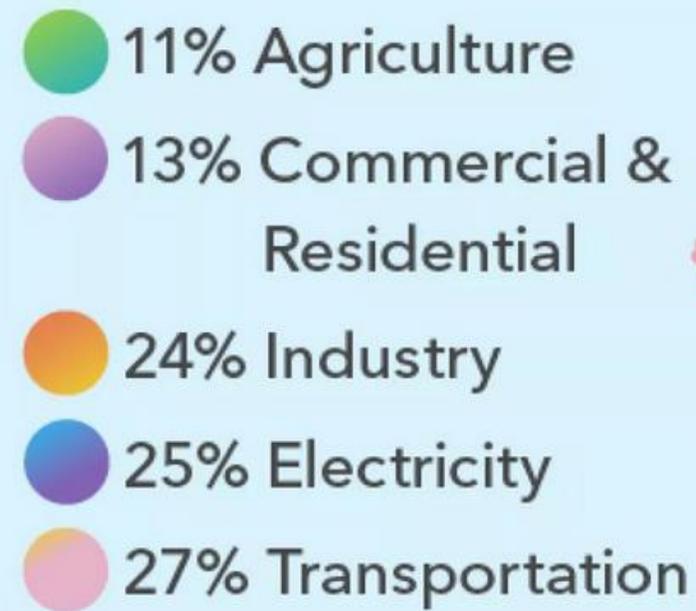
Global Warming Index (aggregate observations) - updated to Dec 2020



<https://www.globalwarmingindex.org/>

Human-driven causes of climate change

TOTAL U.S. GREENHOUSE GAS EMISSIONS BY ECONOMIC SECTOR (2020):



References

- Hess, D. (2014): McKnight's physical geography: a landscape appreciation. 11th ed. Harlow: Pearson. Pearson new international edition. ISBN 978-1-292-02091-4
- <http://www....>

Thank you for your attention