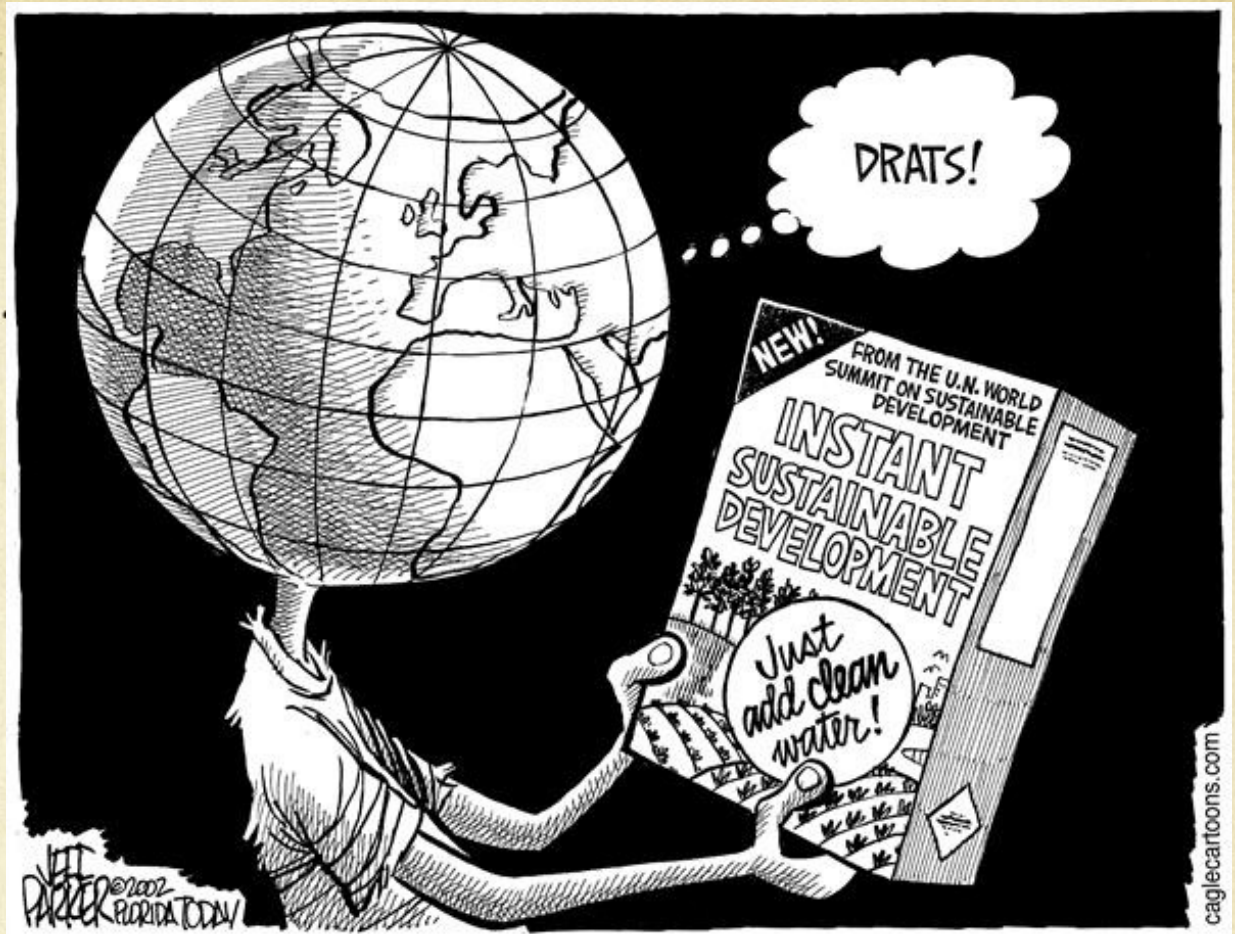




How Will Our Species Survive?

Geo-climate 15 Feb 24

Brian Rasnow, Ph.D.

How did you come to studying global warming?

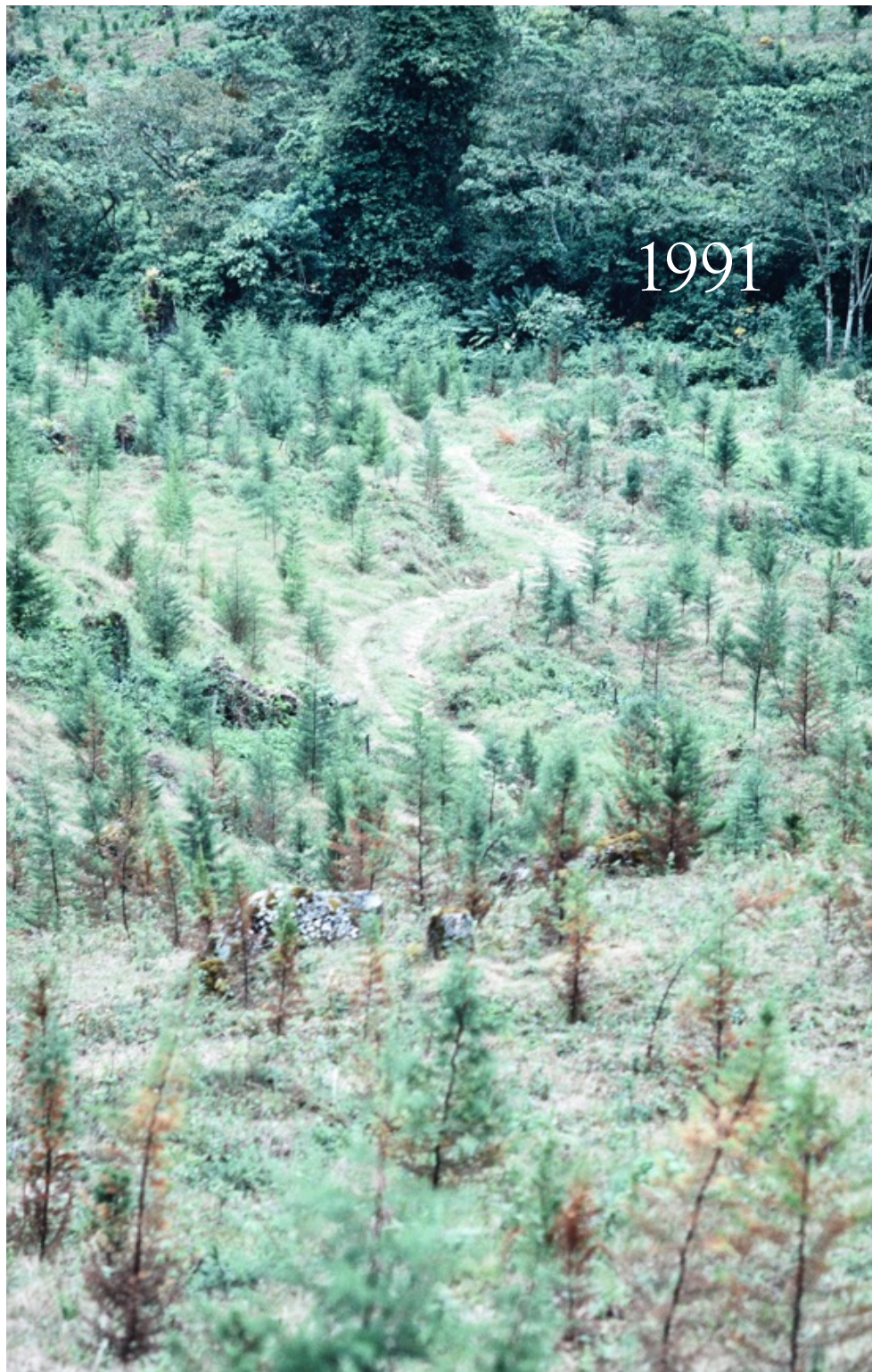
- Ph.D in biophysics and Postdoc in neurobiology at Caltech
- Principle Scientist at Amgen in Research and Automation Technologies
- Lecturer in Physics, Computer Science/Mechatronics, and University programs at CI



1980



1980

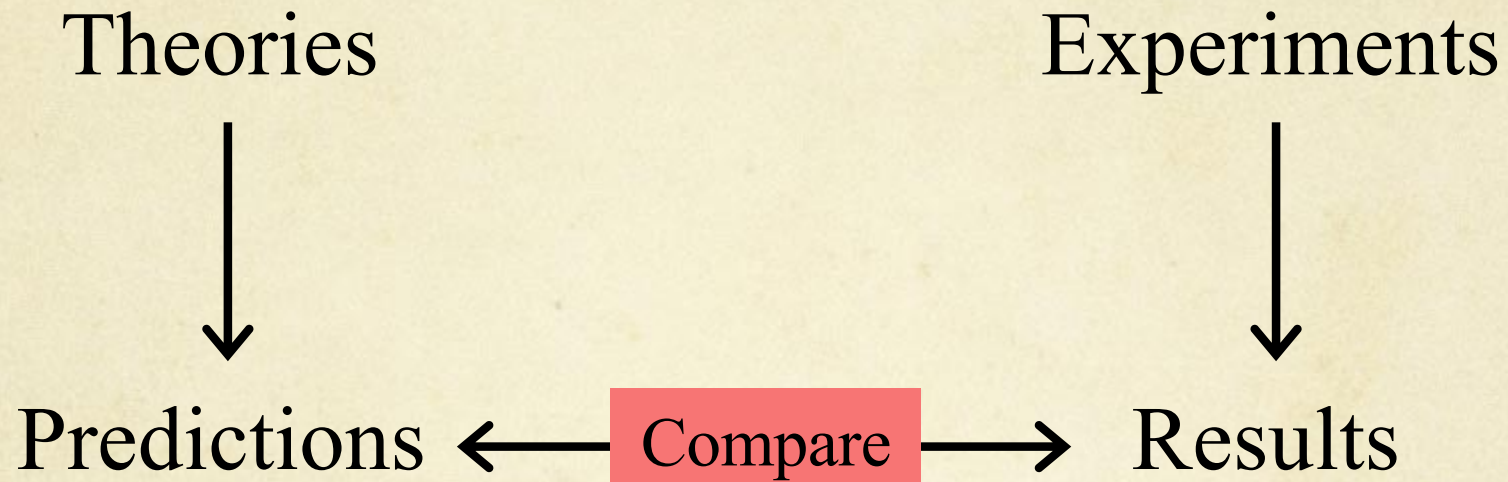


Global climate is conceptually simple and mind-boggling complex!

- Physics gives us powerful understanding of the forces that drive climate (and life)
- Scientists have pieced together key facts from laboratory, field, computer models, and theory.
- Complex systems and their models have inherent uncertainties that can be misinterpreted.



Two “worlds” of Theory and Experiments



The scientific method compares predictions and results.

- When they agree, confidence in the theory increases
- When they disagree, theory must be modified
 - “Extraordinary claims require extraordinary proof” – Carl Sagan

The Little Golden Book of
**ALTERNATE
FACTS**



Table



cat



Butterfly



Marbles



Sword



Wagon



Soup



Pancakes



Mnuchin



Yellow



socks



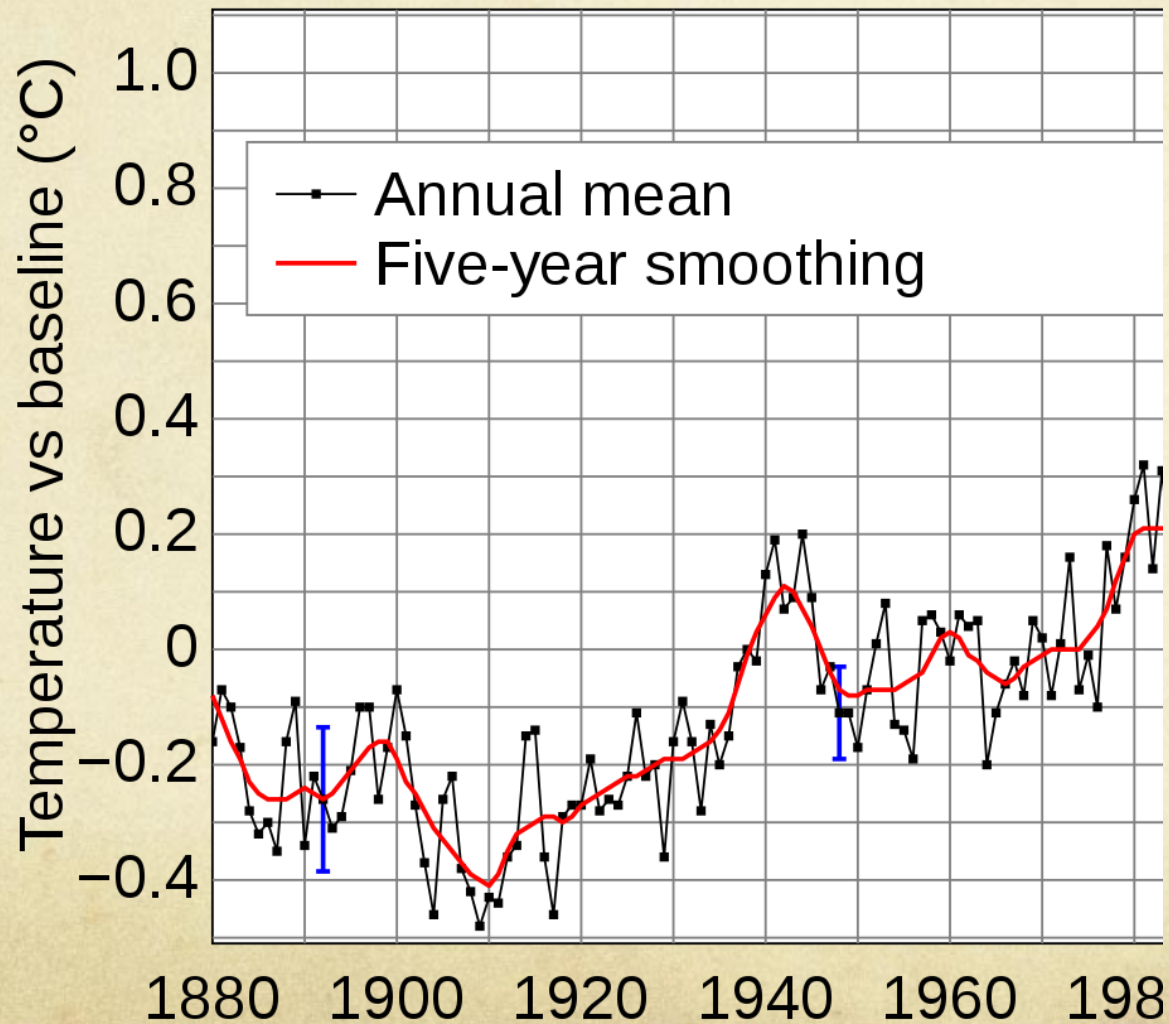
pirate

1
rocket

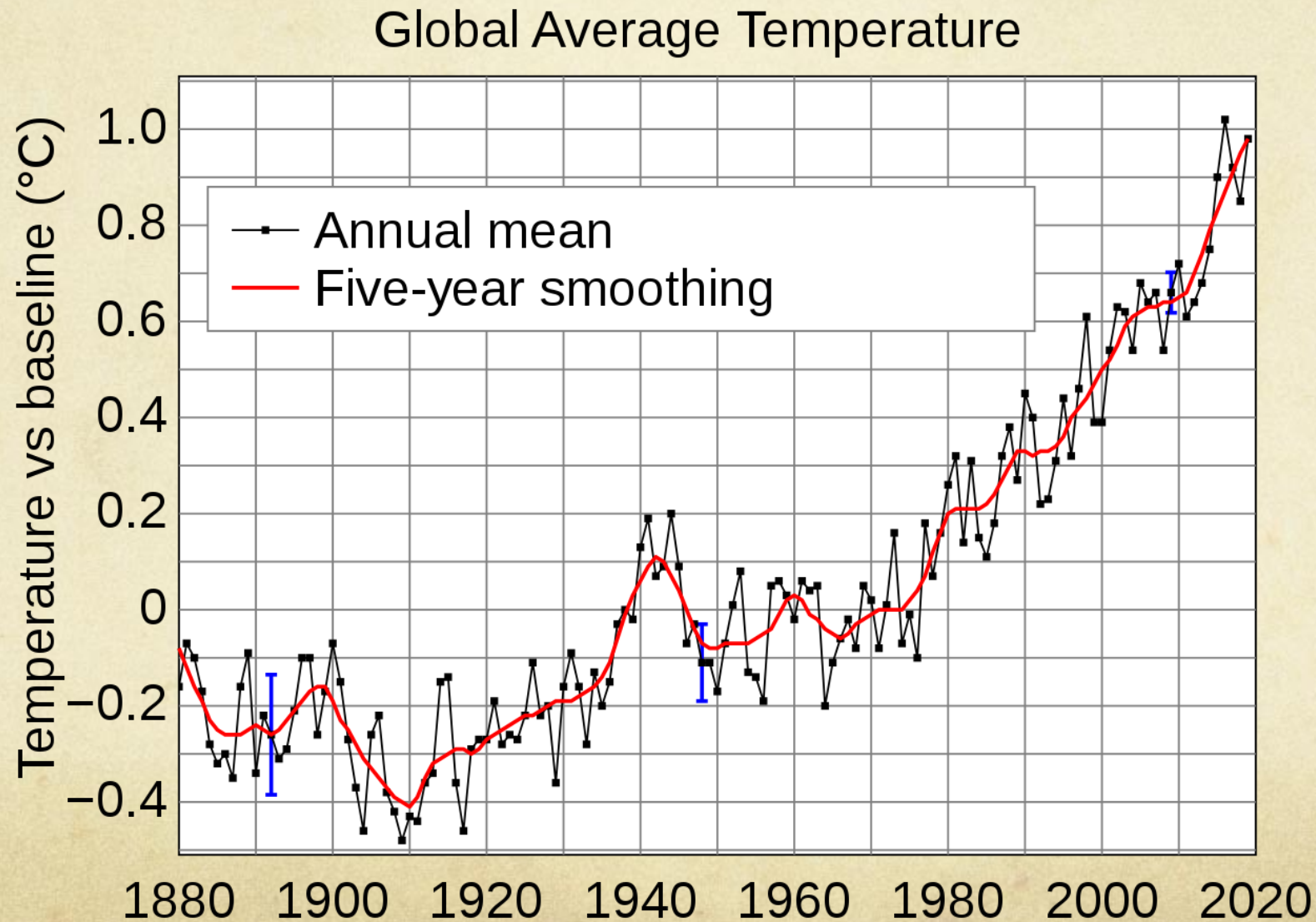
A LITTLE GOLDEN BOOK

I've been studying global warming since ~1984

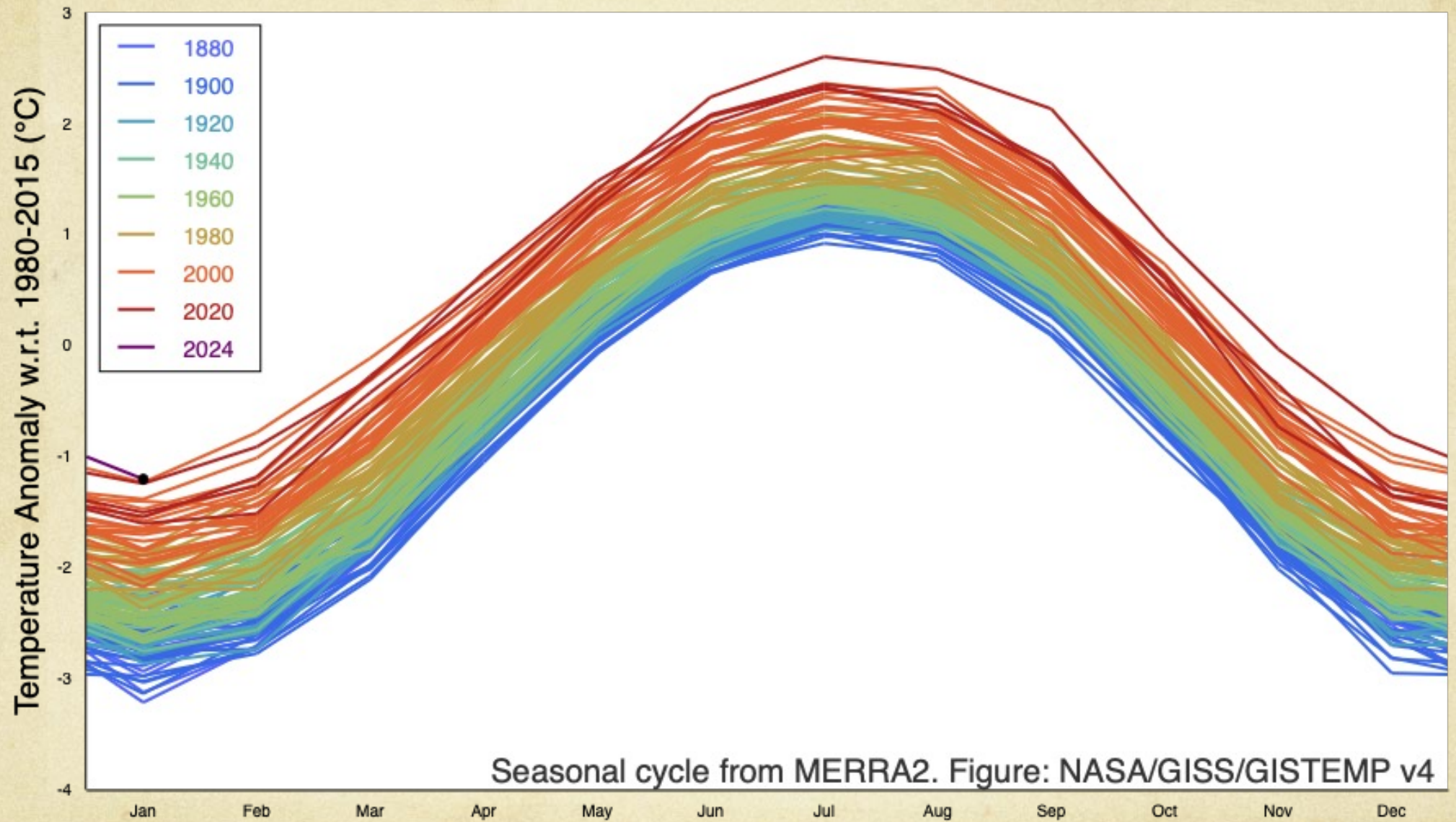
Global Average Temperatu



Is global warming a hoax?



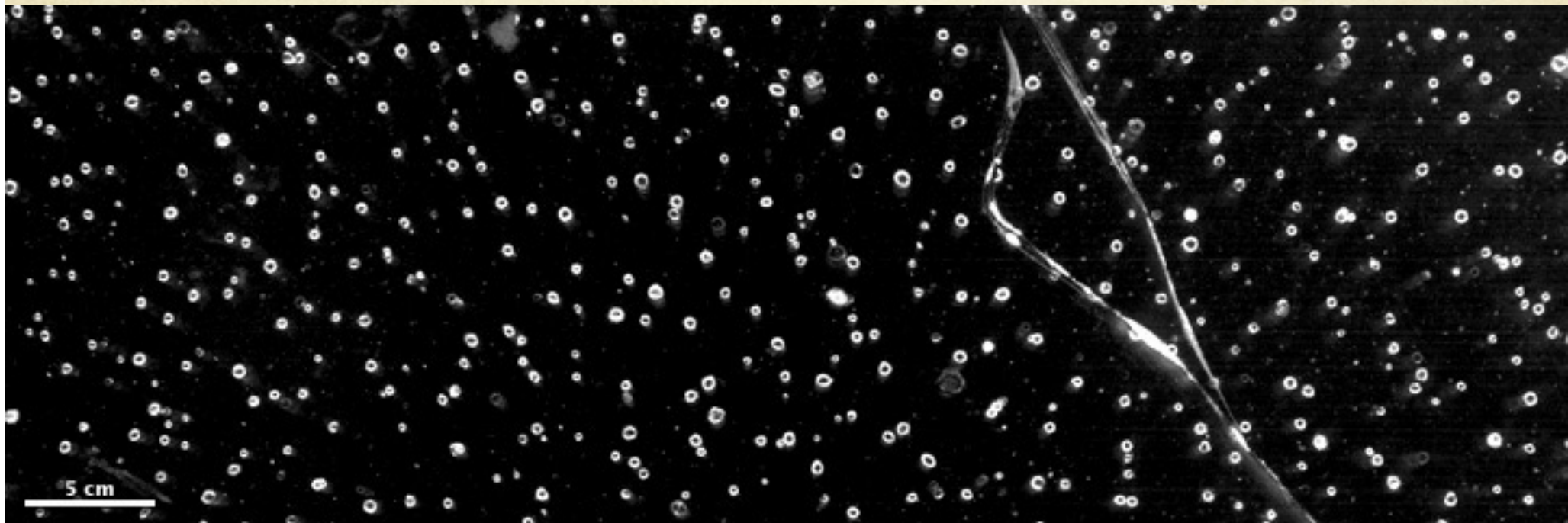
GISTEMP Seasonal Cycle since 1880



What evidence indicates how the climate has changed over time?

Air bubbles in glacial ice trap samples of Earth's atmosphere

- Provide a history of greenhouse gases that stretches back more than 800,000 years.
- The chemical make-up of the ice provides clues to the average global temperature.



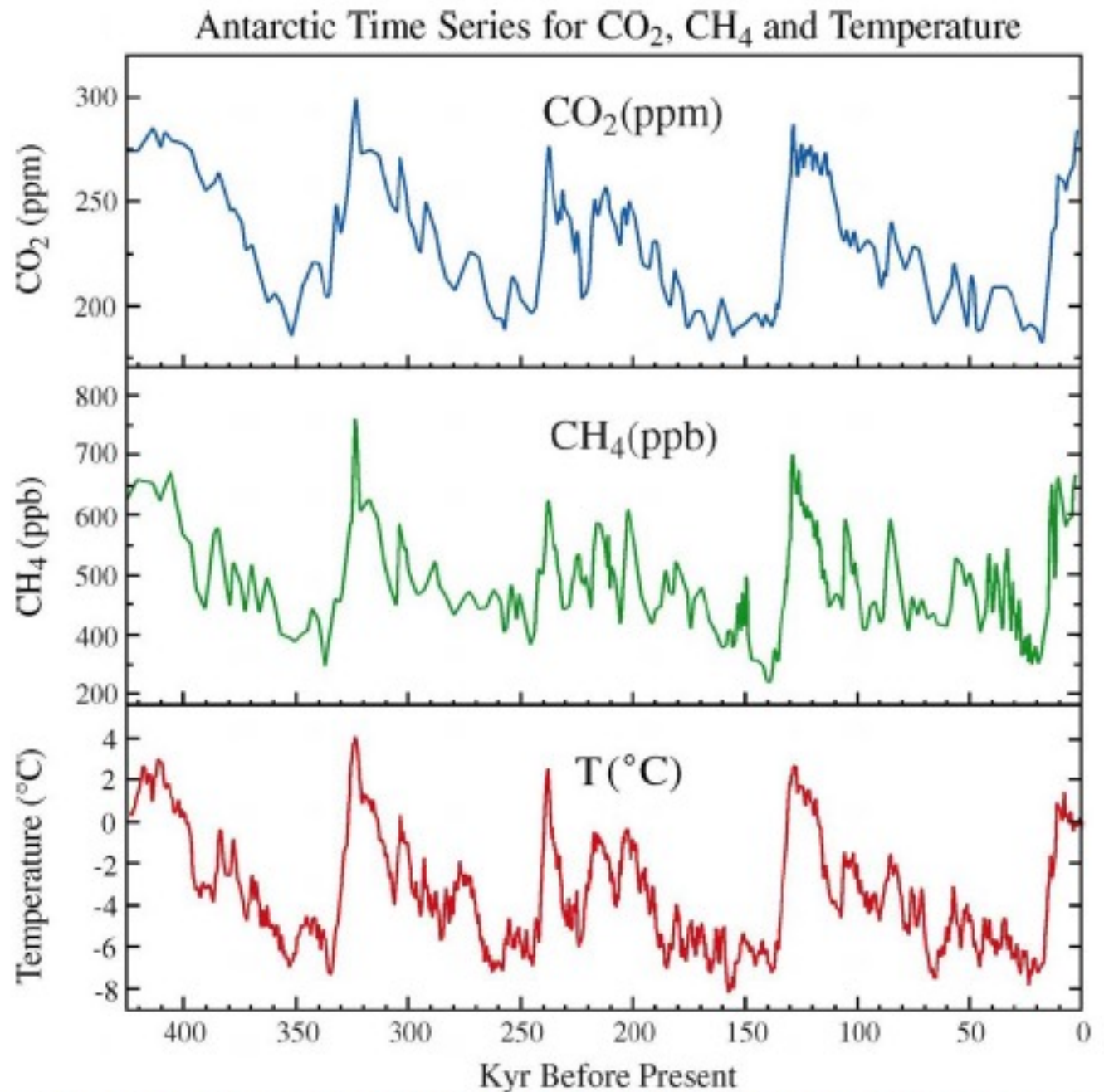
Ice Core Data

These are the major greenhouse gases (GHGs) and temperatures from Antarctica

They've been confirmed in Greenland and other places ...

When did humans evolve?

When did civilization appear?



CO₂, CH₄ and temperature records from Antarctic ice core data

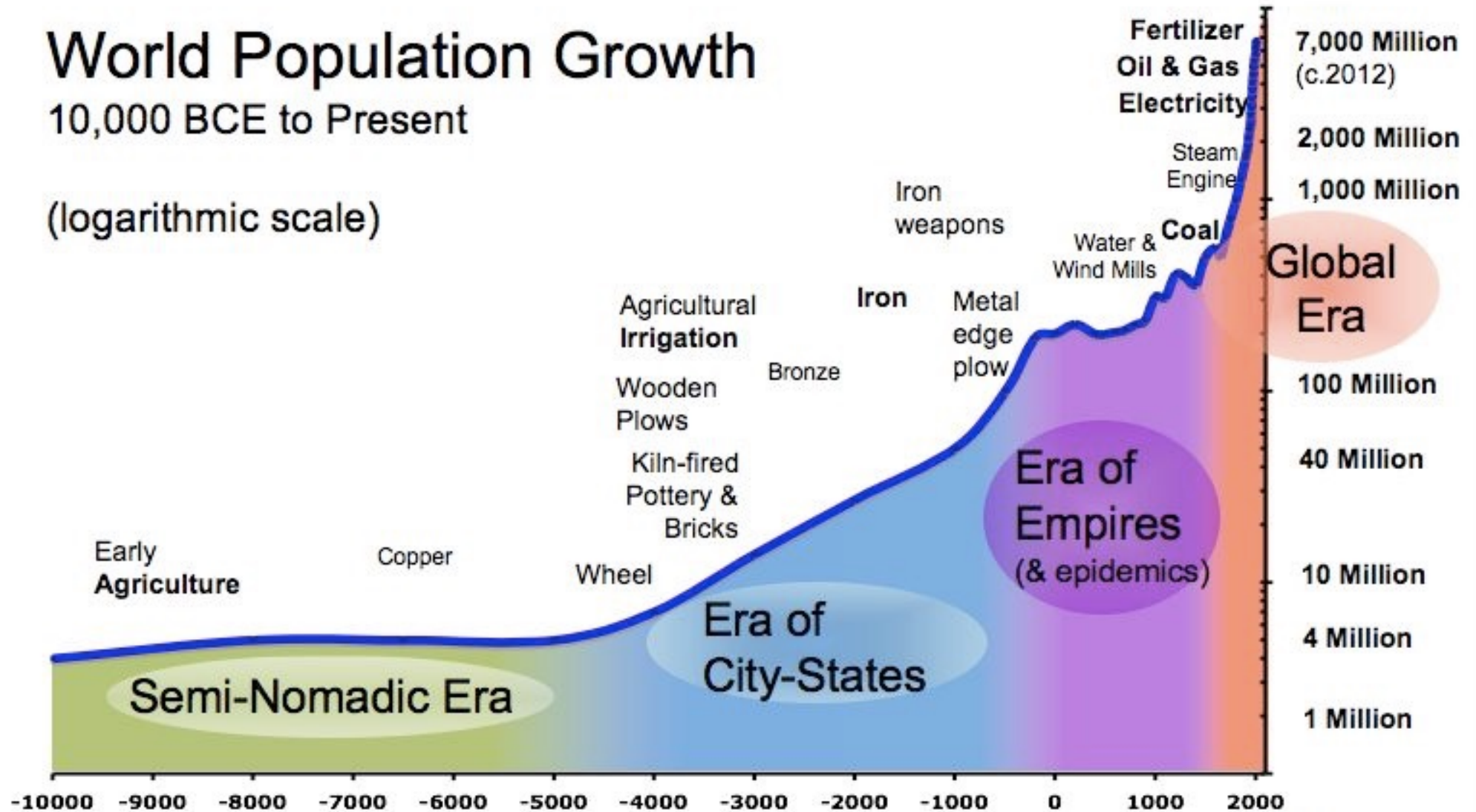
Source: Vimeux, F., K.M. Cuffey, and Jouzel, J., 2002, "New insights into Southern Hemisphere temperature changes from Vostok ice cores using deuterium excess correction", *Earth and Planetary Science Letters*, 203, 829-843.

How does population correlate?

World Population Growth

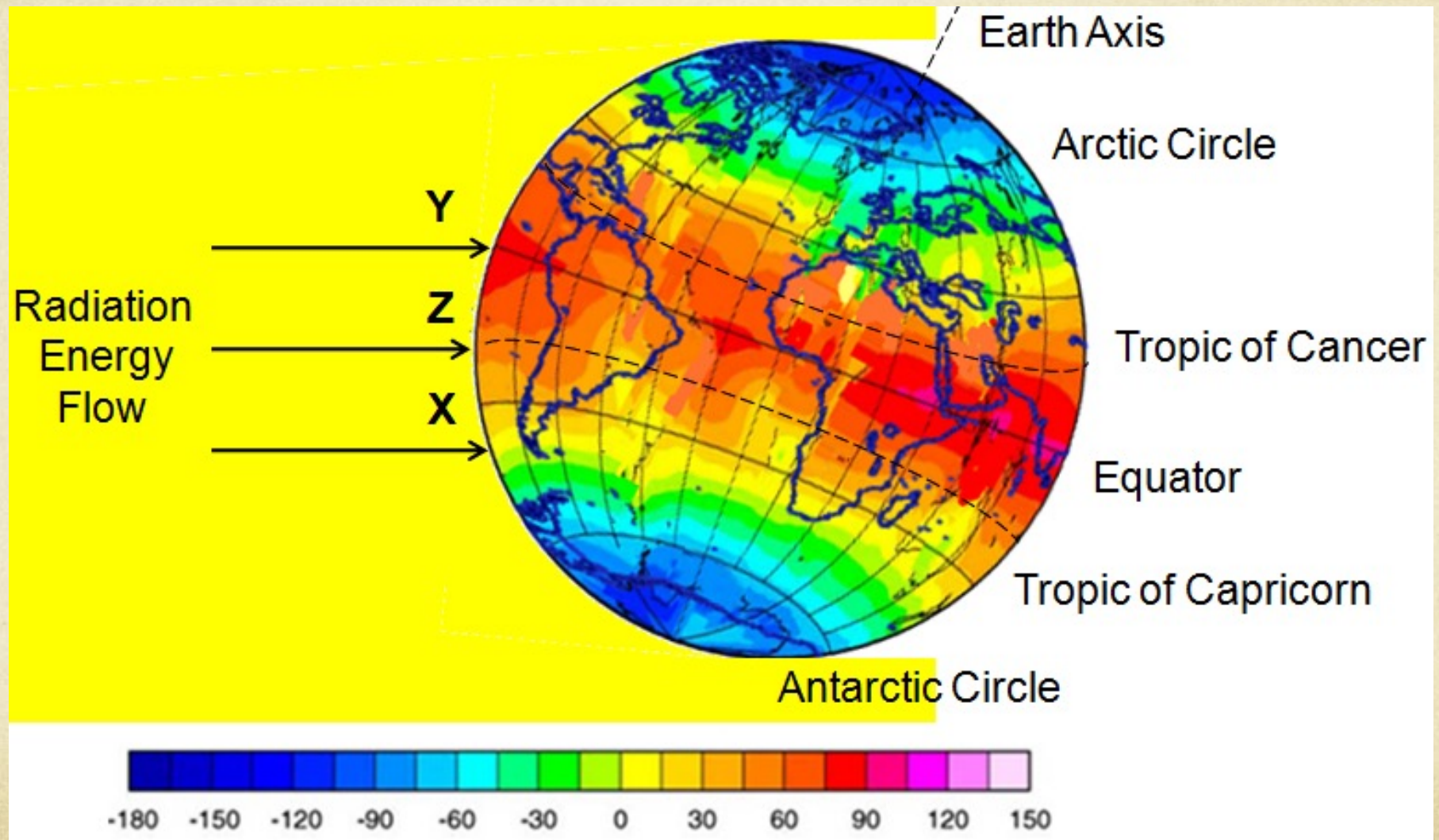
10,000 BCE to Present

(logarithmic scale)

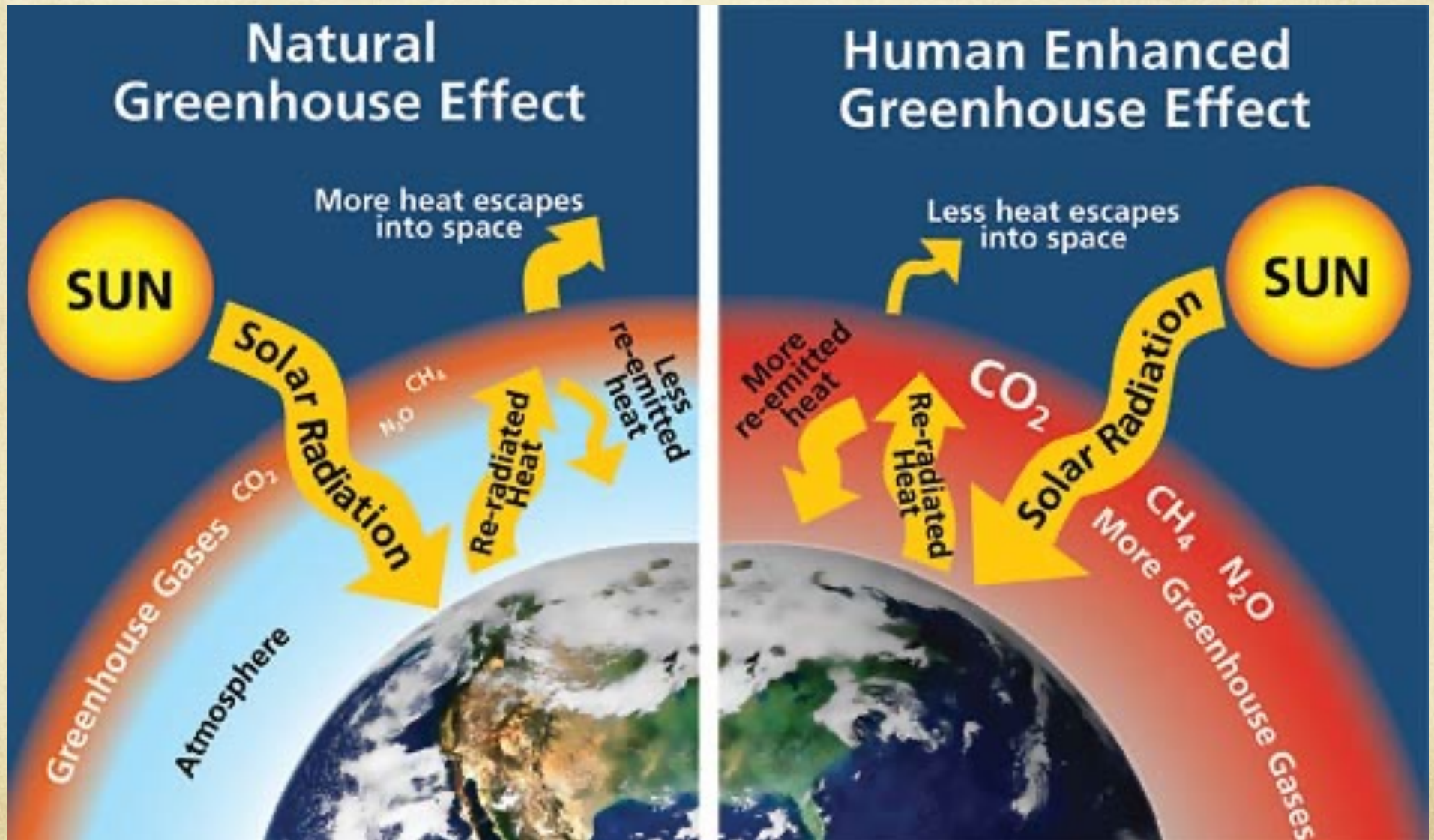


How does the Sun's radiation
impact the Earth temperature?

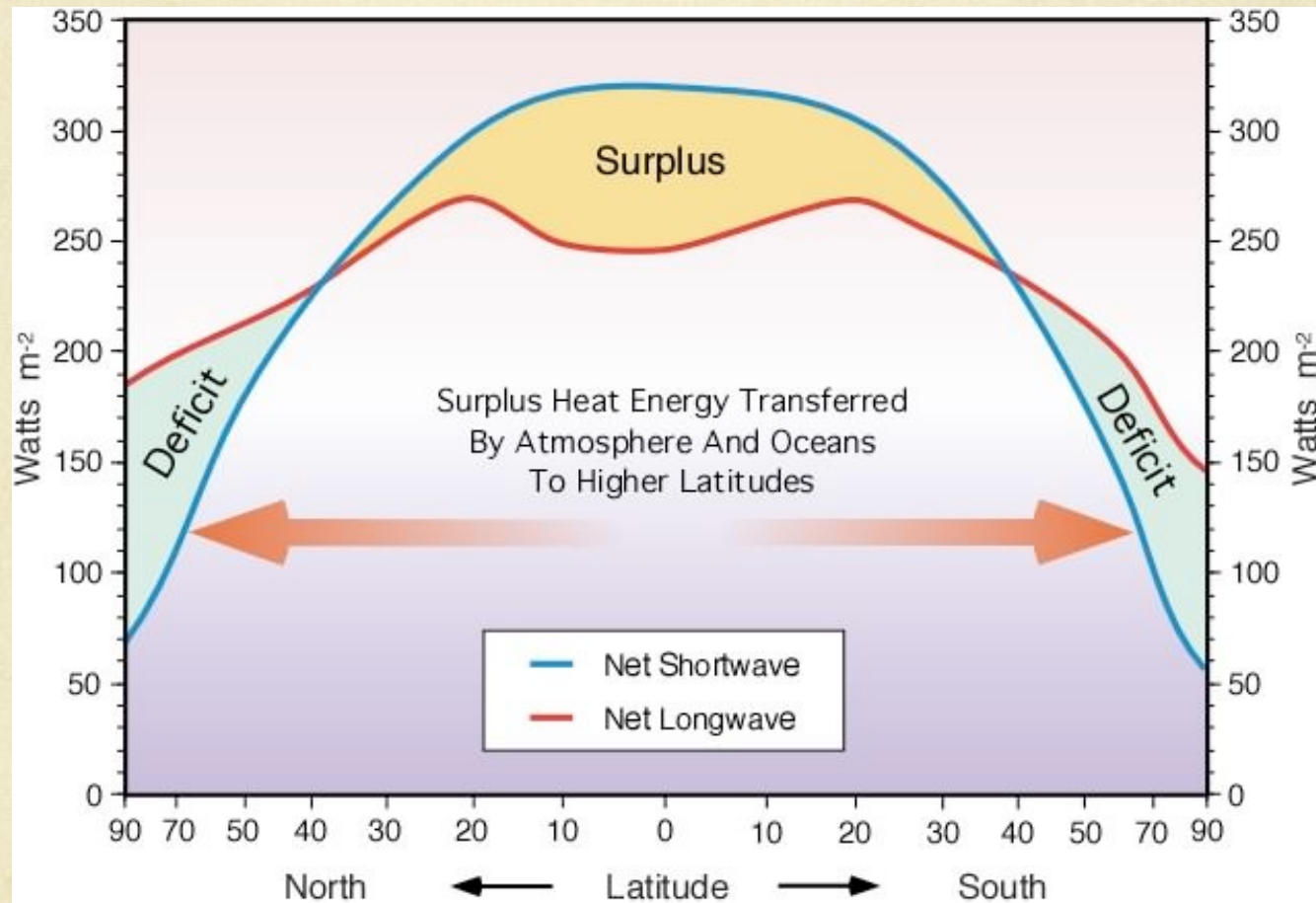
Earth's temperature begins with the Sun.



The Greenhouse Effect

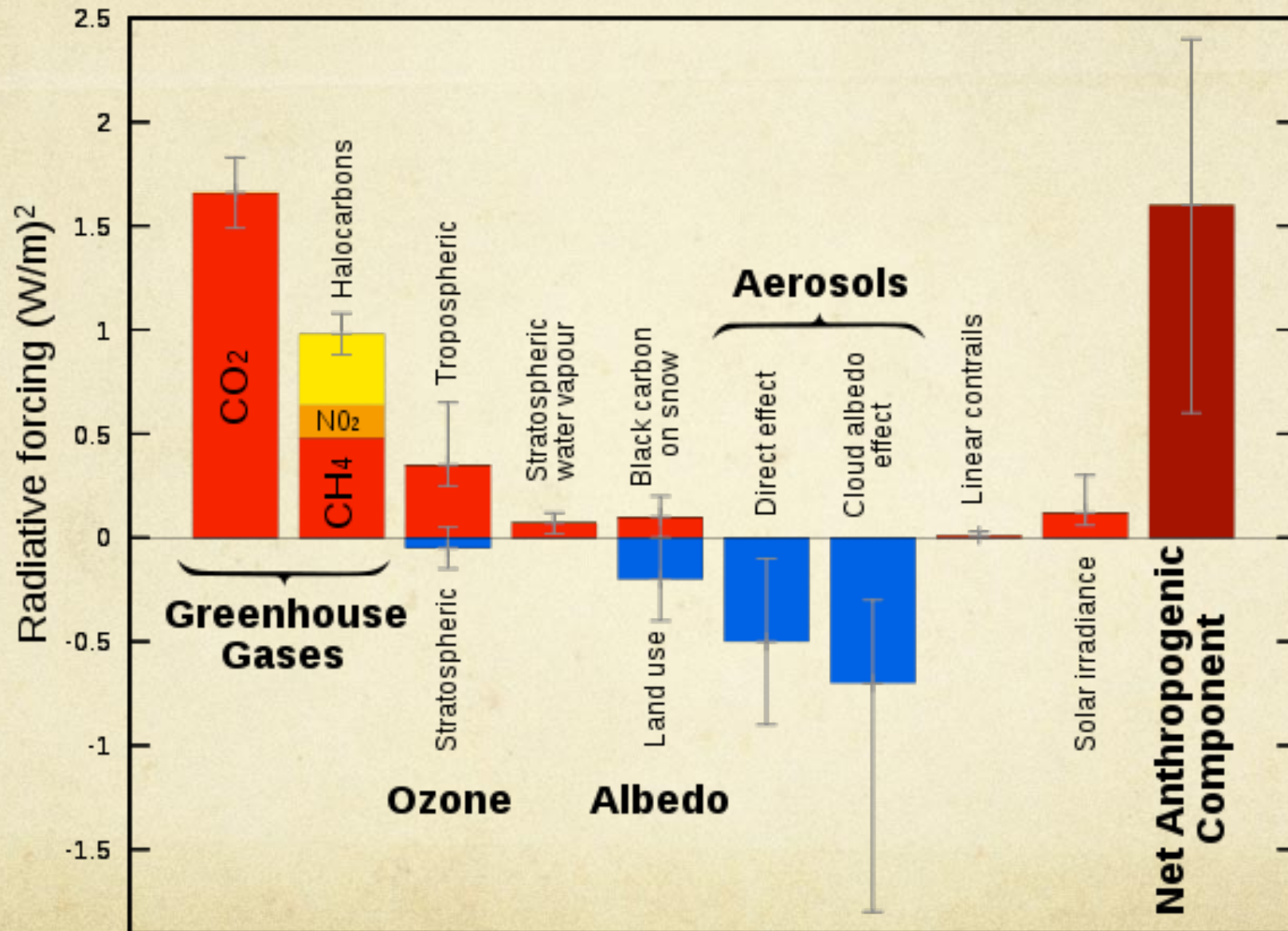


The equator receives more radiant solar energy than it radiates – so it's hotter.



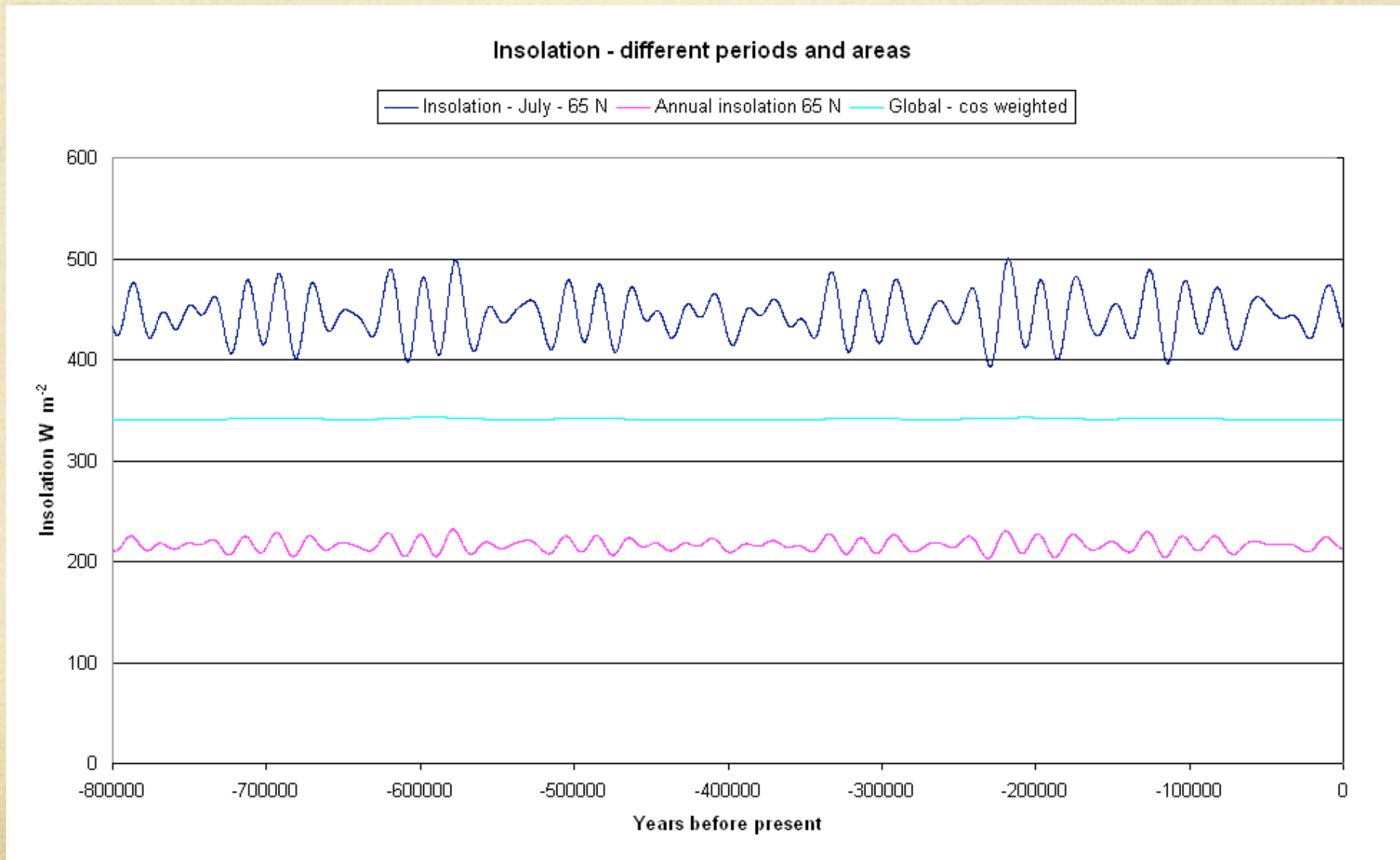
The poles radiate more energy than they absorb from space – so they're cooler.

Radiative Forcing Components

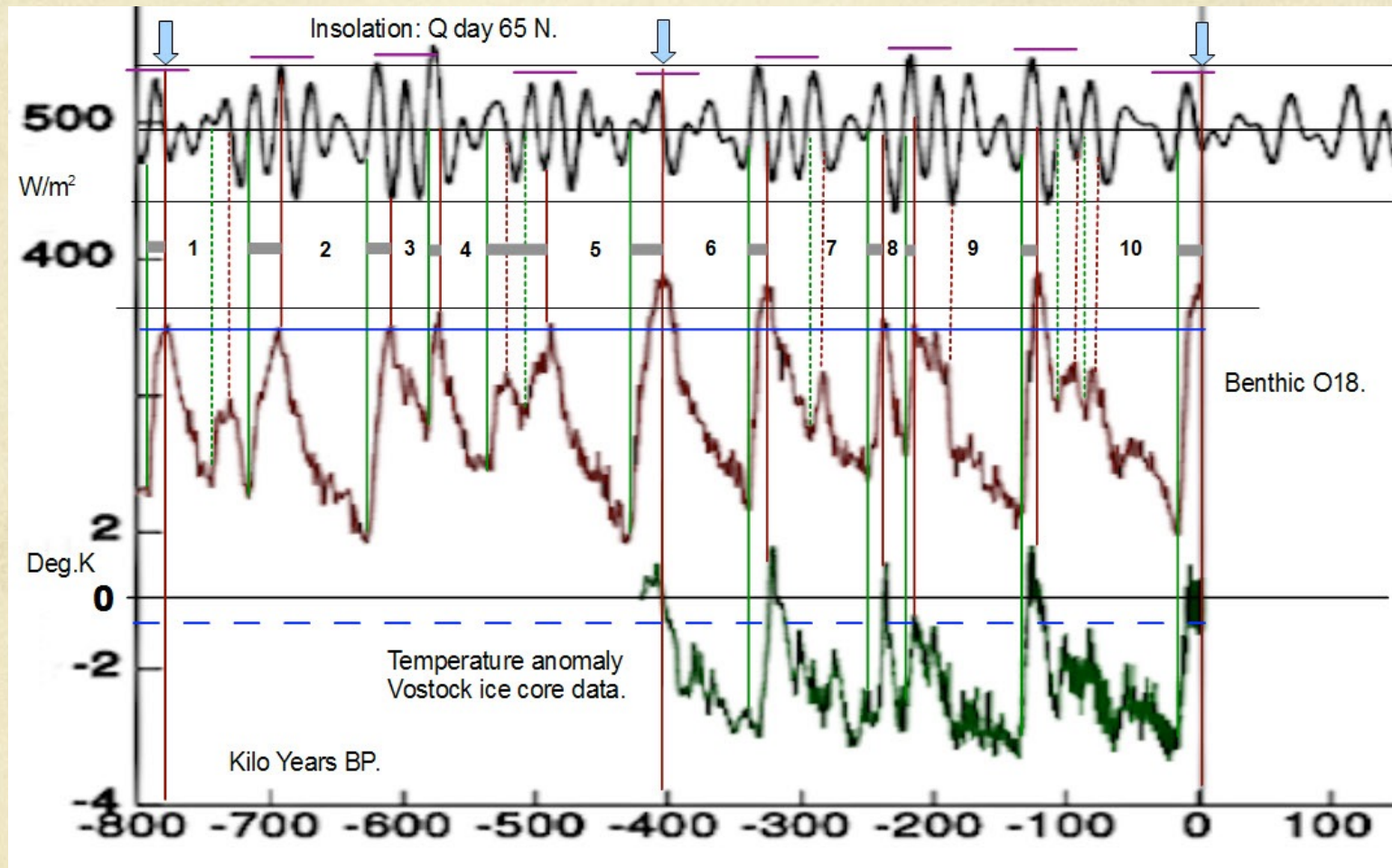


Does the Earth's orbit around the Sun influence global temperature?

Milankovic cycles are periodic changes in Earth's orbit.



Do these cycles explain the observed variations?

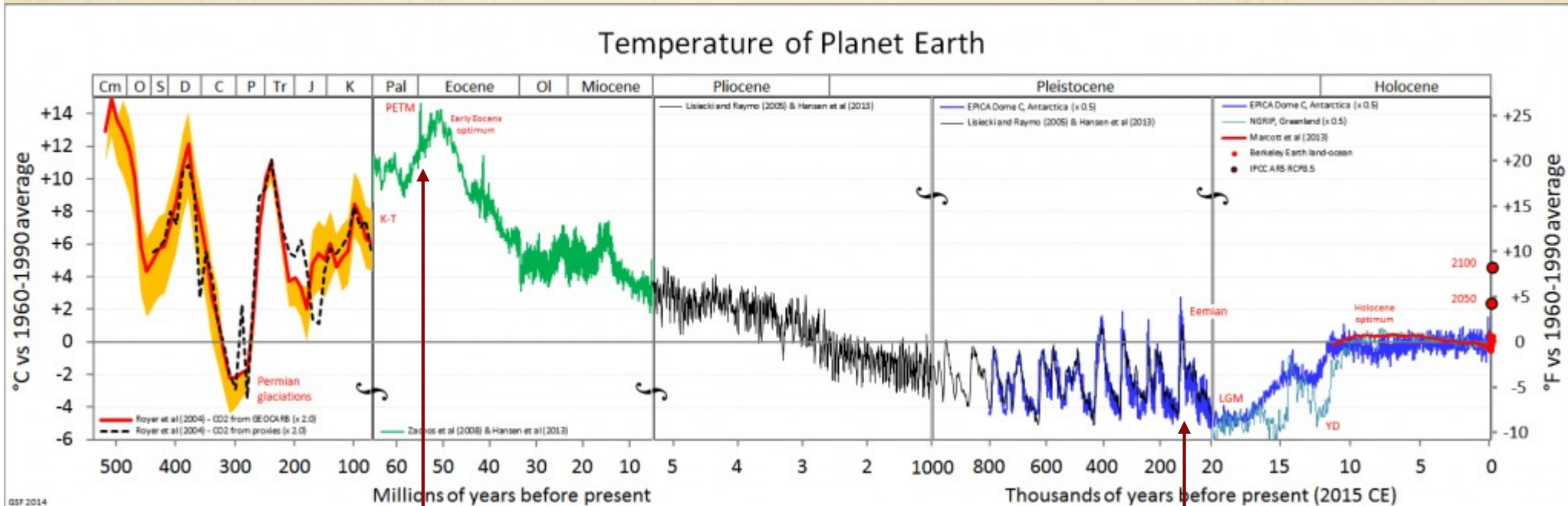


There is correlation but other phenomena must also contribute.

Has the Earth ever been as
warm as it is today?

Global Temperature History

Large human societies have only existed during a stable climate



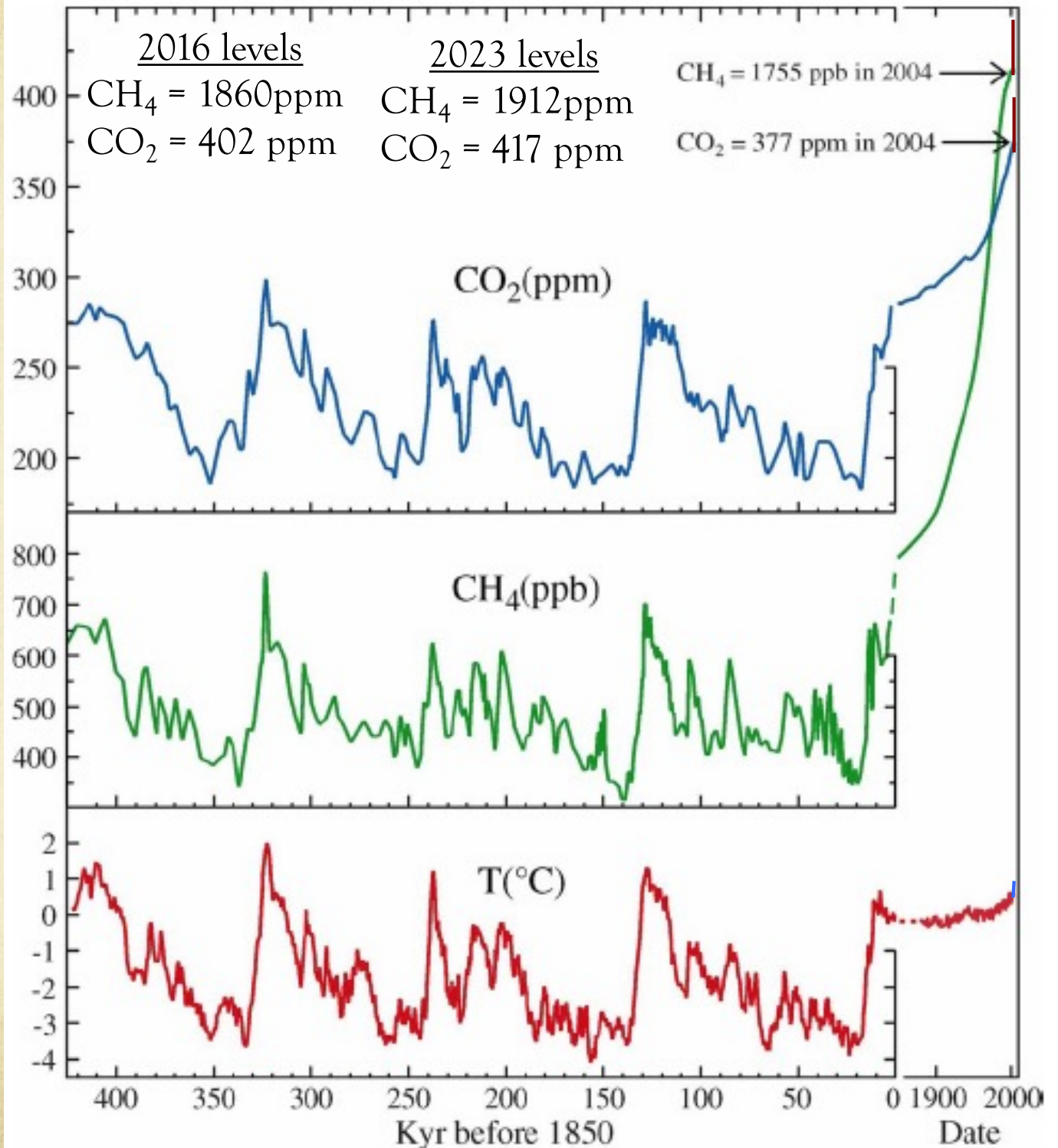
55.5 million
years ago
2500ppm CO₂

130,000
years ago
280ppm CO₂

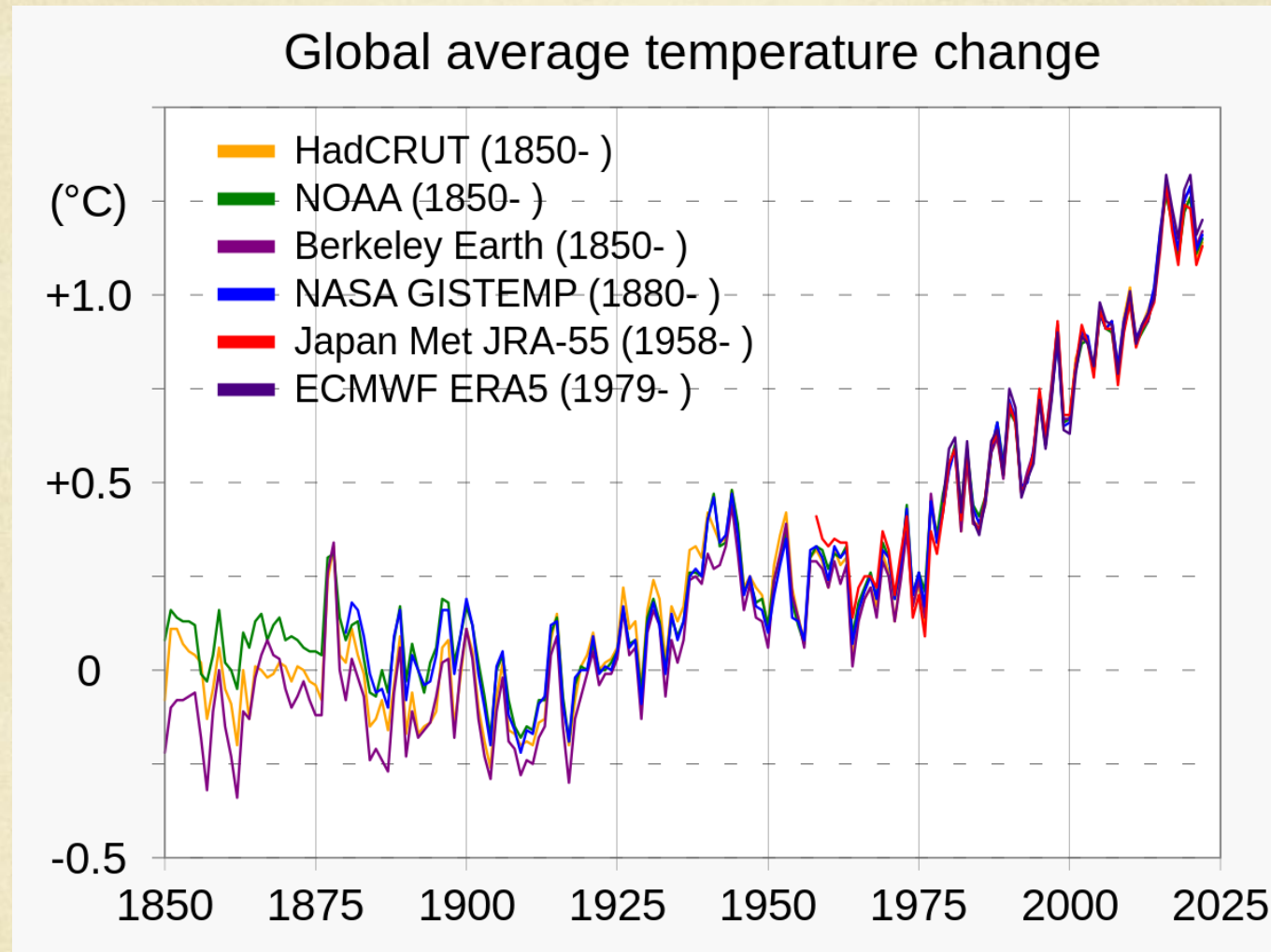
Where are we now?

Before the Industrial Revolution, Earth's climate changed due to natural causes unrelated to human activity.

(Note the right side of the graph is on a very different time scale.)



Recent warming anomaly began with the Industrial Revolution



The CO₂ (and methane) increases have the isotopic signatures of fossil fuels.

What do fossil fuels have to do with it?

- We accurately know how much fossil fuel is burned each year – since energy companies sell it (10 GTC/year, or 35 GTCO₂/yr)
- Atmospheric CO₂ increase is ~ 1/2 of that, the other 1/2 is absorbed by the ocean, increasing its acidity and threatening the planet's the food chain
- The amounts match measurements!
- The isotopic signature matches fossil fuels
- The timing matches fossil fuels
 - ... therefore, the warming must be from wobbles in the orbit, sunspots, cosmic rays, ... democrats ...

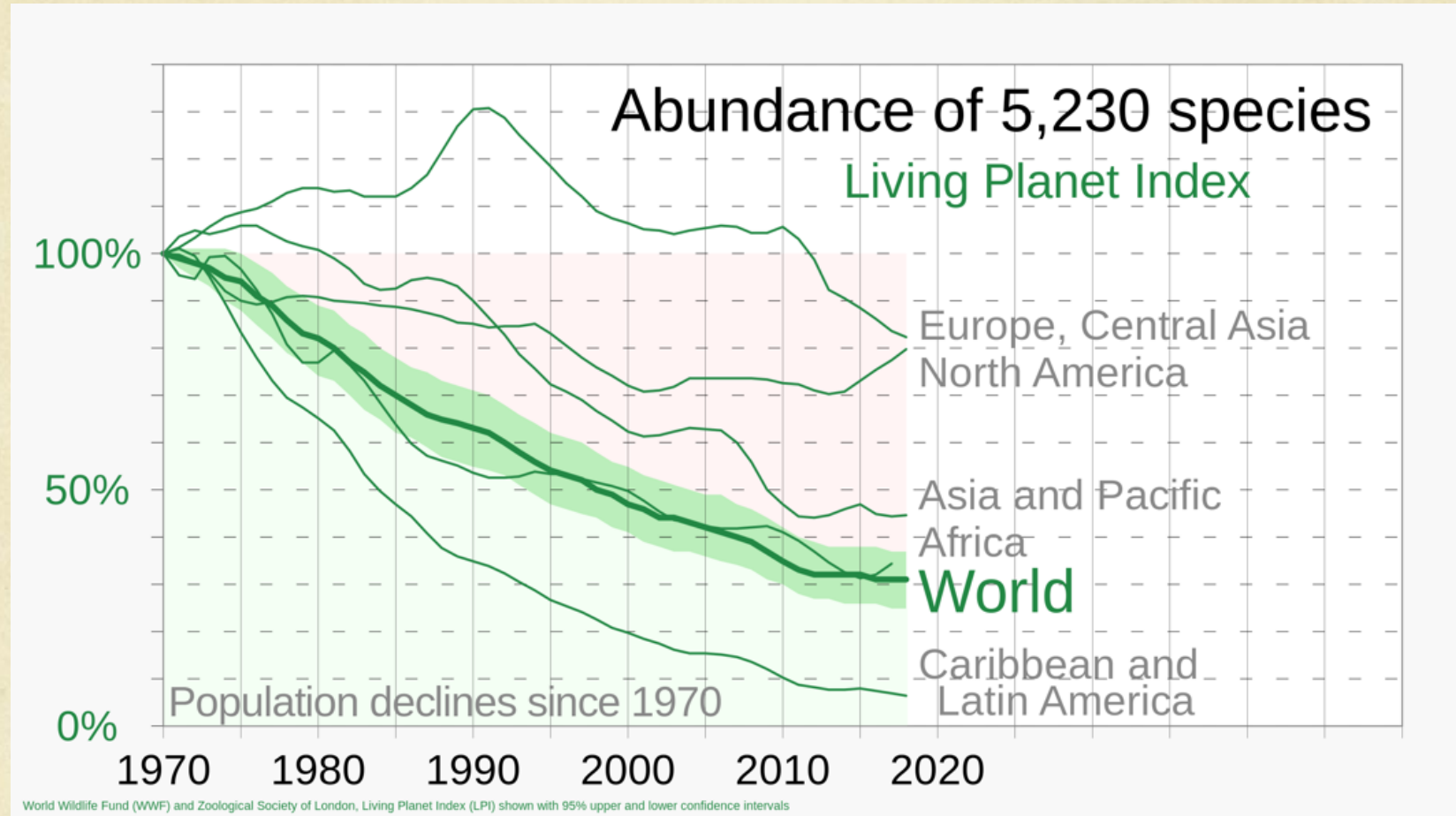
How will this impact people
and the planet?

Canada's Athabasca Glacier



The glacier has been shrinking by about 15 meters per year. In the past 125 years, the glacier has lost half its volume and has retreated more than 1.5 kilometers.

Global Warming and Biodiversity



There is a biodiversity crisis – half the world's forests have been logged in the last 100 years, >90% of the ocean's large fish are gone, 70% decline in wildlife since 1970, etc.

Poor people are disproportionally affected

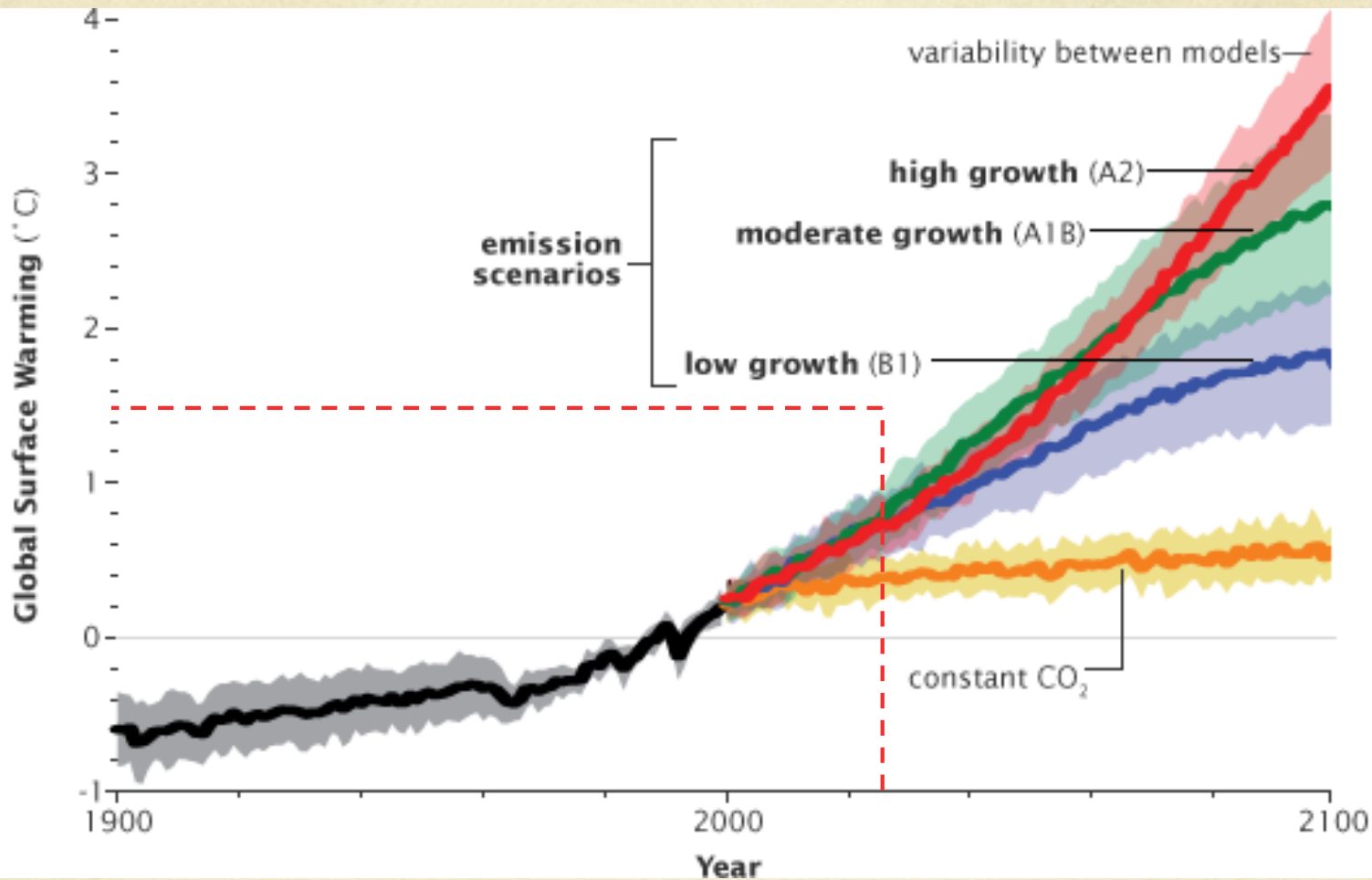


They contributed the least to the problem, and their communities often lack resiliency

Some impacts of global warming

- Melts ice caps and glaciers, more rain vs. snow
 - More floods and droughts
 - Rising sea levels frequently flood coastal cities
- More intense and frequent devastating storms (stronger atmospheric heat engine)
- Longer growing season in polar regions, lethal heat in the tropics disrupt food production
 - Disrupting pollination and animal migration patterns
 - Local and global starvation
- More refugees
- Alters the ranges of some infectious diseases
- *Many of these factors are synergistic -- global warming amplifies uncertainty, chaos, violence, authoritarian responses (“only I can restore order ...”), etc.*

Future warming models by the Intergovernmental Panel on Climate Change



Earth will warm $\sim 2\text{-}6^{\circ}\text{C}$ over the next century, depending on how fast carbon dioxide emissions grow

What is the biggest issue for
climate change?

People are causing global warming.

People must mitigate global warming.

- Keep fossil fuels in the ground.
- Invest in renewable energy.
- Make homes energy efficient.
- Make manufacturing environmentally clean.
- Make farming environmentally neutral.
- Protect forests.
- Protect the oceans.
- Reduce global emissions in transportation.
- Reduce consumption.

*Achieving most of these requires governmental (and individual) actions.
Focusing on personal “carbon footprints” is a propaganda ploy to maintain
the current system.*

Make Governments More Democratic

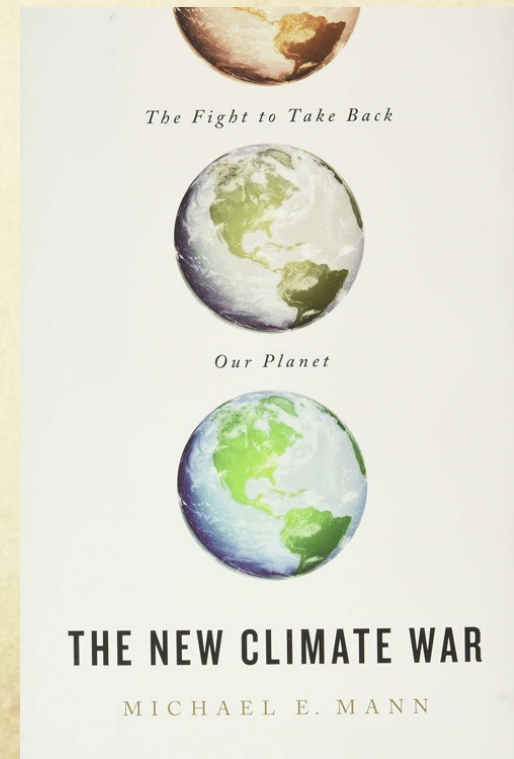
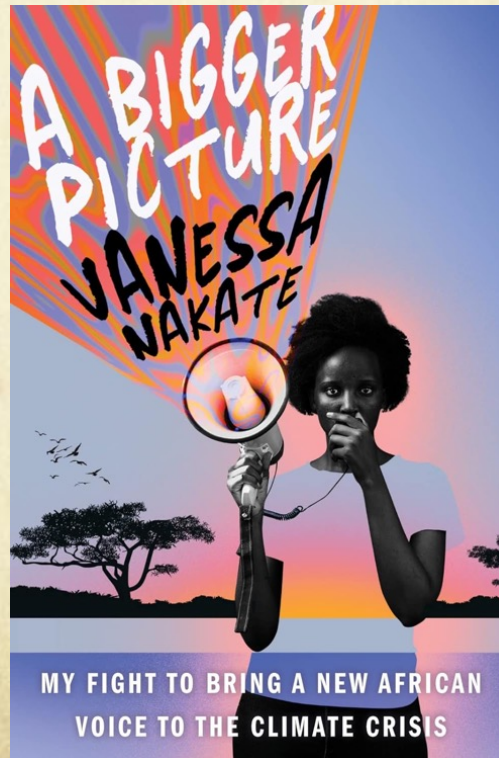
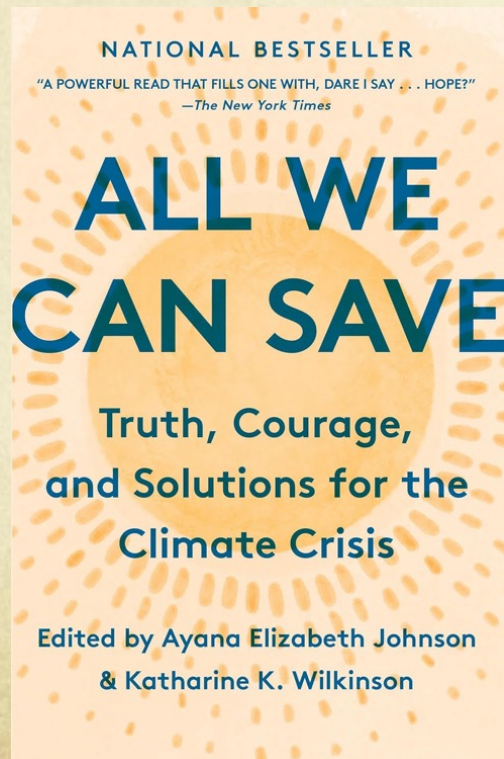
- Governments should serve the collective interests of its citizens and future generations, vs. a small group of wealthy donors and lobbyists
- Limit money in politics.
 - How much have *you* paid your lobbyists this week?
- Enforce ethics standards for public offices.
- Establish equitable tax policy for individuals and corporations.
- Produce long-term budgets, policies, regulations.
- Increase public engagement.
- Heavily fine polluters.

Some Practical Solutions

- Uruguay converted its electrical system to >90% renewable over 10 years (98% green in some years)
 - “The biggest challenge, however, was to change the “narrative” about renewables”¹
 - Political stability and a national goal for energy independence
 - They are now converting public transport to electric and encouraging private transport to switch

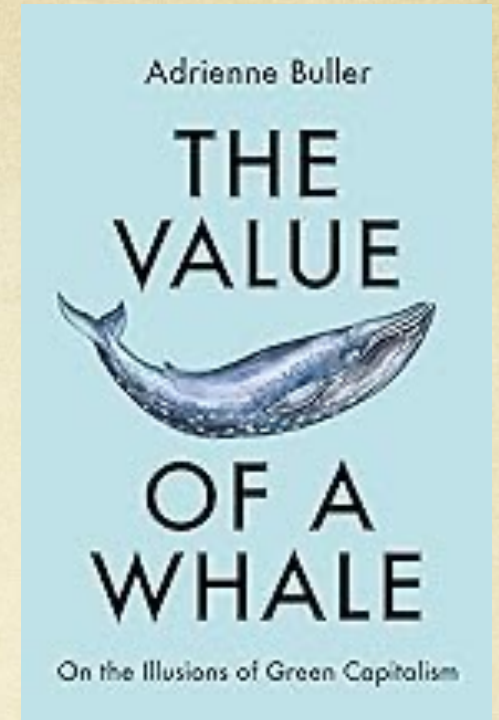
Building local resiliency

- Following Hurricane Maria, Puerto Rico found strength in community rebuilding --
<https://www.youtube.com/watch?v=xBddgaPzHIQ>



Our Successes

- We collectively banned commercial whaling in 1986 – preserving a keystone ocean species, a local tourism industry, ...
- We collectively stopped CFC pollution that was destroying polar stratospheric ozone
- We collectively stopped (legal) slavery – in most countries without resorting to a bloody civil war
- We collectively can do positive things!!





CLIMATE SUMMIT

WHAT IF IT'S
A BIG HOAX AND
WE CREATE A BETTER
WORLD FOR NOTHING?

- ENERGY INDEPENDENCE
- PRESERVE RAINFORESTS
- SUSTAINABILITY
- GREEN JOBS
- LIVABLE CITIES
- RENEWABLES
- CLEAN WATER, AIR
- HEALTHY CHILDREN
- ETC. ETC.



11/7/19 USA TODAY

DEL
PITT

Choices

Which of these sunrises do you want for your grandkids?





Foto: Brian Rasnow

*Thank you!!
Questions!!*

(Photo of my son, and Guatemala's 2012 Earth Day Poster)

Supporting slides

Greenhouse effect is necessary for life.

- Naturally occurring greenhouse gases have a mean warming effect of about 33 °C (59 °F) on Earth.



740K



290K



240K

How does energy enter and leave the atmosphere?

Solar radiation reaches us from the sun.

Some of it reflects off clouds and particles in the atmosphere before it even reaches the Earth's surface.

Because the Earth is so much warmer than space, it continually gives off heat as infrared radiation.

Some more reflects off bright features on the Earth, like snow and ice.

Most of that heat escapes into space, but some reflects off greenhouse gases in the atmosphere and returns to Earth.

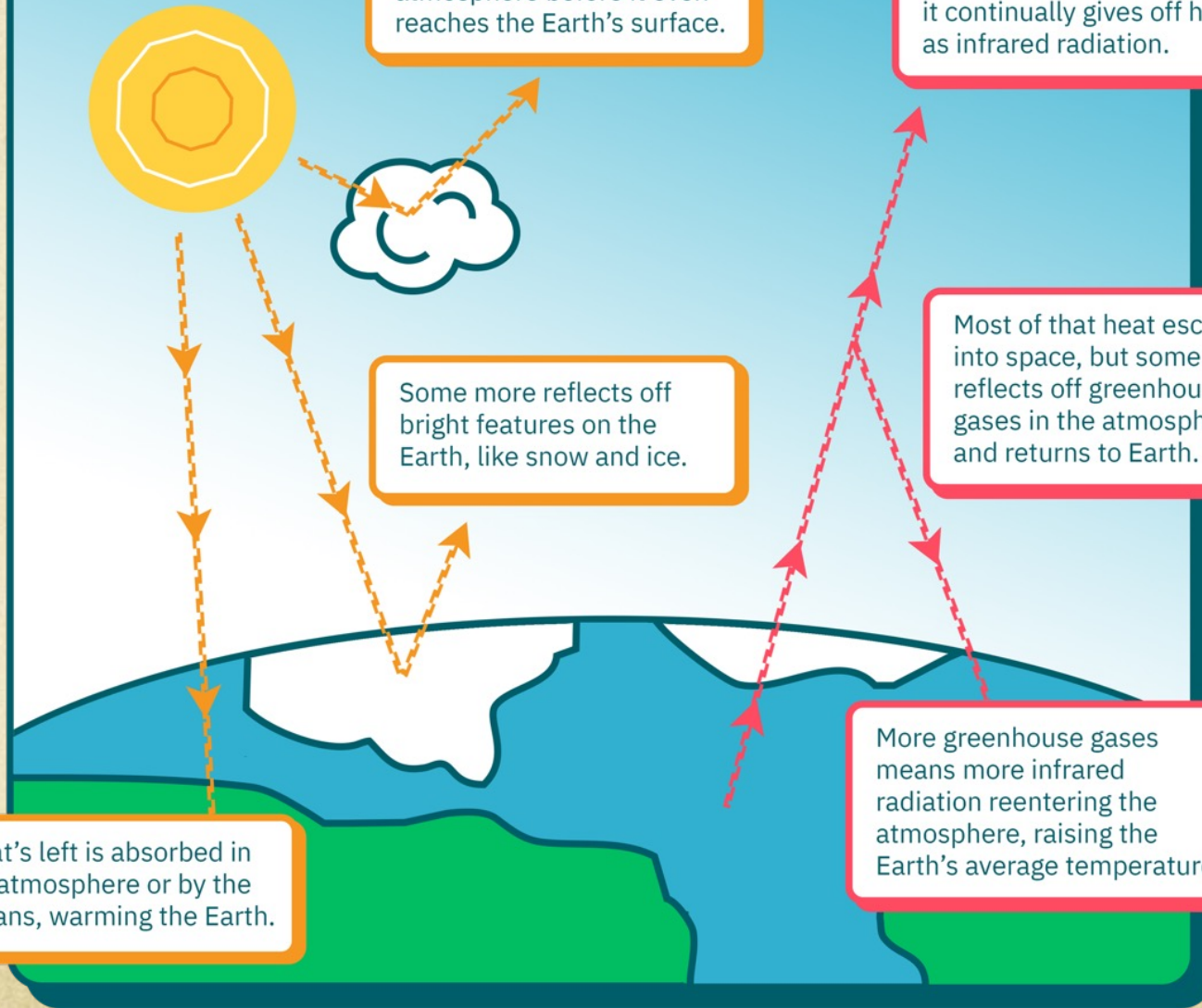
What's left is absorbed in the atmosphere or by the oceans, warming the Earth.

More greenhouse gases means more infrared radiation reentering the atmosphere, raising the Earth's average temperature.

Roughly 30 percent of incoming sunlight is reflected back into space by bright surfaces like clouds and ice.

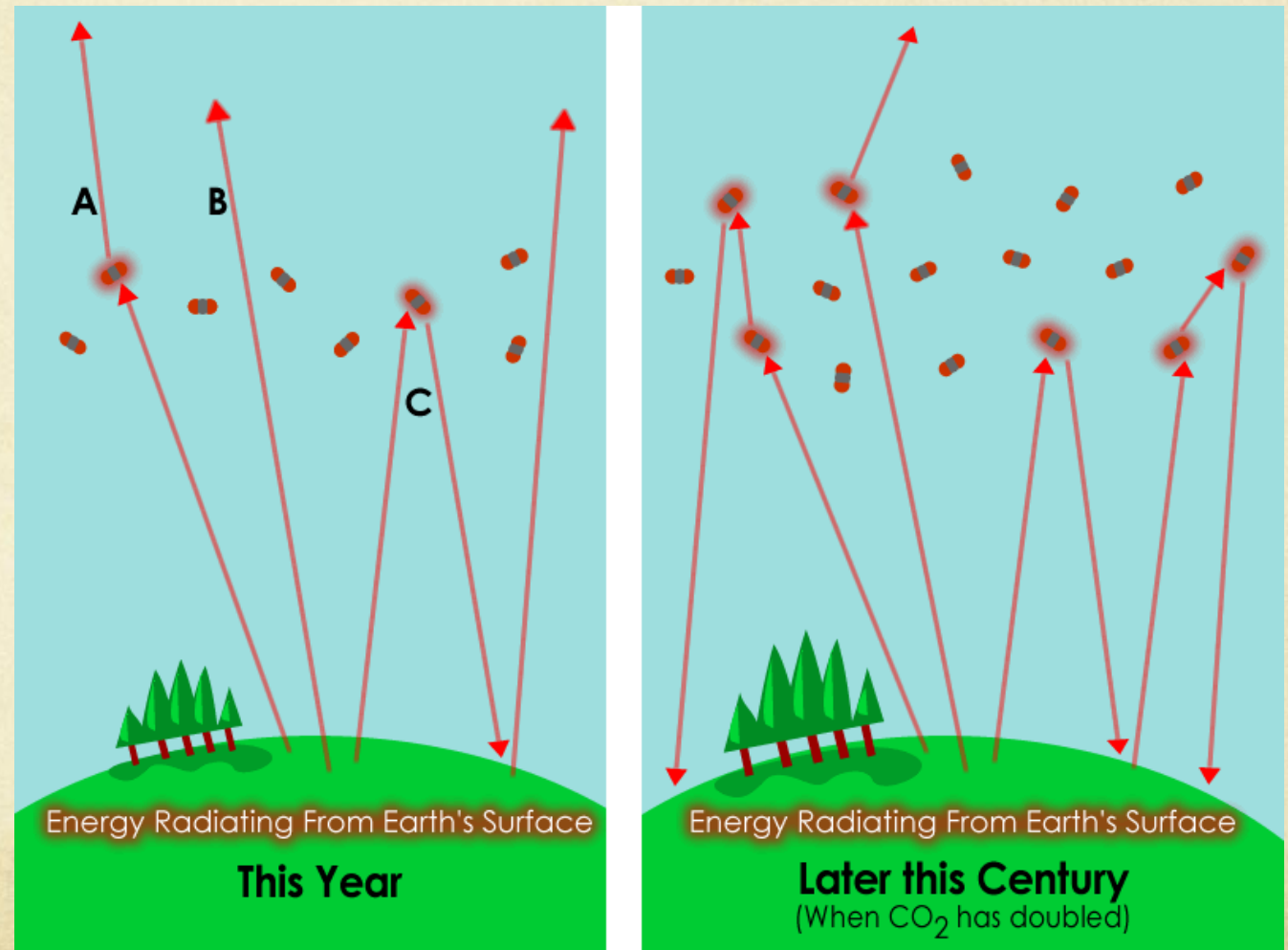
Of the remaining 70 percent, most is absorbed by the land and ocean.

The rest is absorbed by the atmosphere.



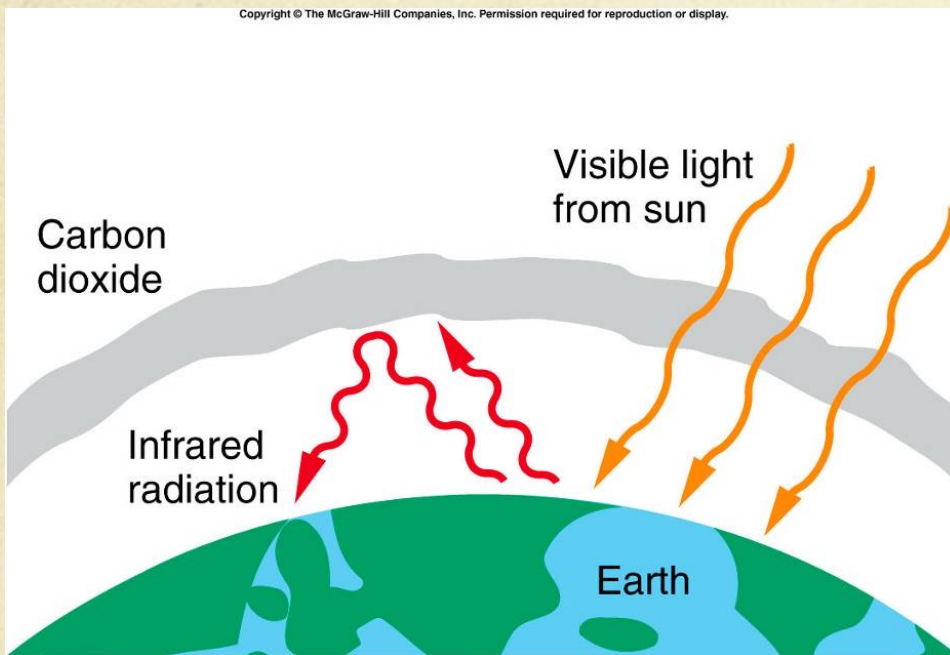
As the rocks, the air, and the seas warm, they radiate “heat” energy

As more CO₂ enters the atmosphere, the radiation is reflected back towards earth rather than escaping into space – thus heating the earth even more.

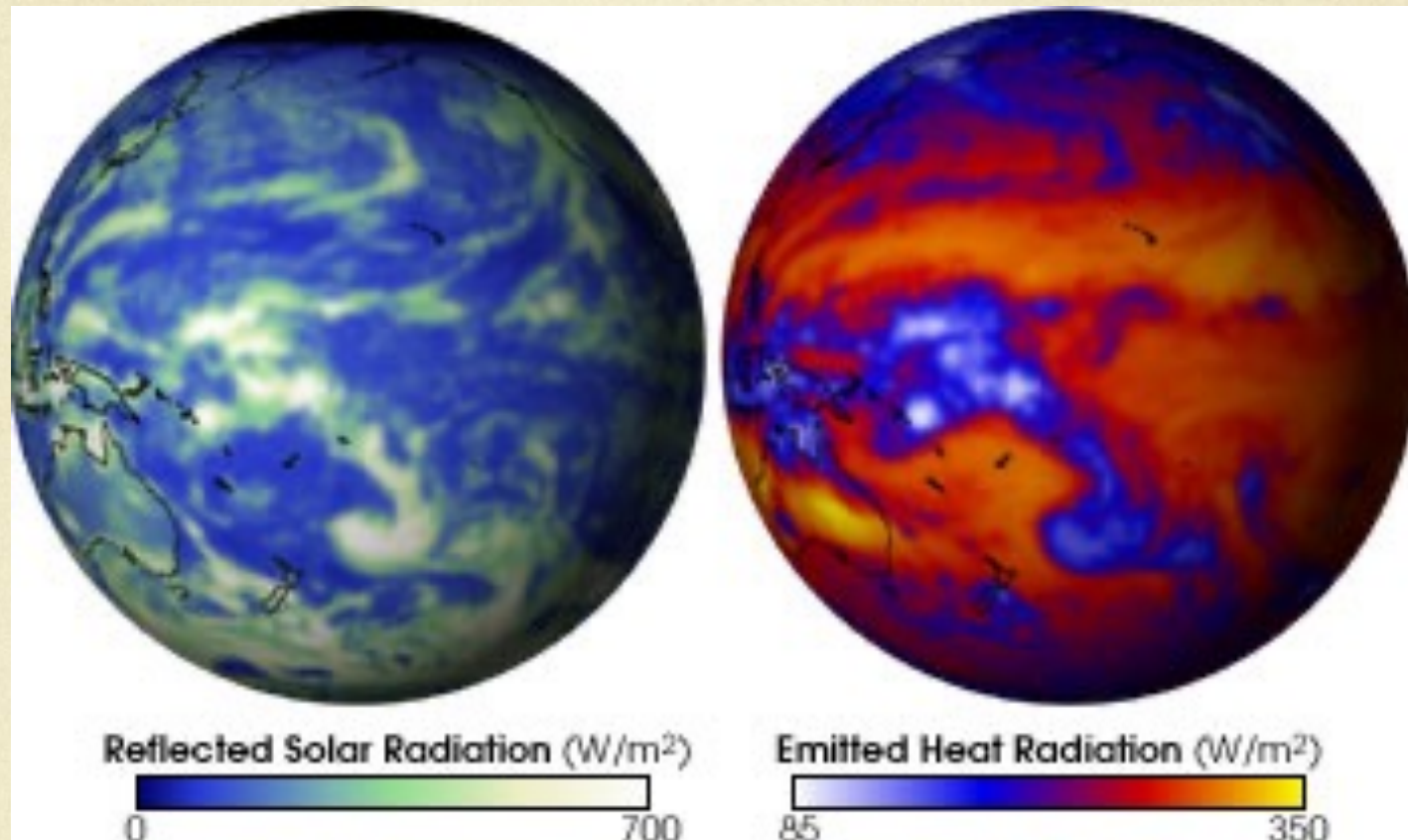


What is the Global warming?

- Greenhouse gases reflect IR radiation.
- Act just like the windows in your car.



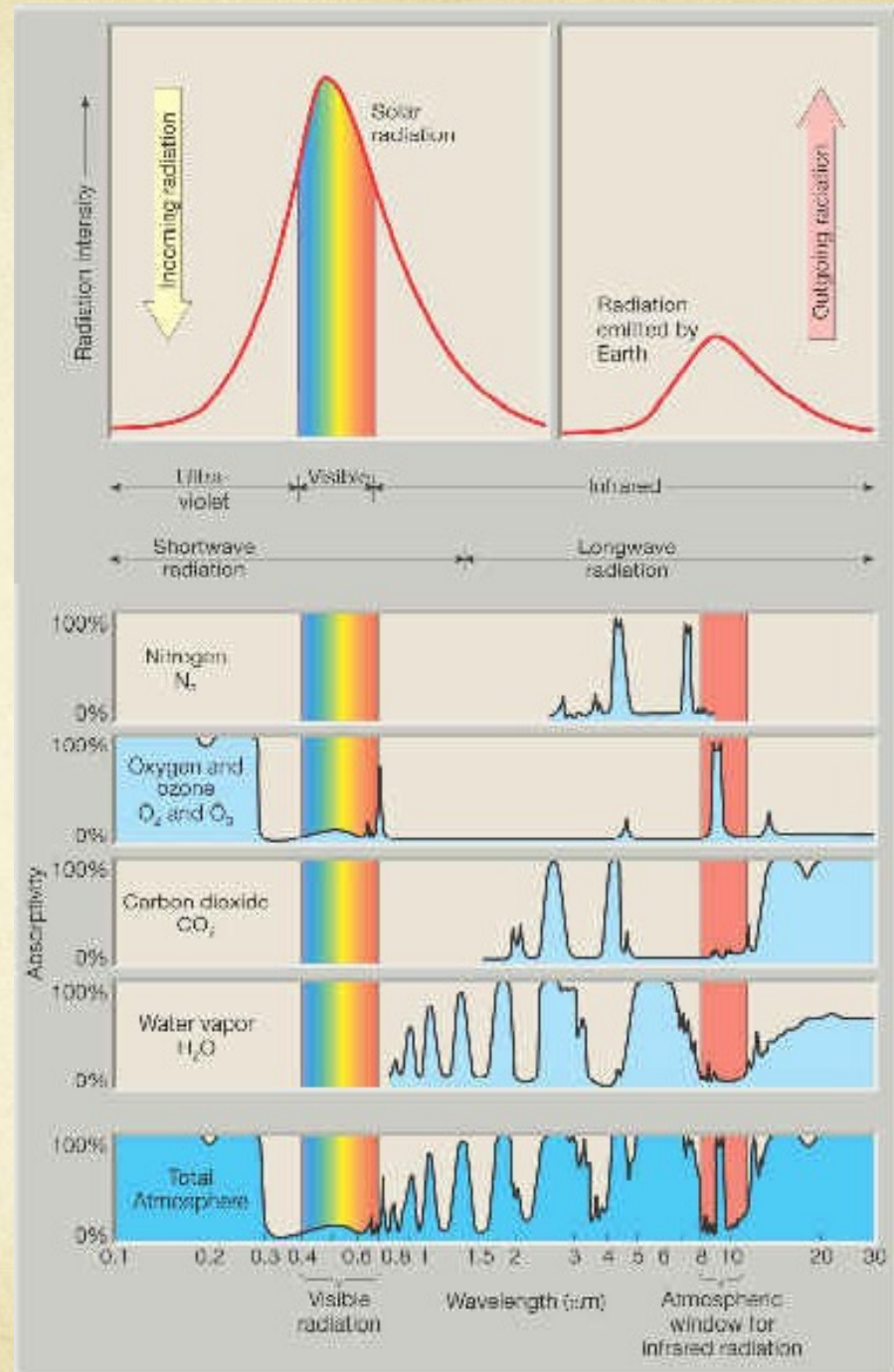
Earth is absorbing more energy than it is radiating back to space.



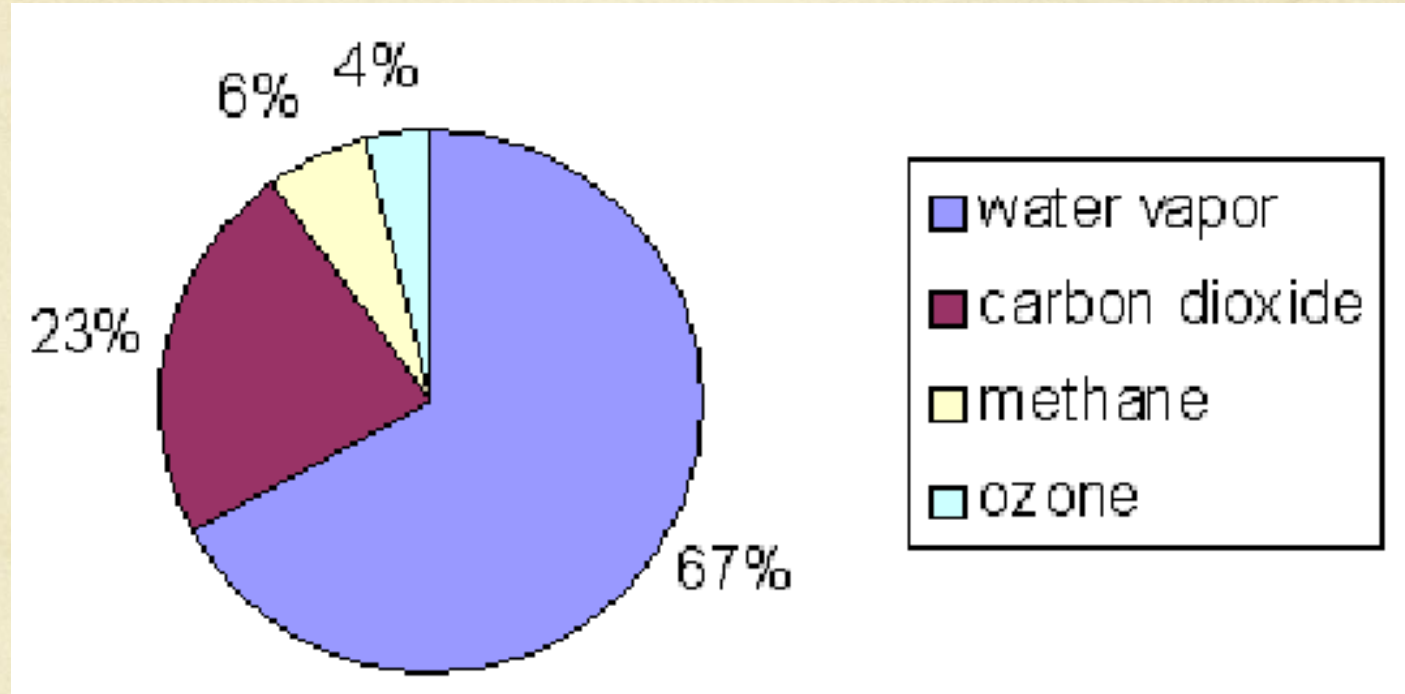
- About 0.85 Watts per square meter

Radiation from Sun and Earth

Absorption of light by the atmosphere.

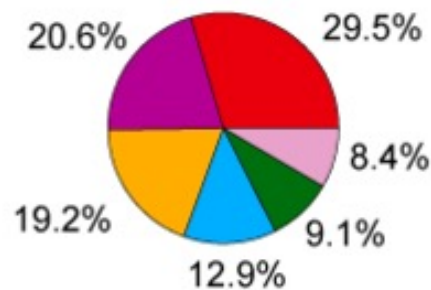
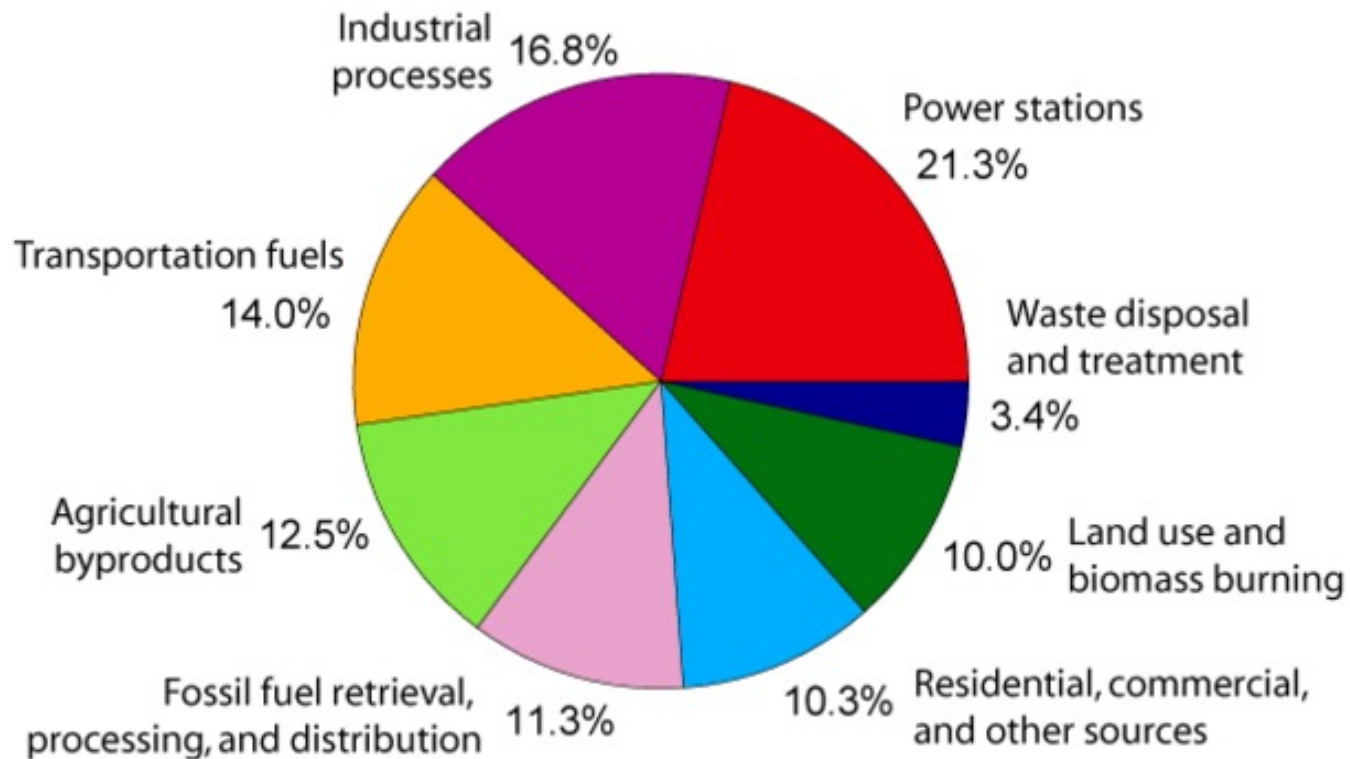


Greenhouse gas contributors (approximate).

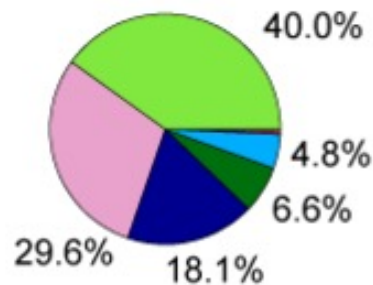


- This is a combination of the strength of the greenhouse effect of the gas and its abundance.
- Methane is a much stronger greenhouse gas than carbon dioxide, but is present in much smaller concentrations.

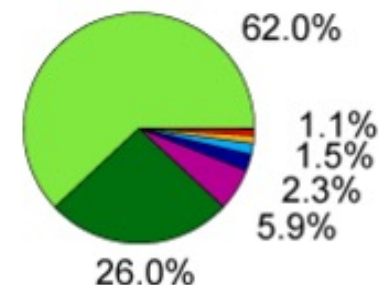
Annual Greenhouse Gas Emissions by Sector



Carbon Dioxide
(72% of total)



Methane
(18% of total)



Nitrous Oxide
(9% of total)

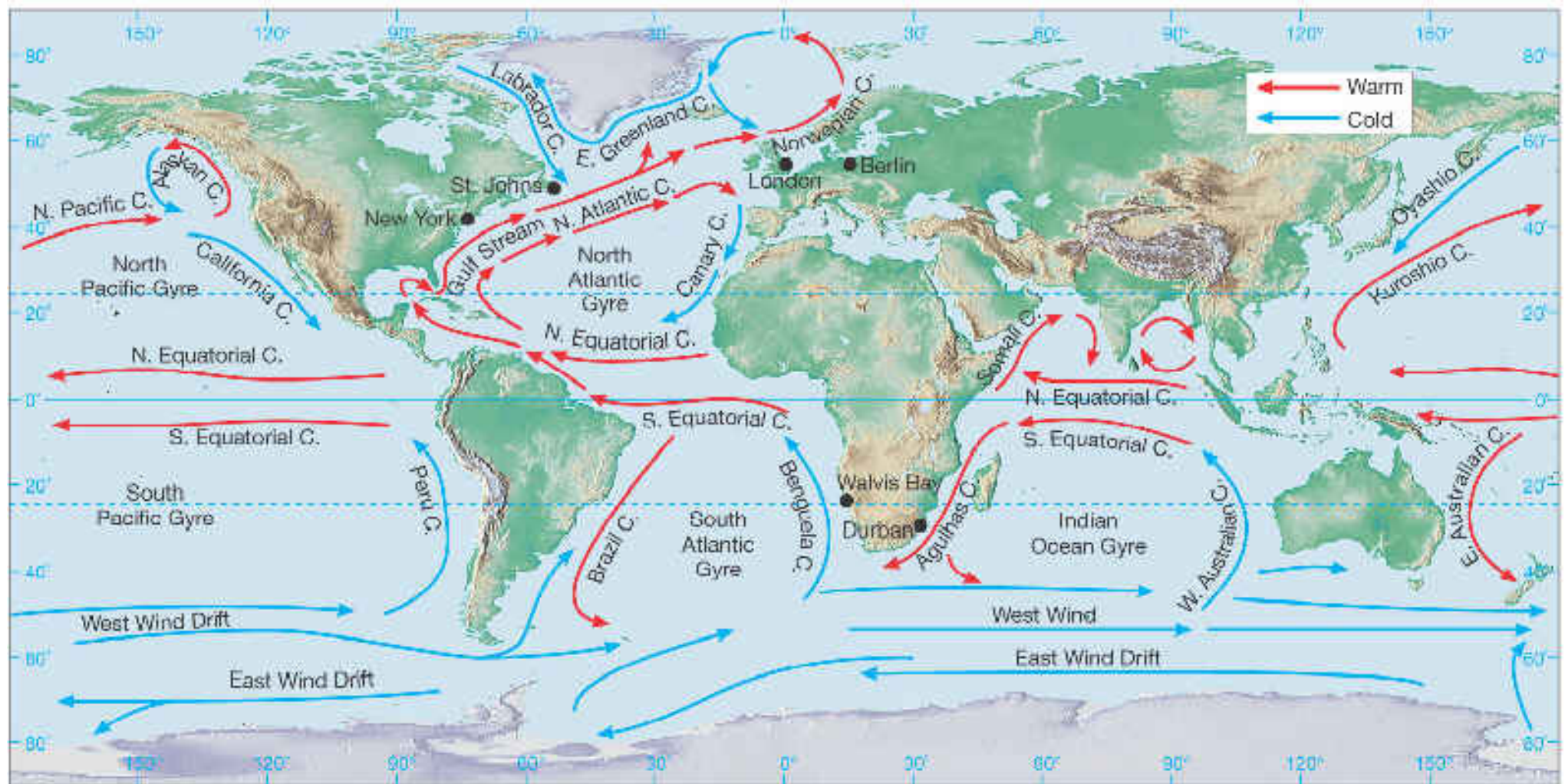
Primary sources of methane

- Fossil fuel extraction is the largest source of methane (35%)
- Livestock (32%)
- Landfill and wastewater emissions (20%)
- Paddy rice farming (8%)
- Land use and wetland changes
 - Exacerbated by global warming

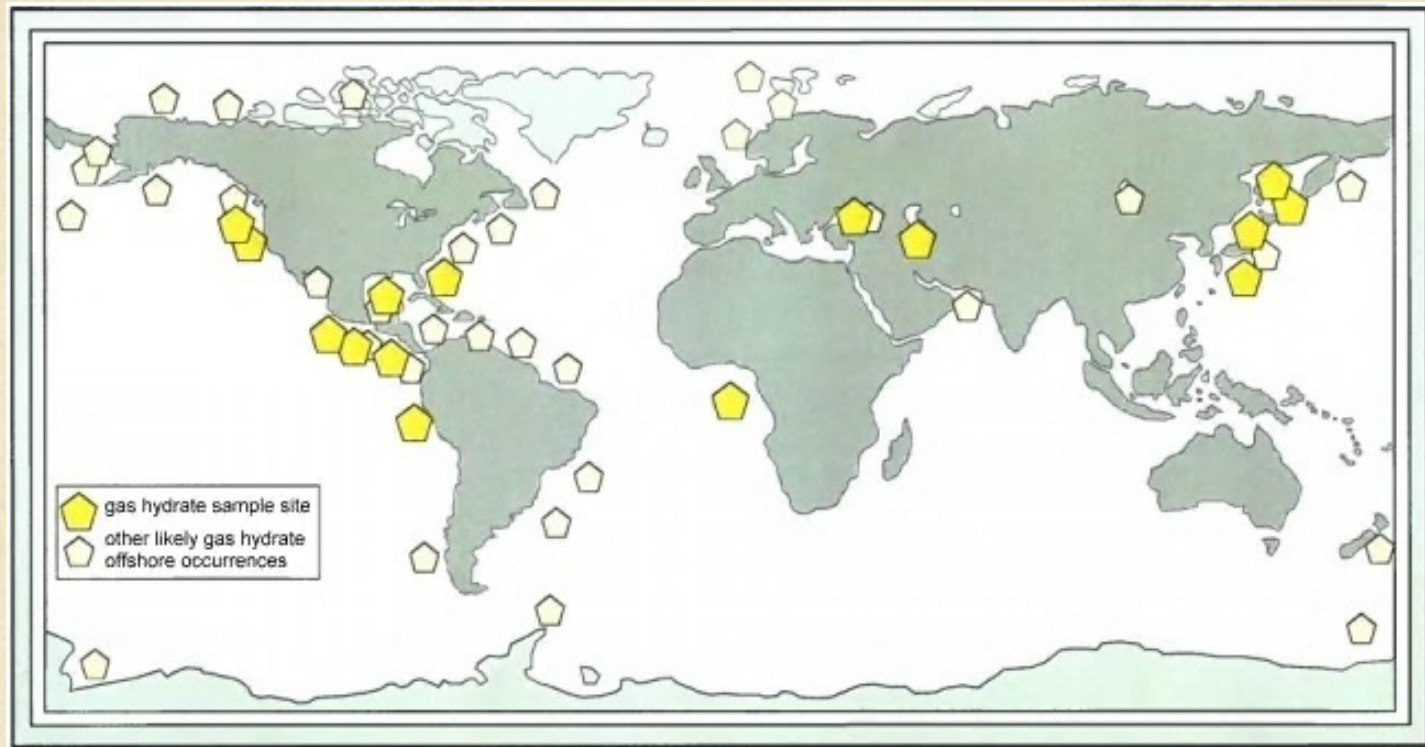


<https://www.unep.org/resources/report/global-methane-assessment-benefits-and-costs-mitigating-methane-emissions> (2021)

Ocean currents may change.



Heating may release large deposits of methane from the ocean floors.



- Sudden releases of large amounts of methane gas could have caused past runaway greenhouse effects and climate changes.
 - Permian-Triassic extinction event (about 251 million years ago)
 - Paleocene-Eocene Thermal Maximum (about 55 million years ago).