Global Warming has happened before!

What have we learned?

By: Pauline Witzke, Hons. B. Sc, Earth Sciences, 1982

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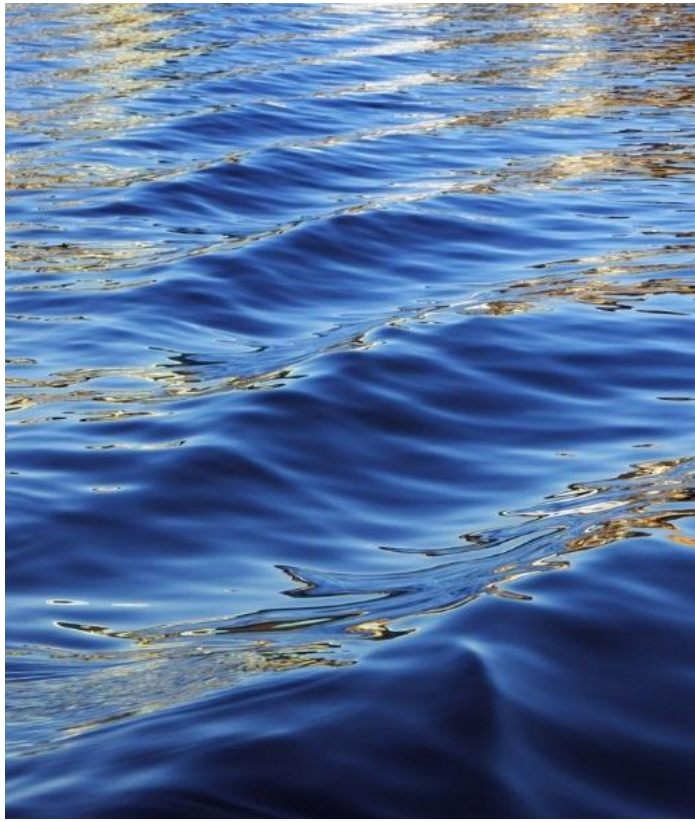


Today's discussion

- What exactly is global warming?
- When and why has global warming happened before;
- Why is global warming happening now?
  - How bad will it get?
  - How quickly?

Increasing average global temperature

- A balance between absorption of the sun's energy and reflection back into the universe
- Rising levels of greenhouse (insulating) gases in the atmosphere changes the balance

What we can learn from studying the earth's geology?

- There were global warming events tens of millions of years ago that lasted for thousands of years, based on fossils (leaves, pollen, animals) and stable isotopes (oxygen, carbon as indicators of temperature) – based on decades of research.
- Greenhouse gas increases on a global scale were caused by:
  - Massive volcanic eruptions over very large areas, releasing inorganic CO_2;
  - Forest fires and burning coal seams ignited by volcanic activity, releasing organic CO_2; and
  - Large-scale melting of permafrost, which releases methane hydrates, an even more potent greenhouse gas than CO_2.

Comparable Global warming events – continents in their current locations, comparable thickness in earth's layers (crust/mantle/core)

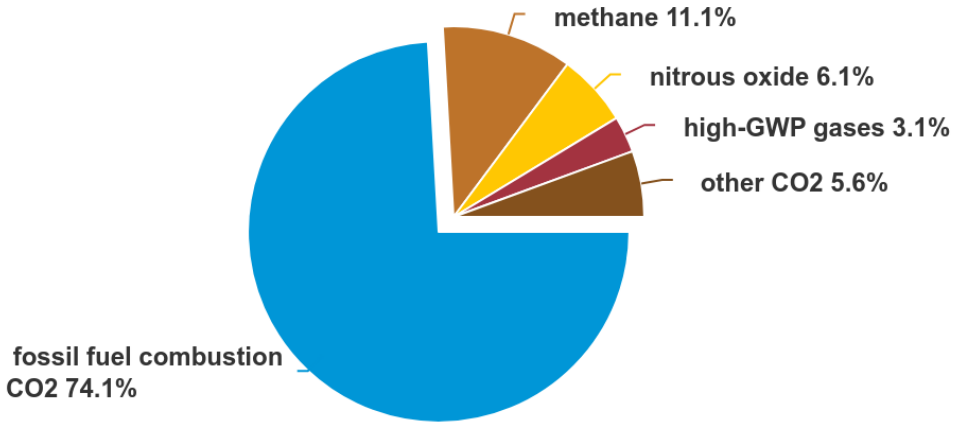
Time Period	# of Years Ago	Atmospheric CO_2 levels (ppmv)	Change in atmospheric temperature (°C) *	Impacts
Today	August 2025	425 (NOAA)	1.5	Disruptions in global weather
Pre-industrial	150	208	0	N/A
Paleocene-Eocene Thermal Maximum	55 million	650-3500 ppm, volcanic eruptions, burning coal seams, wildfires – current rate of CO2 increase is five times faster than PETM	5	Terrestrial die-off at equator, reduction in size/abundance moving away from equator, followed by rebound and diversification after 40,000 years
Cretaceous-Tertiary Boundary	66 million	350-500, rising to 2300 – volcanic eruption in Asia coupled with Chixilub meteorite impact	5-8	Extinction of 50-75% of all life on earth
Ocean Anoxic Events	94 million	Rising to 500-3000 – massive volcanic eruption	5	Massive Extinctions in deep ocean, some extinction in shallow ocean due to lack of oxygen

*There is a lag of about 50 years between atmospheric CO2 increases and temperature rise

Today's Global Warming – a different cause

U.S. greenhouse gas emissions by gas, 2022

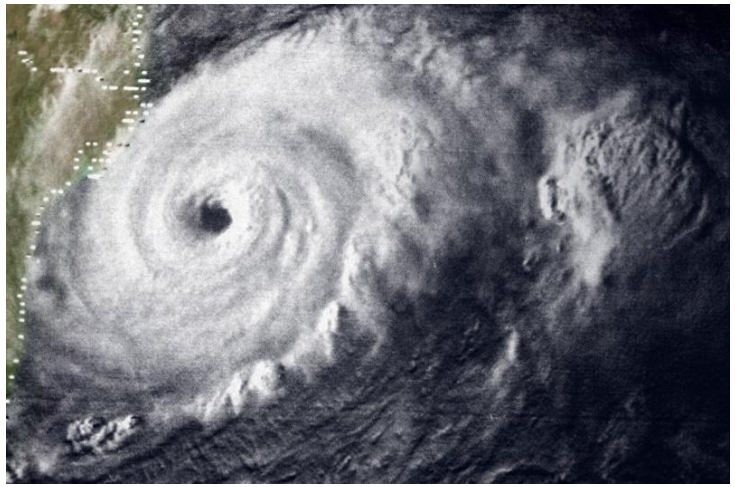
total = 6,343 million metric tons of carbon dioxide equivalent (CO_2e)

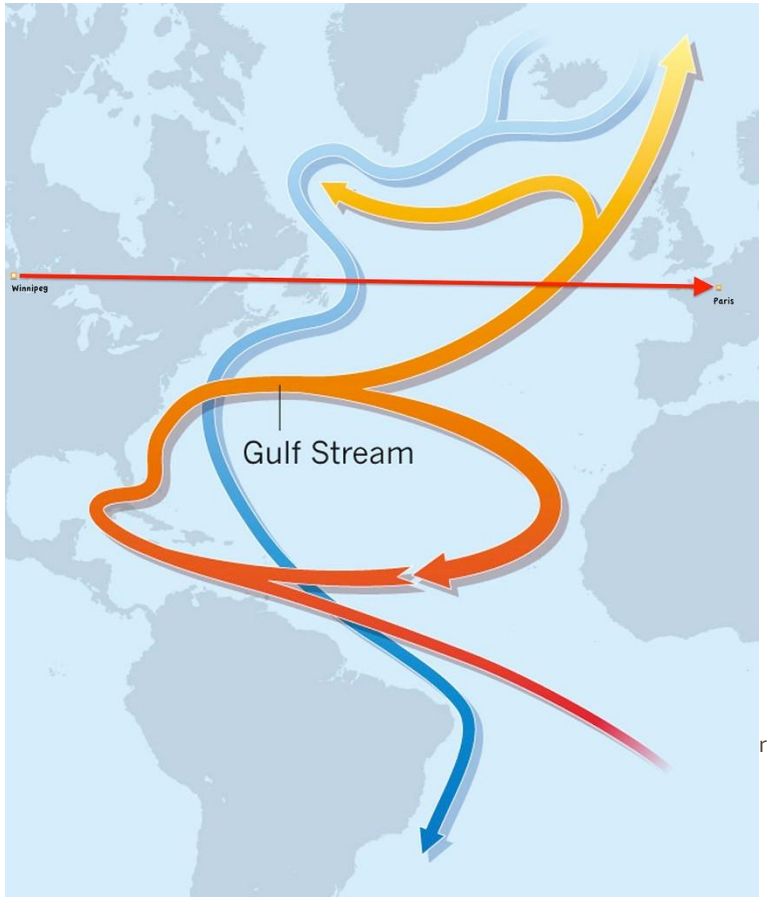


- the burning of fossil fuels in the industrial age contributes ¾ of today's greenhouse gases

Data source: U.S. Environmental Protection Agency (EPA), Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2022, April 2024
Note: Data are CO_2e based on 100-year global warming potential. Total is gross emissions.

So why is global warming a bad thing?

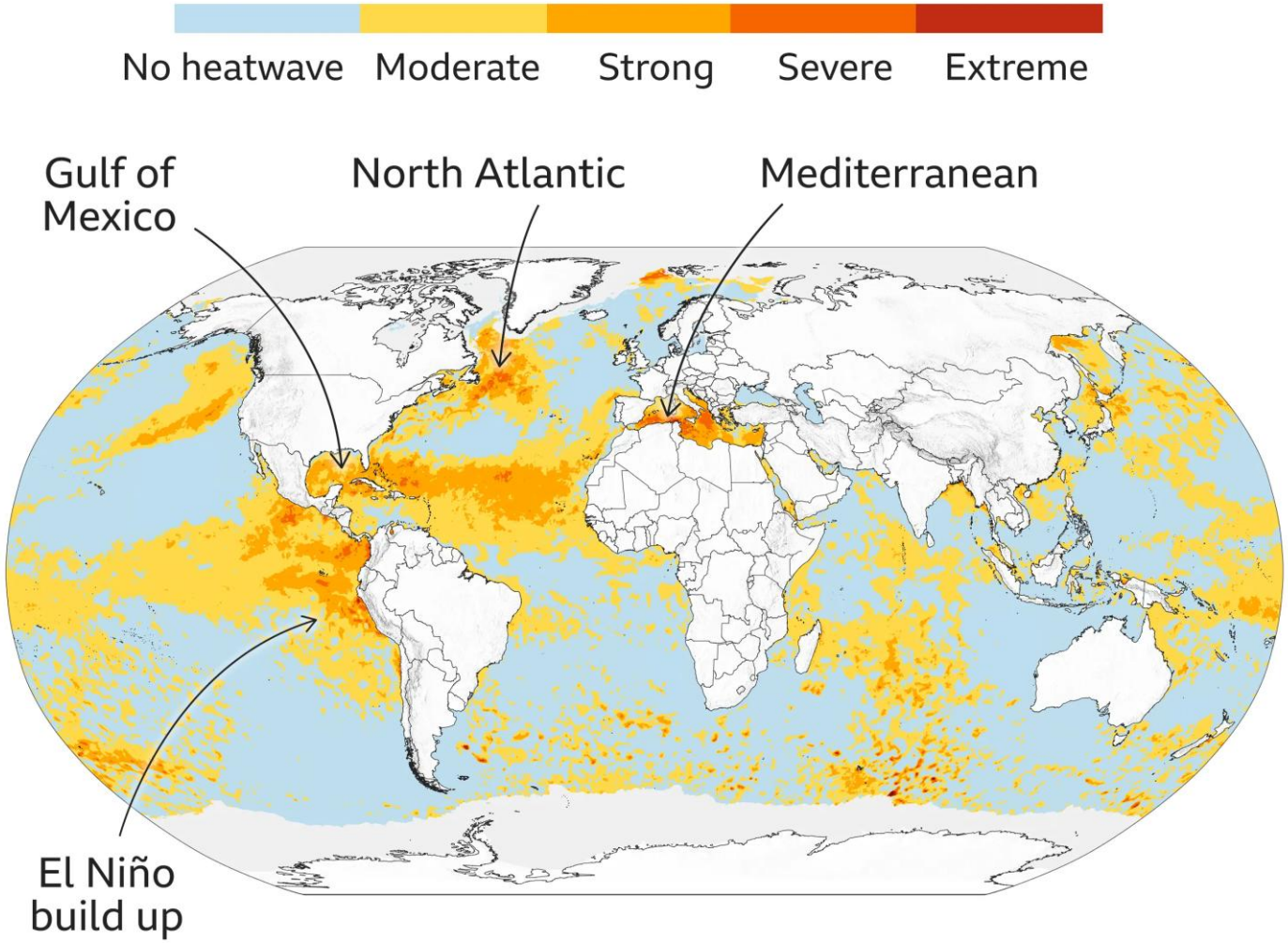




Failed crops and Algal Blooms – climate refugees

Multiple marine heatwaves across the globe

Severity of marine heatwaves on 24 July 2023



Note: heatwave classifications are calculated from sea surface temperatures. Areas affected by sea ice are excluded and shown in grey.

Source: NOAA Coral Reef Watch, reference period 1985 to 2012

BBC

How much time do we have before it's too late? A 2018 study

- The point of no return for climate change is approaching, and some say it could be reached as early as 2035 or likely by mid-century.
- In 2018, global average temperature was expected to rise above 1.5°C by 2032 (**reached in 2024**).
- Scientists warn that if average global temperatures rise by 3°C compared to pre-industrial times, it will be "catastrophic" for people across the world.

What can we take from this?

- Human activity is causing the current global warming event
- **Things are happening faster than we believed a few years ago.**
- If we cross the tipping point in the next 10 to 25 years, the earth will warm to the point where all life is at risk.
- We are not yet at the point of no return. We can still stop this event if we act quickly and change drastically – **we must stop burning fossil fuels**. Carbon capture has not progressed to the point where it can save us.