Climate change and fossil fuels

Filip Černoch
cernoch@mail.muni.cz

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Explaining the climate change

- „How could scientists predict the climate in 100 years when they cannot predict the weather for tomorrow?“

- Weather: short-term conditions (minutes to weeks).
- Climate: atmospheric conditions over a long period of time (years to centuries).
- Consequences for prediction – climate undergoes more gradual changes (than weather) and is easier to predict.

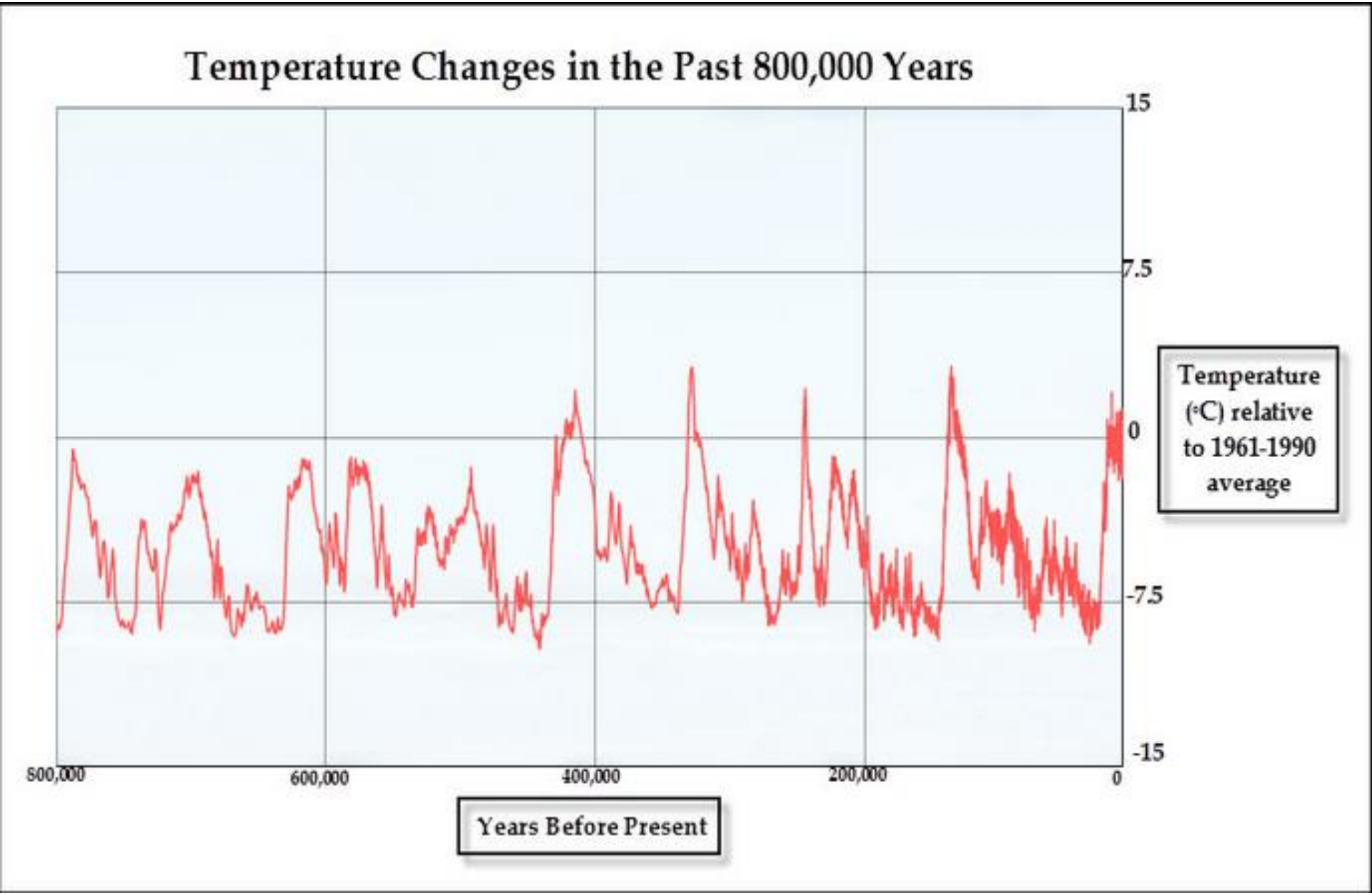
1) The planet´s temperature is rising

- Over the past 130 years, the global average temperature has increased by 0,8°C, with more than half of that increase in last 35 years.
- Ancient ice samples (from Antarctica and other places) – layers are dated and gas bubbles inside are analysed.
  - CO_2 concentration is measured by infrared spectroscopy or mass spectrometry.
  - Isotope ratios of water molecules are measured to determine historical temperatures (^{16}O and ^{18}O).


© Pavel Kapler

The planet´s temperature is rising

- Earth's climate has always fluctuated. The cooler periods are known as ice ages or glacial periods; the warmer periods are called interglacial periods.
- Factors influencing these fluctuations include:
  - Orbital variations (Milankovitch cycles)
  - Solar output
  - Volcanic activity
  - Plate tectonics
  - Among others.
- The rate of change has become more dramatic since the Industrial Revolution, indicating anthropogenic origins.
- One of the problems is adaptation; the change is happening too fast.



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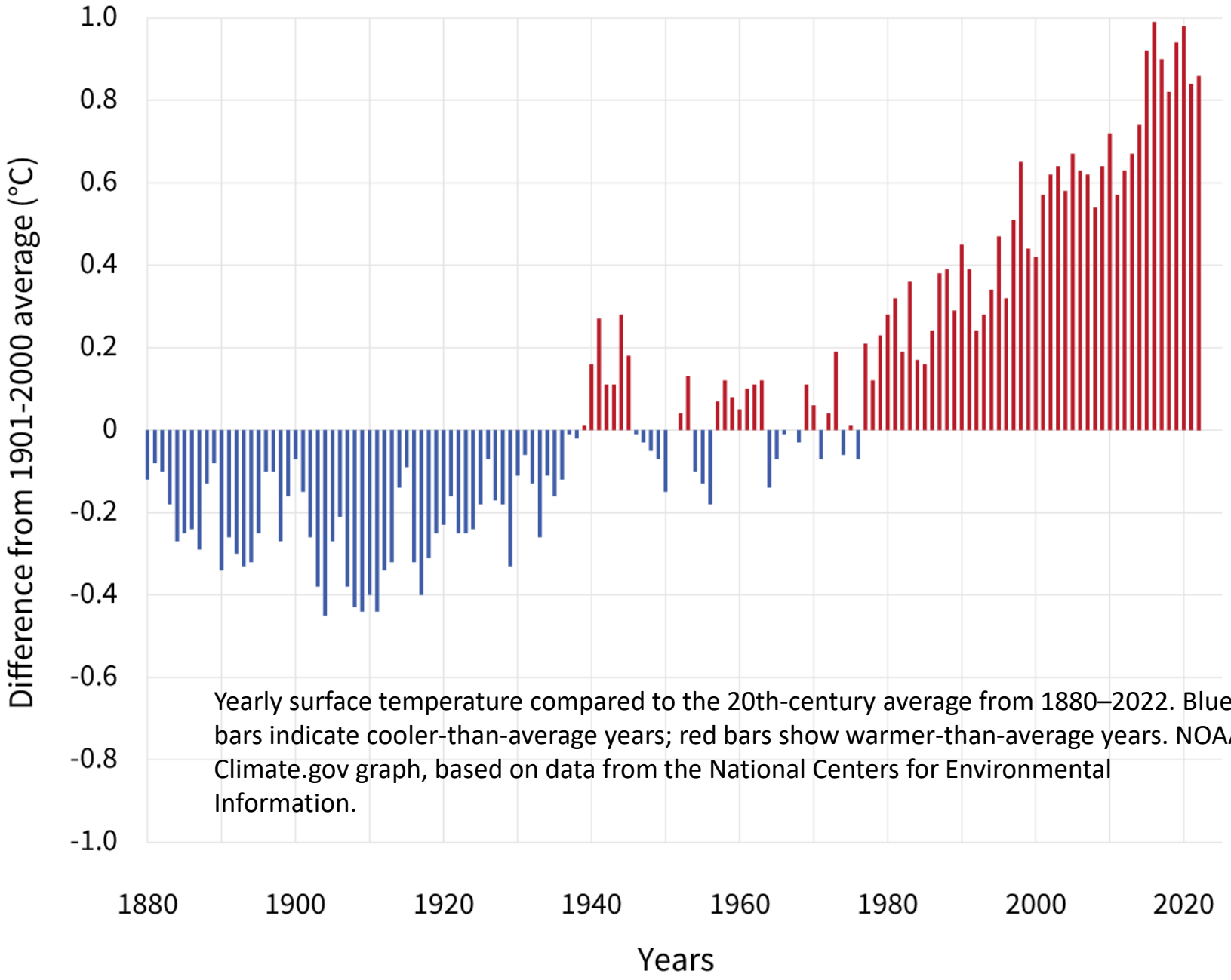
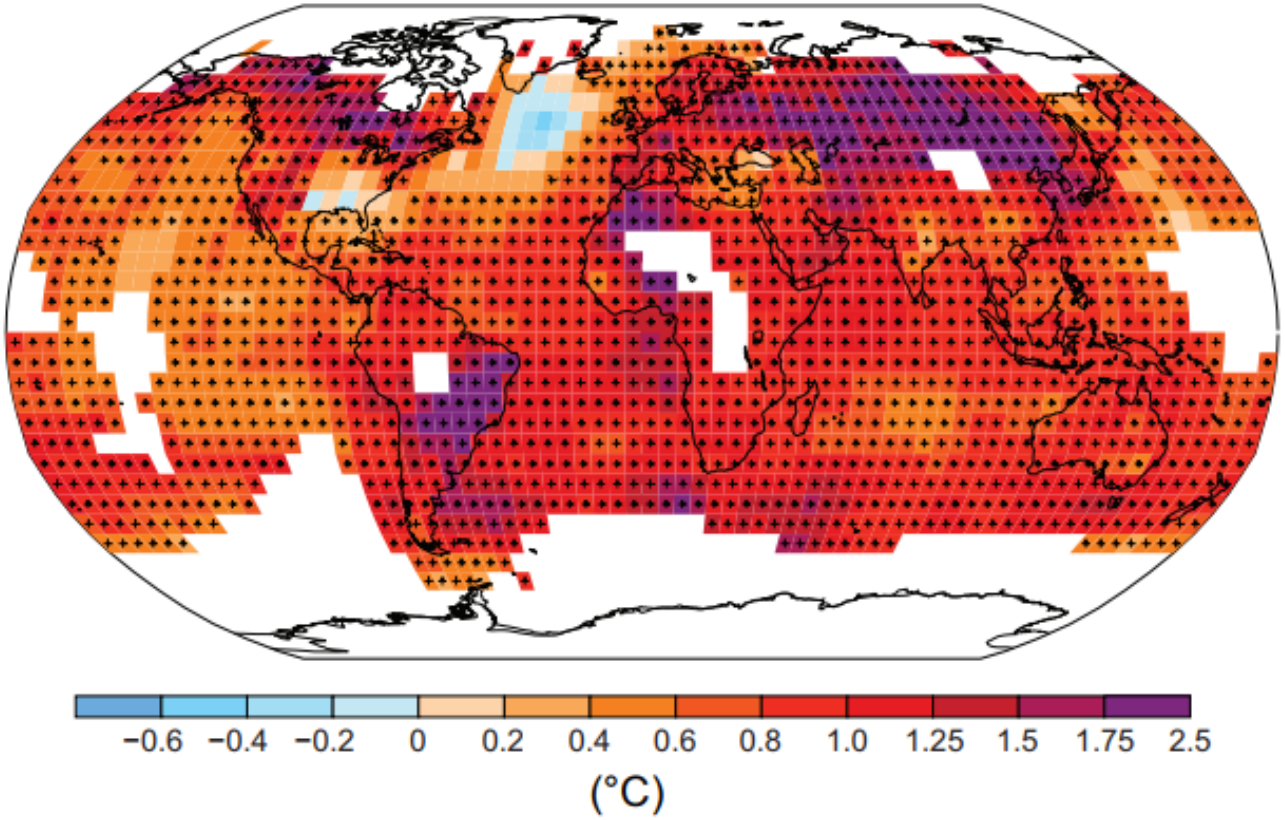
GLOBAL AVERAGE SURFACE TEMPERATURE



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.

Observed change in surface temperature 1901 - 2012



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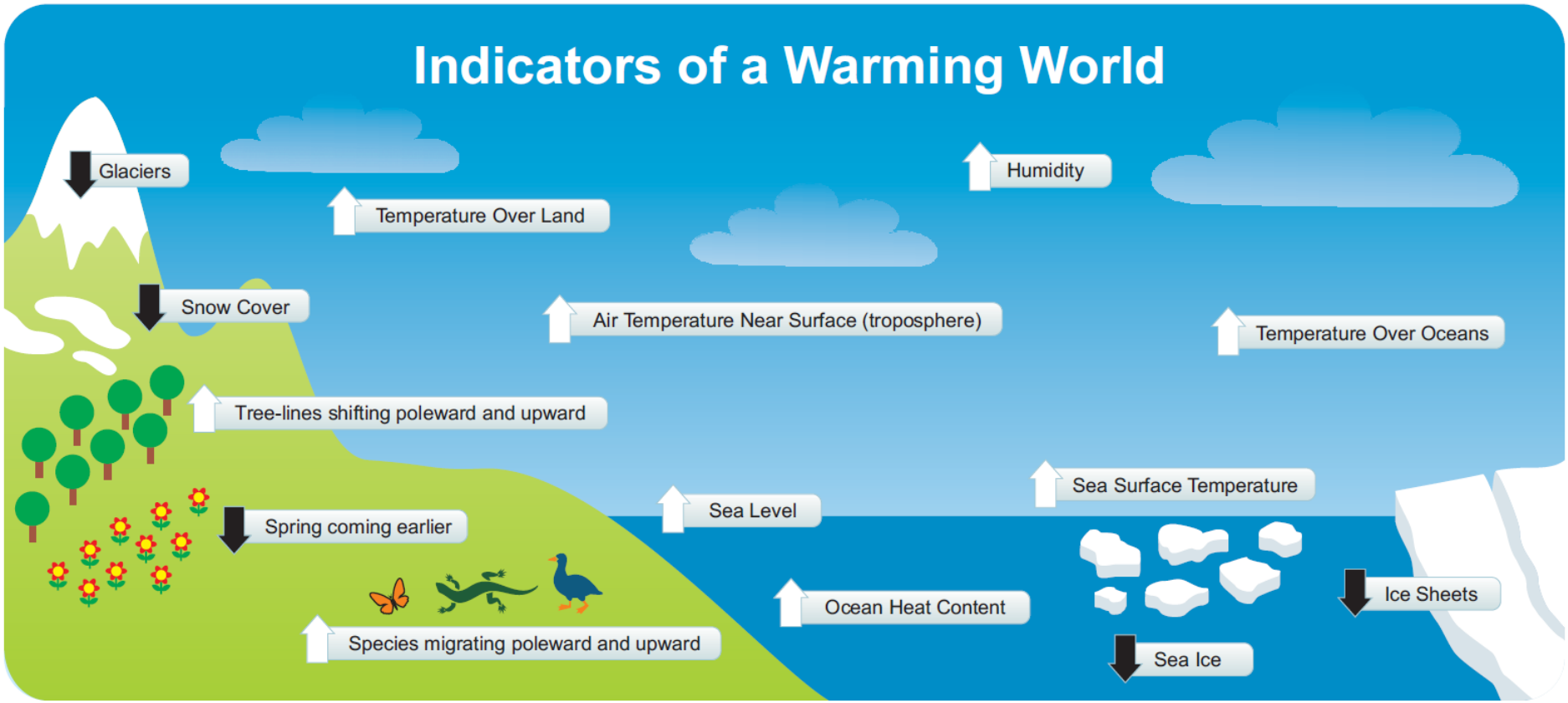

Parmesan & Yohe 2003[32], NOAA[34]

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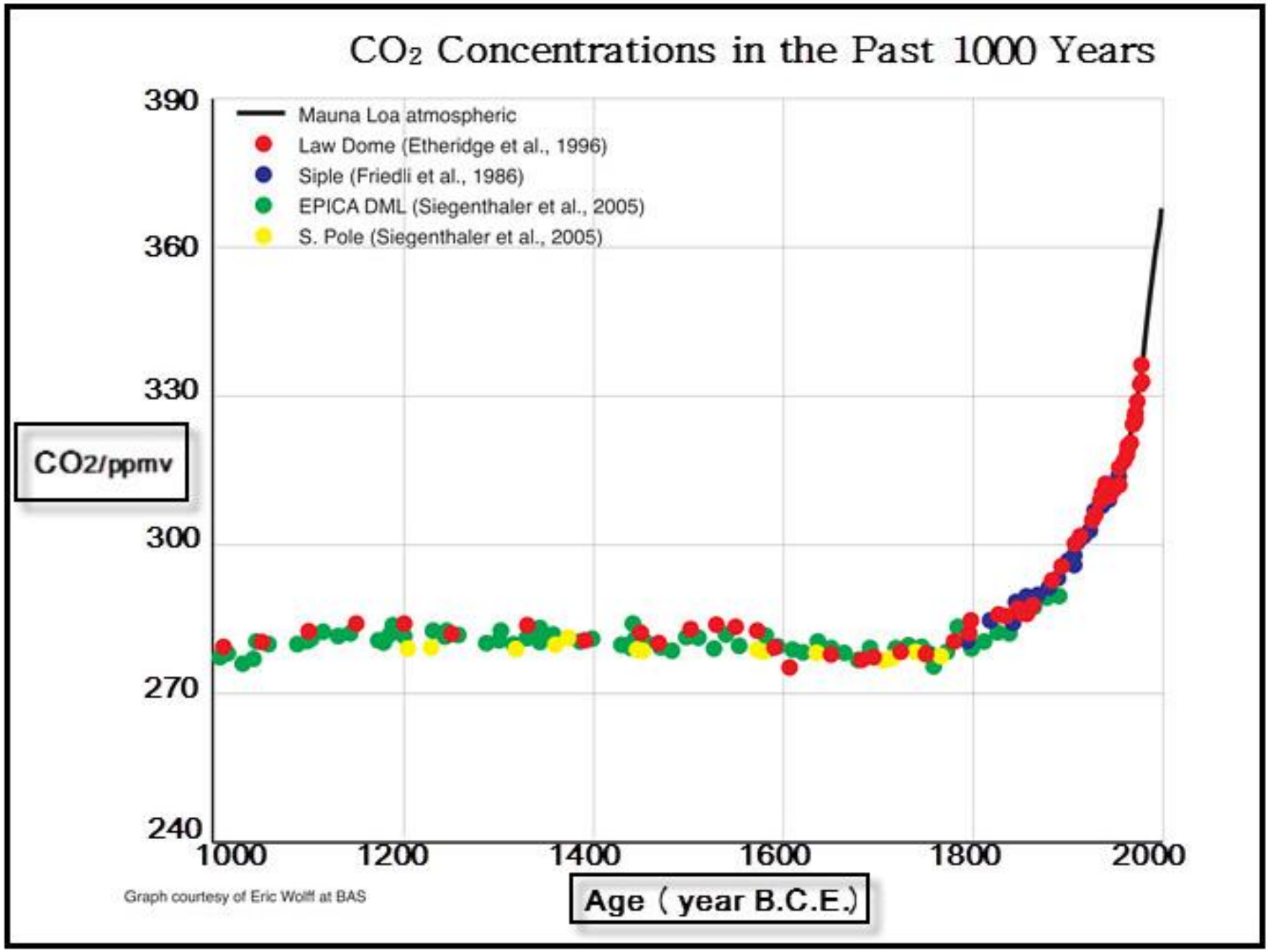
2) CO_2 level is increasing (also methane and nitrous oxide)

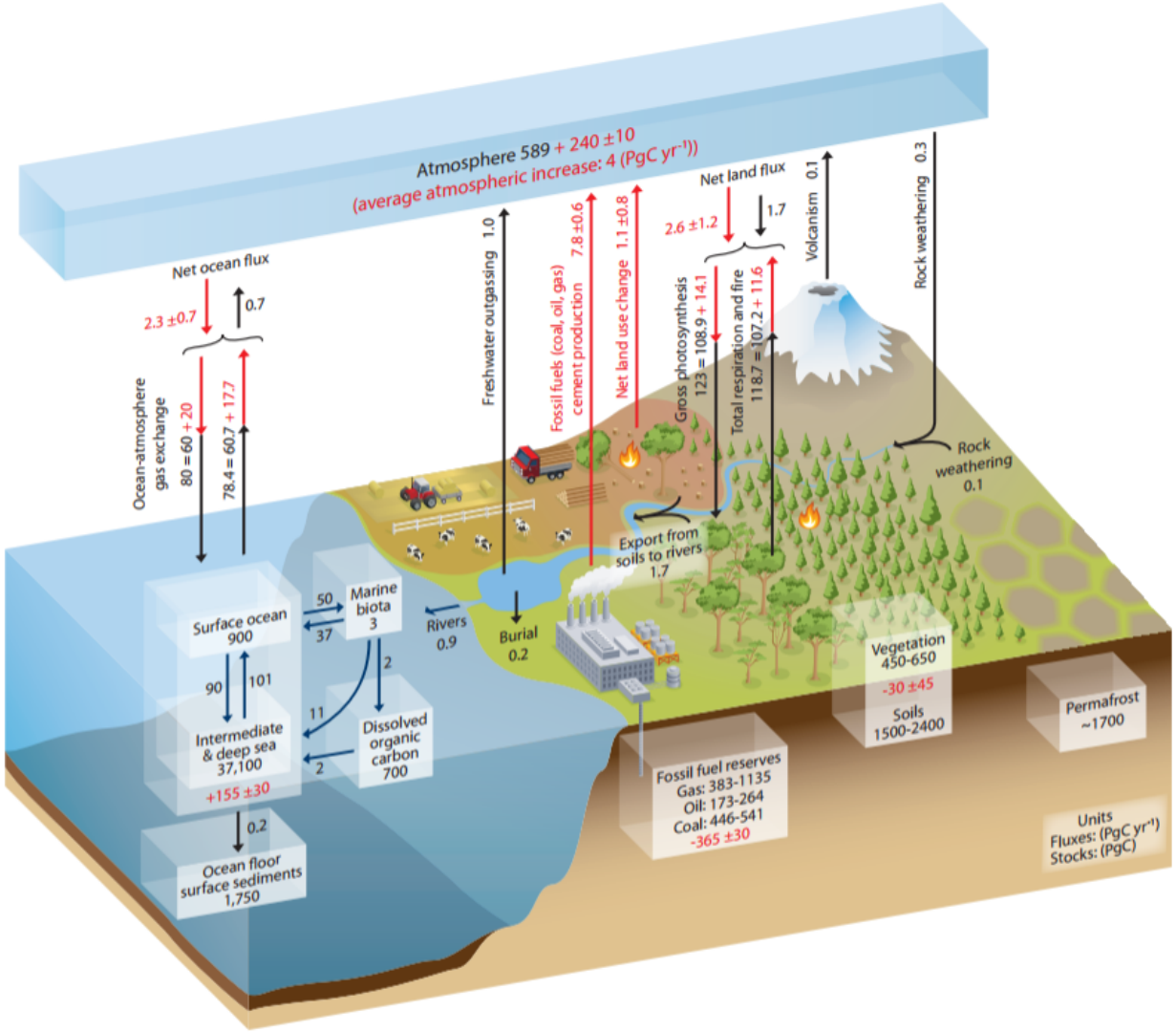
- The concentration of CO_2 has increased by 40% since pre-industrial times.
- The ocean has absorbed about 30% of this increase, which has caused ocean acidification.
- Methane and nitrous oxide concentrations have also increased by 150% and 20%, respectively.

Rates of Change in the Past 250 Years



3) We are responsible for the increase in CO_2

- Human CO_2 emissions, at 20 billion tons per year, are small compared to natural emissions (~776 billion tons/year).
- However, natural absorptions (~788 billion tons/year) roughly balance these natural emissions.
- The ratio of carbon-12 isotope to carbon-13 isotope is increasing.



Global carbon cycle. Numbers represent reservoir mass (carbon stocks) and annual carbon exchange fluxes. Black numbers and arrows indicate reservoir mass and exchange fluxes estimated for the time prior to the Industrial Era (about 1750). Red indicate annual anthropogenic fluxes averaged over the 2000-2009.

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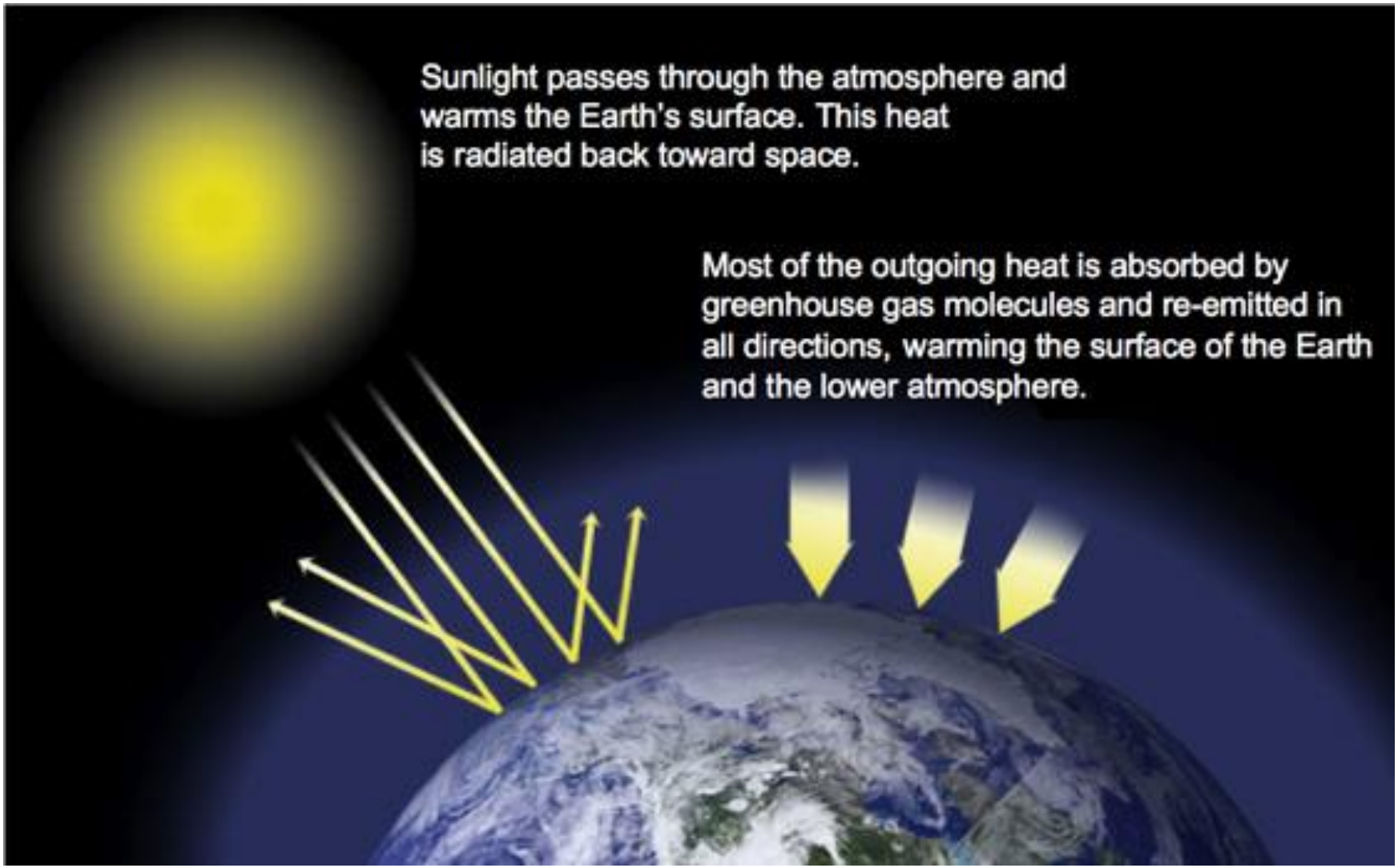
4) Increased CO_2 is the primary driver of greenhouse effect

- Inbound solar radiation, characterized by short wavelengths and high energy content, passes through the Earth's atmosphere.
- Some of this energy is absorbed by the ground, which warms up as a result, and some is reflected back into space.
- The reflected radiation possesses lower energy levels and longer wavelengths. Around 80% of this outgoing longwave radiation is trapped in the lower troposphere.
- The energy retained in the troposphere subsequently warms the surface.
- The presence of more greenhouse gases (GHGs) in the atmosphere enhances the trapping of this outgoing radiation, leading to a warming of the planet = anthropogenic climate change.



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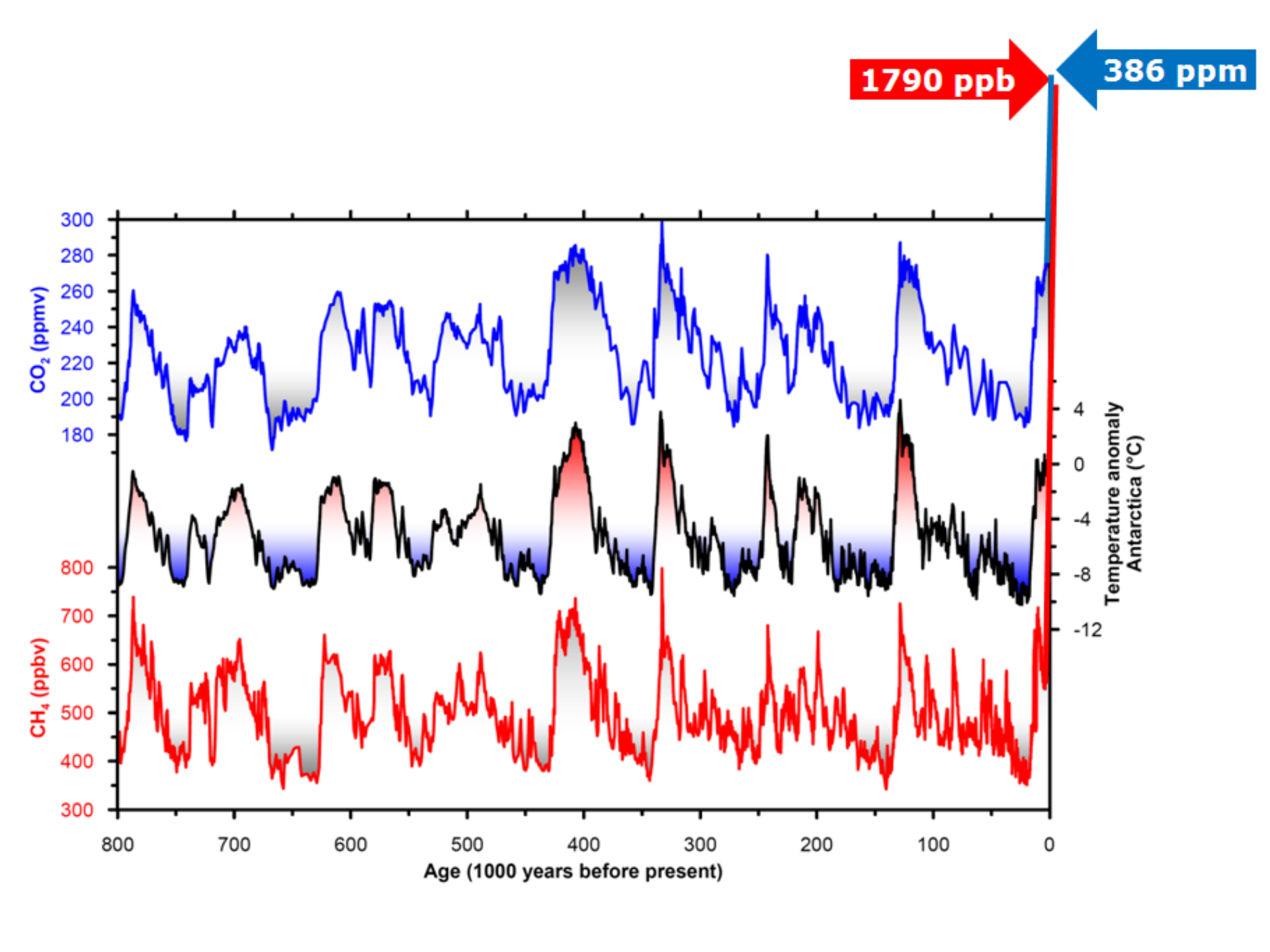
4) Increased CO_2 is the primary driver of greenhouse effect

- Carbon dioxide absorbs and re-emits infrared radiation, a fundamental aspect of the greenhouse effect.
- This has been confirmed through laboratory experiments and reinforced by satellite data since the 1970s, which shows a decrease in the amount of infrared radiation escaping into space.
- The data indicate an enhanced greenhouse effect, with more thermal energy being retained in the Earth's atmosphere over recent decades.


1790 ppb
386 ppm
300
280
260
240
220
200
180
CO_2 (ppmv)
800
700
600
500
400
300
CH_4 (ppbv)
4
0
-4
-8
-12
Temperature anomaly
Antarctica (°C)
800
700
600
500
400
300
200
100
0
Age (1000 years before present)

Climate change uncertainty

- Positive/Negative feedbacks: Historical analyses reveal that feedbacks either magnify or mitigate initial warming effects.
- Positive feedback
  - Warming increases atmospheric water vapor, which traps more heat.
  - Warming induces carbon release (e.g., methane) in the Arctic from thawing permafrost or methane hydrates.
  - Forest fires and desertification reduce rainforests.
  - Albedo effect: diminishing ice and snow cover increases absorption of sunlight.
- Negative feedback
  - Increased water vapor can form more clouds, which reflect sunlight.
  - Enhanced vegetation leads to greater photosynthesis and carbon uptake.

Permafrost example

- About 700 – 800 Gt of CO_2 in the atmosphere. Up to 1700 Gt in permafrost in Siberia, Canada…
- Higher temperature leads to faster thawing which leads to faster releasing of CO_2, which leads to increase in the temperature….
- With about 3°C expected average temperature increase (= 6°C in Arctic, due to the uneven distribution) about 30 – 85% of near-surface permafrost is to melt.
- According to the UNEP, by 2100 about 43-135Gt of CO_2 may be released.
- Unreliable data about deeper layers of permafrost.
- Plus methane.

Summary

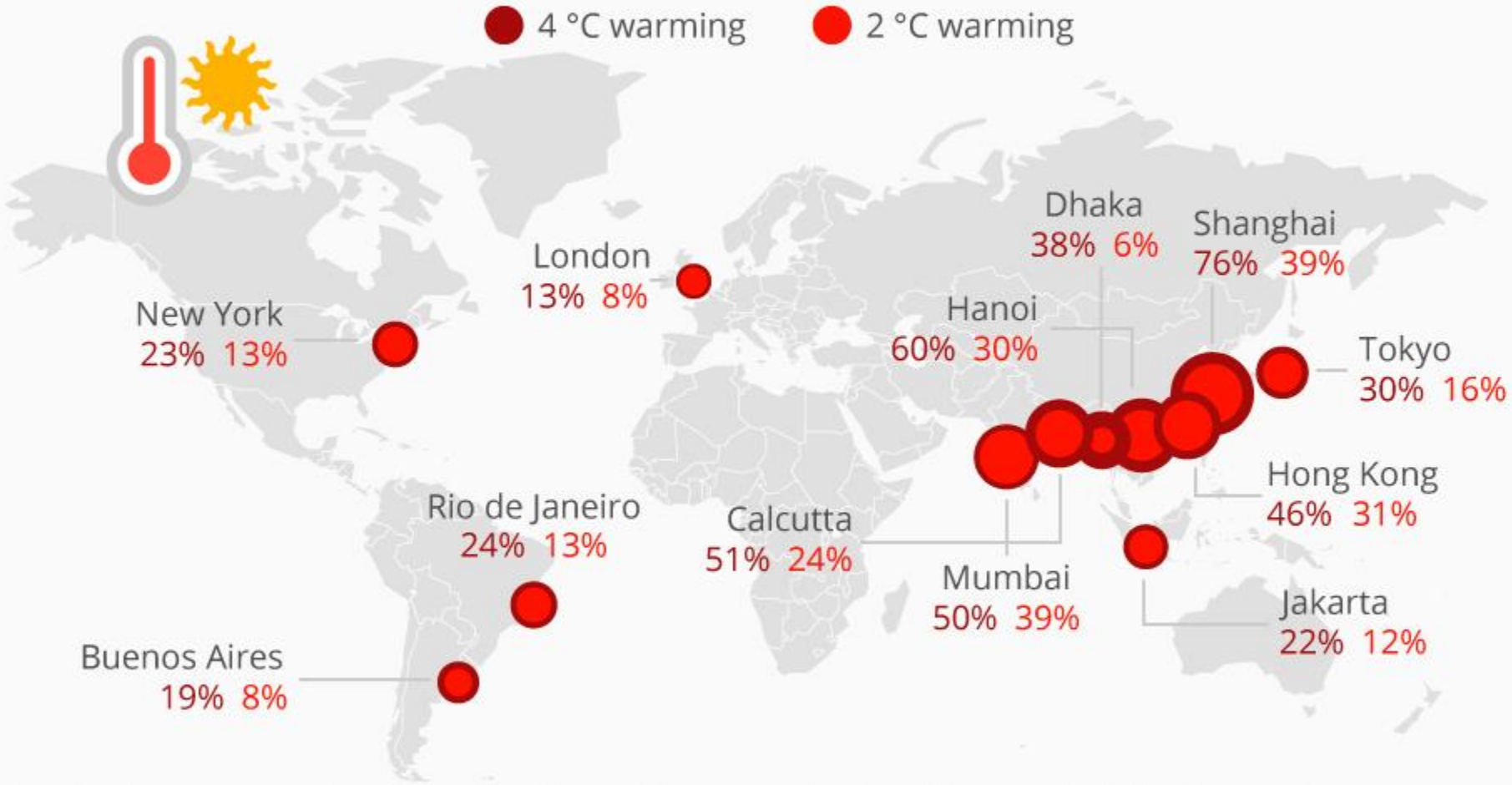
- Earth's climate has undergone changes over long periods, including several ice ages and periods of warming.
- Previous changes were dramatic yet gradual, unfolding over thousands of years.
- Today's change is extremely rapid, with the pace increasing.
- 'Global warming' vs. 'climate change': The former suggests that Earth's climate is warming on average, but this is not entirely accurate.

Climate change impacts

- Melting ice
  - The world's glaciers are melting faster than they can be replenished.
  - One-third of the North Pole's ice sheets have melted since the 1990s.
- Accelerated sea-level rise, increase coastal flooding.
  - There was a 20 cm rise in the last century, with 40% due to thermal expansion and 60% due to the melting of land ice.
  - The current rate is 3 mm/year.
  - This presents a problem for low-lying communities, such as Bangladesh.
  - It is also a problem for some smaller islands, such as Kiritimati in the Pacific, which is no more than 2 meters above sea level at its highest point.
- Extreme weather events (heat waves, coastal flooding, extreme precipitation events, more severe droughts).

The cities most threatened by rising sea levels

Percentage of population affected by rising sea levels in selected cities in 2010



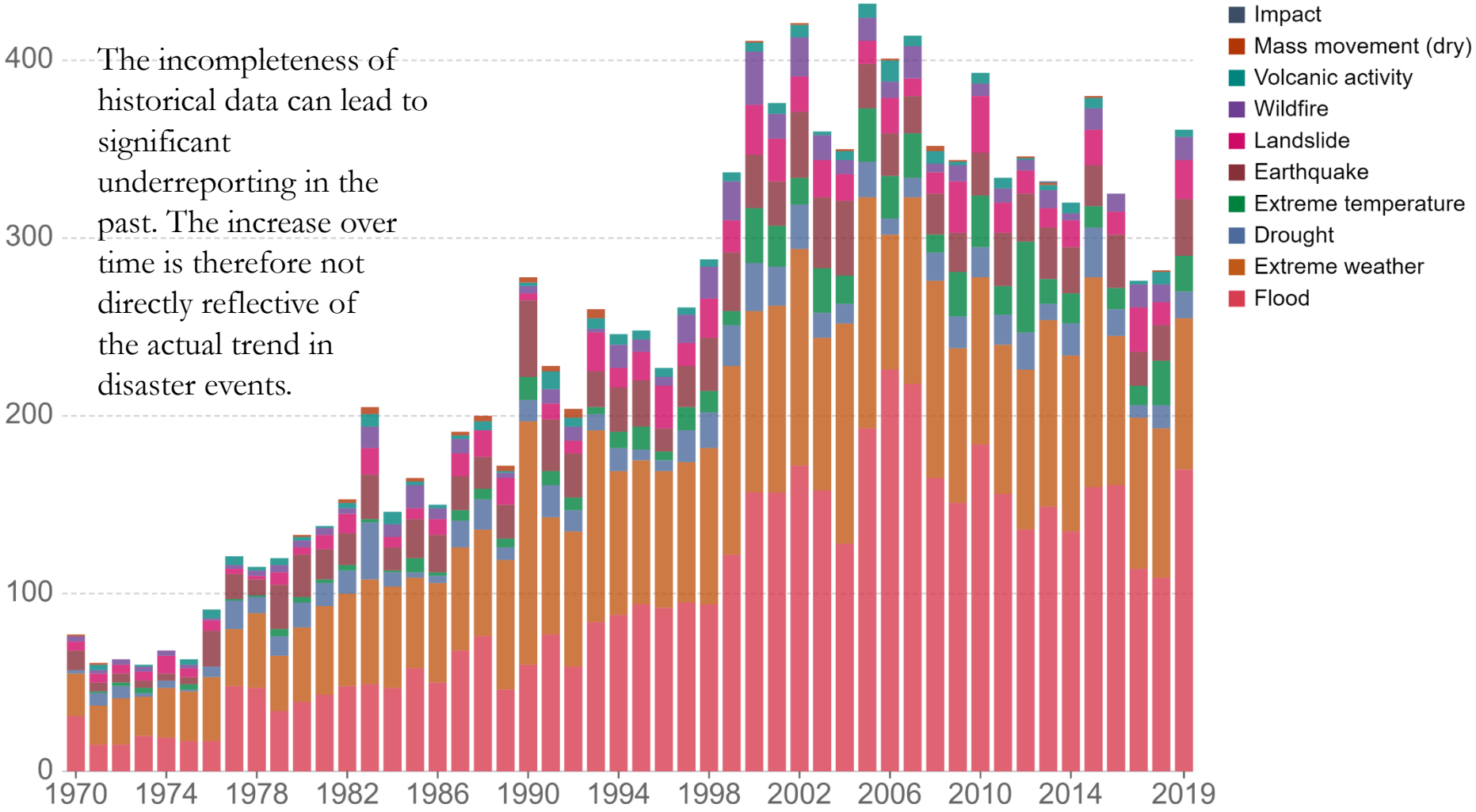
* only urban agglomerations with total 2010 populations exceeding 10 million are included in this analysis

Source: Climate Central

Global reported natural disasters by type, 1970 to 2019

The annual reported number of natural disasters, categorised by type. This includes both weather and non-weather related disasters.

Our World in Data



Source: EMDAT (2020): OFDA/CRED International Disaster Database, Université catholique de Louvain – Brussels – Belgium

Climate change impacts

- Health impacts include longer and more intense allergy seasons, the spread of insect-borne diseases, and more frequent heatwaves and flooding, which present costly risks to public health.
- Mosquito-borne diseases such as Zika virus, West Nile virus, Chikungunya virus, dengue, and malaria are spreading.

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Climate change impacts

- Food problems and water - according to IPCC 1°C = 65 million people starving. Increase of the temperature of more than 2°C = 3 billion people without water supply.
- Between 18-35% of plant and animal species is to extinct by 2050 (ocean acidification – destabilising the whole oceanic food chain). About 1 billion people depend on the ocean for more than 30% of their animal protein.

Possible Effects of Climate Change

	Eventual Temperature Rise Relative to Pre-Industrial Temperatures				
Type of Impact	**1°C**	**2°C**	**3°C**	**4°C**	**5°C**
Freshwater Supplies	Small glaciers in the Andes disappear, threatening water supplies for 50 million people	Potential water supply decrease of 20–30% in some regions (Southern Africa and Mediterranean)	Serious droughts in southern Europe every 10 years. 1–4 billion more people suffer water shortages	Potential water supply decrease of 30–50% in southern Africa and Mediterranean	Large glaciers in Himalayas possibly disappear, affecting ¼ of China's population
Food and Agriculture	Modest increase in yields in temperature regions	Declines in crop yields in tropical regions (5–10% in Africa)	150–550 million more people at risk of hunger. Yields likely to peak at higher latitudes	Yields decline by 15–35% in Africa. Some entire regions out of agricultural production	Increase in ocean acidity possibly reduces fish stocks
Human Health	At least 300,000 die each year from climate–related diseases. Reduction in winter mortality in high latitudes	40–60 million more exposed to malaria in Africa	1–3 million more potentially people die annually from malnutrition	Up to 80 million more people exposed to malaria in Africa	Further disease increase and substantial burdens on health care services
Coastal Areas	Increased damage from coastal flooding	Up to 10 million more people exposed to coastal flooding	Up to 170 million more people exposed to coastal flooding	Up to 300 million more people exposed to coastal flooding	Sea-level rise threatens major cities such as New York, Tokyo, and London
Ecosystems	At least 10% of land species facing extinction. Increased wildfire risk	15–40% of species potentially face extinction	20–50% of species potentially face extinction Possible onset of collapse of Amazon forest	Loss of half of Arctic tundra Widespread loss of coral reefs	Significant extinctions across the globe

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Climate refugees

- There is no legally internationally recognized definition of a 'climate refugee´.
- They are not covered by the UN 1951 Refugee Convention.

- The numbers are increasing. The World Bank expects that, only in the regions of Sub-Saharan Africa, South Asia, and Latin America, climate change could force more than 143 million people to move internally by 2050, which could eventually be reflected in general migration patterns.

- Problem in numbers and resources?

Expected economic impacts of climate change

	Temperature rise scenario, by mid-century			
	Well-below 2°C increase	2.0°C increase	2.6°C increase	3.2°C increase
	Paris target	*The likely range of global temperature gains*		*Severe case*
Simulating for economic loss impacts from rising temperatures in % GDP, relative to a world without climate change (0°C)				
World	−4.2%	−11.0%	−13.9%	−18.1%
OECD	−3.1%	−7.6%	−8.1%	−10.6%
North America	−3.1%	−6.9%	−7.4%	−9.5%
South America	−4.1%	−10.8%	−13.0%	−17.0%
Europe	−2.8%	−7.7%	−8.0%	−10.5%
Middle East & Africa	−4.7%	−14.0%	−21.5%	−27.6%
Asia	−5.5%	−14.9%	−20.4%	−26.5%
Advanced Asia	−3.3%	−9.5%	−11.7%	−15.4%
ASEAN	−4.2%	−17.0%	−29.0%	−37.4%
Oceania	−4.3%	−11.2%	−12.3%	−16.3%

Source: Swiss Re

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Global greenhouse gas emissions by sector

This is shown for the year 2016 – global greenhouse gas emissions were 49.4 billion tonnes CO_2eq.

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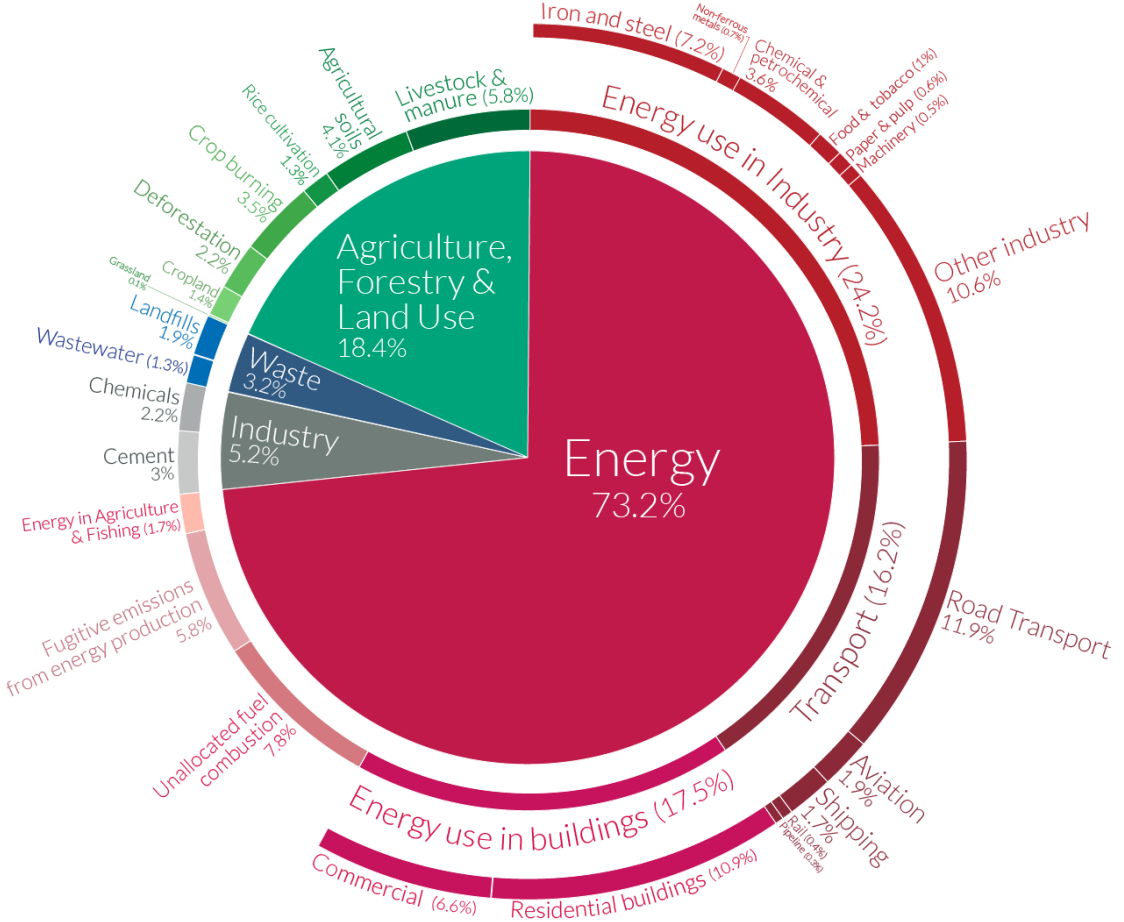

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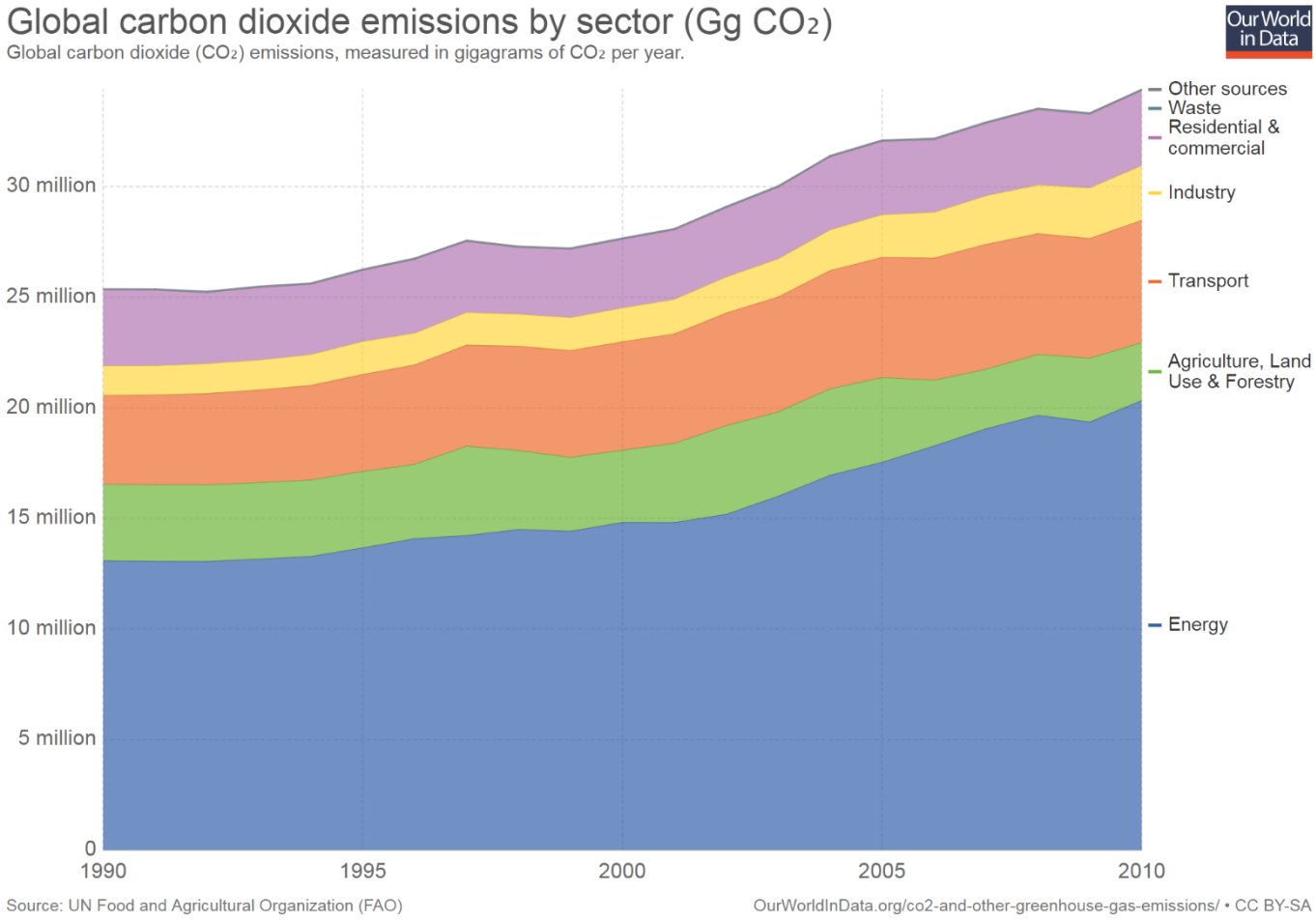

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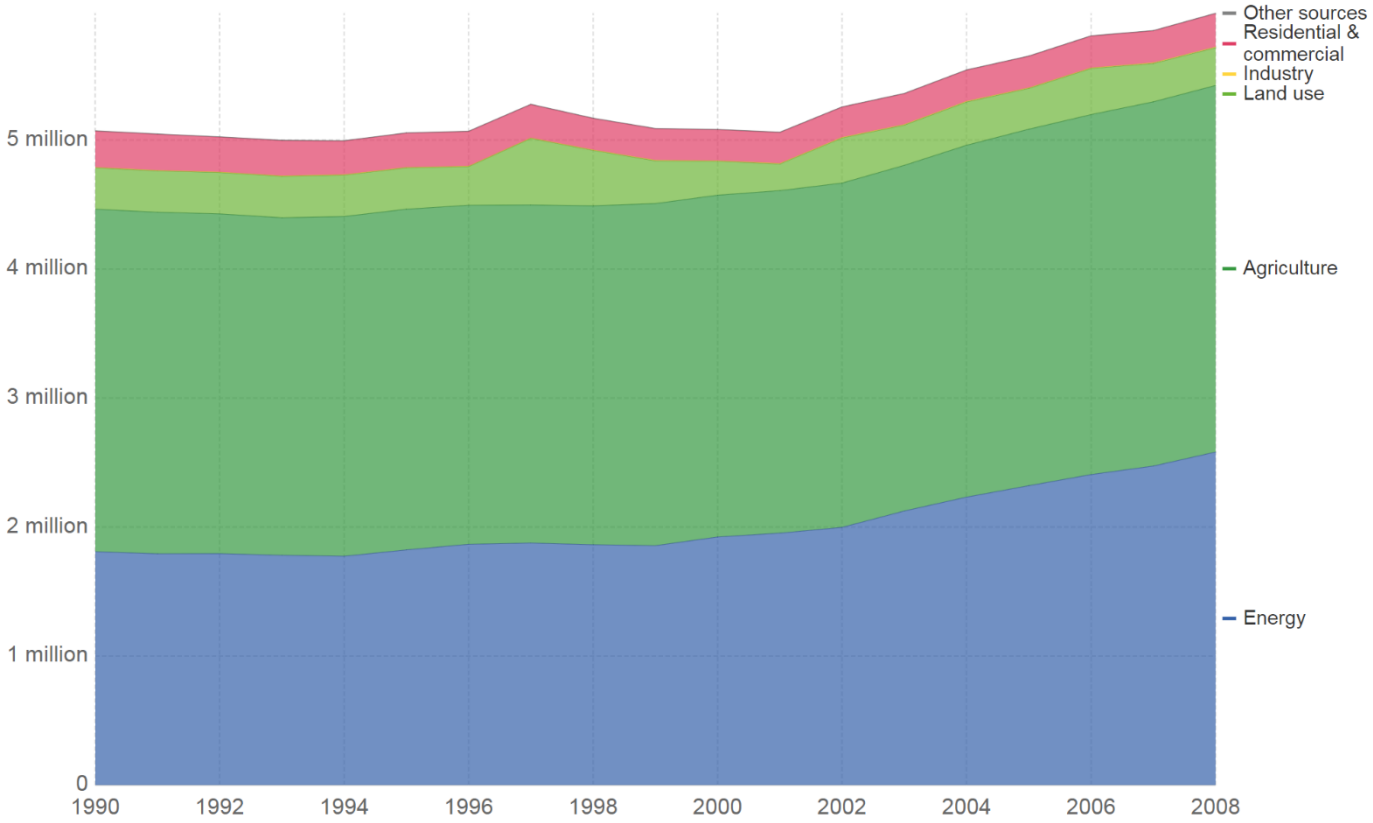
Methane emissions by sector (Gg CO_2e)

Breakdown of total global methane (CH_4) emissions by sector, measured in gigagrams of carbon-dioxide equivalents (CO_2e). Carbon dioxide equivalents measures the total greenhouse gas potential of the full combination of gases, weighted by their relative warming impacts.

Our World in Data



Source: UN Food and Agricultural Organization (FAO)

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

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Nitrous oxide emissions by sector (Gg CO_2e), World

Breakdown of total global nitrous oxide (N_2O) emissions by sector, measured in gigagrams of carbon-dioxide equivalents (CO_2e). Carbon dioxide equivalents measures the total greenhouse gas potential of the full combination of gases, weighted by their relative warming impacts.

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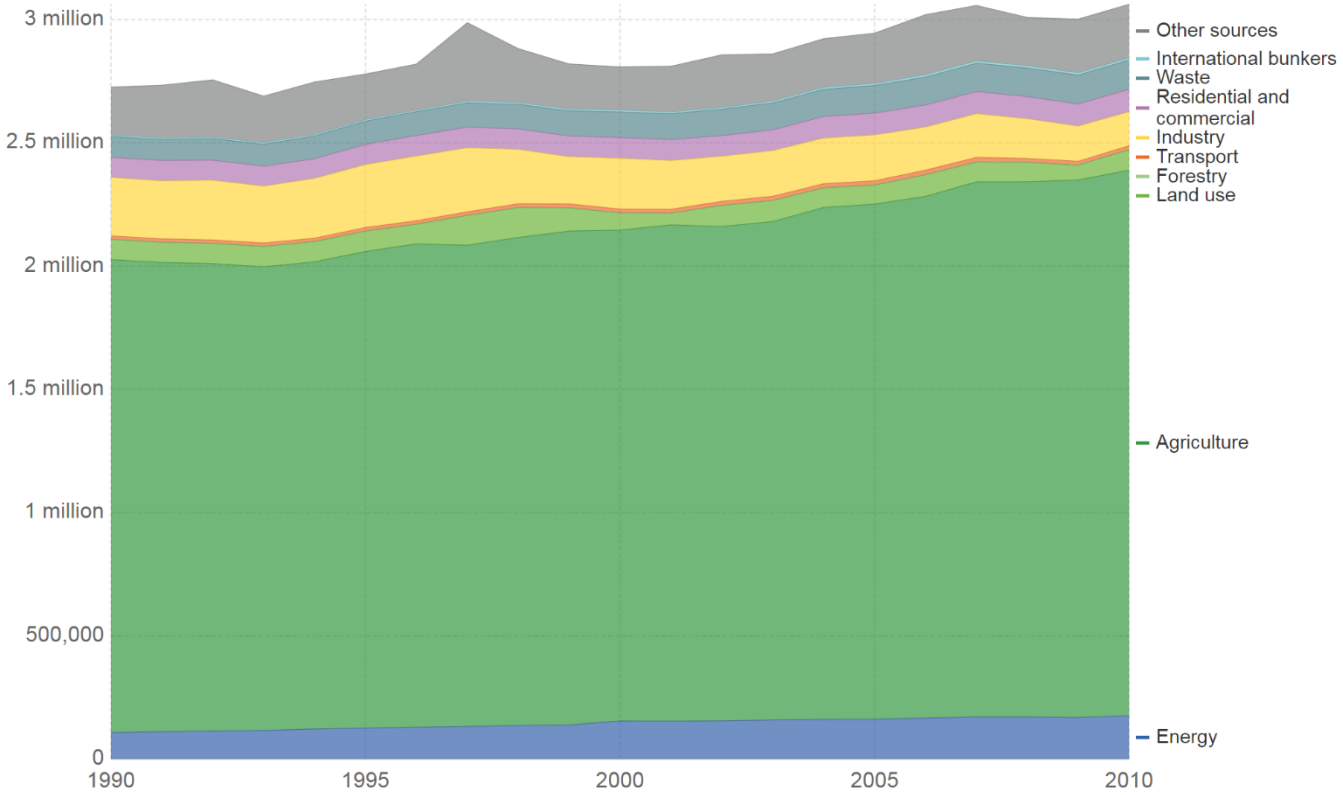

Source: UN Food and Agricultural Organization (FAO)

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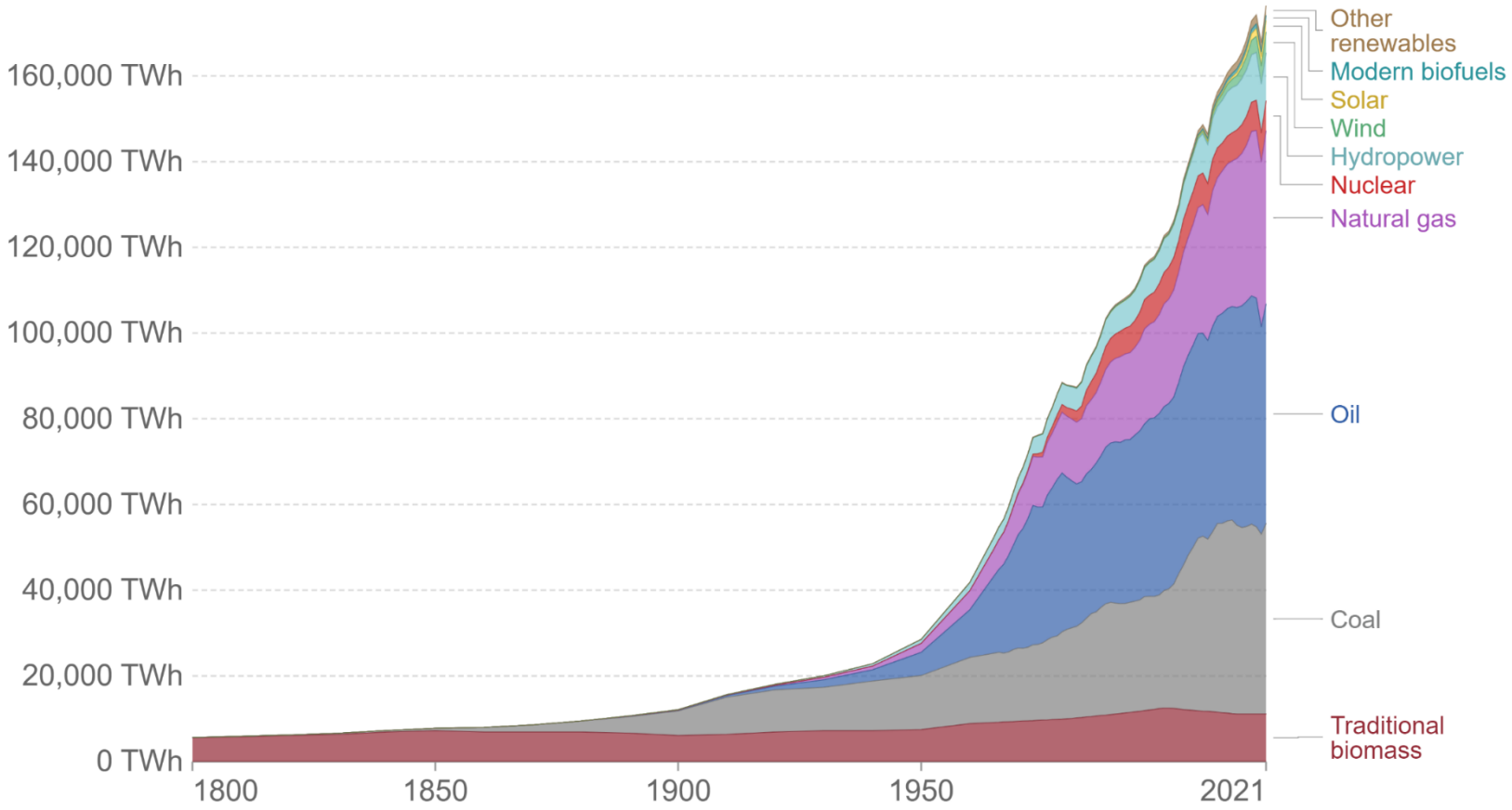
Global primary energy consumption by source

Primary energy is calculated based on the 'substitution method' which takes account of the inefficiencies in fossil fuel production by converting non-fossil energy into the energy inputs required if they had the same conversion losses as fossil fuels.

Our World in Data



Source: Our World in Data based on Vaclav Smil (2017) and BP Statistical Review of World Energy

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