



# EARTH DAY 2022



**Project Learning Tree®**



# **SAMUEL BECKETT (*ENDGAME*)**

“You’re on Earth.  
There’s no cure for  
that”



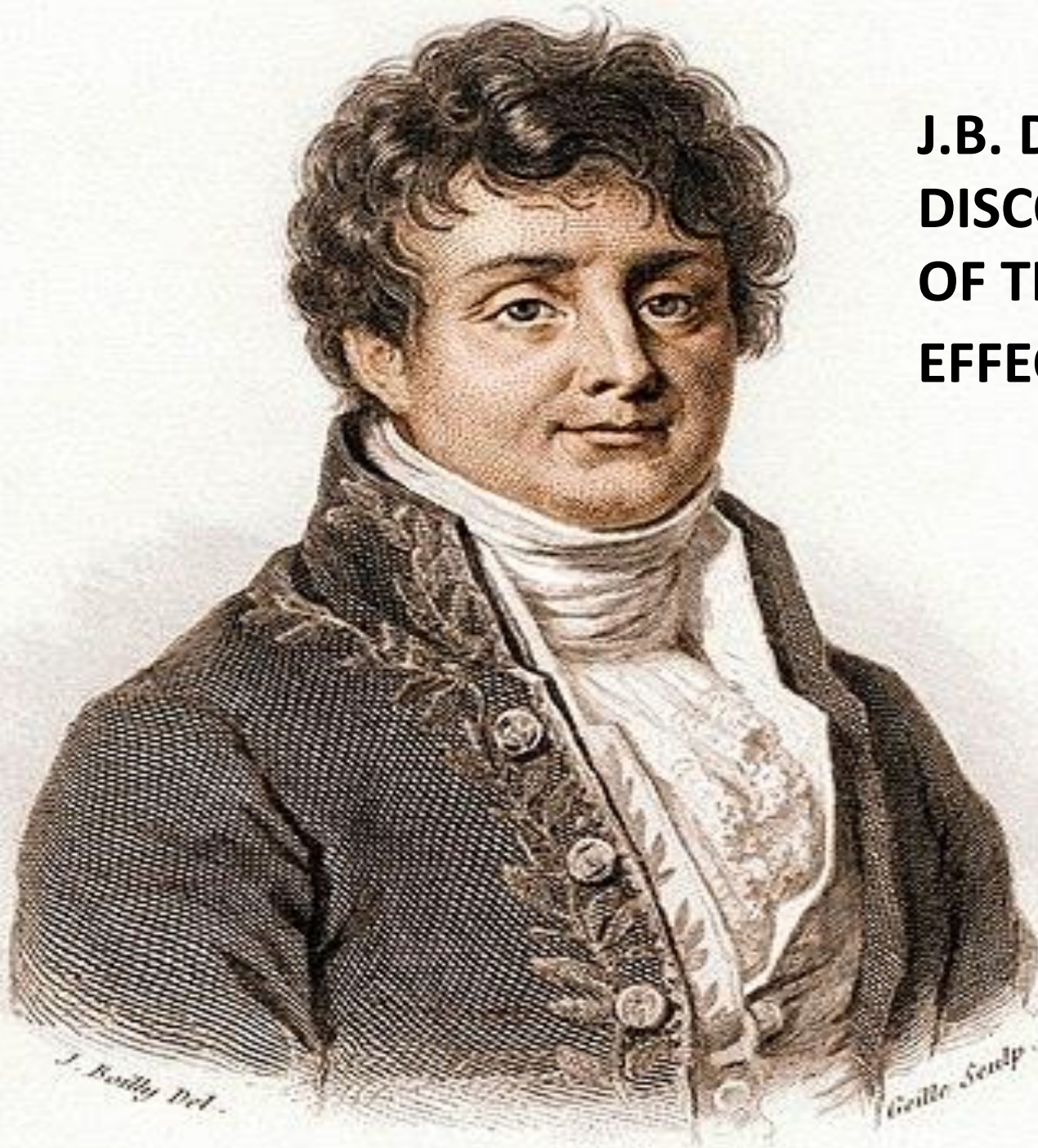
**She's Beautiful**



**It's All We've Got**

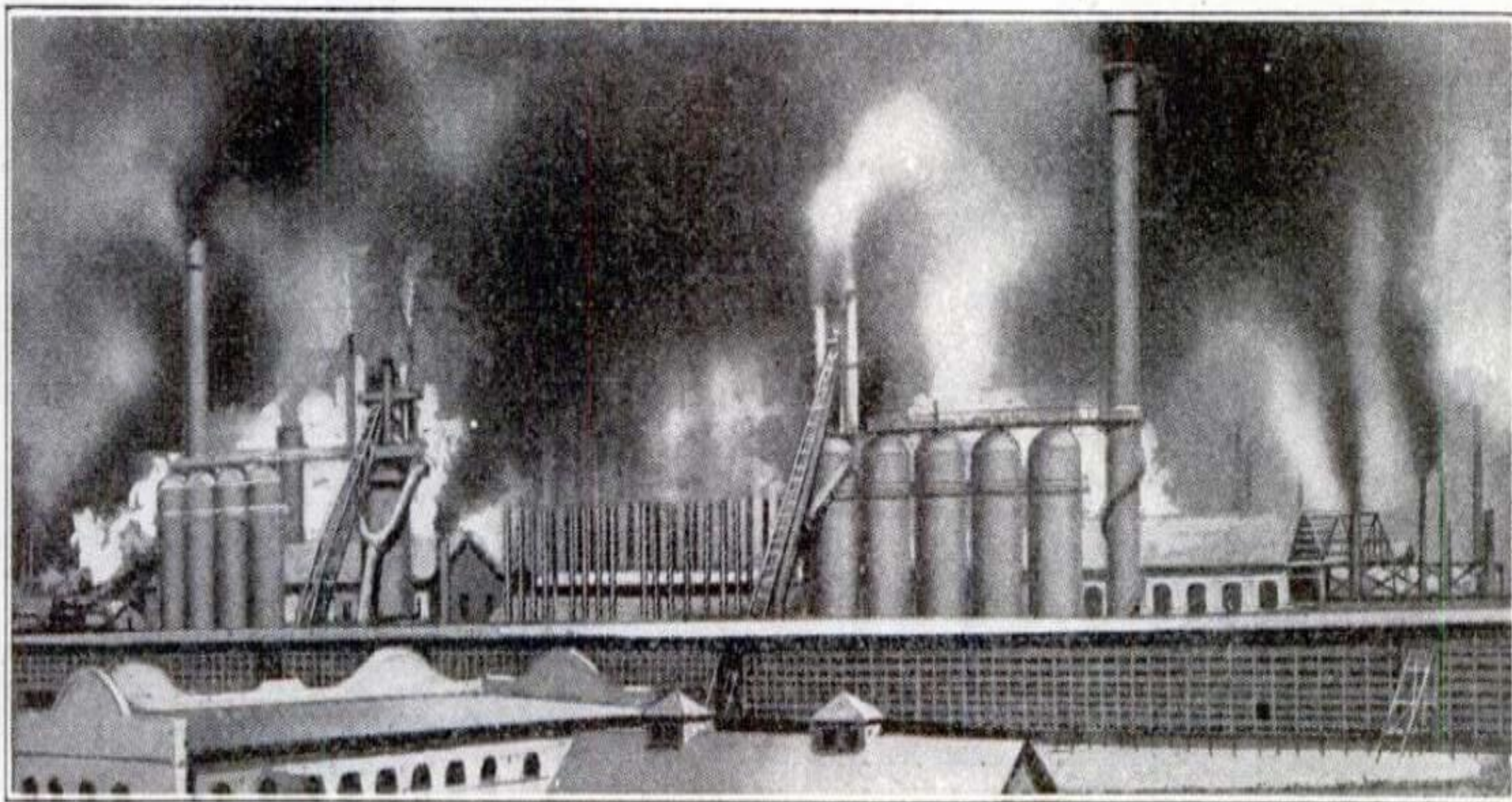






**J.B. DE FOURIER:  
DISCOVERER  
OF THE GREENHOUSE  
EFFECT 1824-1828**





The furnaces of the world are now burning about 2,000,000,000 tons of coal a year. When this is burned, uniting with oxygen, it adds about 7,000,000,000 tons of carbon dioxide to the atmosphere yearly. This tends to make the air a more effective blanket for the earth and to raise its temperature. The effect may be considerable in a few centuries.



**EARTH'S  
CLIMATE  
IS  
COMPLEX**



# Global warming and climate change

Causes and effects

Agriculture

**Fossil fuels**

Deforestation

*Causes*

**Greenhouse gases**

Carbon dioxide, methane,  
nitrous oxide, water vapor, ...

Water vapor,  
methane

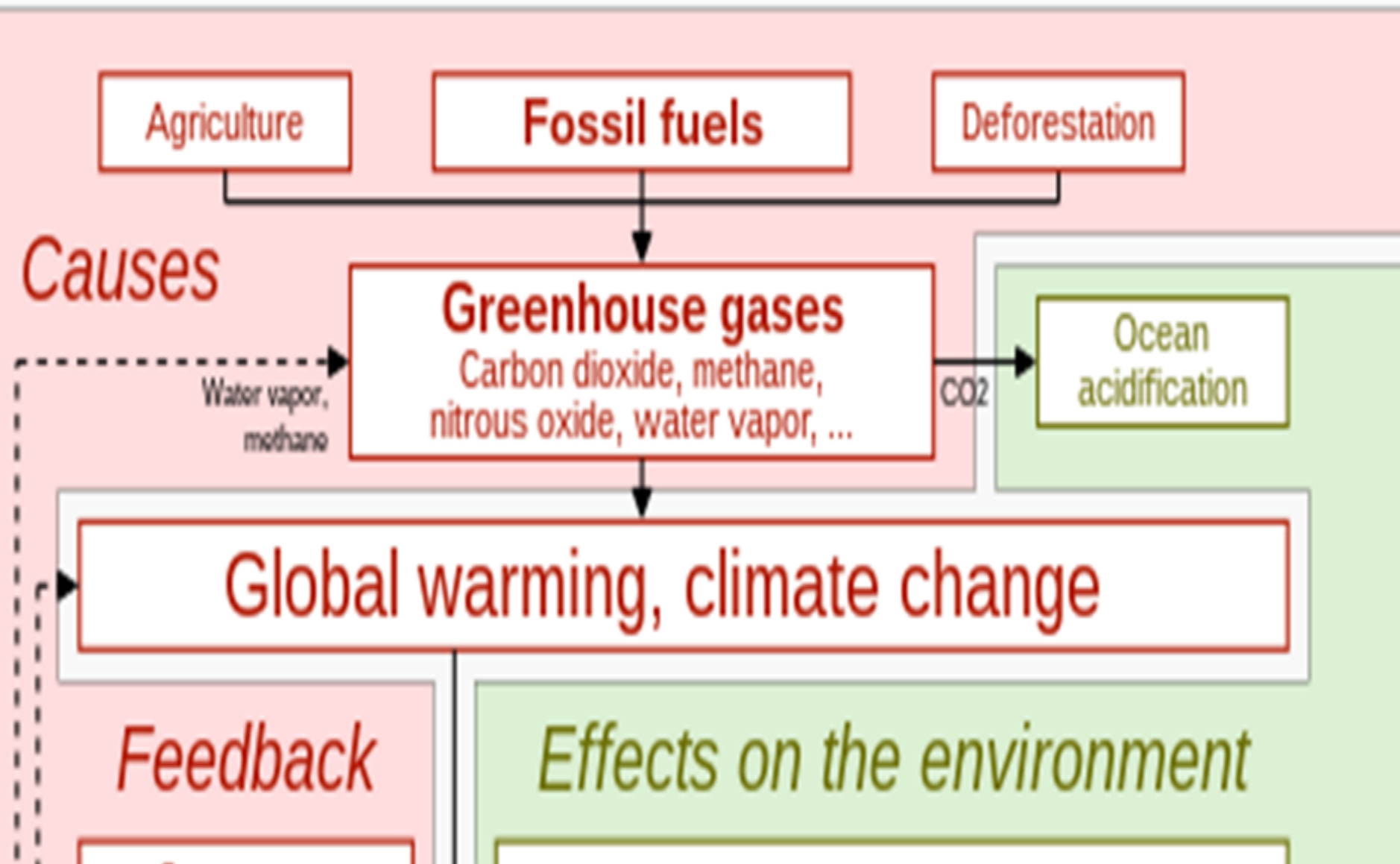
Ocean  
acidification

CO<sub>2</sub>

**Global warming, climate change**

*Feedback*

*Effects on the environment*



# **WAYS TO MEASURE LONG TERM**

## **CLIMATE CHANGE: HOW WE KNOW**

- 1.) Rocks/Radioactivity/Organisms; Sediments. Layers
- 2.) Ice cores (2 miles down in Antarctica and Greenland)  
(100 of thousands years); Boreholes; Ice Sheets;  
Glaciers;
- 3.) Networks of Floating Instruments; Ships temperatures;  
Weather stations; isotope readings
- 4.) Drilling Deep; Soils (cores); Geological records
- 5.) Satellites (e.g., NASA)
- 6.) Tree rings
- 7.) Animal Remains; Corals; Shells; Microfossils
- 8.) Biogeography (distributions, movements of organisms)
- 9.) Abundance of Experts in various fields of weather,  
earth sciences from a great many Institutions,  
Universities, Think Tanks, Community of Experts;  
computer predictions; historical records



Guliya 2015

## DRILLING ICE CORES







# ICE CORE WITH ENTRAPPED ATMOSPHERES











## **Institutes studying climate change**

- 1.) **NASA** (and Goddard Space Flight Center; JPL)
- 2.) **IPCC** (Intergovernmental Panel on Climate Change); **UN groups; World Resources Institute; Earth system science data (essd); Global Carbon Project**
- 3.) **NOAA** (National Oceanic & Atmospheric Administration); **EPA; IEA** (International Energy Agency); **World Meteorological Association**; US Energy Inform. Administration (**EIA**); US DOD; AAAS
- 4.) Columbia University Earth Center; Many other **Universities** (hundreds) & **Scientific Institutions**
- 5.) Berkeley Earth (UC Berkeley); Nat. Cent. Atmosph. Res
- 6.) **Japanese** Meteorological Agency; **UK** Meteorological office (Met Office Hadley Centre); National Climate Assessment ; US Global Change Reassessment Program;



# **THE GREENHOUSE EFFECT: GREENHOUSE GASES**





# The Greenhouse Effect



Some sunlight that hits Earth is reflected back into space, while the rest becomes heat

Greenhouse gases prevent heat from escaping into space, warming the planet



# RADIATION FROM THE SUN

**Most of the Sun's energy goes right through our atmosphere,** to the Earth's surface

(the ozone layer protects us by absorbing a lot of the harmful UV rays)

30% on average – bounces off clouds, ice, snow, deserts and other bright surfaces

**70% absorbed by land or water, which then heats up**

**The Earth – emits some light (mostly infrared radiation (heat) – the greenhouse gases absorb some of the escaping infrared radiation in the lower atmosphere and returns that energy/warmth to the Earth** (with less of the radiation from the Earth's surface getting to outer space, which would happen without those gases) thus warming the Earth --causing the Greenhouse effect



# THE CARBON CYCLE

A balance between carbon emitters (like humans and other animals when breathing, emits CO<sub>2</sub>), and carbon absorbers/sinks/sequesterers (like ocean, soil (mostly at the top), and the trees--esp. tropical rainforests, plants, other photosynthetic organisms like phytoplankton).

The Balance - When the same amount of air that's being pumped into the air, is being sucked out by something else. (IN AND OUT)

The ocean (esp. its surface) is the biggest sink – 86% of all CO<sub>2</sub> in the world

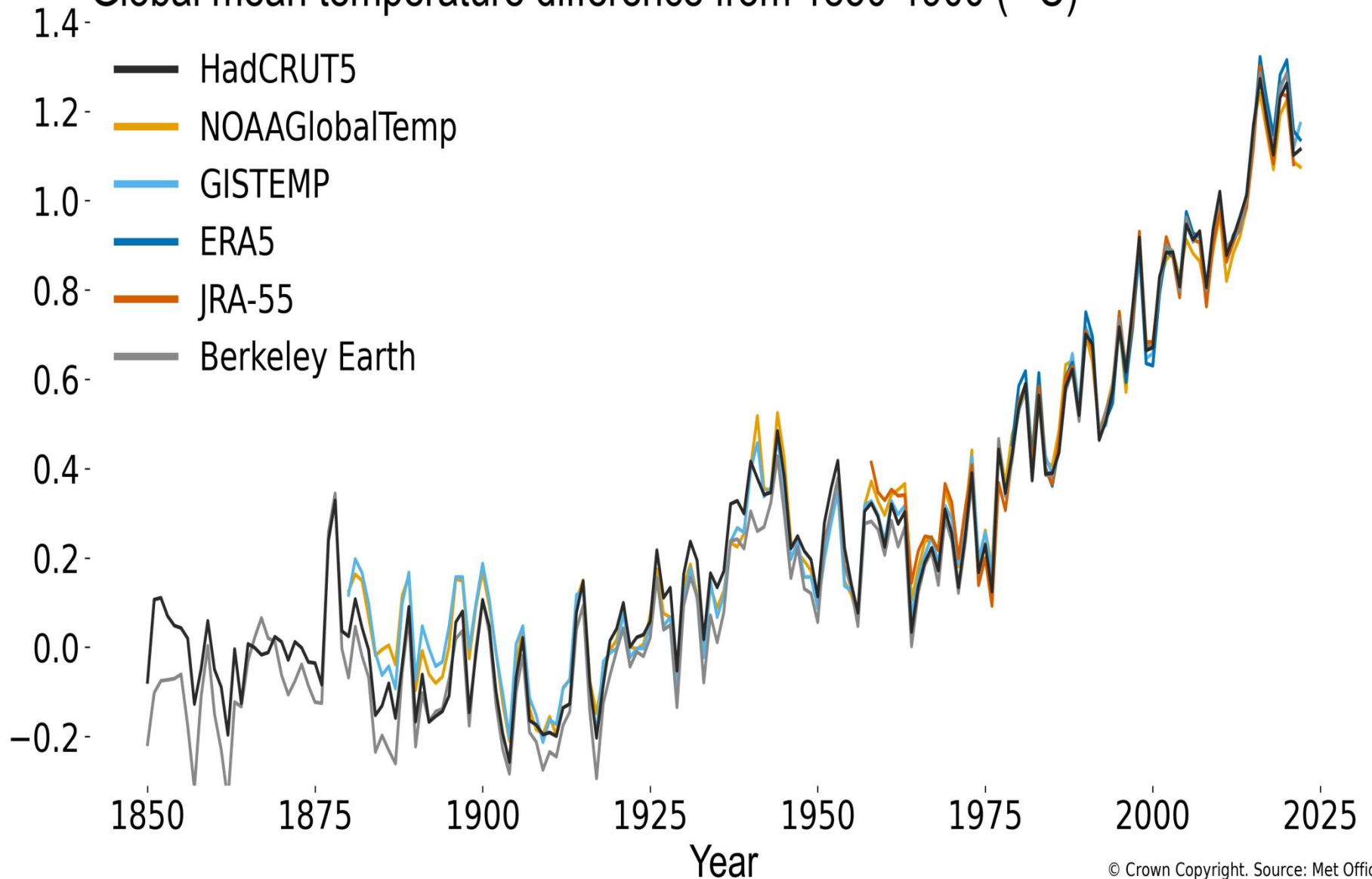
Huge process involving air, land and sea



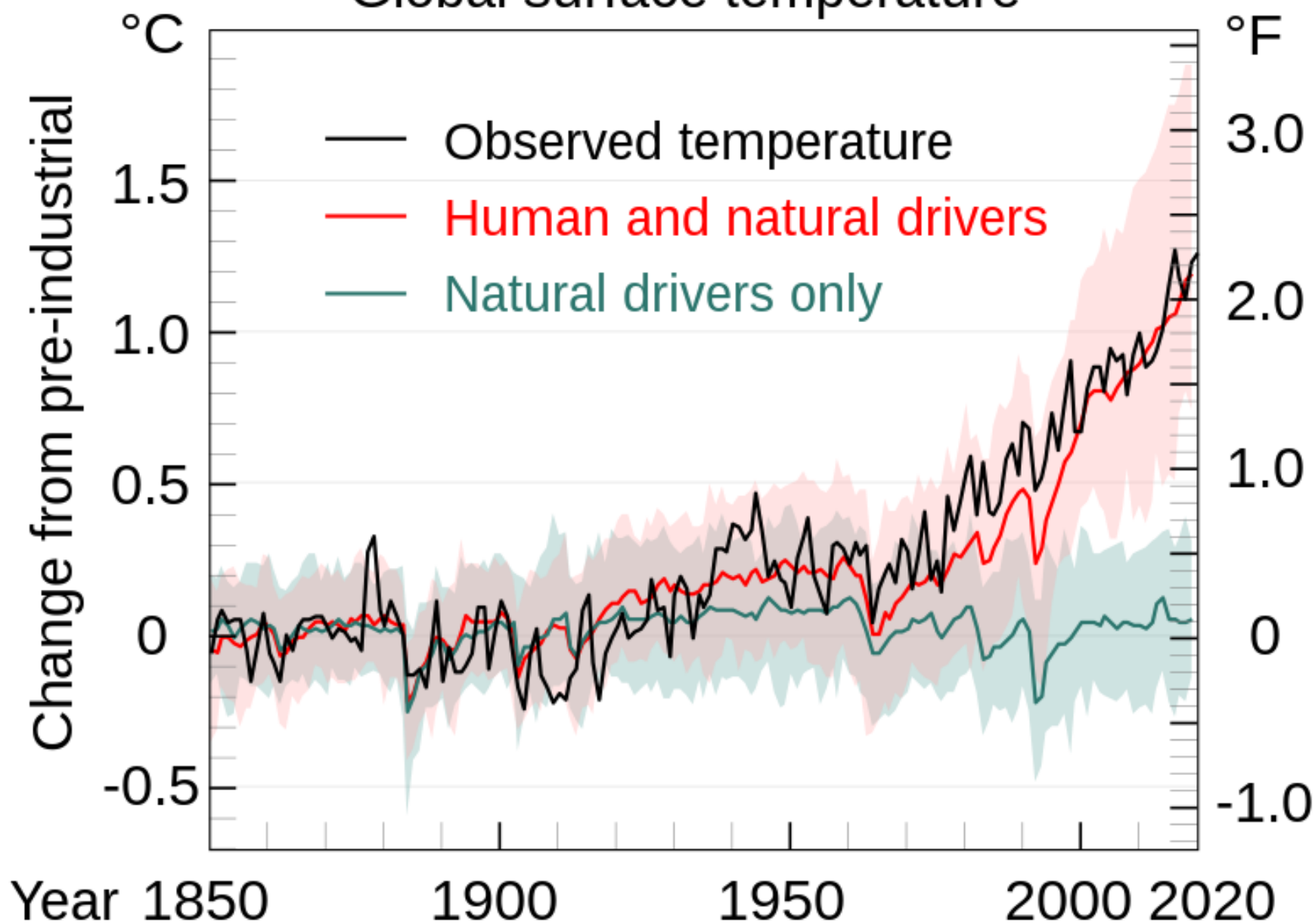


# GLOBAL TEMPERATURE INCREASING

Global mean temperature difference from 1850-1900 ( $^{\circ}\text{C}$ )



# Global surface temperature





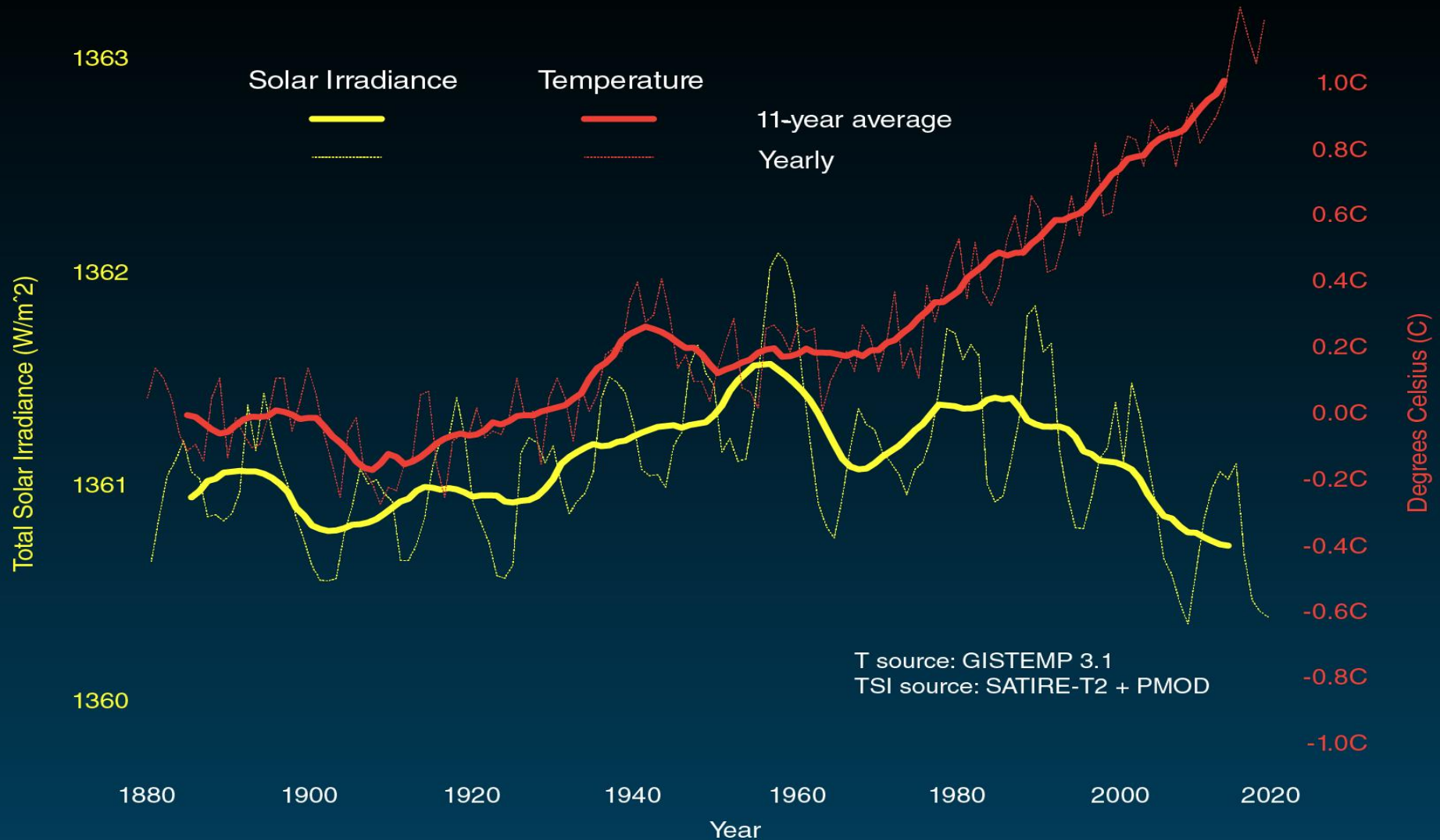
# **BUT - HAS NOT THERE ALWAYS BEEN CLIMATE CHANGE OVER THE EONS??**

YES, BUT **NOW** IT'S THE NUANCES, EVIDENCES-FACTS: NOW:

- 1.) **Much more Rapid** (tempo much different than before)
- 2.) **Not Secondary to Natural Causes** (as it was before Industrial Revolution, or over time) (I.E., NOT DUE TO SOLAR INCREASES, VOLCANOES, EARTH ORBITS/TILT, ETC)

# Global warming **not** due to change in solar activity

Temperature vs Solar Activity (or volcanos or Earth's orbit)



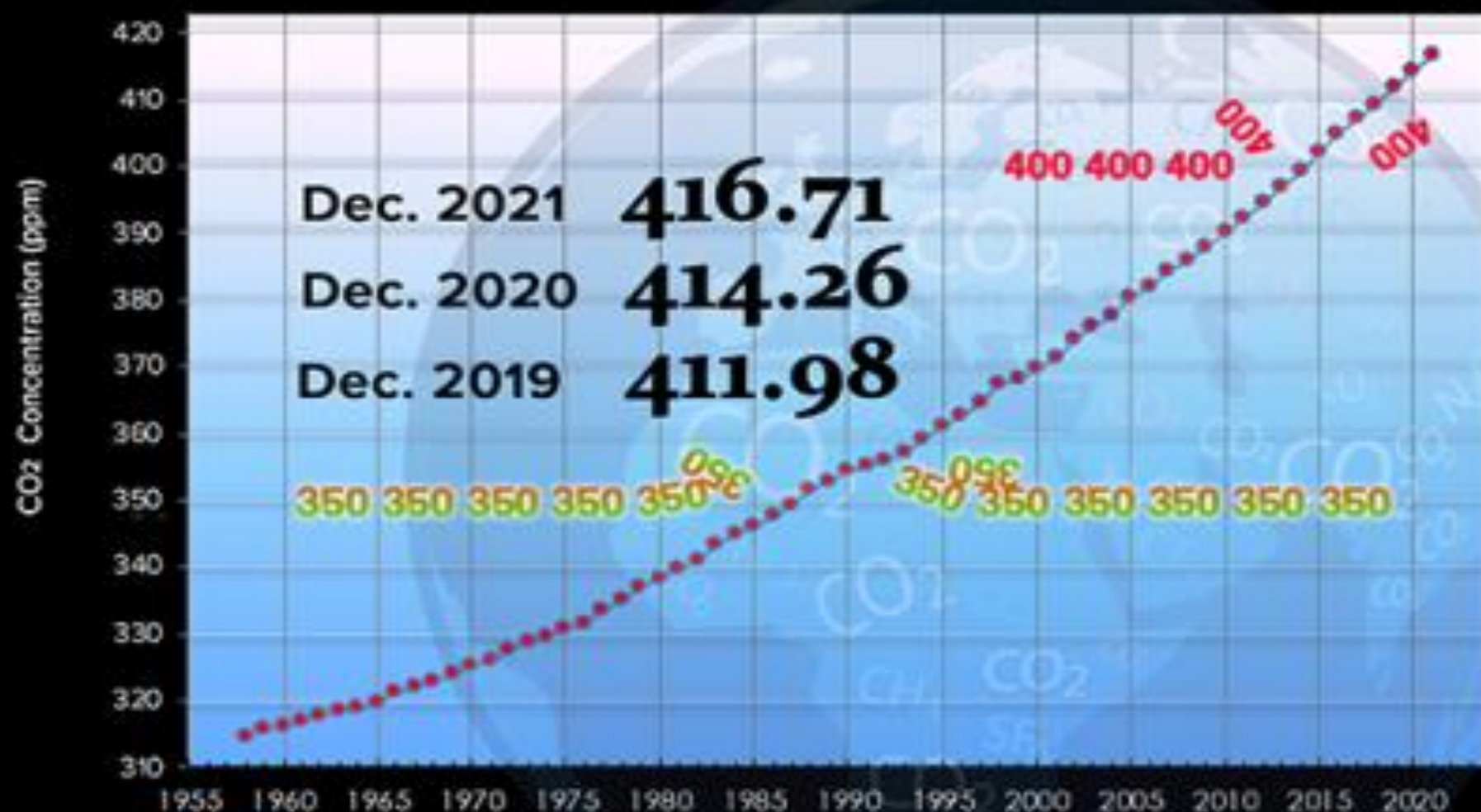
**INCREASED  
CO<sub>2</sub> IN  
ATMOSPHERE  
(a Potent  
Greenhouse Gas)**



December 1958 - December 2021

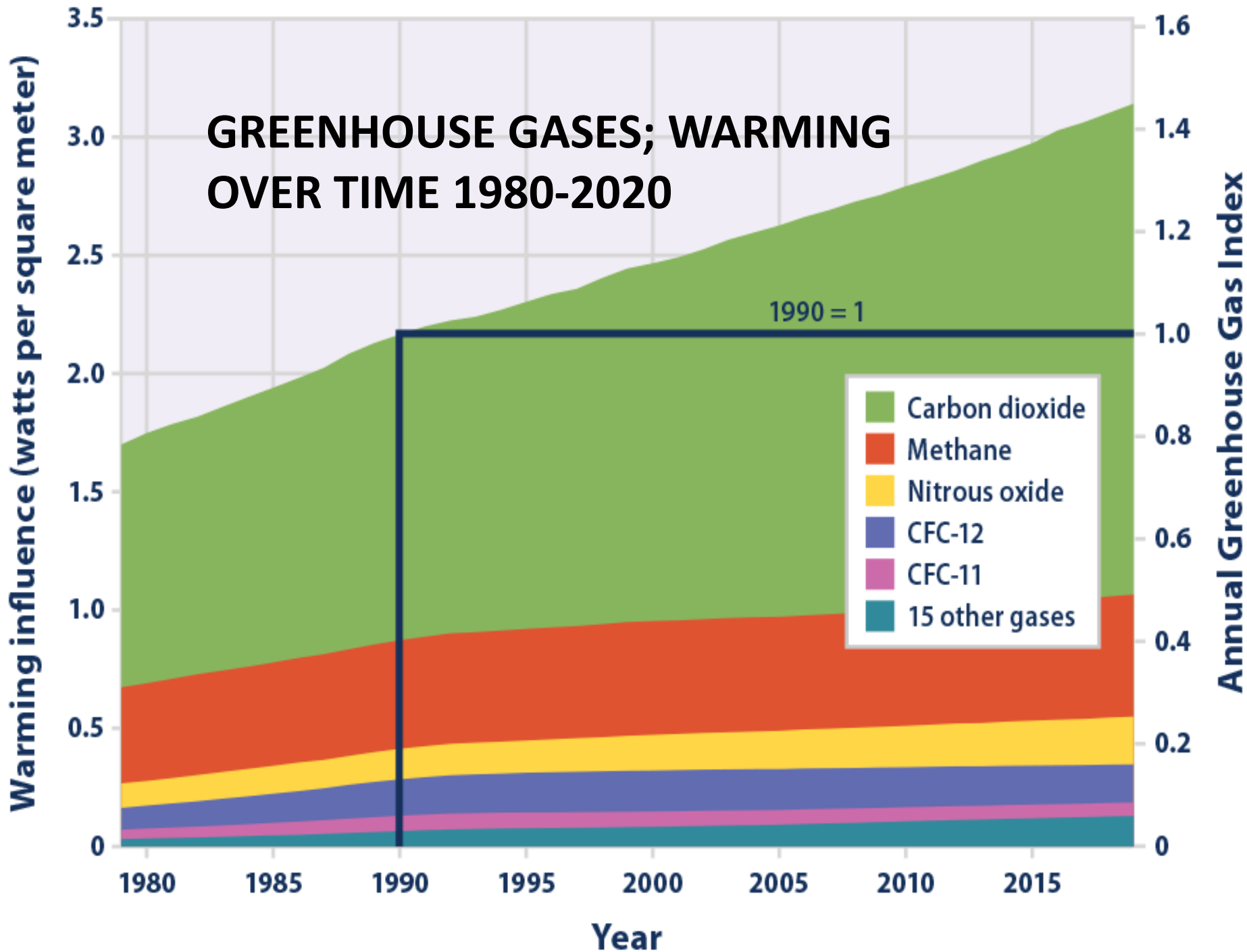
# Atmospheric CO<sub>2</sub>

December CO<sub>2</sub> | Year-Over-Year | Mauna Loa Observatory



**CO<sub>2</sub>-earth** Featuring NOAA data of January 5, 2022

# GREENHOUSE GASES; WARMING OVER TIME 1980-2020







# **FOSSIL FUELS**

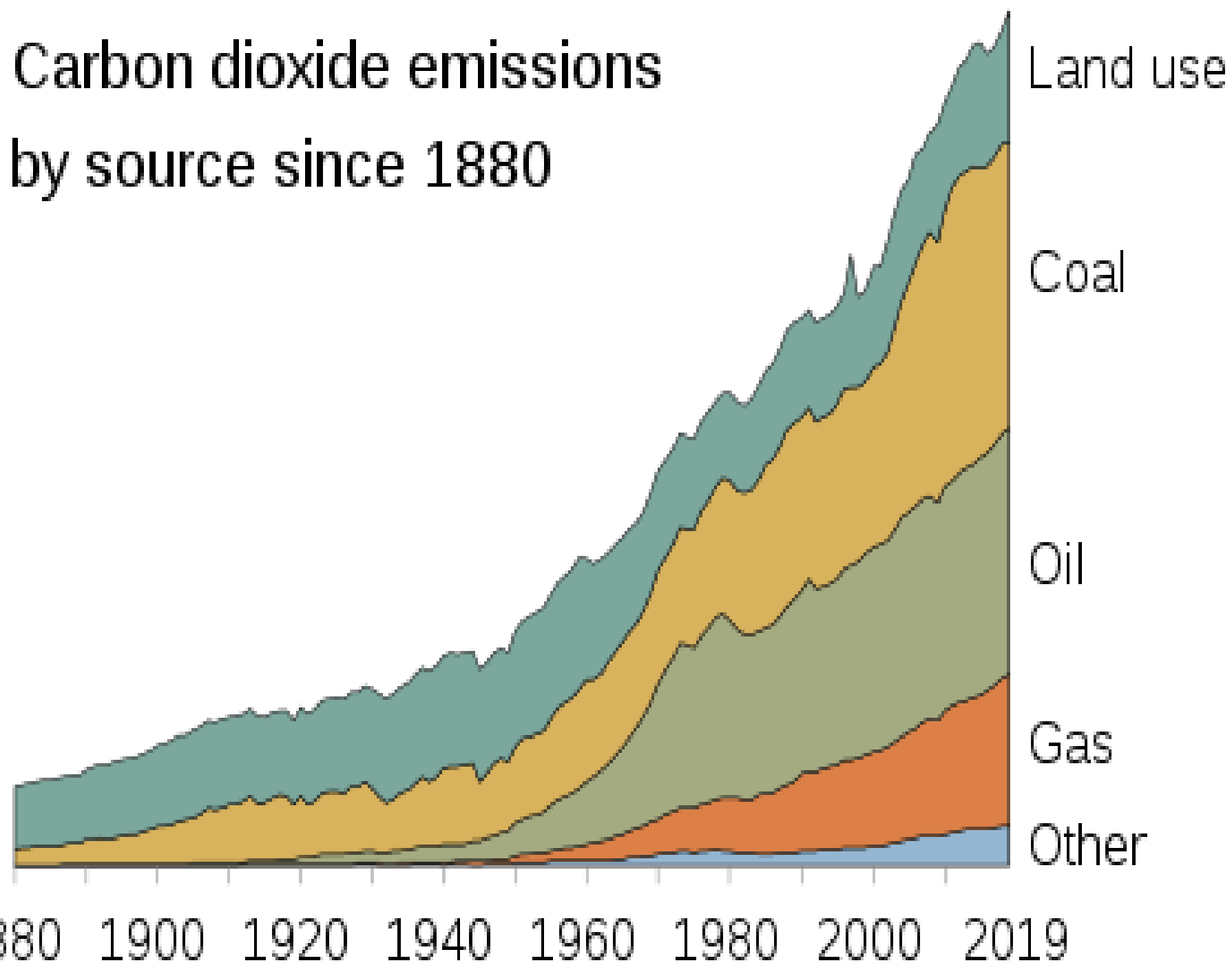
**80% OF WORLD'S ENERGY IN 2018**

**The fossil fuel that produces the most greenhouse gas emissions is coal, and burning coal to produce electricity is the major source of coal-related greenhouse gases**

**Burning 1 ton of coal produces 2.86 tons of CO<sub>2</sub>**

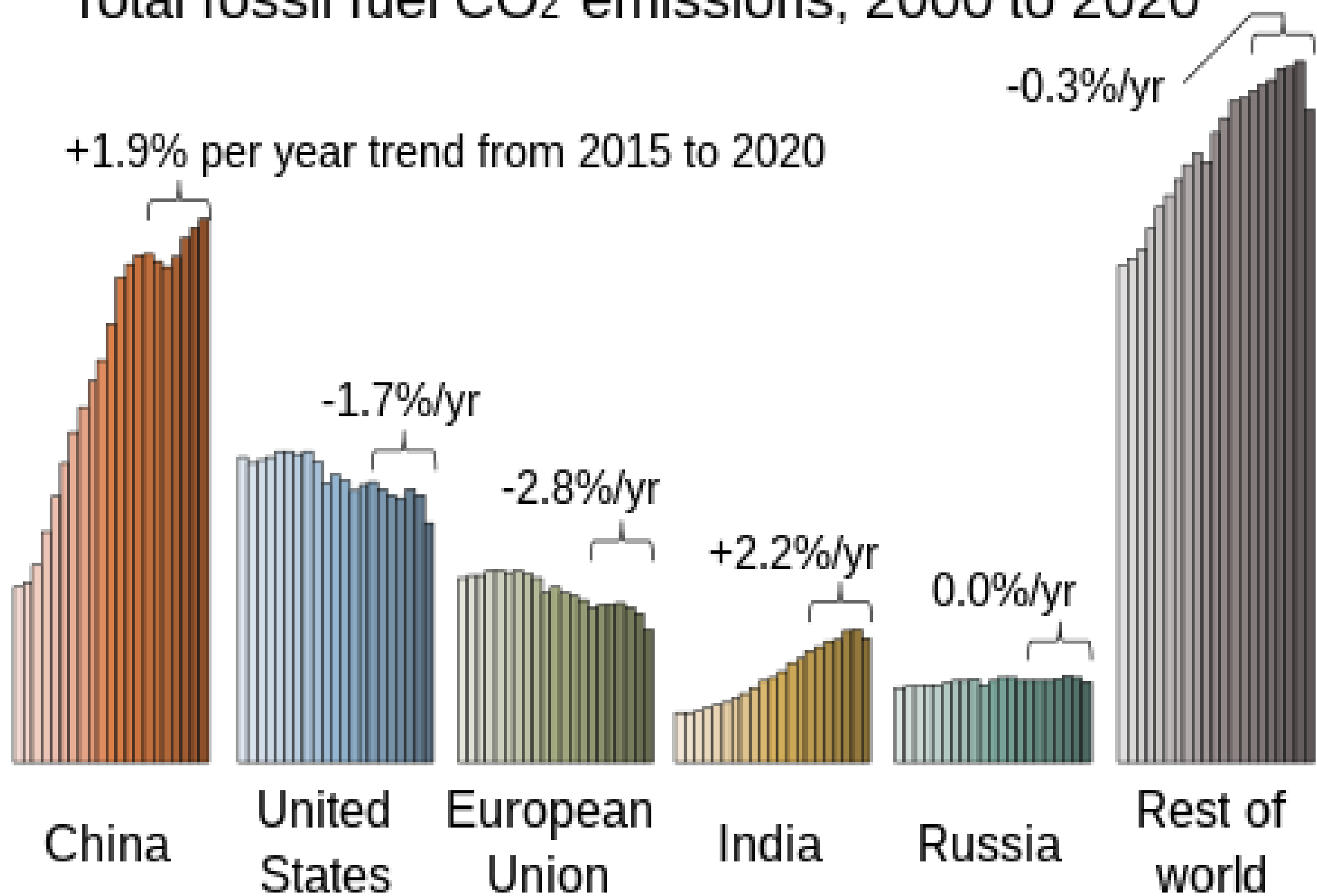


# Carbon dioxide emissions by source since 1880

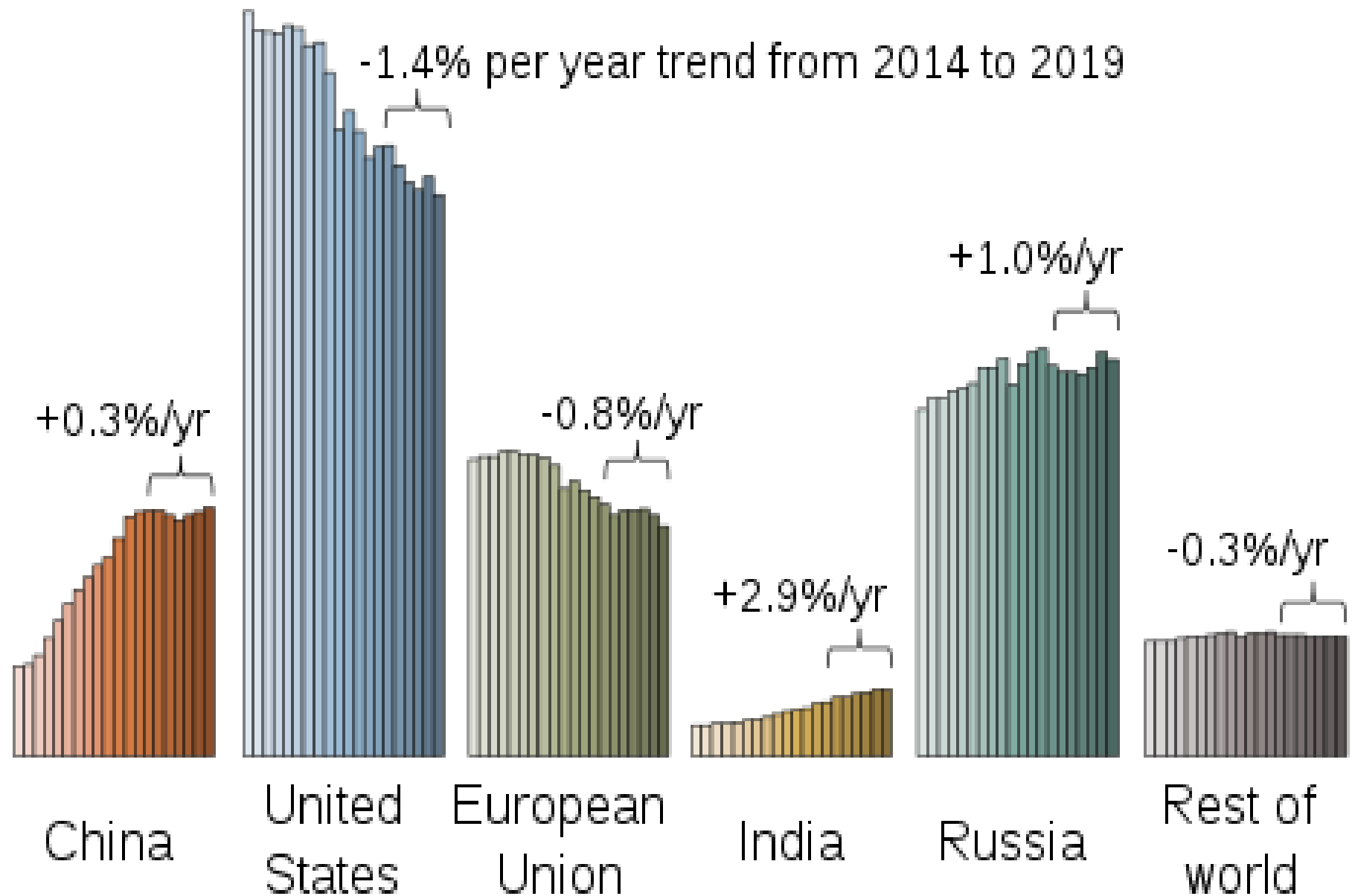




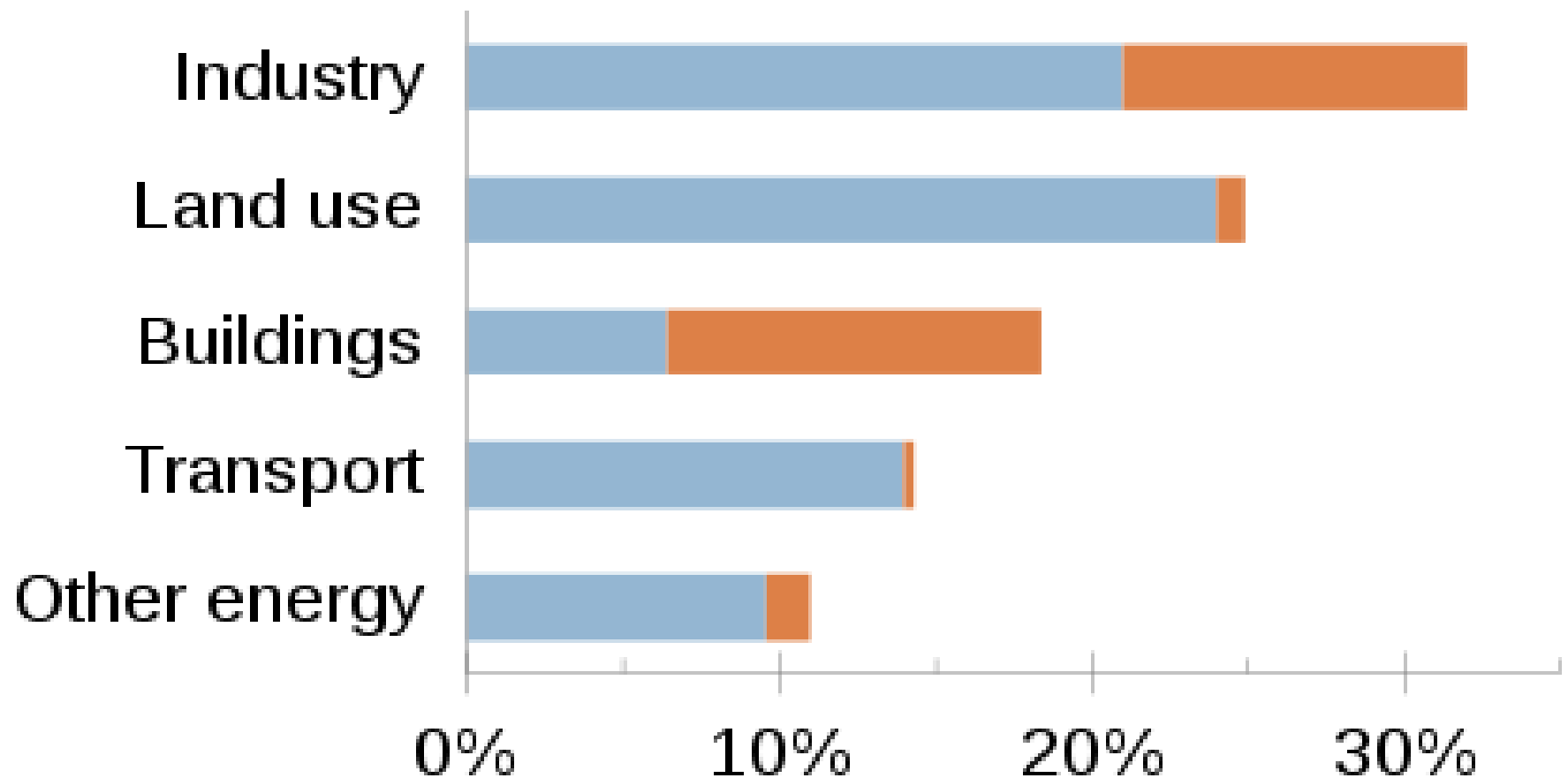
# Total fossil fuel CO<sub>2</sub> emissions, 2000 to 2020



# Per capita fossil CO<sub>2</sub> emissions, 2000 to 2019



# Greenhouse emissions by economic sector



■ Direct emissions (75% of total)

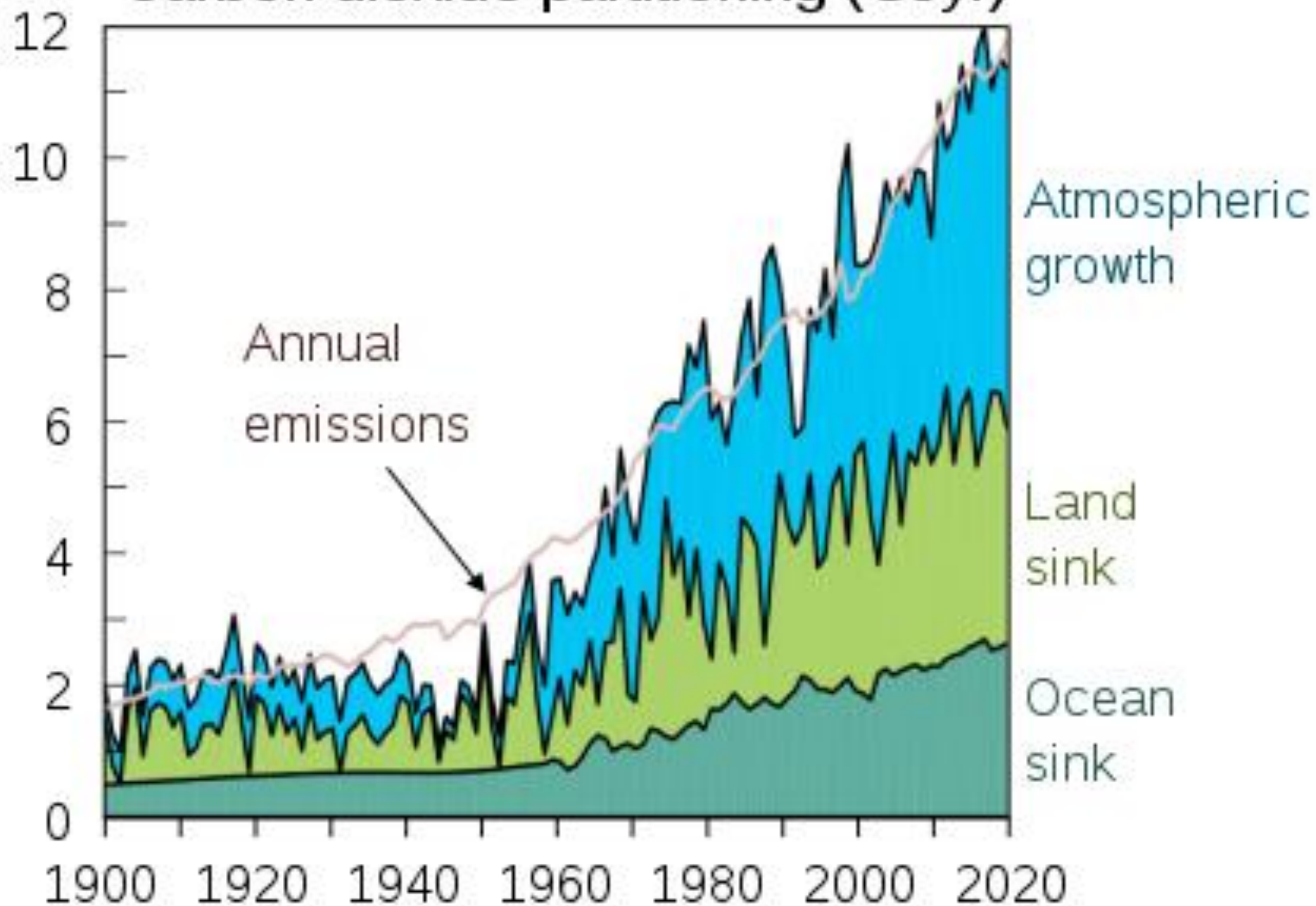
■ Emissions from electricity and heat production used by sector (25% of total)



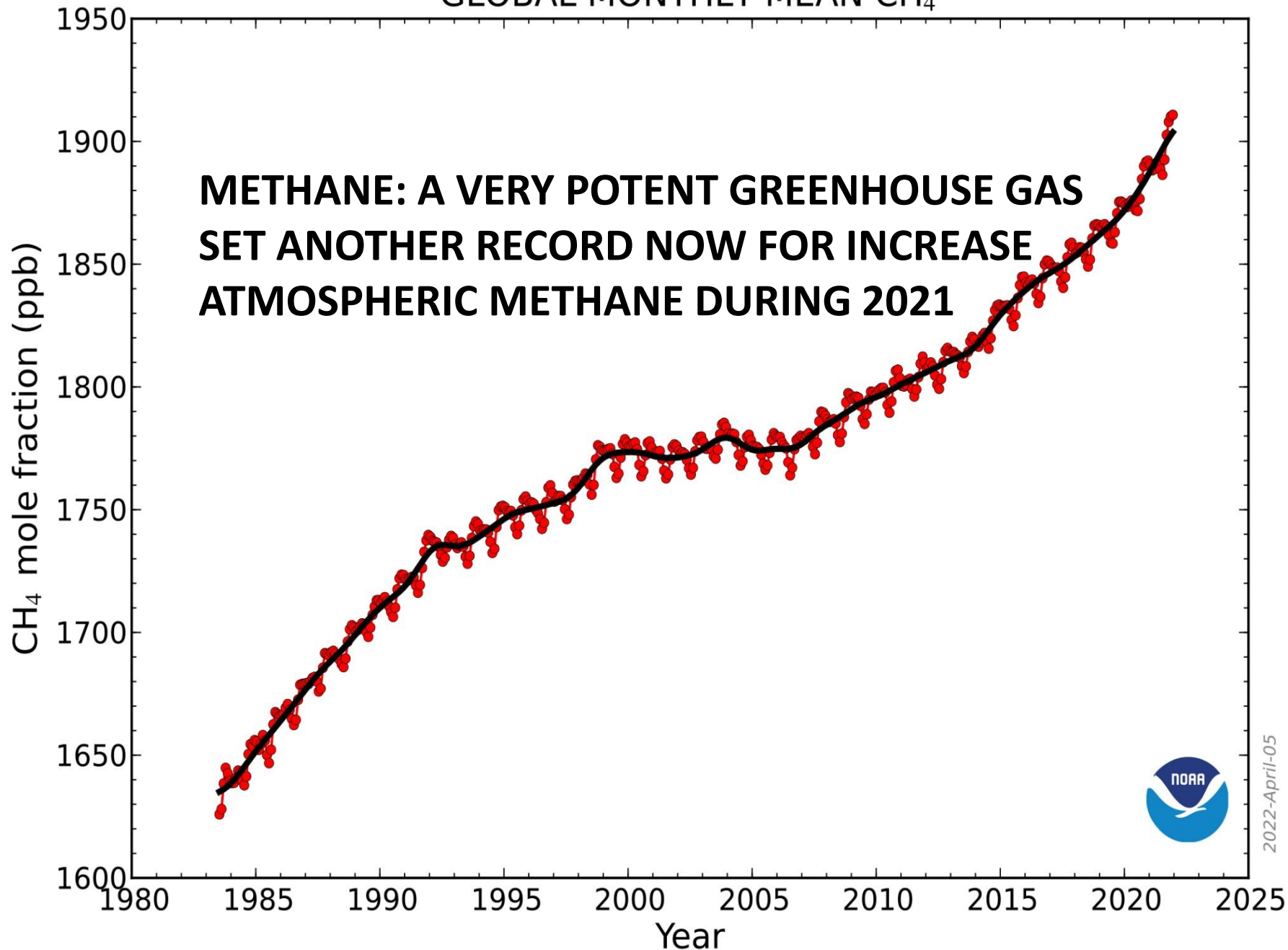
# **CLIMATE CHANGE (AKA GLOBAL WARMING): EFFECTS AIR, SEA, LAND**

- 1.) Increased production of human-made CO<sub>2</sub>**
- 2.) Increased CO<sub>2</sub> in our atmosphere**  
(scientific records of CO<sub>2</sub> levels in the atmosphere go back 800,000 years-35% more now)
- 3.) Increased Acid Rain and Acid Waters**
- 4.) Soil: Global Tree changes; changes in Soil moisture, content**

# Carbon dioxide partitioning (Gt/yr)



## GLOBAL MONTHLY MEAN CH<sub>4</sub>





# FEEDBACK SYSTEMS

Environmental  
changes

Environmental  
changes

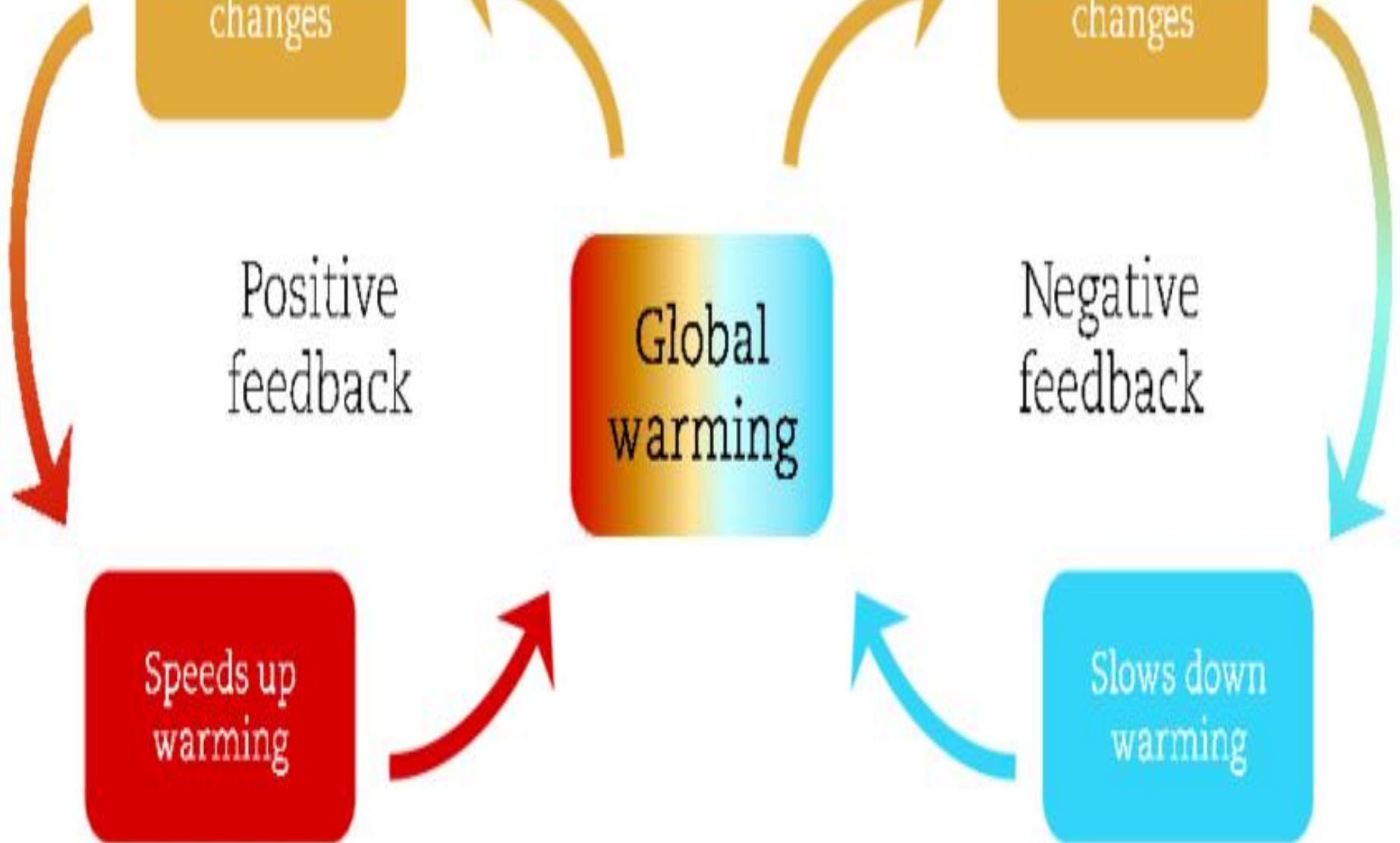
Positive  
feedback

Global  
warming

Negative  
feedback

Speeds up  
warming

Slows down  
warming



**PROBLEM:** SOME **MAJOR FEEDBACK SYSTEMS** MAKING THINGS WORSE: AMPLIFIED, CASCADING, ACCELERATED CHANGES--SPEEDS UP: ***"POSITIVE FEEDBACK"*** (ENHANCES FEEDBACK; **OUT OF BALANCE, CONTROL**)

**H2O VAPOR IN ATMOSPHERE** (50% of contributor to Greenhouse: **H2O in atmosphere increases as a function of temperature; warm air holds more moisture**-increasing Greenhouse warming); CO2 has a very long atmospheric lifetime (100,000 years)

**Deforestation:** increases Greenhouse and Earth's land surface (esp. forests) **leads to loss of significant Carbon sink for CO2; releases chemicals**-influences clouds/wind patterns in tropics, temperate areas –**leads to increased warming**

**Oceans absorb CO2:** increased CO2 uptake by oceans lead to decreased fraction of uptake of CO2 leads to acid waters and loss, alteration of sea life via loss of O2, decrease in snow cover, sea ice – more energy absorbed with less reflecting of light; melting permafrost releases CO2 and methane; less O2

**Alters Cloud Cover and types of Clouds:** Higher, thinner Clouds – an insulator – reflecting heat down; decreased snow, ice cover – **decrease reflectivity & melting permafrost releases CO2 and methane**

**Soils with carbon** – release carbon; at higher CO2 concentration – **absorbs a decreased fraction** of our CO2 emissions; **fires** release CO2 – increase warming

# EFFECTS OF GLOBAL WARMING:

AIR, SEA, LAND,  
PLANTS & ANIMALS  
(INCLUDING  
HUMANS)



# Global warming, climate change

## Feedback

Snow cover reduction: less sunlight reflection

Water vapor increase

Permafrost melt; methane release

## Effects on the environment

Habitat destruction

Ecosystem collapse:  
Arctic, Barrier Reef, ...

Biodiversity loss,  
species extinction

Intensified weather events:  
Heat, storms, floods, droughts, wildfires...

Glacial retreat,  
ice sheet melt

Freshwater loss,  
desertification

Disease carrier,  
pest propagation

Coral bleaching,  
fish stock decline

Sea level rise,  
coastal submersion

Direct impact on  
human health

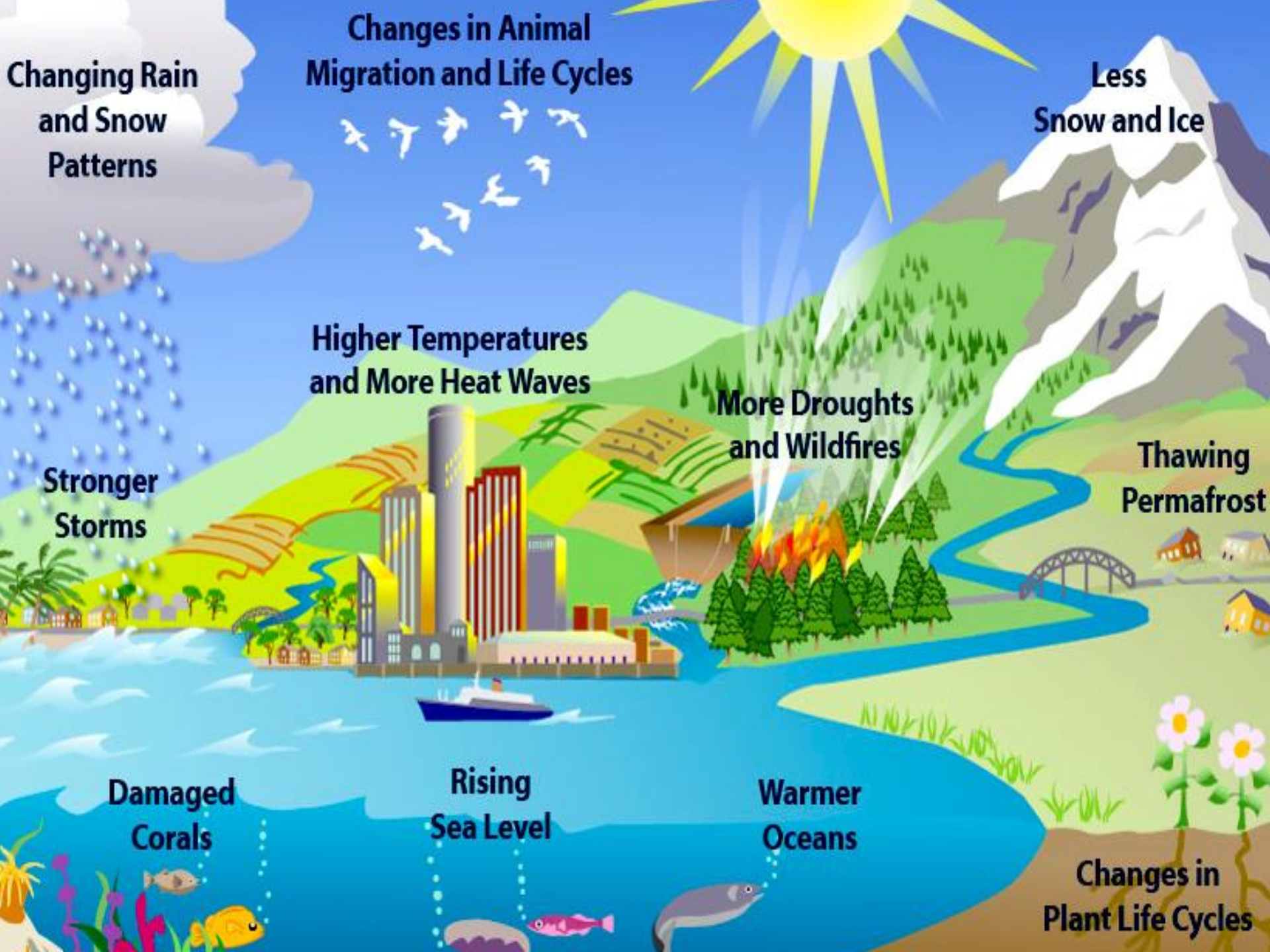
Human migration  
and conflict

Flooded cities,  
farmland

Crop failure,  
farmland loss

Direct physical  
harm to humans

## Effects on humans



**Changing Rain  
and Snow  
Patterns**

**Changes in Animal  
Migration and Life Cycles**

**Less  
Snow and Ice**

**Higher Temperatures  
and More Heat Waves**

**More Droughts  
and Wildfires**

**Thawing  
Permafrost**

**Stronger  
Storms**

**Damaged  
Corals**

**Rising  
Sea Level**

**Warmer  
Oceans**

**Changes in  
Plant Life Cycles**

# **SOME OF THE EFFECTS OF GLOBAL** **WARMING AROUND THE WORLD**

**Drought; Forest-fires** – intense, longer) ; longer heat waves;  
Deserts expanding

**Evaporating Lakes** (evaporation; ship traffic)

**Floods** (warmer air – contains more moisture; sudden deluge events; heavier rainfalls); water – air pollution

**Major Storms** (extreme intense storms, weather; hurricanes)

**Melting Glaciers** (loss of drinking water); melting permafrost  
loosen mountain walls-rock falls

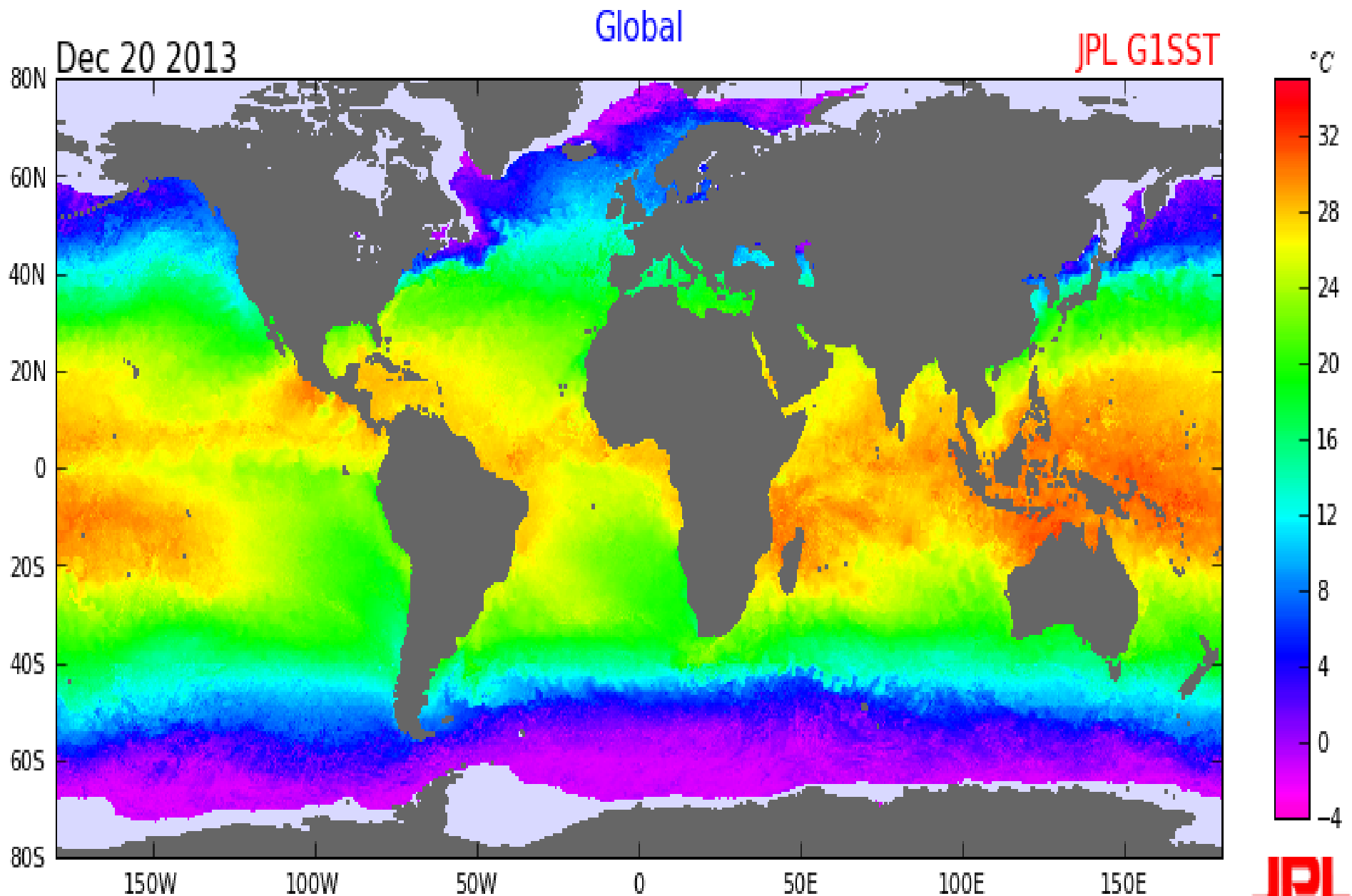
**Rising Sea Levels** (water expands when it gets warmer): oceans  
expanding, ice sheets in Greenland, Antarctica collapse –  
coastal cities threatened); increase erosion; freshwater  
contamination

**Loss of Native Species** of plants and animals; stressed fisheries;  
Vulnerable Agriculture; **Loss of biologic diversity (UN)**

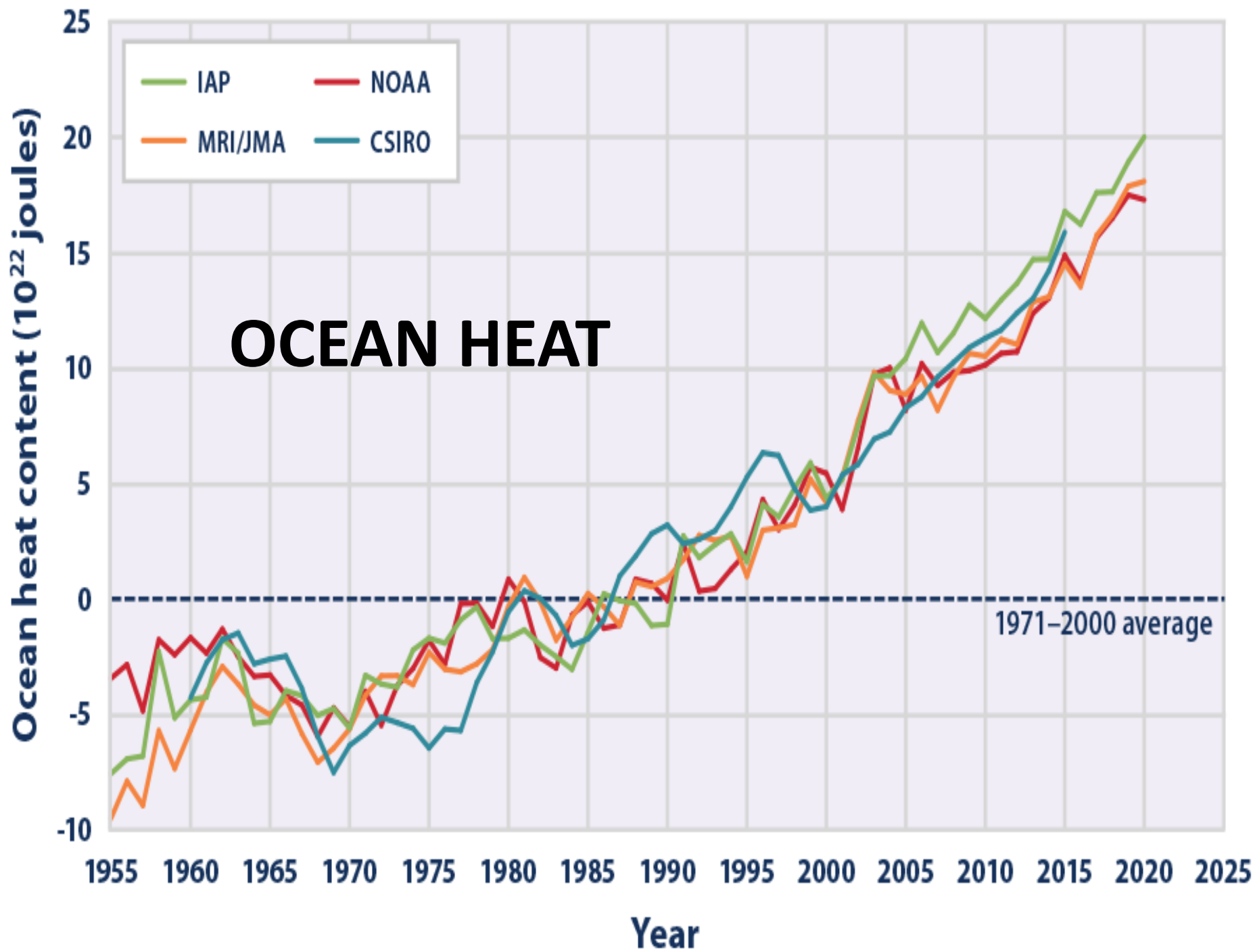
Alterations of **Ocean Currents** (e.g., Gulf stream)

Human **Health** (malnutrition, CV, infections, CNS; **Economic** loss)

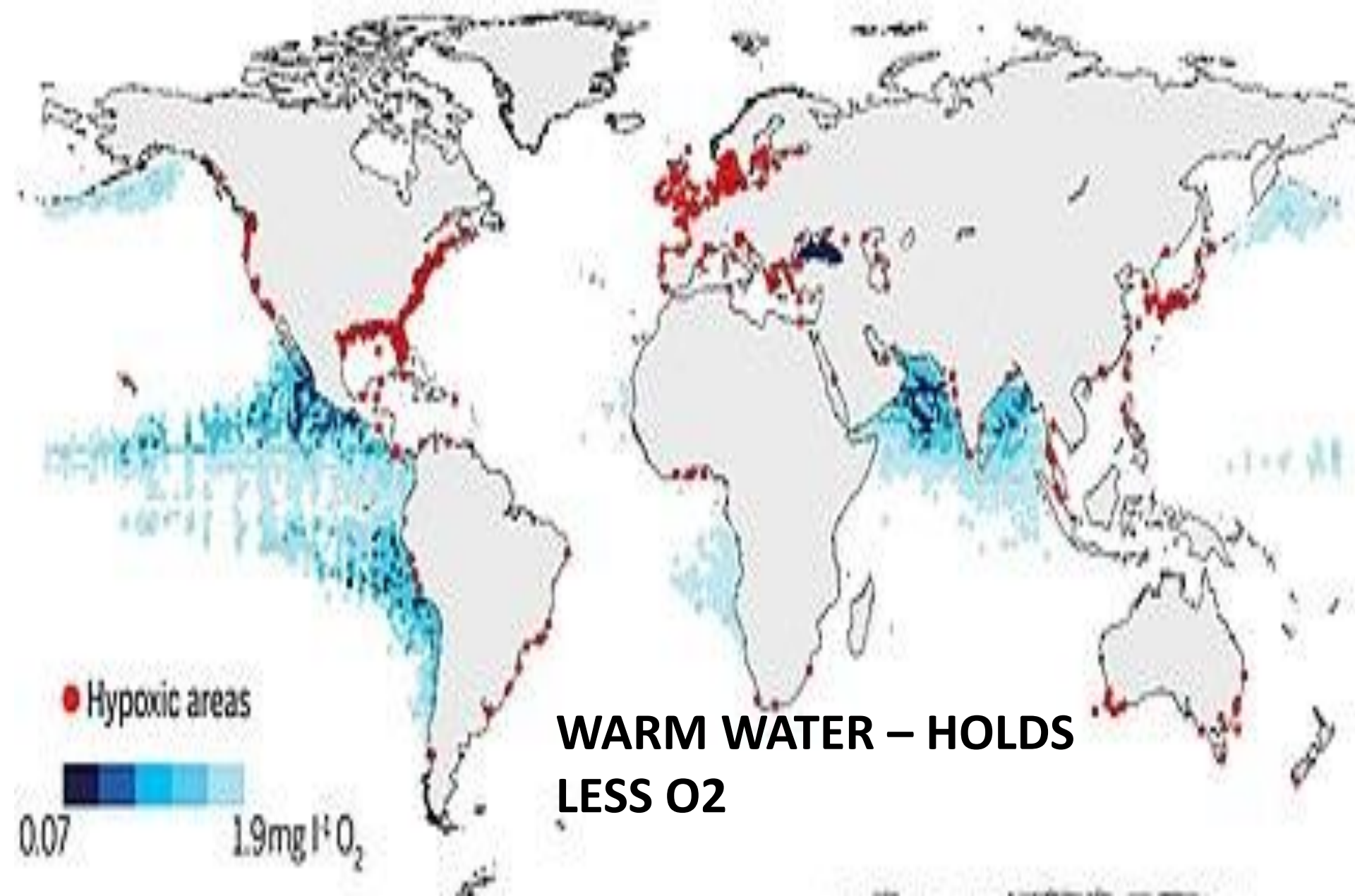
# OCEAN WARMING





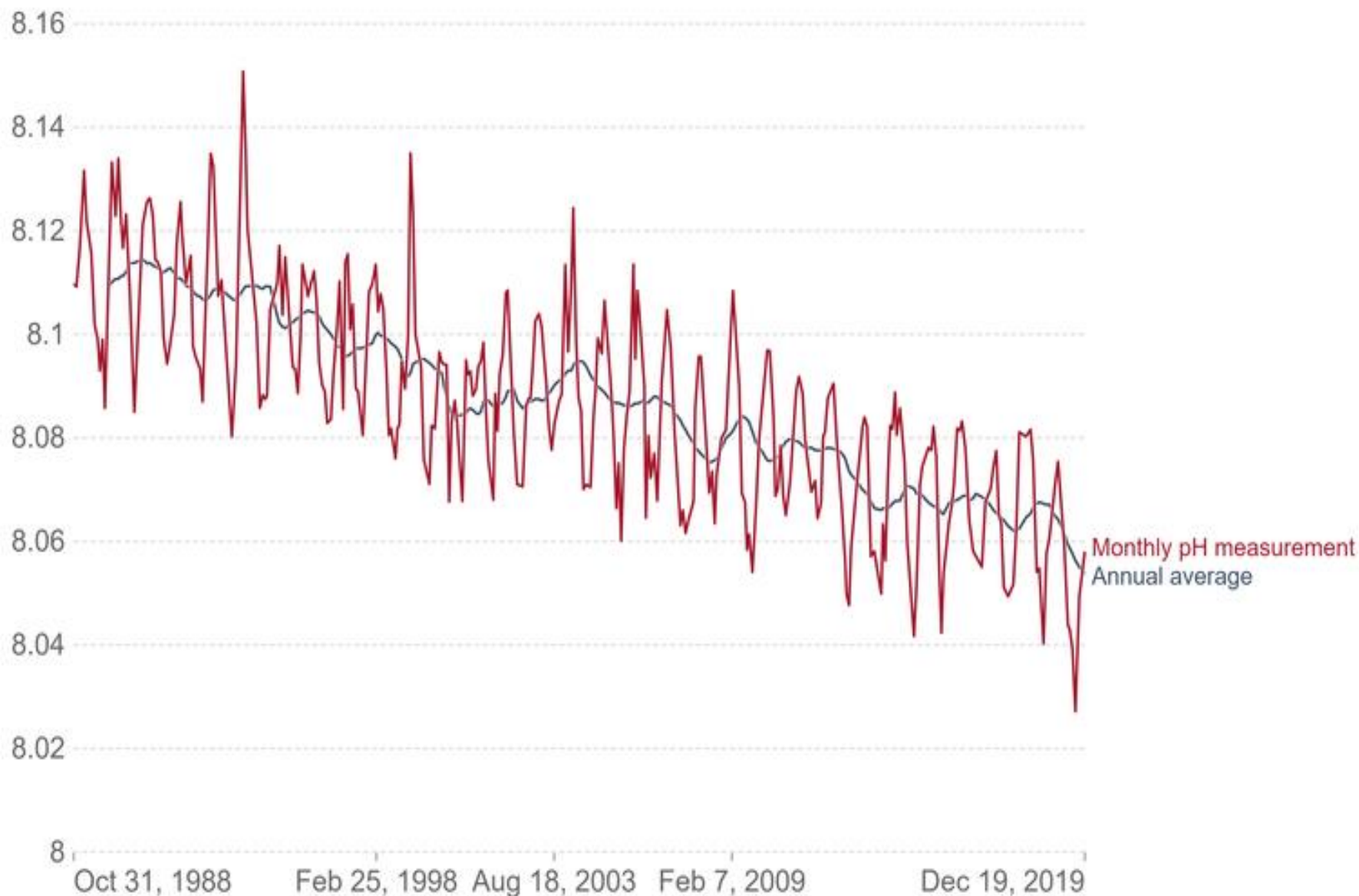


# GLOBAL MAP OF LOW, DECLINING O<sub>2</sub> IN WATERS



# Ocean acidification: mean seawater pH

Mean seawater pH is shown based on in-situ measurements of pH from the Aloha station.

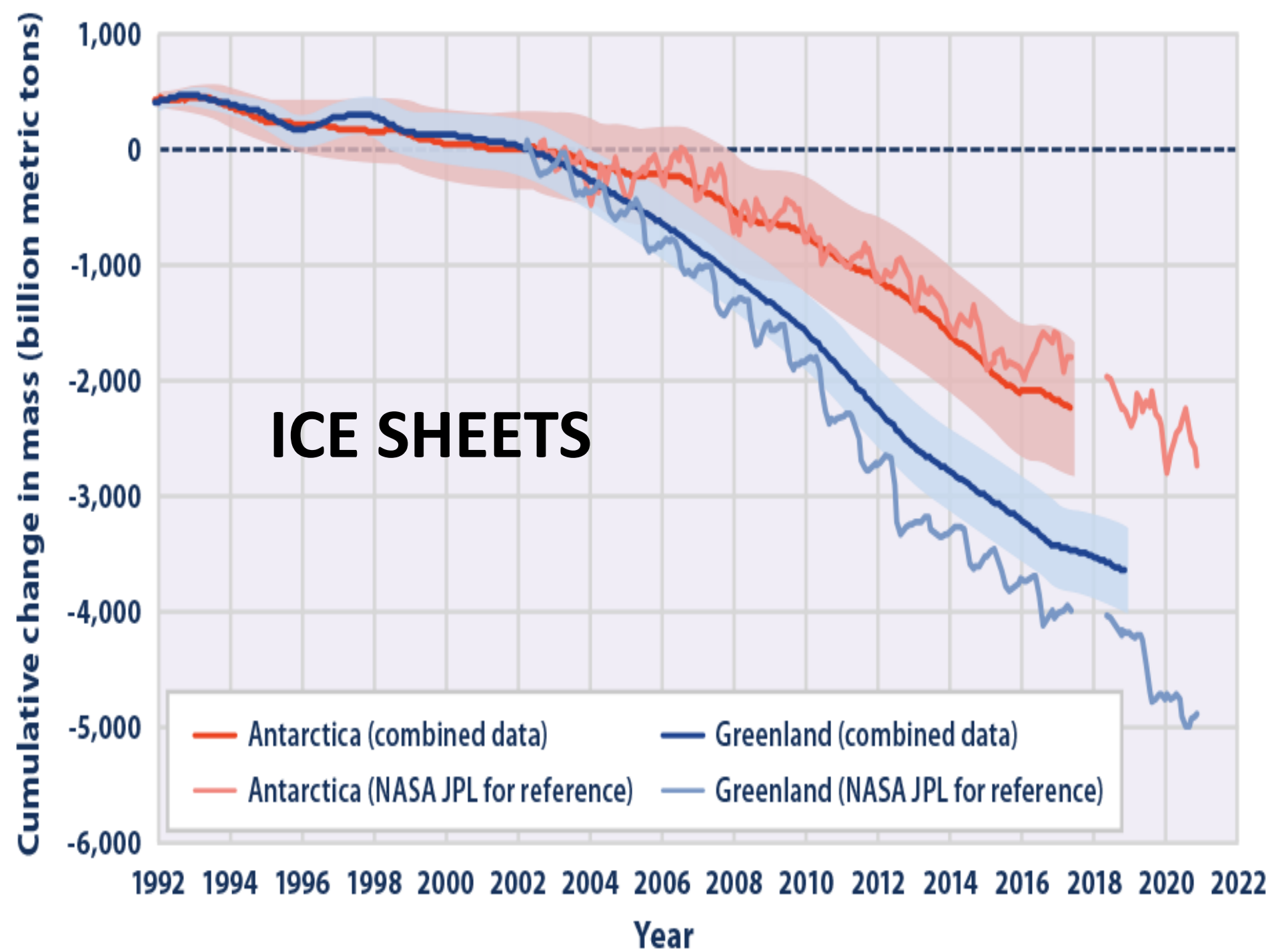




**CORAL  
BLEACHING \***

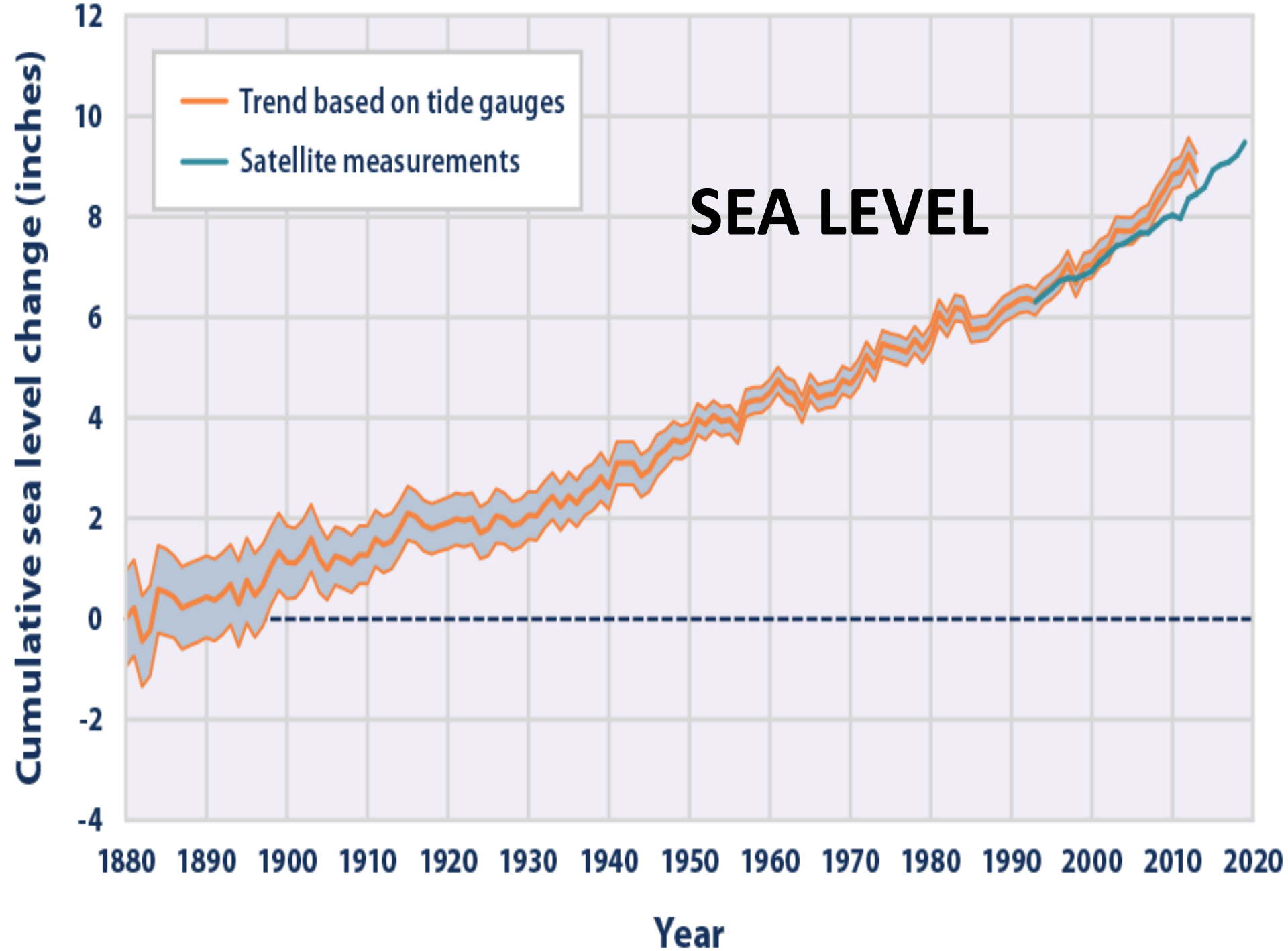






**WHAT HAPPENS IN THE ARCTIC  
DOESN'T STAY IN THE ARCTIC**

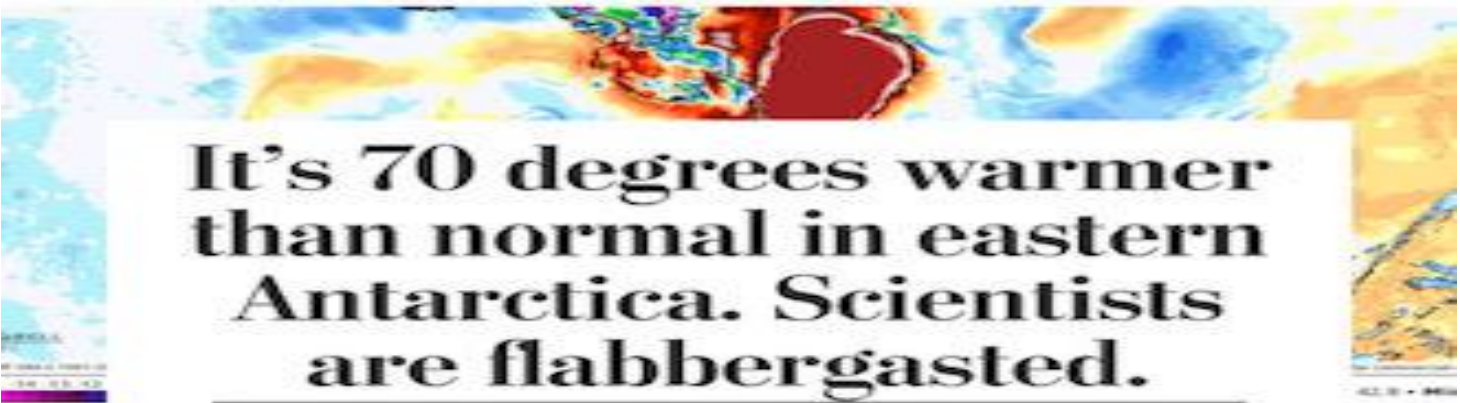












# It's 70 degrees warmer than normal in eastern Antarctica. Scientists are flabbergasted.

BY JASON SAMENOW AND KASHA PATEL

MARCH 18 AT 5:06 PM

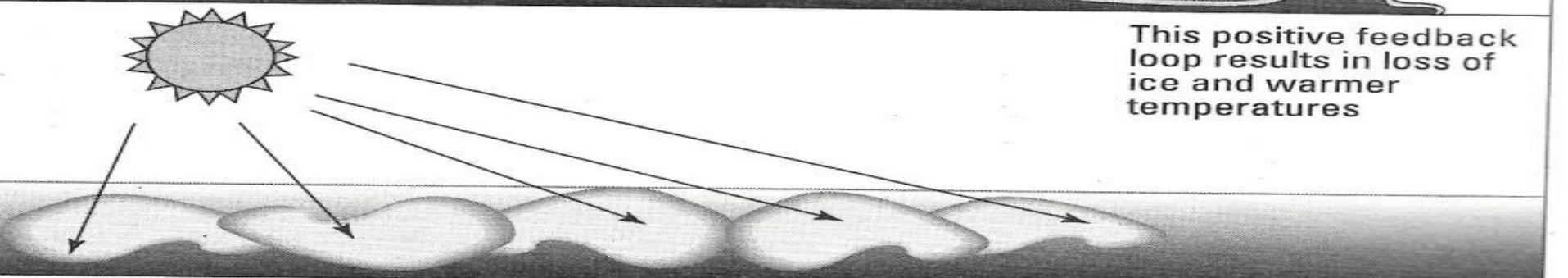
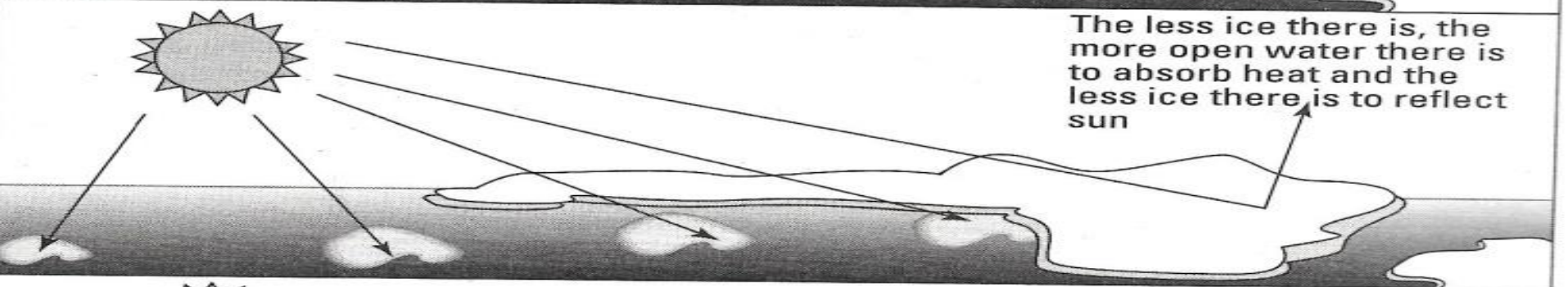
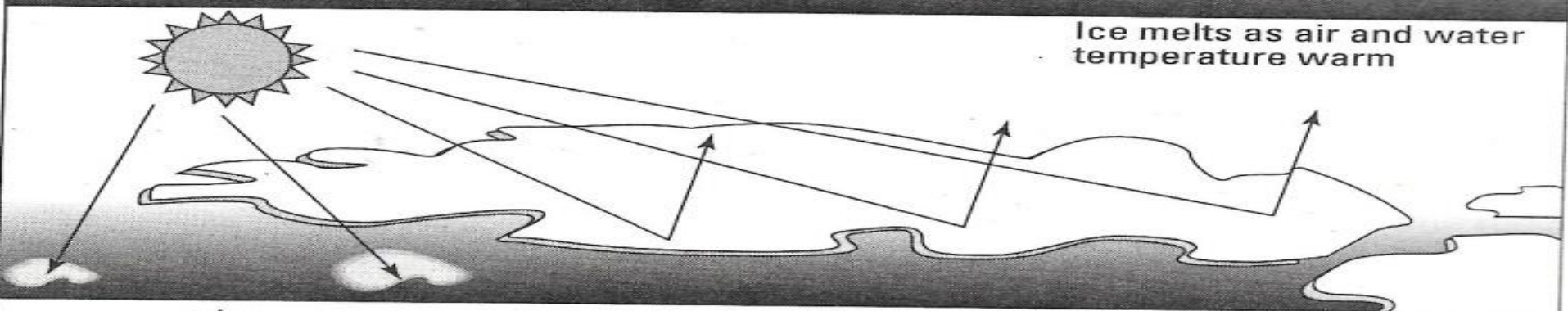
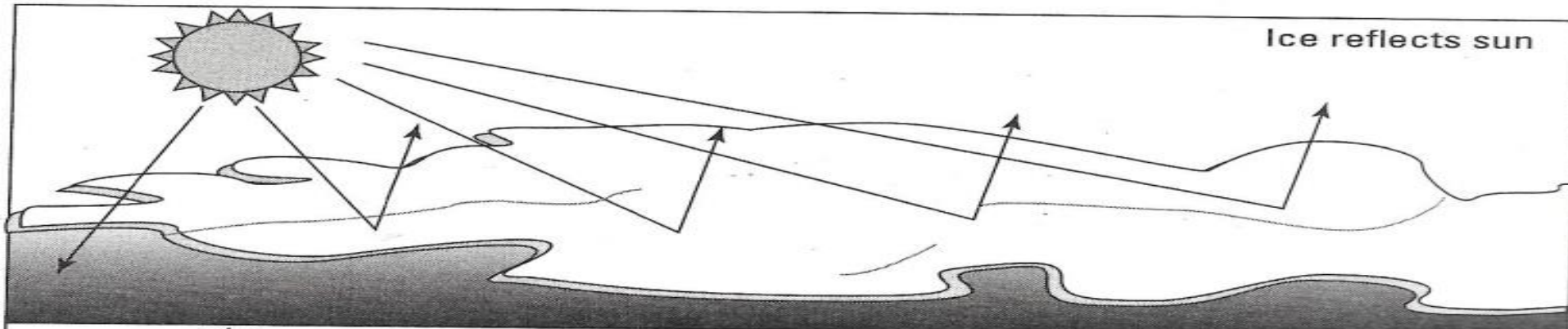
WASHINGTON  
POST  
3/2022

The coldest location on the planet has experienced an episode of warm weather this week unlike any ever observed, with temperatures over the eastern Antarctic ice sheet soaring 50 to 90 degrees above normal. The warmth has smashed records and shocked scientists.

“This event is completely unprecedented and upended our expectations about the Antarctic climate system,” said Jonathan Wille, a researcher studying polar meteorology at Université Grenoble Alpes in France, in an email.

**Ice shelf collapses in  
East Antarctica for first time in  
human history. It's the size of  
New York City.**

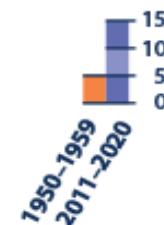
**Seth Borenstein**  
Associated Press  
March 25, 2022





# COSTAL FLOODING

Average number of flood days per year:





# **DEFORESTATION: RESPONSIBLE FOR ONE QUARTER OR MORE OF GREENHOUSE GAS EMISSIONS**

**Rainforests (Tropical regions) good at soaking up CO<sub>2</sub>**  
– they breathe all year round

Older trees hold on to the carbon they absorb (CO<sub>2</sub>), storing it for the duration of their lives:

Thus, when **forests cut down to make way for farmland, highways and cities** – they release their stored carbon

When **cut down or burned**– less CO<sub>2</sub> absorbed out of the atmosphere, and damages the soil, which the soil, when **drier and exposed to the air, releases CO<sub>2</sub>** into the atmosphere...

# DEFORESTATION

\*\*\*

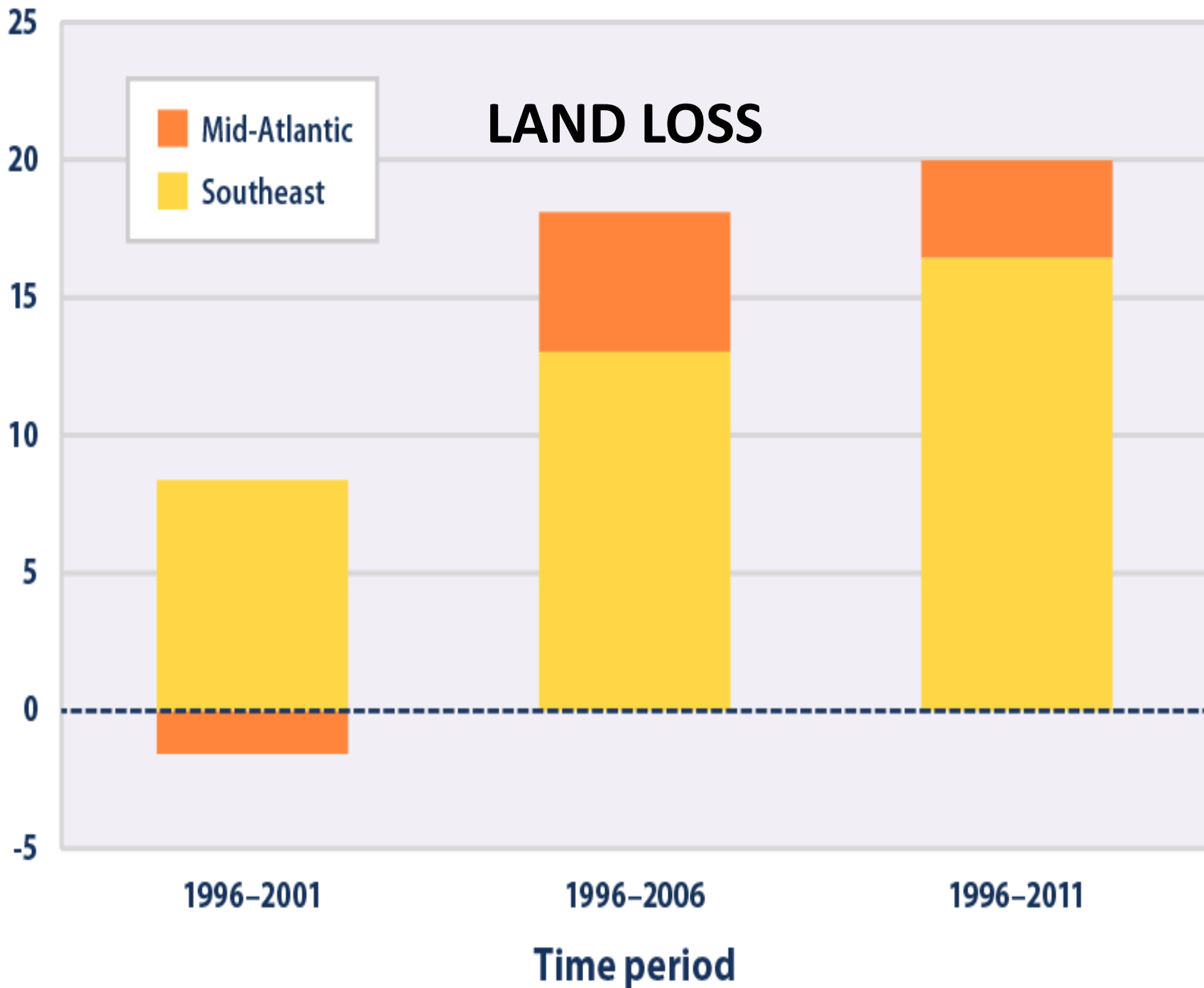




Cumulative area lost since 1996  
(square miles)

## LAND LOSS

- Mid-Atlantic
- Southeast





# DROUGHT IN COLUMBIA





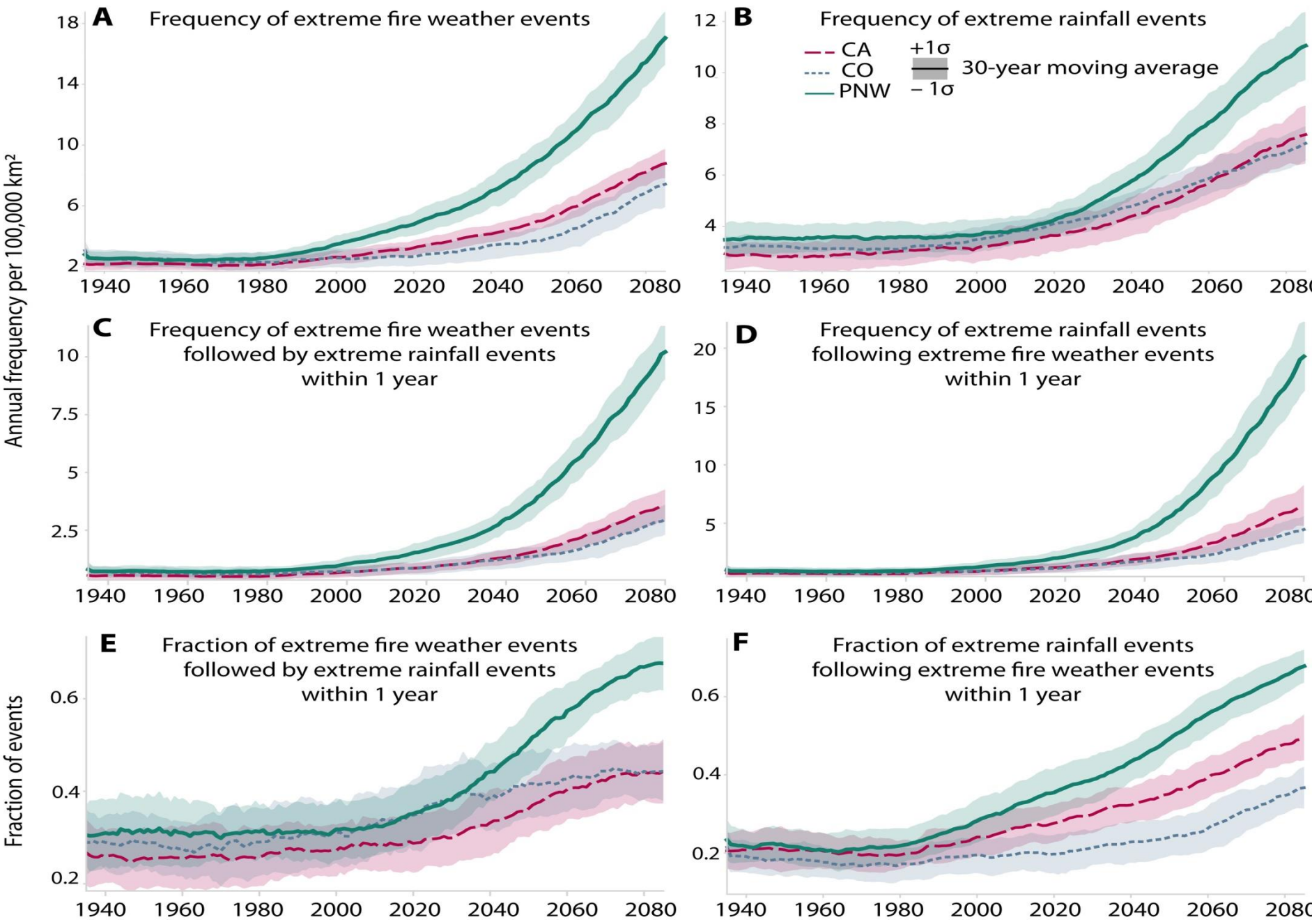
**SOIL DEGRADATION:** RED=VERY; YELLOW=DEGRAD; GREEN=  
STABLE; WHITE = NO VEGETATION; 52% ALREADY DEGRADED



Anthropogenic forcing is found to yield large **twenty-first-century increases in the frequency of wet extremes**, including a more than threefold increase in sub-seasonal events comparable to California's 'Great Flood of 1862'. Smaller but statistically robust increases in dry extremes are also apparent. **As a consequence, a 25% to 100% increase in extreme dry-to-wet precipitation events is projected**, despite only modest changes in mean precipitation. Such hydrological cycle intensification would **seriously challenge California's existing water storage, conveyance and flood control infrastructure**.

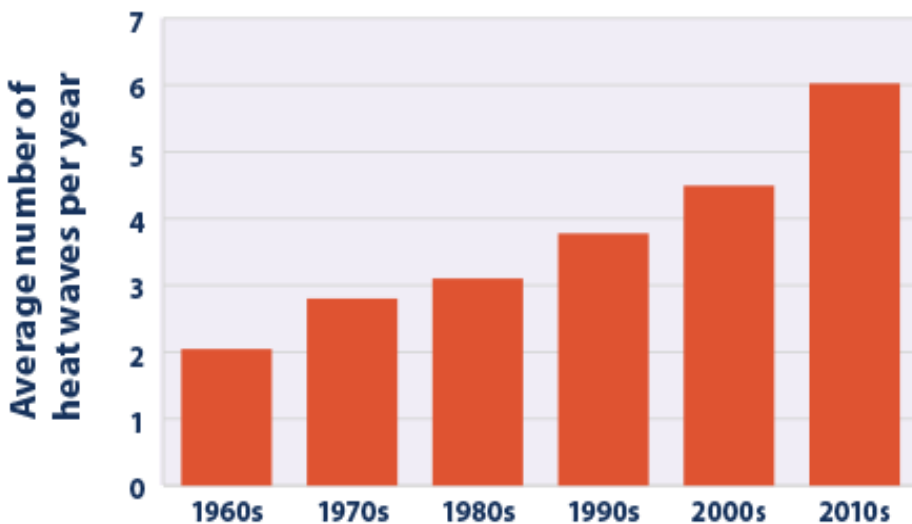
# EXTREME EVENTS: RAIN, FIRE

Annual frequency of extreme events  
30-year moving average

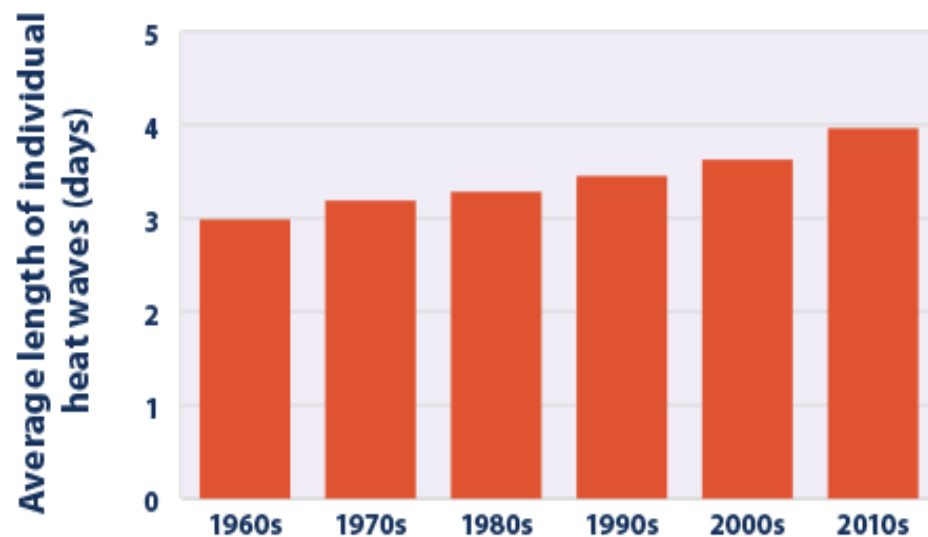




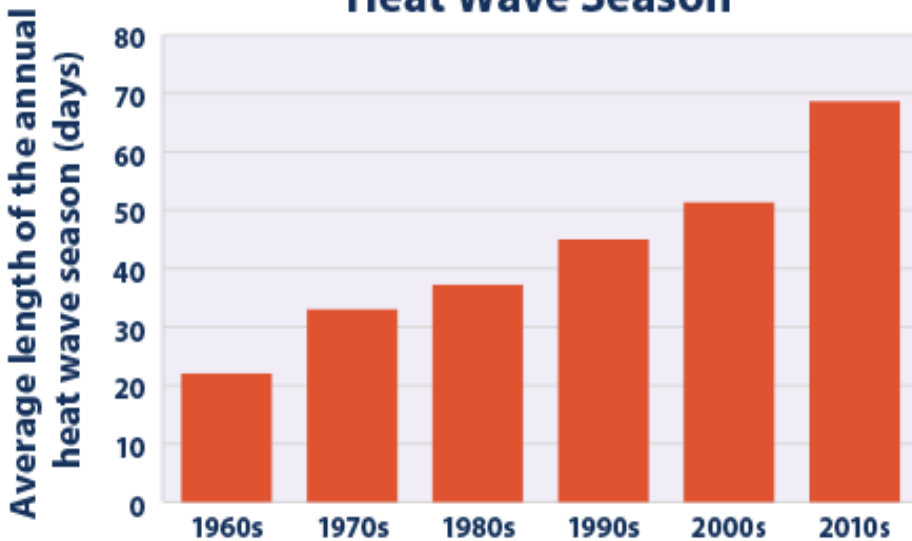
### Heat Wave Frequency



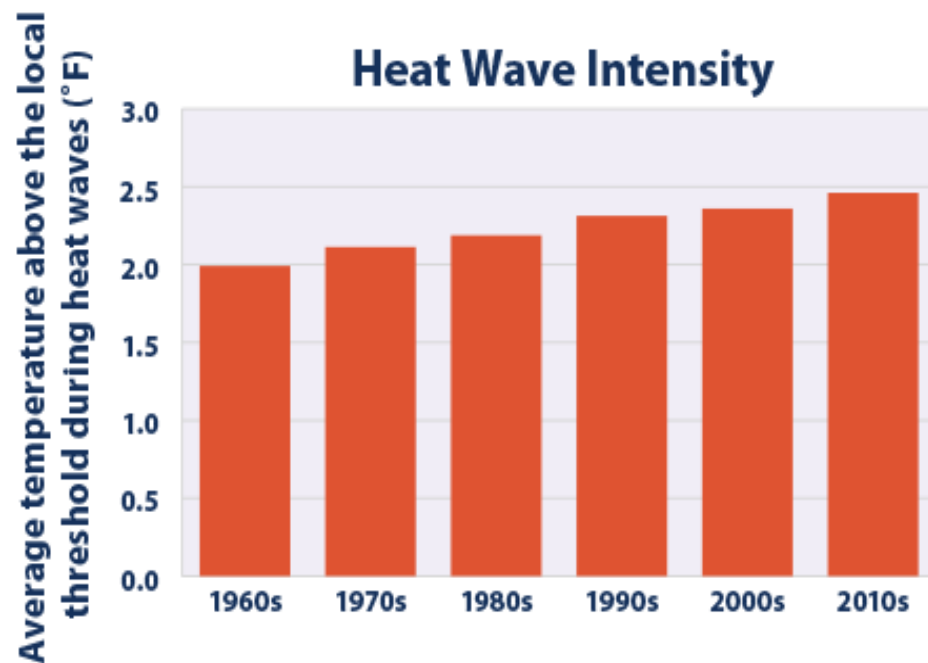
### Heat Wave Duration



### Heat Wave Season



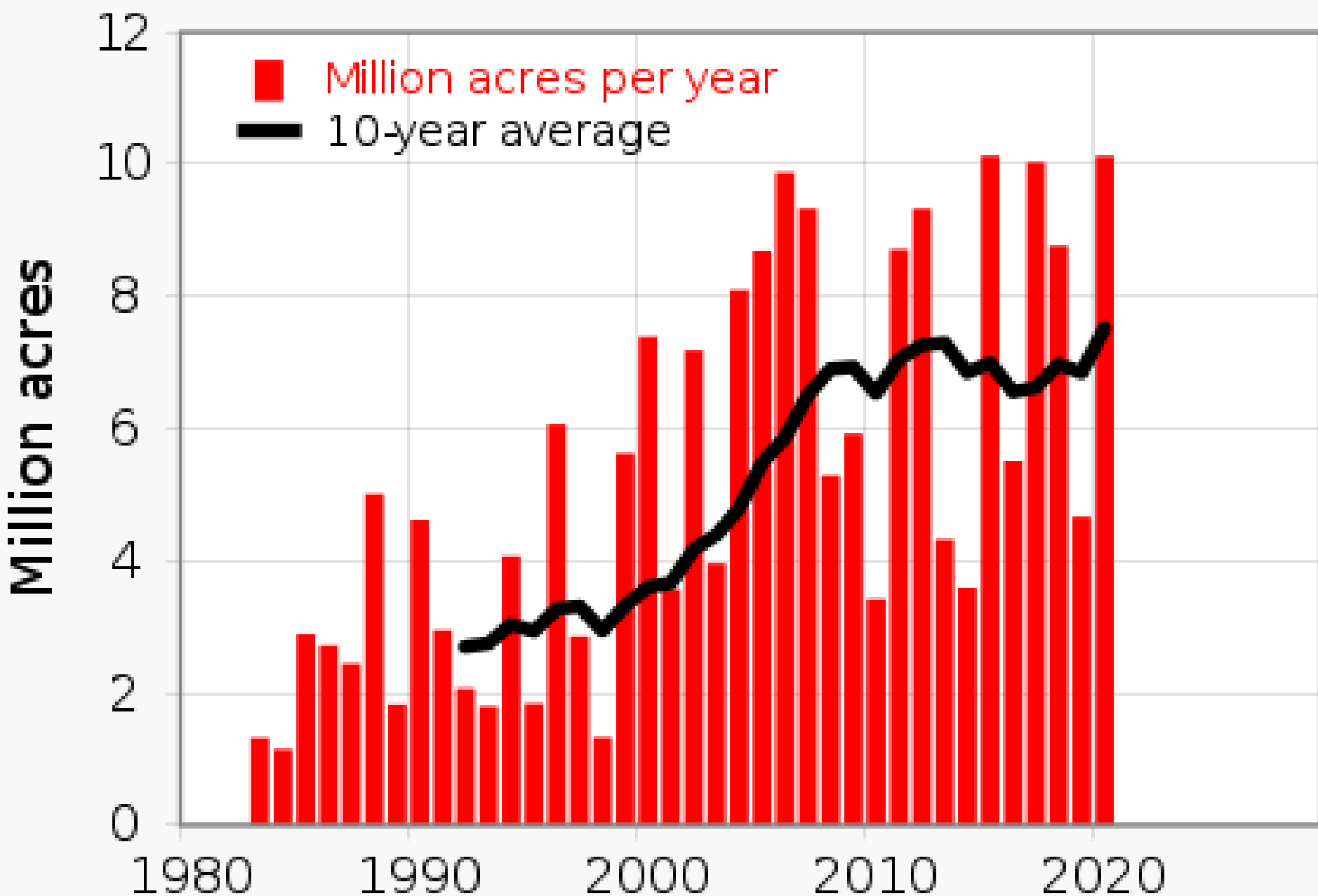
### Heat Wave Intensity



Decade



# Acres burned by wildfire (U.S.)





# **U.S. Fires Four Times Larger, Three Times More Frequent Since 2000**

**New analysis confirms a palpable change in fire dynamics already suspected by many**

**TUESDAY, MARCH 15, 2022**

**Fires have gotten larger, more frequent and more widespread across the United States since 2000,** according to a new CIRES

Earth Lab-led paper. Recent wildfires have stoked concern that climate change is causing more extreme events, and the work published today in [\*Science Advances\*](#) shows that large fires have not only become more common, **they are also spreading into new areas, impacting land that previously did not burn.**

# **GLOBAL HUMAN HEALTH: SMOG IN CHINA**



**Climate change is the  
greatest threat to global  
health in the 21<sup>st</sup> century**

***World Health  
Organization 2015***

**Fossil Fuel contamination of air –  
kills over 9 million people/year  
(more than COVID, Wars or  
Terrorism) (*NYTimes; The New  
Yorker*)**

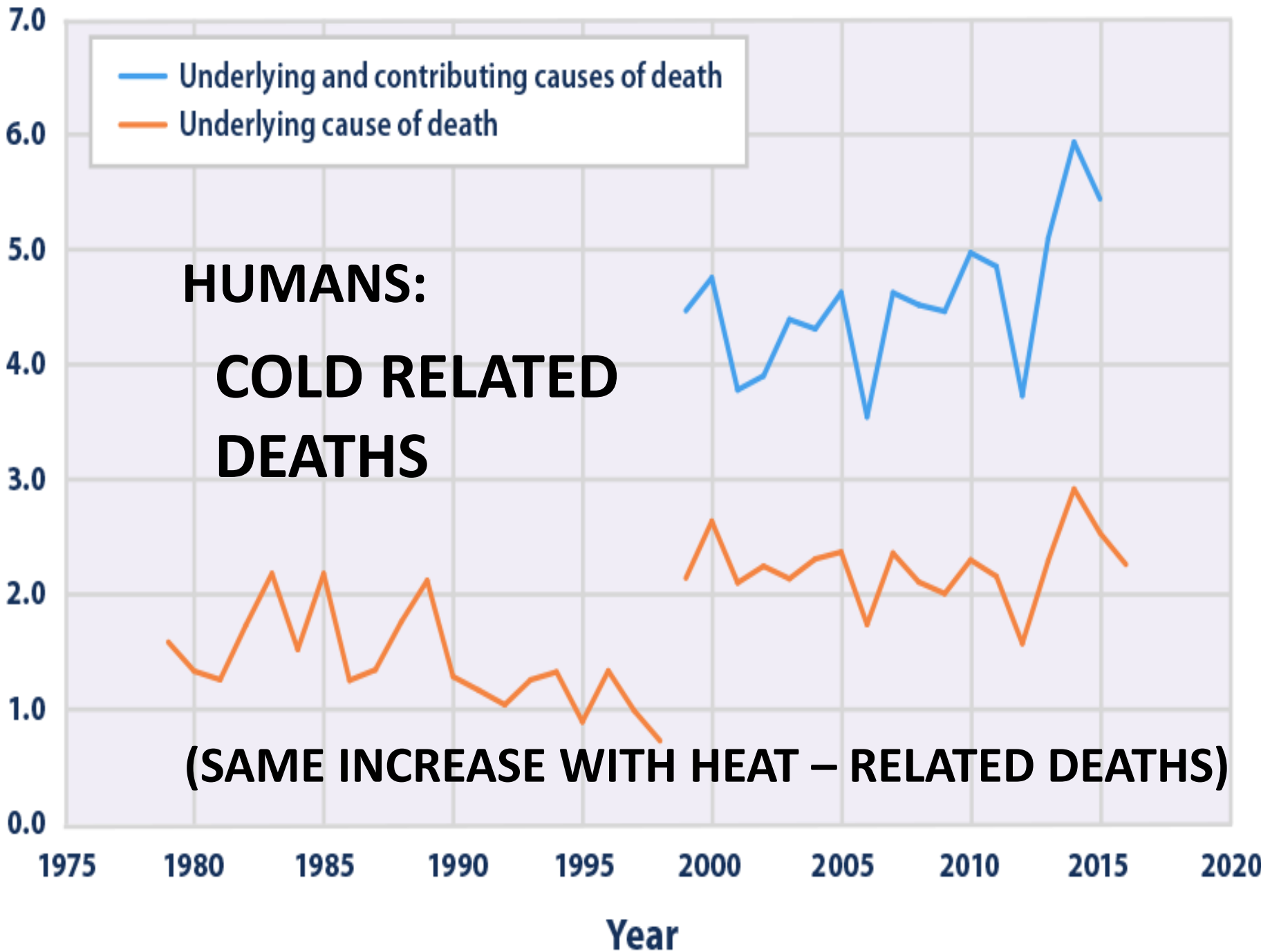


Death rate (per million people)

Underlying and contributing causes of death  
Underlying cause of death

**HUMANS:  
COLD RELATED  
DEATHS**

**(SAME INCREASE WITH HEAT – RELATED DEATHS)**



# •Global Burden of Disease from Major Air Pollution Sources (GBD MAPS): A Global Approach

[Erin McDuffieRandall V MartinHao YinMichael Brauer](#)

**Research Report 210,2021**

Research Report 210, available for downloading below, presents a study conducted by Dr. Erin McDuffie and Dr. Randall Martin of Washington University in St. Louis, Missouri, Dr. Michael Brauer at The University of British Columbia in Canada, and colleagues.

The investigators produced the first comprehensive global estimates of contributions from the most common sources of air pollution to people's exposure to fine particles (PM<sub>2.5</sub>) and to the world's burden of disease from various causes. They estimated source contributions at global, world region, and national scales using updated emissions inventories categorized by sector and fuel, satellite data and air quality modeling, and the most recent relationships between air quality and health.

Among the key findings:

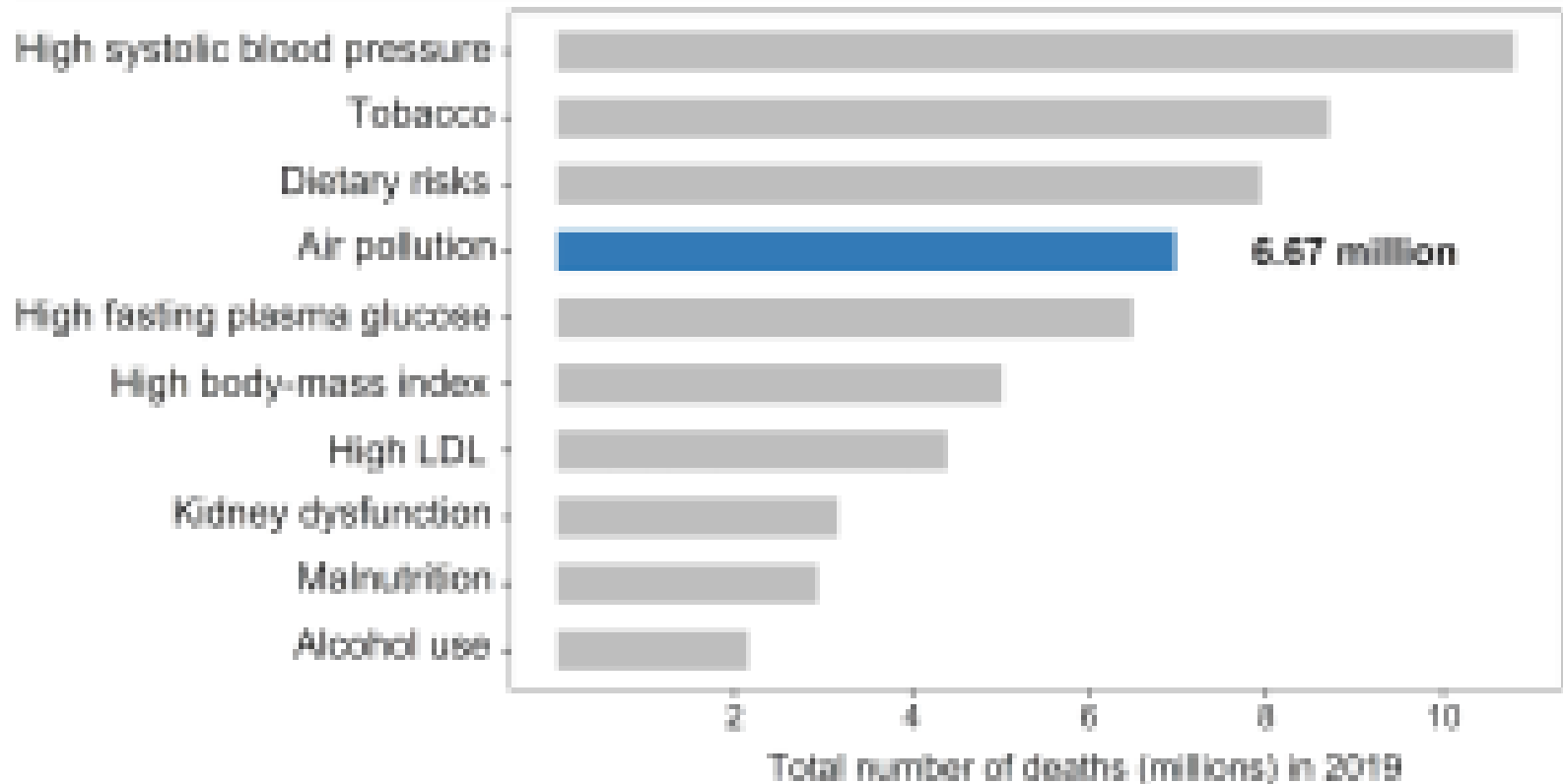
- **Combustion of fossil fuels (coal, oil, and natural gas) contributed to an estimated one million deaths globally (27.3% of all mortality); 800,000 of those deaths were in South Asia or**

**East Asia.**

BOSTON, MASSACHUSETTS, December 15, 2021 – **Fossil fuel combustion, a major source of air pollution, contributed to more than one million deaths globally in 2017**, more than 27% of all deaths from outdoor fine particulate matter (PM2.5), says a new report published today by the **Health Effects Institute (HEI)**. **Coal combustion alone was responsible for half of those deaths, with natural gas and oil combustion accounting for the other half.** The burning of solid biofuels, such as wood for indoor heating and cooking, is another major source of PM2.5, accounting for an additional 740,000 deaths, especially across South Asia and Sub-Saharan Africa

# GLOBAL AIR REPORT 2020 (DATA - 2019)

## TOTAL DEATH FROM ALL CAUSES





# Extreme Weather Has Affected One in Three Americans; 4/6/22; GALLUP POLL BY [JEFFREY M. JONES](#)

Residents of the **South (39%)** and **West (35%)** are significantly more likely than those living in the East (24%) and Midwest (27%) to say they have recently experienced an extreme weather event. Southern residents are most likely to say they were affected by **extreme cold (12%)** or **hurricanes (12%)** and, to a lesser extent, **tornadoes (7%)**.

Among Western residents, **wildfires (13%)**, **extreme heat (8%)** and **drought (7%)** are most commonly reported. **Floods (6%)** and **hurricanes (6%)** are the most frequent responses among Eastern residents, while Midwestern residents most often mention snow or **ice storms (7%)**, **floods (6%)**, or **tornadoes (6%)**.

**THE FIRST LARGE  
MAMMAL FACING  
EXTINCTION FROM  
GLOBAL WARMING--  
20,000 LEFT  
IN THE WORLD**

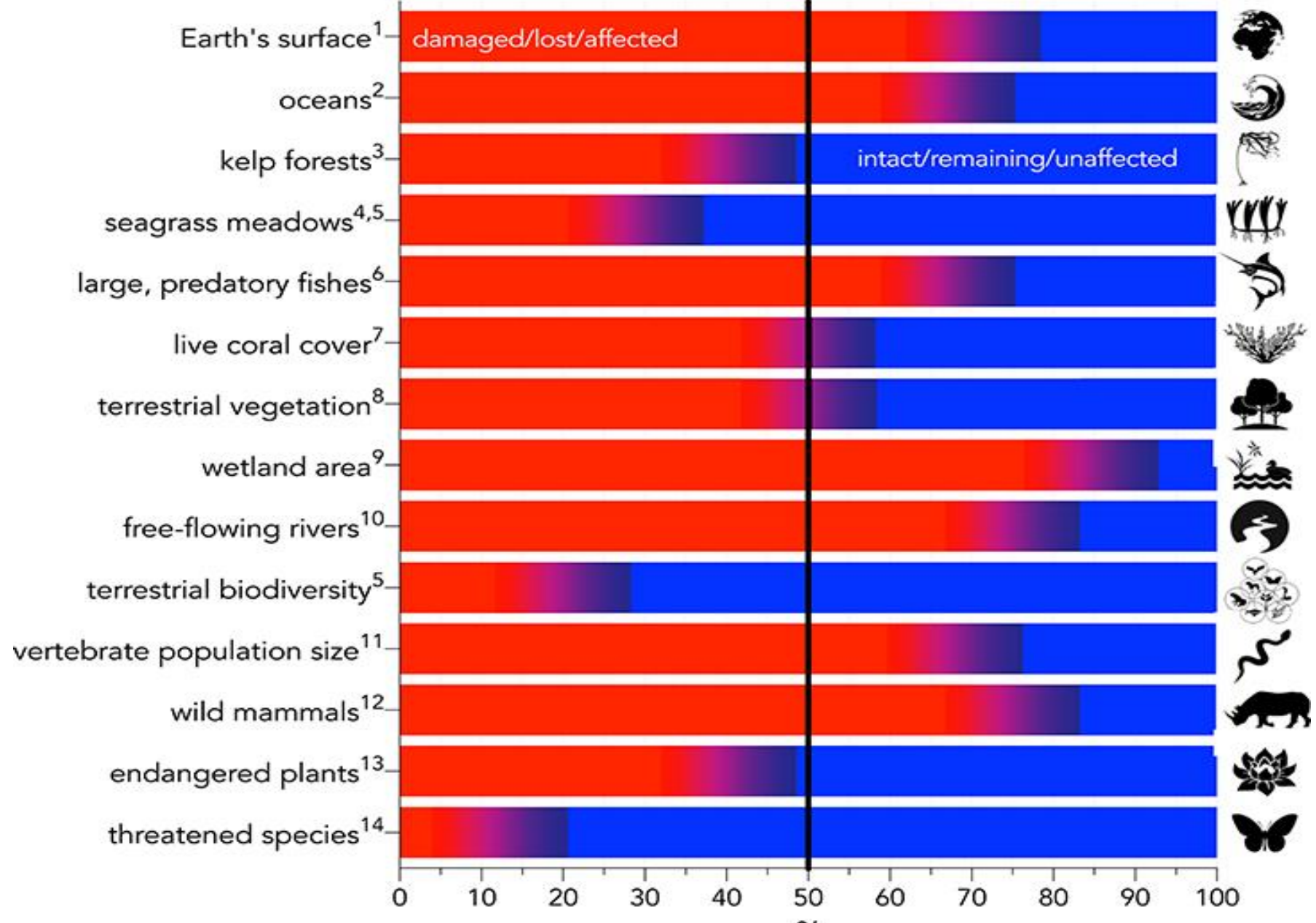


# E.O. WILSON

“Mass extinction – on order of 10,000 X more than naturally occurring background extinction rate”

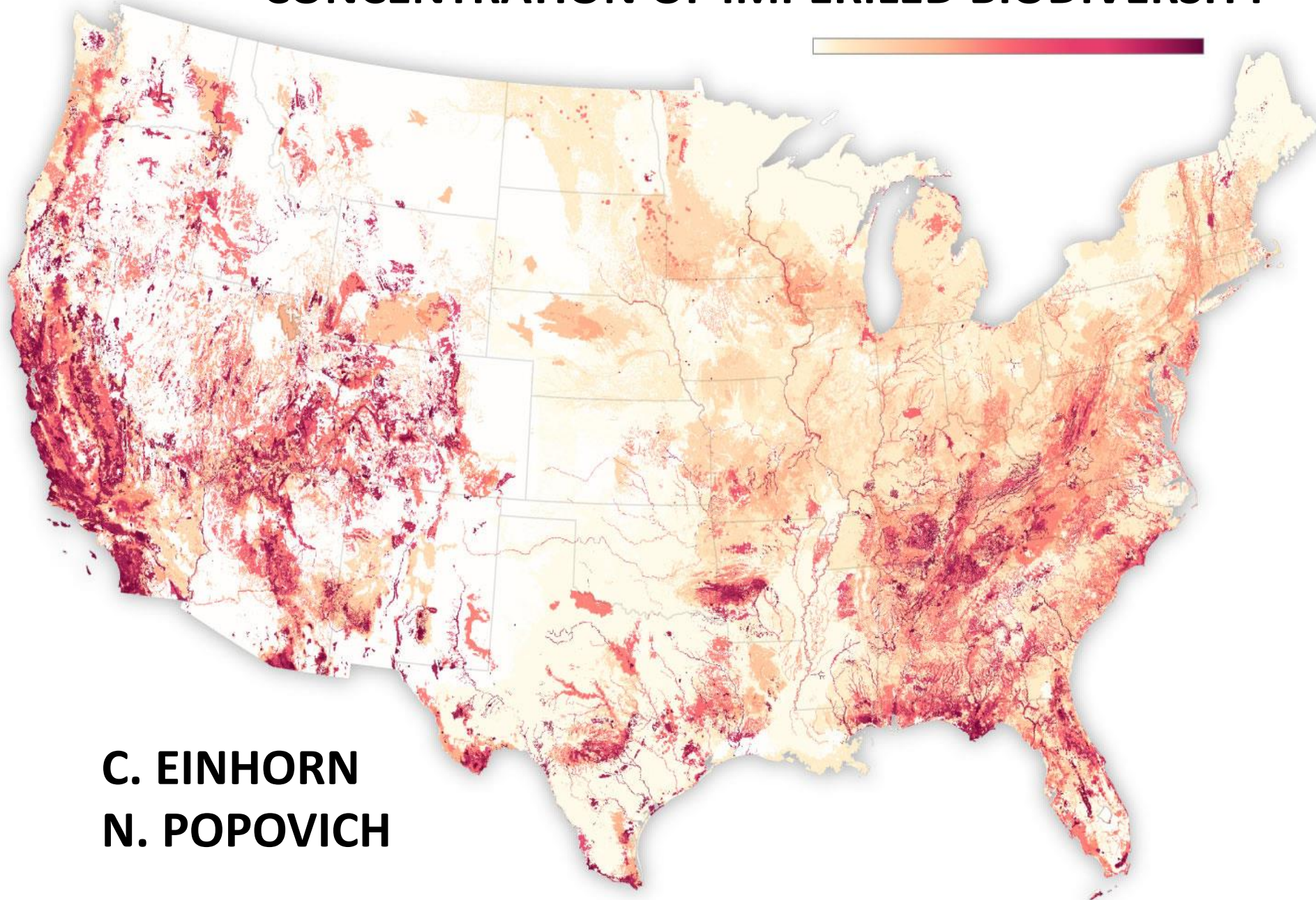


**SUMMARY OF BIODIVERSITY CHANGES : RED – HUMAN DRIVEN; BLUE - TOTAL**



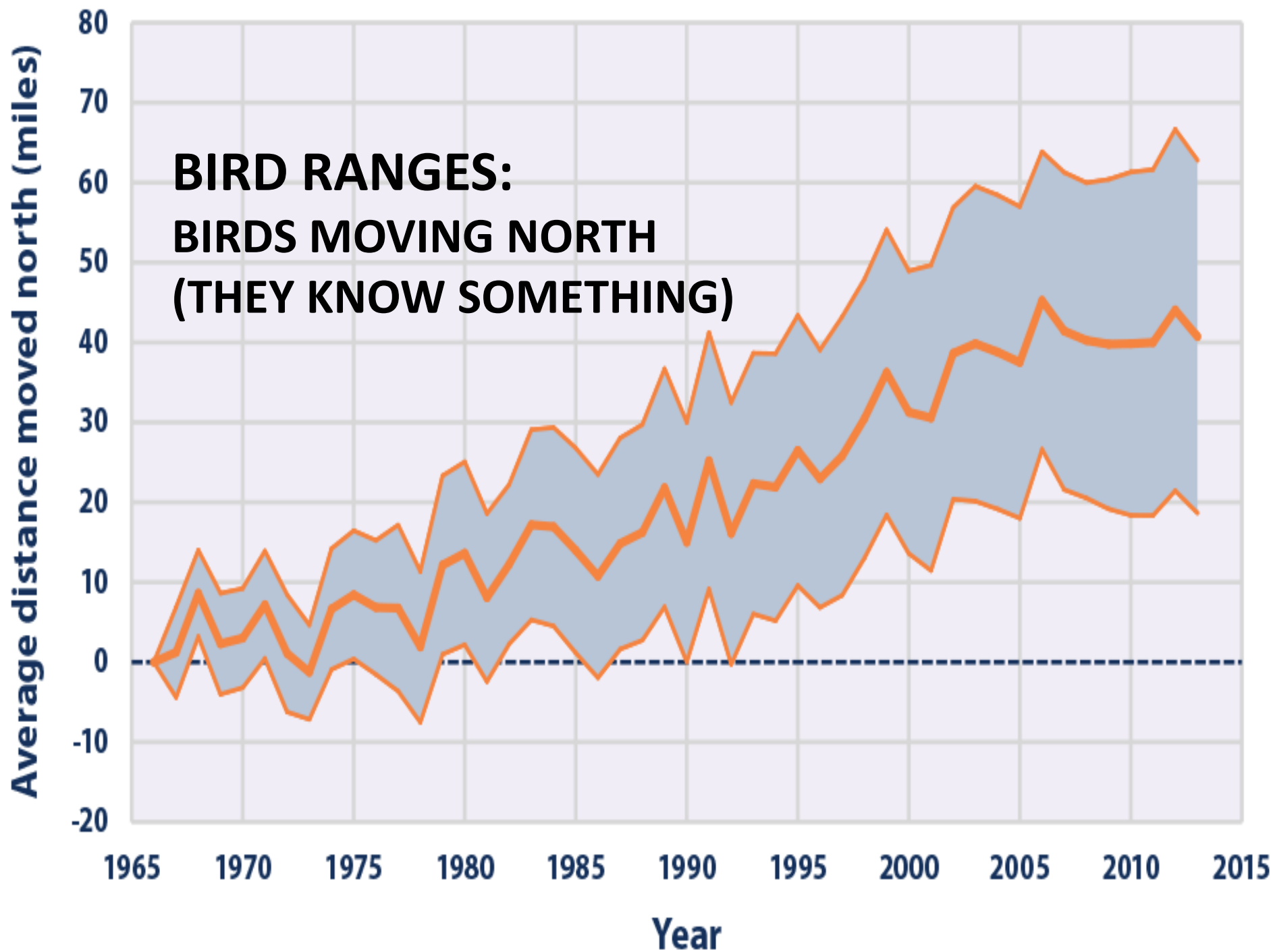


# CONCENTRATION OF IMPERILED BIODIVERSITY

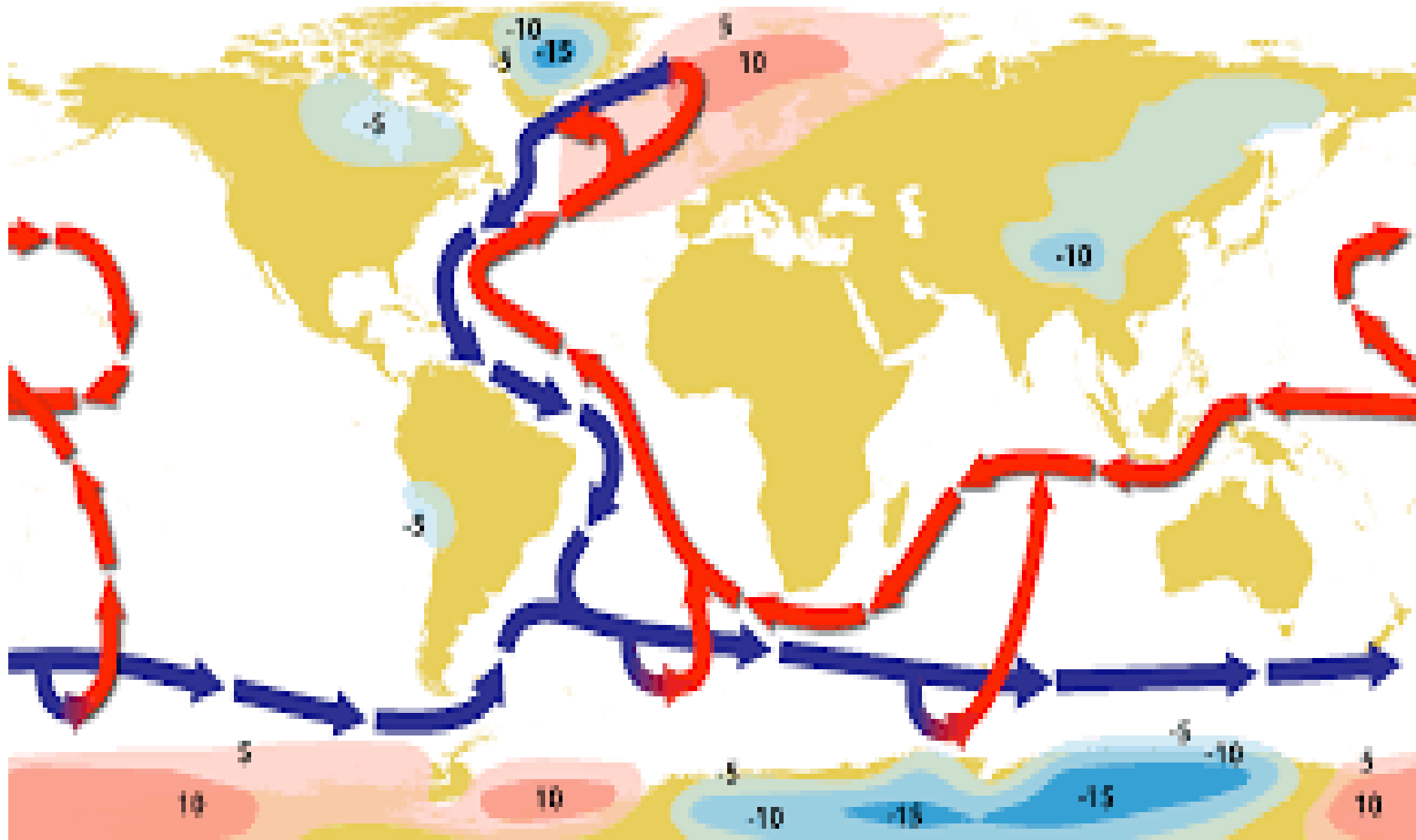


**C. EINHORN**  
**N. POPOVICH**

**BIRD RANGES:  
BIRDS MOVING NORTH  
(THEY KNOW SOMETHING)**



**OCEAN CIRCULATION (ATLANTIC):** IF STOP – THEN EUROPE – ICE AGE;  
NORTH AMERICA – INCREASE SEA LEVEL (NYC; BOSTON)



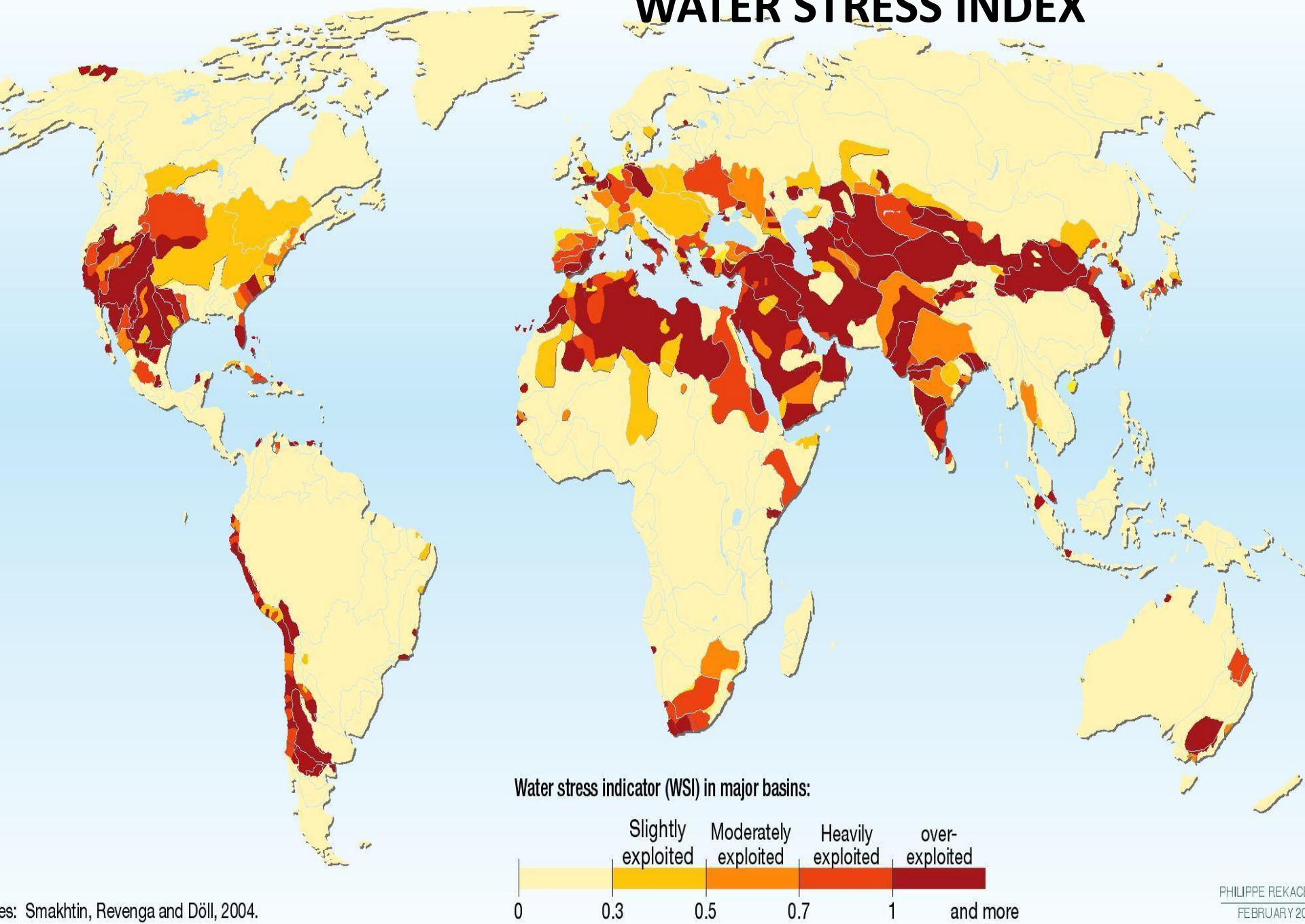


# **WATER STRESS**

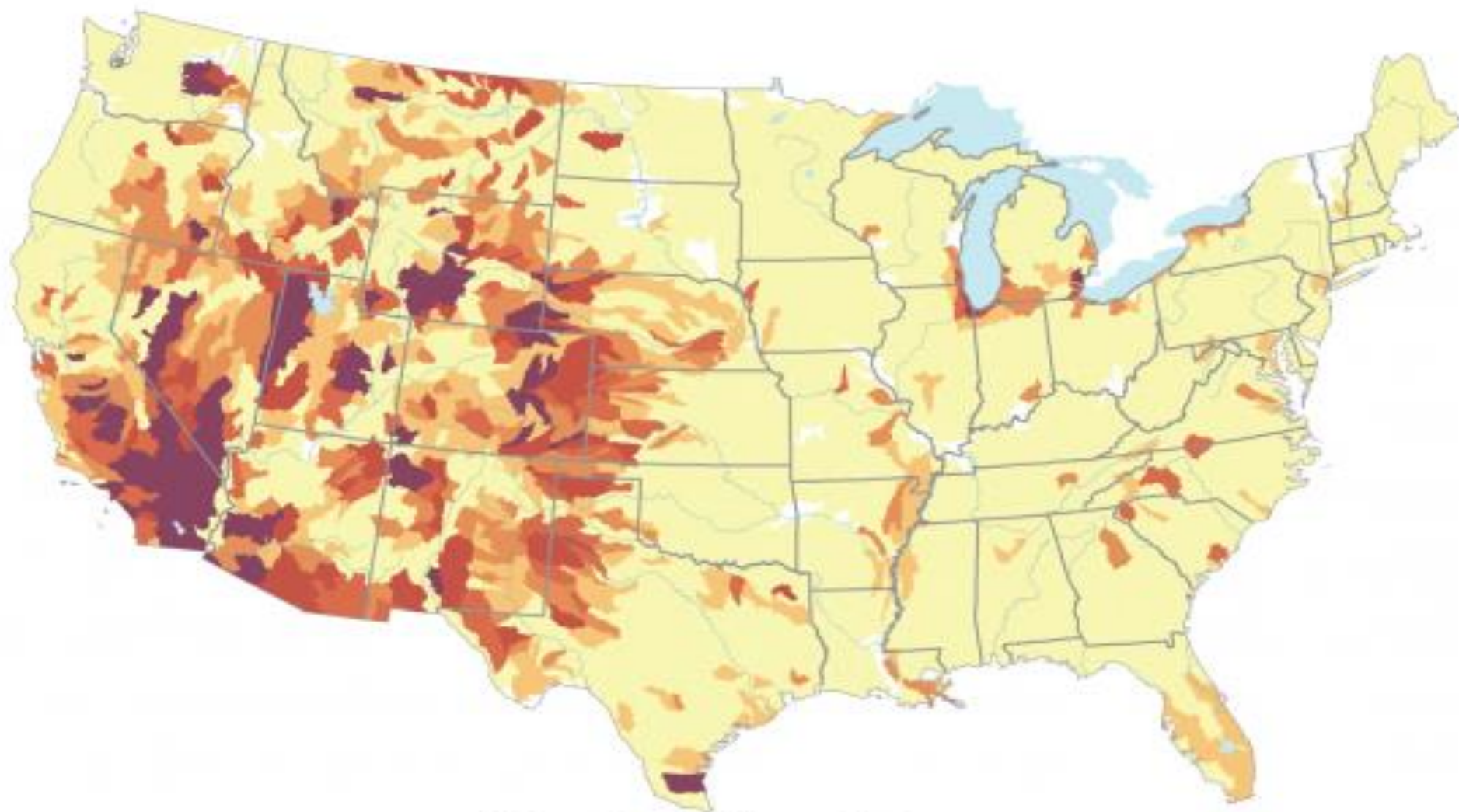




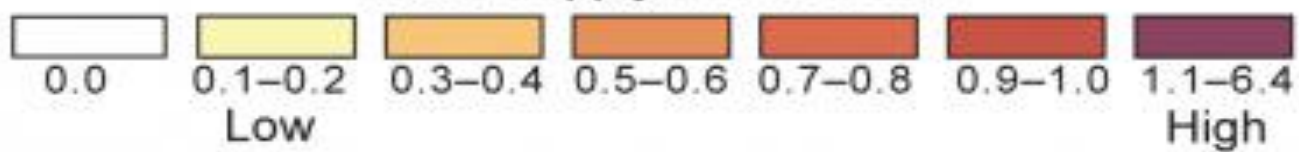
# WATER STRESS INDEX



# Water Stress in the U.S.



Water Supply Stress Index





# **SCIENTIFIC CONSENSUS ON** **CLIMATE CHANGE (GLOBAL WARMING):** **91-97%; MOST RECENTLY OVER 99%**

**Academy of Sciences** (68 National)\e.g, International Council at the  
Academy of Engineering and Technological Sciences); no  
academic center disagrees

**United Nations Intergovernmental Panel on Climate Changes (IPCC)**

**AAAS/US National Regional Council**

The 5 major **Physics and Chemical Societies/Academies**

American **Geophysical Union**

American **Meteorological Society**

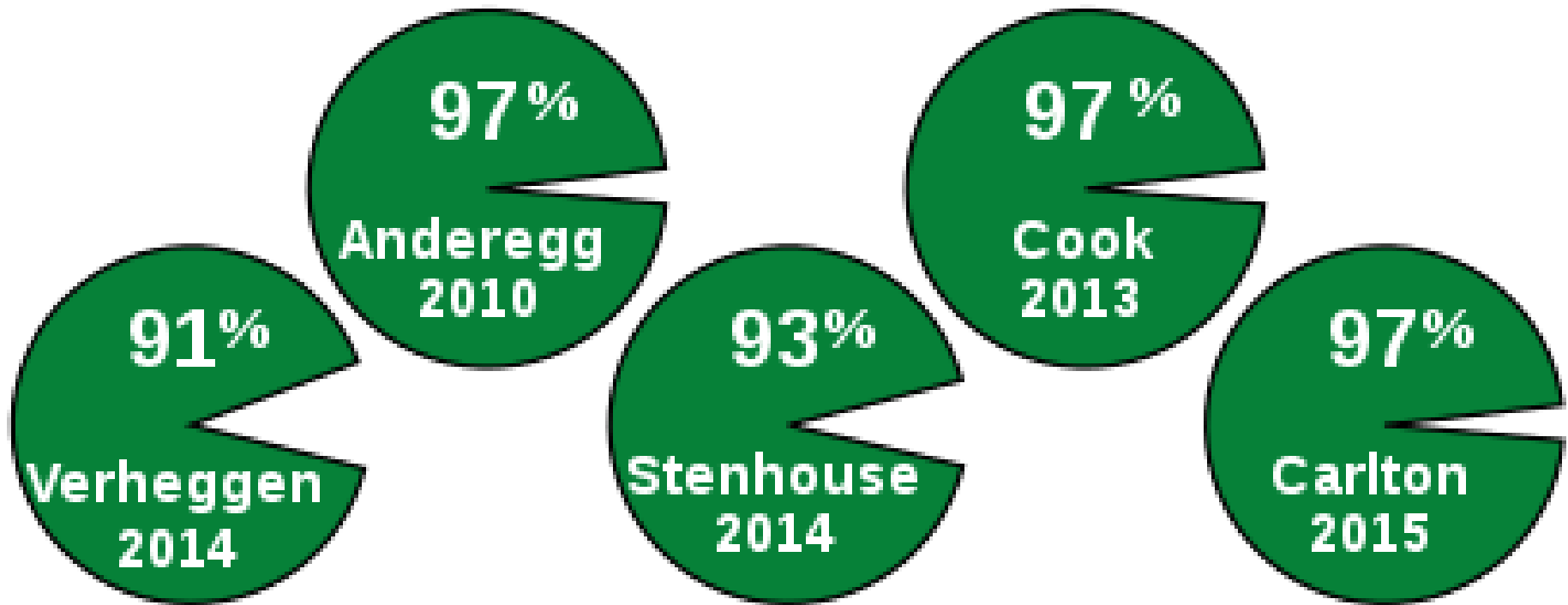
**NASA; EPA; TNTC (too numerous to count)**

Council on Geological Sciences/National Oceanographic and  
Atmospheric Council (**NOAA**)

Columbia University 's Earth Center (and many other **Universities**)

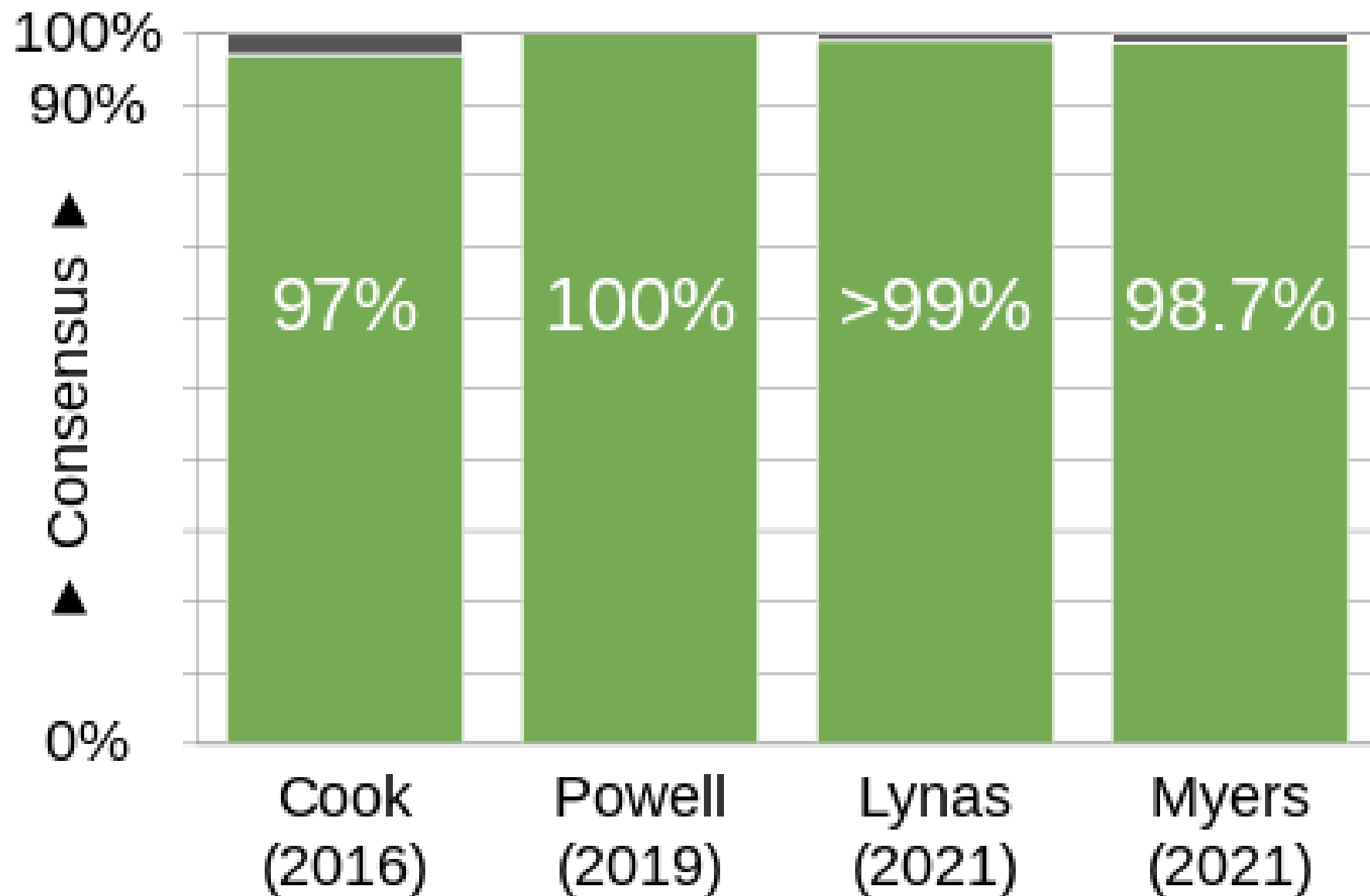


## Academic studies of scientific consensus on human-caused global warming



**META-ANALYSIS: 2010-2015**

## Academic studies of scientific consensus on human-caused global warming



**IPCC SIXTH REPORT: Climate Change  
2022:Impacts, Adaptation and  
Vulnerability; approved by  
governments of 195 countries  
(Summary: available LifeQuest)**

**(over 780 expert authors in the field of climate  
change from 67 countries; over 78,000  
citations/references; over 180,000 review  
comments (Feb 27, 2022; 3675 pages; 18 chapters)**

**SPM.B.1 Human-induced climate change, including more frequent and intense extreme events, has caused widespread adverse impacts and related losses and damages to nature and people, beyond natural climate**

**variability.** Some development and adaptation efforts have reduced vulnerability. Across sectors and regions the most vulnerable people and systems are observed to be disproportionately affected. The rise in weather and climate extremes has led to some irreversible impacts as natural and human systems are pushed beyond their ability to adapt.



**SPM.B.1.3 Climate change including increases in frequency and intensity of extremes have reduced food and water security,** hindering efforts to meet Sustainable Development Goals (high confidence). Although overall agricultural productivity has increased, climate change has slowed this growth over the past 50 years globally (medium confidence), related negative impacts were mainly in mid- and low latitude regions but positive impacts occurred in some high latitude regions (high confidence). Ocean warming and ocean acidification have adversely affected food production from shellfish aquaculture and fisheries in some oceanic regions (high confidence). Increasing weather and climate extreme events have exposed millions of people to acute food insecurity and reduced water security

**SPM.B.1.4 Climate change has adversely affected physical health of people globally (very high confidence) and mental health of people in the assessed regions (very high confidence).** Climate change impacts on health are mediated through natural and human systems, including economic and social conditions and disruptions (high confidence). In all regions extreme heat events have resulted in human mortality and morbidity (very high confidence). The occurrence of climate-related food-borne and water-borne diseases has increased (very high confidence). The incidence of vector-borne diseases has increased from range expansion and/or increased reproduction of disease vectors (high confidence). Animal and human diseases, including zoonoses, are emerging in new areas (high confidence). Water and food-borne disease risks have increased regionally

**UN panel's grim climate change report: 'Parts of the planet will become uninhabitable'**

**Dinah Voyles PulverDoyle Rice**

**USA TODAY Feb 28, 2022**

# Has global warming caused you or climate researchers you know to reconsider major life decisions such as:

Decisions about where to live

41%

A horizontal bar chart with an orange segment representing 41% and a light blue segment representing the remaining 59%.

Decisions to have children

17%

A horizontal bar chart with an orange segment representing 17% and a light blue segment representing the remaining 83%.

Lifestyle choices (including diet, transportation and travel)†

21%

A horizontal bar chart with an orange segment representing 21% and a light blue segment representing the remaining 79%.

†Write-in answers.



# Ukraine invasion: rapid overview of environmental issues

[February 25, 2022](#)

Conflict and Environment Observatory

48 hours in and we are already seeing a pattern of environmental harm in Ukrai

(Armed conflict previously shown to also be hazardous to environment)

# MITIGATION OF CLIMATE CHANGE/GLOBAL WARMING (6<sup>TH</sup> IPCC 2022; THIRD REPORT)

- 1.) **Decrease in CO<sub>2</sub> emissions**
- 2.) **Enhance CO<sub>2</sub> Sinks-** absorb CO<sub>2</sub> from atmosphere by land/forest sinks, Carbon capture, etc
- 3.) **Clean, Renewable Energy** (solar; wind; hydroelectric; electric cars; geothermal energy; smart buildings; hydrogen-extraction; maybe even nuclear fusion in the future)

e.g., *Kyoto Protocol* (2012); *Paris Agreement* (2015-not above 2 degrees C by 2030; 0 net carbon emissions by mid-century); etc.

# Climate Change 2022: Mitigation of Climate Change

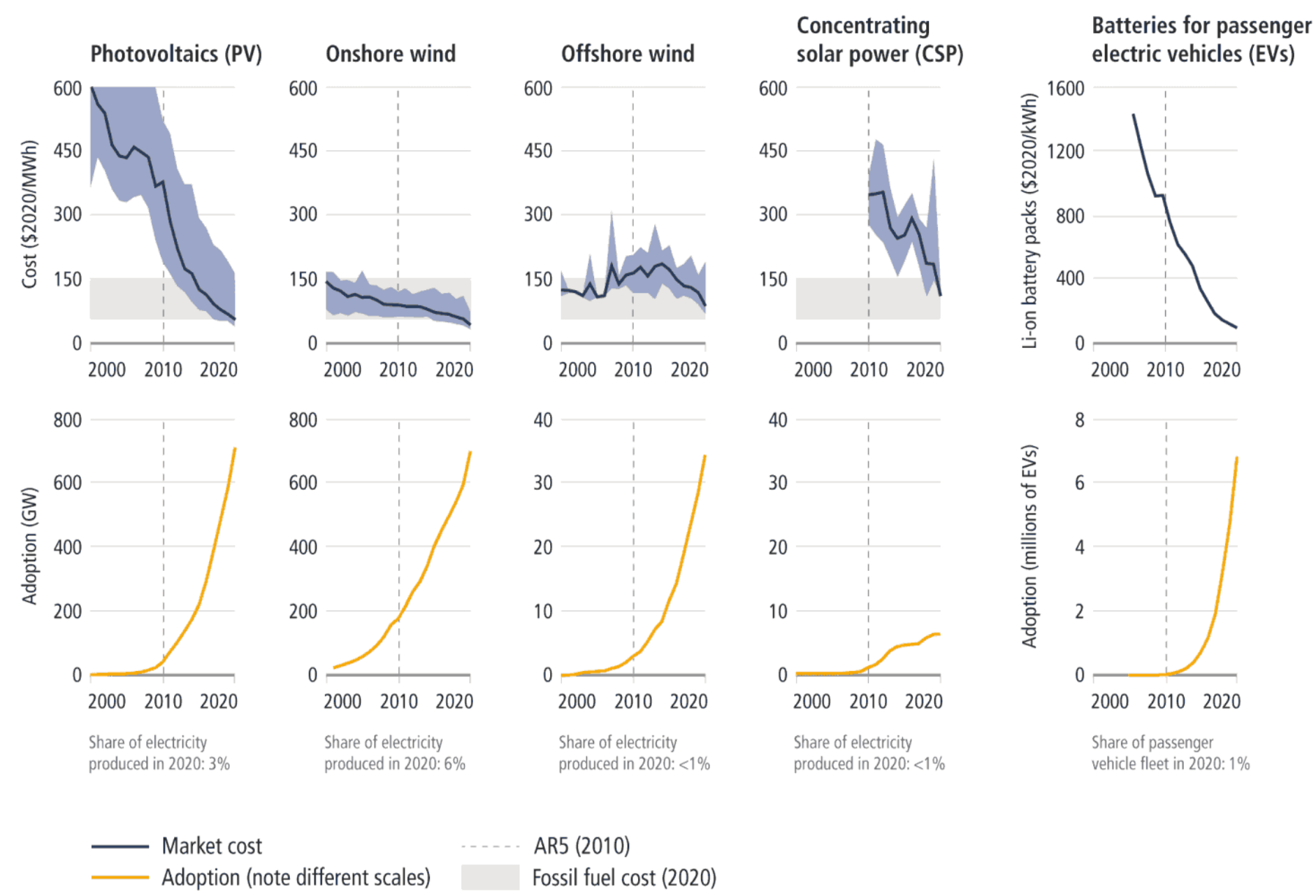
The Working Group III report provides an updated global assessment of climate change mitigation progress and pledges, and examines the sources of global emissions. It explains developments in emission reduction and mitigation efforts, assessing the impact of national climate pledges in relation to long-term emissions goals. **64 pages; 80+ authors (available at Lifequest)**

Summary for Policymakers (SPM) provides a high-level summary of the key findings of the Working Group III Report and is approved by the IPCC member governments line by line.

The Technical Summary (TS) provides extended summary of key findings and serves as a link between the comprehensive assessment of the Working Group III Report and the concise SPM.

The 17 Chapters of the Working Group III Report assess the mitigation of climate change, examine the sources of global emissions and explain developments in emission reduction and mitigation efforts.

The unit costs of some forms of renewable energy and of batteries for passenger EVs have fallen, and their use continues to rise.





# CLIMATE DENIAL

- 1.) **Misinformation/Disinformation**
- 2.) **Conservative groups: Industry, Politics,** (compare with Tobacco companies in the past)
- 3.) **Contrarian scientists** (about 1% nowadays) (cherry-pick, not in field of mainline earth science; even if have a PhD from Harvard; ? paid by coal, oil or gas companies)

Cook, J., Supran, G., Lewandowsky, S.,  
Oreskes, N., & Maibach, E., (2019).

America Misled: *How the fossil fuel  
industry deliberately misled Americans  
about climate change.* Fairfax, VA:  
George Mason University Center for  
Climate Change Communication.

Harvard; Univ. Bristol; Available at  
<https://www.climatechangecommunication.org/america-misled>

cf: cigarette industry & heart/lung  
medical problems

**IT'S THE NUANCES:  
THINK LONG-TERM-  
NOT JUST YOUR  
NEXT ELECTION**



Is global warming occurring?

Democrats:

Yes

Don't know

No

Republicans:

Yes

Don't know

No

Are oil/gas companies responsible?

Democrats:

Completely/mostly

Some-what

No

Republicans:

Completely/mostly

Somewhat

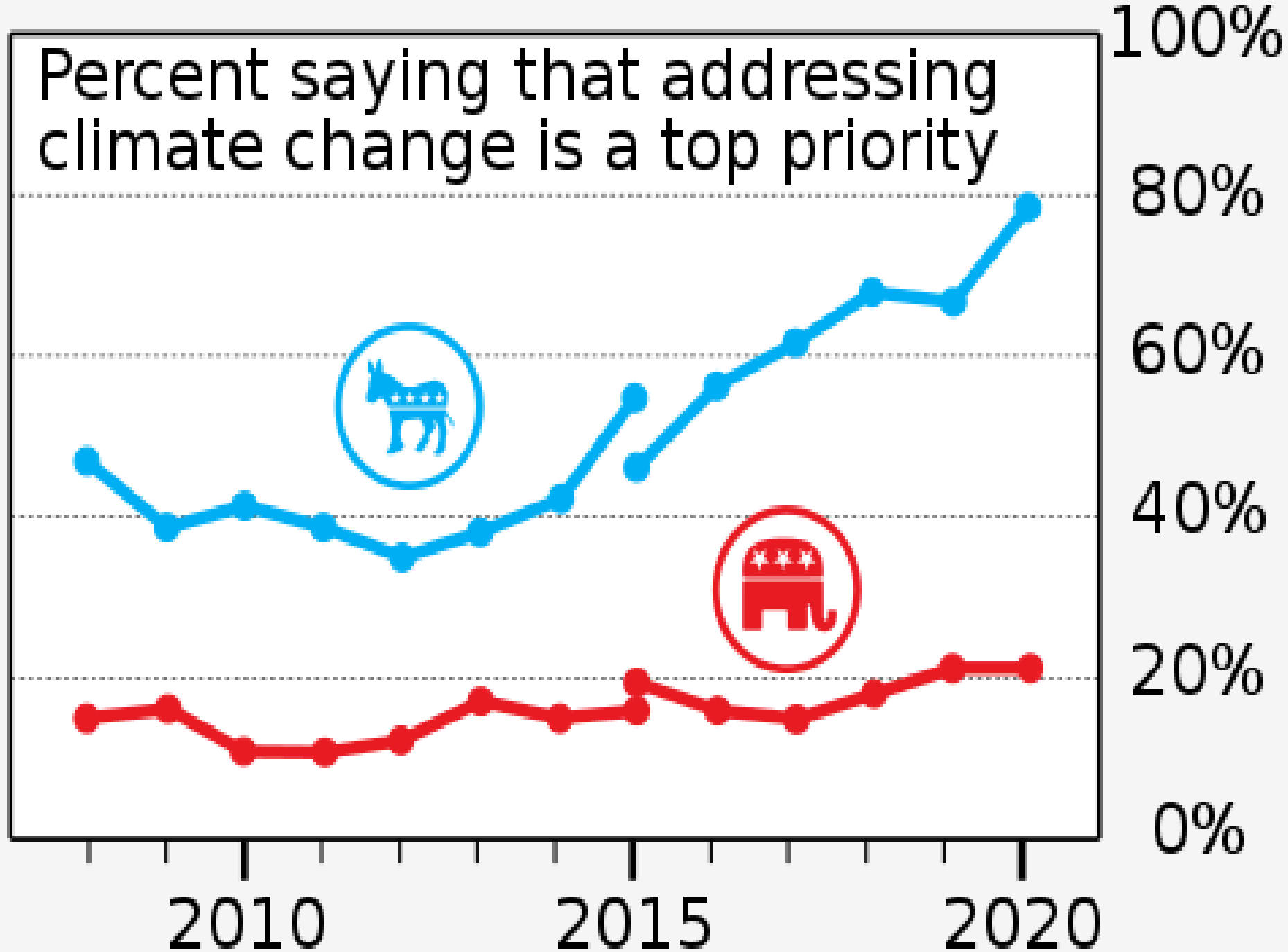
No

Climate change doesn't exist

0% 10 20 30 40 50 60 70 80 90 100



# Percent saying that addressing climate change is a top priority





**Donald J. Trump** ✓

@realDonaldTrump



Following

# 2014

Snowing in Texas and Louisiana, record setting freezing temperatures throughout the country and beyond. Global warming is an expensive hoax!

RETWEETS

428

LIKES

358



1:27 AM - 29 Jan 2014



# **IN CALIFORNIA DURING 2020 WILDFIRES RE: GLOBAL WARMING**

“It’ll start getting cooler, you just  
watch...

I don’t think science knows, actually”

US President Trump, Sept. 13, **2020**

**Trump** claimed we were at the “single most dangerous time for our country in history” thanks to the threat of nuclear weapons, somewhat downplaying decades in which the exact same threat lingered.

“And yet you have people like John Kerry **worrying about the climate! The climate!**” Trump continued. “Oh, I heard that the other day. Here we are, [Russian President Vladimir Putin is] threatening us [and] he’s **worried about the ocean will rise one-hundredth of one percent over the next 300 f---n’ years.**” **3/26/2022;**  
Commerce, Georgia



# **CLIMATE DENIERS: 139 ELECTED OFFICIALS (SENATE; HOUSE) IN 117<sup>TH</sup> CONGRESS (2021): *American Progress***

Still deny scientific consensus of human-caused climate science...(mostly but not all Republicans)

These 139 received over \$61 million in contributions from the coal, oil and gas industries....not including the Democrat Senator from West Virginia (Joe Manchin)

A dark blue, short-sleeved t-shirt is displayed against a white background. The t-shirt has a crew neck and a straight hem. Centered on the chest is a four-line text graphic in a bold, white, sans-serif font. The text reads: "SCIENCE", "IS NOT", "A LIBERAL", and "CONSPIRACY".

**SCIENCE  
IS NOT  
A LIBERAL  
CONSPIRACY**

# **“THE CONTRARIAN SCIENTIST”:**

## **AGAINST THE MAINSTREAM SCIENCE**

- 1.) **Not an expert in that specific field of study** (even if have PhD from Harvard!); not trained in science of climatology; credibility needed for analysis of sophisticated climatology
- 2.) **Publications must be in peer-review scholarly journals, with expert critical editorial review**; materials & methods, body of work – from community of scholars; not announcement by press release
- 3.) **Always can “cherry-pick”** (find an, often older, outlier); for every contrarian can find thousands of experts in the field; not bending science to reach particular conclusions=not political or financial stance; balanced views, verify , all evidence
- 4.) **Often funded (receive \$\$) from groups** like the API, mining industry, or money from lectures, books, need to clarify relationships with companies, etc)
- 5.) **Wanting to be a Galileo-type** (a lot more non-Galileo-types, than Galileo); anecdotes – not systemic analysis-nuances
- 6.) Maybe sincere-but remember -**The easiest person to fool in the world is yourself; need a community of interacting scholars**
- 7.) **Confirmation bias** – only finding studies that support your stand
- 8.) **Wants to be Known and/or remembered** (because they think they might be shown to be right) (unlikely)

# WHY NOT CONVINCED DESPITE ALL THE SCIENTIFIC EVIDENCE/DENIALISM!!

- 1.) **Politics**: conservative: following party line; mental model
- 2.) **Lack of Trust** of Climate Science/Scientists: Scientists more career oriented or don't understand; no knowledge of science; scientists muddled their explanations; economy
- 3.) **Cherry-pick**: Can always find a scientist who doesn't believe; not consensus by science
- 4.) **Media**: either not covered or Listen to Negative Facts ('if it bleeds it leads'); need to go to original/primary source, article (M&M)
- 5.) **Long-Term**: **less a priority than acute things like jobs, \$\$,** economics; only think of one thing at a time – can't multitask; put bad news behind them (cf. flu and lack of vaccines)
- 6.) **Change is Hard**: people don't want to change; put behind them
- 7.) **Complex: Mixing** of Weather, Climate Change and Global Warming; **Climate Change is Complex; there are nuances**





**Man did not weave the web of  
life,**

**he is merely a strand in it**

**Whatever he does to the web  
he does to himself.....**

**All things are bound together  
all things connect**

**Chief Seattle**

# GEORGE WASHINGTON IN HIS FAREWELL SPEECH TO THE AMERICAN PUBLIC

**WARNED AGAINST:**

“ungenerously throwing upon  
posterity the burden which we  
ourselves ought to bear”





# HOW TO LEARN ABOUT CLIMATE CHANGE/GLOBAL WARMING

- 1.) **Do not just read an unconfirmed source on the Internet;** go to bonafide sources (e.g., *AP*, *Reuters*, *IPCC*, *NOAA*, *NASA*, *WSJ*, *NYTimes*, CBS, NBC, ABC, PBS, NPR etc); not just a headline or hook
- 2.) **Learn the Strengths of Science** and How Science is the best way of knowing about our Natural world (communication of many expert-experienced scholars in the field, who are often conservative but rigorous, transparent, with verifiable data, and know they are being watched by their peers; spent much time studying and analyzing the topic; math, statistics; measurements; various methods); not cherry-picking
- 3.) **Go to Original Sources (learning how to read the scientific literature):** Intro, M&M, Results, Discussion, References, Tables, Graphs, etc
- 4.) **Seek Confirmation** from Multiple bonafide science sources; from multiple independent perspectives

# **IF YOU DON'T BELIEVE WHAT SCIENCE TELLS YOU (or like what science tells you)...then...**

- Stop your **pills, medications**, vaccines
- Stop seeing, listening to your **physician(s)**
- Stop **trying to live a longer**, better life
- Stop using your iPhone, **Communications**
- Stop using your TV, Other **Recreational devices**
- Stop using your **Transportation** devices
- Stop using your Bridges, Highways, Buildings
- Stop using your safe **Food and Drink**
- Stop using your **House, apartment, utilities**
- Stop using your knowledge (**DON'T DO THESE!**)



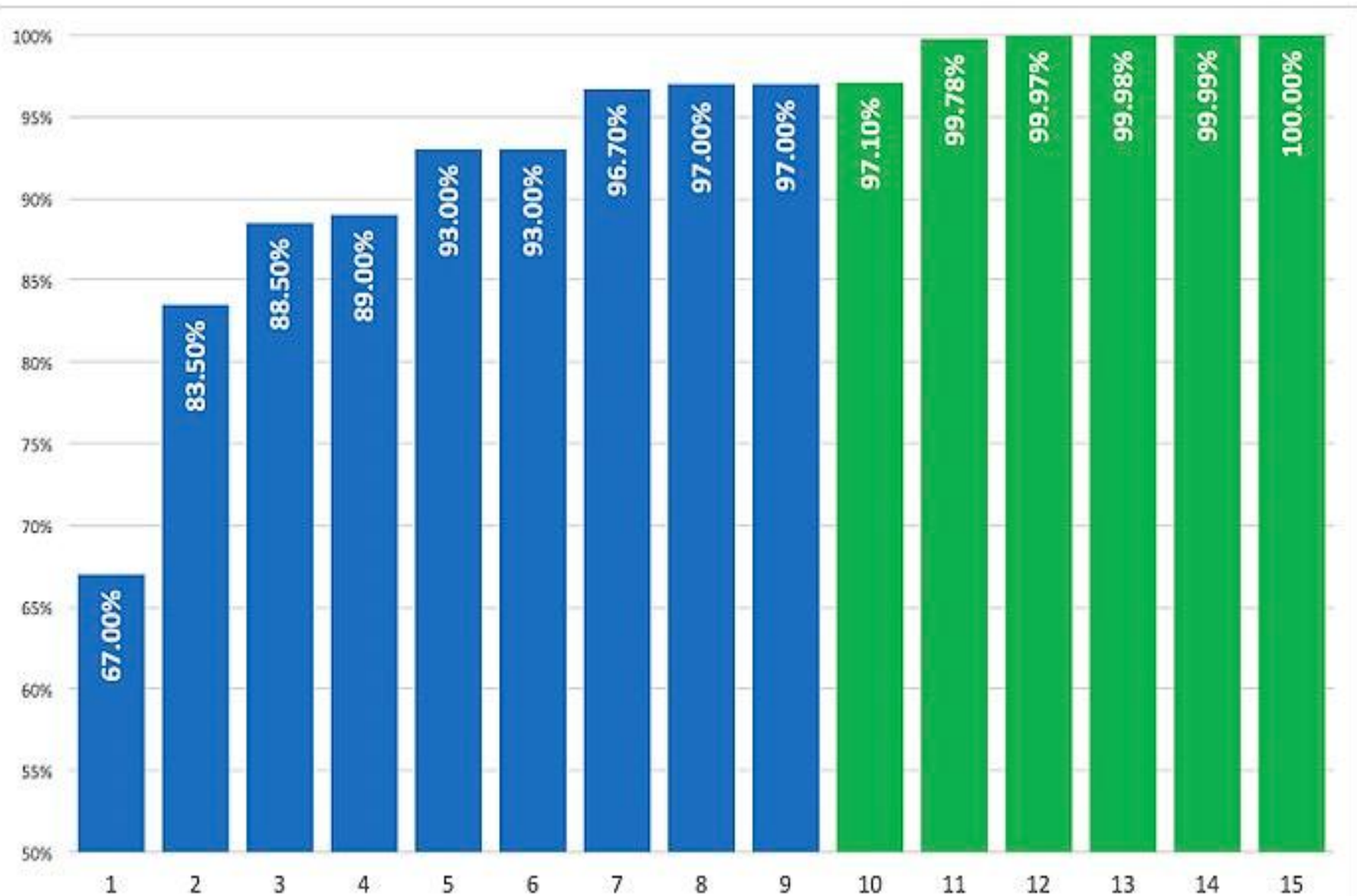






**APPENDIX:**  
**SLIDES IN NO**  
**PARTICULAR**  
**ORDER**

**(another 250+ slides  
on global warming +  
80 slides on science)**



Peer-reviewed Studies of the Consensus on Anthropogenic Global Warming

Blue=opinion, Green =literature surveys

Average consensus from 54,195 articles in studies 11-15: 99.94%

[www.jamespowell.org](http://www.jamespowell.org)

# CLIMATE CHANGE AND GLOBAL WARMING: PROOFS-STRENGTHS

- 1.) **Measurements:** Huge number; Over time; Air – Land - Sea
- 2.) **Mechanisms:** Explaining how things happen
- 3.) See **Effects of Climate change** (e.g., Glacier melting, Wild Weather Extremes and Other Changes Explained)
- 4.) Computer **Modeling; Predictions**
- 5.) **Consensus** (over 99%) of Scientists (who love debate) in the Field of Study (does anything have a 99% agreement?)
- 6.) **Multiple, Independent Ways** of Scientific Study (Science – works; most successful way of knowing; different methods)
- 7.) Widely Different Expert Groups (many countries, **interdisciplinary; cohesive**)
- 8.) Rate **Changes (Over Time)**
- 9.) Human-related (**Rule-out Natural Causes**); compared with Pre-industrial times
- 10.) **Explanations of Denials; Responses to Critiques**

# **CLIMATE CHANGE: GLOBAL WARMING REVIEW: WHAT WE WENT OVER**

- **Why Important**
- **Known for Awhile: Over 150 years!**
- Climate, Weather: Complex; Chaotic: How is Climate Measured Long Term? Who does the Measuring?
- The Greenhouse Effect
- Global Warming
- Increased CO<sub>2</sub> in Atmosphere
- Increased CO<sub>2</sub> in Seas, Land
- Effects: Rising Seas; Storms; Wildfires; Animals; Humans



# GLOBAL WARMING IS BAD: YOU (OR YOUR PROGENY) WON'T GET 'OVER IT!'

**Shrug off**, just don't care; a Minor thing – one at a time!—can only live with **one problem at a time; tired**, living with it; not frightened - **familiar**; put it behind us; how to live with something..

**Get used to living with it**; beaten to death re: it (like addiction's **tachyphylaxis**

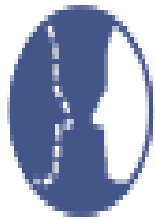
**Hard to convince**; Underestimated; but tip of the iceberg  
Don't personally see it; People get excited about acute (all at once things) or shocking things – **not chronic things**

Only **affect others** – delayed; Congress-not very interested (**not interested in 'long-term'**)

Make fun of, or people who believe in it ('those guys!')

# 5 CHARACTERISTICS OF SCIENCE DENIAL

F



Fake  
Experts

L



Logical  
Fallacies

I



Impossible  
Expectations

C

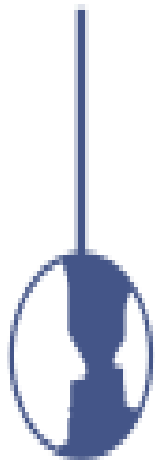


Cherry  
Picking

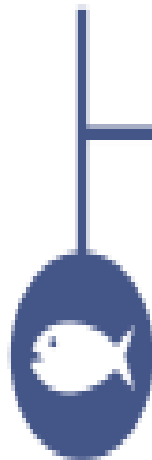
C



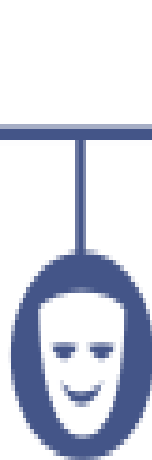
Conspiracy  
Theories



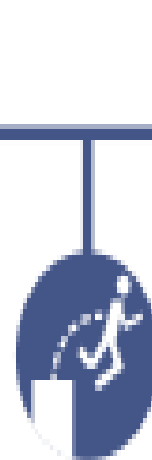
Magnified  
Minority



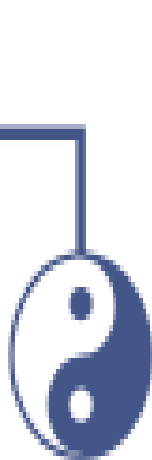
Red  
Herring



Misrepresentation



Jumping to  
Conclusions



False  
Dichotomy

# GLOBAL WARN(M)ING: ANSWERING THESE QUESTIONS (NYTIMES, 2021)

(it's complex; chaotic; there are nuances; but scientific)

- 1.) **How do we know** is it really happening?
- 2.) How much **agreement among scientists**?
- 3.) Do we really have **over 150 years of climate data**?
- 4.) How do we know its **caused by humans**?
- 5.) Since **Greenhouse is natural** – how know its due to increased Earth's temperature?
- 6.) Why worry if Earth's **temperature only increases** 2 degree F?
- 7.) Is Climate change due to our **planet's natural cycles**?
- 8.) How do we know that its **not secondary to Sun, Volcanoes**?
- 9.) **Winters and places are colder**, yet Earth is warming?
- 10.) **Bad weather and wildfires** have always been with us – what is the connection to global warming?
- 11.) **How bad** will climate change effects be?
- 12.) **What is the cost** of doing nothing?

# CLIMATE CHANGE: MULTIPLE LINES OF EVIDENCES

- 1.) **Overall Temperature**; increased temperature globally
- 2.) **Heat waves and Wildfires** more common
- 3.) **Increased warming of Arctic, Greenland** (melting permafrost, glacial retreat, sea ice loss); **Increased Sea Levels**; changes in sea currents; changes in distribution of heat
- 4.) **More Intense Storms and Weather extremes**
- 5.) Forcing many **species to relocate, become extinct**
- 6.) **Changes in coral reefs (bleaching), shells**
- 7.) Food and water scarcity for humans
- 8.) **Increased flooding**, extreme heat, more disease, economic loss, human migration and conflict
- 9.) **WHO** – the greatest threat to global health in the 21<sup>st</sup> Century
- 10.) **Warmer more acidic oceans** (less oxygen in waters affecting sea life); acid rain

# EFFECTS OF CLIMATE CHANGE: OCEANS, ICE, WEATHER

- 1.) **Increased Droughts, Heat Waves, Wet/Dry, Wildfires,**
- 2.) **Increased Hurricanes, Typhoons** (and in the future – tropical cyclones?); more intense storms
- 3.) **Increased Global Sea Rise** (melting ice sheets Greenland & Antarctica; increased loss of Arctic)
- 4.) **Shrinking and Thinning Arctic Sea Ice** (Loss of Sunlight-reflecting snow cover; increased heat absorption)
- 5.) Collapse of certain **Ocean Currents**
- 6.) **Deserts** expanding,
- 7.) **Nature and Wildlife:** Species driven to higher altitudes or extinction; loss of wetlands; plants flowering earlier, inhibits plant growth
- 8.) **People: health** - diseases, food and water shortages, extreme heat, coastal flooding, livelihoods-economic loss, migrations, conflict



# GLOBAL WARMING: EVIDENCE

- 1.) Every major **glacier** on Earth is receding
- 2.) The **Northern Polar ice has thinned** by an average of 50%/last 50 years\
- 3.) Large parts of Greenland (second-largest ice sheet) thawing out
- 4.) Section of Antarctica (Larsen Ice Shelf C) broke off/stability of ice sheets/shelves now in question
- 5.) Last few years: **hottest ever recorded**
- 6.) Earth's average temperature increased by about 1.3 Celsius in past century
- 7.) On average, **summer is about 1 week longer** than in the past
- 8.) Seeing more and **more "one hundred-year-events** (e.g., forest fires, floods, droughts, hurricanes, etc)

# NOAA WEATHER STATION: HAWAII



# CLIMATE: COMPLEX

– MULTIFACTORIAL –  
FEEDBACK SYSTEMS; THERE  
ARE NUANCES

- 1.) **Sun** – energy- power variations
- 2.) Tilt, Wobble, **Orbit** of Earth
- 3.) Plate Tectonics – **Volcanoes**
- 4.) Changes in **Water** (heat; ice – reflective);  
land bridges; changes in **Soil**/land
- 5.) **Atmosphere**; Increase in CO<sub>2</sub>, etc
- 6.) Ocean/Wind **Currents**

# DEFINITION - SCIENCE (SOCIETY FOR ENVIRONMENTAL TOXICOLOGY AND CHEMISTRY)

Organized investigation and  
observation conducted by  
**qualified personnel** using  
**documented** methods and  
leading to **verifiable** results  
and conclusions

Results from rigorously obtained,  
**empirical and data-driven**  
observations

(**reliable – reproducible-peer review**)

# SCIENCE: A COMMUNITY OF TRUTH SEEKERS 2021

Thousands of experts with relevant expertise devoted enormous quantities of **time/learning** to better understand the issues, more familiar with more sophisticated **methods for gathering data, analyzing the results** and drawing **justified conclusions**, who have studied these topics from **multiple (often independent) perspectives**, thought about them every day for years on end collectively



# SCIENCE'S STRENGTHS

**Multiple, Independent, Transparent,  
Rigorous, Measurements, of Different  
Lines of Evidence with incredible  
Statistical Robustness (in Physics – 5  
sigma = 1 in 3.5 million chance of being in  
error – not correlated, due to “noise”)  
with Approved Methods and Critical  
Review by Experts in the Field**

# SCIENCE: SEARCHING FOR THE BEST EXPLANATION:

**Testability (Falsifiable):** “No amounts of experimentation can ever prove me rights; a single experiment can prove me wrong” (Einstein)

**Fruitfulness** (Novel Predictions; Opens up new lines of research)

**Broad Scope** (Cohesion with Known Corpus of Theories; explains and predicts the most diverse phenomena)

**Simplicity** (Parsimonious – Occam’s Razor; fewest assumptions)

**Conservatism** (**fits best with established beliefs**; fewer well-established beliefs it conflicts with)

Use of Imagination

Minimize Confounding Variables (change only one thing)

Use of Controls (and Placebos)

Often Blinded or Double Blinded; Replication



**Wind power produced more  
electricity than coal and nuclear  
sources for first time ever**

**Jordan Mendoza**

**APRIL 14, 2022**

**USA TODAY**

---

## Hint to Coal Consumers.

A Swedish professor, Svend Arrhenius, has evolved a new theory of the extinction of the human race. He holds that the combustion of coal by civilized man is gradually warming the atmosphere so that in the course of a few cycles of 10,000 years the earth will be baked in a temperature close to the boiling point. He bases his theory on the accumulation of carbonic acid in the atmosphere, which acts as a glass in concentrating and refracting the heat of the sun.

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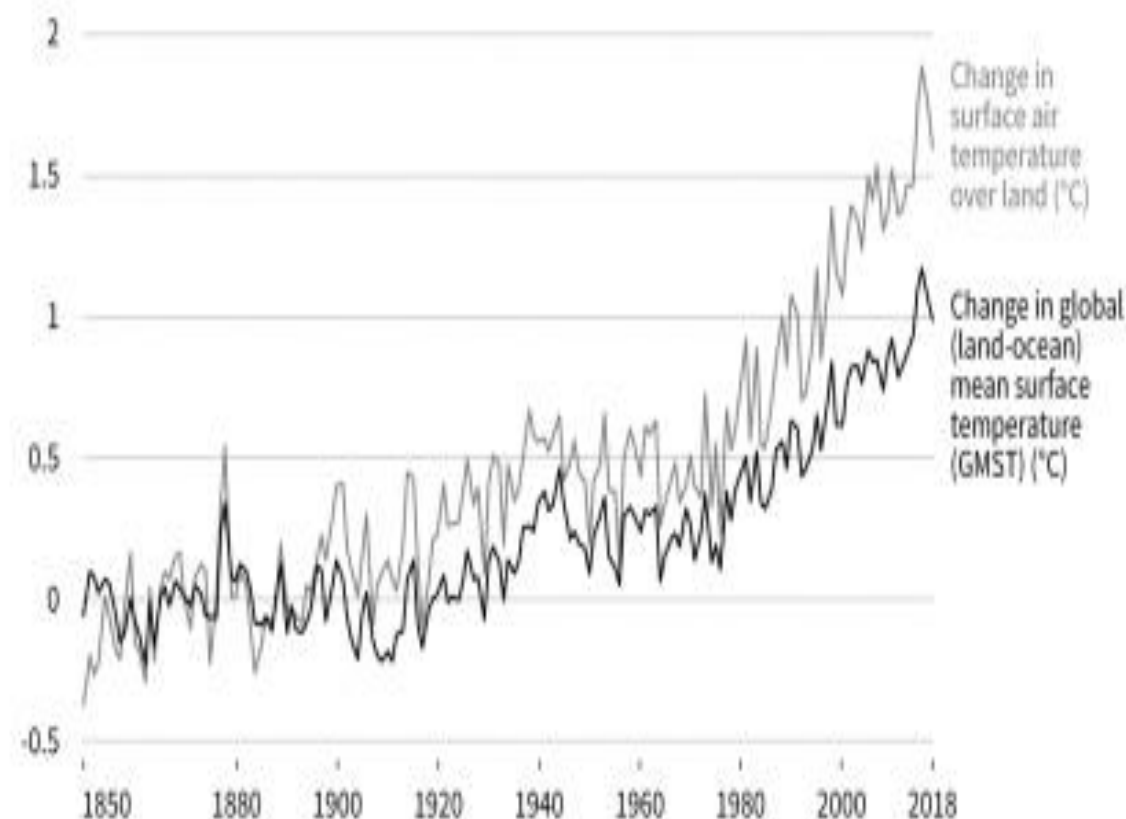


# Land use and observed climate change

## A. Observed temperature change relative to 1850-1900

Since the pre-industrial period (1850-1900) the observed mean land surface air temperature has risen considerably more than the global mean surface (land and ocean) temperature (GMST).

CHANGE in TEMPERATURE rel. to 1850-1900 (°C)



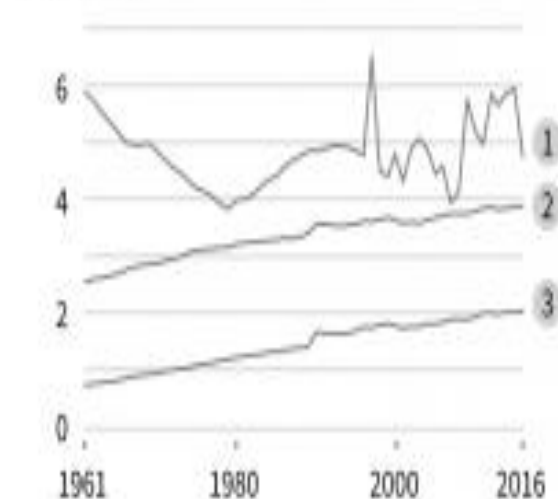
## B. GHG emissions

An estimated 23% of total anthropogenic greenhouse gas emissions (2007-2016) derive from Agriculture, Forestry and Other Land Use (AFOLU).

CHANGE in EMISSIONS since 1961

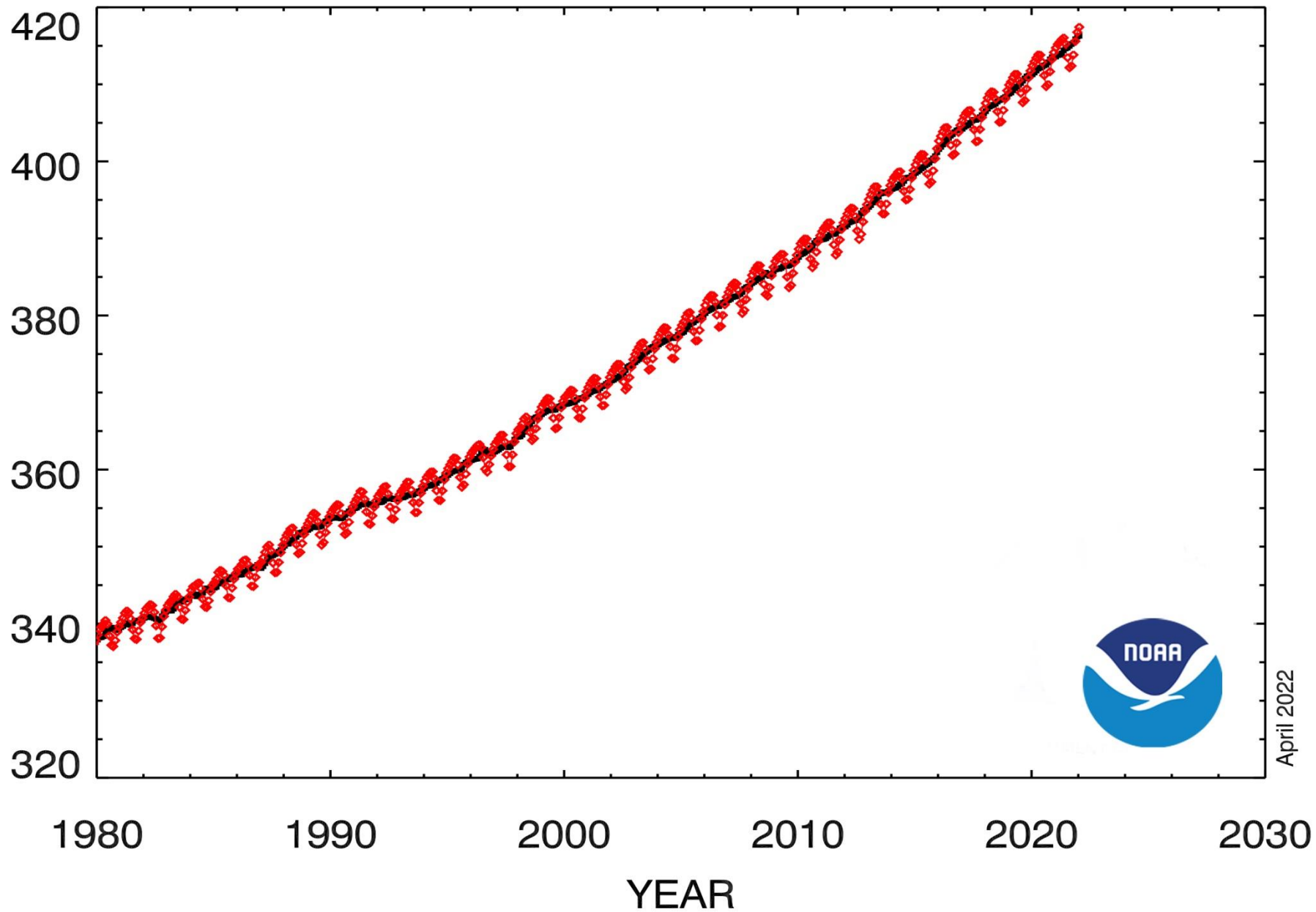
- 1 Net CO<sub>2</sub> emissions from FOLU (GtCO<sub>2</sub> yr<sup>-1</sup>)
- 2 CH<sub>4</sub> emissions from Agriculture (GtCO<sub>2</sub>eq yr<sup>-1</sup>)
- 3 N<sub>2</sub>O emissions from Agriculture (GtCO<sub>2</sub>eq yr<sup>-1</sup>)

GtCO<sub>2</sub>eq yr<sup>-1</sup>



# GLOBAL MONTHLY MEAN CO<sub>2</sub>

PARTS PER MILLION



April 2022

Published: 14 April 2022

# **Elevated extinction risk of cacti under climate change**

Michiel Pillet,

Barbara Goettsch,

Cory Merow,

Brian Maitner,

Xiao Feng,

Patrick R. Roehrdanz &

Brian J. Enquist

*Nature Plants* (2022)

# War and wildlife: linking armed conflict to conservation

[Kaitlyn M Gaynor](#), [Kathryn J Fiorella](#), [Gillian H Gregory](#), [David J Kurz](#), [Katherine L Seto](#), [Lauren S Withey](#), [Justin S Brashares](#)

Frontiers in Ecology and the Environment

First published: 01 December 2016

<https://doi.org/10.1002/fee.1433>

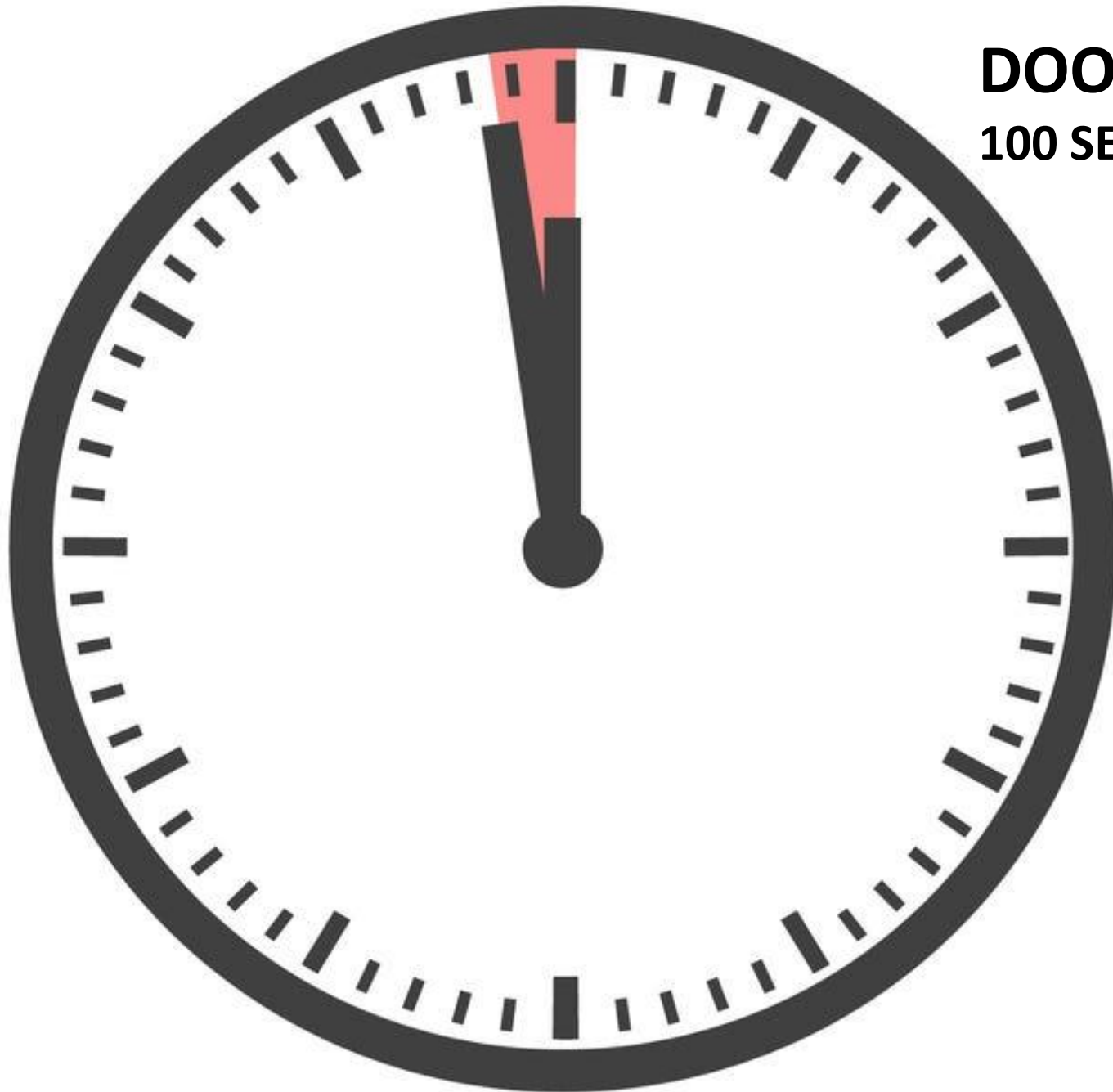
## Abstract

Armed conflict throughout the world's biodiversity hotspots poses a critical threat to conservation efforts. To date, research and policy have focused more on the ultimate outcomes of conflict for wildlife rather than on the ecological, social, and economic processes that create those outcomes. Yet the militarization that accompanies armed conflict, as well as consequent changes in governance, economies, and human settlement, has diverse influences on wildlife populations and habitats. To better understand these complex dynamics, we summarized 144 case studies from around the world and identified 24 distinct pathways linking armed conflict to wildlife outcomes

## **WORKING GROUP III CONTRIBUTION TO THE IPCC SIXTH ASSESSMENT REPORT (AR6)**

**Summary for Policymakers** Drafting Authors: Jim Skea (United Kingdom), Priyadarshi R Shukla (India), Andy Reisinger (New Zealand), Raphael Slade (United Kingdom), Minal Pathak (India), Alaa Al Khourdajie (United Kingdom/Syria), Renée van Diemen (the Netherlands/United Kingdom), Amjad Abdulla (Maldives), Keigo Akimoto (Japan), Mustafa Babiker (Sudan/Saudi Arabia), Quan Bai (China), Igor Bashmakov (Russian Federation), Christopher Bataille (Canada), Göran Berndes (Sweden), Gabriel Blanco (Argentina), Kornelis Blok (the Netherlands), Mercedes Bustamante (Brazil), Edward Byers (Austria), Luisa F. Cabeza (Spain), Katherine Calvin (the United States of America), Carlo Carraro (Italy), Leon Clarke (the United States of America), Annette Cowie (Australia), Felix Creutzig (Germany), Diriba Korecha Dadi (Ethiopia), Dipak Dasgupta (India), Heleen de Coninck (the Netherlands), Fatima Denton (the Gambia), Shobhakar Dhakal (Nepal/Thailand), Navroz K. Dubash (India), Oliver Geden (Germany), Michael Grubb (United Kingdom), Céline Guivarch (France), Shreekanth Gupta (India), Andrea Hahmann (Chile), Kirsten Halsnaes (Denmark), Paulina Jaramillo (the United States of America), Kejun Jiang (China), Frank Jotzo (Australia), Tae Yong Jung (Republic of Korea), Suzana Kahn Ribeiro (Brazil), Smail Khennas (Algeria), Şiir Kılıç (Turkey), Silvia Kreibiehl (Germany), Volker Krey (Austria), Elmar Kriegler (Germany), William Lamb (Germany), Franck Lecocq (France), Shuaib Lwasa (Uganda), Nagmeldin Mahmoud (Sudan), Cheikh Mbow (Senegal), David McCollum (the United States of America), Jan Christoph Minx (Germany), Catherine Mitchell (United Kingdom), Rachid Mrabet (Morocco), Yacob Mulugetta (Ethiopia), Gert-Jan Nabuurs (the Netherlands), Gregory Nemet (the United States of America/Canada), Peter Newman (Australia), Leila Niamir (Germany/Iran), Lars J. Nilsson (Sweden), Sudarmanto Budi Nugroho (Indonesia), Chukwumerije Okereke (Nigeria/United Kingdom), Shonali Pachauri (India), Anthony Patt (Switzerland), Ramón Pichs-Madruga (Cuba), Joana Portugal Pereira (Brazil), Lavanya Rajamani (India), Keywan Riahi (Austria), Joyashree Roy (India/Thailand), Yamina Saheb (France/Algeria), Roberto Schaeffer (Brazil), Karen Seto (the United States of America), Shreya Some (India), Linda Steg (the Netherlands), Ferenc L. Toth (Hungary), Diana Ürge-Vorsatz (Hungary), Detlef van Vuuren (the Netherlands), Elena Verdolini (Italy), Purvi Vyas (India), Yi-Ming Wei (China), Mariama Williams (Jamaica/the United States of America), Harald Winkler (Republic of South Africa (64 page Summary for Policymakers)





# **DOOMSDAY CLOCK**

**100 SEC. TILL MIDNITE**

**2022**

- **NUCLEAR**
- **CLIMATE**
- **COVID**
- **DISRUPTIVE**
- **TECHNOLOGIES**

**BULLETIN  
OF THE ATOMIC  
SCIENTISTS  
(FOUNDED BY  
EINSTEIN & UNIV.  
CHICAGO 1945)**

## **Intense Atmospheric Rivers can Weaken Ice shelf stability at the Antarctic Peninsula**

[Jonathan D. Wille,](#)

[Vincent Favier,](#)

[Nicolas C. Jourdain,](#)

[Christoph Kittel,](#)

[Jenny V. Turton,](#)

[Cécile Agosta,](#)

[Irina V. Gorodetskaya,](#)

[Ghislain Picard,](#)

[Francis Codron,](#)

[Christophe Leroy-Dos Santos,](#)

[Charles Amory,](#)

[Xavier Fettweis,](#)

[Juliette Blanchet,](#)

[Vincent Jomelli](#) &

[Antoine Berchet](#)

[Communications Earth & Environment](#) **volume 3, NATURE**

Article number: 90 (2022)

# Rapid declines of large mammal populations after the collapse of the Soviet Union

Eugenia V Bragina<sup>1,2</sup>, A R Ives<sup>3</sup>, A M Pidgeon<sup>4</sup>, T Kuemmerle<sup>5</sup>, L M Baskin<sup>6</sup>, Y P Gubar<sup>7</sup>, M Piquer-Rodríguez<sup>5</sup>, N S Keuler<sup>8</sup>, V G Petrosyan<sup>6</sup>, V C Radeloff<sup>4</sup>

CONSERVE BIOLOGY 2015

DOI: [10.1111/cobi.12450](https://doi.org/10.1111/cobi.12450)

**BANFF GLACIER (COLUMBIA) RECEEDING  
IN JUST 3 YEARS (SEEN BY JEAN/FRED S)**

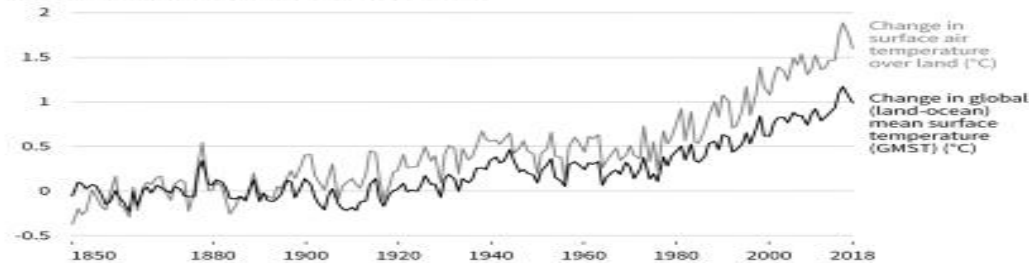


# Land use and observed climate change

## A. Observed temperature change relative to 1850-1900

Since the pre-industrial period (1850-1900) the observed mean land surface air temperature has risen considerably more than the global mean surface (land and ocean) temperature (GMST).

CHANGE in TEMPERATURE rel. to 1850-1900 (°C)

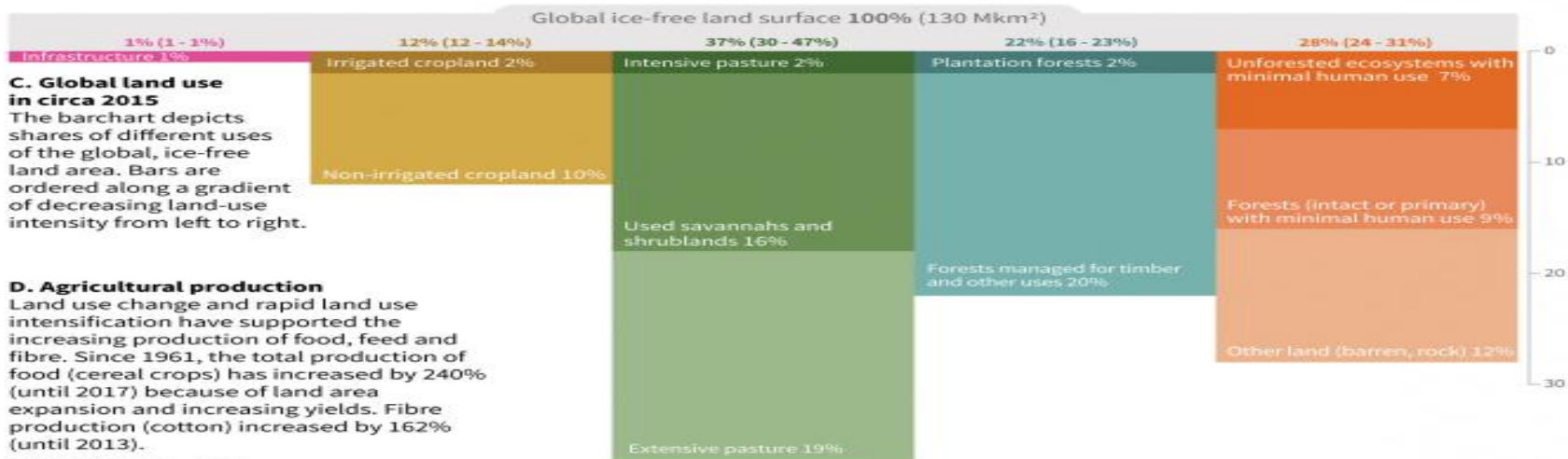
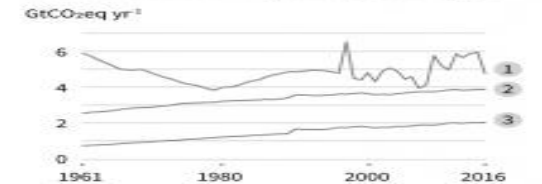


## B. GHG emissions

An estimated 23% of total anthropogenic greenhouse gas emissions (2007-2016) derive from Agriculture, Forestry and Other Land Use (AFOLU).

CHANGE in EMISSIONS since 1961

- 1 Net CO<sub>2</sub> emissions from FOLU (GtCO<sub>2</sub> yr<sup>-1</sup>)
- 2 CH<sub>4</sub> emissions from Agriculture (GtCO<sub>2</sub>eq yr<sup>-1</sup>)
- 3 N<sub>2</sub>O emissions from Agriculture (GtCO<sub>2</sub>eq yr<sup>-1</sup>)

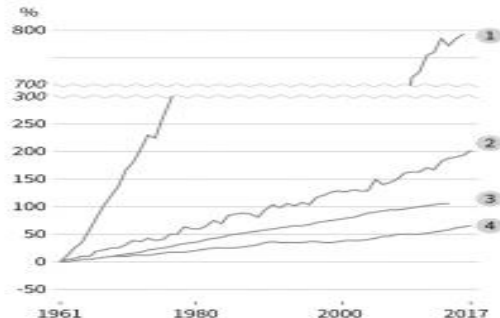


## D. Agricultural production

Land use change and rapid land use intensification have supported the increasing production of food, feed and fibre. Since 1961, the total production of food (cereal crops) has increased by 240% (until 2017) because of land area expansion and increasing yields. Fibre production (cotton) increased by 162% (until 2013).

CHANGE in % rel. to 1961

- 1 Inorganic N fertiliser use
- 2 Cereal yields
- 3 Irrigation water volume
- 4 Total number of ruminant livestock

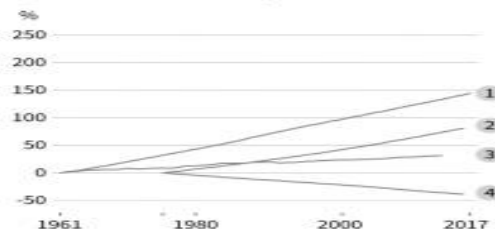


## E. Food demand

Increases in production are linked to consumption changes.

CHANGE in % rel. to 1961 and 1975

- 1 Population
- 2 Prevalence of overweight + obese
- 3 Total calories per capita
- 4 Prevalence of underweight

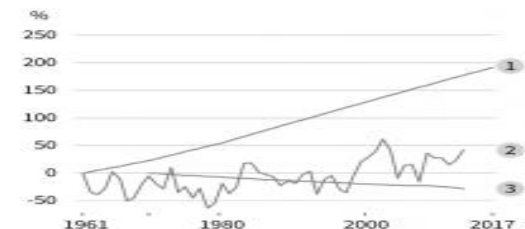


## F. Desertification and land degradation

Land-use change, land-use intensification and climate change have contributed to desertification and land degradation.

CHANGE in % rel. to 1961 and 1970

- 1 Population in areas experiencing desertification
- 2 Dryland areas in drought annually
- 3 Inland wetland extent



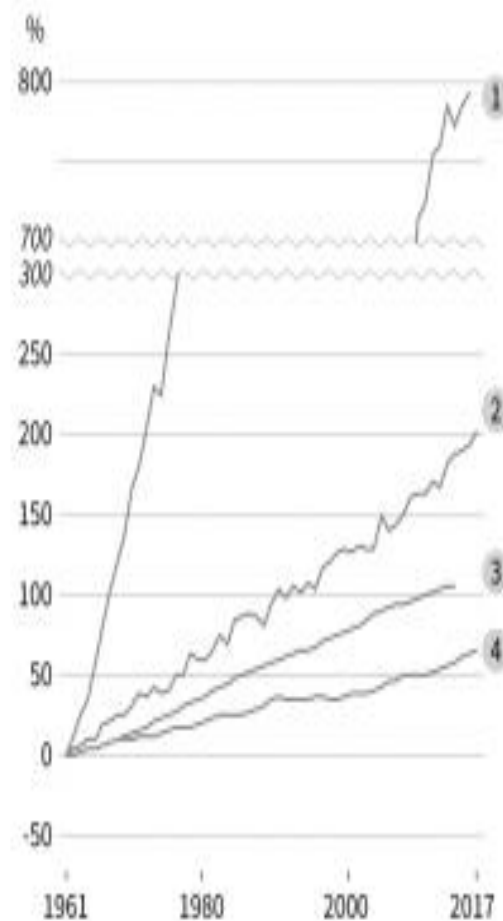


production (cotton) increased by 162% (until 2013).

Extensive pasture 19%

CHANGE in % rel. to 1961

- 1 Inorganic N fertiliser use
- 2 Cereal yields
- 3 Irrigation water volume
- 4 Total number of ruminant livestock

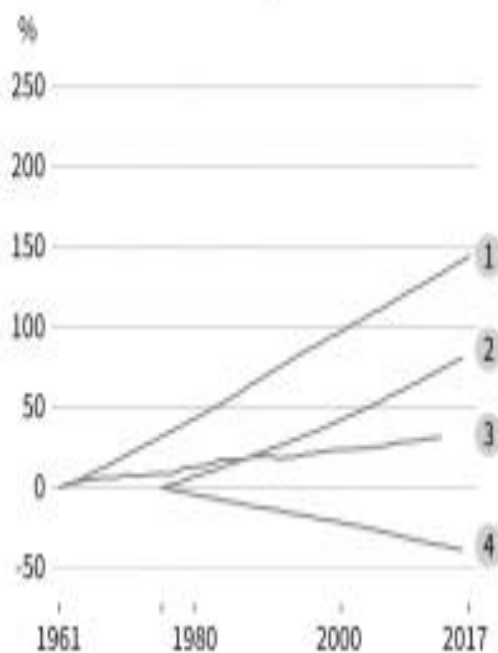


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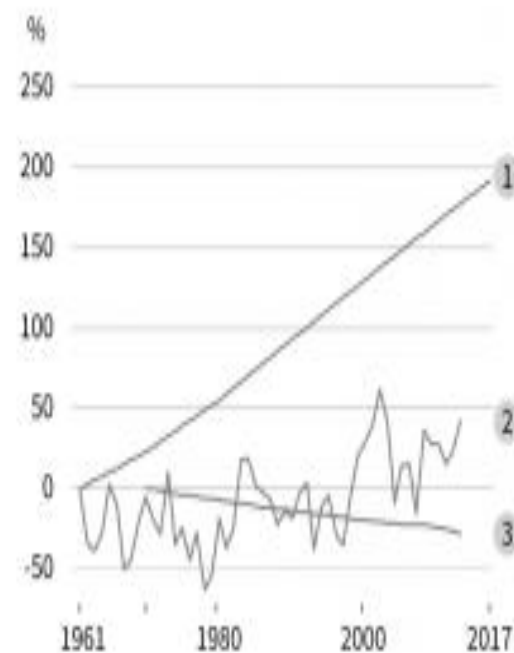


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- 2 Dryland areas in drought annually
- 3 Inland wetland extent



# Rapid intensification of the emerging southwestern North American megadrought in 2020–2021

A. Park Williams,  
Benjamin I. Cook &  
Jason E. Smerdon

*Nature Climate*

*Change* **volume 12**, pages232–234 (2022)

# Climate change increases risk of extreme rainfall following wildfire in the western United States

[DANIELLE TOUMA](#) [SAMANTHA STEVENSON](#) [DANIEL L. SWAIN](#), [DEEPTI SINGH](#) [A. KALASHNIKOV](#), [XINGYIN G HUANG](#)

***SCIENCE ADVANCES*** • 1 Apr  
2022 • Vol 8, Issue 13 • [DOI:](#)  
[10.1126/sciadv.abm0320](https://doi.org/10.1126/sciadv.abm0320)

# Rapid rise in premature mortality due to anthropogenic air pollution in fast-growing tropical cities from 2005 to 2018

[KARN VOHRA](#) [ELOISE A. MARAIS](#) [WILLIAM J. BLOSS](#) -  
[JOEL SCHWARTZ](#) [LORETTA J. MICKLEY](#) [MARTIN VAN DAMME](#) -  
[LIEVEN CLARISSE](#) [PIERRE-F. COHEUR](#)

***SCIENCE ADVANCES*** • 8 Apr 2022 • Vol 8, Issue 14 •

Here, we conduct targeted sampling of recent (2000s to 2010s) observations of air pollutants from space-based instruments over 46 fast-growing tropical cities. We quantify **significant annual increases in nitrogen dioxide (NO<sub>2</sub>) (1 to 14%), ammonia (2 to 12%), and reactive volatile organic compounds (1 to 11%) in most cities, driven almost exclusively by emerging anthropogenic sources** rather than traditional biomass burning. We estimate **annual increases in urban population exposure to air pollutants** of 1 to 18% for fine particles (PM<sub>2.5</sub>) and 2 to 23% for NO<sub>2</sub> from 2005 to 2018 and attribute 180,000 (95% confidence interval: -230,000 to 590,000) **additional premature deaths in 2018 (62% increase relative to 2005) to this increase in exposure**. These cities are predicted to reach populations of up to 80 million people by 2100, so regulatory action targeting emerging anthropogenic sources is urgently needed.

Anthropogenic forcing is found to yield large **twenty-first-century increases in the frequency of wet extremes**, including a more than threefold increase in sub-seasonal events comparable to California's 'Great Flood of 1862'. Smaller but statistically robust increases in dry extremes are also apparent. **As a consequence, a 25% to 100% increase in extreme dry-to-wet precipitation events is projected**, despite only modest changes in mean precipitation. Such hydrological cycle intensification would **seriously challenge California's existing water storage, conveyance and flood control infrastructure**.



**Increase in atmospheric  
methane set another record  
during 2021 (a very very  
potent greenhouse gas)**

**Carbon dioxide levels also  
record a big jump**

**4/7/2022**

**NOAA**

# Assessing Adverse Health Effects of Long-Term Exposure to Low Levels of Ambient Air Pollution: Implementation of Causal Inference Methods

Francesca DominiciAntonella

ZanobettiJoel SchwartzDanielle

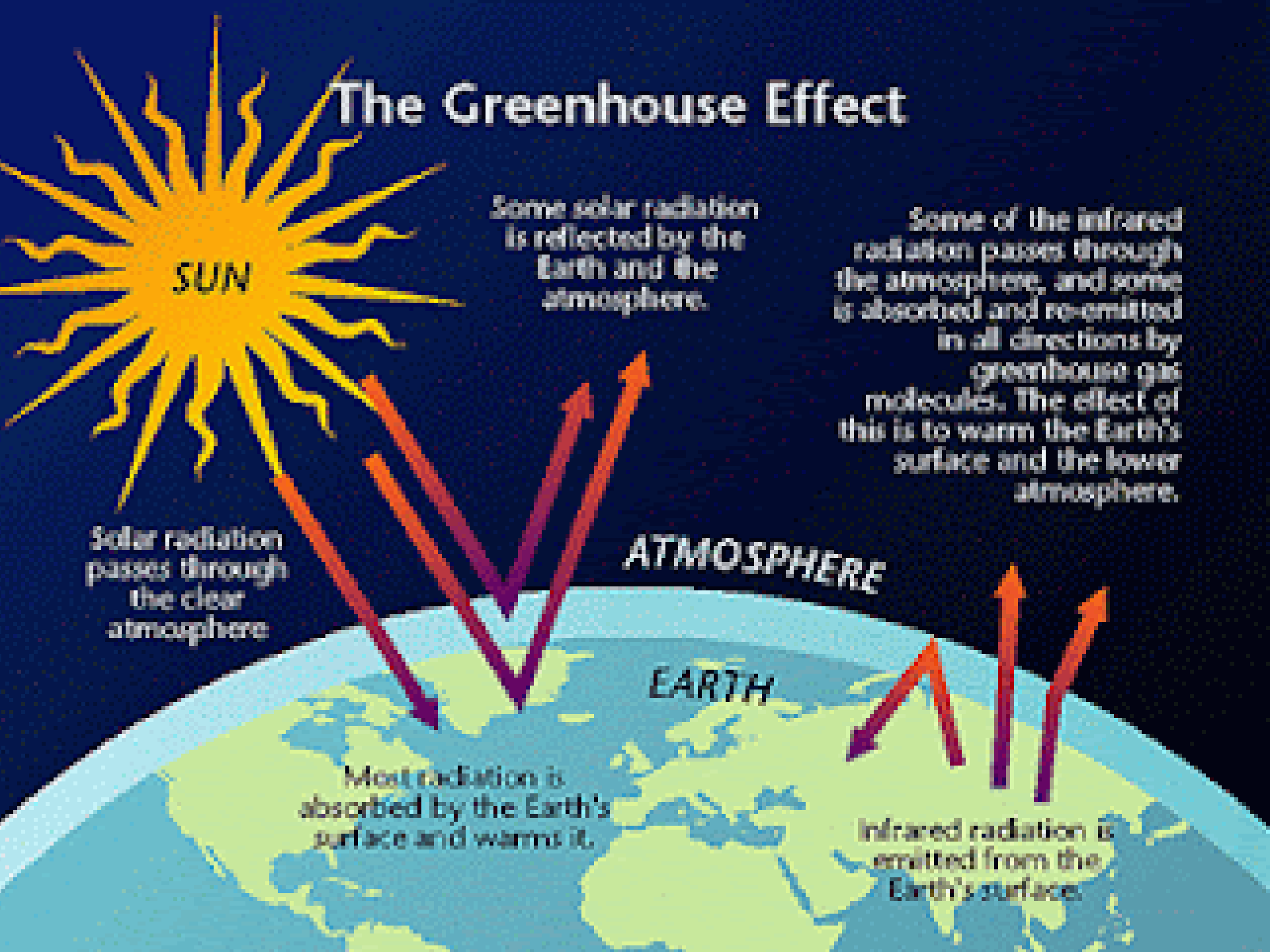
BraunBen SabathXiao Wu

Research Report 211,2022

HEALTH EFFECTS INSTITUTE

BOSTON

# The Greenhouse Effect



SUN

Some solar radiation  
is reflected by the  
Earth and the  
atmosphere.

Some of the infrared  
radiation passes through  
the atmosphere, and some  
is absorbed and re-emitted  
in all directions by  
greenhouse gas  
molecules. The effect of  
this is to warm the Earth's  
surface and the lower  
atmosphere.

Solar radiation  
passes through  
the clear  
atmosphere

ATMOSPHERE

EARTH

Most radiation is  
absorbed by the Earth's  
surface and warms it.

Infrared radiation is  
emitted from the  
Earth's surface.

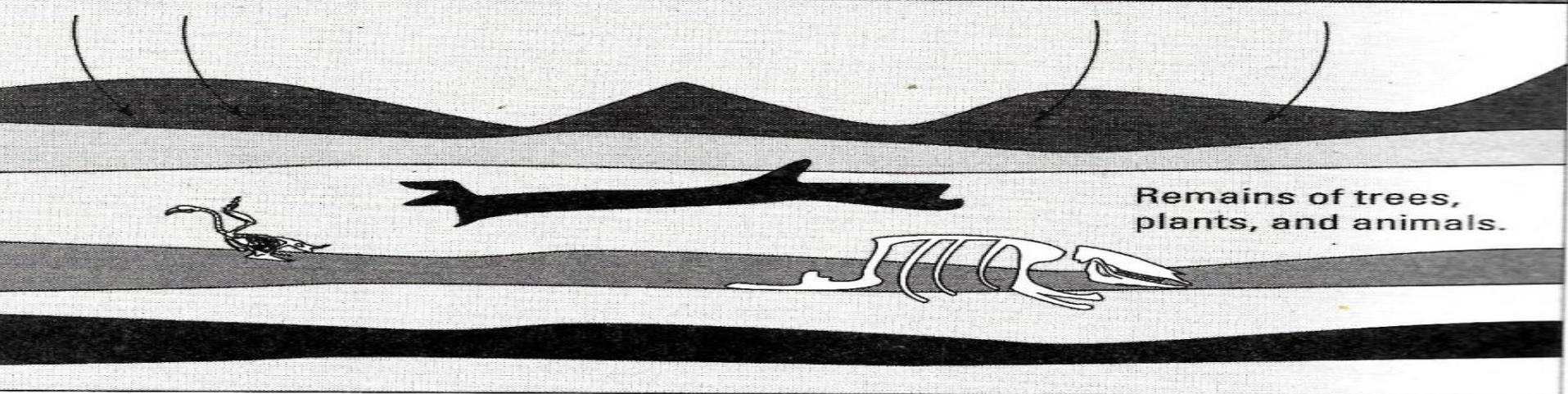
# The Creation of Fossil Fuels

The sun is the ultimate source of energy.

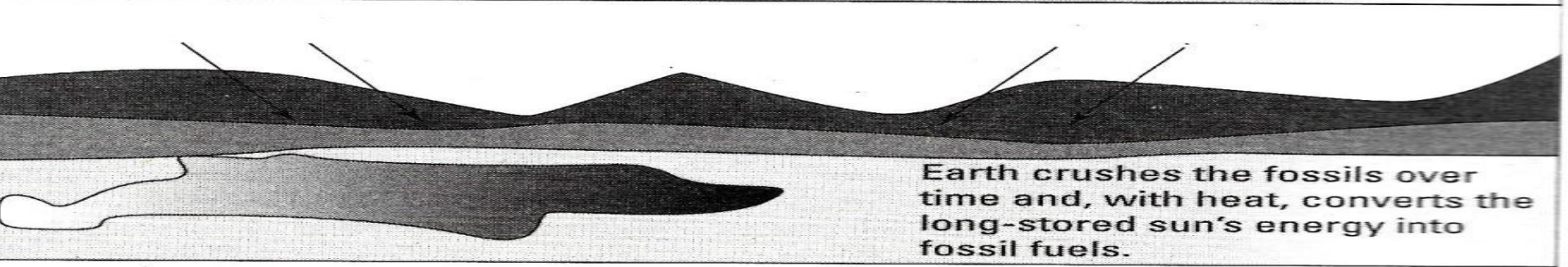
Tree, plants, and animals absorb the sun's energy.



Remains of trees, plants, and animals.



Earth crushes the fossils over time and, with heat, converts the long-stored sun's energy into fossil fuels.





**'It's now or never': UN  
climate report shows globe is  
on 'track toward an unlivable  
world'**

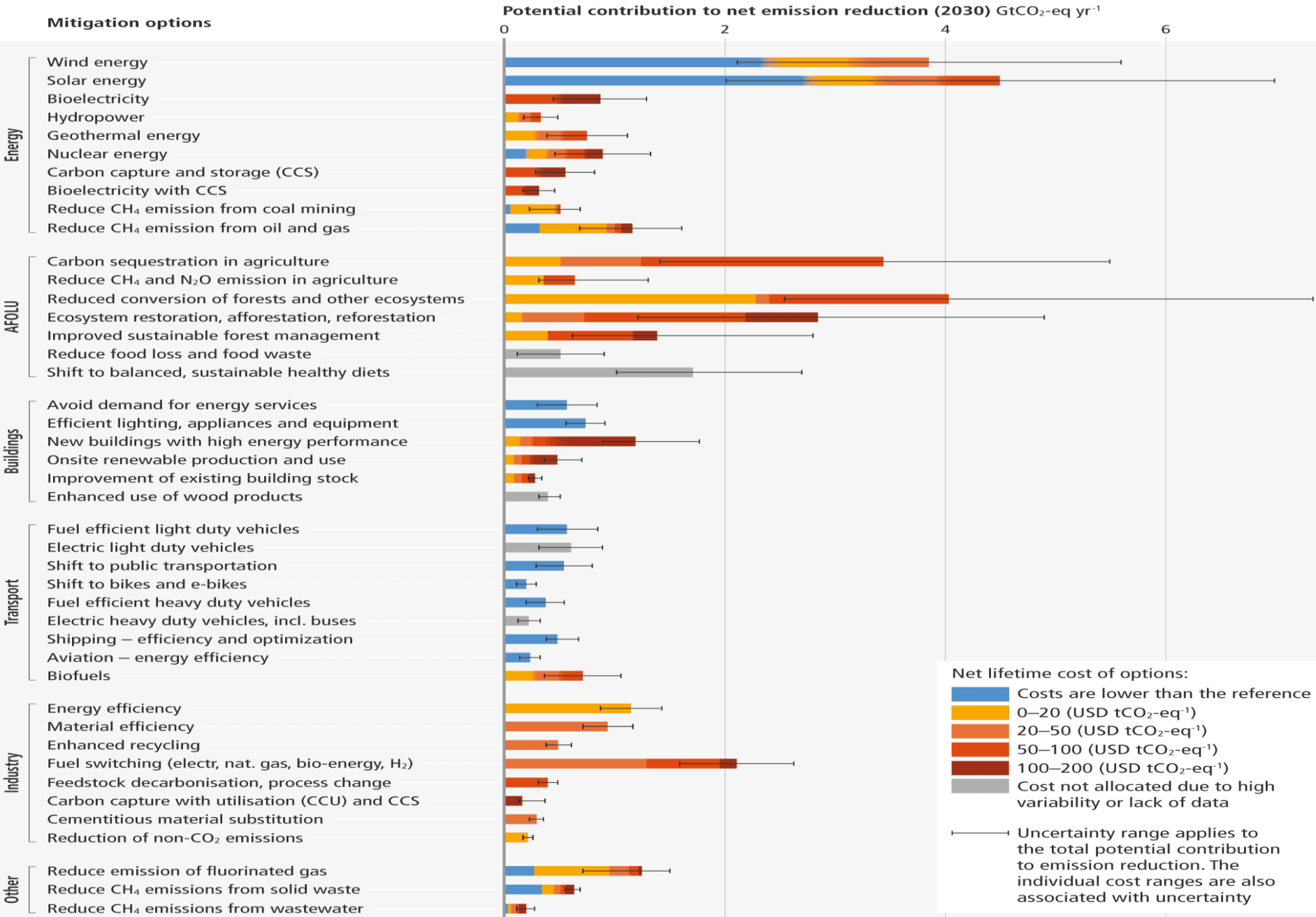
Doyle Rice, Dinah Voyles Pulver

USA TODAY

4/4/2022



Many options available now in all sectors are estimated to offer substantial potential to reduce net emissions by 2030. Relative potentials and costs will vary across countries and in the longer term compared to 2030.

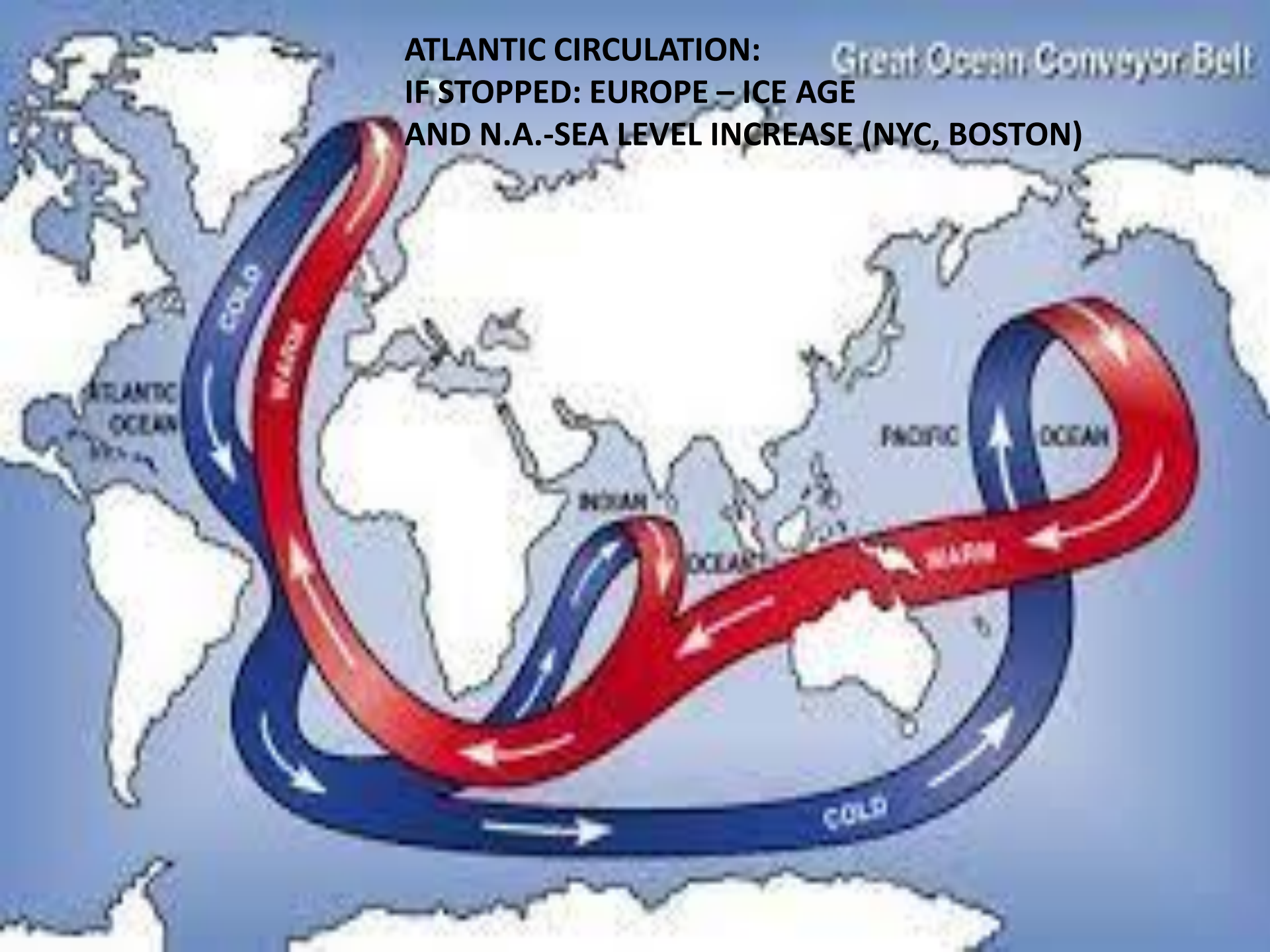


**ATLANTIC CIRCULATION:**

**IF STOPPED: EUROPE – ICE AGE**

**AND N.A.-SEA LEVEL INCREASE (NYC, BOSTON)**

Great Ocean Conveyor Belt



**Methane emissions soared to a record high in 2021 in an 'alarming' trend, NOAA says**

**Doyle Rice**

USA TODAY

4/9/2022

# World Scientists' Warning to Humanity

From WikipediaThe ***World Scientists' Warning to Humanity*** was a document written in 1992 by [Henry W. Kendall](#) and **signed by about 1,700 leading scientists.**

25 years later, in **November 2017**, 15,364 scientists signed ***World Scientists' Warning to Humanity: A Second Notice*** written by [William J. Ripple](#) and seven co-authors calling for...drastically diminishing [per capita](#) consumption of [fossil fuels](#), [meat](#), and other [resources](#).<sup>[a]</sup> The ***Second Notice*** has **more scientist cosigners and formal supporters than any other journal article ever published.**<sup>[1]</sup>

# **Quantifying Regional Methane Emissions in the New Mexico Permian Basin with a Comprehensive Aerial Survey**

Yuanlei Chen\*

, Evan D. Sherwin

, Elena S.F. Berman

, Brian B. Jones

Kairos Aerospace, Mountain View, California 94040,  
United States

*Environ. Sci. Technol.* 2022, 56, 7, 4317–4323

Publication Date: March 23, 2022

<https://doi.org/10.1021/acs.est.1c06458>

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**More methane from oil and gas than thought:  
Methane--more potent greenhouse effect than CO<sub>2</sub>**



## **Society for Conservation Biology 2009**

**Abstract:** *Conservation efforts are only as sustainable as the social and political context within which they take place. The weakening or collapse of sociopolitical frameworks during wartime can lead to habitat destruction and the erosion of conservation policies, but in some cases, may also confer ecological benefits through altered settlement patterns and reduced resource exploitation. **Over 90% of the major armed conflicts between 1950 and 2000 occurred within countries containing biodiversity hotspots, and more than 80% took place directly within hotspot areas.** Less than one-third of the 34 recognized hotspots escaped significant conflict during this period, and most suffered repeated episodes of violence. This pattern was remarkably consistent over these 5 decades. Evidence from the war-torn Eastern Afromontane hotspot suggests that biodiversity conservation is improved when international nongovernmental organizations support local protected area staff and remain engaged throughout the conflict. With **biodiversity hotspots concentrated in politically volatile regions, the conservation community must maintain continuous involvement during periods of war, and biodiversity conservation should be incorporated into military, reconstruction, and humanitarian programs in the world's conflict zones.***

# Warfare and wildlife declines in Africa's protected areas

Joshua H. Daskin &

Robert M. Pringle

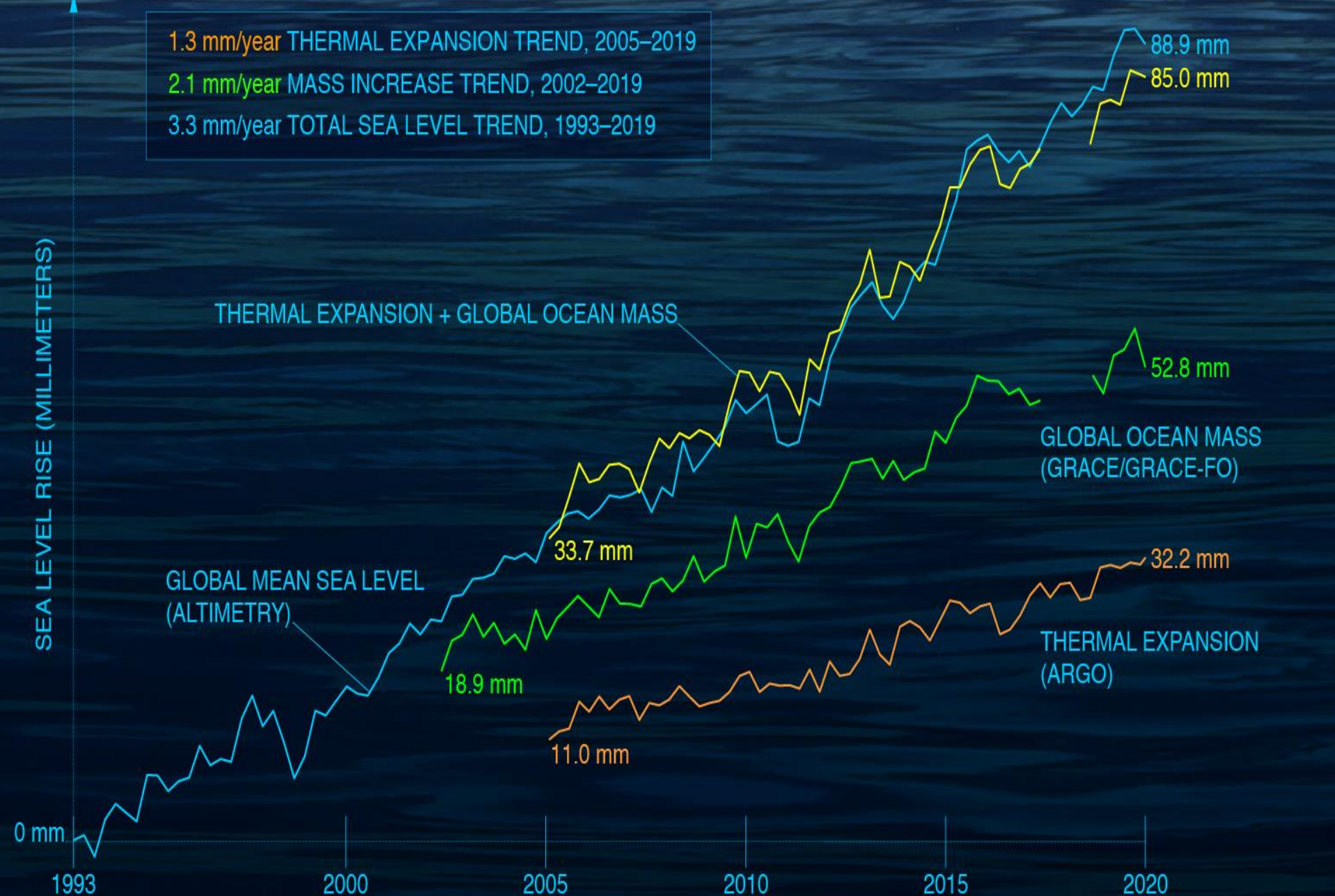
*Nature*

**volume 553**, pages 328–332 (2018)

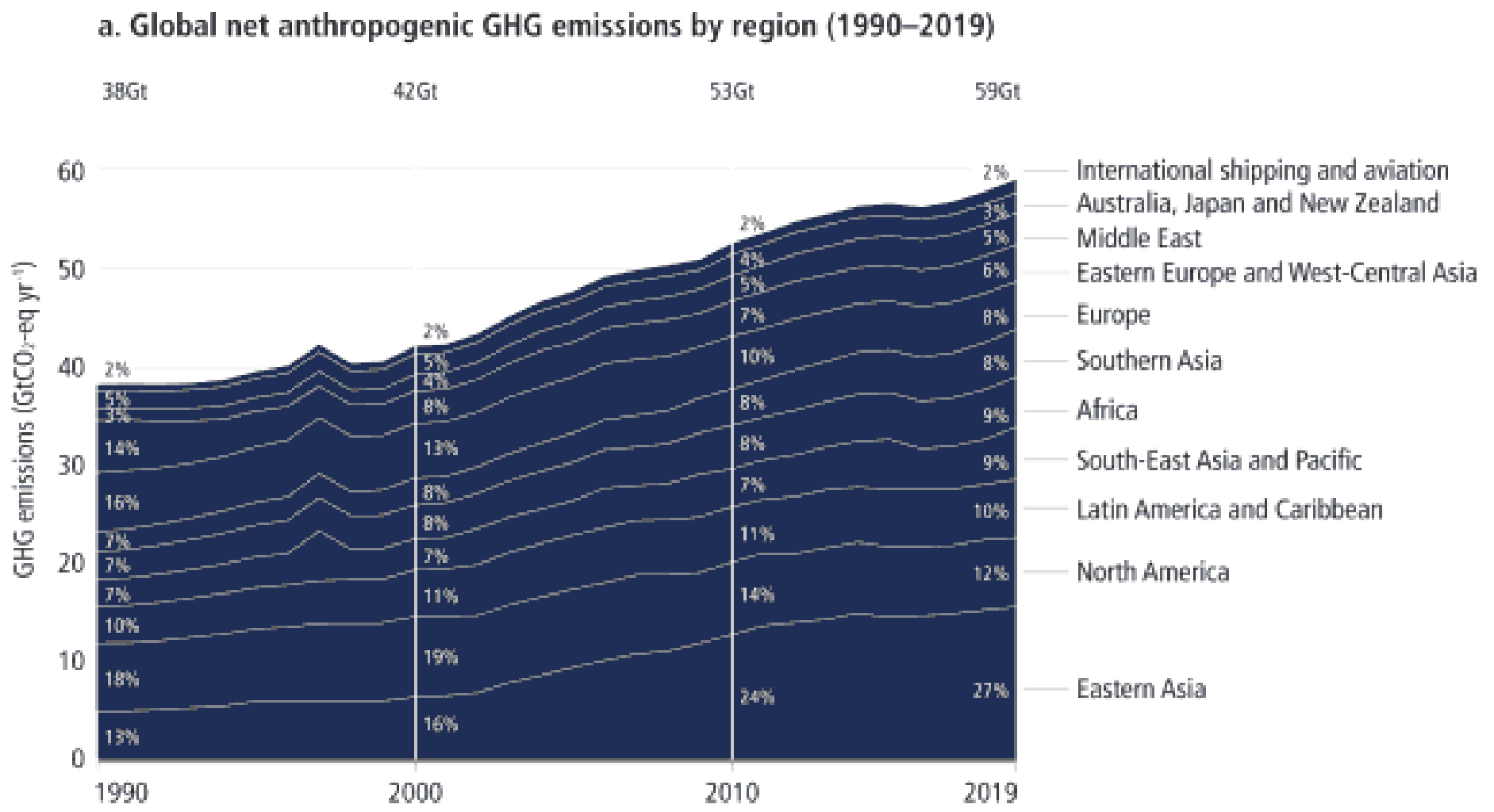
1.3 mm/year THERMAL EXPANSION TREND, 2005–2019

2.1 mm/year MASS INCREASE TREND, 2002–2019

3.3 mm/year TOTAL SEA LEVEL TREND, 1993–2019



Emissions have grown in most regions but are distributed unevenly, both in the present and cumulatively since 1850.



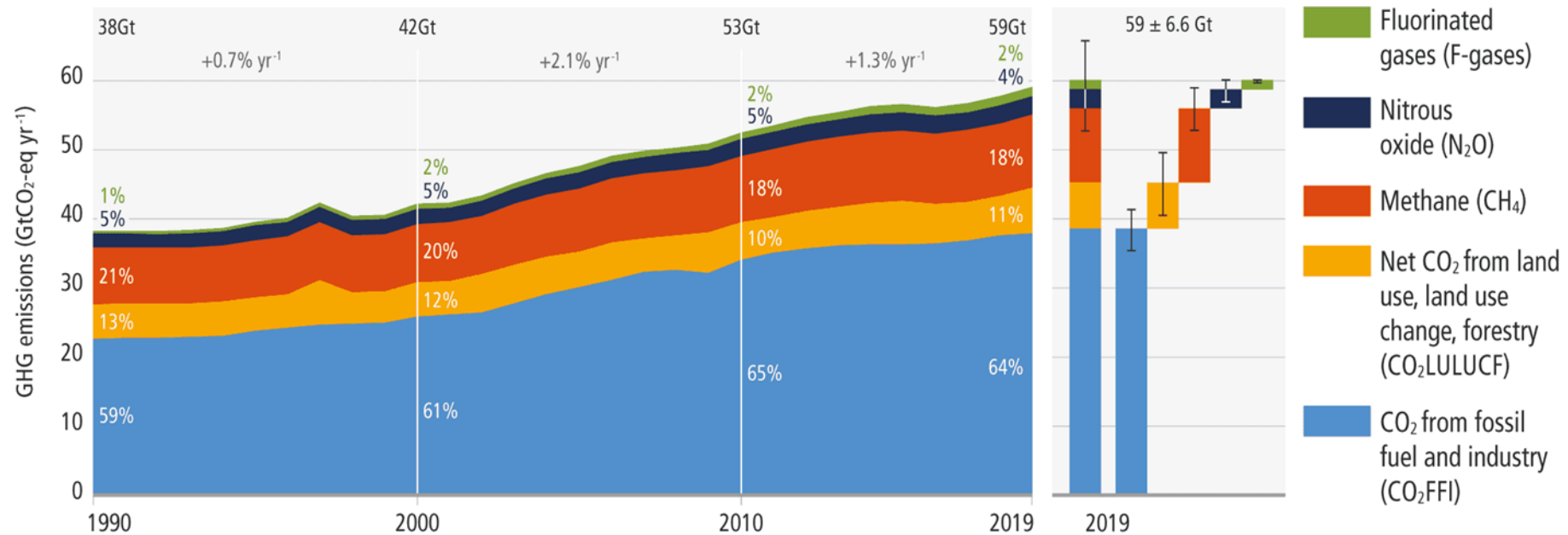
b. Historical cumulative net anthropogenic CO<sub>2</sub> emissions per region (1850–2019)

c. Net anthropogenic GHG emissions and for total population, per region

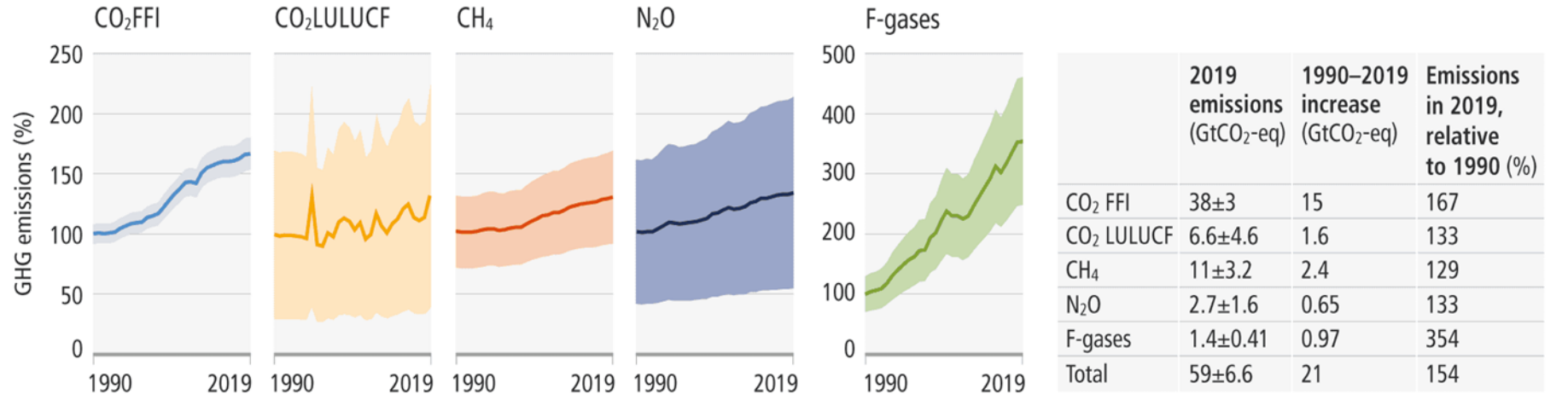
North America

# Global net anthropogenic emissions have continued to rise across all major groups of greenhouse gases.

a. Global net anthropogenic GHG emissions 1990–2019 <sup>(5)</sup>



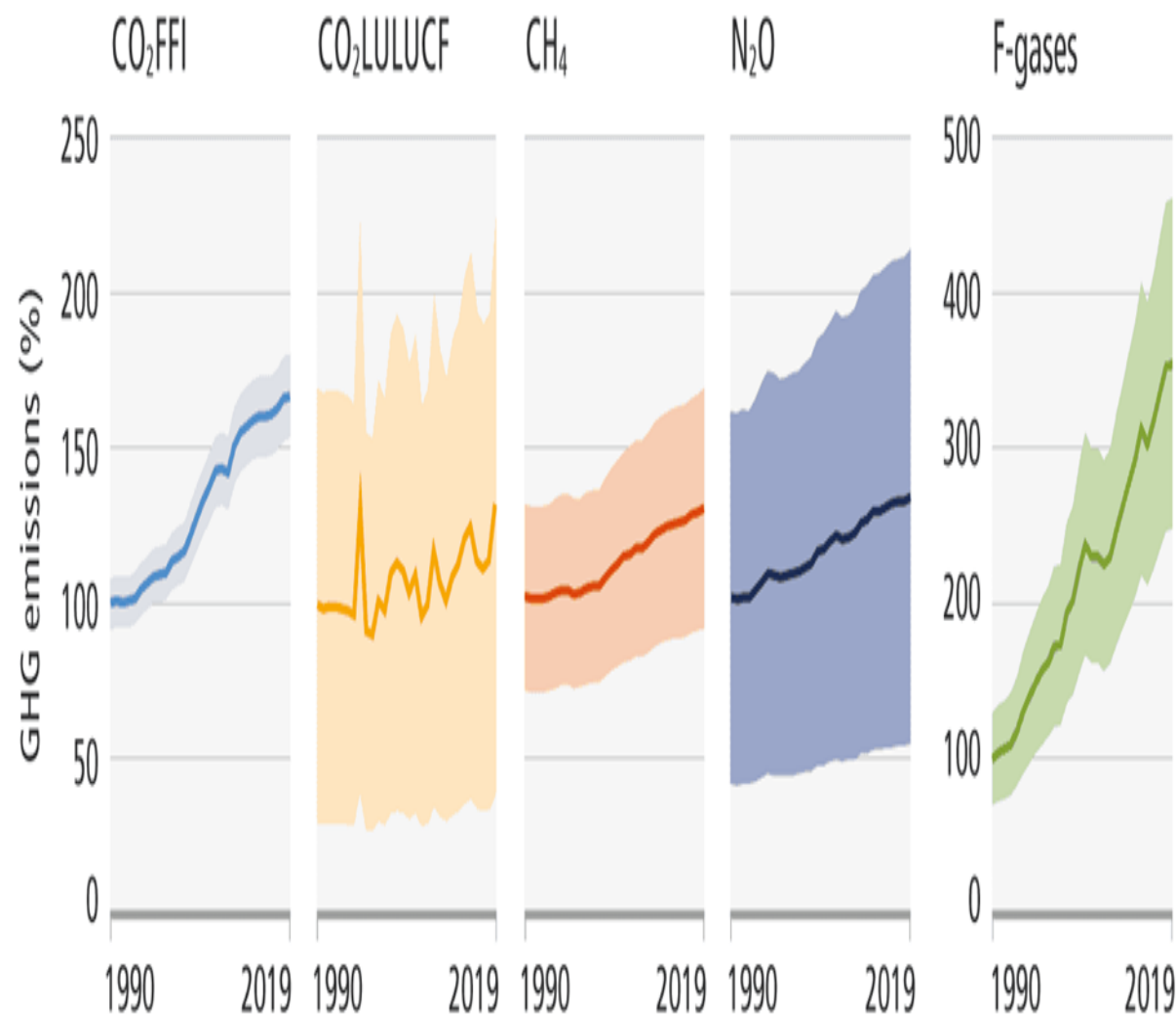
b. Global anthropogenic GHG emissions and uncertainties by gas – relative to 1990



The solid line indicates central estimate of emissions trends. The shaded area indicates the uncertainty range.



## b. Global anthropogenic GHG emissions and uncertainties by gas – relative to 1990



	2019 emissions (GtCO <sub>2</sub> -eq)	1990–2019 increase (GtCO <sub>2</sub> -eq)	Emissions in 2019, relative to 1990 (%)
CO <sub>2</sub> FFI	38±3	15	167
CO <sub>2</sub> LULUCF	6.6±4.6	1.6	133
CH <sub>4</sub>	11±3.2	2.4	129
N <sub>2</sub> O	2.7±1.6	0.65	133
F-gases	1.4±0.41	0.97	354
Total	59±6.6	21	154

The solid line indicates central estimate of emissions trends. The shaded area indicates the uncertainty range.



# VAGRANCY IN BIRDS

Alexander Lees &  
James Gilroy



# **META- AND META-META ANALYSIS OF HEALTH EFFECTS SECONDARY CLIMATE CHANGE**

R.J. ROCQUE ET AL. *BMJ*: 11. 2021. Review of 94 systemic reviews – 1/5<sup>th</sup> with Meta-analysis

- 1.) Infections (e.g., mosquitoes expanding territories)
- 2.) Mortality
- 3.) Respiratory, Cardiovascular, Nervous systems

THE RODNEY AND OIAMATEA TIMES,  
WEDNESDAY, AUGUST 14 1912.

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## Science Notes and News.

---

### COAL CONSUMPTION AFFECT- ING CLIMATE.

---

The furnaces of the world are now burning about 2,000,000,000 tons of coal a year. When this is burned, uniting with oxygen, it adds about 7,000,000,000 tons of carbon dioxide to the atmosphere yearly. This tends to make the air a more effective blanket for the earth and to raise its temperature. The effect may be considerable in a few centuries.

---



# WATER STRESS RANKINGS

By Reig, Maddocks & Gassert



## WATER STRESS BY COUNTRY

ratio of withdrawals to supply

- Low stress ( $< 10\%$ )
- Low to medium stress (10-25%)
- Medium to high stress (25-40%)
- High stress (40-60%)
- Extremely high stress ( $> 60\%$ )

This map shows the average exposure of water users in each country to water stress. The ratio of total withdrawals to total available supply in a given area. A higher percentage means more water users are competing for limited supplies. Source: WRI Aqueduct, Global 1.0, 2013.





# THE FIRST GLOBAL SCIENTIFIC CONFERENCE (TORONTO, 1988)

Described Climate Change:

“Humanity is conducting an unintended, uncontrolled, globally pervasive experiment whose ultimate consequence could be second only to a global nuclear war”

2012



# THE GREATEST HOAX

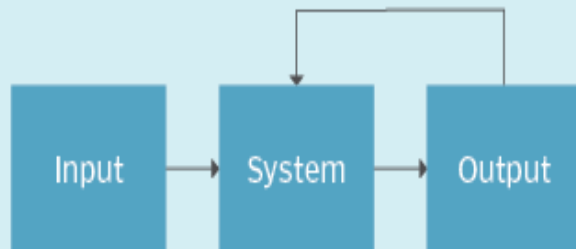
HOW THE GLOBAL WARMING CONSPIRACY  
THREATENS YOUR FUTURE

U.S. SENATOR JAMES INHOFE

# Types of feedback loops

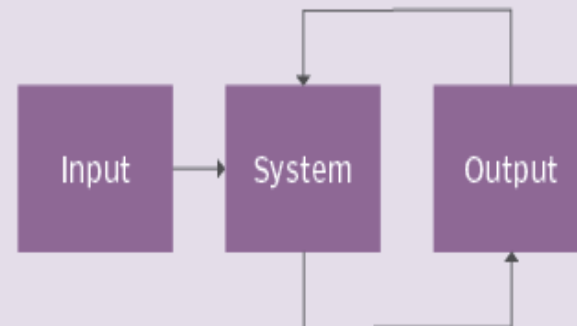
## Positive

POSITIVE FEEDBACK

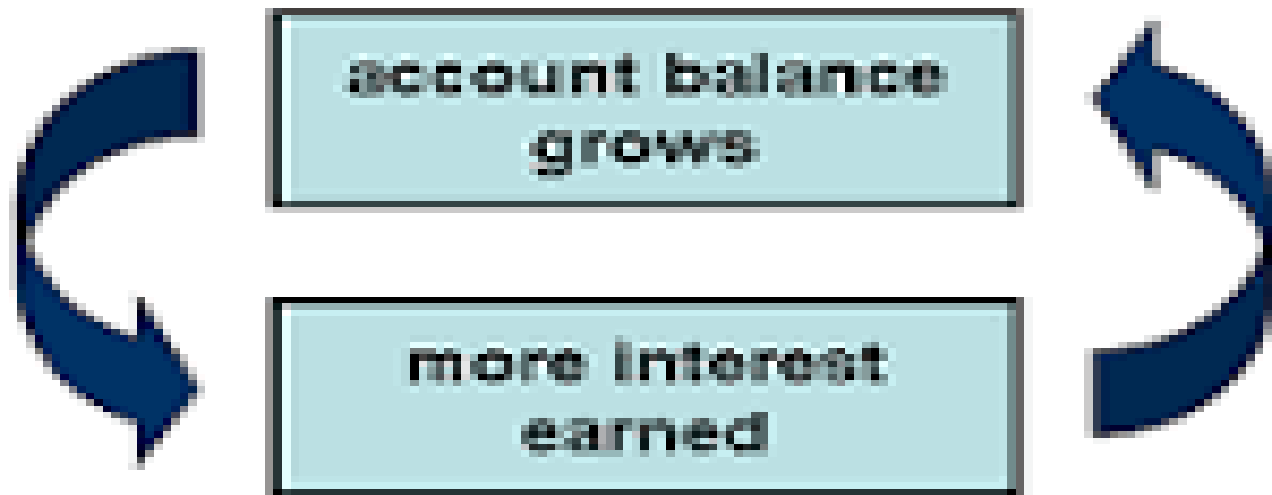


## Negative

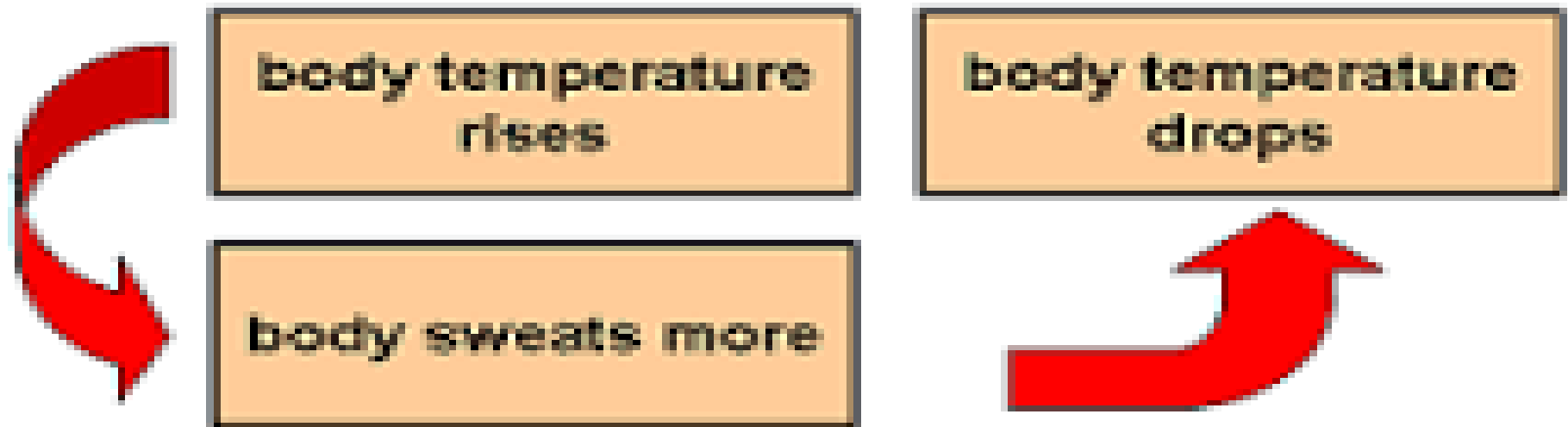
NEGATIVE FEEDBACK



## Positive feedback



## Negative feedback

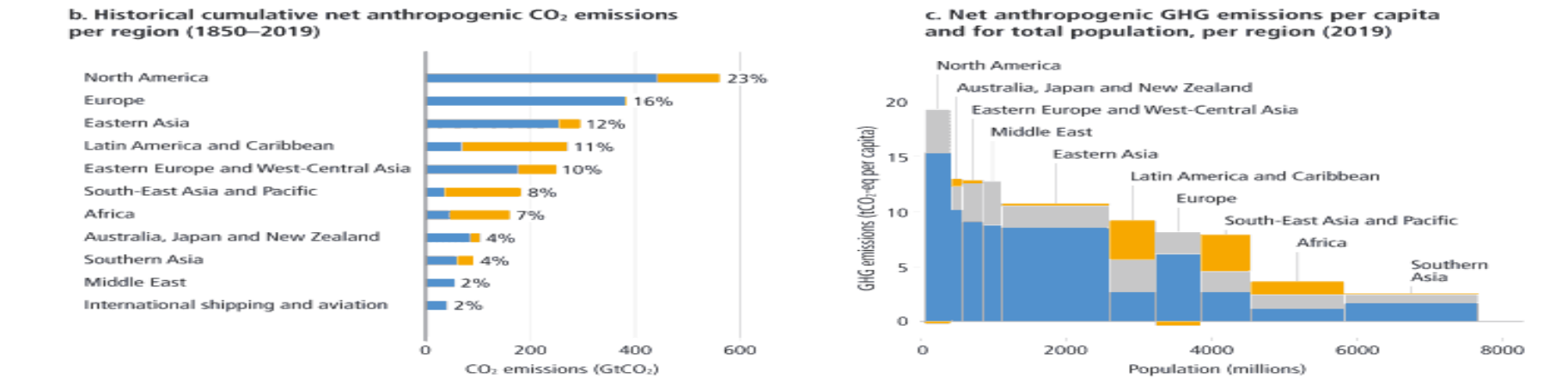
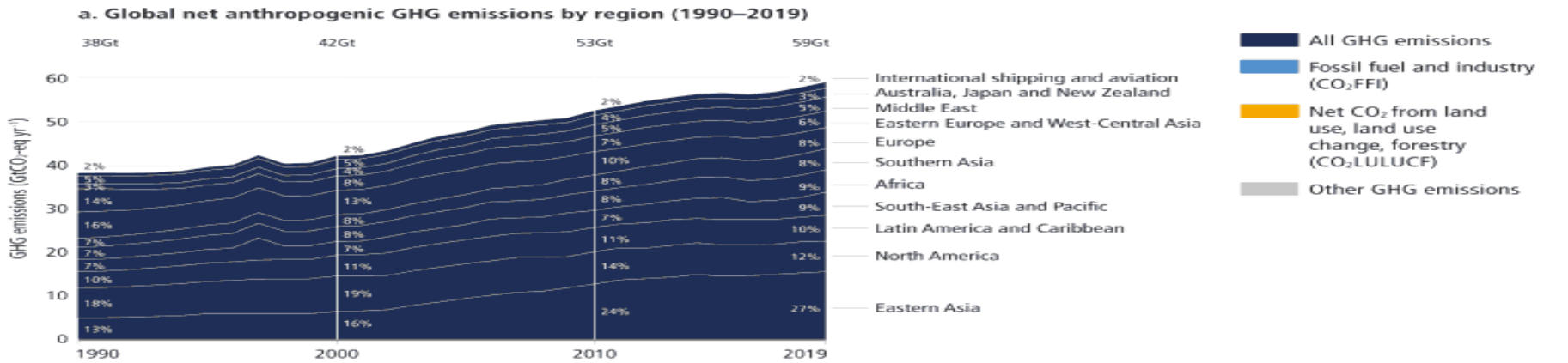


**Lynas et al. Oct 19, 2021. Environmental Research Letters 16:11,  
2021**

**Our finding is that the broadly-defined scientific consensus likely far exceeds 99% regarding the role of anthropogenic GHG emissions in modern climate change, and may even be as high as 99.9%. Of course, the prevalence of mis/disinformation about the role of GHG emissions in modern climate change is unlikely to be driven purely by genuine scientific illiteracy or lack of understanding [[14](#)]. Even so, in our view it remains important to continue to inform society on the state of the evidence. According to the IPCC AR6 summary and many other previous studies, mitigating future warming requires urgent efforts to eliminate fossil fuels combustion and other major sources of anthropogenic greenhouse gas emissions. **Our study helps confirm that there is no remaining scientific uncertainty about the urgency and gravity of this task.****



Emissions have grown in most regions but are distributed unevenly, both in the present day and cumulatively since 1850.



**d. Regional indicators (2019) and regional production vs consumption accounting (2018)**

	Africa	Australia, Japan, New Zealand	Eastern Asia	Eastern Europe, West-Central Asia	Europe	Latin America and Caribbean	Middle East	North America	South-East Asia and Pacific	Southern Asia
Population (million persons, 2019)	1292	157	1471	291	620	646	252	366	674	1836
GDP per capita (USD1000 <sub>2017</sub> per person) <sup>1</sup>	5.0	43	17	20	43	15	20	61	12	6.2
<b>Net GHG 2019<sup>2</sup> (production basis)</b>										
% GHG contributions	9%	3%	27%	6%	8%	10%	5%	12%	9%	8%
GHG emissions intensity (tCO <sub>2</sub> -eq / USD1000 <sub>2017</sub> )	0.78	0.30	0.62	0.64	0.18	0.61	0.64	0.31	0.65	0.42
GHG per capita (tCO <sub>2</sub> -eq per person)	3.9	13	11	13	7.8	9.2	13	19	7.9	2.6
<b>CO<sub>2</sub>FFI, 2018, per person</b>										
Production-based emissions (tCO <sub>2</sub> FFI per person, based on 2018 data)	1.2	10	8.4	9.2	6.5	2.8	8.7	16	2.6	1.6
Consumption-based emissions (tCO <sub>2</sub> FFI per person, based on 2018 data)	0.84	11	6.7	6.2	7.8	2.8	7.6	17	2.5	1.5

<sup>1</sup> GDP per capita in 2019 in USD2017 currency purchasing power basis.  
<sup>2</sup> Includes CO<sub>2</sub>FFI, CO<sub>2</sub>LULUCF and Other GHGs, excluding international aviation and shipping.  
The regional groupings used in this figure are for statistical purposes only and are described in Annex II, Part I.

# Increasing precipitation volatility in twenty-first-century California

[Daniel L. Swain](#),

[Baird Langenbrunner](#),

[J. David Neelin](#) &

[Alex Hall](#)

[Nature Climate Change](#) **volume 8**, pages 427–433  
(2022)

# LETTER • THE FOLLOWING ARTICLE IS **OPEN ACCESS**

**Greater than 99% consensus on human caused climate change in the peer-reviewed scientific literature**

Mark Lynas<sup>4,1</sup>, Benjamin Z Houlton<sup>2</sup> and Simon Perry<sup>3</sup>

Published 19 October 2021 • © 2021 The Author(s). Published by IOP Publishing Ltd

[Environmental Research Letters](#), [Volume 16](#), [Number 11](#) **Citation** Mark Lynas *et al* 2021 *Environ. Res. Lett.* **16** 114005

**Mark Lynas. 2021. Environmental Research letters.**

From a dataset of **88125 climate-related papers** published since **2012**, when this question was last addressed comprehensively, **we examine a randomized subset of 3000 such publications.** We

also use a second sample-weighted approach that was specifically biased with keywords to help identify any sceptical peer-reviewed papers in the whole dataset. **We identify four sceptical papers out of the sub-set of 3000**, as evidenced by abstracts that were rated as implicitly or explicitly sceptical of human-caused global warming. **In our sample utilizing pre-identified sceptical keywords we found 28 papers that were**

**implicitly or explicitly sceptical. We conclude with high statistical confidence that the scientific consensus on human-caused contemporary climate change—expressed as a proportion of the total publications—exceeds 99% in the peer reviewed scientific literature.**

## **What's taking on climate change...**

### **The Securities and Exchange**

**Commission**. Yesterday, the SEC voted to propose regulations that would require publicly traded companies to report their greenhouse gas emissions. And how climate change exposure is affecting their business. It's the first time companies are facing mandatory disclosure rules. While all would need to report how much greenhouse gas emissions they emit, only larger companies would need to report how much they're indirectly responsible for (think: from suppliers and customers). It's not yet clear how many employees a company would need to have in order to meet the higher bar. Next up: the proposal goes to the public for comment.

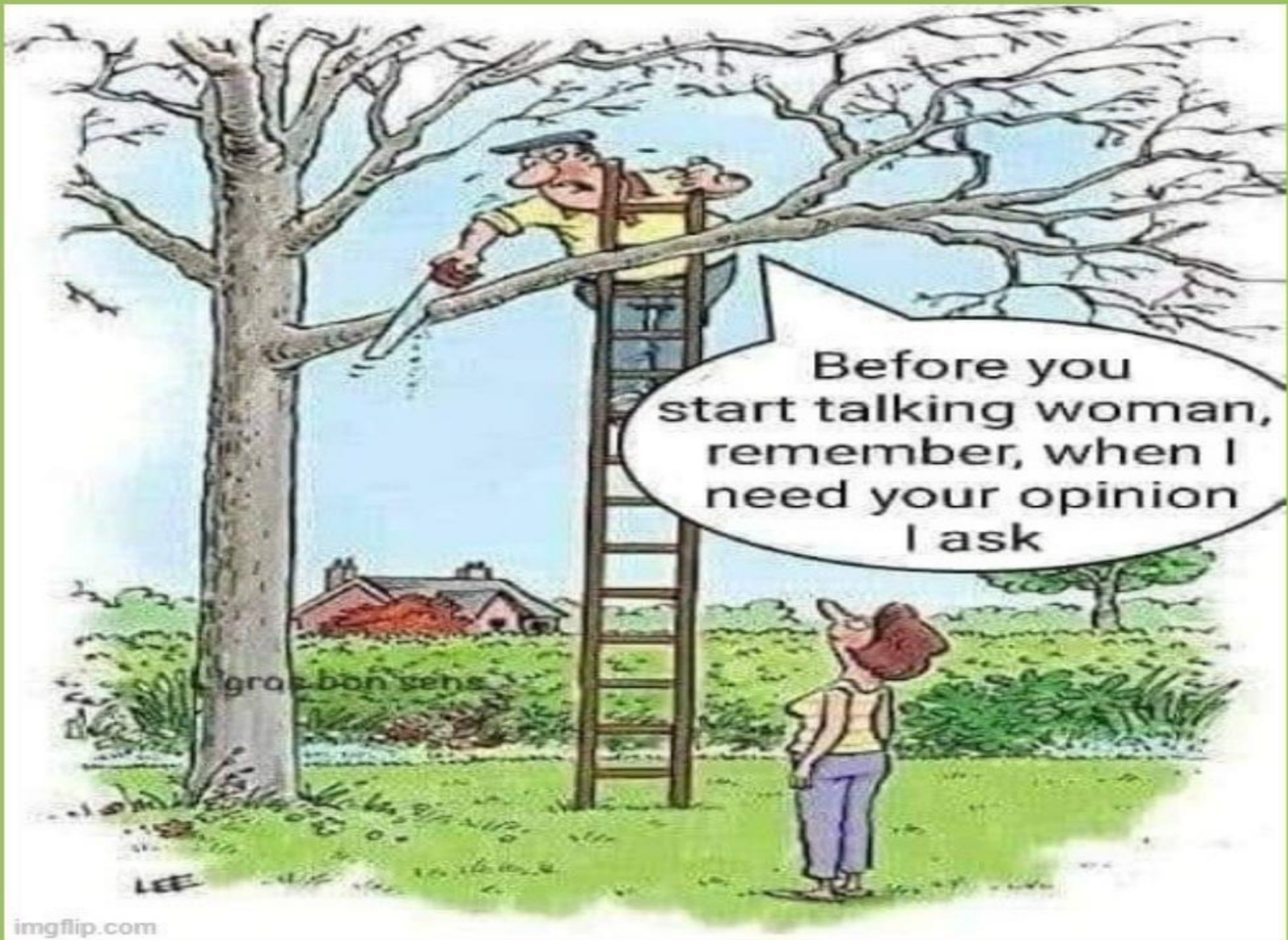


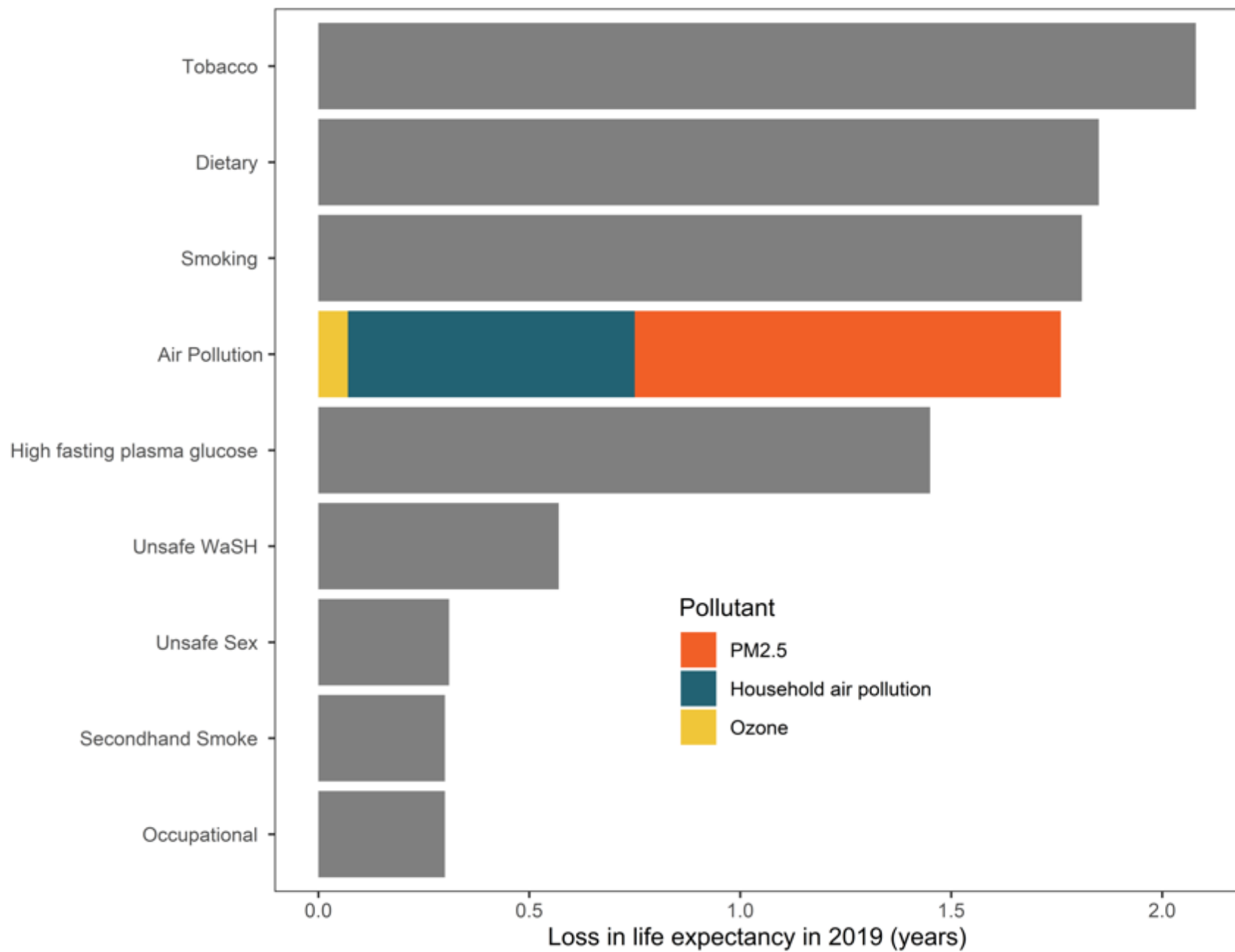
# **Misinformation is derailing renewable energy projects across the United States**

**NPR**

March 28, 2022 5:00 AM ET

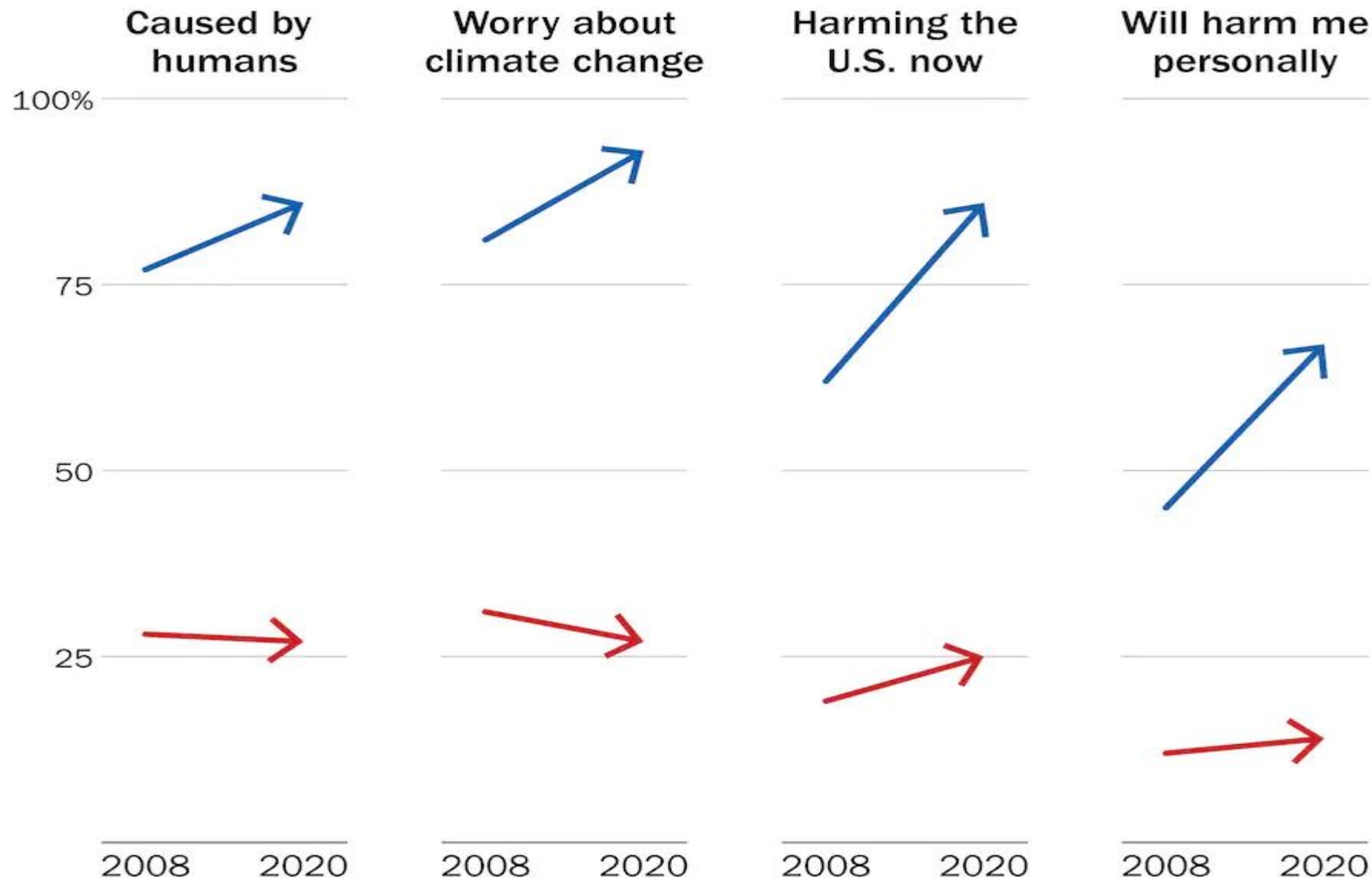
**JULIA SIMON**





# Views of climate change by party and ideology

➡ Liberal Democrat ➡ Conservative Republican



Source: Yale Program on Climate Change Communication

THE WASHINGTON POST

# **In Brief: NASA 2021**

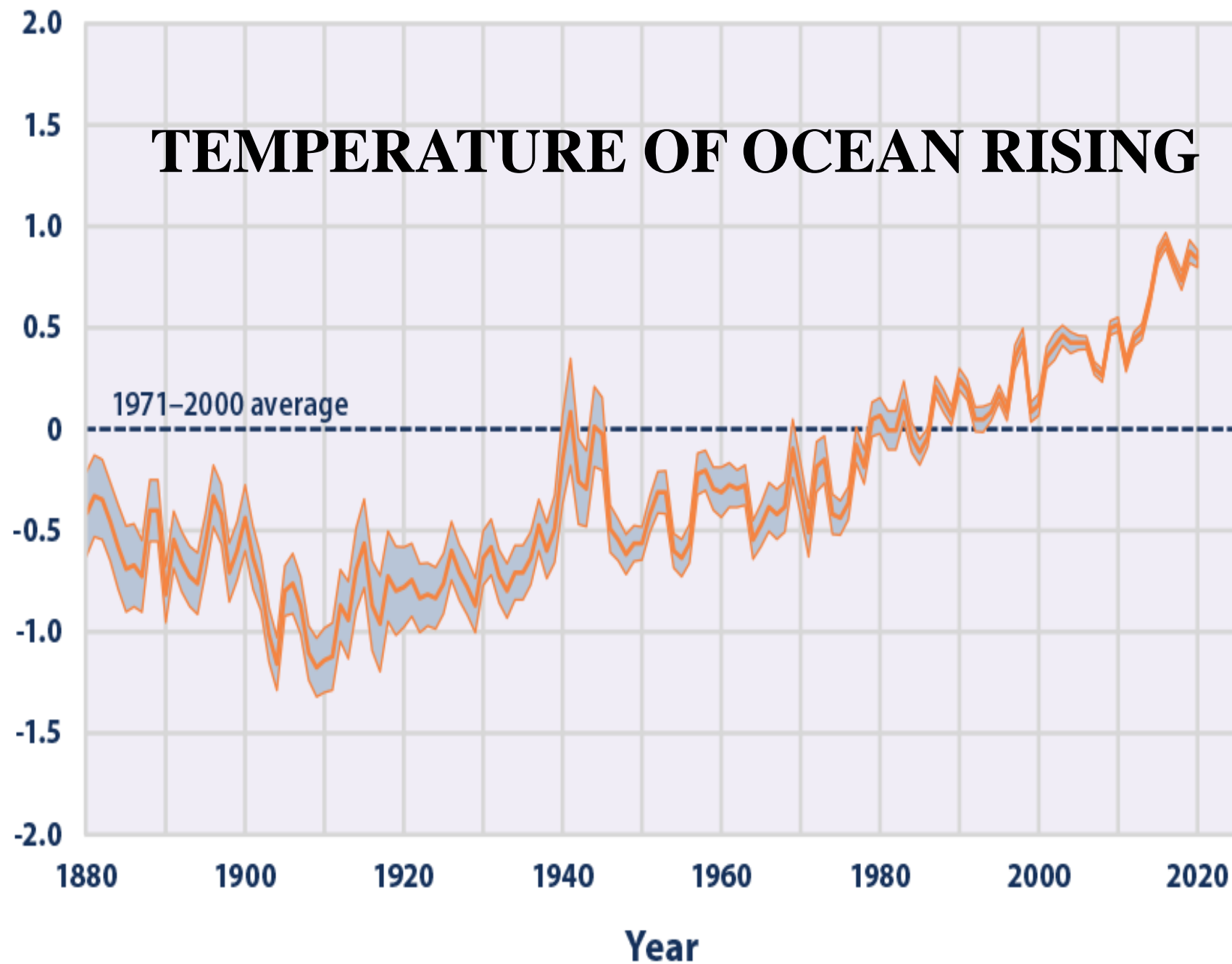
Global sea levels are rising as a result of human-caused global warming, with recent rates being unprecedented over the past 2,000-plus years.

Sea level rise is caused primarily by two factors related to global warming: the added water from melting ice sheets and glaciers and the expansion of seawater as it warms. The first graph tracks the change in sea level since 1993 as observed by satellites.

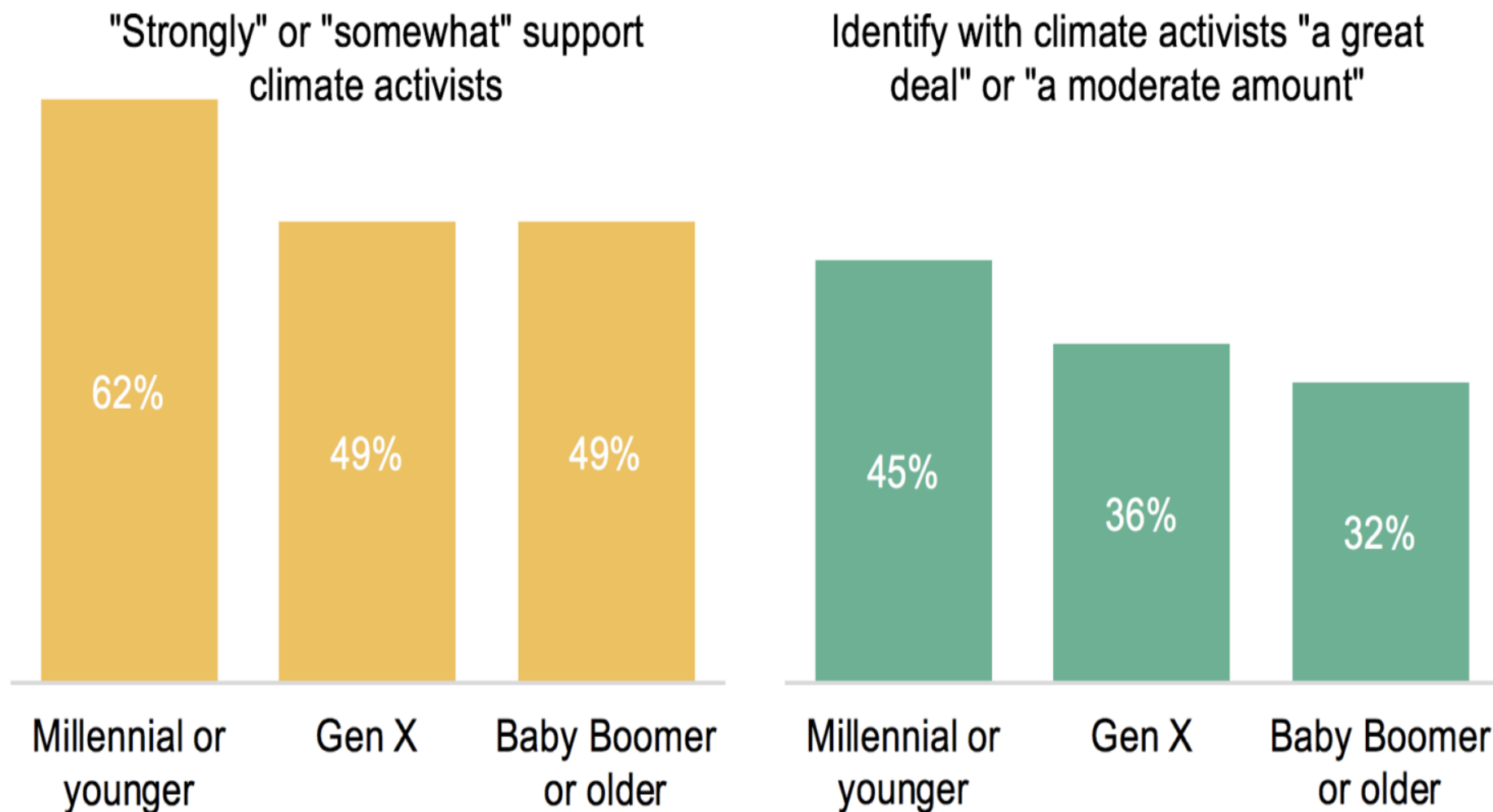


# TEMPERATURE OF OCEAN RISING

Temperature anomaly (°F)



# Younger generations of Americans, more than older generations, support and identify with climate activists who urge elected officials to act on global warming



Nov 2019. Base: 1,303 U.S. adults – Millennial or younger (1981 or later)  $n = 375$ ; Gen X (1965 – 1980)  $n = 336$ ; Baby Boomer or older (1964 or earlier)  $n = 592$



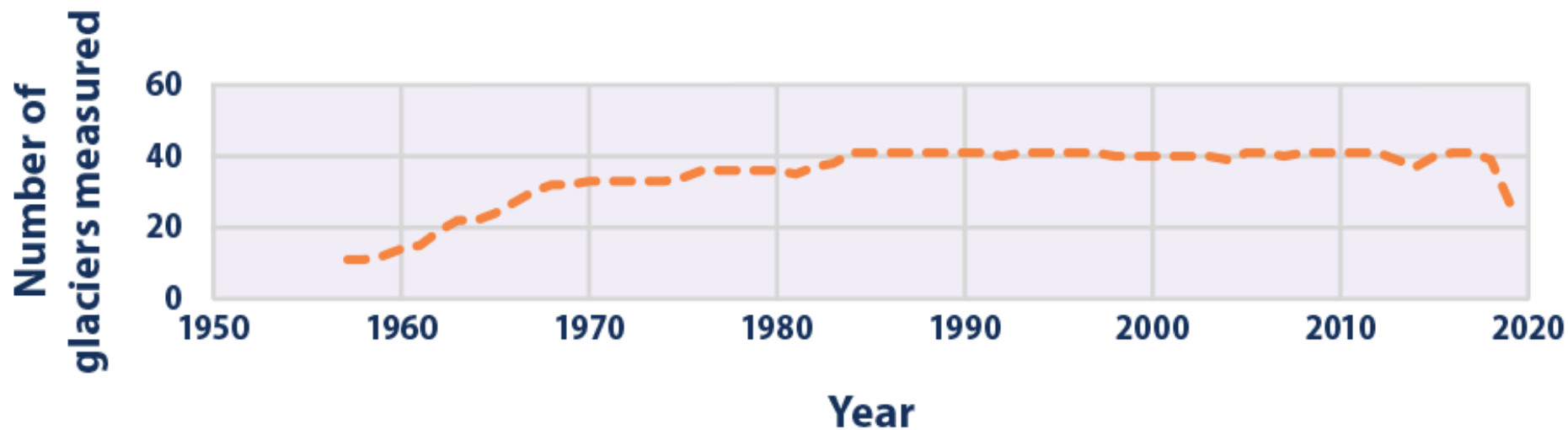
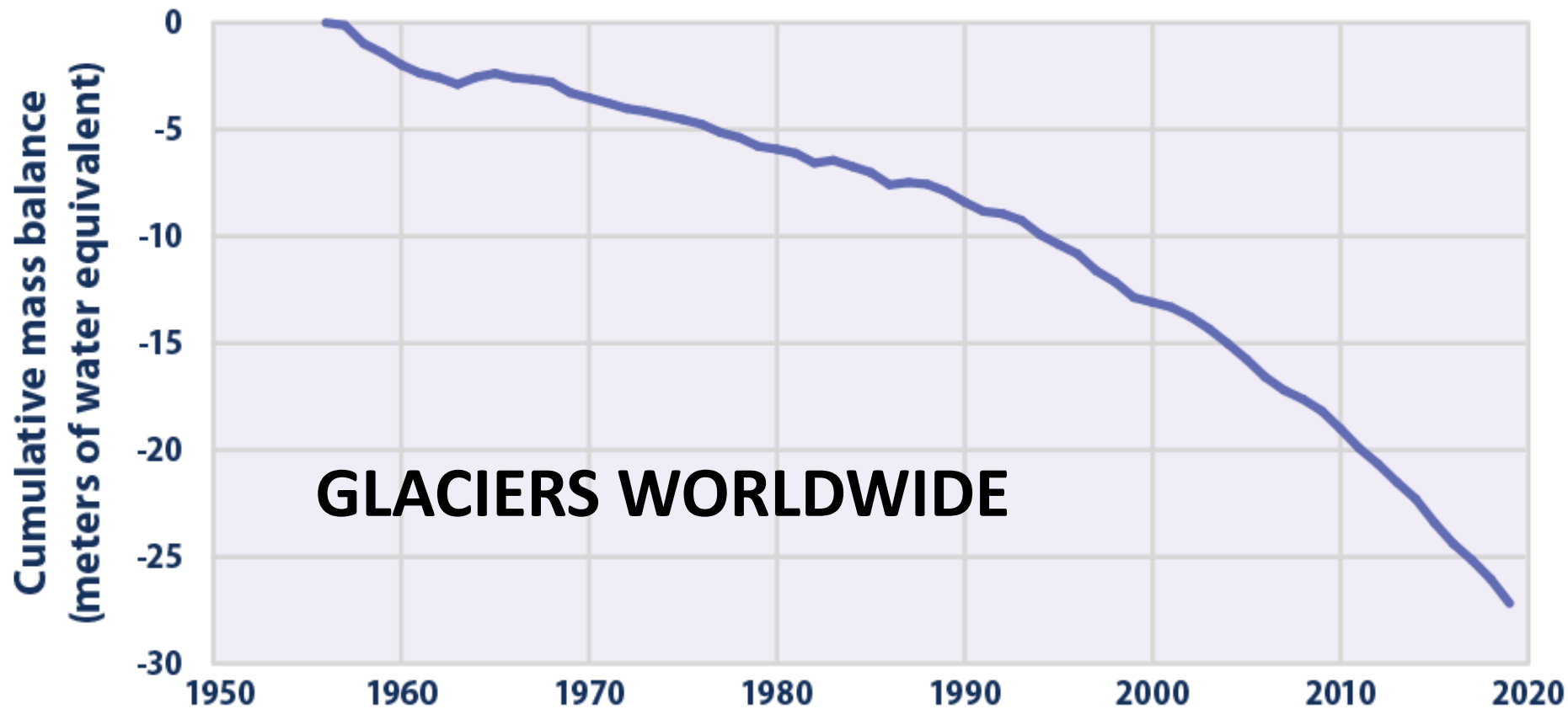
YALE PROGRAM ON  
Climate Change  
Communication

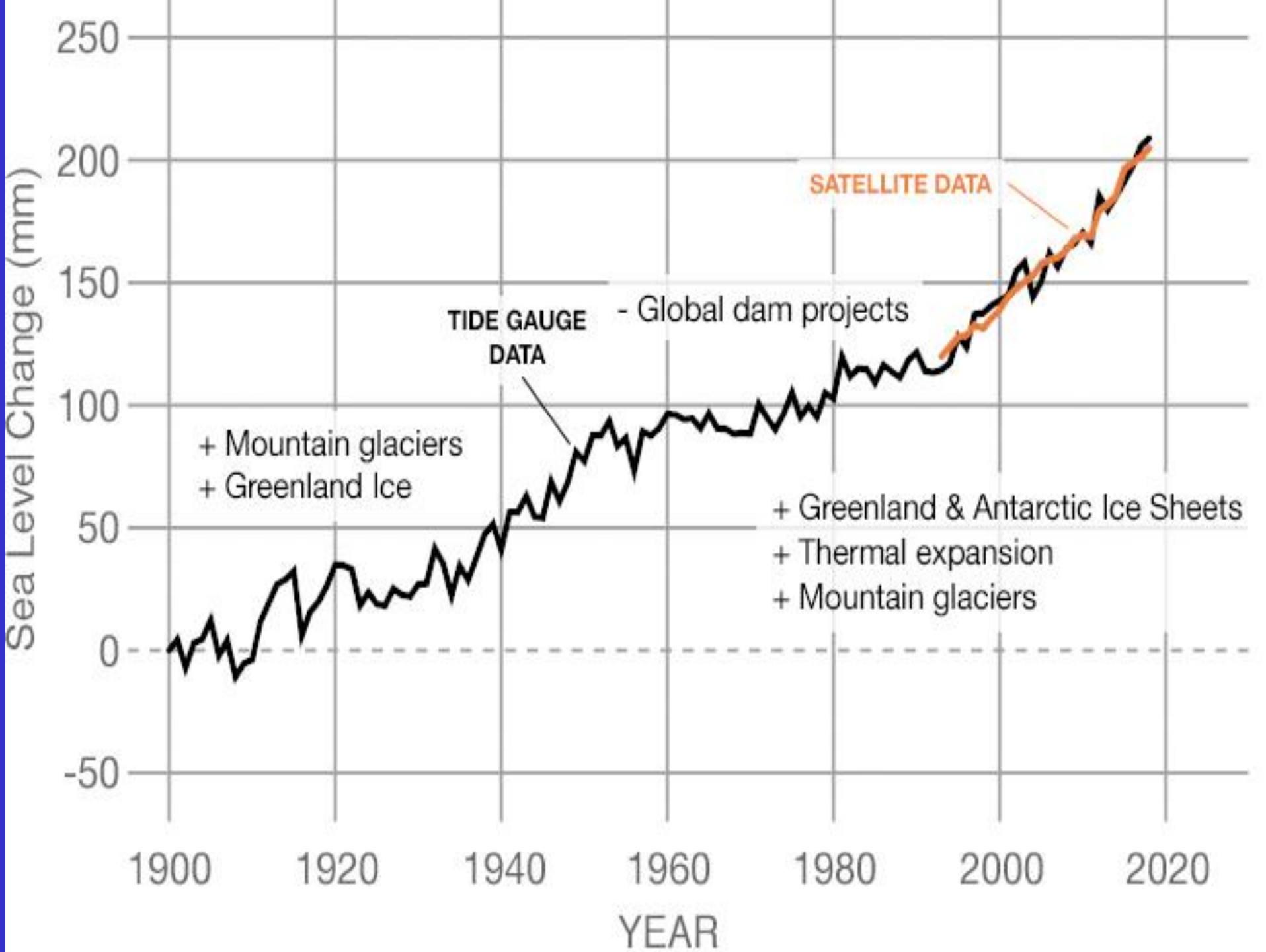


GEORGE MASON UNIVERSITY  
CENTER for CLIMATE CHANGE  
COMMUNICATION

# NEVER WASTE A CRISIS: HOW A TENNESSEE BILL SILENCES COMMUNITIES IN THE NAME OF ENERGY SECURITY

- ~~The Climate Reality Project~~ ~~3/17/2022~~ of the assault on democracy in Ukraine to undermine democracy and community self-determination at home. Chances are, it's just the beginning. Credit the fossil fuel crowd for never missing an opportunity to turn current events into a pretext for more pipelines. (Aka, doing what they wanted to do anyway.)  
For the in this never-waste-a-crisis







# Does drought alter hydrological functions in forest soils?

**Katharina F. Gimbel<sup>1</sup>, Heike**

**Puhlmann<sup>2</sup>, and Markus Weiler<sup>1</sup>**  
Hydrology,  
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Resources, University of Freiburg, Freiburg,  
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**Accepted: 29 Feb 2016 – Published: 01 Apr 2016.** Climate change is expected to impact the water cycle and severely affect precipitation patterns across central Europe and in other parts of the world, leading to more frequent and severe droughts

# **Global Assessment Report on Biodiversity and Ecosystem Services**

IPBES is to perform regular and timely assessments of knowledge on biodiversity and ecosystem services and their interlinkages at the global level. Also addressing an invitation by the Conference of the Parties of the Convention on Biological Diversity (CBD) to prepare a global assessment of biodiversity and ecosystem services building, inter alia, on its own and other relevant regional, subregional and thematic assessments, as well as on national reports.

# Consensus on consensus: a synthesis of consensus estimates on human-caused global warming

John Cook<sup>16,1,2,3</sup>, Naomi Oreskes<sup>4</sup>, Peter T Doran<sup>5</sup>, William R L Anderegg<sup>6,7</sup>, Bart Verheggen<sup>8</sup>, Ed W Maibach<sup>9</sup>, J Stuart Carlton<sup>10</sup>, Stephan Lewandowsky<sup>11,2</sup>, Andrew G Skuce<sup>12,3</sup>, Sarah A Green<sup>13</sup> Published 13 April

2016 • © 2016 IOP Publishing Ltd

[Environmental Research Letters](#), [Volume 11](#), [Number 4](#)

**Citation** John Cook *et al* 2016 *Environ. Res. Lett.* **11** 048002

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The consensus that humans are causing recent global warming is shared by 90%–100% of publishing climate scientists according to six independent studies by co-authors of this paper. Those results are consistent with the 97% consensus reported by Cook *et al* (*Environ. Res. Lett.* [8 024024](#)) based on 11 944 abstracts of research papers, of which 4014 took a position on the cause of recent global warming. A survey of authors of those papers ( $N = 2412$  papers) also supported a 97% consensus. Tol (2016 *Environ. Res. Lett.* [11 048001](#)) comes to a different conclusion using results from surveys of non-experts such as economic geologists and a self-selected group of those who reject the consensus. We demonstrate that this outcome is not unexpected because the level of consensus correlates with expertise in climate science. At one point, Tol also reduces the apparent consensus by assuming that abstracts that do not explicitly state the cause of global warming ('no position') represent non-endorsement, an approach that if applied elsewhere would reject consensus on well-established theories such as plate tectonics. We examine the available studies and **conclude that the finding of 97% consensus in published climate research is robust and consistent with other surveys of climate scientists and peer-reviewed studies.**

# SMOG IN CHINA





**DEFORTESTATION**





Impact of fire on montane snowpack energy  
balance in Snow Gum forest stands

Author links open overlay panel [Andrew](#)

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**SUMMARIES OF  
SIXTH IPCC  
REPORT  
FOLLOWS  
(2022)**

# **IPCC SIXTH REPORT: Climate Change 2022: Impacts, Adaptation and Vulnerability (270 authors; 67 countries (Feb 27, 2022; 3675 pages)**

The Working Group II contribution to the IPCC Sixth Assessment Report assesses the impacts of climate change, looking at ecosystems, biodiversity, and human communities at global and regional levels. It also reviews vulnerabilities and the capacities and limits of the natural world and human societies to adapt to climate change.

**SPM.B.1 Human-induced climate change,** including more frequent and intense extreme events, has caused widespread adverse impacts and related losses and damages to nature and people, beyond natural climate variability. Some development and adaptation efforts have reduced vulnerability.

Across sectors and regions the most vulnerable people and systems are observed to be disproportionately affected. The rise in weather and climate extremes has led to some irreversible impacts as natural and human systems are pushed beyond their ability to adapt. (high confidence)



**SPM.B.1.1 Widespread, pervasive impacts to ecosystems, people, settlements, and infrastructure have resulted from observed increases in the frequency and intensity of climate and weather extremes, including hot extremes on land and in the ocean, heavy precipitation events, drought and fire weather (high confidence).**

**SPM.D.5 It is unequivocal that climate change has already disrupted human and natural systems. Past and current development trends (past emissions, development and climate change) have not advanced global climate resilient development (very high confidence).** Societal choices and actions implemented in the next decade determine the extent to which medium- and long-term pathways will deliver higher or lower climate resilient development (high confidence).

Importantly climate resilient development prospects are increasingly limited if current greenhouse gas emissions do not rapidly decline, especially if 1.5°C global warming is exceeded in the near term (high confidence). These prospects are constrained by past development, emissions and climate change, and enabled by inclusive governance, adequate and appropriate human and technological resources, information, capacities and finance (high confidence).

**SPM.B.1.2 Climate change has caused substantial damages, and increasingly irreversible losses, in terrestrial, freshwater and coastal and open ocean marine ecosystems** (high confidence). The extent and magnitude of climate change impacts are larger than estimated in previous assessments (high confidence). Widespread deterioration of ecosystem structure and function, resilience and natural adaptive capacity, as well as shifts in seasonal timing have occurred due to climate change (high confidence), with adverse socioeconomic consequences (high confidence). Approximately half of the species assessed globally have shifted polewards or, on land, also to higher elevations (very high confidence). Hundreds of local losses of species have been driven by increases in the magnitude of heat extremes (high confidence), as well as mass mortality events on land and in the ocean (very high confidence) and loss of kelp forests (high confidence).

**SPM.B.1.3 Climate change including increases in frequency and intensity of extremes have reduced food and water security**, hindering efforts to meet Sustainable Development Goals (high confidence). Although overall agricultural productivity has increased, climate change has slowed this growth over the past 50 years globally (medium confidence), related negative impacts were mainly in mid- and low latitude regions but positive impacts occurred in some high latitude regions (high confidence). Ocean warming and ocean acidification have adversely affected food production from shellfish aquaculture and fisheries in some oceanic regions (high confidence). Increasing weather and climate extreme events have exposed millions of people to acute food insecurity<sup>30</sup> and reduced water security

**SPM.B.1.4 Climate change has adversely affected physical health of people globally** (very high confidence) and mental health of people in the assessed regions (very high confidence). Climate change impacts on health are mediated through natural and human systems, including economic and social conditions and disruptions (high confidence). In all regions extreme heat events have resulted in human mortality and morbidity (very high confidence). The occurrence of climate-related food-borne and water-borne diseases has increased (very high confidence). The incidence of vector-borne diseases has increased from range expansion and/or increased reproduction of disease vectors (high confidence). Animal and human diseases, including zoonoses, are emerging in new areas (high confidence). Water and food-borne disease risks have increased regionally



**SPM.B.1.5 In urban settings, observed climate change has caused impacts on human health, livelihoods and key infrastructure** (high confidence). Multiple climate and non-climate hazards impact cities, settlements and infrastructure and sometimes coincide, magnifying damage (high confidence). Hot extremes including heatwaves have intensified in cities (high confidence), where they have also aggravated air pollution events (medium confidence) and limited functioning of key infrastructure (high confidence). Observed impacts are concentrated amongst the economically and socially marginalized urban residents,

**SPM.B.2 Vulnerability of ecosystems and people to climate change differs substantially among and within regions** (very high confidence), driven by patterns of intersecting socio-economic development, unsustainable ocean and land use, inequity, marginalization, historical and ongoing patterns of inequity such as colonialism, and governance<sup>31</sup> (high confidence). Approximately 3.3 to 3.6 billion people live in contexts that are highly vulnerable to climate change (high confidence). A high proportion of species is vulnerable to climate change (high confidence). Human and ecosystem vulnerability are interdependent (high confidence). Current unsustainable development patterns are increasing exposure of ecosystems and people to climate hazards (high confidence)

**SPM.B.2.1 Since AR5 there is increasing evidence that degradation and destruction of ecosystems by humans increases the vulnerability of people** (high confidence). Unsustainable land-use and land cover change, unsustainable use of natural resources, deforestation, loss of biodiversity, pollution, and their interactions, adversely affect the capacities of ecosystems, societies, communities and individuals to adapt to climate change (high confidence). Loss of ecosystems and their services has cascading and long-term impacts on people globally

**SPM.B.3 Global warming, reaching 1.5°C in the near-term, would cause unavoidable increases in multiple climate hazards and present multiple risks to ecosystems and humans (very high confidence).** The level of risk will depend on concurrent near-term trends in vulnerability, exposure, level of socioeconomic development and adaptation (high confidence). Near-term actions that limit global warming to close to 1.5°C would substantially reduce projected losses and damages related to climate change in human systems and ecosystems, compared to higher warming levels, but cannot eliminate them all (very high confidence)

**SPM.B.4 Beyond 2040 and depending on the level of global warming, climate change will lead to numerous risks to natural and human systems (high confidence).** For 127 identified key risks, assessed mid- and longterm impacts are up to multiple times higher than currently observed (high confidence). The magnitude and rate of climate change and associated risks depend strongly on near-term mitigation and adaptation actions, and projected adverse impacts and related losses and damages escalate with every increment of global warming (very high confidence).



**SPM.B.5 Climate change impacts and risks are becoming increasingly complex and more difficult to manage.** Multiple climate hazards will occur simultaneously, and multiple climatic and non-climatic risks will interact, resulting in compounding overall risk and risks cascading across sectors and regions. Some responses to climate change result in new impacts and risks. (high confidence)

**SPM.B.6 If global warming transiently exceeds 1.5°C in the coming decades or later (overshoot)<sup>37</sup>, then many human and natural systems will face additional severe risks, compared to remaining below 1.5°C (high confidence). Depending on the magnitude and duration of overshoot, some impacts will cause release of additional greenhouse gases (medium confidence) and some will be irreversible, even if global warming is reduced (high confidence).**

**Economic damages from climate change have been detected** in climate-exposed sectors, with regional effects to agriculture, forestry, fishery, energy, and tourism (high confidence), and through outdoor labour productivity (high confidence). Some extreme weather events, such as tropical cyclones, have reduced economic growth in the short-term (high confidence).

With the tragedy unfolding in Ukraine unsettling global energy markets and inflation a real concern for millions, pro-fossil fuel lawmakers turned what was supposed to be an innocuous measure to study energy infrastructure into a virtual blank check for energy developers.

The bill in question is the combination of Senate Bill 2077 (SB 2077) and House Bill 2246 (HB 2246). After beginning life with a very different focus, the bill was rewritten in early March with amendments that would pre-empt or void any local government ordinance restricting energy development in any county in Tennessee. The effect would be to strip local communities and legislators of any say or decision-making power when it comes to where oil and gas pipelines, storage tanks, infrastructure are placed. I

# **PHYSICAL MODELS VIA COMPUTER TESTING: PREDICTON OF CLIMATE CHANGE**

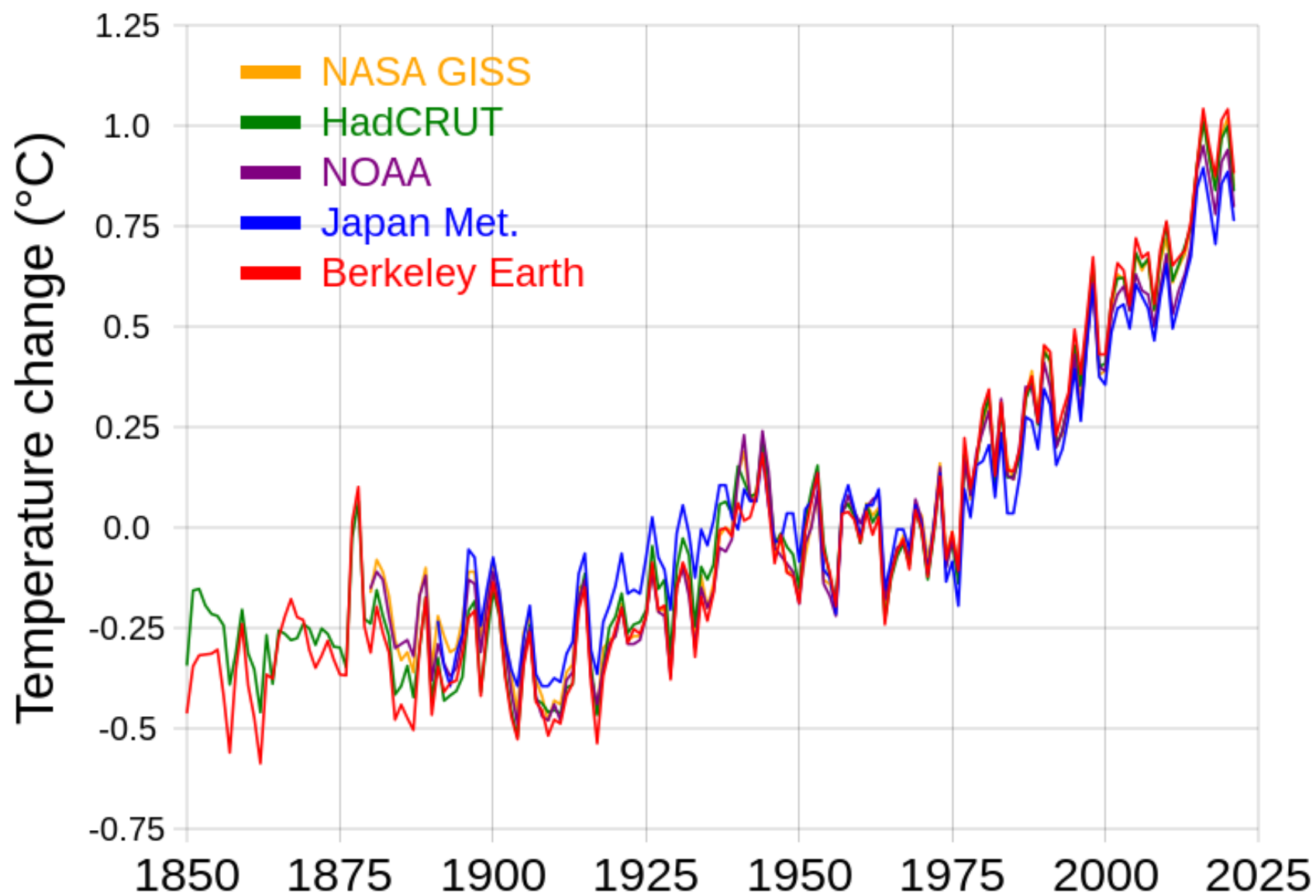
- Arctic shrinking
- Precipitation
- Sea level rise
- Relevant Feedback systems

(Actually all getting worse, than initial predictions)

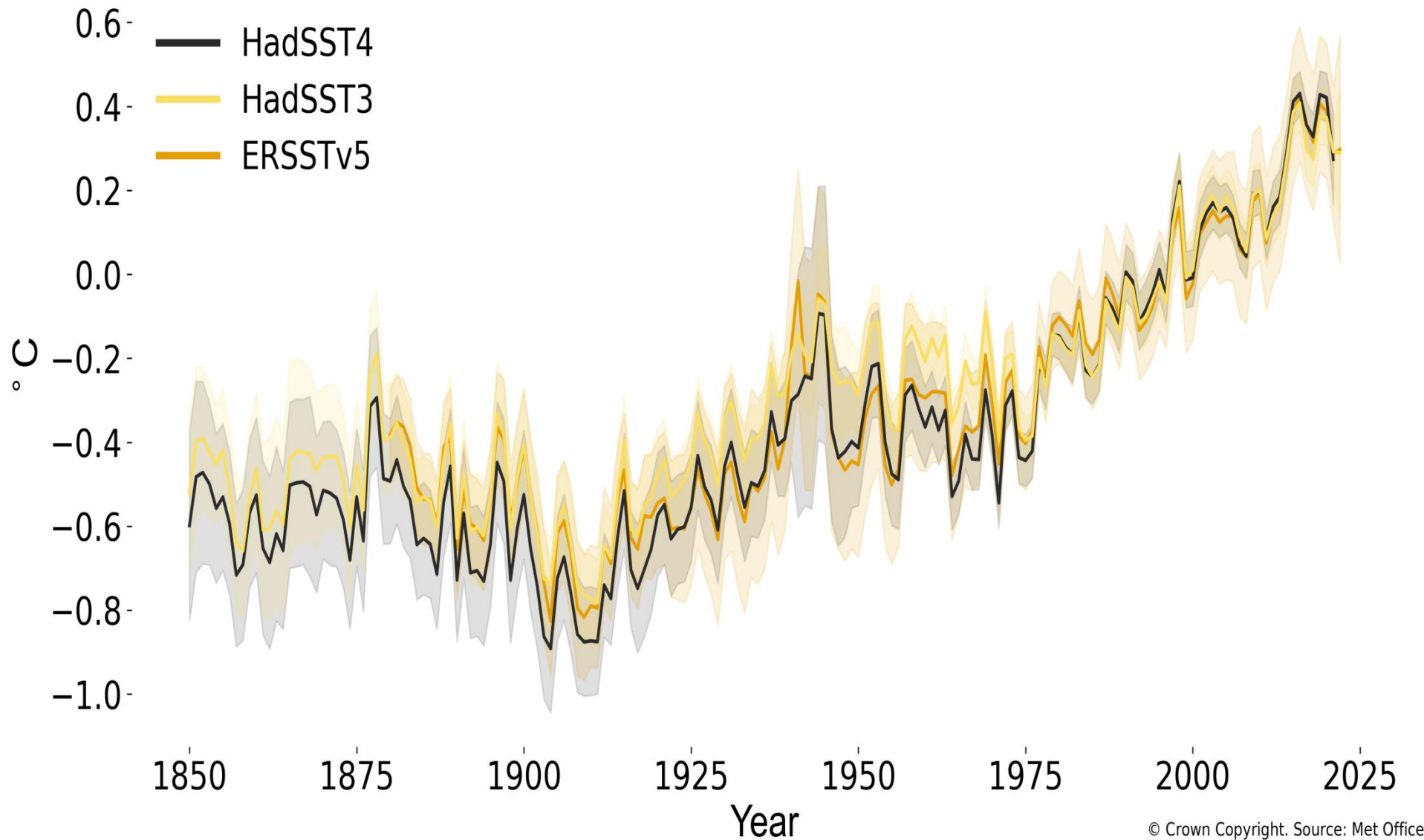
(Now getting better predictions)



# Global average temperature change



## Sea surface temperature difference from 1981-2010 (°C)



Post-wildfire extreme rainfall events can have destructive impacts in the western United States. Using two climate model large ensembles, we assess **the future risk of extreme fire weather events being followed by extreme rainfall in this region**. By mid-21st century, in a high warming scenario (RCP8.5), we report large increases in the number of extreme fire weather events followed within 1 year by at least one extreme rainfall event. By 2100, the frequency of these compound events increases by 100% in California and 700% in the Pacific Northwest in the Community Earth System Model v1 Large Ensemble. We further project that more than 90% of extreme fire weather events in California, Colorado, and the Pacific Northwest will be followed by at least three spatially colocated extreme rainfall events within five years. Our results point to a **future with substantially increased post-fire hydrologic risks across much of the western United States**. *Science D. Touma. Nat. Cnt. Atmosph. Res. 2022*







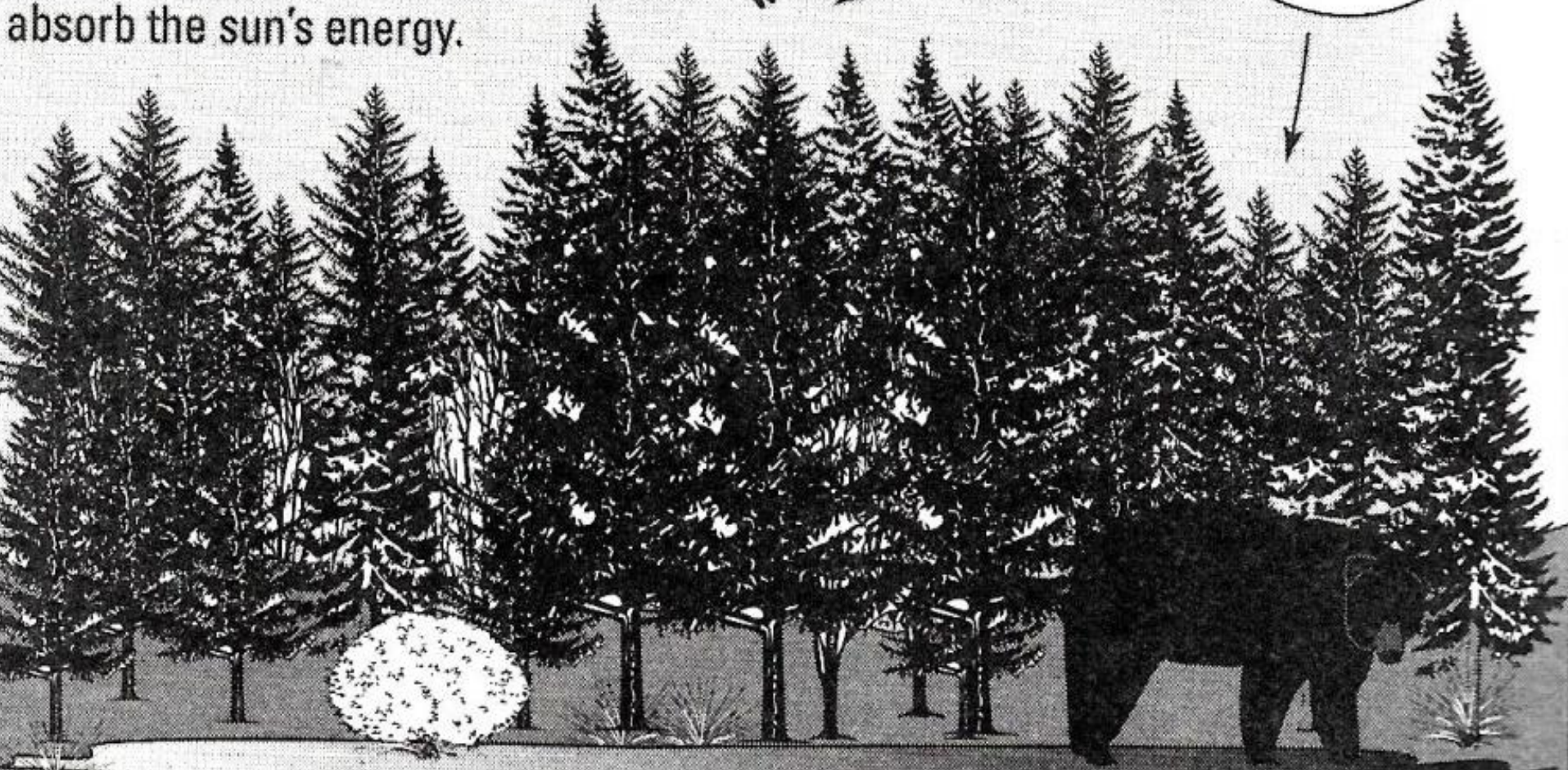




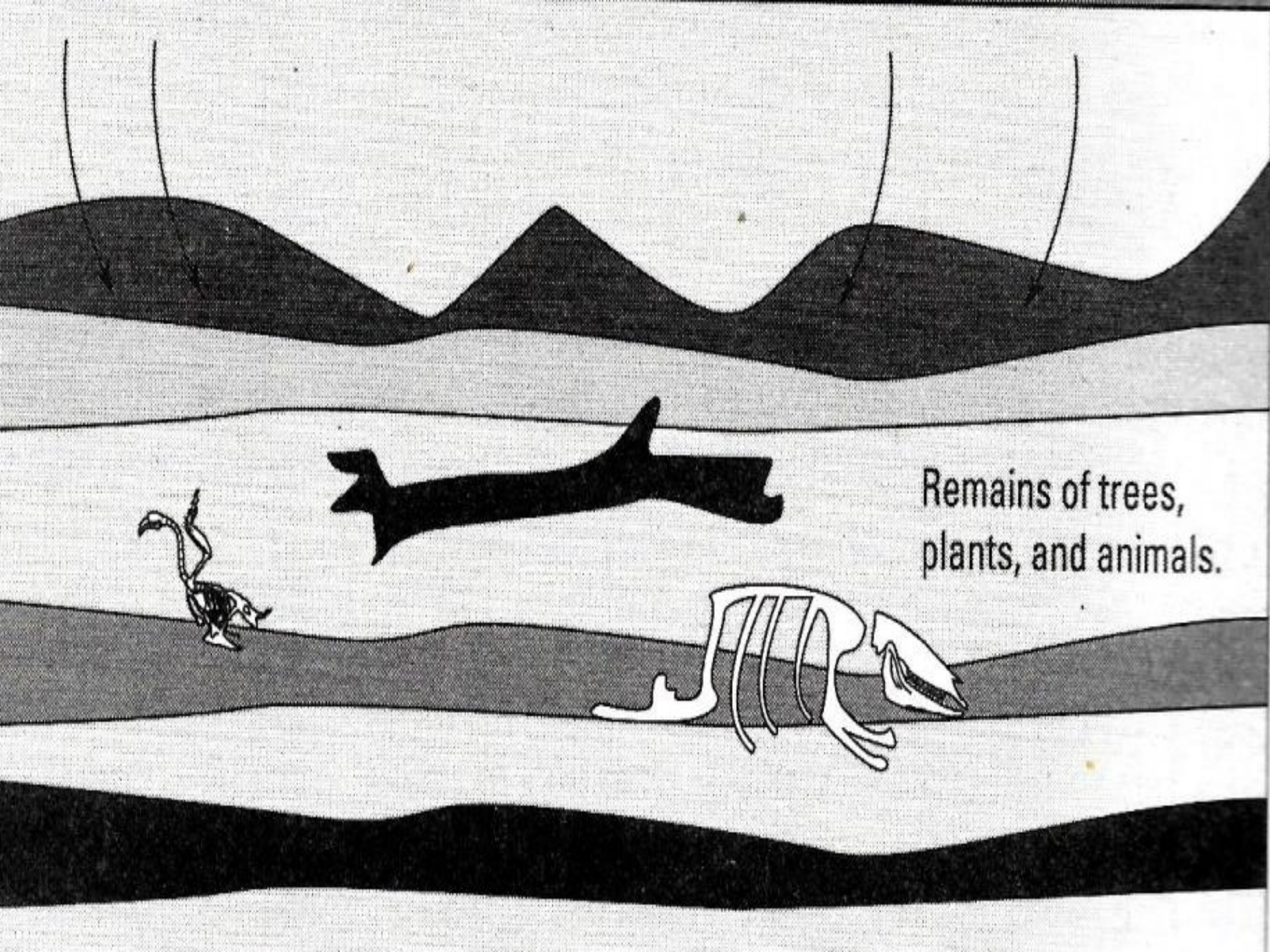
# The Creation of Fossil Fuels

The sun is the  
ultimate source  
of energy.

Tree, plants, and animals  
absorb the sun's energy.

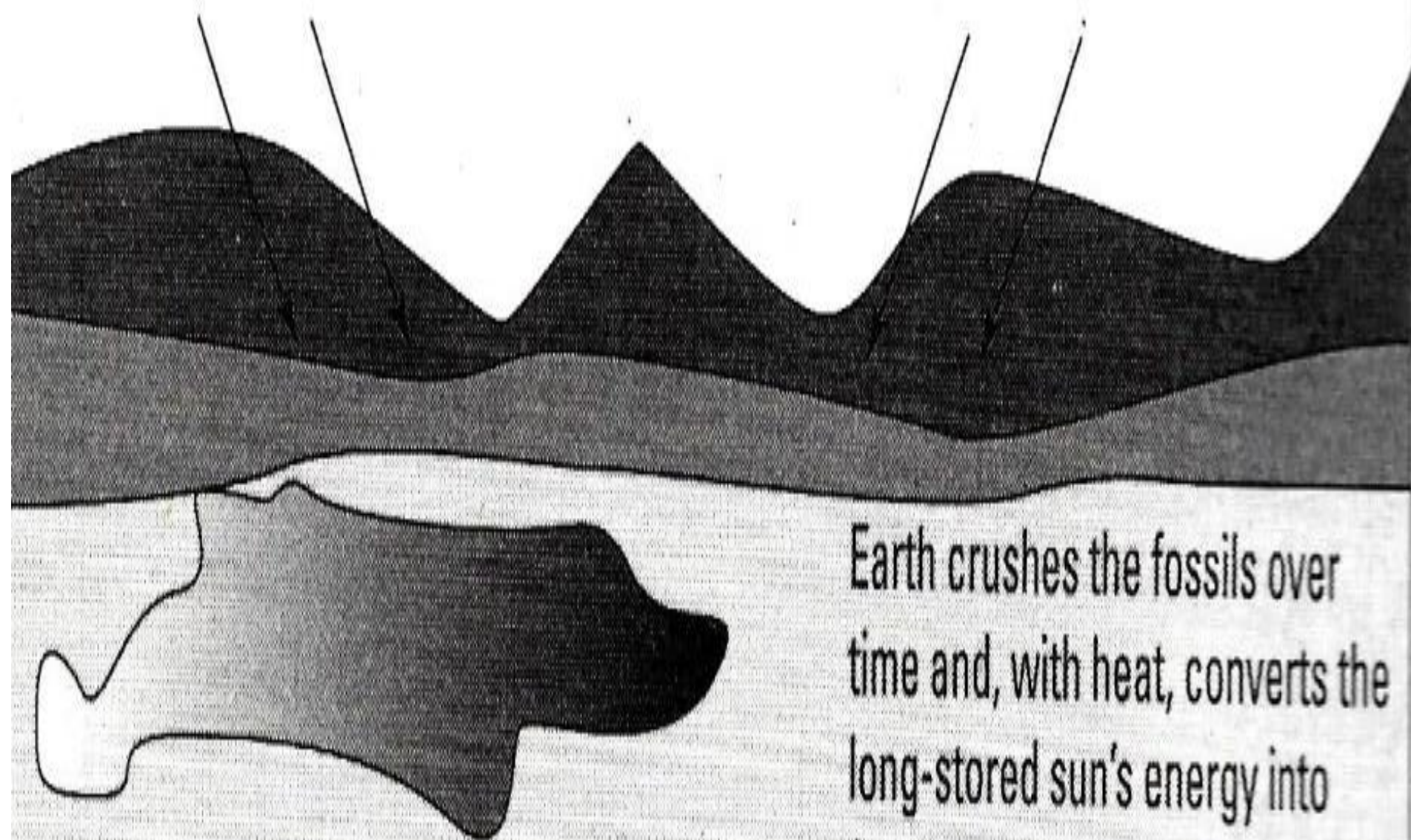






Remains of trees,  
plants, and animals.





Earth crushes the fossils over time and, with heat, converts the long-stored sun's energy into fossil fuels.



**Water withdrawal as a percentage of total available water**



**WATER STRESS: 2021**

Ratio of withdrawals to supply:

- Low (<10%)
- Low - medium (10-20%)
- Medium - high (20-40%)
- High (40-80%)
- Extremely high (>80%)

The map displays global water stress levels in 2021. High stress (red) is concentrated in North Africa, the Middle East, and parts of Central Asia and South America. Medium to high stress (orange) is seen in Australia, China, and parts of Europe and Africa. Low to medium stress (yellow) is prevalent in North America, South America, and parts of Europe and Africa. Low stress (light yellow) is found in Russia and parts of Europe and Africa.

- Low (<10%)
- Low - medium (10-20%)
- Medium - high (20-40%)
- High (40-80%)
- Extremely high (>80%)

Low - medium (10-20%)

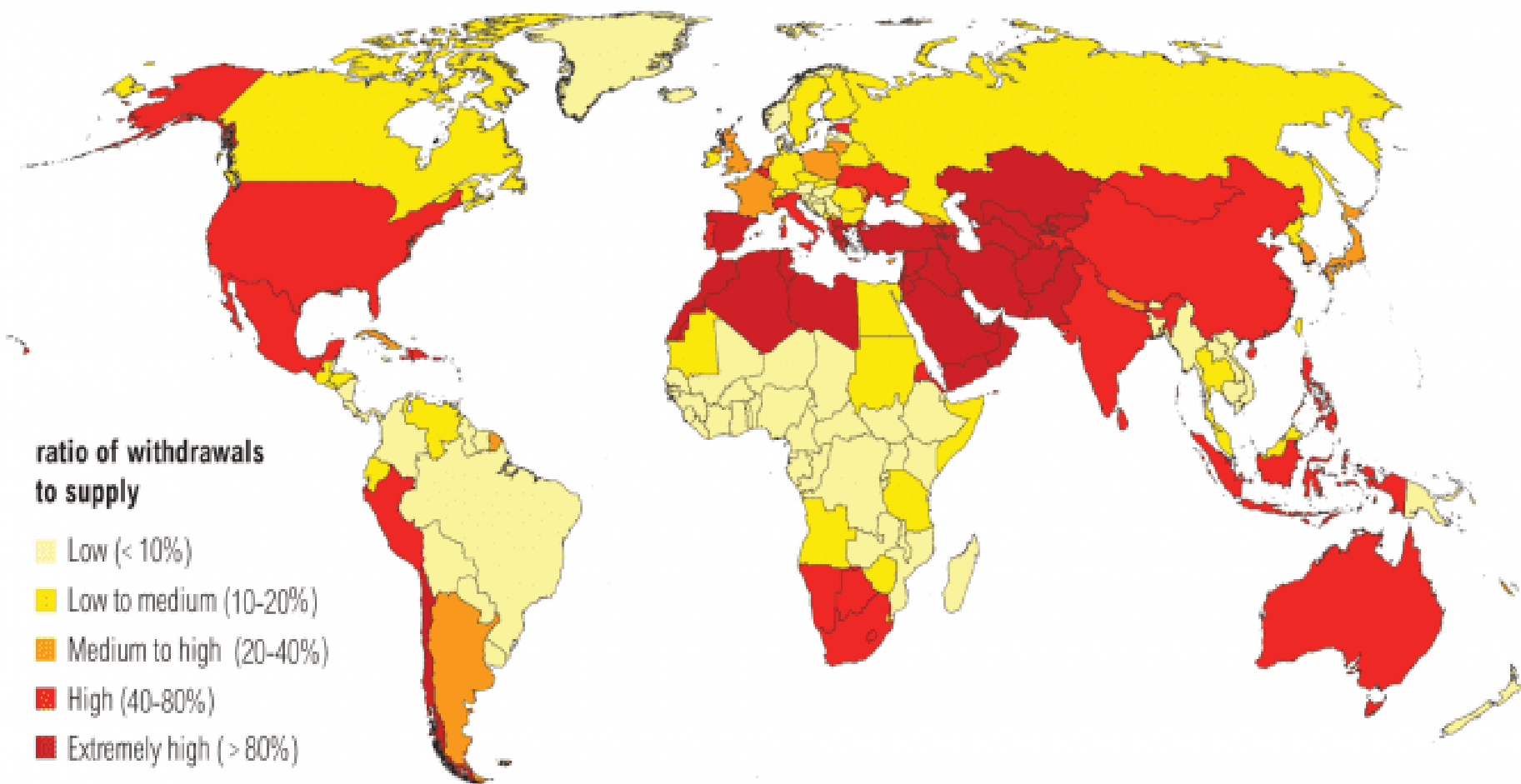
Medium - high (20-40%)

■ High (40-80%)

Extremely high (>80%)



# Water Stress by Country: 2040



**NOTE:** Projections are based on a business-as-usual scenario using SSP2 and RCP8.5.





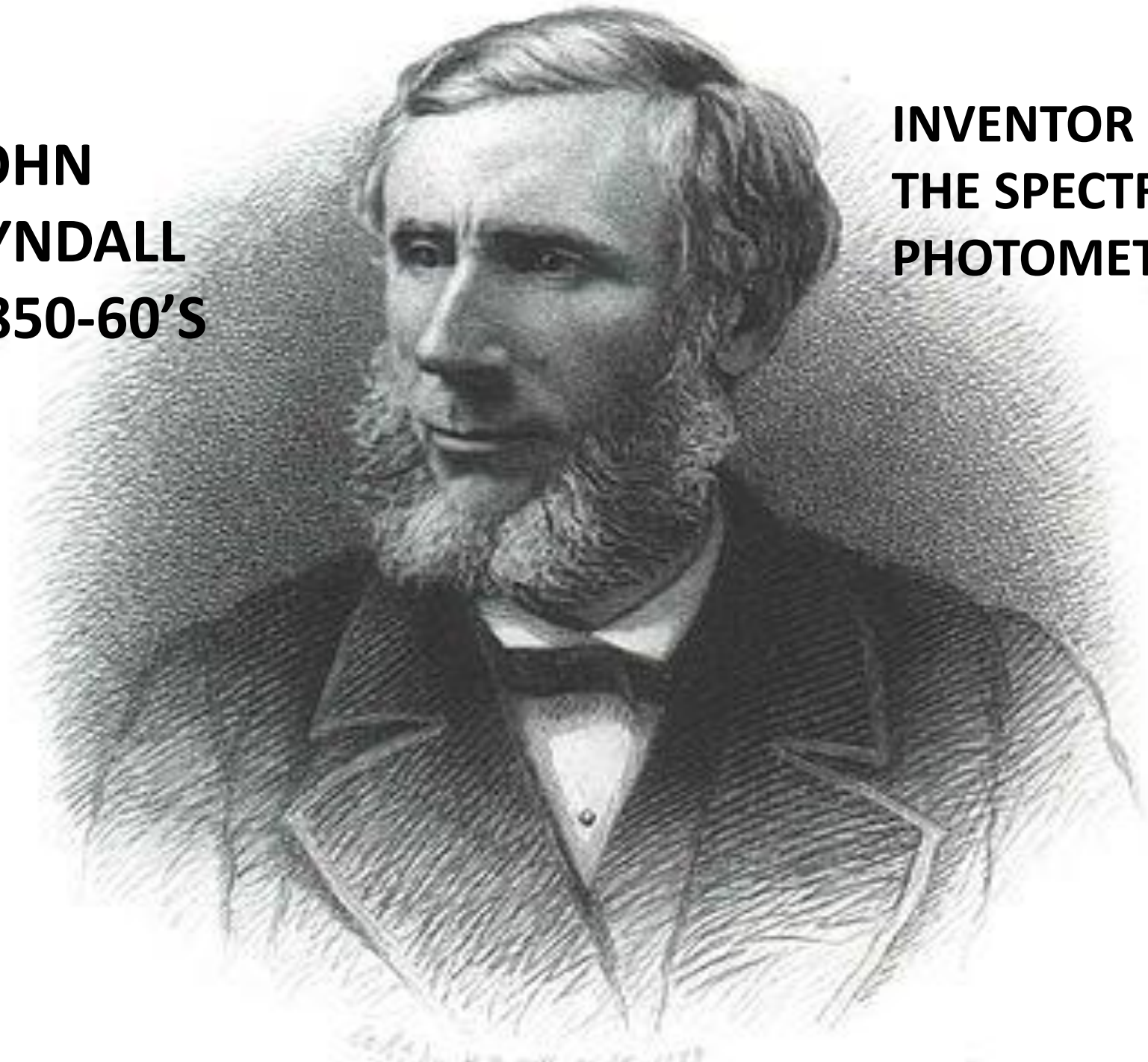
**VENUS:**

**GREENHOUSE  
OUT OF  
CONTROL?**

**?OUR FUTURE**

**JOHN  
TYNDALL  
1850-60'S**

**INVENTOR OF  
THE SPECTRO-  
PHOTOMETER**



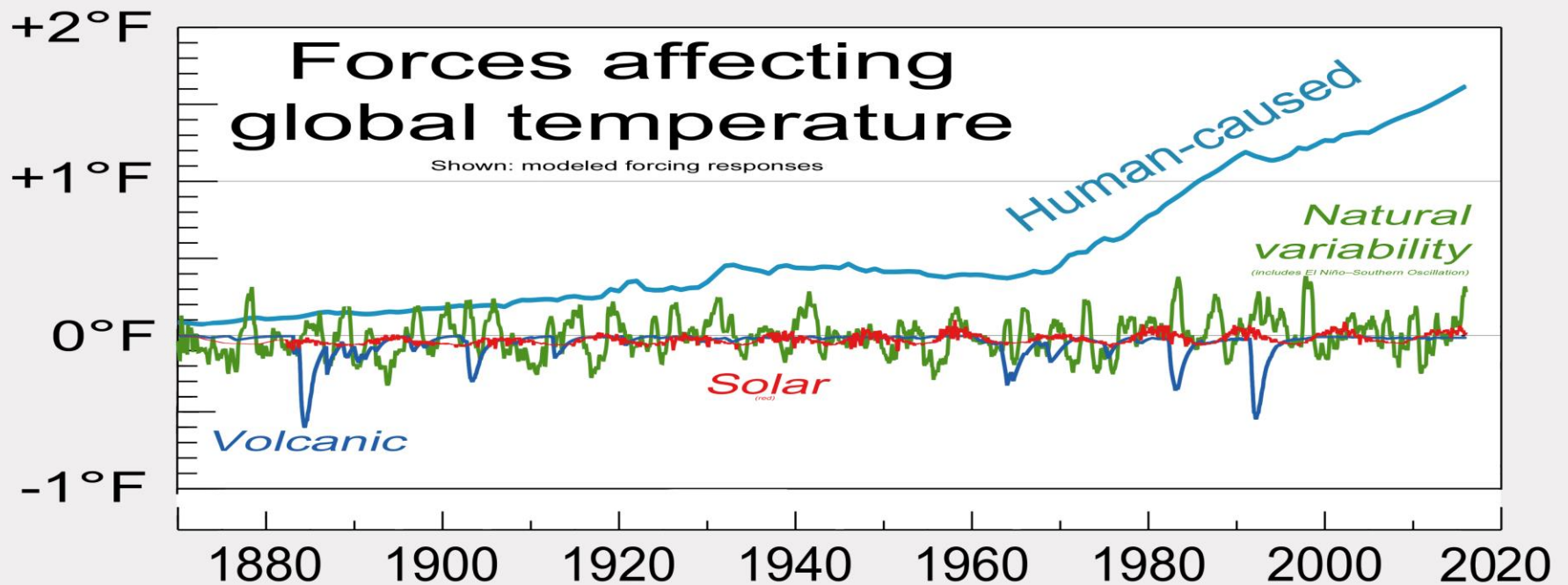
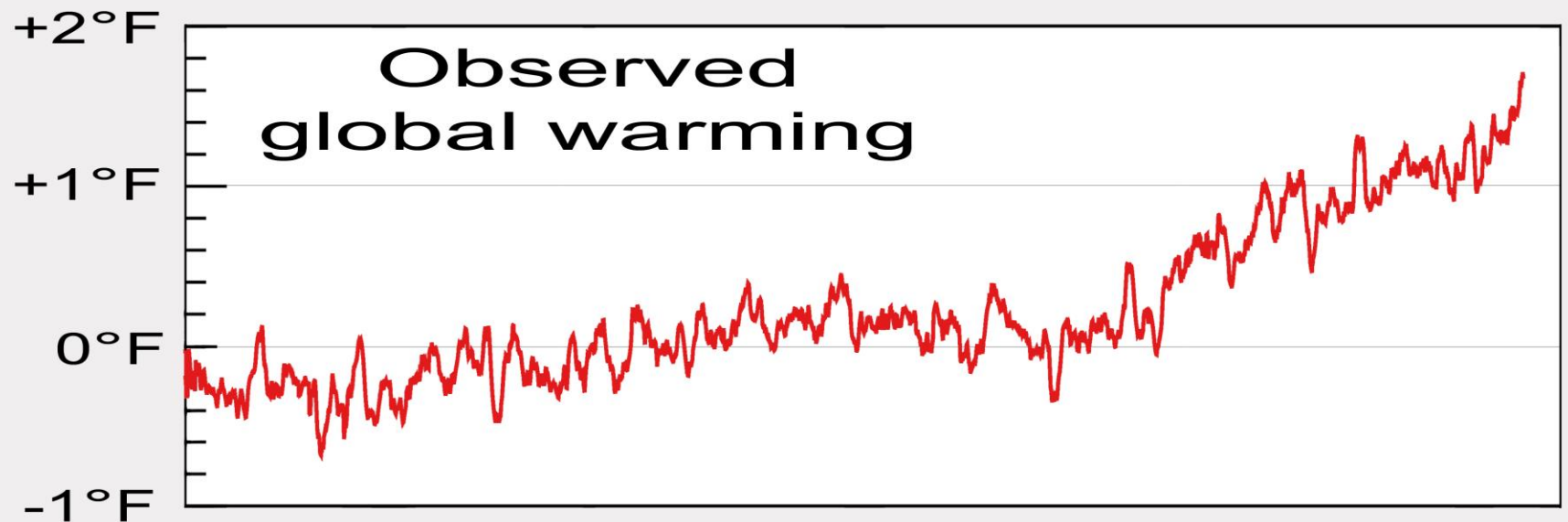
While controls over the Earth's climate system have undergone rigorous hypothesis-testing since the 1800s, questions over the scientific consensus of the role of human activities in modern climate change continue to arise in public settings. We update previous efforts to quantify the scientific consensus on climate change by searching the recent literature for papers sceptical of anthropogenic-caused global warming. From a dataset of 88125 climate-related papers published since 2012, when this question was last addressed comprehensively, we examine a randomized subset of 3000 such publications. We also use a second sample-weighted approach that was specifically biased with keywords to help identify any sceptical peer-reviewed papers in the whole dataset. We identify four sceptical papers out of the subset of 3000, as evidenced by abstracts that were rated as implicitly or explicitly sceptical of human-caused global warming. In our sample utilizing pre-identified sceptical keywords we found 28 papers that were implicitly or explicitly sceptical. We conclude with high statistical confidence that the scientific consensus on human-caused contemporary climate change—expressed as a proportion of the total **publications—exceeds 99% in the peer reviewed scientific literature.**

# GREENHOUSE GASES

Earth's atmosphere contains 24 different greenhouse gases, including **water vapor (60% of planet's warming)-not human-made**, CO<sub>2</sub>, N<sub>2</sub>O (6% of greenhouse effect-biggest source is fertilizer) , SO<sub>2</sub>, halogens, etc

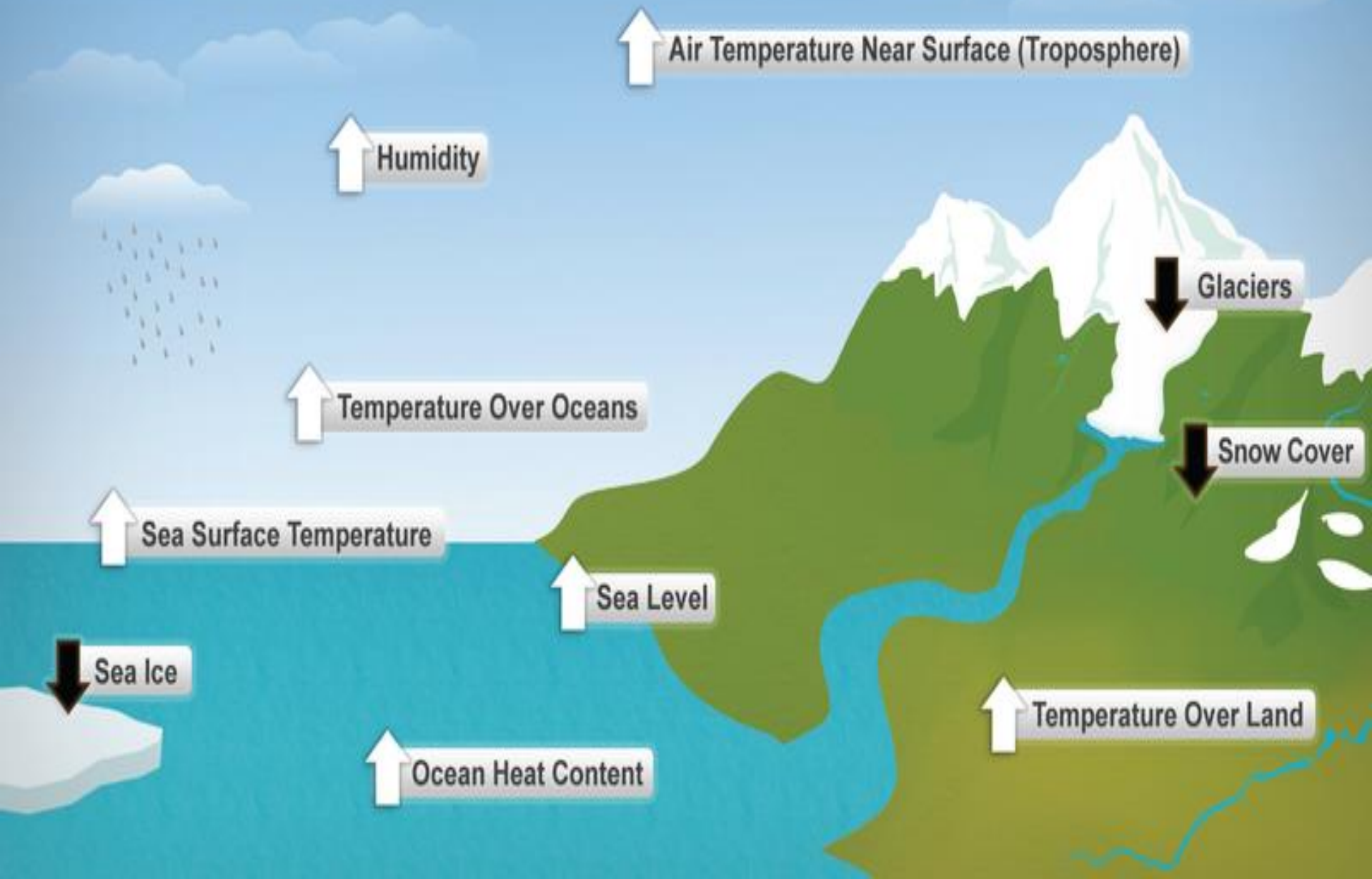
Just one of them accounts for the **overwhelming majority of the rising human-induced effect – CO<sub>2</sub>**) 63% in long run; by 2010 – 91% in the short term; agriculture – wheat and corn, etc.

However, in carbon equivalents – one unit of **methane** equals 21 units of carbon (i.e., even in small amounts it is more potent, molecule for molecule); methane accounts for about 18.6% of the overall global warming effect from the greenhouse gases (World Meteorological Organization), and 20-50X more potent than CO<sub>2</sub>. 2/3 of methane comes from agriculture (half of that from rice crops). The rest from animals (e.g., raising cattle), and humans – through treating wastewater and from landfills





# Ten Indicators of a Warming World



# INDUSTRIAL AMOUNTS OF CO<sub>2</sub>

Since the Industrial Revolution (around 1850), the amount of greenhouse gases in the atmosphere has risen drastically – due to the burning of fossil fuels, as well as clearing forests – almost doubled the CO<sub>2</sub> emissions in just over a century (today) the CO<sub>2</sub> emissions have been higher than ever been in recorded history-more than one-third increase in the last 800,000 years and higher than millions of years ago (and faster)!

# **CARBON SINKS**

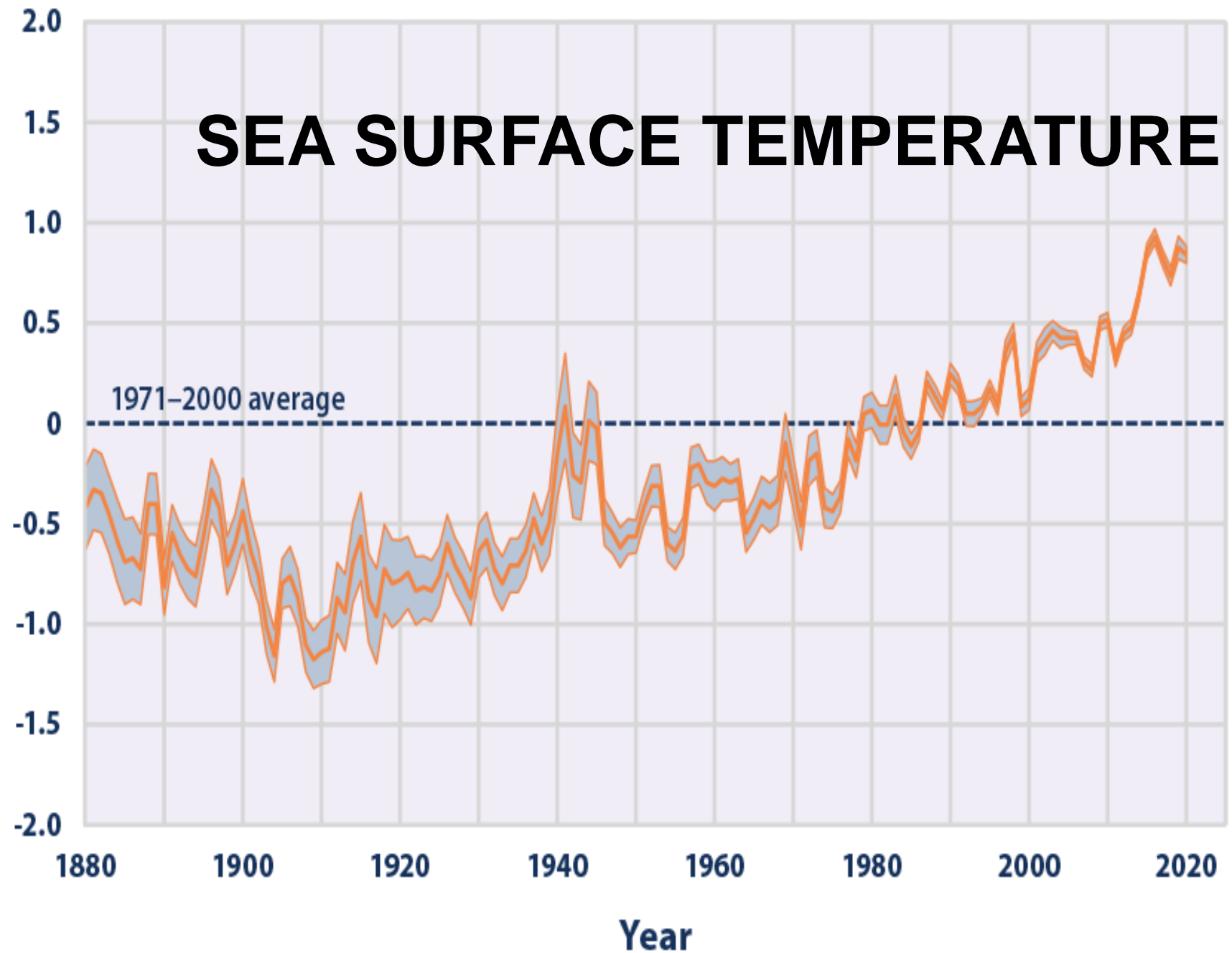
**Plants and soil are the major carbon sinks that soak up CO<sub>2</sub> from the atmosphere; when they become so full – they can't absorb any more CO<sub>2</sub>**

**Cutting down forests, over-tilling the soil: CO<sub>2</sub> is released, not absorbed**

**Land use has thus increased CO<sub>2</sub> emissions**

# SEA SURFACE TEMPERATURE

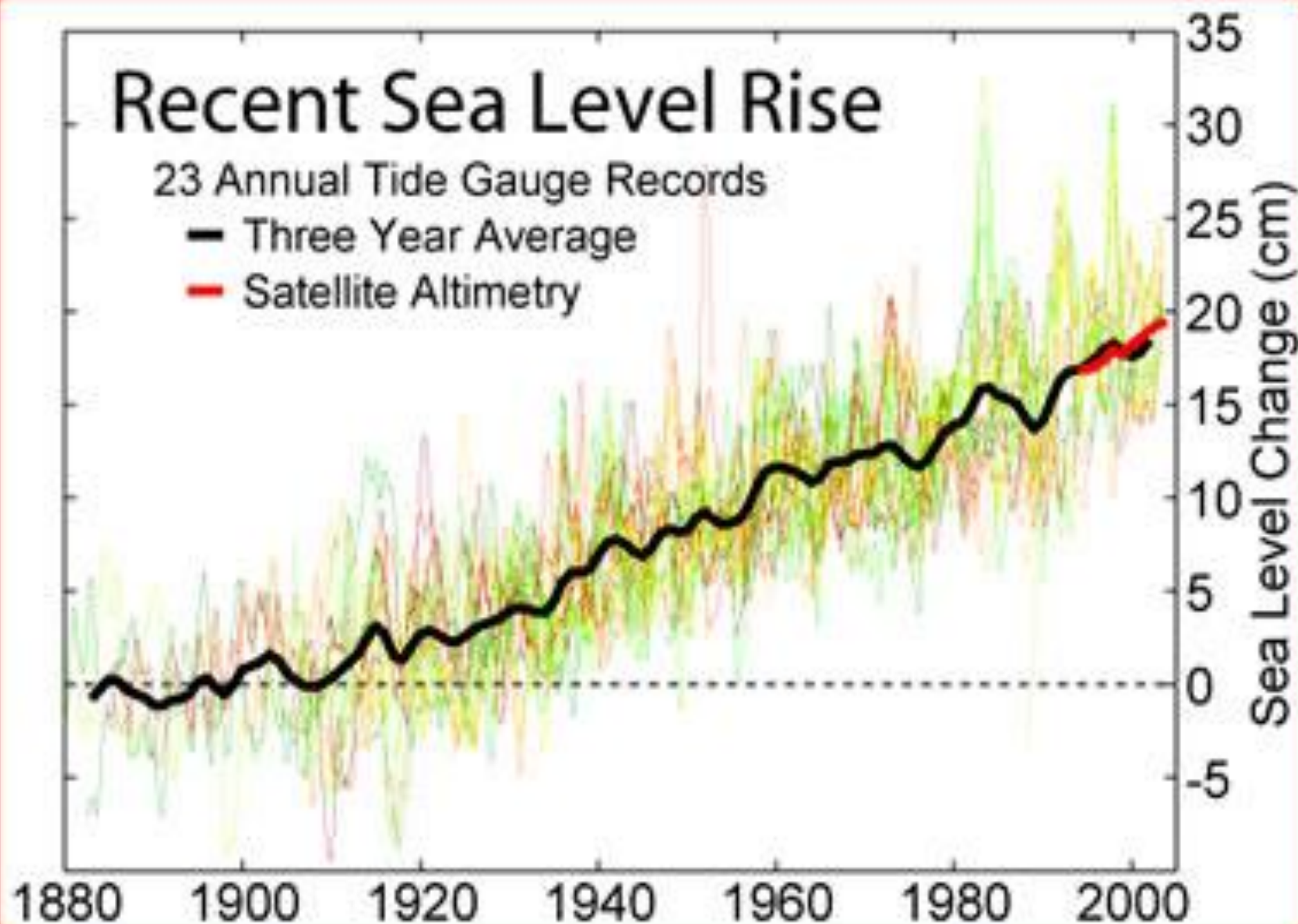
Temperature anomaly (°F)



# Recent Sea Level Rise

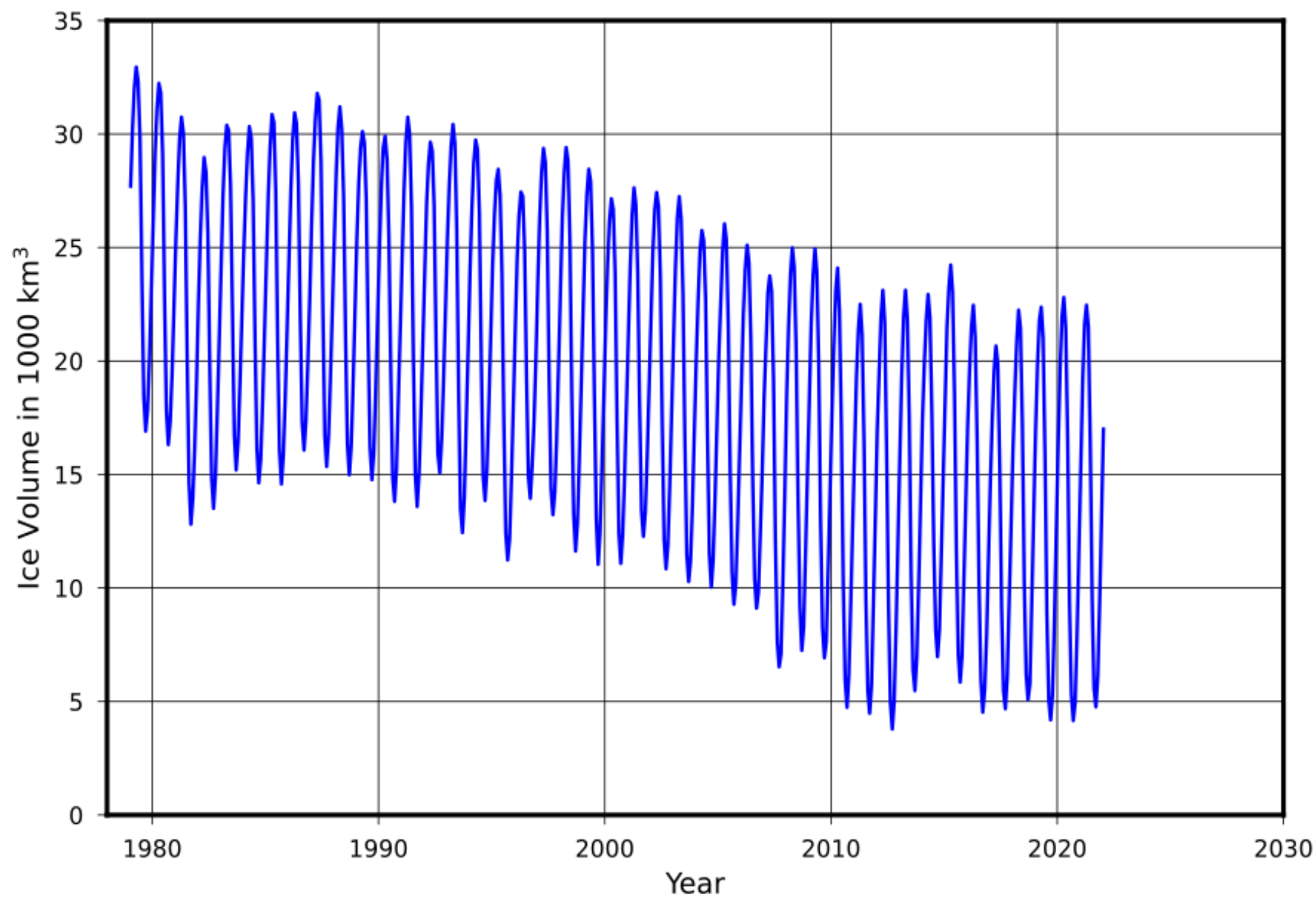
23 Annual Tide Gauge Records

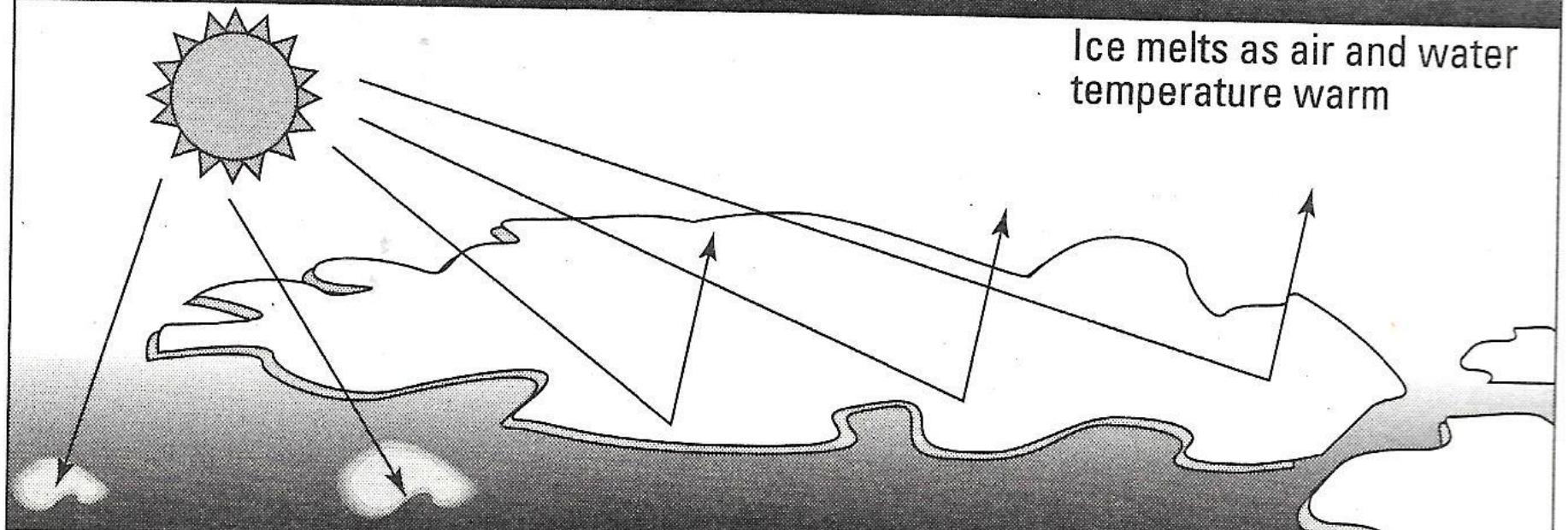
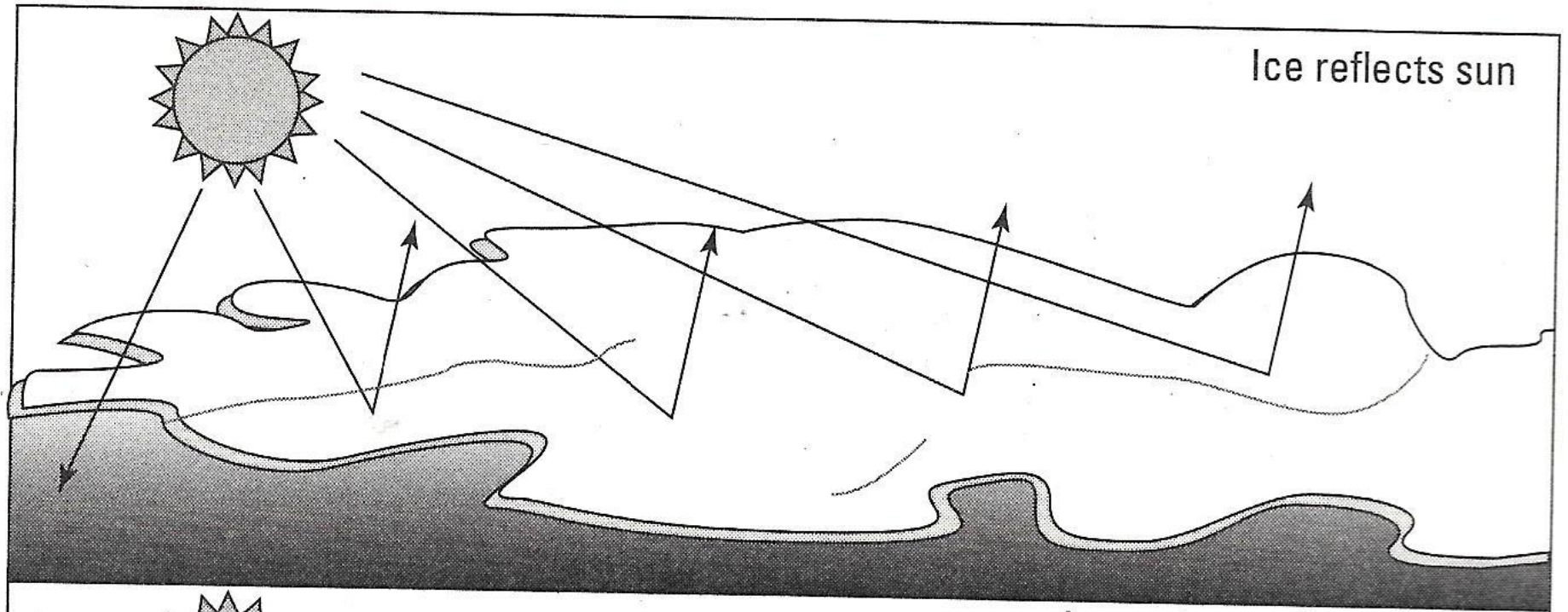
- Three Year Average
- Satellite Altimetry

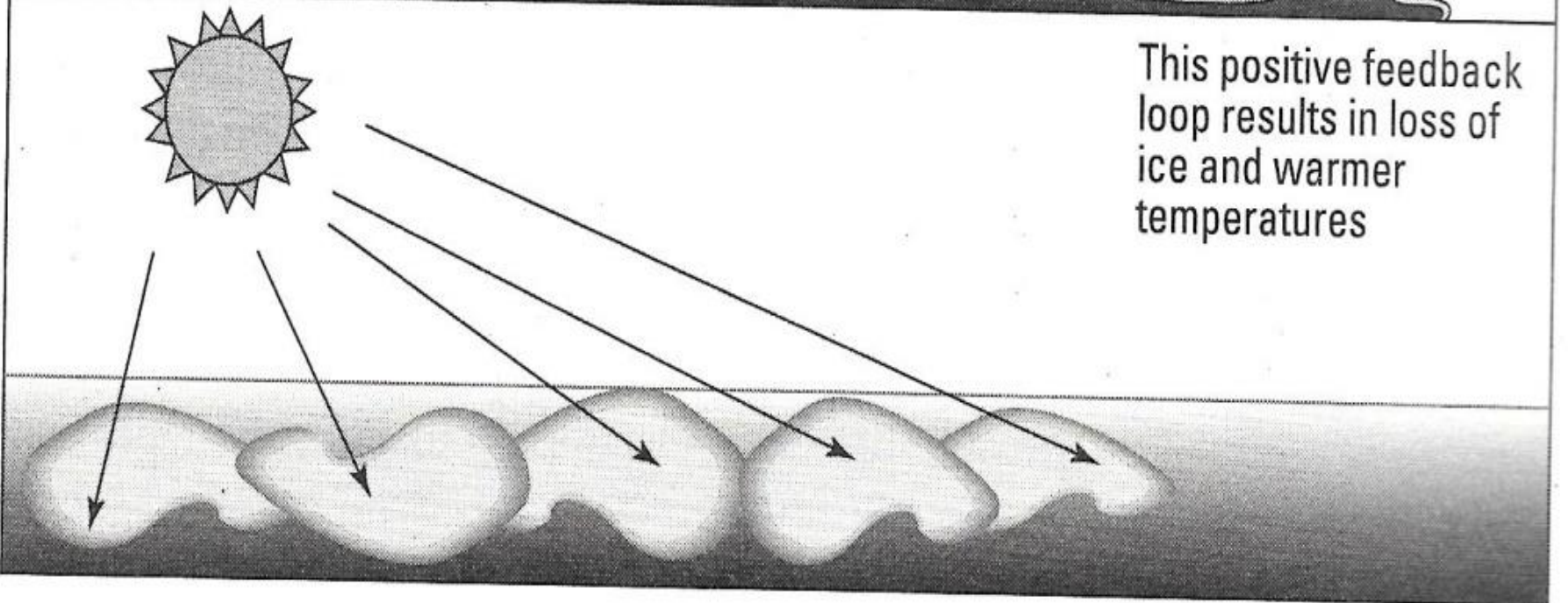
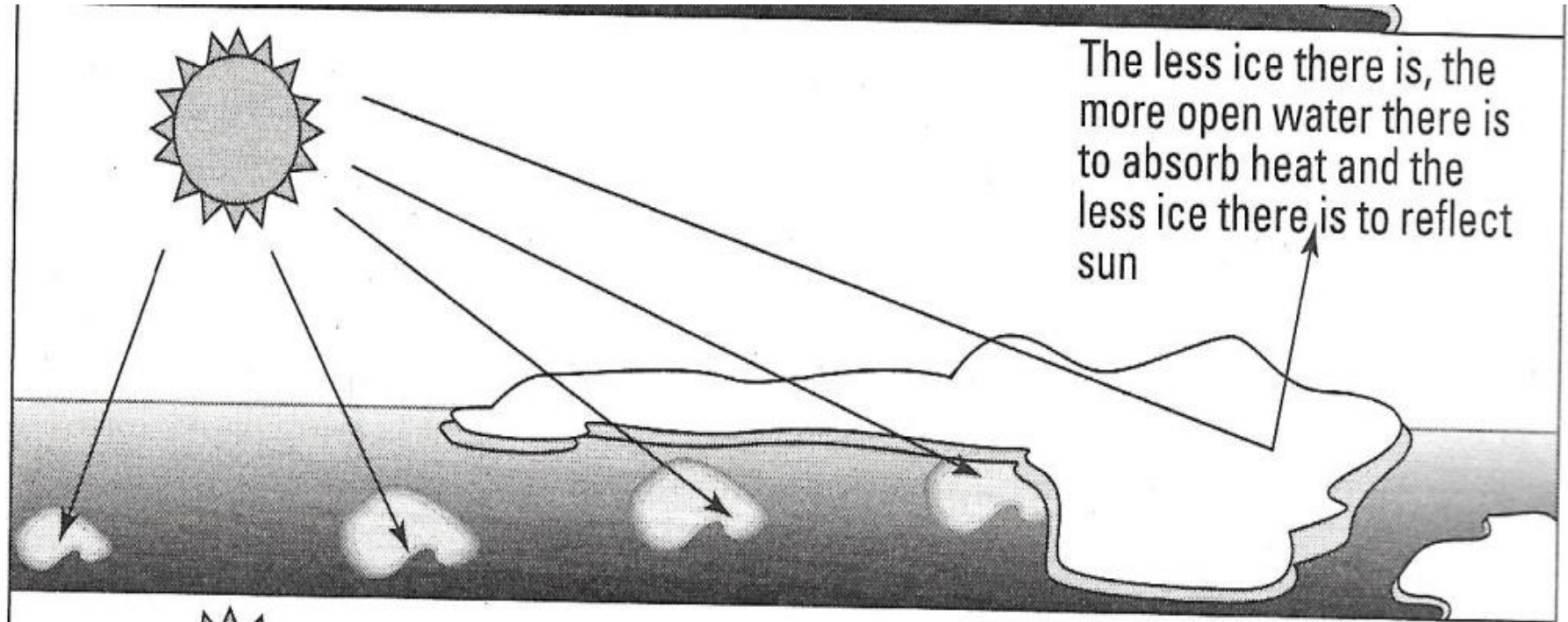




# PIOMAS Arctic Sea Ice Volume









# INTACT FOREST







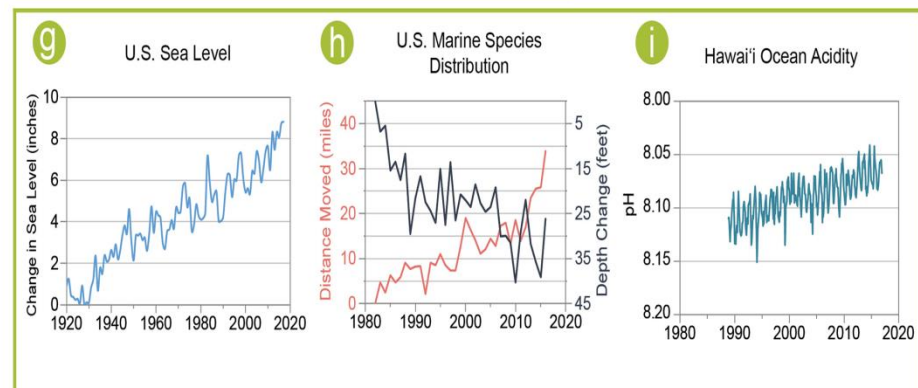
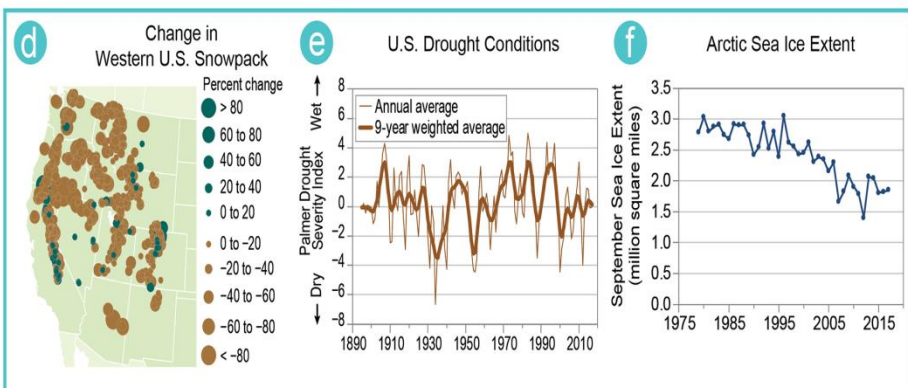
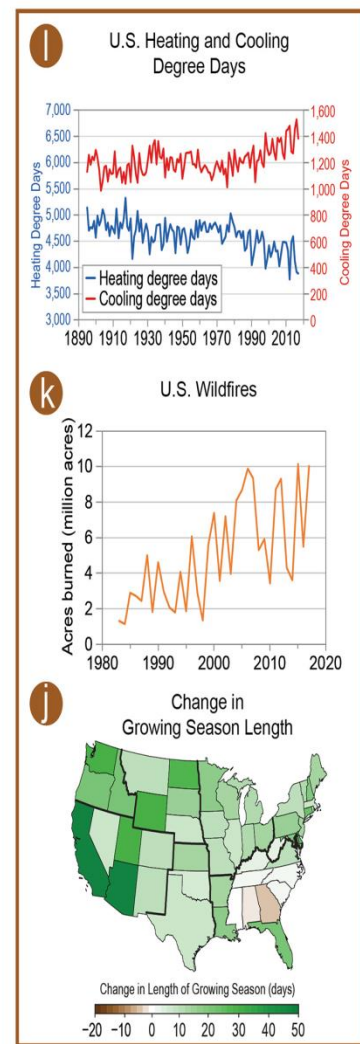
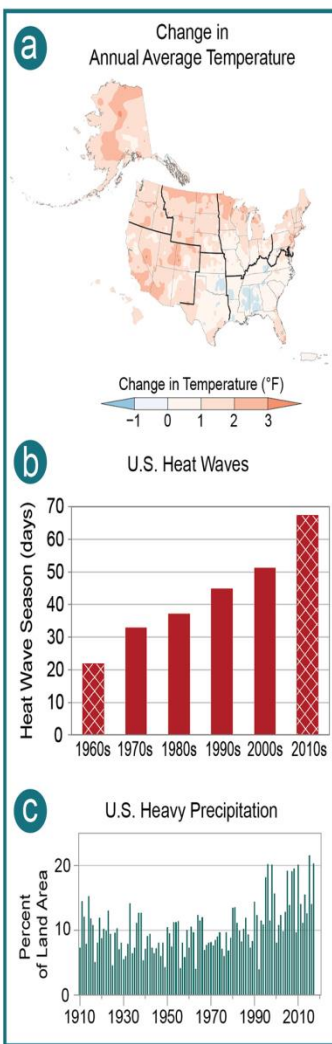


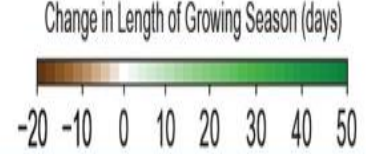
# DEFORESTATION





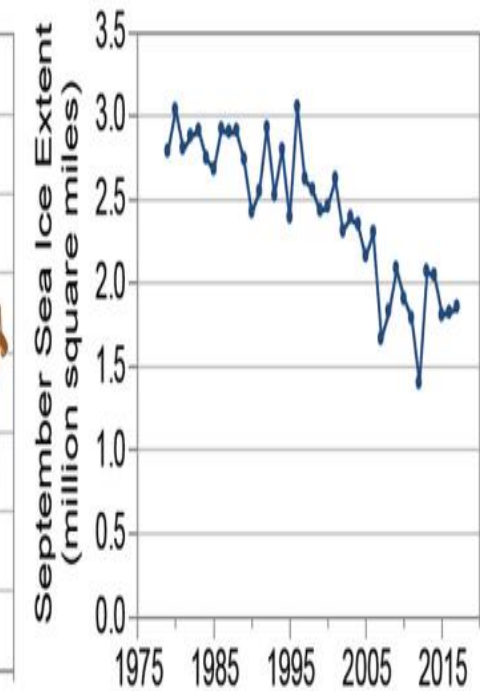






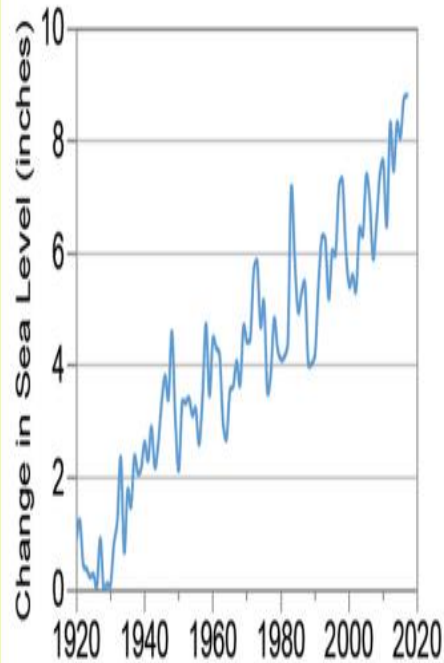
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Arctic Sea Ice Extent



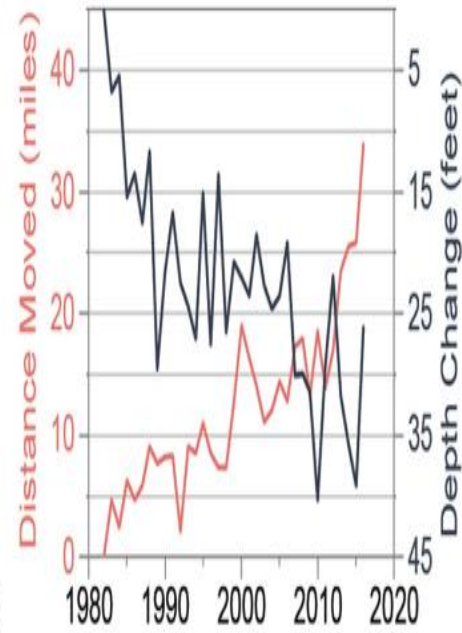
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U.S. Sea Level



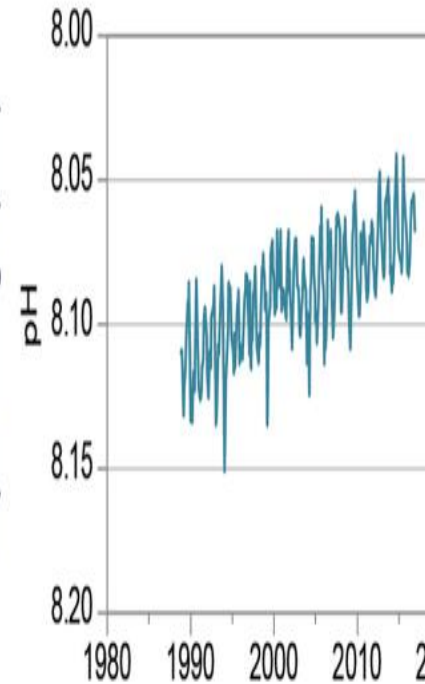
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U.S. Marine Species Distribution

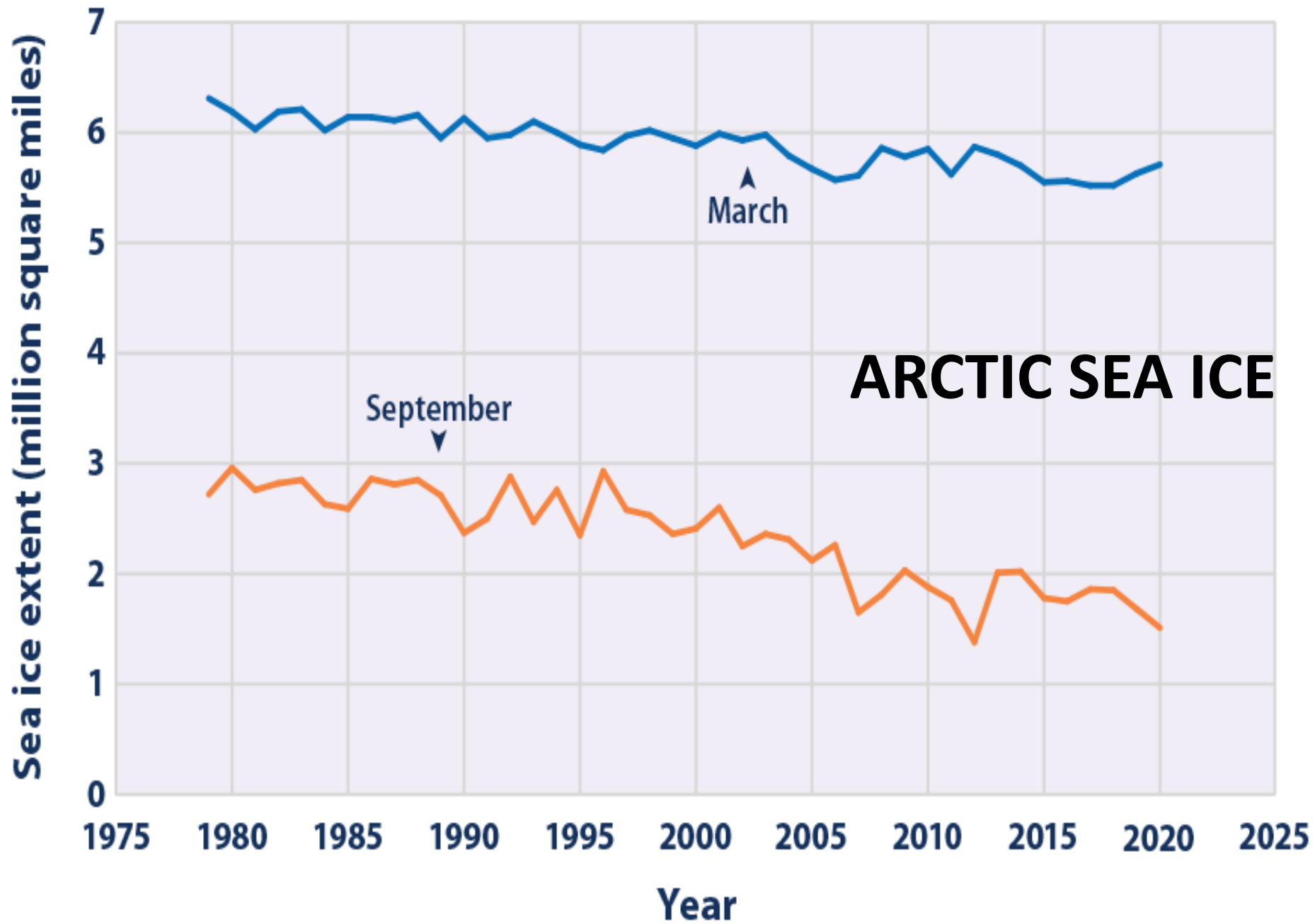


i

Hawai'i Ocean Acidity

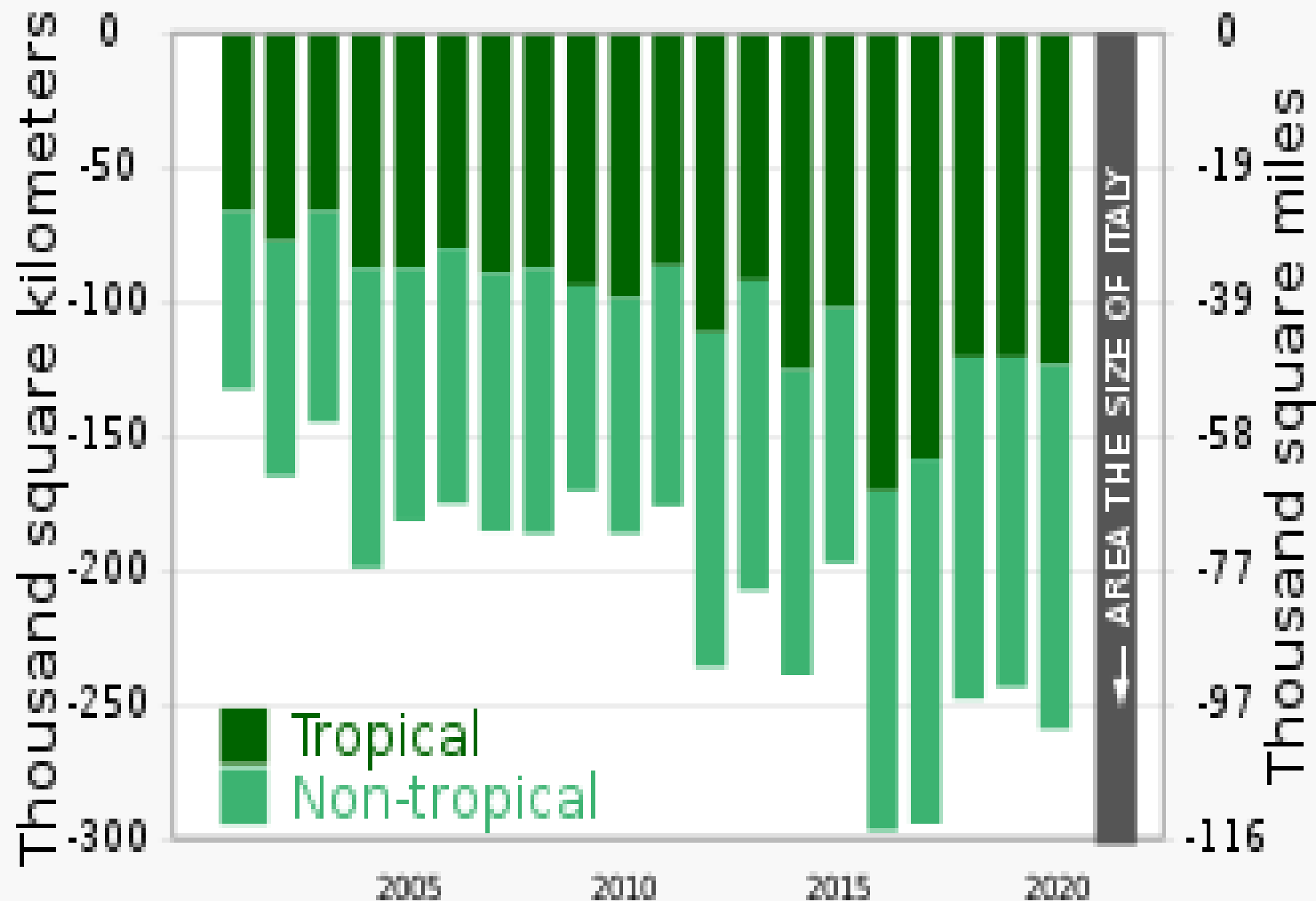




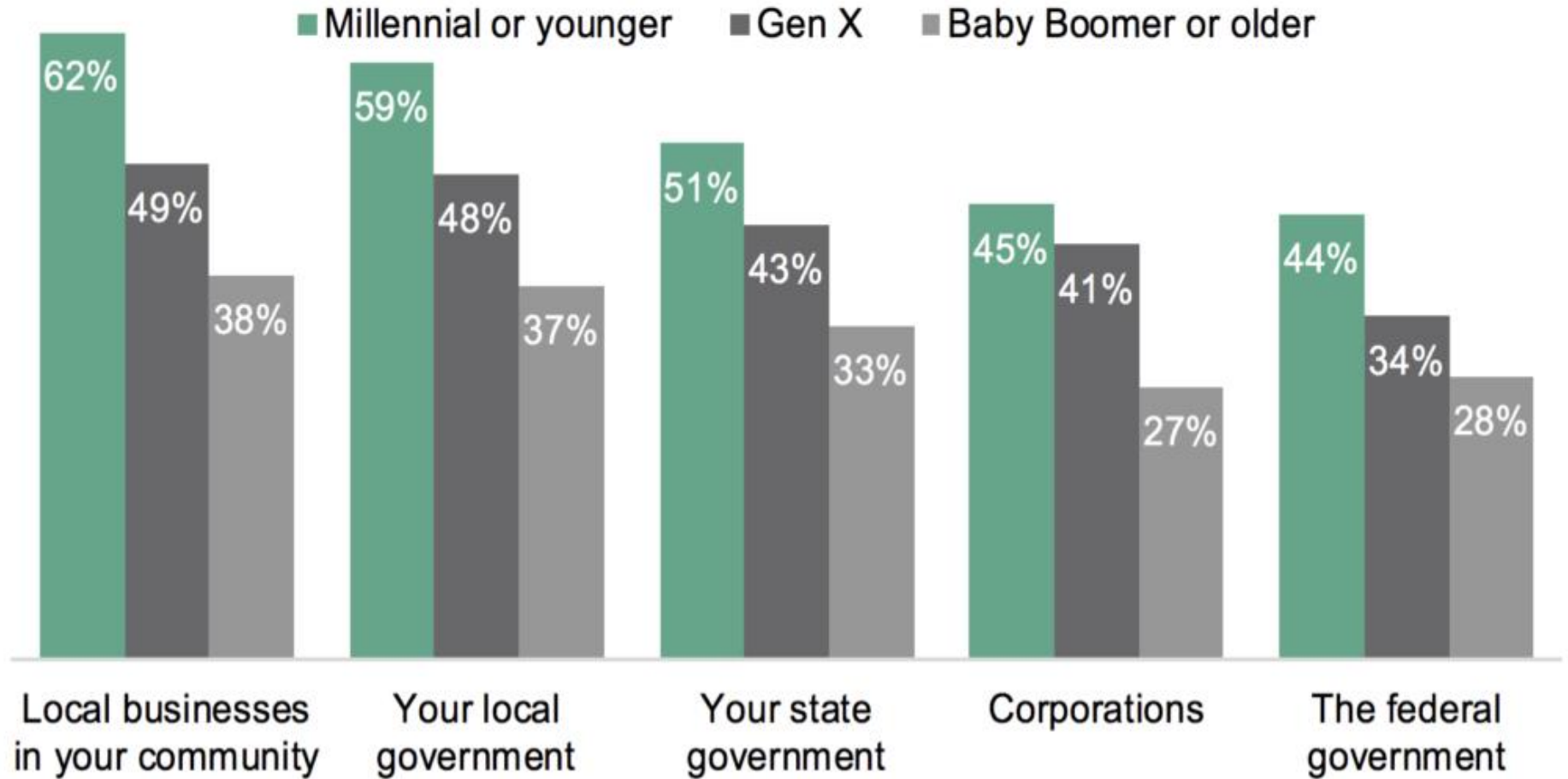




# Global tree cover: annual loss



# Younger generations of Americans are more confident they can influence decision-makers than are older generations



How confident are you that people like you, working together, can affect what \_\_\_\_ do/does about global warming?

% who are "extremely," "very," or "moderately" confident

Nov 2019. Base: 1,303 U.S. adults – Millennial or younger (1981 or later)  $n = 375$ ; Gen X (1965 – 1980)  $n = 336$ ; Baby Boomer or older (1964 or earlier)  $n = 592$



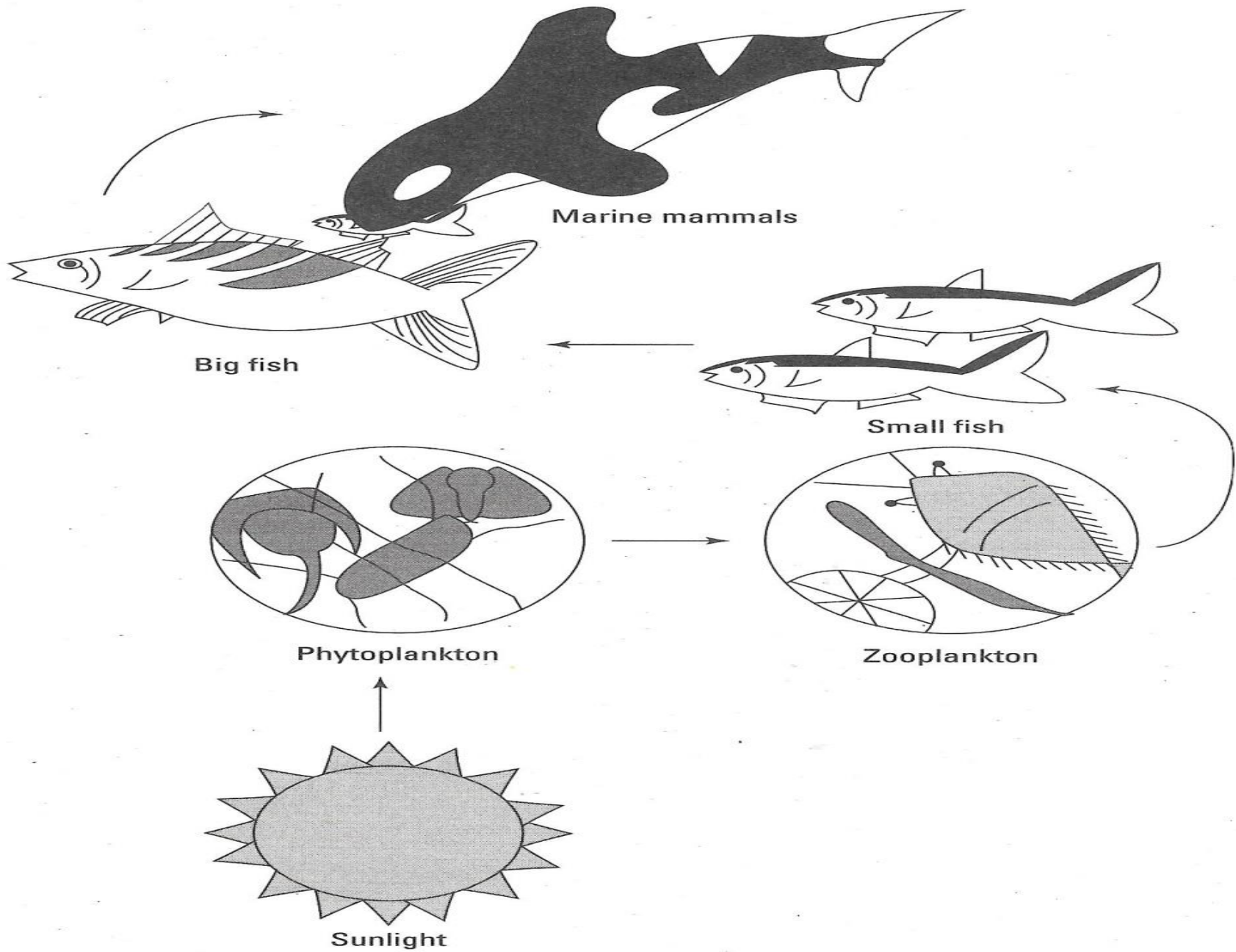
YALE PROGRAM ON  
Climate Change  
Communication



GEORGE MASON UNIVERSITY  
CENTER for CLIMATE CHANGE  
COMMUNICATION



# The Marine Food Chain



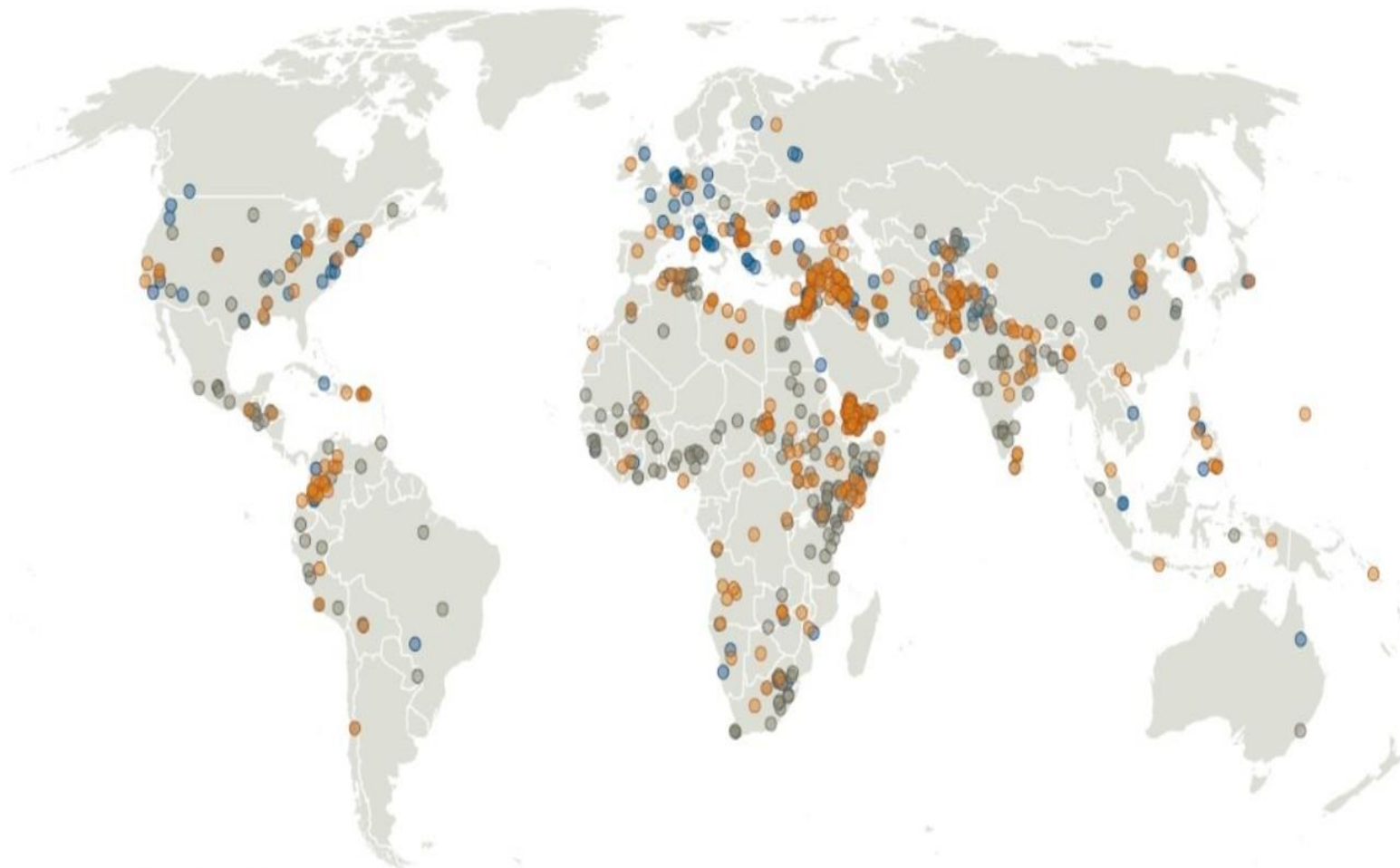
## Water world

Water conflict, 3000BC - 2019AD

● Water resources or water systems  
as a **casualty** of conflict

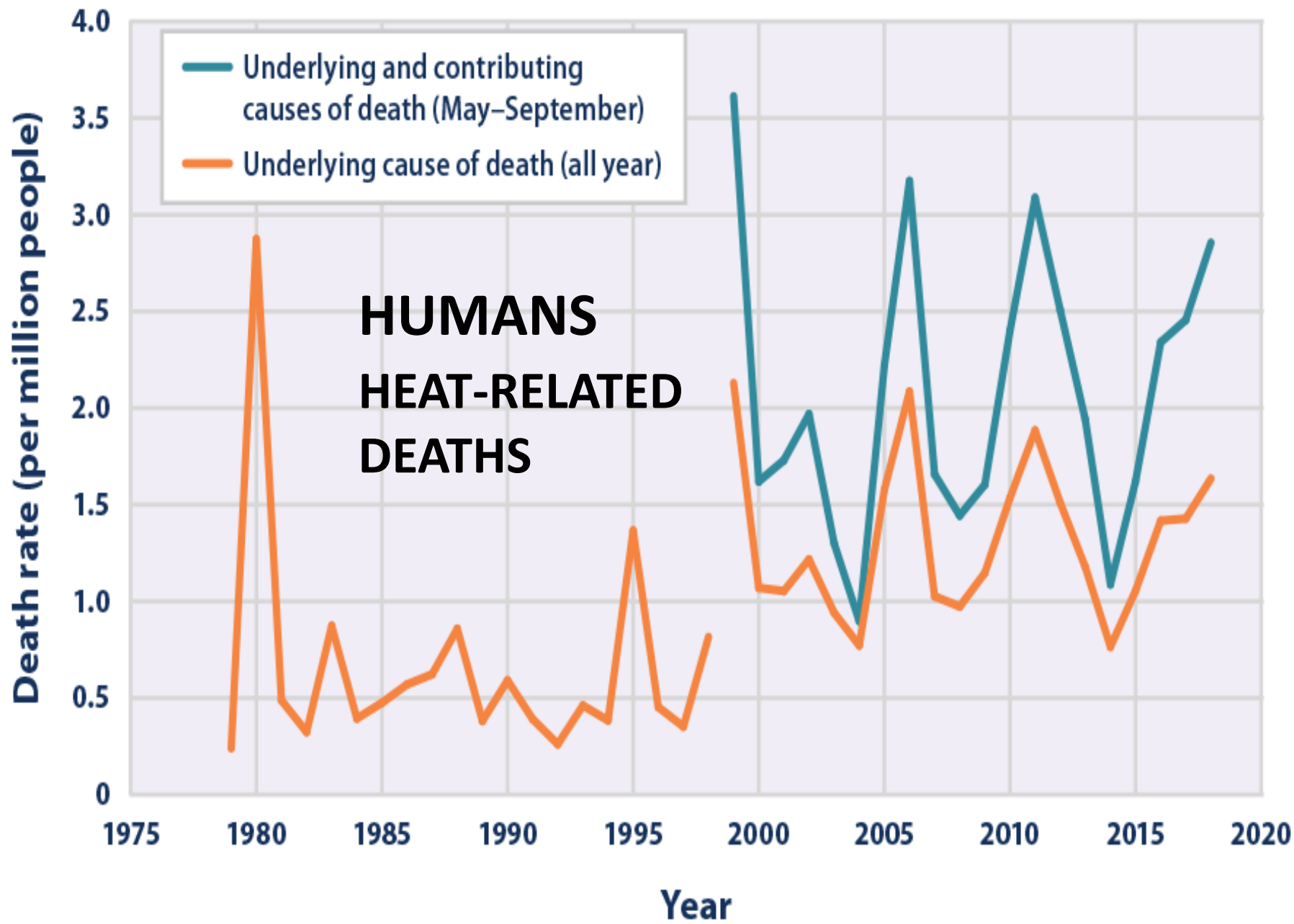
● Water as a trigger or  
root cause of conflict

● Water as a **weapon**  
of conflict



Source: Pacific Institute, Water Conflict Chronology





**Increased use of coal was the main factor driving up global energy-related CO2 emissions by over 2 billion tonnes, their largest ever annual rise in absolute terms (Global Energy Review, 2021)**

**USA Today, March 8, 2022**

**Annual Energy Outlook 2022 (AEO2022) For Annual  
Energy Outlook 2022 Release at the Bipartisan Policy  
Center March 3, 2022 | Washington, DC By Stephen  
Nalley, Acting EIA Administrator Angelina LaRose,  
Assistant Administrator for Energy Analysis AEO2022**

**Highlights** • Petroleum and natural gas remain the most-consumed sources of energy in the United States through 2050, but renewable energy is the fastest growing • Wind and solar incentives, along with falling technology costs, support robust competition with natural gas for electricity generation, while the shares of coal and nuclear power decrease in the U.S. electricity mix • U.S. crude oil production reaches record highs, while natural gas production is increasingly driven by natural gas exports AEO2022

Press Release March 3, 2022

# **Climate Change Indicators in the United States**

The Earth's climate is changing. Temperatures are rising, snow and rainfall patterns are shifting, and more extreme climate events – like heavy rainstorms and record high temperatures – are already happening. Many of these observed changes are linked to the rising levels of carbon dioxide and other greenhouse gases in our atmosphere, caused by human activities.

**EPA partners with more than 50 data contributors from various government agencies, academic institutions, and other organizations to compile a key set of indicators related to the causes and effects of climate change.**

# **TEMPERATURE RISING**

**Well-done, peer-reviewed, multiple, independent, instrumental data set (quantitative long-term) studies**

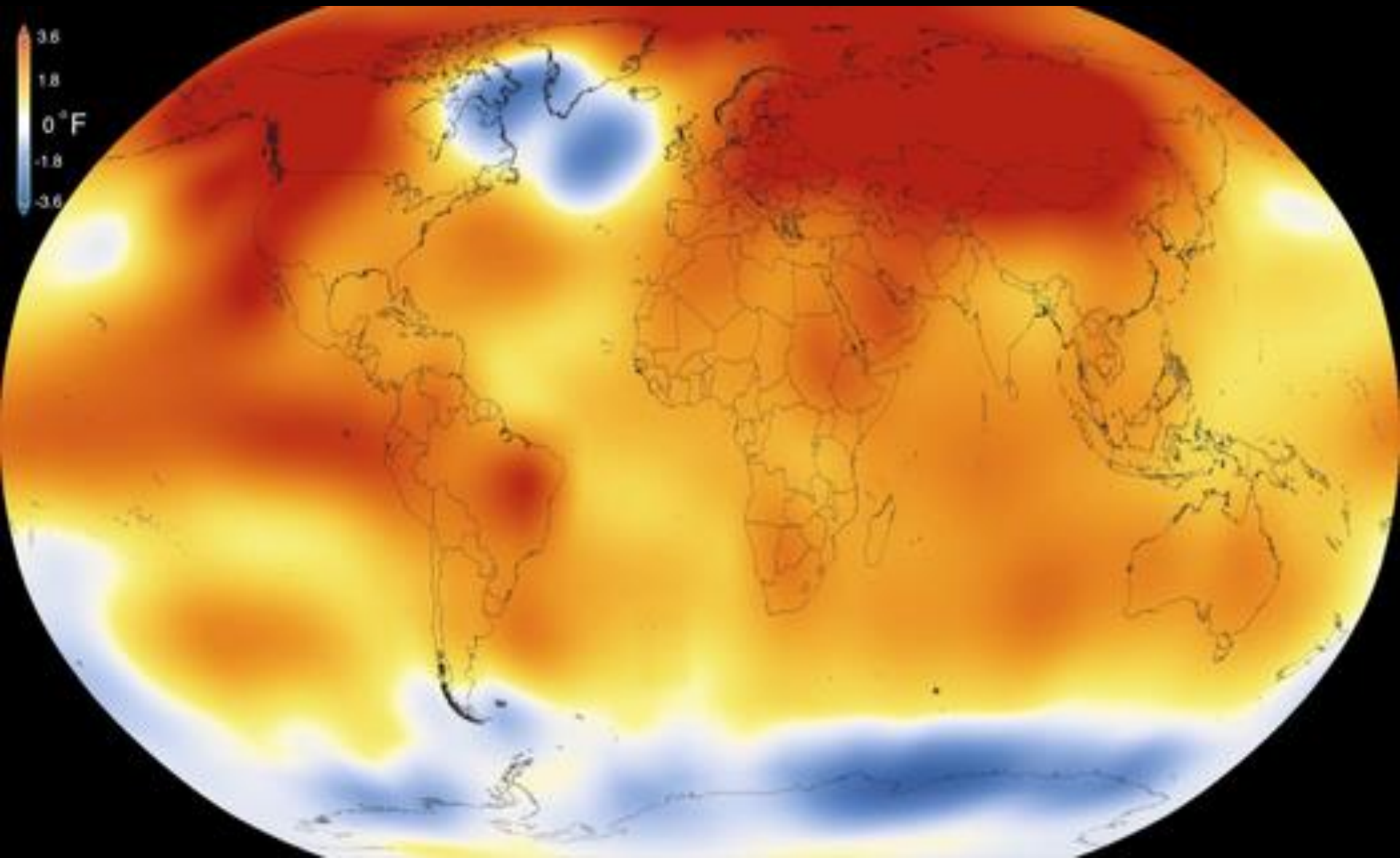
**e.g., 2011-2020: Ave. 1.09 degree C increase  
compared to 1850-1900**

**2020: compared to pre-industrial times: up 1.2  
degrees C**

**After 1950: number of cold days/nights decreased  
and hot days/nights increased**

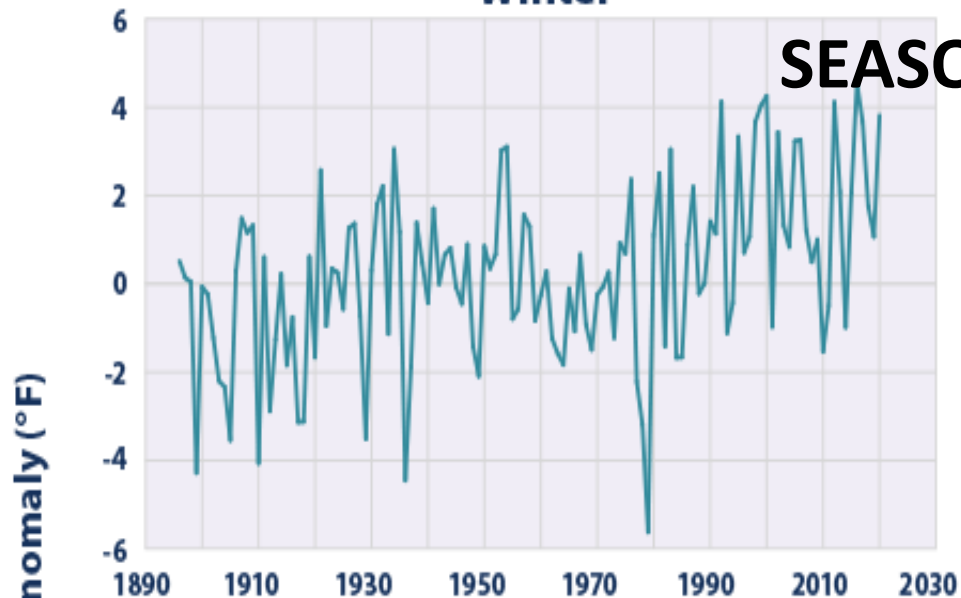


# NASA - 2015

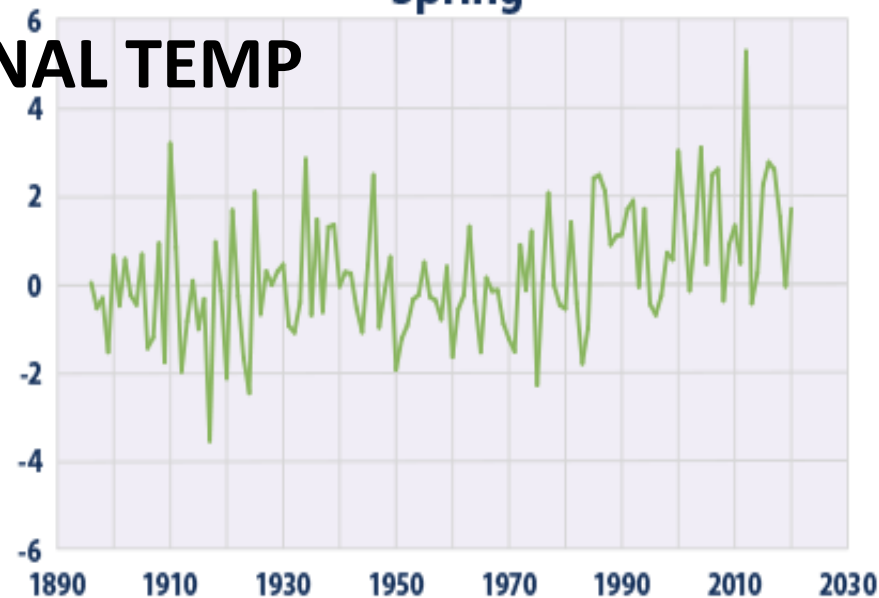


# SEASONAL TEMP

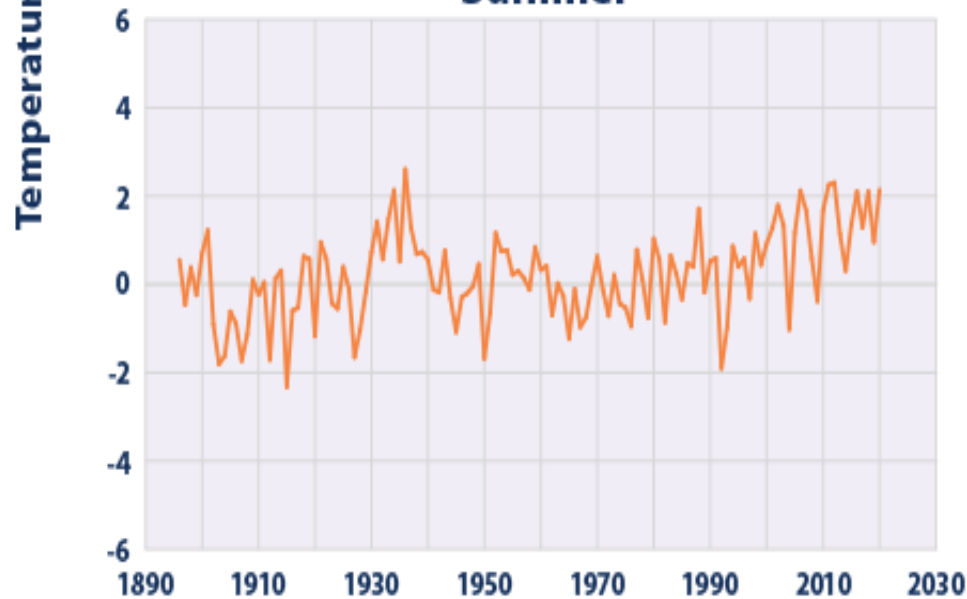
## Winter



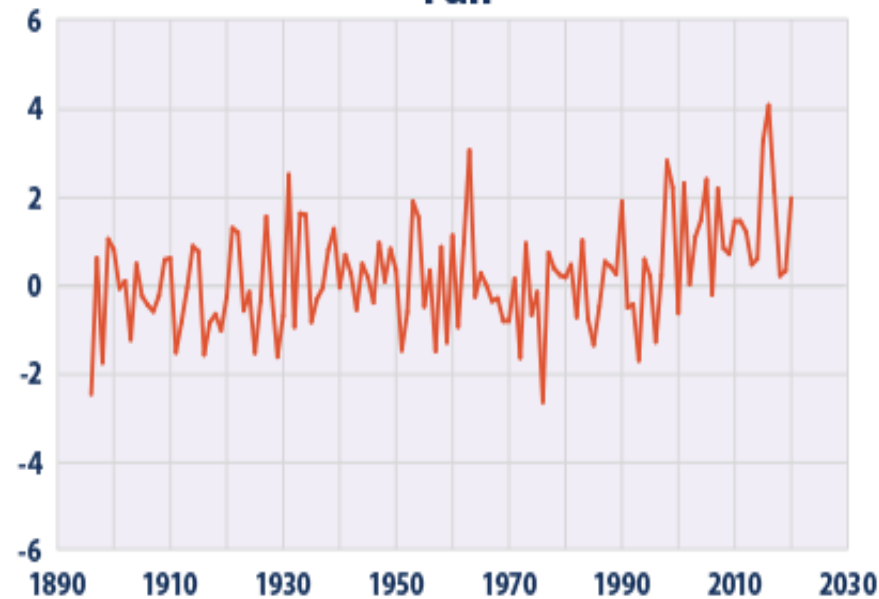
## Spring



## Summer



## Fall

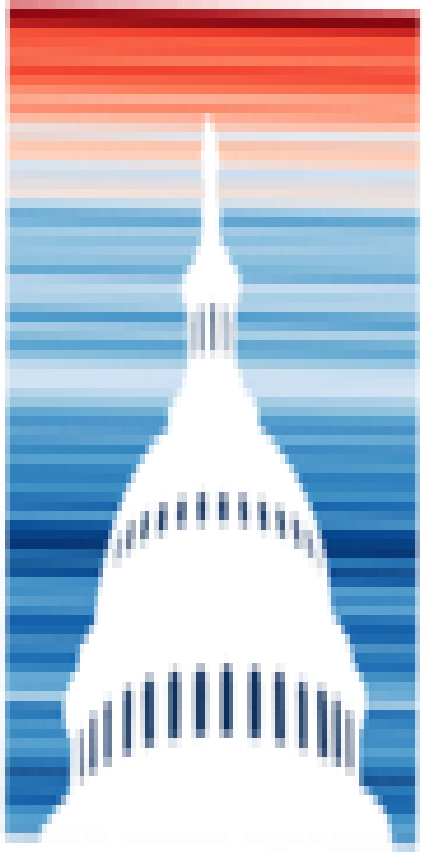


Year

# DIFFERENT LAYERS OF ATMOSPHERE

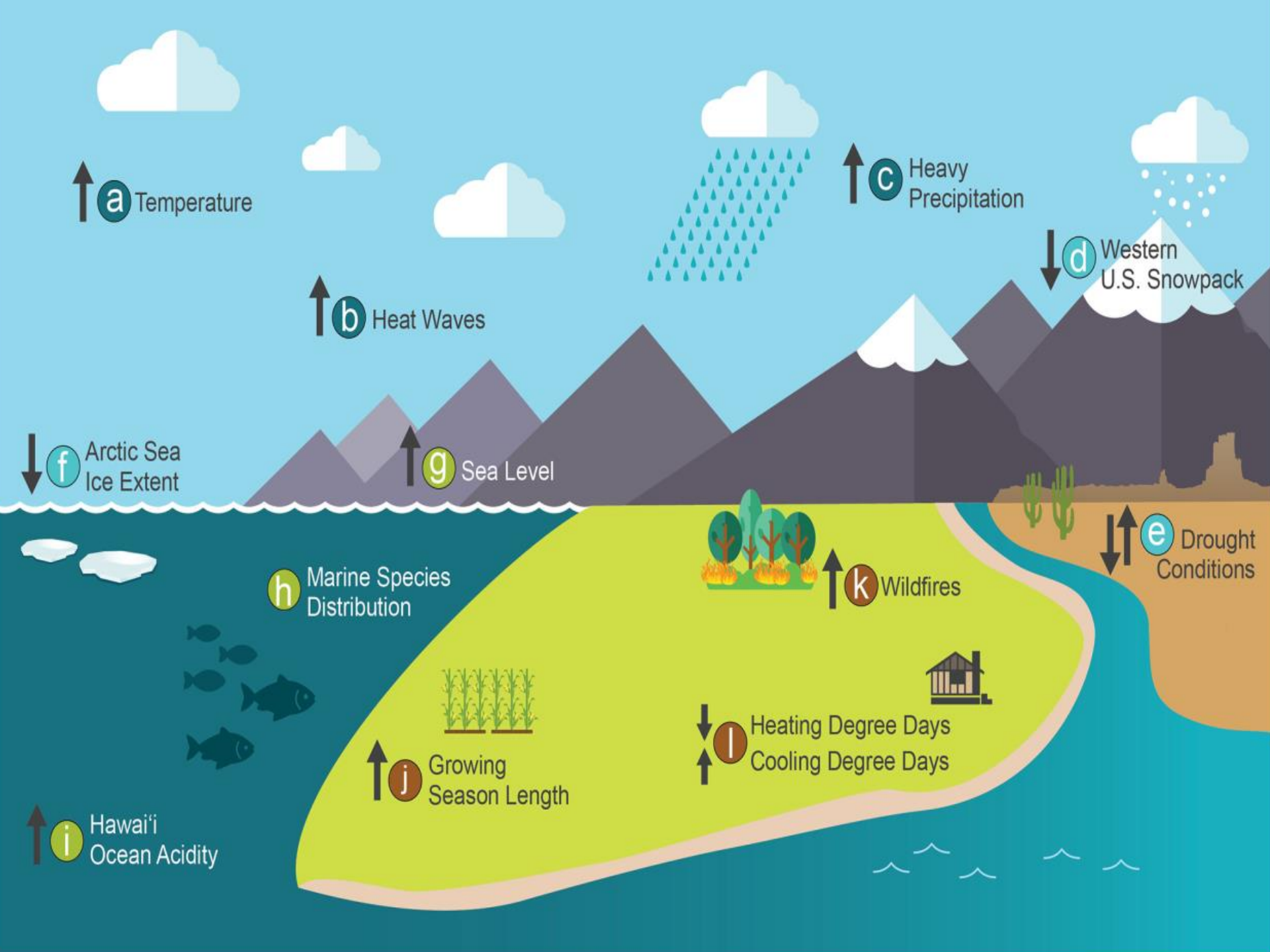
**Only the lower part of the atmosphere (troposphere) is warmed with Greenhouse effect; not upper layers (stratosphere) = thus, increased temps not due to Sun's output variability**

Cooling of upper atmosphere leads to heat trapped near Earth's surface and not radiated into space



# HOUSE SELECT COMMITTEE ON THE CLIMATE CRISIS

**ABOLISHED WHEN THE REPUBLICANS GAINED CONTROL OF  
CONGRESS IN 2011 (RESTARTED AGAIN IN 2019)**



↑ **a** Temperature

↑ **b** Heat Waves

↑ **c** Heavy Precipitation

↓ **d** Western U.S. Snowpack

↓ **f** Arctic Sea Ice Extent

↑ **g** Sea Level

**h** Marine Species Distribution

↑ **k** Wildfires

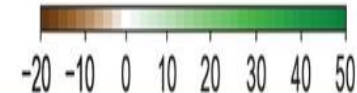
↑↓ **e** Drought Conditions

↑ **i** Hawai'i Ocean Acidity

↑ **j** Growing Season Length

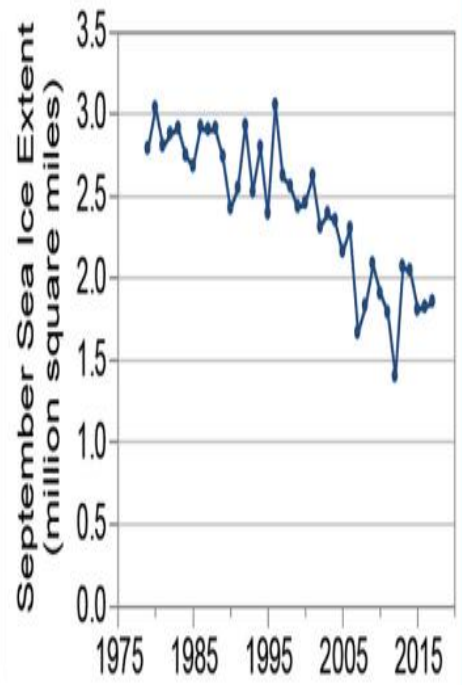
↓ **l** Heating Degree Days  
↑ Cooling Degree Days





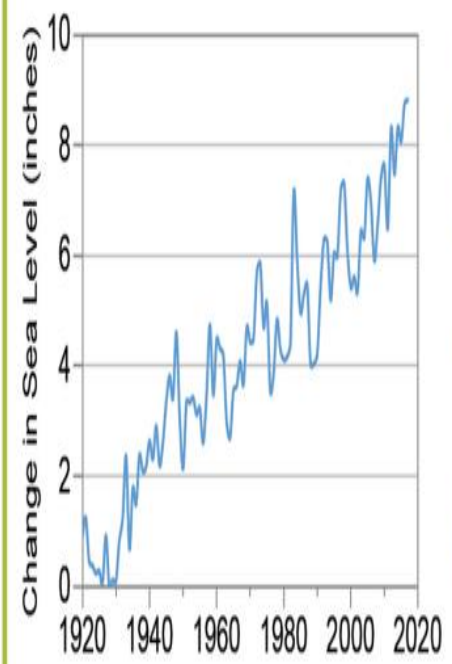
f

Arctic Sea Ice Extent



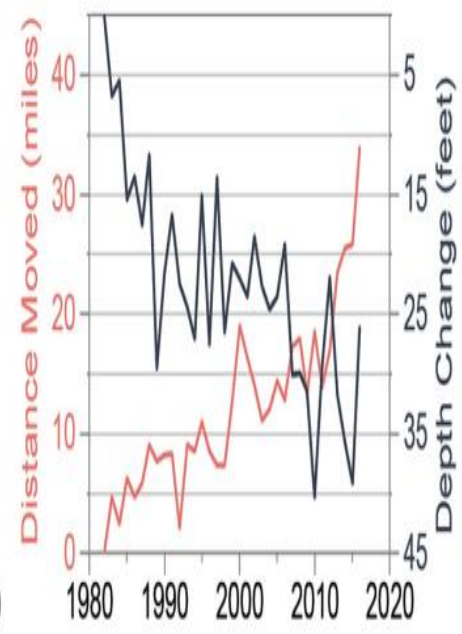
g

U.S. Sea Level



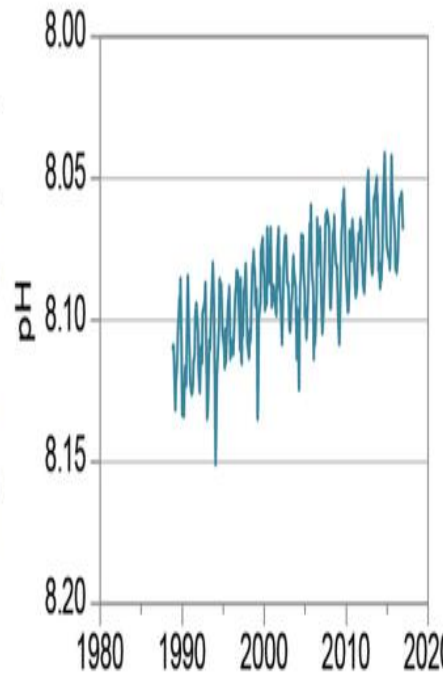
h

U.S. Marine Species Distribution



i

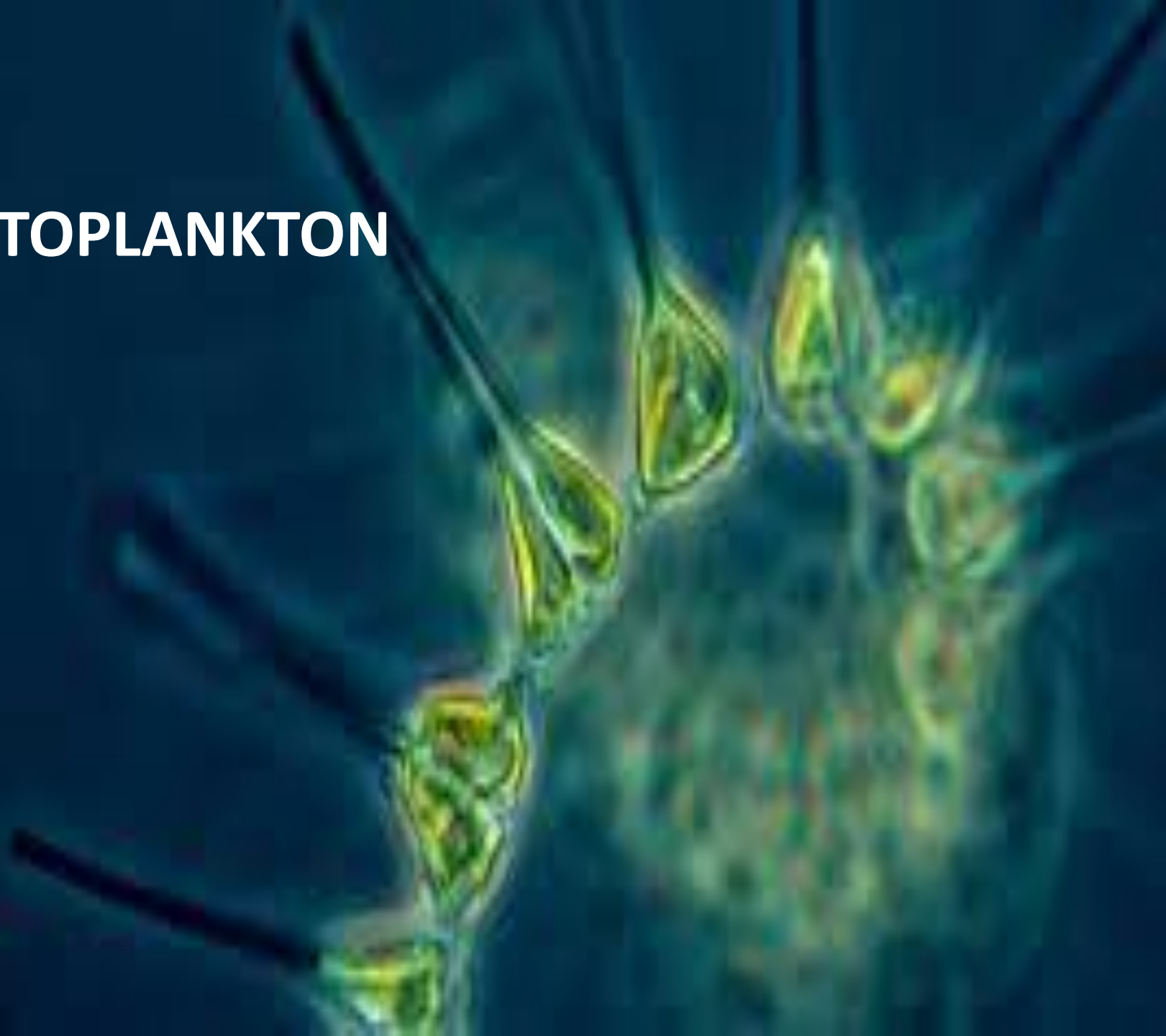
Hawai'i Ocean Acidity



# PHYTOPLANKTON COMMUNITY

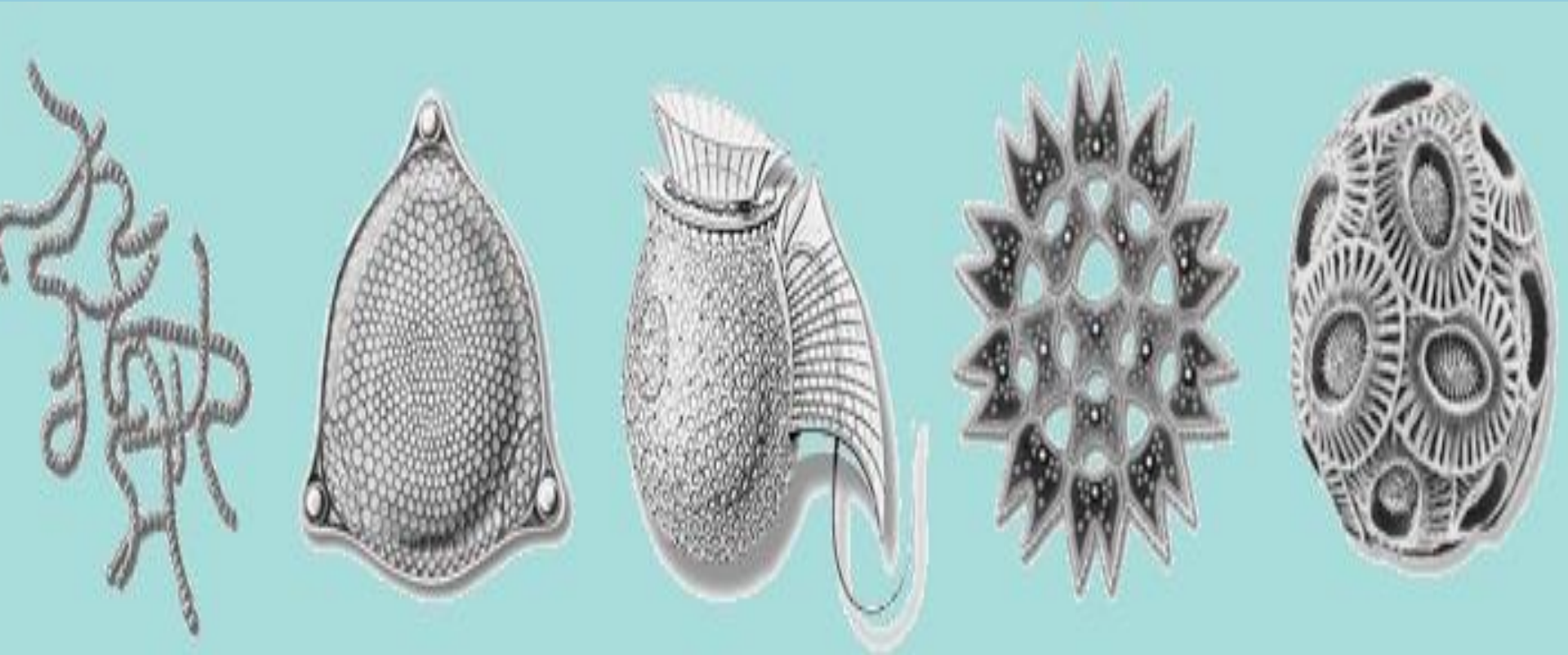


# PHYTOPLANKTON





# PHYTOPLANKTONS



**CYANOBACTERIA**

**DIATOMS**

**DINOFLAGELLATES**

**GREEN ALGAE**

**ETC**

# Phytoplankton

VS

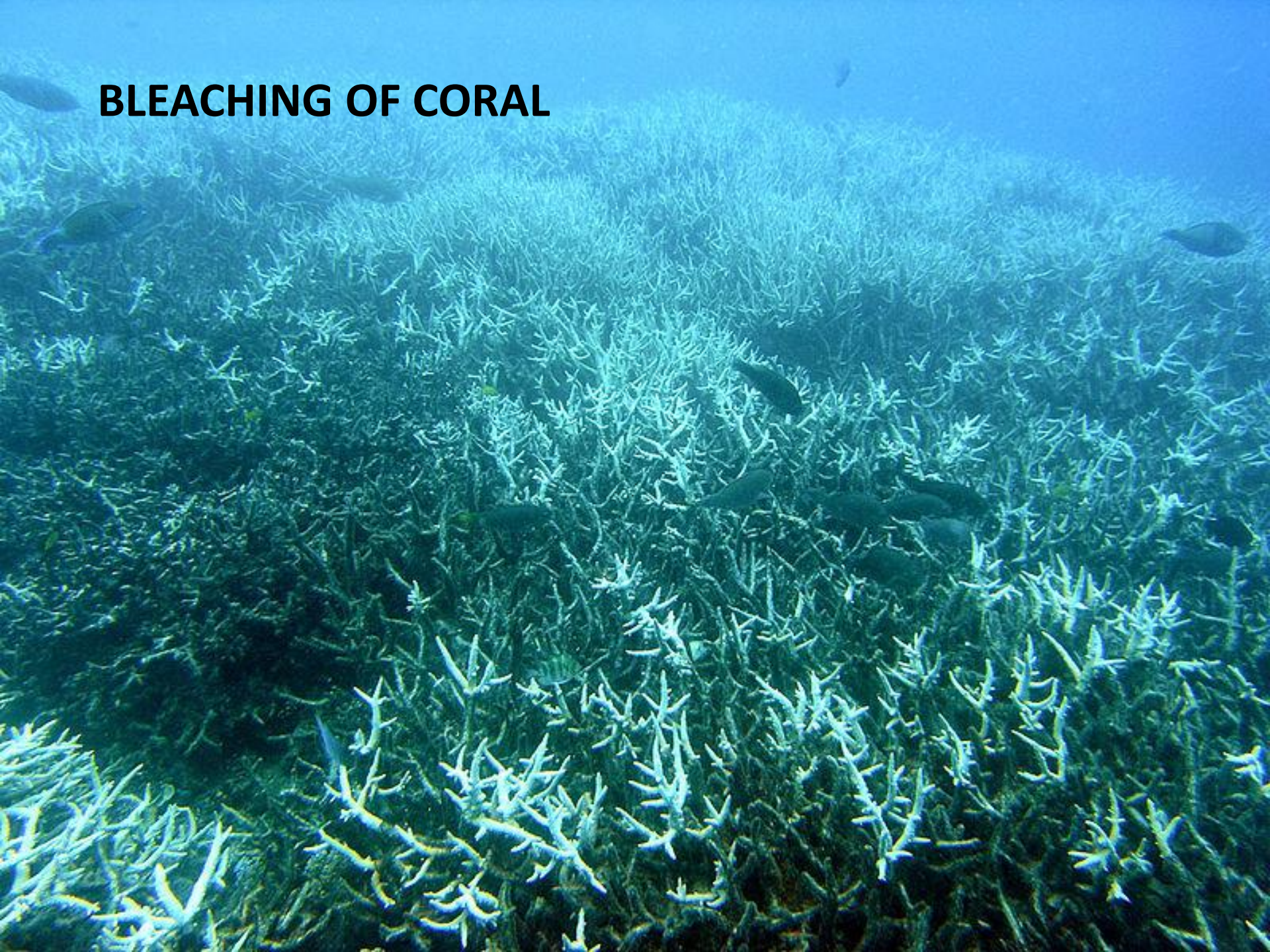
# Zooplankton



BioDifferences



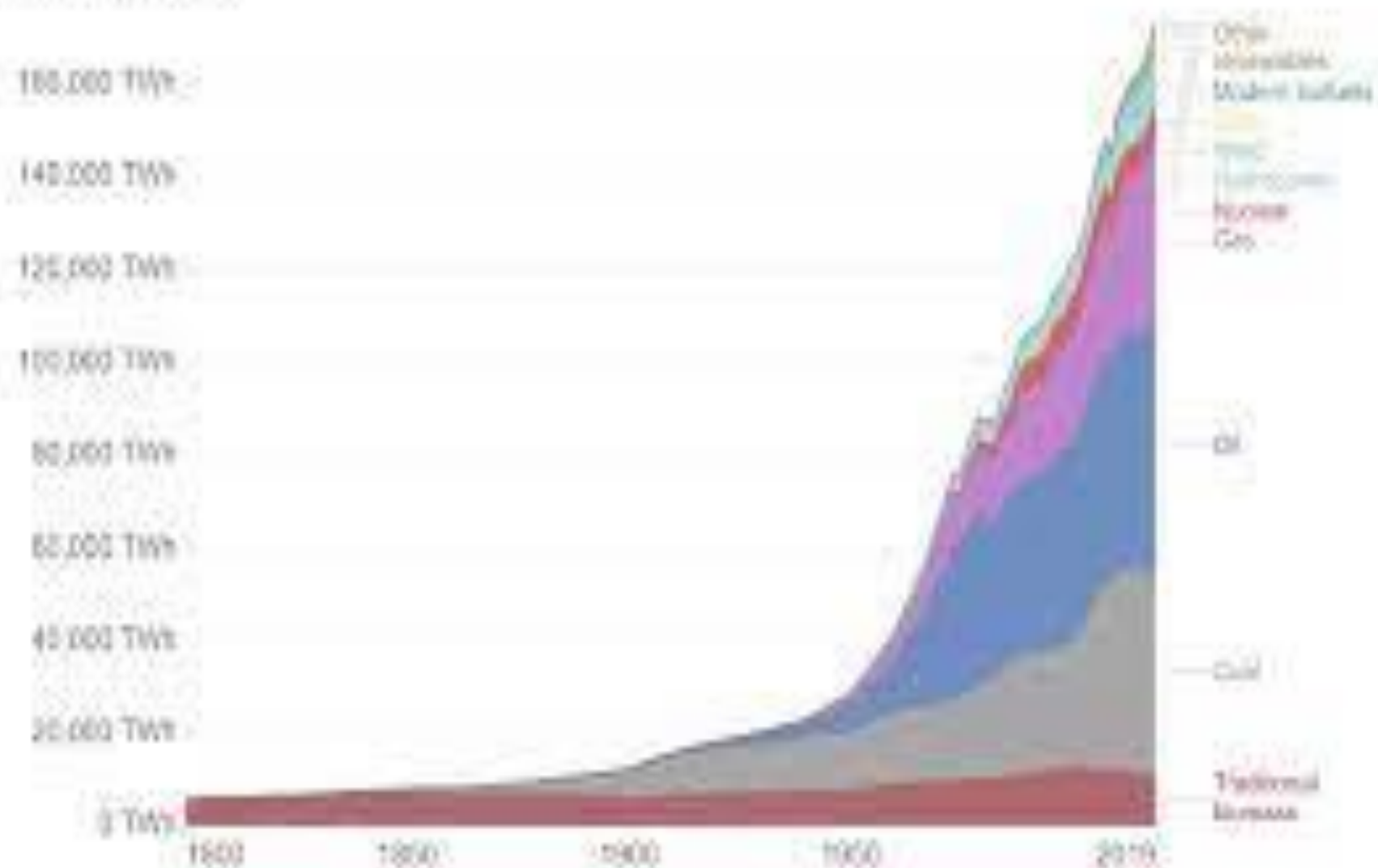
# BLEACHING OF CORAL





# 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.



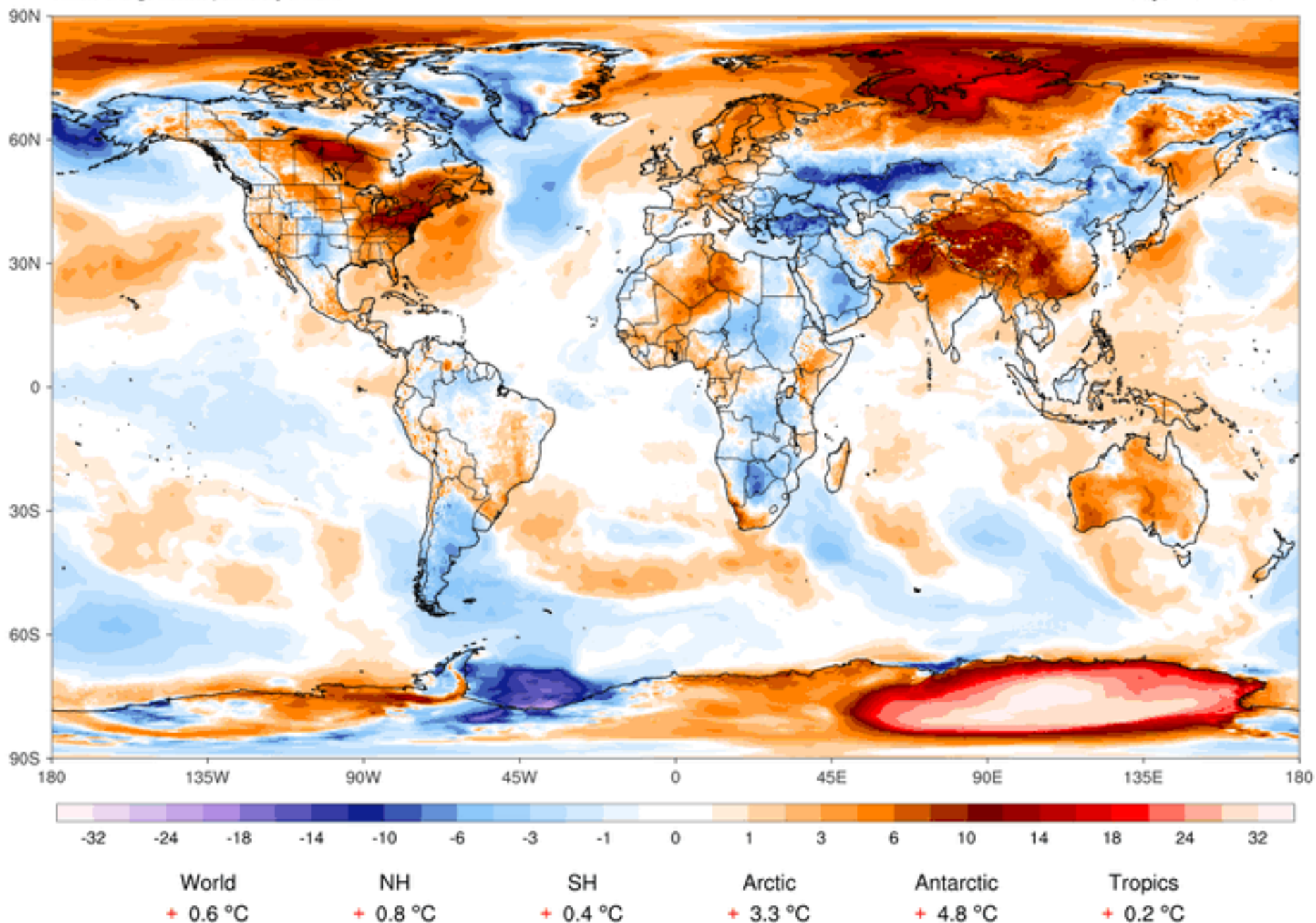
# PLUGGING UP THE CARBON SINKS

The Earth's carbon sinks (oceans, soil, plants) are not able to keep up with humanity's increased CO<sub>2</sub> production

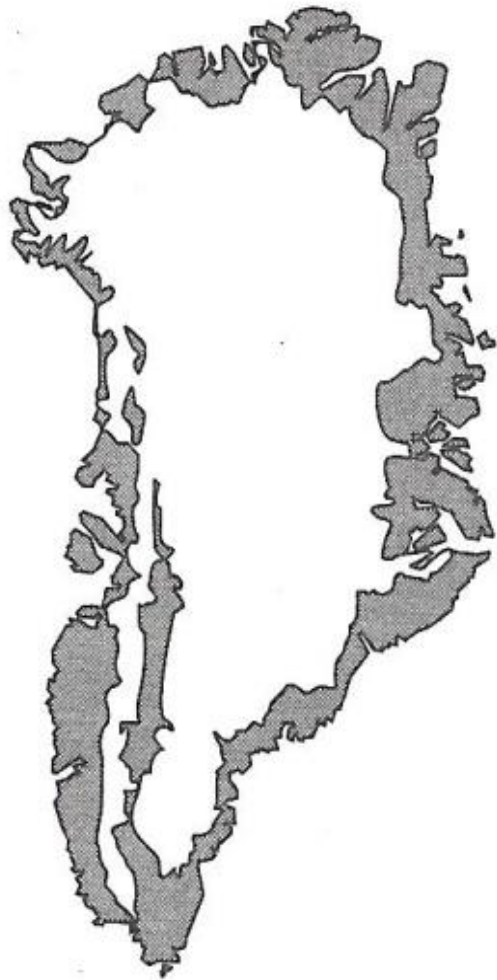
And, the **carbon sinks become so full, and can no longer absorb any more CO<sub>2</sub>**. For example – the oceans push the CO<sub>2</sub> that they can not dissolve into the air, and

The CO<sub>2</sub> intake of some sinks (e.g., trees) slow down the further intake of CO<sub>2</sub>

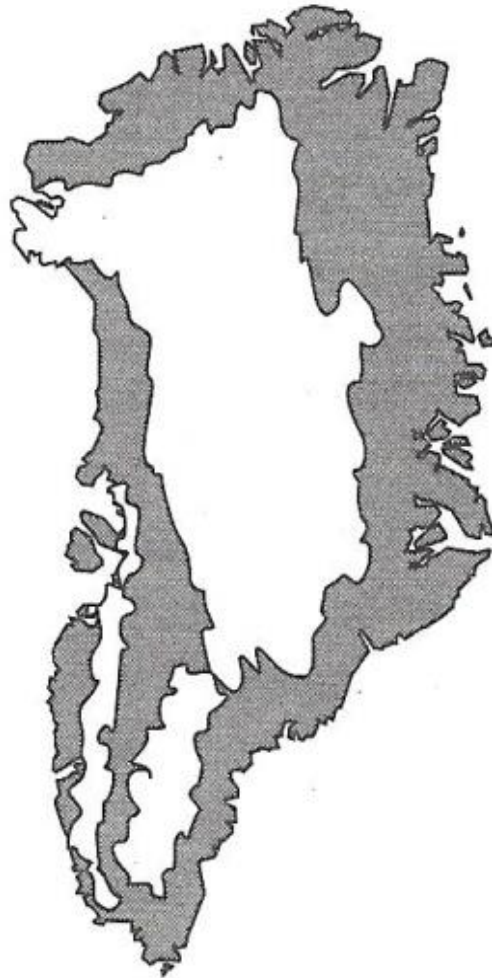
And they may give it up (release CO<sub>2</sub>)



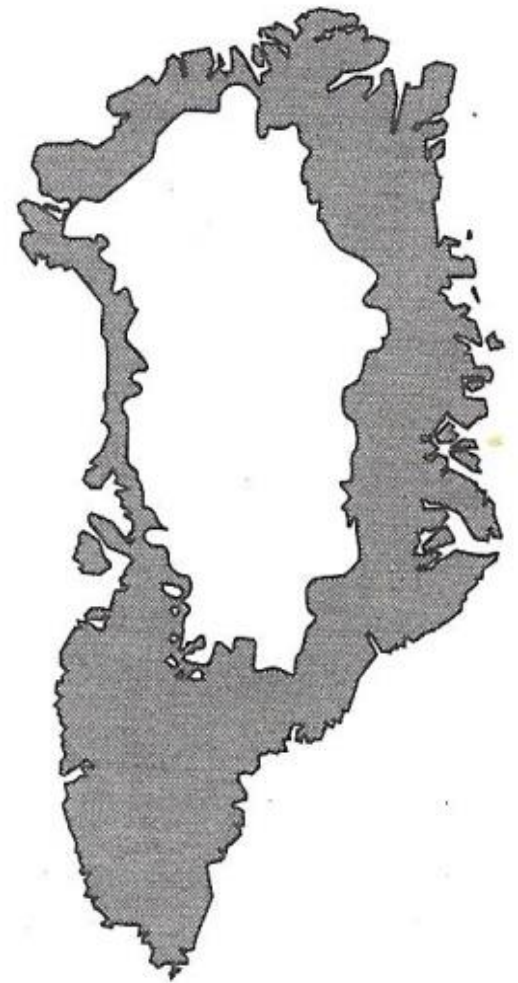
## Greenland Seasonal Ice Melt



1992



2002



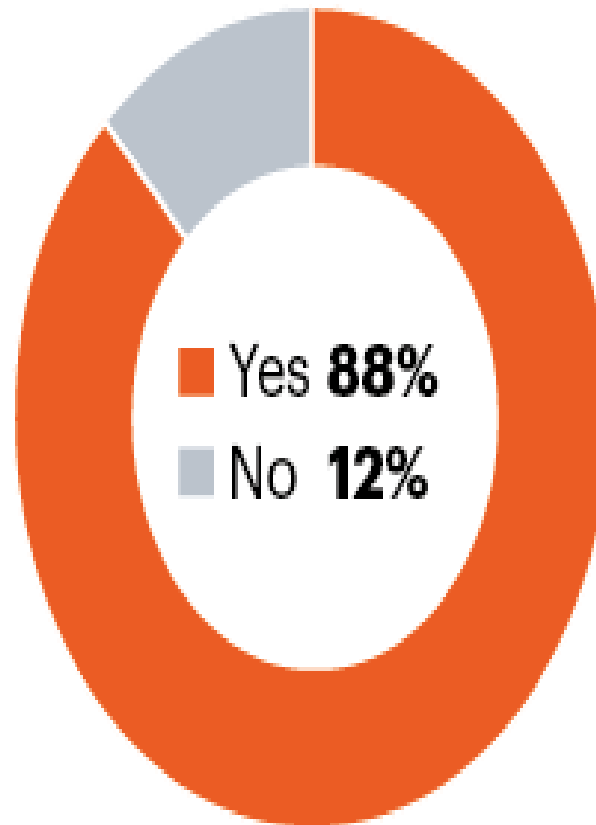
2005

*Based on NASA Greenland imaging*



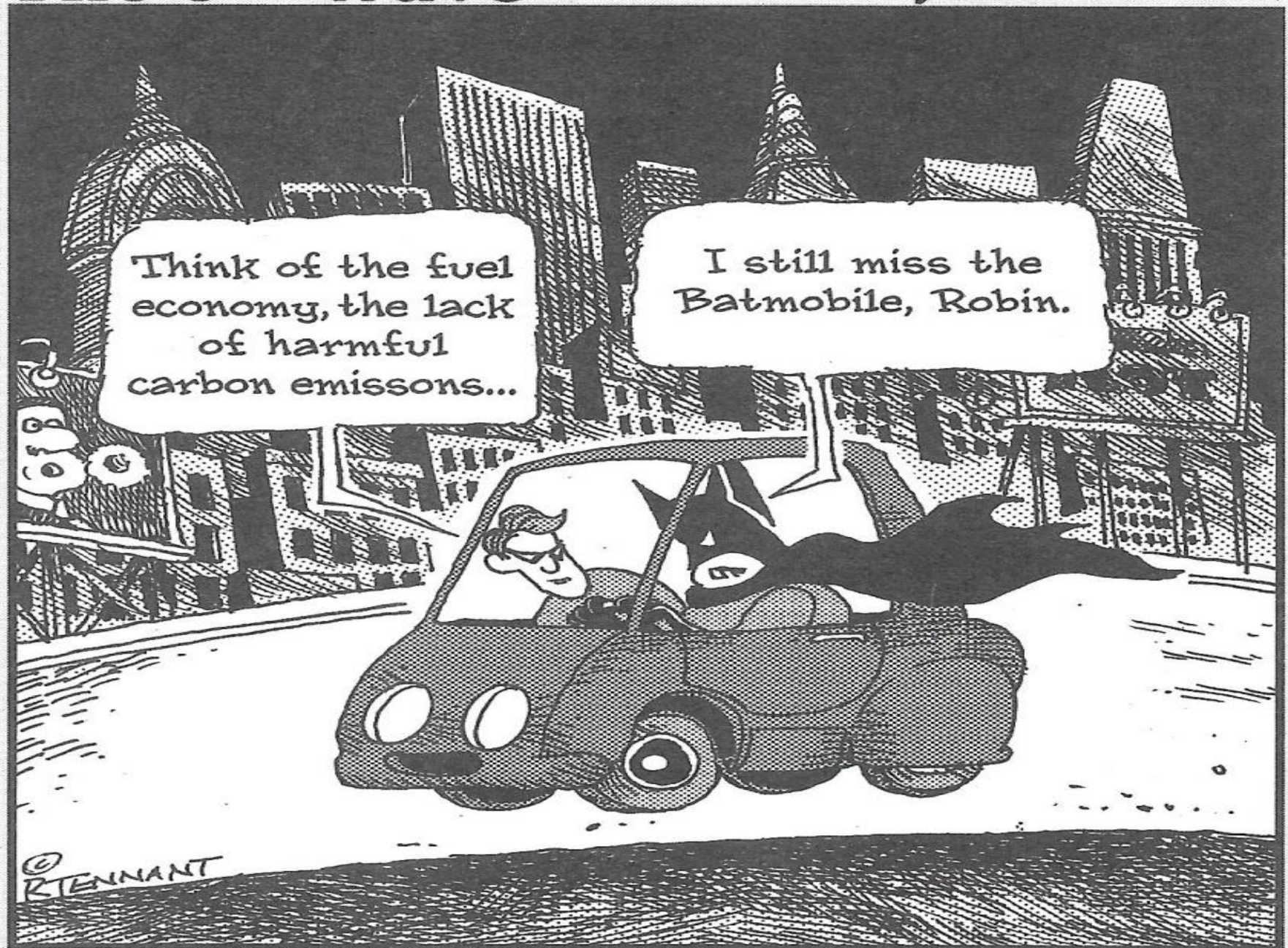
**Do you think the  
world is  
experiencing a  
'climate crisis'?**

**STUDY IN  
*NATURE*  
2021**



# The 5th Wave

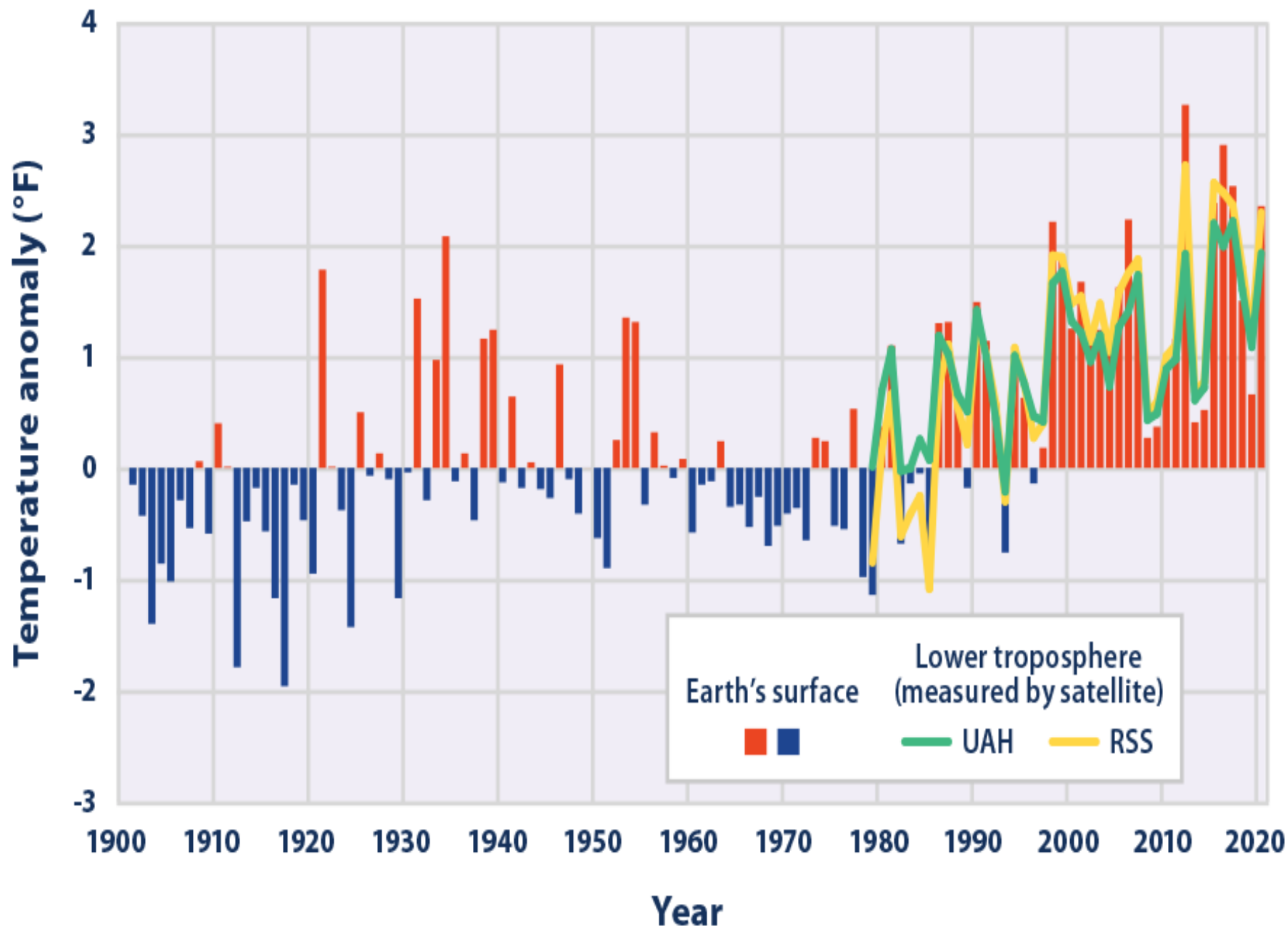
By Rich Tennant



Think of the fuel economy, the lack of harmful carbon emissions...

I still miss the Batmobile, Robin.

© RTENNANT



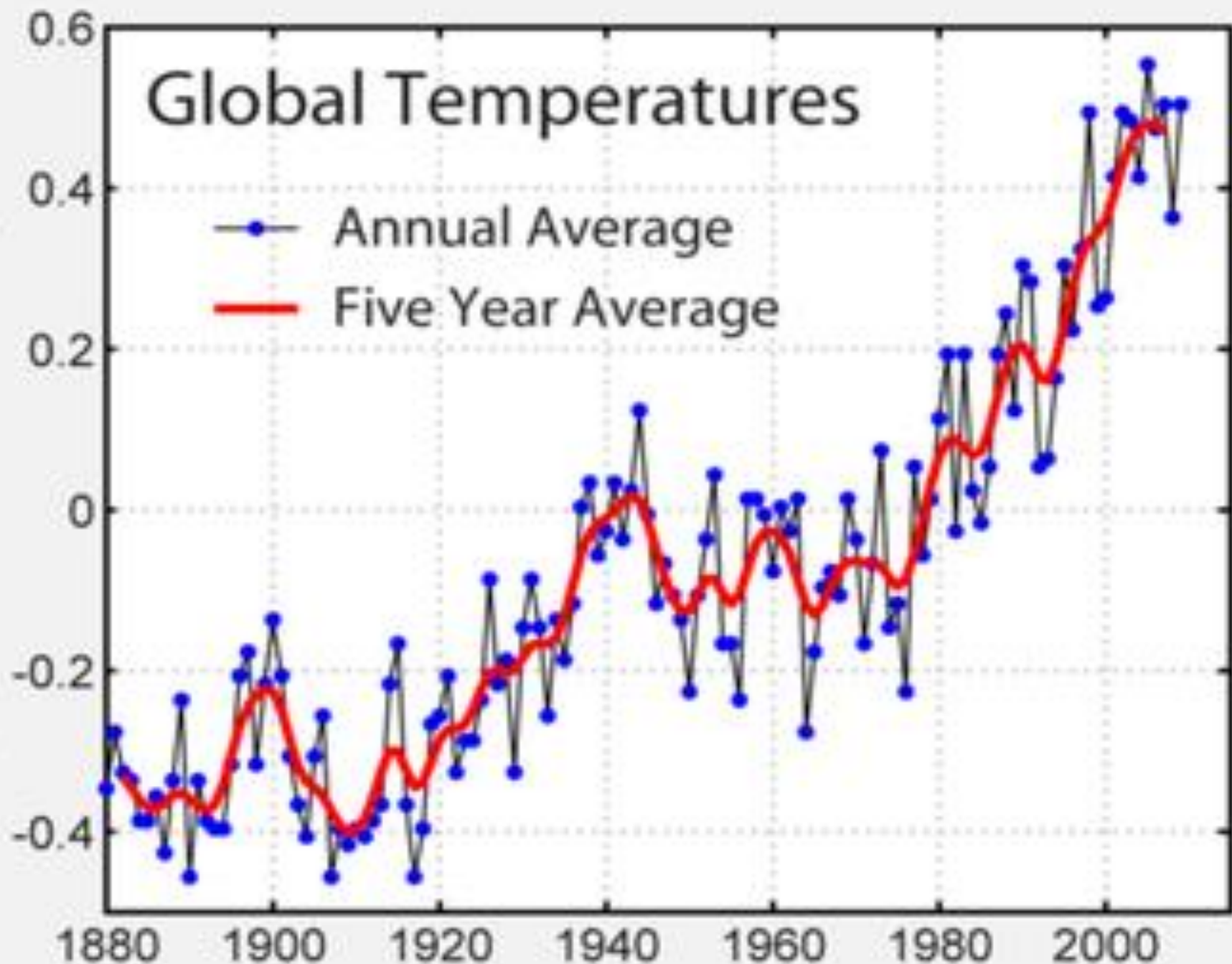




Temperature Anomaly ( $^{\circ}\text{C}$ )

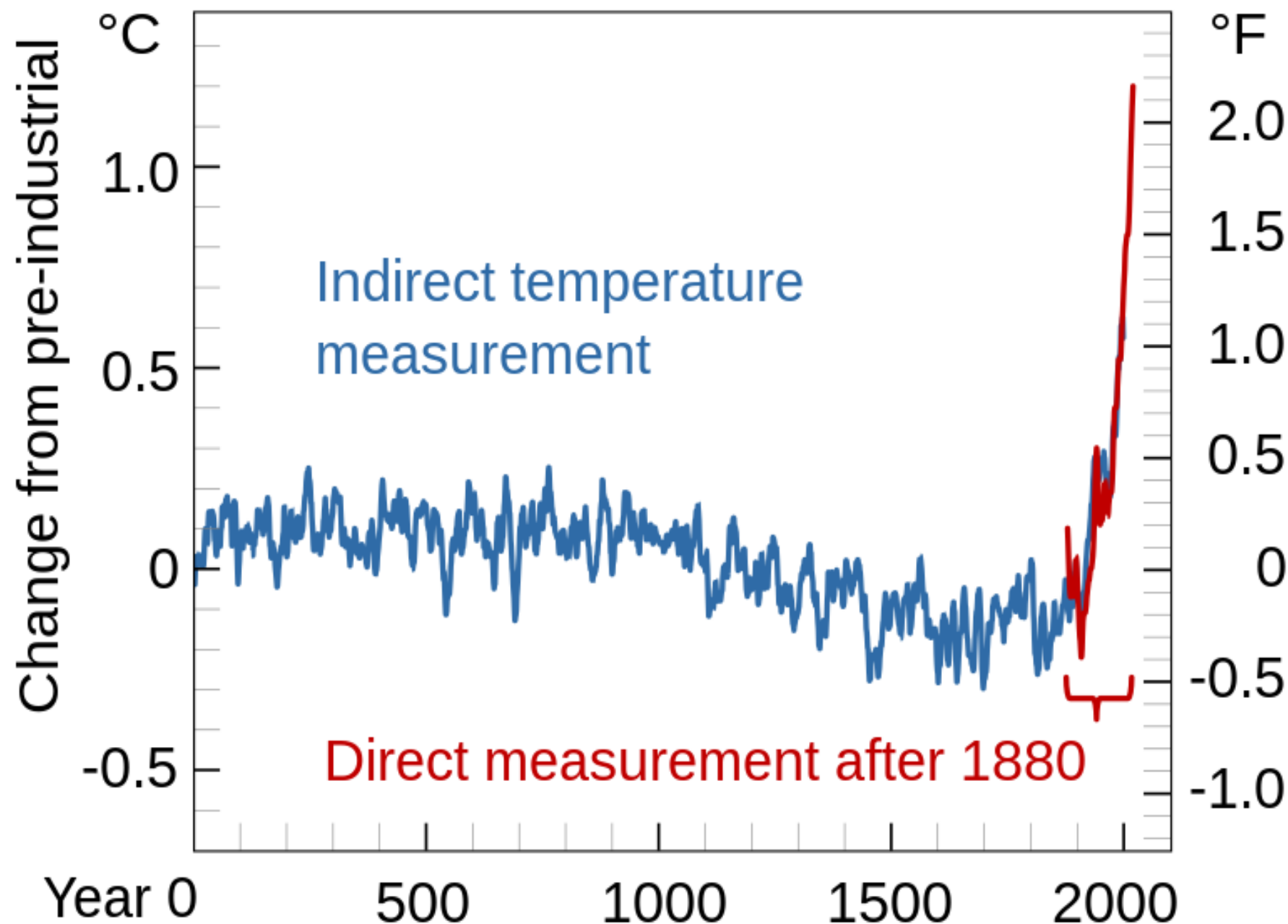
# Global Temperatures

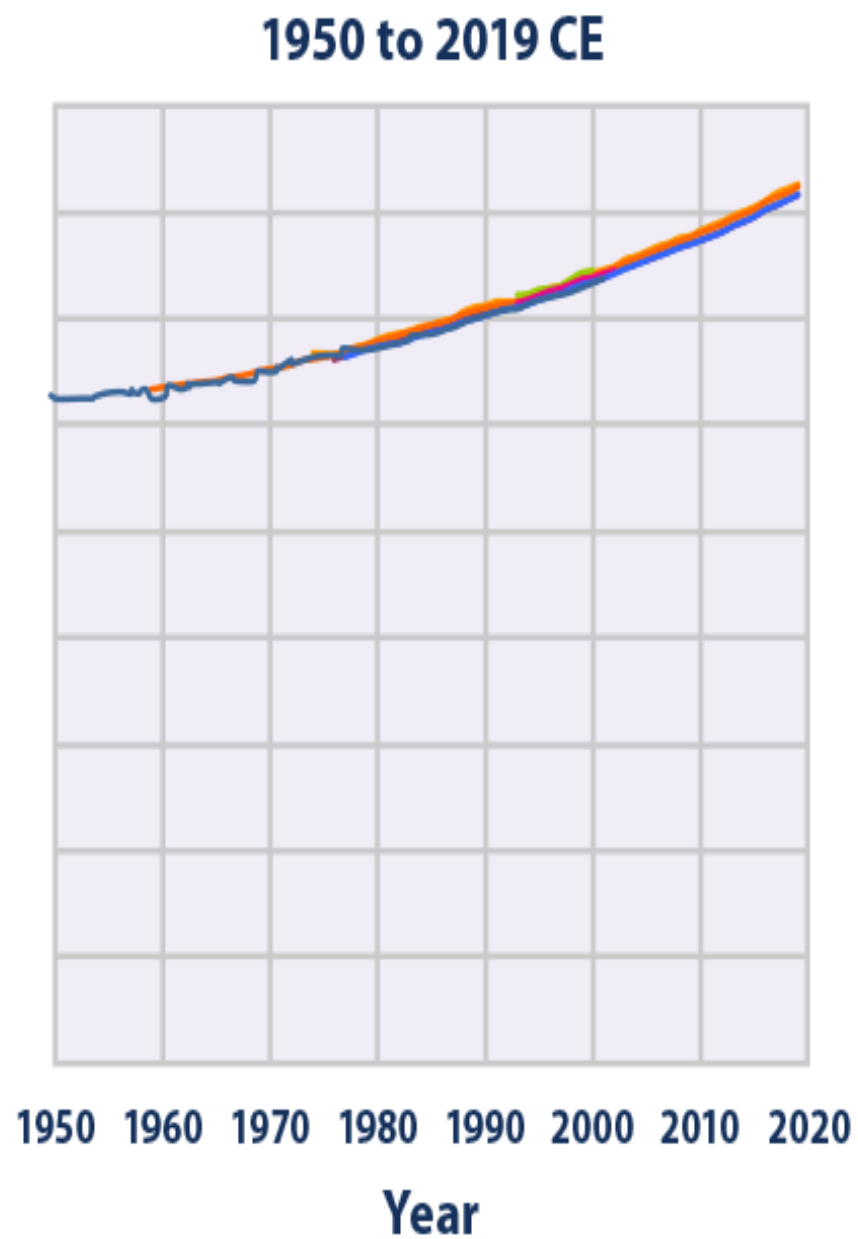
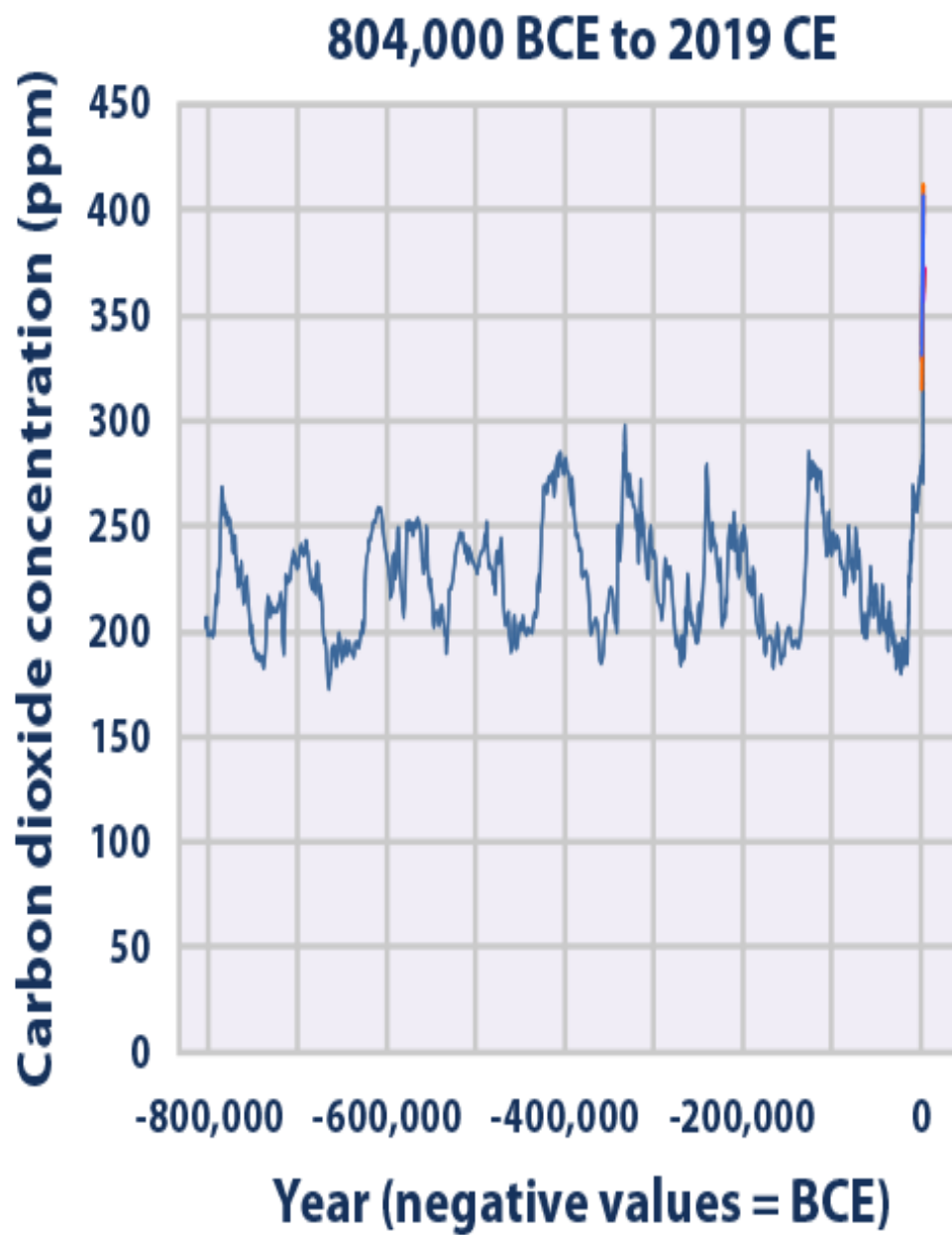
- Annual Average
- Five Year Average



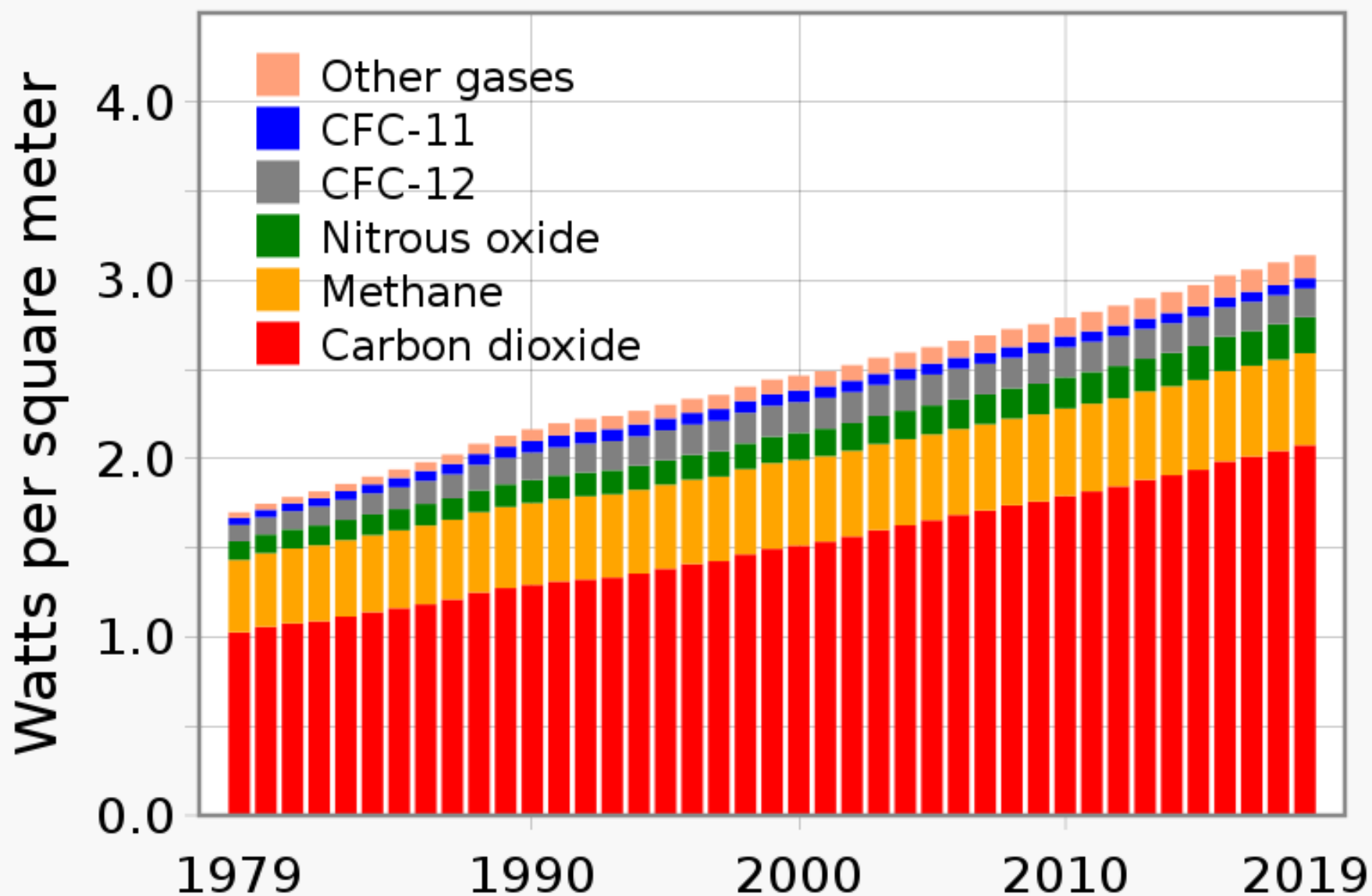


# Global temperature in the Common Era





# Warming influence of greenhouse gases



# **CLIMATE CHANGE: GLOBAL WARMING AND ITS IMPACT ON EARTH'S WEATHER PATTERNS**

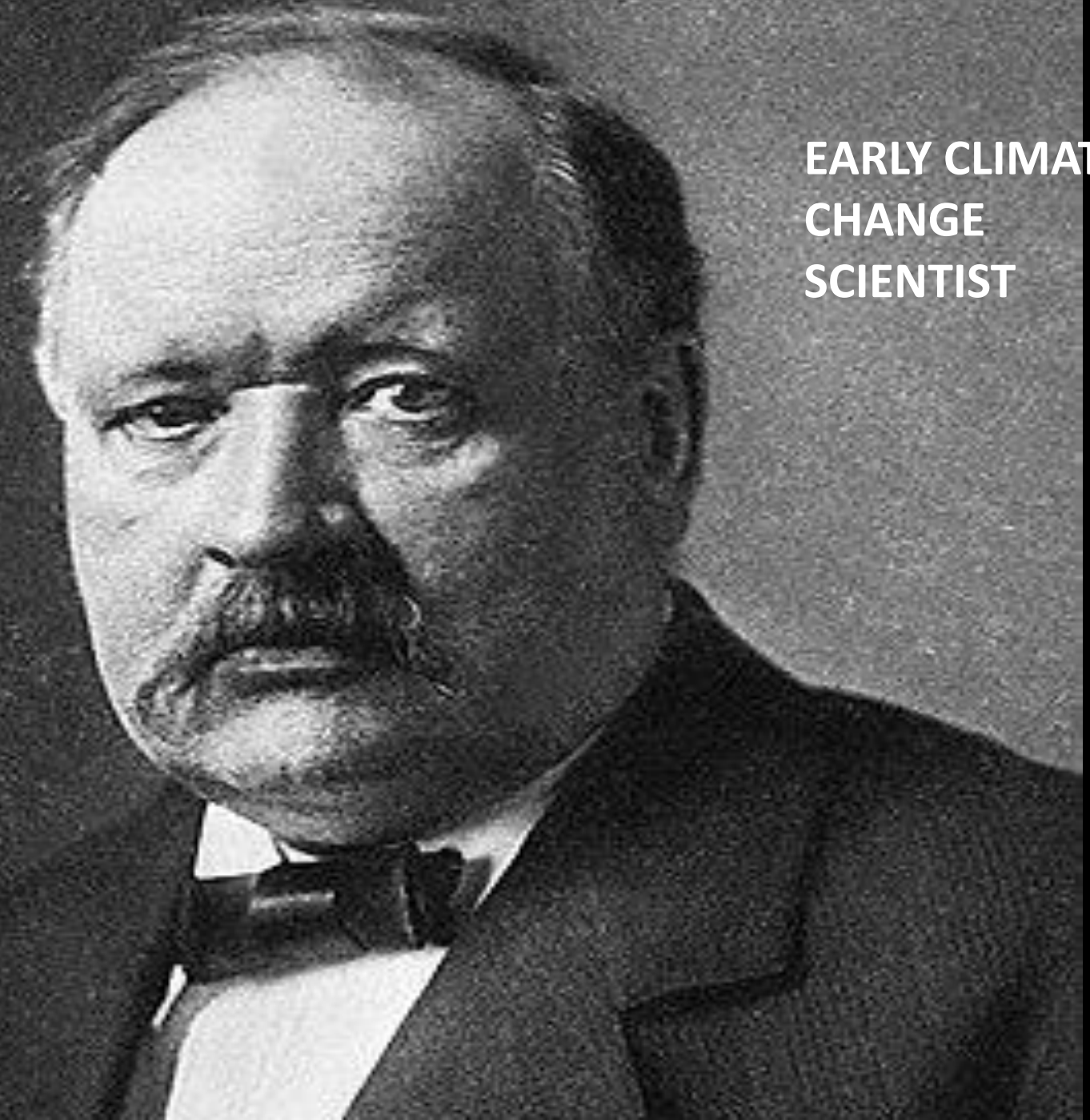
**(2 TERMS OFTEN USED  
INTERCHANGABLE)**

**“GLOBAL WARMING”: FIRST USED: 1988  
BY JAMES HANSEN/NASA TO US SENATE  
(Studied since 1850's – Tyndall)**

**2019: Oxford Language:  
“Climate Emergency” word of the year**

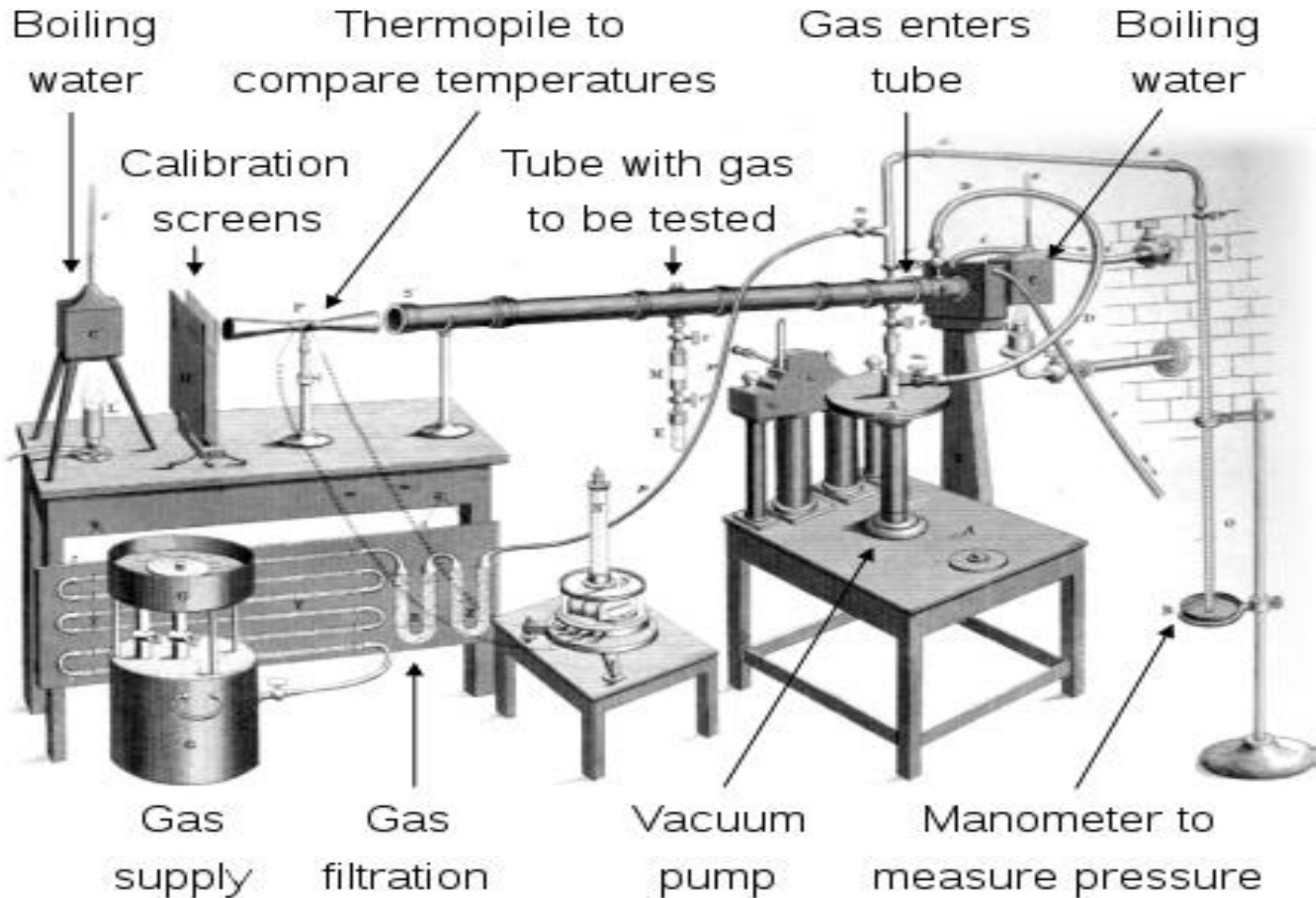
**SVANTE  
ARRHENIUS**

**EARLY CLIMATE  
CHANGE  
SCIENTIST**



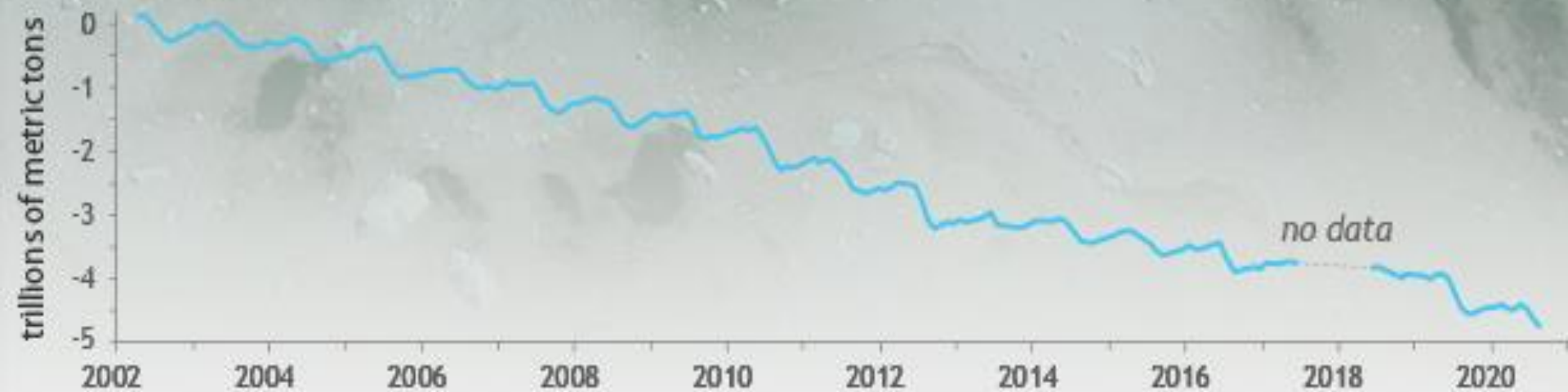


# JOHN TYNDALL'S APPARATUS 1861: STUDY OF RADIATION/GAS



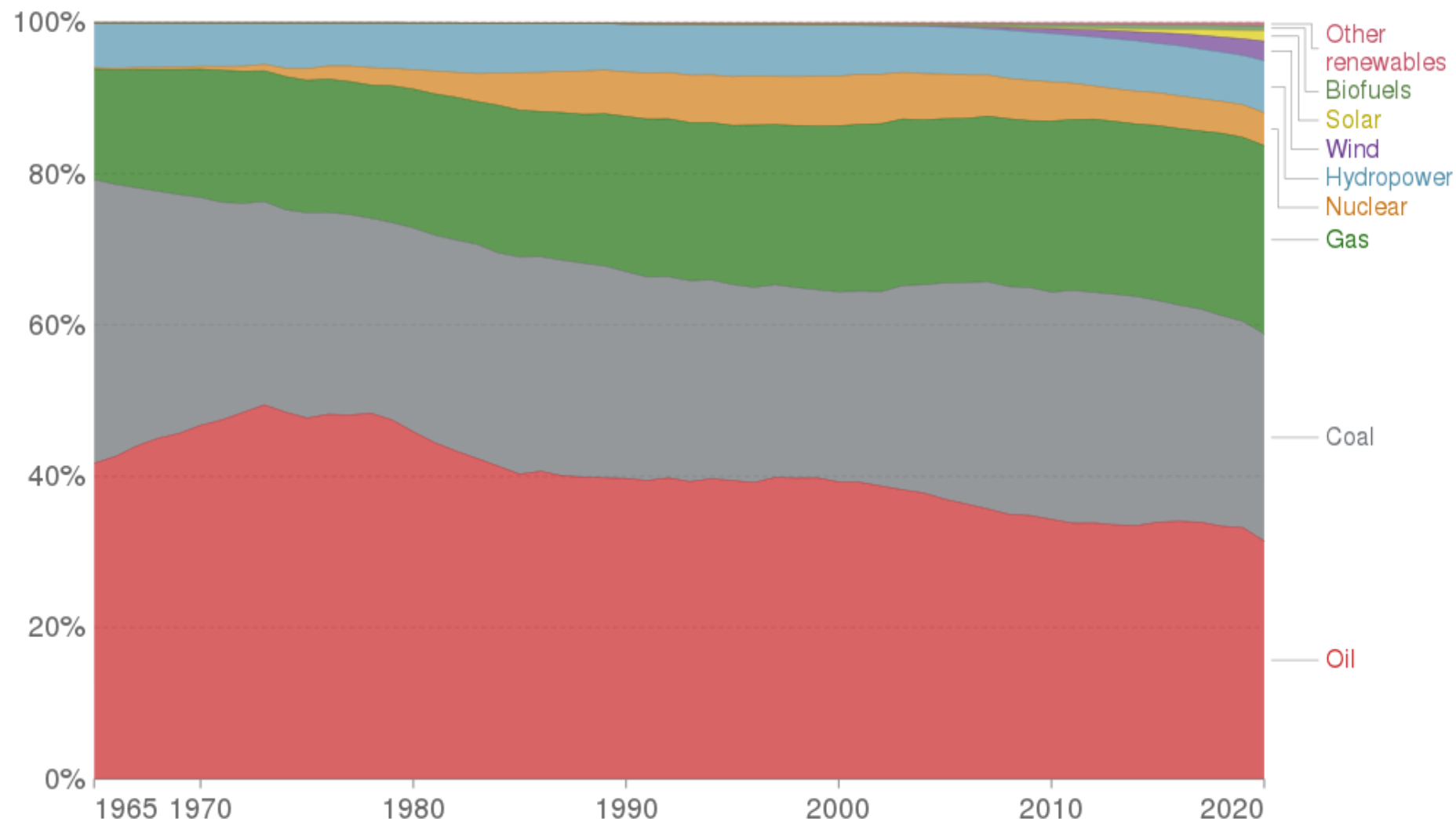


## GREENLAND ICE SHEET MASS LOSS



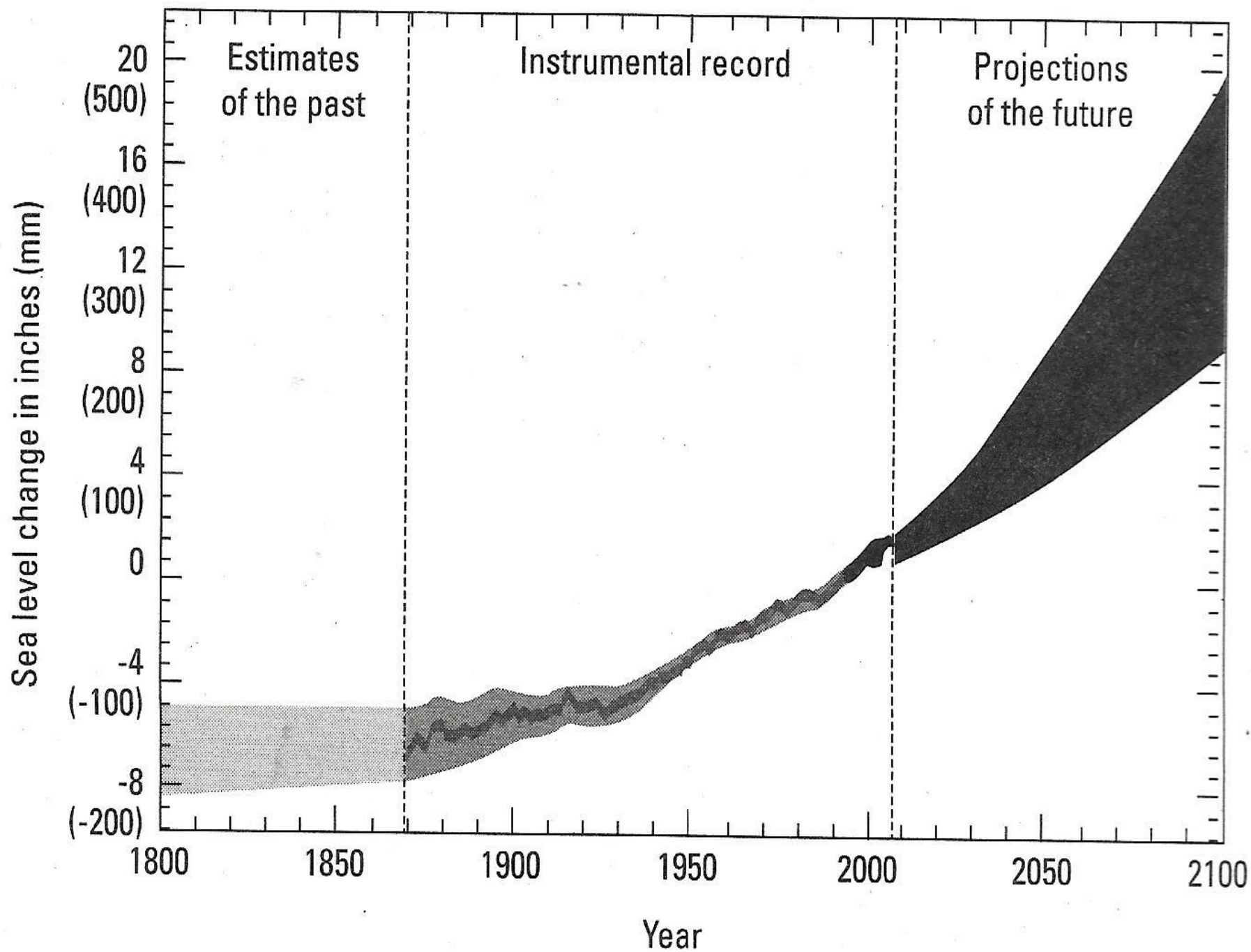
# Energy consumption by source, World

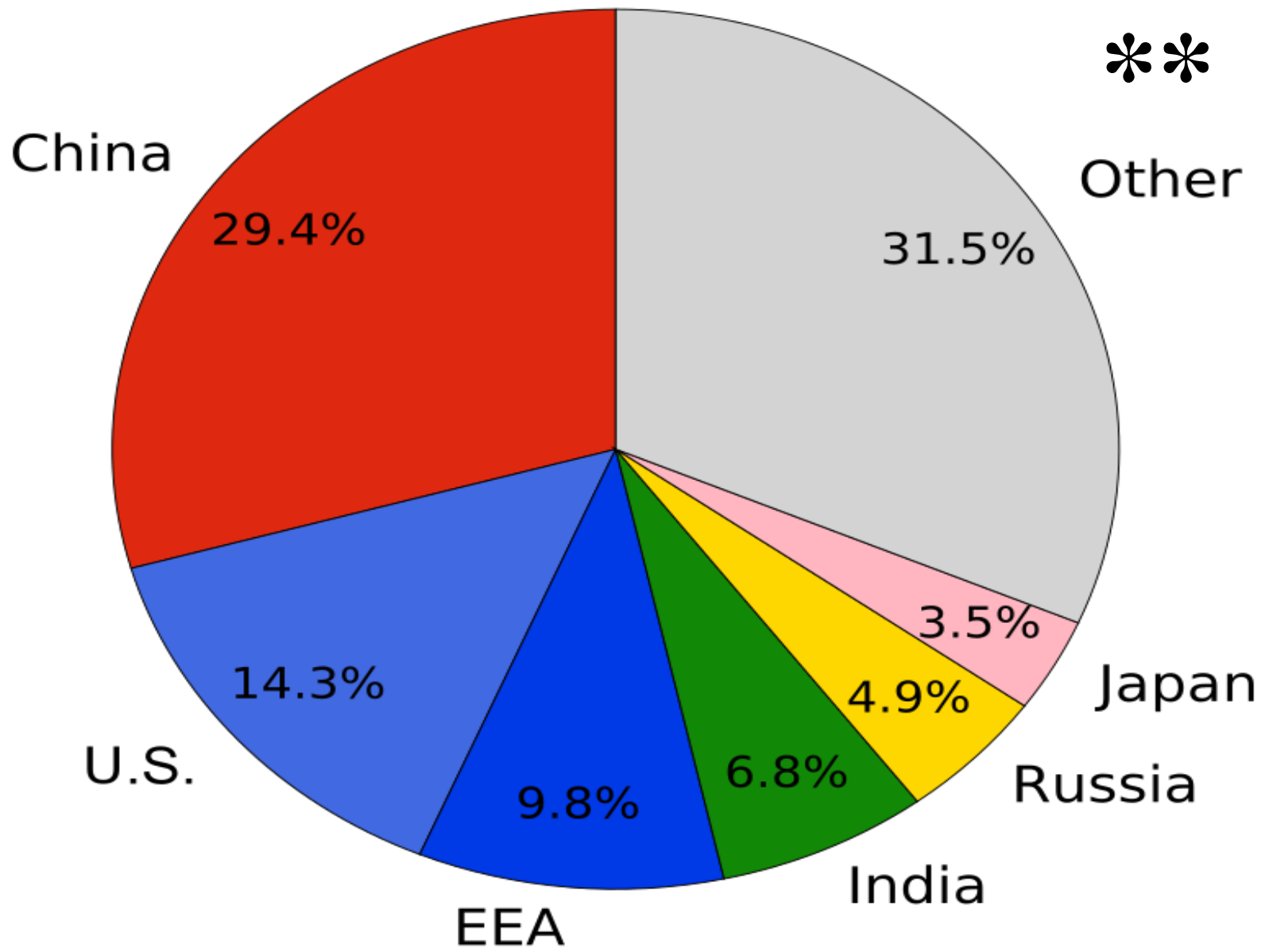
Primary energy consumption is measured in terawatt-hours (TWh). Here an inefficiency factor (the 'substitution' method) has been applied for fossil fuels, meaning the shares by each energy source give a better approximation of final energy consumption.



Source: BP Statistical Review of World Energy

Note: 'Other renewables' includes geothermal, biomass and waste energy.







**'Not a good sign': The temperature was 70 degrees above average near South Pole, a troubling record**

**Maria Jimenez Moya USA TODAY**

**March 19, 2022**

# **Hot poles: Antarctica, Arctic 70 and 50 degrees above normal**

**By SETH BORENSTEIN**

USA Today/AP News

March 19, 2022

**Not a good sign': The temperature was 70 degrees above average near South Pole, a troubling record**

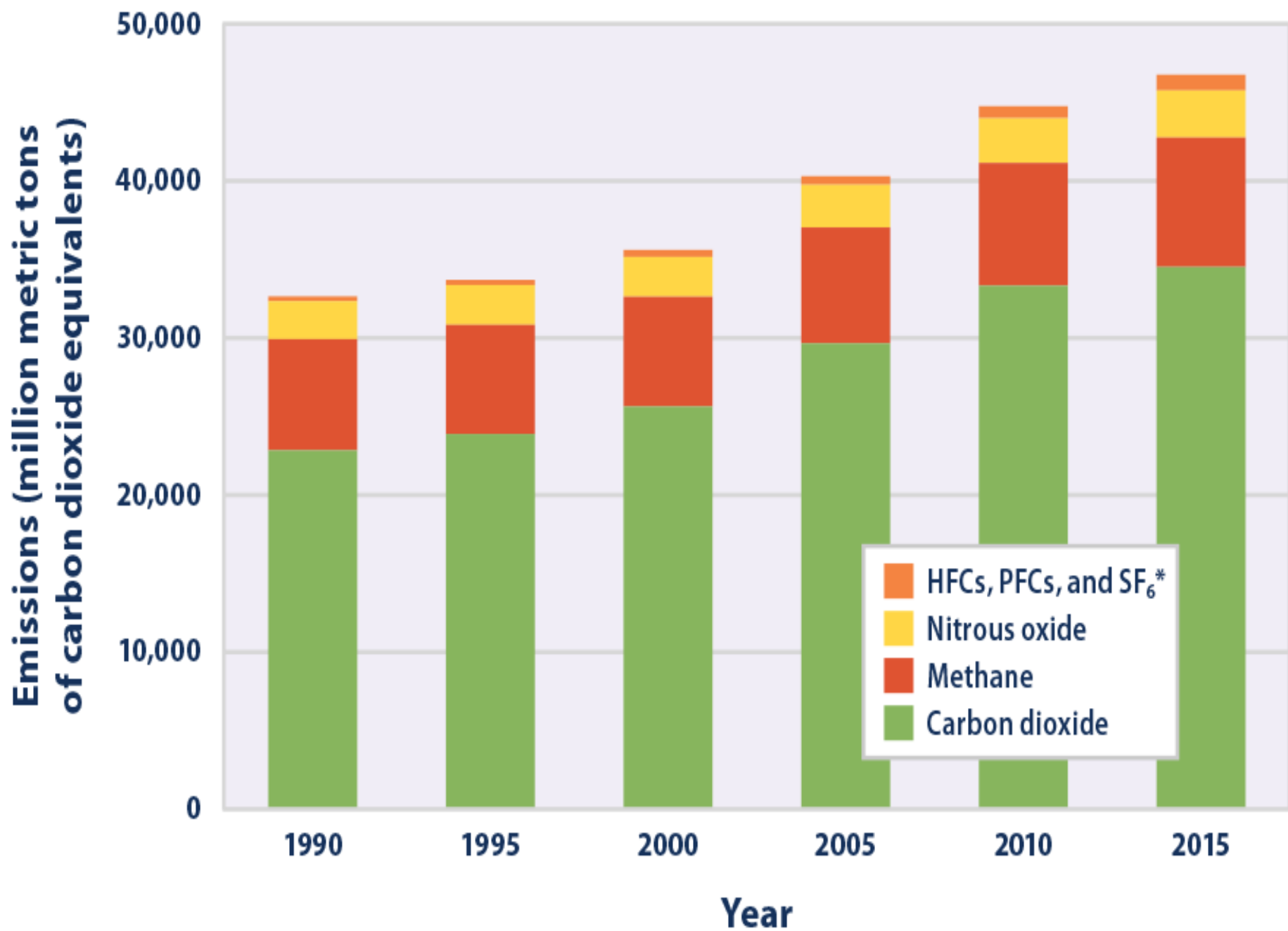
**[Maria Jimenez Moya](#)** USA TODAY

March 19, 2022

Earth's poles are undergoing simultaneous freakish extreme heat with parts of Antarctica more than 70 degrees (40 degrees Celsius) warmer than average and areas of the Arctic more than 50 degrees (30 degrees Celsius) warmer than average.

Weather stations in Antarctica shattered records Friday as the region neared autumn.







# Global greenhouse gas emissions by gas

Greenhouse gas emissions are converted to carbon dioxide-equivalents (CO<sub>2</sub>e) by multiplying each gas by its 100-year 'global warming potential' value: the amount of warming one tonne of the gas would create relative to one tonne of CO<sub>2</sub> over a 100-year timescale. This breakdown is shown for 2016.

F-gases  
(HFC, PFC & NF<sub>3</sub>)  
1.7%

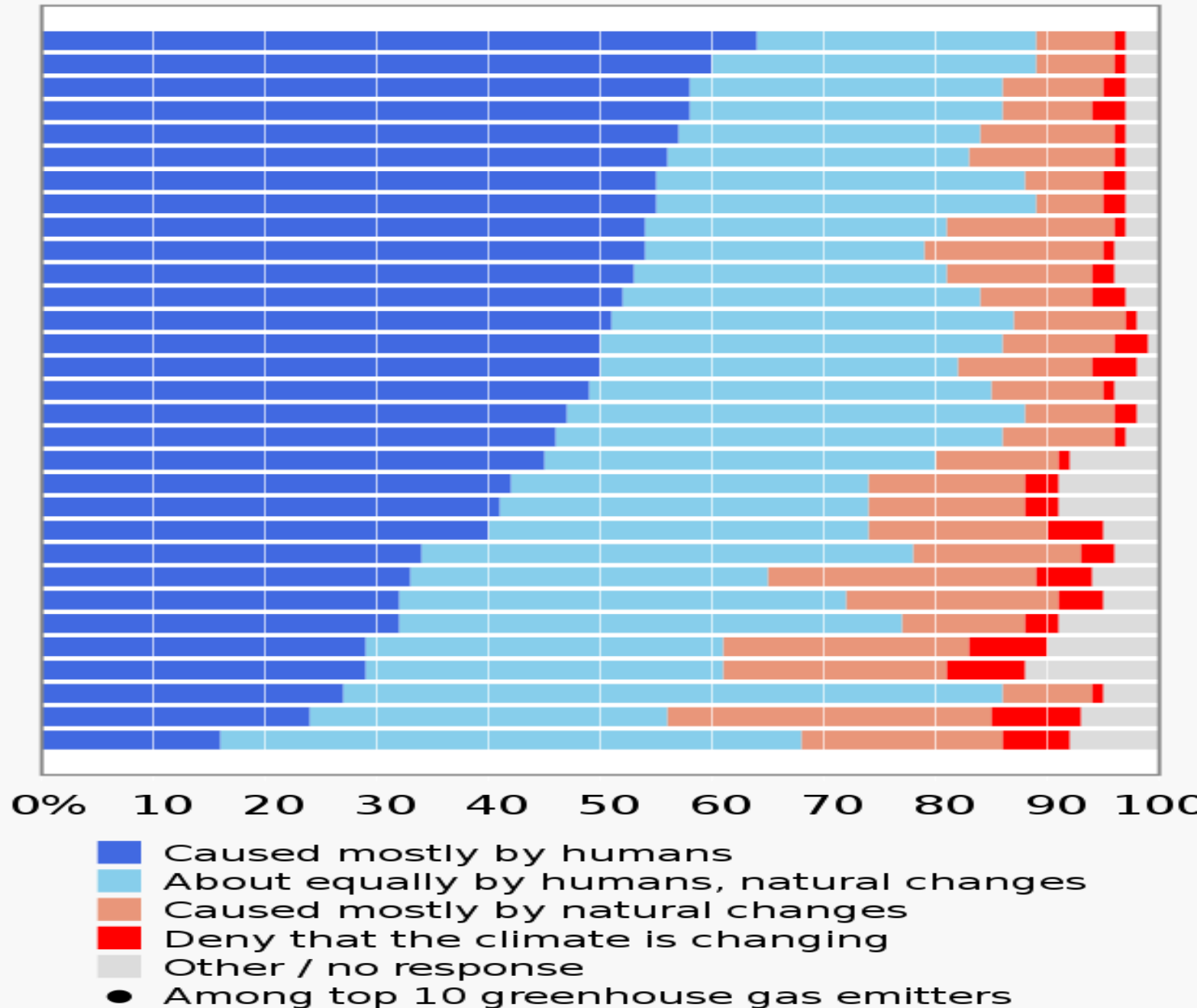
Carbon dioxide (CO<sub>2</sub>)  
74.4%

Methane (CH<sub>4</sub>)  
17.3%

Nitrous oxide (N<sub>2</sub>O)  
4.2%

# Public opinion: causes of climate change

Spain  
Italy  
Ireland  
Taiwan  
Costa Rica  
Argentina  
U.K.  
France  
Mexico  
Colombia  
● Brazil  
Netherlands  
● Japan  
● Canada  
Australia  
● Germany  
Poland  
Czech Rep.  
Thailand  
● India  
Turkey  
● U.S.A.  
● Russia  
South Africa  
Philippines  
Malaysia  
Egypt  
Saudi Arabia  
Vietnam  
Nigeria  
● Indonesia

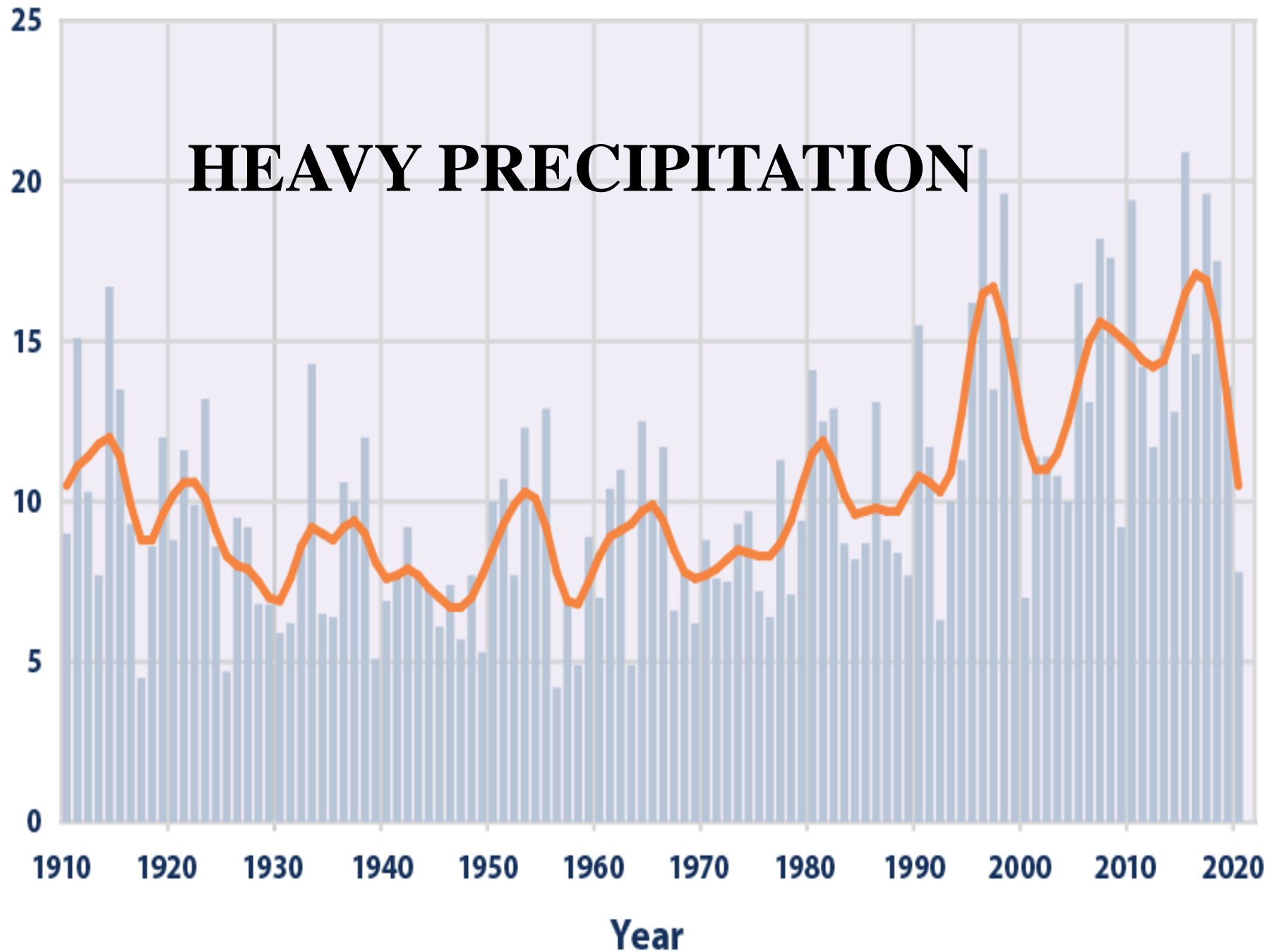






# HEAVY PRECIPITATION

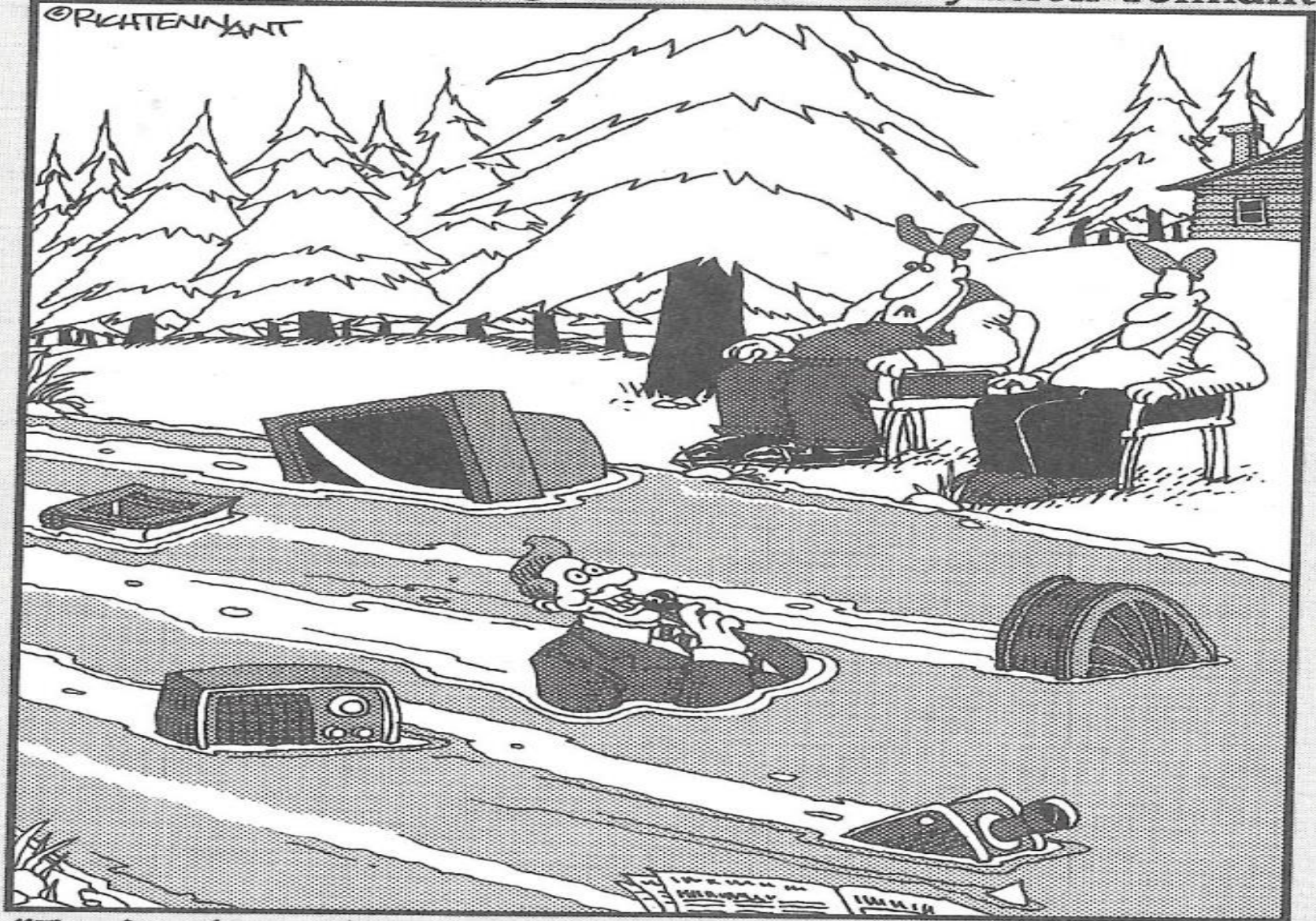
Percent of land area



# The 5th Wave

By Rich Tennant

©RICH TENNANT



"Isn't that the guy who was reporting from the glacier fields about global warming still being a theory?"



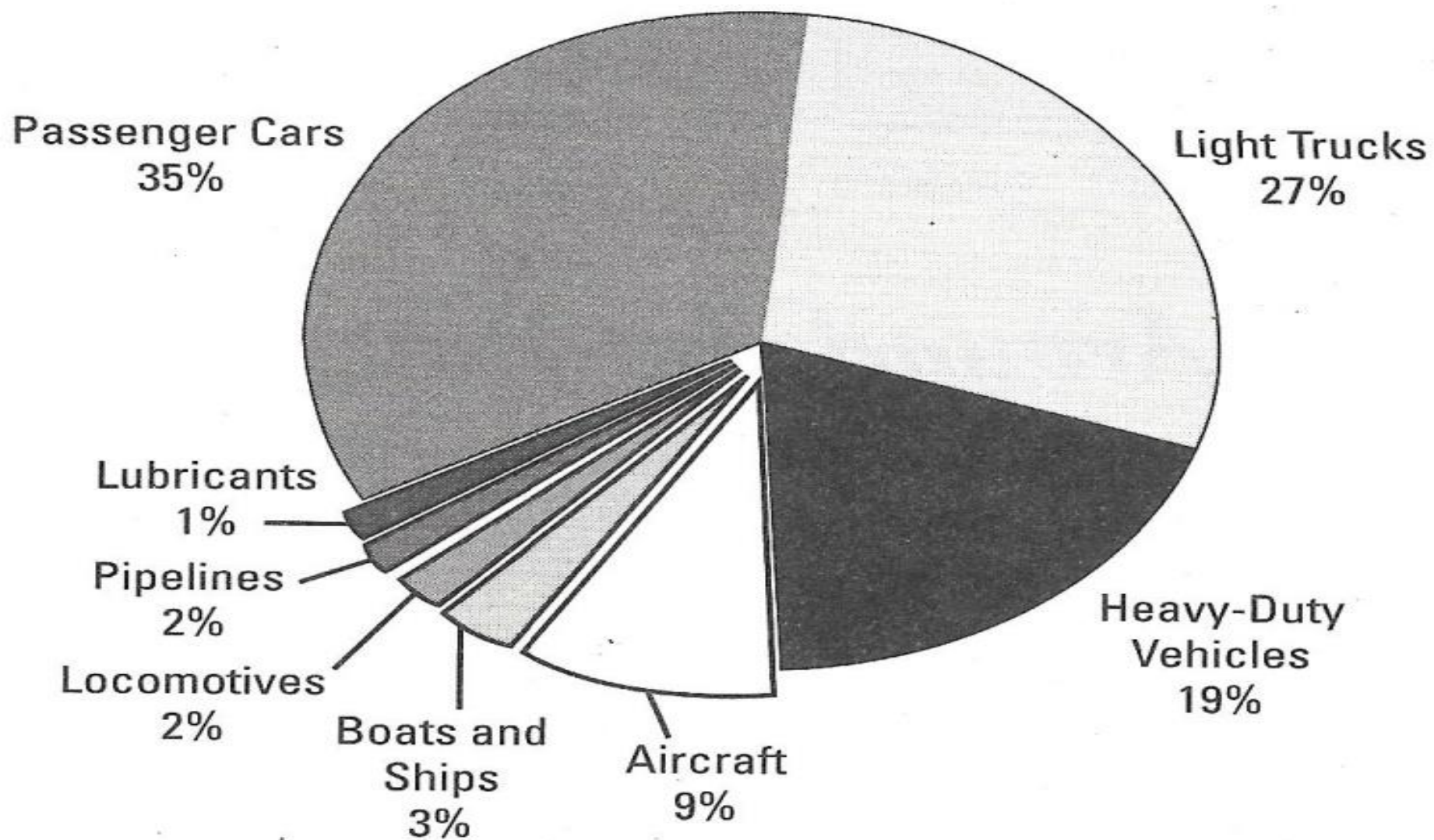


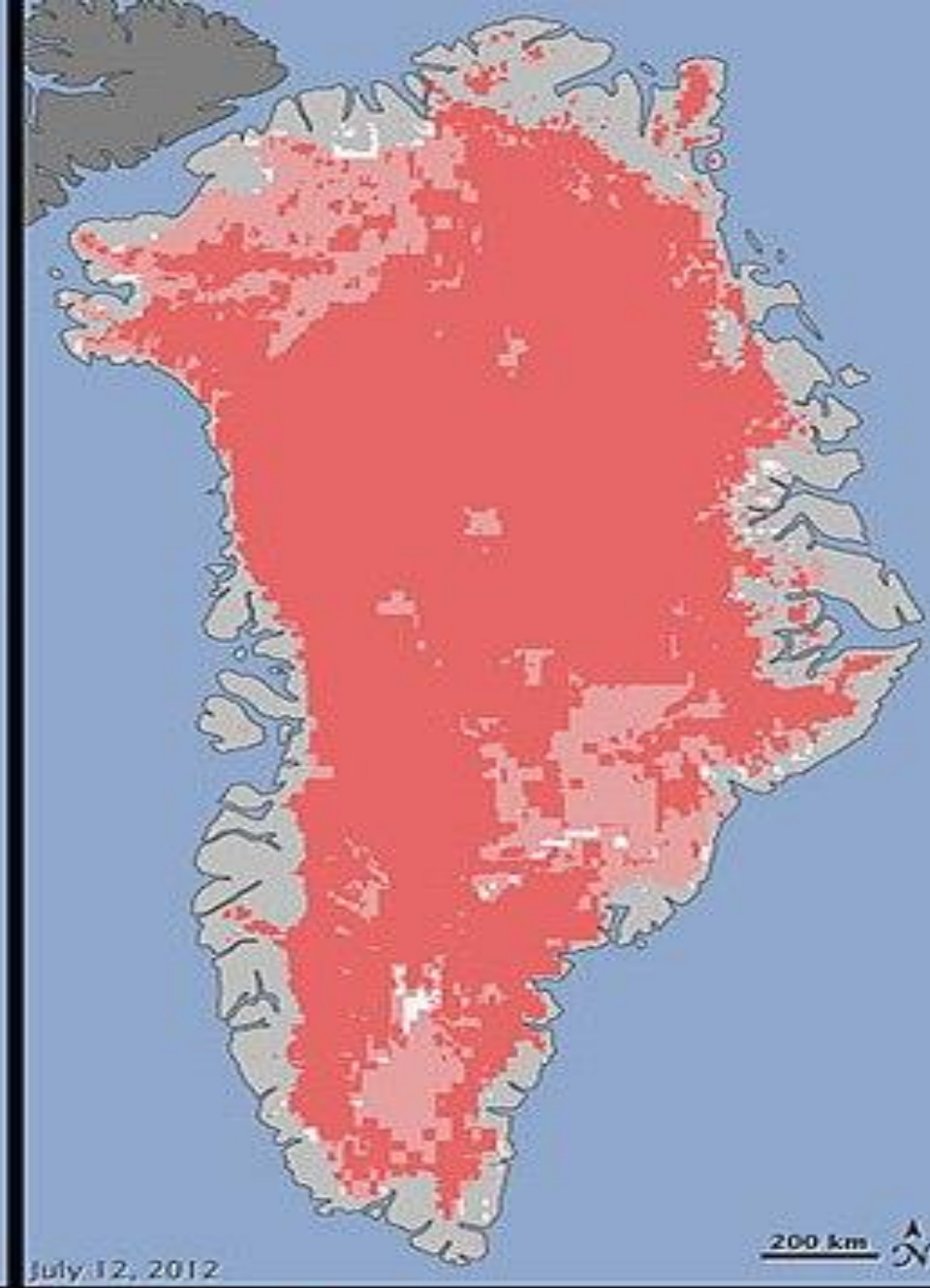
8-9

8-11



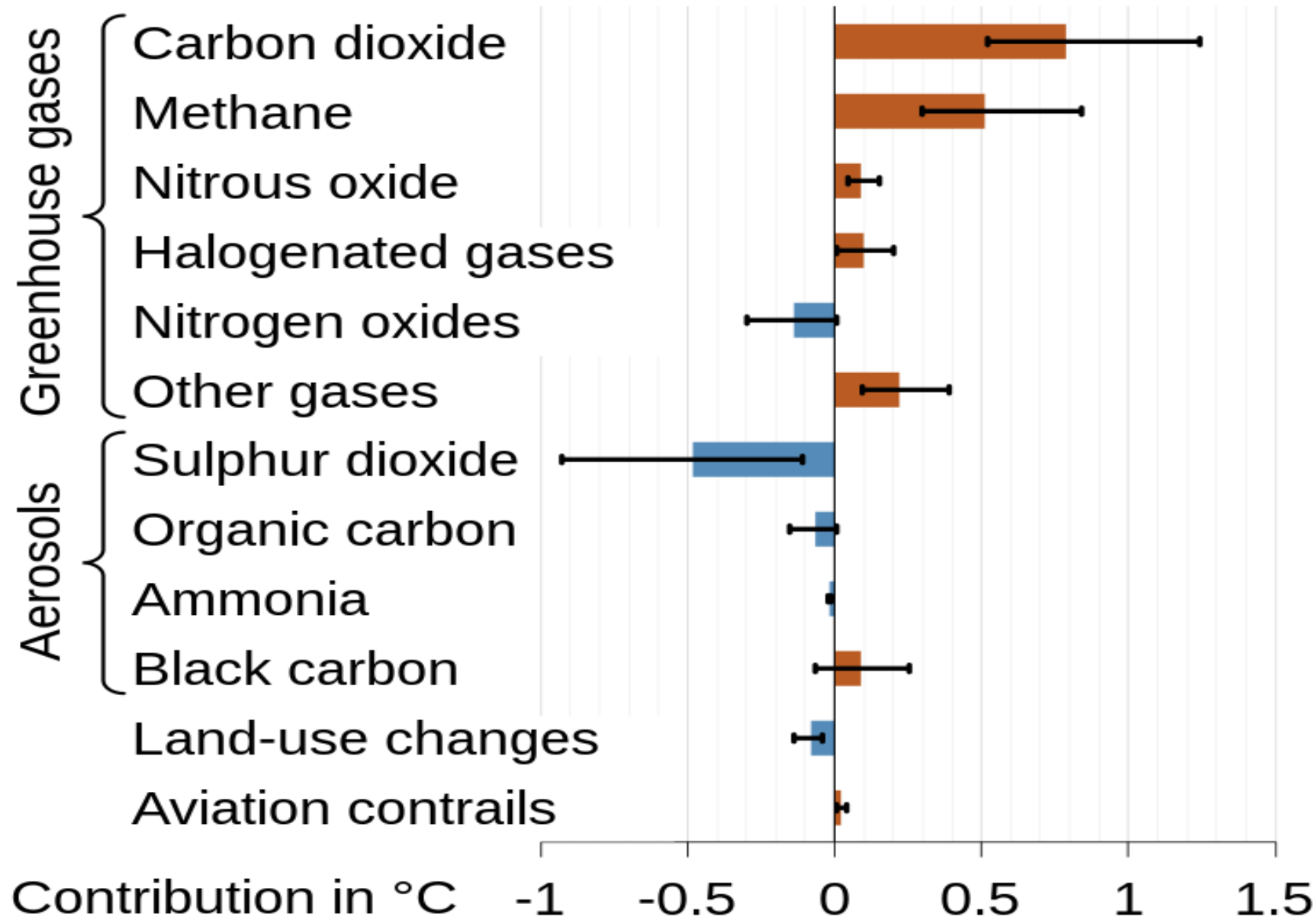
## Transportation Greenhouse Gas Emissions by Source





No Data   Ice/Snow Free   Probable Melt   Melt   No Melting

## Physical drivers of climate change

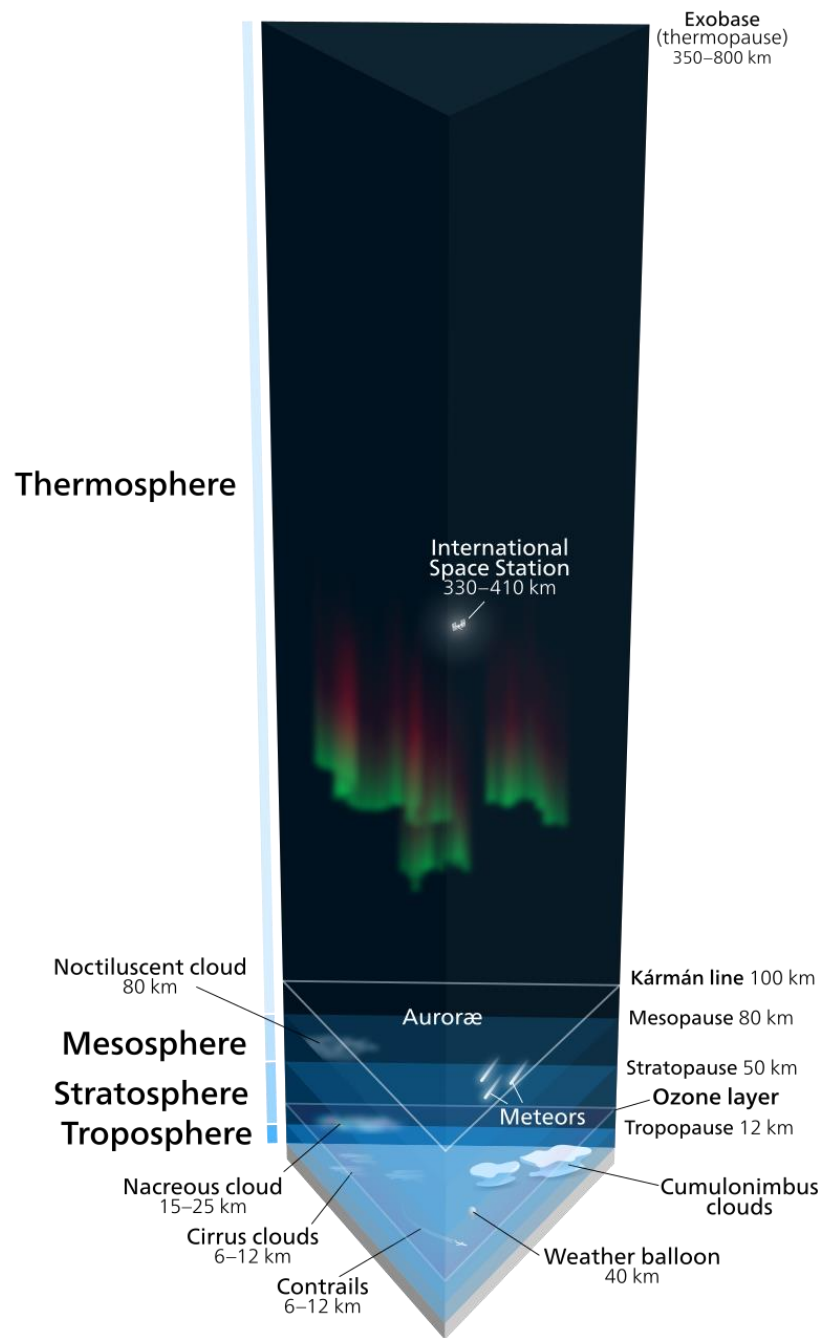




# **SLASH AND BURN SCORCED EARTH**







OBJECTS WITHIN LAYERS NOT DRAWN TO SCALE

Noctiluscent cloud  
80 km

**Mesosphere**  
**Stratosphere**  
**Troposphere**

Nacreous cloud  
15–25 km

Cirrus clouds  
6–12 km

Contrails  
6–12 km

Auroræ

Meteors

Kármán line 100 km

Mesopause 80 km

Stratopause 50 km

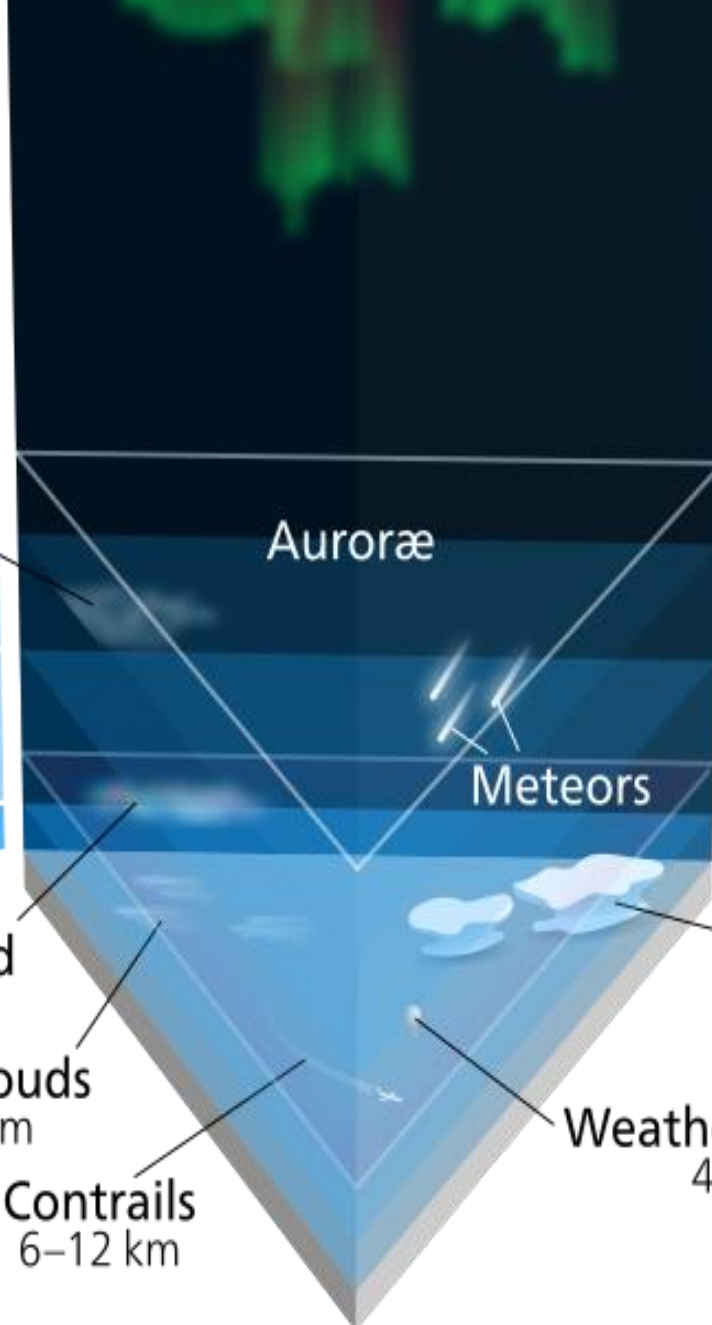
Ozone layer

Tropopause 12 km

Cumulonimbus  
clouds

Weather balloon  
40 km

OBJECTS WITHIN LAYERS NOT DRAWN TO SCALE





# BLEACHING OF CORALS



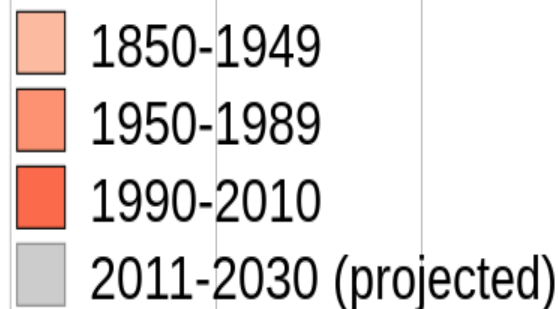


# GREENLAND ICE SHEET



USA  
EU-27  
China  
Russia  
Rest of Africa  
Rest of SE Asia  
Indonesia  
Rest, Latin Amer  
India  
Brazil  
Japan  
Middle East  
Canada  
AUS/New Zeal  
Ukraine  
Mexico  
Other EU  
South Africa  
South Korea  
Turkey  
Nigeria  
Rest of Asia  
Saudi Arabia

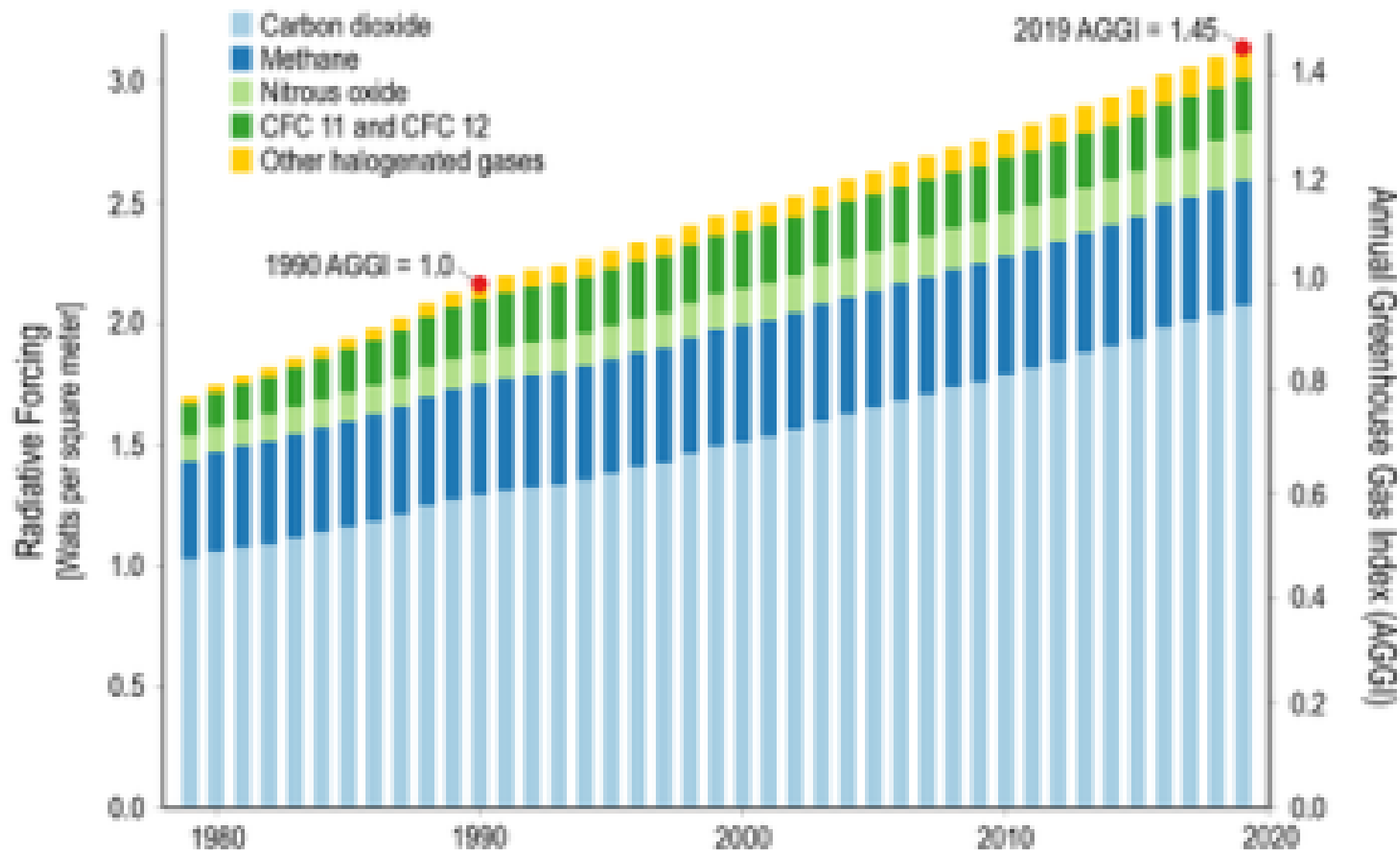
## Greenhouse gas emissions (cumulative and projected)



Gigatons CO<sub>2</sub> equivalent



# Annual Greenhouse Gas Index



# **MARCH 2022**

**Emission CO2 highest in history**  
(International Energy Agency)

**Past 20 years – World temperature  
increased 2/3 degree F (NOAA)**

**Coal – 40% of overall growth in  
global CO2 emission 2021; all  
time high – 15.3 billion metric  
tons; Natural gas – 7.5 billion;  
China increased 205 to 750  
million**

# Nature article

01 November 2021

**Top climate scientists are sceptical that nations will rein in global warming**

*A Nature* survey reveals that many authors of the latest IPCC climate-science report are anxious about the future and expect to see catastrophic changes in their lifetimes.

## **Staggering decline of bird populations**

Drawing on such data for North America, Rosenberg *et al.* report wide-spread population declines of birds over the past half-century, resulting in the cumulative **loss of billions of breeding individuals across a wide range of species and habitats.** They show that declines are not restricted to rare and threatened species—those once considered common and wide-spread are also diminished. These results have major implications for ecosystem integrity, the conservation of wildlife more broadly, and policies associated with the protection of birds and native ecosystems on which they depend

# **CLOUD COVER: PROBABLY THE RESULT, NOT A CAUSE OF CLIMATE CHANGE**

**Depending on the thickness and shape – can reflect light during the day, and hold in surface heat overnight**

The amount of water vapor in the air has recently increased – more clouds, means more rainfall.  
Maybe explaining why nighttime temperatures are rising more than daytime temperature in global warming trends...



# ***WIKIPEDIA* (April 2022)**

Good Central (Initial) Source for Study:  
Refereed by Experts

- 248 References (Peer-reviewed)
- 12 IPCC Reports
- Over 100 Additional Peer-Reviewed Sources

# OCEANS

Increasing CO<sub>2</sub> in the water: acidic

Increasing water temperature

Shifting ocean movements: currents mix warmer with colder waters, and vis versa

Loss of Phytoplankton (secondary to loss of edge of the sea ice for the phytoplankton) – primary food source for entire ocean food web; loss of krill that feed on phytoplankton, and their predators die

**The Global Tree Assessment (GTA)** is assessing the conservation status of every known tree species.

Over 500 experts; over 60 Institutional Partners involved

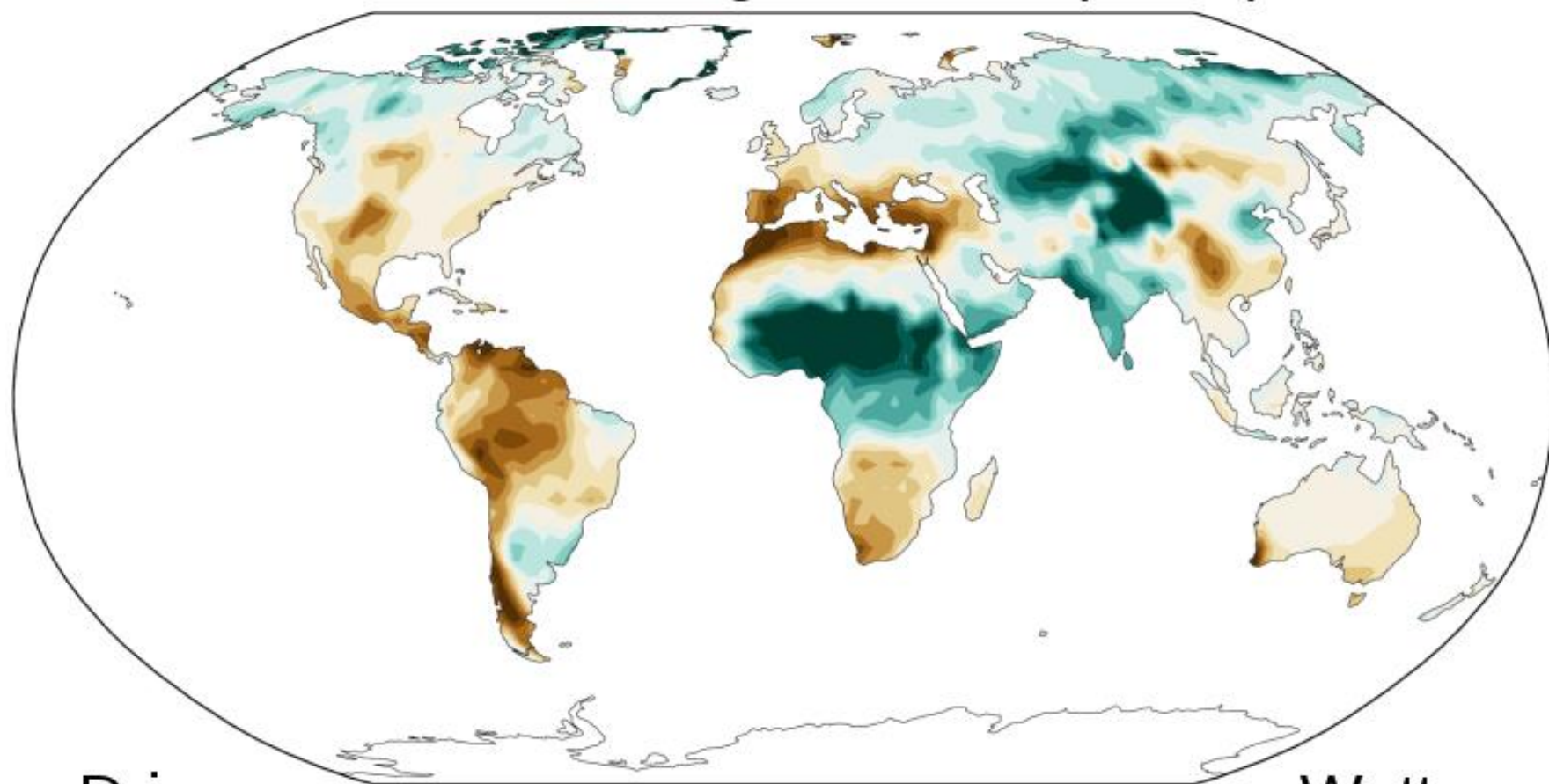
OUR EARTH HAS 60,000 SPECIES OF TREES: ONE-THIRD ARE THREATENED WITH EXTINCTION; trees support 1/2 of known terrestrial plant and animal species;

Nature knows more than we do

## State of the World's Trees Report

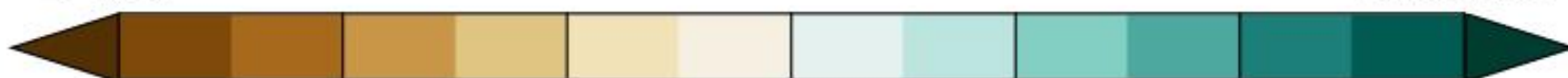
Through the Global Tree Assessment, intensive research has been undertaken over the past five years to compile extinction risk information on the 58,497 tree species worldwide. **We now know that 30% of tree species are threatened with extinction, and at least 142 tree species are recorded as extinct.** The main threats to tree species are forest clearance and other forms of habitat loss, direct exploitation for timber and other products and the spread of invasive pests and diseases. Climate change is also having a clearly measurable impact.

## Soil moisture change at 2.0°C (3.6°F)



Drier

Wetter



-1.5

-1.0

-0.5

0

0.5

1.0

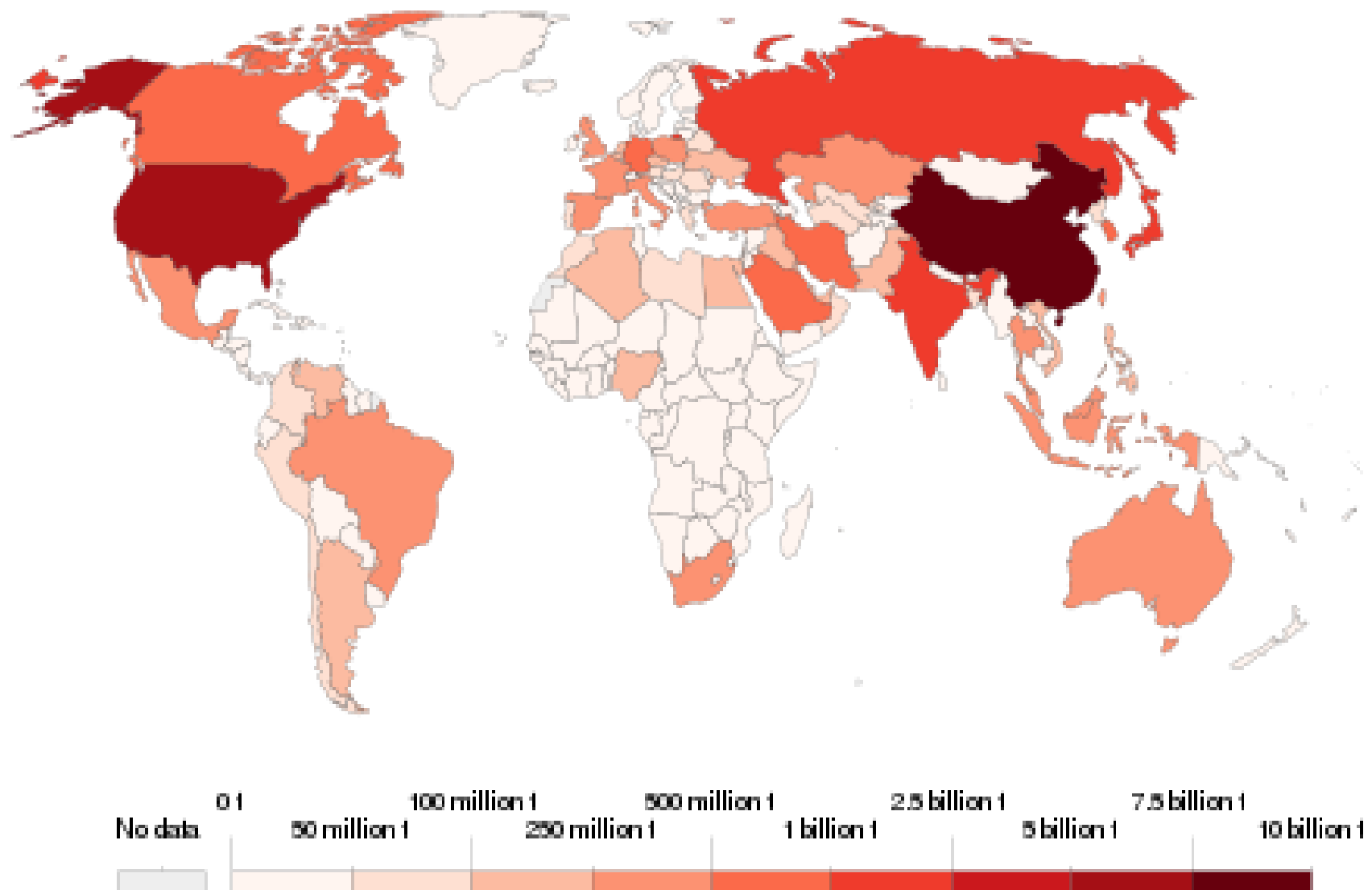
1.5

Standard deviations from 1850-1900 average



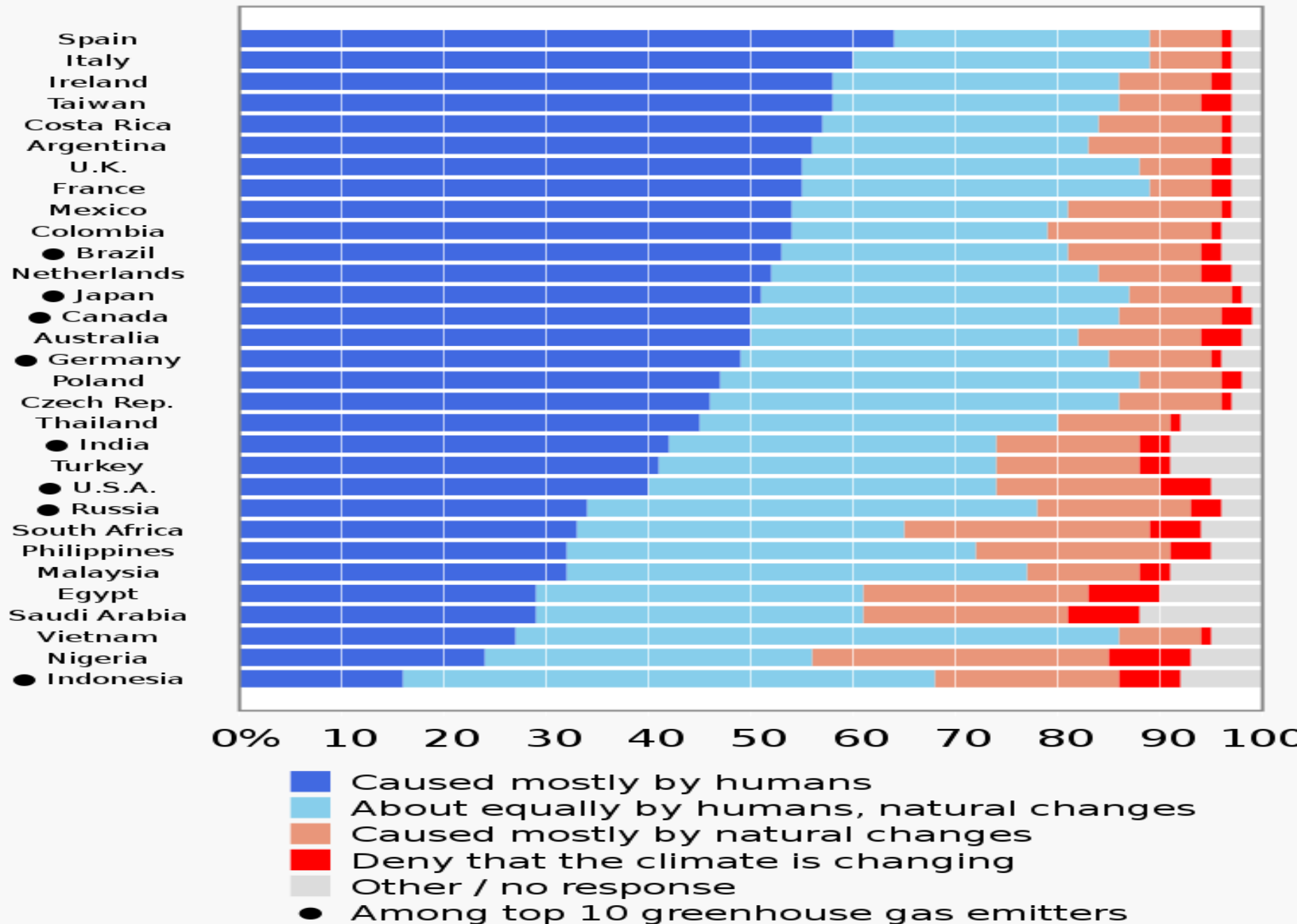
# Annual CO<sub>2</sub> emissions, 2017

Annual carbon dioxide (CO<sub>2</sub>) emissions, measured in tonnes per year.

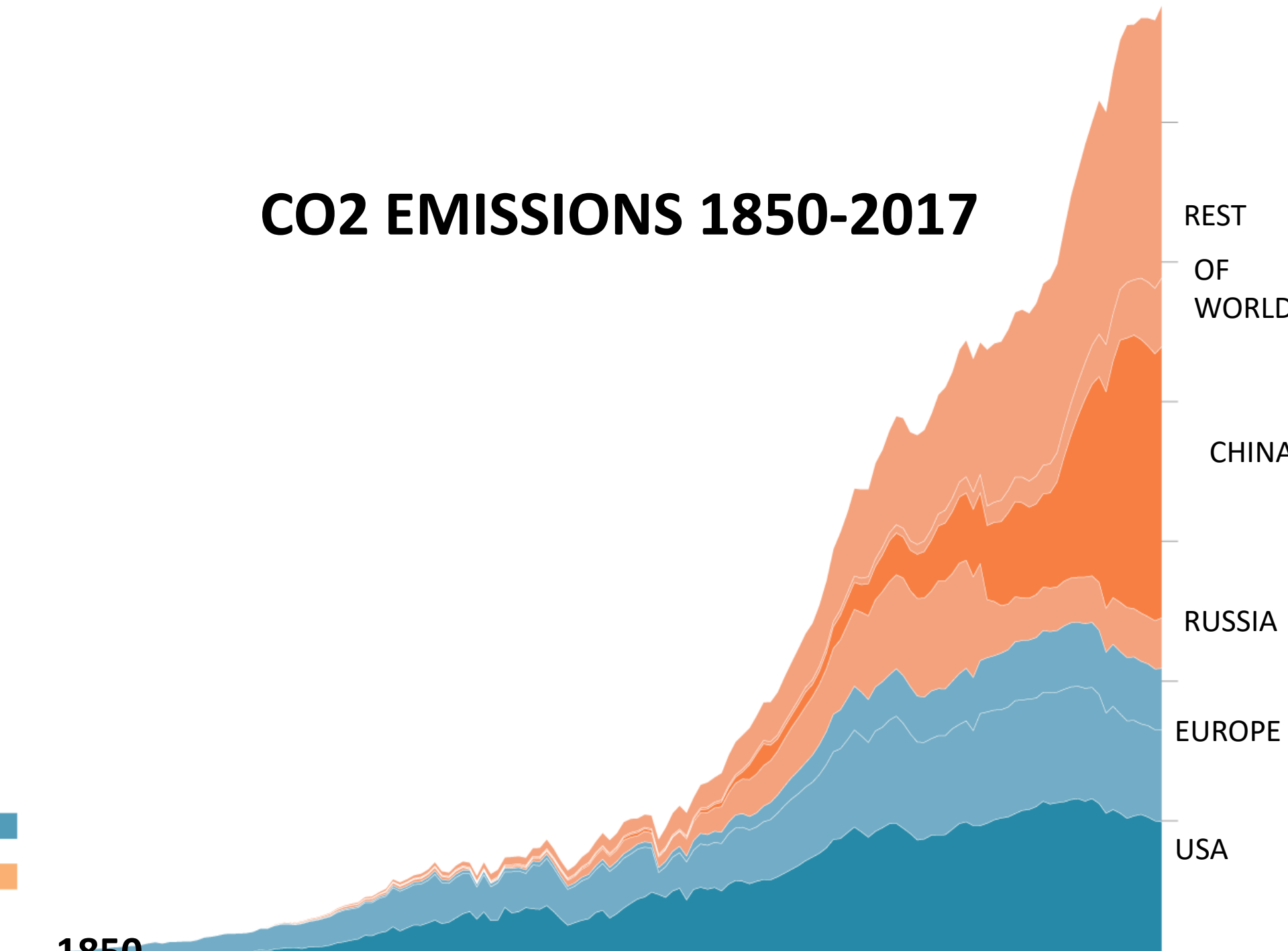


Source : Global Carbon Project; Carbon Dioxide Information Analysis Centre (CDIAC)

# Public opinion: causes of climate change



# CO2 EMISSIONS 1850-2017

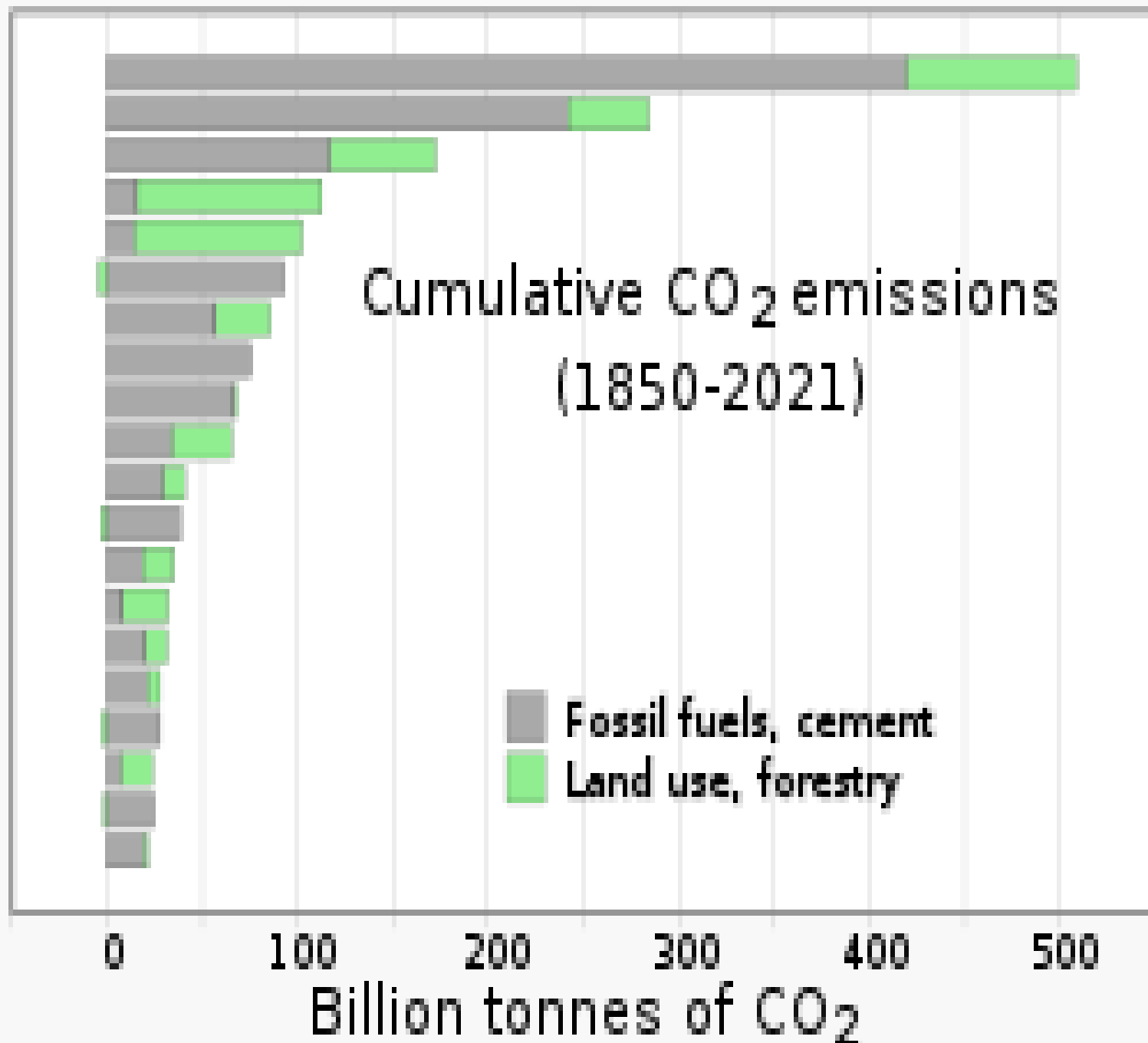


USA  
China  
Russia  
Brazil  
Indonesia  
Germany  
India  
UK  
Japan  
Canada  
Ukraine  
France  
Australia  
Argentina  
Mexico  
S. Africa  
Poland  
Thailand  
Italy  
Iran

## Cumulative CO<sub>2</sub> emissions (1850-2021)

■ Fossil fuels, cement  
■ Land use, forestry

0 100 200 300 400 500  
Billion tonnes of CO<sub>2</sub>



# COAL, OIL (carbon) and NATURAL GAS (mostly methane)

Fossils of past living matter; in swamps 300-400 million years ago (From before the time of the dinosaurs); land plants and trees rot away into the soil, anaerobes, sink into the bottom, peat, compressed, water squeezed out – turn into fossil fuels (also deep in the seas)

Decomposing plant material (not decomposing dinosaurs) ; when burned , as well as retrieved from the earth, gives up CO<sub>2</sub> and other gases that the ancient plants stored

Coal contains: Sulfur dioxide, mercury, polycyclic aromatic hydrocarbons, arsenic, cyanide, and carcinogens such as benzene naphthalene, toluene, etc (Clean coal doesn't exist)

The US uses coal for 50% of its electricity



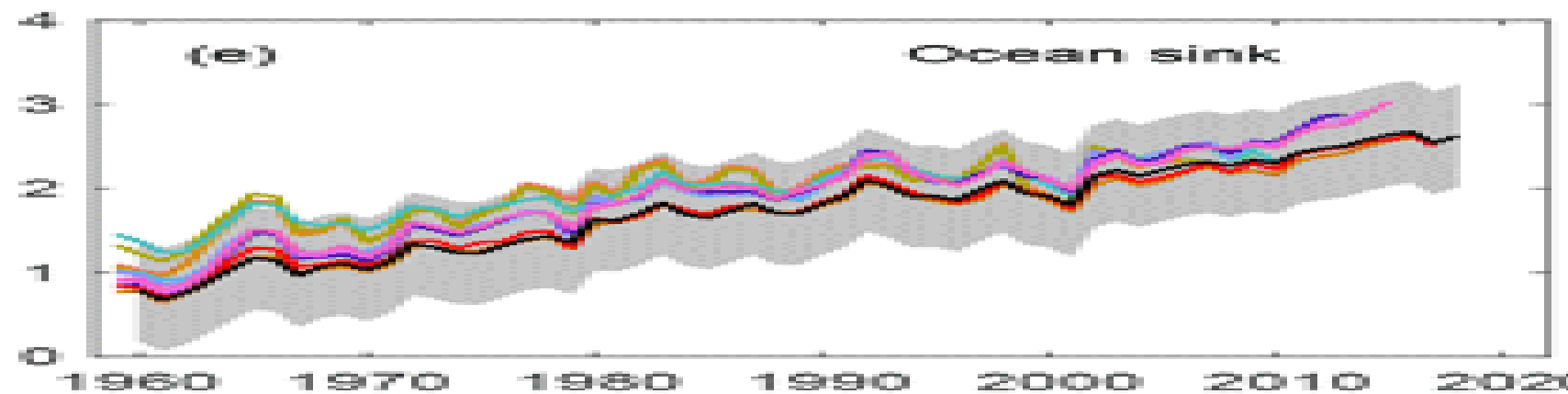
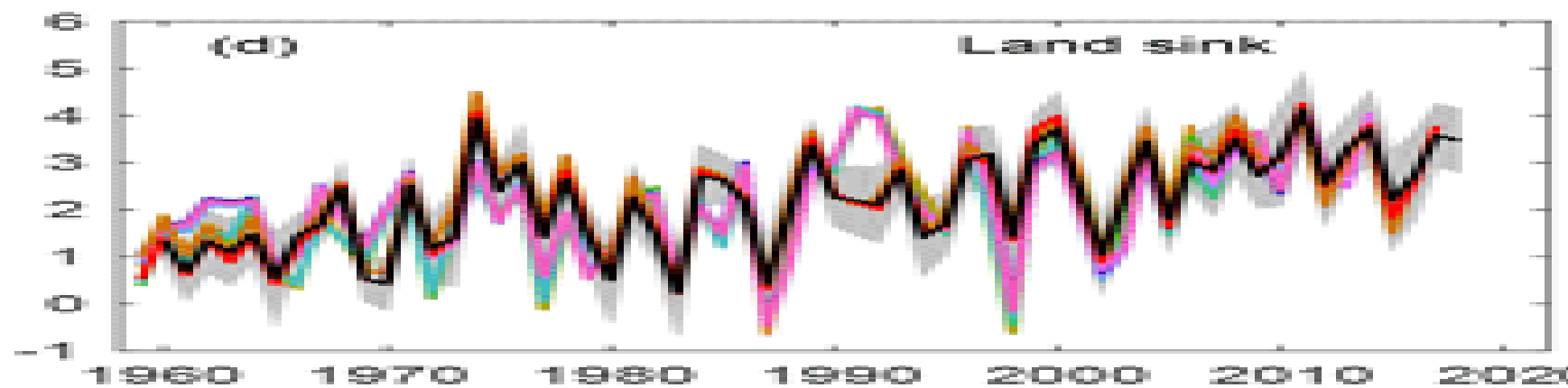
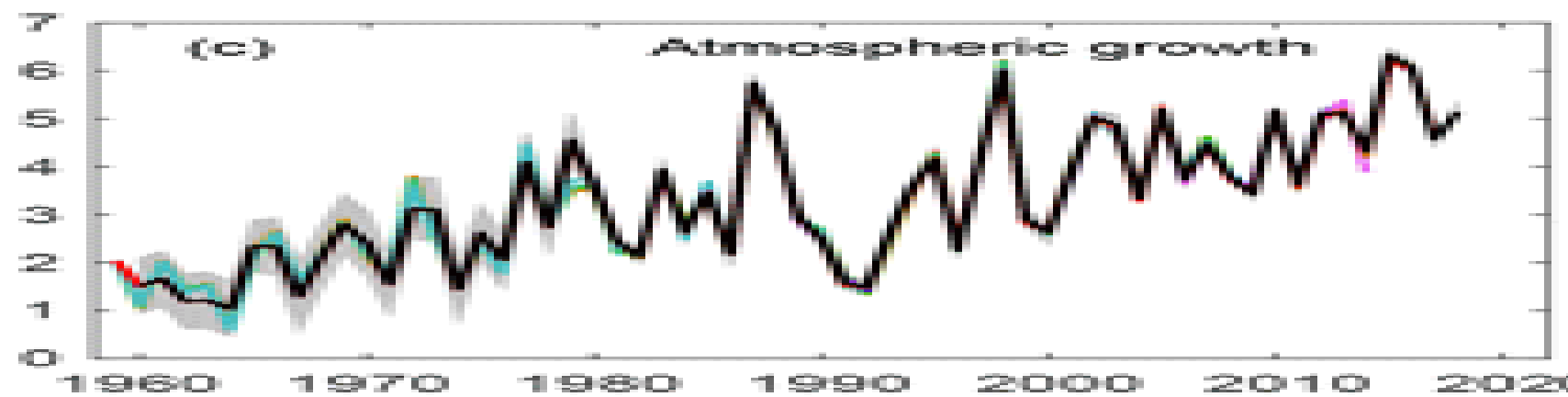
# **COAL-RELATED GREENHOUSE GAS EMISSIONS (in order)**

#1.) Coal, burning coal to produce electricity

#2.) Gasoline and diesel for transportation

#3.) Burning oil to generate heat and electricity

$\text{CO}_2$  partitioning ( $\text{GtC yr}^{-1}$ )



## SATELLITE DATA: 1993-PRESENT

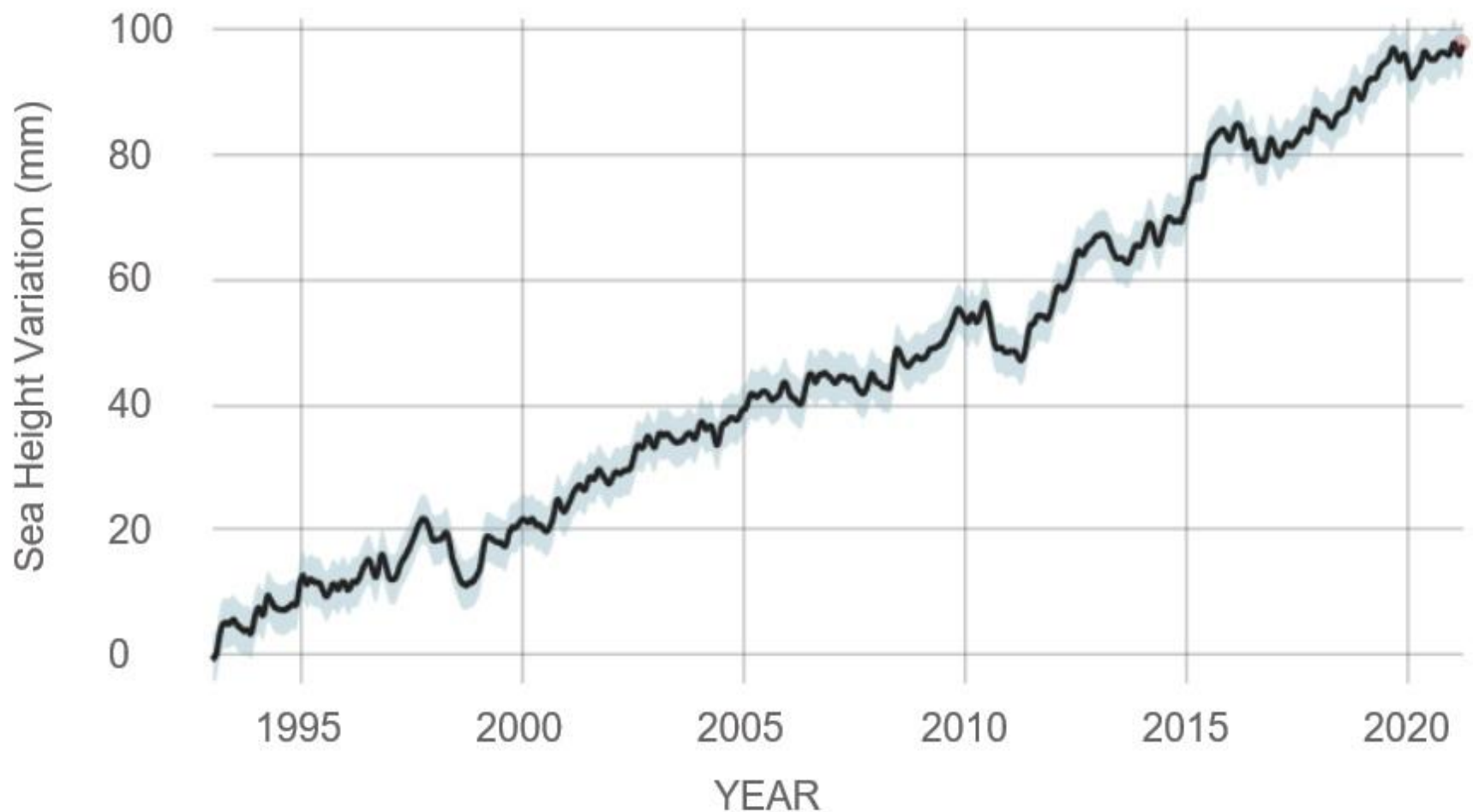
Data source: Satellite sea level observations.

Credit: NASA's Goddard Space Flight Center

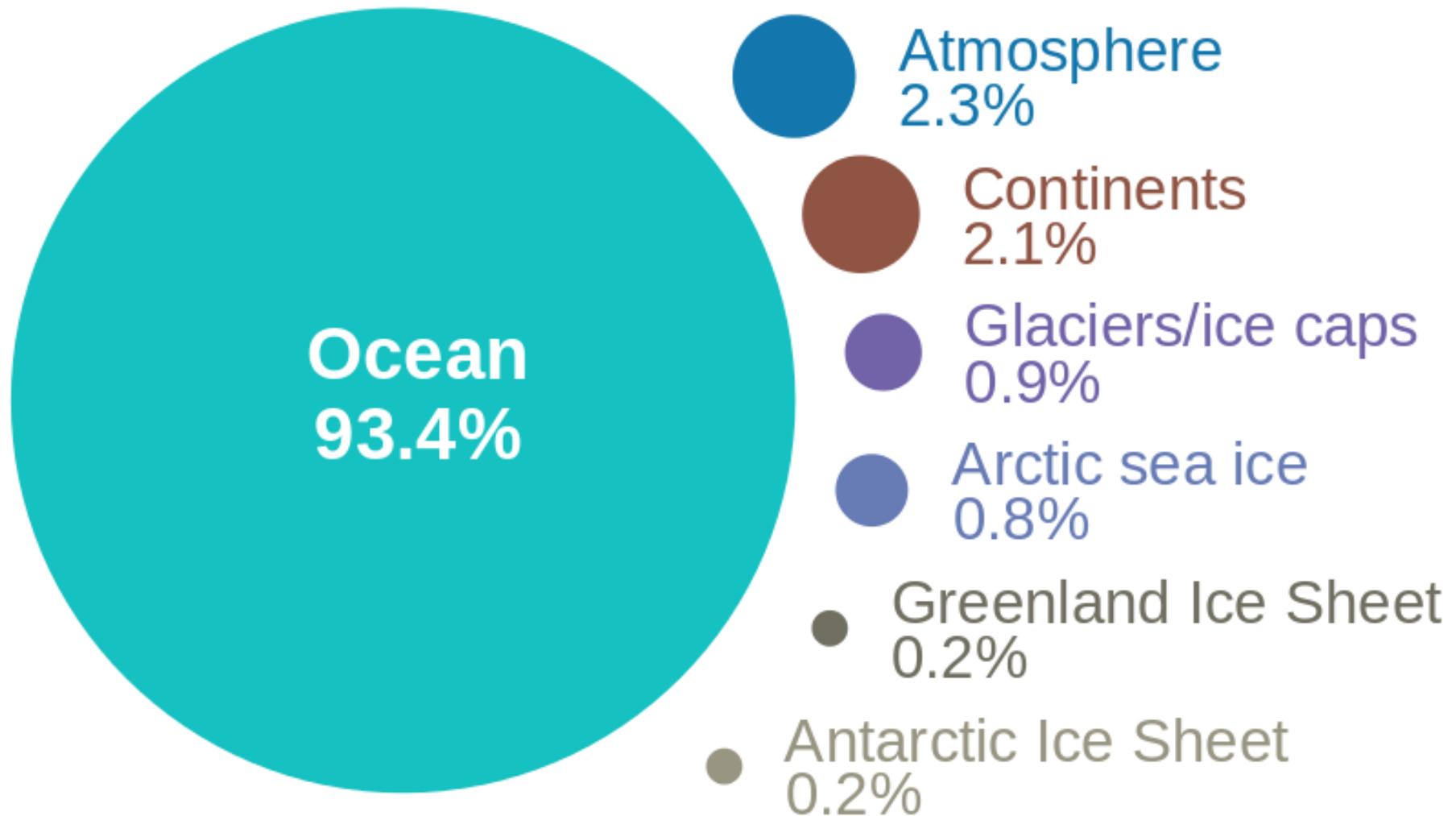
RATE OF CHANGE

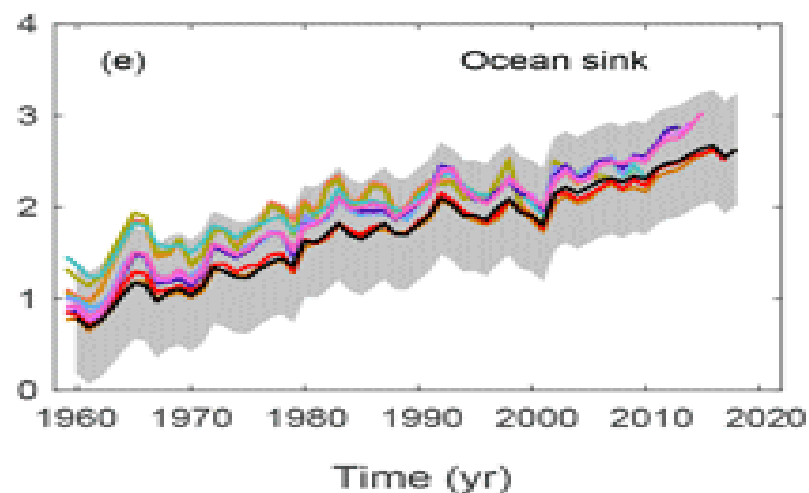
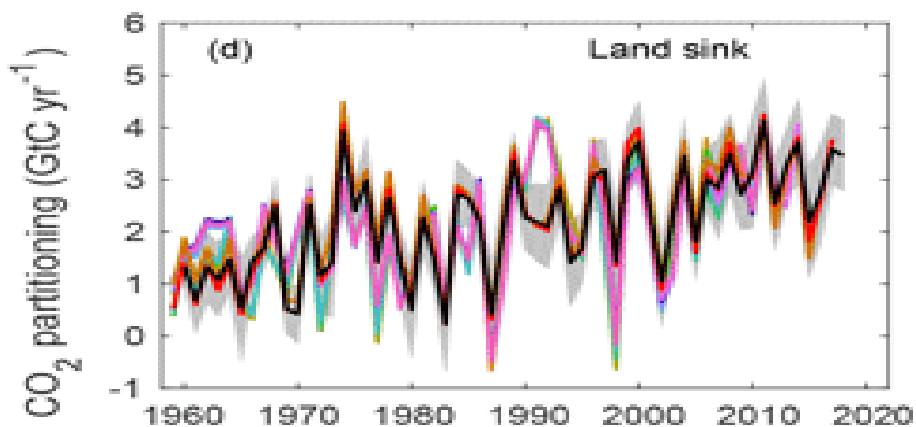
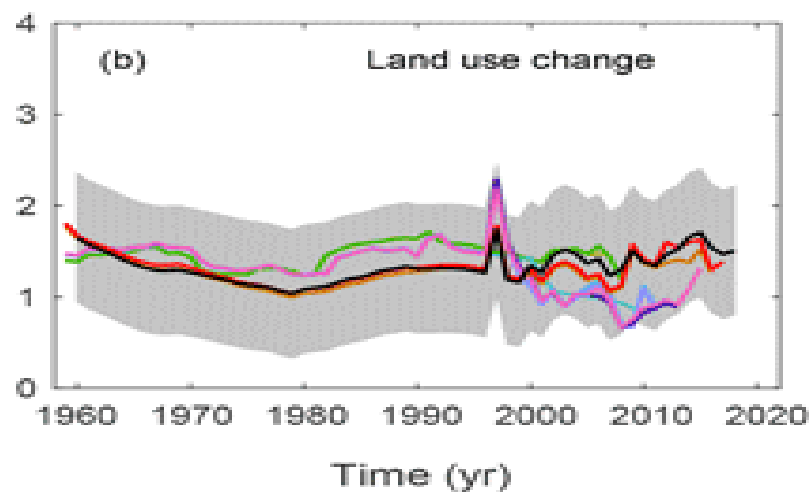
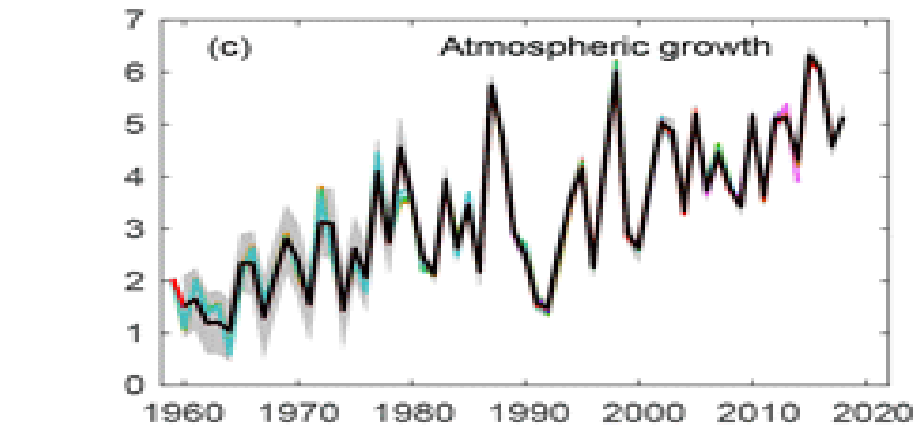
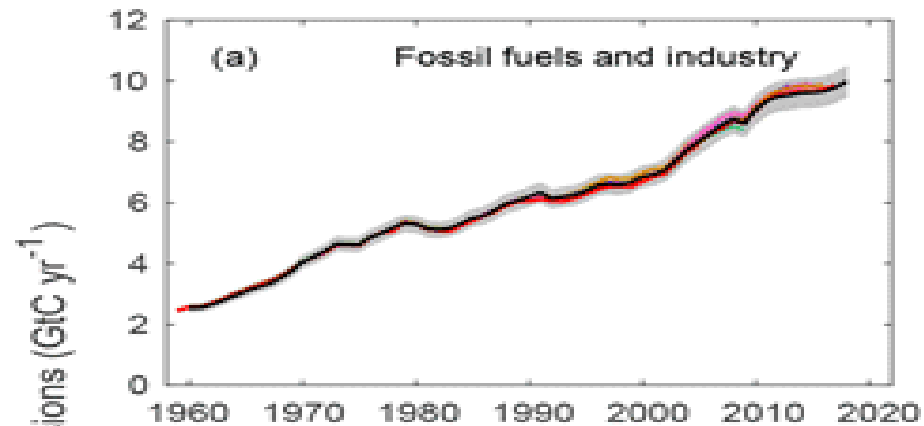
↑ 3.4

millimeters per year



# Where is global warming going?







# **COMPARING SCIENTIFIC AUTHORITY VS MEDIA VISABILITY**

NATURE: A.M. Petersen et al; 2019; 10:3502

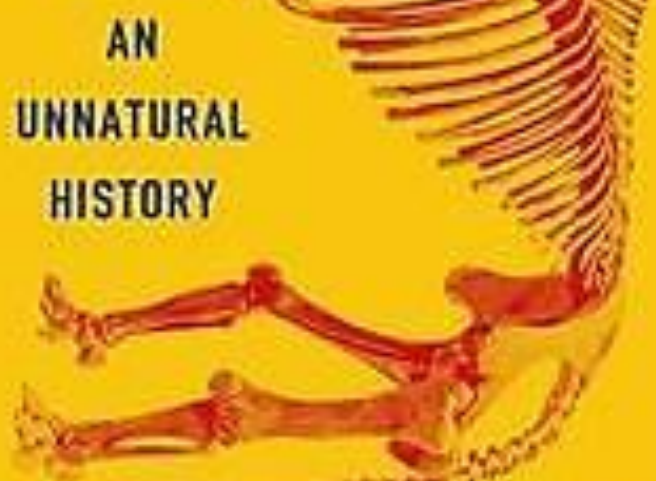
Compared 386 with 386 of each: 200,000  
publications

50% of contrarian's works more than scientific  
authorities

# JAMES HANSEN (NASA)

“Man made pollution – already in atmosphere traps as much extra heat energy every 24 hours as released by explosion of 400,000 Hiroshima-class nuclear bombs”

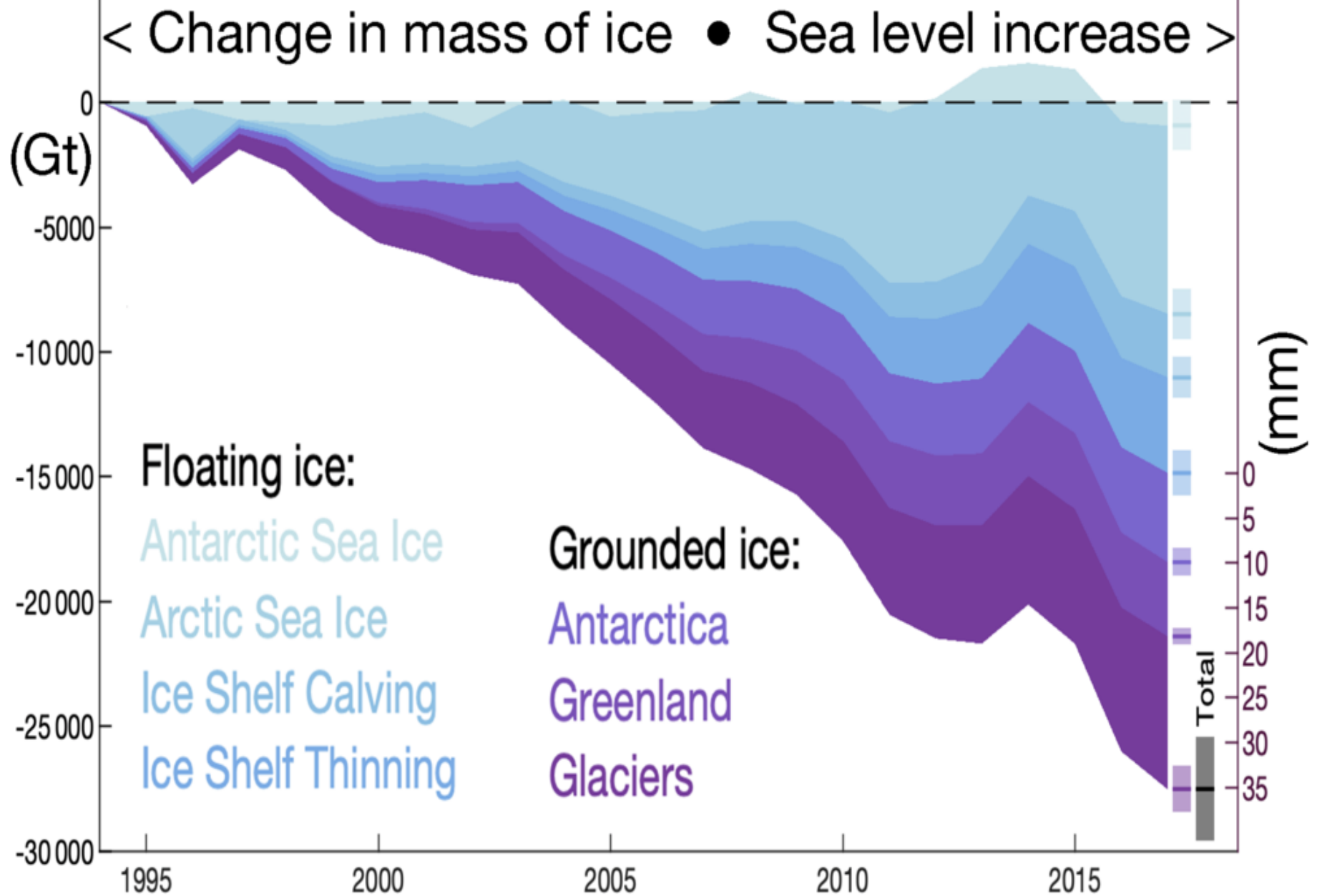
# The **SIXTH** EXTINCTION



AN  
UNNATURAL  
HISTORY

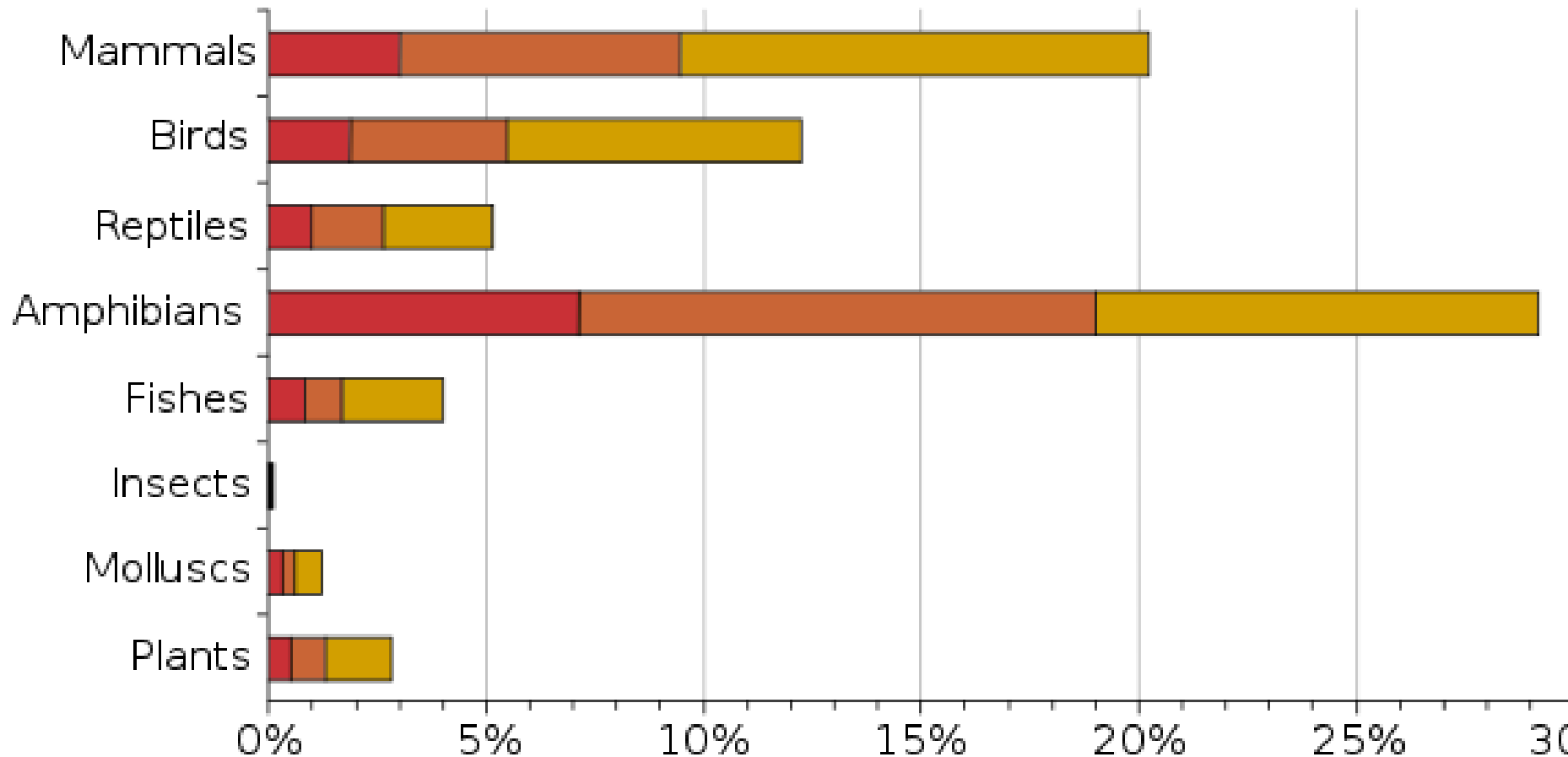
**ELIZABETH KOLBERT**

*Author of FIELD NOTES  
FROM A CATASTROPHE*



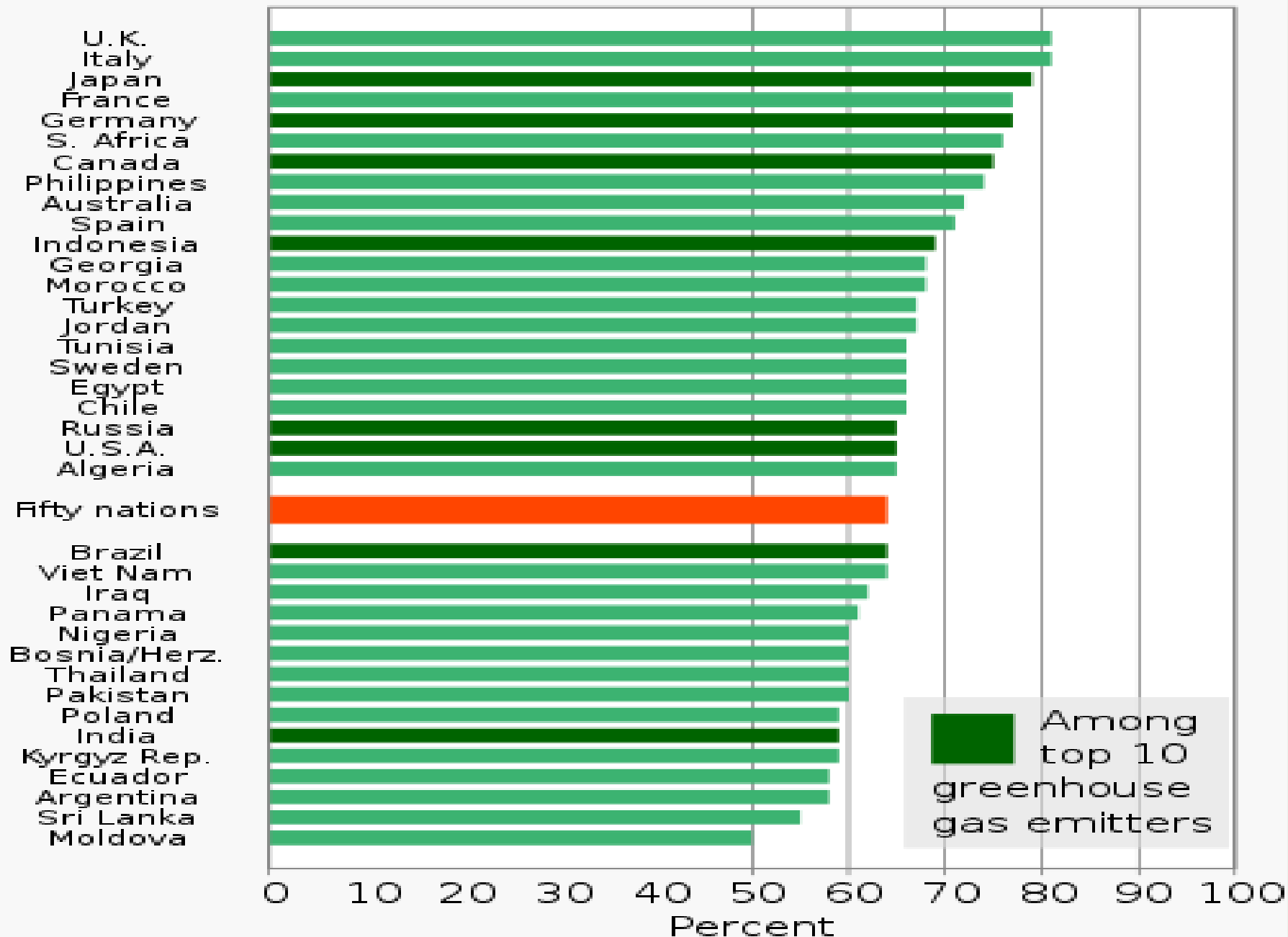
EARTH LOST 28 TRILLION TONES OF ICE BETWEEN 1994-2017 WITH MELTING GROUNDED ICE (ICE SHEETINGS AND GLACIERS) RAISING THE SEA LEVEL BY 36.6 MM. Rate risen 57% since 1990

**IUCN (DARK RED = CRITICALLY ENDANGERED; LIGHT RED = ENDANGERED; YELLOW=VULNERABLE)**



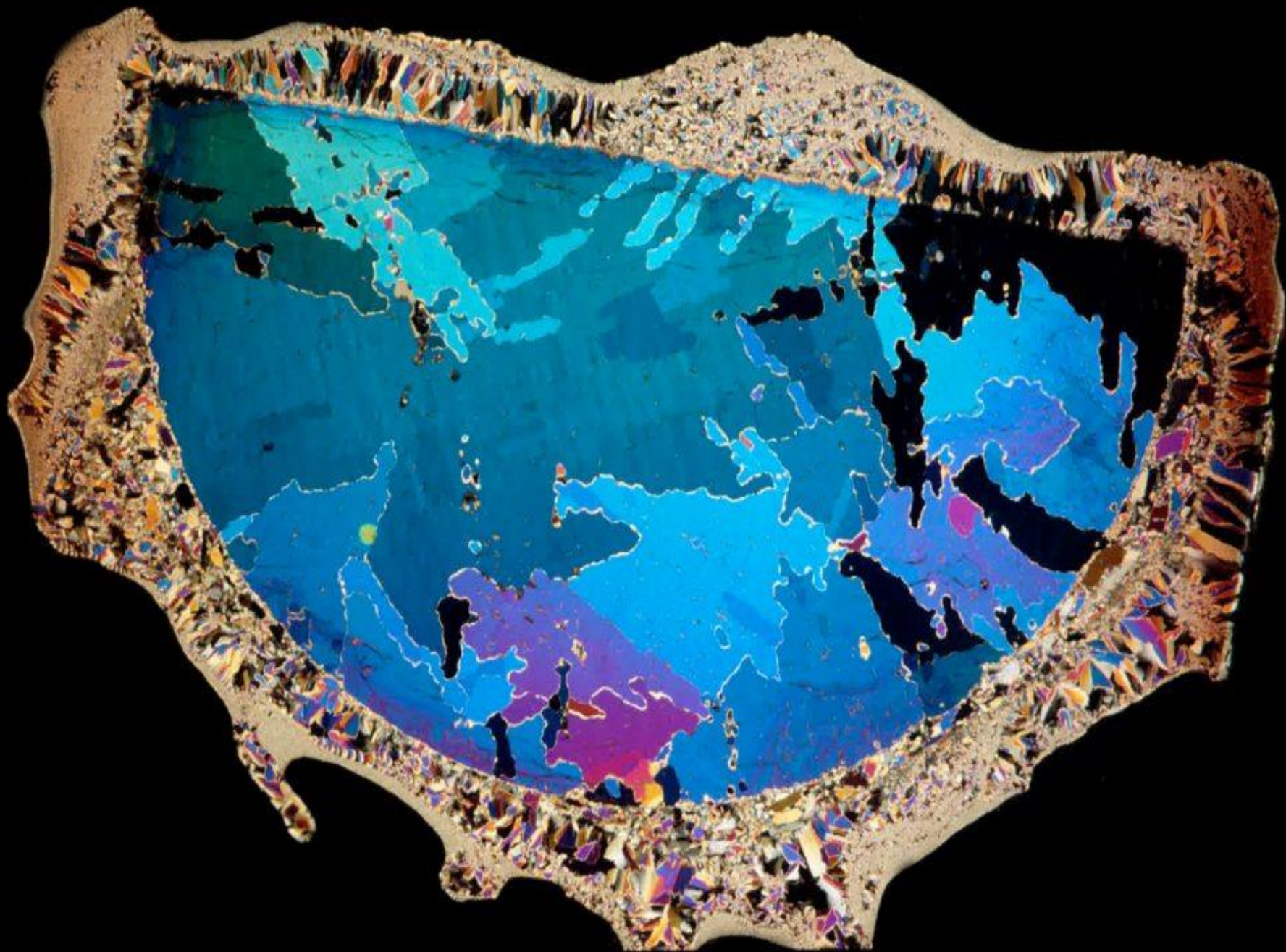


# Public belief in climate emergency



**VENUS**









[illegible]



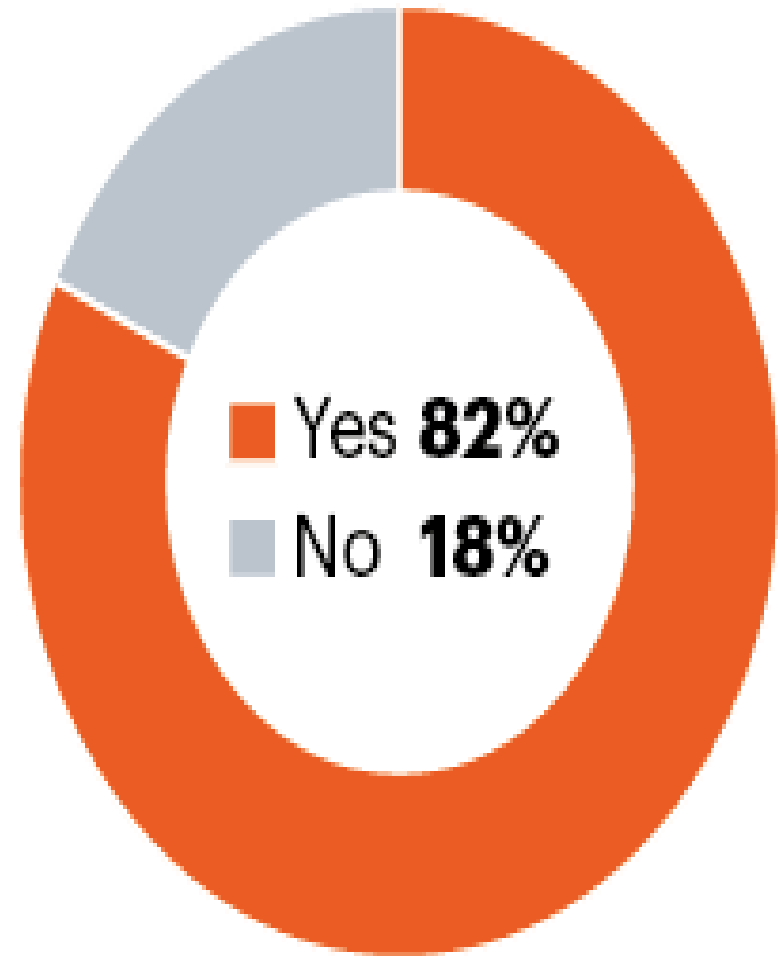
# GLOBAL TEMPERATURES RISING

When heat buildup in the ocean is taken into account:

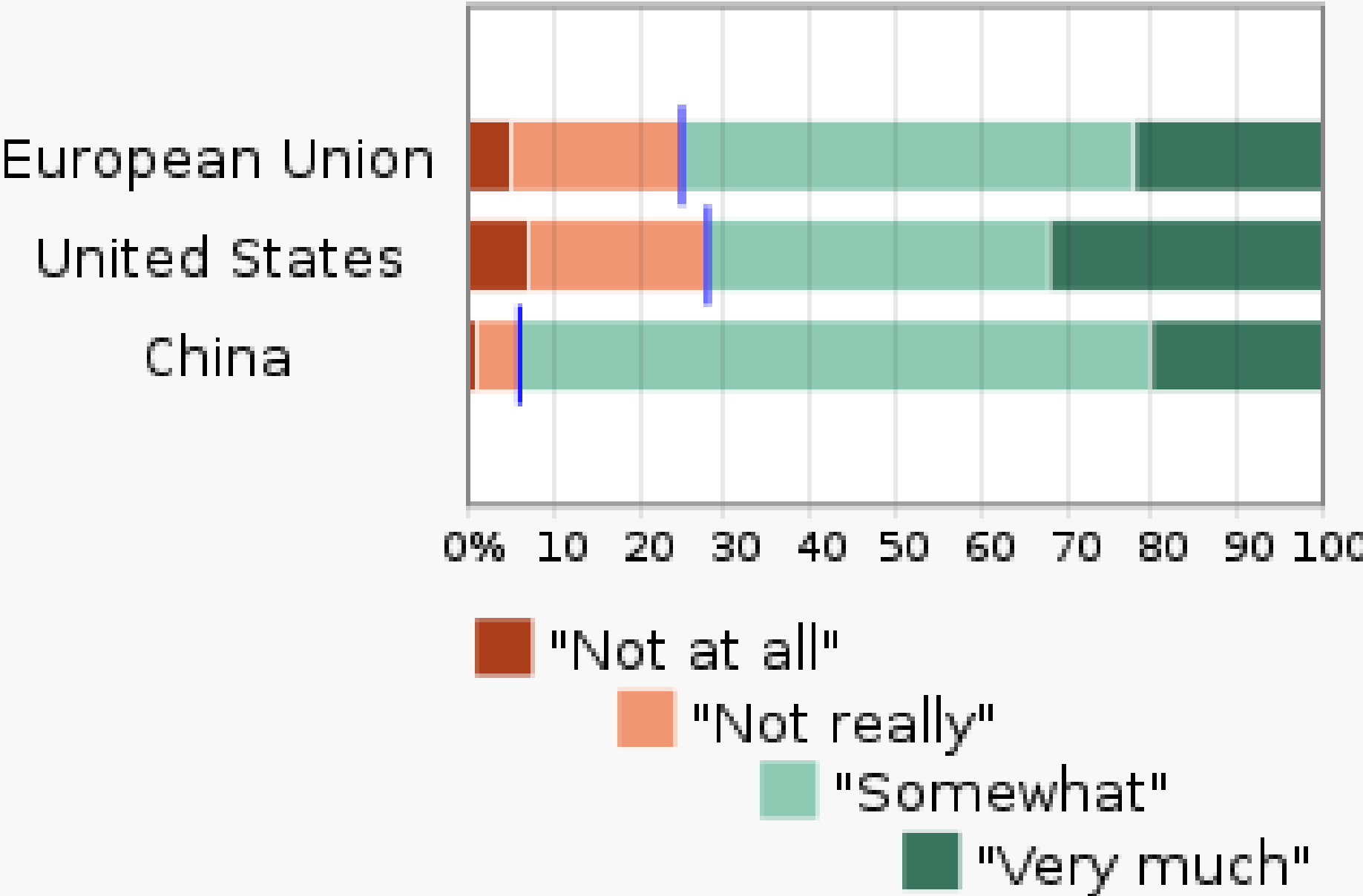
Scientists calculated that the heat accumulating throughout the Earth because of human emissions is roughly equal to the energy of that would be released by 400,000 Hiroshima atomic bombs exploding across the planet every day

Rate of warming in Arctic regions twice the global average (average -not indicative of extremes)

**Do you think you will  
see catastrophic  
impacts of climate  
change in your  
lifetime?**

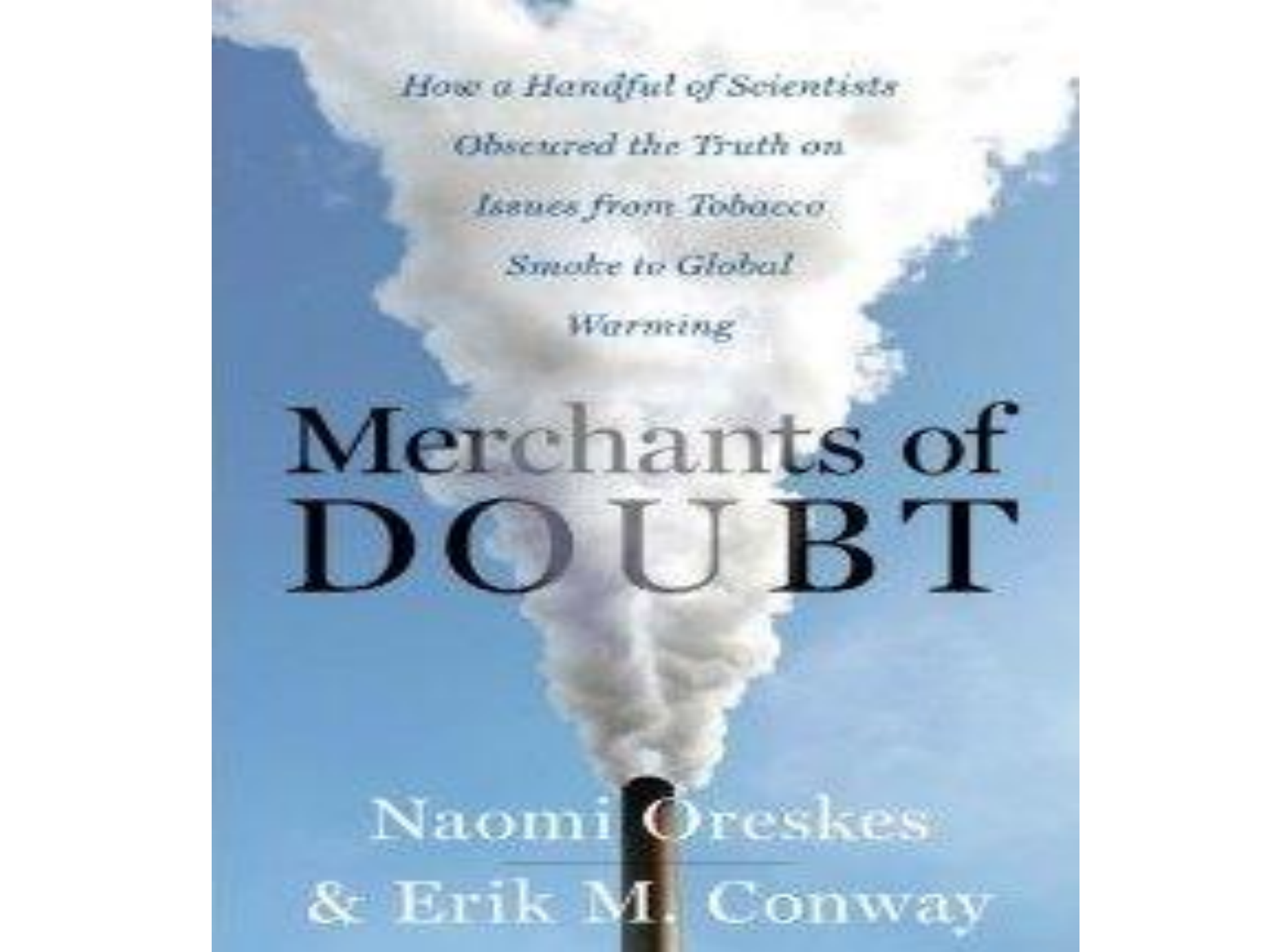


# Survey: Does climate change impact daily life



**COAL**





*How a Handful of Scientists  
Obscured the Truth on  
Issues from Tobacco  
Smoke to Global  
Warming*

# Merchants of DOUBT

Naomi Oreskes  
& Erik M. Conway



**CLIVE  
HAMILTON**



**REQUIEM  
FOR A  
SPECIES**

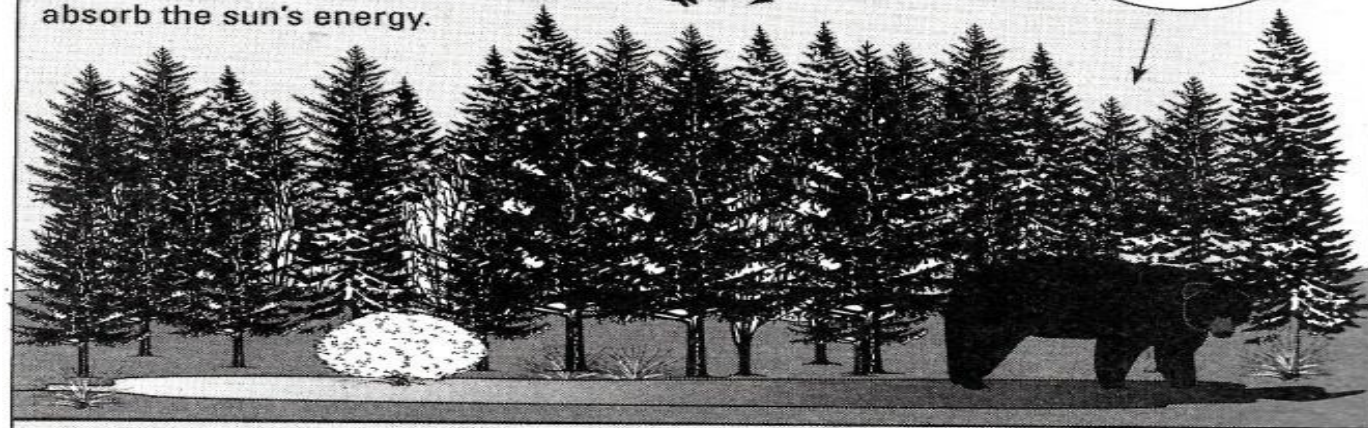


WHY WE RESIST THE TRUTH  
ABOUT **CLIMATE CHANGE**

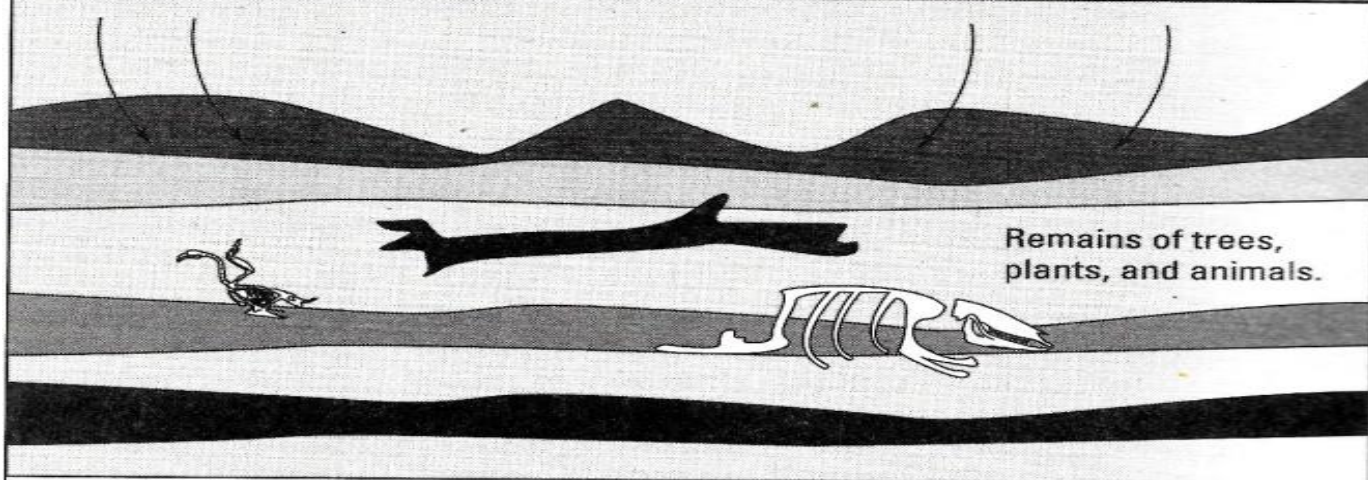
## The Creation of Fossil Fuels

The sun is the ultimate source of energy.

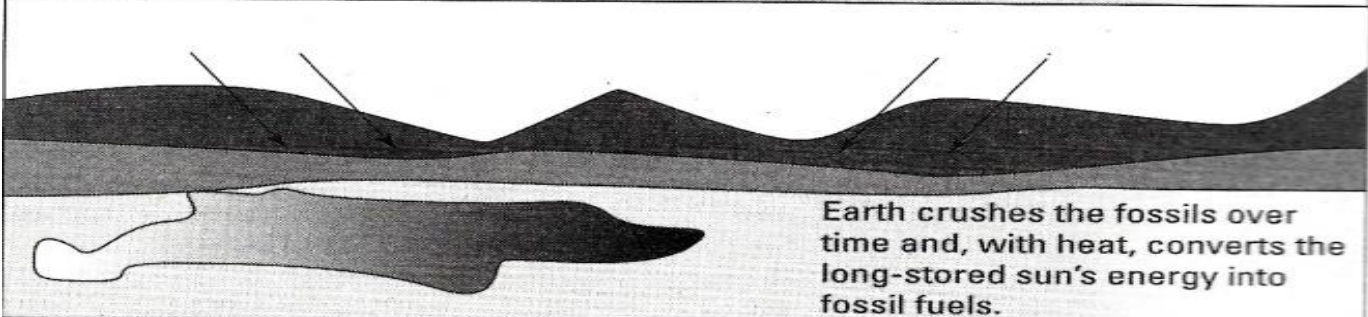
Tree, plants, and animals absorb the sun's energy.



Remains of trees, plants, and animals.

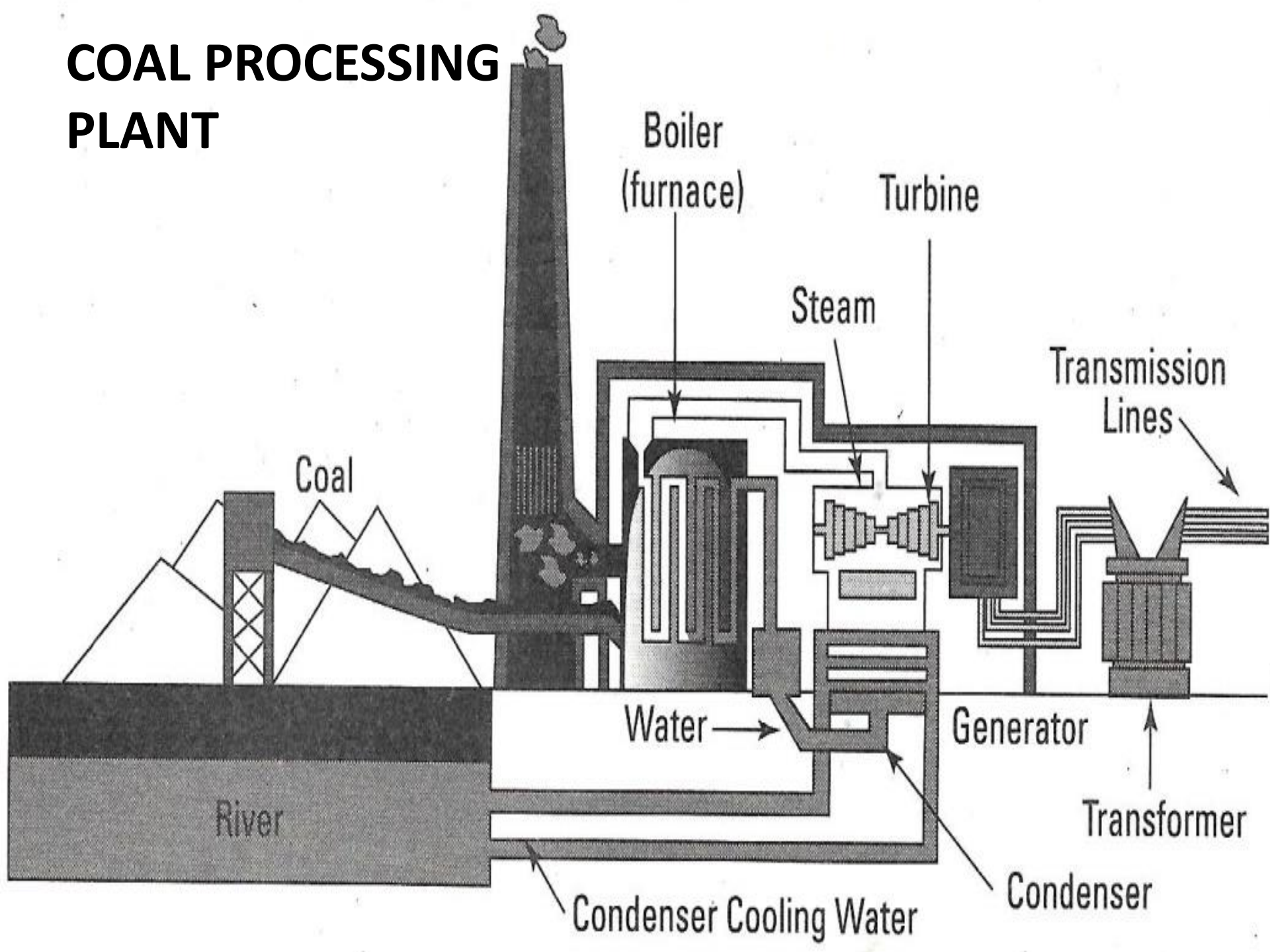


Earth crushes the fossils over time and, with heat, converts the long-stored sun's energy into fossil fuels.





# COAL PROCESSING PLANT



# **UNITED NATIONS CONVENTION FOR PROTECTION OF BIOLOGICAL DIVERSITY**

“climate change is likely to become the dominant direct driver of biodiversity loss by the end of the century”

# GLOBAL WARMING'S DIRECT EFFECT ON PEOPLE

Violent weather events (e.g., low lying islands, coastal regions)

Disease: e.g., malaria, cholera, asthma (problems with air quality), infectious disease vectors, cold or heat-related deaths, contaminated drinking water, food supply problems, dengue fever, diarrheal diseases, lyme disease, skin cancer, vermin,

Injuries:

Human-built buildings: highways, waterworks, electricity demand, sewage systems, transmission lines, transportation,





# PREPARING FOR MASS EXTINCTIONS

Extinctions are Irreversible

Affects Migratory species: environment, food changes faster than species can change...

Loss of breeding areas...

Water-stress: especially small mammals,-habitat ranges at risk; water birds – drought, lowered water tables; amphibians and reptiles – frogs and lizards disease outbreaks

# **NOT MAJOR INFLUENCES IN GLOBAL WARMING**

- 1.) Solar Luminosity (less than  $1/4^{\text{th}}$  the effect of CO<sub>2</sub>)
- 2.) Volcanic Eruptions
- 3.) Variation of Earth's Orbit

# INDUSTRY USING THE MOST ENERGY

#1.) Metals (iron and steel)using: Coke

#2.) Mineral production (Cement)

#3.) Oil

#4.) Pulp and paper

*Nº 986. Biblioteca dei fondi governativi.*

**Lehrbuch**  
der  
**kosmischen Physik**

von

**Dr. Svante August Arrhenius**

Professor der Physik an der Hochschule Stockholm.



*13-18*  
**Erster Teil**

*G-58-1*  
*BFS-263*

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1903.



# INSTITUT INTERNATIONAL DE CHIMIE-SOLVAY

PREMIER CONSEIL DE CHIMIE. - BRUXELLES, 21-27 AVRIL 1922.



BENJAMIN COOPER, PHOTO.

28, AVENUE LOUISE, BRUXELLES

M. DELÉPINE	G. CHAVANNE	O. DONY-HÉNAULT	F. SWARTS	CH. MAUGUIN	E. HERZEN	L. FLAMACHE	E. HANCON	AUG. PICCARD		
E. BILMANN	H. WUYTS	T.-M. LOWRY	G. URBAIN	J. PERRIN	F.-M. JAEGER	A. DEBIERNE	H. RUPE	A. BERTHOUD	R.-H. PICKARD	
CH. MOUREU	F.-W. ASTON	SIR W.-H. BRAGG	H.-E. ARMSTRONG	SIR W. POPE	E. SOLVAY	A. HALLER	S. ARRHÉNIUS	F. SODDY		

# ENERGY: ACCOUNTS FOR 2/3 OF HUMAN-CAUSED GREENHOUSE GASE EMISSIONS IN THE WORLD

Half of all the world's energy-link emissions come  
from Group of Eight (G8) countries:

Canada

France

Germany

Italy

Japan,

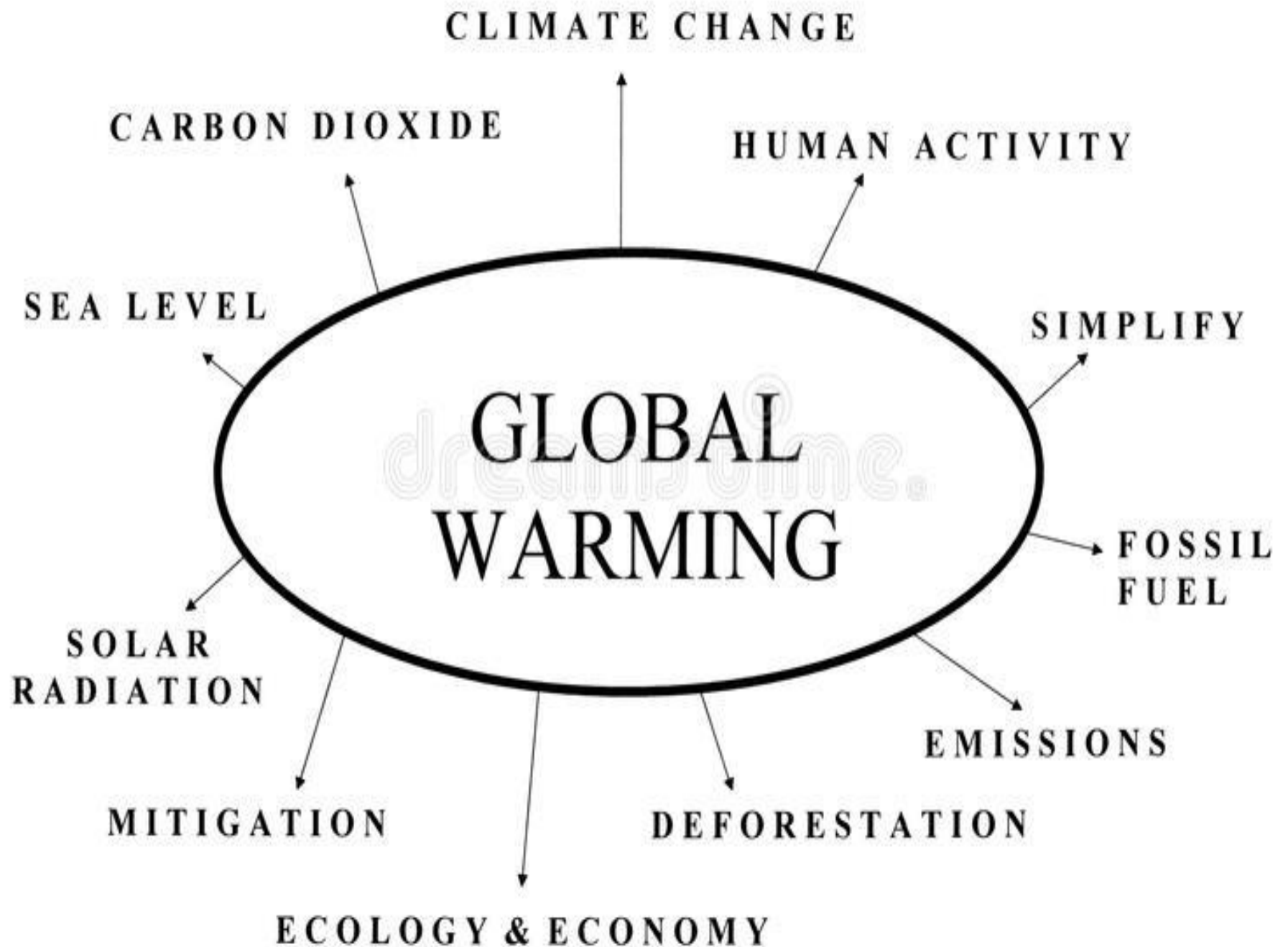
Russia,

UK

USA

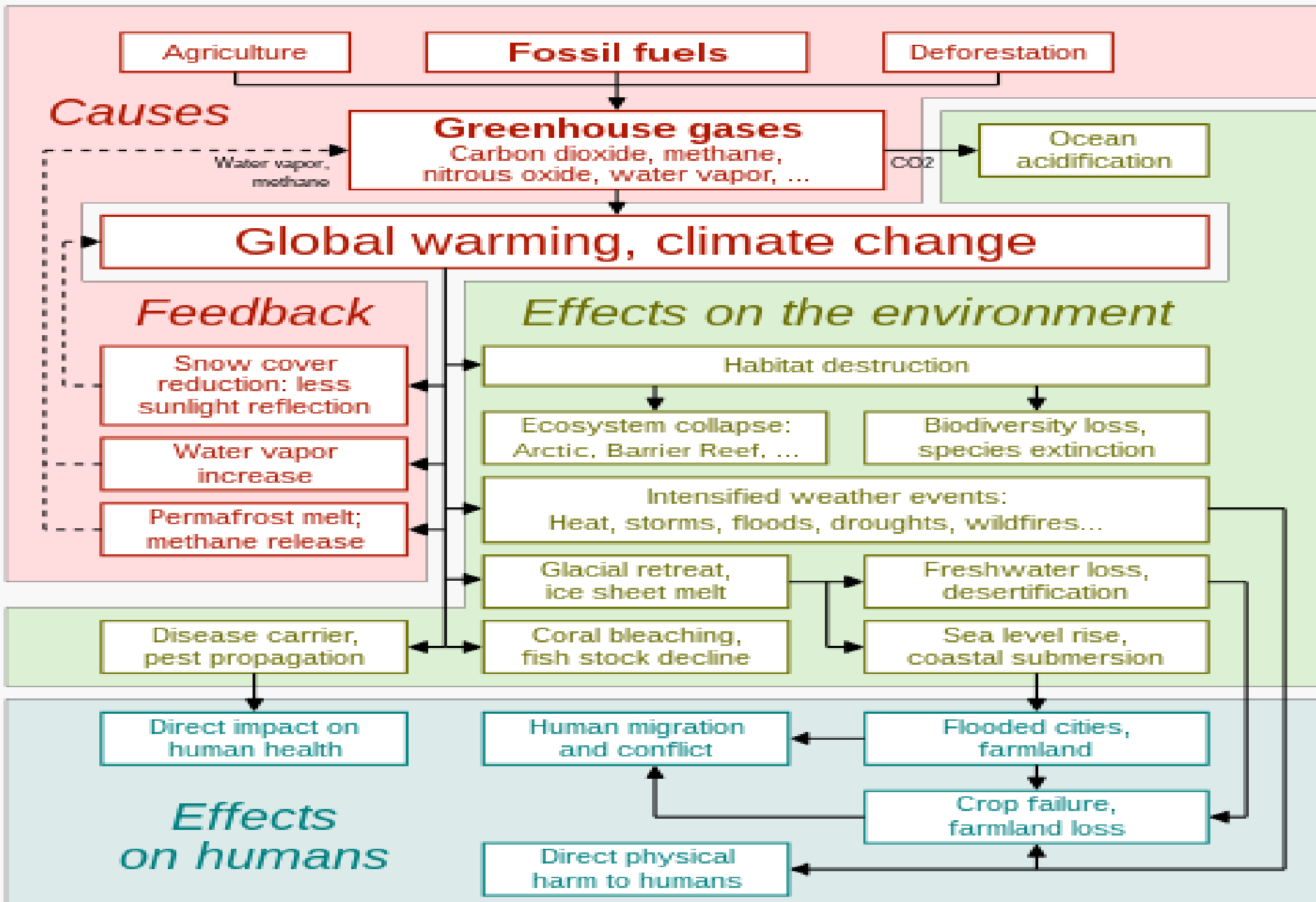
# EARTH'S ATMOSPHERE





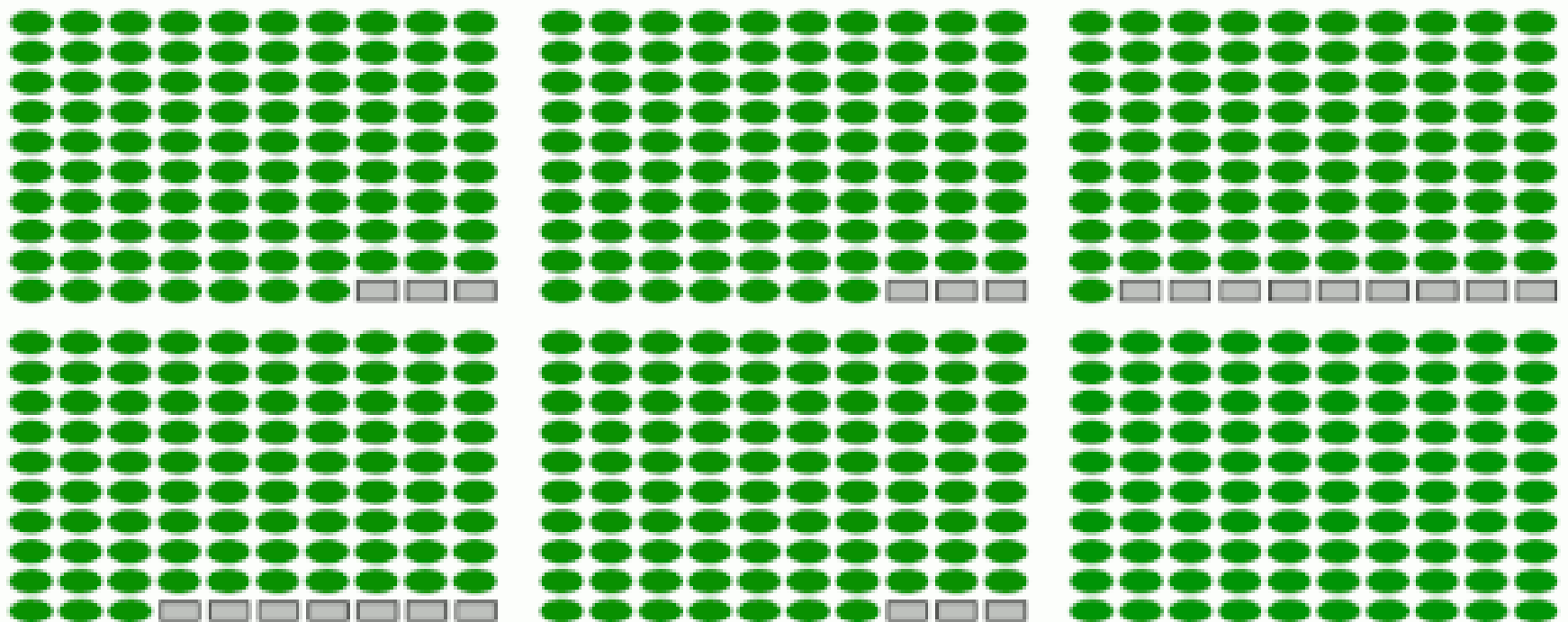
# Global warming and climate change

## Causes and effects

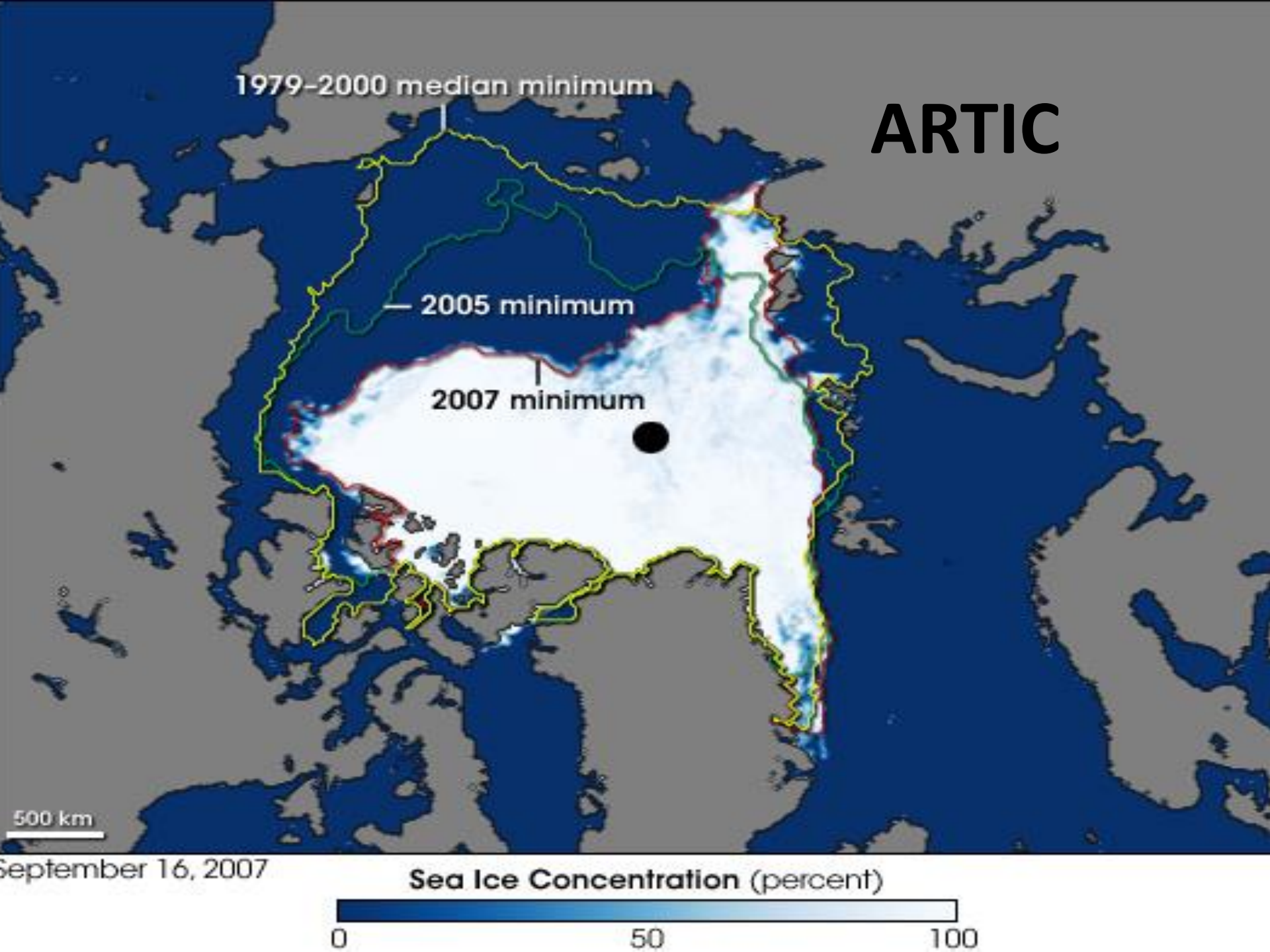




# Academic studies of scientific consensus on human-caused global warming



# ARTIC











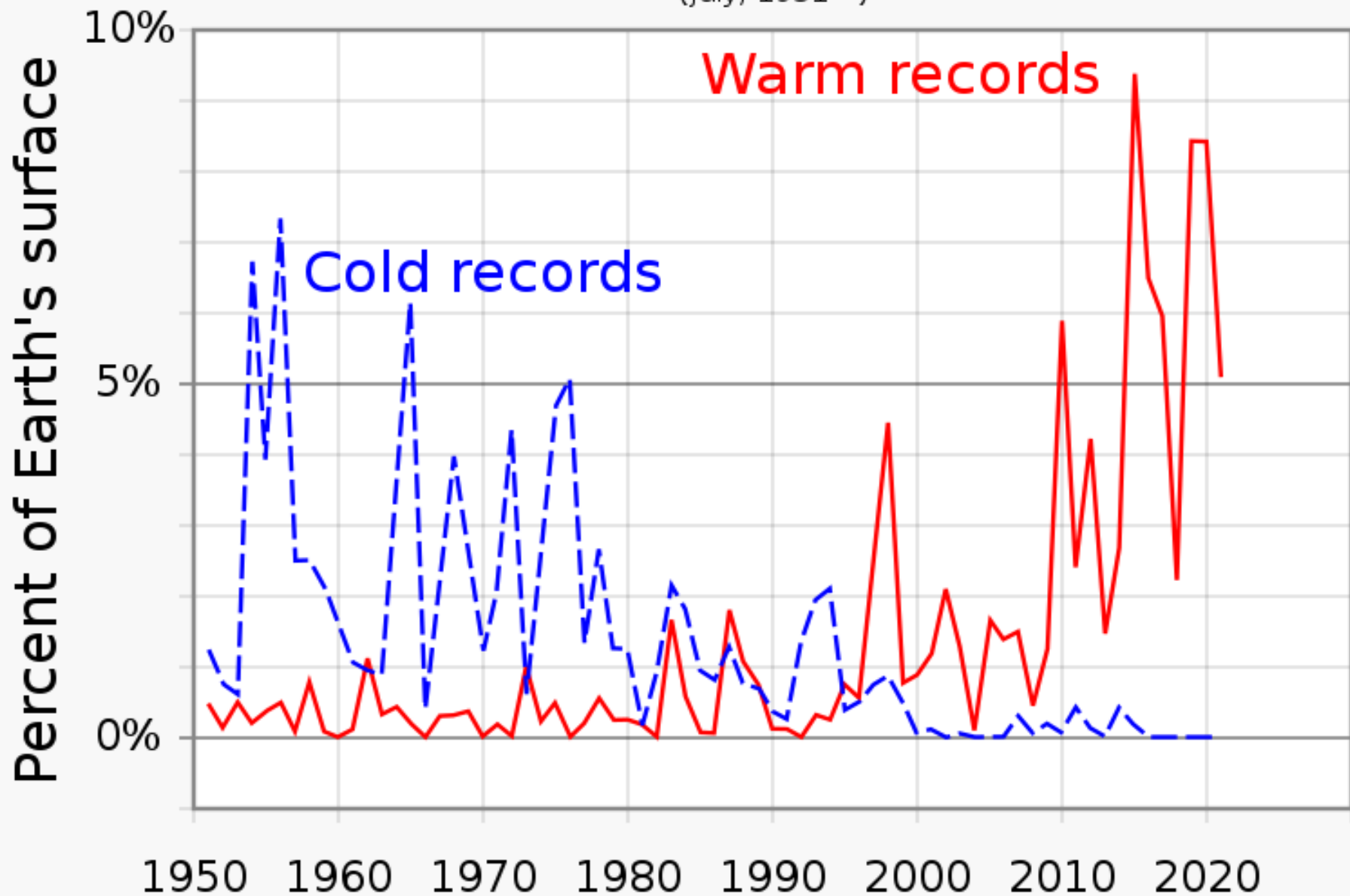


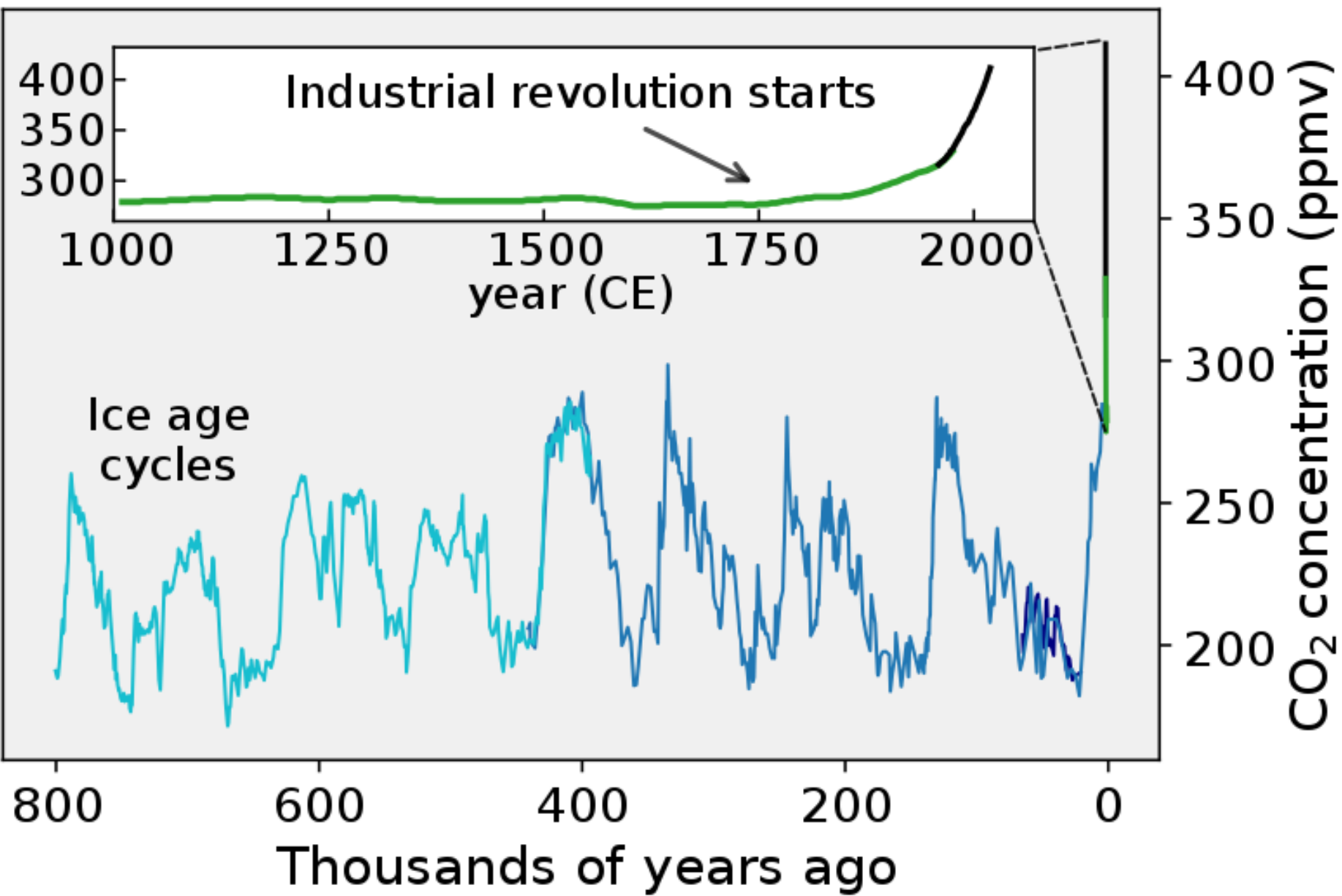




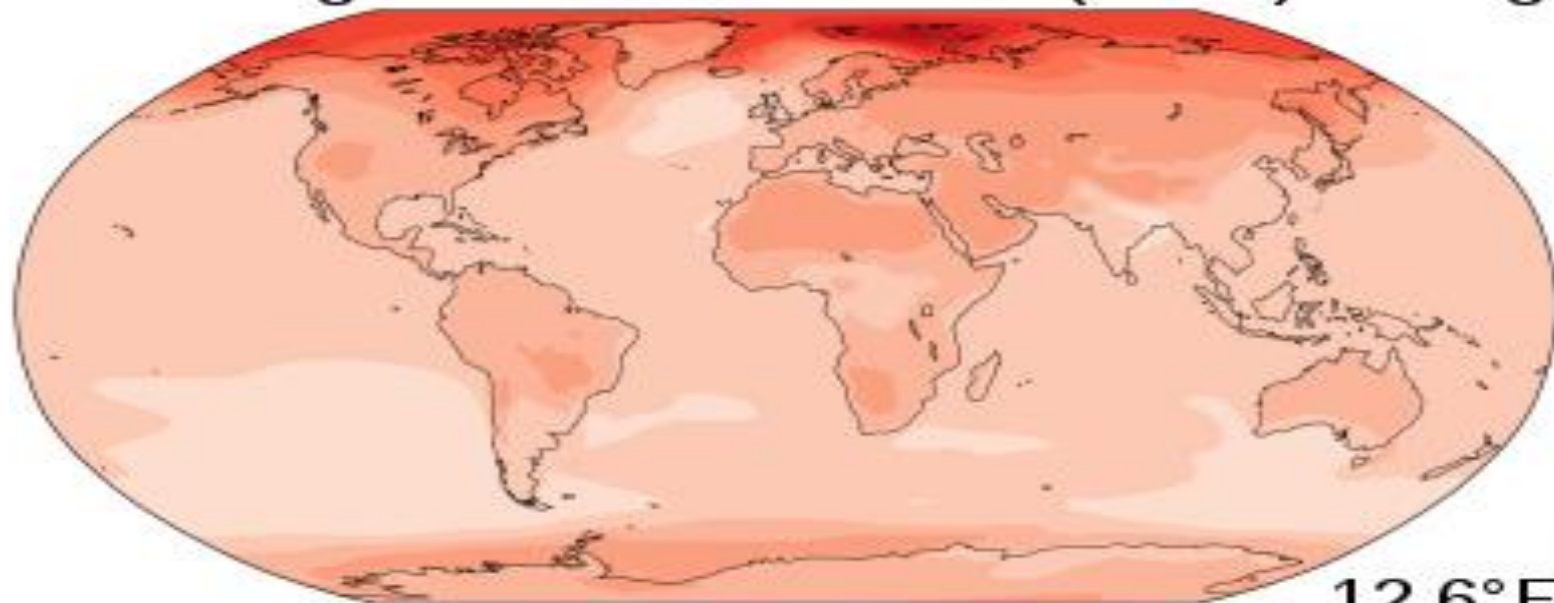
# Global area reaching record temperatures

(July; 1951—)





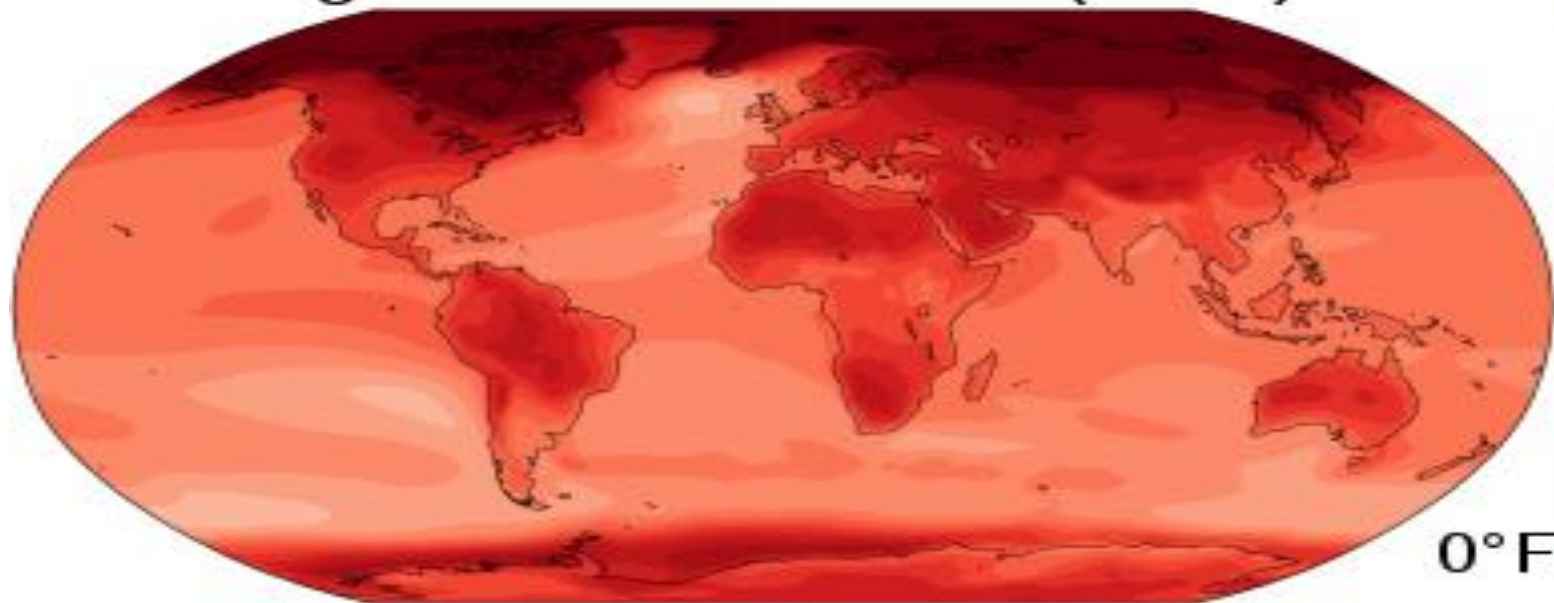
Warming distribution at 1.5° C (2.7° F) average



12.6° F

7° C

Warming distribution at 4.0° C (7.2° F)



0° F

0° C

- **Emissions of carbon dioxide rose by 6% in 2021 to 36.3 billion metric tons.**

COVID-19 restrictions in 2020 caused a massive plunge in fossil fuel use.

Coal accounted for over 40% of the overall growth in global CO<sub>2</sub> emissions in 2021.

Worldwide emissions of carbon dioxide – the greenhouse gas most responsible for global warming – have rebounded to their highest level in history, experts reported Tuesday, as the world economy rebounded strongly from the COVID-19 crisis and relied heavily on coal to power that growth.

# **Global Assessment Report on Biodiversity and Ecosystem Services**

**IPBES** is to perform regular and timely assessments of knowledge on biodiversity and ecosystem services and their interlinkages at the global level. Also addressing an invitation by the Conference of the Parties of the Convention on Biological Diversity (CBD) to prepare a global assessment of biodiversity and ecosystem services building, inter alia, on its own and other relevant regional, subregional and thematic assessments, as well as on national reports.



Species extinctions have defined the global biodiversity crisis, but extinction begins with loss in abundance of individuals that can result in compositional and functional changes of ecosystems. Using multiple and independent monitoring networks, we report population losses across much of the North American avifauna over 48 years, including once-common species and from most biomes. Integration of range-wide population trajectories and size estimates indicates a **net loss approaching 3 billion birds, or 29% of 1970 abundance**. A continent-wide weather radar network also reveals a similarly steep decline in biomass passage of migrating birds over a recent 10-year period. This loss of bird abundance signals an urgent need to address threats to avert future avifaunal collapse and associated loss of ecosystem integrity, function, and services.

# CLIMATE (ECO-) ANXIETY

C. Hickman et al, *Lancet*, Dec. 2021

10 Country Survey – 10,000 between 16-25 yrs

45% - worry that climate change – affect their  
daily lives

3/4 – future frightening

56% - humanity doomed

# DOOMSDAY CLOCKS OVER TIME



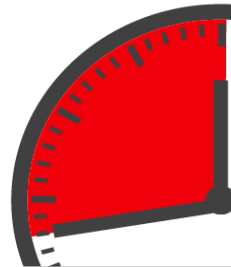
**2022 Nuclear, Climate, COVID  
Disruptive technologies**



**2020 Nuclear, Climate**



**2019 Nuclear, Climate**



**1991 Cold war ends;  
Decrease nuclear arsenal**



**1953 First Hydrogen bomb**

# 75% of Amazon rainforest shows signs of loss, a 'tipping point' of dieback, study shows

[Doyle Rice](#) USA TODAY 3/7/2022

"Deforestation and climate change are likely the main drivers of this decline."

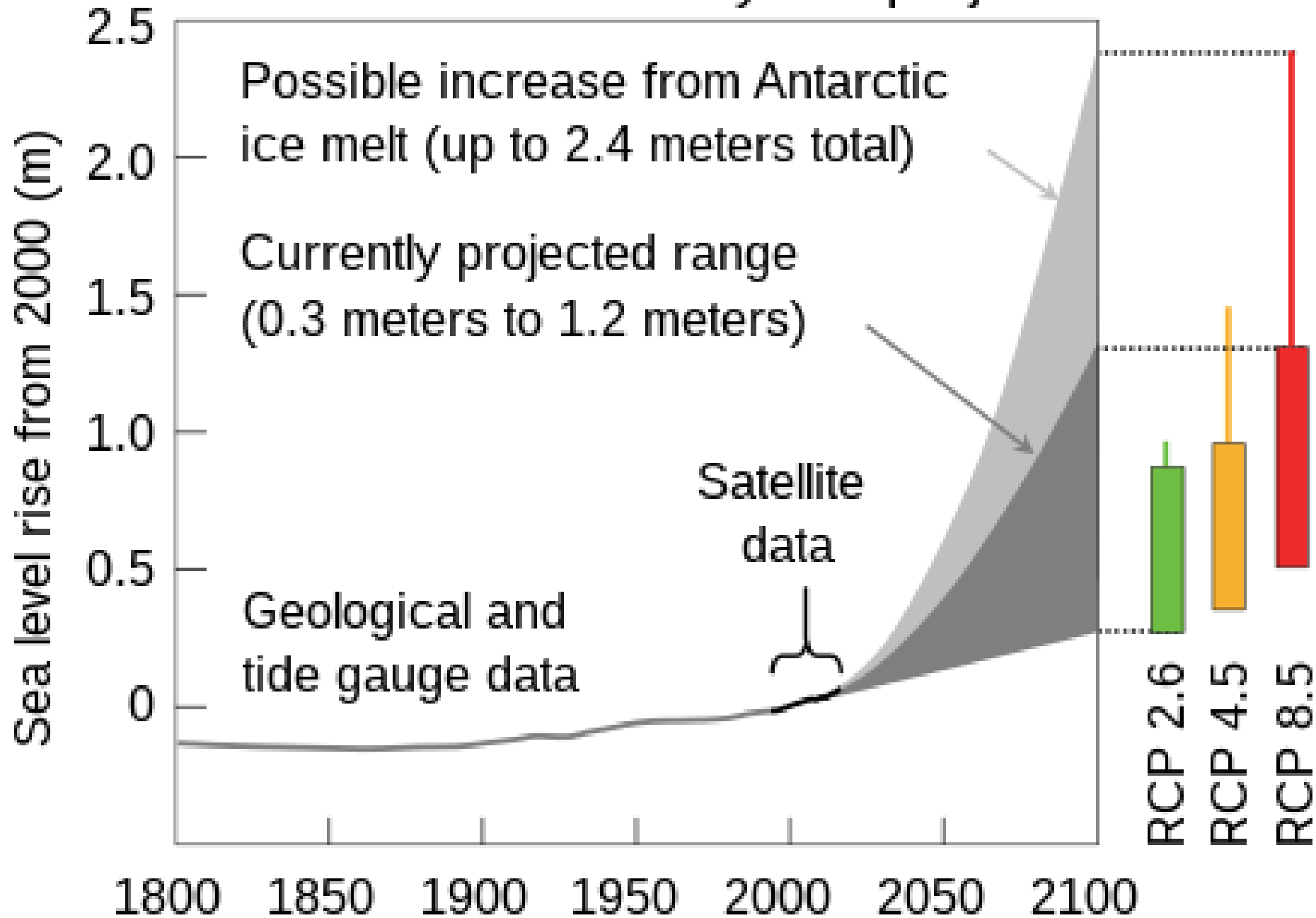
The Amazon rainforest is biologically the richest region on Earth, hosting about 25% of global biodiversity..The study was published Monday in the peer-reviewed British journal Nature Climate Change..The Amazon rainforest may be nearing a "tipping point" of dieback, the point where rainforest will turn to savanna, a new study shows.

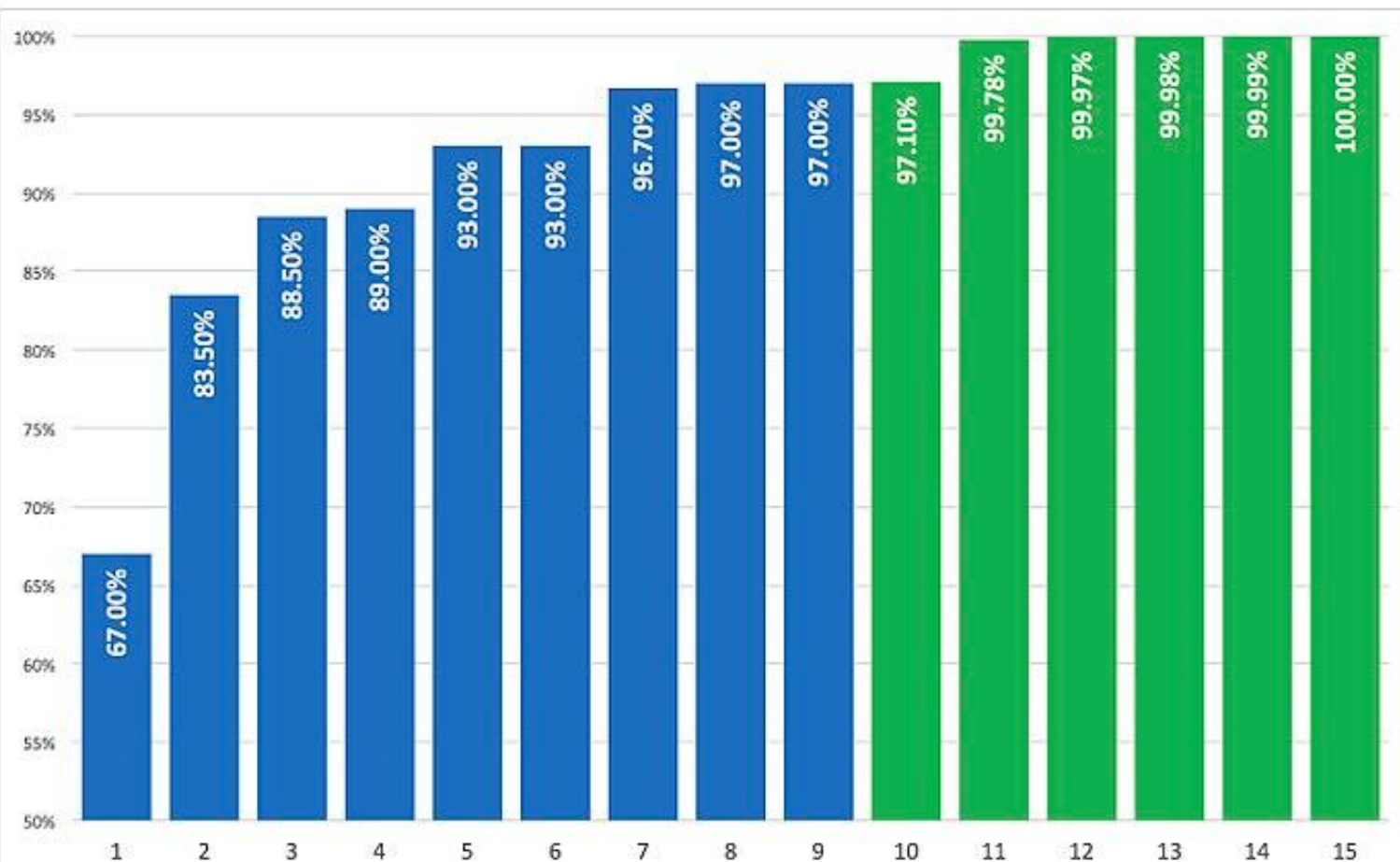
Signs of loss have been found in more than 75% of the rainforest since the early 2000s, according to research





# Global sea level history and projections





Peer-reviewed Studies of the Consensus on Anthropogenic Global Warming

Blue=opinion, Green=literature surveys

Average consensus from 54,195 articles in studies 11-15: 99.94%

[www.jamespowell.org](http://www.jamespowell.org)

# GLOBAL WARMING THE DEBATE

## SCIENTIFIC EVIDENCE

Are scientists convinced?

**YES**  
**97%**

of climate scientists  
think global warming  
is significantly due  
to human activity

**NO**  
**3%**

of climate scientists  
do not think  
global warming is  
significantly due to  
human activity

Surveys have found that over 97% of actively publishing climate scientists are convinced humans are significantly changing global temperatures (Doran, 2009). Not only is there a vast difference in the number of convinced versus unconvinced scientists, there is also a considerable gap in expertise between the two groups (Woodsong, 2013).



There's a consensus of scientists  
because there's a consensus of evidence

## MEDIA COVERAGE

Does reporting reflect the consensus?

**YES**  
**28%**

of news coverage  
depicts human  
contribution  
to warming as  
significant

**NO**  
**72%**

of news coverage  
includes a skeptic  
viewpoint or denies  
man-made warming

Because of the institutionalized journalistic norm of balanced reporting, United States television news coverage has perpetuated an informational bias by significantly diverging from the consensus view in climate science that humans contribute to global warming (Boykoff, 2008).



Media coverage misrepresents scientific  
understanding of man-made global warming

## PUBLIC PERCEPTION

Are the public convinced?

**YES**  
**26%**

of people believe  
global warming  
is happening  
and humans  
are causing it

**NO**  
**74%**

of people are not  
convinced or deny  
humans are causing  
global warming

A recent poll by the BBC / Populus suggests that since the 'climategate' coverage in the media there has been an increase in the amount of people sceptical about man-made global warming. However, the scientific consensus has not changed over this period (BBC News).



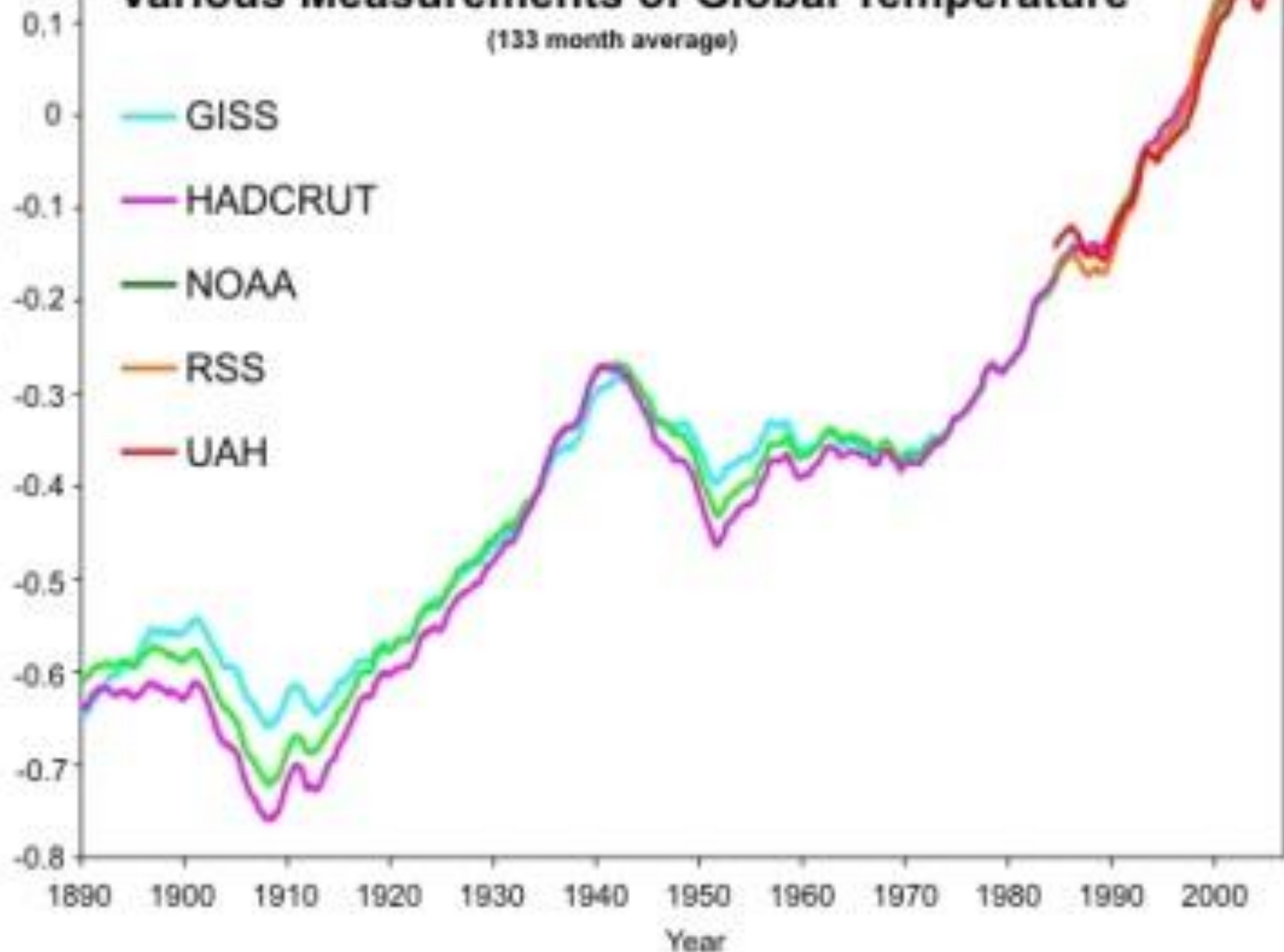
Media coverage of global warming is not 'balanced'  
and is affecting public opinion throughout the world

# Various Measurements of Global Temperature

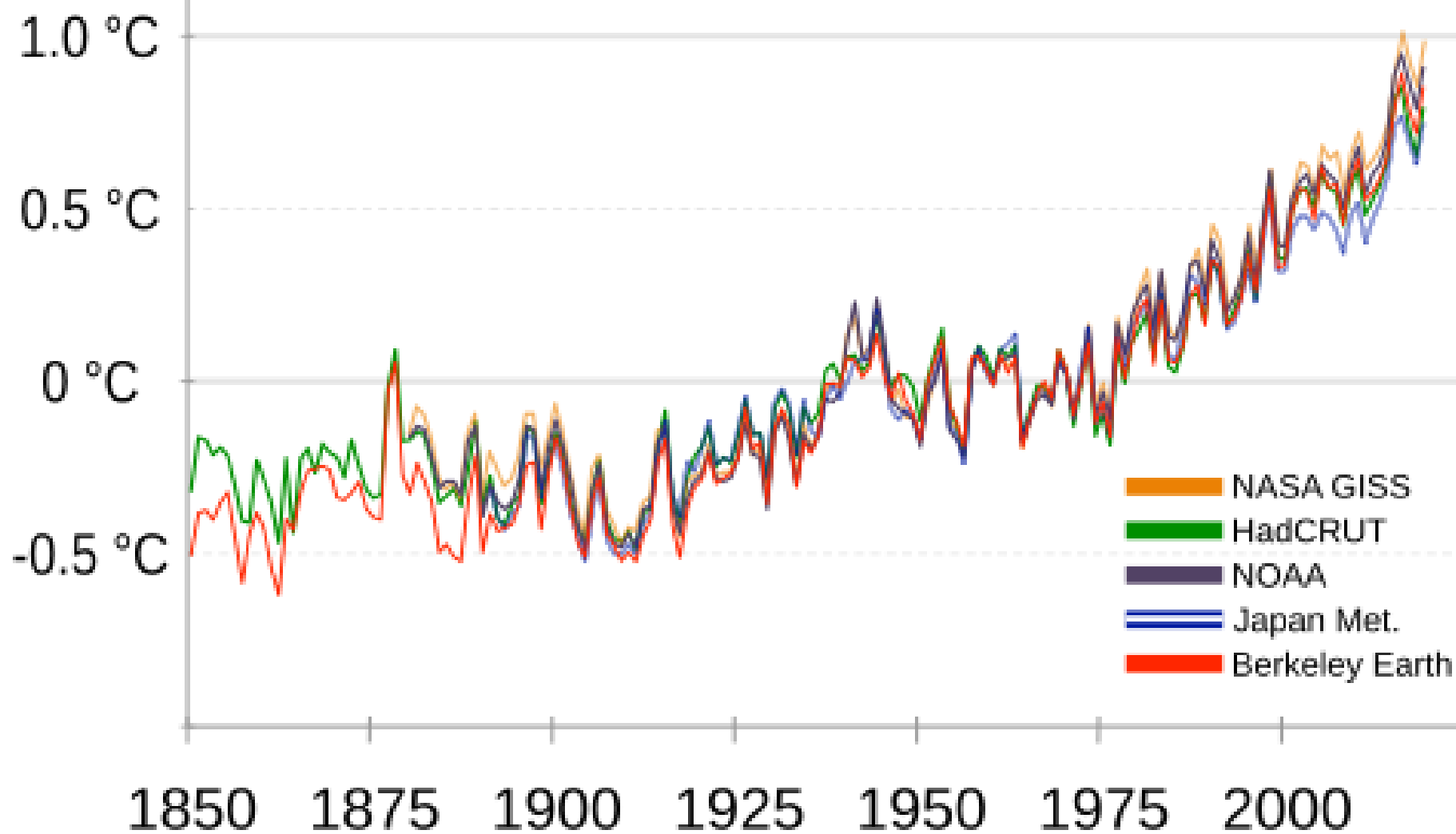
(133 month average)

Temperature Anomaly in Degrees C

- GISS
- HADCRUT
- NOAA
- RSS
- UAH

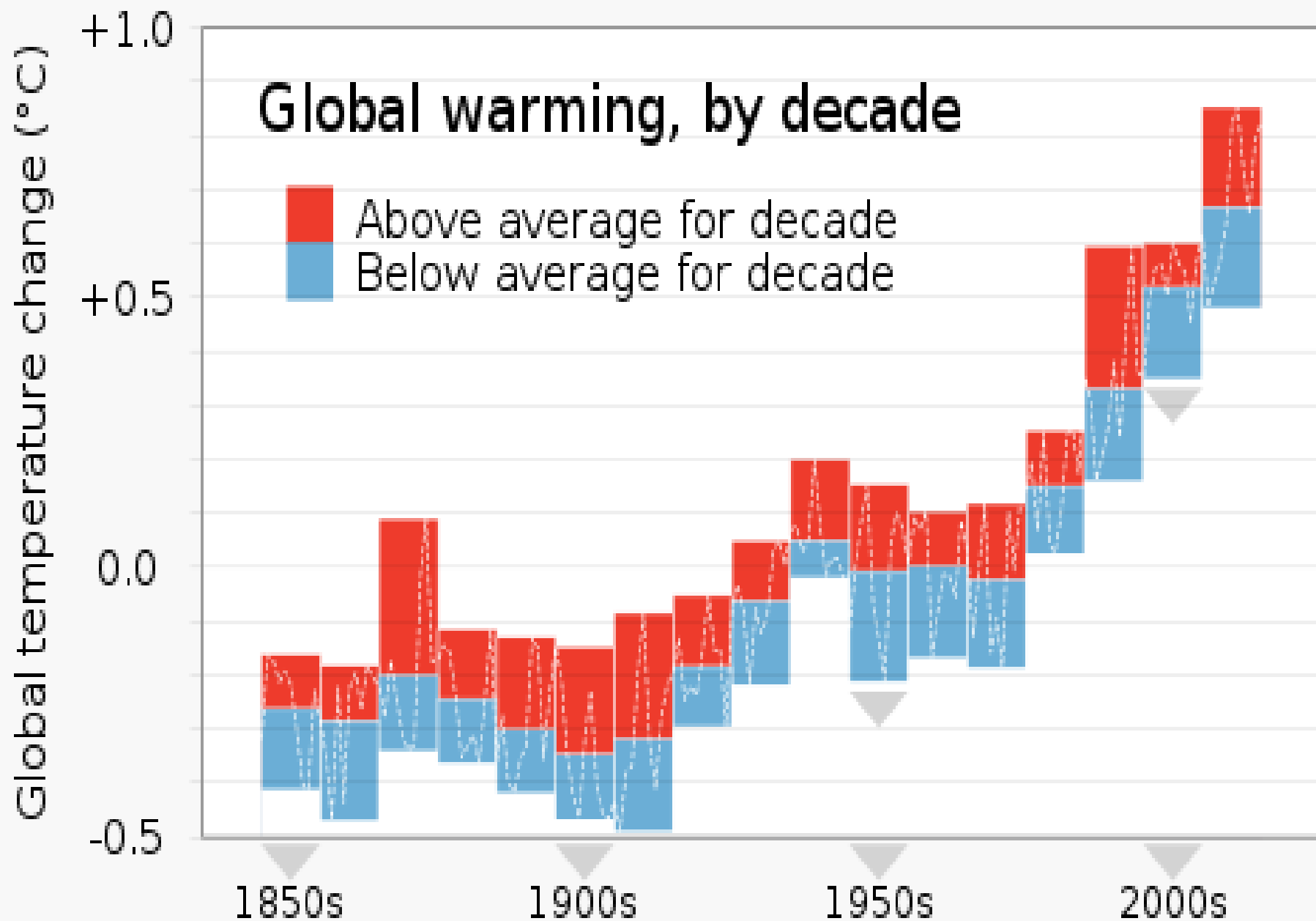


# Global average temperature change

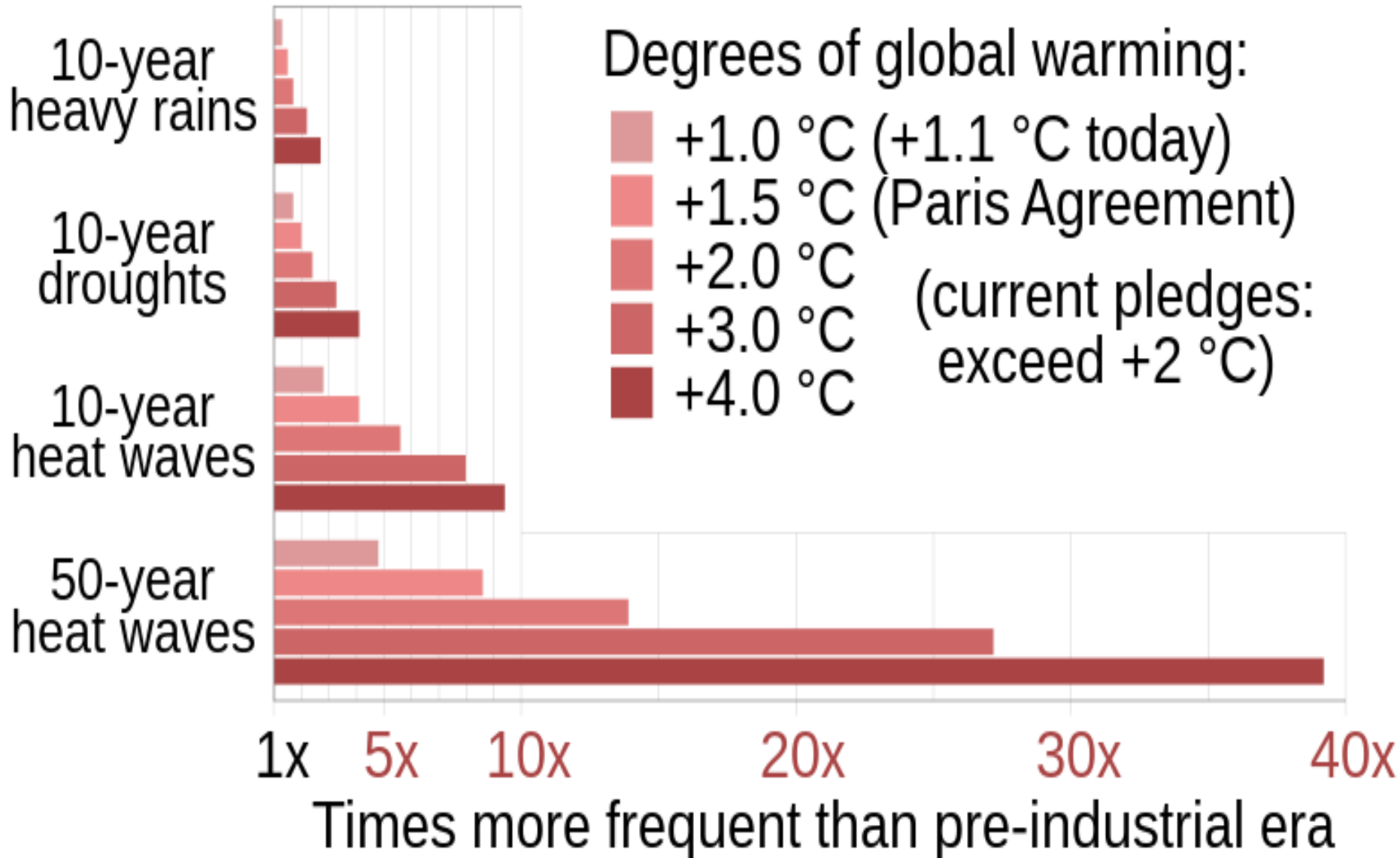




# Global warming, by decade



# More frequent extreme weather with global warming



**Emissions (million metric tons  
of carbon dioxide equivalents)**

50,000

40,000

30,000

20,000

10,000

0

1990

1995

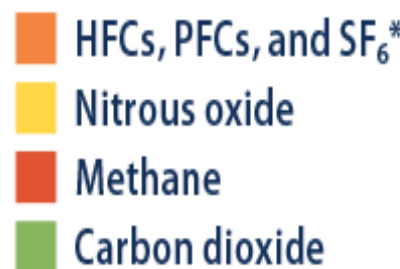
2000

2005

2010

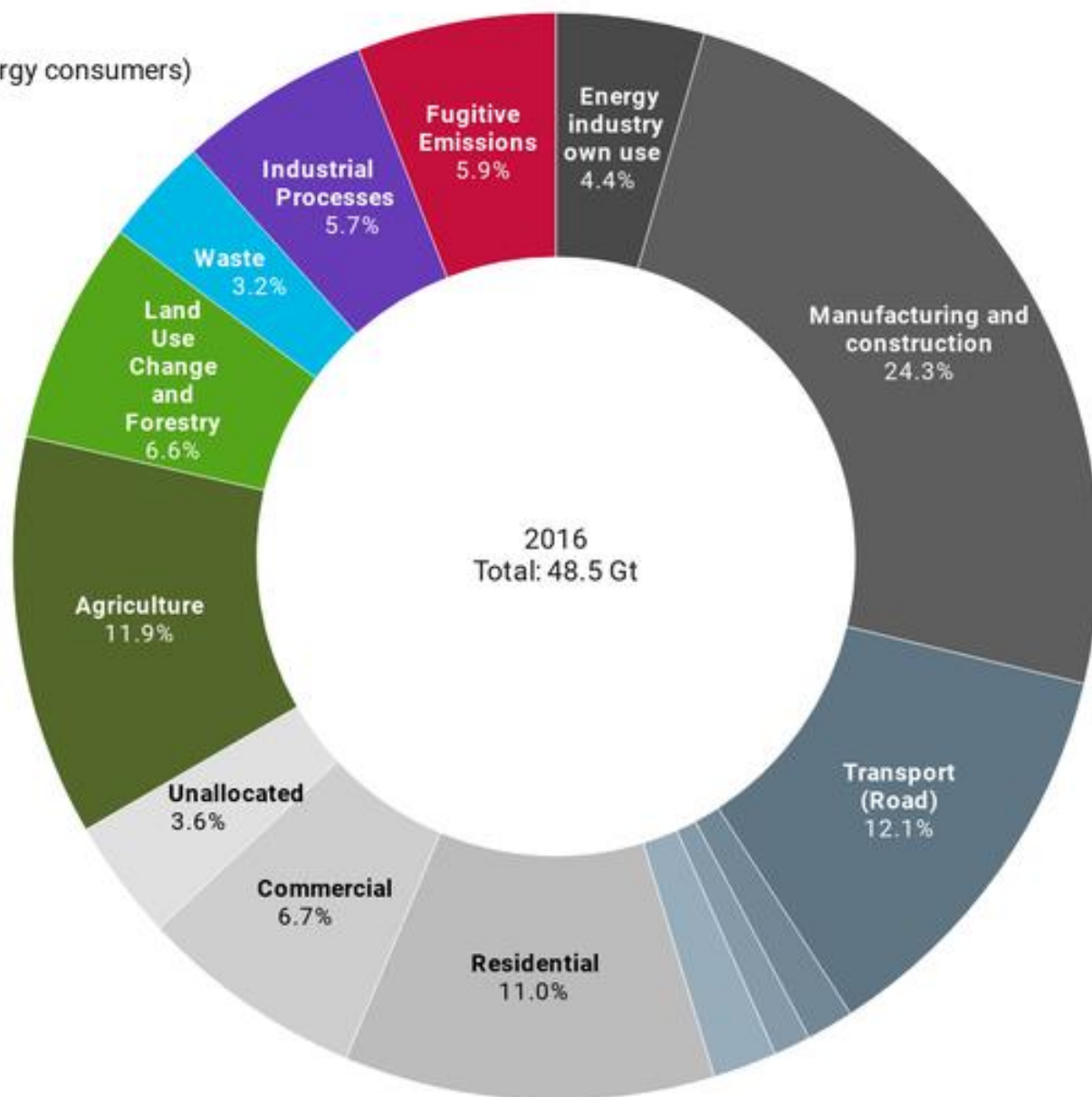
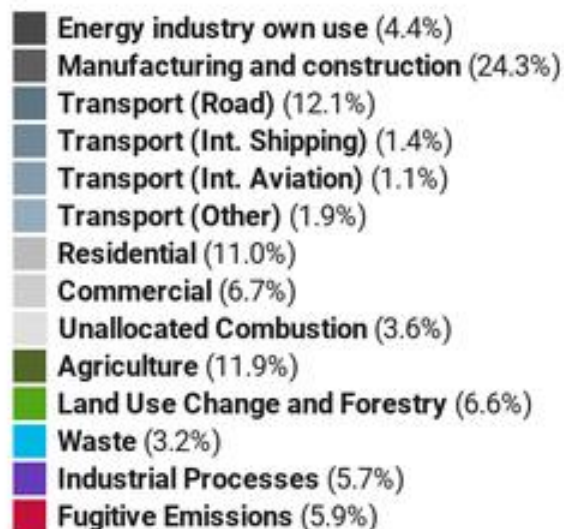
2015

**Year**



# Global GHG Emissions by Sector

2016 global emissions of greenhouse gases  
(fuel combustion emissions attributed to energy consumers)

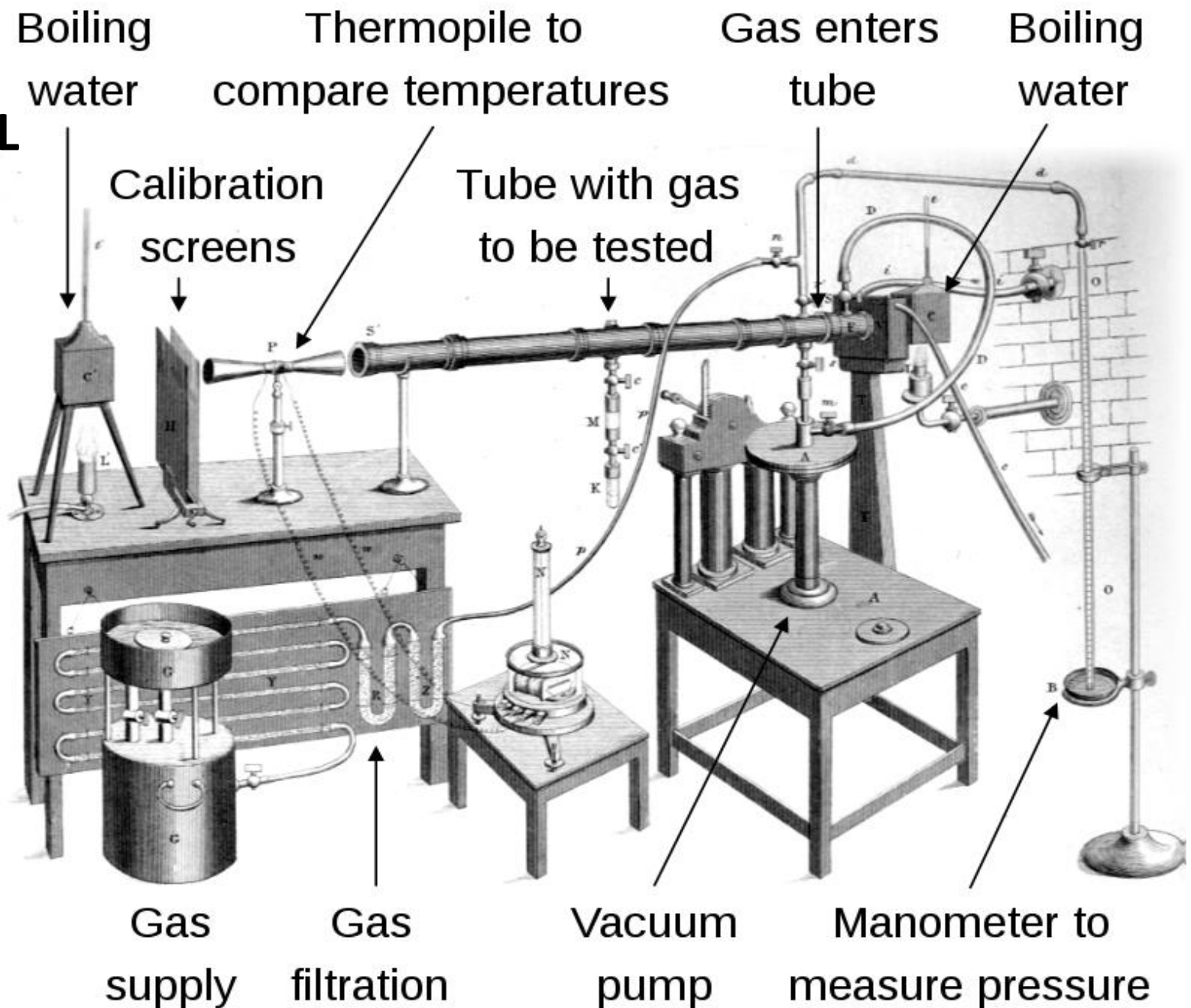


# ANTHROPOCENE: EARTH SYSTEMS AFFECTED

- 1.) Global atmosphere
- 2.) Water cycle
- 3.) Ocean's heat absorption
- 4.) Ocean acidity (coral reefs)
- 5.) Soil moisture and drought  
conditions
- 6.) Plant destruction by pests/non-  
indigenous fauna or heat stress
- 7.) Heat regulation by the Earth's ice,



**TYNDALL  
1861**



# EARTH'S CLIMATE: COMPLEX AND CHANGING

Depends on the heat balance of the planet  
= the amount of heat coming in from the sun minus the heat that escapes into space (and the ways that this heat is transferred among the oceans (ocean circulation and currents), land, air (prevailing winds), and ice (glaciers))

8 million years ago: land masses and oceans as now-the present)

2-3 Million year ago Ice ages start: Last Glacial Period: 12,500 years ago

# CLIMATE CHANGE

## INFOGRAPHICS

Hendrerit in vulputate velit esse molestie consequat, vel illum feugiat nulla facilisis at vero eros et accumsan et iusto qui blandit praesent luptatum



34%

### SEA LEVEL

Lorem ipsum dolor sit amet consectetur adipiscing baram sun rakuda ya



62%

### POLLUTION

Typi trathabent clarita insitam usus legen dolor amet da mara



2,330,000

### VEGETATION

Mirum est notare quam lit sadu gothica quam nunc putam iusto odio dignissimos



69%

### SOLAR RADIATION

At vero eos et accusamus iusto odio dignissimos du qui blanditiis praes



845,000

### GENETIC DIVERSITY

Ium est notare quam litter gothica quam putam parum qui seba daram



28%

### TEMPERATURE

Lorem ipsum dolor sit consectetur adipiscing quam nunc putam parum



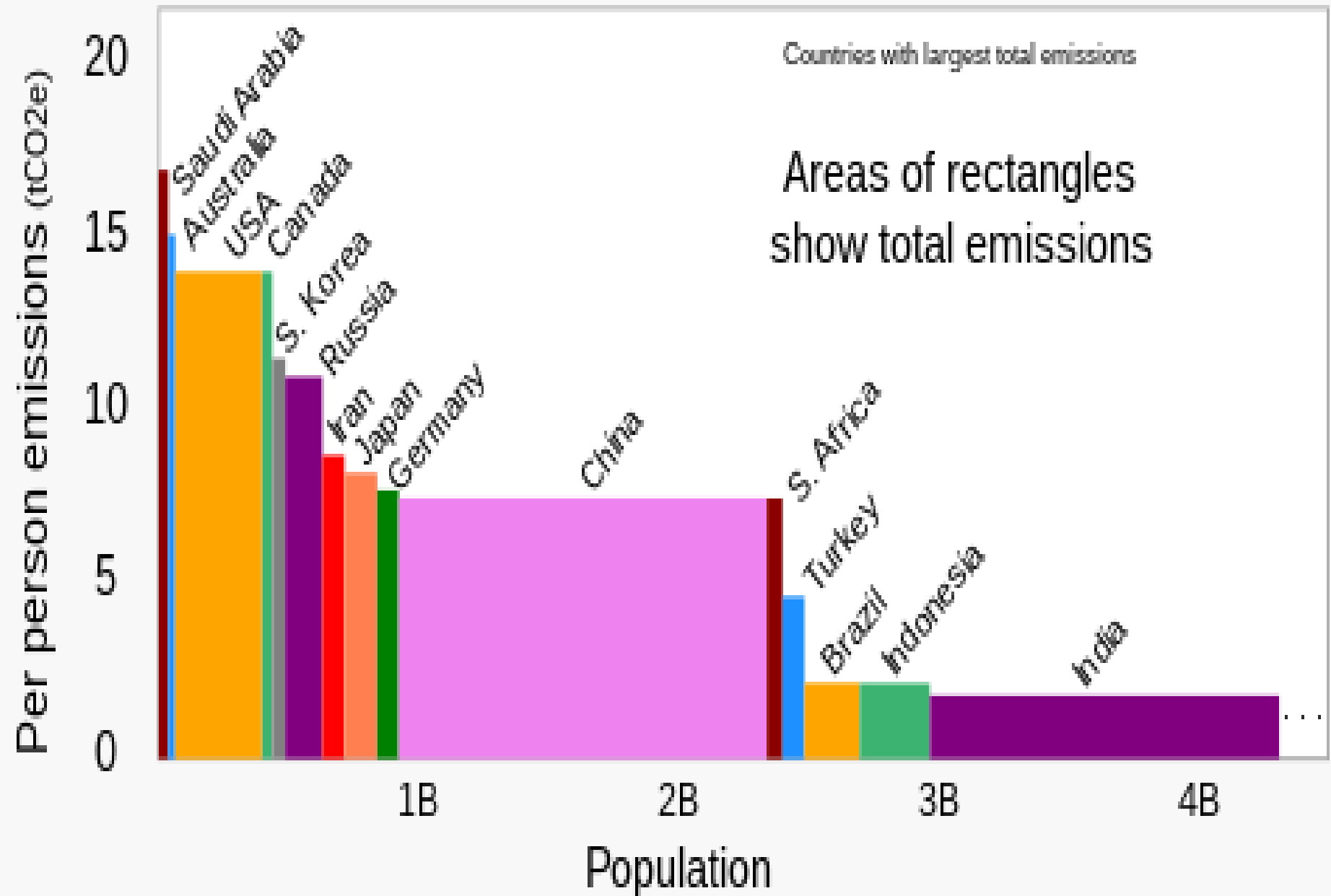
47%

### GLACIERS

Dolore magnam aliquam luptatem enim ad veniam, quis consectetur adipiscing



# Carbon dioxide emissions per person



# The psychological impacts of global climate change.

Doherty, Thomas J. Clayton, SusanCitation

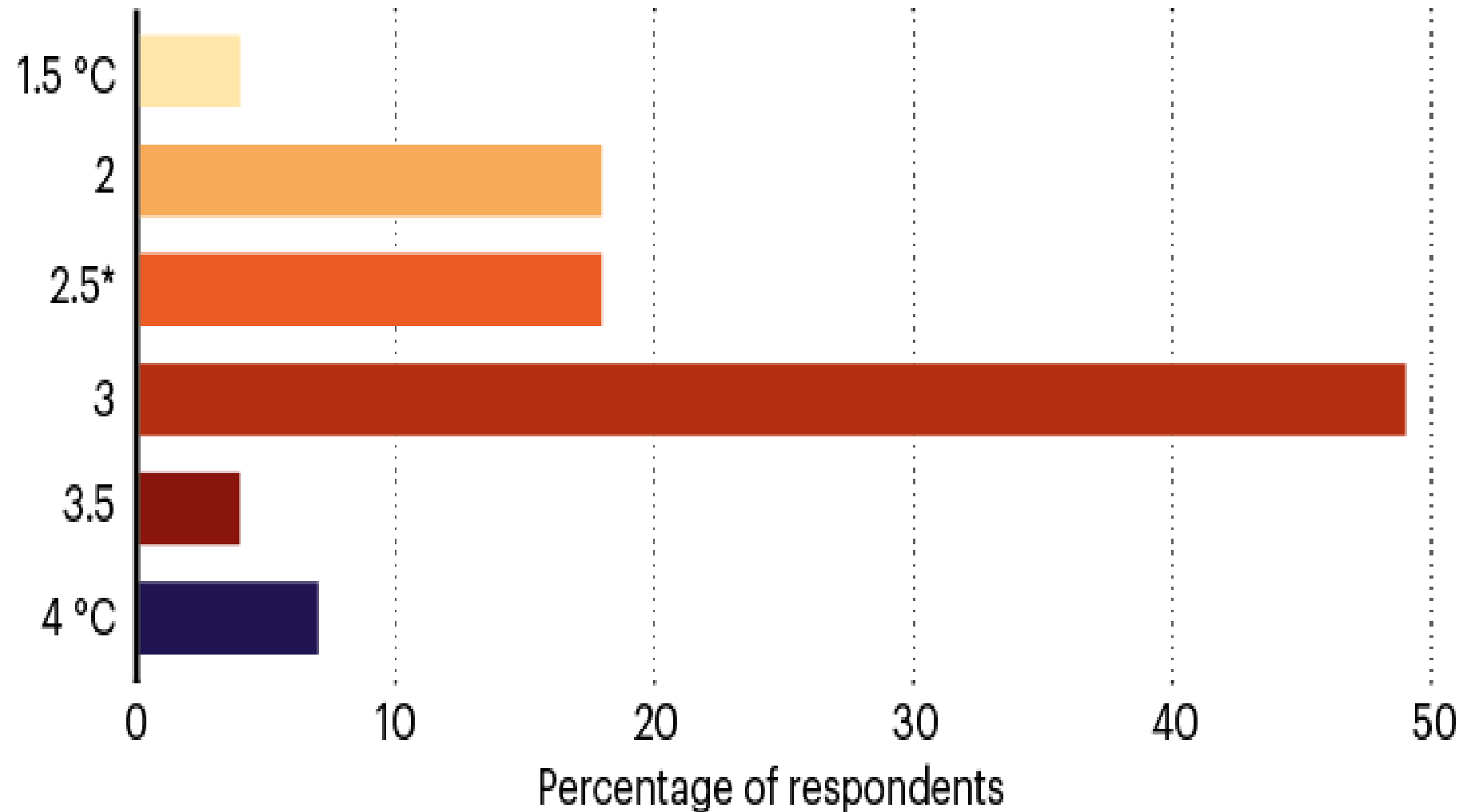
Doherty, T. J., & Clayton, S. (2011). The psychological impacts of global climate change. *American Psychologist*, 66(4), 265–276. <https://doi.org/10.1037/a0023141>

## Abstract

An appreciation of the psychological impacts of global climate change entails recognizing the complexity and multiple meanings associated with climate change; situating impacts within other social, technological, and ecological transitions; and recognizing mediators and moderators of impacts. This article describes three classes of psychological impacts: direct (e.g., acute or traumatic effects of extreme weather events and a changed environment); indirect (e.g., threats to emotional well-being based on observation of impacts and concern or uncertainty about future risks); and psychosocial (e.g., chronic social and community effects of heat, drought, migrations, and climate-related conflicts, and postdisaster adjustment). Responses include providing psychological interventions in the wake of acute impacts and reducing the vulnerabilities contributing to their severity; promoting emotional resiliency and empowerment in the context of indirect impacts; and acting at systems and policy levels to address broad psychosocial impacts. The challenge of climate change calls for increased ecological literacy, a widened ethical responsibility, investigations into a range of psychological and social adaptations, and an allocation of resources and training to improve psychologists' competency in addressing climate change–related impacts. (PsycINFO Database Record (c) 2016 APA, all rights reserved)

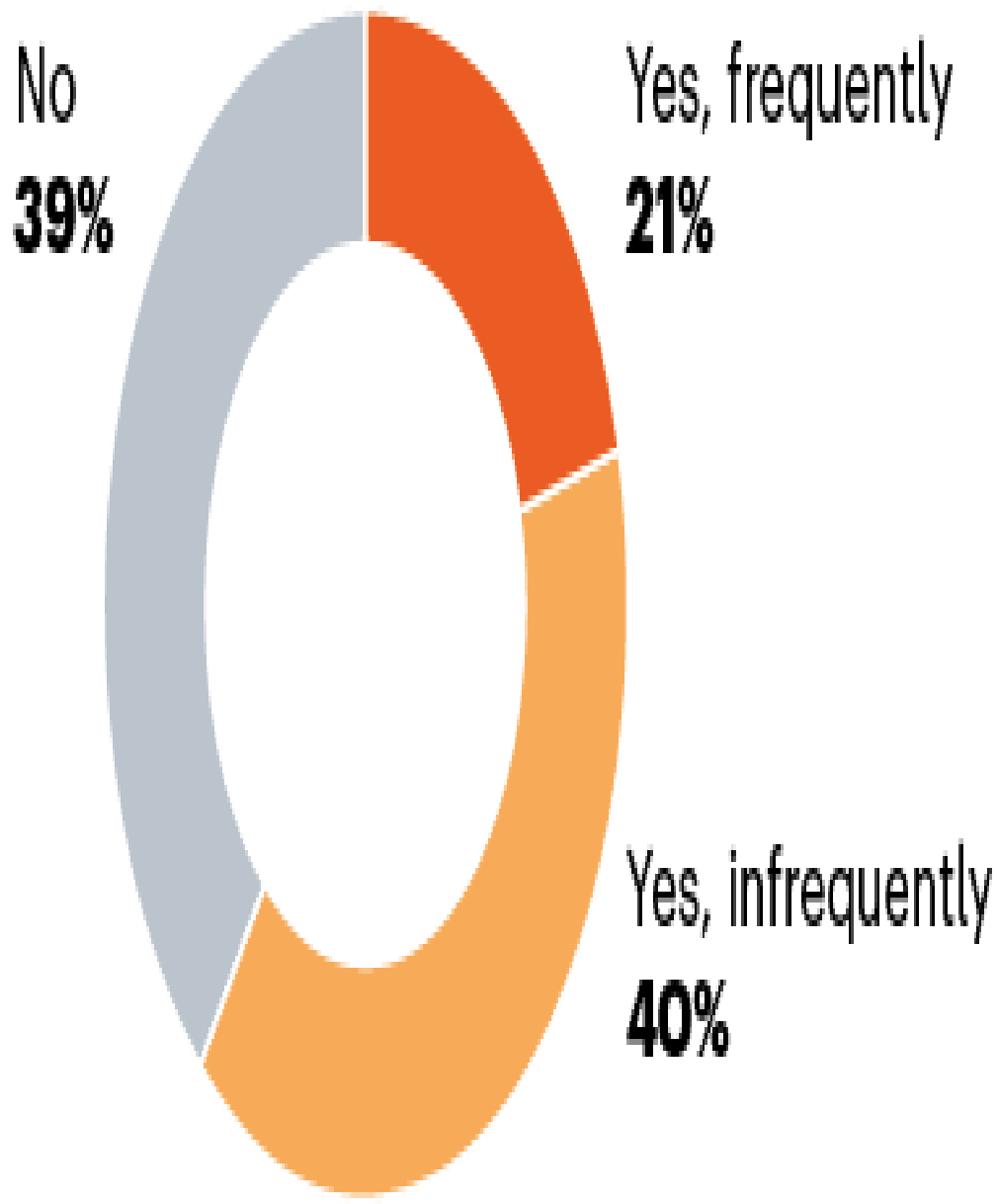


# How much warming above pre-industrial times do you think is likely by 2100?



\*Includes 2 responses between 2.7 °C and 2.75 °C; 2.5 °C and 3.5 °C were write-in answers.

**Do you experience anxiety, grief or other distress because of concerns over climate change?**



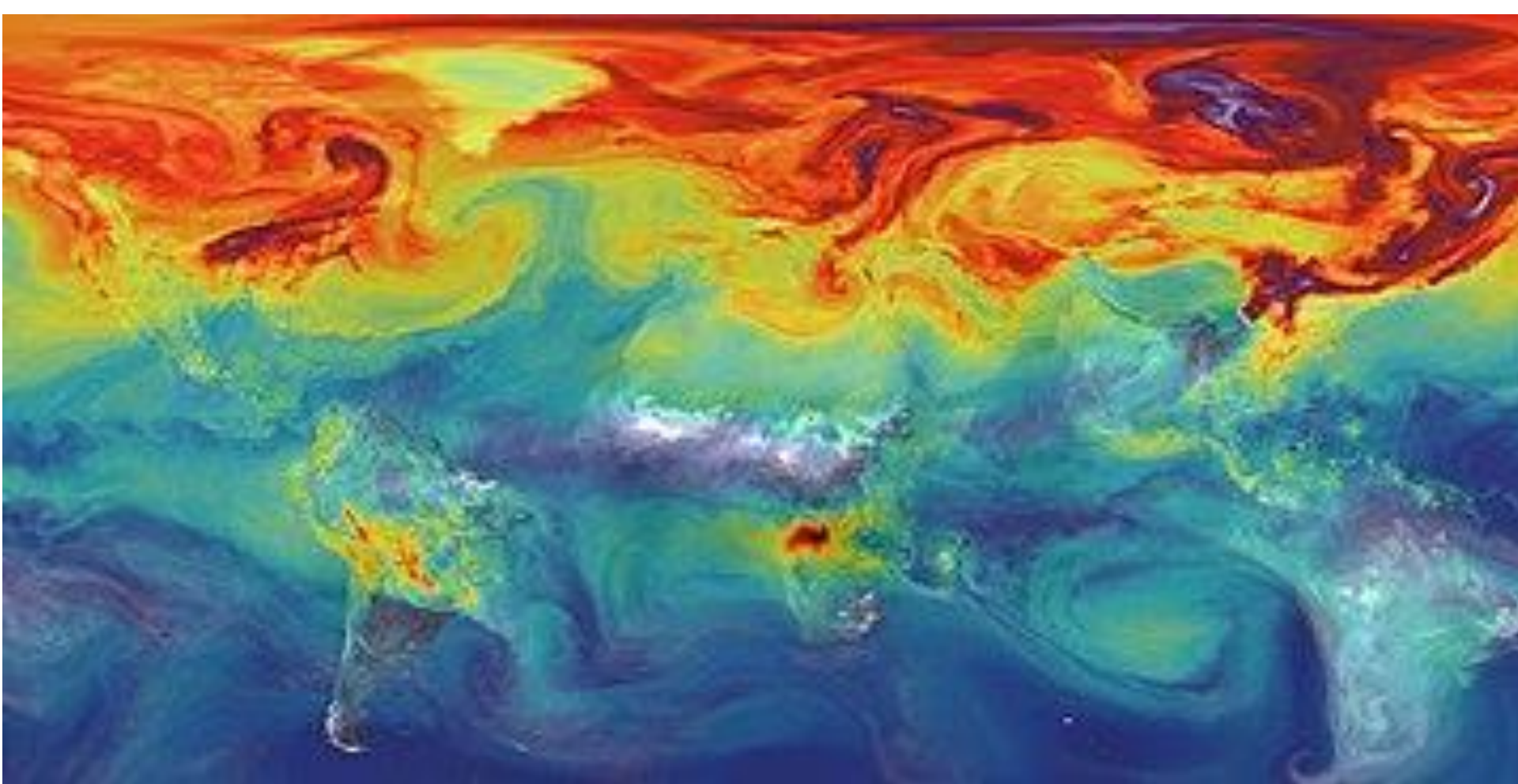
- EWS FEATURE

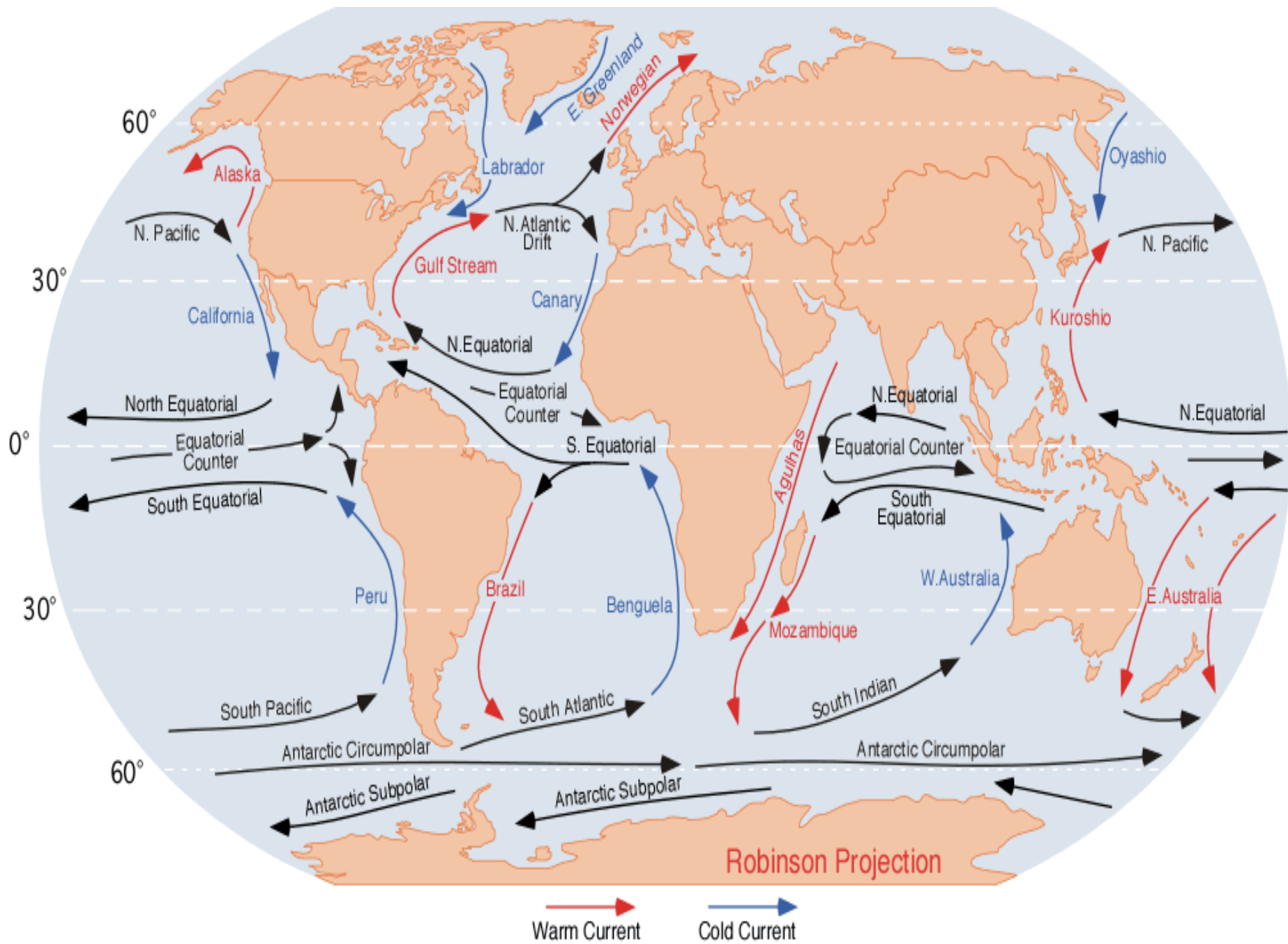
01 November 2021

**Top climate scientists are sceptical  
that nations will rein in global  
warming**

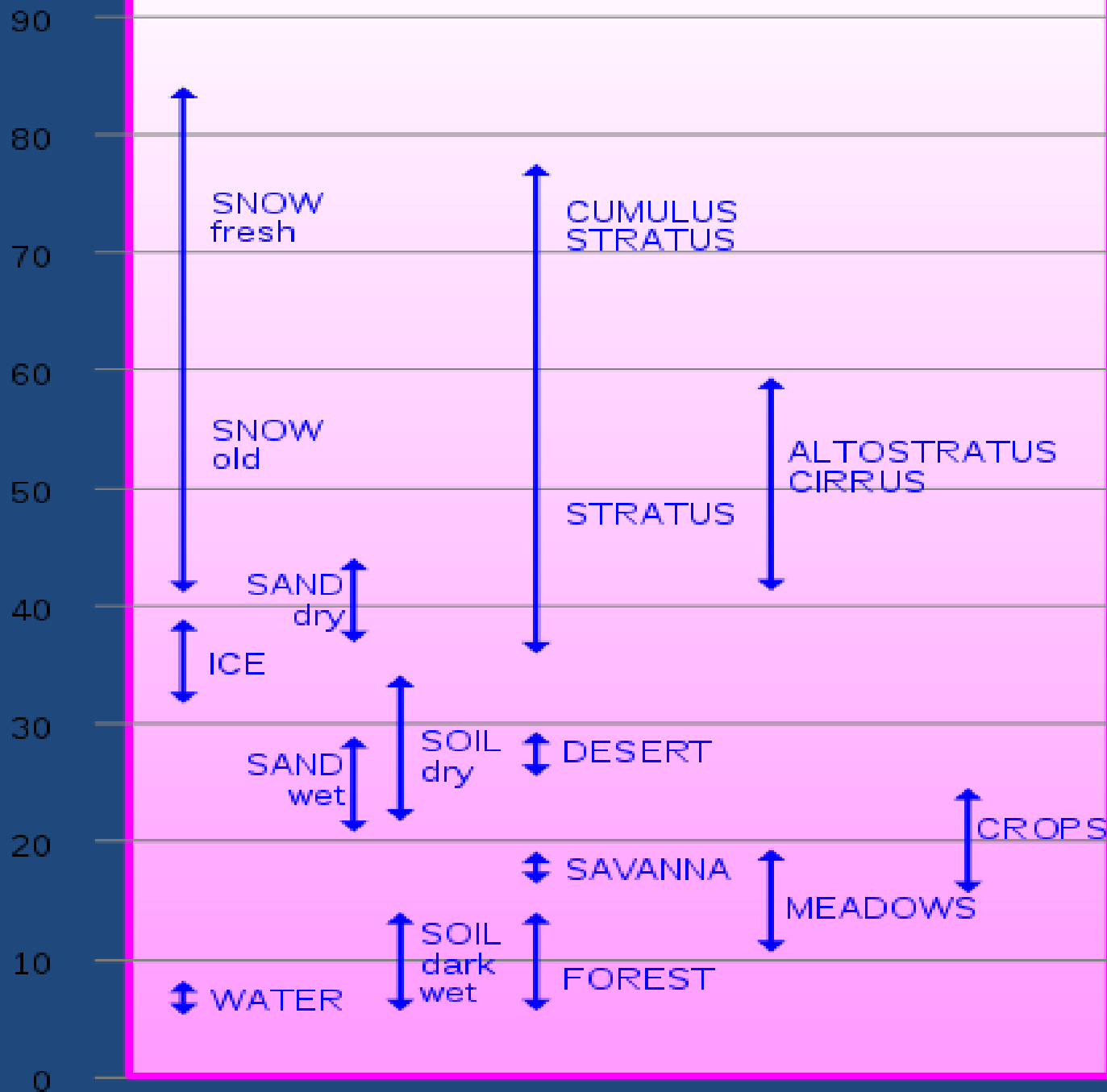
**Nature 2022**

**EARTH'S CO<sub>2</sub> ATMOSPHERE: IF HALF OF GLOBAL WARMING EMISSION NOT ABSORPT**



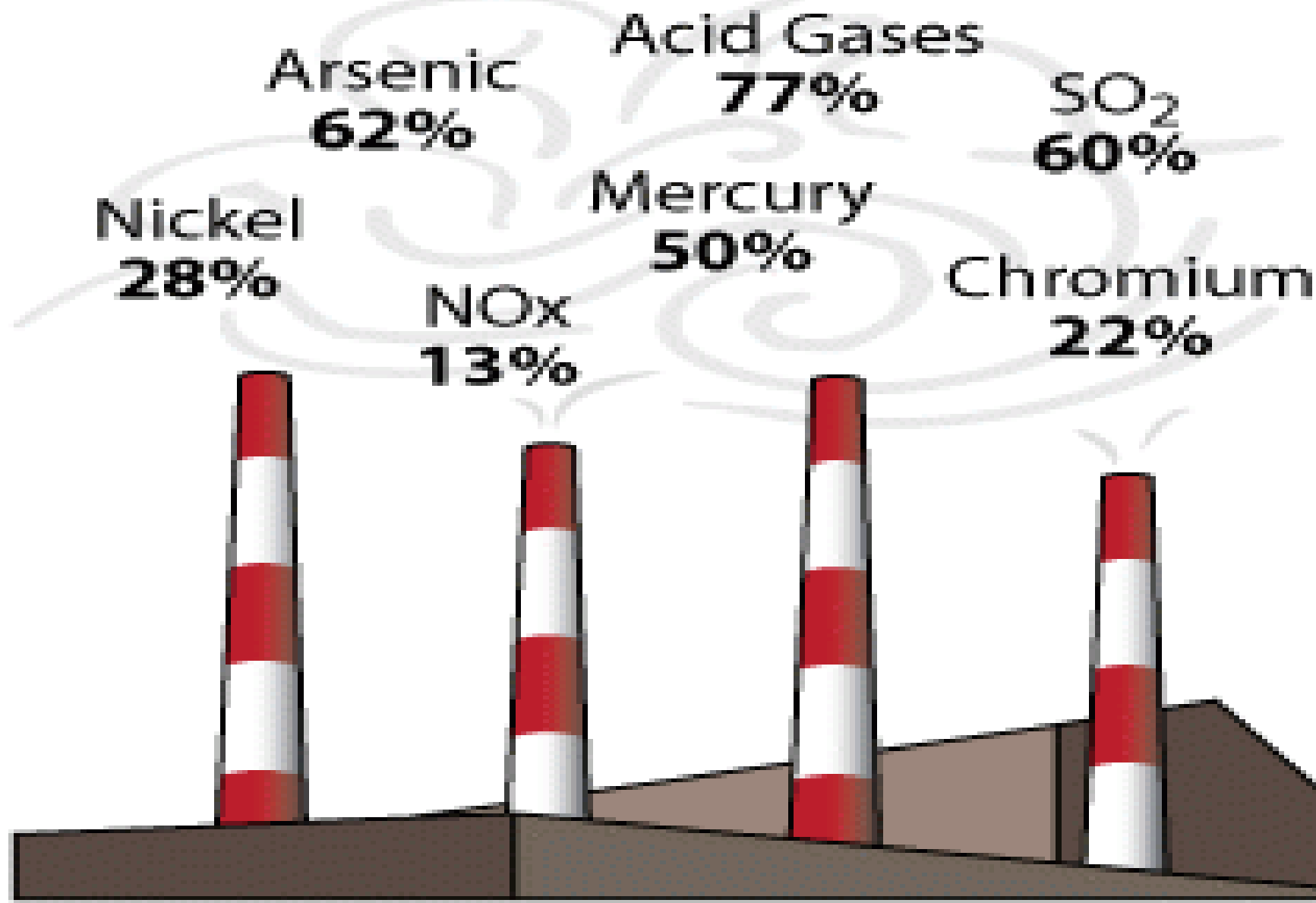






**PERCENTAGE  
OF DIFFUSELY  
REFLECTED  
SUNLIGHT**

# Portion of U.S. air pollution that comes from power plants







# WORLD METEOROLOGICAL ORGANIZATION

## World Meteorological Organization

Abbreviation

WMO

Formation

23 March 1950; 71 years ago

Type

[United Nations specialized agency](#)

Legal status

Active

Headquarters

[Geneva](#), Switzerland







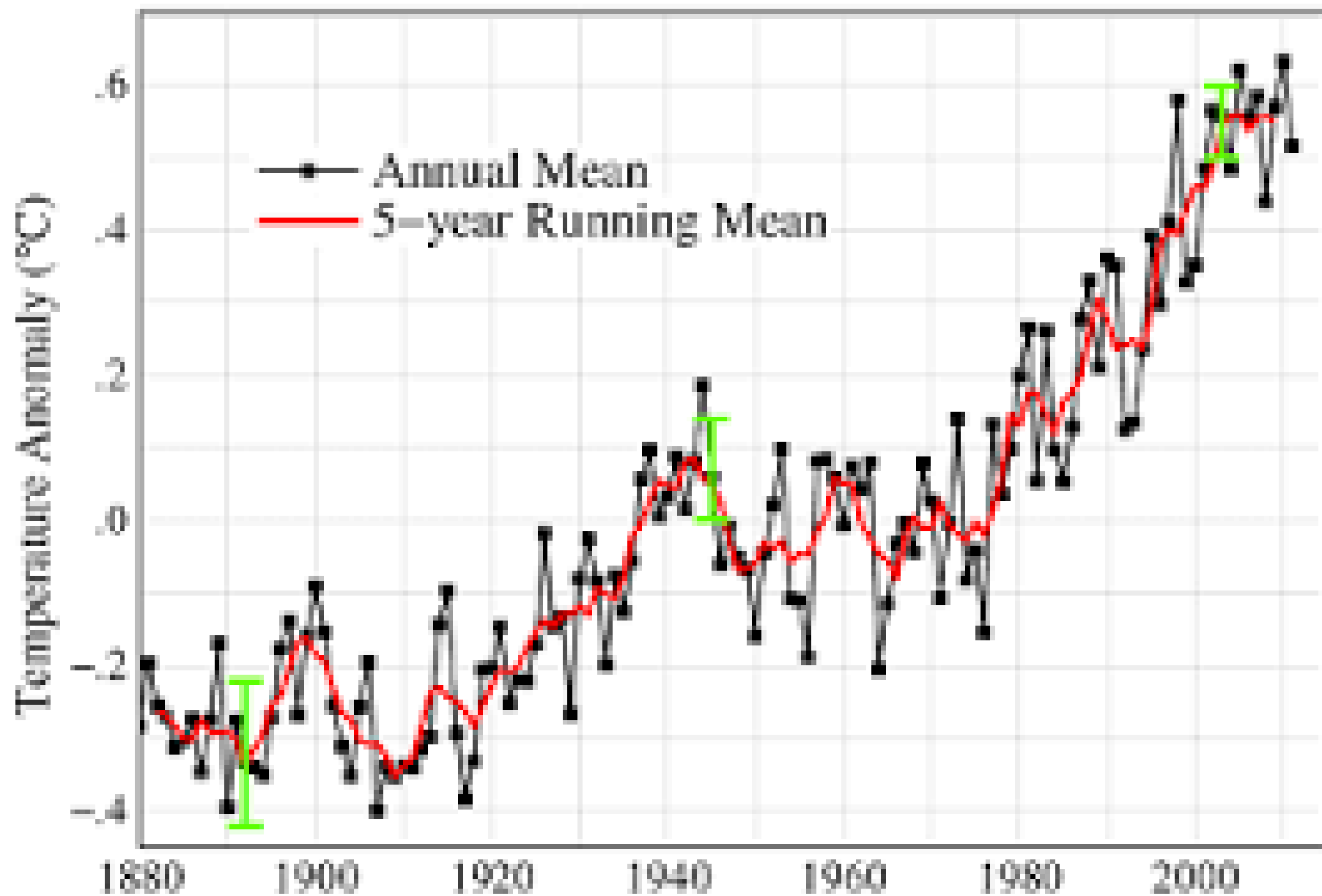








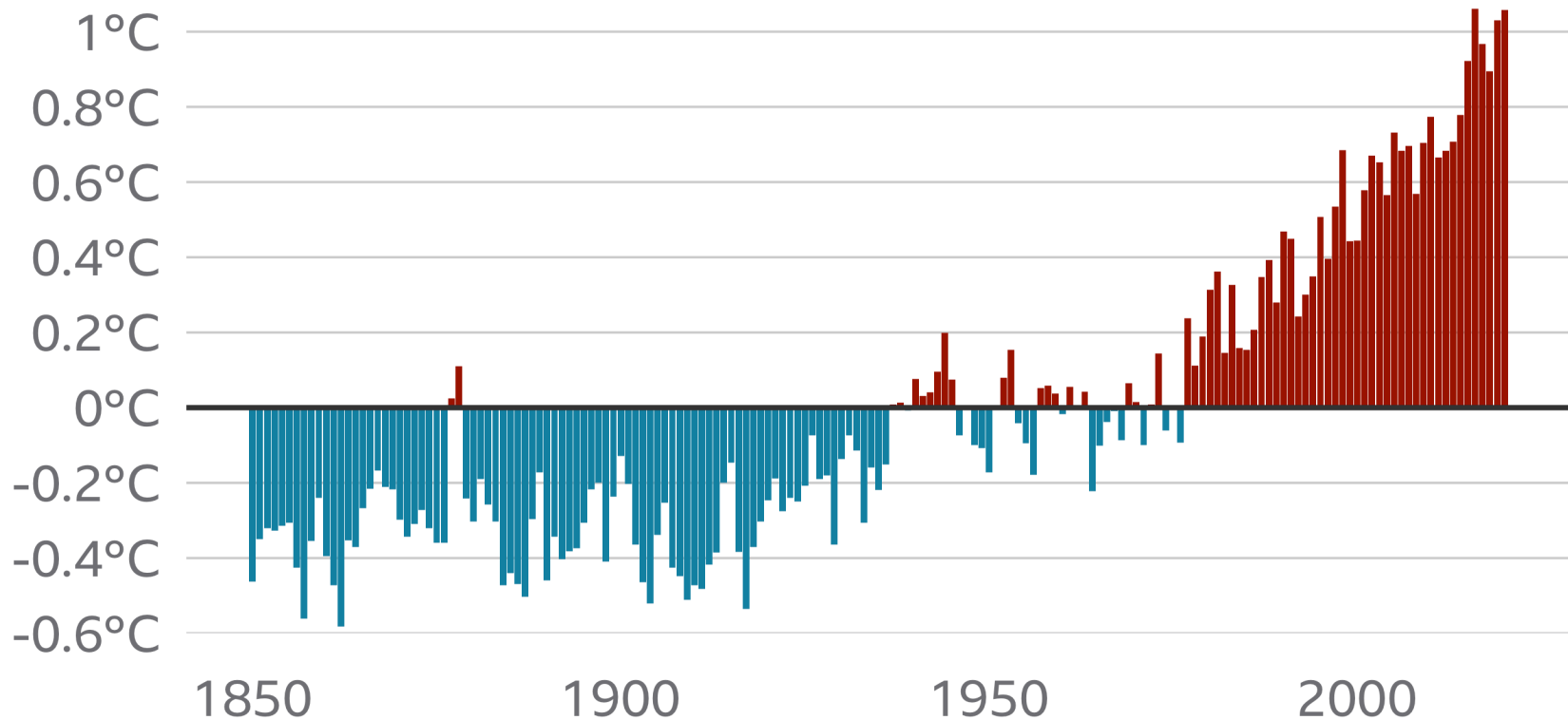
# Global Land–Ocean Temperature Index





# The world is getting warmer

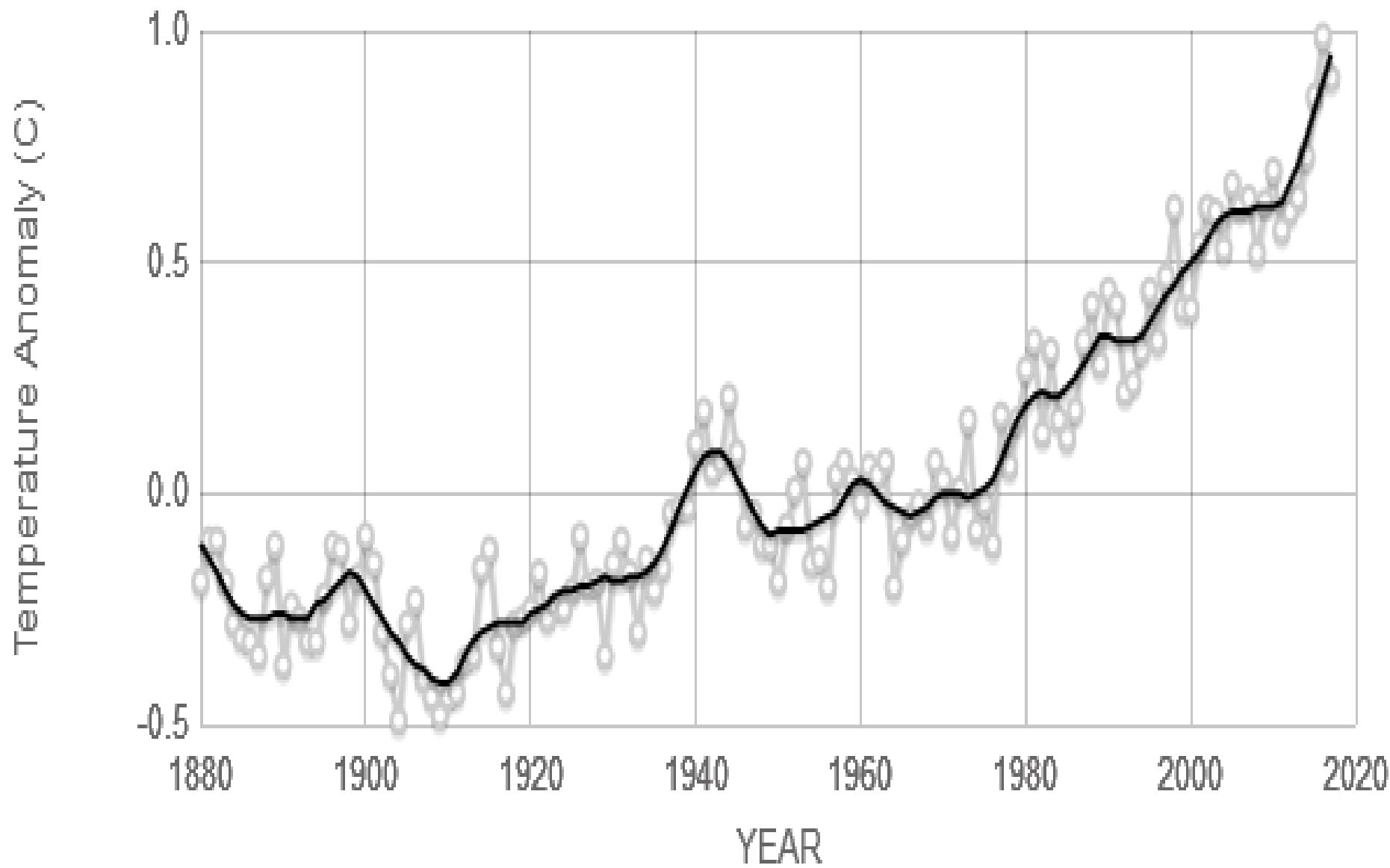
Annual mean land and ocean temperature above or below average, 1850 to 2020



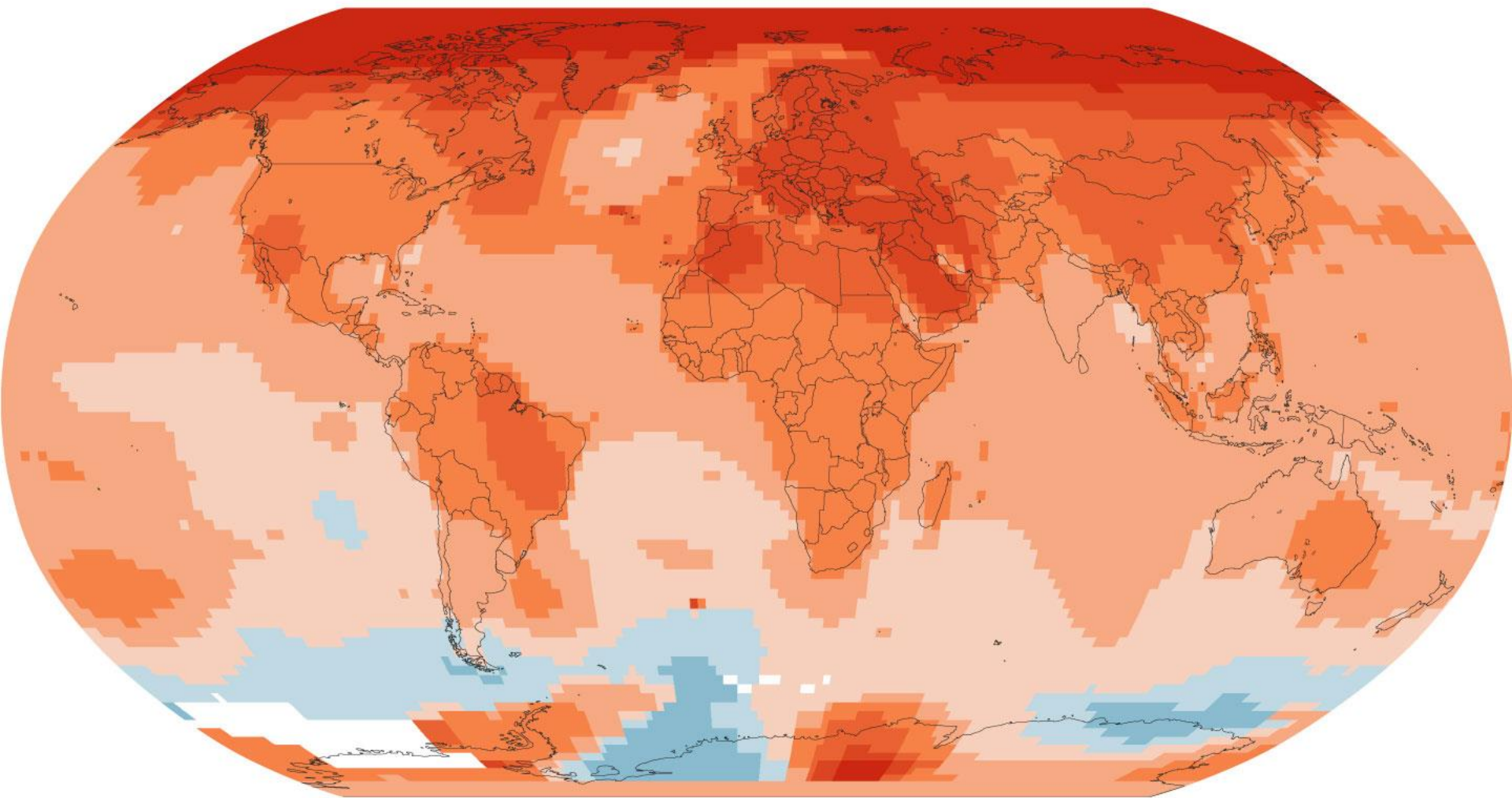
Note: Average calculated from 1951 to 1980 data

Source: University of California Berkeley





Source: [climate.nasa.gov](https://climate.nasa.gov)

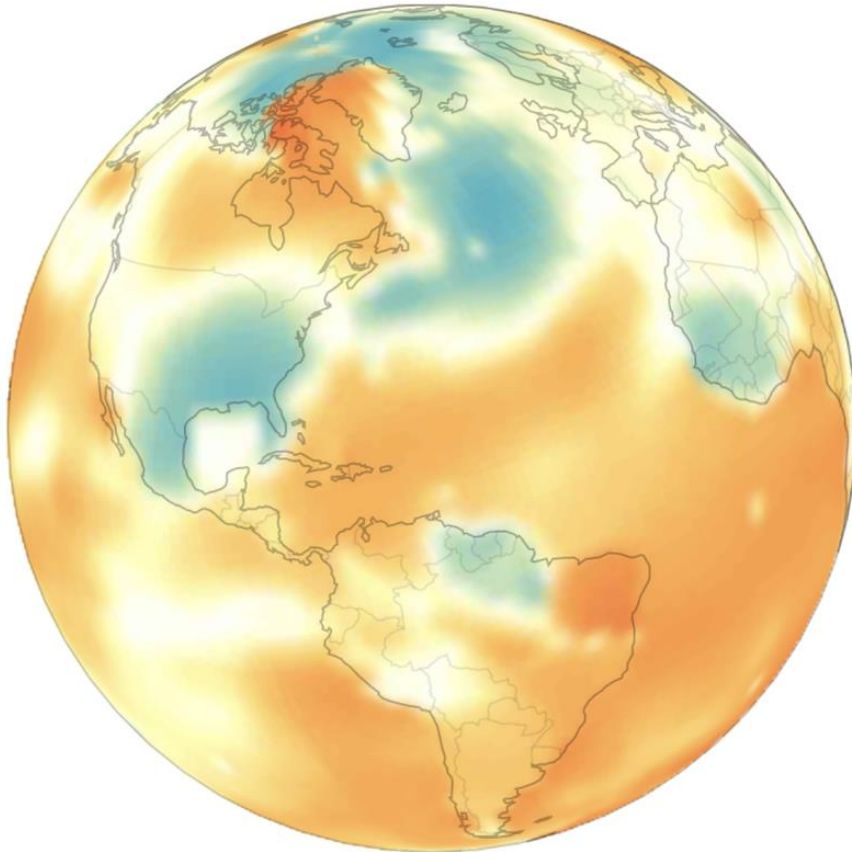


## Temperatures before and after Hansen's Senate testimony

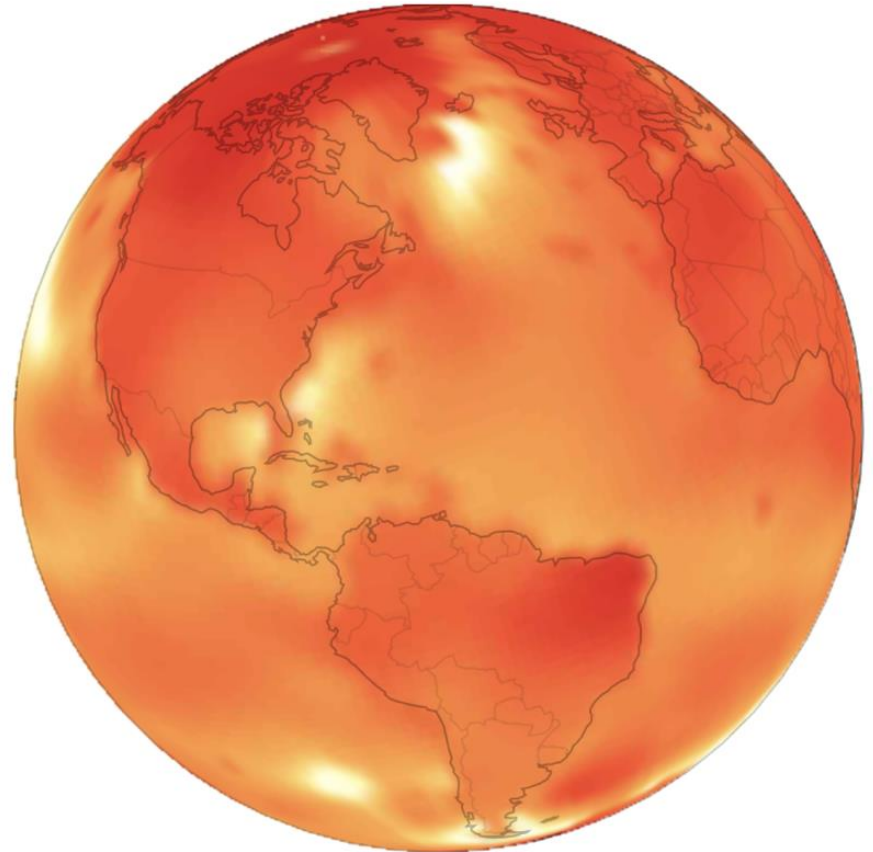
Temperature anomaly (°F), 1901-2000 baseline



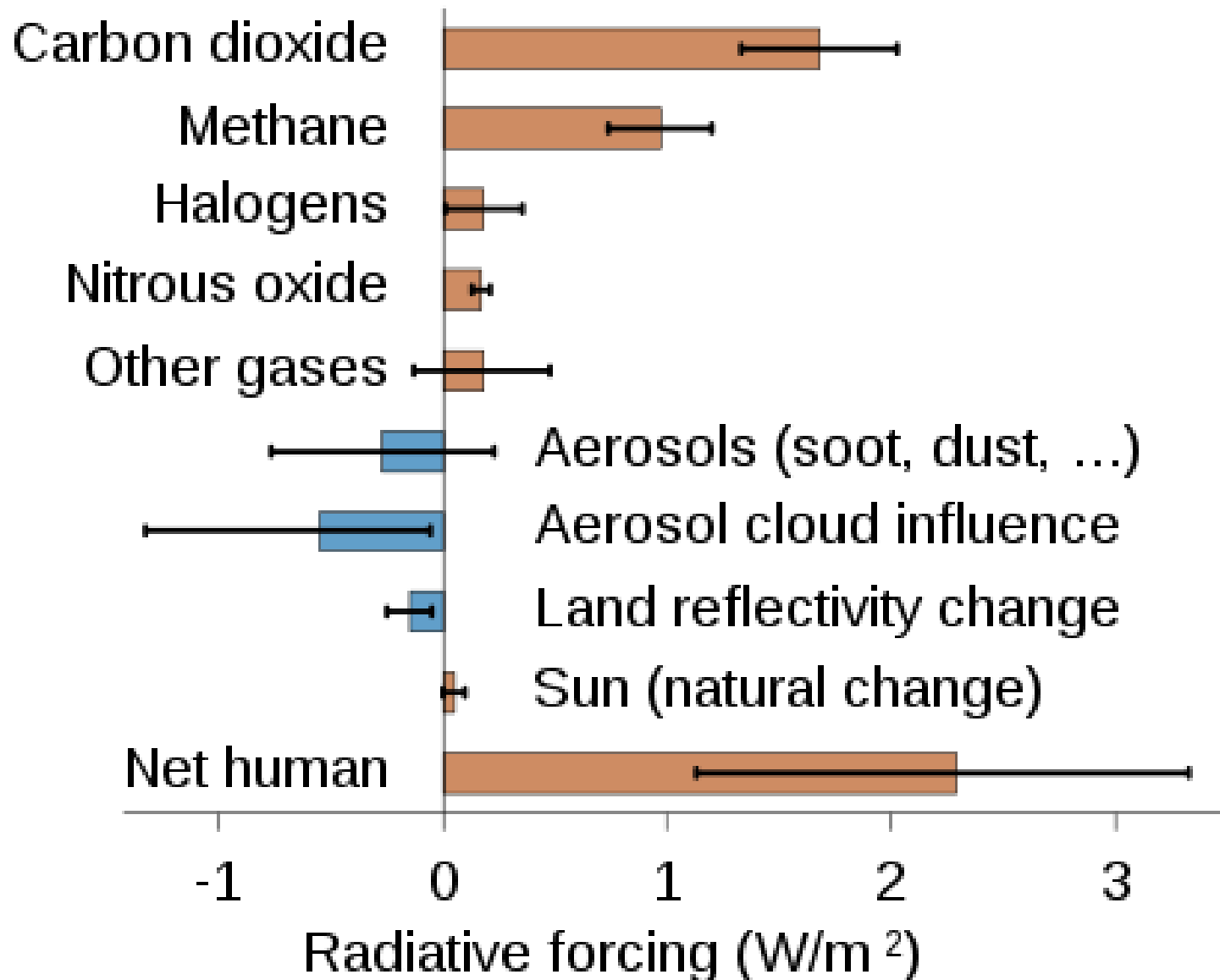
1959–1988



1988–2017

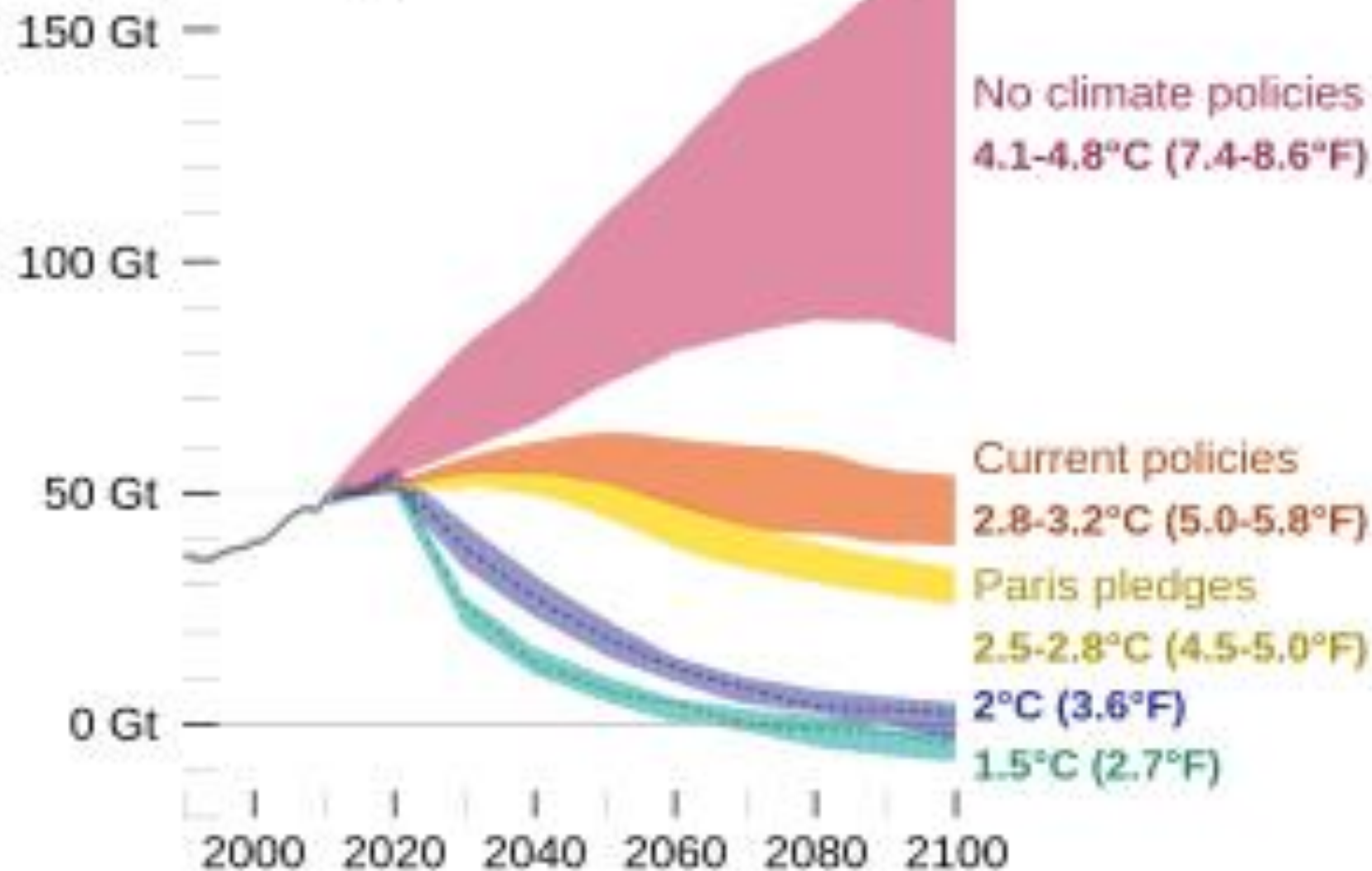


## Physical drivers of climate change

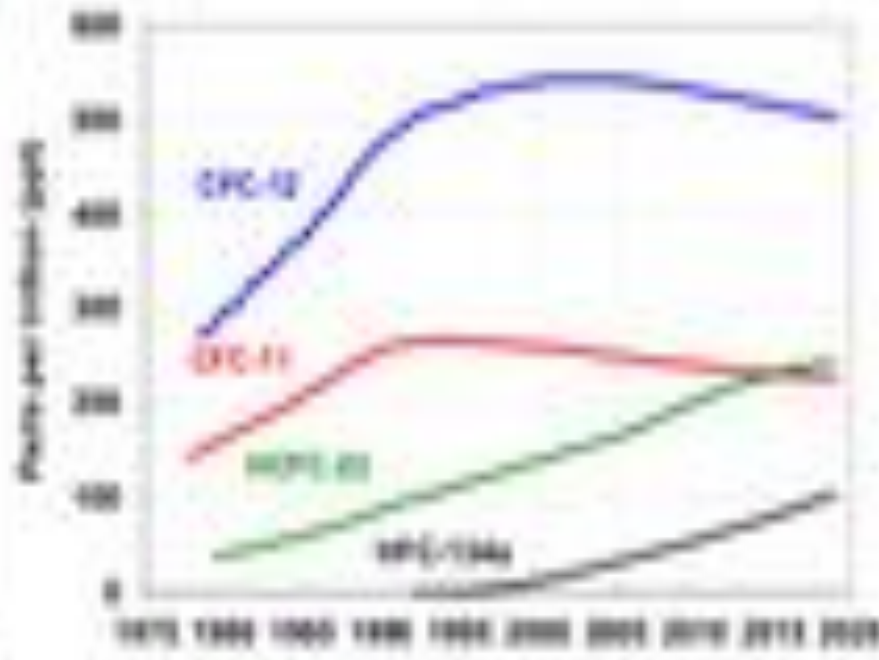
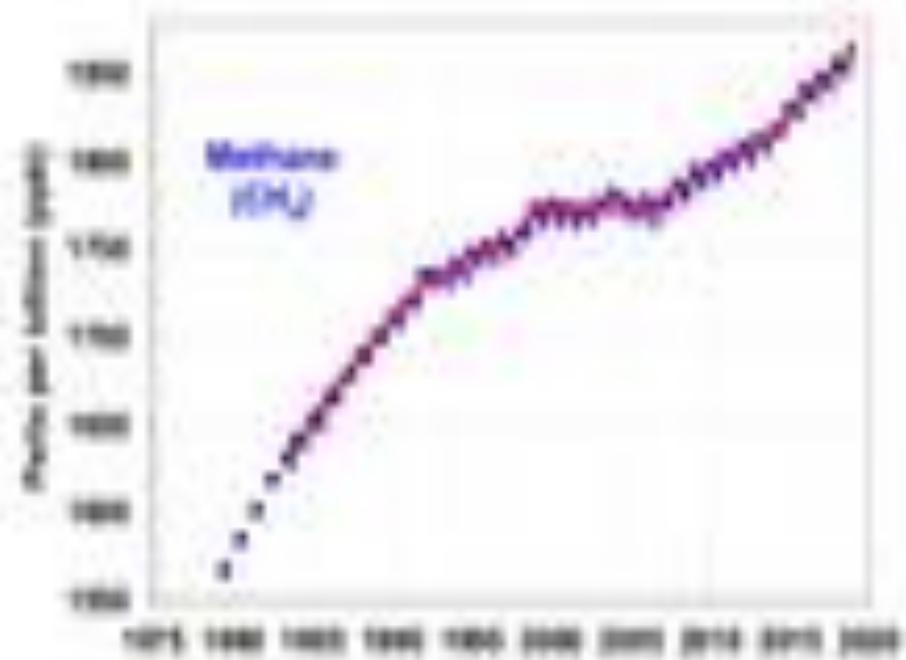
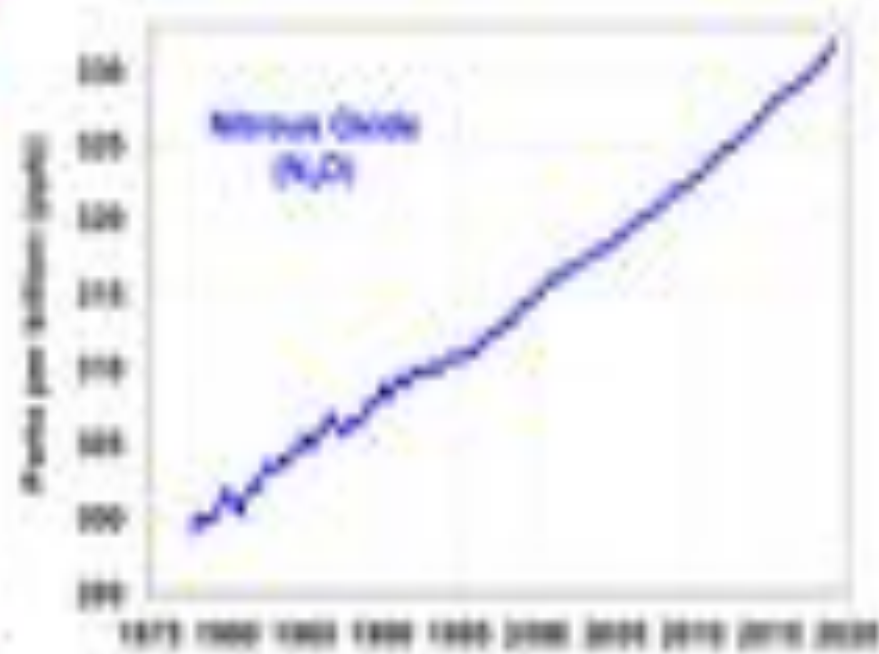
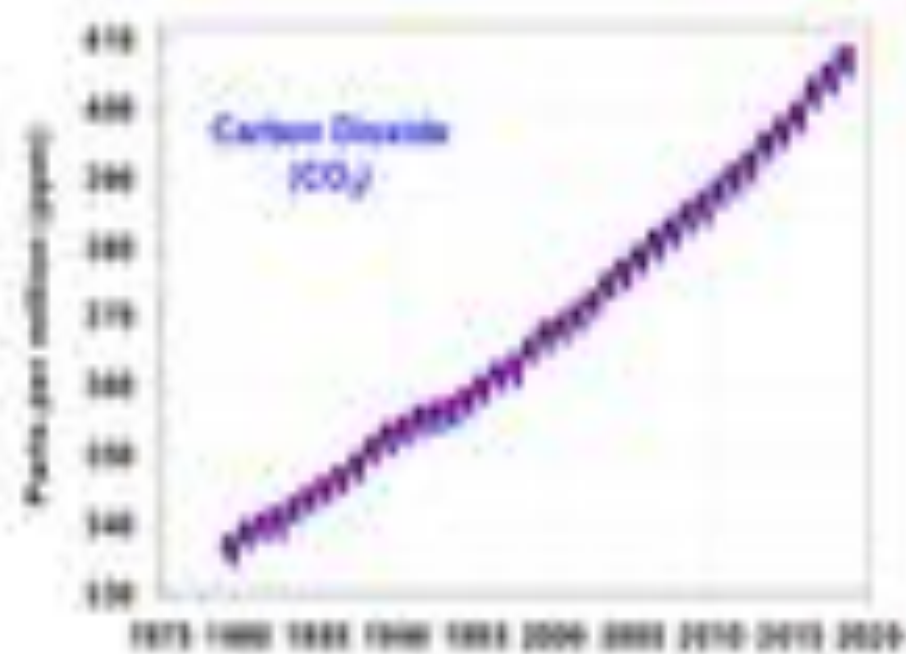


# Global greenhouse gas emission pathways

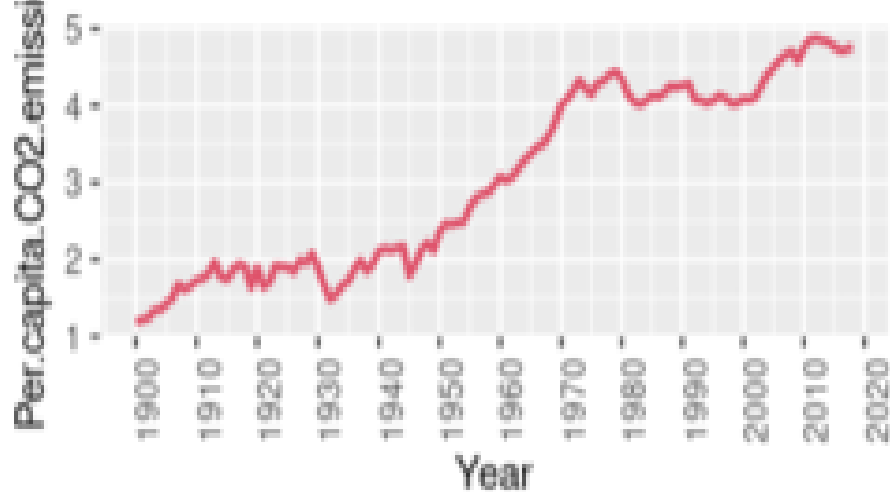
Annual global greenhouse gas emissions  
CO<sub>2</sub>-equivalent gigatonnes



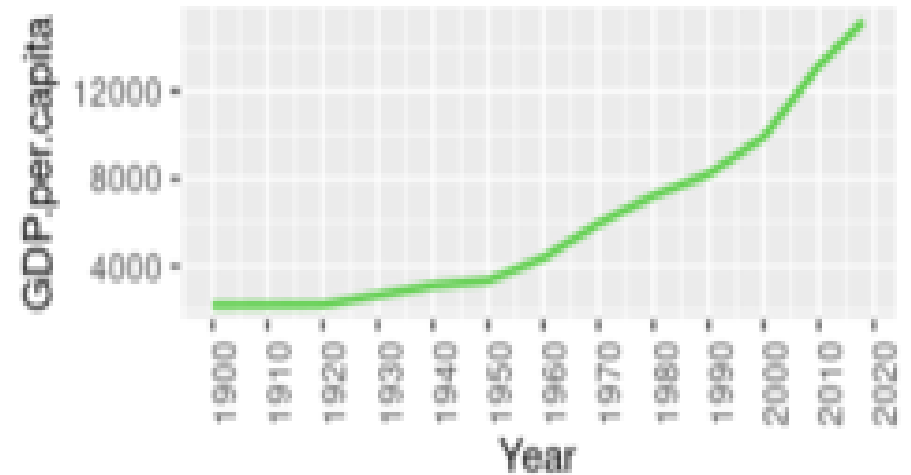




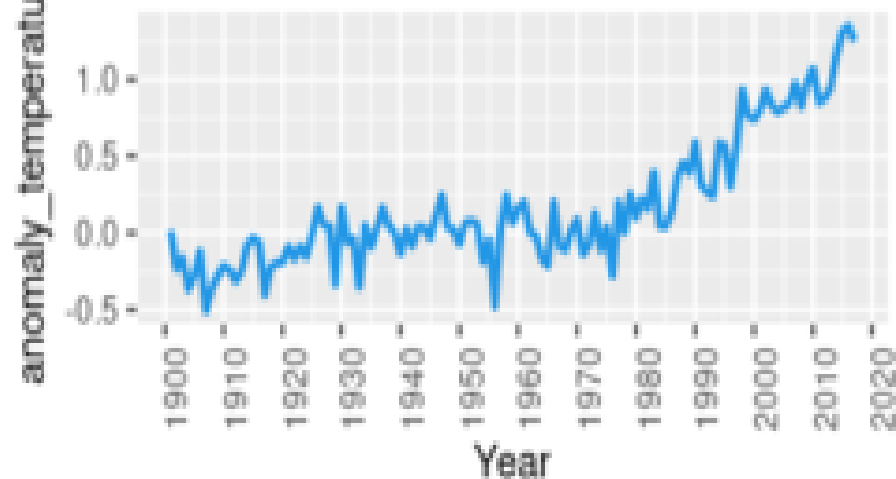
Per capita CO2 emissions in tons  
worldwide from 1900 to 2018

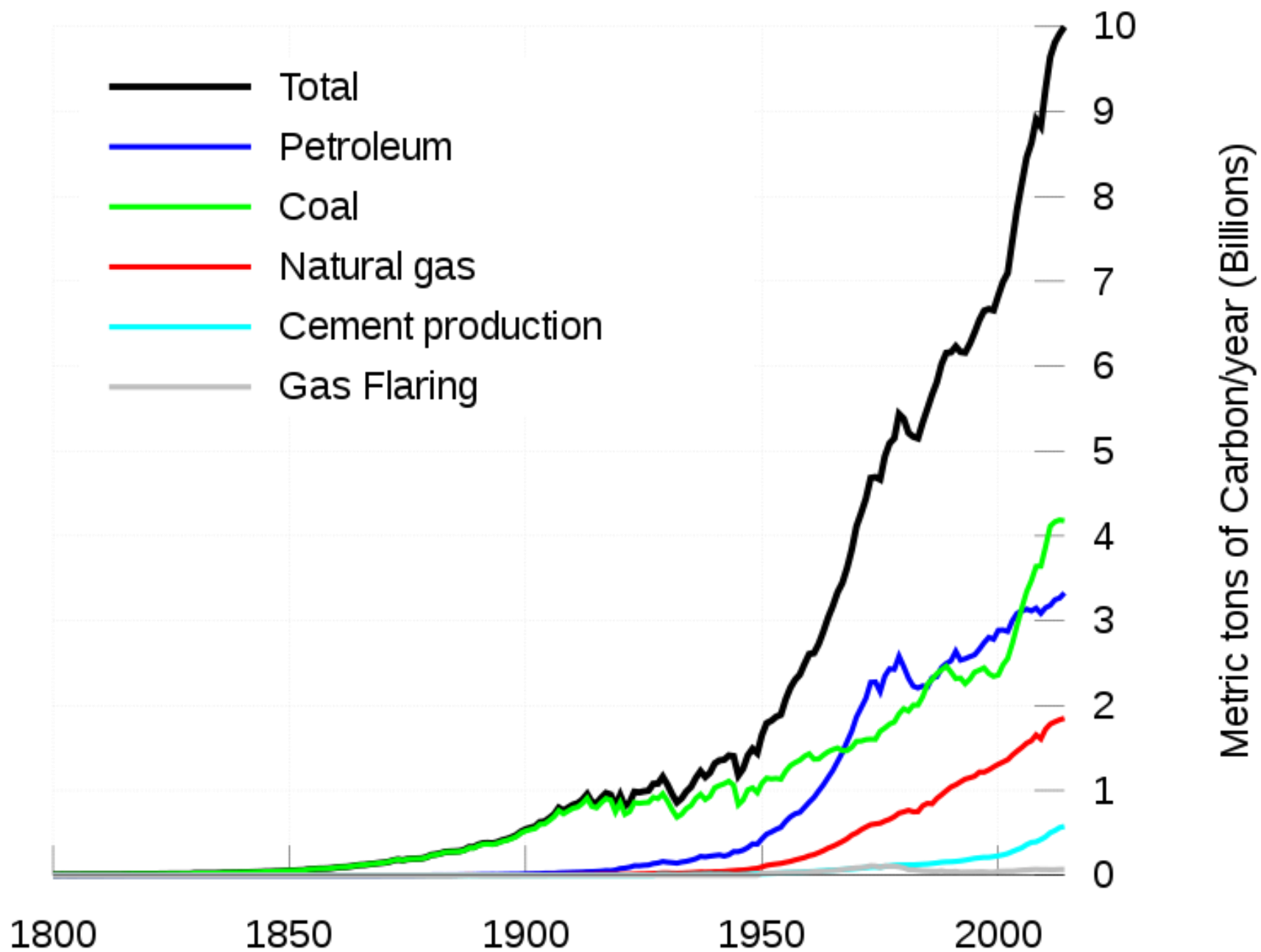


GDP per capita in dollars  
in the world from 1900 to 2018



World temperature rise in °C  
from 1900 to 2018





# HAZARDS TO EARTH

## Nuclear War

**Asteroids** (rocky left-overs); Comets (dirty-iceballs);  
Rogue Planets and Other disturbances of our Solar  
System, etc

Technology: **AI**; gray-goo of **Nanobots**

## Climate Change

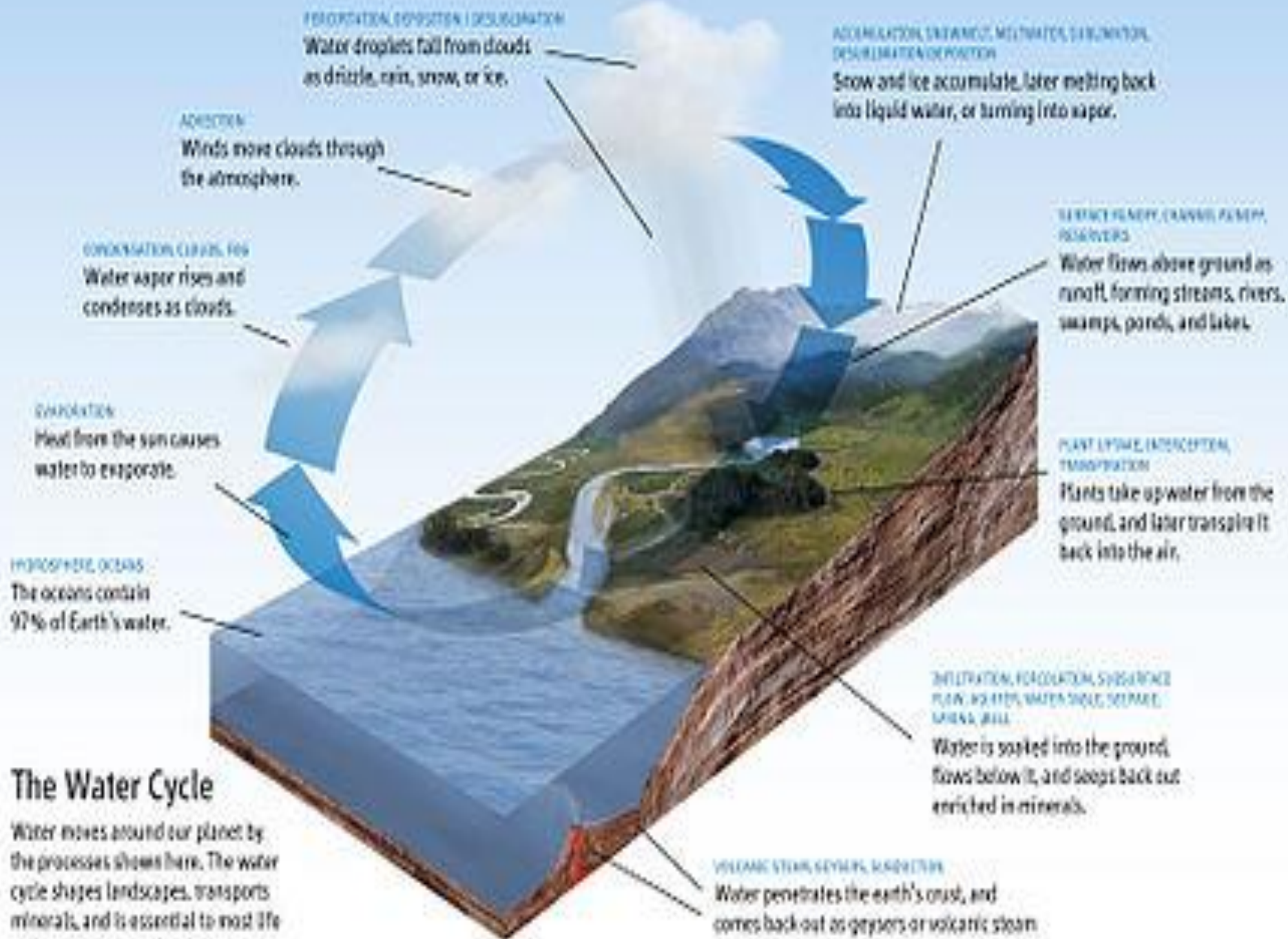
**Emerging Viruses** (e.g., COVID-like; Ebola-like)

Long Term: Our Sun going into a Red Giant Star, then a  
white dwarf, then black dwarf); Colliding Galaxies  
(Andromeda – 2.5 million light years away);

Higgs-Field Collapse

Last – “Heat Death” of our Universe

Etc (Things not even thought about yet!)

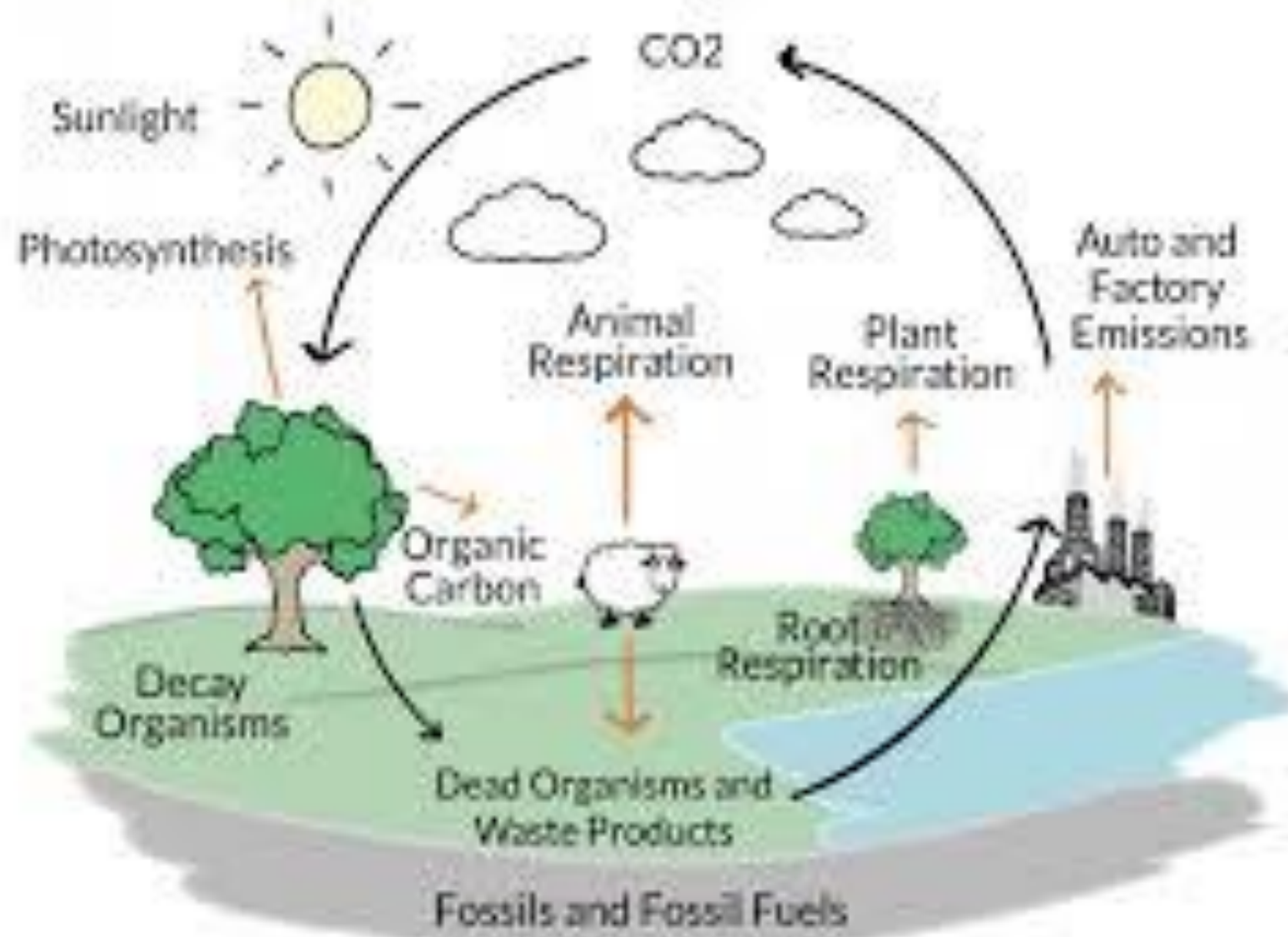


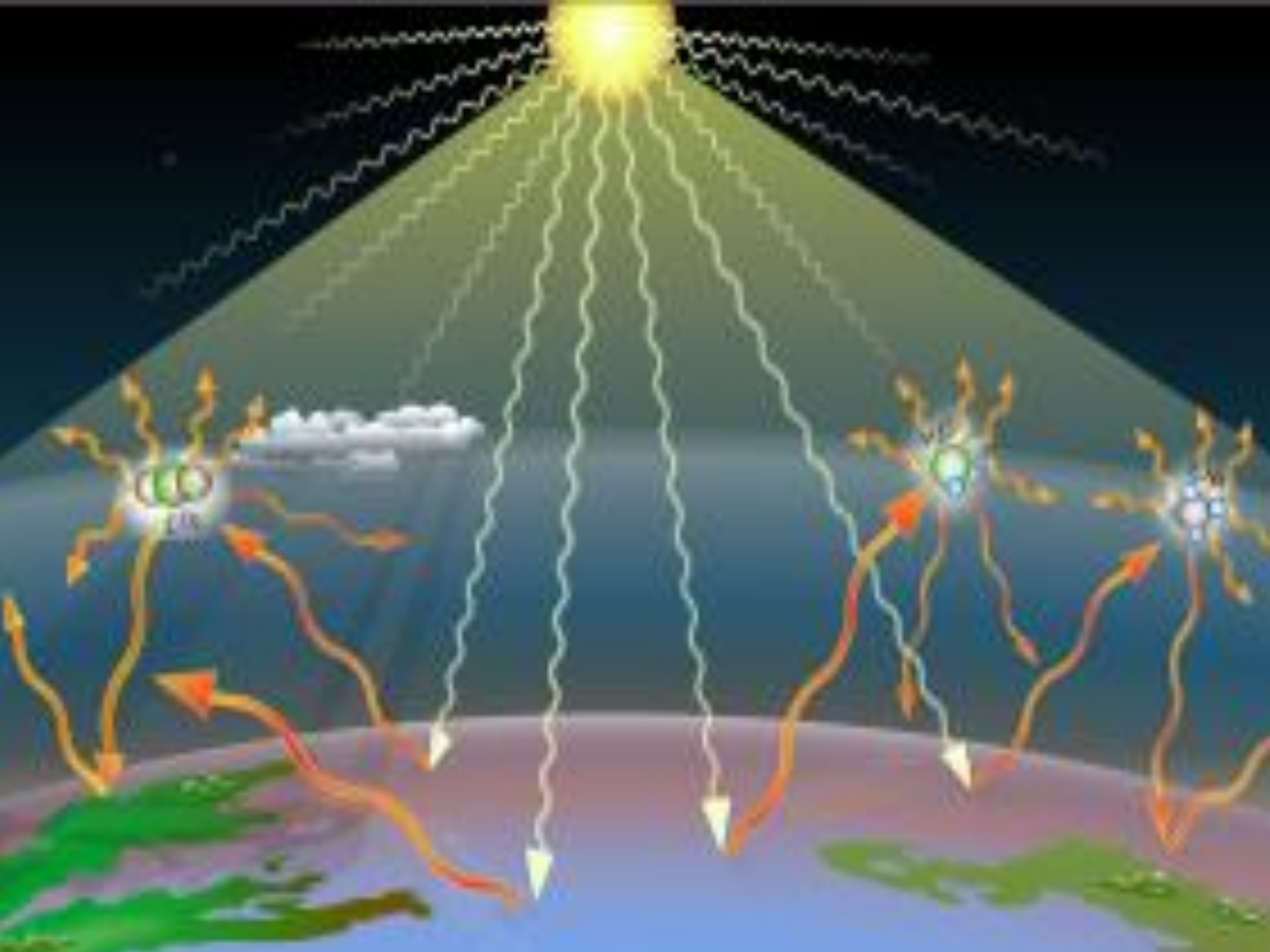
## The Water Cycle

Water moves around our planet by the processes shown here. The water cycle shapes landscapes, transports minerals, and is essential to most life and ecosystems on the planet.

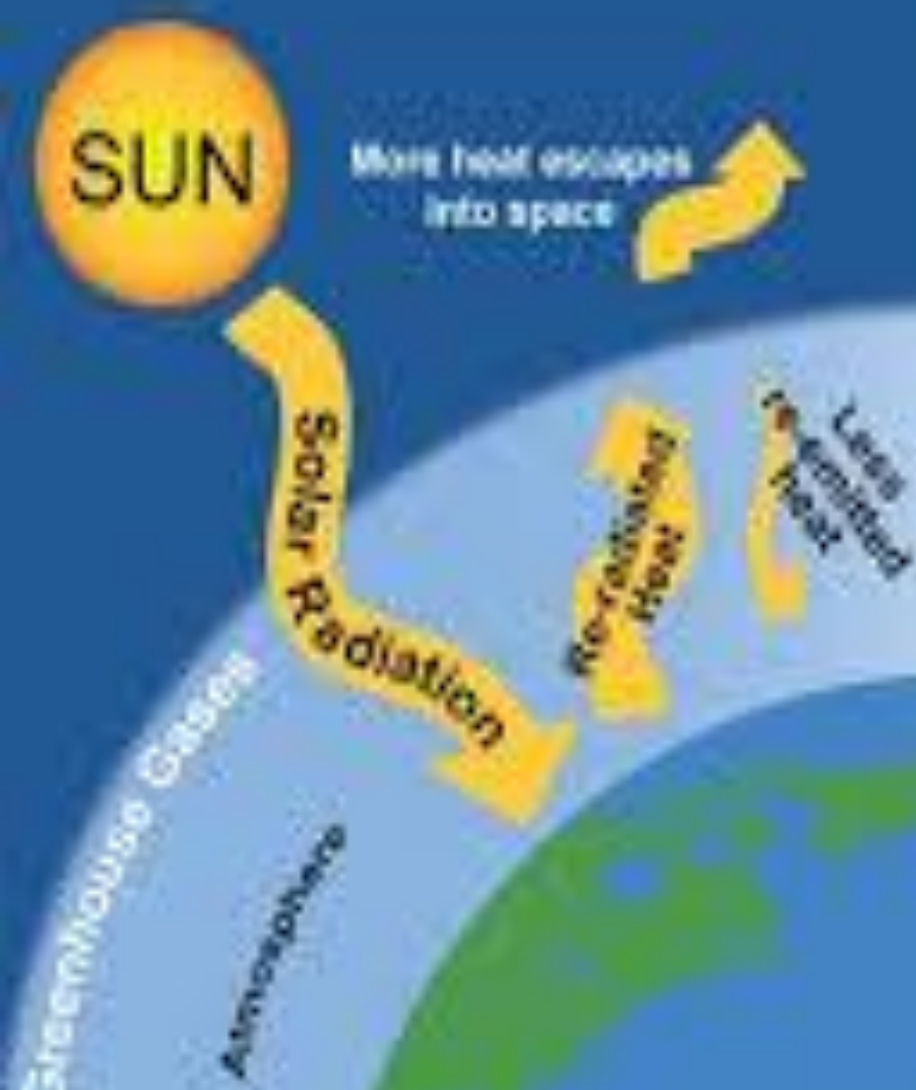


# Carbon Cycle

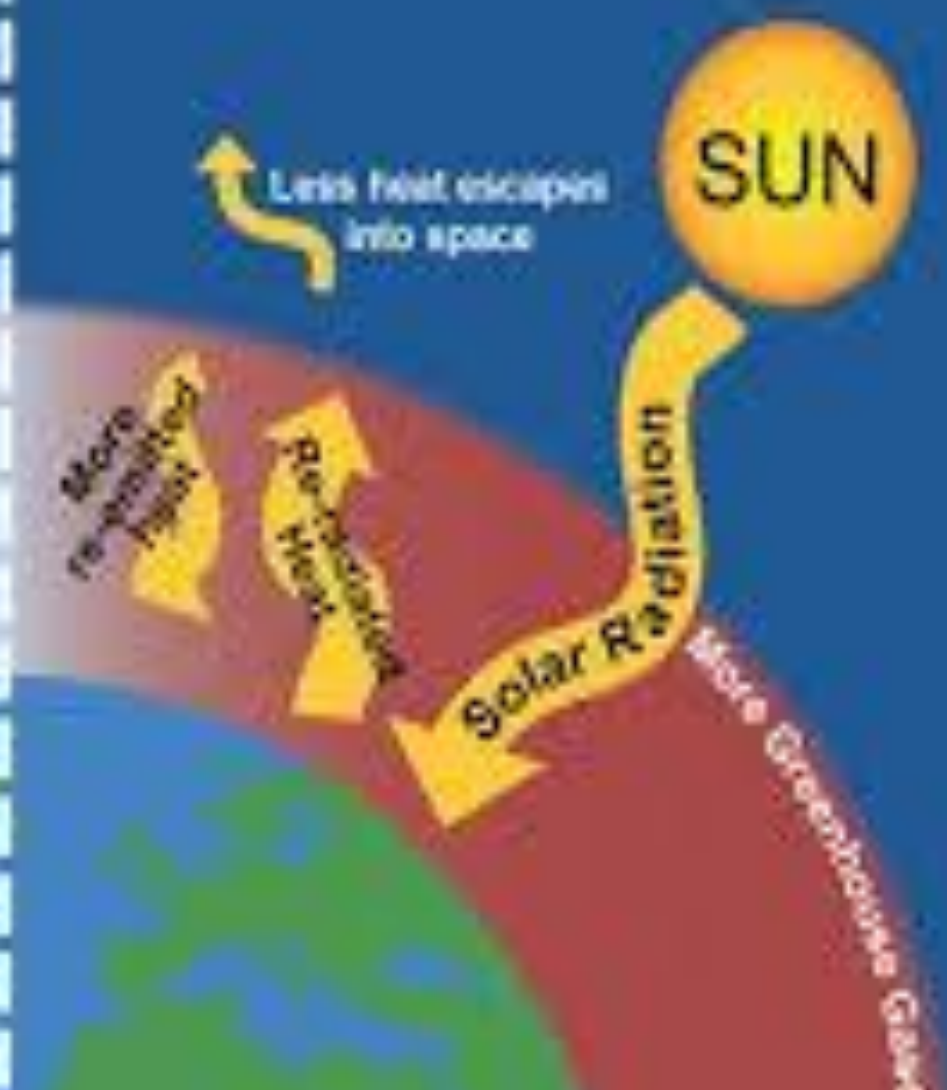




## Natural Greenhouse Effect

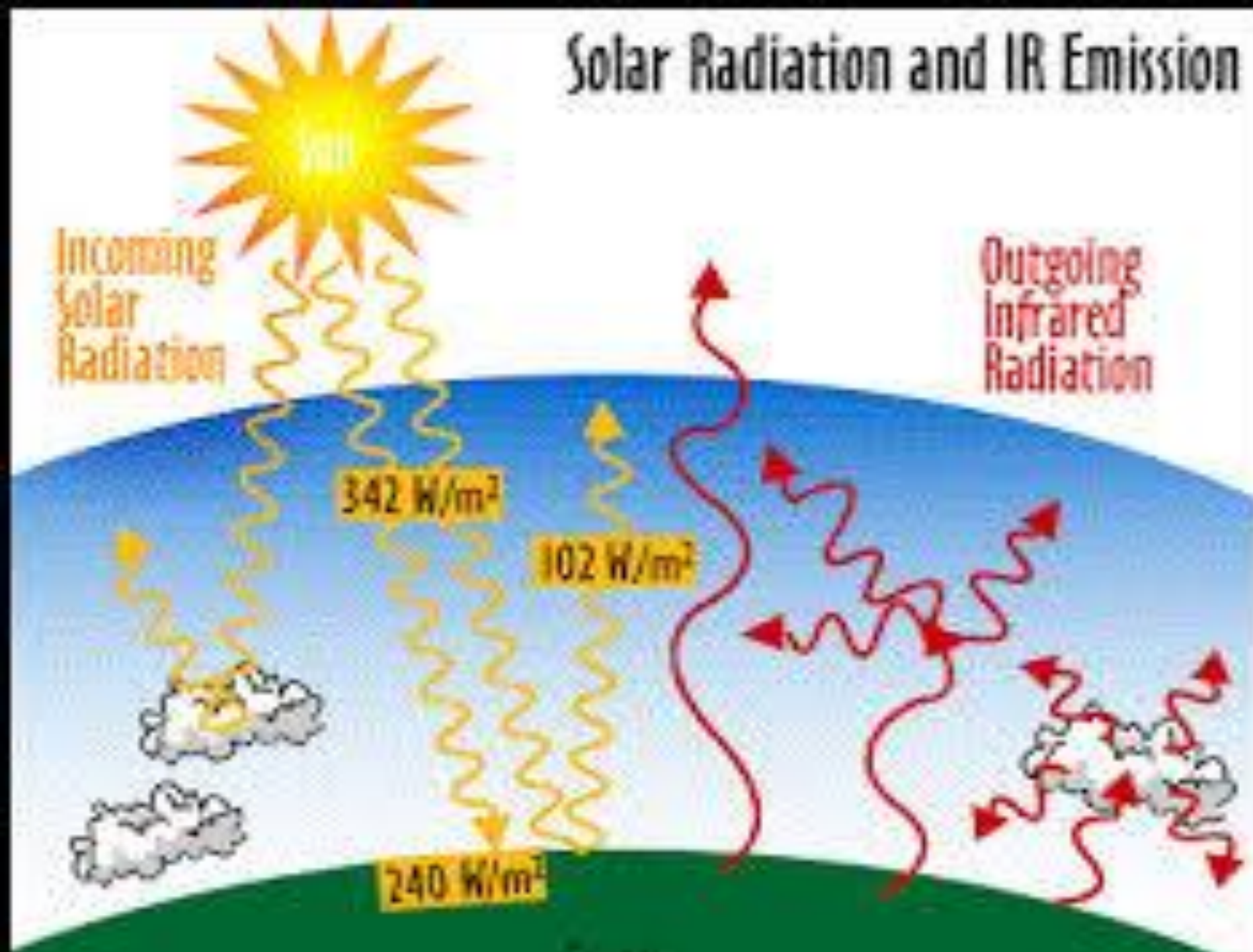


## Human Enhanced Greenhouse Effect





# Solar Radiation and IR Emission



## DRIVERS OF GLOBAL WARMING

### Human (Anthropogenic) forcing

- Burning of fossil fuels
- Rate technological development
- Land use land cover change

### Natural forcing

- Volcanic eruptions
- Plate tectonics
- Change of sun's orbit
- The movement of oceans
- Burning of meteorites

### Climate change/variability

- Increasing mean temperature
- Increasing minimum and maximum temperature
- Increasing the duration of hot days
- Increasing the variability of rainfall

Global warming

### Leads to extreme events

- Drought
- Tornados/hurricanes
- Glacial melting
- Sea level rising
- Species extinction

### Consequences

- famine
- starvation
- hunger
- political chaos
- Displacement



# Causes and Effects of Climate Change

## Causes

- Rapid industrialization
- Energy use
- Agricultural practices
- Deforestation
- Consumer practices
- Livestock
- Transport
- Resource extraction
- Pollution



## Effects

- Rising temperatures
- Rising sea levels
- Unpredictable weather patterns
- Increase in extreme weather events
- Land degradation
- Loss of wildlife and biodiversity

## What are the social impacts of climate change?

Displaced people, Poverty, Loss of livelihood, Hunger, Malnutrition, Increased risk of diseases, Global food and water shortages.

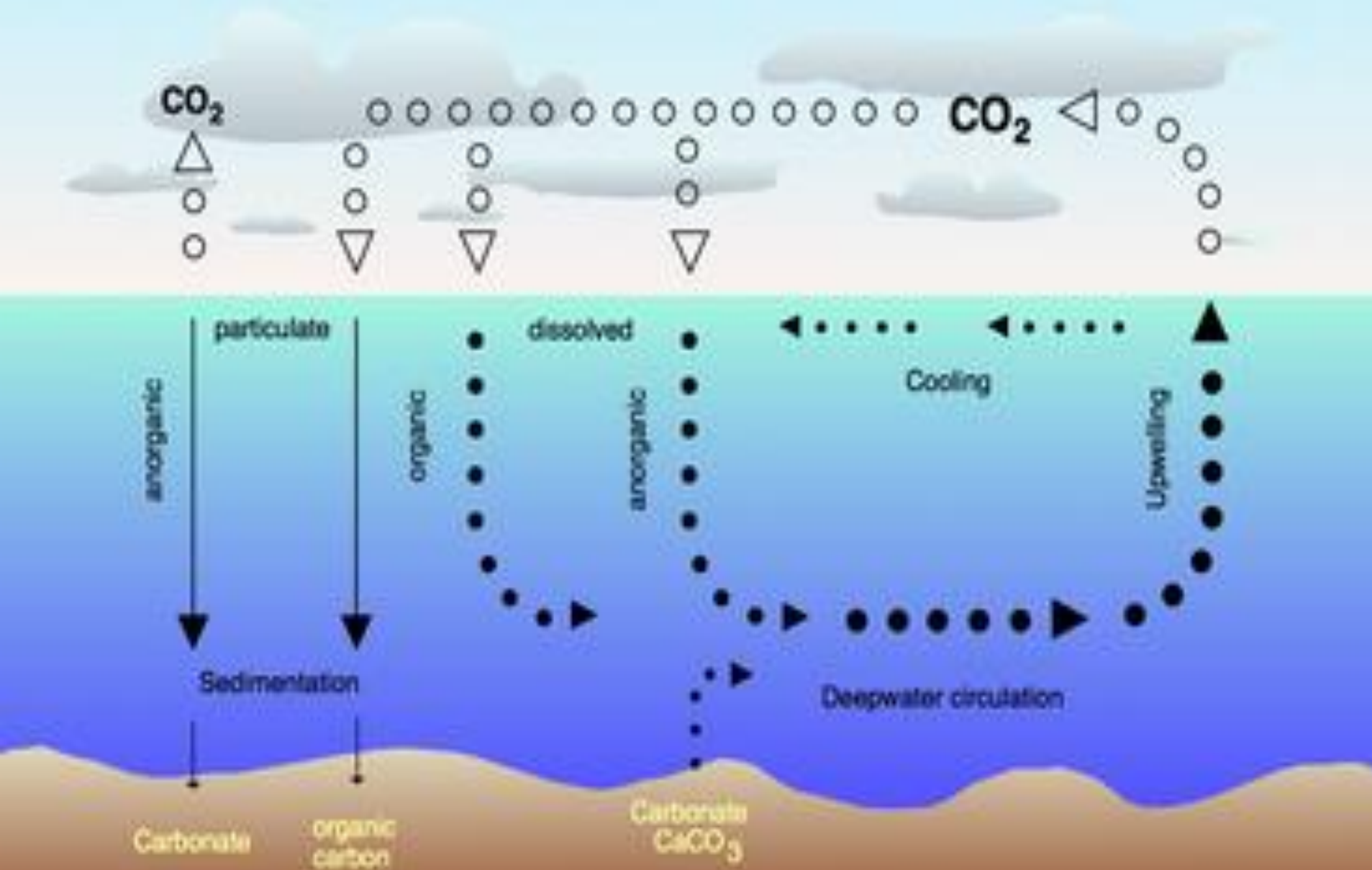
## “EARTH SETS A TEMPERATURE RECORD FOR THE THIRD STRAIGHT YEAR”

Since 1880: first time global warming data – blown past the previous record 3 years in a row (4 government agencies – NASA, NOAA, nonprofit Berkeley group, Japanese groups, etc – from surface – ships, buoys, weather stations; satellites )

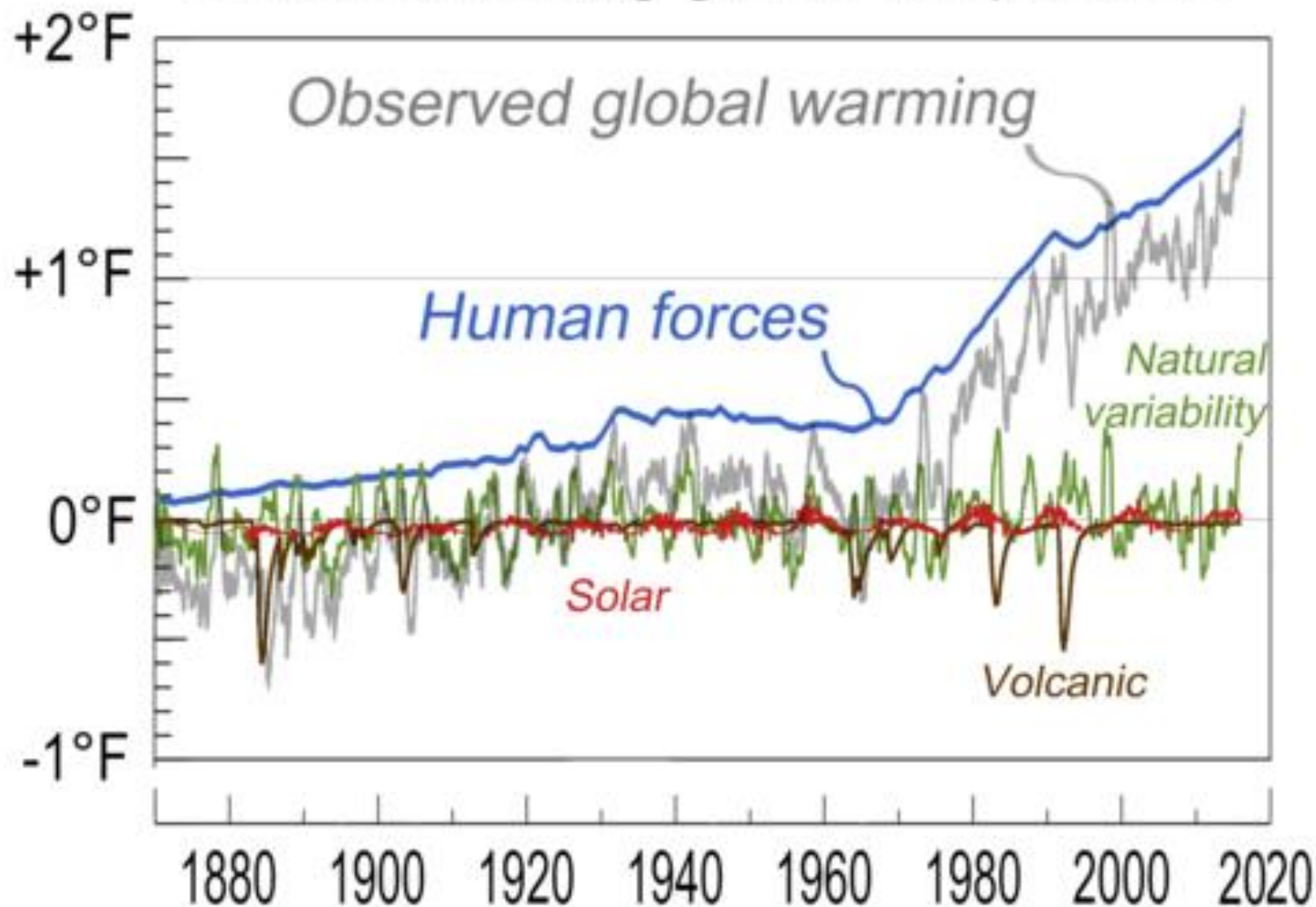
“In reality, the Earth is heating up, a point long beyond serious scientific dispute, but one becoming more evident as the records keep falling” (NYTimes; 1/19/2017):

Being driven by increasing levels of carbon dioxide and other greenhouse gases

# Biological and physical pumps of carbon dioxide



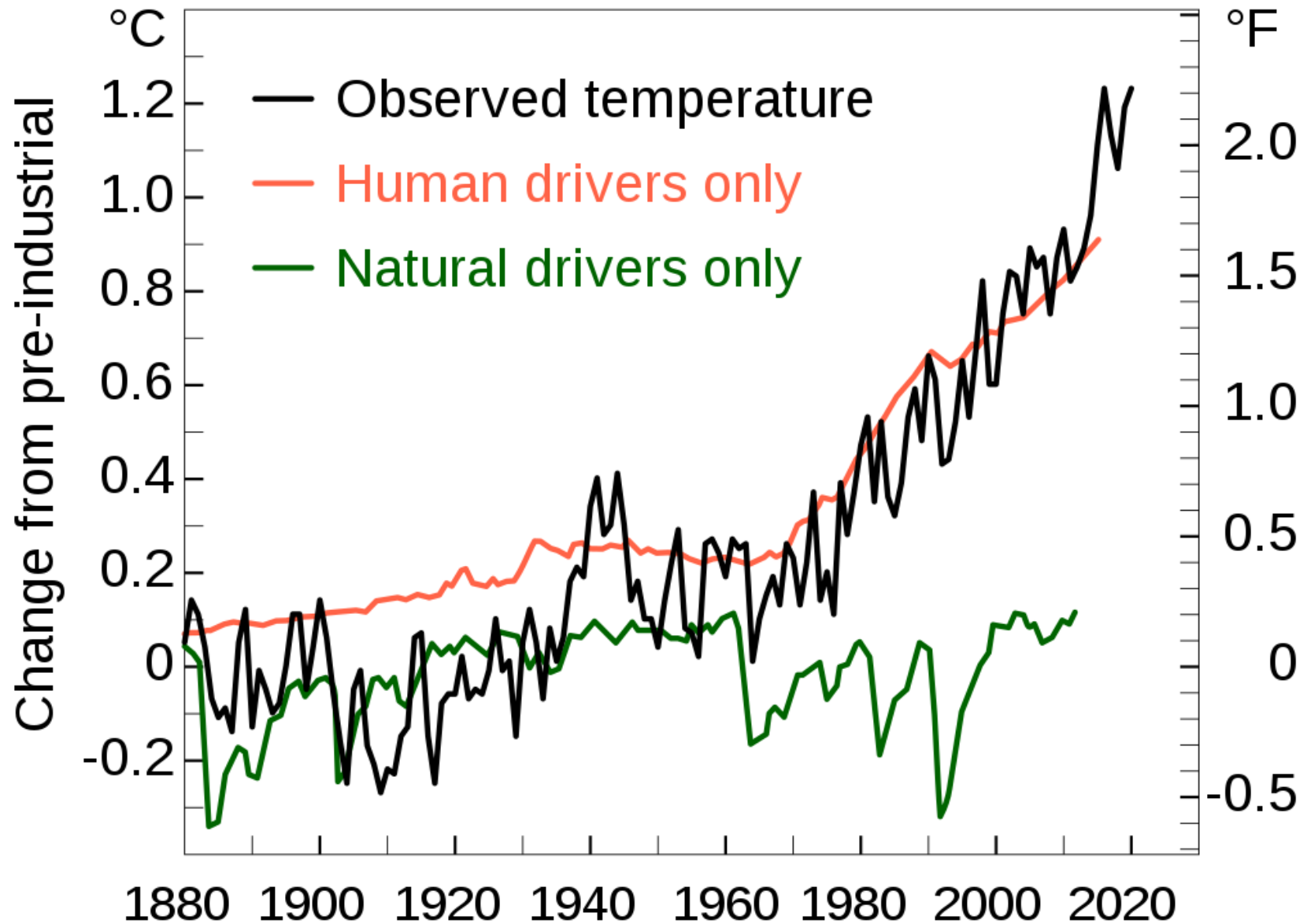
# Forces affecting global temperature



Adapted from U.S. Global Change Research Program (USGCRP)  
Climate Science Special Report: Fourth National Climate Assessment (NCA4), Volume I, Chapter 3, Fig. 3.3. (2017)  
Natural variability includes El Niño / Southern Oscillation

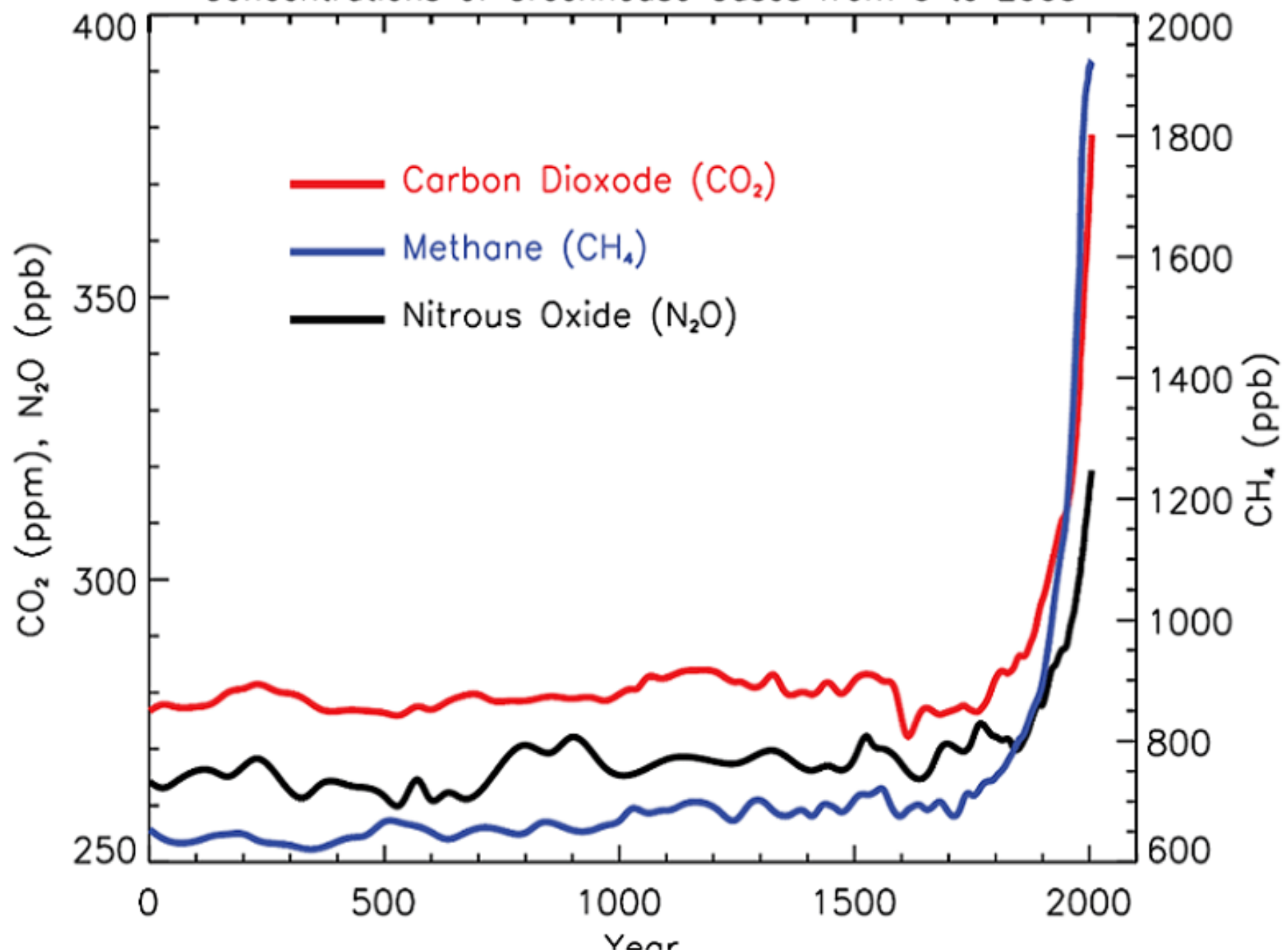


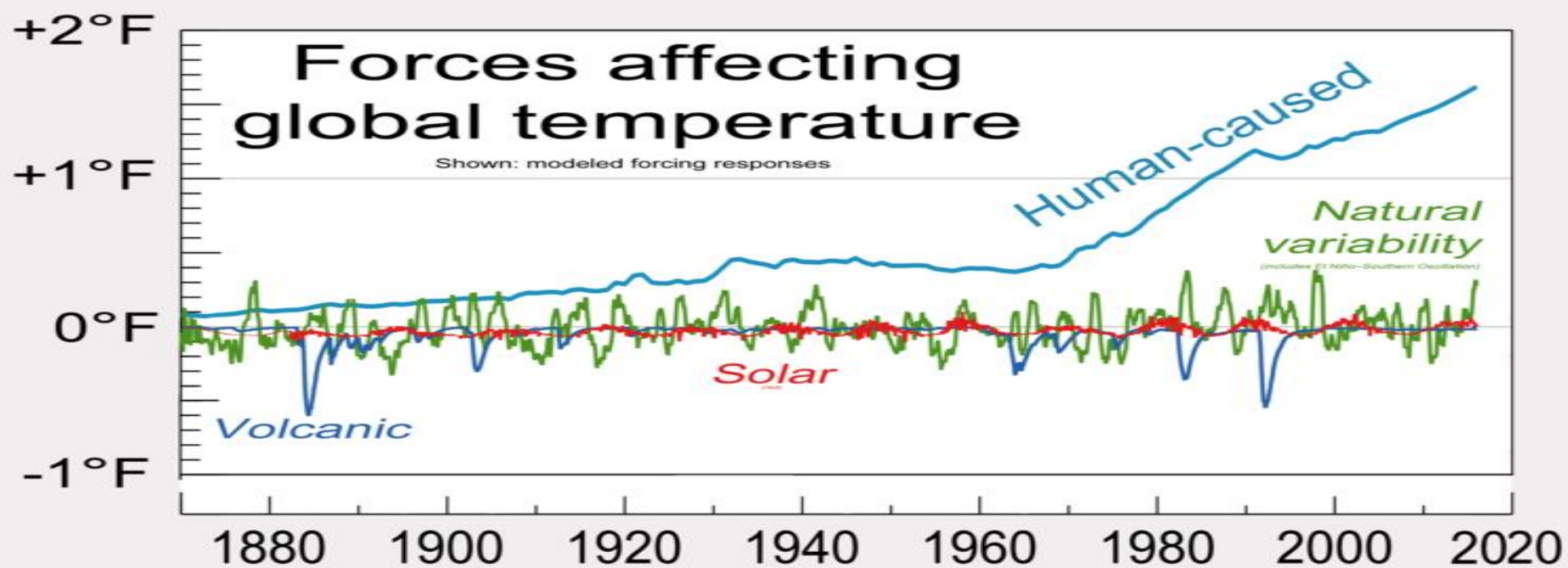
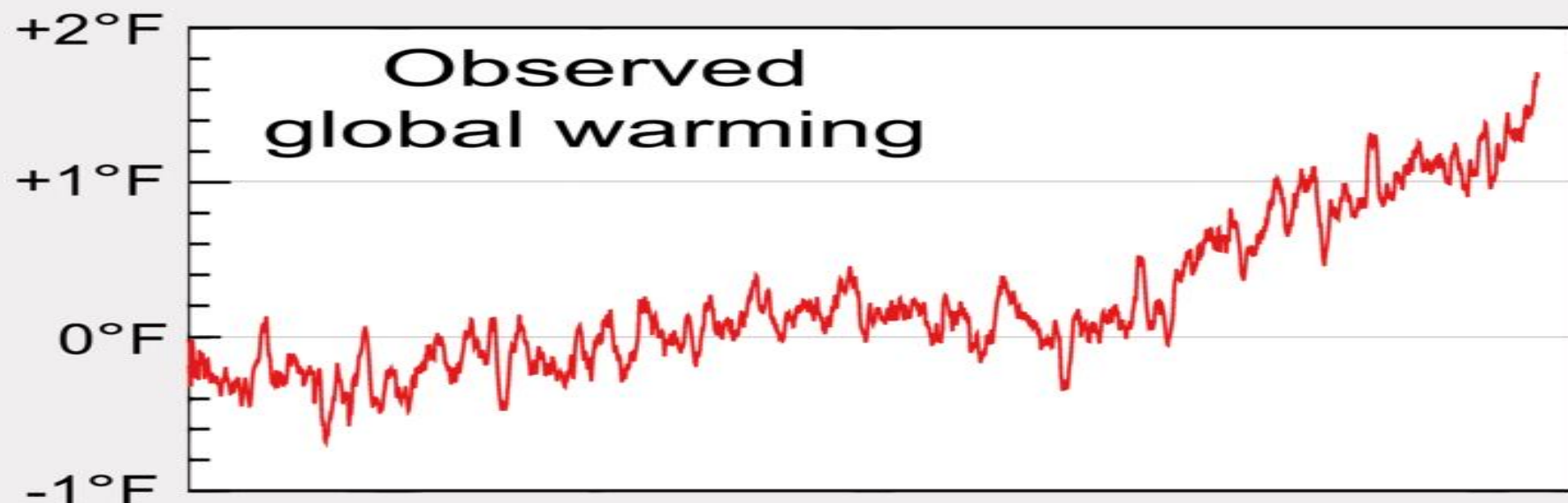
# Global surface temperature





Concentrations of Greenhouse Gases from 0 to 2005





# TEN SAID CONTROVERSIES AGAINST GLOBAL WARMING

- 1.) Really about: Anti-Biden//Democrats/Control
- 2.) CO2 not cause temperature increase or sea rise
- 3.) Severe storms not increasing in frequency or intensity
- 4.) Warming not hurt Coral reefs
- 5.) CO2 increase not across high time spans
- 6.) Undermining of Peer-review; telling scientists what to do
- 7.) Man-made increases or Natural
- 8.) Is warming really bad?
- 9.) Is CO2 really bad?
- 10.) Increase Flood and Drought
- 11.) Can find people (even scientist) against Global warming
- 12.) Just listen to my thoughts (know science)

# SCIENCE:

why it works

how it works

proof it works

# ISAAC ASIMOV

“Science is a system for  
testing your thoughts  
against the Universe and  
seeing whether they  
match”



# SCIENCE: A NOUN AND A VERB:

1.) **Body of Knowledge**  
(Justified true belief)

2.) A **Process/Procedure:**

How to approach the truth of  
Natural Phenomena; a way  
of thinking

# THE ROYAL SOCIETY

**SCIENCE IS A COMMUNAL  
EFFORT BY REBELIOUS  
PEOPLE**



**EXPERTS** (Veritas): better position to know;  
considered judgement; more true beliefs (but no  
one person can be the definitive final authority  
on a complex subject)

Interest (can't get enough); Talent; Skill

**Training** (Higher Degree (PhD, Masters:  
Post-doctoral training)

**Experience** in that field; Practice

**Apprenticeship** with Mentors; from what  
(phenomenon)—how/why (mechanism)

**Studies in depth** (produce peer-review  
papers, chapters, books, conferences)

**Academic Positions**; Licensing (Specialty  
Boards); Other Credentials;

# **EXPERTS** (Veritas) II: better position to know; considered judgement; more true beliefs

Teaching; Longevity in special area

**Academic Societies**; Journal Editorial-  
Boards; Professional Societies

Awards; Grants; NIH/NSF Study Groups

**Evaluated by Peers** (Professorships;  
University Tenure; Chiefs--Chairs)

Engaging with Other Experts in the  
Field; not going outside of your field

**Advancing Field Forward** (Generates  
New Knowledge)

# **SCIENTIST: ACHIEVEMENTS AND NATIONAL/INTERNATIONAL REPUTATION: Standing Among Peers**

- 1.) University Training and often Faculty Appointments (retention, promotion/tenure based upon productivity): Rising through the Ranks
- 2.) Original Scientific Studies that result in Scientific Publications in High Quality Peer-reviewed journals; later Important/quality Books, Reviews and Chapters
- 3.) Peer-reviewed Grants and Contracts
- 4.) Editorial Board, Major Scientific Journals; Reviewers
- 5.) NIH/NSF/etc. Study Sections or Groups/Committees
- 6.) Invited Addresses, Lectures/Professorships/Courses, Seminars
- 7.) Endowed Chairs and Chairmanships
- 8.) Other Academic Prizes/Awards (e.g, Nobel, Lasker, etc)
- 9.) Activities in Notable Scientific Societies/Academies
- 10) Quality of Training Programs (Graduate; Postdoctoral)





# **WHAT REFUTES SCIENCE?**

## **better science**

# **WHAT DOESN'T REFUTE SCIENCE?**

Your feelings

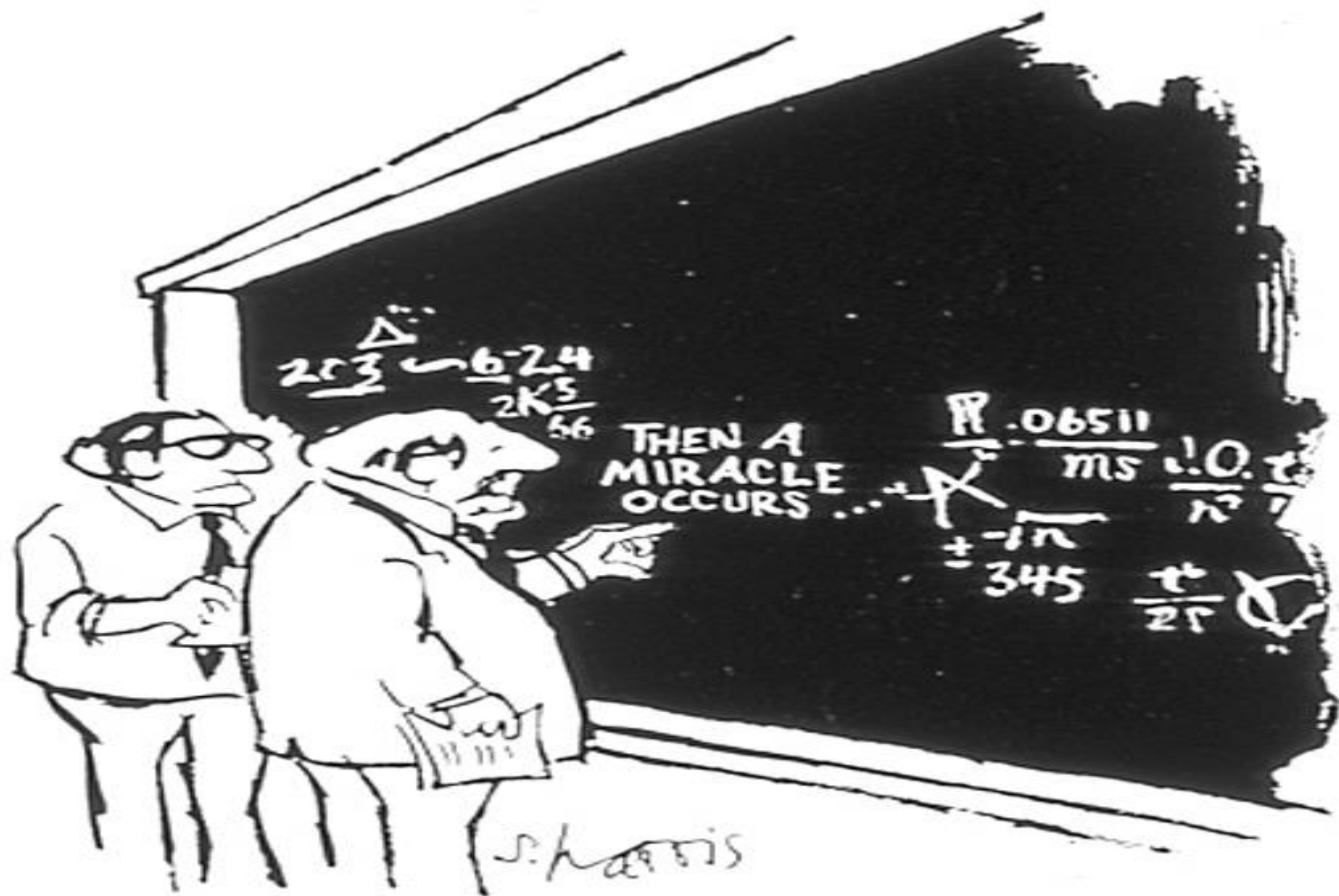
Your religion

Your favorite politician

Your half-baked opinion after

watching 2 YouTube videos or

finding it on social media



"I THINK YOU SHOULD BE  
MORE EXPLICIT HERE IN STEP TWO."

# **“SCIENTIFIC METHODS”**

**Different Kinds/Types of Science—No single kind of science: Different sciences employ different Methods; most seek causation and/or mechanisms; Testable and Falsifiable**

Some historical/observational only, others theoretical or experimental; some with Laws; many still evolving; newer technologies may help

# “**SCIENTIFIC METHODS**”

- 1.) Define a **question**
- 2.) Gather information and resources (**observe**)
- 3.) **Form an explanatory** hypothesis (mechanism)
- 4.) **Test the hypothesis** by performing an experiment and collecting data in a reproducible manner



# **“SCIENTIFIC METHODS”**

**5.) Analyze the data**

**6.) Interpret the data** and draw conclusions that serve as a starting point for new hypothesis

**7.) Publish results in peer-review journals/**Present to peers

**8.) Retest** (critiques and replication frequently done by other scientists)

# AVENUES TO REALITY/TRUTH

- 1.) **Correspondence** Theory: accurately describes, relates, conforms to external reality; successive approach to the truth
- 2.) **Coherence** Theory: fits within whole system: complete, comprehensive, support each other. Connections--webs of relationships
- 3.) **Consensus** Theory: Agreed upon by a specified group of experts in that area
- 4.) **Pragmatic theory**: It works!  
Verified/confirmed by putting ones concepts into practice; “just calculate”

In science, “fact” can only mean  
“confirmed to such a degree that  
it would be perverse to withhold  
provisional assent.

I suppose the apples might start  
to rise tomorrow, but the  
possibility does not merit equal  
time in physics classrooms”

S.J.Gould

# SCIENCE ILLITERACY

2018: Survey of 15 year olds in US

Ranked 18<sup>th</sup> in Ability to explain scientific concepts

Behind China, Singapore, UK and Poland and Slovenia

2019: Pew Survey: US: Average of 6.7 of 11

questions (40% couldn't answer need for a control group for a new drug

39% could answer need a base for Tx of peptic acid problems

Problem: Social Media (wrong ones)

# **ROBERT FROST (1914)**

**“Why abandon a belief/Merely  
because it ceases to be true?”**



# **FACTS ARE STUBBORN THINGS: THEY DO EXIST!**

**“FACTS DO NOT CEASE TO EXIST BECAUSE THEY ARE  
IGNORED”**

Aldous Huxley

The intensity of a conviction – no bearing on whether it is  
true or not

Facts: you close your eyes, and they are still there..

The same for everybody...universal

Evidence: Data: Testing Theories: Experimentation,  
Observation, Measurements

# WHY IS SCIENCE IMPORTANT?

- 1.) Science is important to **humanity's future wellbeing**: makes life easier, happiness, prevents catastrophes (electrical appliances; optics; GPS, solar/nuclear power)
- 2.) Engine of **Prosperity, jobs, economy** (STEM), productivity, innovations
- 3.) **Medicine** (Ab, HGI, Public health; hygiene, drugs; medical imaging; vaccines)
- 4.) **Inspiring/Awe/Role** modeling/Exploring

# VALIDITY OF SCIENCE: CHECKS/BALANCES

- **Colleagues/Department/Co-Authors/Peers**
- Individual's reputation; **Peer reputation**
- **Universities/Institutions/Labs/IRBs**
- Journal clubs/**Journals-peer review**/Organizations
- Consequences; prediction; finding of things not looked for; questions now answered
- Data sharing/Sharing of methodologies-materials

# REALITY

**Things as they appear/measure/react (Empiricism)**

**Things as they are; things in themselves (Metaphysics)**

Form/structure/facets vs. true nature (e.g. electron)

E.Kant: there can be no appearances without anything that appears....

We are unable to construct a scientific apparatus in anything other than classical dimensions ---so we cannot see what electrons really are (electron-in-itself) –as intelligent beings, experiencing a classical world, this is the only language /measures we have...

# TRUTH

Old English: meaning 'cognate'; also 'faithful', having good faith, steadfast as an oak, word of honour, religious faith, belief

Qualities of faithfulness, fidelity, loyalty, sincerity, veracity (veritas)

- 1.) In accord/agreement with fact or reality;  
conforms to the external reality; accurately copying 'objective reality'
- 2.) Correspondence of language or thought to an independent reality/actual state of affairs



# REASON

Rational, logical ground of explanation

Power of comprehending, inferring or thinking in orderly, sensible ways

Intuition, Perception and Understanding

Tools of Logic: Intense Study: Deduction, Induction, Inference, Generation of Hypotheses, Recognition of Fallacies, etc. etc.

RICHARD FEYNMAN

“SCIENCE IS WHAT WE DO TO  
KEEP FROM LYING TO  
OURSELVES”

“To care about evidence is thus to act in accordance with a well-vetted set of practices that have been sanctioned by the scientific community because they have historically led to well-justified beliefs”

*The Scientific Attitude*  
by Lee McIntyre

# SCIENCE IS SUCCESSFUL – THE DRIVE

- 1.) The essence of the picture is the  
frame (focusing down on nature)  
(restriction of subject)
- 2.) The art of the doable/possible
- 3.) Counter-intuitive/know of own biases
- 4.) Anti-animism (mechanisms)
- 5.) Diverse community of interacting  
critical experts
- 6.) Evidence: Discerning, collecting,  
recording, generating, analyzing,
- 7.) Curiosity driven
- 8.) Technology driven

# SCIENCE: WHY SUCCESSFUL

Endorsed by **overwhelming numbers of scientists who have relevant expertise to evaluate the evidence, analysis, inferences and conclusions**, and no good reasons to have emerged to seriously doubt the mainstream scientific views, and because the most common objections have been convincingly answered



# **SIMPLIFYING COMPLEX IDEAS FOR THE GENERAL READER: THINGS ARE NOT SO SIMPLE**

“Technical complexities that are lost in the distillation process that produces such simple pictures” (as in the news for the general reader).

Leonard Mlodinow: *The Upright Thinkers*, 2016.

There is an immense amount of scientific information about just about all physical entities: ?ever been in a science library??

# **FIVE GLOBAL TRENDS INCREASING THE RISK OF A PANDEMIC (GOLDSMITH) (or human activity is largely responsible for the spread of disease)**

- 1.) Climate Change (aka Global warming)
- 2.) Disruption of animal habitats
- 3.) Increased air travel
- 4.) Crowding and megacities
- 5.) Overuse and misuse of antibiotics

(“Nearly everything we understand about global warming was understood in 1979”)

# SCIENTIFIC THEORY

## (Bas van Fraassen)

“Any scientific theory is born into a life of fierce competition, a jungle red in tooth and claw. Only the successful theories survive.”

# WHY PEOPLE REJECT GOOD SCIENCE

- 1.) Asked to believe something that conflicts with a deeply held view (political, religious, personal); undermines our identity-not about what you know, but it's about who you are, not thinking about the evidence/arguments, but what side you're on
- 2.) Polarization: Rise of social media, more partisan press, dearth of universally-accepted experts, greater access to information (the way you search for information), Motivated reasoning, perpetuating own beliefs, confirmation bias, echo chambers, discount anything that runs against own prior views
- 3.) Confidence in institutions in decline; cynical view of politics, media, etc

# VALIDITY OF SCIENCE: CHECKS/BALANCES

Colleagues/Department/Co-Authors

Individual's reputation; Peer reputation

Schools/Institutions/IRBs

Journal clubs/Journals-peer review

Other scientists (uninvolved with the study)

Consequences; prediction; finding of things not  
looked for

Data sharing/Sharing of methodologies-materials



# Pepper . . . and Salt

THE WALL STREET JOURNAL



"Let's have some fun—let's make them responsible for their own actions."

“Theories are like withered leaves,  
which drop off after having enabled  
the organism of science  
to breath for a time.”

E. Mach

# HOW DO SCIENTIFIC THINGS/THEORIES BECOME ACCEPTED

- 1.) Go through the training to become a full-fledged member of the community of scientists
- 2.) Study, hypothesize, complete projects
- 3.) Write papers using the language/notations common to that science
- 4.) Present papers at scientific conferences
- 5.) Submit papers to peer-reviewed scientific journals (and get them published)
- 6.) Get Promoted/Tenured at Major Institutions; Editorial Boards of major journals; NIH/NSF Study Sections; etc.
- But remember that Science is “self-correcting”



# EXTINCTIONS



# ANTHROPOCENE EPOCH

- Climate Change (Global warming)
- Loss of a million species
- Overfishing
- Clearing large tracts of land
- Dumping of single-use plastics (in Pacific ocean – twice the size of Texas; Arctic and Mariana Trench)

# TROUBLES

1.) Arctic: temps running 20-30 degree F above normal across large stretches: e.g., costal erosion

2.) Africa: drought and starvation

3.) e.g., May 19, 2016: Phalodi, India: hottest day in record: 123.8 degrees Fahrenheit

# EXTINCTION

Estimated that ecologically rich areas (those potentially suffering the heaviest losses) might see a doubling of the present carbon dioxide levels/rising temperatures...which could eliminate 56,000 plant and 3,700 animal species



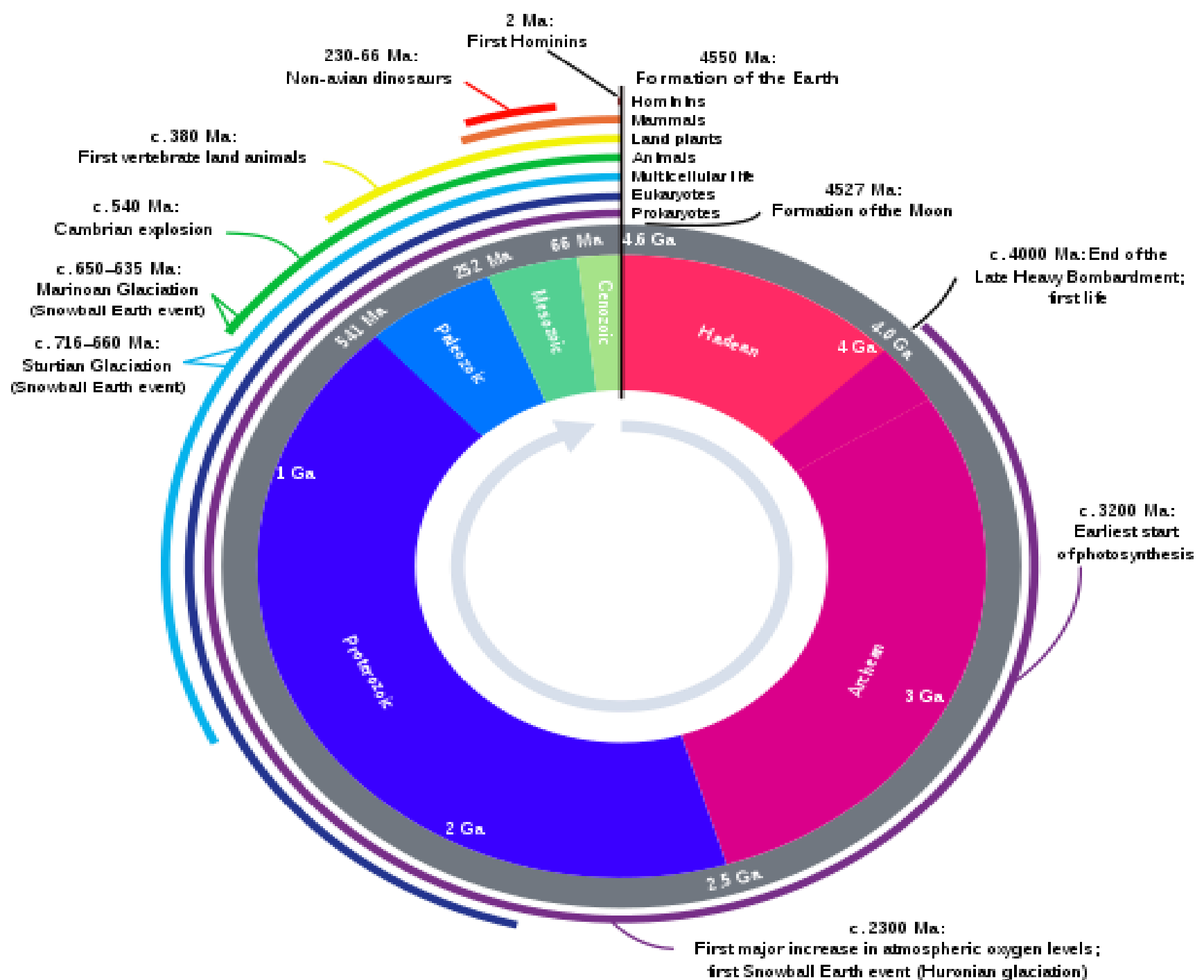






# AGENTS OF DESTRUCTION (HIPPO)

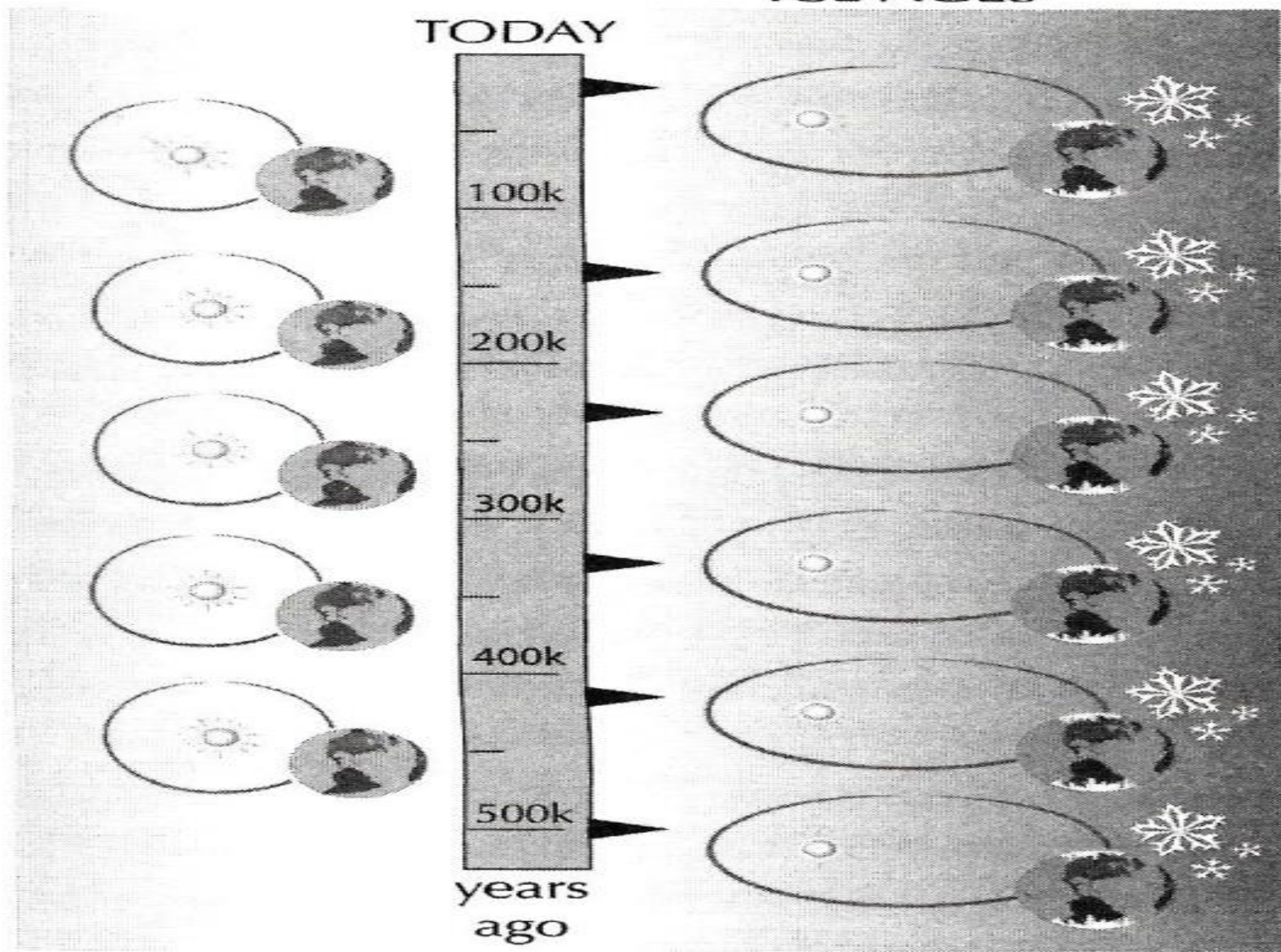
- 1.) Habitat Loss (deforestation,  
conversion of grass land, climate  
change)
- 2.) Invasive Species (transport)
- 3.) Pollution
- 4.) Population Growth
- 5.) Over harvesting



# ICE AGES

- 1.) Multiple ice ages (at least 5 major ones);
- 2.) ?Causes: multifactorial, complex causes
- 3.) Between Ice ages – interglacial periods
- 4.) First ice age – 2.4-2.1 Billion years ago
- 5.) Most severe (Snowball Earth): 720-630 mya  
(Million years ago) – glacial ice to equator
- 6.) Others: 460-420 mya; 360-260; 2.58 mya
- 7.) Last Interglacial – 100,000 years ago , until  
now – we live in a warm interglacial epoch –  
our last ice age – 22,000 – 12,000 years ago
- 8.) Land bridges – e.g., Beringia (Asia – Alaska)

## ICE AGES



The 100,000-year cycle relates to changes in the shape of Earth's orbit: ice ages tend to occur more in eccentric periods.

# **MOST RECENT ICE AGE**

Coldest period – just over 20,000  
years ago

Starting 12,000 years ago – global  
temperatures settled into  
warmer/more stable

Beginning of Farming, Larger groups  
of people



# CLIMATE CHANGE RESPONSES

- 1.) Mitigation: Reducing CO<sub>2</sub>; carbon tax; regulations;
- 2.) Clean energy
- 3.) Energy efficiency
- 4.) Sustainable agriculture/Green industrial policy
- 5.) Carbon sequestration
- 6.) Adaptation
- 7.) International Climate agreements

# ORIGINS

- 1.) Origin of the Universe
- 2.) Origin of Stars, Galaxies, and Planets
- 3.) Origin of Earth
- 4.) Origin of Life on Earth
- 5.) **Origin of Development of Life on Earth/Evolution**
- 6.) Origin of Humans
- 7.) Origin of the Brains
- 8.) The Future of Humans (Transhumanism)

# COAL AND OIL

Not from dead dinosaurs

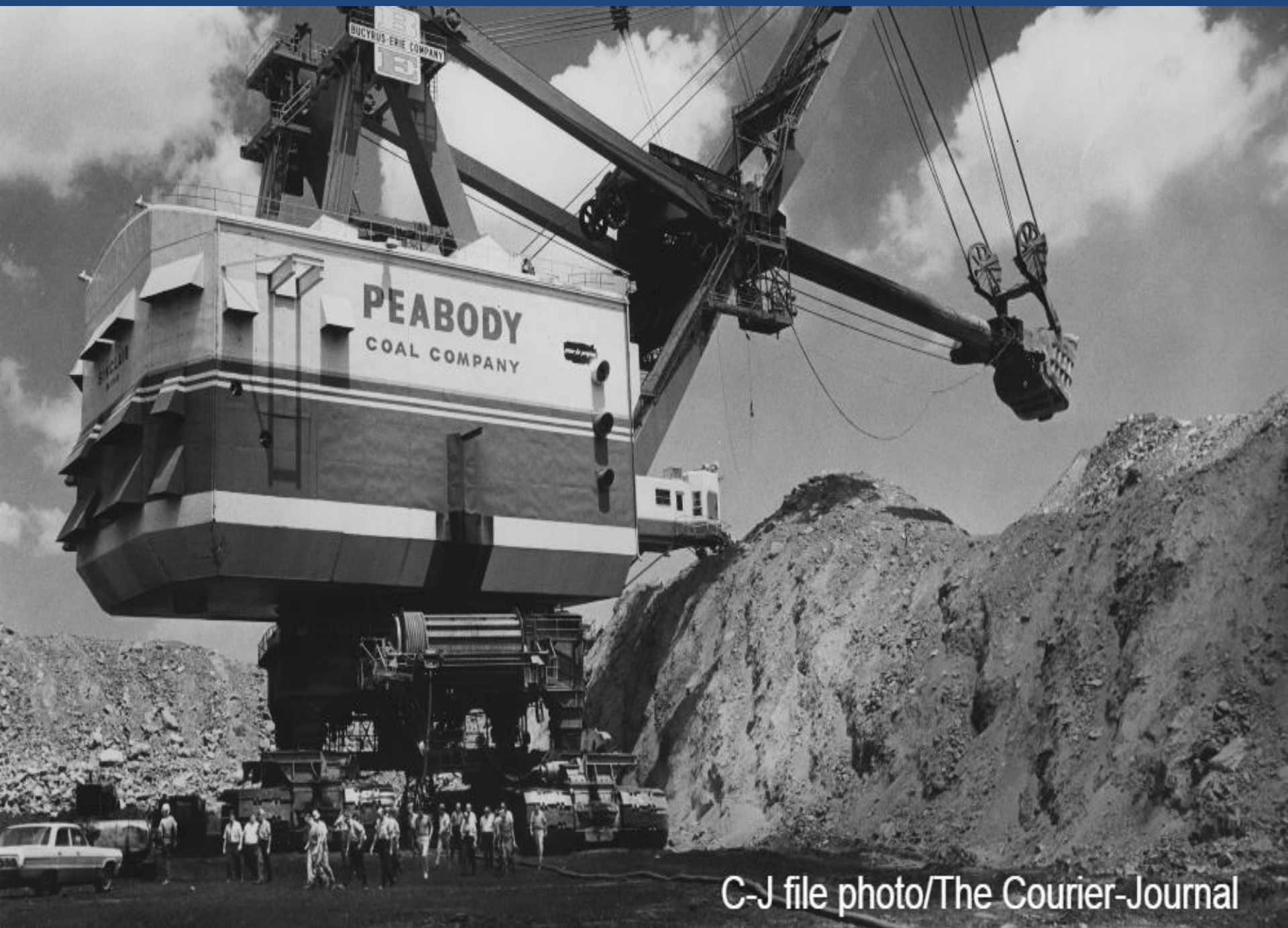
From forests (360-300 million years ago) buried,  
along with the carbon they had drawn  
down from the atmosphere

Over time they fossilized

Today: 90% of coal deposits buried during  
period of high oxygen levels



**COAL**



C-J file photo/The Courier-Journal





“We are part of something wonderful, something that can change us forever; a vision of the Universe that tells us undeniably how tiny and insignificant, and how rare and precious we all are. A vision that tells us we belong to something greater than ourselves. That we are not, that none of us, are alone.”

Ellie Arroway (Carl Sagan's Contact)

# EXTINCTION RATES

Extinctions have occurred before  
humans

So what is the base-rate/background  
rate/”noise”

Current rate of global species  
extinction estimated at 100-  
1000 times background rate\

In the future: 10,000 times higher

## 2010: EXPERT TEAMS: 155 RESEARCH GROUPS AROUND THE WORLD

Assessed status of 25,780 vertebrate species  
(mammals, birds, reptiles, amphibians,  
fishes)

One-fifth of all were 'threatened' (ave.  
52/year toward extinction)

Extinction rates 100-1000 times higher than  
before the global spread of humanity

Some concern for the living world that gave  
us birth

# EXTINCTION

The Holocene extinction (human-caused)

70% of biologists believe that the Earth is currently in the early stages of a human-caused mass extinction

Up to 20% of all living populations could become extinct by 2028



# EXTINCTION (AKA 'BIOTIC ATTRITION')

The end of an organism or a group of organisms, normally a species

More than 99.9% of all species, amounting to over 5 billion species that have ever lived on Earth are estimated to be extinct

(estimates and Earth's current species 10-14 million)

Species become extinct when they are no longer able to survive in changing conditions or against superior competition

# CAUSES OF EXTINCTION

Variety of causes: “Just as each species is unique, so is each extinction”

Any species that cannot survive and reproduce in its environment and cannot move to a new environment where it can do so, dies out/extinction

Can occur suddenly (toxic pollution) or gradually (loses out in competition for food to better adapted competitors)

# OTHER GROUPS OF EXTINCTION

One third of all reef-building corals

One third of all fresh-water mollusks

One third of sharks and rays

One quarter of all mammals

One fifth of all reptiles

One sixth of all birds

# PRIMATES

Since 2000, 85 new primate species identified (now total 505), with 7 new ones to be announced this year

Finding new primate species because the destruction of forests – making it easier to reach once remote populations

Rush: If don't find them/describe them, will be lost without us ever knowing: loss of unique mutations

# MOST PRIMATE SPECIES THREATENED WITH EXTINCTION

A.Rylands et al (*Science Advances*, 2017)

Study of unprecedented scope: team of 31  
primatologists:

Three-quarters of primate species in decline  
60% now threatened with extinction (from  
gorillas to gibbons), now in worse shape than  
in recent decades because of devastation from  
agriculture, hunting and mining



# PRIMATES

The ones doing OK are the ones that  
aren't super-specialists, the ones  
that are most flexible

“Worse than we thought 10 yrs ago”

Every species of ape (gorillas, chimps,  
bonobos, orangutans, 19 species of  
gibbons) threatened

87% of lemur species are threatened (17  
lemur species extinct after  
humans arrived 2000 years ago

Critically endangered: spider monkeys, red  
colobus, macaques

“Homo sapiens might not only be the agent of the sixth extinction, but also risks being on of its victims.”

Richard Leakey

“In pushing other species to extinction, humanity is busy sawing off the limb on which is perches.”

Paul Ehrlich

# THE TALE OF TWO CITIES (VIEWS)

“It was the best of times, it was the worst of times, it was the age of wisdom, it was the age of foolishness. It was the epoch of belief, it was the epoch of incredulity, it was the season of Light, it was the season of Darkness, it was the spring of hope, it was the winter of despair, we had everything before us, we had nothing before us, we were all going direct to Heaven, we were all going direct the other way...”











# GANDHI

Our **beliefs** become our **thoughts**

Our thoughts become our **words**

Our words become our **habits**

Our habits become our **values**

Our values become our **destiny**

# UPTON SINCLAIR

“IT IS DIFFICULT TO GET A MAN  
TO UNDERSTAND SOMETHING,  
WHEN HIS **SALARY** (\$\$)  
DEPENDS UPON HIS NOT  
UNDERSTANDING IT” (or your  
Mental/World model)

Or to their Bosses, also his/her  
Tribal (Partisan) Position; or  
answering to your Board of  
Directors, Stock Holders, Regents

# DUNNING-KRUGER EFFECT

The least-competent people were the least likely to know they were wrong or to know that others were right, the most likely to try to fake it, and the least able to learn anything

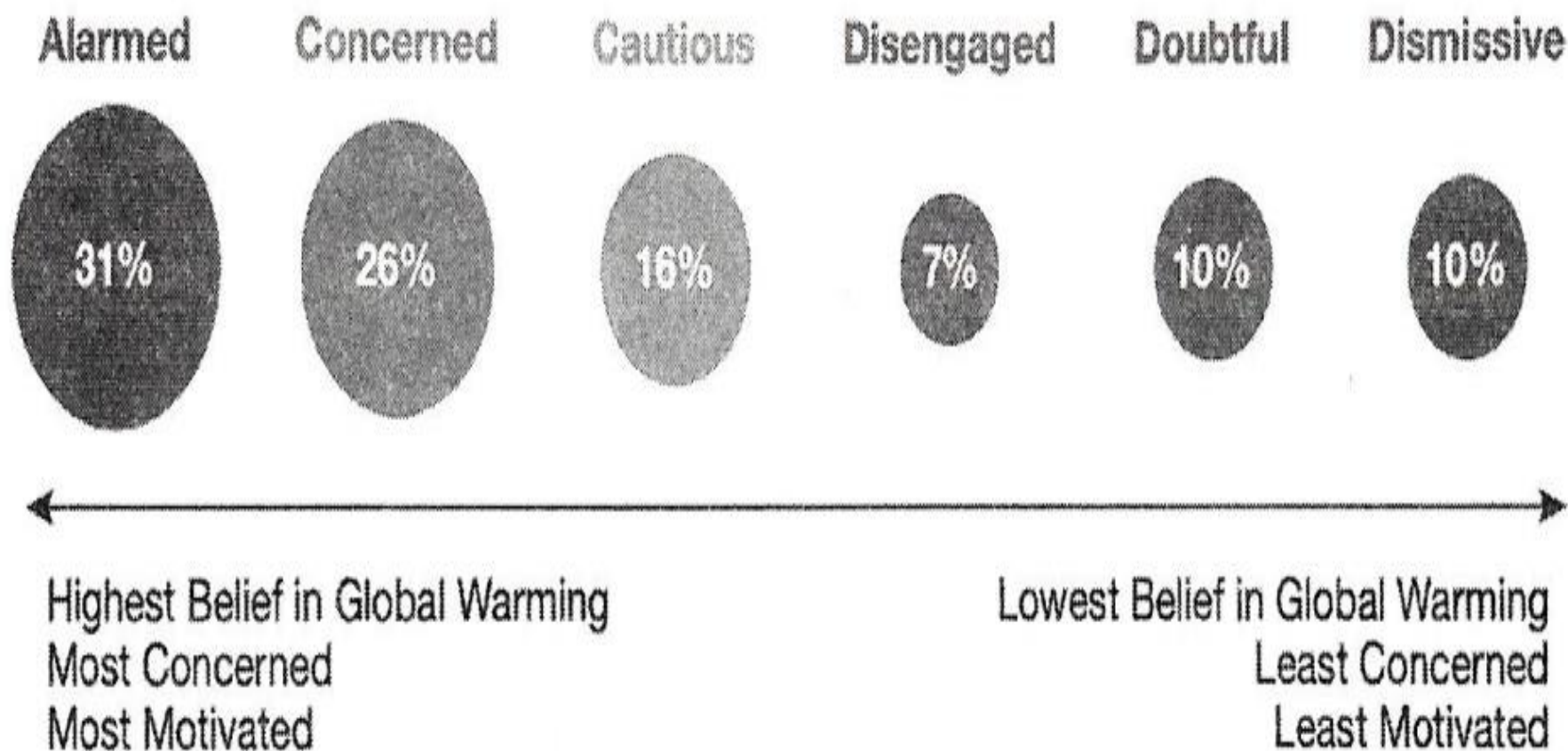
**PS:** If you think you are a 'very stable genius'— you probably aren't!

# THOUGHT FOR THE DAY

**“You cannot reason a person out of a position he did not reason himself into in the first place”**

(including yourself – you are the easiest person in the world to fool)

Jonathan Swift *Seeking Wisdom*



November 2019. Base: Americans 18+ (N = 1,303).



YALE PROGRAM ON  
Climate Change  
Communication



GEORGE MASON UNIVERSITY  
CENTER for CLIMATE CHANGE  
COMMUNICATION



# Confidence in Science, 1975 and 2021

Now I am going to read you a list of institutions in American society. Please tell me how much confidence you, yourself, have in each one -- a great deal, quite a lot, some, or very little? How about -- Science?



# **STANFORD UNIVERSITIES STANFORD HISTORY EDUCATION GROUP**

“Never have we had so much information at our fingertips. Whether this bounty will make us smarter and better informed or more ignorant and narrow minded will depend on our awareness of this problem and our educational response to it”







**THANKS TO RENE DESCARTES  
(CARTESIAN COORDINATES):**

**PLOTTING ONE VALUE WITH  
ANOTHER...**

