



Past and Projected Changes in the Earth's Climate: The Science

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Scientists are Regularly Asked to Assess the Science of the Changing Climate and its Societal Impacts

2017

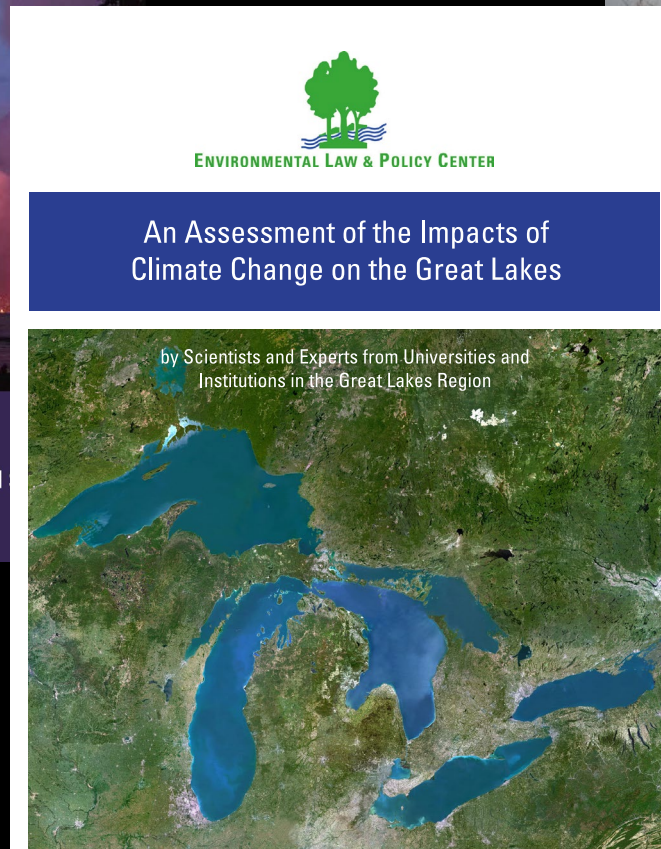


Fourth National Climate Assessment □ Volume I

U.S. Global Change Research Program

Fourth National Climate Assessment

2019



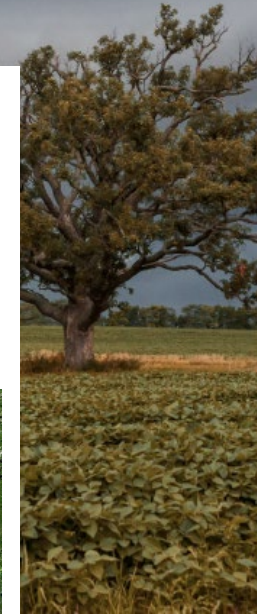
An Assessment of the Impacts of Climate Change on the Great Lakes

by Scientists and Experts from Universities and Institutions in the Great Lakes Region

AN ASSESSMENT OF THE IMPACTS OF CLIMATE CHANGE IN ILLINOIS

2021

2021



ipcc INTERGOVERNMENTAL PANEL ON climate change Climate Change 2021 The Physical Science Basis

WGI

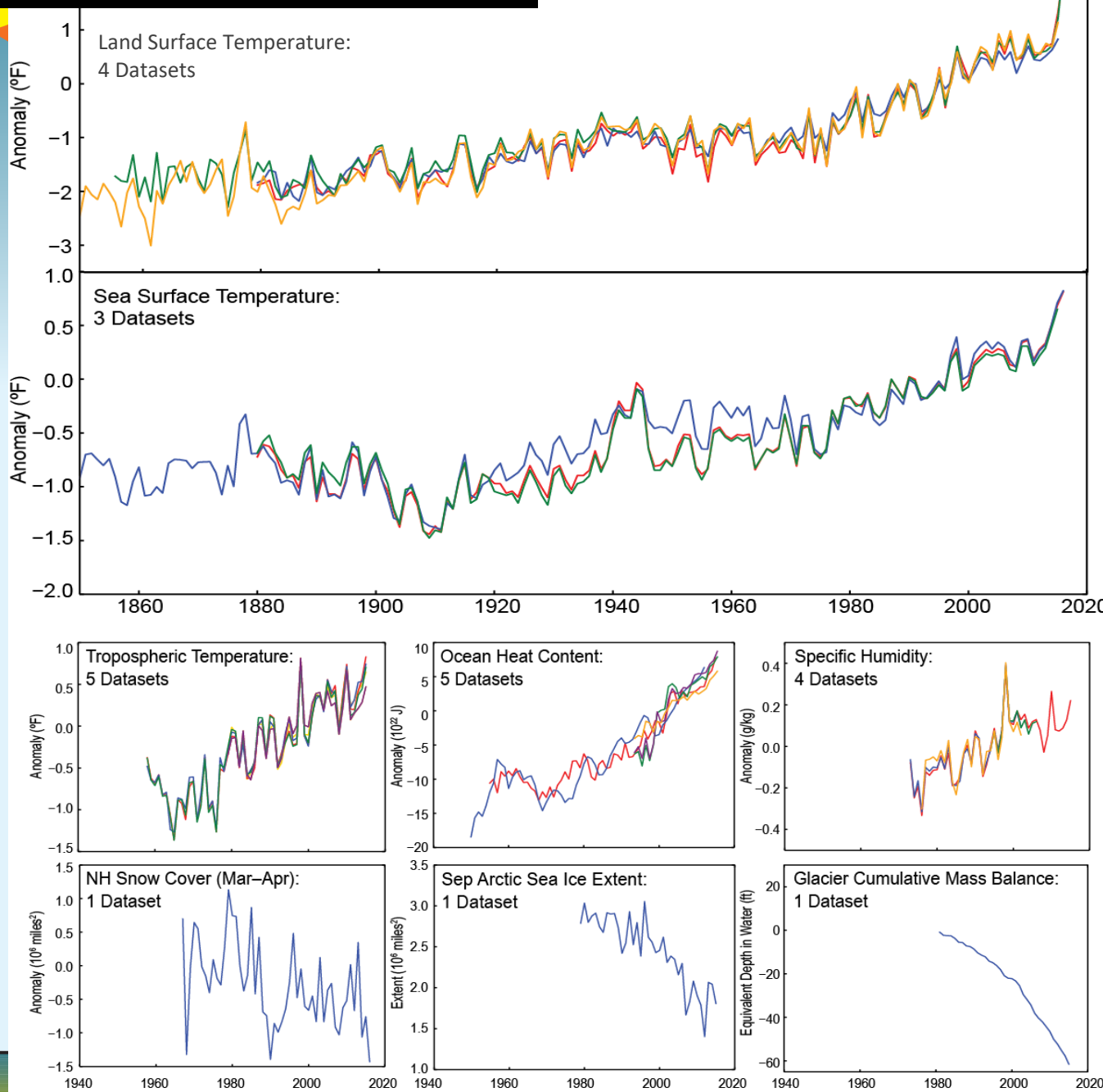
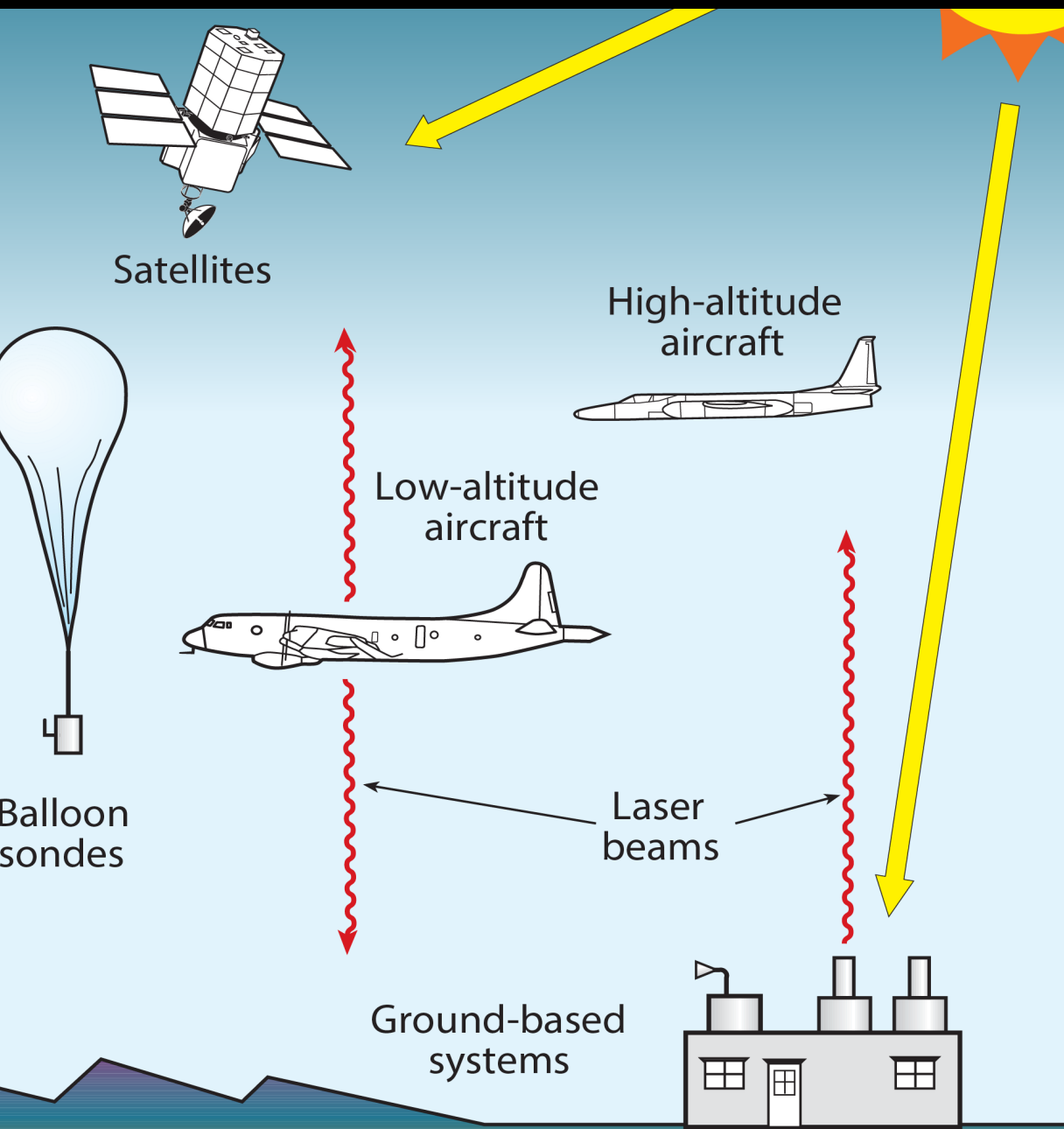
Working Group I contribution to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change



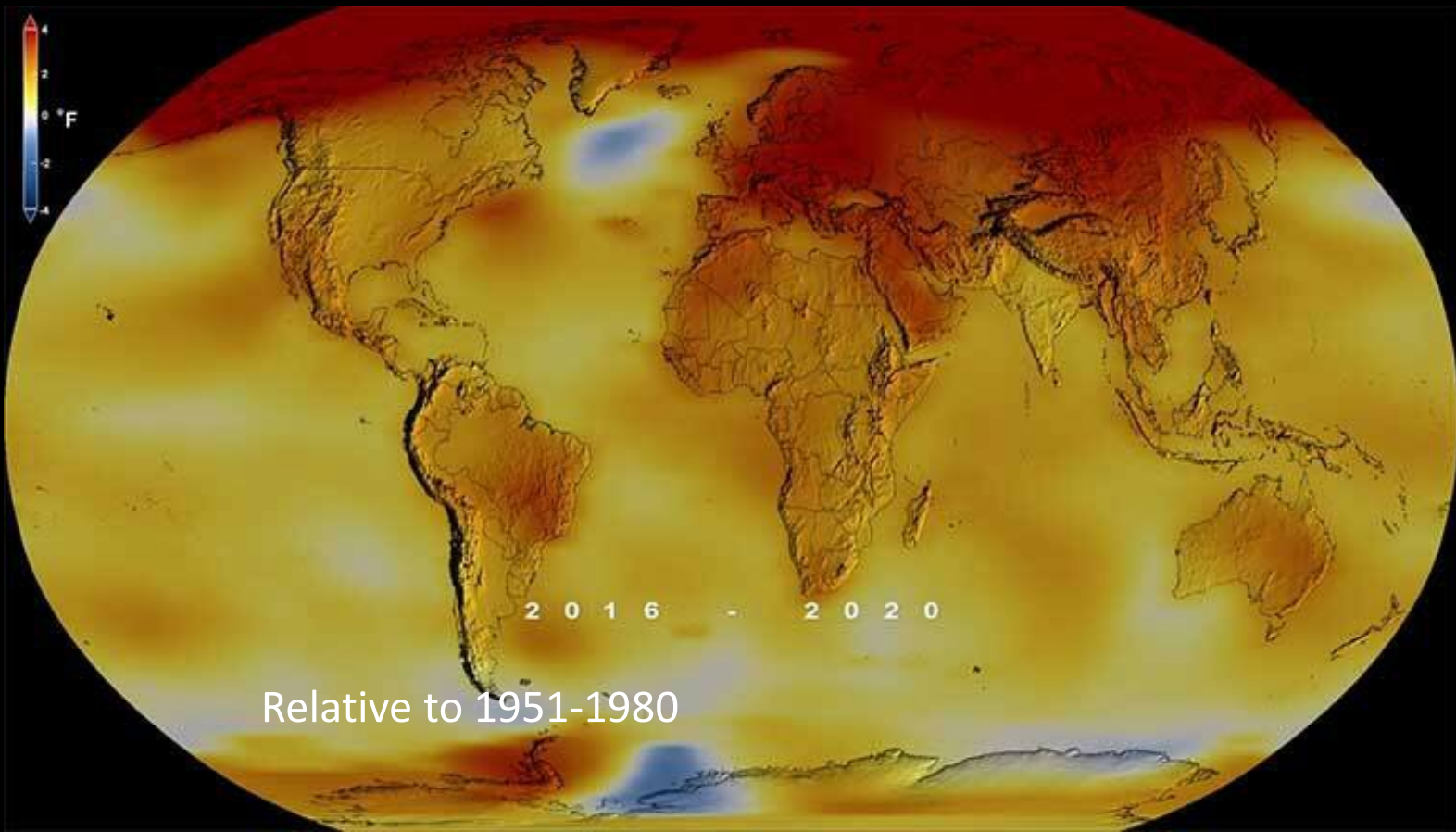
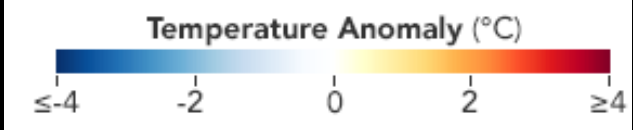
The Science of Climate Change: The Bottom Line

- Our climate is changing,
 - It is happening now;
 - It is happening extremely rapidly;
- Severe weather is becoming more intense;
- Sea levels are rising;
- It is largely happening because of human activities and associated pollution;
- The climate will continue to change over the coming decades.

Many Different Observations Show a Changing Climate



...ing from Multiple Datasets



The global long-term warming trend is continuing.

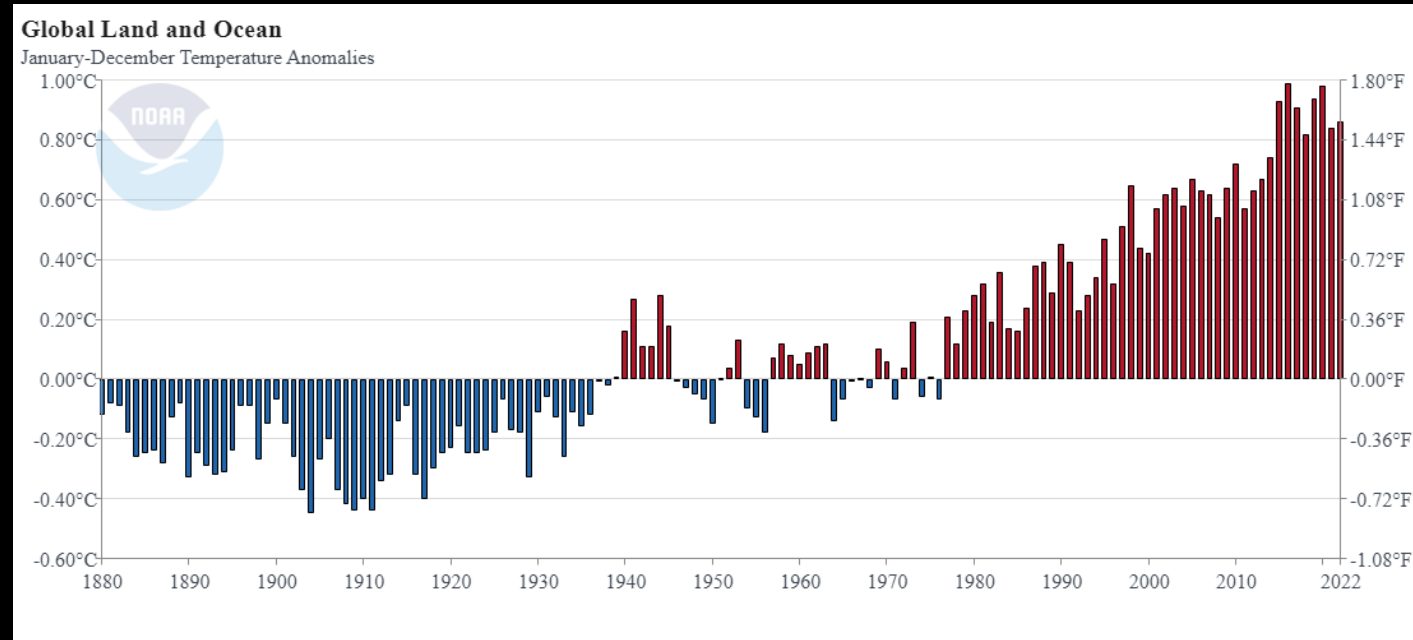
Arctic warming at twice the rate of the rest of the world

Land warming faster than oceans

Our Climate Continues to Change Rapidly

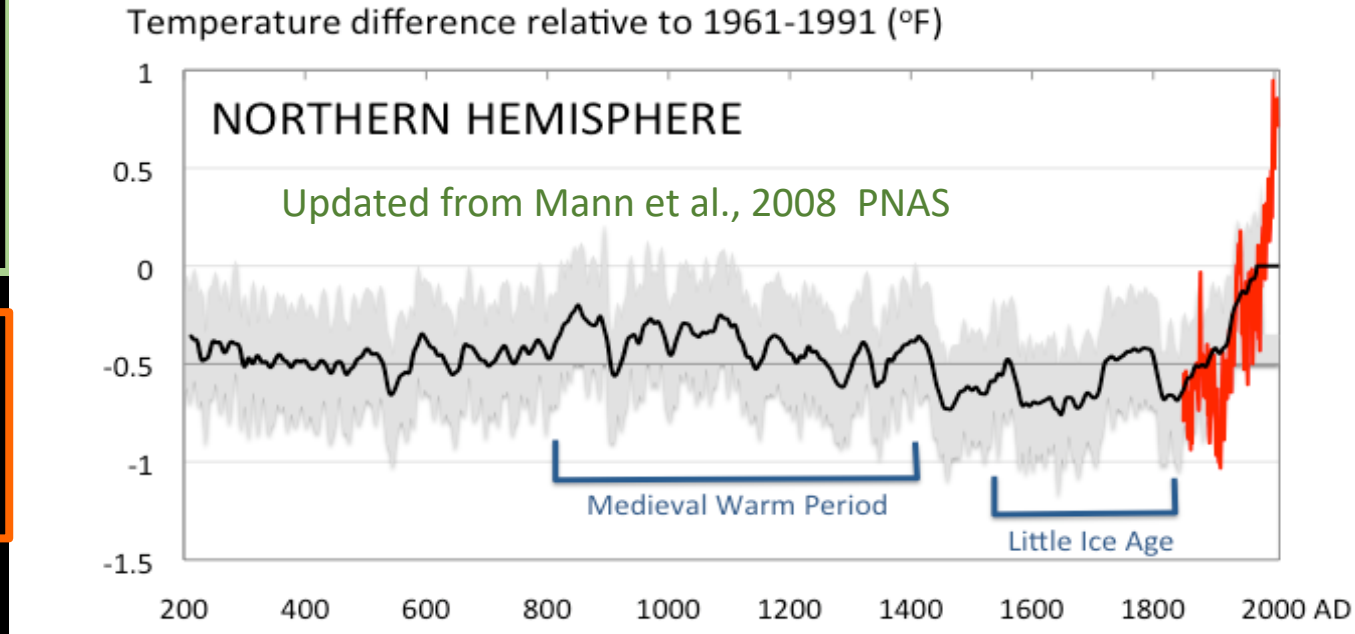
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Global Annually-Averaged Temperature Record (NOAA, through 2022)



Global, annually-averaged temperature has increased by 1.14°C (2.1°F) from 1901-2022

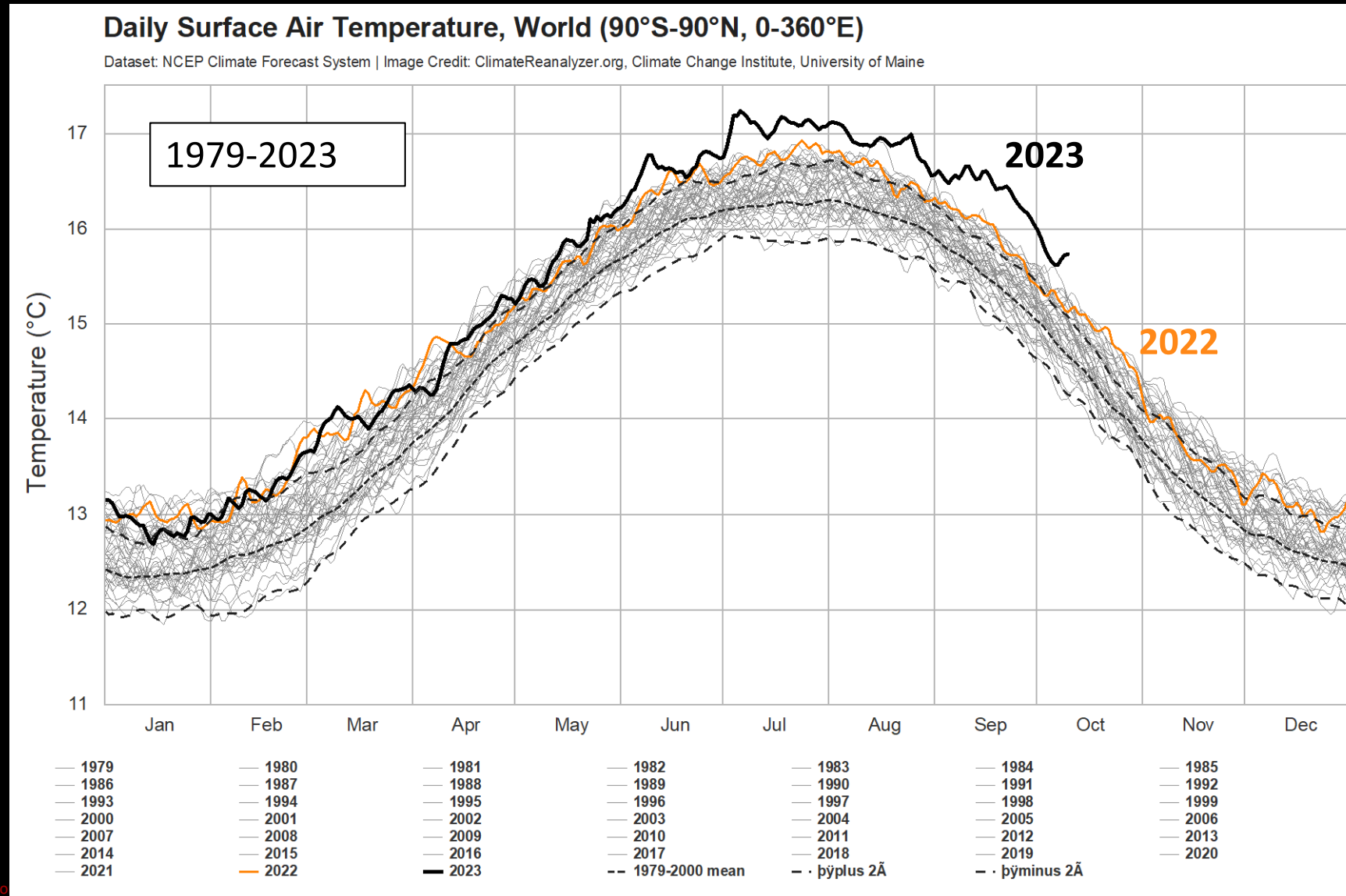
2020 and 2016 tied for warmest years on record.



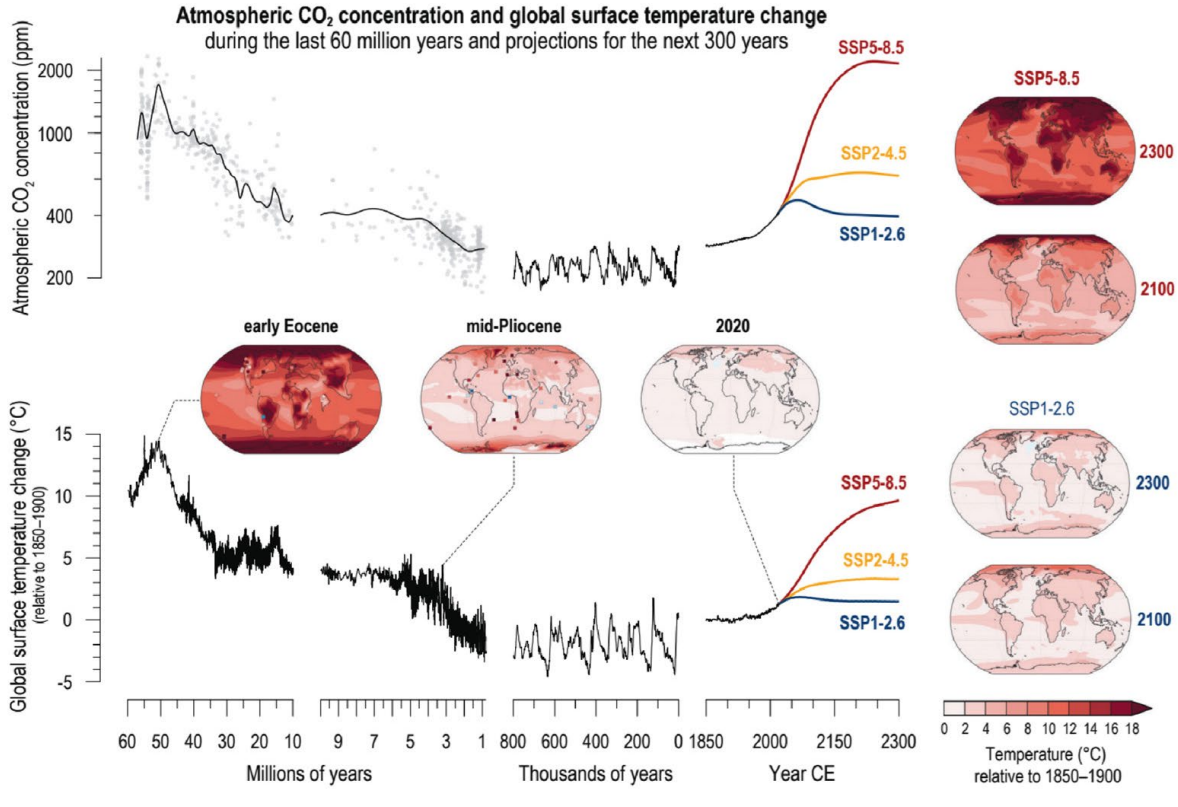
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Our Climate Continues to Change Rapidly

2023 will be warmest year in history!



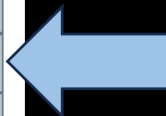
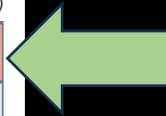
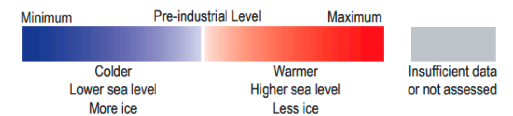
IPCC AR6 (2021): Past Earth Climates Linked to CO₂



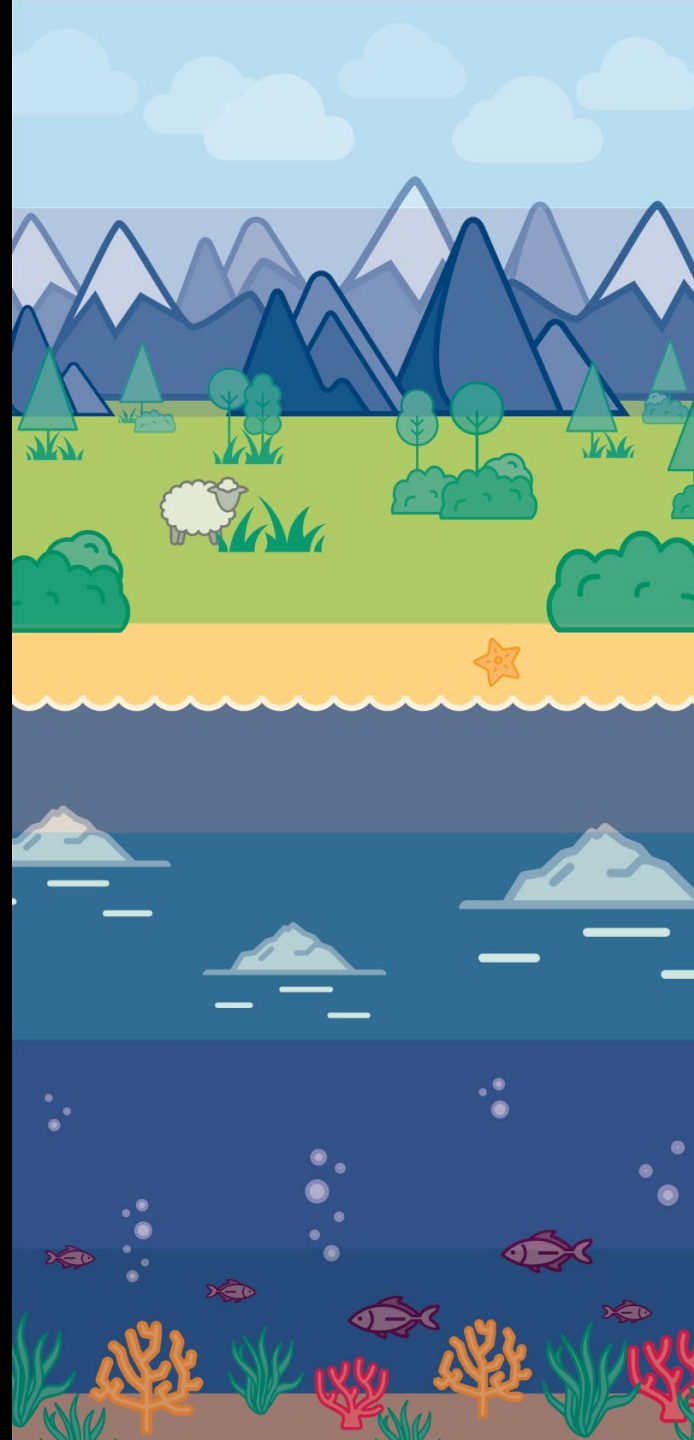
Selected large-scale climate indicators from the Cenozoic era to the recent past

	Atmosphere	Cryosphere	Biosphere	Ocean			
	CO ₂ (ppm)	CO ₂ rate of change (ppm/100 yr)	Temperature relative to 1850–1900 (°C)	Glacier extent relative to 1850–1900	Northern tree line relative to 1850–1900 (°lat)	Sea level relative to 1900 (m)	Sea level rate of change (mm/yr or m/1000 yr)
Recent past (1995–2014 CE)	360 → 397	192 to 198	0.66 to 1.00		0.5 to 1.0	0.15 to 0.25	2.9 to 3.6
Approximate pre-industrial (1850–1900 CE)	286 → 296	17 to 27	-0.15 to 0.11		0	-0.03 to 0.00	0.4 to 0.6
Last Millennium (850–1850 CE)	278 to 285	-7 ~ 5	-0.14 ~ 0.24		-1.5 to 1.5	-0.05 to 0.03	-1.1 ~ 0.7
Mid-Holocene (6.5–5.5 ka)	260 to 268		0.2 to 1.0		1 to 3	-3.5 to 0.5	
Last Deglacial Transition (18–11 ka)	193 → 271	10			-6 → 1	-120 → -50	24 to 44
Last Glacial Maximum (23–19 ka)	188 to 194		-5 to -7		-23 to -17	-134 to -125	
Last Interglacial (129–116 ka)	266 to 282		0.5 to 1.5		8 to 2	5 to 10	
Mid-Pliocene warm period (3.3–3.0 Ma)	360 to 420		2.5 to 4.0		4 to 10	5 to 25	
Early Eocene climate optimum (53–49 Ma)	1150 to 2500		10 to 18			70 to 76	
Paleocene-Eocene thermal maximum (55.9–55.7 Ma)	900 → 2000	4 to 42	10 to 25				

X to Y: very likely range, unless otherwise stated in FAIR data table
 X → Y: start to end of period, with no stated uncertainty
 X ~ Y: lowest and highest values, with no stated uncertainty



Recent changes in climate are unprecedented in thousands of years



Concentrations of carbon dioxide unmatched for at least 2 million years

Glacial retreat unmatched for 2,000+ years

Last decade warmer than any period for ~125,000 years

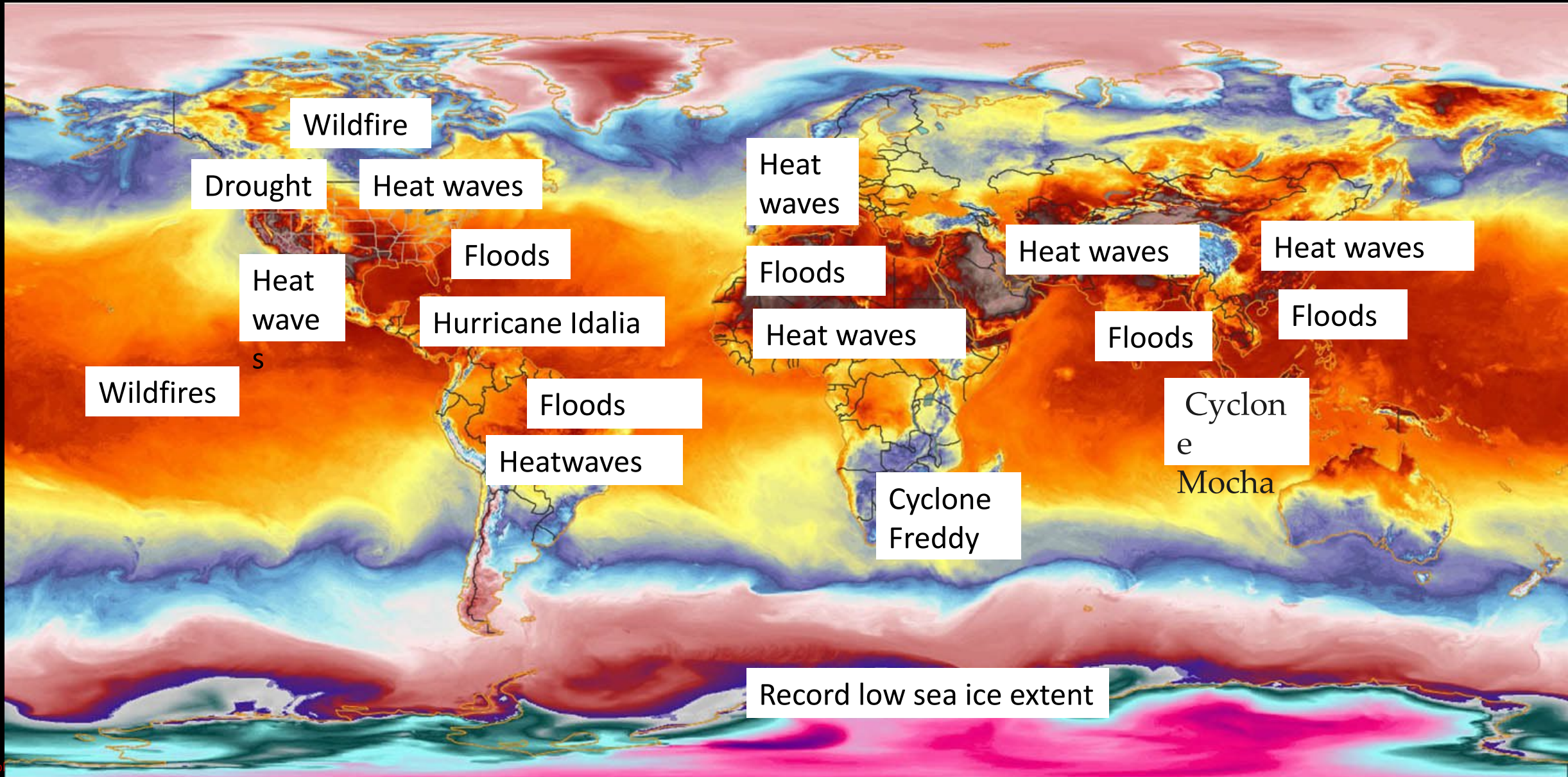
Sea level rise faster than any prior century for 3,000 years

Summer Arctic ice coverage smaller than anytime in last 1,000 years

Ocean warming faster than at any time since end of the last ice age

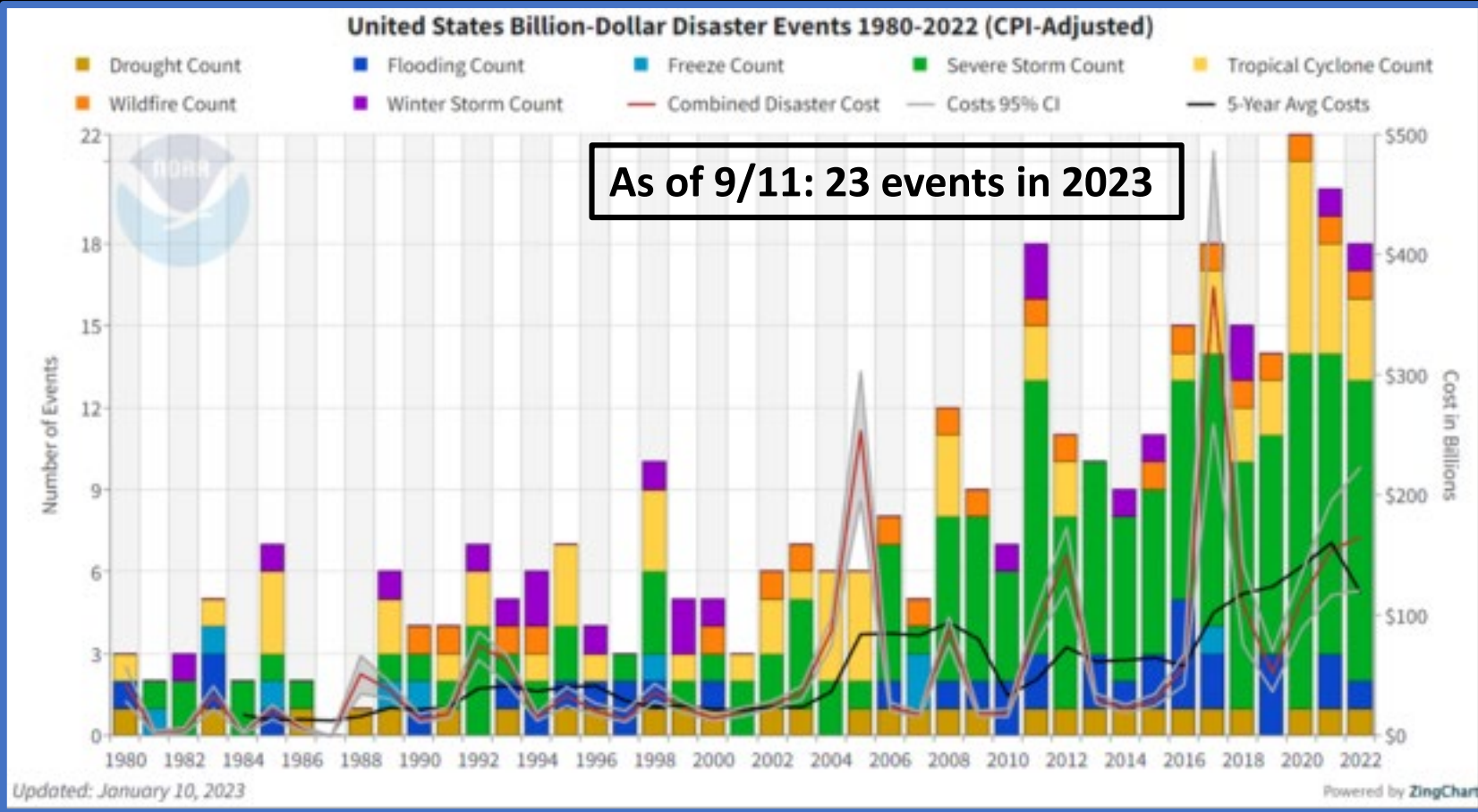
Ocean acidification at highest level of last 26,000 years

2023 is Dramatic Year for Extreme Events

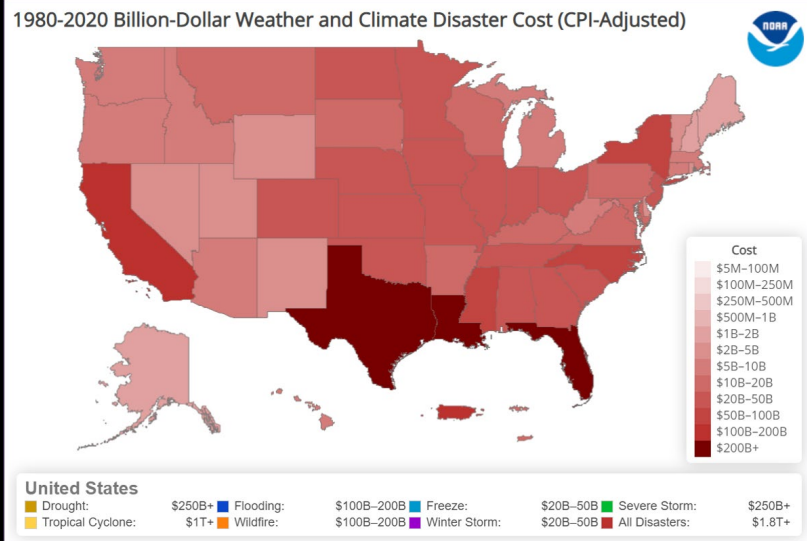


NOAA: Increasing impact of Severe Weather on U.S. economy: Over \$2.6 trillion

Every U.S. region is affected



Billion-dollar weather and climate disasters frequency: 1980-2022 (accounts for inflation)

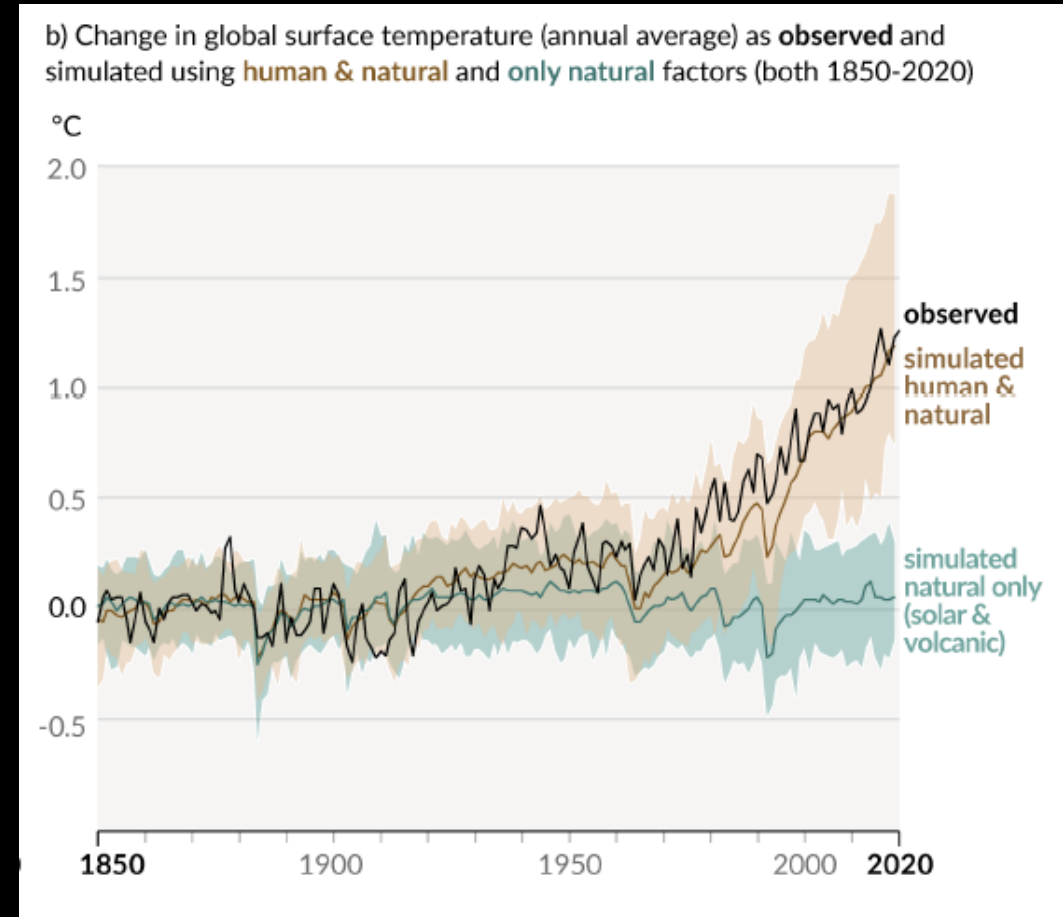


Similar trend globally

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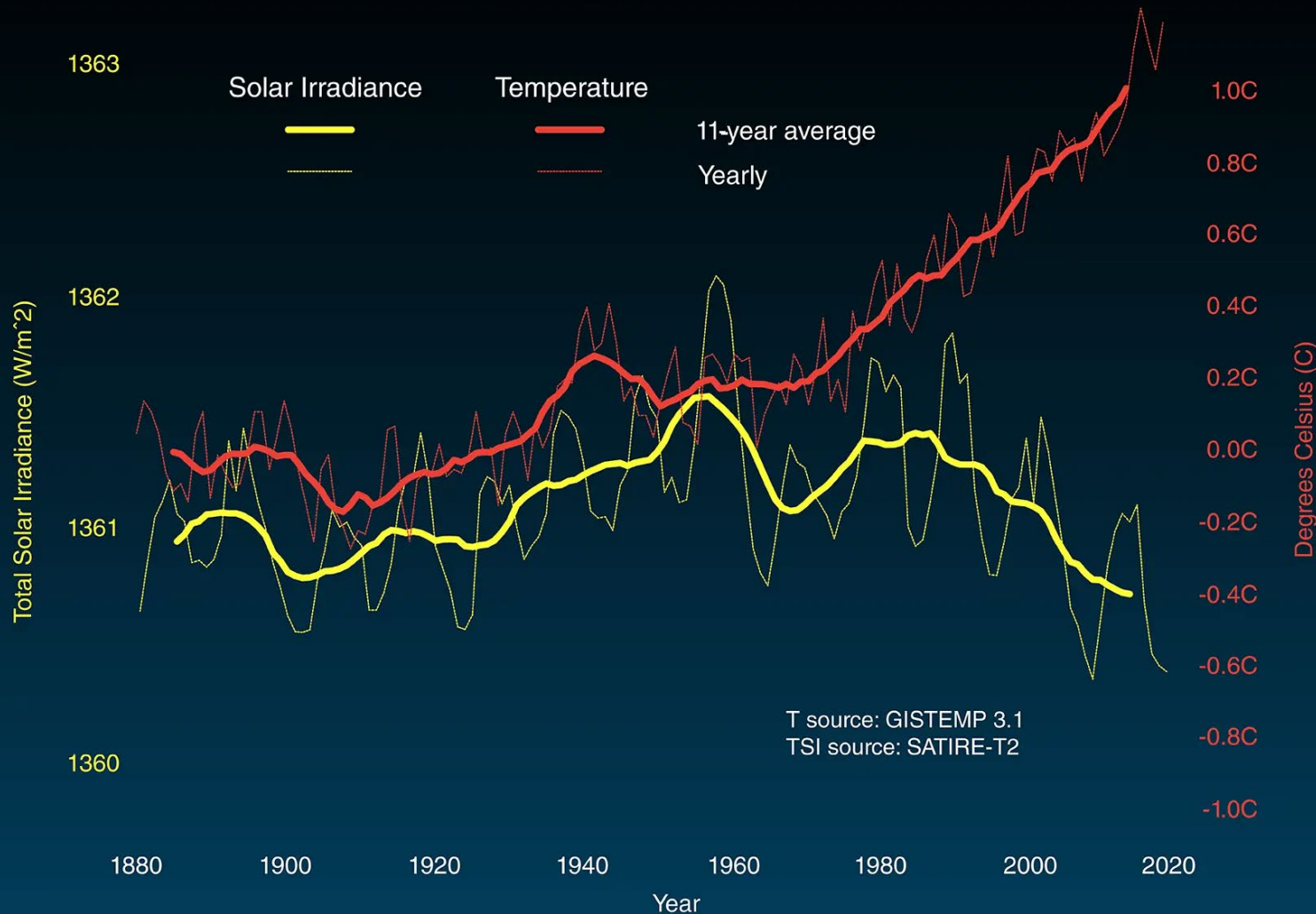
What is Causing Climate Change?

- Many lines of evidence demonstrate that **human activities**, especially emissions of greenhouse gases, are primarily responsible for the observed climate changes.
- For the period extending over the last century, there are no credible alternative explanations supported by the extent of the observational evidence.
 - **It's not the Sun**
 - **It's not natural cycles**



It's Not the Sun!

Temperature vs Solar Activity



T source: GISTEMP 3.1
TSI source: SATIRE-T2

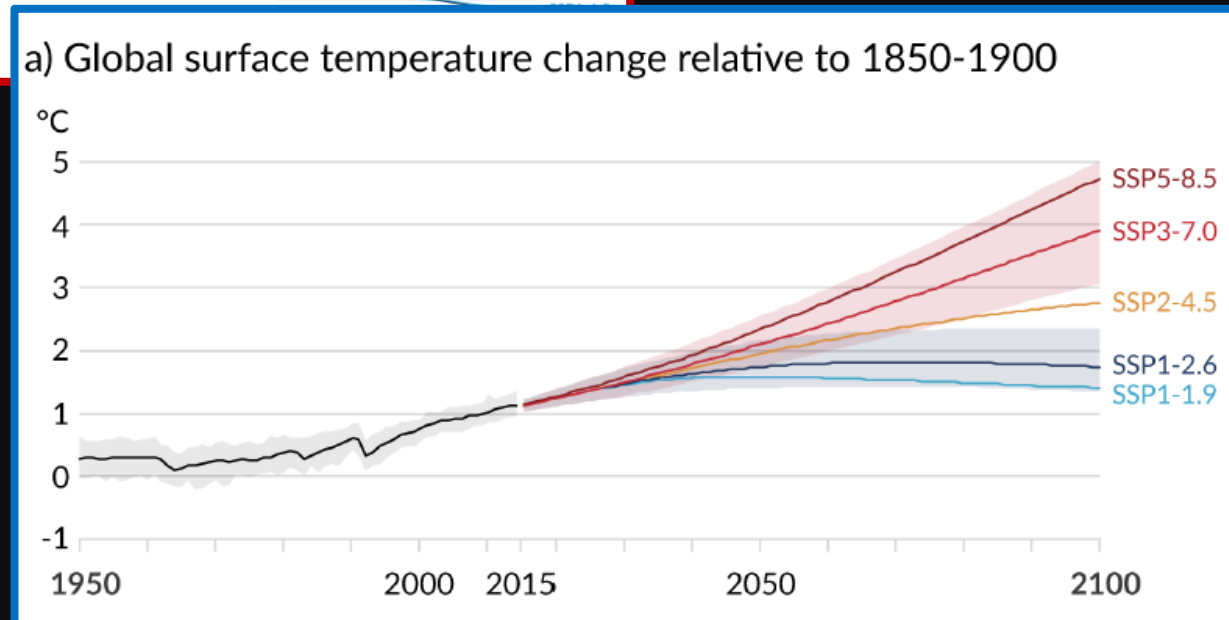
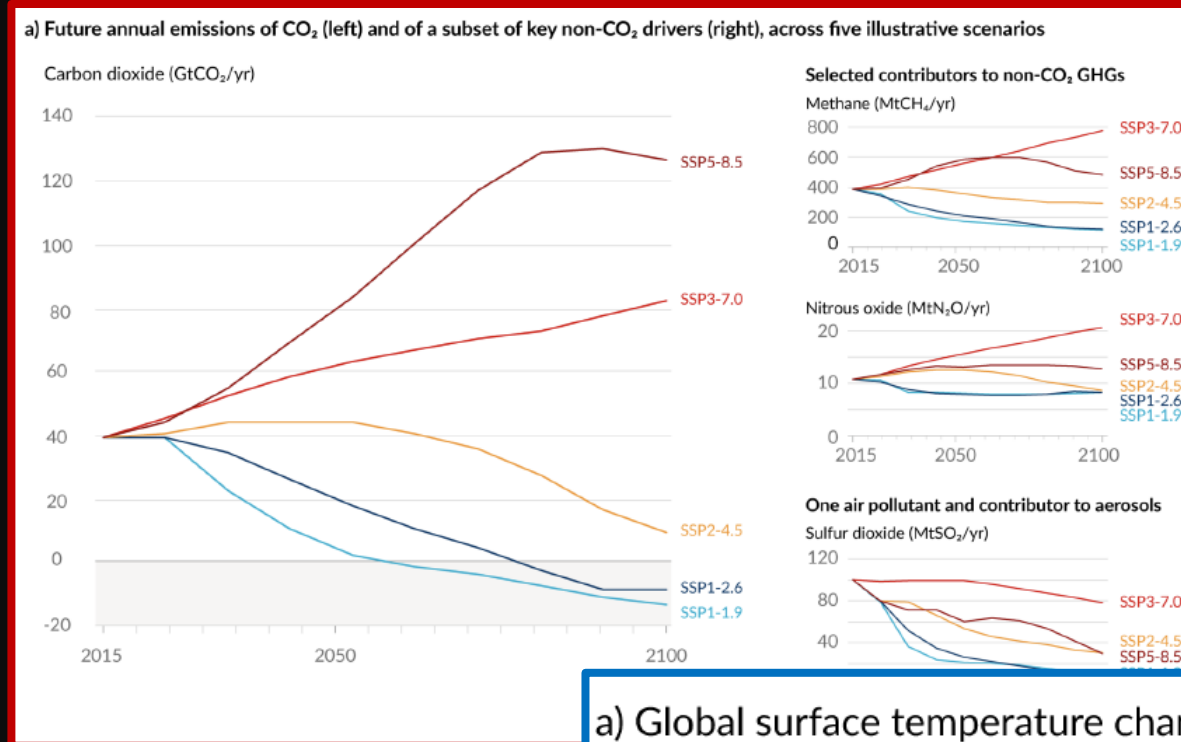
climate.nasa.gov

Variations in solar energy (received at Earth) are too small to explain changes in climate.

Solar output is decreasing over last 40 years).

The Forecast: Climate will Continue to Change

Climate change beyond the next few decades depends primarily on the heat-trapping gases emitted and the sensitivity of Earth's climate to those emissions.

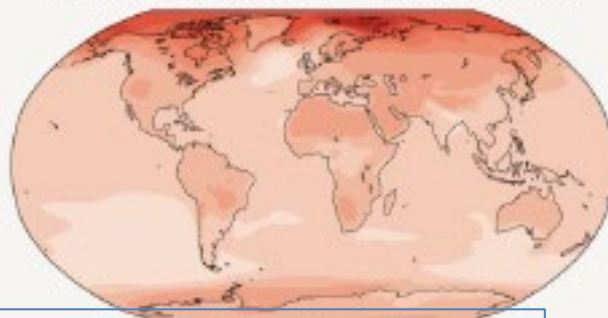


Temperature and Precipitation Projections

b) Annual mean temperature change (°C) relative to 1850-1900

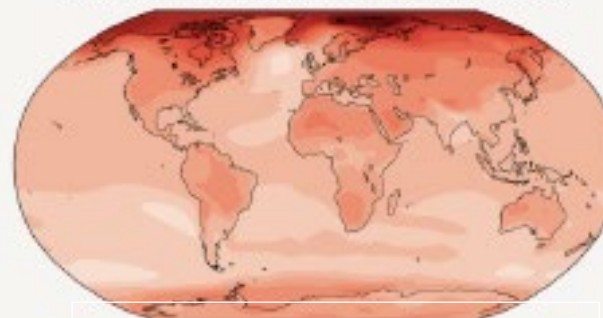
Across warming levels, land areas warm more than oceans, and the Arctic and Antarctica warm more than the tropics.

Simulated change at 1.5 °C global warming



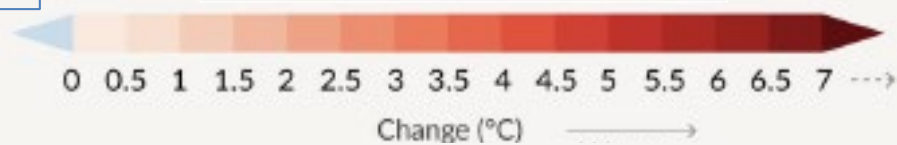
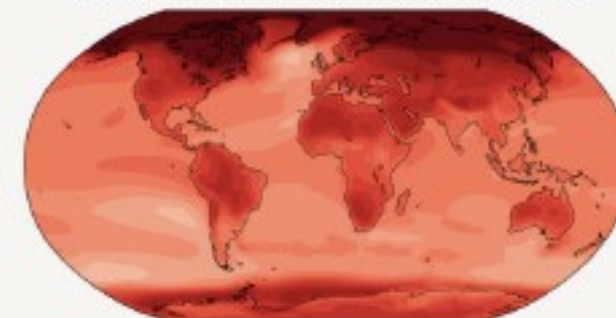
Likely reach 2027-2037

Simulated change at 2 °C global warming



Likely reach 2041-2053

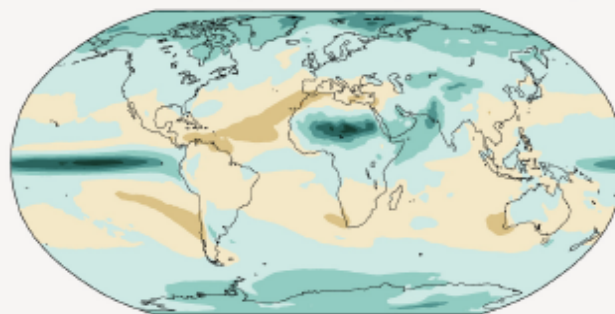
Simulated change at 4 °C global warming



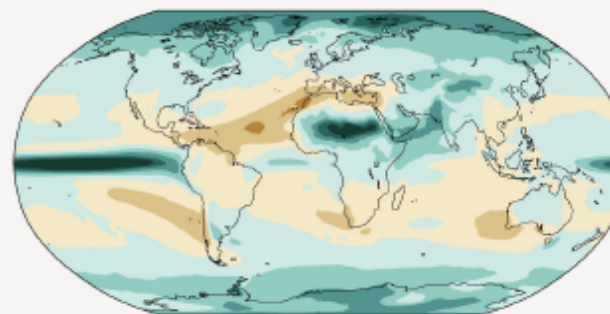
c) Annual mean precipitation change (%) relative to 1850-1900

Precipitation is projected to increase over high latitudes, the equatorial Pacific and parts of the monsoon regions, but decrease over parts of the subtropics and in limited areas of the tropics.

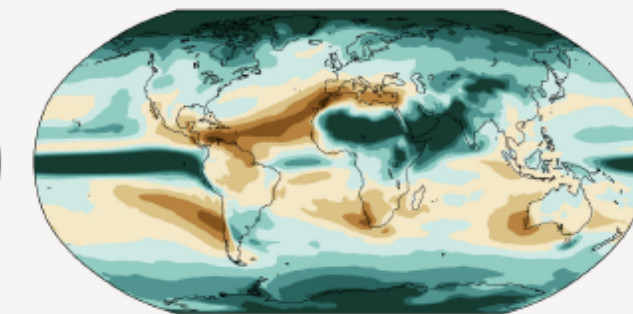
Simulated change at 1.5 °C global warming



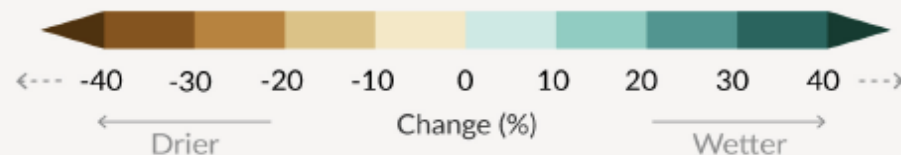
Simulated change at 2 °C global warming



Simulated change at 4 °C global warming



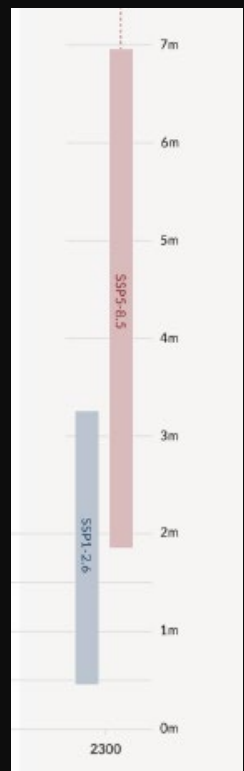
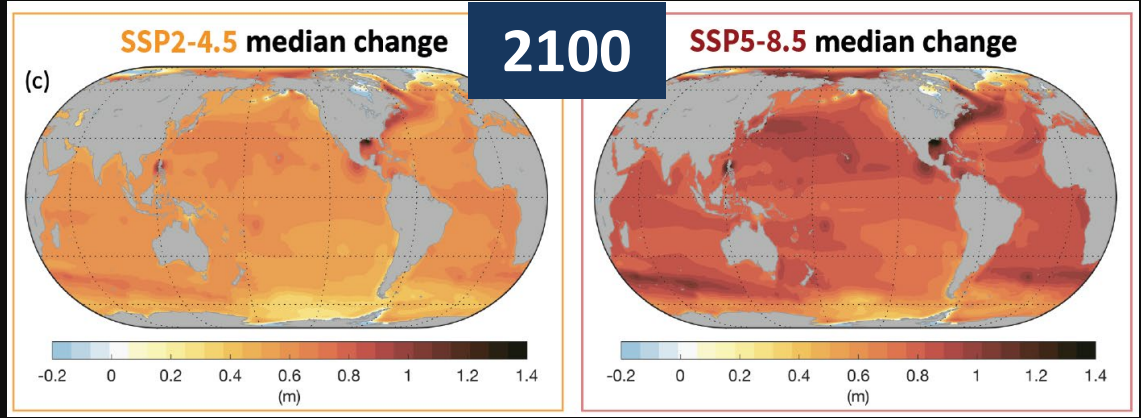
Relatively small absolute changes may appear as large % changes in regions with dry baseline conditions



Changes in the Oceans

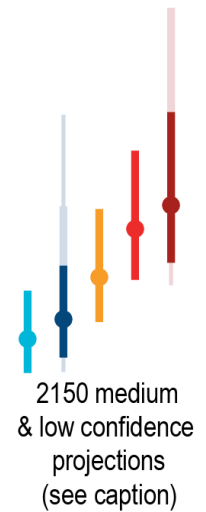
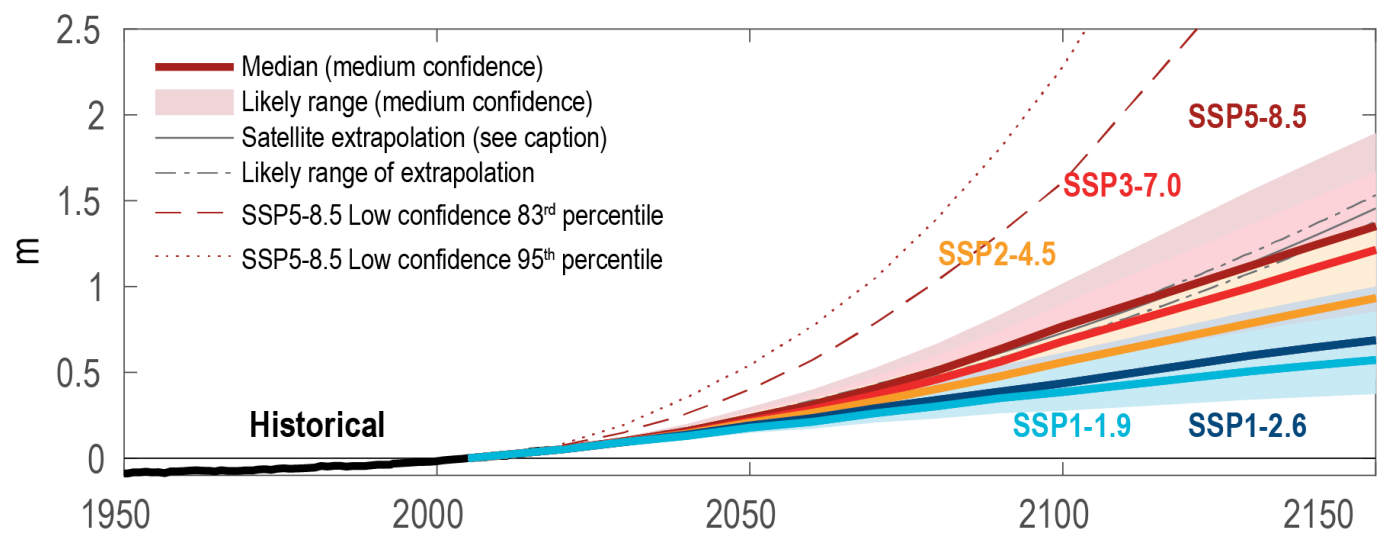
- Sea levels have risen ~8 inches since 1900
- Sea Level Rise at Highest Rate in at least 2800 years
- Nuisance flooding issues
- Sea levels expected to rise another 1-4 feet this century
- Acidification of the Oceans
- Changing ocean circulation

to 2300



1950 to 2150

Projected global mean sea level rise under different SSP scenarios



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What should we do?

There are only three options:

- **Mitigation**: measures to reduce the pace & magnitude of the changes in climate.
- **Adaptation**: measures to reduce the adverse impacts on human well-being resulting from climate change.
- **Suffering**: the adverse impacts and societal disruption not avoided by mitigation or adaptation.

Minimizing suffering can only be achieved by doing a lot of mitigation and a lot of adaptation.

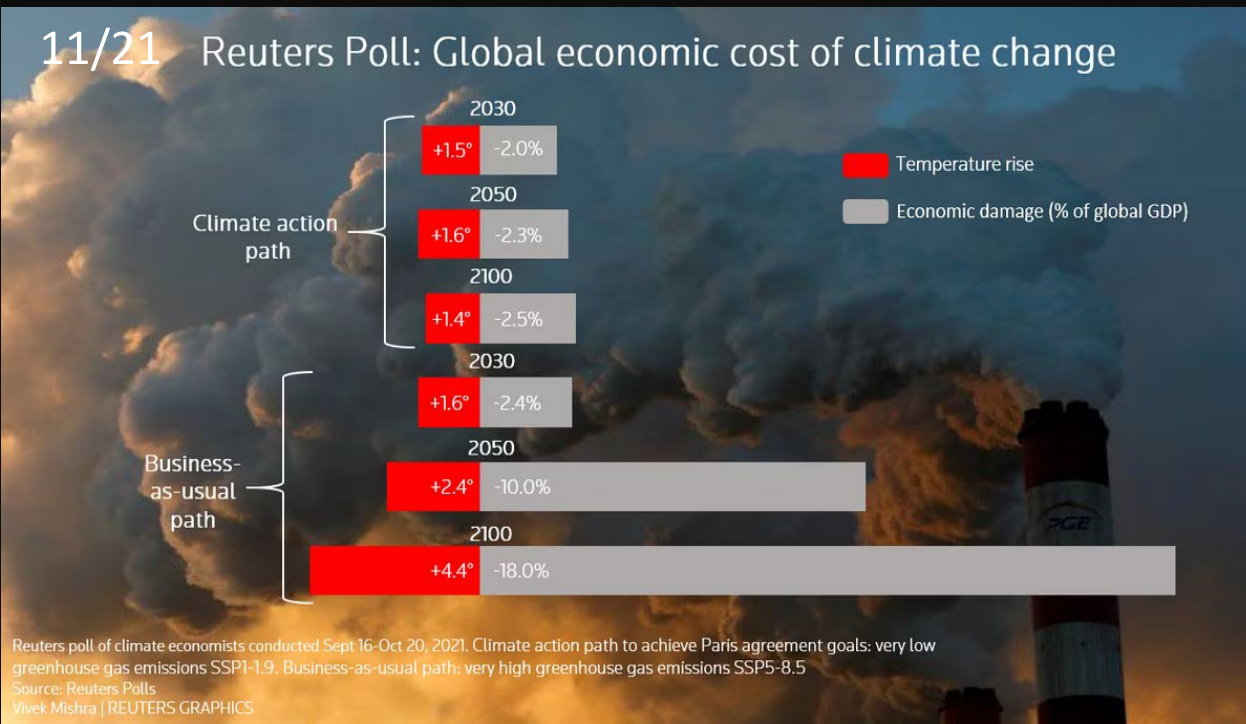
Costs of Climate Inaction are far greater than Taking Action

➤ Global GDP in 2100 lower by 37% unless take action (UCL, 2023)

➤ Deloitte: Climate change will cost the US Economy \$14.5 Trillion by 2070

➤ Heal (2017): Reducing U.S. emissions 80% by 2050 would cost \$1.2-3.9 trillion

➤ Other studies say there could be a net gain from the energy transition!

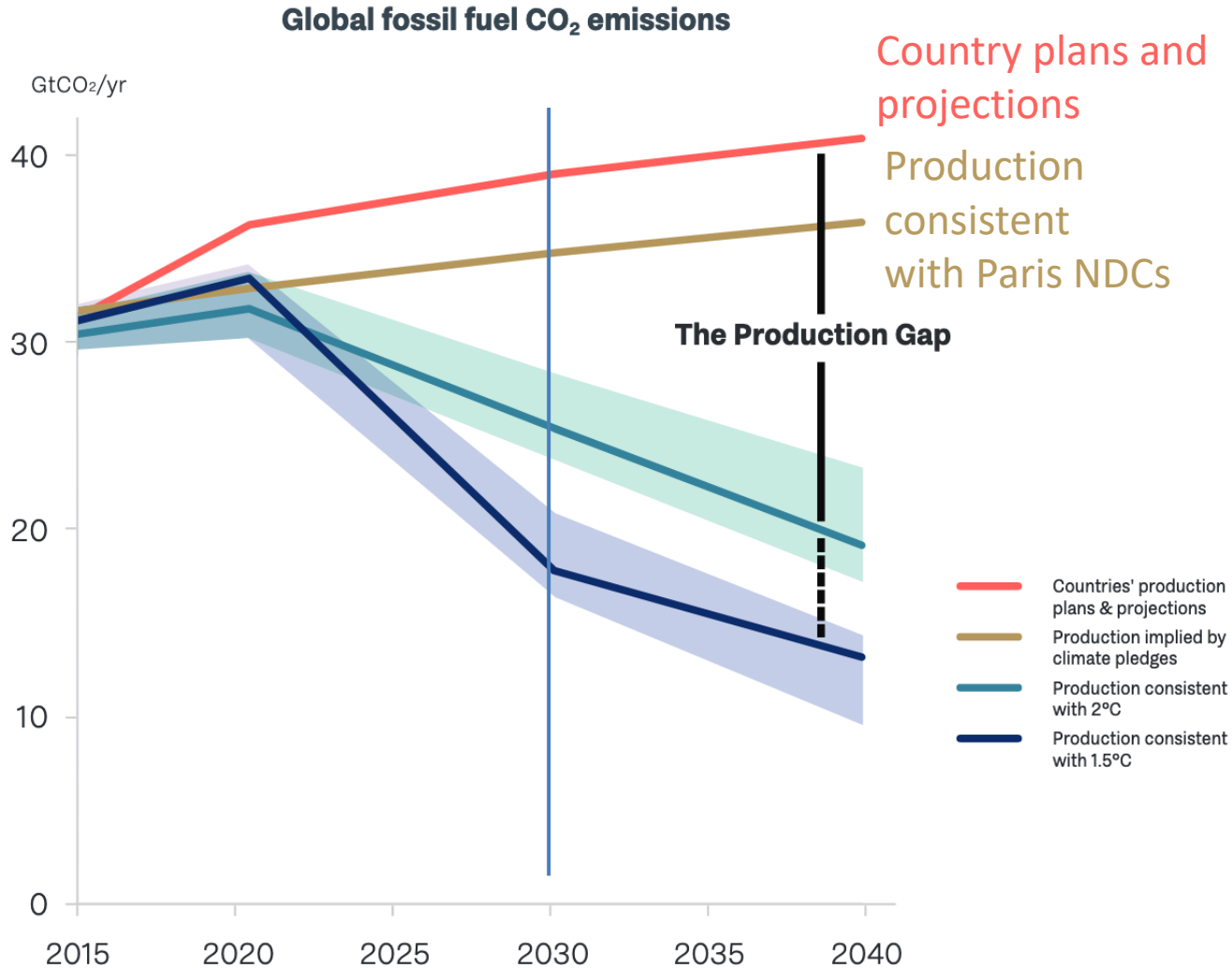


The Paris Agreement: December 2015

The Paris Agreement establishes a bridge between today's policies and climate neutrality before the end of the century.

The Paris Agreement: Avoiding High Risks

The fossil fuel production gap — the difference between national production plans and low-carbon pathways (1.5°C and 2°C), as expressed in fossil fuel carbon dioxide (CO₂) emissions — widens between 2015 and 2040.

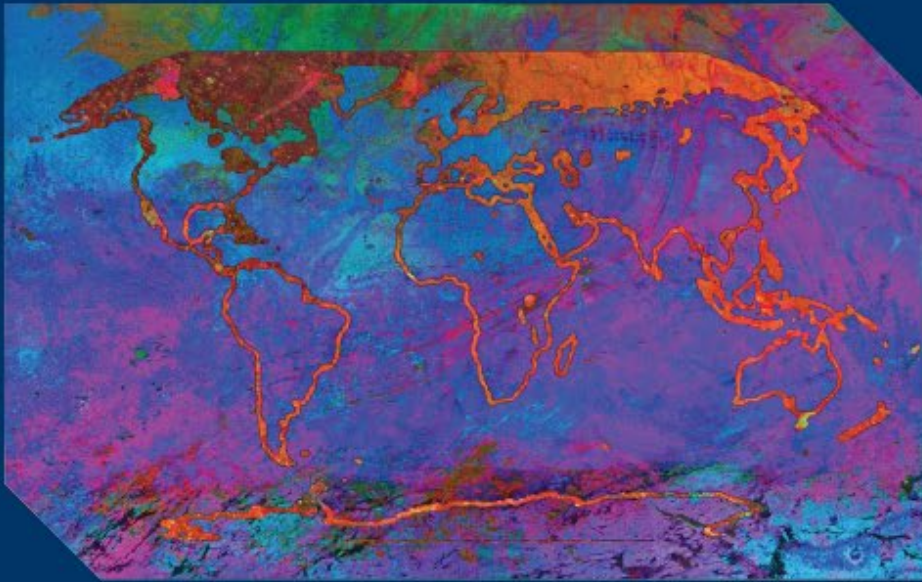


International agreed upon targets of 1.5 to 2 °C require rapid reductions in emissions. starting now.

Getting to Net Zero Emissions by 2050 (or 2060) Means Greatly Reducing Emissions from Burning of Fossil Fuels

Maintain a Sense of Hope

- Our future depends on how we act to limit climate change.
- We also need to be Resilient: Adaptation is not a choice – our choice is whether to adapt proactively or respond to the consequences.
- We can respond to the changing climate while making this into an engine for a winning economy.



“

The climate we experience in the future depends on our decisions now.



Thank you!

We Each Can Be the Difference!

There is Much We Can Do



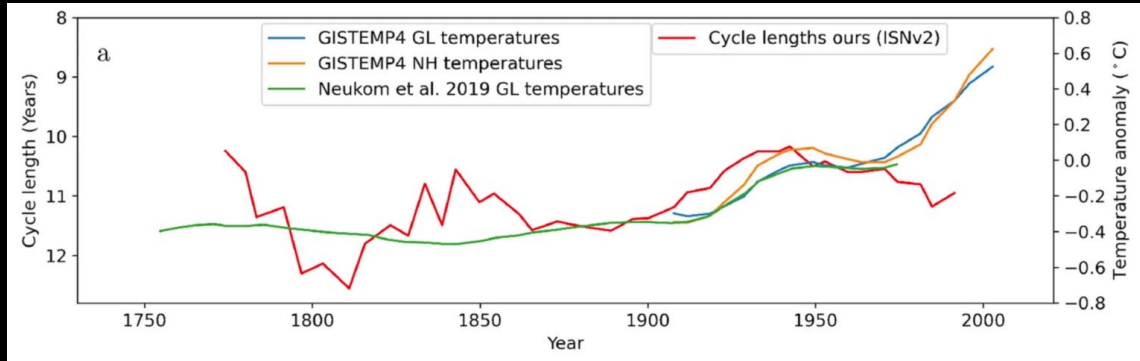
Communicate!!!!

- Speak up!
- Contact your representatives
- Influence friends and family!
- Vote with care

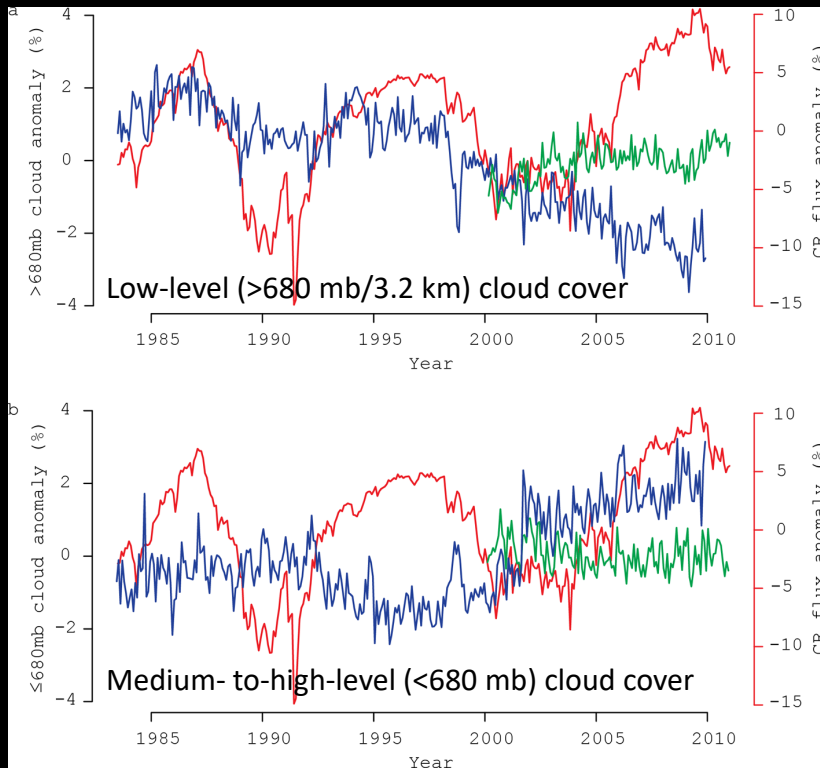
Reduce emissions and adapt

- **Be energy efficient!**
 - Use solar or renewable energy
 - Drive a fuel efficient or electric vehicle
 - Use mass transit, walk, etc.
 - LED light bulbs.
 - Get efficient appliances.
 - Be water efficient

It's Not the Sun!



Chatzistergos (2023):
It's not the length of the solar cycle



Laken et al. (2012):
It's not cosmic rays effects on clouds

Key Mitigation Realities

- Human CO₂ emissions are the biggest piece of the problem (50% and growing)
 - About 85% comes from burning coal, oil, & natural gas (providing >80% of world energy)
 - Most of the rest comes from land use change – e.g., deforestation & burning in the tropics
- Developing countries now exceed industrialized ones in total CO₂ emissions (but not per capita).
- Global energy system can't be changed quickly: ~\$20T is invested in it; normal turnover is ~40 yrs.
- Deforestation trends are not easy to change: embedded in economics of food, fuel, timber, trade, & development.
- Achieving 1.5 °C with little to no overshoot means nearly “net zero” GHG emissions by 2050. And 40-58% by 2030.