Health Impacts of Climate Change

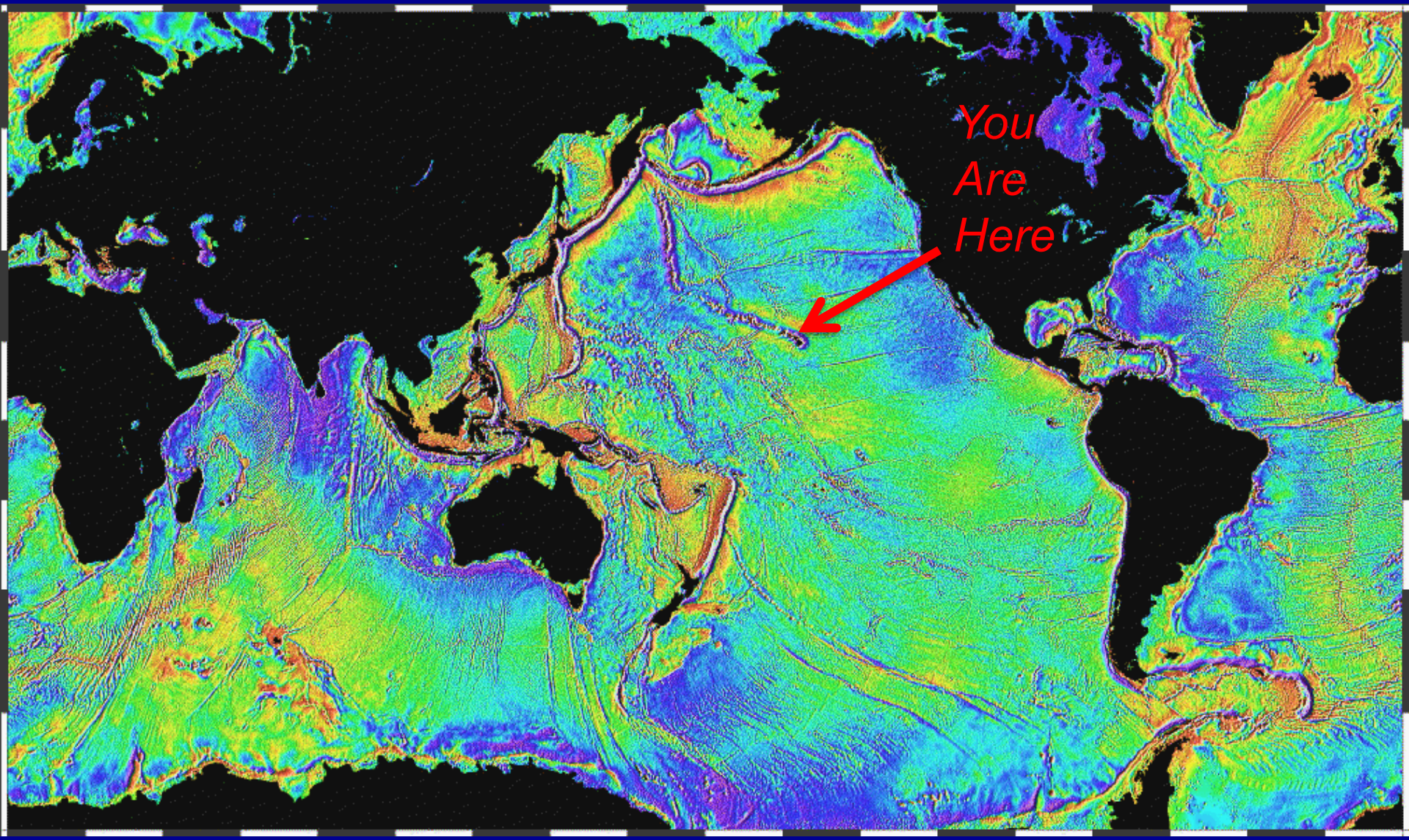
Michael Wysession, Professor of Geophysics
Executive Director, Center for Teaching and Learning
Department of Earth, Environmental, and Planetary Sciences
Washington University, St. Louis, MO
HREM, Oahu, March 10, 2026

Disclosures

I have nothing to disclose


Kilauea Volcano, Hawaii (Big Island) (February, 2026)

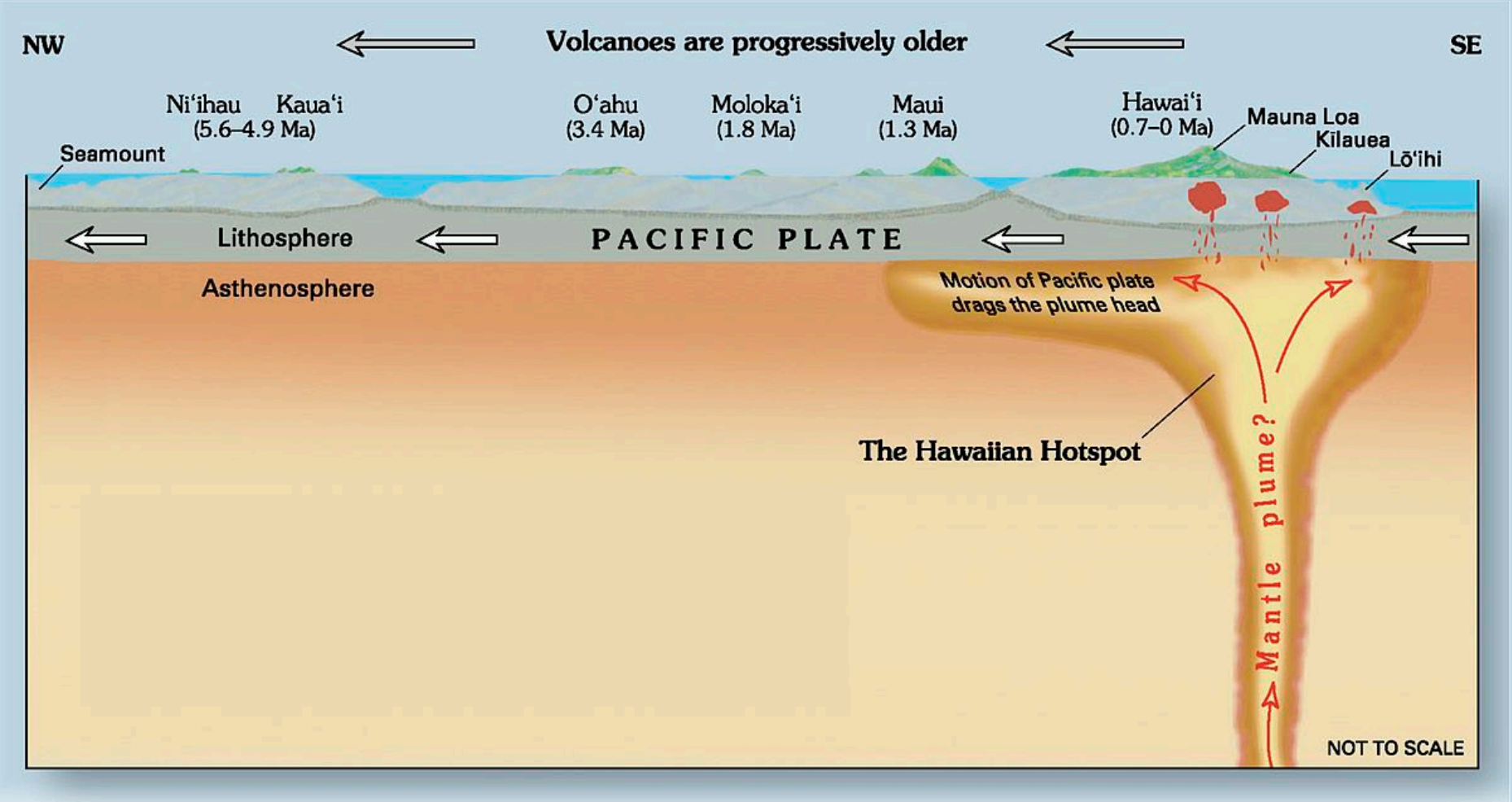
HAWAI'IAN HOTSPOT



Gravity Map, Showing Sea-Floor Bathymetry

HAWAI'IAN HOTSPOT

Hawai'i Sits Over a Mantle Plume of Rising Hot Rock



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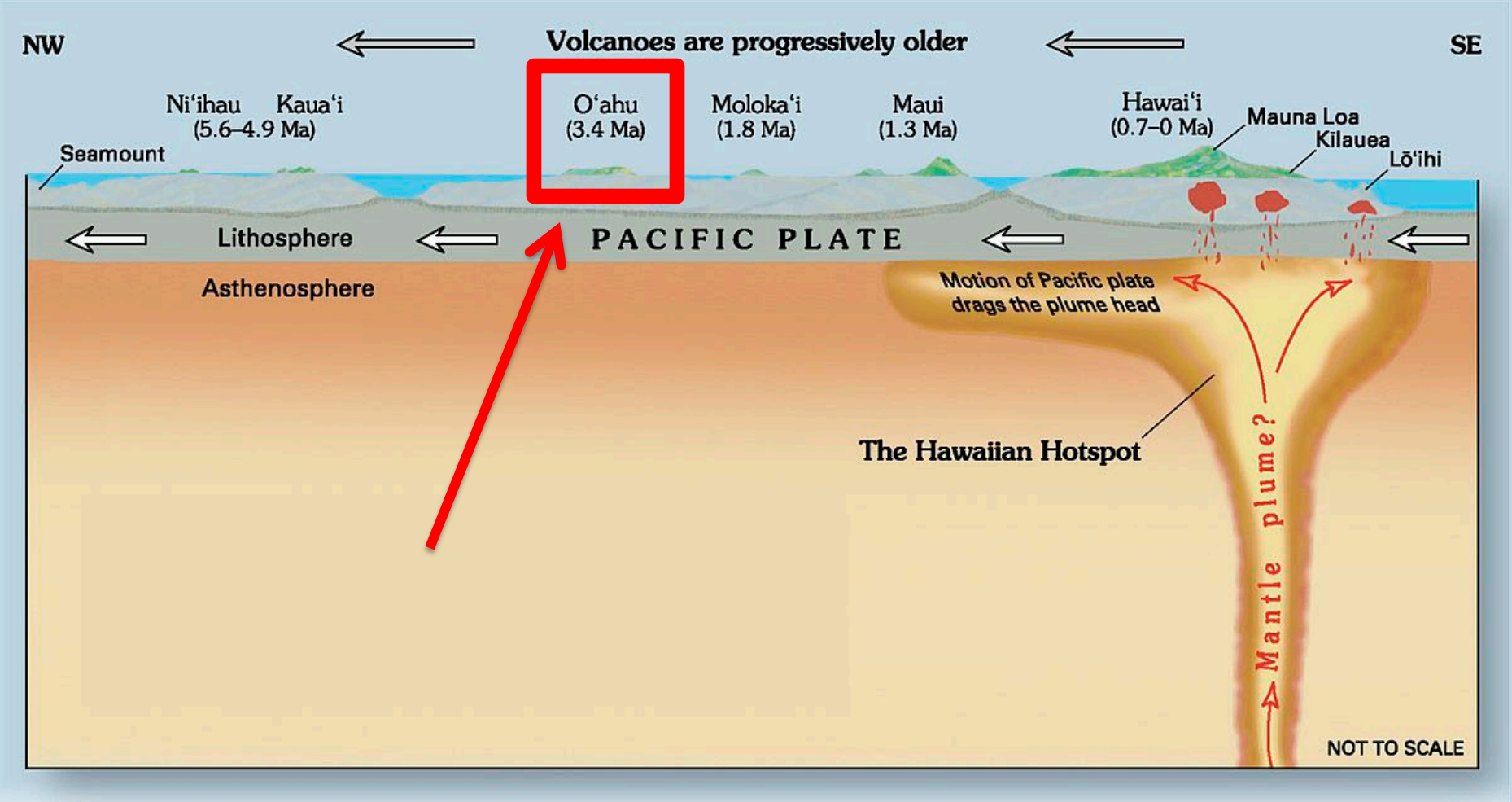
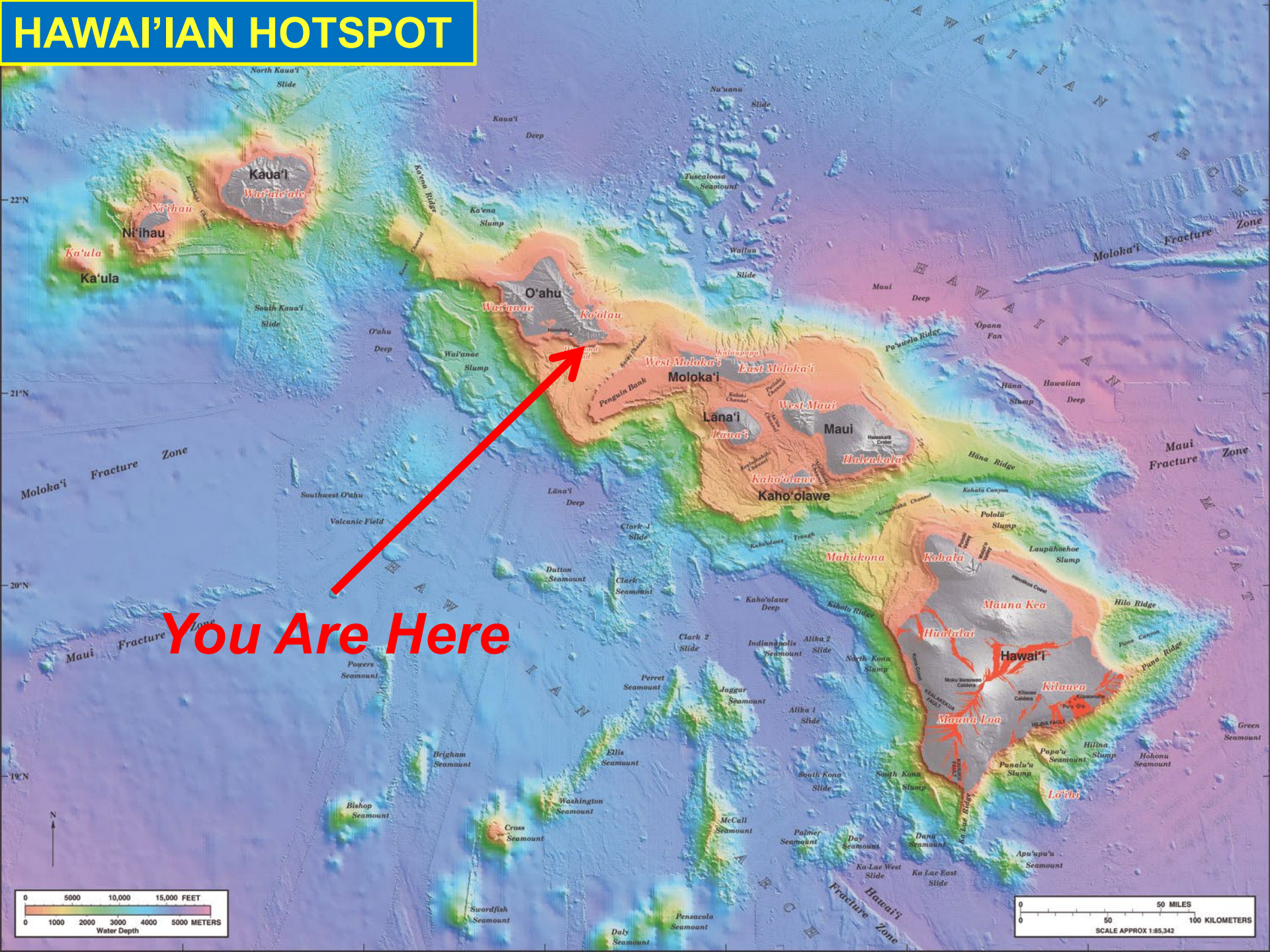
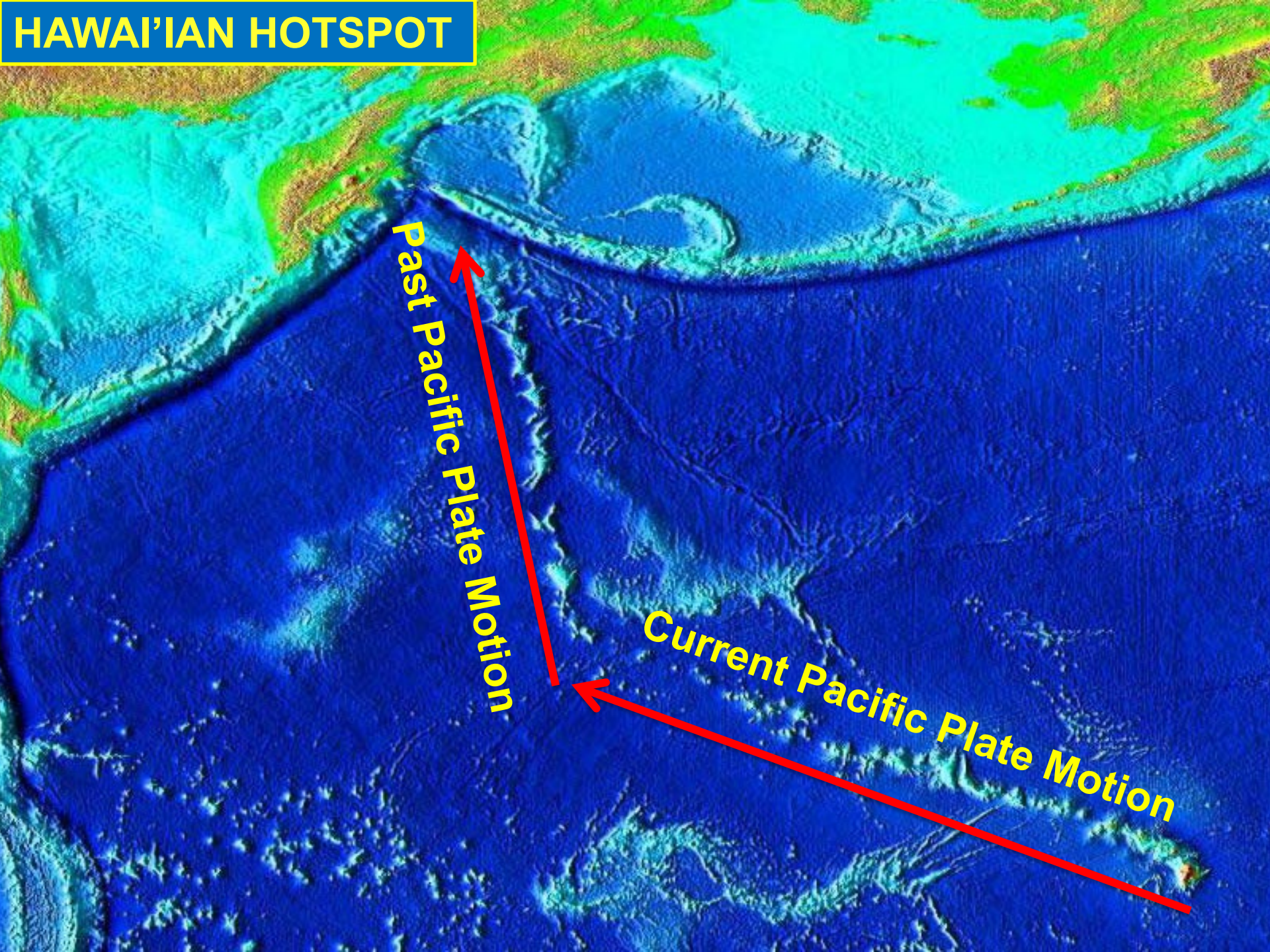
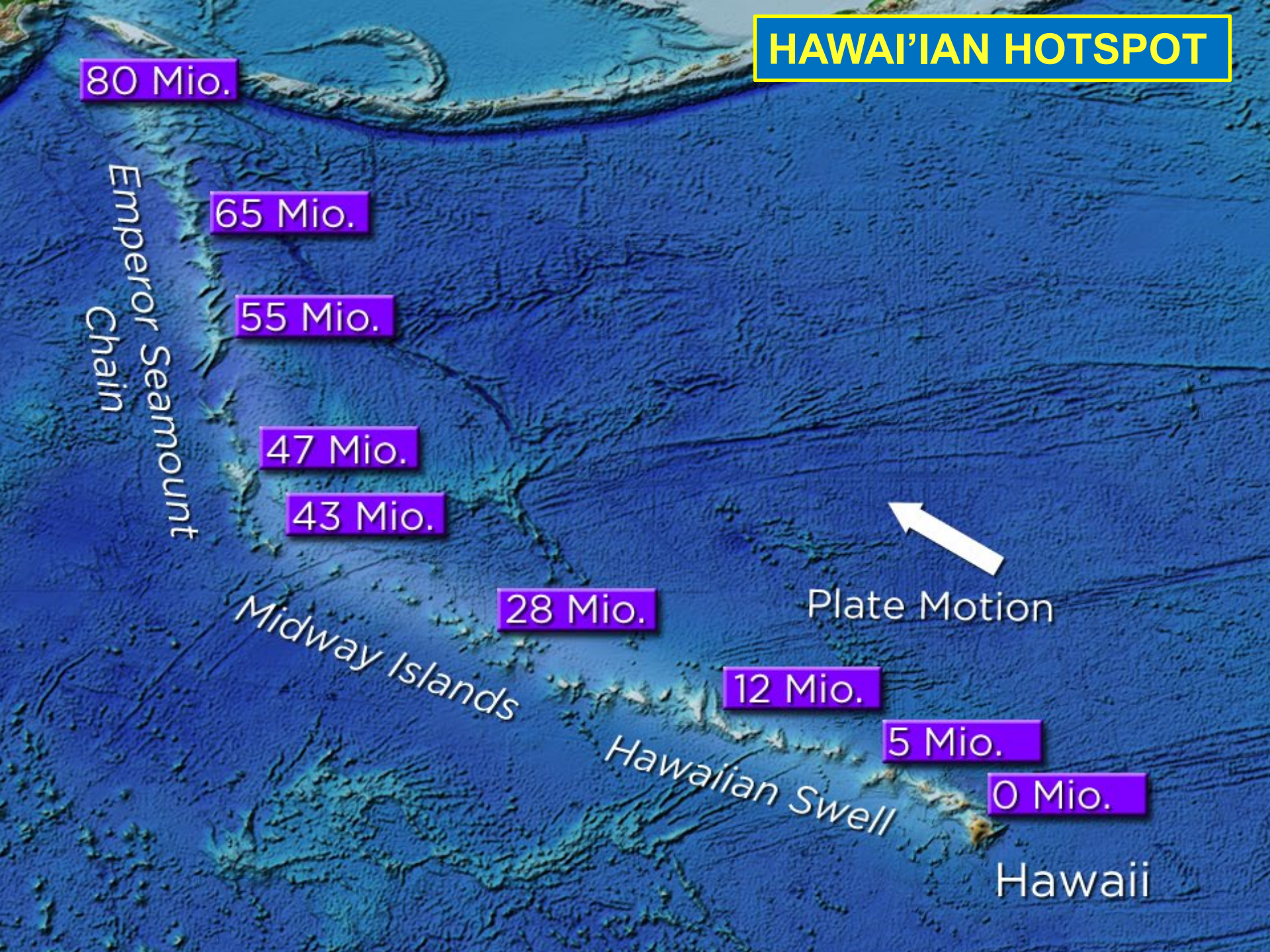


Hawai’ian Islands

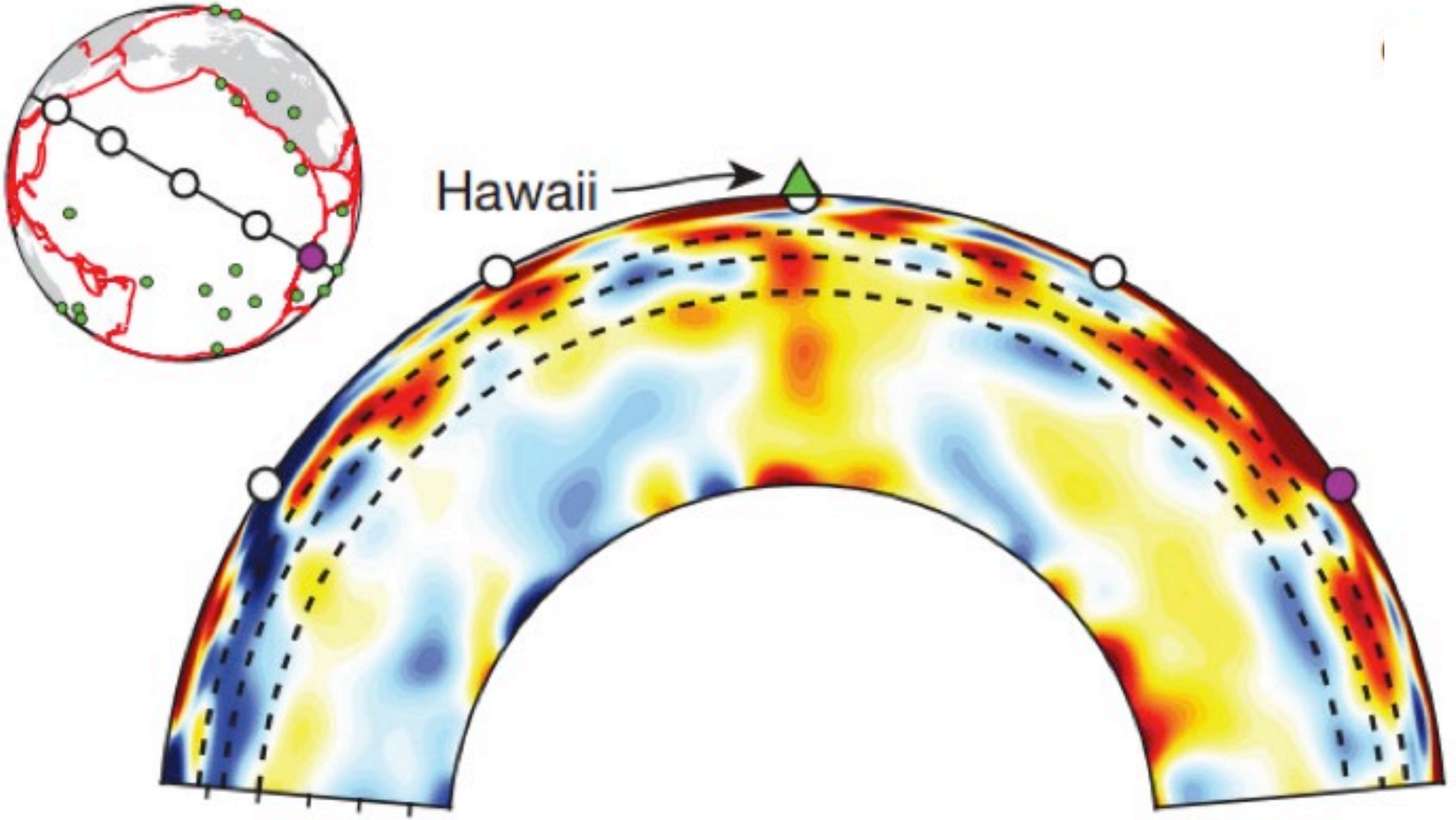
HAWAI'IAN HOTSPOT




HAWAI'IAN HOTSPOT
Past Pacific Plate Motion
Current Pacific Plate Motion


HAWAI'IAN HOTSPOT
80 Mio.
65 Mio.
55 Mio.
47 Mio.
43 Mio.
28 Mio.
12 Mio.
5 Mio.
0 Mio.
Emperor Seamount Chain
Midway Islands
Hawaiian Swell
Plate Motion
Hawaii

SEISMIC TOMOGRAPHY: HAWAI'IAN MANTLE PLUME



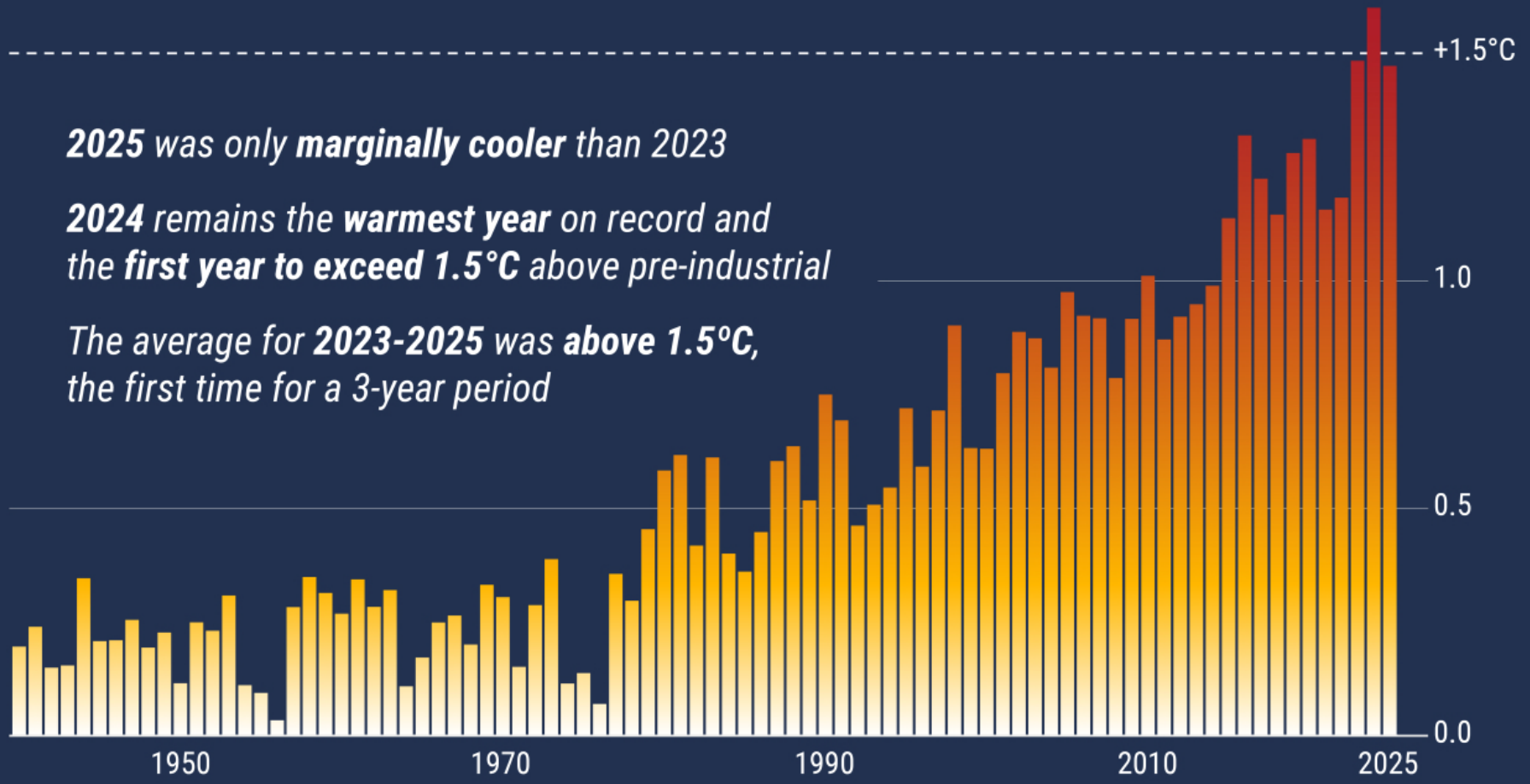

KAIMUKI
Kalani High School
Whole Foods Market
Treat Your Loved Ones
Kapi'olani Community College
WAIALAE - KAHALA
Kāhala Beach
Kāhala Beach Cove
Hunakai Pool Service
Hunakai Park
Hunakai Beach
Diamond Head Memorial Park
Diamond Head State Monument
Kuilei Cliffs
Tracy Wright Corvo Photography
Hawaiian Style Cooking Classes
Shangri La Museum of Islamic Art, Culture...
Diamond Head Road Vista Point
Kaalawai Beach
Diamond Head Rd
Kilauea Ave
Pāhoa Ave
Harding Ave
Kaimuki Ave
Maunaloa Ave
Waialae Ave
Kahala Ave
Aukai Ave
Monsarrat Ave
Wauke St
Hayden St
Edna St
Huanui St
Iiwi St
Kolohala St
Ulili St
Elepaio St
Puu Panini Ave
Luawai St
Hunakai St
Pueo St
Kealaolu Ave
Moa St
Farmers Rd
Waiholo St
Waiiki St
Laukahi St
Sunset Ave
Ocean View Dr
Alohea Ave
Kanaina Ave
Martha St
Herbert St
Castle St
Brokaw St
Catherine St
Duval St
Esther St
Francis St
Kaina St
Hinano St
Makini St
Kaunaoa St
Hōlei St
8th Ave
9th Ave
10th Ave
12th Ave
14th Ave
15th Ave
17th Ave
18th Ave
20th Ave
22nd Ave
H1
72
You Are Here
Google Maps

Diamond Head

- Oahu Age: ~3.4 billion years
- Diamond Head volcanism: ~200,000-150,000 years
- Most recent Oahu volcanism: ~30,000 years

2025 was the third-warmest year on record

Global annual surface air temperature increase above pre-industrial level since 1940



***2025** was only **marginally cooler** than 2023*

***2024** remains the **warmest year** on record and the **first year to exceed 1.5°C** above pre-industrial*

*The average for **2023-2025** was **above 1.5°C**, the first time for a 3-year period*

Data: ERA5 • Reference period: pre-industrial (1850–1900) • Credit: C3S/ECMWF

PROGRAMME OF THE EUROPEAN UNION

Copernicus Europe's eyes on Earth

Climate Change Service

IMPLEMENTED BY ECMWF

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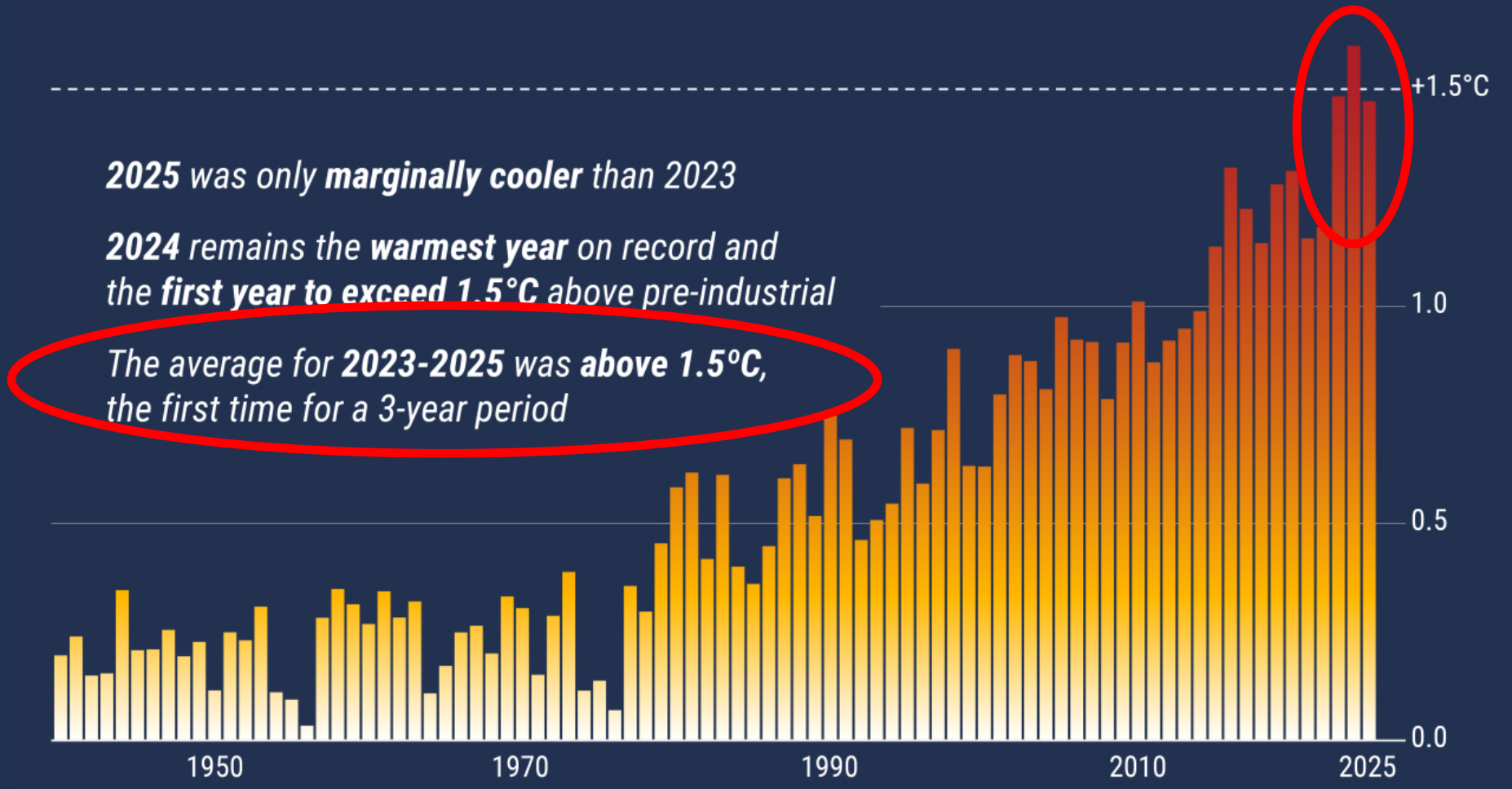

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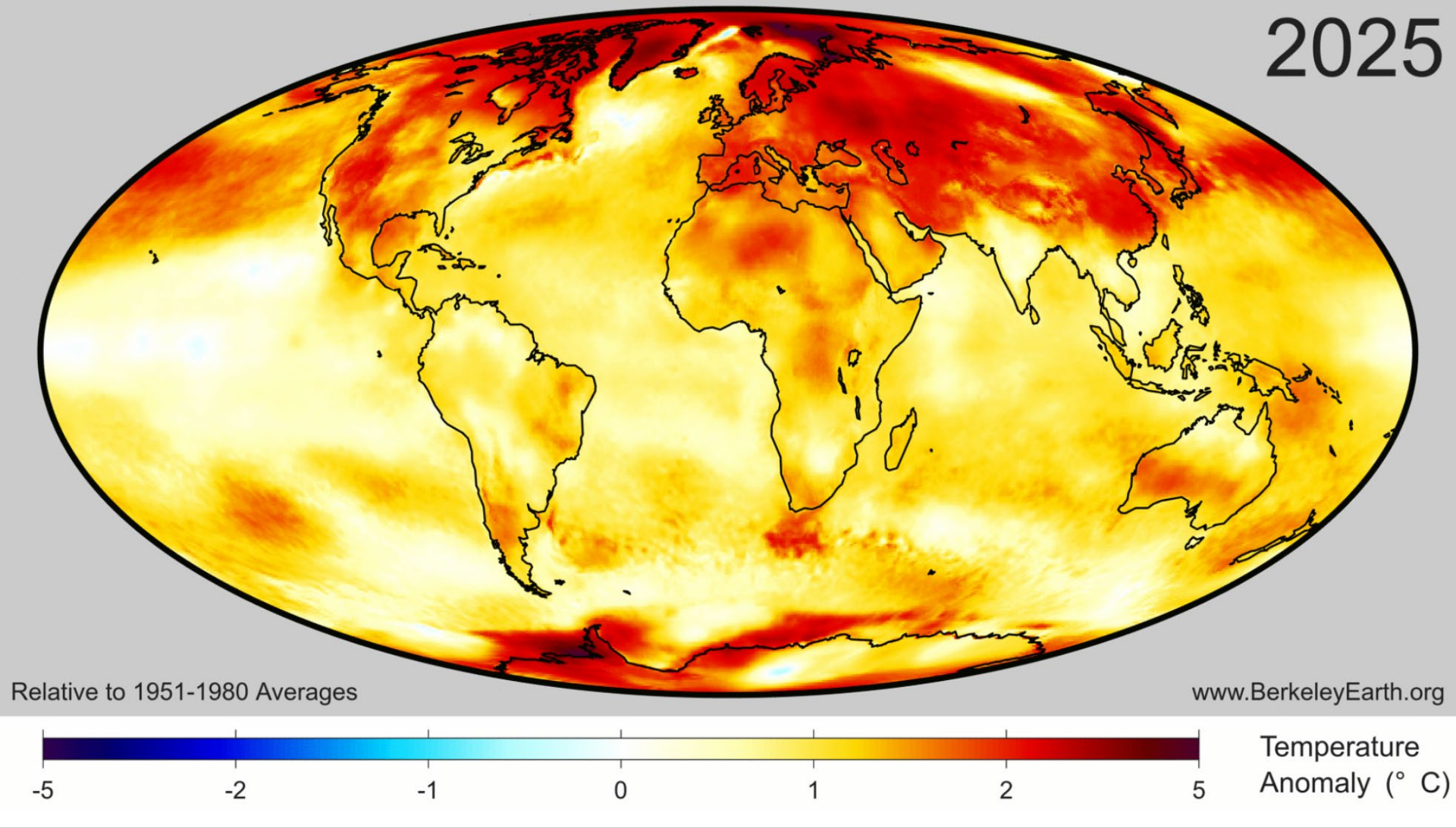
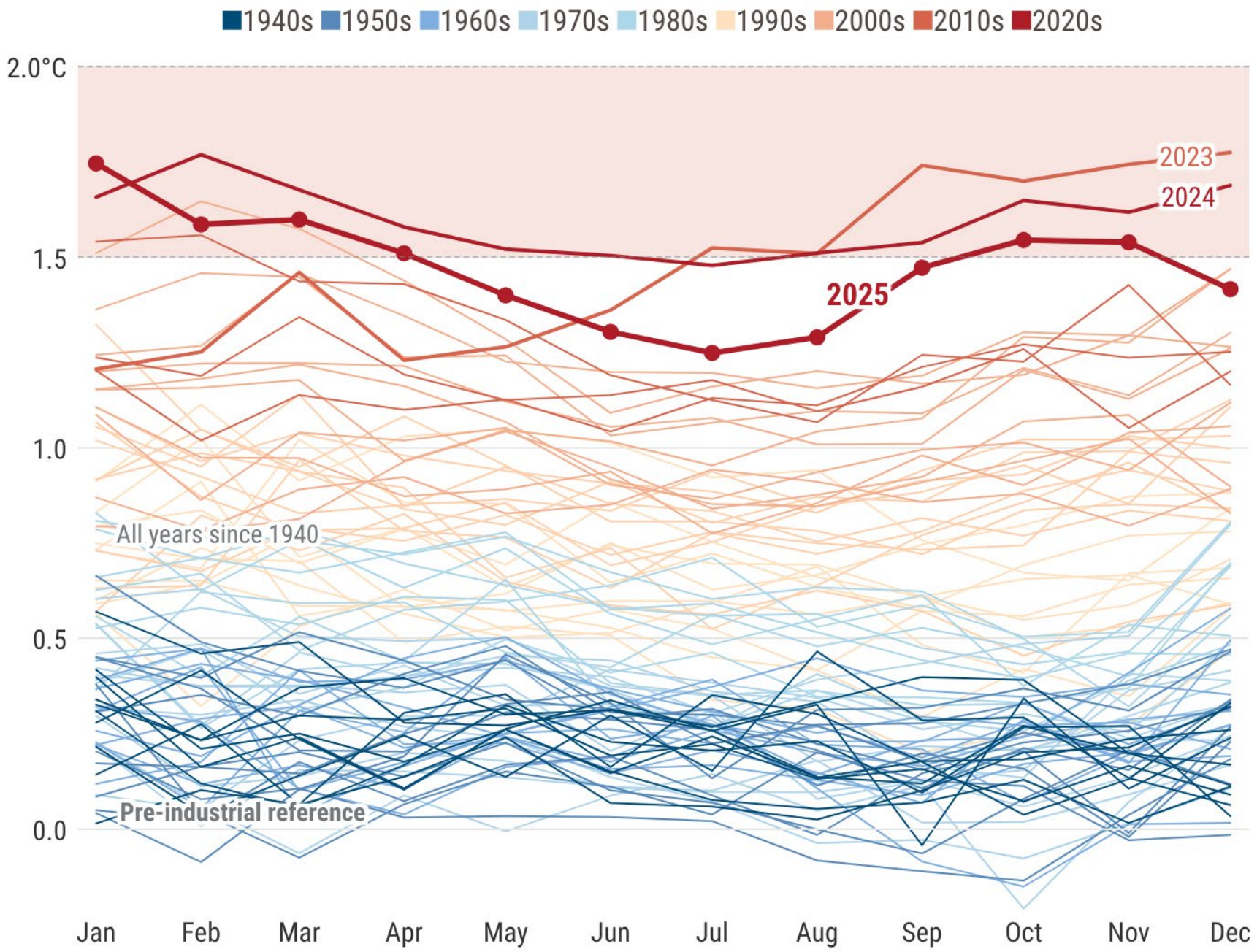
IMPLEMENTED BY ECMWF

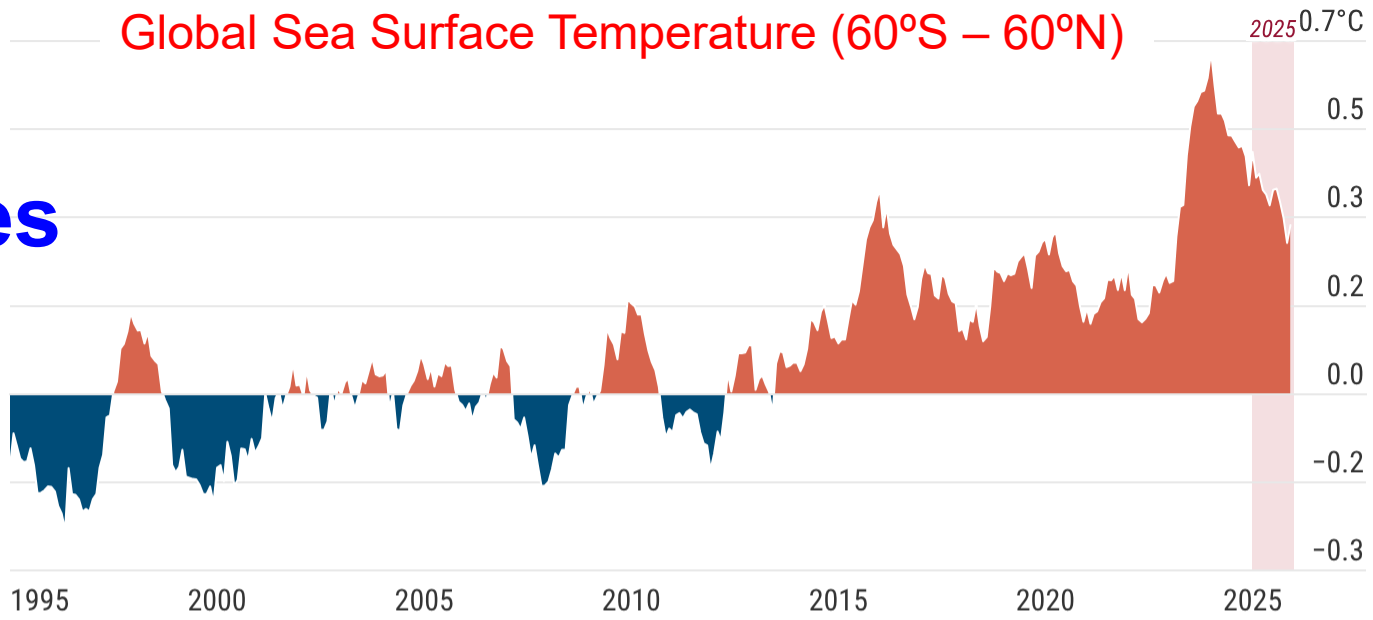
Land Temperatures Increase About 2x Faster than Ocean Surface Temperatures

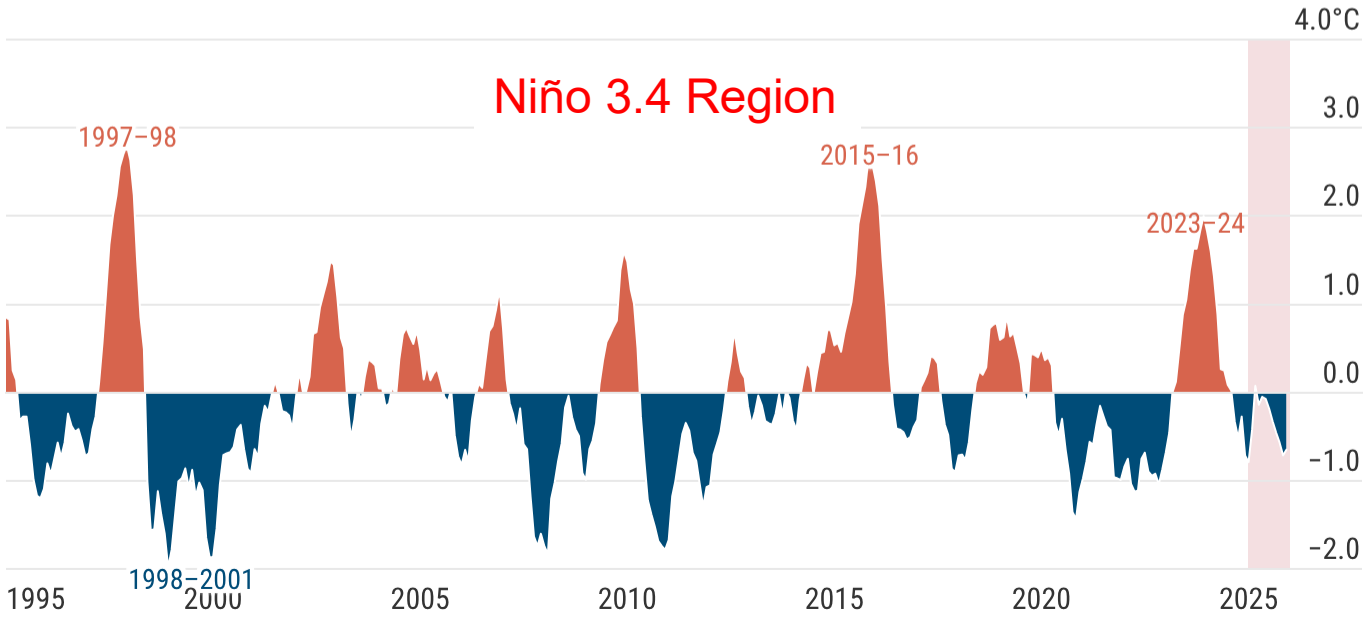


2025 was Cooler than 2023/2024, but not by Much

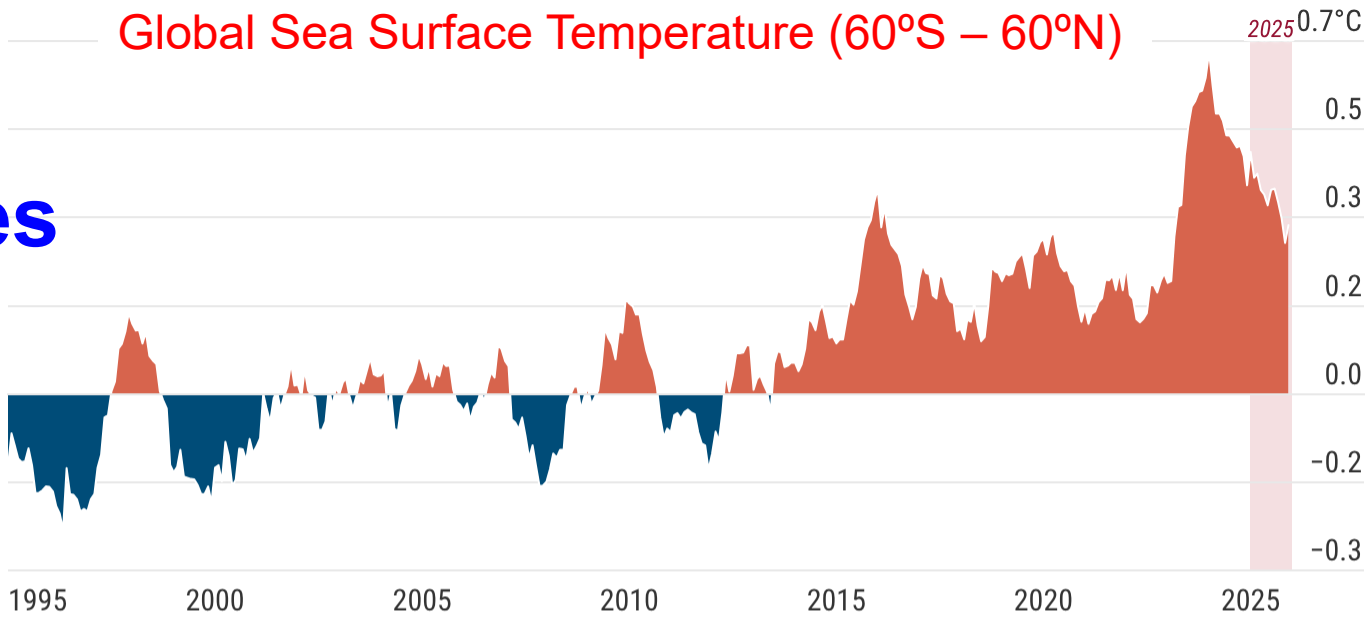


Ocean Surface Temperatures

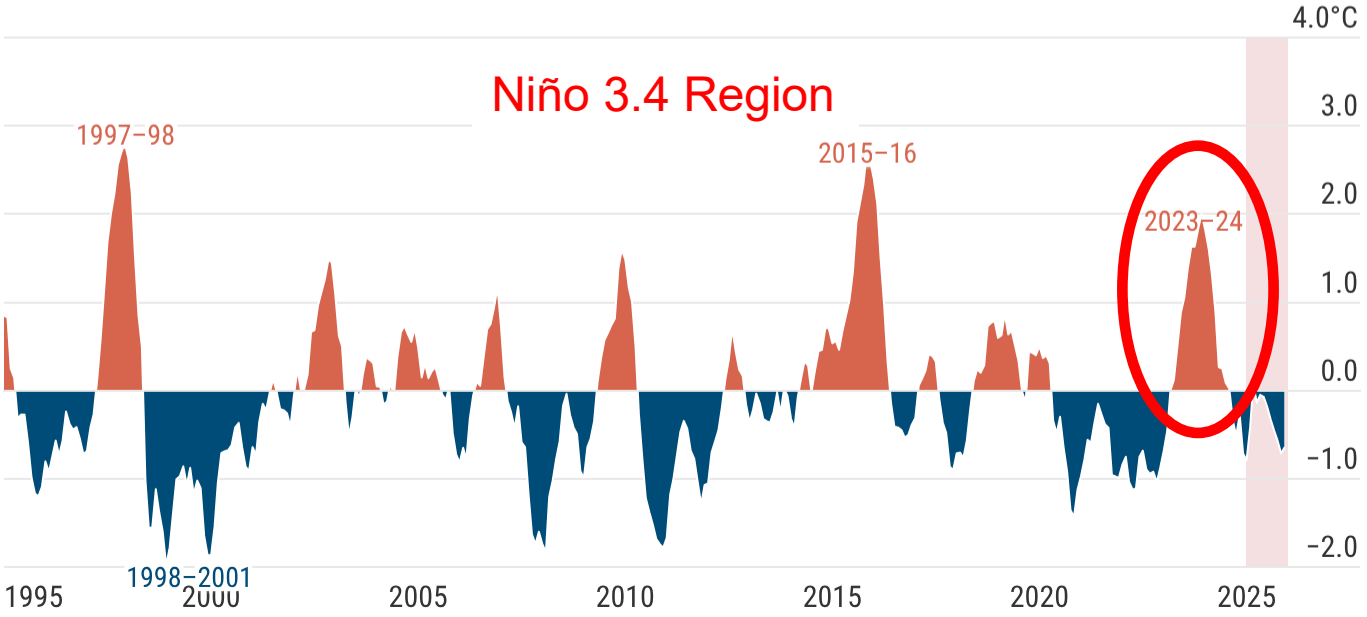




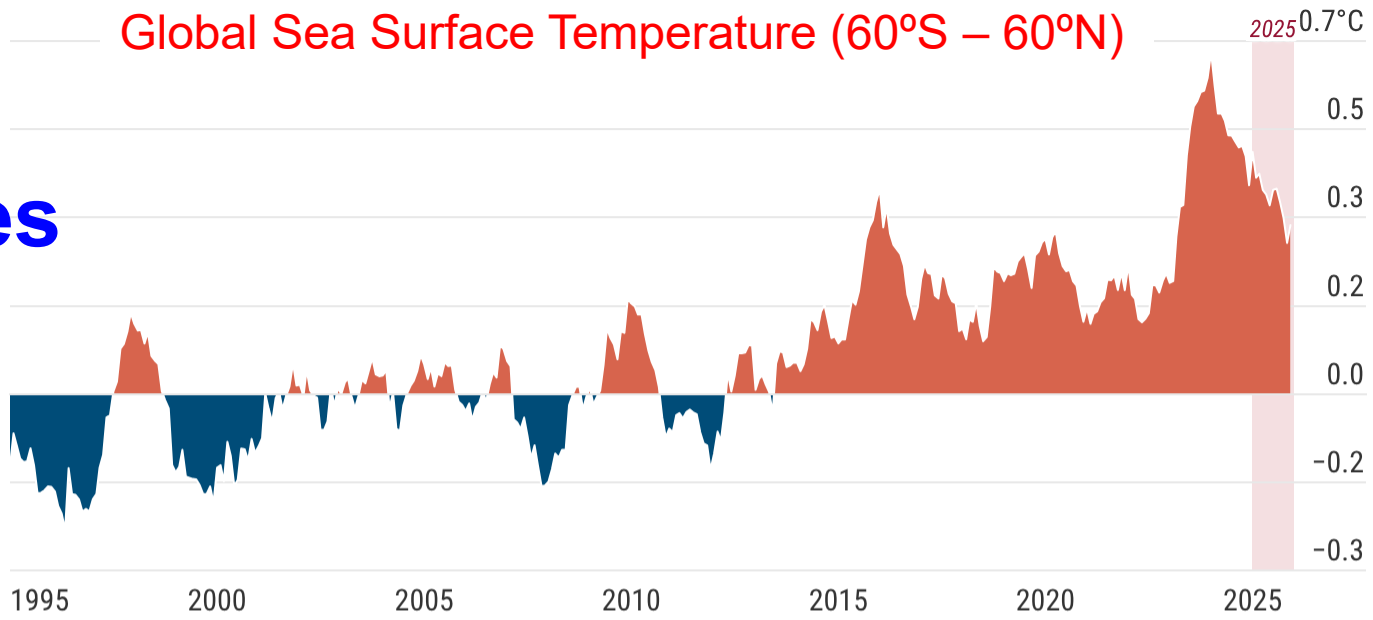
Ocean Surface Temperatures

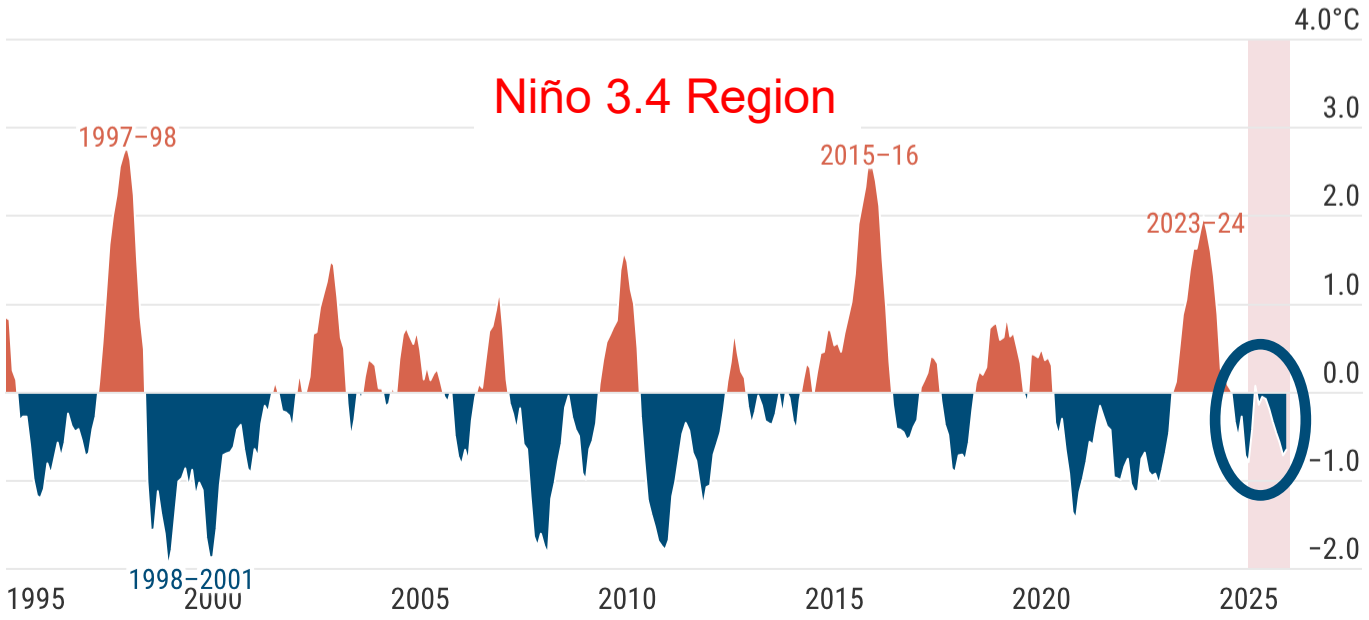


2023-2024: A Pacific *El Niño*



Ocean Surface Temperatures





2025: A Pacific *La Niña*

The Solar Cycle Peaked in 2024

SPACE WEATHER PREDICTION CENTER
NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION

Wednesday, January 28, 2026 20:36:22 UTC

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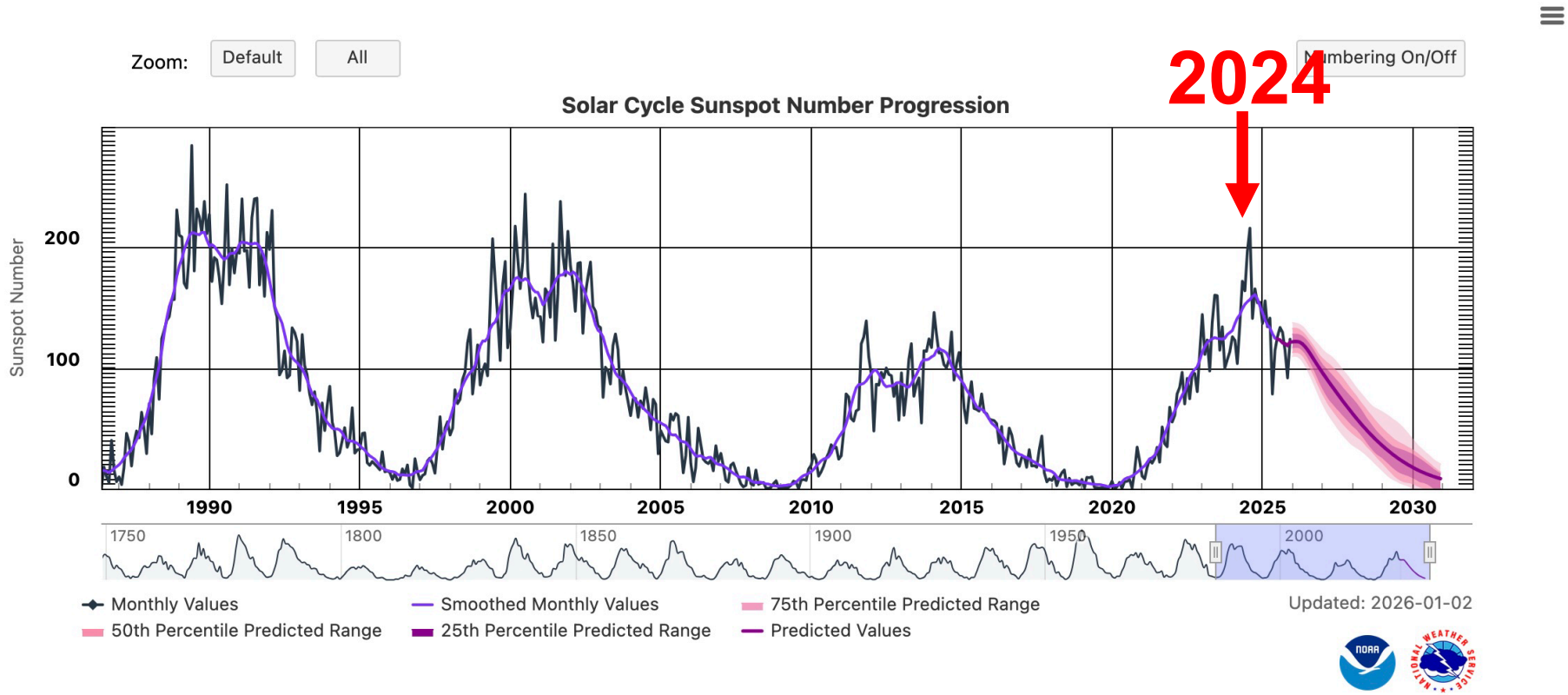
Home > Products and Data > Forecasts > Solar Cycle Progression

CURRENT SPACE WEATHER CONDITIONS on NOAA Scales

R none | S none | G none

SOLAR CYCLE PROGRESSION



Add/Remove Series...

The Solar Cycle Peaked in 2024: Drop in 2025

SPACE WEATHER PREDICTION CENTER
NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION

Wednesday, January 28, 2026 20:36:22 UTC

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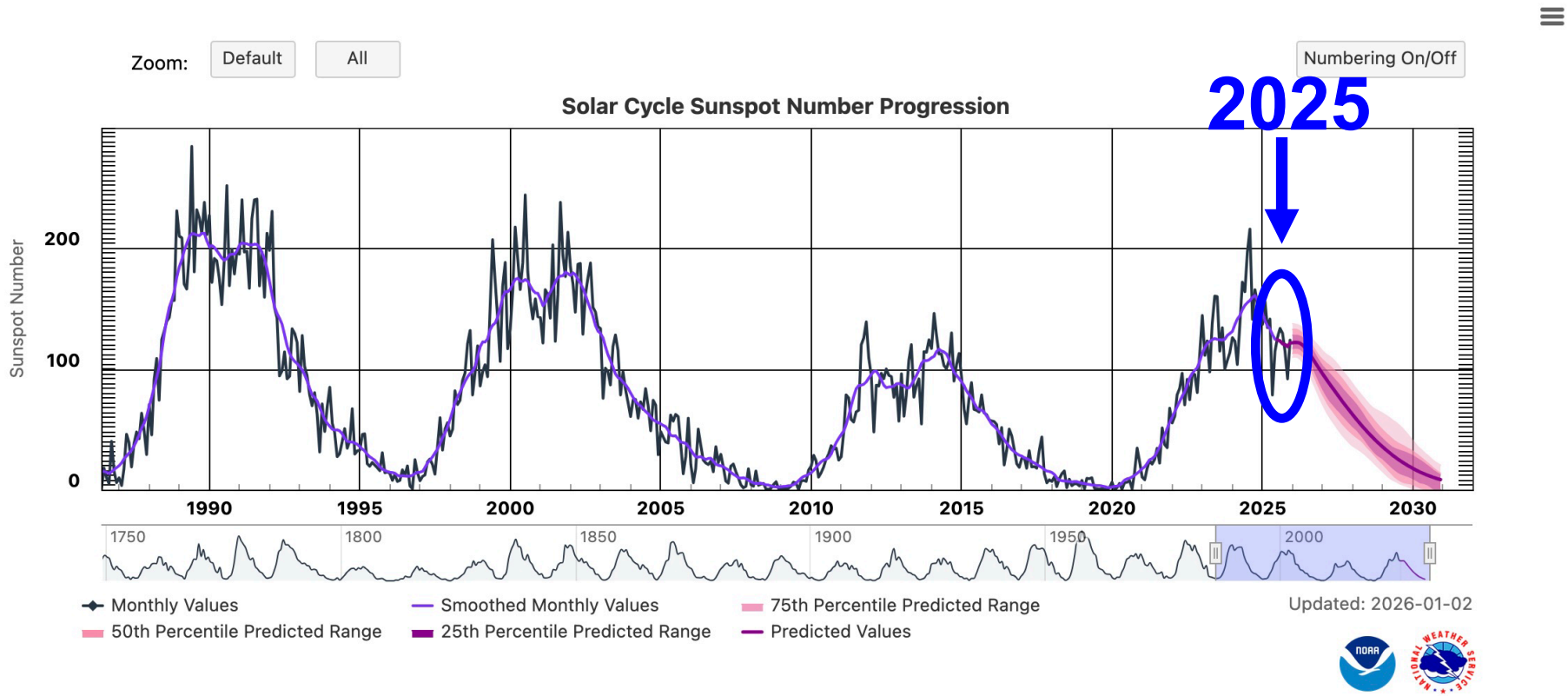
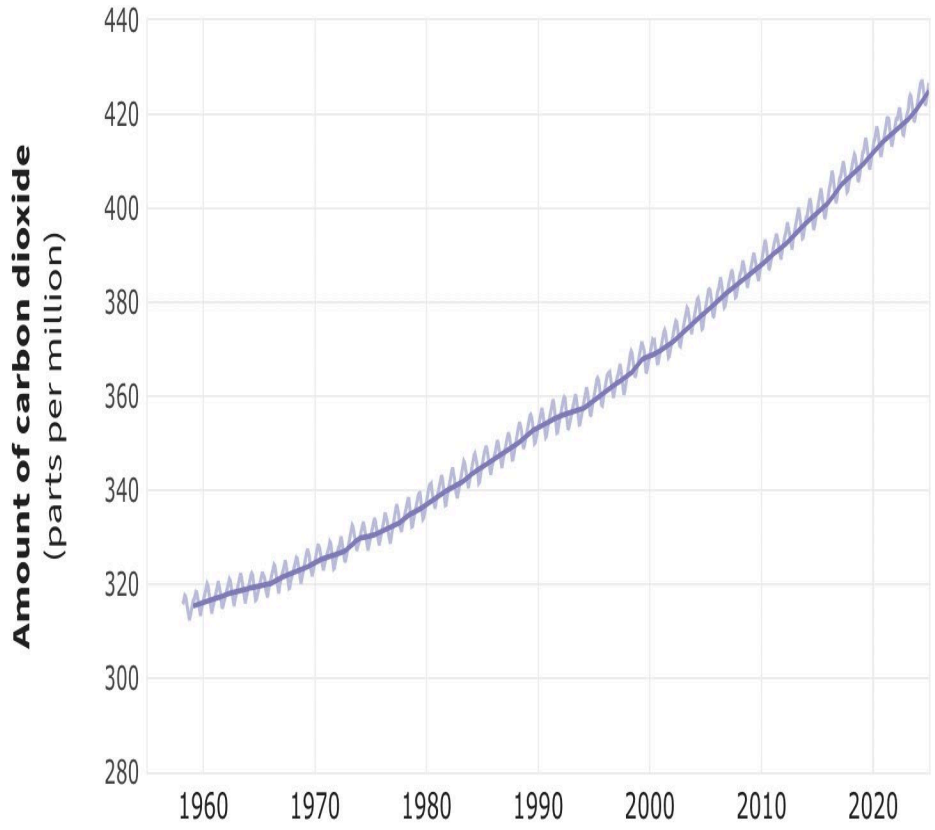
SOLAR CYCLE PROGRESSION



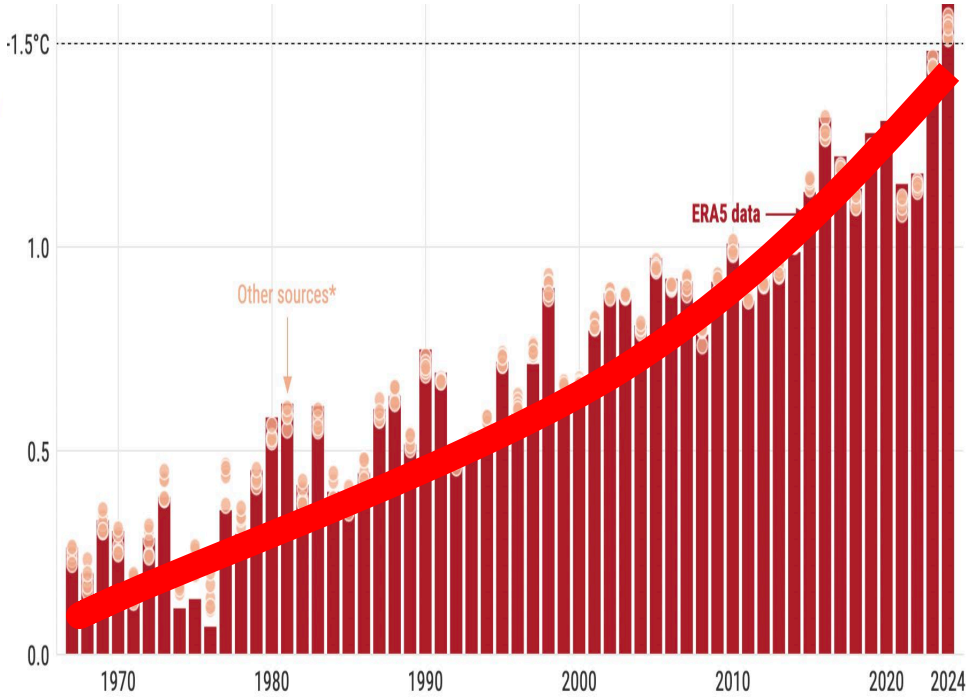
Add/Remove Series...

The Global Temperature Increase Tracks the Increase in Atmospheric Carbon Dioxide

ATMOSPHERIC CARBON DIOXIDE



GLOBAL MEAN TEMPERATURE



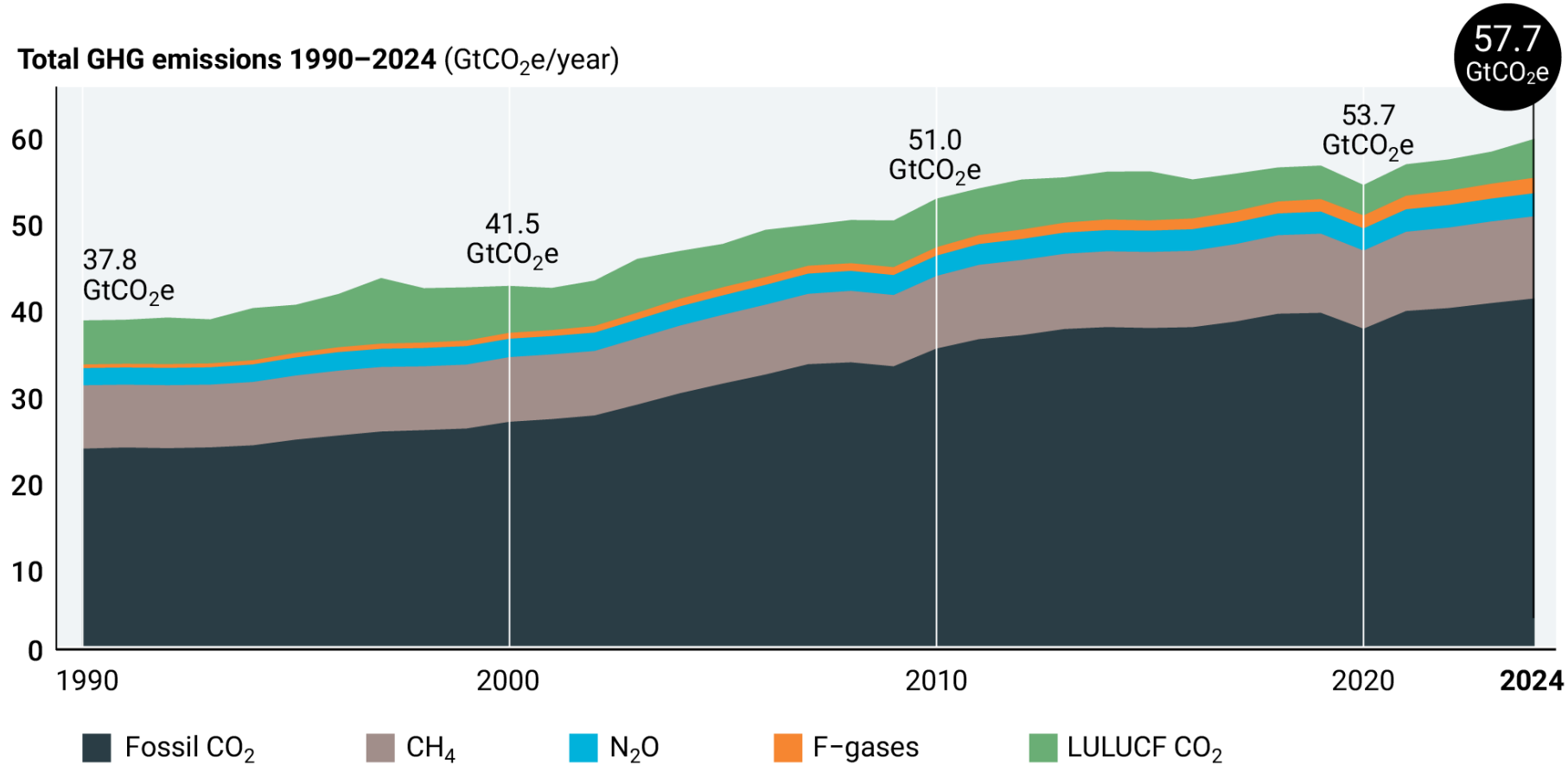
PROGRAMME OF THE EUROPEAN UNION

Copernicus Europe's eyes on Earth

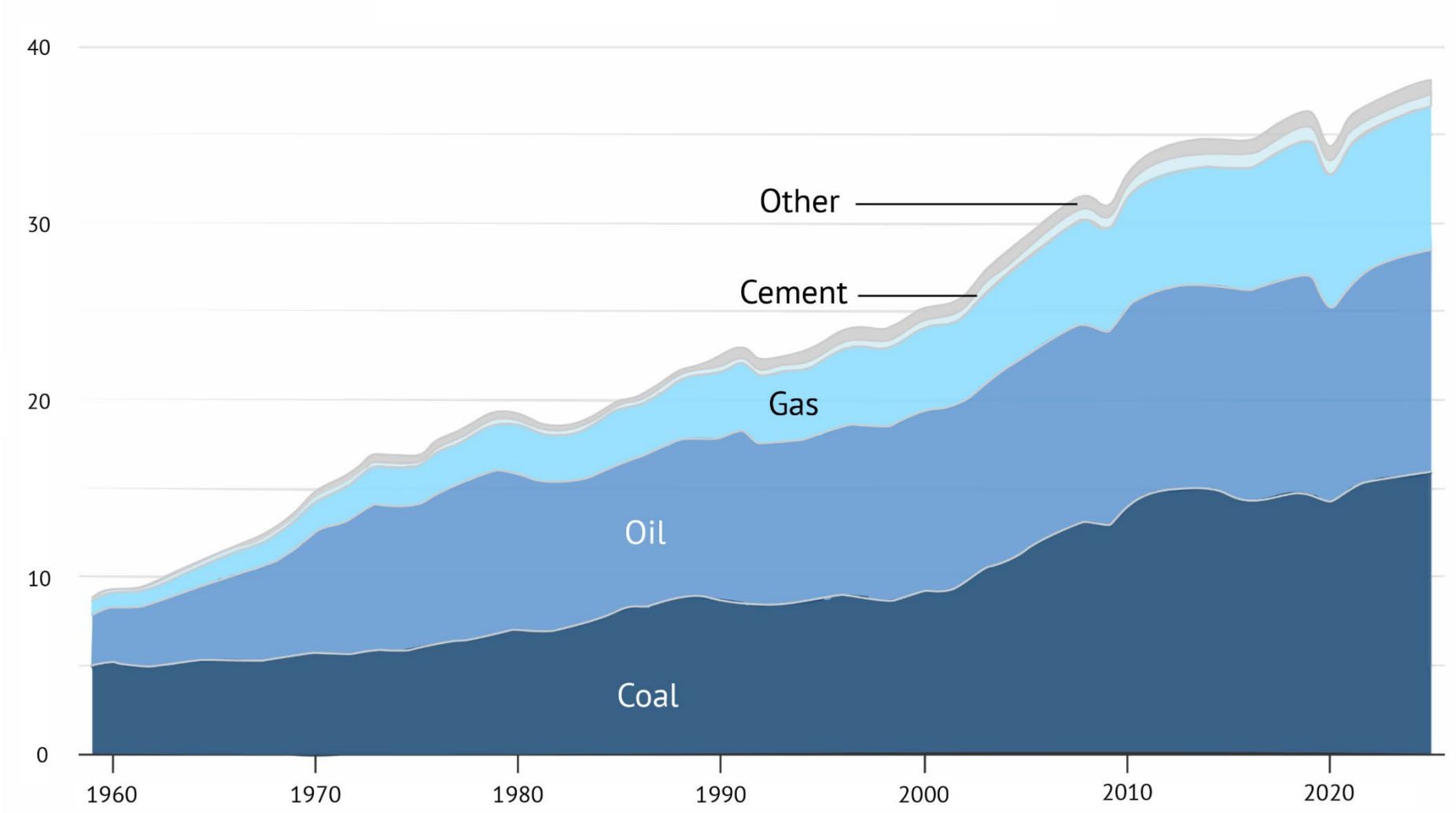
ECMWF

Climate Change Service
climate.copernicus.eu

Anthropogenic Greenhouse Gas Emissions Continue to *Rise*, Despite All the Talk



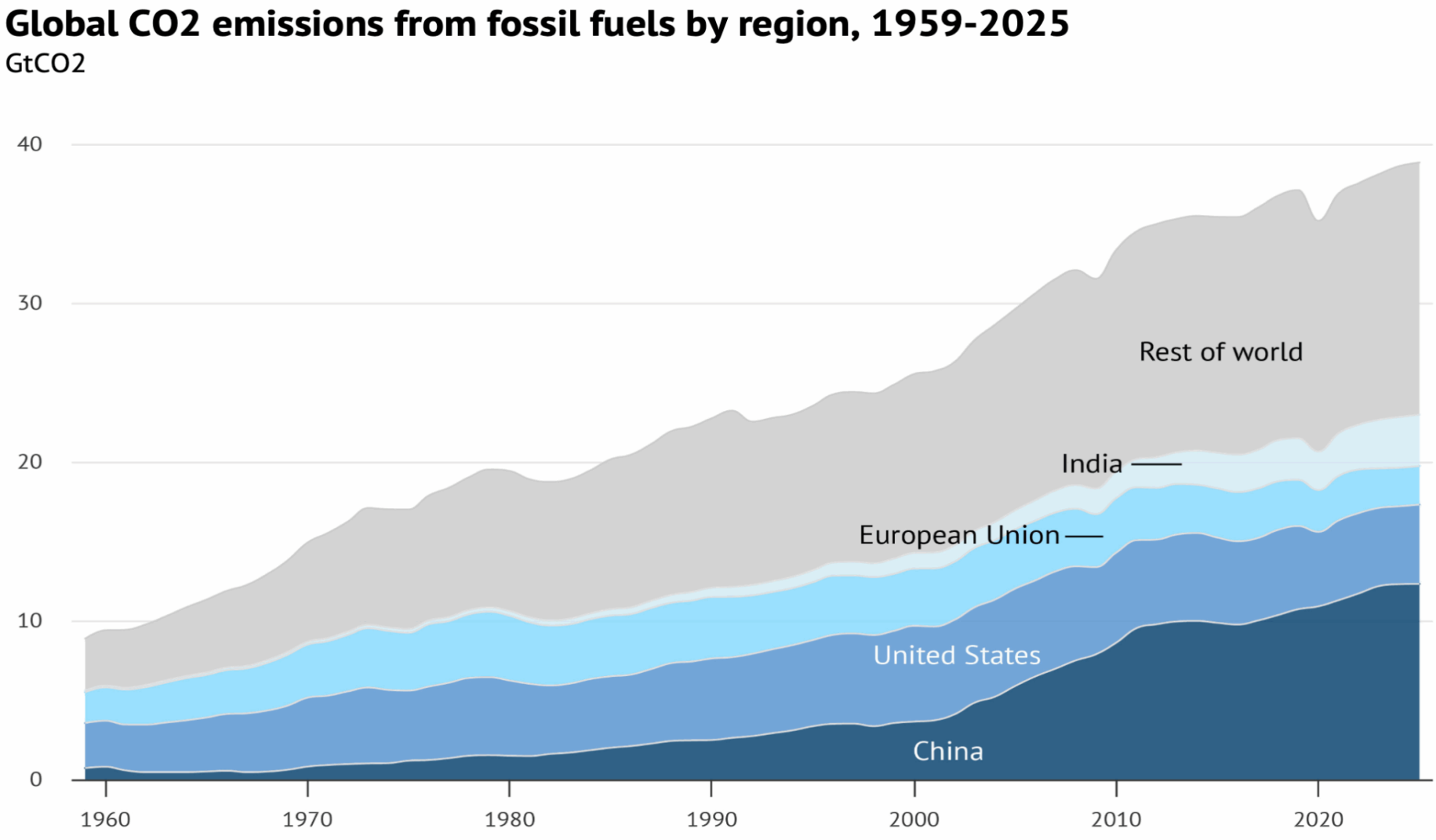
1959 – 2025: Annual Greenhouse Gas Emissions by Source (Billion Tons per Year)



Source: Global Carbon Project

CarbonBrief
CLEAR ON CLIMATE

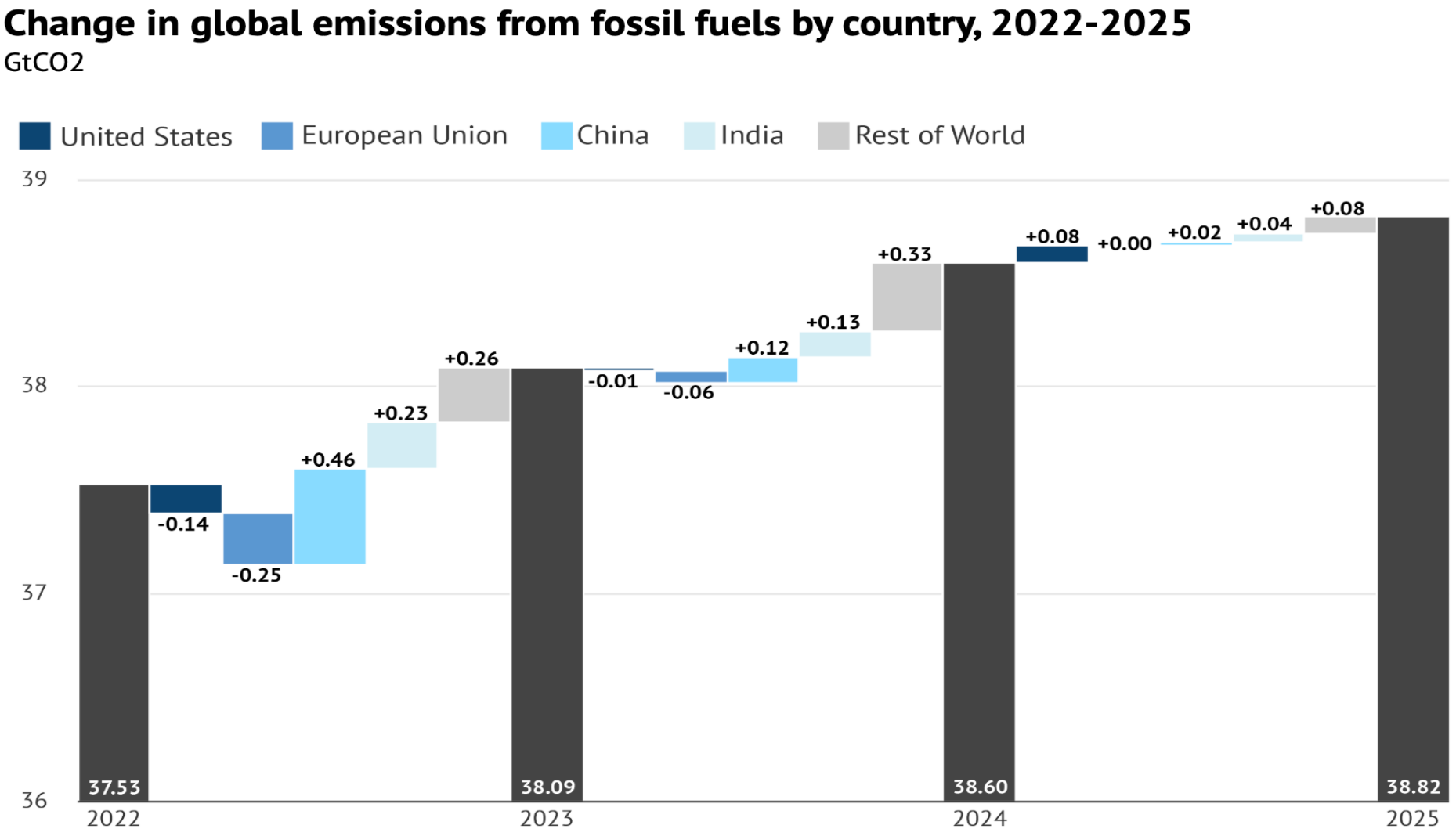
The United States is Not the Major Contributor to Global CO_2 Emissions….



Source: Global Carbon Project

CarbonBrief
CLEAR ON CLIMATE

….but Accounted for More than 1/3 of the CO_2 Increase in 2025

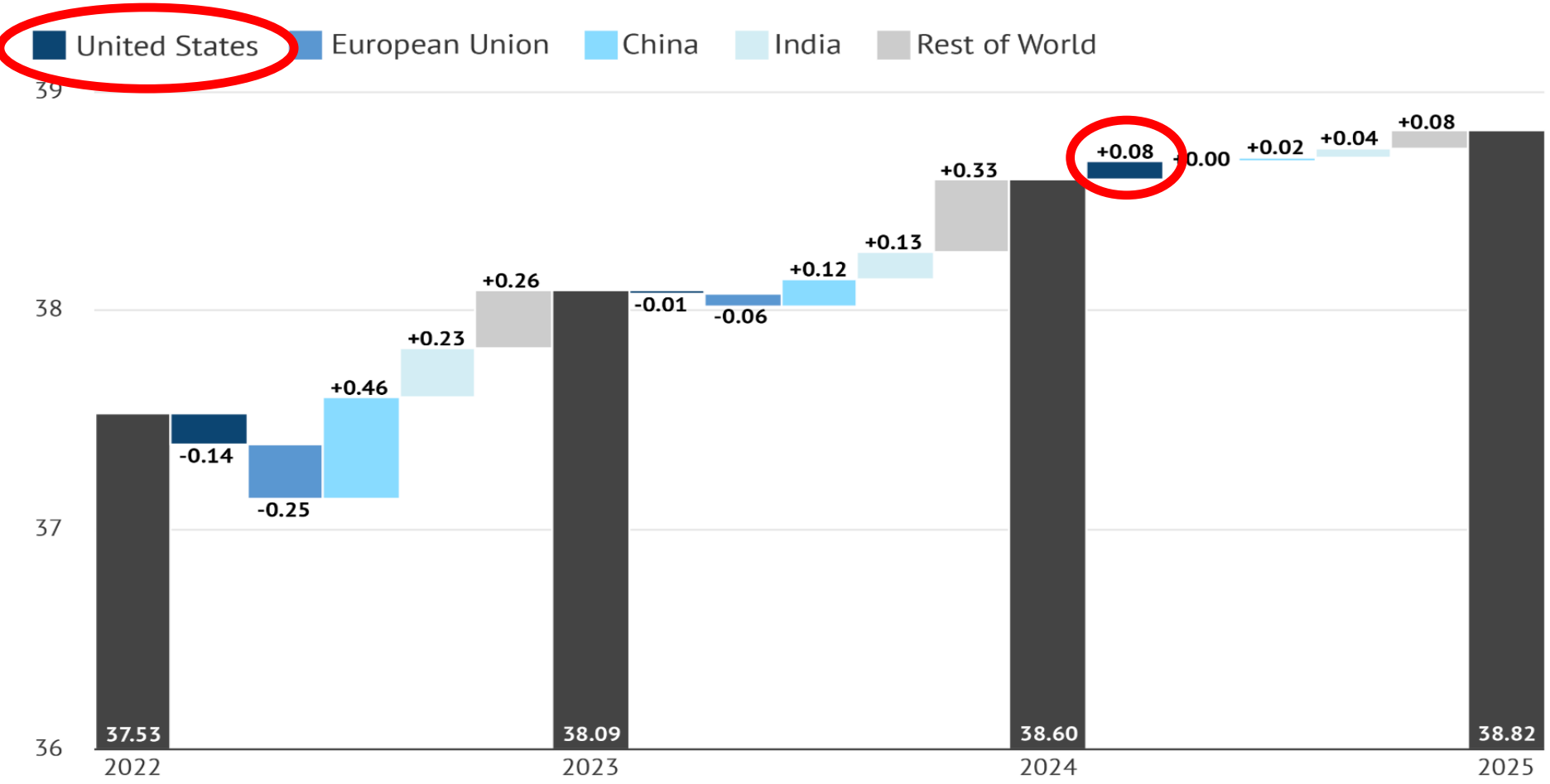


….but Accounted for More than 1/3 of the CO_2 Increase in 2025

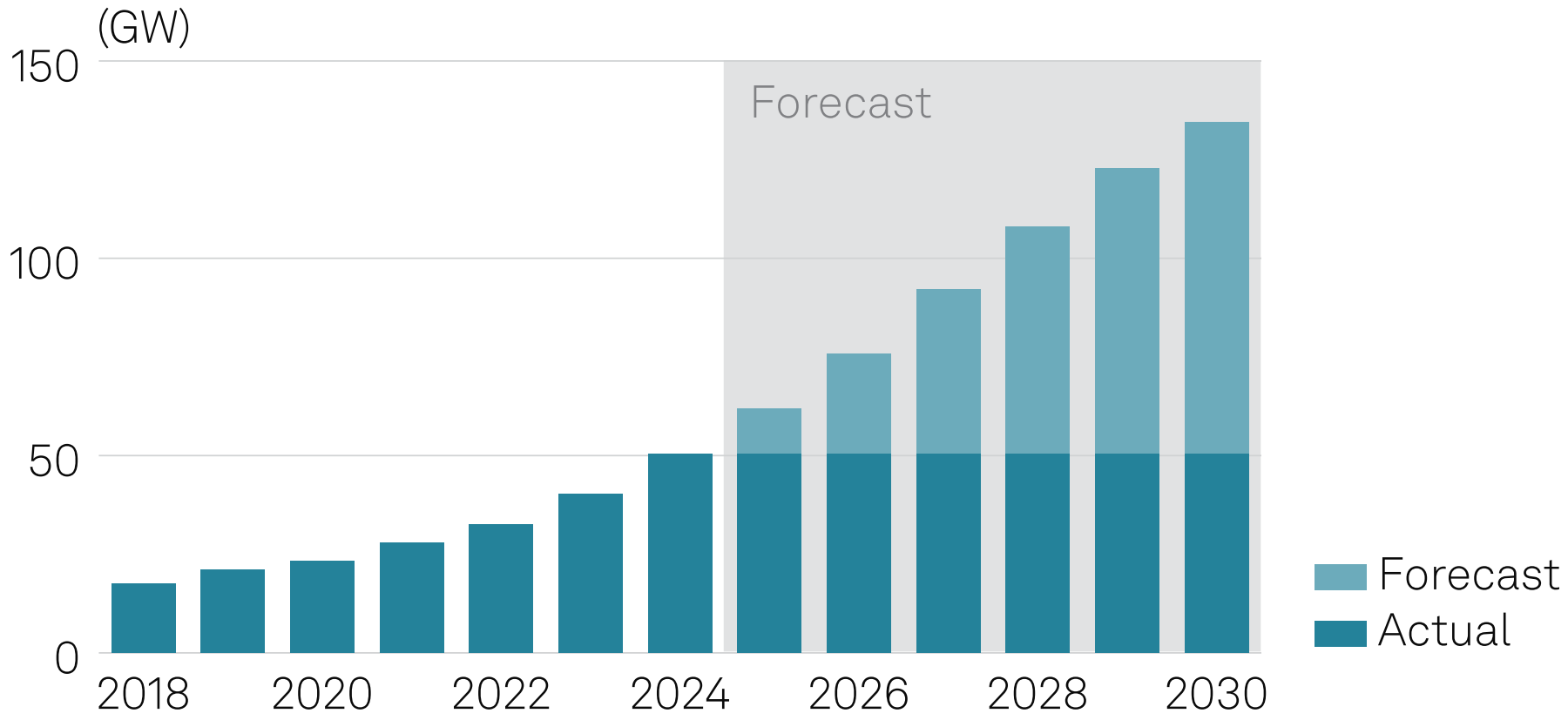
→ *A 2.4% Increase in U.S. CO_2 Emissions*

Change in global emissions from fossil fuels by country, 2022-2025

GtCO2



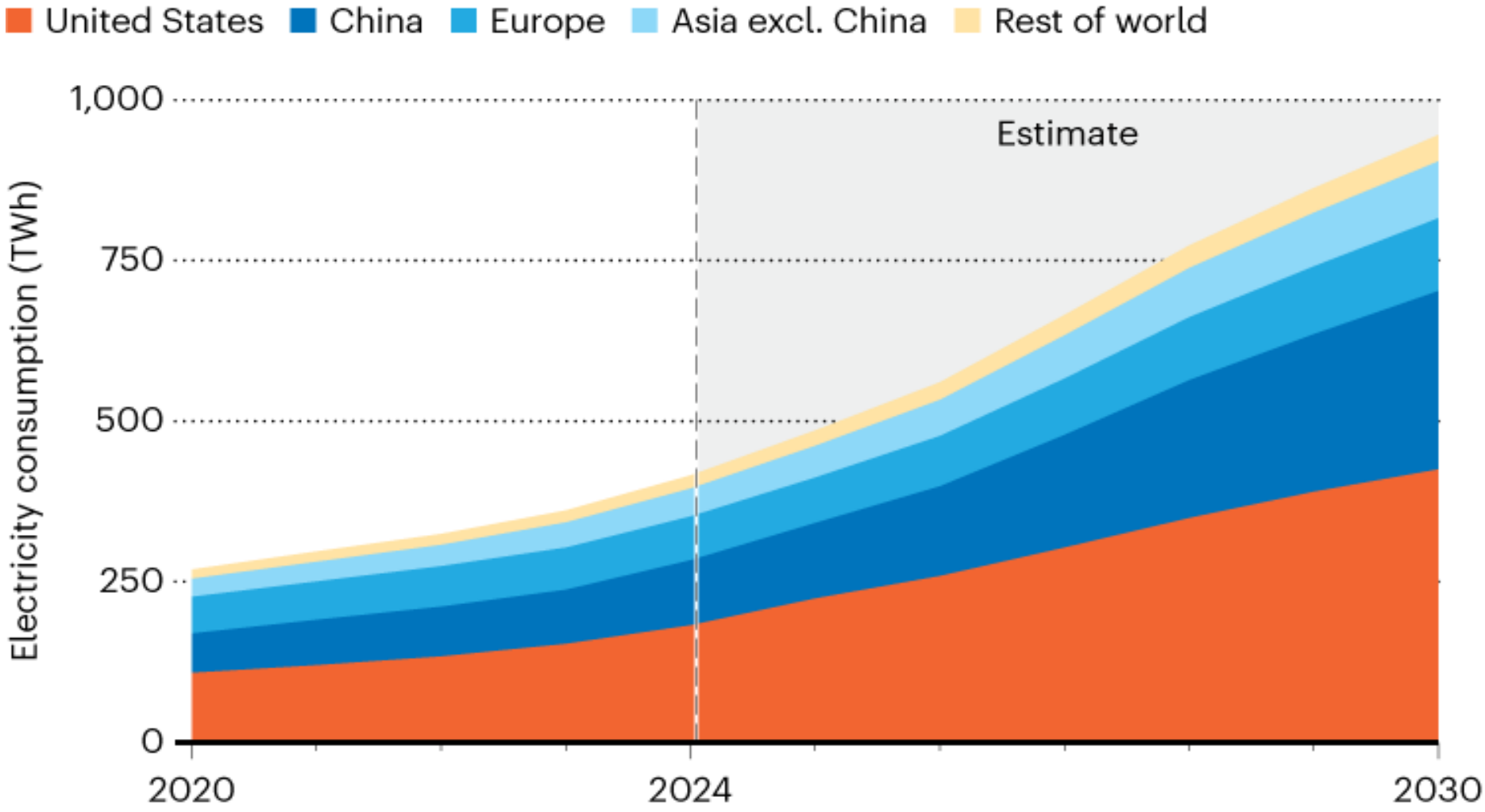
US power demand from data centers expected to more than double from current levels



Utility power represents actual and forecasted total electricity supplied to data centers from the power grid, including IT equipment, cooling, lighting, offices and security systems as of the market monitor release date.
Source: S&P Global Market Intelligence; 451 Research Data center Services & Infrastructure Market Monitor & Forecast: US focused released Sept. 24, 2025.

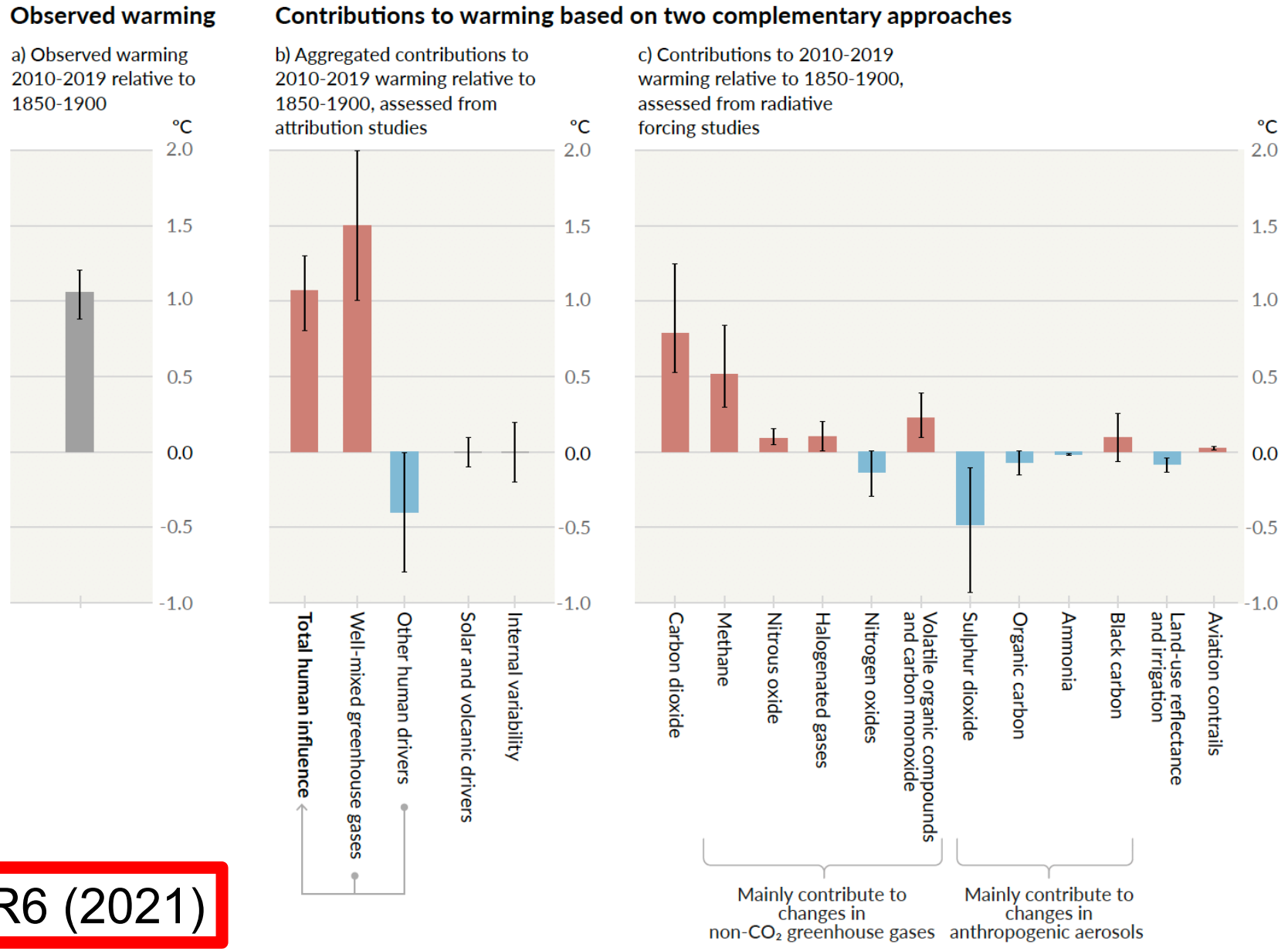
Global Data Center Growth (by Region)

China and the United States are predicted to account for nearly 80% of the global growth in electricity consumption by data centres up to 2030*.



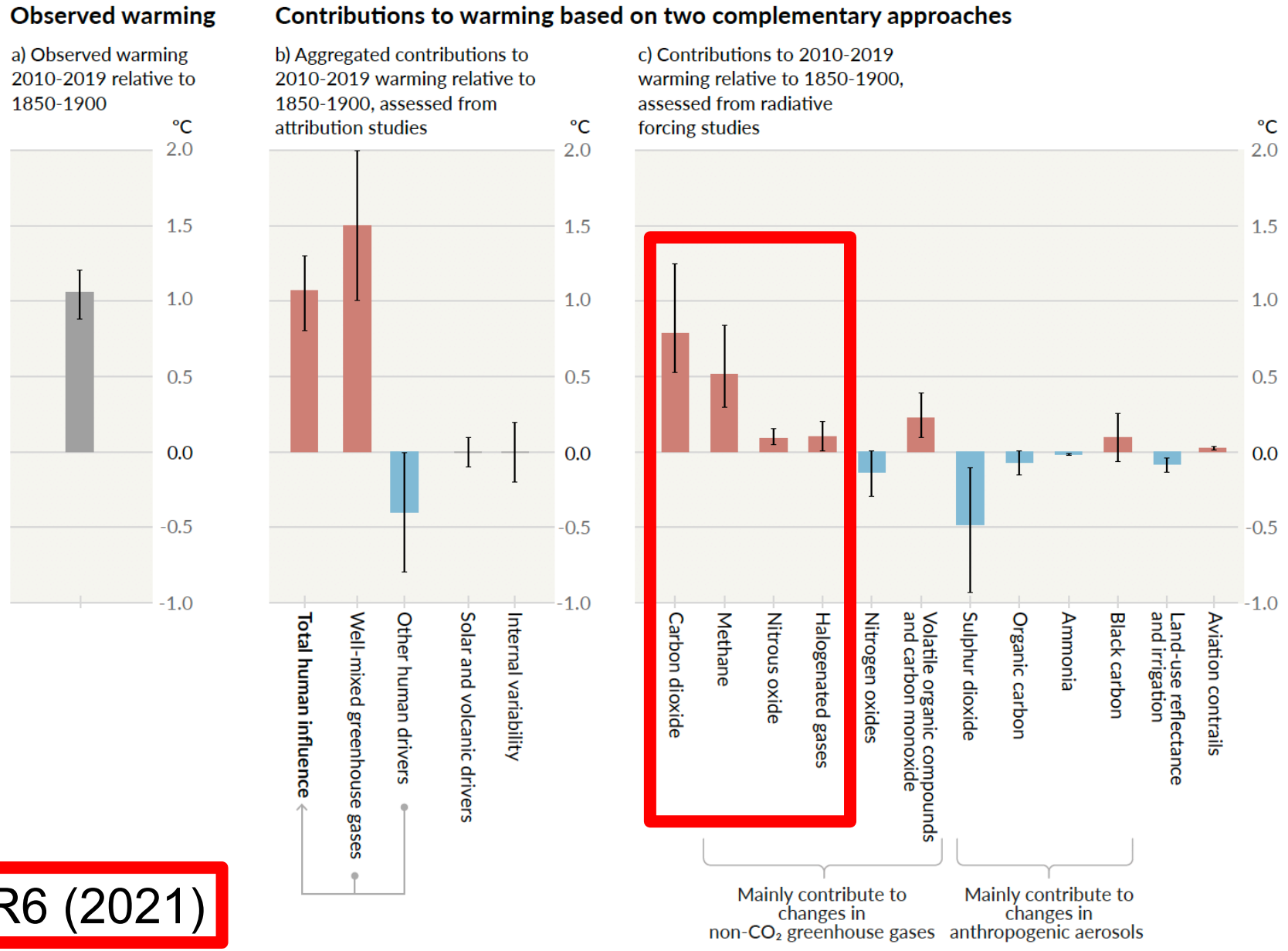
*Predicted trajectory under current regulatory conditions and industry projections.

The Full Impact of Greenhouse Gases has been Masked by Sulfate Aerosol Pollution



AR6 (2021)

The Full Impact of Greenhouse Gases has been Masked by Sulfate Aerosol Pollution



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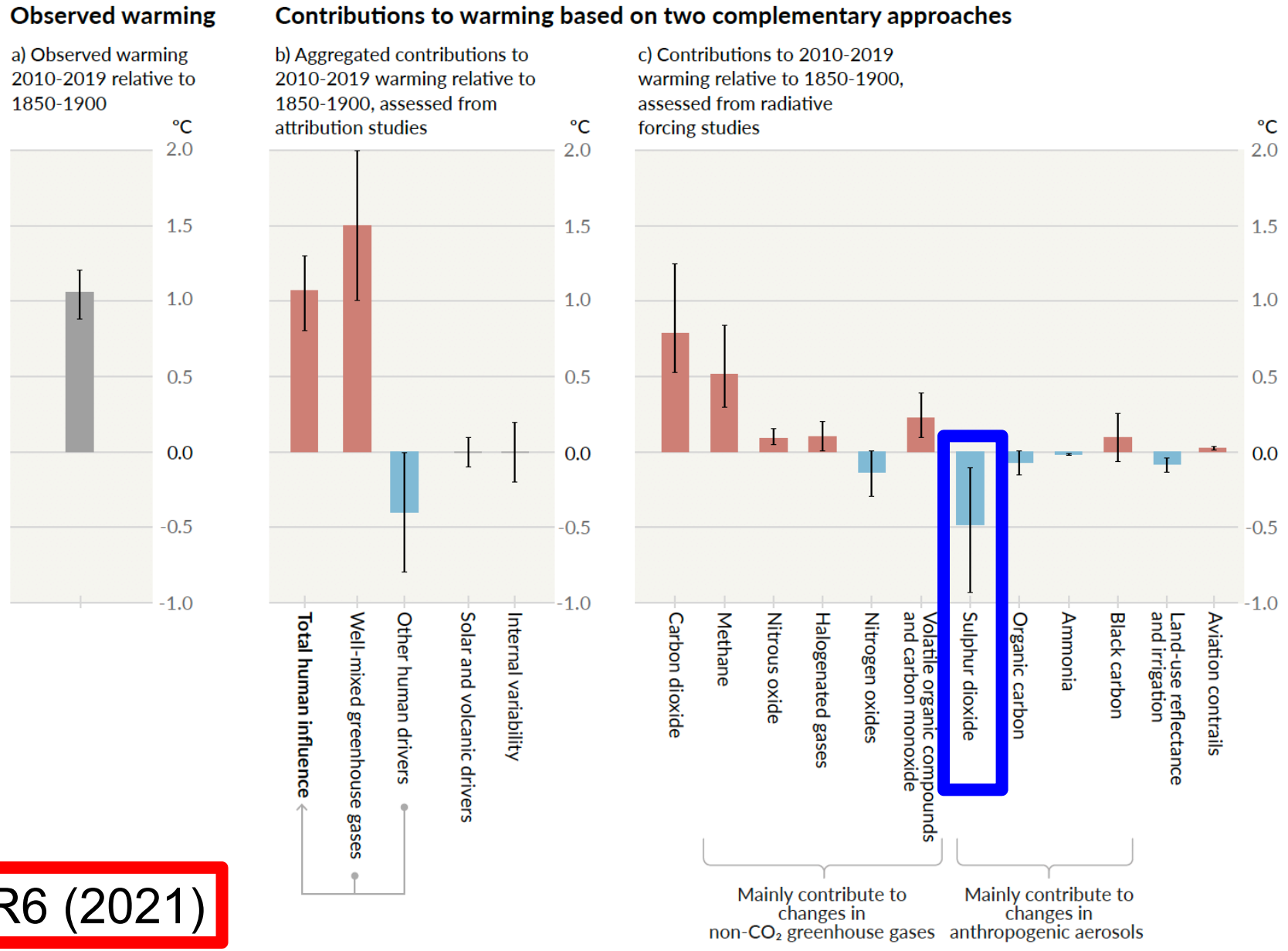

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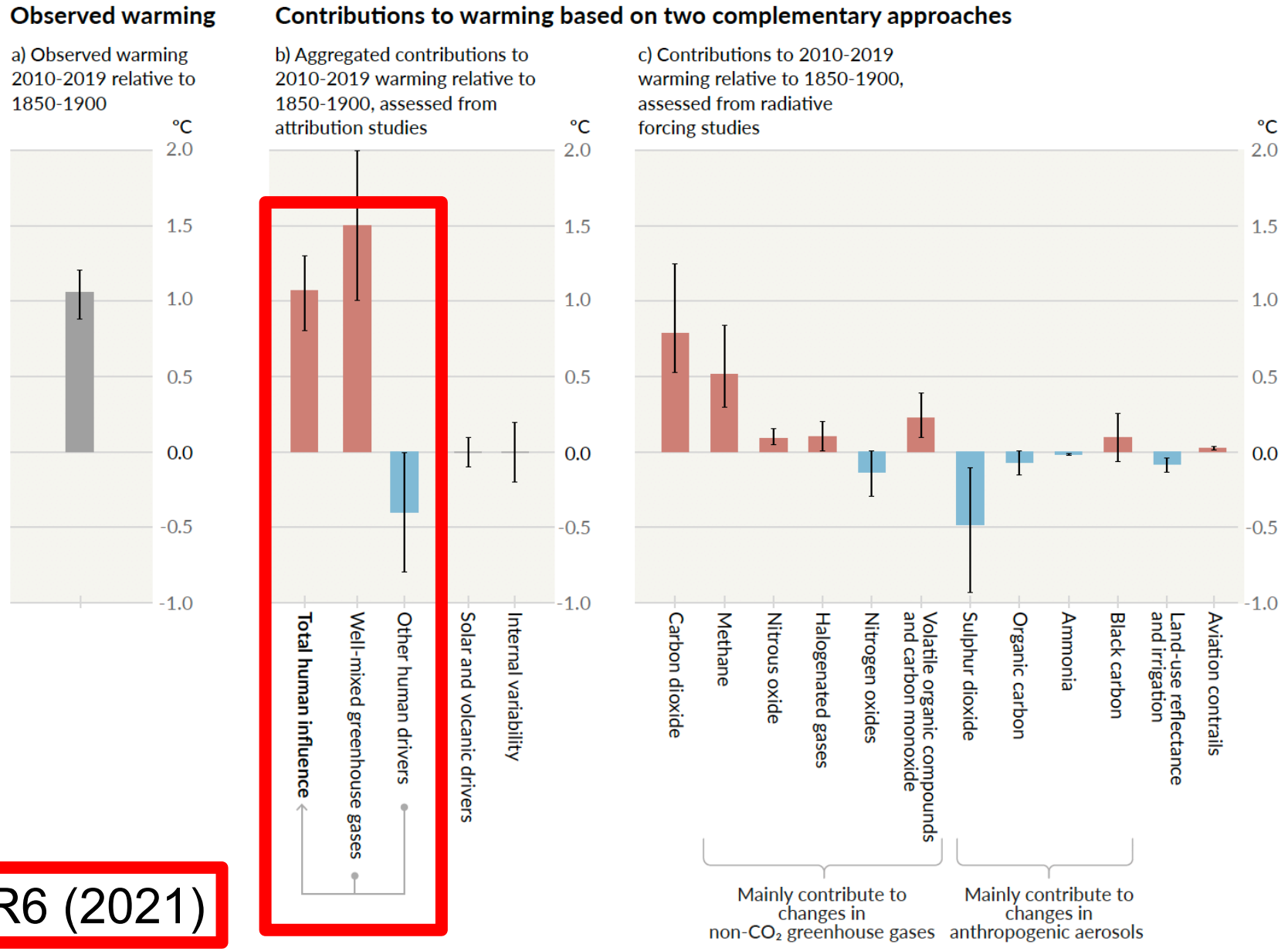

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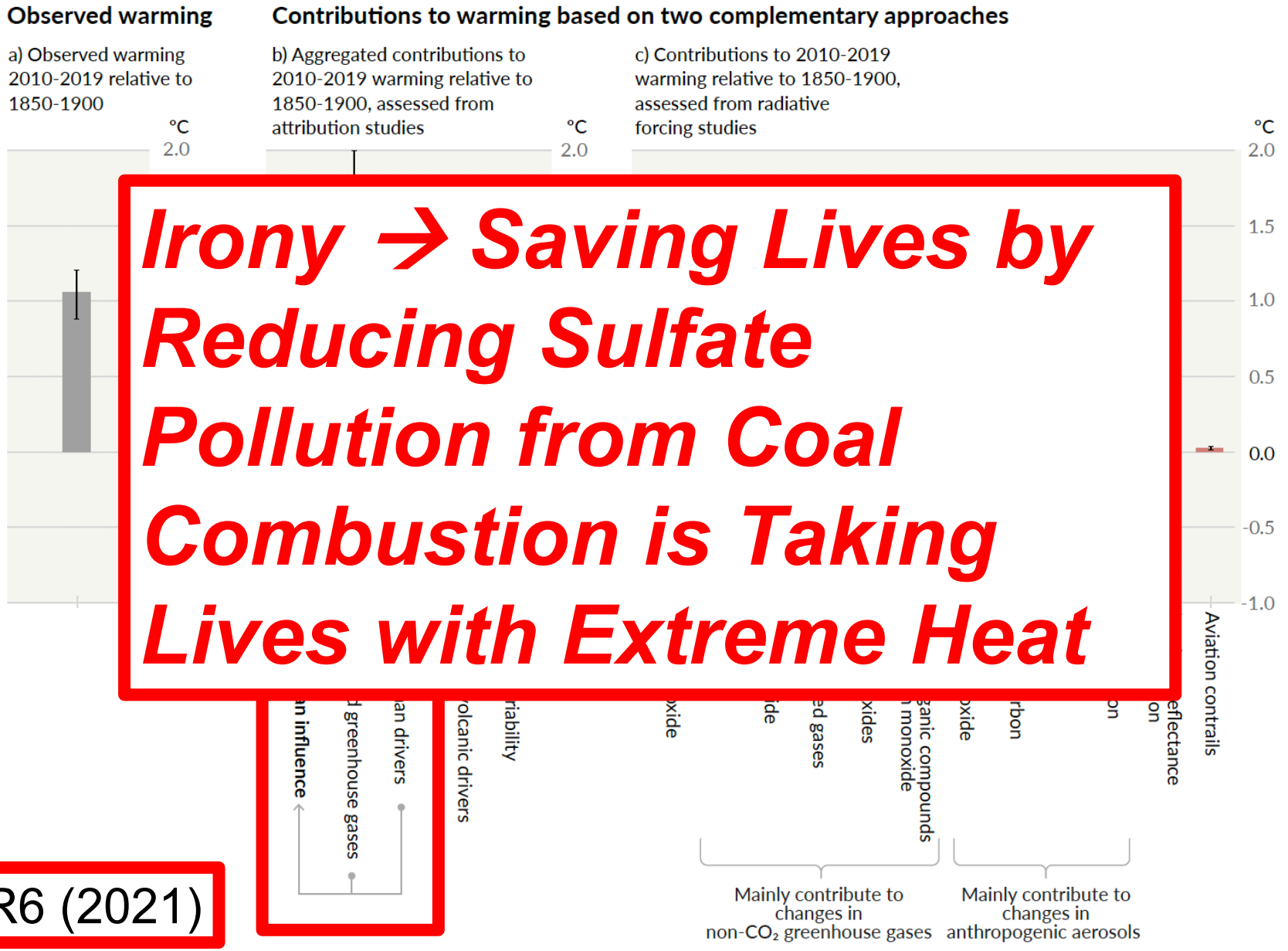
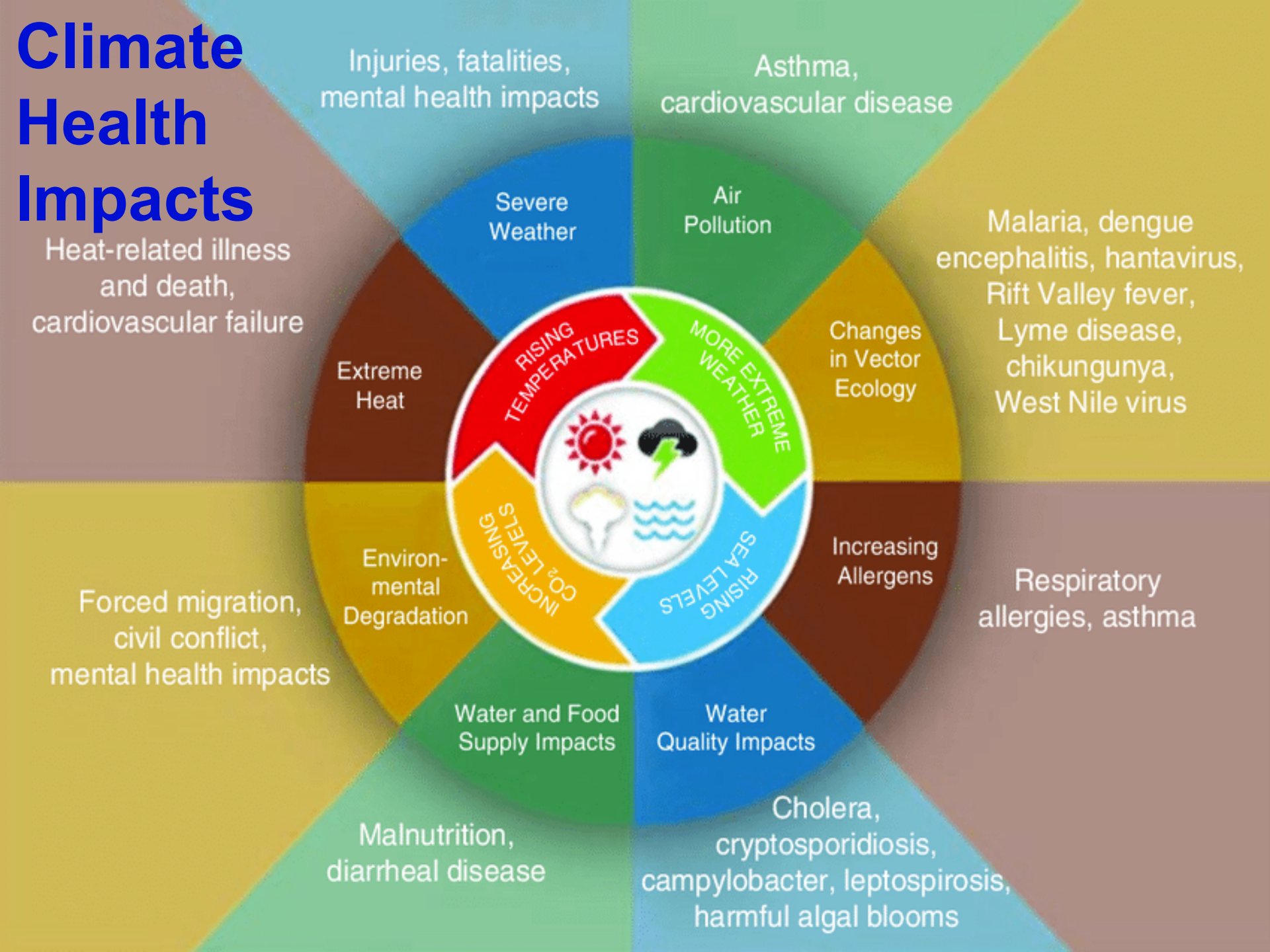


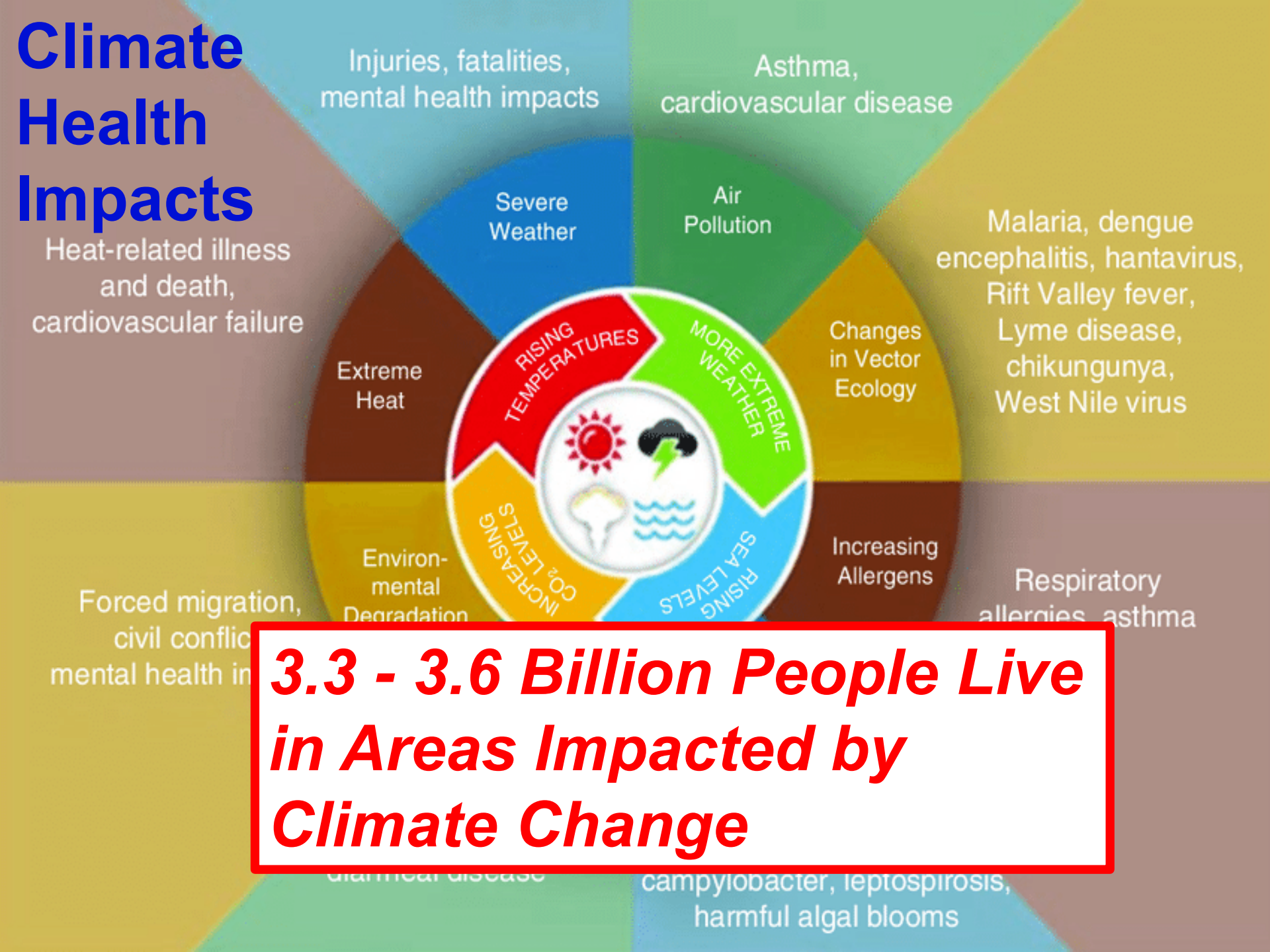
Irony → Saving Lives by Reducing Sulfate Pollution from Coal Combustion is Taking Lives with Extreme Heat

AR6 (2021)

Climate Health Impacts



Climate Health Impacts



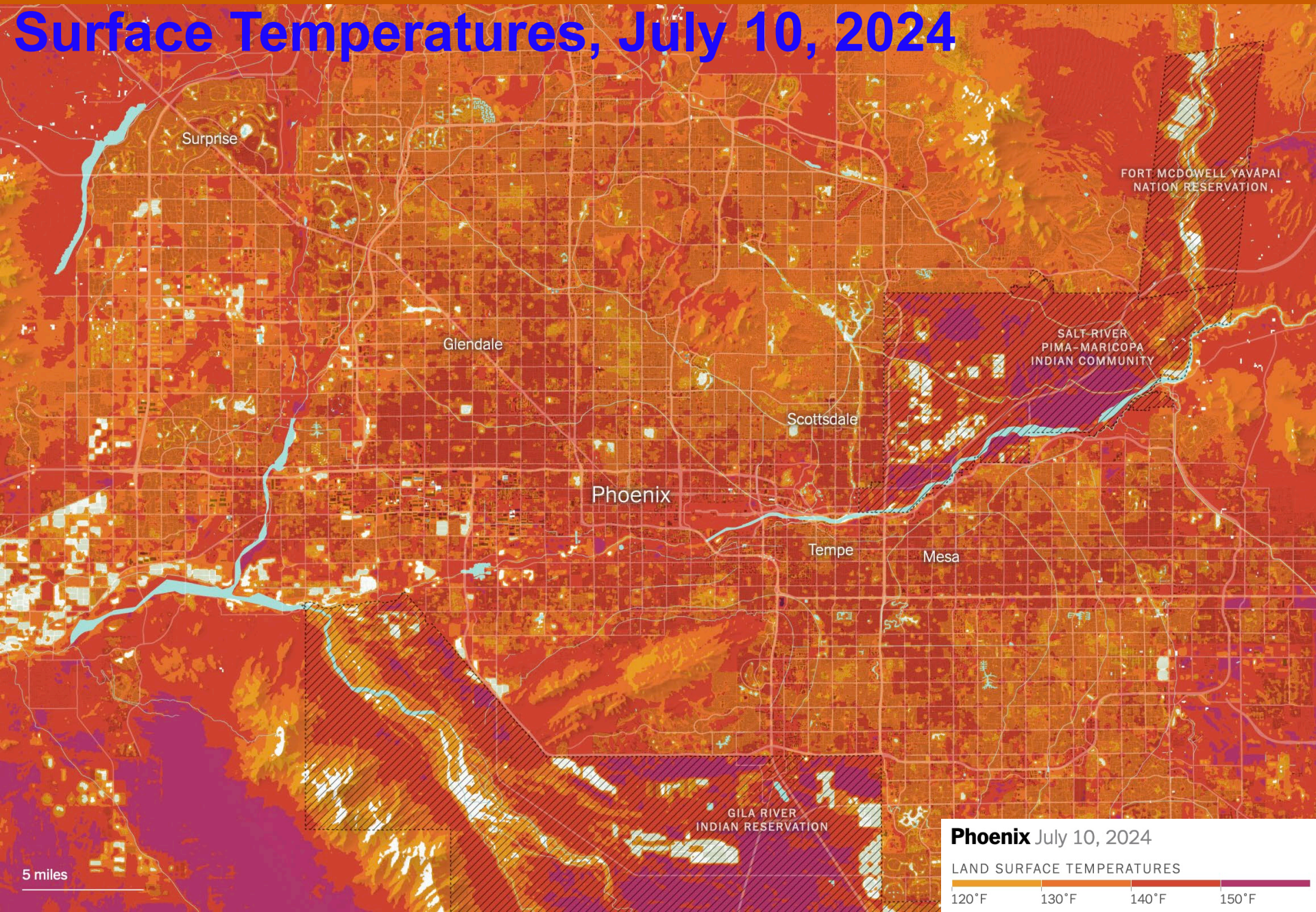
3.3 - 3.6 Billion People Live in Areas Impacted by Climate Change

How *Climate Change* Impacts Health

- Heat: Heat Stress, Heat Stroke

NASA LandSat Map of Phoenix

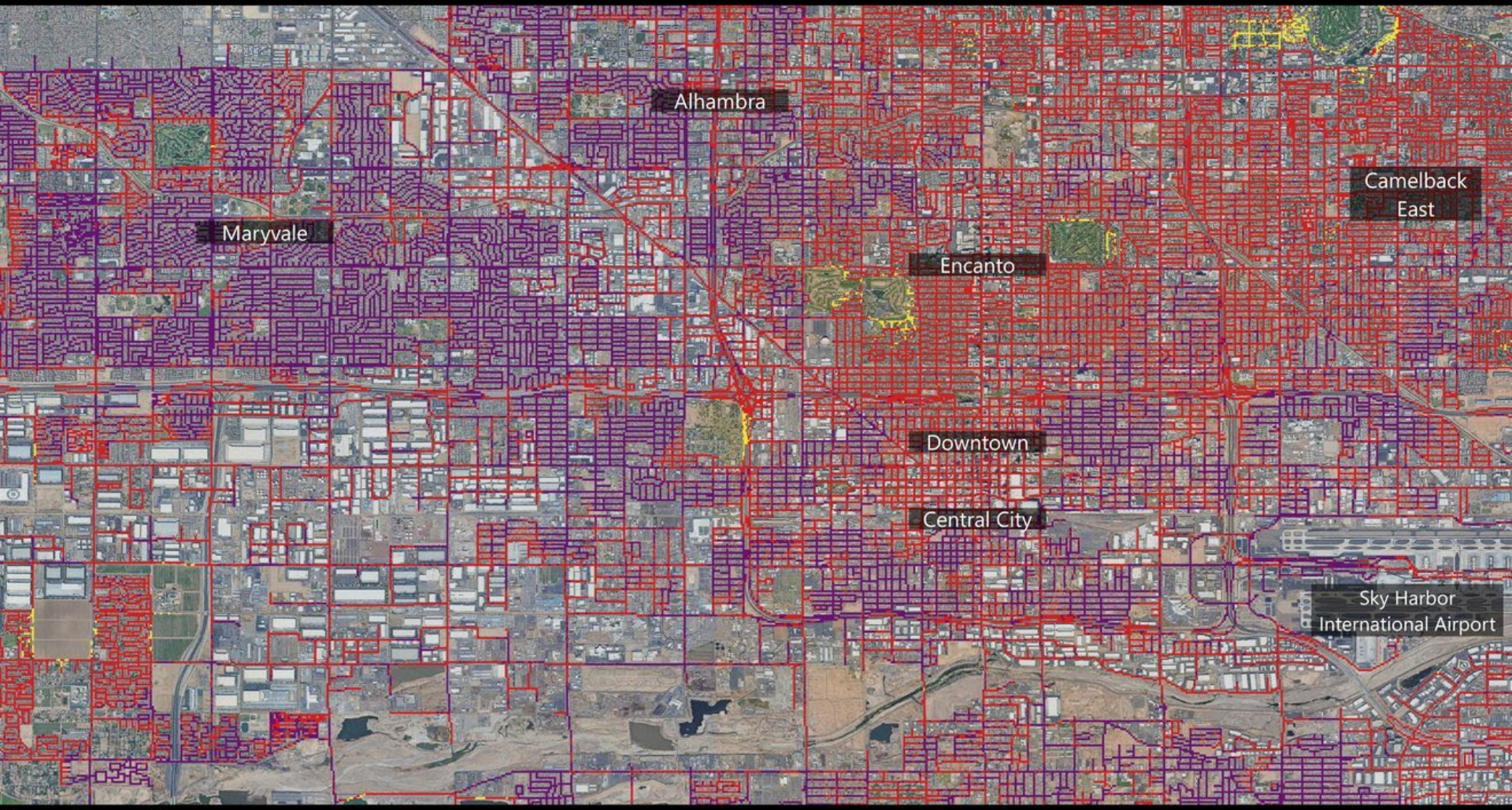
Surface Temperatures, July 10, 2024



ECOSTRESS Land Surface Temperature
Thermal Burn Risk Level Map – Phoenix, Arizona

ECOSTRESS

Jet Propulsion Laboratory
California Institute of Technology



0 1 2 km

June 19, 2024
1:02 PM Local Time

Moderate | High | Very High

120°F 130°F 140°F 160°F

Thermal Burn Risk Level

Surface Temperature

The New York Times

120 ºF on Thursday, July 11, 2024

(Fifth Straight Day of >115 ºF)

Las Vegas Heat Breaks Records and Stuns Even the Forecasters

A brutal heat wave that has gripped the West for days will shift eastward on the weekend, while much of sweltering Houston still lacks electricity.

The Las Vegas Strip on Sunday. The temperature that day hit 120 degrees, the highest on record for the city. John Locher/Associated Press

National Weather Service 4-Level ”Heat Risk” Metric: July 12, 2024

National Weather Service
National Oceanic and Atmospheric Administration

Bookmark Download KML Graphics En español

NWS HeatRisk

Identifying Potential Heat Risks in the Seven Day Forecast

Map | Overview | What's in HeatRisk? | Understanding HeatRisk | CDC-NWS Collaboration | Verification | Looking for Resources?

Fri 7/12	Sat 7/13	Sun 7/14	Mon 7/15	Tue 7/16	Wed 7/17	Thu 7/18

Click map for potential heat risks and NWS forecast for a location.

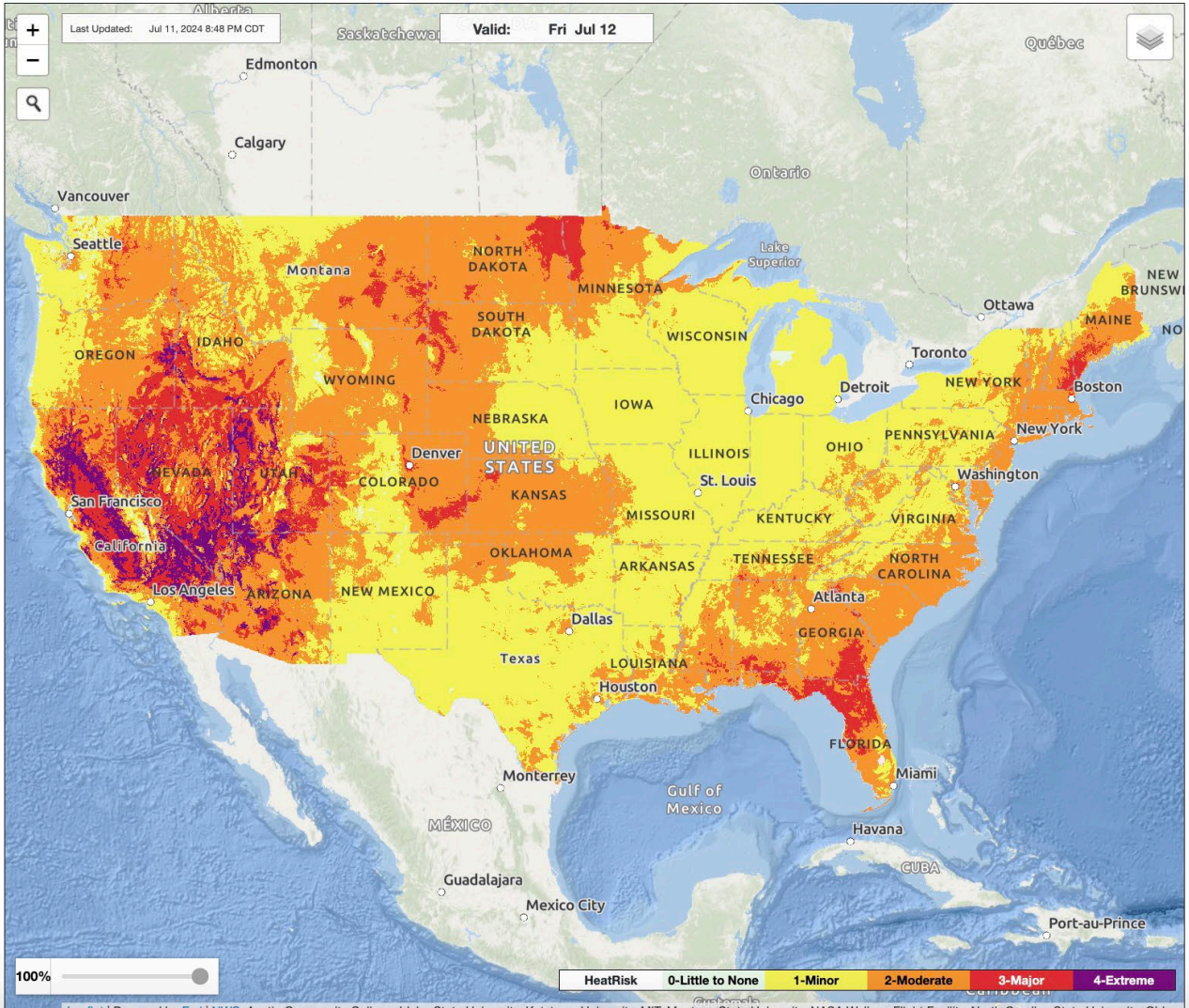
The NWS HeatRisk is an experimental color-numeric-based index that provides a forecast risk of heat-related impacts to occur over a 24-hour period. HeatRisk takes into consideration:

- How unusual the heat is for the time of the year
- The duration of the heat including both daytime and nighttime temperatures
- If those temperatures pose an elevated risk of heat-related impacts based on data from the CDC

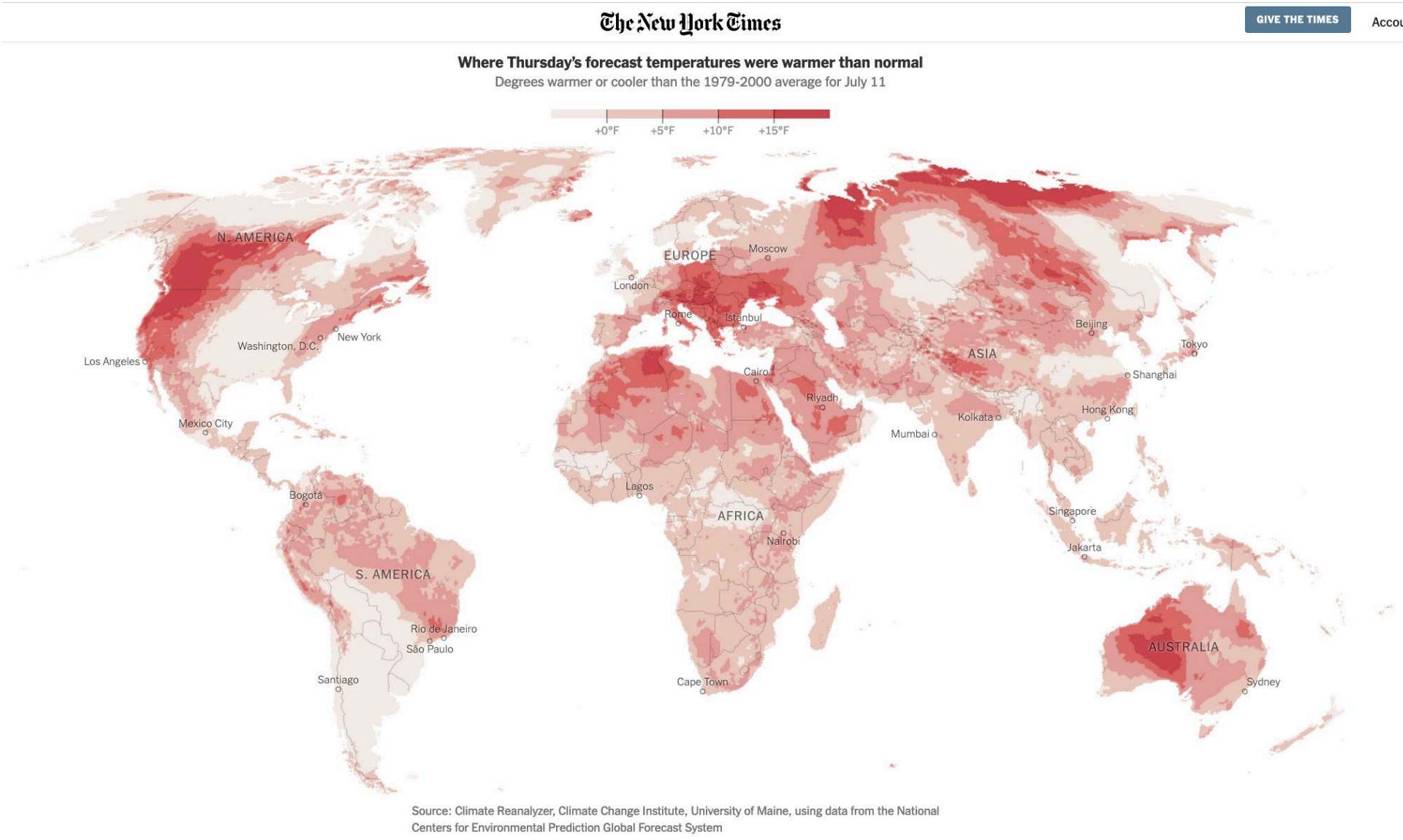
This index is supplementary to official NWS heat products and is meant to provide risk guidance for those decision makers and heat-sensitive populations who need to take actions at levels that may be below current NWS heat product levels.

Category	Risk of Heat-Related Impacts
Green 0	Little to no risk from expected heat.
Yellow 1	Minor - This level of heat affects primarily those individuals extremely sensitive to heat, especially when outdoors without effective cooling and/or adequate hydration.
Orange 2	Moderate - This level of heat affects most individuals sensitive to heat, especially those without effective cooling and/or adequate hydration. Impacts possible in some health systems and in heat-sensitive industries.
Red 3	Major - This level of heat affects anyone without effective cooling and/or adequate hydration. Impacts likely in some health systems, heat-sensitive industries and infrastructure.
Magenta 4	Extreme - This level of rare and/or long-duration extreme heat with little to no overnight relief affects anyone without effective cooling and/or adequate hydration. Impacts likely in most health systems, heat-sensitive industries and infrastructure.

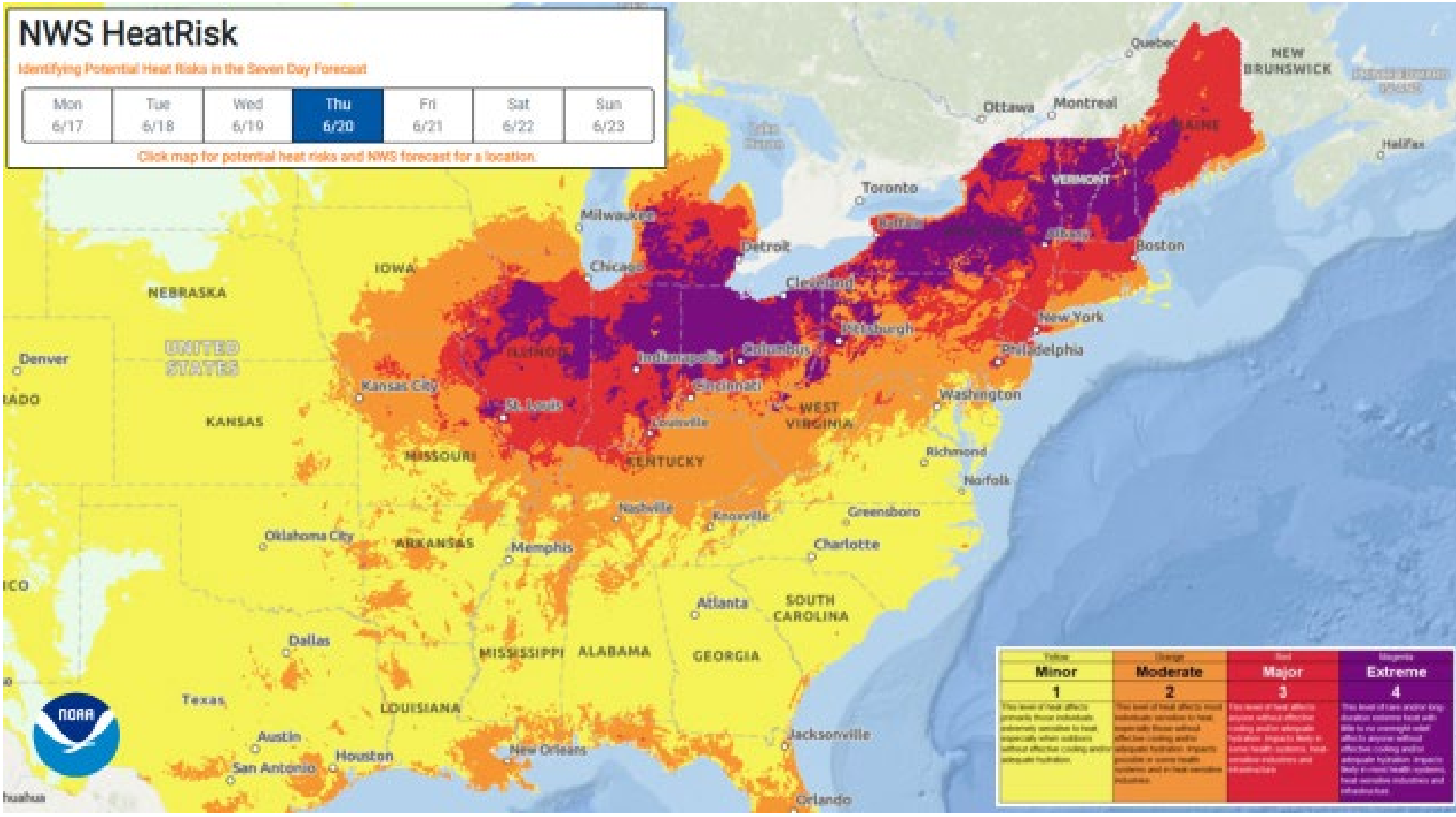
Comments? Questions? Please Contact Us.



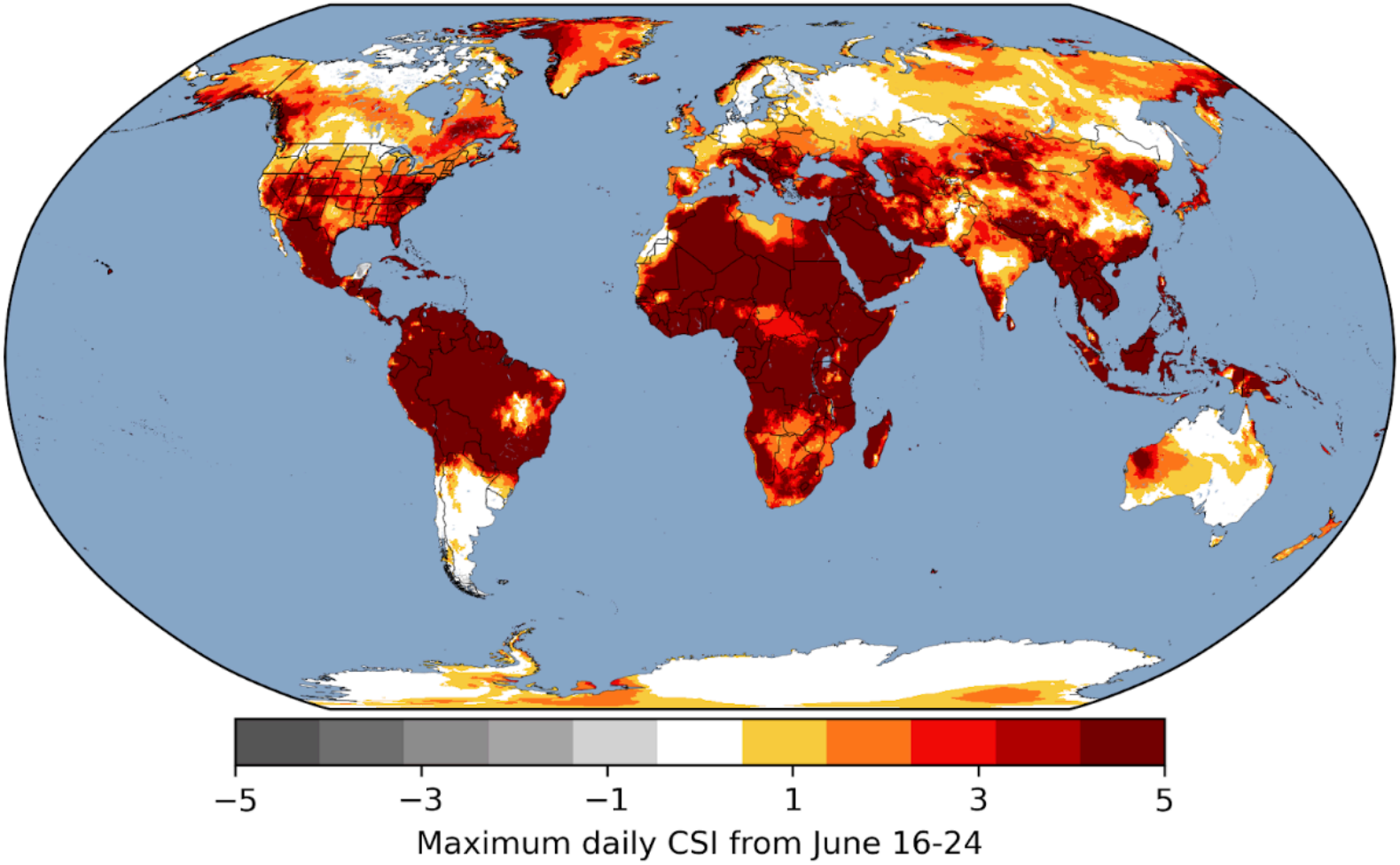
July 11, 2024: Global Temperature Anomalies



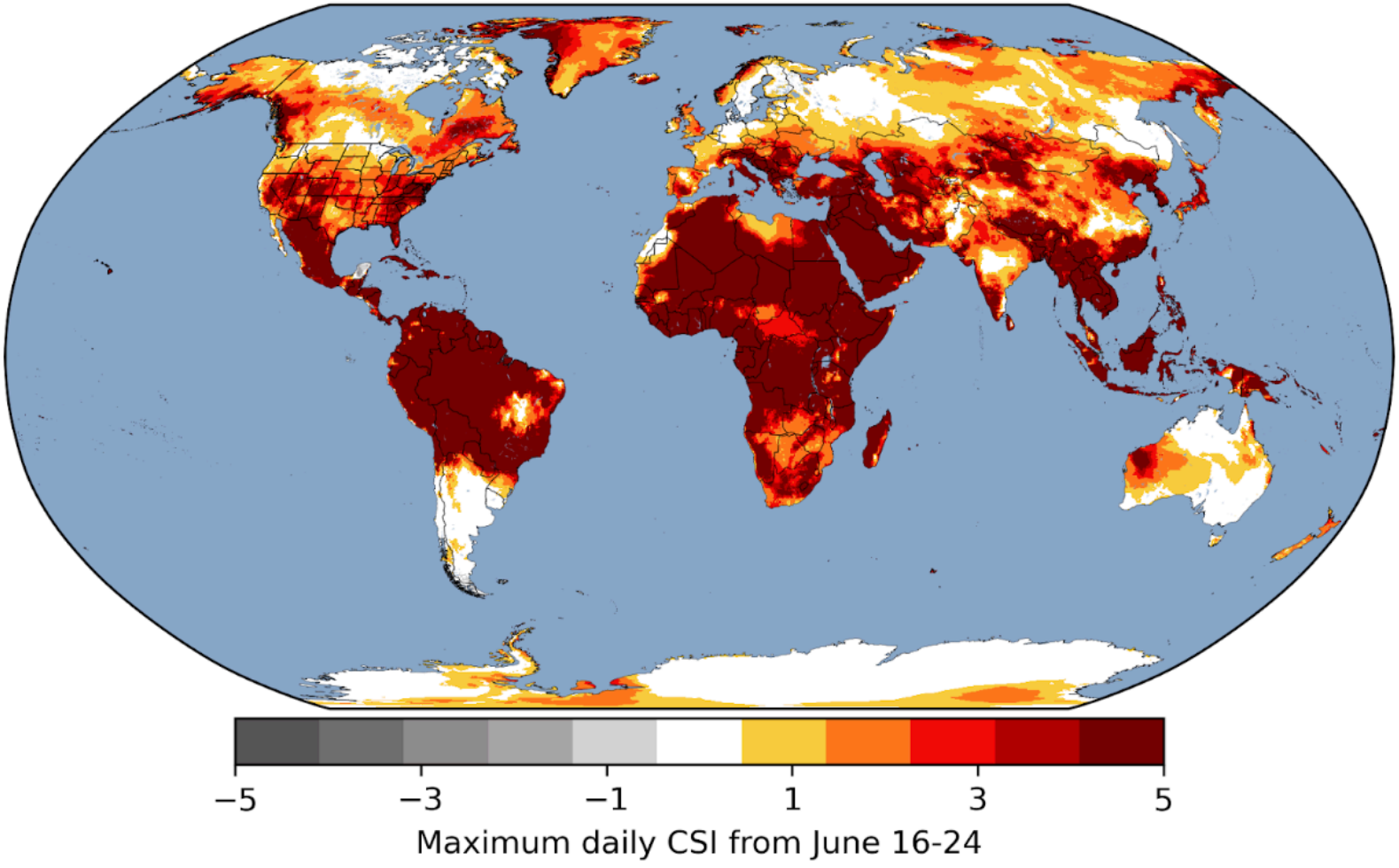
Heat Wave of June 16-24, 2024, as it Reached the Eastern United States



During the Heat Waves of June 16-24, 2024, 5 Billion People Experienced Extreme Heat



→Climate Change Made this Heat Wave 35x More Likely to Have Occurred

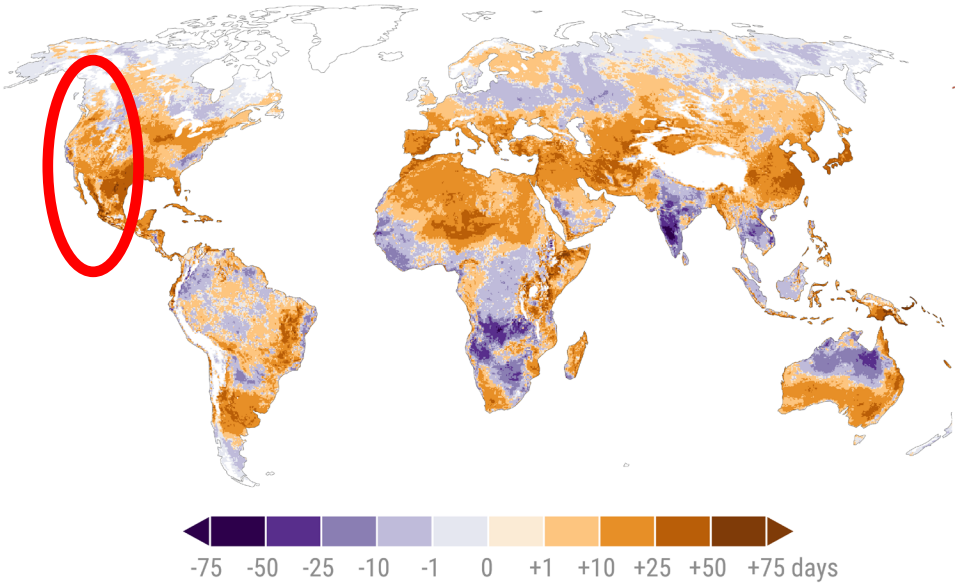


2025: Parts of Western U.S. Experienced

→ >25 Additional Strong Heat Stress Days

Half of the globe experienced more days than average with at least strong heat stress in 2025

Anomalies in the number of days with at least strong heat stress



A day with **at least strong heat stress** has a maximum feels-like temperature of **32°C or more**, and a day with **at least strong cold stress** a minimum feels-like temperature of **-13°C or below**.

Data: ERA5-HEAT Universal Thermal Climate Index (UTCI) • Reference period: 1991–2020 • Credit: C3S/ECMWF

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Climate Change Service
IMPLEMENTED BY ECMWF

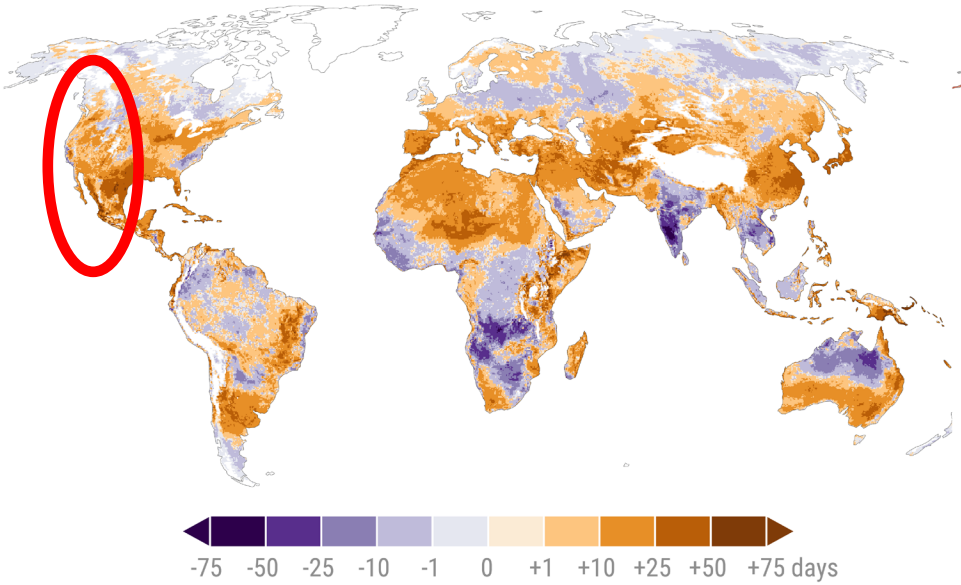
2025: Parts of Western U.S. Experienced

→ >25 Additional Strong Heat Stress Days

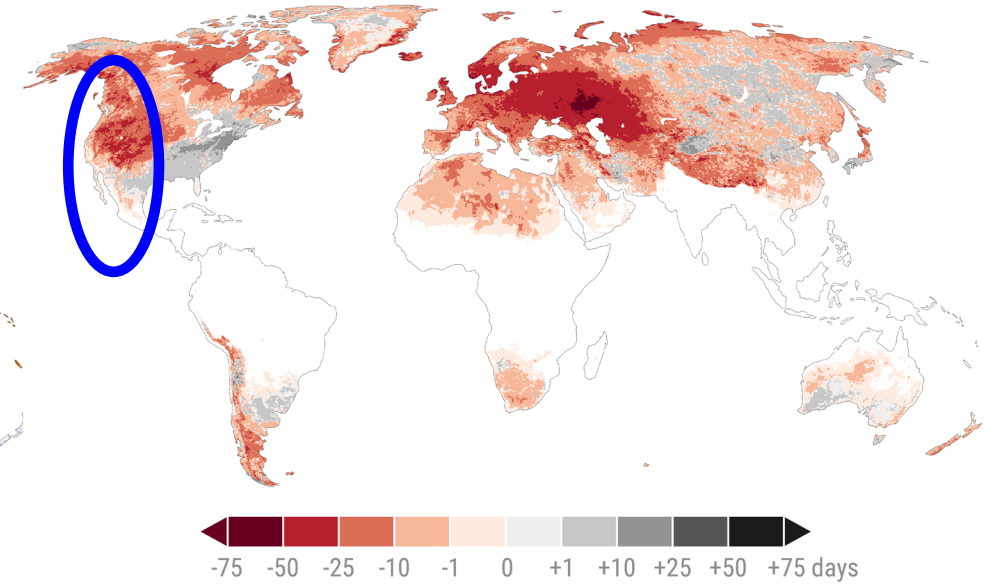
→ >25 Fewer Strong Cold Stress Days

Half of the globe experienced more days than average with at least strong heat stress in 2025

Anomalies in the number of days with at least strong heat stress



Anomalies in the number of days with at least strong cold stress



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Health Hazards of Extreme Heat

Mild Heat Illnesses

Heat Rash
Swelling of Hands and Feet
Heat Syncope (Fainting)

Heat Exhaustion

Headache
Nausea
Vomiting
Dizziness

Heat Stroke

Core body Temps Above 104 ºF
Confusion
Seizures and Other Mental Status Changes
Brain Damage
Muscle Breakdown
Kidney Failure

Potential Actions Needed (Minutes Matter):

Cool Patients as Fast As Possible

→Cold Water or Ice Bath

Hydrate Quickly and Restore Electrolytes

→ IV Fluids

Cardiopulmonary Bypass

Children at Higher Risk

Sweat Less

Hydrate Less

Older People at Higher Risk

More likely to have chronic medical conditions such as diabetes, kidney disease and heart failure

→ Interfere with the body's ability to regulate temperature and balance fluids

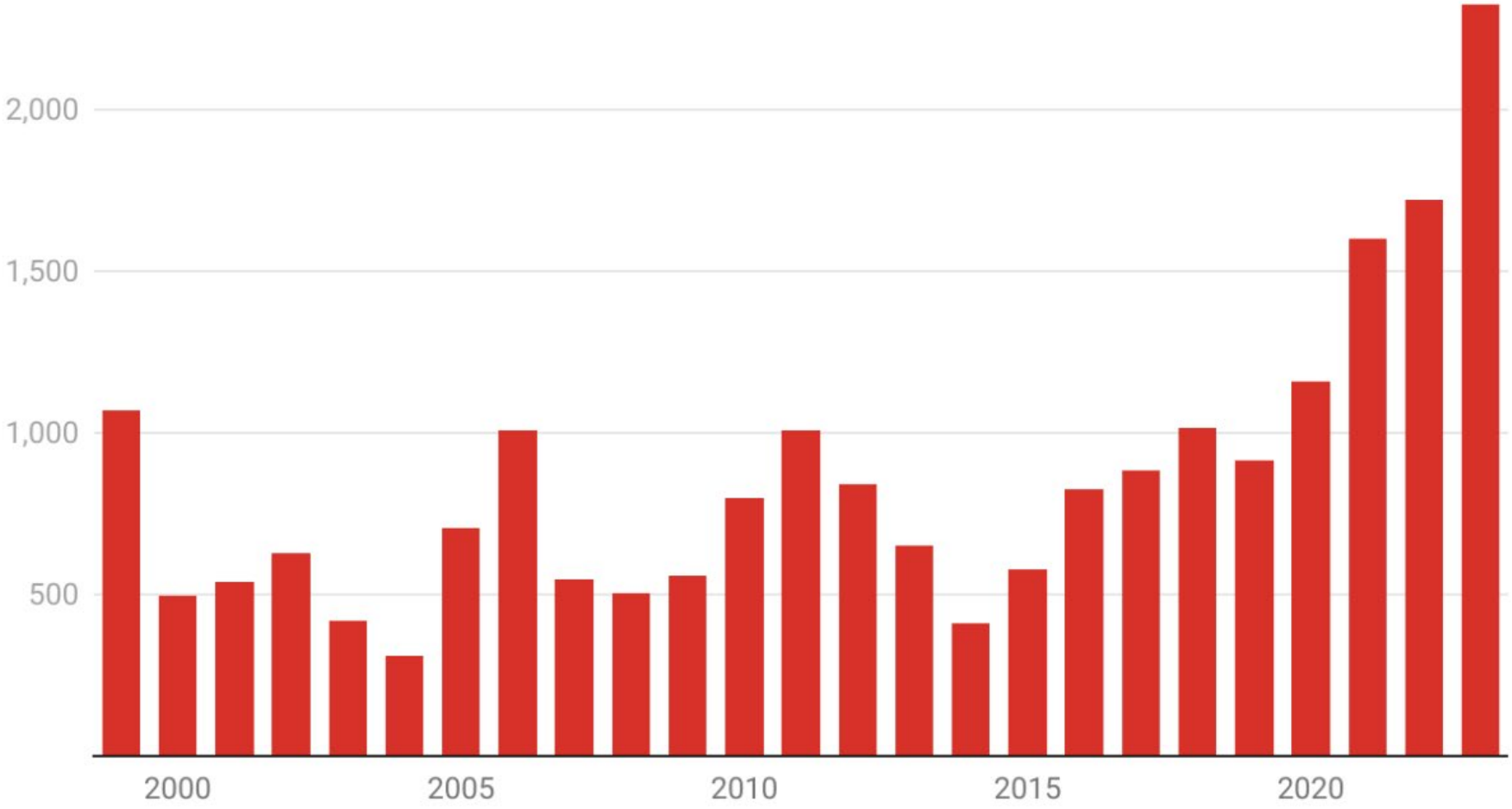
Treatments like blood pressure medications that keep the heart rate down or diuretics that clear fluids out of the body

→ Impair the body's ability to compensate for extreme heat

People with depression or dementia may also not realize they're thirsty and forget to drink water

Heat-related deaths in the US (Through 2023)

The number of heat-related deaths reported to the U.S. Centers for Disease Control and Prevention increased in recent years as the U.S. saw some of its hottest years on record.

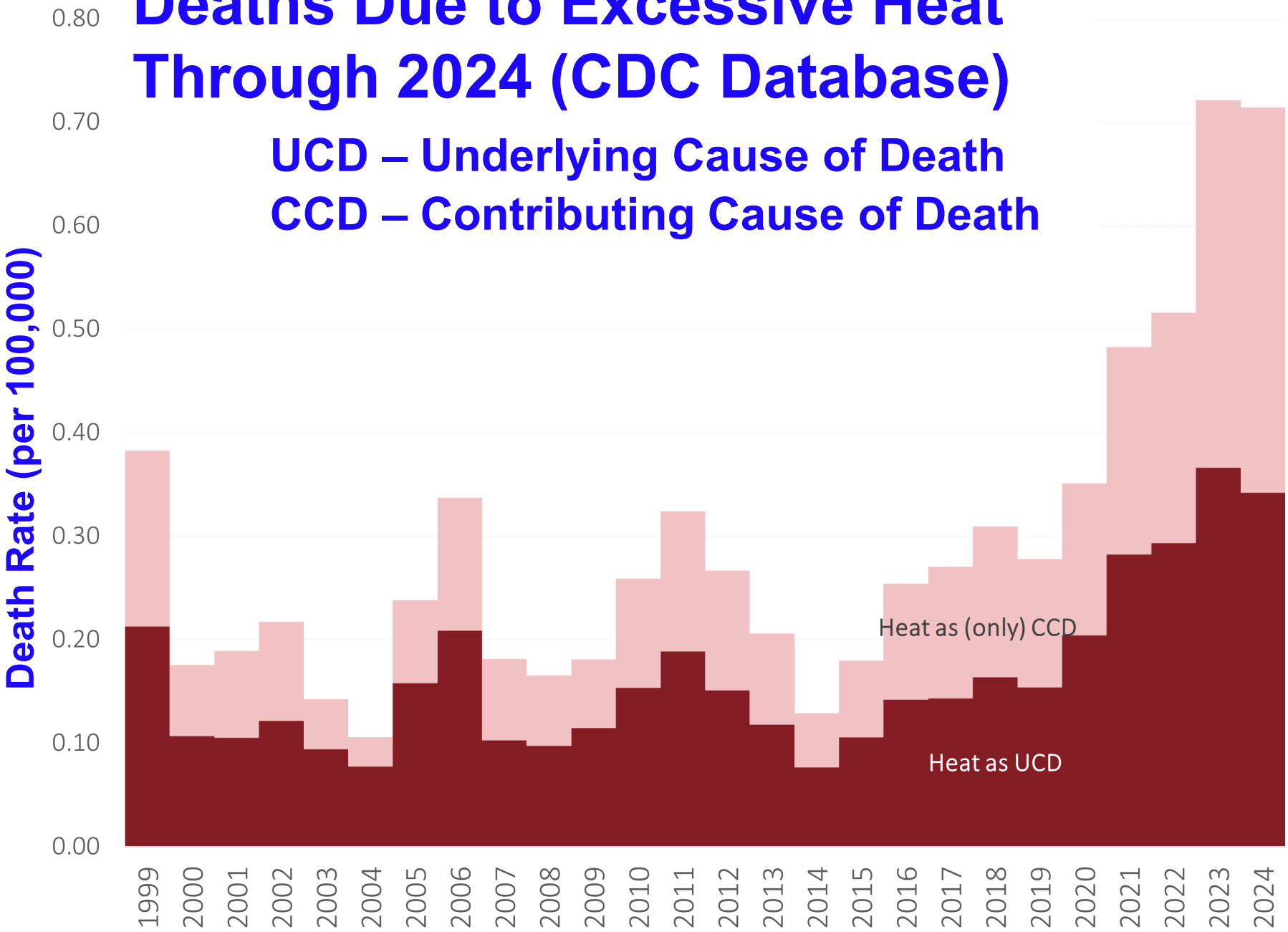


2023 count was provisional data

Chart: The Conversation, CC-BY-ND • Source: Jeffrey T. Howard, et al., JAMA, 2024 • Created with Datawrapper

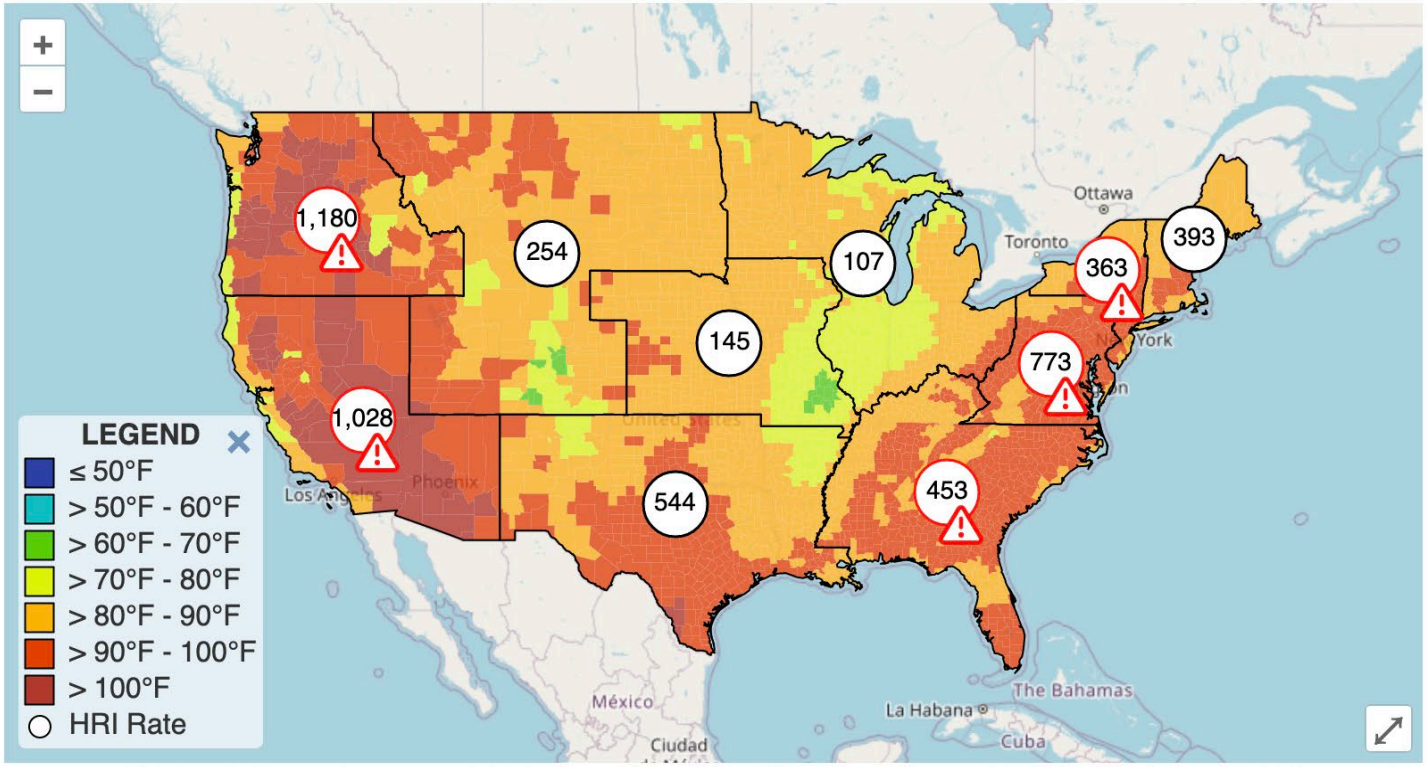
Deaths Due to Excessive Heat Through 2024 (CDC Database)

UCD – Underlying Cause of Death
CCD – Contributing Cause of Death



U.S. Rate (per 100,000) of Heat-Related ED Visits: July 9, 2024

Daily Heat-Related Illness



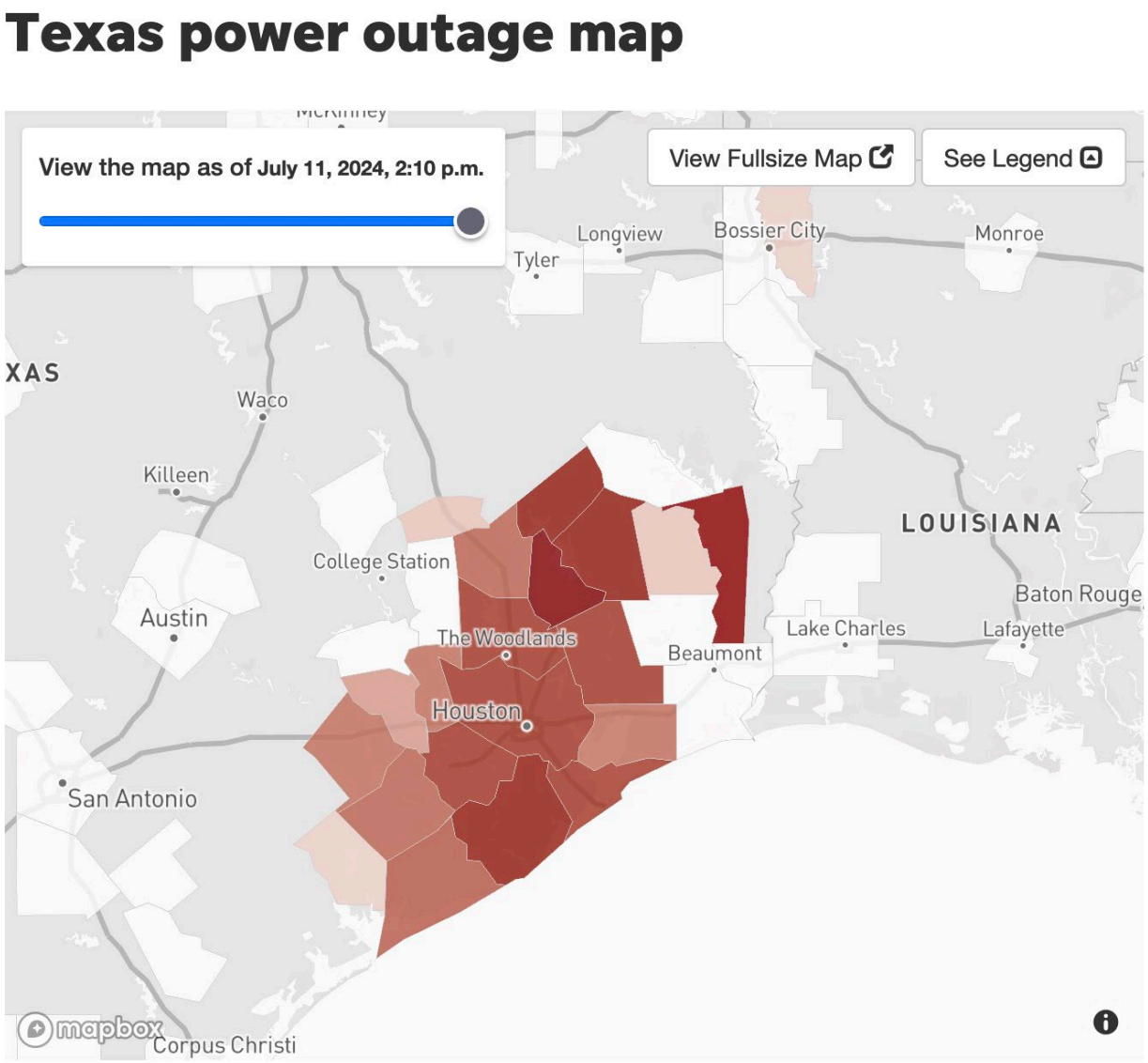
Choose a date
7/9/2024

About the Data

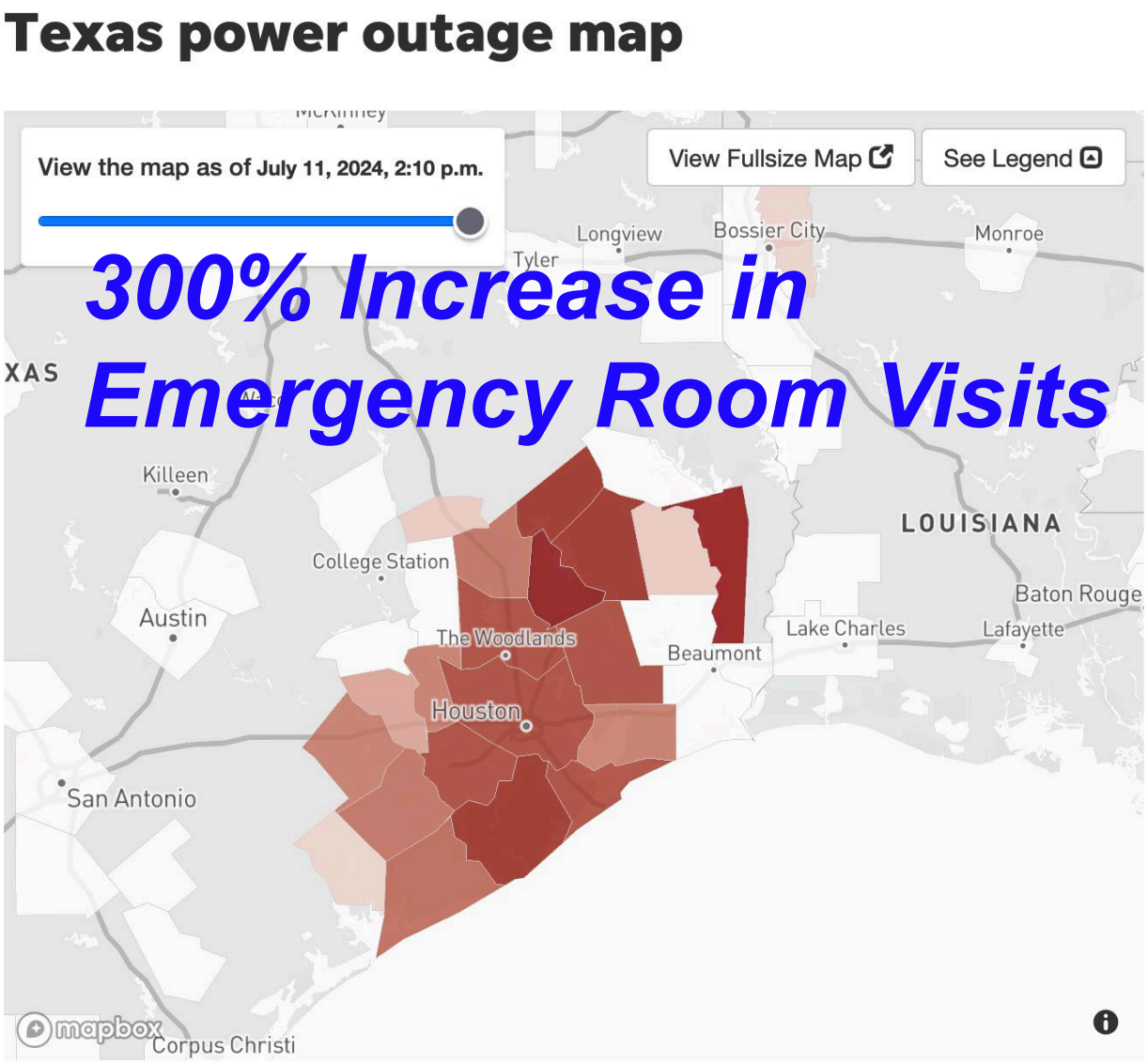
This map shows the rate of emergency department (ED) visits associated with heat-related illness (HRI) per 100,000 ED visits by region. The regions are defined by Health and Human Services for the selected day using data available through the National Syndromic Surveillance Program. Use the above dropdown to change the selected date. The colors on the map show the average maximum temperature by county for the same day and year, using data from the National Center for Environmental Information.

This icon indicates that extremely high rates of heat-related illness were detected in the region. Extremely high rates of heat-related illness are defined as exceeding the 95th percentile based on data from 2018-2023.

July 11, 2024: >1,100,000 People in Houston Without Electricity



July 11, 2024: >1,100,000 People in Houston Without Electricity



Be Prepared for Sustained Electrical Grid Power Failures

Hospitals in Houston 'Backed Up' After Hurricane, as Millions in U.S. Swelter

The health care system in Houston, where more than a million customers lack power, was overwhelmed because some patients couldn't be discharged amid a punishing heat wave.

Share full article 24

July 11, 2024

Officials suspect heat as the cause of more than 90 deaths in the West reported this month, though each death requires a full investigation and could take months to sort out. Raquel Natalicchio, via Getty Images

EDITOR'S PICKS HEALTH SOCIAL JUSTICE SUSTAINABILITY

Study: Phoenix faces health crisis if heatwave, blackout hit at same time

Jasmine Kabiri/Cronkite News

June 5, 2023

High temperatures are nothing new to Valley residents, but a recent study said that if a heatwave coincided with a multiday power outage, the results would be disastrous. Power and emergency management officials call the chances of such a coincidence remote, saying they take extremes into account in their planning. (Photo by Ralph Freso/Getty Images)

LATEST NEWS

'All eyes are on (us)': New-look Big 12 debuts at Las Vegas media days with bold ambitions

Arizona schools combat phone use in the classroom, see effect on youth mental health

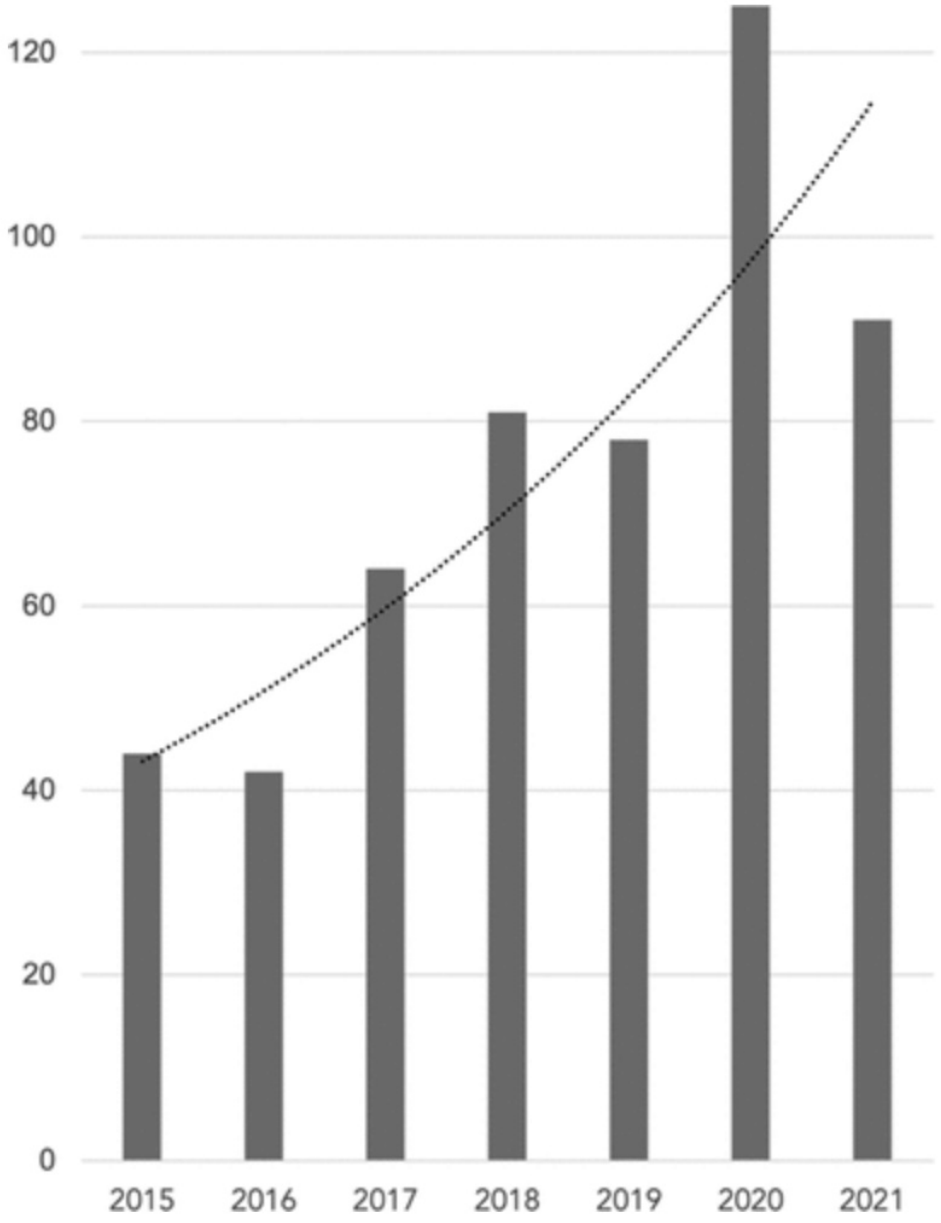
July 9, 2024, Newscast

Feds want to rush aid to public housing residents to stay cool

"How Blackouts during Heat Waves Amplify Mortality and Morbidity Risk"

[Stone et al., *Environ. Sci. Tech*., 2023]

Simulated an Electrical Blackout During a 5-Day Heat Wave in Phoenix, Arizona



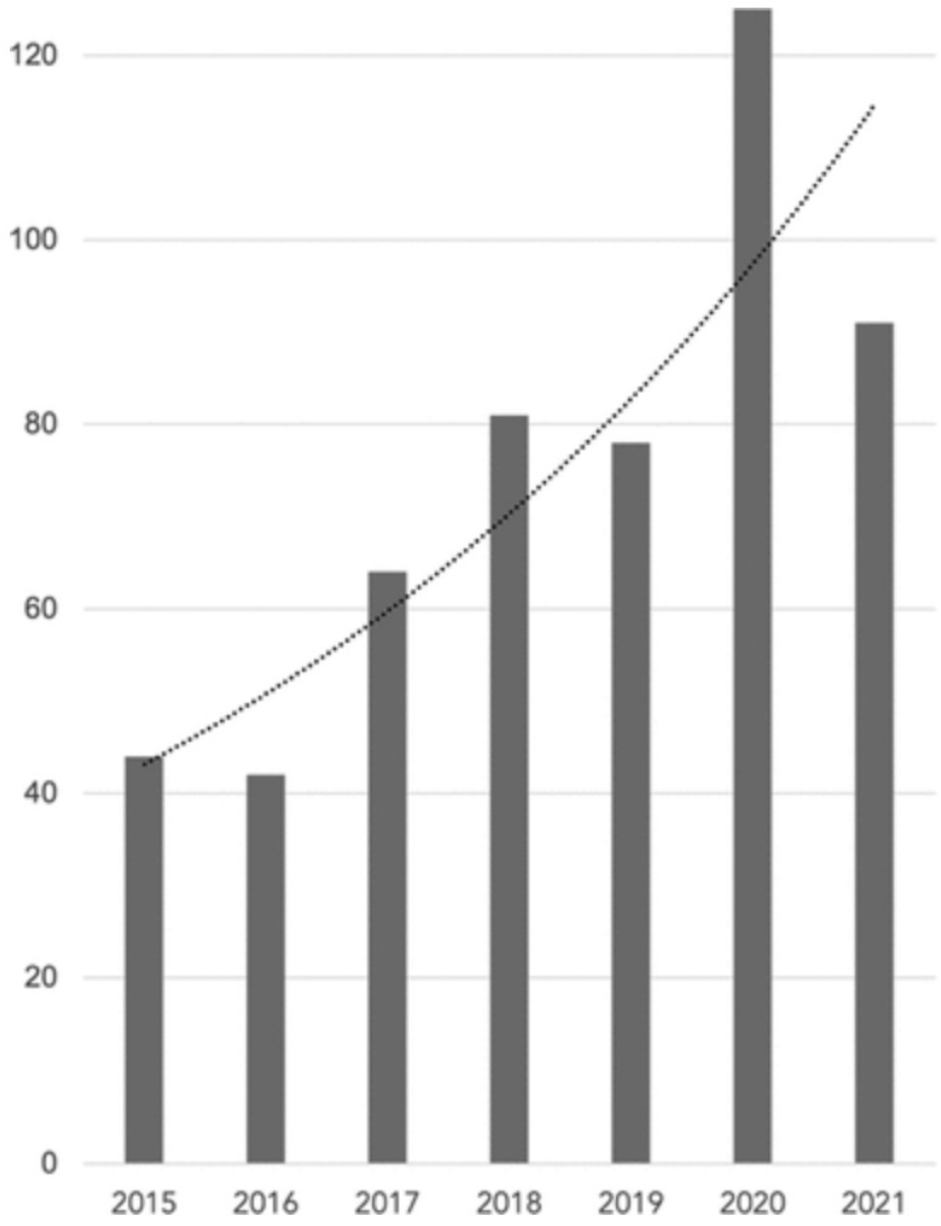
Major U.S. Electrical Grid Failures

"How Blackouts during Heat Waves Amplify Mortality and Morbidity Risk"

[Stone et al., *Environ. Sci. Tech.*, 2023]

Simulated an Electrical Blackout During a 5-Day Heat Wave in Phoenix, Arizona

→ ***~1% of the City Died (~13,000)***



Major U.S. Electrical Grid Failures

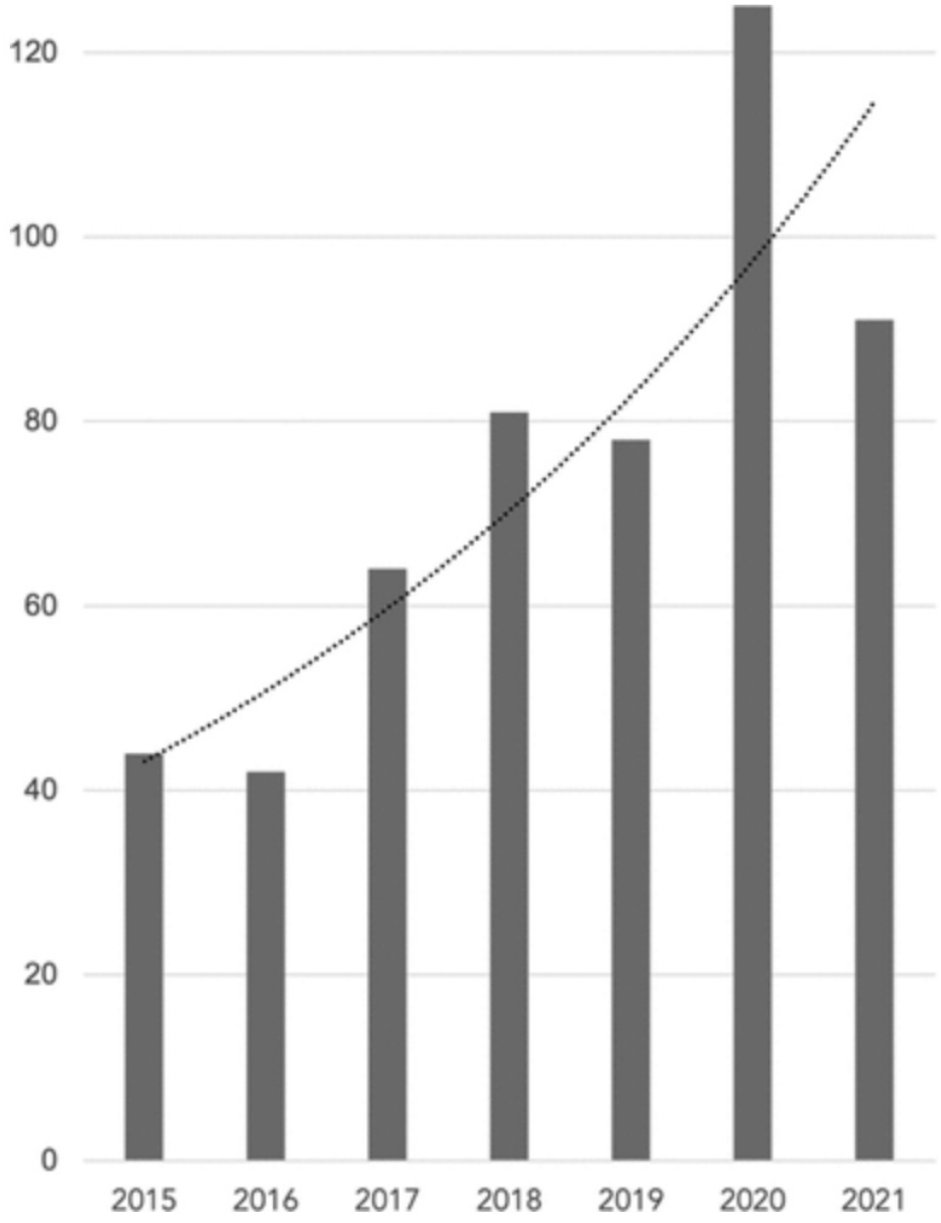
"How Blackouts during Heat Waves Amplify Mortality and Morbidity Risk"

[Stone et al., *Environ. Sci. Tech.*, 2023]

Simulated an Electrical Blackout During a 5-Day Heat Wave in Phoenix, Arizona

→ ***~1% of the City Died (~13,000)***

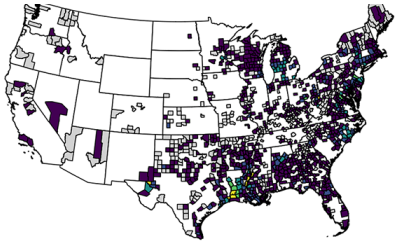
→ ***~50% Required Emergency Medical Care (~817,000)***



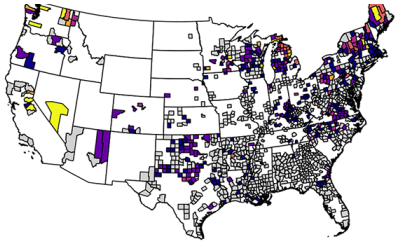
Major U.S. Electrical Grid Failures

Many Regions are Susceptible to Extreme Weather Events that Can Impact Electricity Power Stability

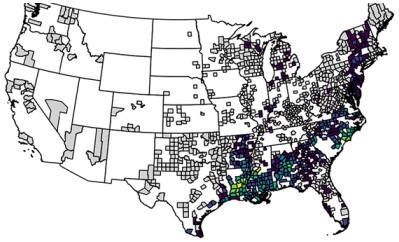
Anomalous Heat



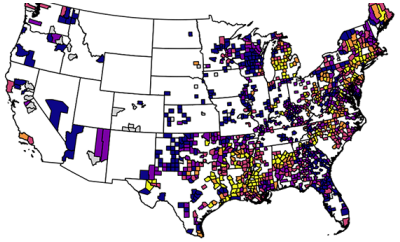
Anomalous Cold



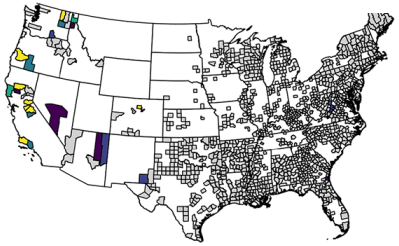
Tropical Cyclone



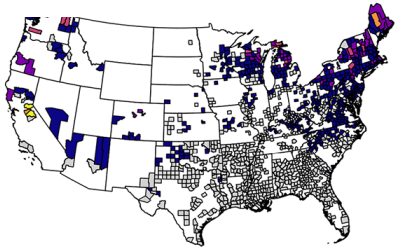
Anomalous Precipitation



Wildfire

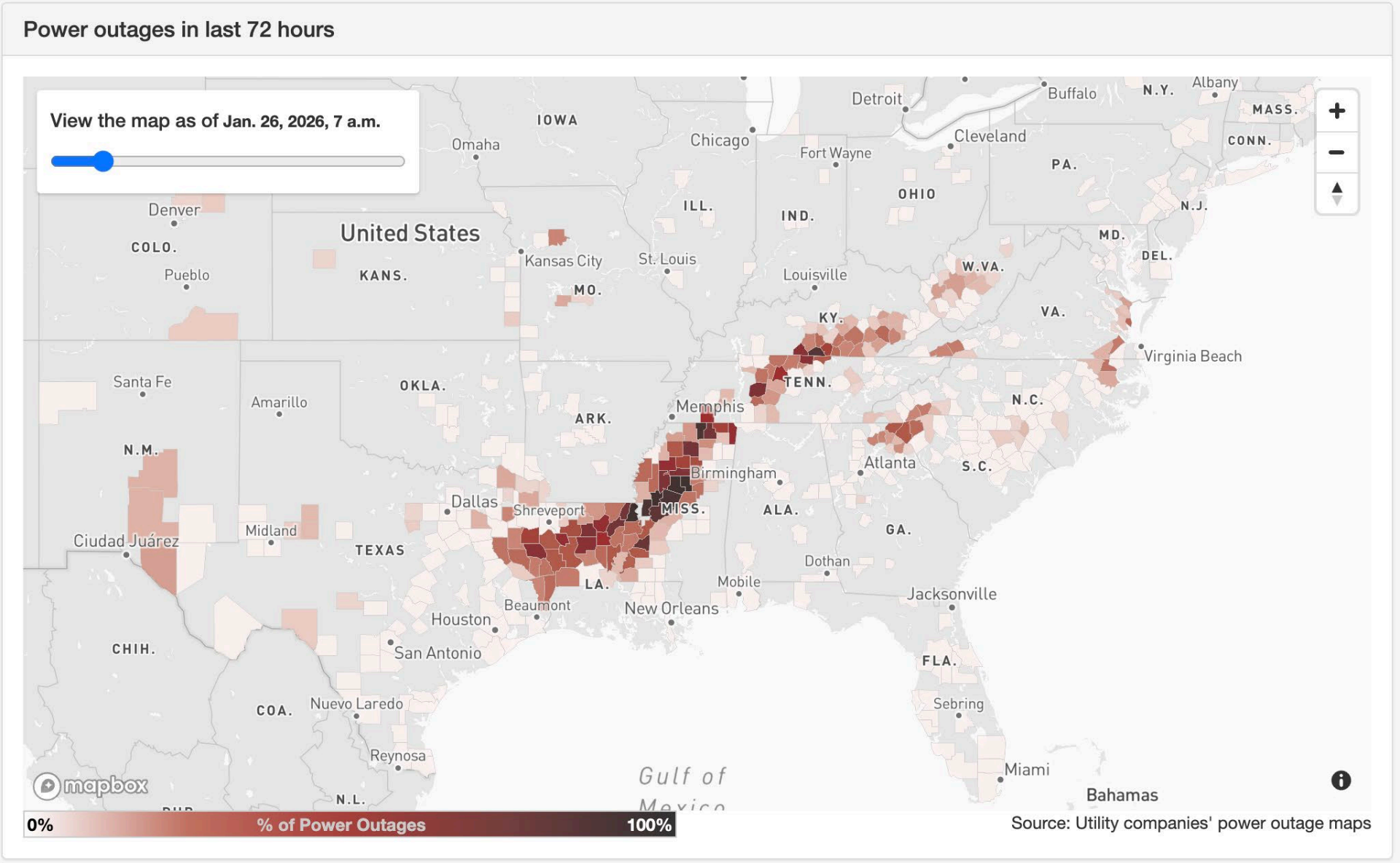


Snowfall

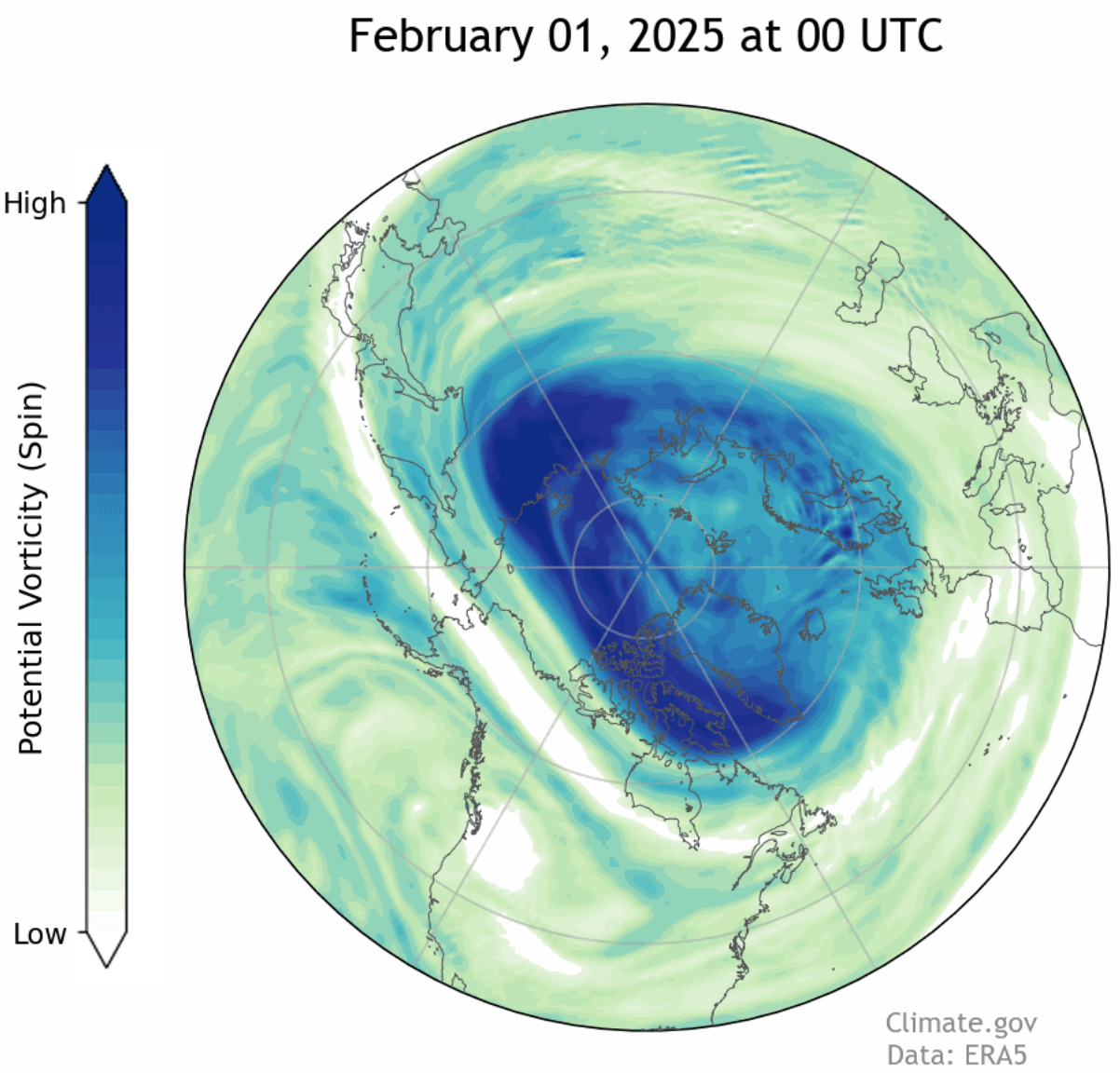


[Spatiotemporal patterns of individual and multiple simultaneous severe weather events co-occurring with power outages in the United States, 2018–2020; Do et al., PLOS Climate, 2025]

More than 1 Million People Lost Power in the U.S. During the Winter Storm This January



There is Evidence that Warming the Arctic and Melting Arctic Sea Ice can Weaken the Winter Polar Vortex, Allowing Cold Air to Come Down Across the United States



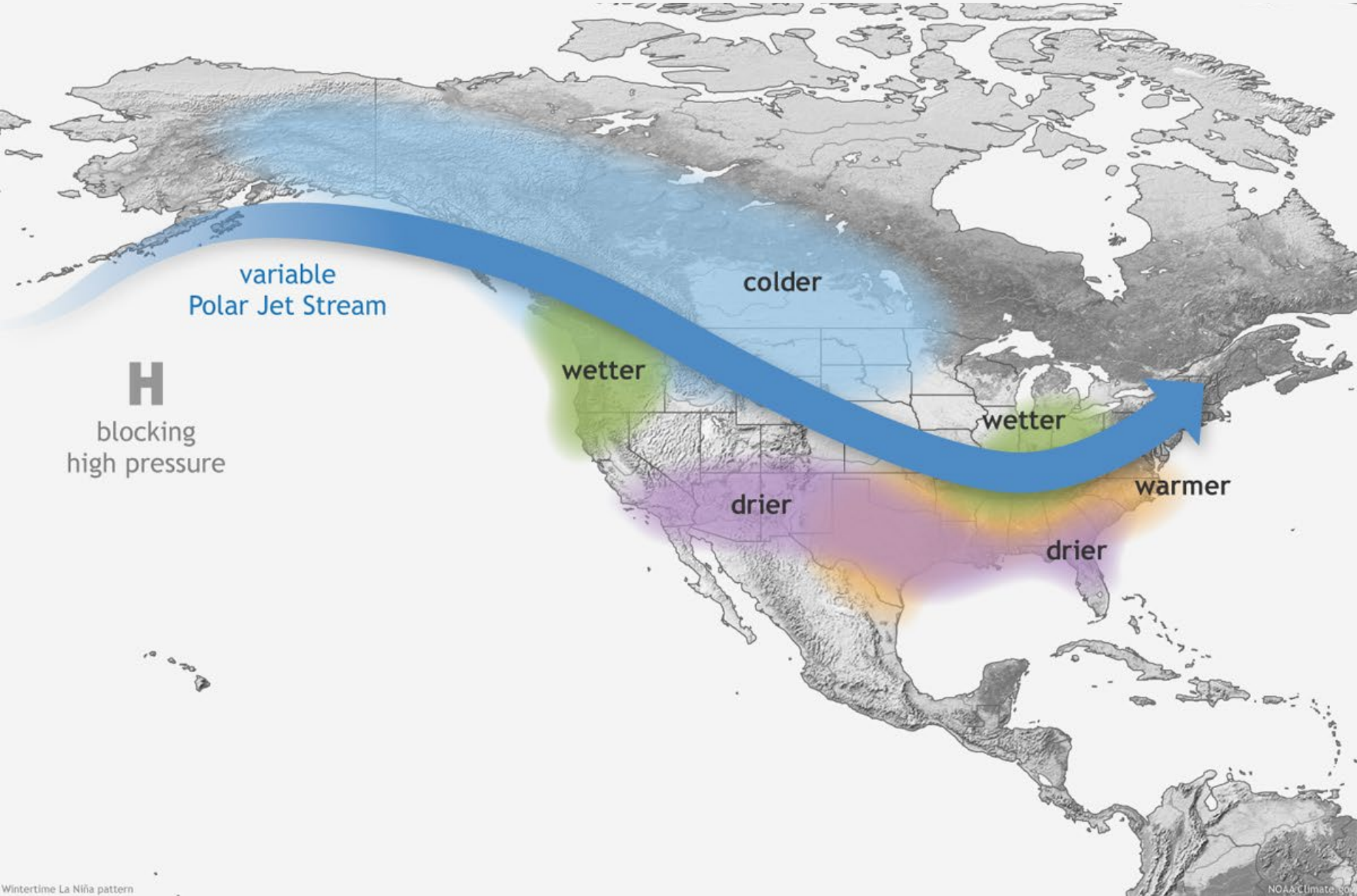
How *Climate Change* Impacts Health

- *Heat: Heat Stress, Heat Stroke*
- Temperature Changes: Fires, Spread of Parasites

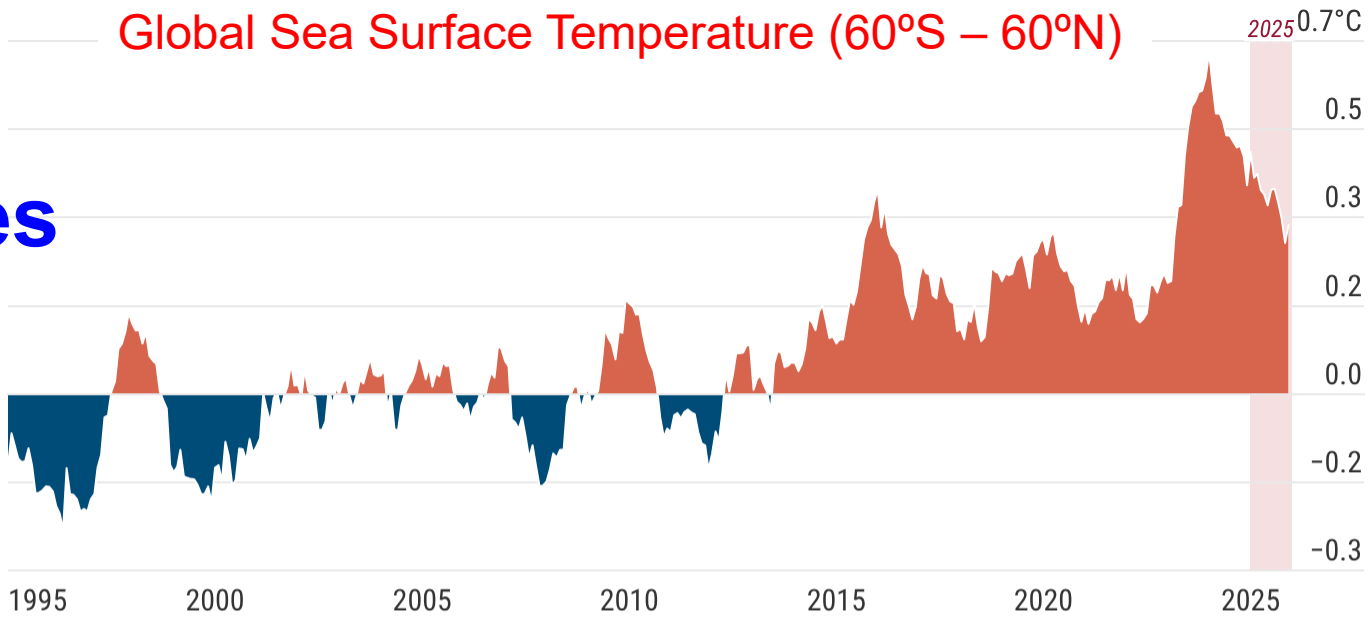
August 2023 Lahaina (Maui) Fires

January 2025 Southern California Wildfires

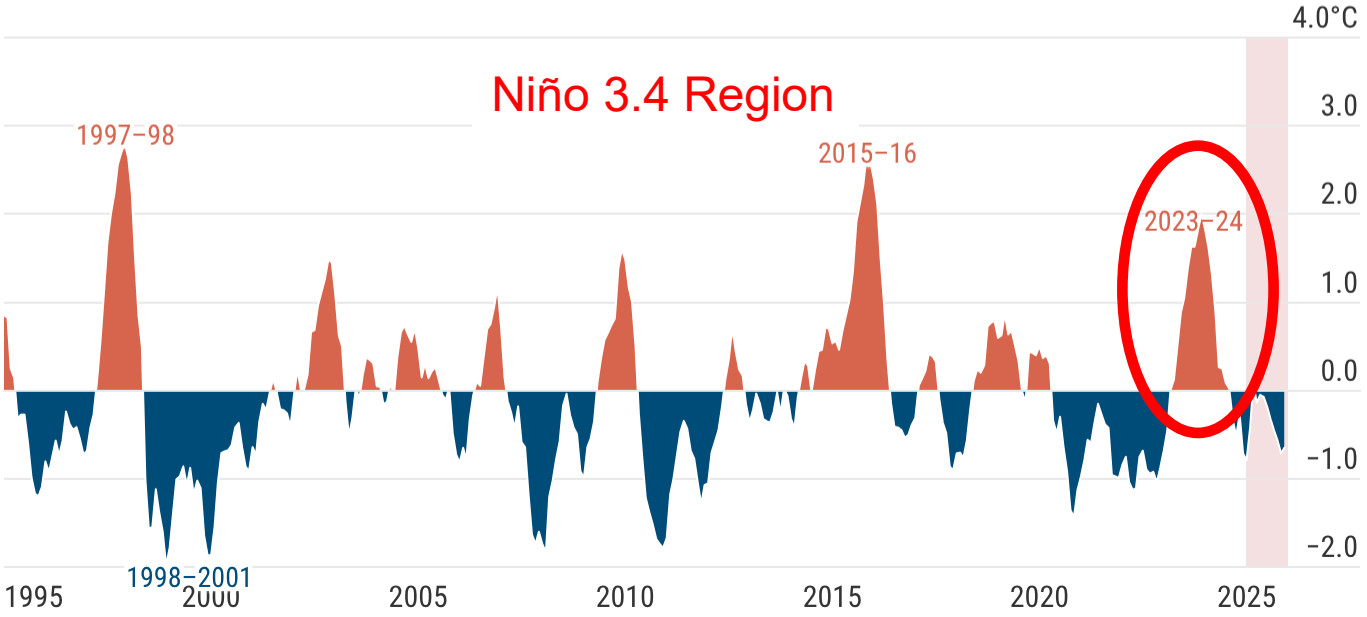
Typical La Niña Winter Jet Stream Patterns



Ocean Surface Temperatures



2023-2024: A Pacific *El Niño*



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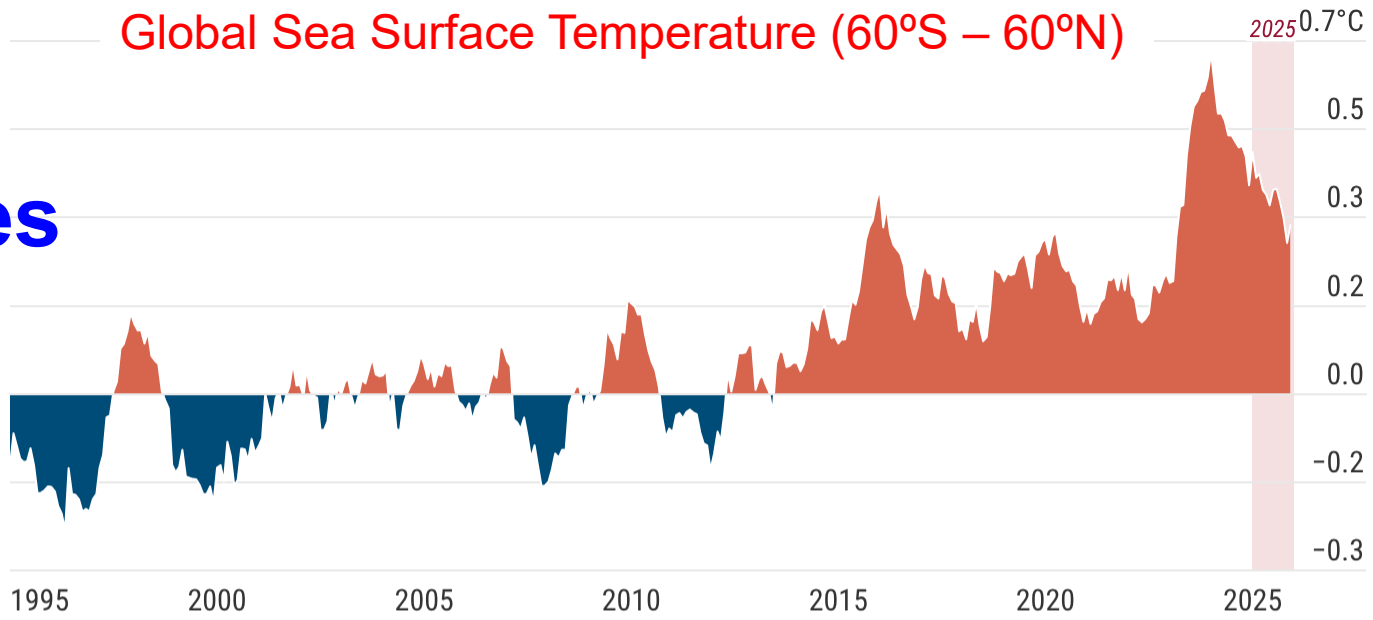
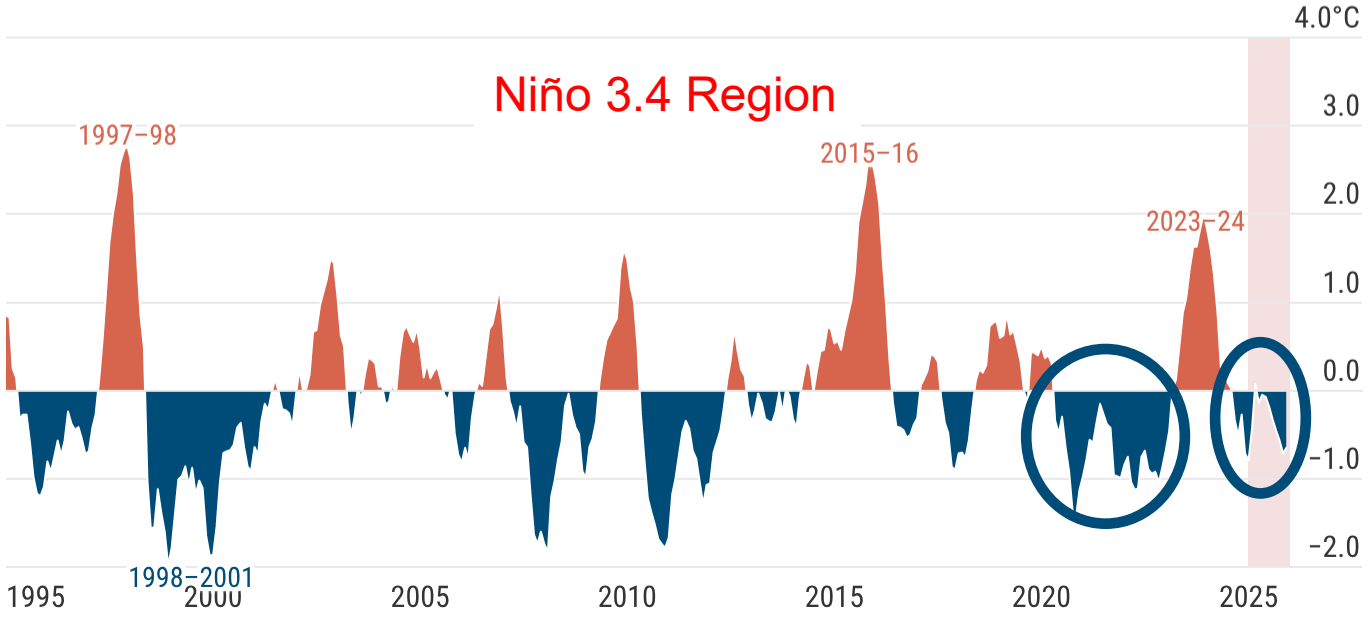
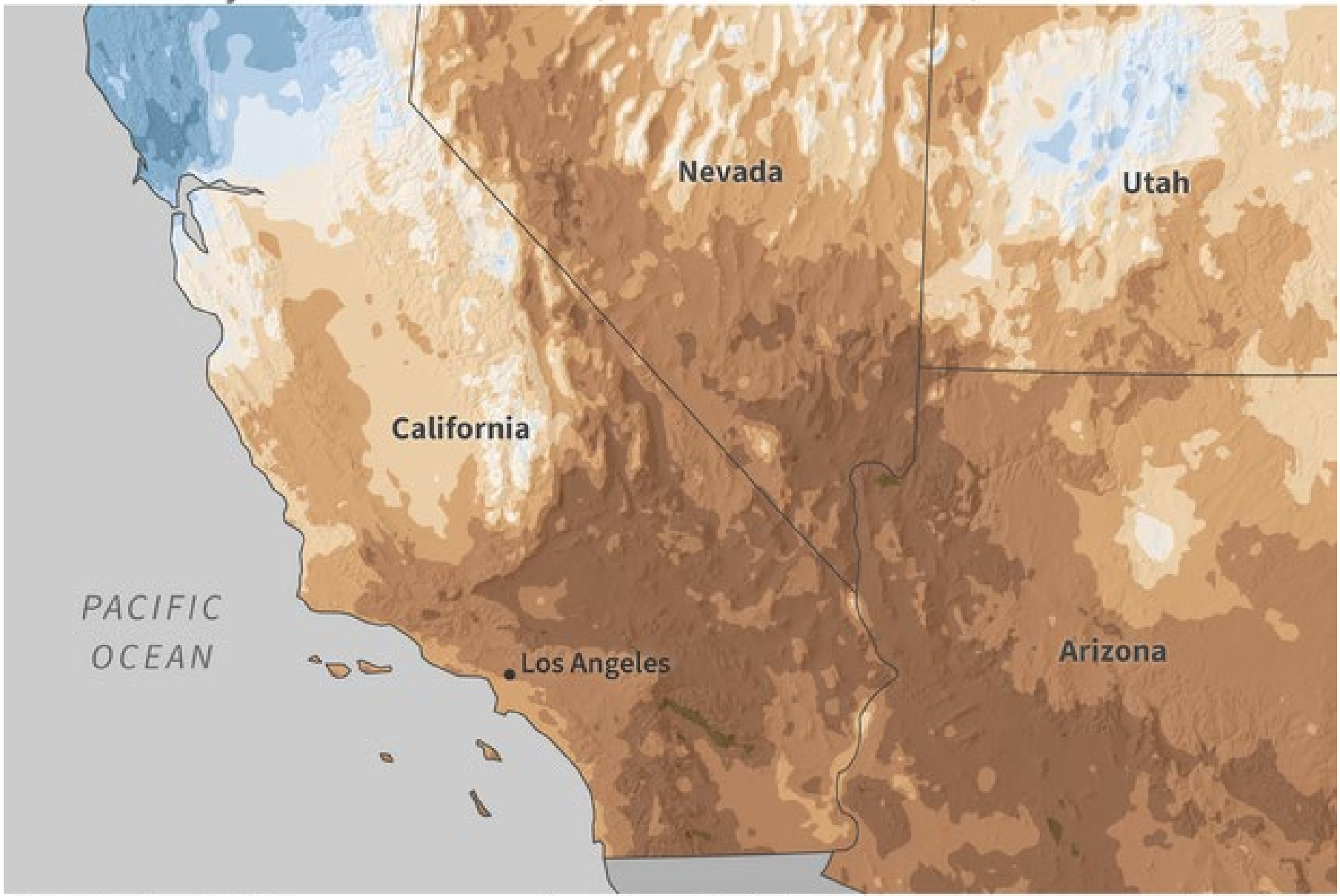


2020-2023 and 2025: Pacific *La Niñas*



Extreme fall dryness in U.S. Southwest (October–December 2024)



Standardized precipitation evaporation index, Oct–Dec 2024

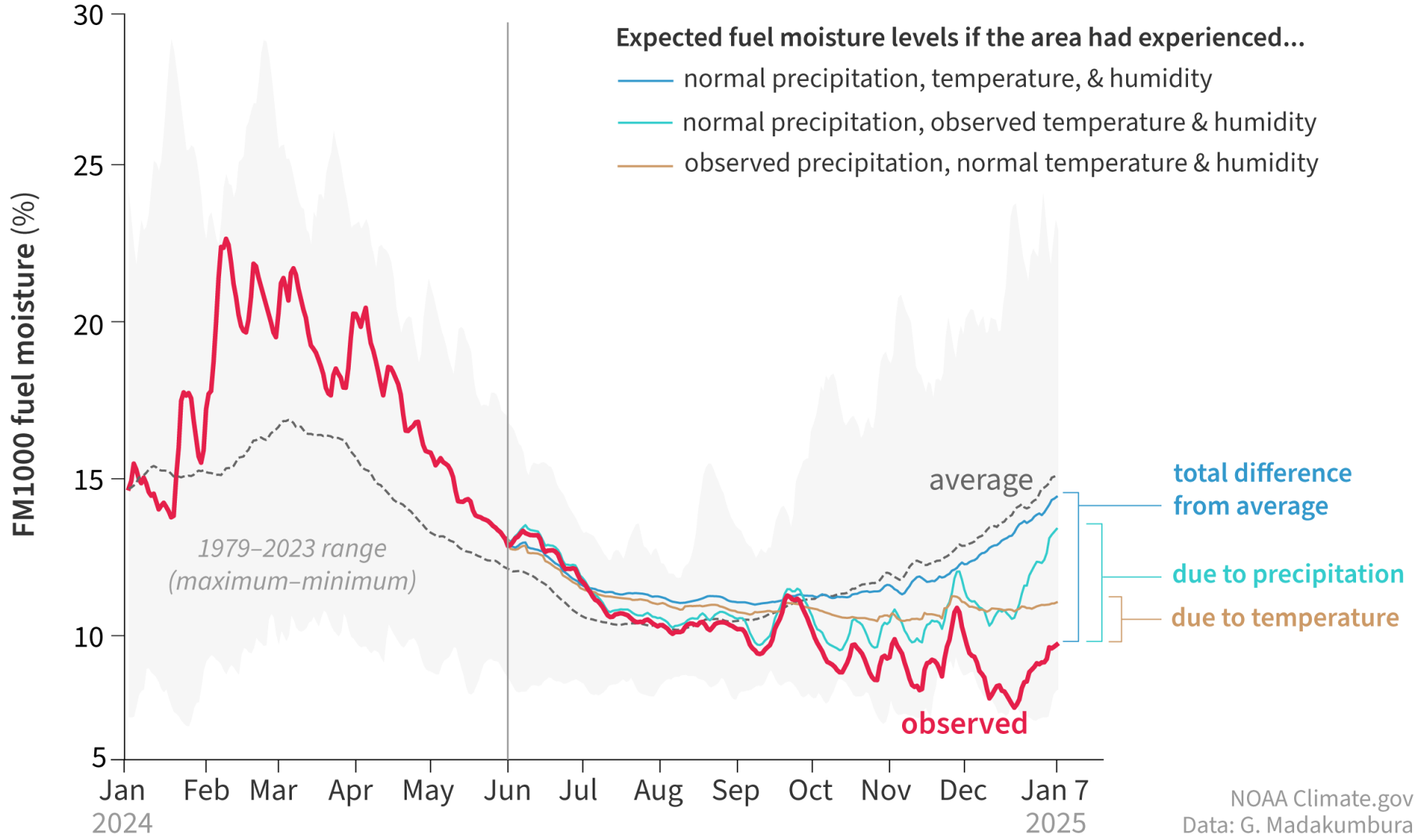
drought severity index

dry −3.76 −2 −1 0 1 2 3 wet

NOAA Climate.gov
Data: PRISM SPEI3

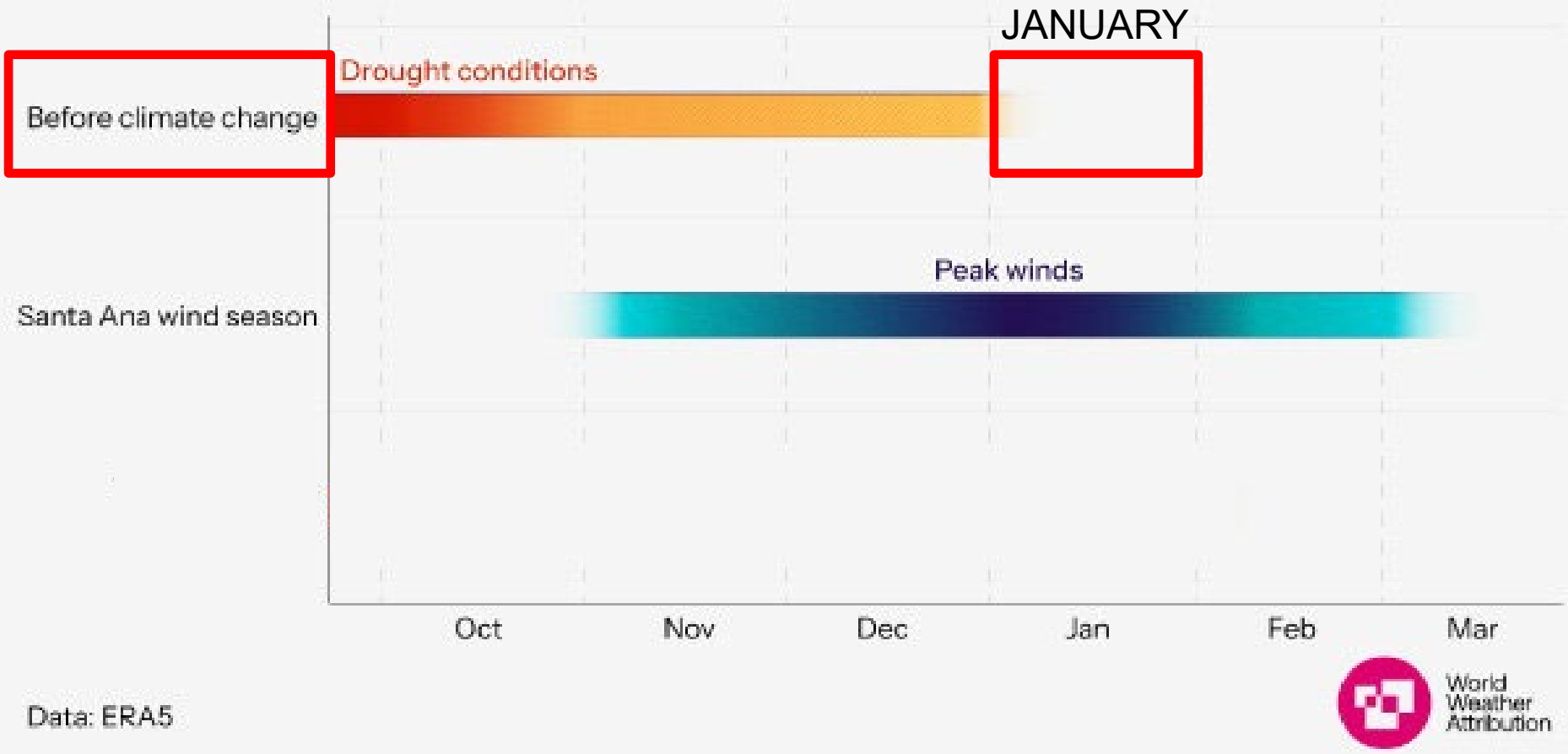
Fuel moisture in Southern California leading up to fires

Relative influence of temperature and humidity versus precipitaiton since June 1



NOAA Climate.gov
Data: G. Madakumbura

Flammable drought conditions are increasingly overlapping with peak Santa Ana winds



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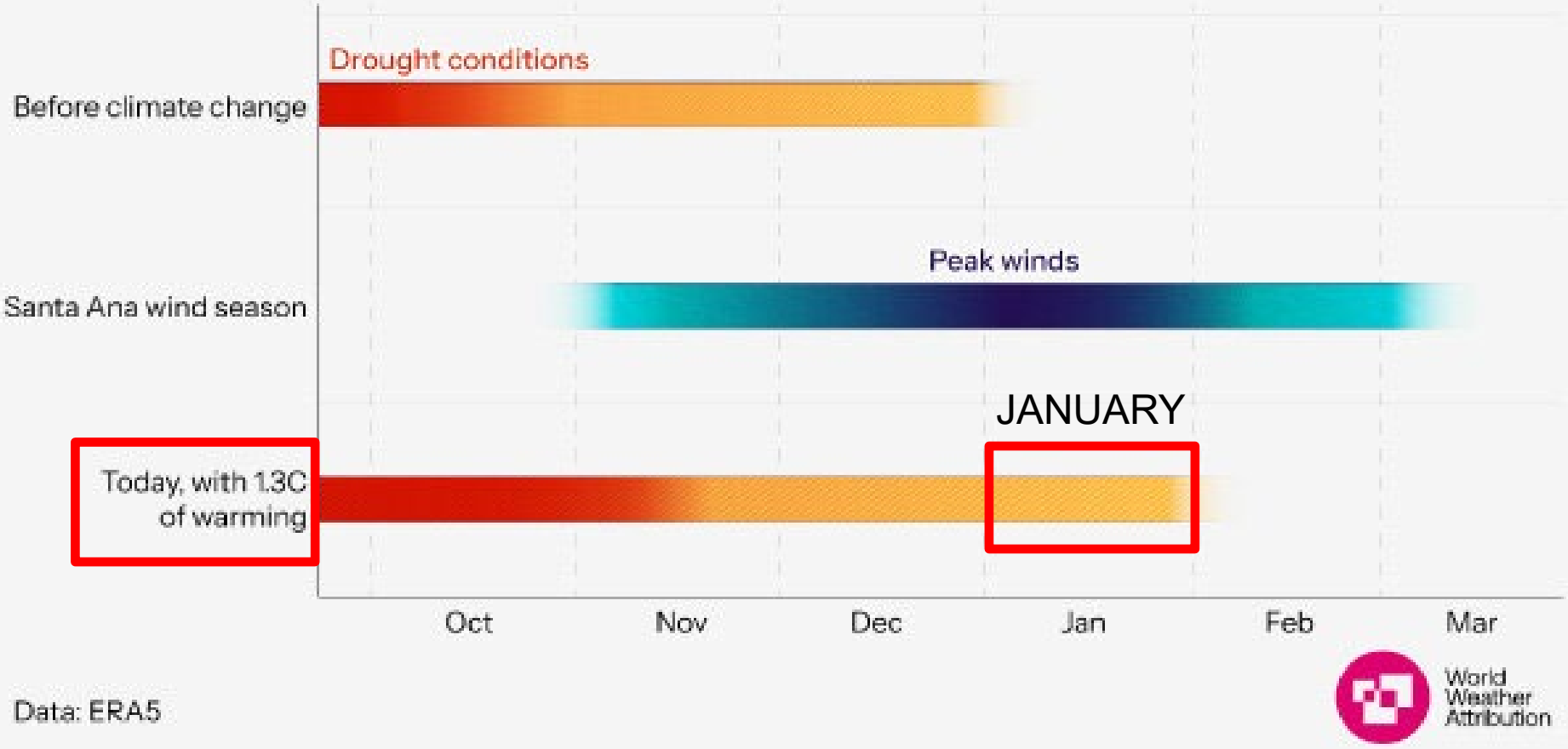
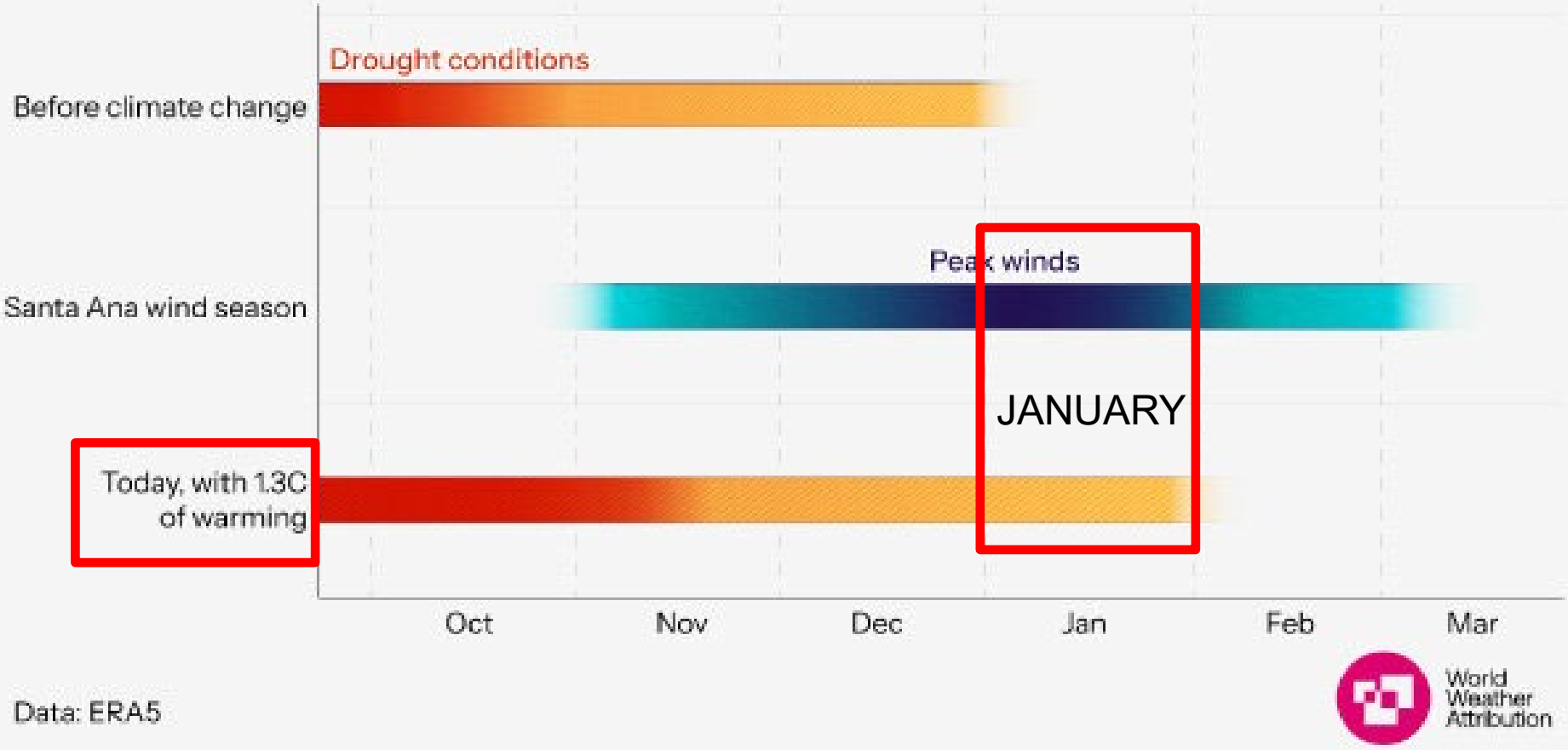


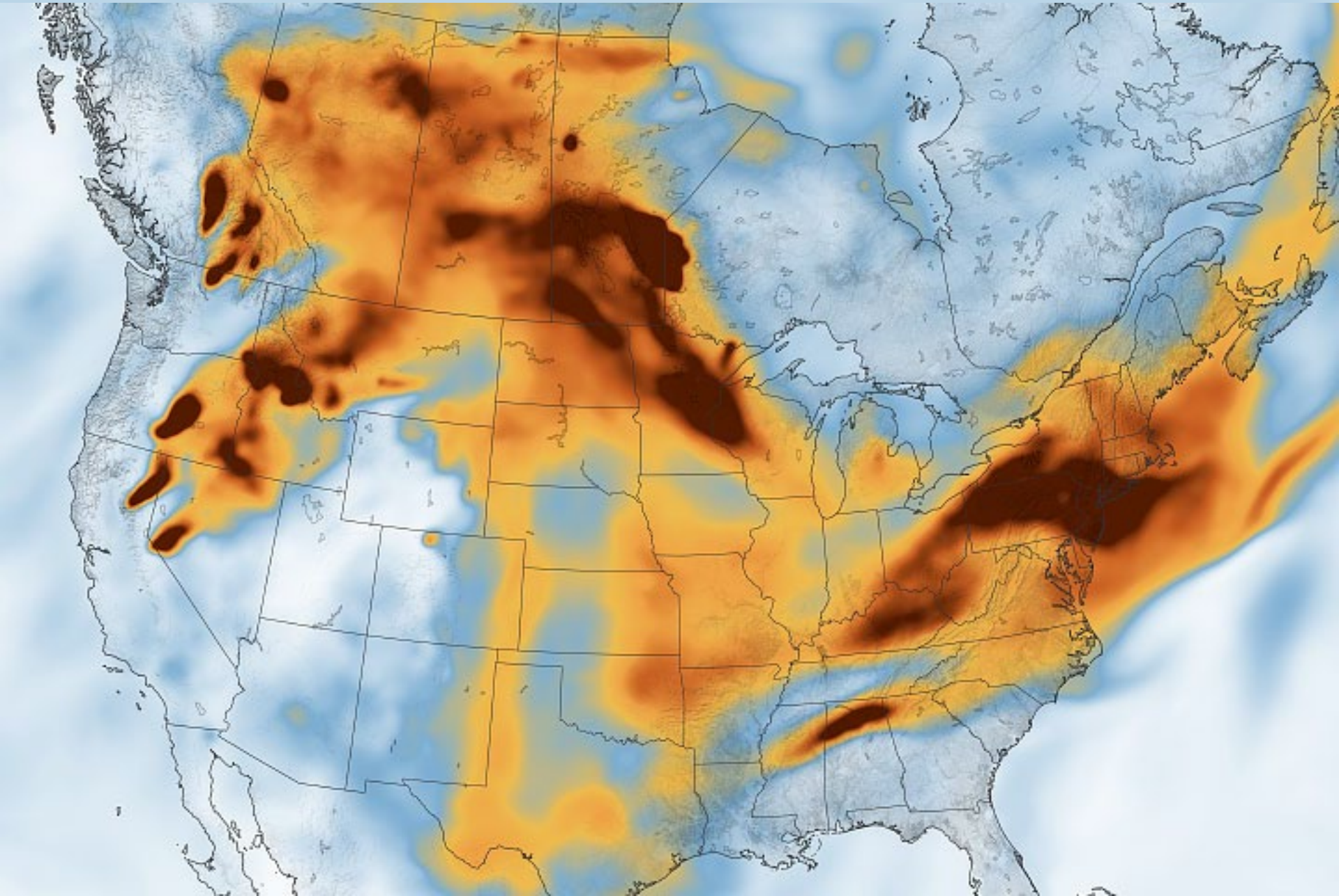
Data: ERA5

World Weather Attribution

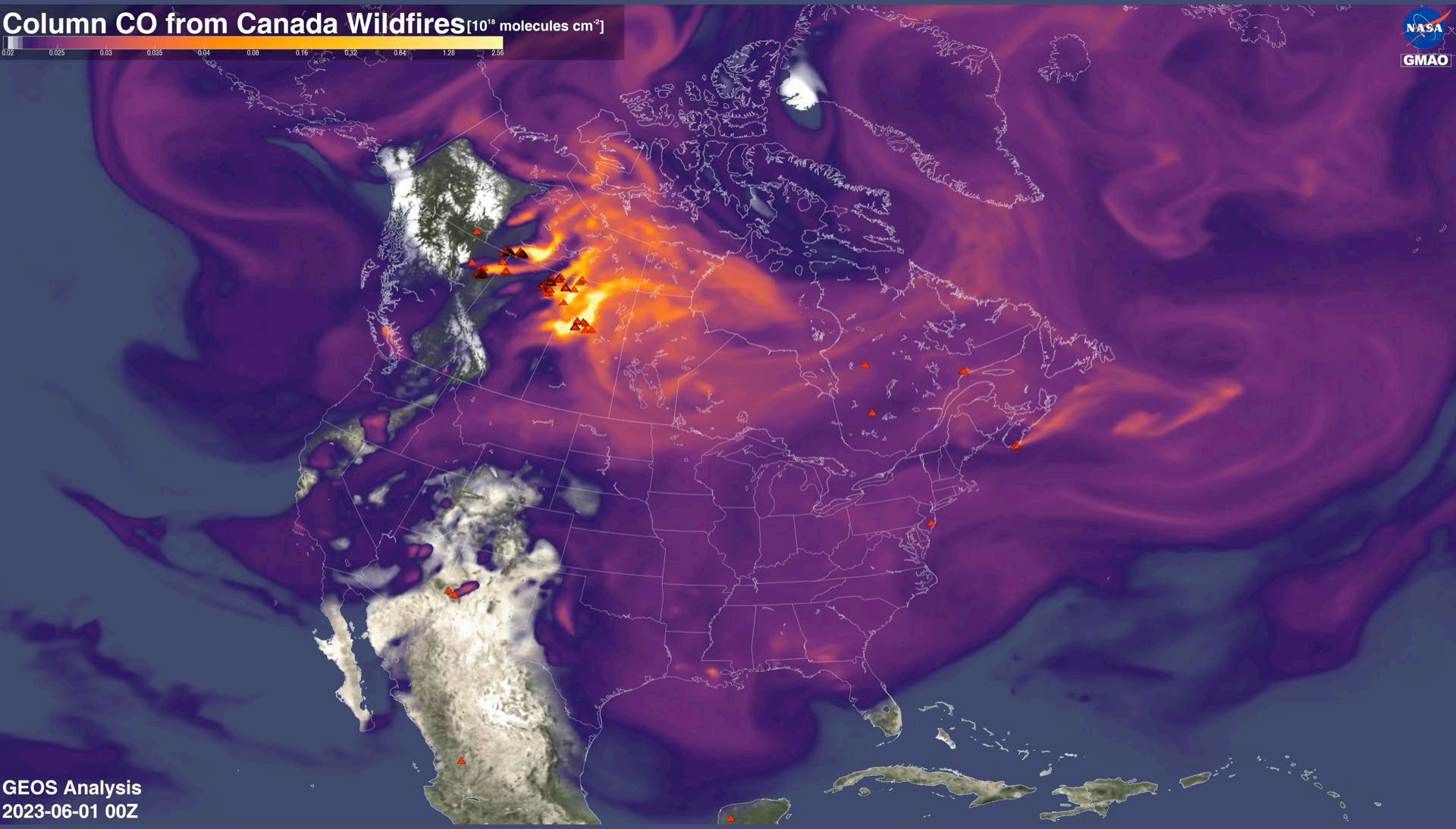
Flammable drought conditions are increasingly overlapping with peak Santa Ana winds

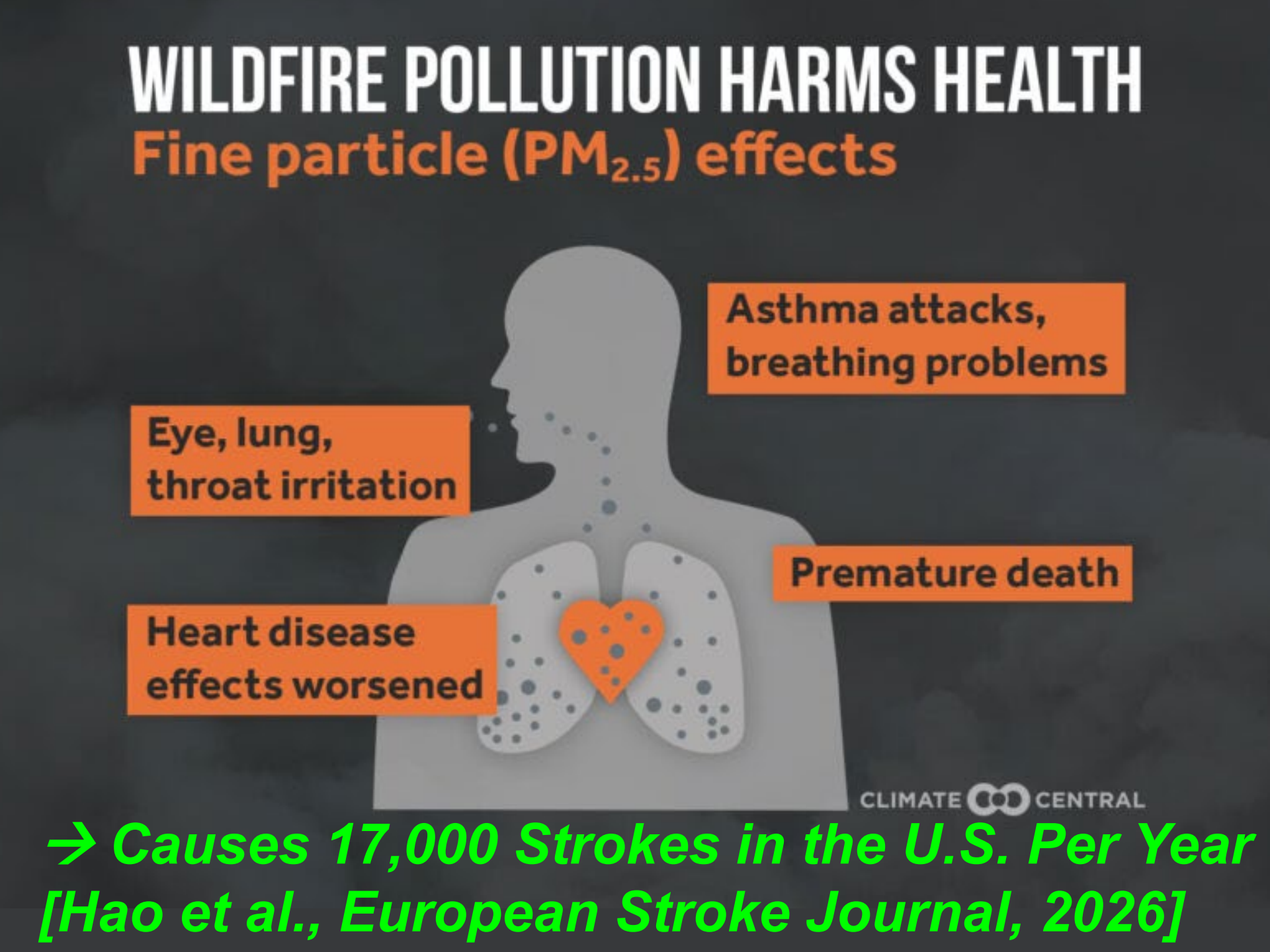


2023 Canadian Fire Smoke Transport



Animation of Carbon Monoxide Plumes from Canadian Wildfires in 2023





→ *Causes 17,000 Strokes in the U.S. Per Year*
[Hao et al., European Stroke Journal, 2026]

The Area Burned by Wildfires in the U.S. is Increasing

In the U.S., the overall number of fires each year has stayed fairly constant, but land area burned has increased over time.

Data from the National Interagency Fire Center

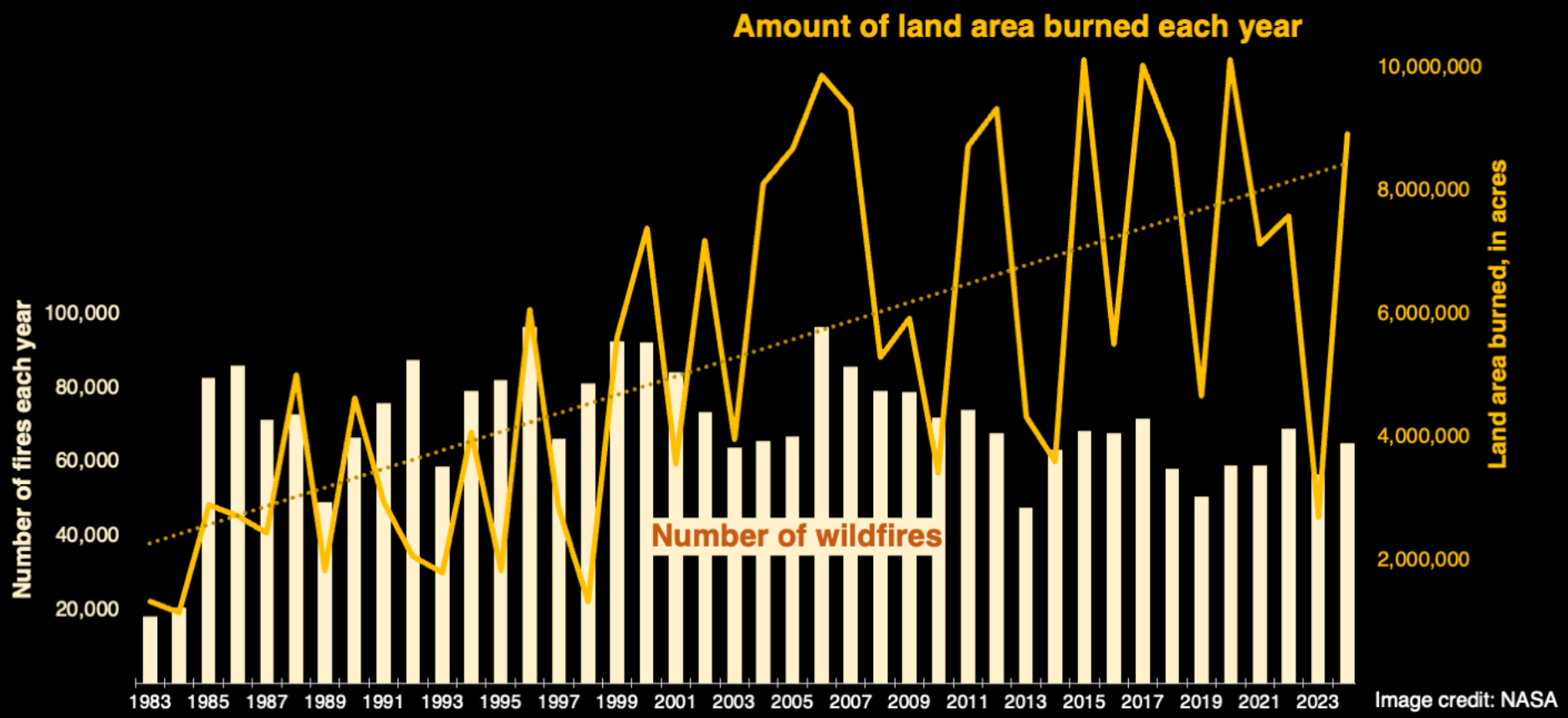
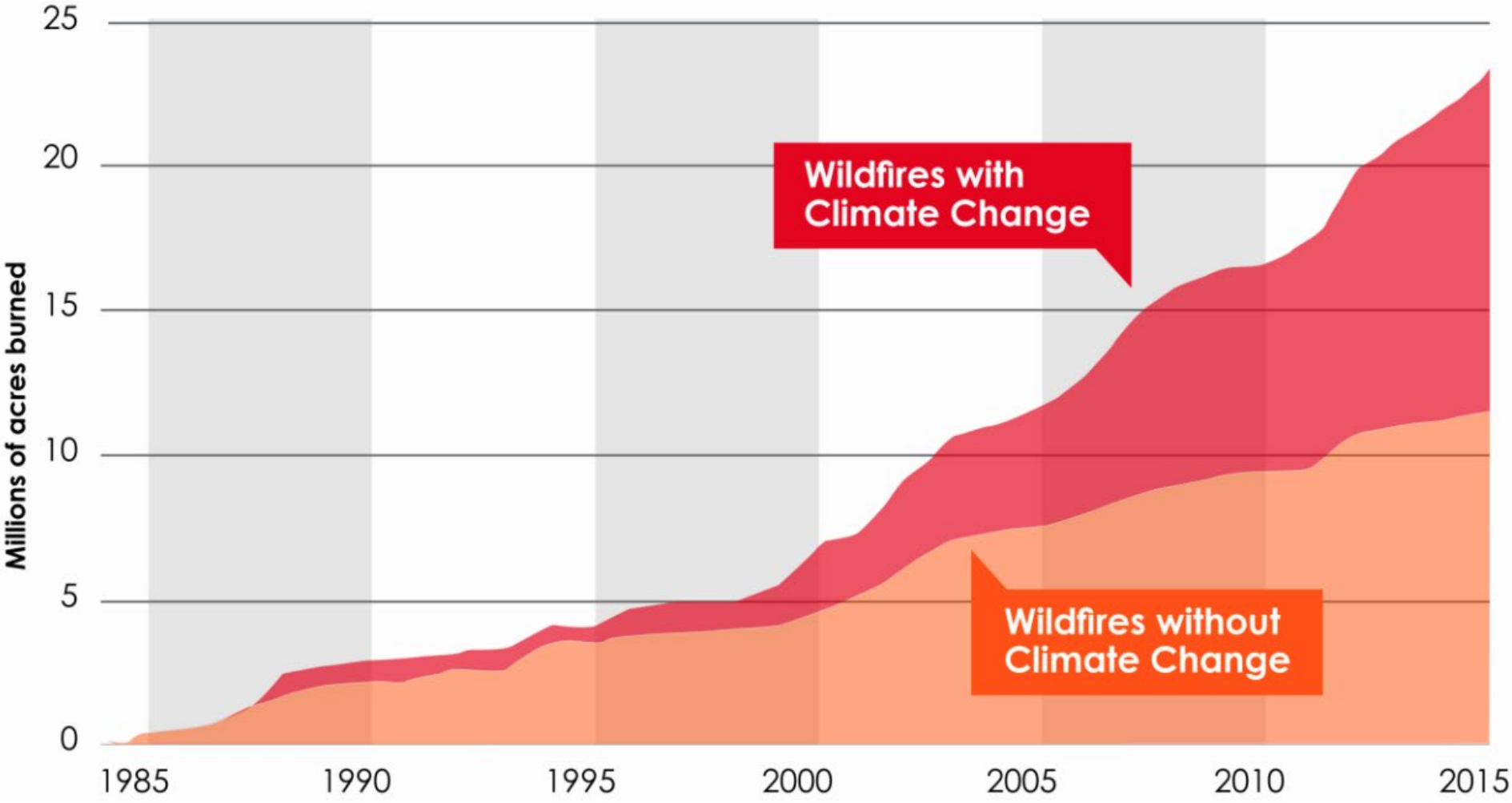


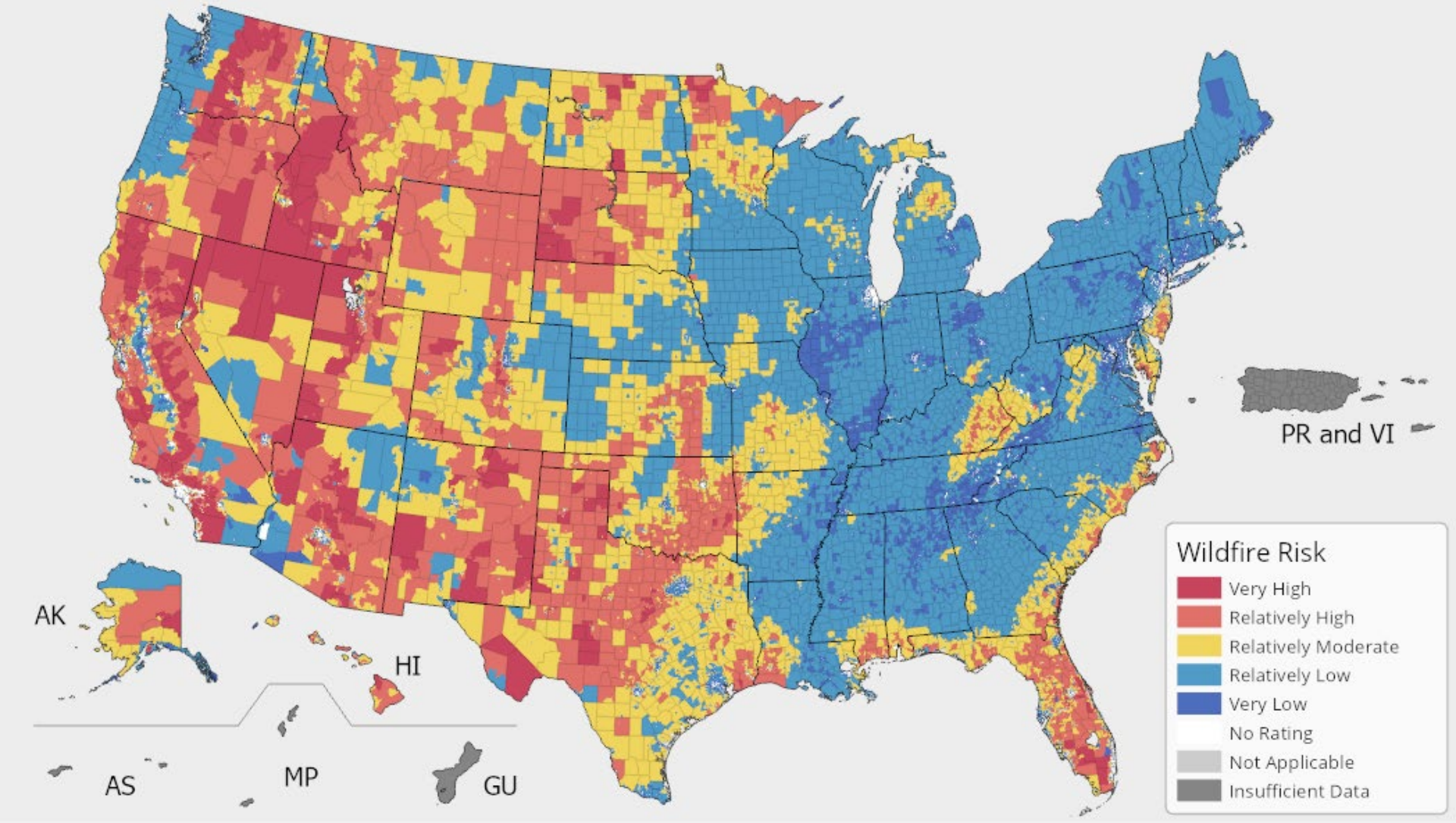
Image credit: NASA

Increase in Western U.S. Land Burned Due to Climate Change

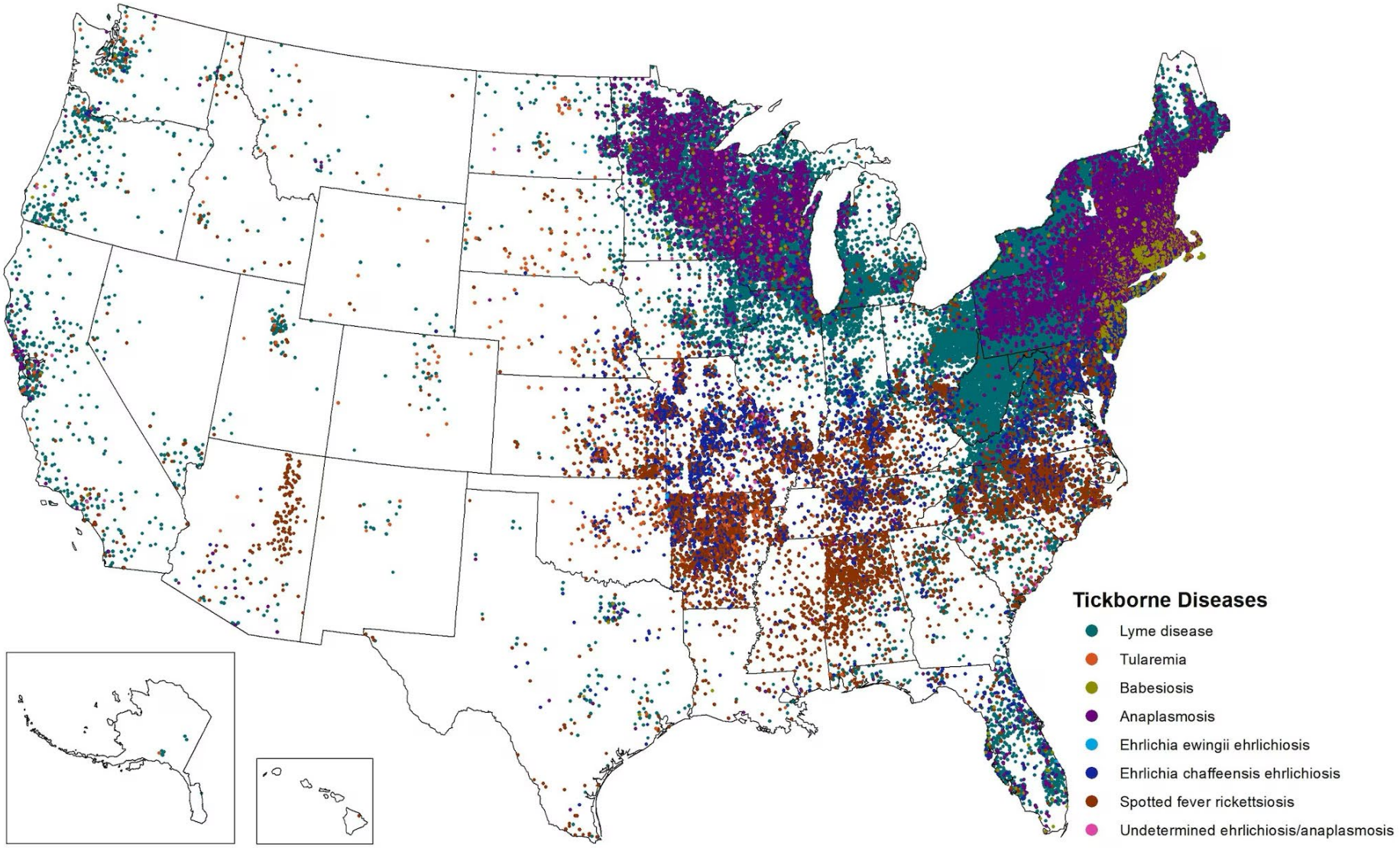


[4th U.S. National Climate Assessment, 2018]

Wildfire Risk (FEMA – Federal Emergency Management Administration)



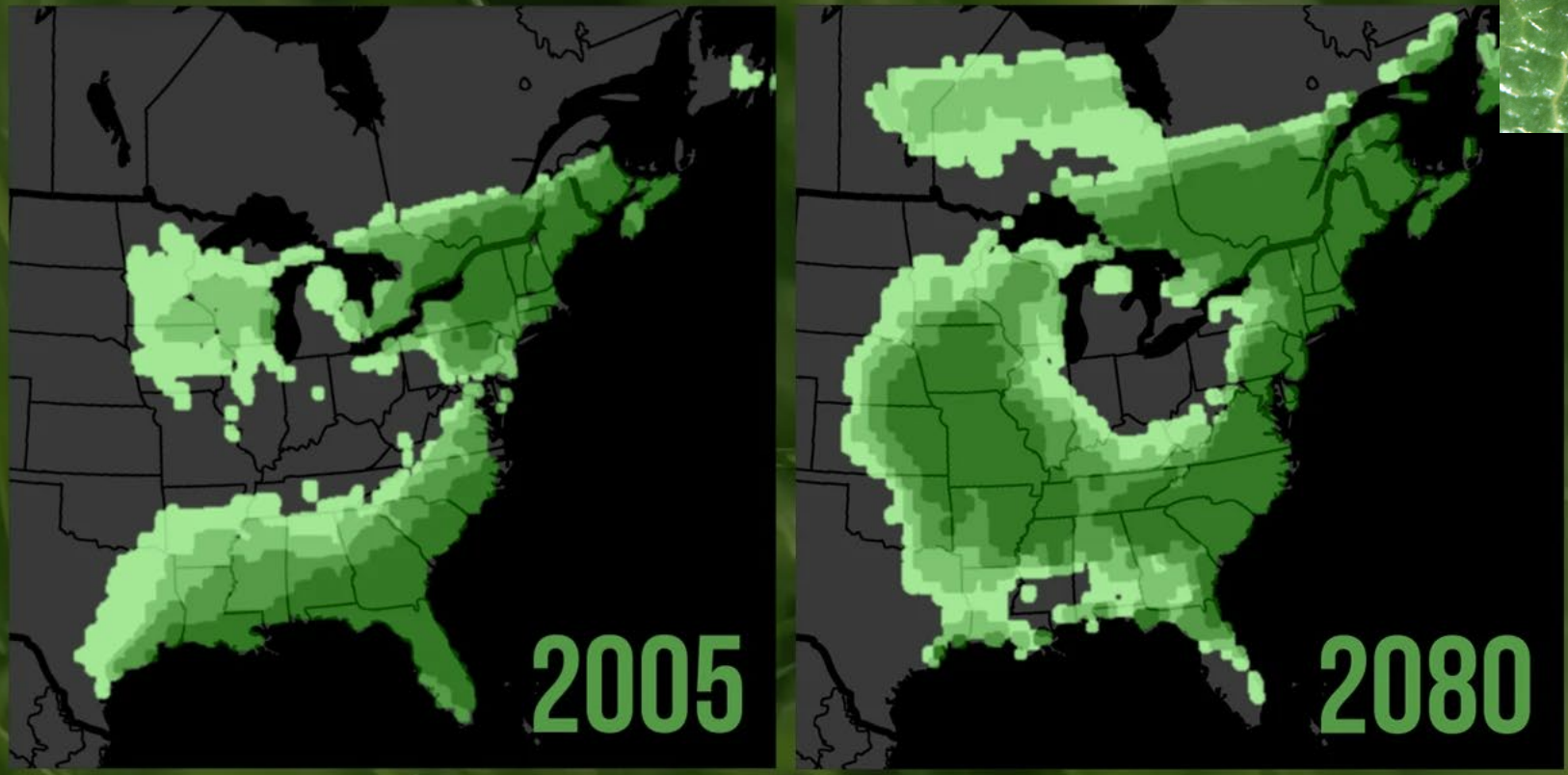
Reported Cases of Tickborne Diseases - United States, 2019-2022



Note: Powassan data not represented on the map. Babesiosis data incomplete for years shown.

TICKS ON THE MARCH

Projections in Deer Tick Habitat



Favorability for deer ticks (%)

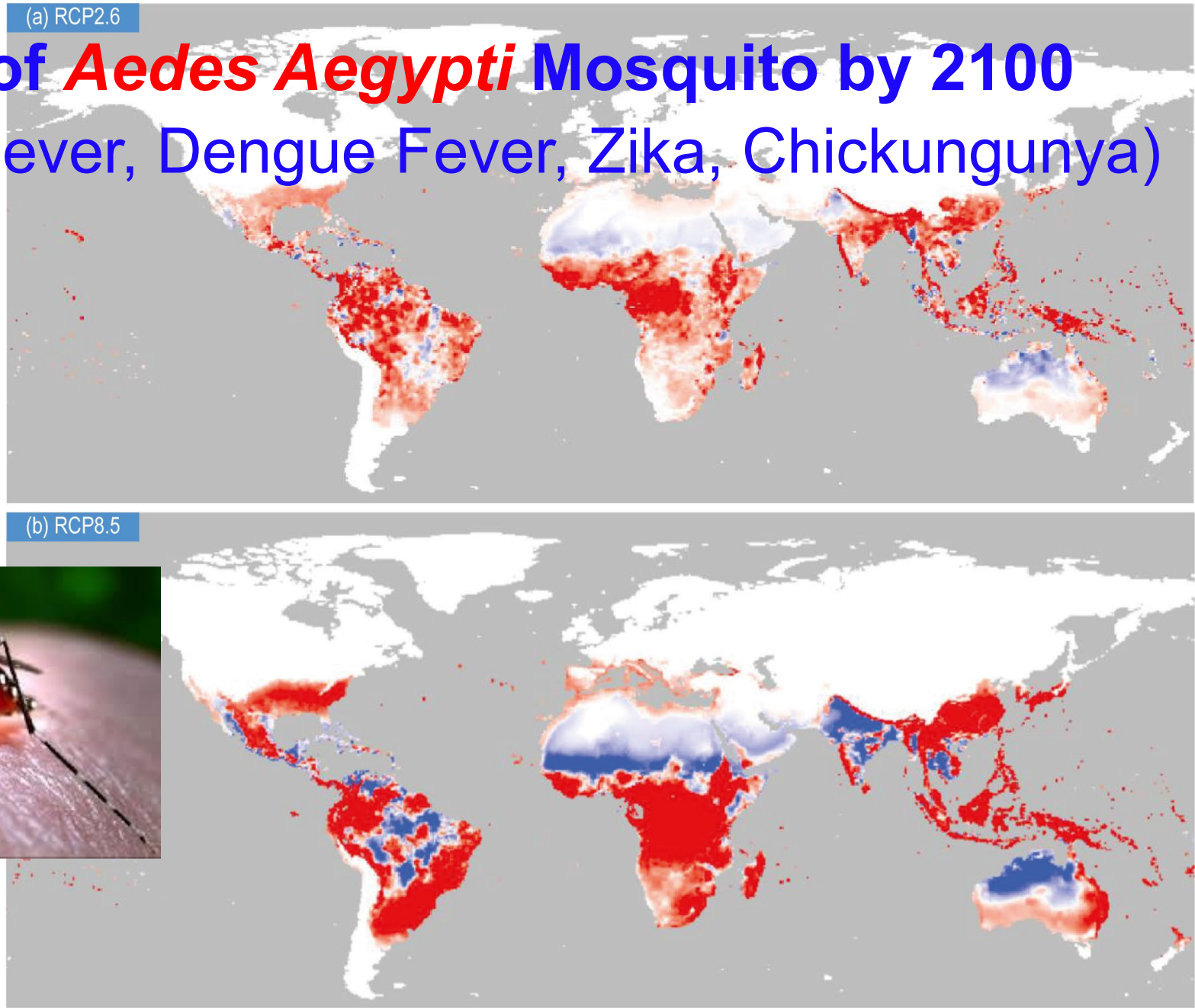
0 20 40 60 80 100

Source: Brownstein, J. S., T. R. Holford, and D. Fish, 2005: Effect of climate change on Lyme disease risk in North America.

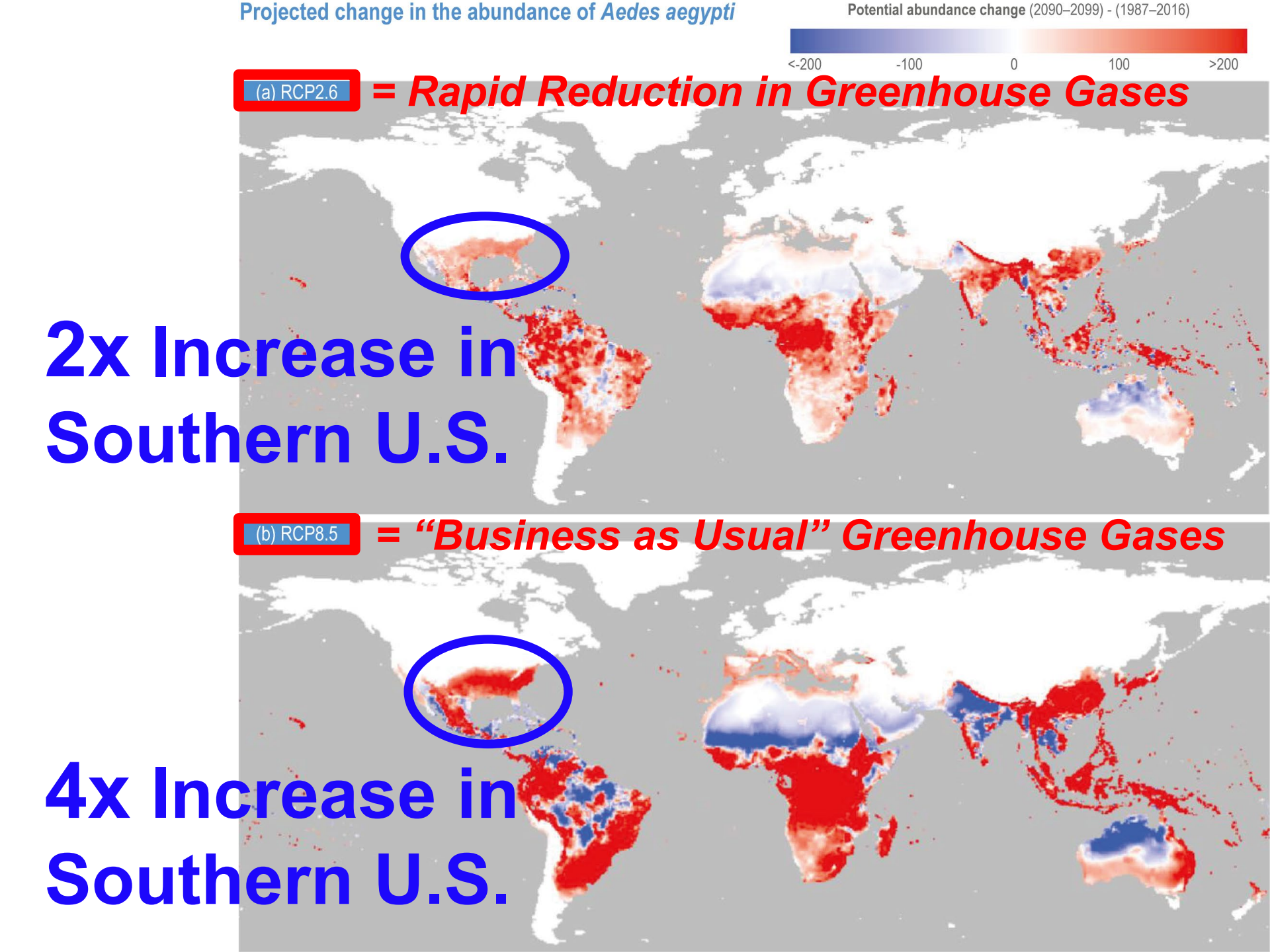
CLIMATE CENTRAL

Spread of *Aedes Aegypti* Mosquito by 2100

(Yellow Fever, Dengue Fever, Zika, Chickungunya)



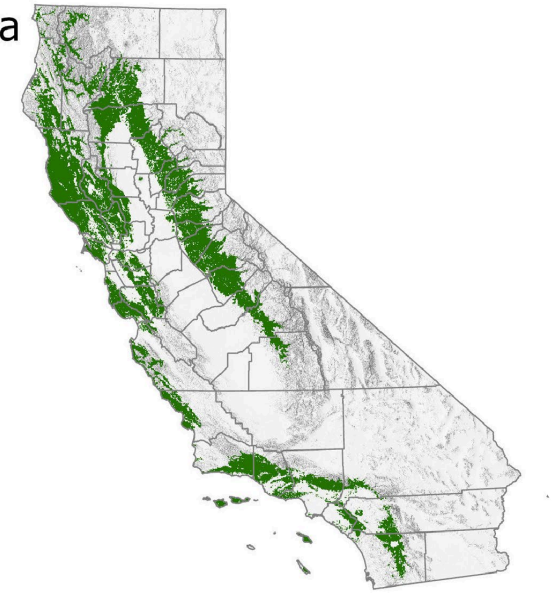
IPCC AR6


Projected change in the abundance of *Aedes aegypti*
Potential abundance change (2090–2099) - (1987–2016)
<-200
-100
0
100
>200
(a) RCP2.6
= Rapid Reduction in Greenhouse Gases
2x Increase in Southern U.S.
(b) RCP8.5
= "Business as Usual" Greenhouse Gases
4x Increase in Southern U.S.

Spread of Western Blacklegged Tick (*Ixodes pacificus*) with Climate Warming

→ *Carries Lyme Disease*

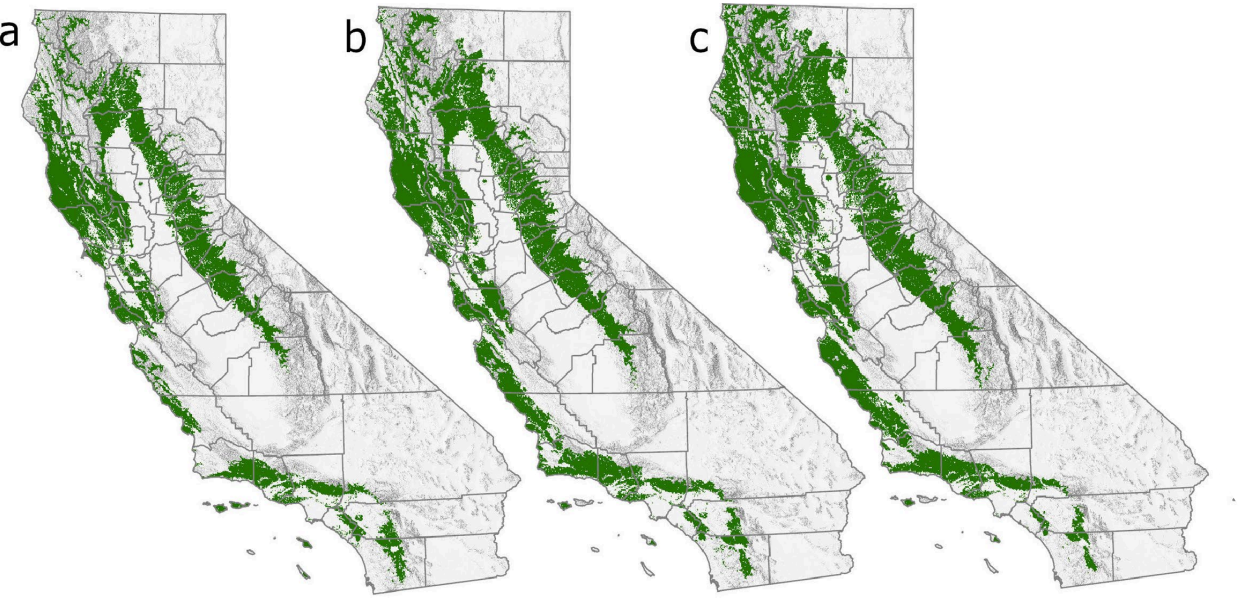
CURRENT



Spread of Western Blacklegged Tick (*Ixodes pacificus*) with Climate Warming

→ *Carries Lyme Disease*

RCP 4.5: AGGRESSIVE REDUCTION IN CARBON EMISSIONS



Spread of Western Blacklegged Tick (*Ixodes pacificus*) with Climate Warming

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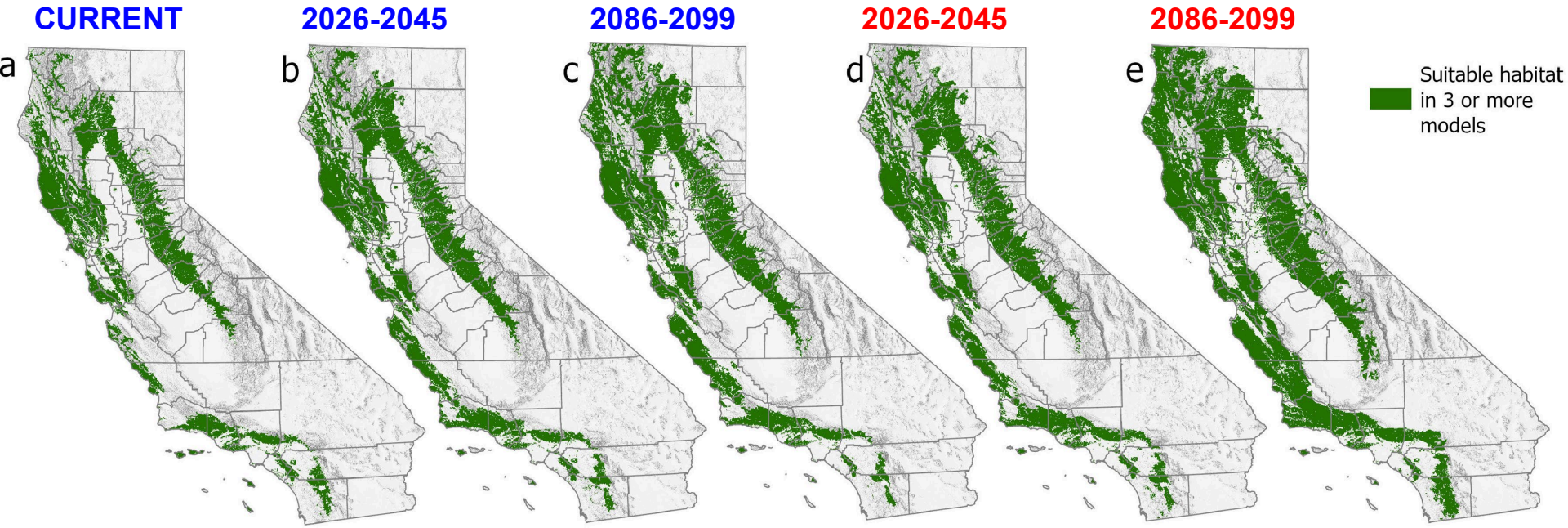
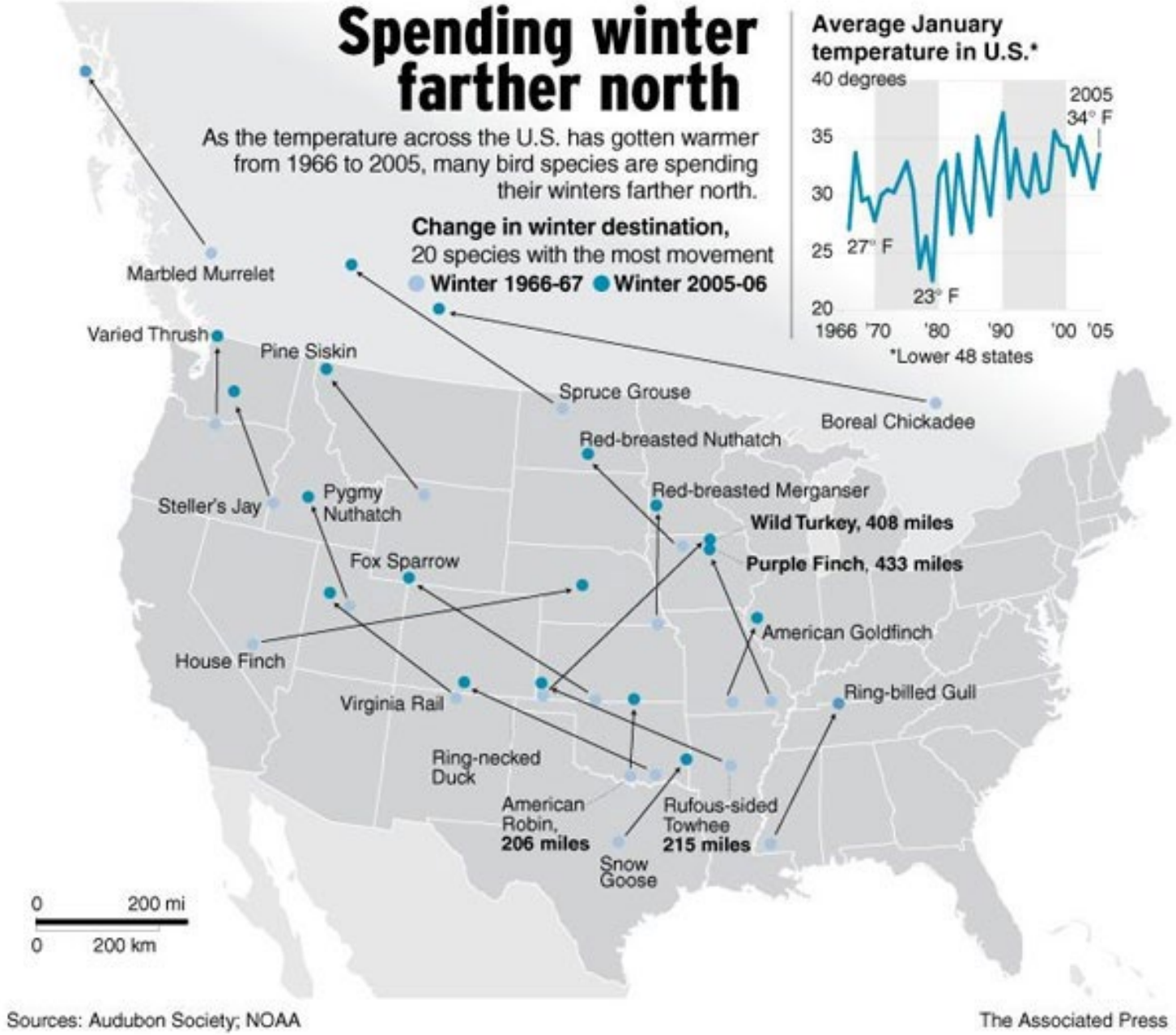
RCP 4.5: AGGRESSIVE REDUCTION IN CARBON EMISSIONS

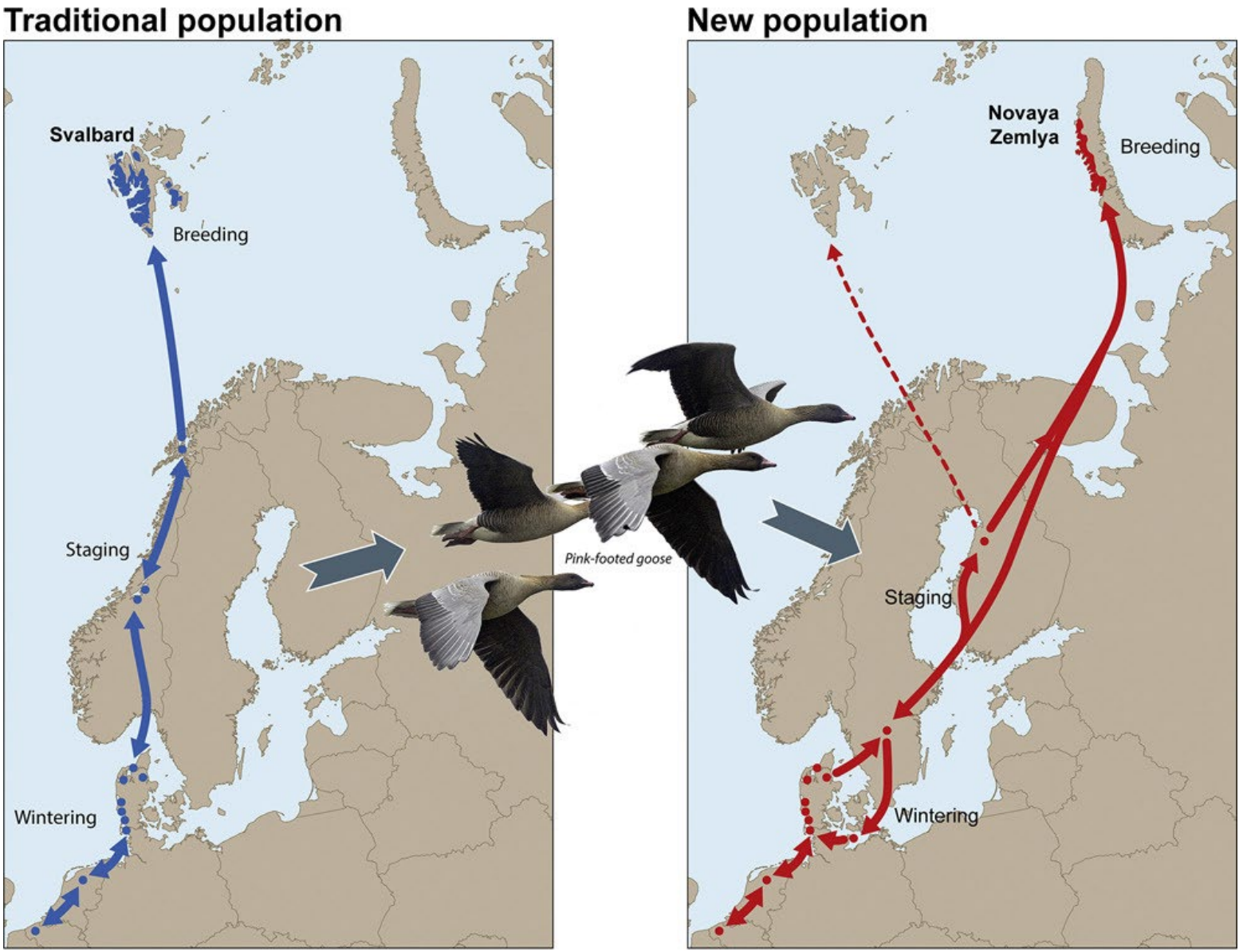
RCP 8.5: "BUSINESS AS USUAL" IN CARBON EMISSIONS



Northward Shift in Annual Bird Migration Patterns

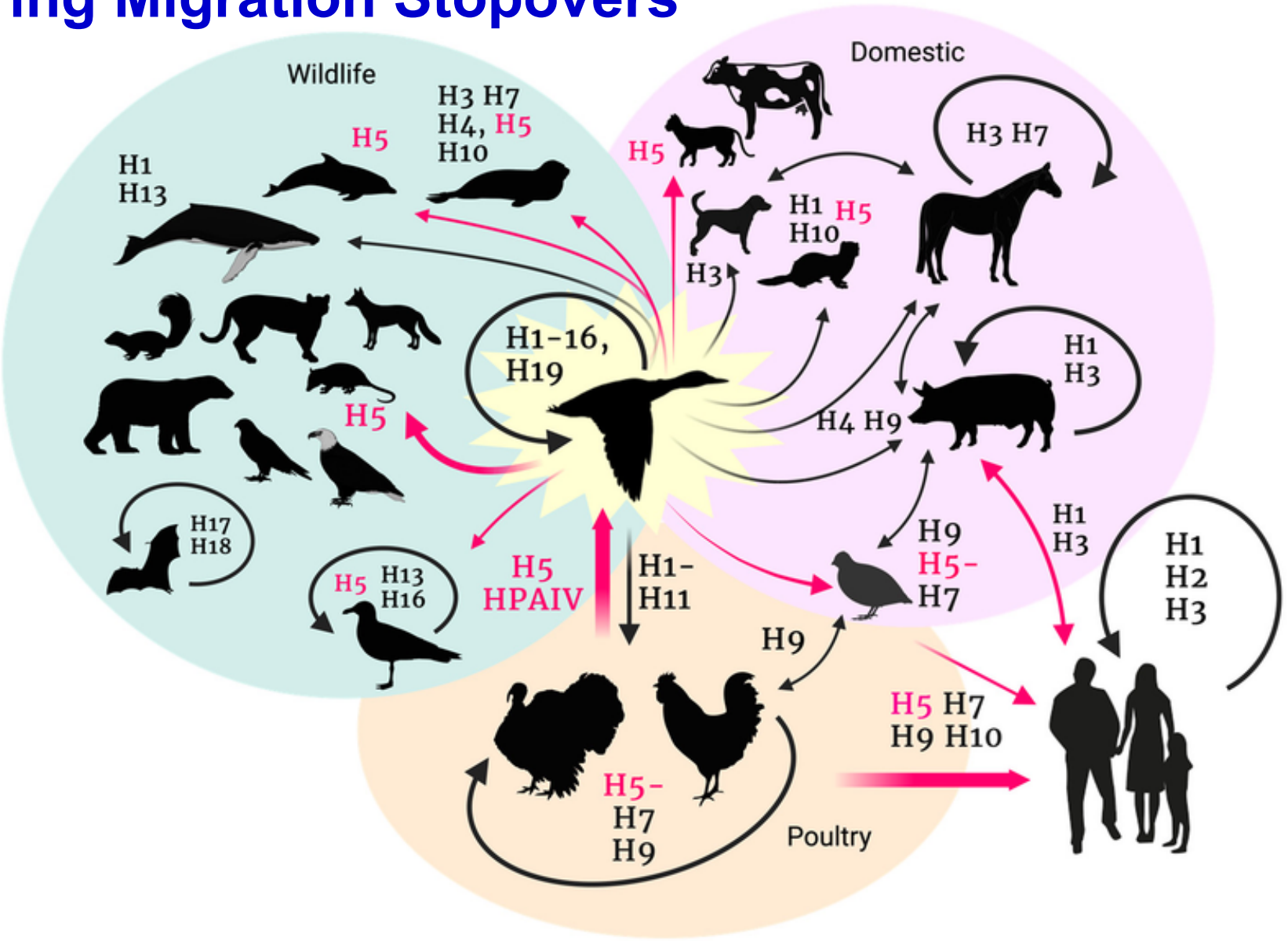


Sudden Shift in Annual Bird Migration Patterns Due to Climate Change

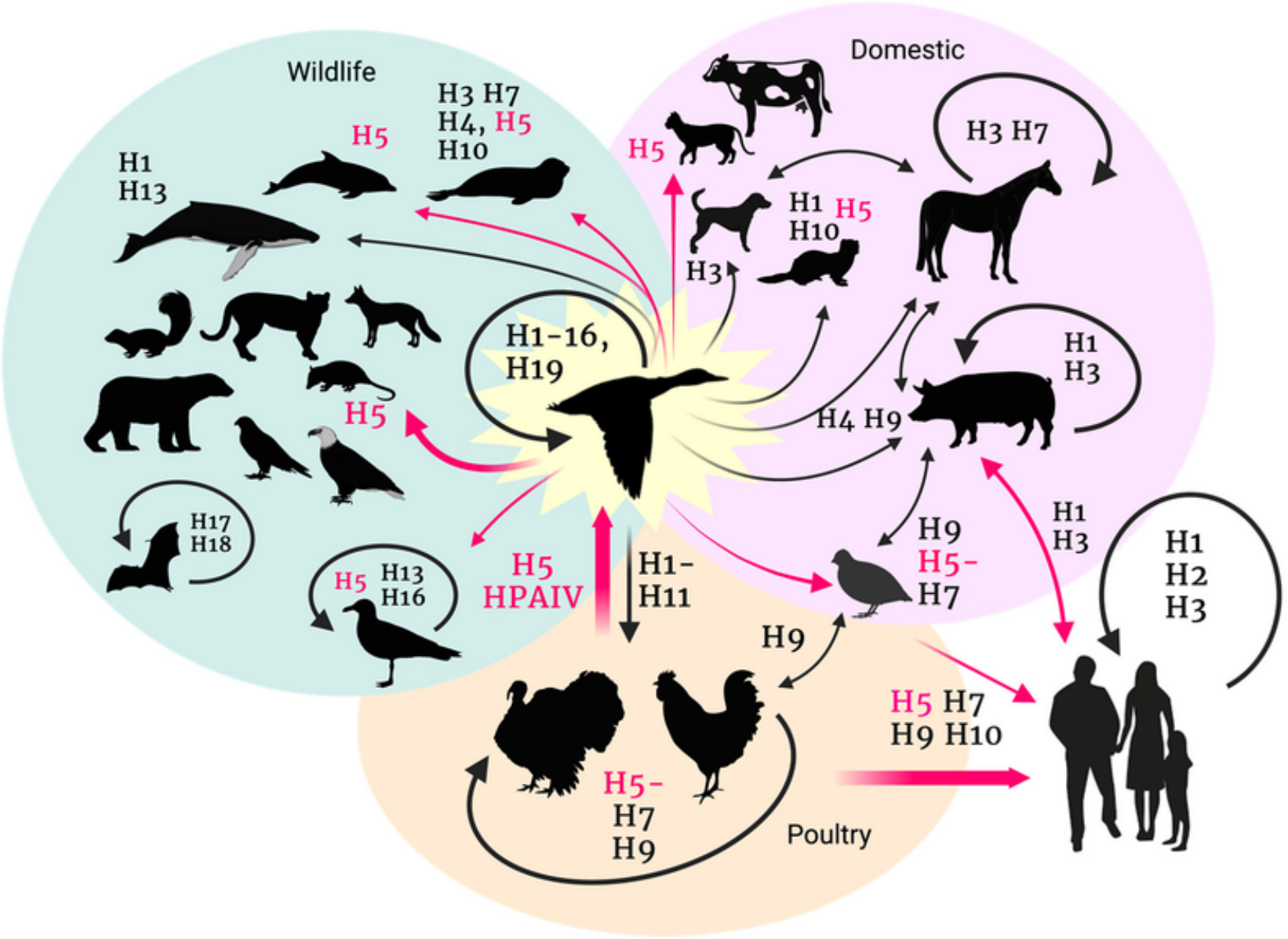


[Madsen et al., *Current Biology*, 2023]

Migrating Wild Aquatic Birds Carry a Huge Reservoir of RNA Viruses That They Infect Other Species With During Migration Stopovers



Each Avian Flu Pandemic (1918, 1957, 1968, 2009) Was Preceded by a Pacific La Niña



How *Climate Change* Impacts Health

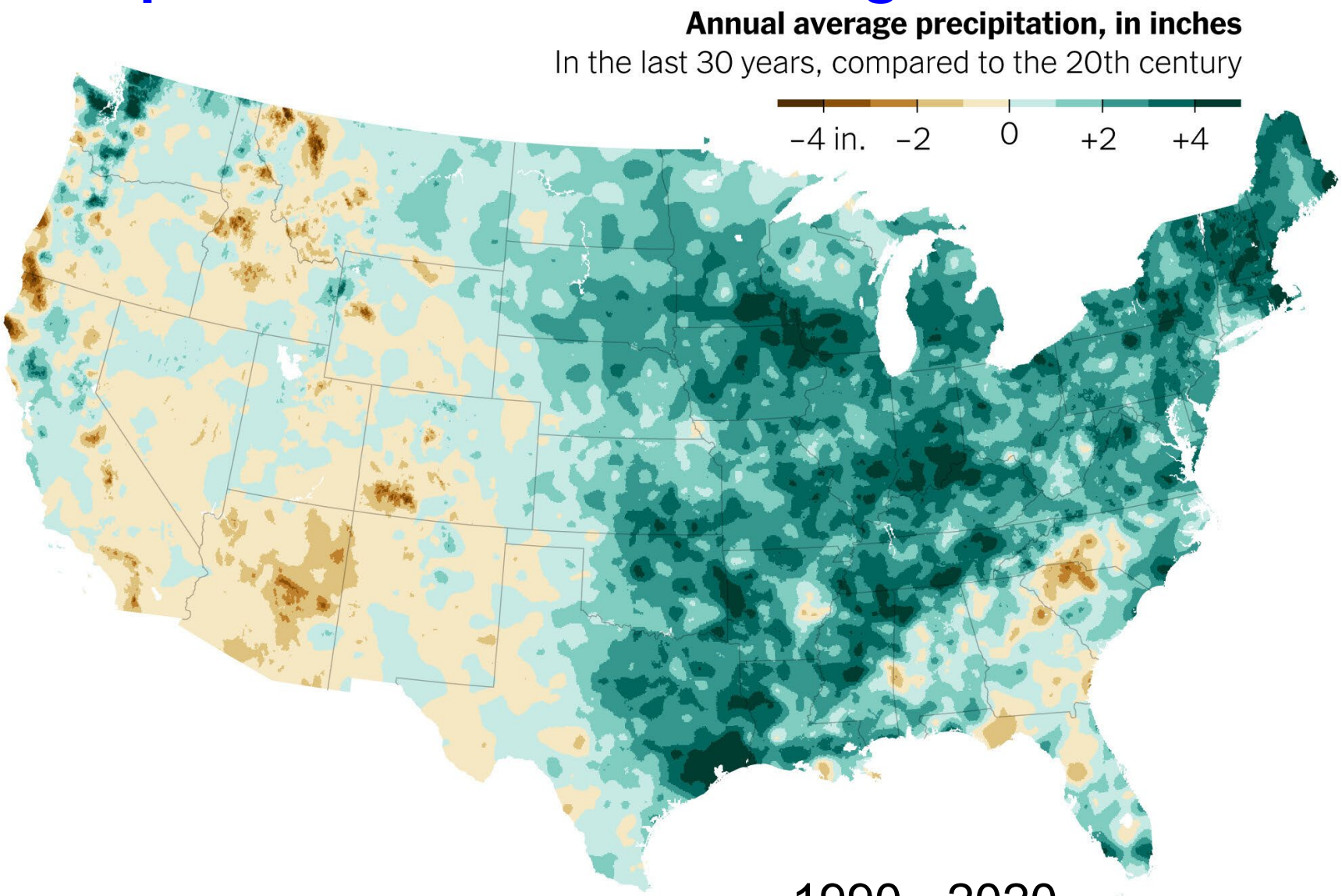
- *Heat: Heat Stress, Heat Stroke*
- *Temperature Changes: Fires, Spread of Parasites*
- Water Distribution Changes: Droughts, Floods, Water-borne Diseases, Fungal Infections

Weather-Related Morbidity/Mortality

- Increases in the incidence and intensity of extreme weather events such as hurricanes and floods

Hurricane Beryl, Houston, TX, July 9, 2024

Change in Precipitation (in Inches) for 1990-2020, Compared to 1900-2000 Average

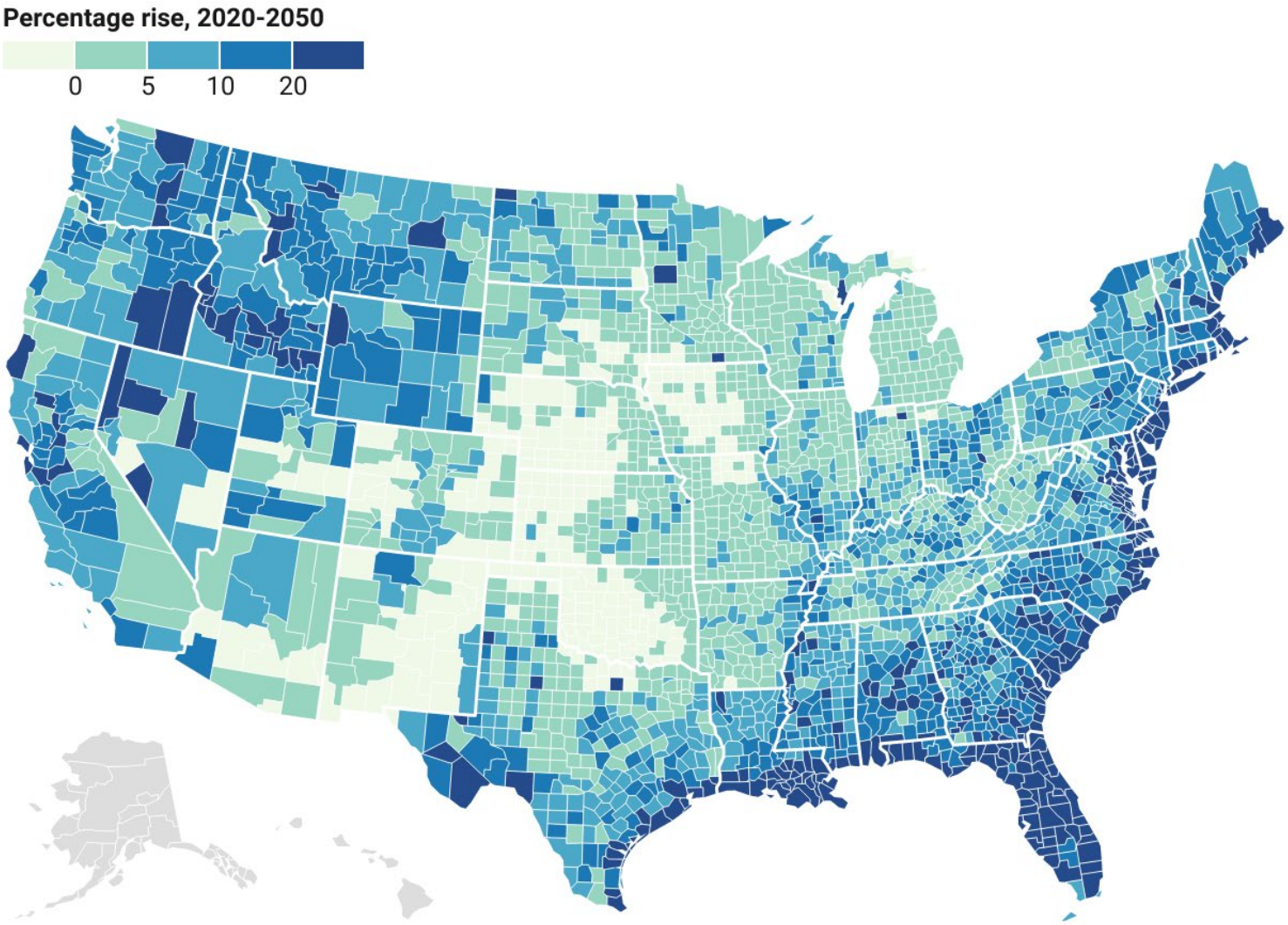


1990 - 2020

NOAA

Where flood risk is projected to rise fastest in the US

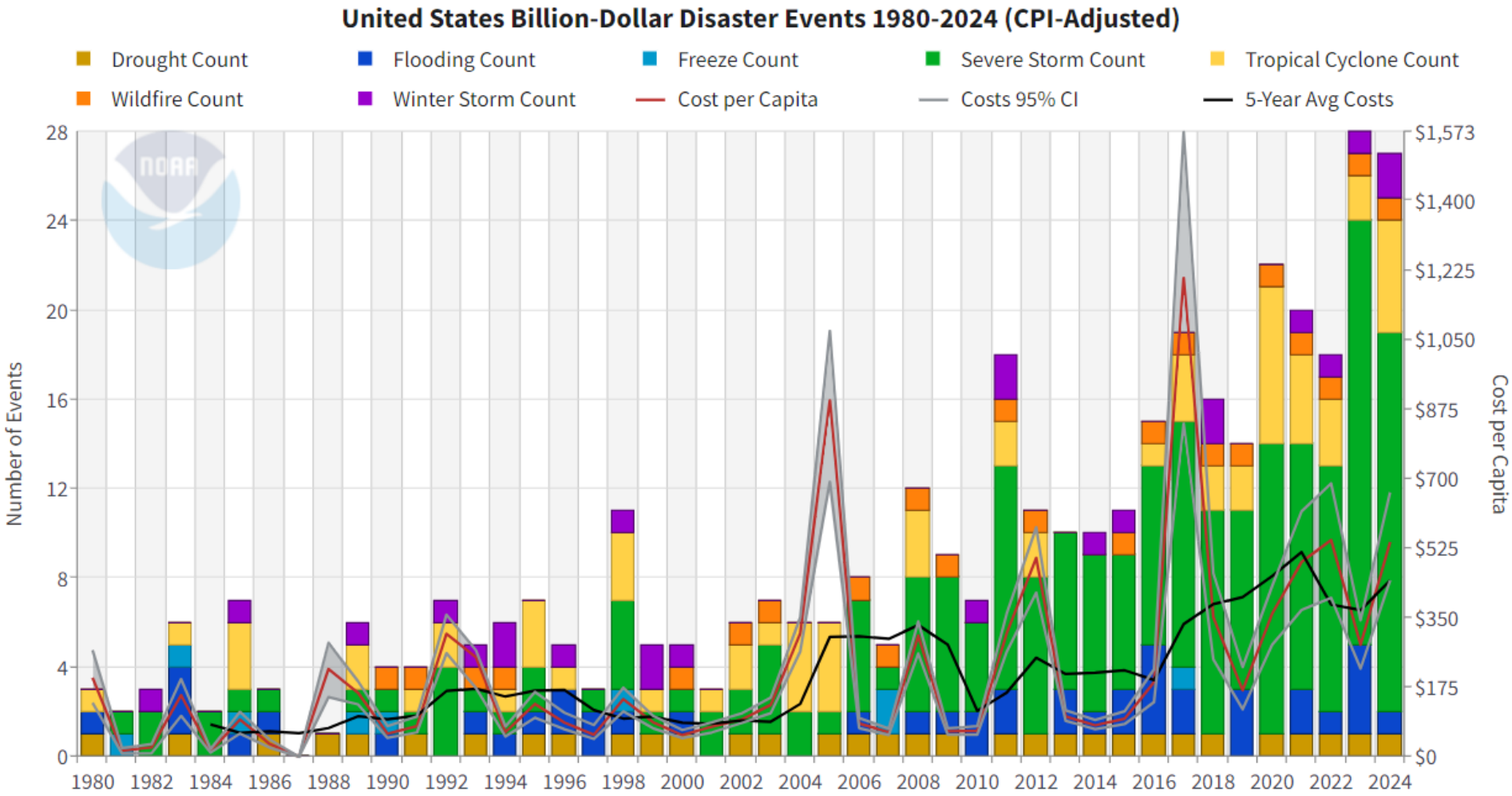
A new analysis projects changes in flood risk between 2020 and 2050 by zooming in on every neighborhood across the U.S. The map shows county-level data on the average annual loss due to flood damage.



Flood damage measured in 2020 U.S. dollars.

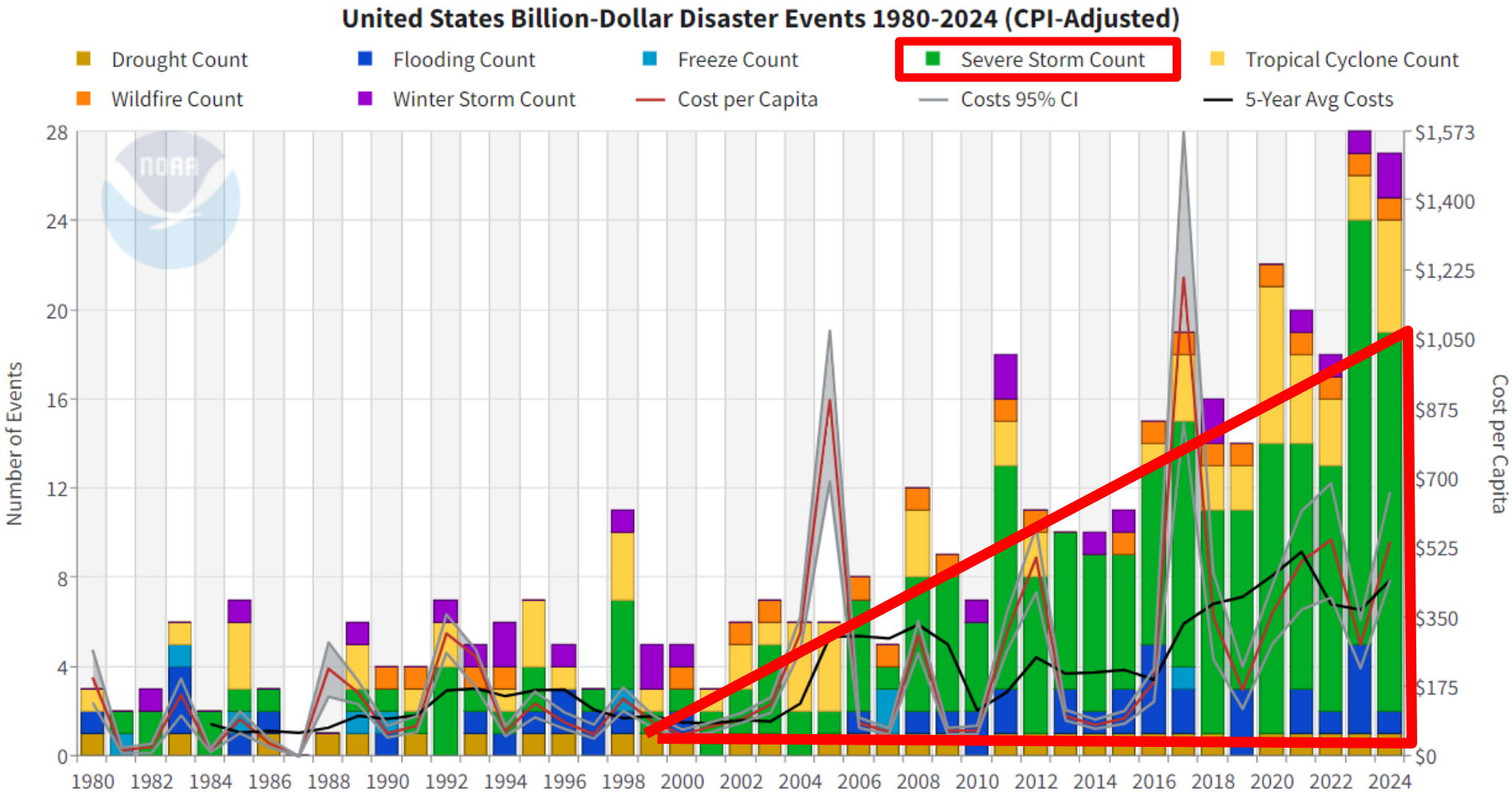
Map: The Conversation/CC-BY-ND • Source: Wing, et al. 2022

United States Billion-Dollar Disasters



[https://www.climate.gov/media/16722]

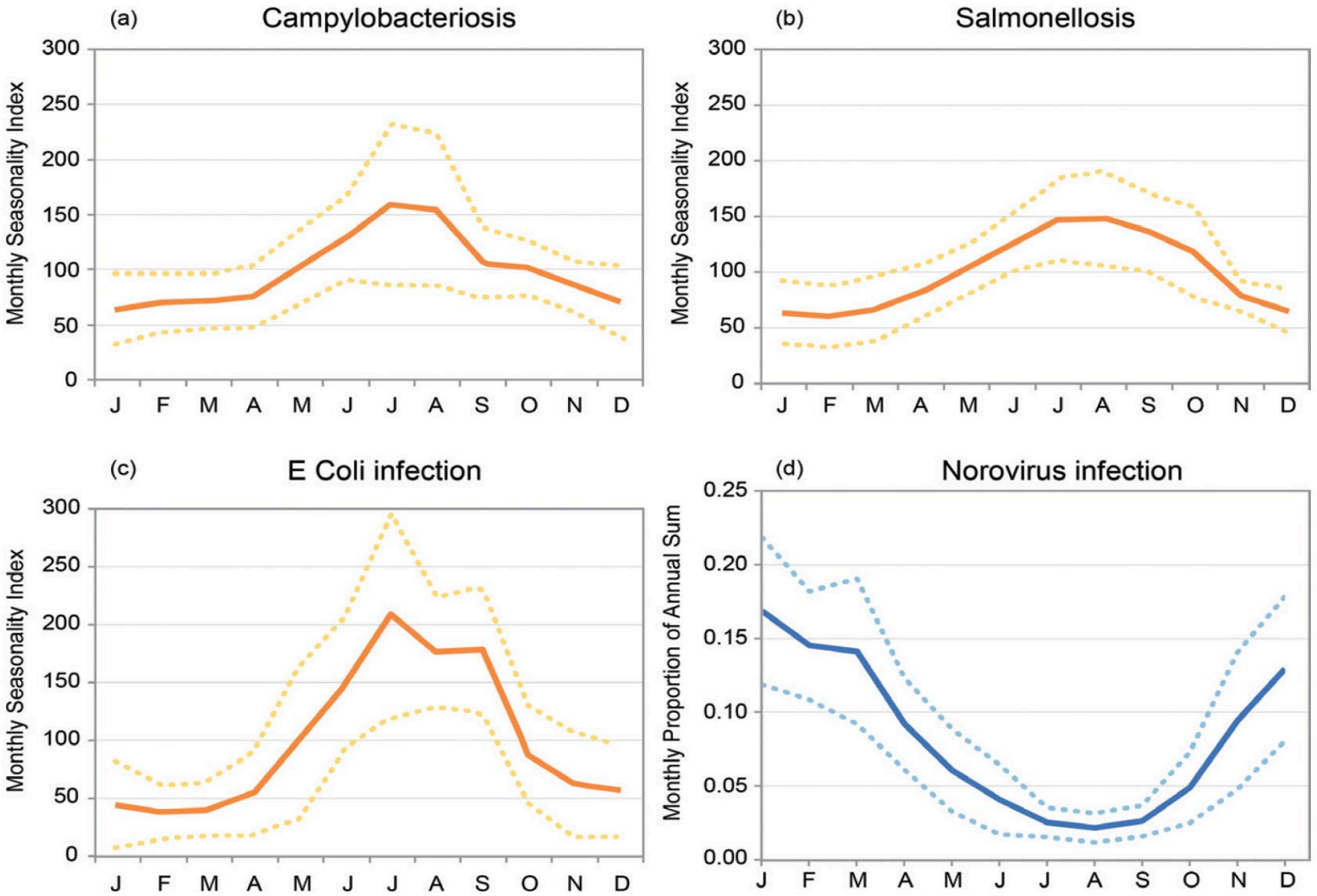
United States Billion-Dollar Disasters



[https://www.climate.gov/media/16722]

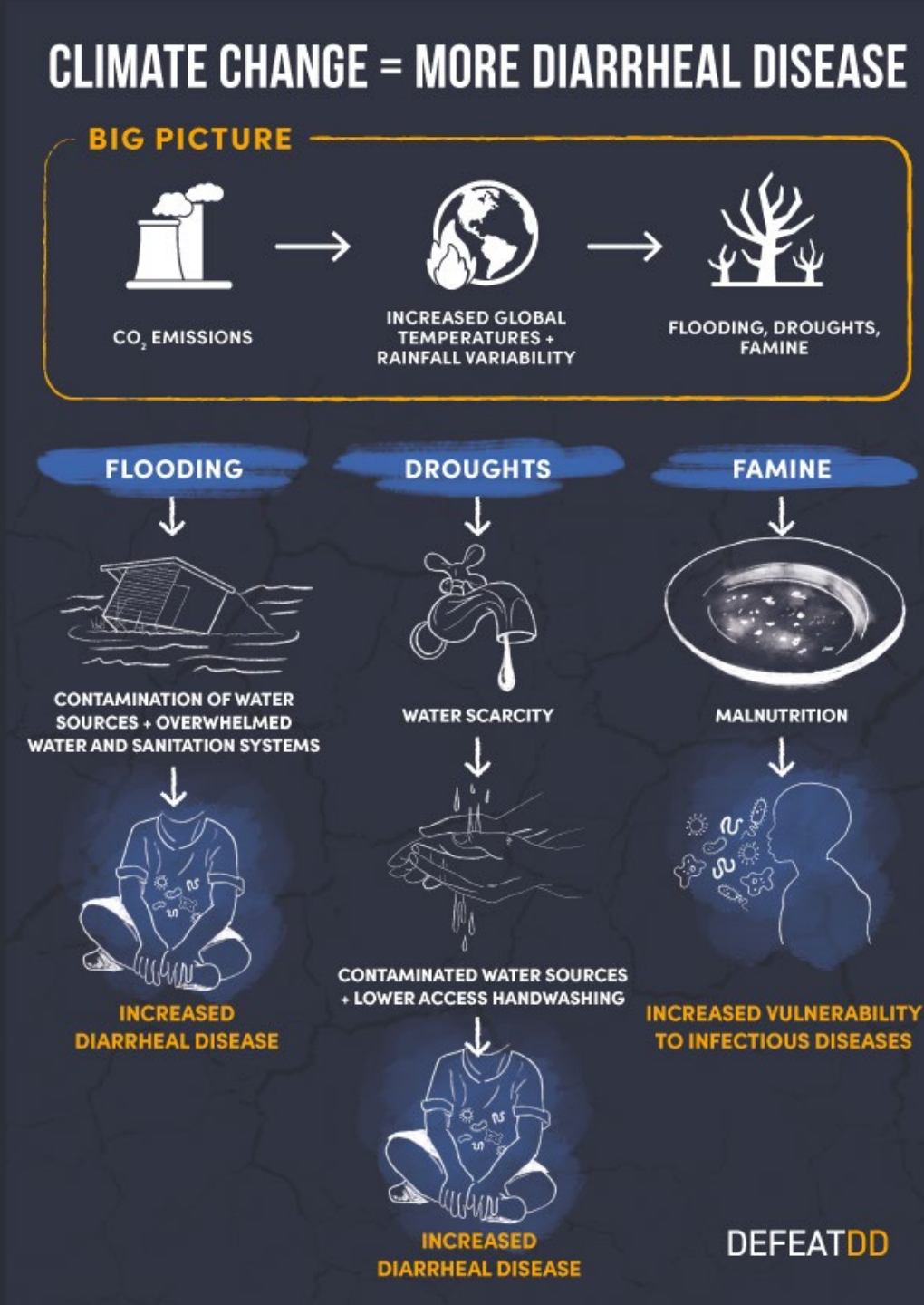
Flooding of Sewage Treatment Plant (Atlanta, GA), Sep 23, 2009

Seasonality of Illnesses Associated with Foodborne Pathogens



“Every 1ºC Increase in Global Temperatures Leads to a 7% Increase in Diarrhea”

[Mellor et al., 2016]



Waterborne Diseases

- Increased Red Tides of Algal Blooms

“Red Tide”

(La Jolla, CA)

Waterborne Diseases

- Increased Exposure to Freshwater Algal Blooms

Silverwood Lake (San Bernardino County, CA)

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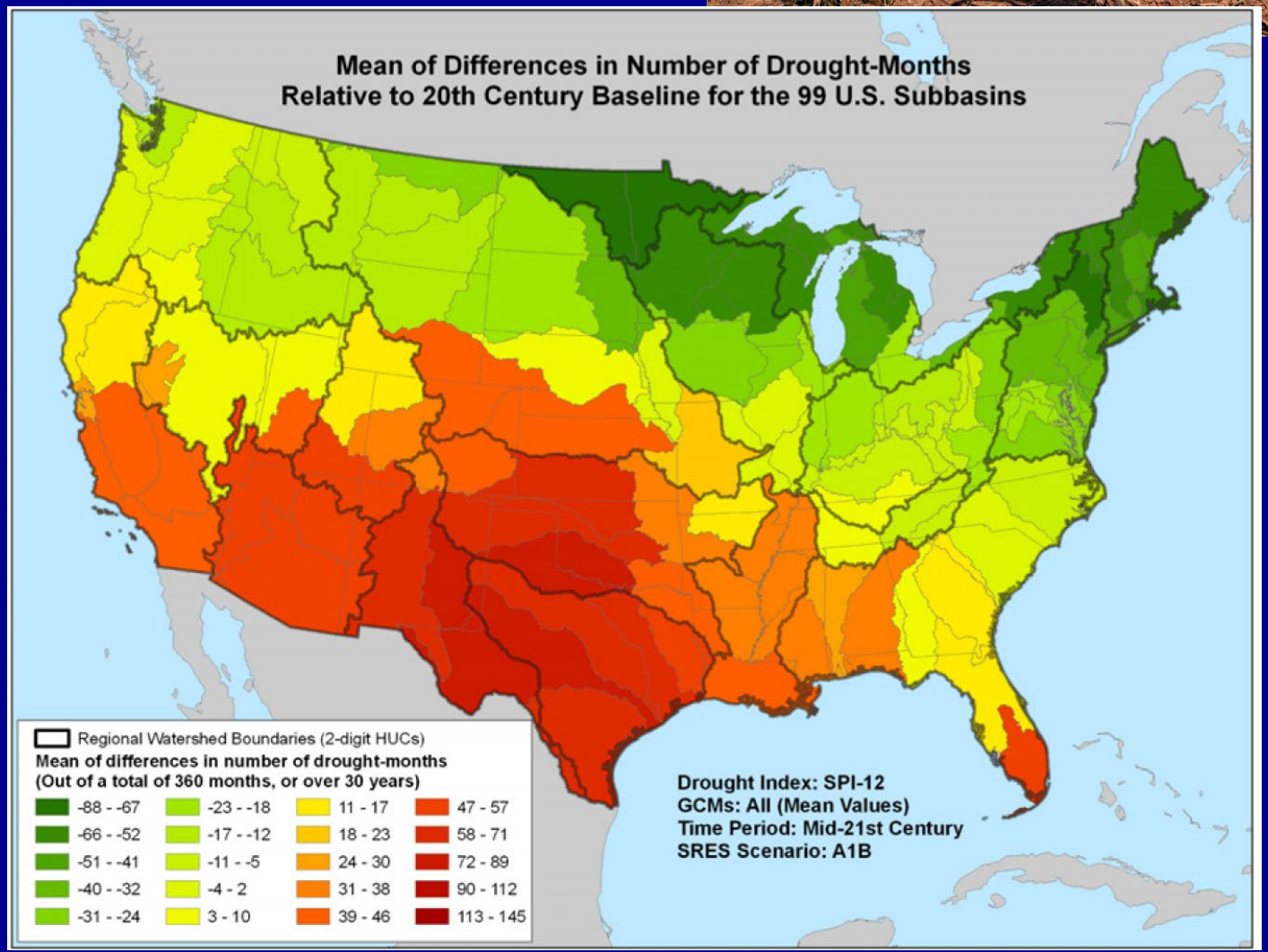
- Agricultural Failures : Famines

Projected Drought Increase by Mid-21st Century



Feb 2, 2026

The New York Times

Snow Drought in the West Reaches Record Levels

Artificial snow at Soldier Hollow Nordic Center in Midway, Utah, in January. Matthew Hamon

Feb 2, 2026

The New York Times

Snow Drought in the West Reaches Record Levels

"The Salt Lake City airport may set a new record this winter for low snowfall. So far, only one-tenth of an inch has fallen; the previous low, in 1933-34, was 14.3 inches."

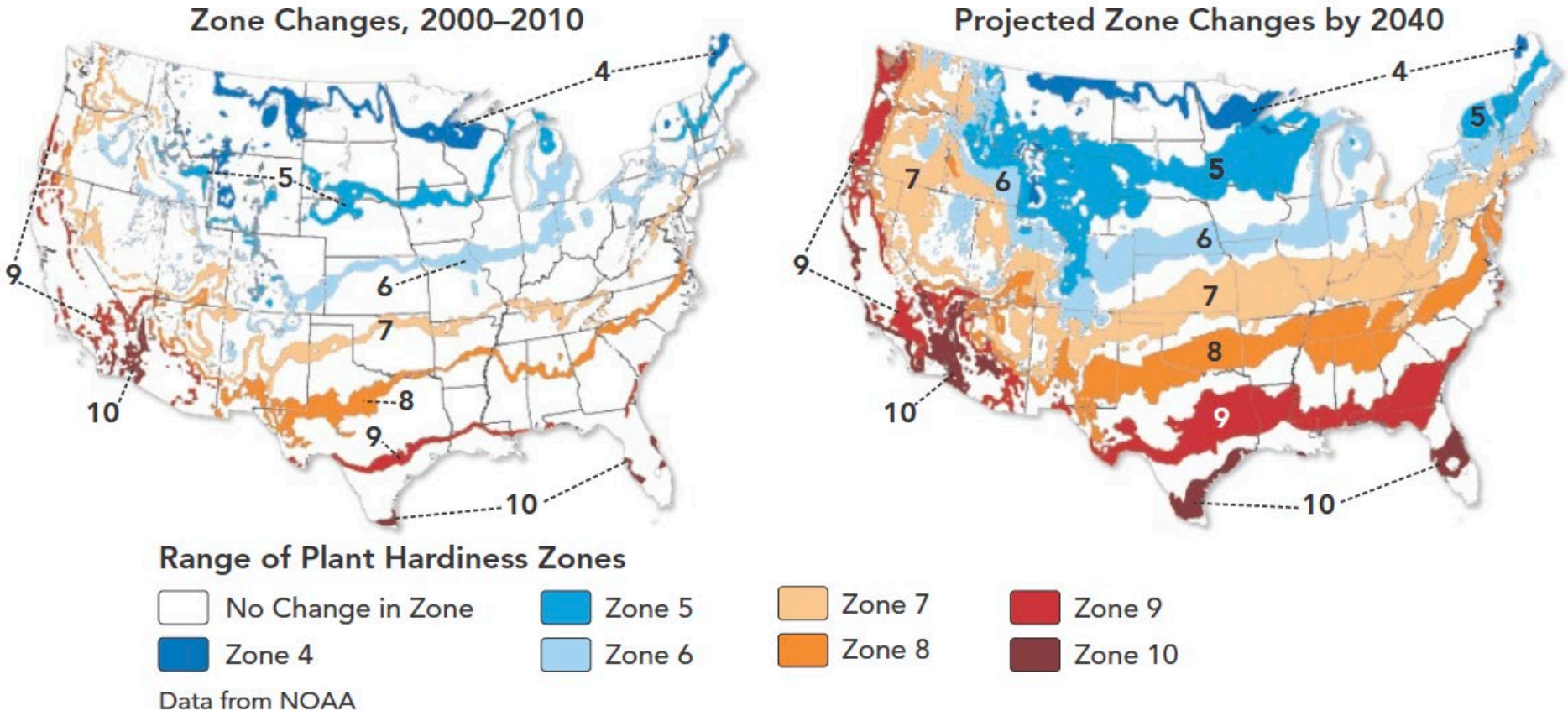
Artificial snow at Soldier Hollow Nordic Center in Midway, Utah, in January. Matthew Hamon

Northward Shift In Plant Zones

Northward Shift Plant hardiness zones define geographic areas where certain plants thrive under a particular set of climate conditions. These conditions are largely a function of average annual extreme low temperatures. Zone 4 has the coldest temperatures while Zone 10 has the warmest.

The widths of the colored bands show the locations of the plant zone boundaries over the 10-year period between 2000 and 2010.

The widths of the colored bands show how the plant zone boundaries are projected to expand and shift by 2040.



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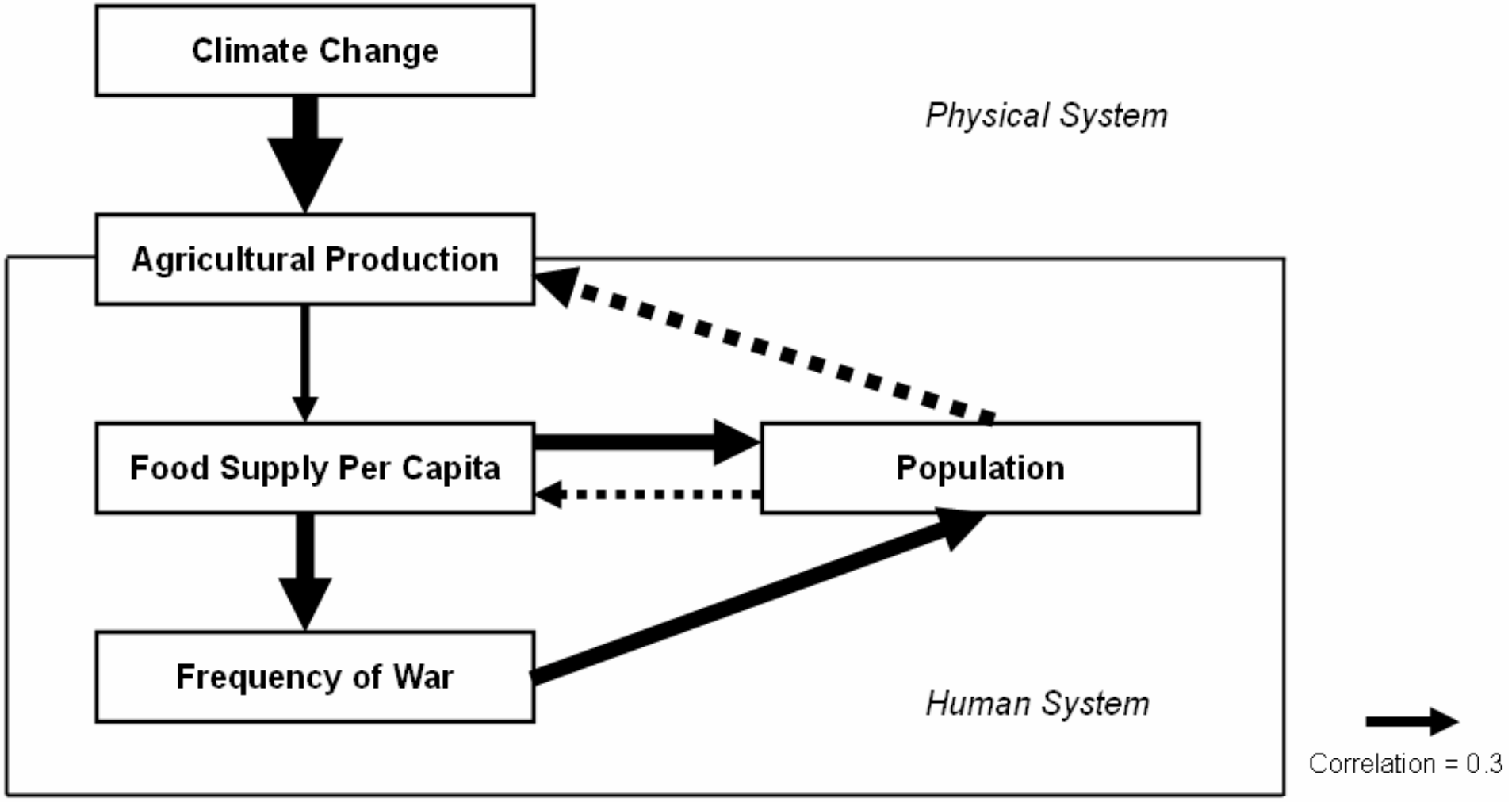
- *Water Distribution Changes: Droughts, Floods, Water-borne Diseases, Fungal Infections*
- *Agricultural Failures: Famines*
- Human Migrations: Spread of Diseases, Conflict, and Warfare



[Zhang et al., 2007]

Businessweek
Economics

Climate Change Has Central Americans Fleeing to the U.S.

Close to one-third of the population of the Northern Triangle is experiencing crisis levels of food insecurity.

Subsistence farming in Honduras. A combination of droughts and hurricanes has led many to seek work in the cities or abroad. *Photographer: Francesca Volpi*

By Michael D McDonald
June 7, 2021, 10:00 PM HST

Businessweek
Economics

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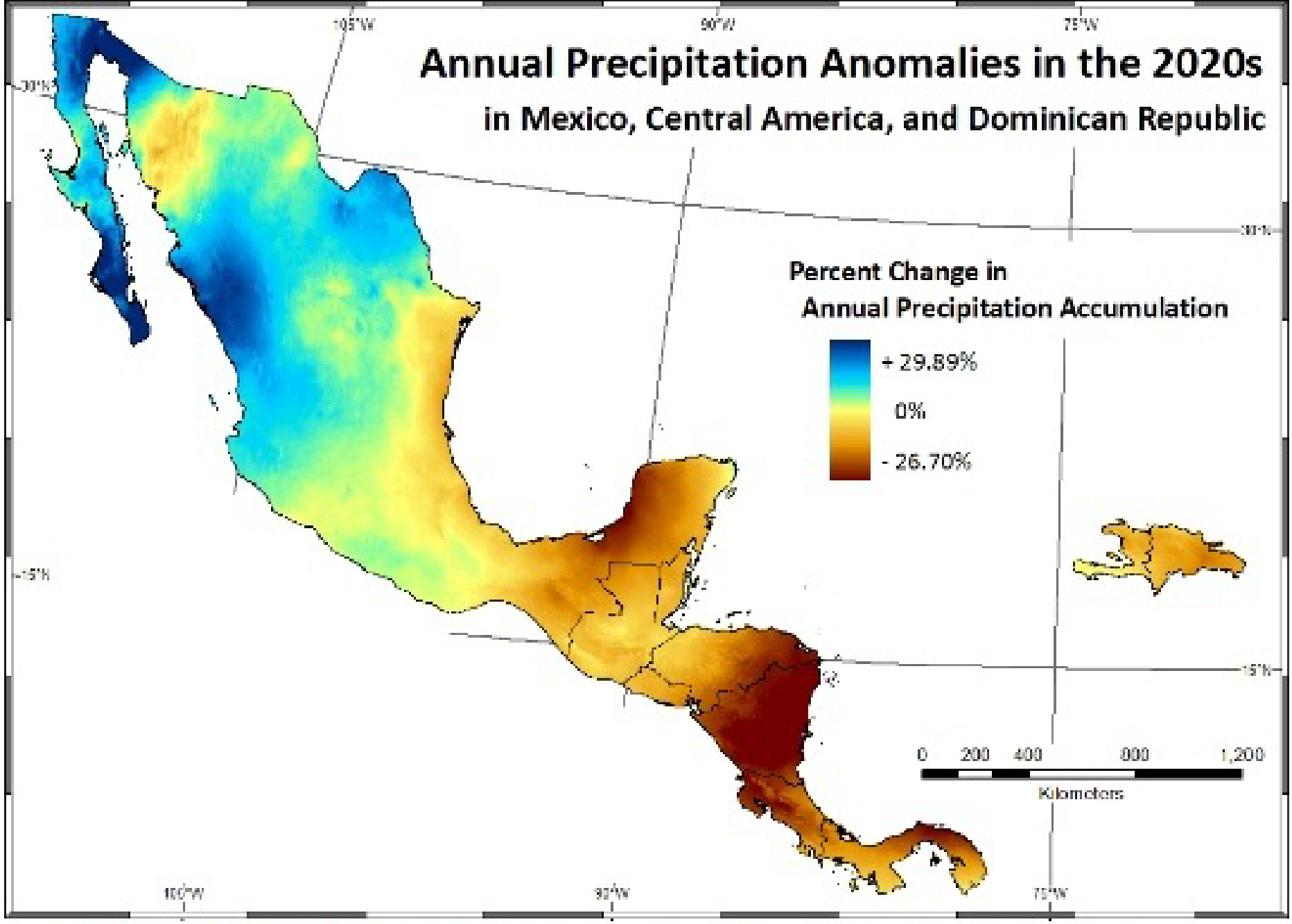
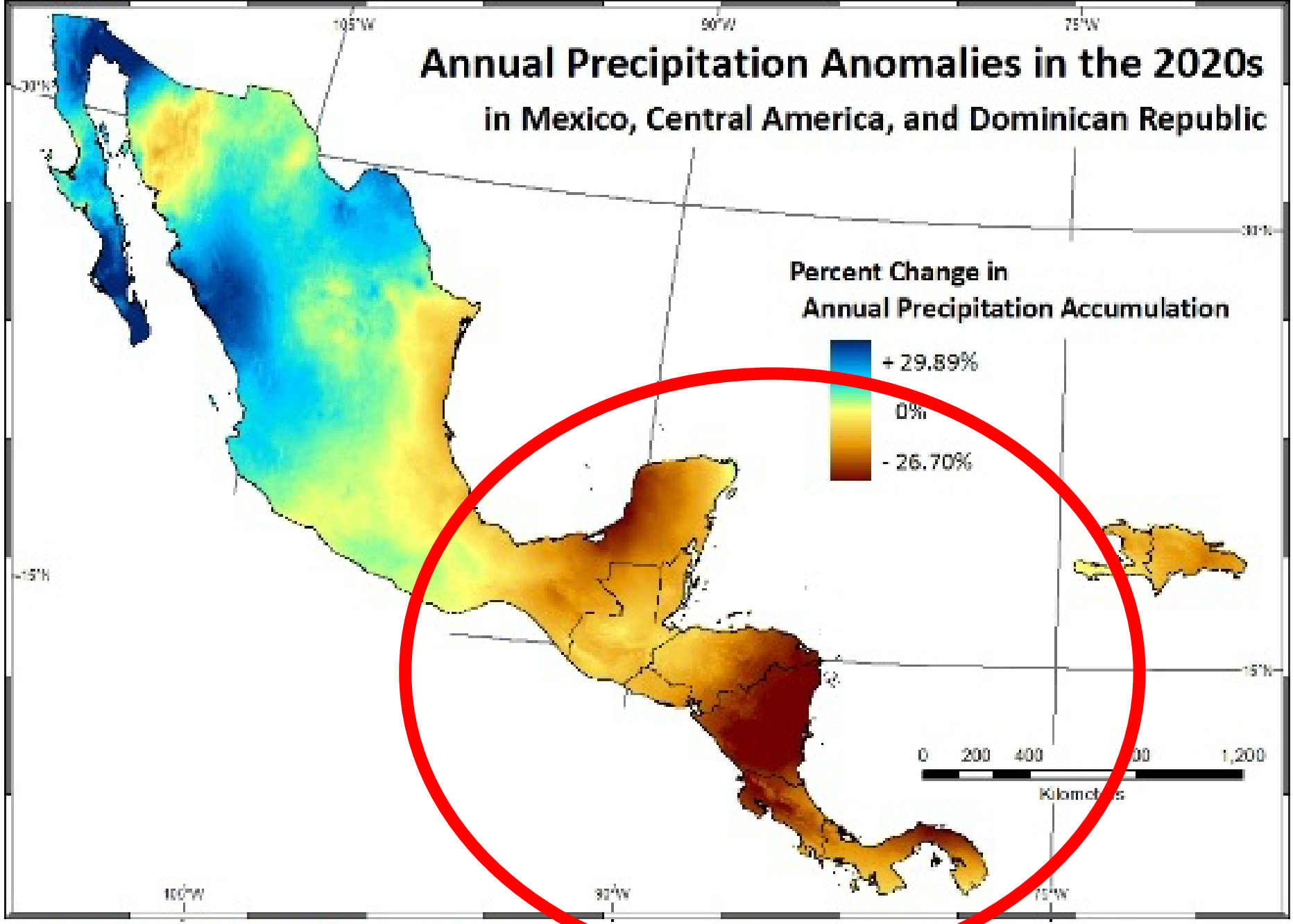


Potential Impacts of Climate Change on Biodiversity, CATHALAC 2008.

Source: Worldclim Climate Grids. Current and Future conditions (HADCM3), 2009.



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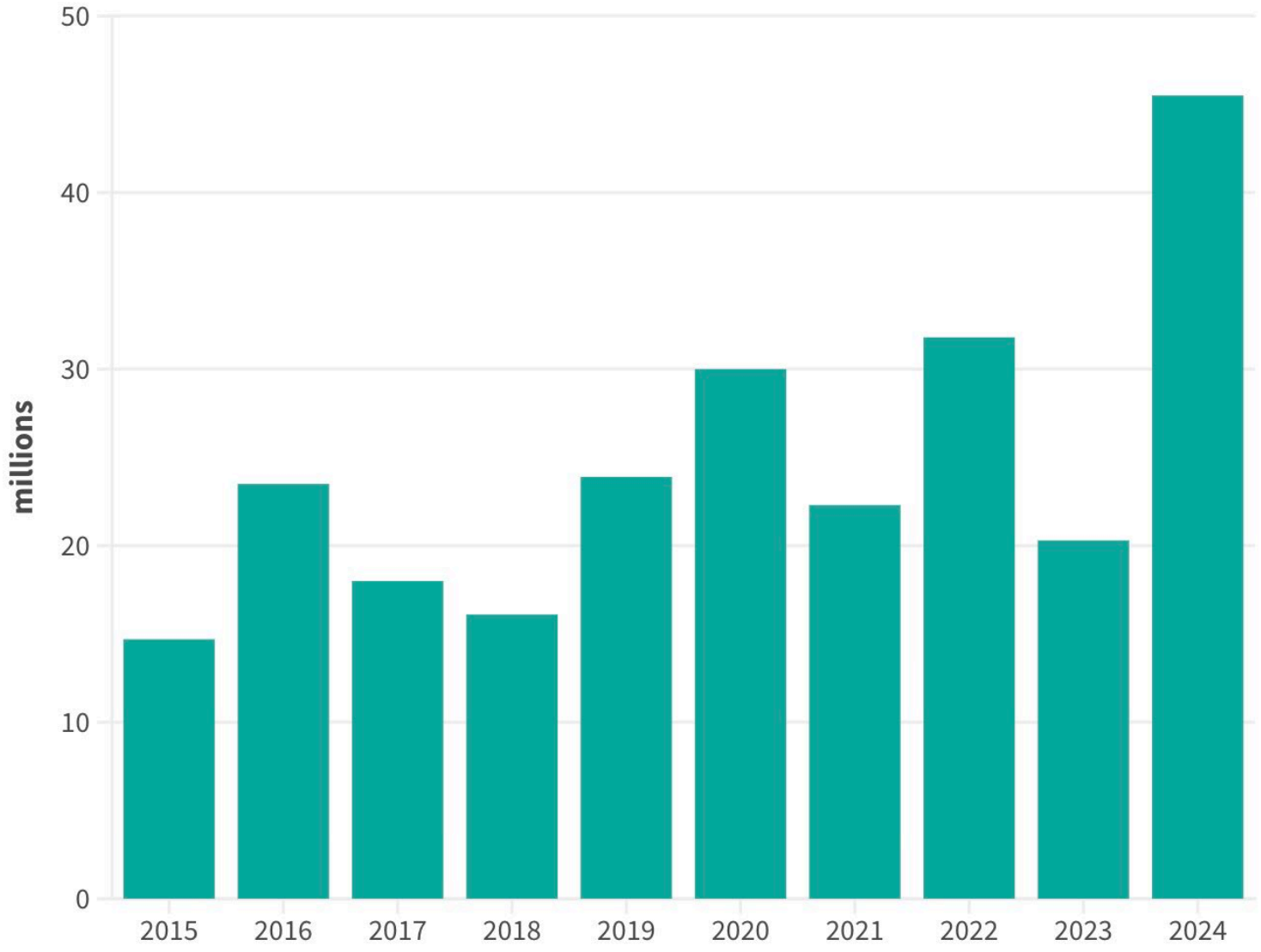
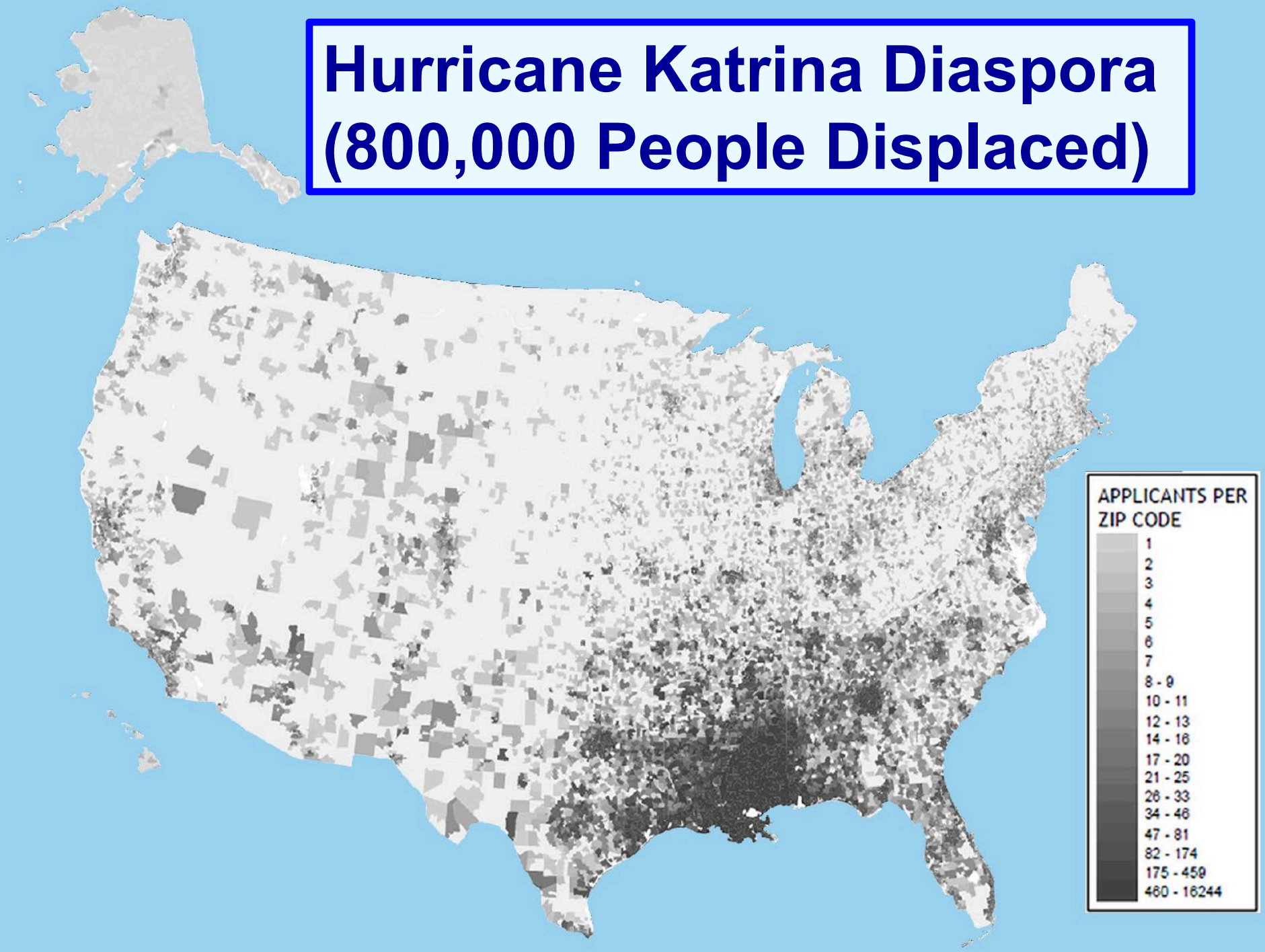
Number of People Displaced by Weather- and Climate-Related Disasters (2015-2024)



[Internal Displacement Monitoring Center, 2025]

Hurricane Katrina Diaspora (800,000 People Displaced)



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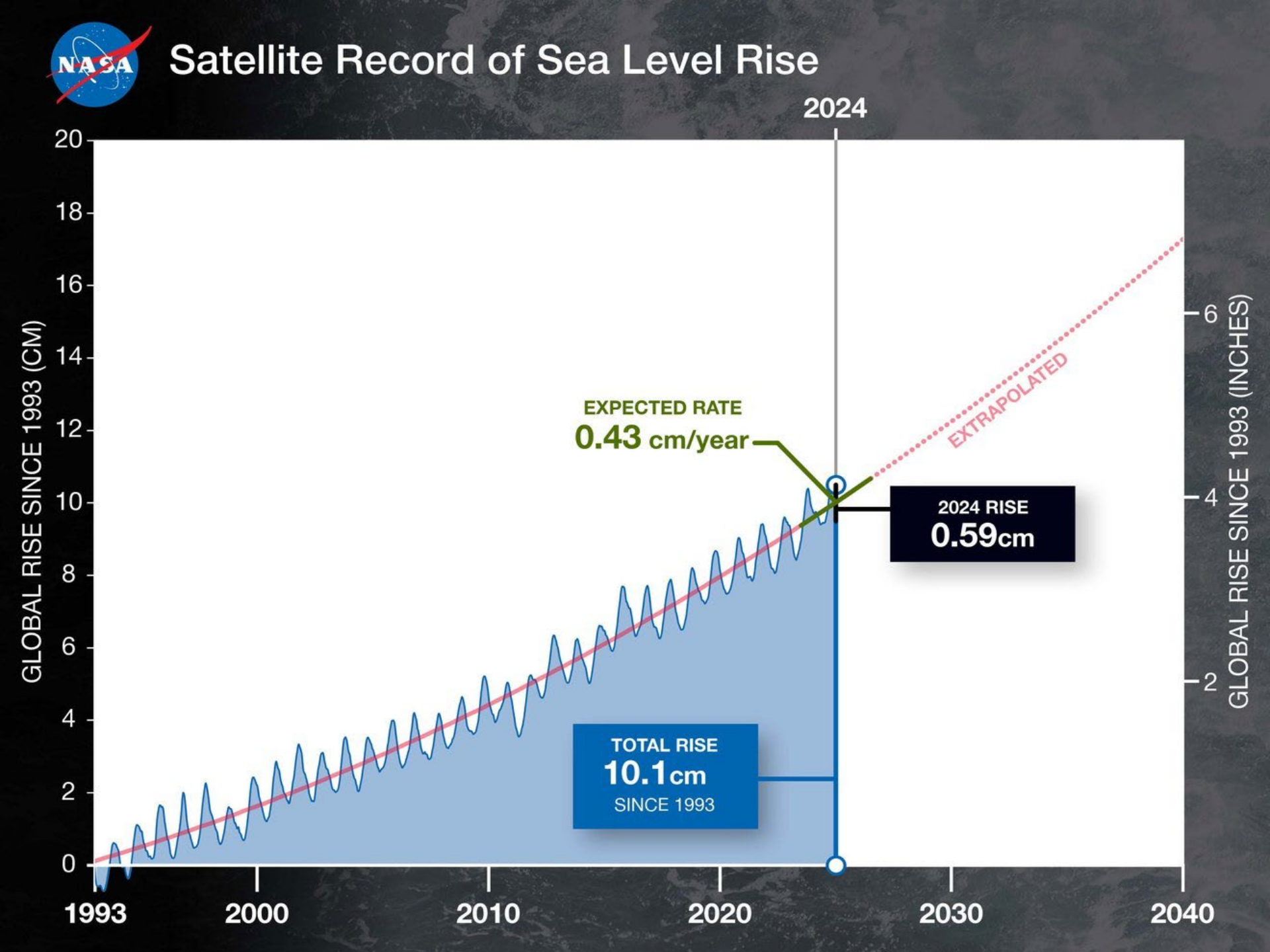
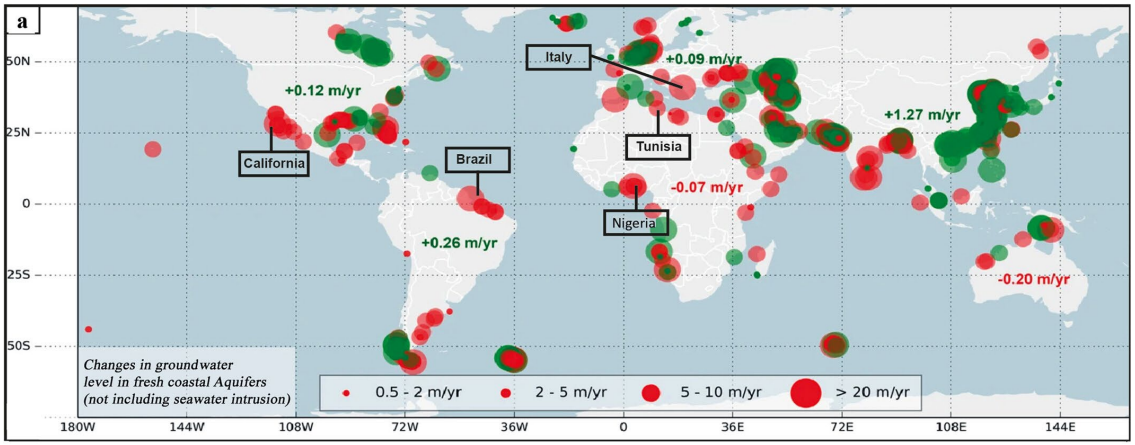
- *Human Migrations: Spread of Diseases, Conflict, and Warfare*
- Sea-Level Rise: Coastal Flooding


Satellite Record of Sea Level Rise
2024
EXPECTED RATE
0.43 cm/year
EXTRAPOLATED
2024 RISE
0.59cm
TOTAL RISE
10.1cm
SINCE 1993
GLOBAL RISE SINCE 1993 (CM)
GLOBAL RISE SINCE 1993 (INCHES)
0
2
4
6
8
10
12
14
16
18
20
2
4
6
1993
2000
2010
2020
2030
2040

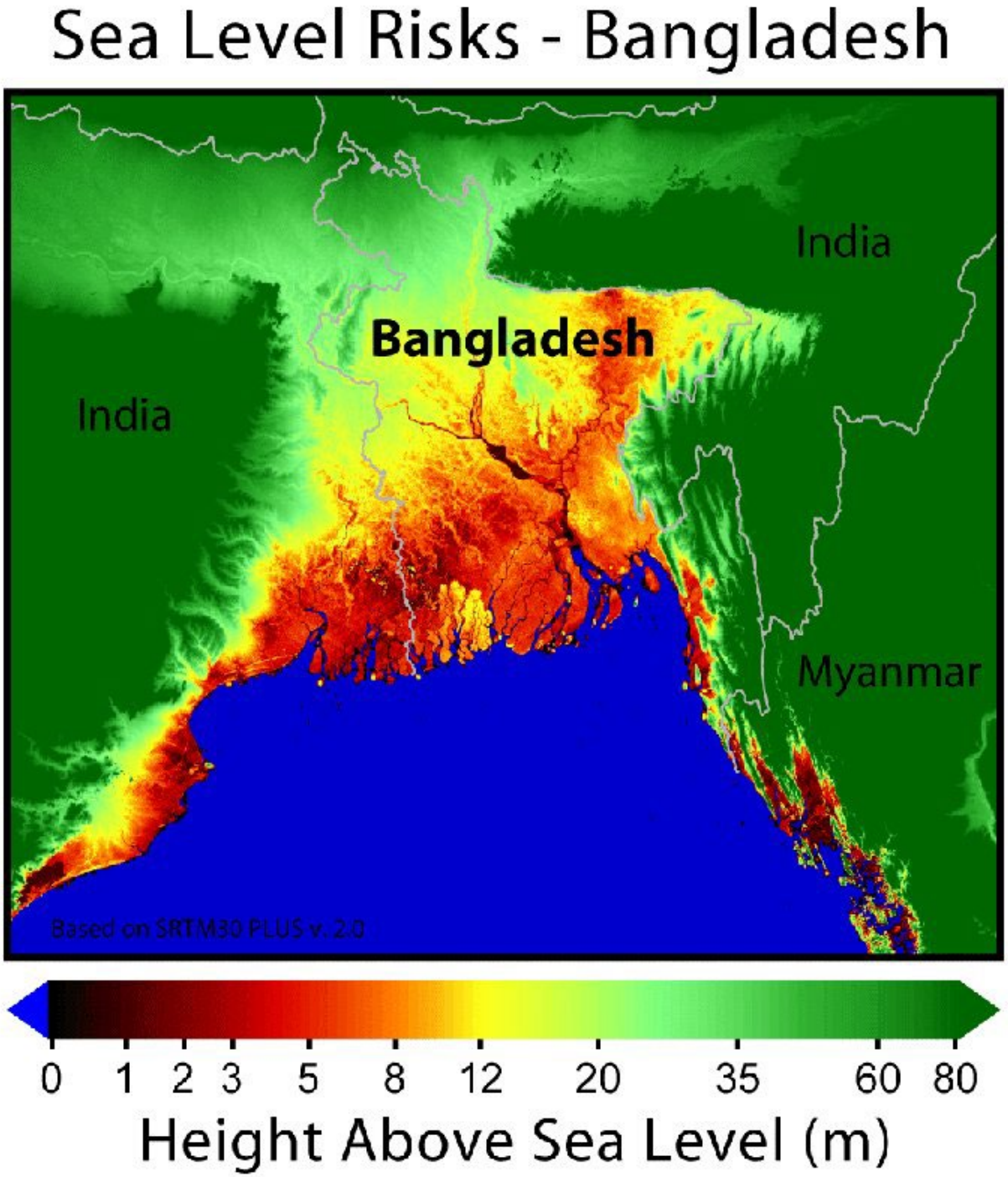
Coastal Communities are Collapsing due to Sea-level Rise, Coastal Flooding, and Salt-Water Inclusion



[Fouad et al., *Geophys. Res. Lett.*, 2025]

“Salinity in Drinking Water and the Risk of (Pre)Eclampsia and Gestational Hypertension in Coastal Bangladesh”

[Khan et al., PLoS One 2014]



Risks of Flooding: Affecting ~100 Million People by 2030

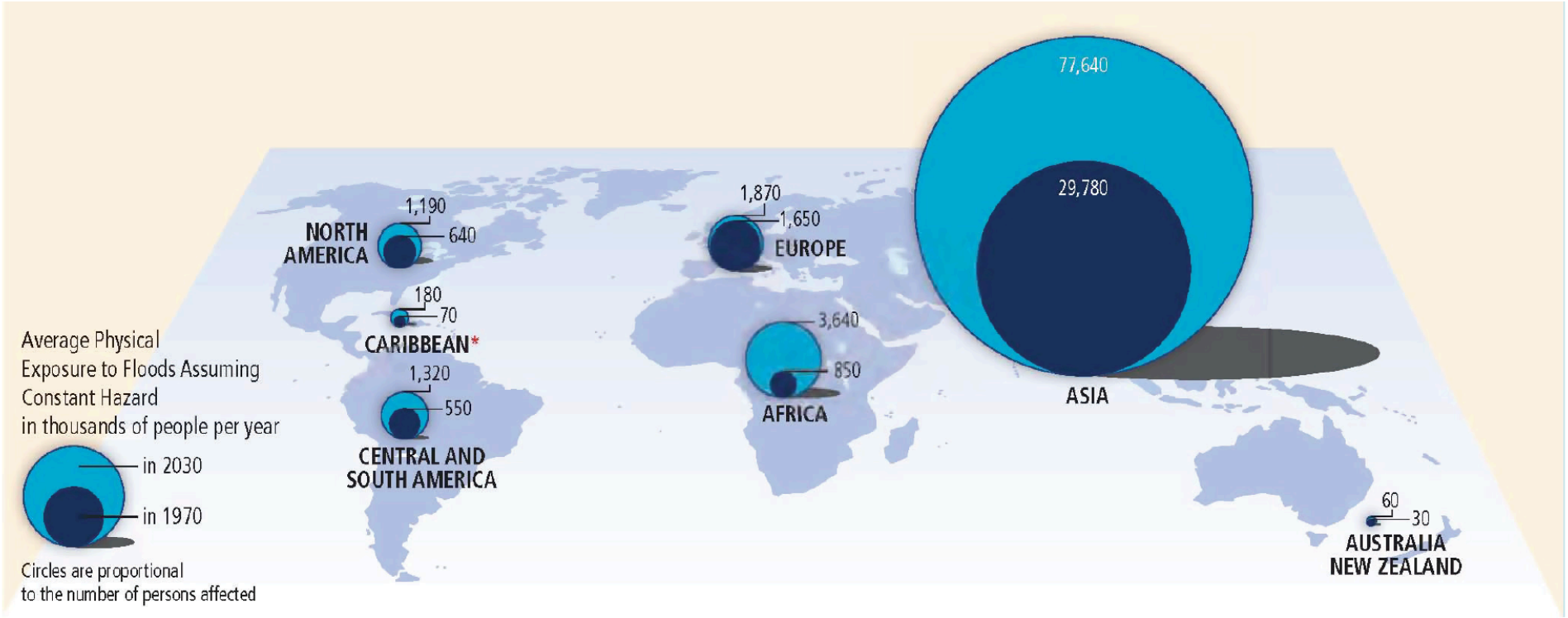


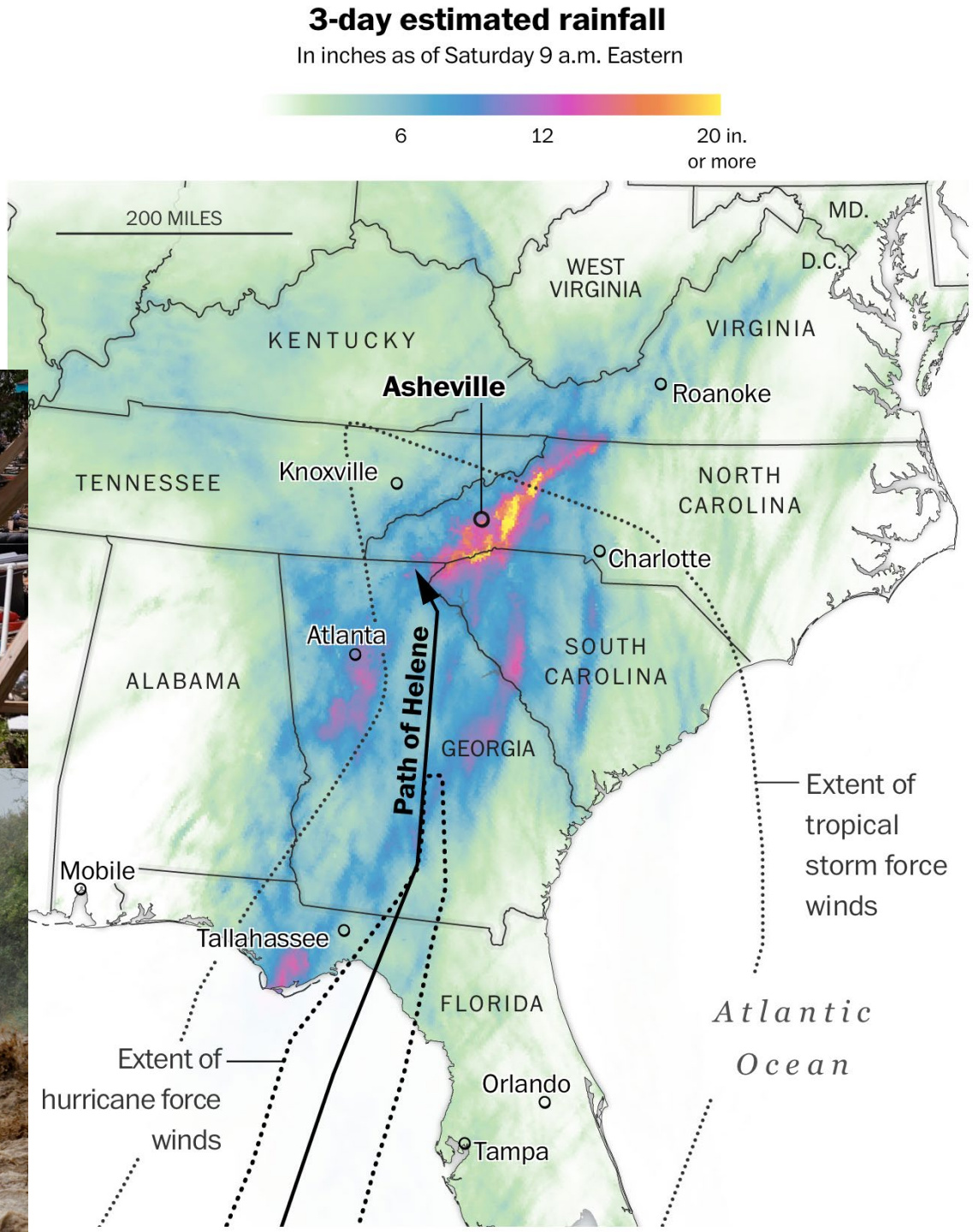
FIGURE 2.9 The projected increase in the number of people (in thousands) exposed to floods in 2030 compared to those in 1970. Only catchments bigger than 1,000k m^2 were included in analysis; therefore, only the largest islands in the Caribbean are covered. Source: IPCC, 2012; Solterra Solutions, 2012.

Sunny-Day Flooding: Increasingly Common in Eastern U.S. Coastal Communities

→ *Worsens Impacts of Hurricane Flooding*

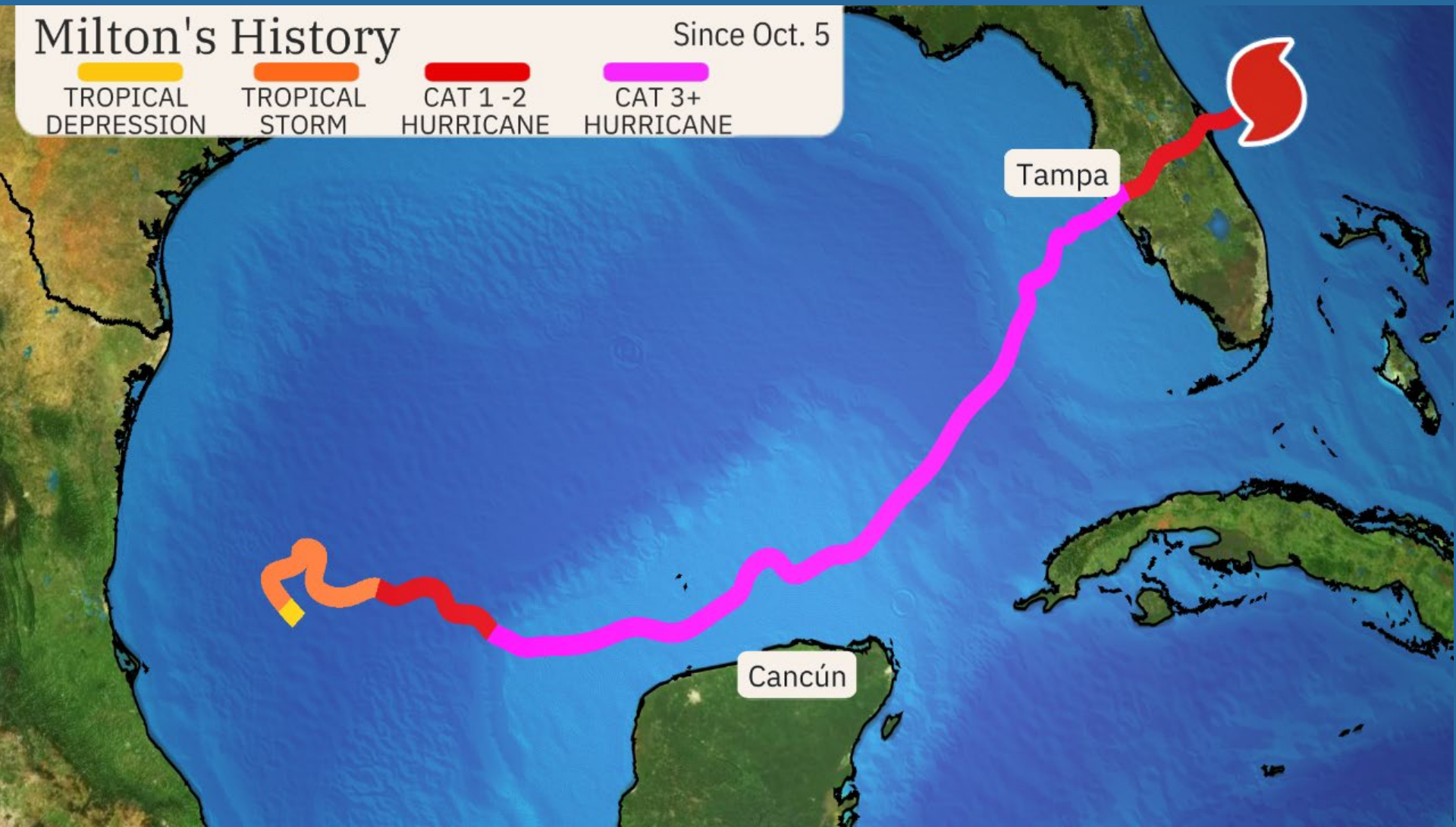
Household Mold After Flooding

Hurricane Helene: September 2024

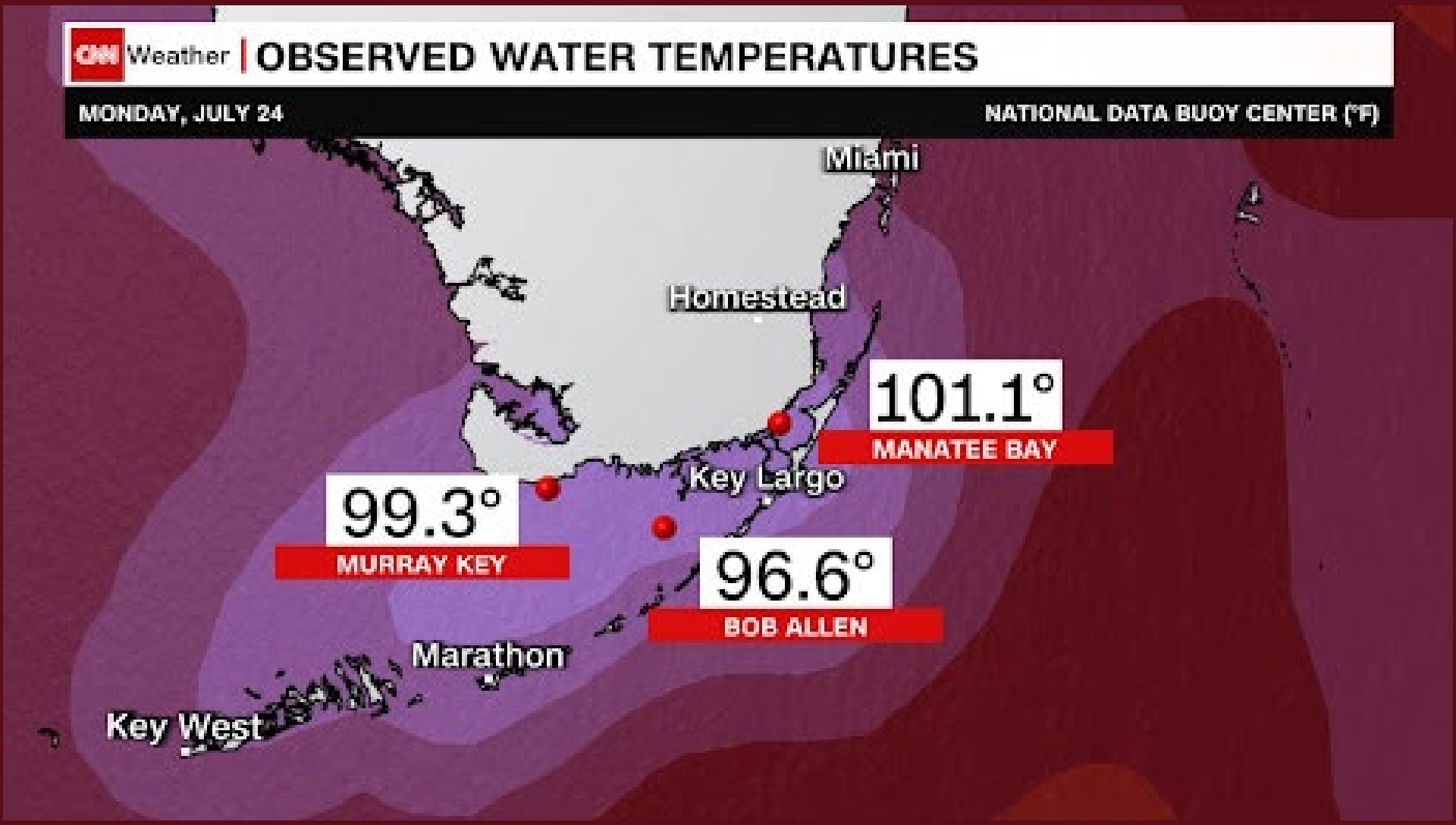


Hurricane Milton: October 2024

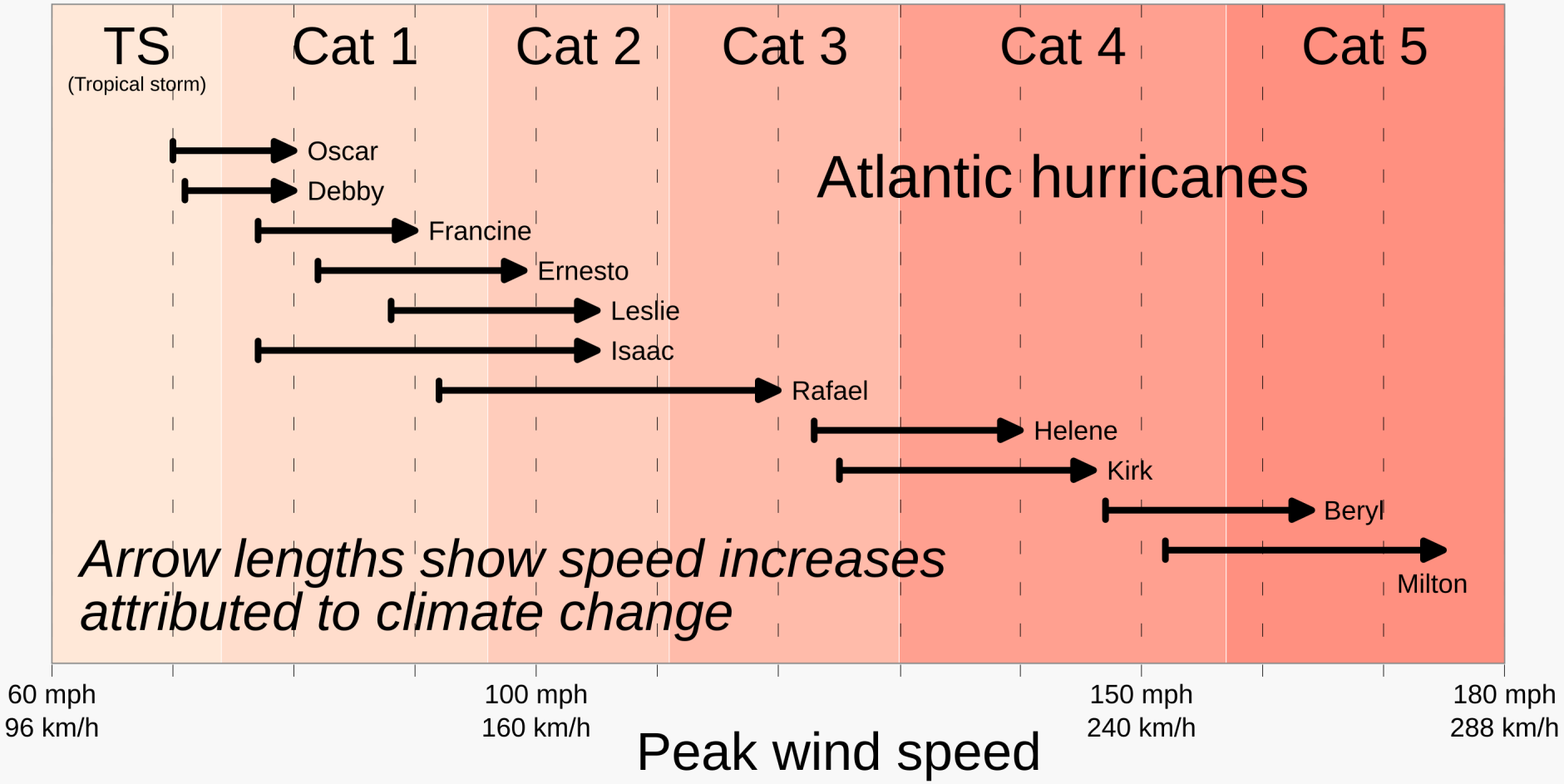
→ Went from Tropical Storm to Category 5 in 1 Day



Florida Water Temperatures Exceeded 100°F on July 24, 2023



Climate Change (Warmer Ocean Surface) Increases Hurricane Wind Speeds



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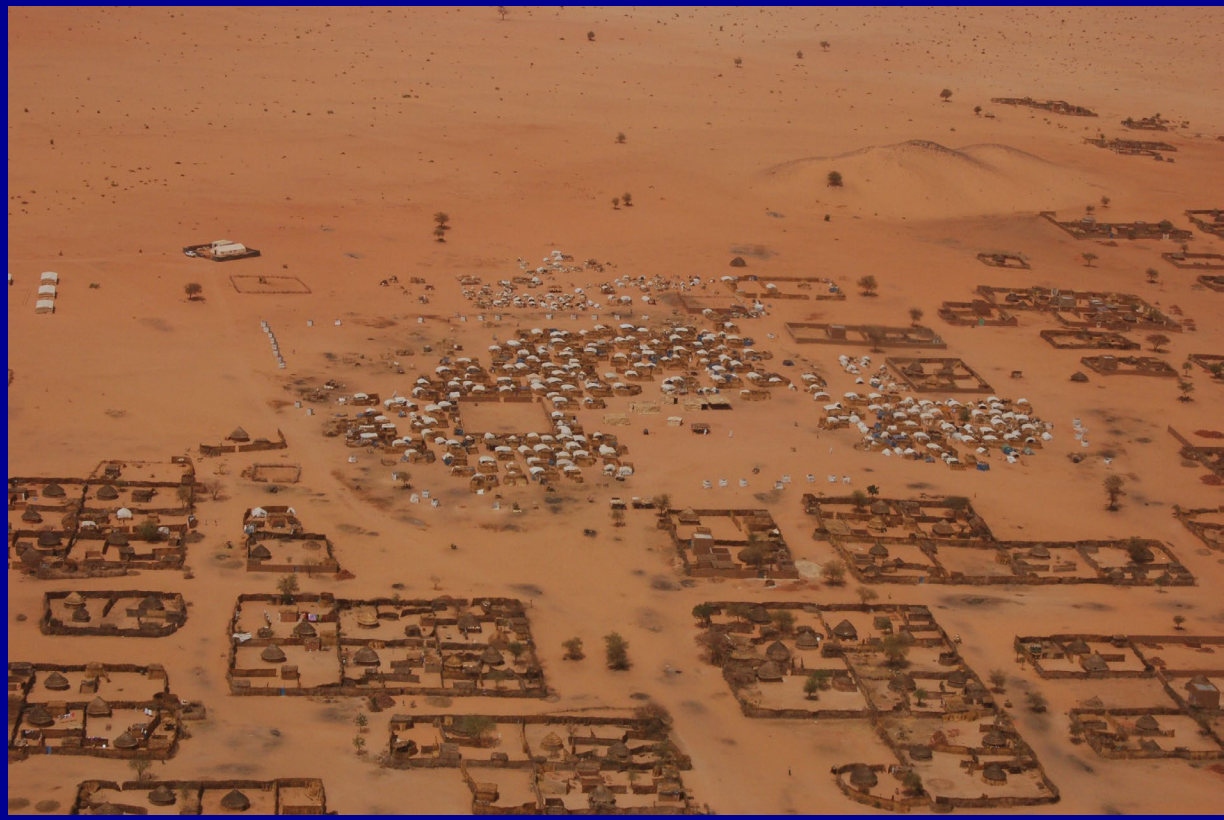
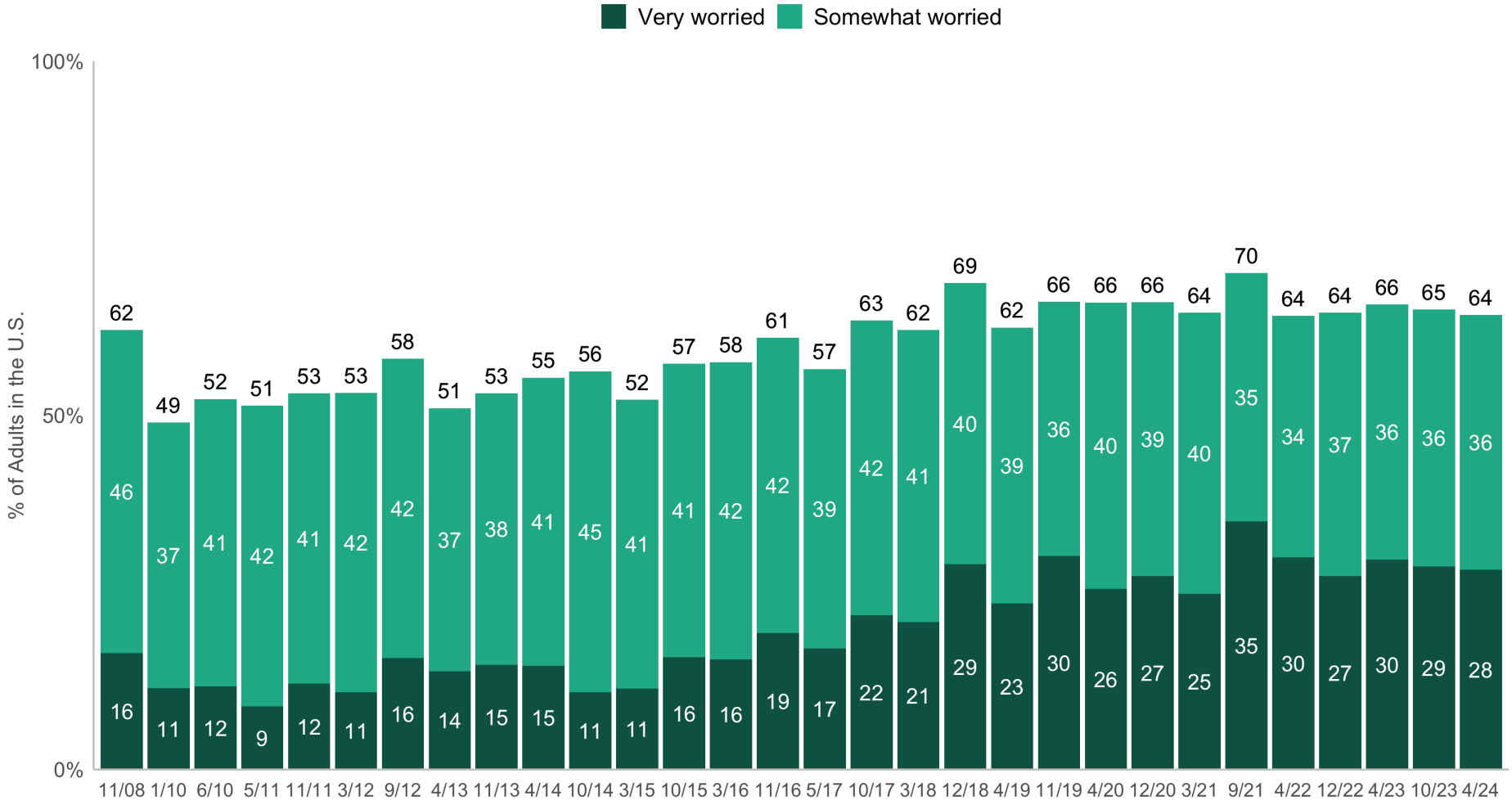
- *Human Migrations: Spread of Diseases, Conflict, and Warfare*
- *Sea-Level Rise: Coastal Flooding*
- Mental Health Disease: Stress, Depression, Loss

Mental Health and Stress-Related Disorders

- Geographic displacement of populations
- Damage to property
- Loss of loved ones
- Chronic stress



A majority of Americans are worried about global warming

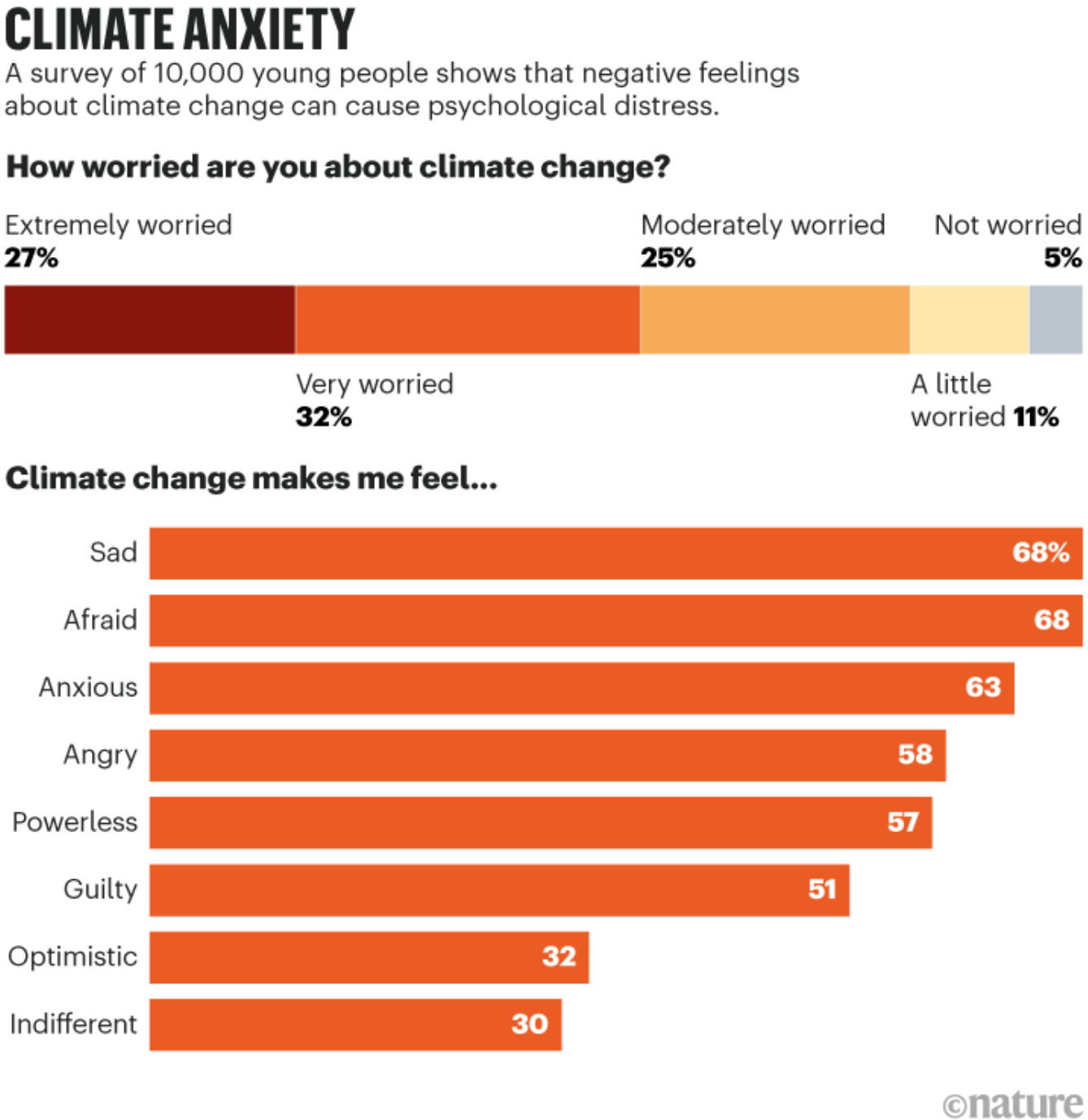


How worried are you about global warming?

Spring 2024

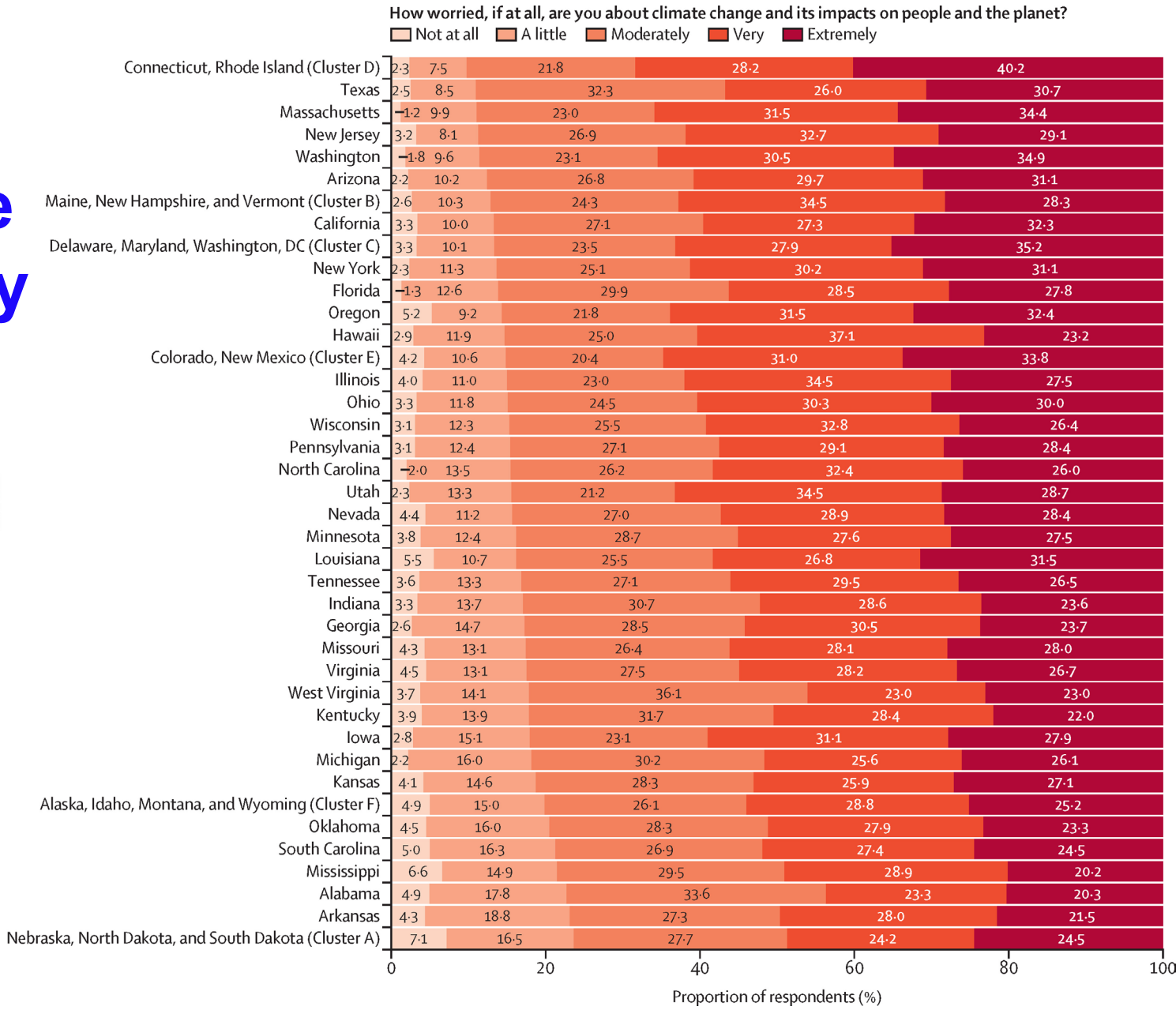
Source: Yale Program on Climate Change Communication;
George Mason University Center for Climate Change Communication

84% of Young People are Moderately to Extremely Worried About Climate Change



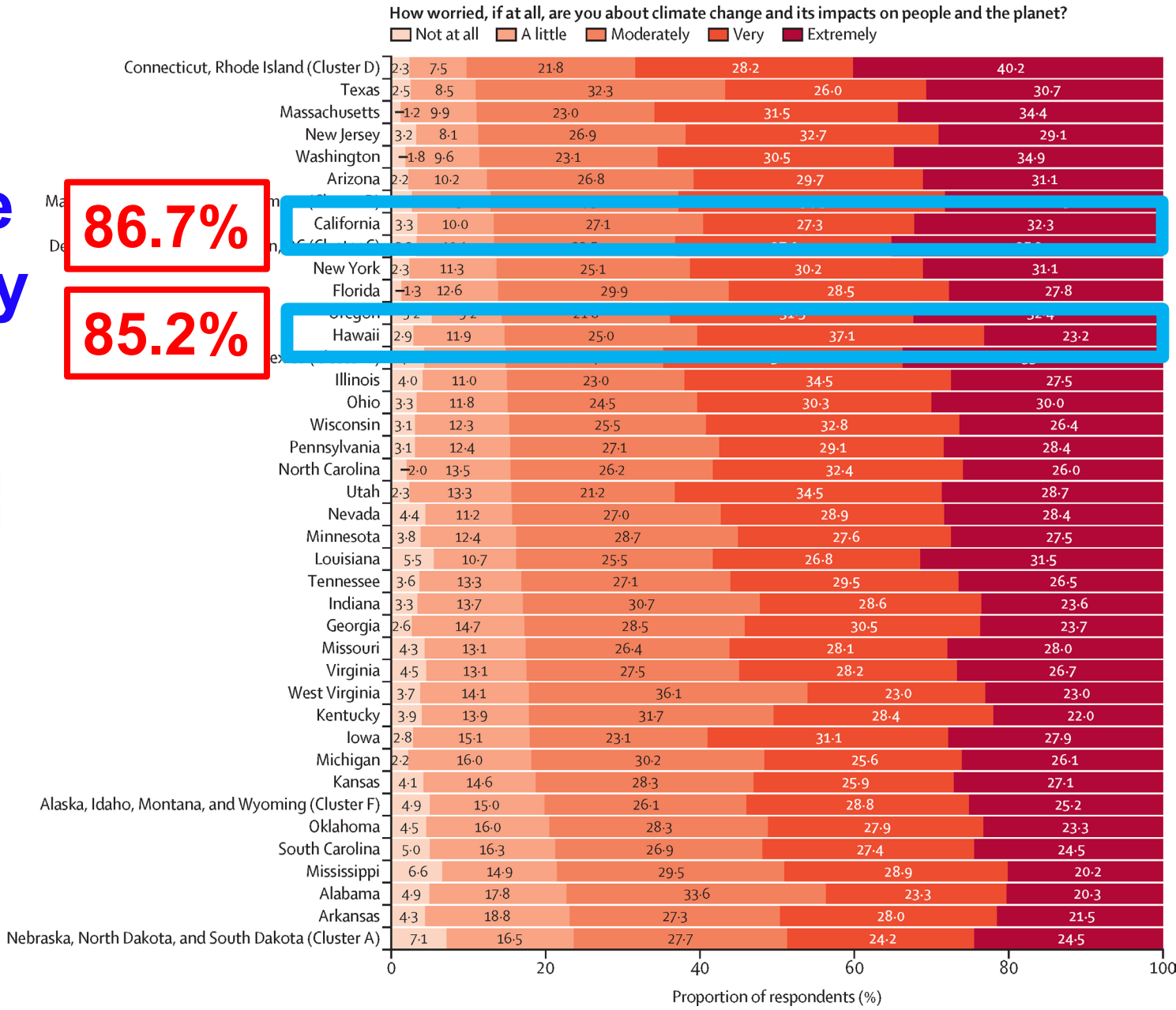
[Hickman et al., *SSRN*, 2021]

2024: 85% of Young People are Moderately to Extremely Worried About Climate Change



[Lewandowski et al., *The Lancet*, 2024]

2024: 85% of Young People are Moderately to Extremely Worried About Climate Change

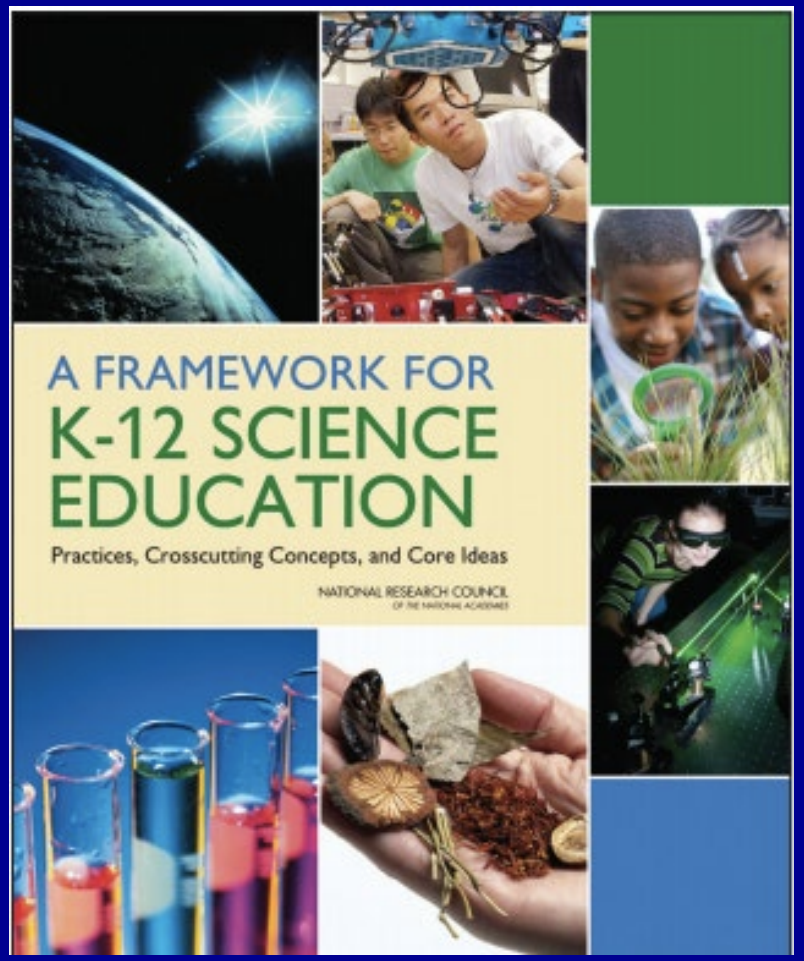


86.7%

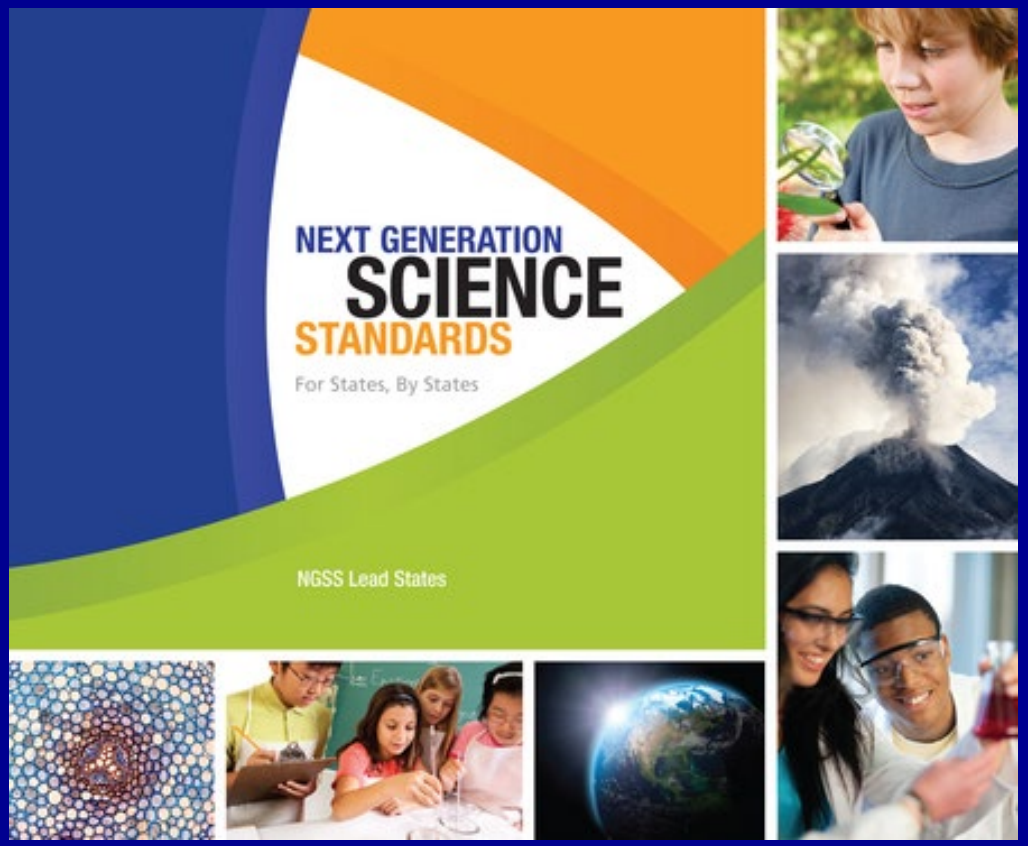
85.2%

[Lewandowski et al., *The Lancet*, 2024]

New Science Standards for Most States Require Substantial High School Climate Science



2011

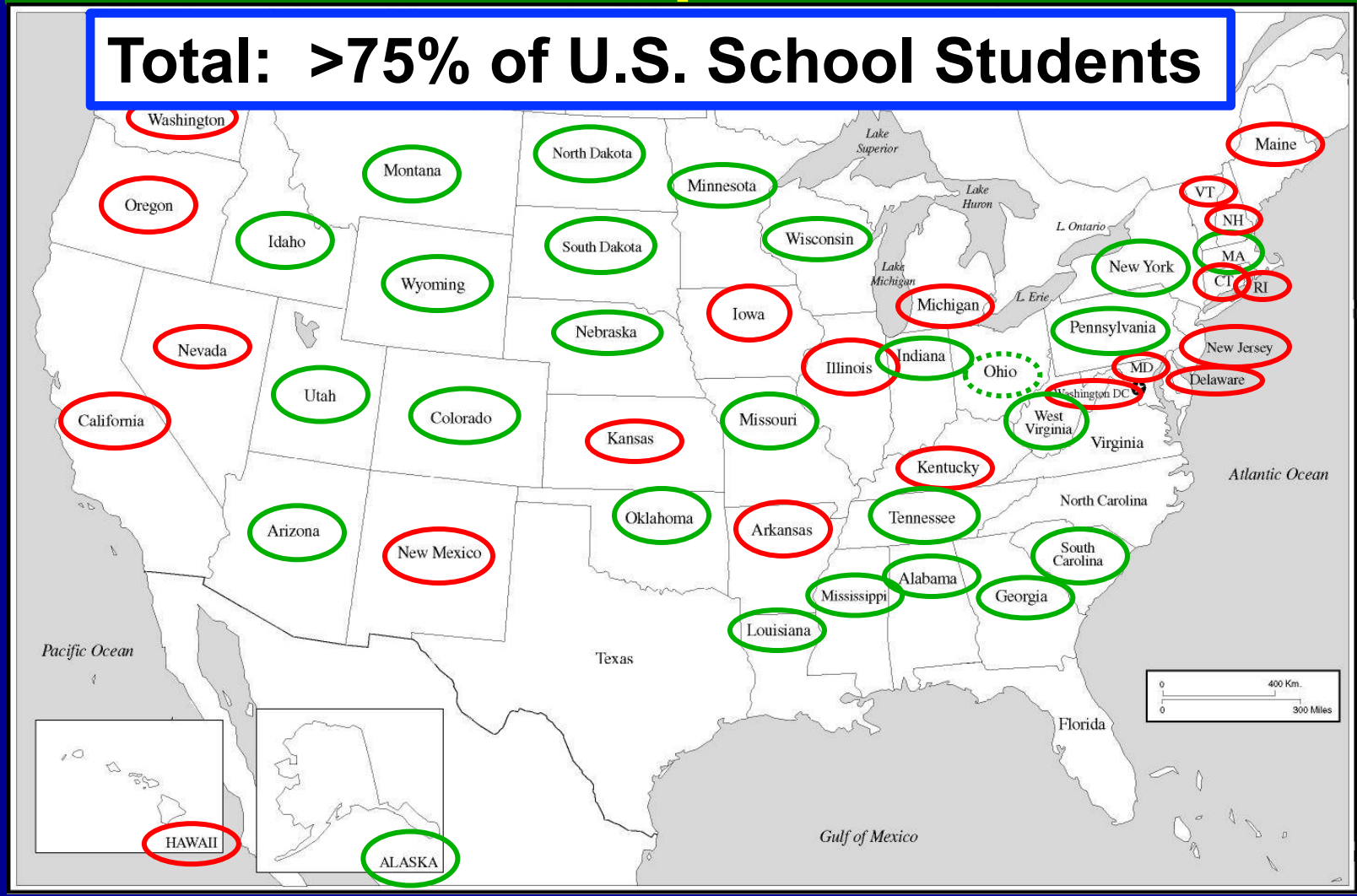


2013

Next Generation Science: State-wise Adoption

NGSS Adopting States:

Arkansas
California
Connecticut
Delaware
Dist. of Col.
Hawaii
Illinois
Iowa
Kansas
Kentucky
Maine
Maryland
Michigan
Nevada
N. Hampshire
New Jersey
New Mexico
Oregon
Rhode Isl.
Vermont
Washington



NGSS Adapting: Alabama, Alaska, Arizona, Colorado, Georgia, Idaho, Indiana, Louisiana, Massachusetts, Minnesota, Mississippi, Missouri, Montana, Nebraska, New York, North Dakota, Oklahoma, Pennsylvania, South Carolina, South Dakota, Tennessee, Utah, West Virginia, Wisconsin, Wyoming

NGSS Science Standards

Middle School: Grade-Banded Standards, 6-8

- 1 year of Life Science
- 1 year of Physical Science (Chemistry & Physics)
- 1 year of Earth and Space Science

High School: Grade-Banded Standards, 9-12

- 1 year of Life Science
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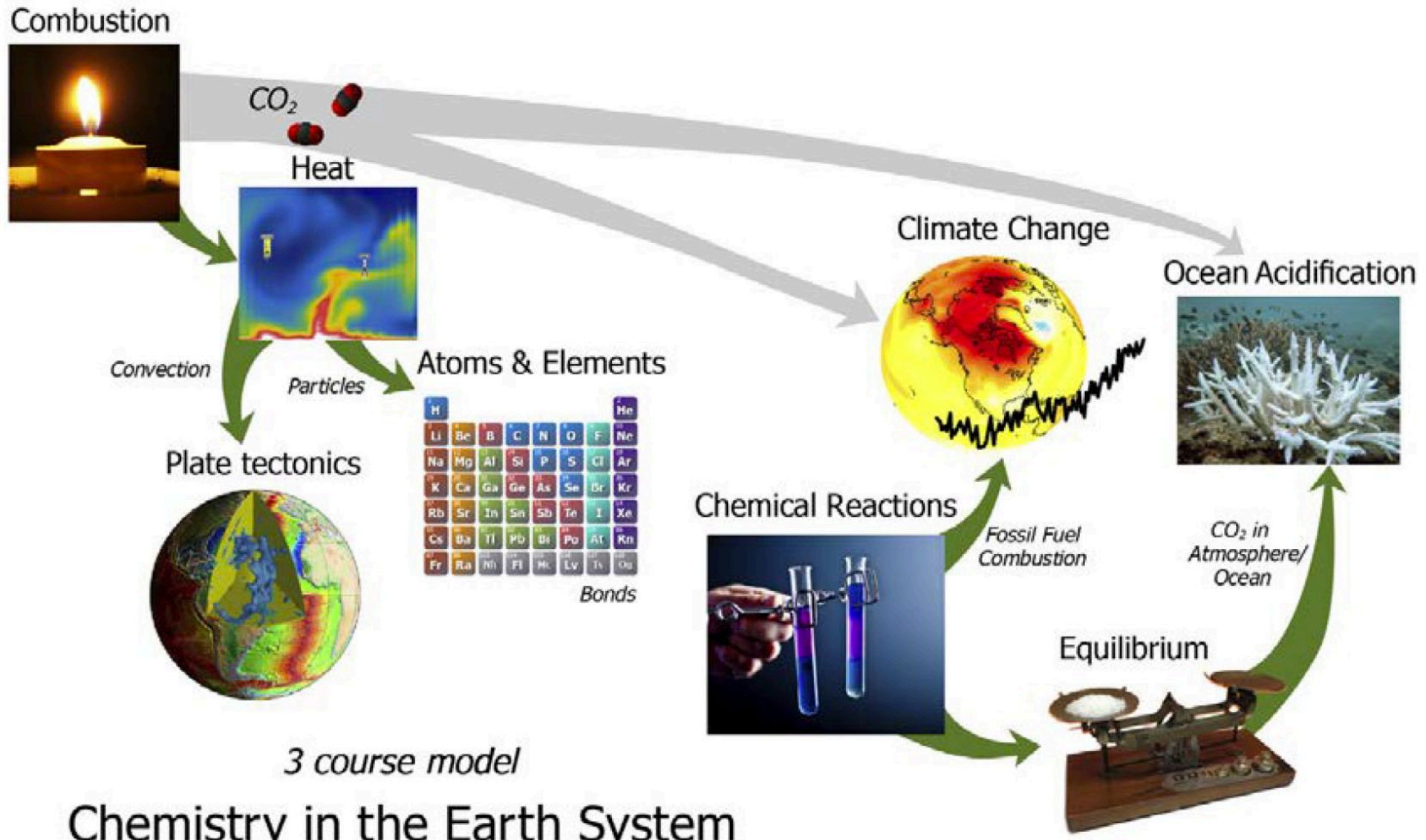
NRC Framework: The *Core Ideas* of Science

Physical Science	Life Science	Earth and Space Science
PS1 Matter and Its Interactions	LS1 From Molecules to Organisms: Structures and Processes	ESS1 Earth's Place in the Universe
PS1A Structure and Properties of matter	**LS1A Structure and Function**	**ESS1A The Universe and Its Stars**
PS1B Chemical Reactions	**LS1B Growth and Development of Organisms**	**ESS1B Earth and the Solar System**
PS1C Nuclear Processes	**LS1C Organization for Matter and Energy Flow in Organisms**	**ESS1C The History of Planet Earth**
PS2 Motion and Stability: Forces and Interactions	**LS1D Information Processing**	ESS2 Earth's Systems
PS2A Forces and Motion	LS2 Ecosystems: Interactions, Energy, and Dynamics	**ESS2A Earth Materials and Systems**
PS2B Types of Interactions	**LS2A Interdependent Relationships in Ecosystems**	**ESS2B Plate Tectonics and Large-Scale System Interactions**
PS2C Stability and Instability in Physical Systems	**LS2B Cycles of Matter and Energy Transfer in Ecosystems**	**ESS2C The Roles of Water in Earth's Surface Processes**
PS3 Energy	**LS2C Ecosystem Dynamics, Functioning, and Resilience**	**ESS2D Weather and Climate**
PS3A Definitions of Energy	**LS2D Social Interactions and Group Behavior**	**ESS2E Biogeology**
PS3B Conservation of Energy and Energy Transfer	LS3 Heredity: Inheritance and Variation of Traits	ESS3 Earth and Human Activity
PS3C Relationship Between Energy and Forces	**LS3A Inheritance of Traits**	**ESS3A Natural Resources**
PS3D Energy and Chemical Processes in Everyday Life	**LS3B Variation of Traits**	**ESS3B Natural Hazards**
PS4 Waves and Their Applications in Technologies for Information Transfer	LS4 Biological Evolution: Unity and Diversity	**ESS3C Human Impacts on Earth Systems**
PS4A Wave Properties	**LS4A Evidence of Common Ancestry**	**ESS3D Global Climate Change**
PS4B Electromagnetic Radiation	**LS4B Natural Selection**	
PS4C Information Technologies and Instrumentation	**LS4C Adaptation**	
	LS4D Biodiversity and Humans	

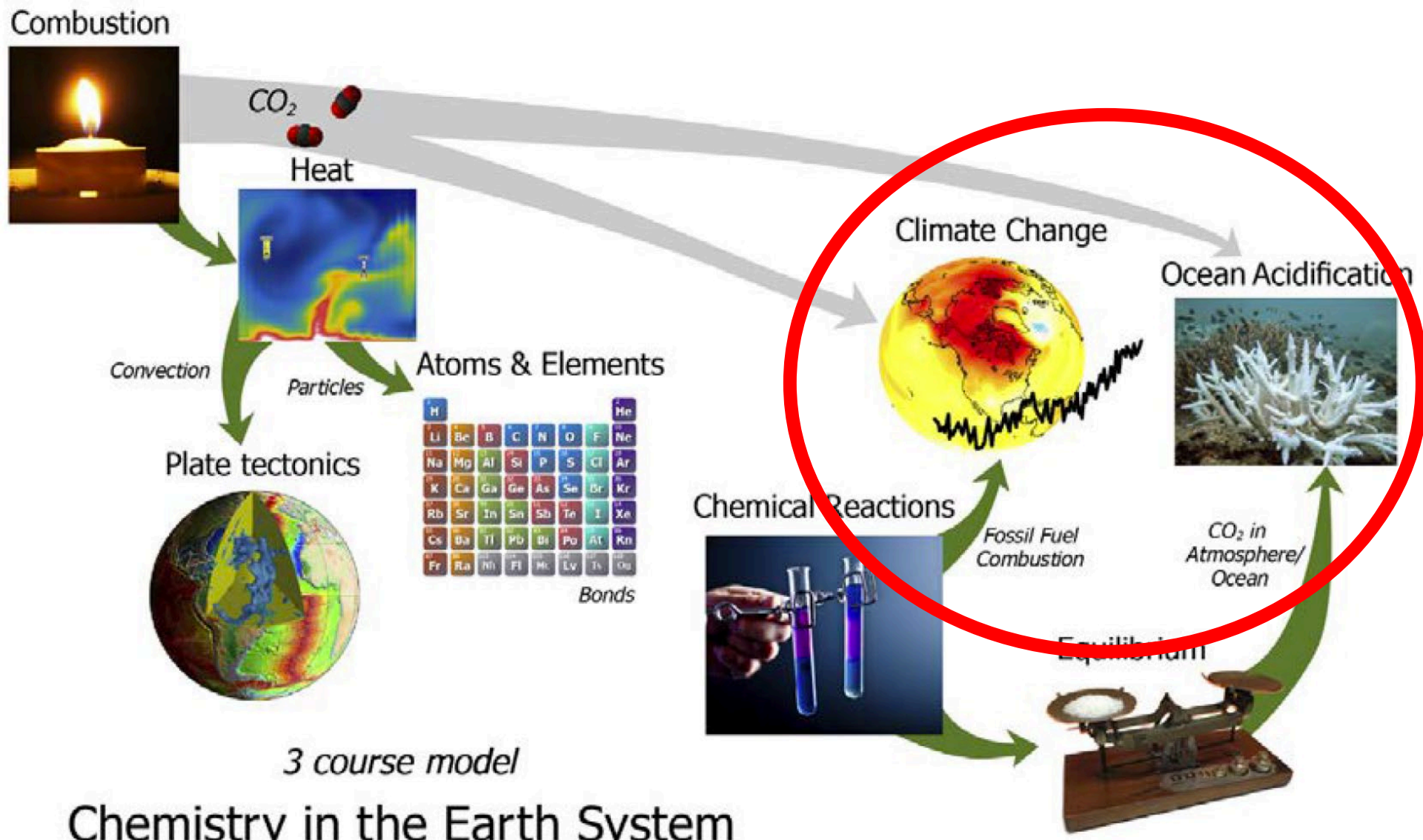
California H.S. Integrated 3-Course Model: CHEMISTRY

Chemistry in the Earth System: Integrating Chemistry and Earth and Space Science



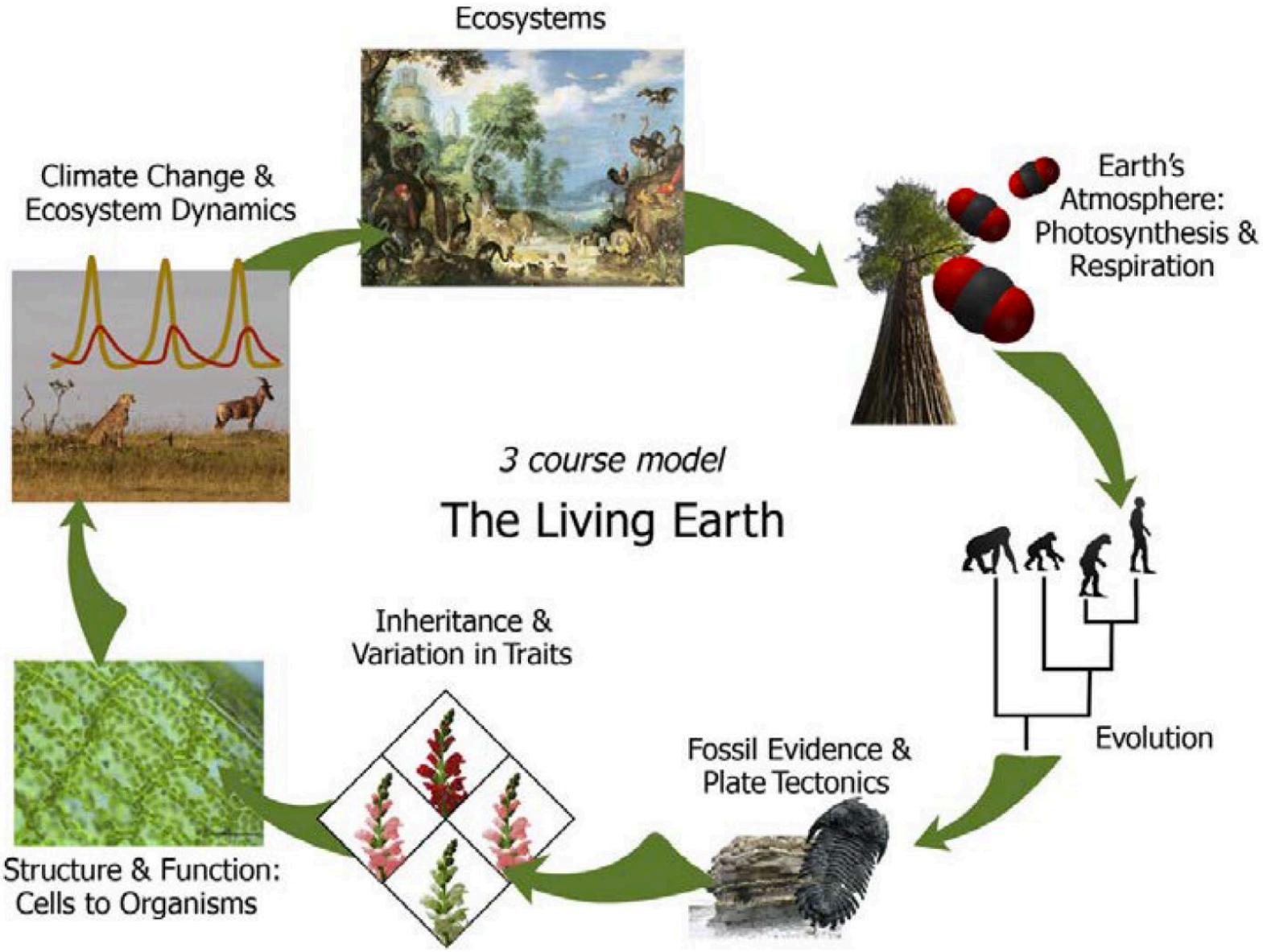
California H.S. Integrated 3-Course Model: CHEMISTRY

Chemistry in the Earth System: Integrating Chemistry and Earth and Space Science



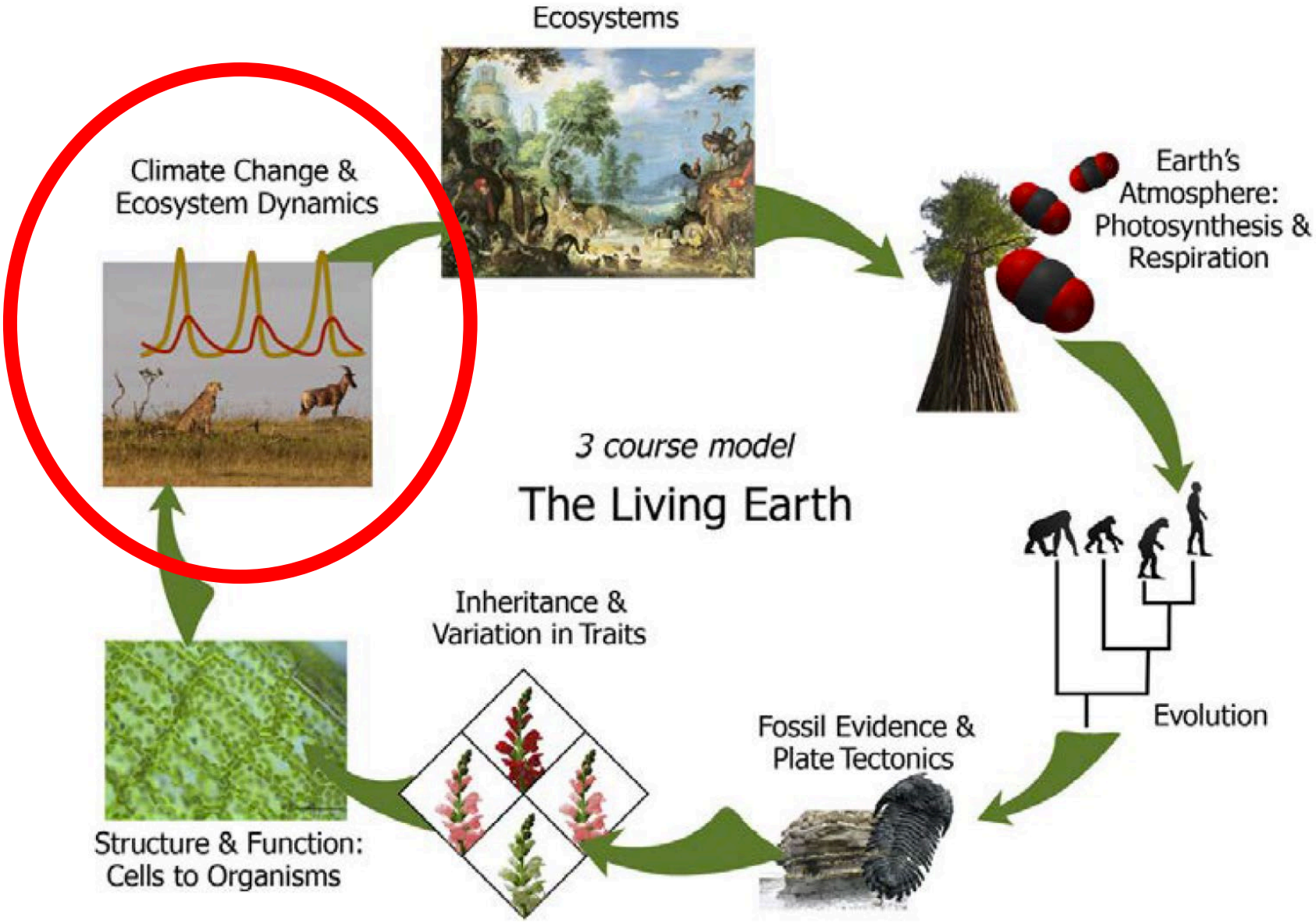
California H.S. Integrated 3-Course Model: BIOLOGY

The Living Earth: Integrating Biology and Earth Science



California H.S. Integrated 3-Course Model: BIOLOGY

The Living Earth: Integrating Biology and Earth Science



“Civilization is a Race Between Education and Catastrophe”

--H.G. Wells