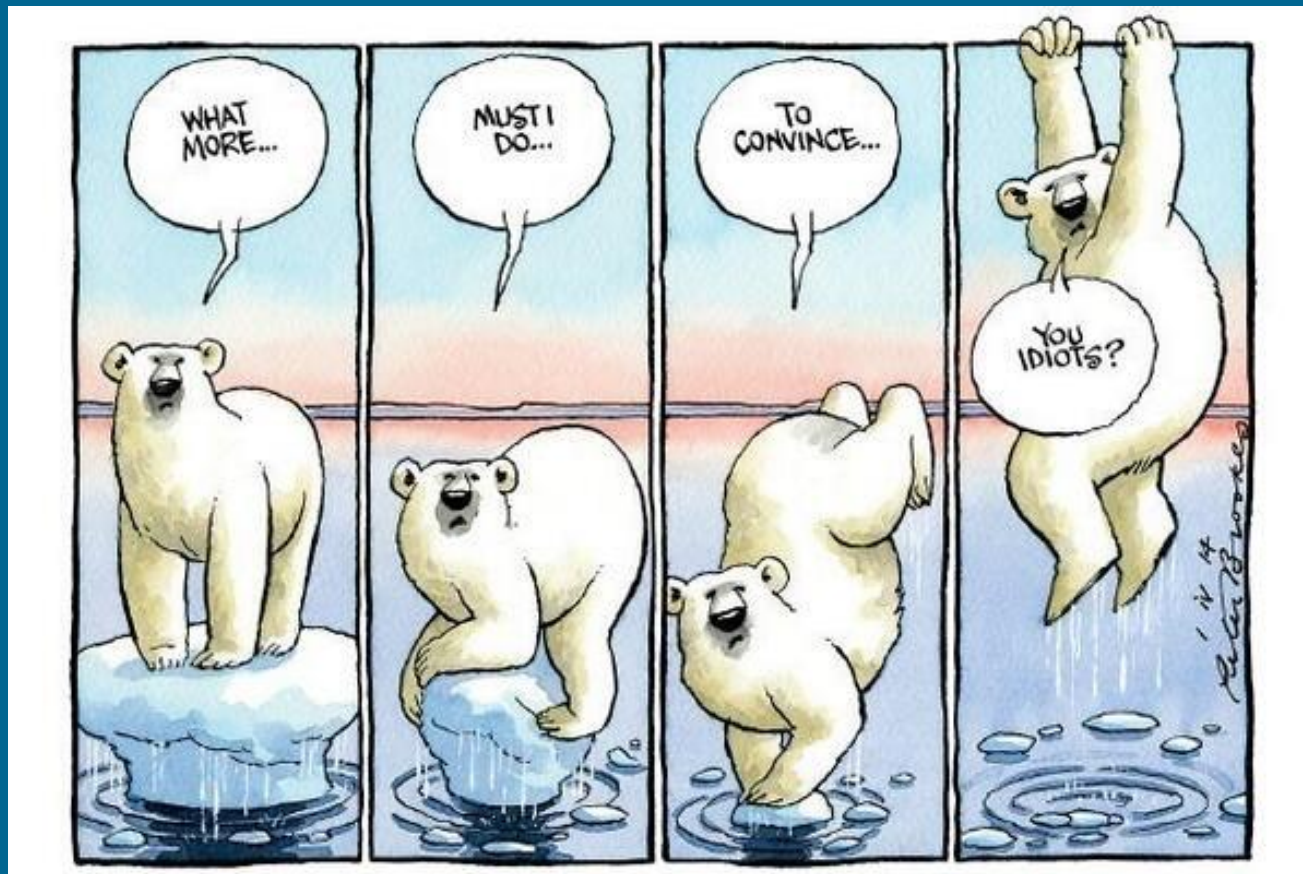


Climate Change: It is real, and it is more than just temperature



Alan Steinman, Ph.D.

Allen and Helen Hunting Research Professor
Annis Water Resources Institute - GVSU

Today's Presentation

- Climate change background
- Air-related effects
- Land-related effects
- Water-related effects
- Mental health-related effects
- Solutions?

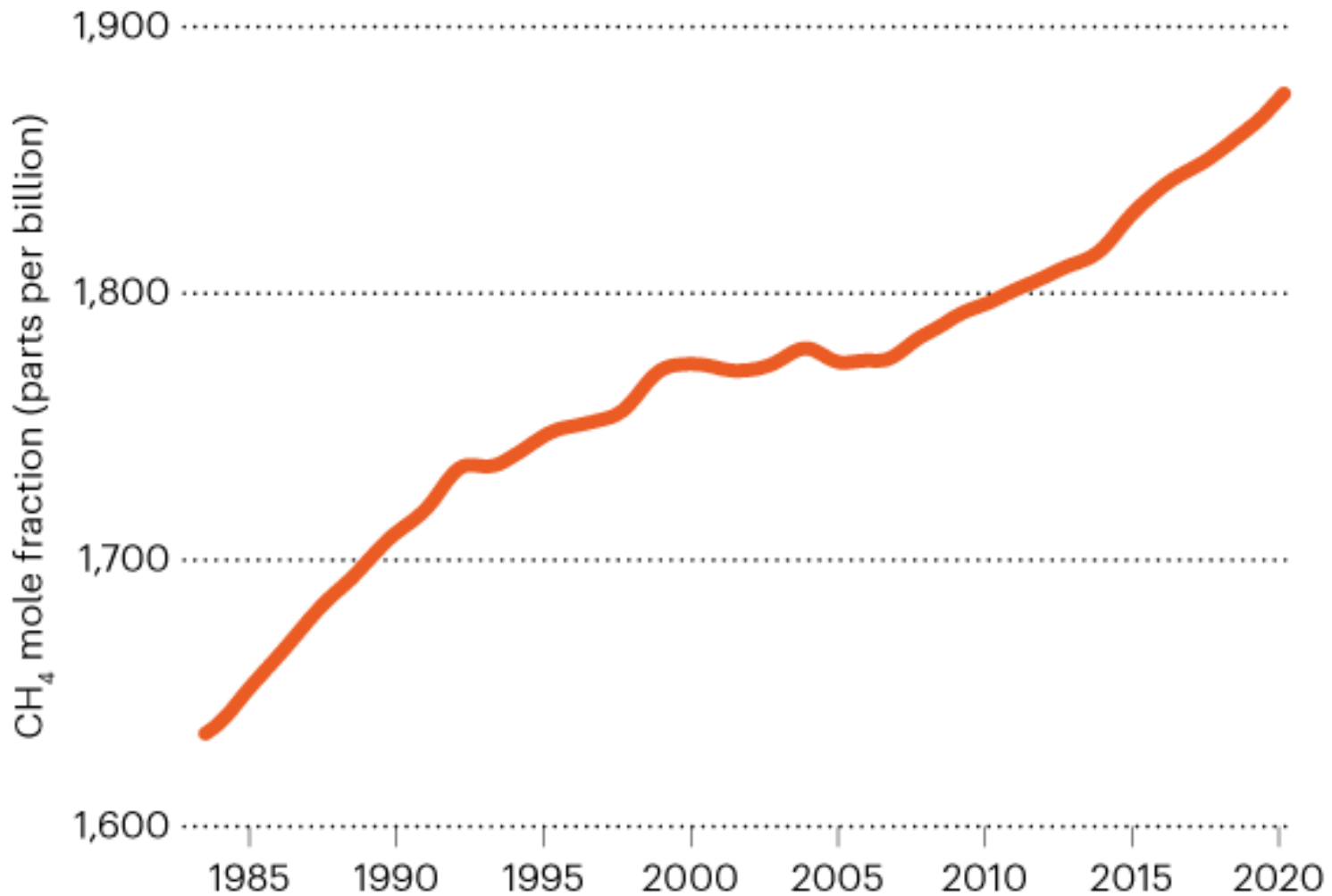
Climate Change Background

Greenhouse gases in our atmosphere:

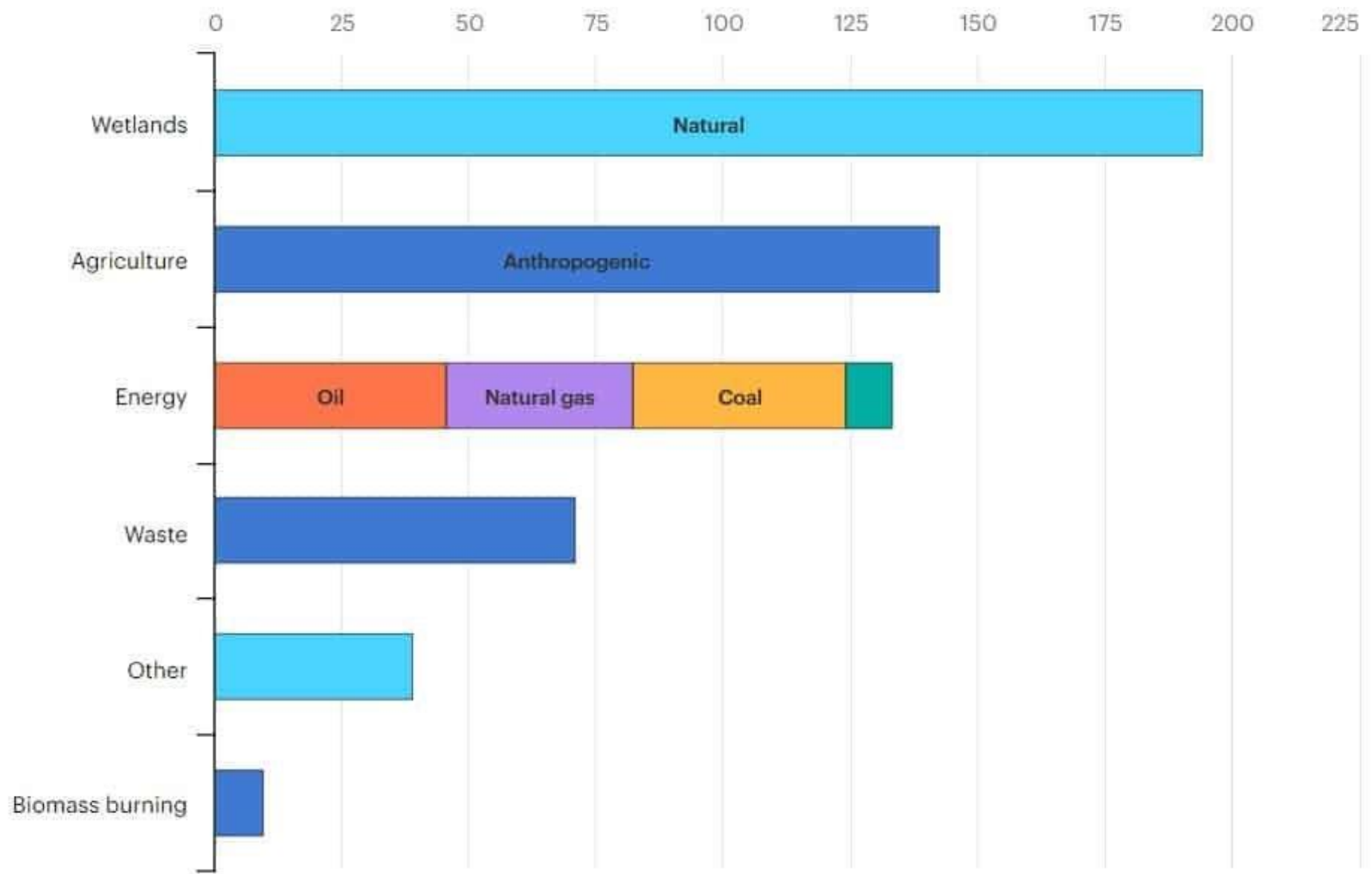
- water vapor
- carbon dioxide
- methane (~30× more potent than CO₂)
- also ozone, nitrous oxide, and halocarbons

RECORD HIGH

Global emissions of methane have risen by nearly 10% over the past two decades, resulting in the highest-ever atmospheric concentrations of the greenhouse gas.



Mt methane

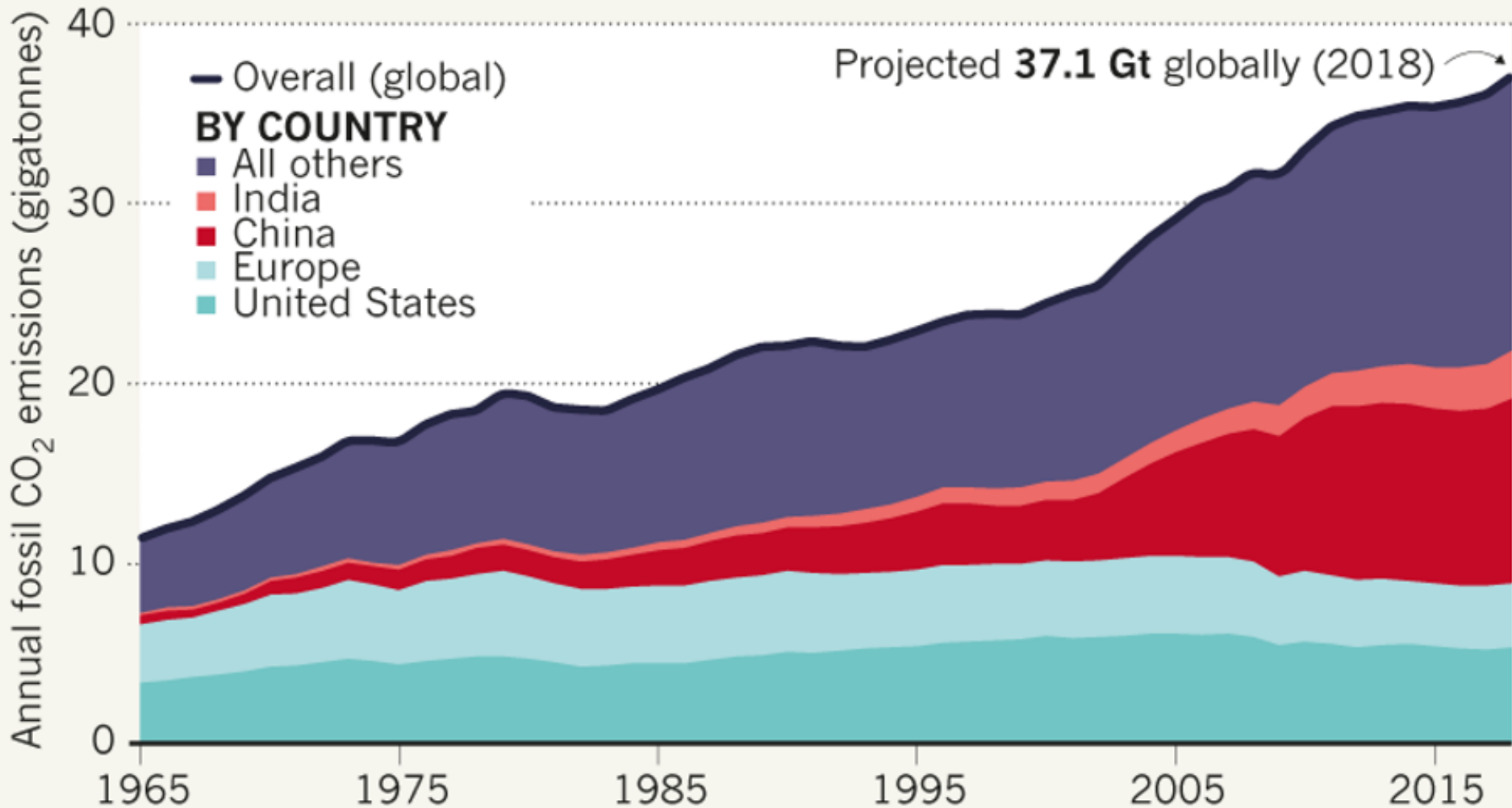


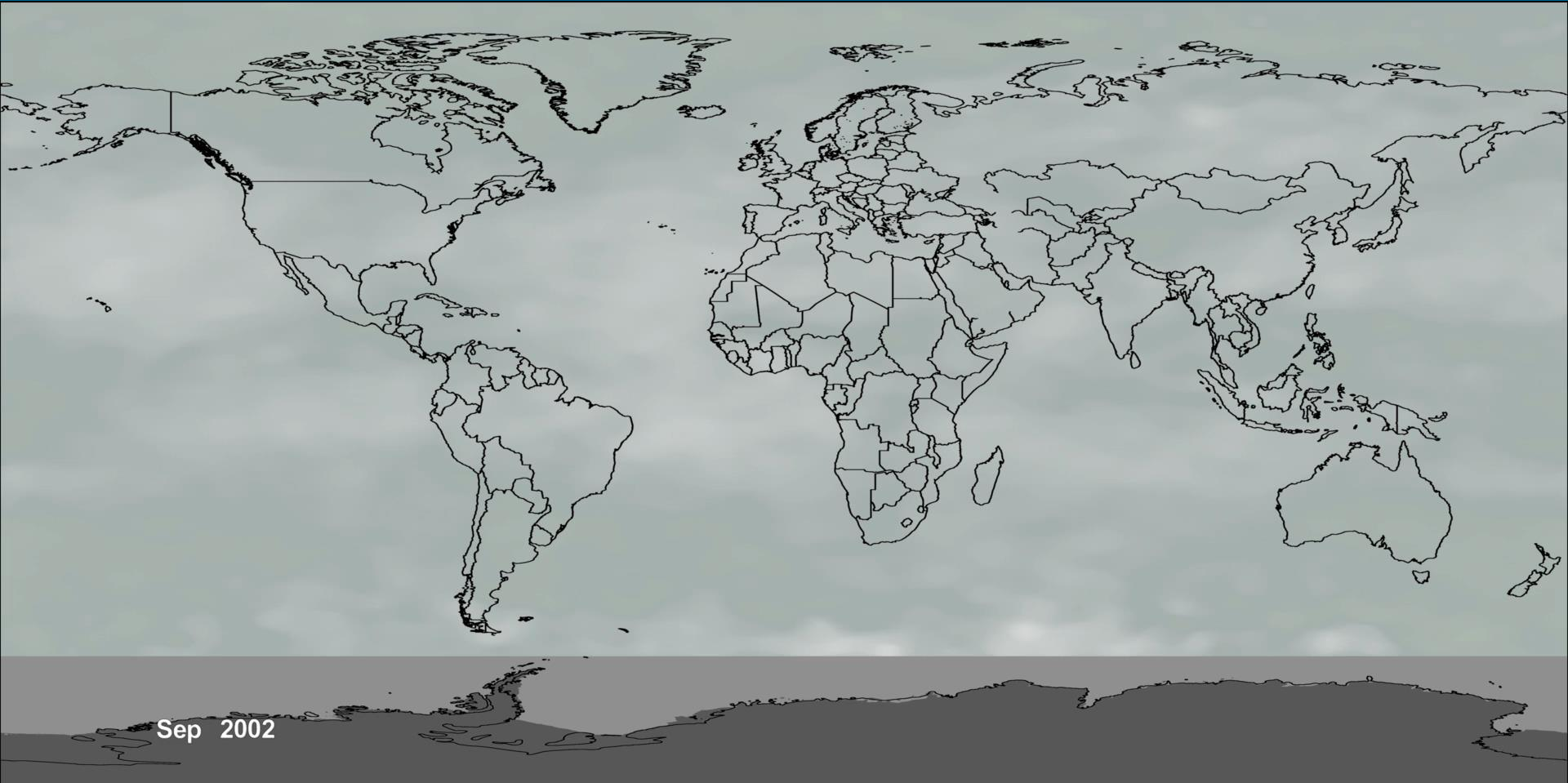
Source: International Energy Agency



EMISSIONS ARE STILL INCREASING

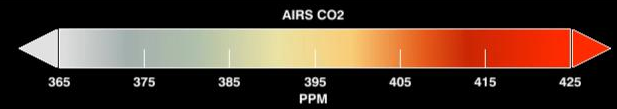
China and India still rely heavily on coal; the United States and the European Union are slowly decarbonizing.





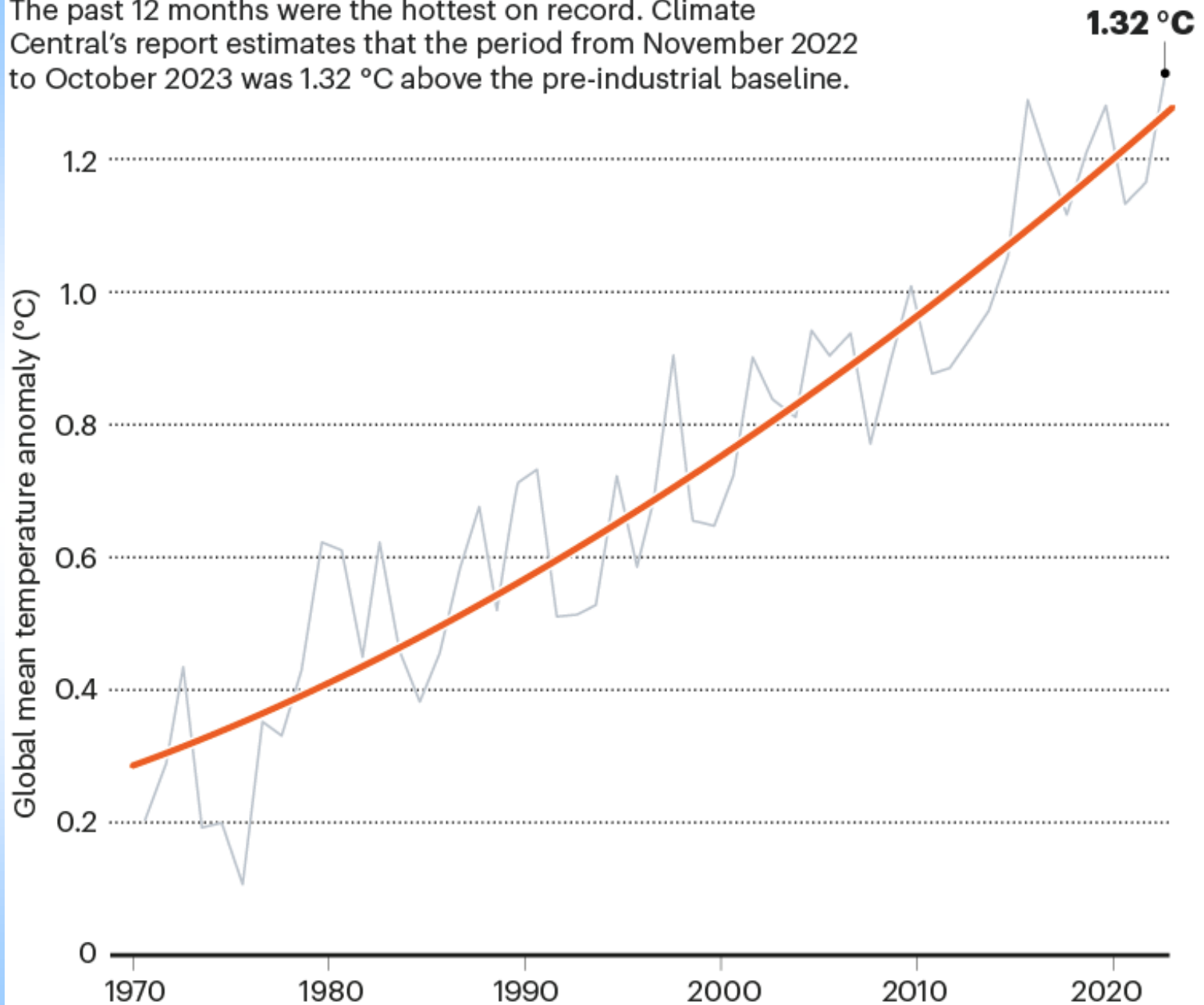
Sep 2002

AIRS Mid-Tropospheric Carbon Dioxide



HEATING PLANET

The past 12 months were the hottest on record. Climate Central's report estimates that the period from November 2022 to October 2023 was 1.32 °C above the pre-industrial baseline.



Climate Change Background

- Earth's climate is constantly changing
- So, how much of the observed warming is due to human activities and how much is due to the natural variability in the climate?

Ice core from the West Antarctic Ice Sheet Divide. The dark band is a layer of volcanic ash that settled on the ice sheet ~21,000 years ago.



L Skinner Science 2012;337:917-919



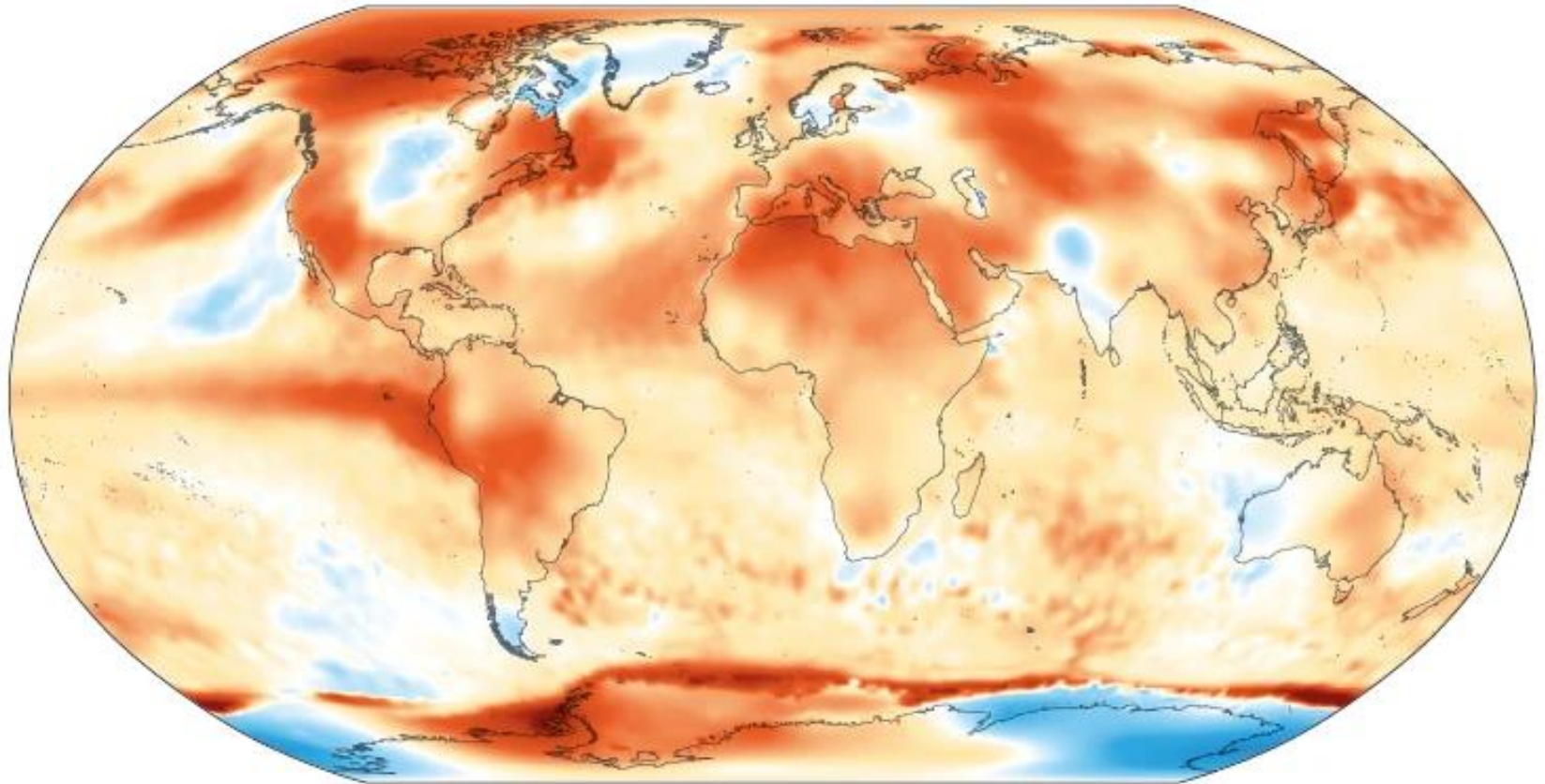
Climate Change Measurements

- Over past 750,000 years, Earth has been thru 8 glacial/interglacial cycles:
 - Ice Age: CO₂ ~ 210 ppm
 - Interglacial: CO₂ ~ 260-280 ppm
 - April 11, 2023: 404 ppm
 - April 11, 2024: 422 ppm

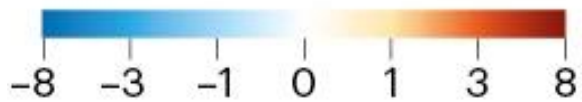
Climate Change Uncertainties

- 1) Climate change impacts will be uneven
 - will be “winners” and “losers”

Hot Spots: 2019



Temperature anomaly (°C)



Polar Vortex



Climate Change Background

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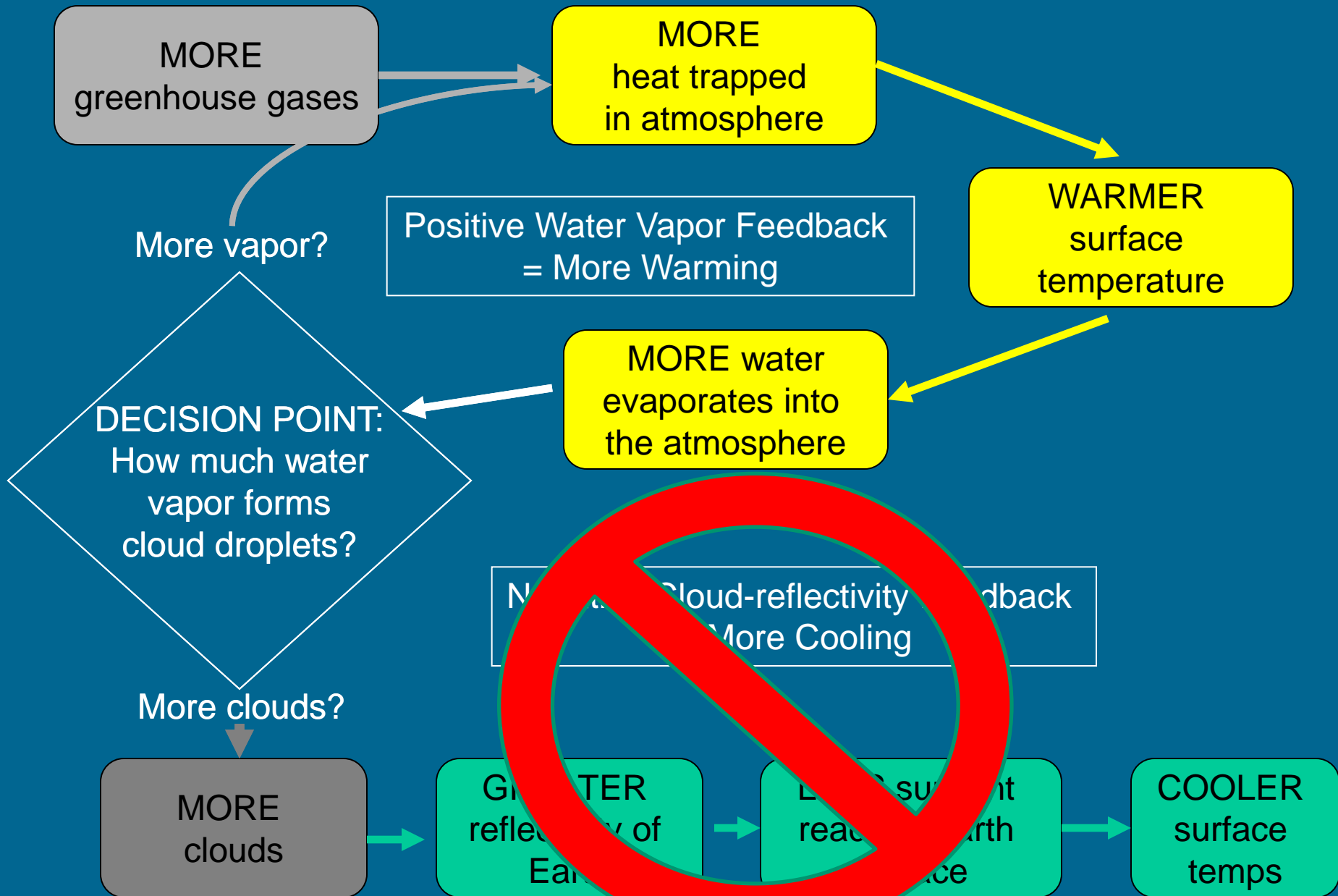
ons

Climate Change Uncertainties

2) Climate Feedbacks

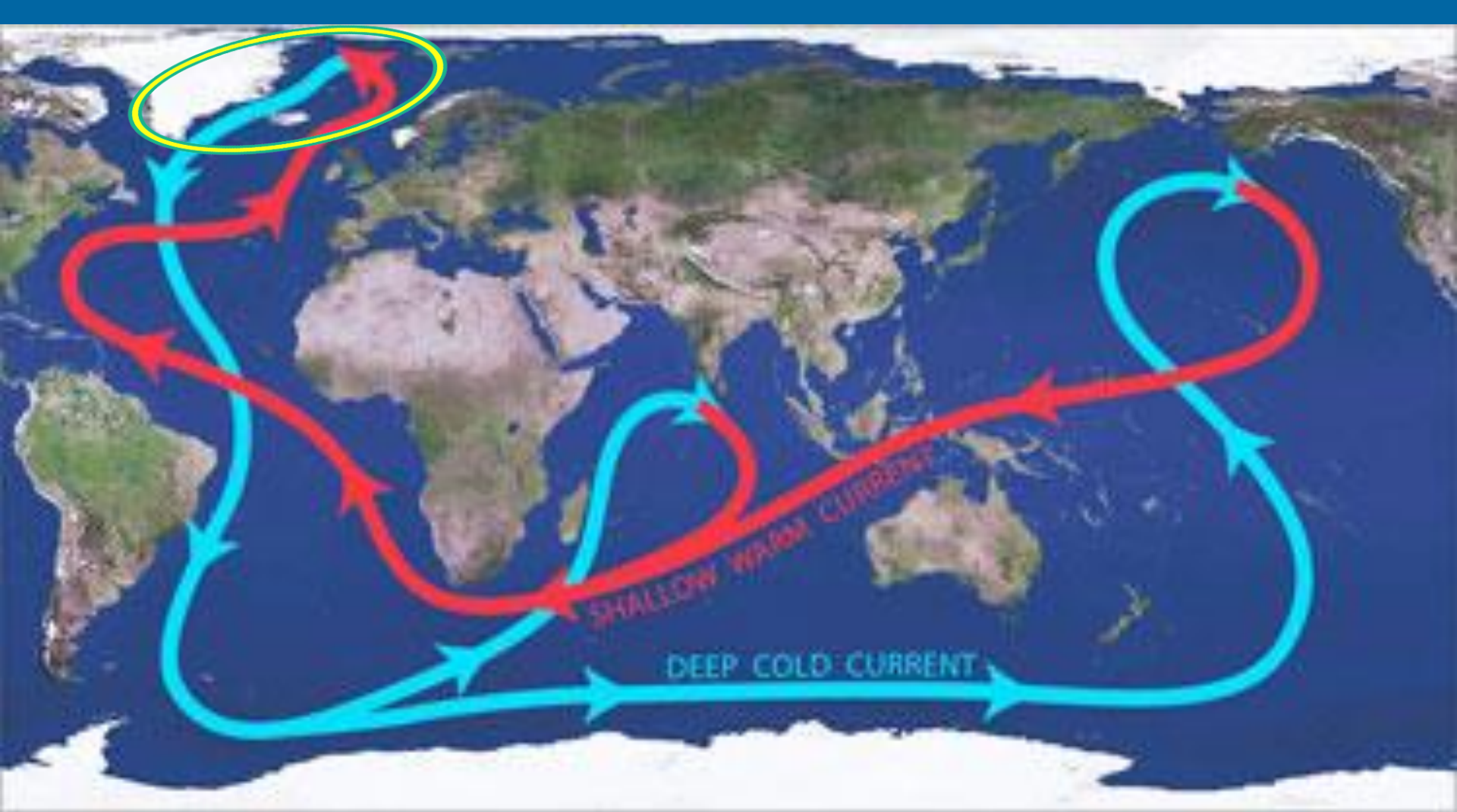
- can either amplify or dampen the climate response to radiative force

Feedback Loops: Water Vapor



Climate Change Uncertainty

- 3) Changes in ocean circulation:
- Possible disruption of ocean “conveyor belt”
 - Ocean storage of CO₂



Red: Warmer, saline water on surface

Blue: Cooler water, becomes denser, sinks, and moves south

Implications

Study* claims ocean circulation currents from 1990 to 2013 have increased by ~15% per decade.

Stronger tropical currents could carry more warm water to higher latitudes.

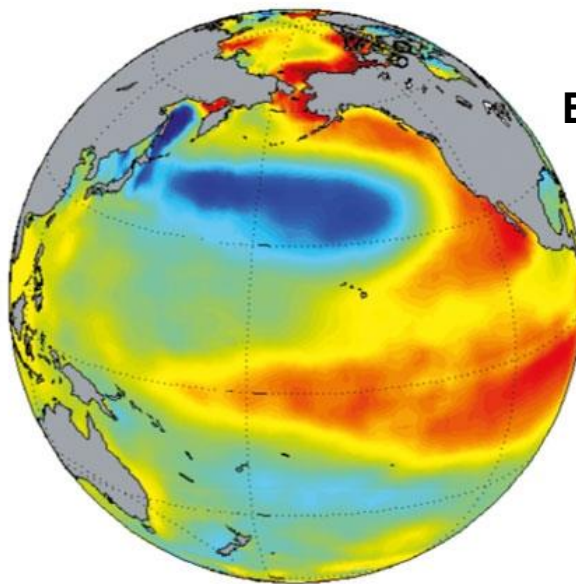
Because carbon dioxide (CO₂) is less soluble in warm water, that could slow the ocean's uptake of CO₂ from the atmosphere.

*Shijian et al. (2020) Science Advances

Climate Change Uncertainties

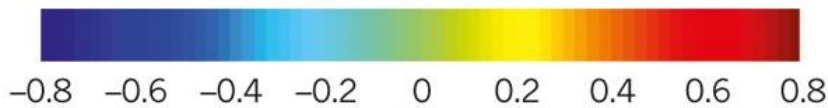
4) Ocean storage and teleconnections

WARM PHASE

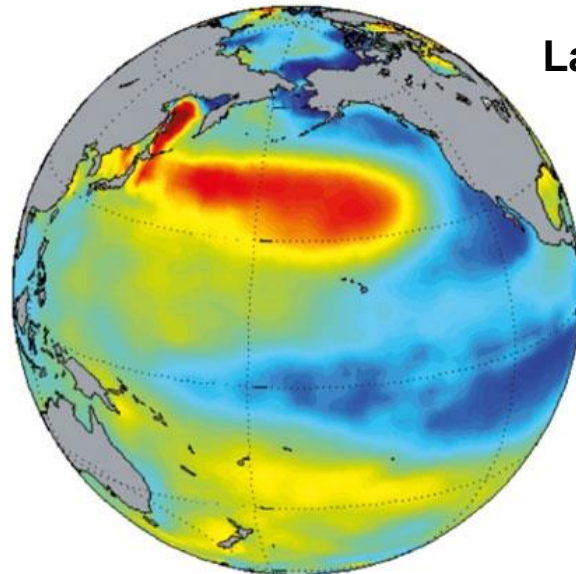


El niño

Departures from average ocean temperatures (°C) associated with the warm and cool phases of the PDO



COLD PHASE



La niña

Pacific Ocean?

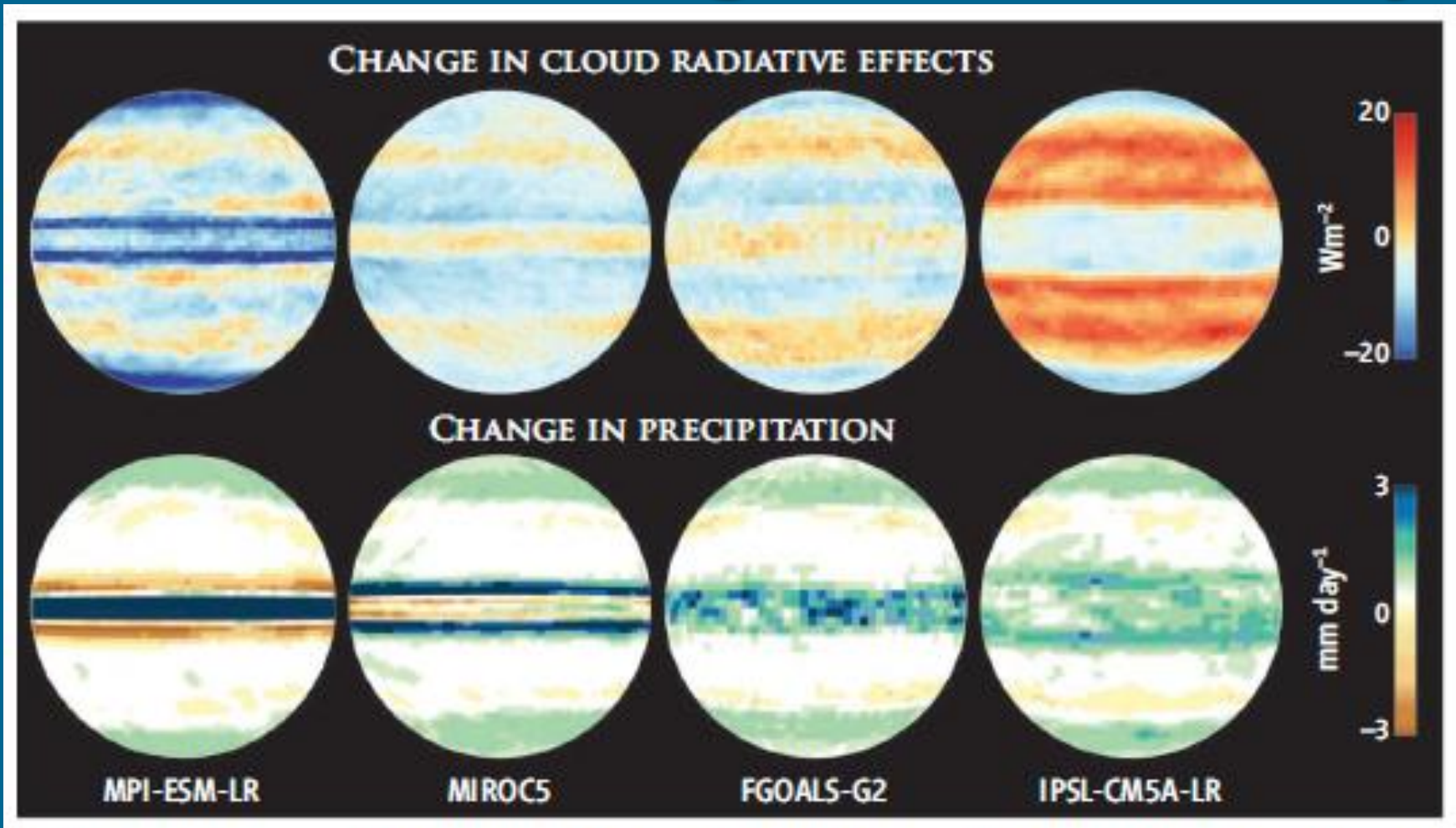
- every few decades, the Pacific flips between warmer and cooler conditions in the Eastern Basin and along the Equator → Pacific Decadal Oscillation (PDO)

Nature (2014)

Climate Change Uncertainties

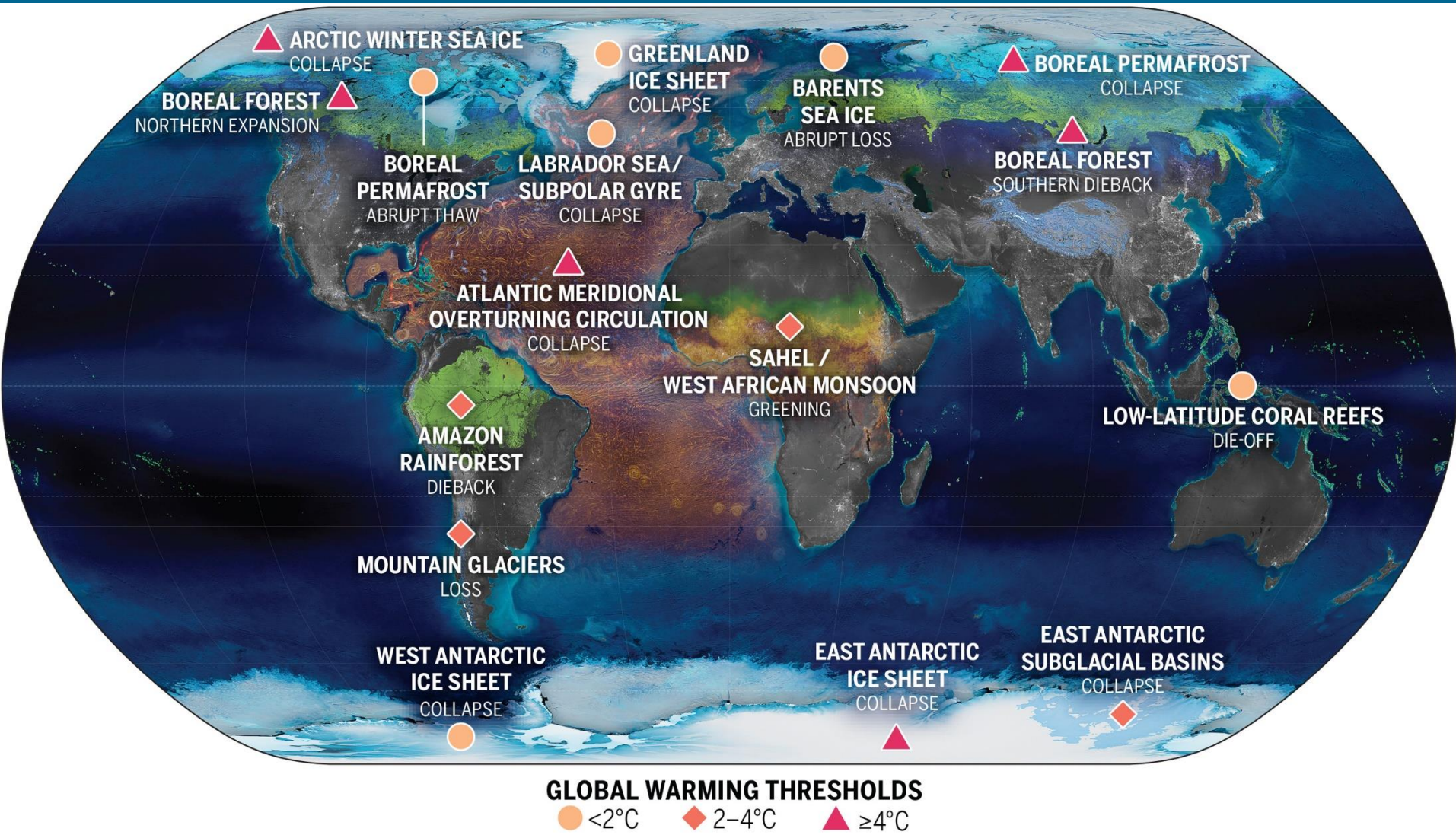
5) General Circulation Model Outputs

Climate Change Uncertainty



Source: Science (2013)

Climate Tipping Points



Source: Science (2022)

Potential Impacts

- Air
- Land
- Water
- Mental Health

Potential Impacts: Air

Particulate Matter

PM_{2.5}: the tiniest particles in smoke that measure 2.5 μm or less in diameter

Potential physiological changes:

- the hormone cortisol and blood glucose spike, which in turn makes heart rhythms less stable and blood more likely to clot.
- The lining of the lungs becomes inflamed, making it more difficult to breathe.

Lots of sources, including wildfire

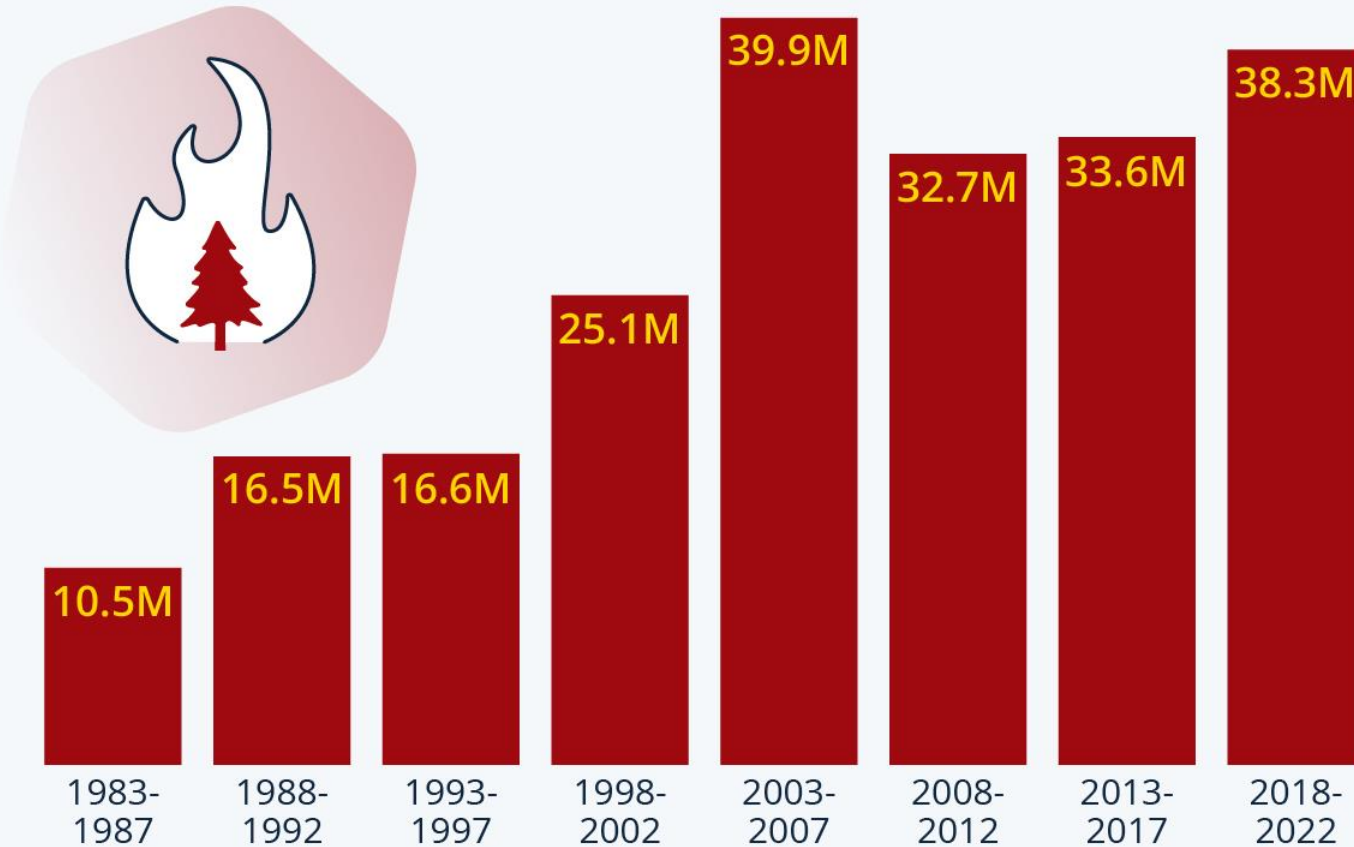
Wildfires

Climate change is a major driver of wildfires. Rising temperatures increase the frequency, intensity, and duration of extreme events (droughts, heatwaves, and high-speed winds)

Land-cover changes (deforestation, urbanization, mining, agriculture and pasture) have all increased the likelihood of extreme wildfires over the past decades (UNEP 2022)

Area Burned by Wildfires Grows in the U.S.

Acres burned by wildfires in the U.S. (1983-2022)



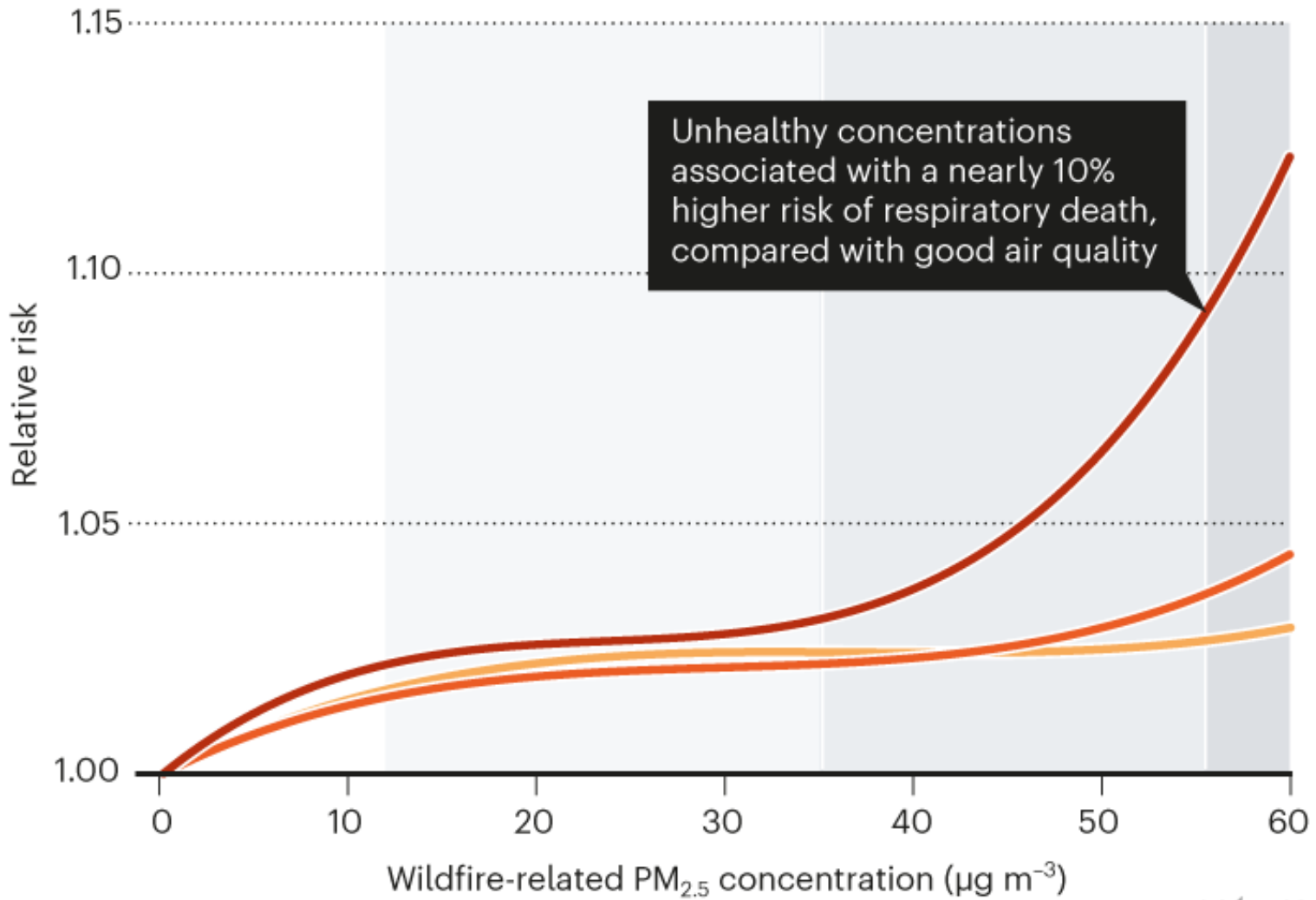
Source: National Interagency Fire Center



Respiratory mortality Cardiovascular mortality All-cause mortality

Air quality index

Good Moderate Unhealthy for sensitive groups Unhealthy



Environmental Justice and Air Quality

People in under-resourced communities are more likely to have outdoor occupations (e.g., agriculture, landscaping)

Greater exposure to particulates, less access to adequate health care and air purifiers

Hence, wildfires are creating an even greater burden for communities of color and low-income

Near fires, $PM_{2.5}$ can reach levels $>15X$ greater than the 24-hr exposure standard of $35 \mu\text{g}/\text{m}^3$
US (EPA)

Environmental Justice and Air Quality

Recent study examined 5,723 urban municipalities and other areas across the U.S. – what extent does nature-based cooling (trees) influence # of heat-related deaths and doctors' visits in those neighborhoods.

Neighborhoods that are predominately people of color have less tree cover.

Led to 190 more deaths and 30,000 more doctors' visits than if their tree cover was same as in white neighborhoods.

Puk

In addition

- Air filter network
- Consider afford
- Social/risk per the elec alerts



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Potential Impacts: Land

Heat

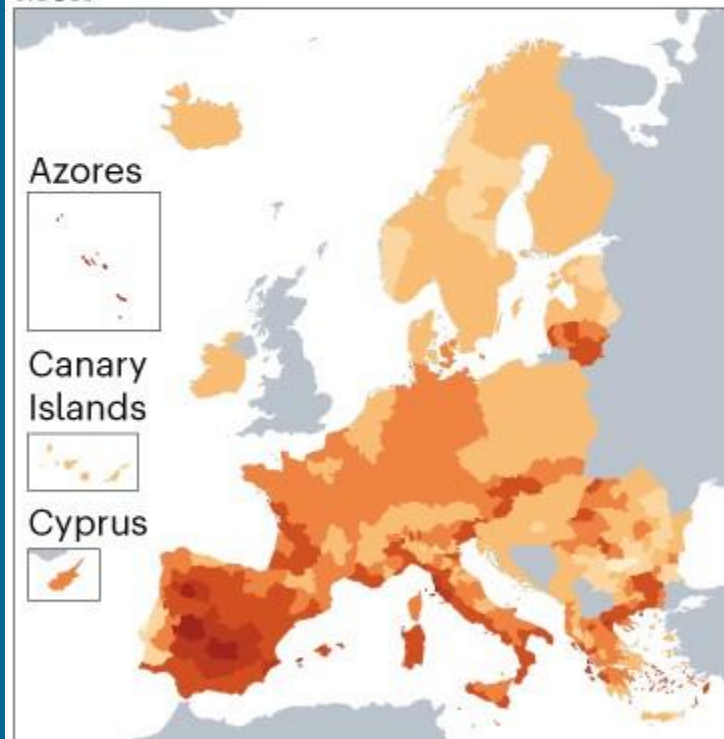
HEAT KILLS

Rates of heat-related deaths increased between 2003–12 and 2013–22 across most of Europe — and rose faster for women than men.

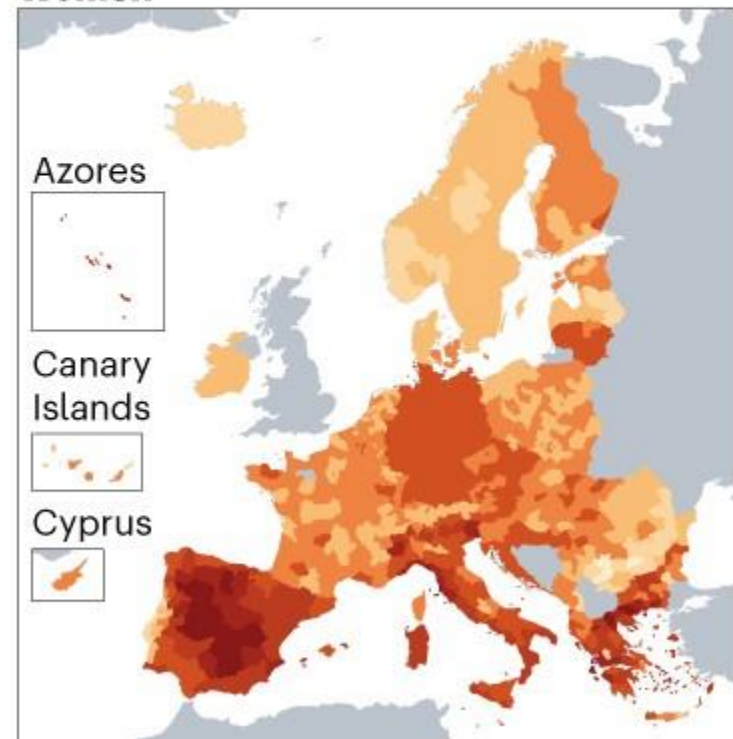
Change in heat-related mortality rate per 100,000 inhabitants

<-20 deaths -20-0 0-10 10-20 20-40 40-60 60-80 >80

Men



Women



Heat



HEALTH

Warming world, deadly problem: Heat-related deaths are surging

The rate of heat-related deaths in the U.S. rose 117% in the last seven years, research finds.

Extreme heat kills more people than hurricanes, floods, and tornadoes combined in an average year in the US

Heat - Solutions

PLANT TREES: The Greening of Detroit in 2022 planted more than 75,000 trees, employed over 300 Detroit residents in tree care and maintenance, and invested \$30 million in Detroit neighborhoods.



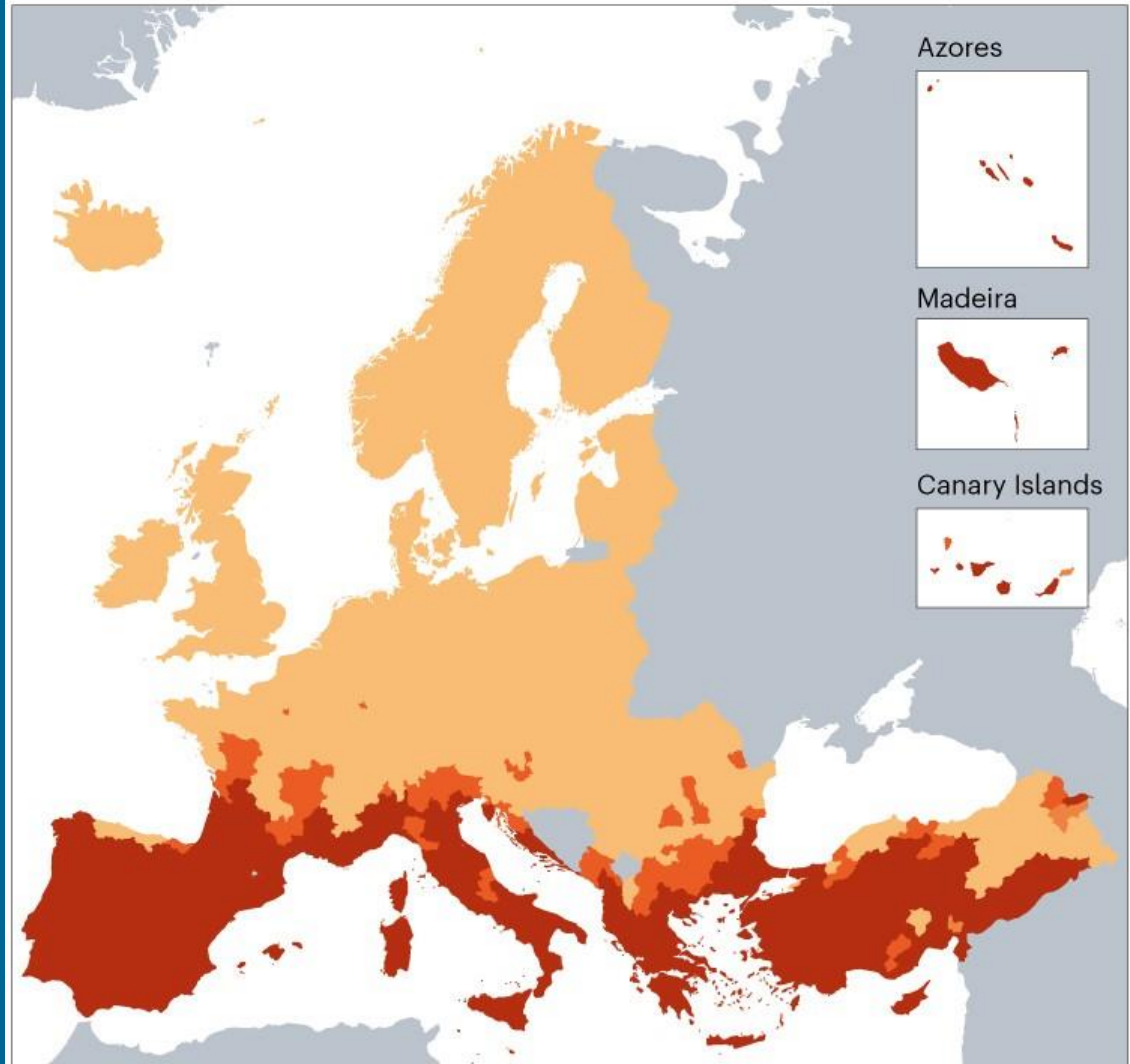
Pathogens

INCHING NORTH

As Europe warms, larger swaths of the continent are becoming hospitable to sandflies (*Leishmania infantum*), which are vectors for the skin disease leishmaniasis.

Predicted climate suitability of *L. infantum*

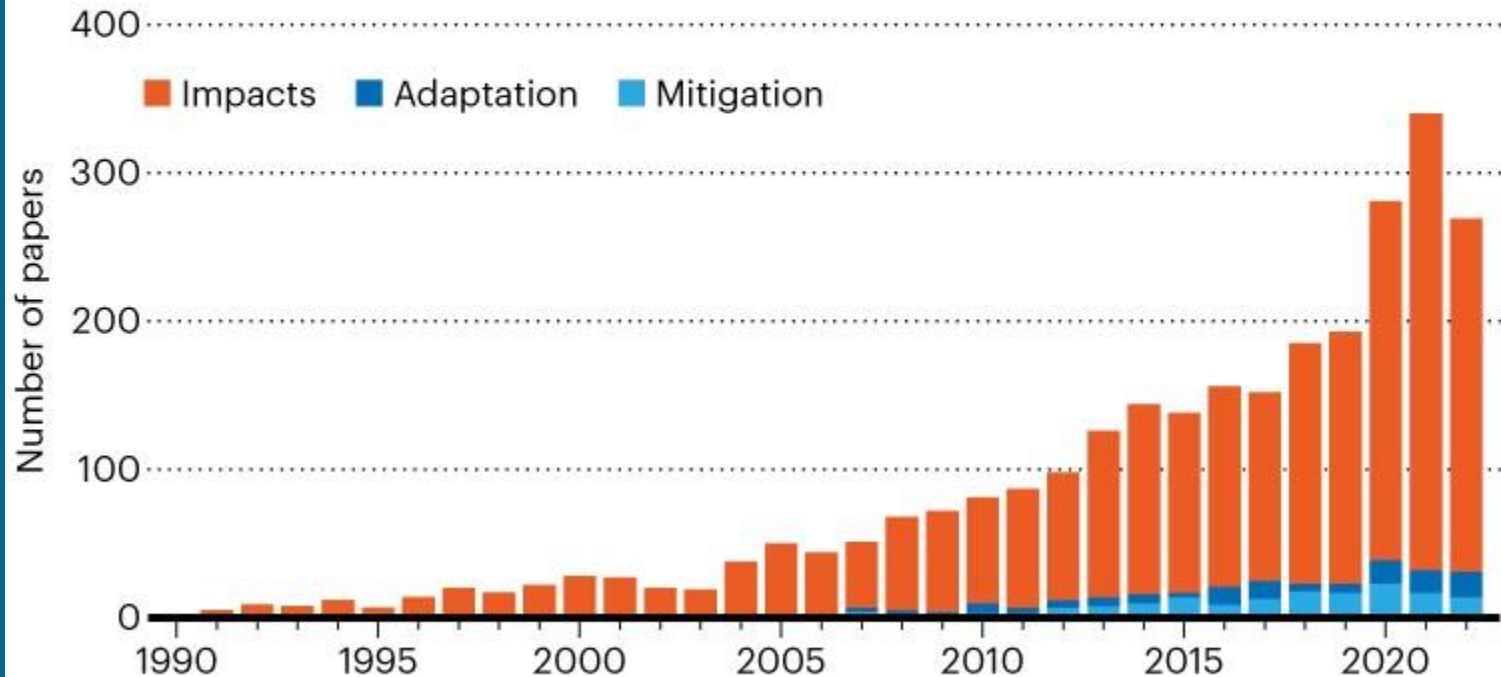
- Suitable in 2001–10 and 2011–20
- Suitable only in 2001–10
- Suitable only in 2011–20
- Unsuitable in both periods



Publications

HOT TOPIC

Research on topics at the intersection between climate change and health in Europe has been growing steadily.



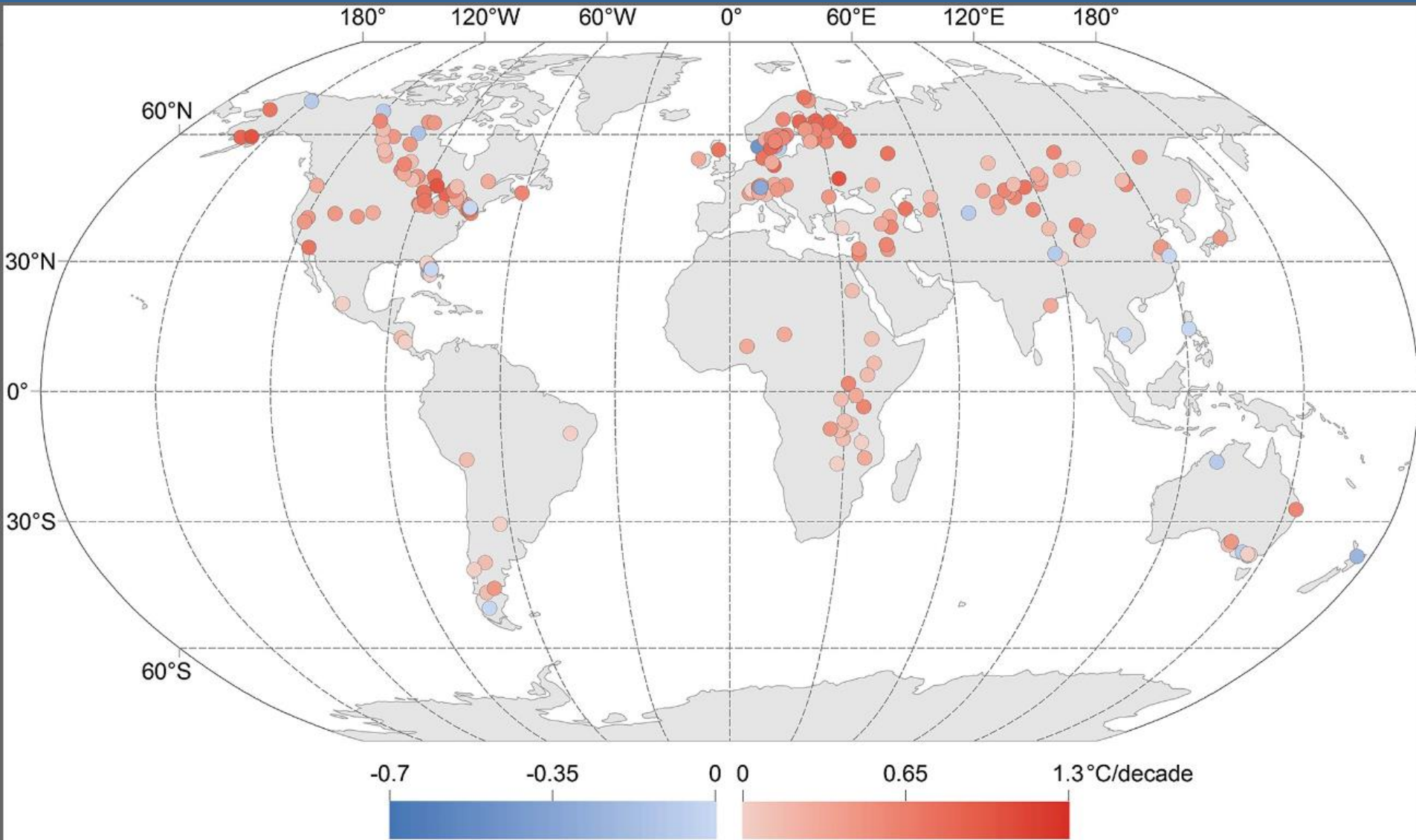
©nature

Only ~2% of the studies published in 2022 on climate health referenced equality, equity or justice. Author Kim van Daalen states: “To properly respond to the climate-related health impacts, it is important to understand which populations are disproportionately affected and most at risk”

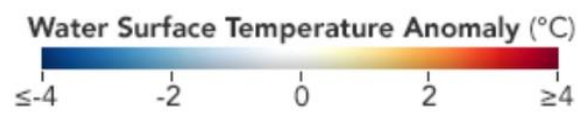
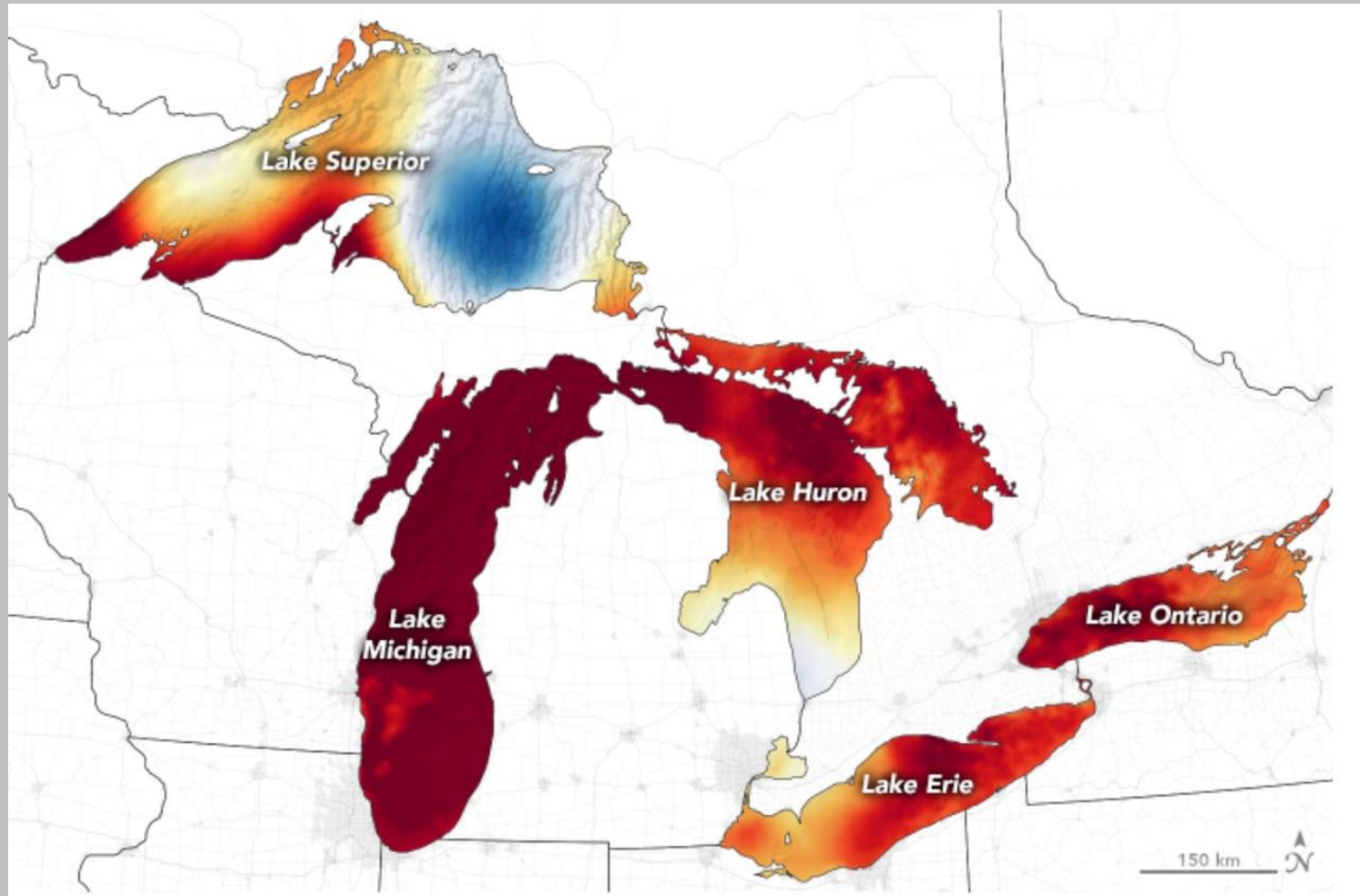
Potential Impacts: Water

- Temperature
- Precipitation
- Extremes

Lake water temperatures will increase



Surface water temperature deviation from long-term average for July 9, 2020 (NOAA)



July 9, 2020



Predictions

© MARK ANDERSON

WWW.ANDERSTOONS.COM



ANDERSON

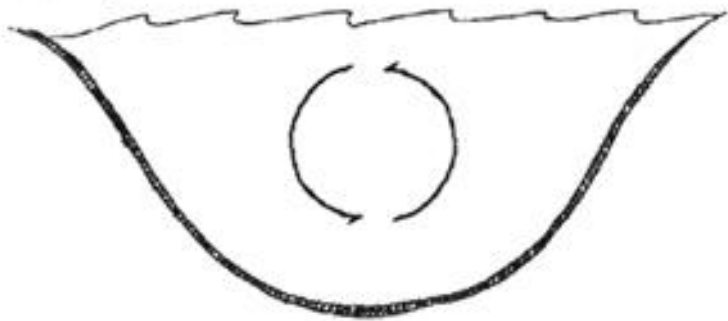
"But to be fair, there's a fifty percent chance of just about anything."

Predictions: warmer waters

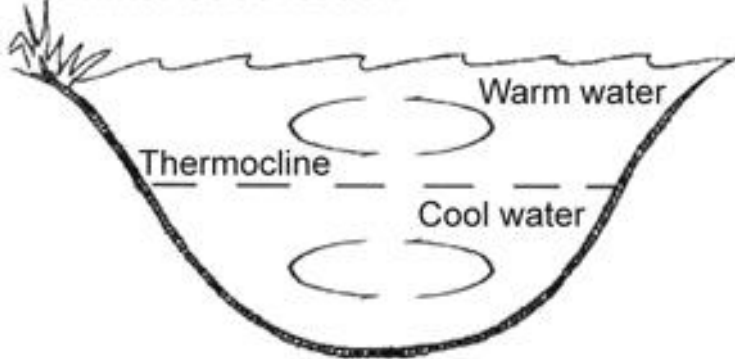
- Increased microbial activity → mobilize contaminants from sediment
- Longer lake stratification → increased anoxia
- Increased harmful algal blooms
- Reduced ice

Lakes

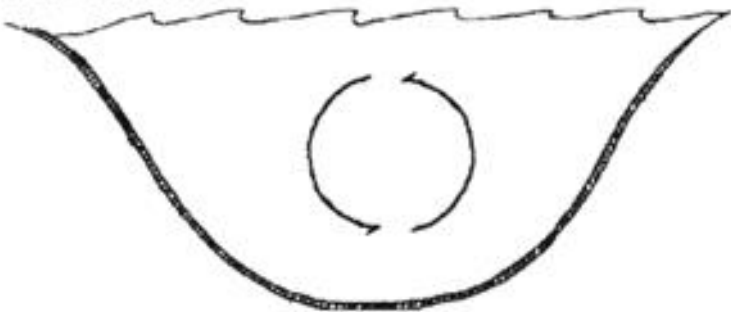
Spring Turnover



Summer Stratification



Fall Turnover



- Duration and strength of summer stratification will increase, adding to risk of oxygen depletion



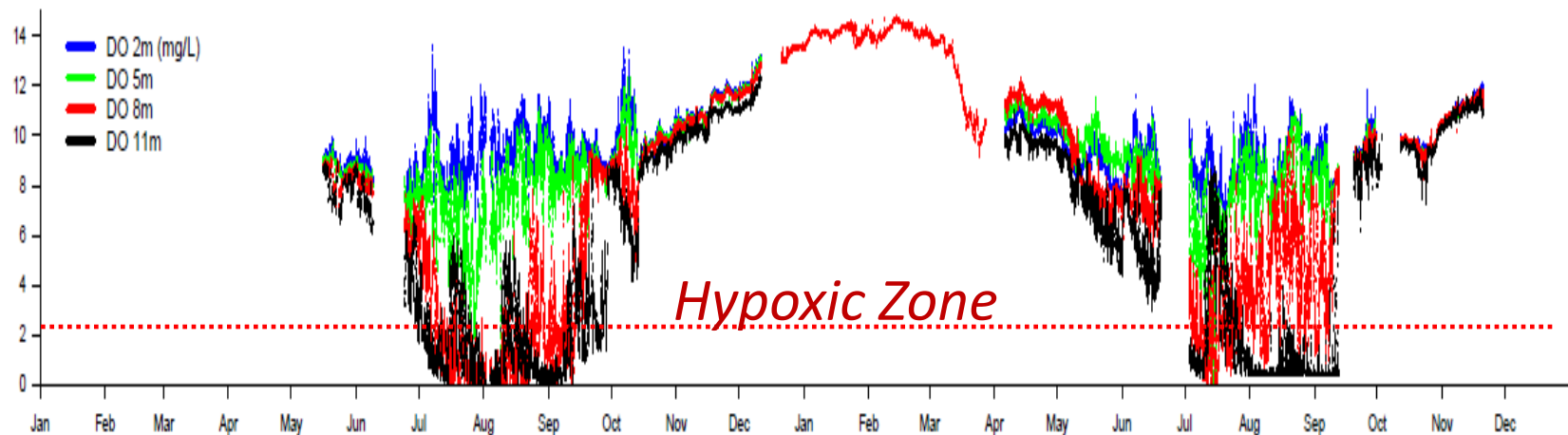
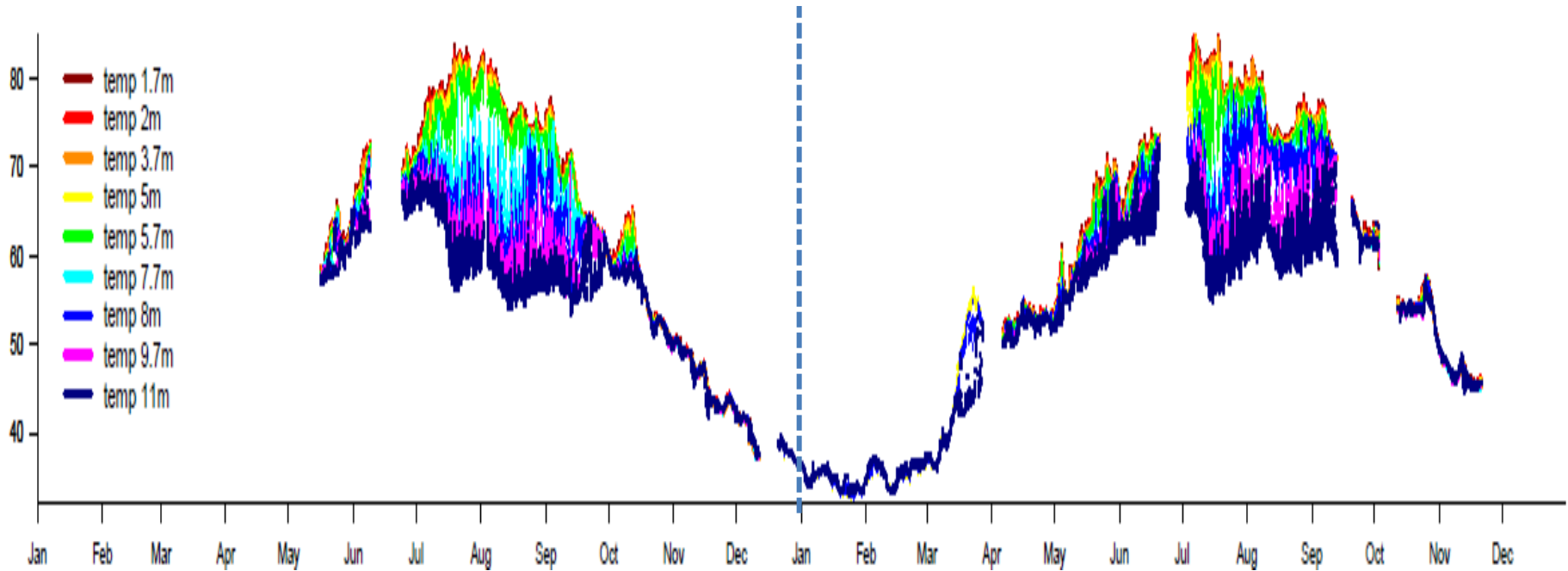
You are Here

Buoy

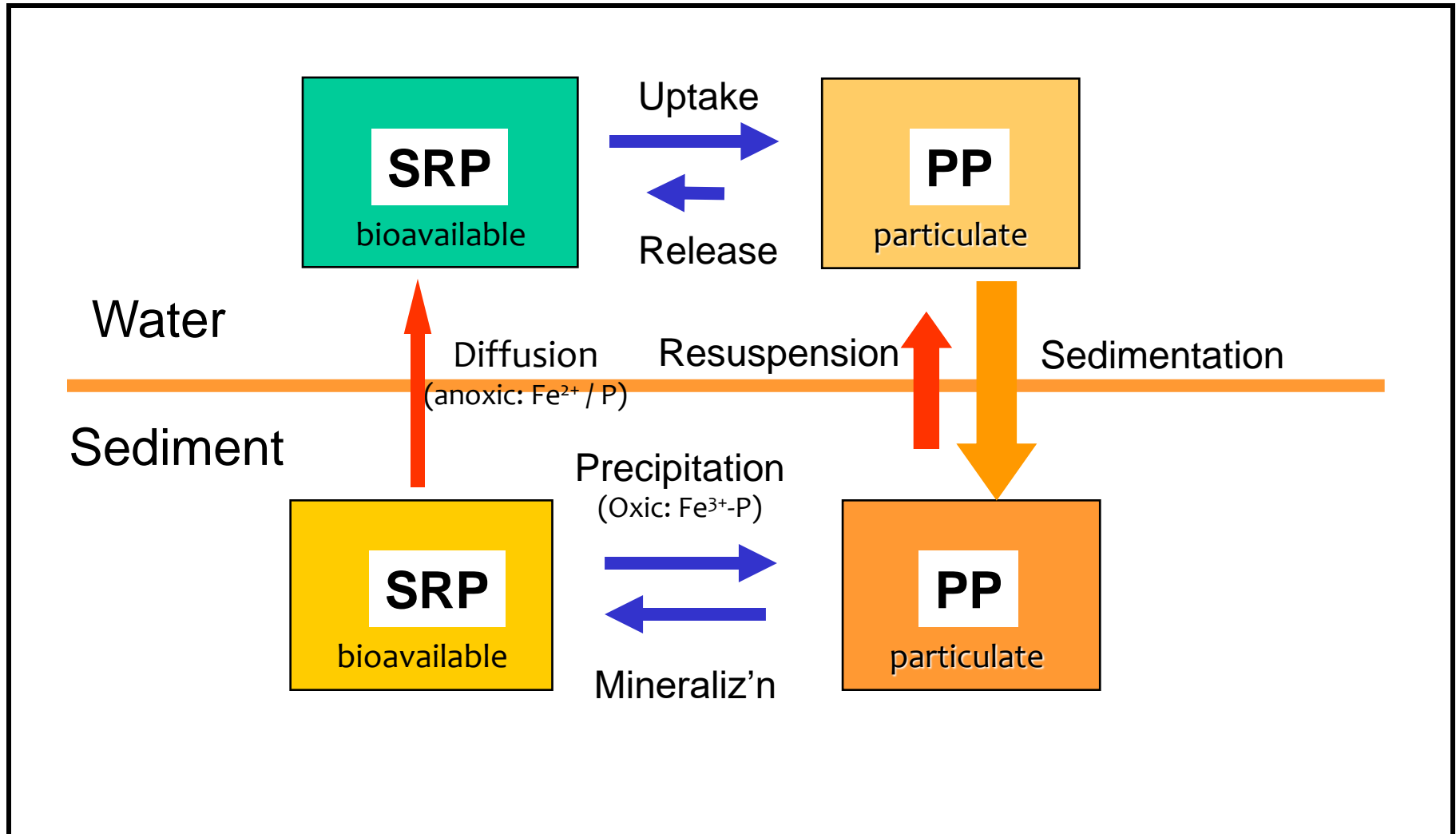


GVSU Research

Tracking Water Column Temperature & DO in Muskegon Lake 2011 through 2012

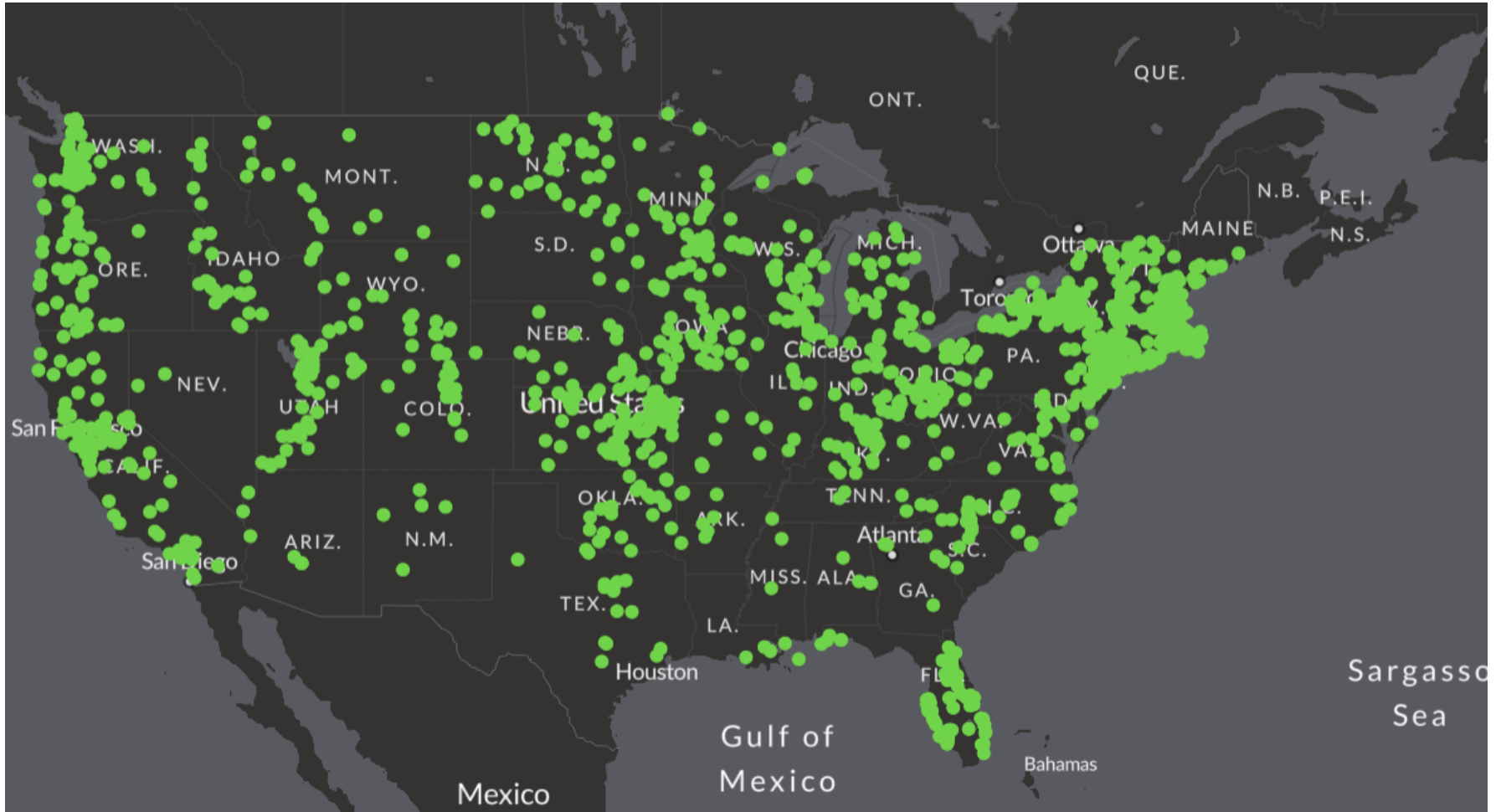


Redox-driven P release





Algal Blooms: 2010 - Present



Harmful Algal Blooms (HABs)

Microcystin is the most common cyanotoxin produced by HABs → hepatotoxin and tumor promotor.

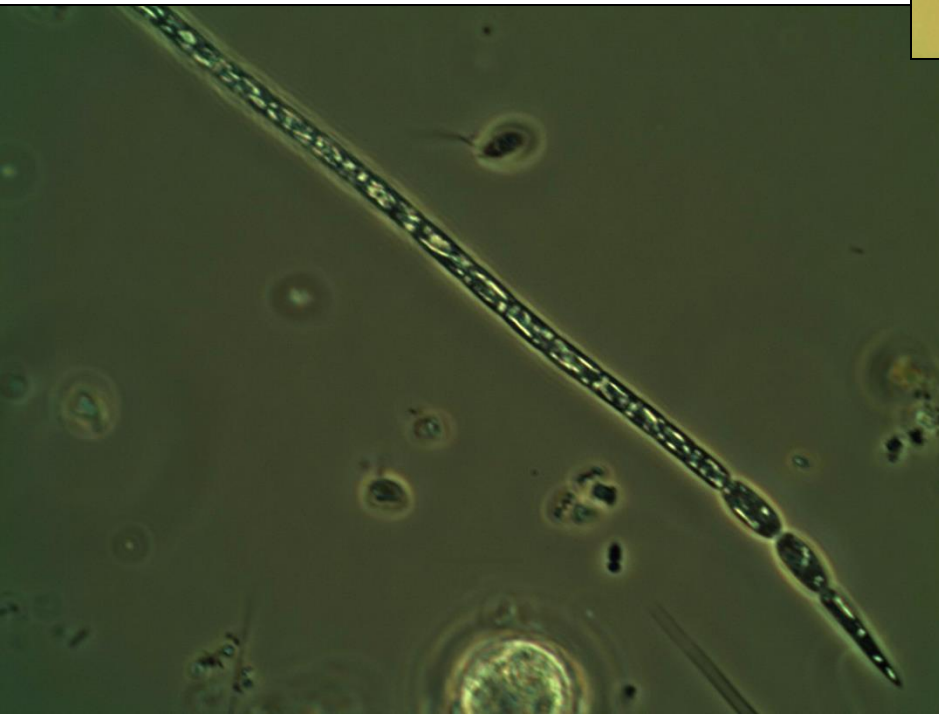
Use	WHO	US EPA*
Drinking Water	1 ppb	0.3 ppb (infants)
		1.6 ppb (school children to adults)
Recreation	20 ppb	8 ppb

Harmful Algal Blooms (HABs)

Microcystin Concentrations

Location	Date	Concentration ($\mu\text{g/L}$)
Mona Lake (bloom)	July, 2007	~350
Lake Erie (bloom)	October, 2011	~4,200
Lake Erie	August, 2014	1-10

Cylindrospermopsis

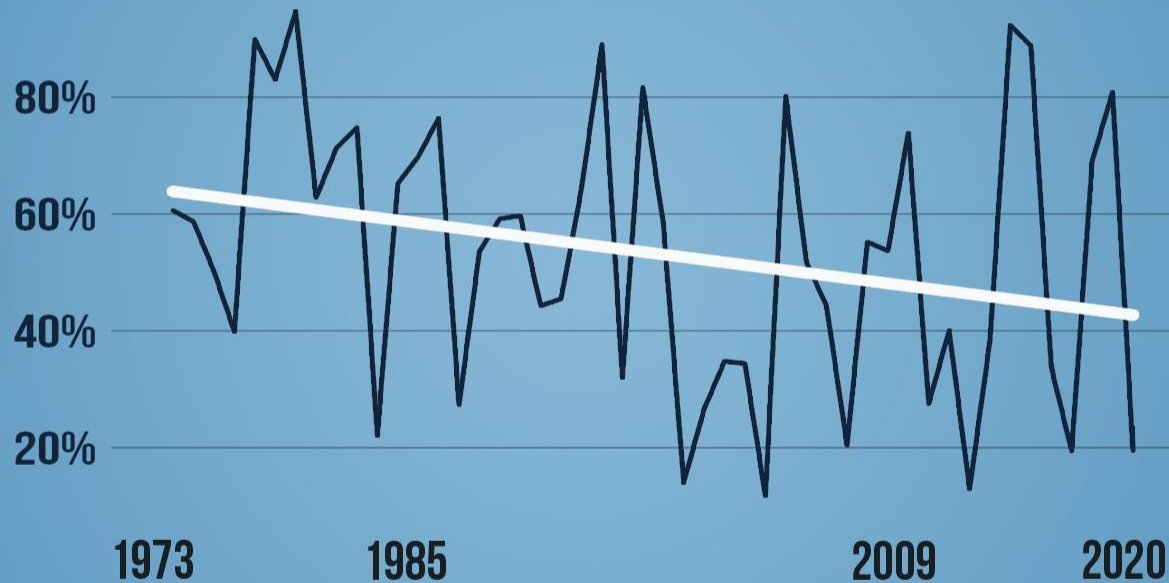


Hong et al. (2006) J. Great Lakes Research
Gillett and Steinman (2011) J. Great Lakes Research

Predictions: ice

5.1%/decade

DECLINING ICE PERCENTAGE OF PEAK ICE COVER



THE GREAT LAKES

Source: NOAA GLERL

CLIMATE  CENTRAL

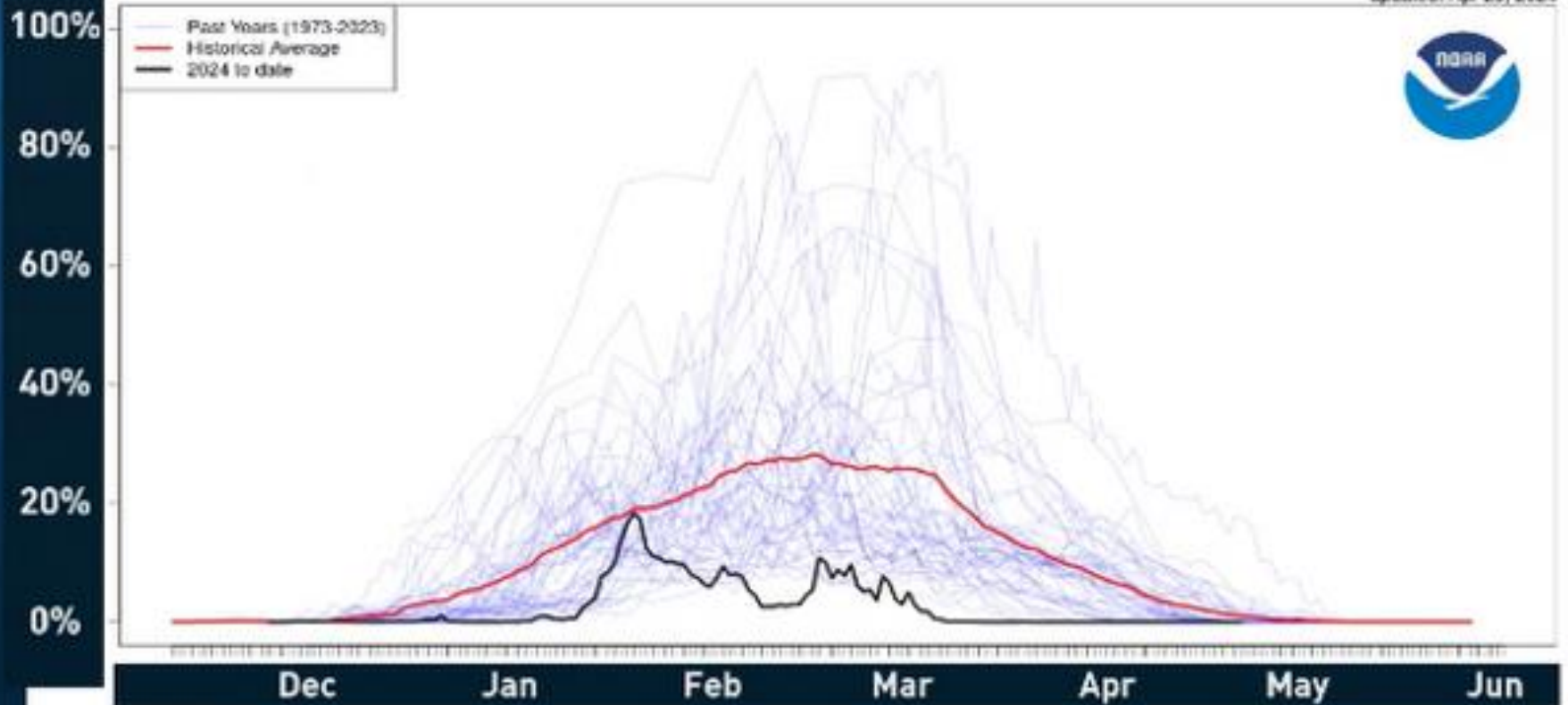
Predictions: ice

> LAKE MICHIGAN ICE COVER » CURRENT YEAR COMPARED TO HISTORICAL AVERAGE



Lake Michigan Average Ice Cover

updated: Apr 25, 2024



ll

er



Modified from Hampton et al. (2024) Science 386, eadl3211, 11 October 2024

Implications of Reduced Ice Cover

- Loss of culturally and economically relevant activities, such as ice-related recreation, ice fishing, and transportation.
- Ice cover reduces carbon emissions as well as evaporative water losses that can contribute to lake-effect precipitation
- Increased shoreline erosion → more wave action
- Reduced native biodiversity via loss of distinctive ecological niches for cold-water fish; loss of winter ice-related algae
- **Benefits: extended open water recreation, reduced infrastructure costs, longer navigation seasons**

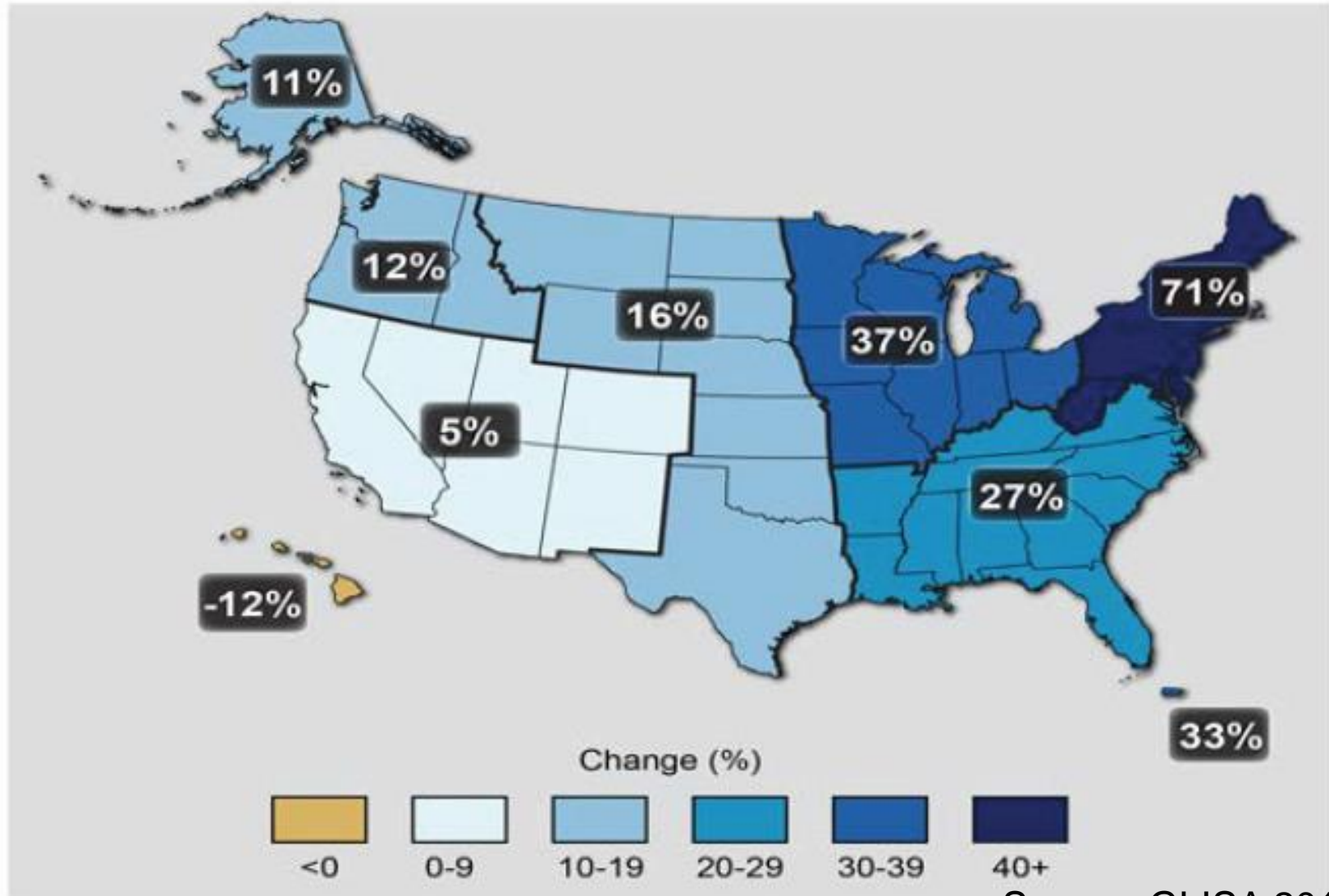
Predictions: Precipitation

- Increase in annual average ppt'n
- Frequency of extreme events will increase
 - Greater intensity
 - Longer dry periods

Predictions: extremes

- Precipitation events in Great Lakes region >2-2.5 inches → stormwater contaminants (McLellan et al. 2007)
- Frequency of events exceeding 2-2.5 inch threshold will increase by 50 to 120% by end of 21st Century (Patz et al. 2008)

Observed Change in Very Heavy Precipitation



Source: GLISA 2014

Heaviest 1% of all daily events from 1958 to 2012 for each region of the continental United States.

Predictions: variability

Greater fluctuations between precipitation events and wider swings between wet and dry episodes.

Impacts of greater variability → less reliable water supplies, altered agricultural yields, disturbed ecosystem functioning, and disturbed economic growth.

Poses new challenges to climate adaptation and the resilience of society.



ENVIRONMENTAL LAW & POLICY CENTER

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



Projected Change in Precipitation (%)

	Great Lakes Basin
2016-2045 Lower Scenario	4.5
2016-2045 Higher Scenario	4.2
2036-2065 Lower Scenario	6.4
2036-205 Higher Scenario	7.0
2070-2099 Lower Scenario	7.2
2070-2099 Higher Scenario	11.4

The future projections for annually-averaged precipitation due to emissions from the higher (RCP8.5) and lower (RCP4.5) scenarios.

Projected Change in Snowfall (%)

	Great Lakes Basin
2020s RCP4.5	-15.7
2020s RCP8.5	-17.0
2050 RCP4.5	-26.2
2050 RCP8.5	-31.6
2080 RCP4.5	-28.2
2080 RCP8.5	-47.5

The future projections for annual snowfall are calculated based on the ensemble mean of 10 statistically-downscaled GCMs by Hybrid Delta for the higher (RCP8.5) and lower (RCP4.5) scenarios (Byun and Hamlet, 2018).

Investments?



Potential Health Impacts: Mental

Eco-distress / Climate Anxiety / Climate Grief

A 2021 survey* of 10,000 people aged 16–25 in 10 countries:

- nearly 60% of respondents were highly worried about climate change
- more than 45% said their feelings about climate change affected their daily lives, such as ability to work or sleep.
- > 55% of young people said that climate change made them feel powerless, and 58% that their government had betrayed them and future generations.

*Source: Hickman, C. & Marks, E. (2021) *Lancet Planet. Health* 5, e863–e873

MICHAP

Michigan Climate and Health Adaptation Program

Protecting Mental Health During Extreme Weather and Climate Change: Session 300
This afternoon: 2:45 pm Caroline Helsen and Stephanie White, Ph.D.

INDICATORS of the Potential Effects of Climate Change on Public Health: Michigan Results, 2011

A Pilot of the Suite of Indicators Proposed by the Climate Change Working Group of the Council of State and Territorial Epidemiologists

December, 2013

Lorraine Cameron, MPH, PhD, Robert Wahl, MS, DVM,
Bethany Waterbury, DVM, Rob W. Konowech, MPH,
Martha Stanbury, MSPH, Dominic Smith, MSA

Michigan Climate & Health Adaptation Program (MICHAP)

www.michigan.gov/climateandhealth

Division of Environmental Health

Bureau of Disease Control, Prevention and Epidemiology

Michigan Department of Community Health

P.O. Box 30195, Lansing, MI 48909

Michigan Department
of Community Health



Rick Snyder, Governor
James K. Haveman, Director

Climate Change in Michigan and the Public Health Response



Prepared by the Michigan Climate and Health Adaptation Program (MICHAP)

This fact sheet highlights some of the major ways that Michigan's climate is changing, shows how those changes might affect human health, and outlines how MICHAP is working to prepare the public health system to adapt.

The climate is changing in the Great Lakes Region

Between 1951 and 2017:

The average annual temperature has increased by 2.3 °F.



The total annual precipitation (snow, ice, rain) has increased by 14%.



Source: GLISA, 2019, glisa.umich.edu/climate-change-in-the-great-lakes-region-references/

How can climate change harm health?

Increasing temperatures and rising amounts of precipitation can affect human health in different ways.



Heat Harm: Heat strains the heart and lungs and can increase the risk of dying for people with cardiovascular disease. Heat can worsen air quality, which increases the risk of respiratory illness.



Spread of Disease: Warmer winters and more frost-free days allow disease-carrying insects and rodents to survive and expand their range.



Threats to Water Quality: More frequent heavy rain events can increase flooding and stress the infrastructure that provides safe drinking water. Warming water temperatures, fertilizer runoff and sewer overflows pollute rivers and lakes, and can cause harmful algal blooms.



Disruptions to Well-Being: Living through natural disasters can cause both short-term and long-term impacts on mental health. Uncertainty about the future can cause anxiety and depression.

Who is most likely to be harmed by climate change?

Impacts from climate change can affect the health of anyone in our community, but some groups of people are at greater risk. The people most likely to be harmed are:

- Children
- Pregnant people
- People with chronic illnesses and allergies
- People who are disabled
- Outdoor workers
- Older adults
- People living in poverty



Recommendations

- Measure the mental-health burden attributable to climate change and track it over time.
- More research in marginalized groups and Indigenous communities
- Develop and evaluate ways to effectively reduce climate change's mental-health burden
- *Connecting Climate Minds* project: research effort in the field of climate-related mental health:
<https://www.connectingclimateminds.org/>

*Source: Nature (2024) 628, 235

Americans on Climate Change: September Gallup Poll (pre-Helene and Milton)

Registered voters were asked to rate the importance of 22 issues in this year's election.

5% of Republicans and Republican-leaning independents, and ~33% of Democrats and Democratic-leaning voters, said climate change was “extremely” important to their vote.

Climate change and transgender rights were the only two of the 22 issues listed by Gallup that half or fewer of respondents said were either “extremely” or “very” important to their presidential vote choice.

Societal Actions

1) Mitigation

2) Adaptaion

Mitigation

Remove CO₂ from the atmosphere:
carbon dioxide removal (CDR), via 3
main approaches:

- Blue and Green carbon
(reforestation, coastal restoration)
- Bioenergy with carbon capture and
storage (BECCS)
- Geoengineering (direct air capture,
ocean fertilization; ocean alkalinity
enhancement)

Adaptation

Changes made to better respond to present or future climatic conditions

- grow different crops
- change zoning/building codes
- change behavior

Climate Change Solutions: Individual

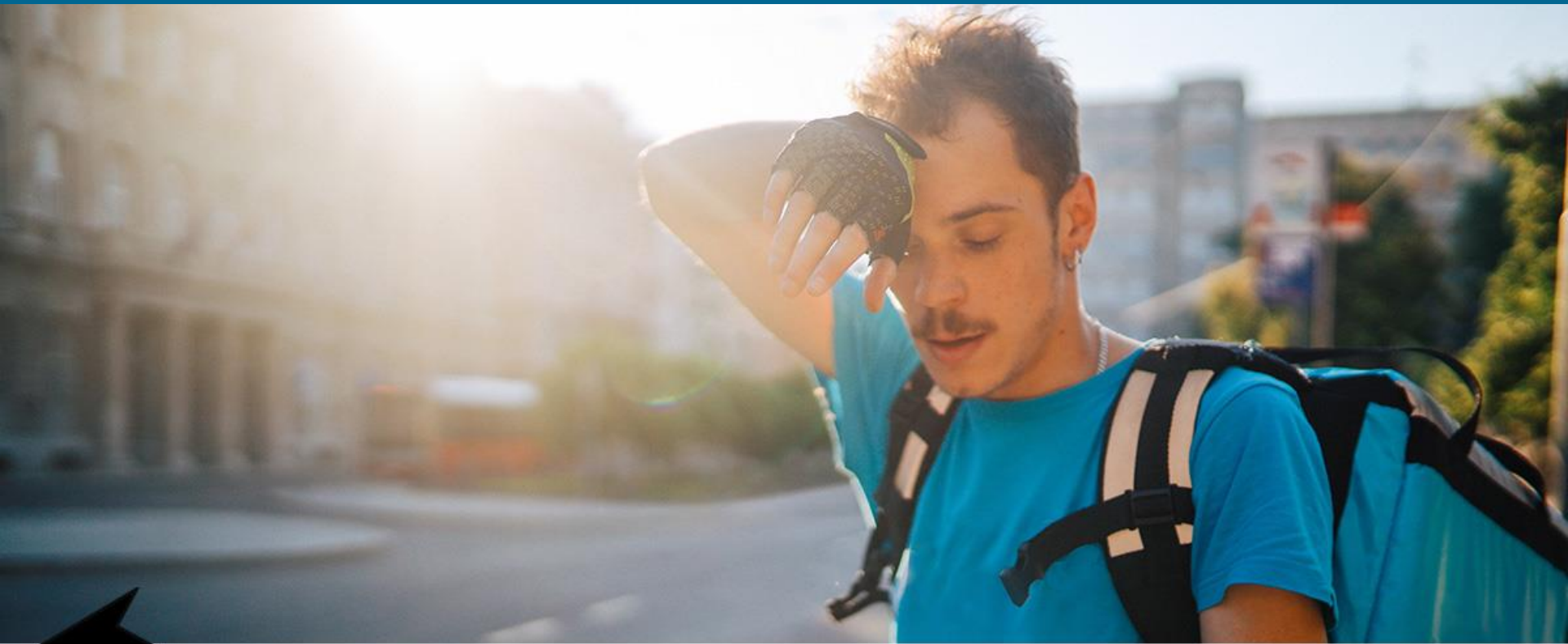
- Save Electricity
 - turn off TV, lights, computer when done
- Study and discuss the issue with others; be aware of mental health
- Bike, bus and walk
- Plant trees
 - they absorb carbon dioxide

Climate Change Solutions: Individual

- Recycle - helps save natural resources
- Buy low-energy appliances (Energy Star®)
- Use solar power if possible
- Use hybrid or gas-efficient automobiles
- Switch your search engine to Ecosia
(less energy; tree-planting)
- Vote wisely



Source: Daily Star, UK



**BASED ON
SCIENCE**

**NATIONAL
ACADEMIES** *Sciences
Engineering
Medicine*

Thank you!

