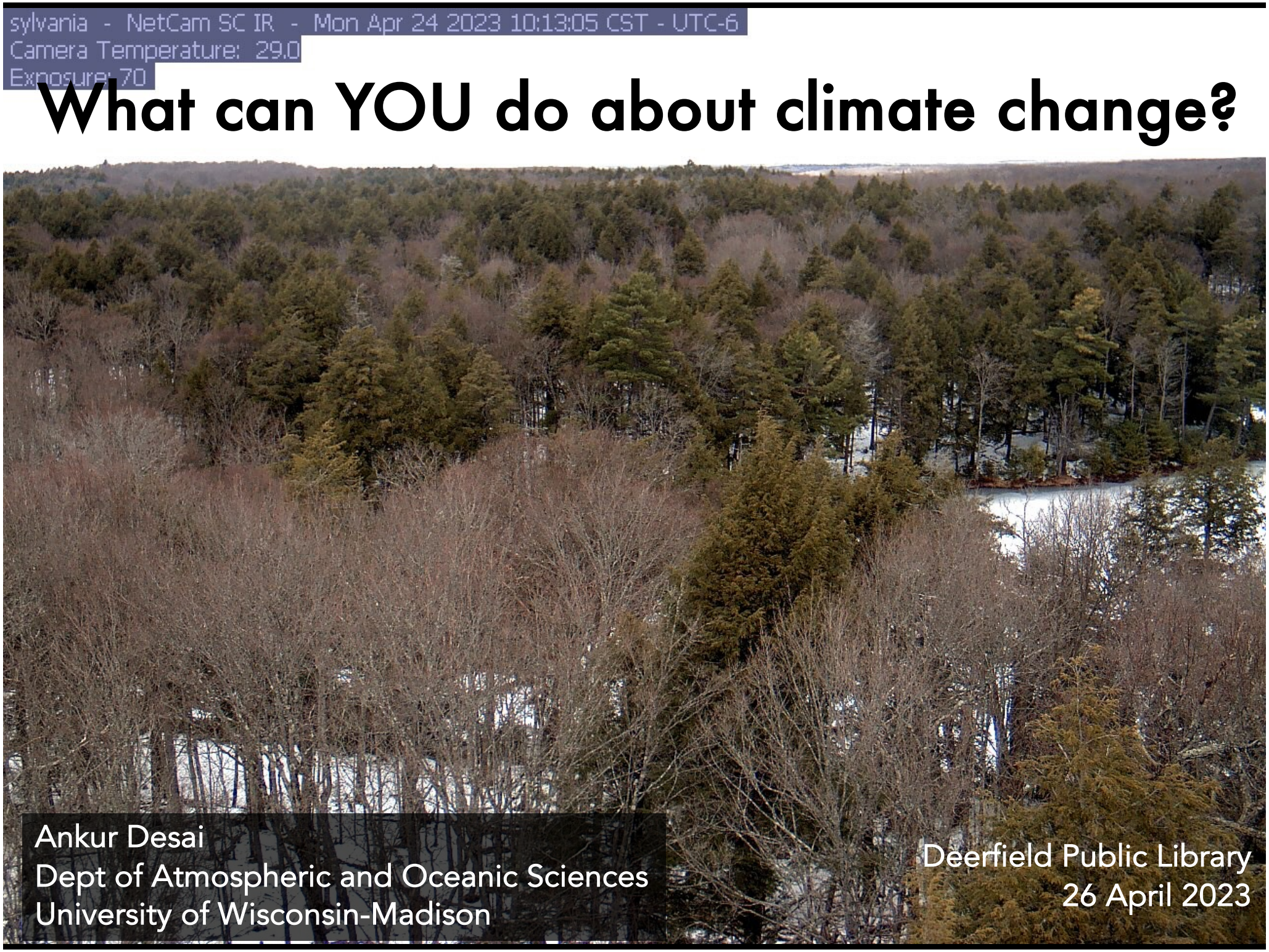
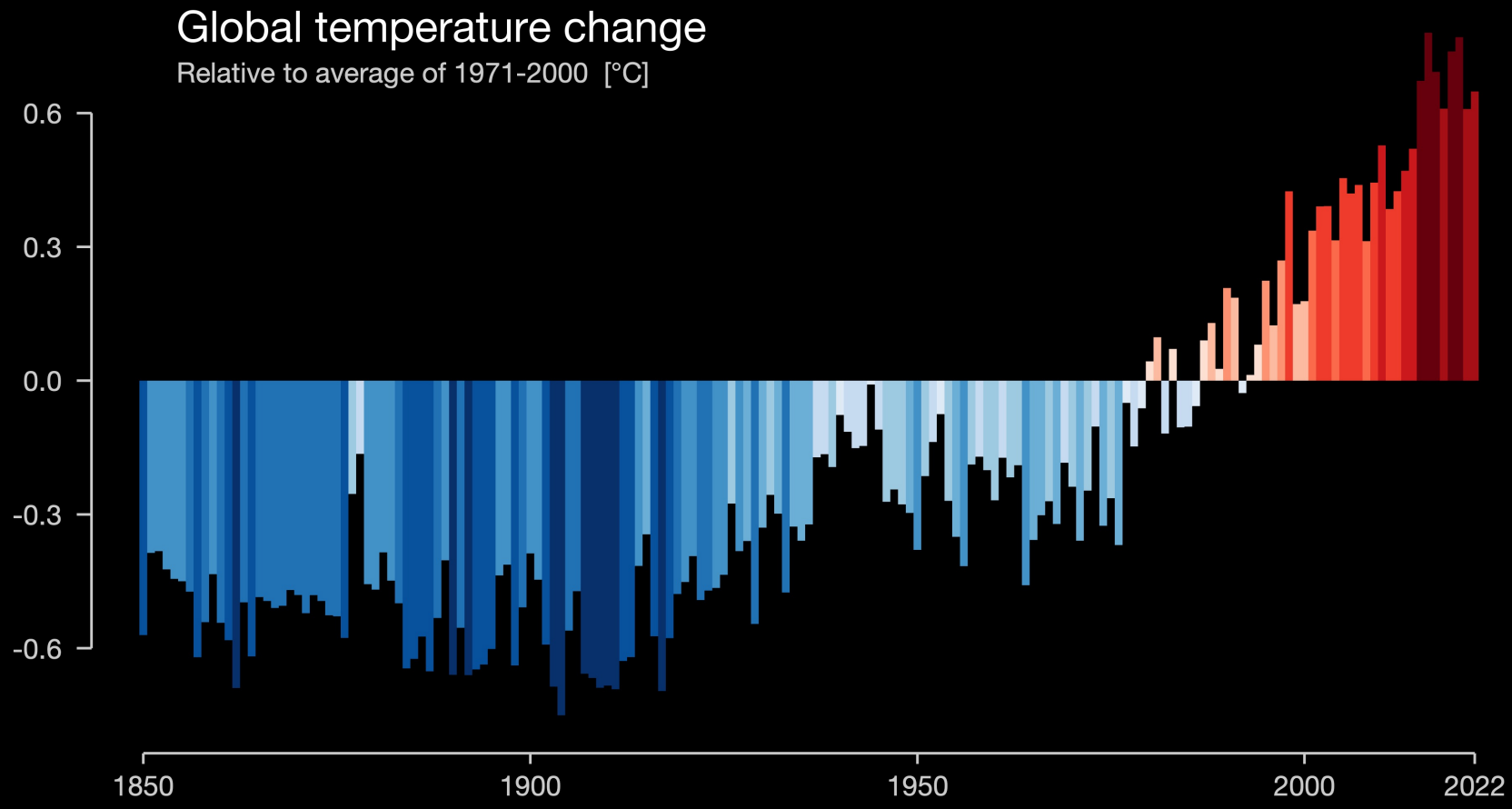


What can YOU do about climate change?

Ankur Desai
Dept of Atmospheric and Oceanic Sciences
University of Wisconsin-Madison

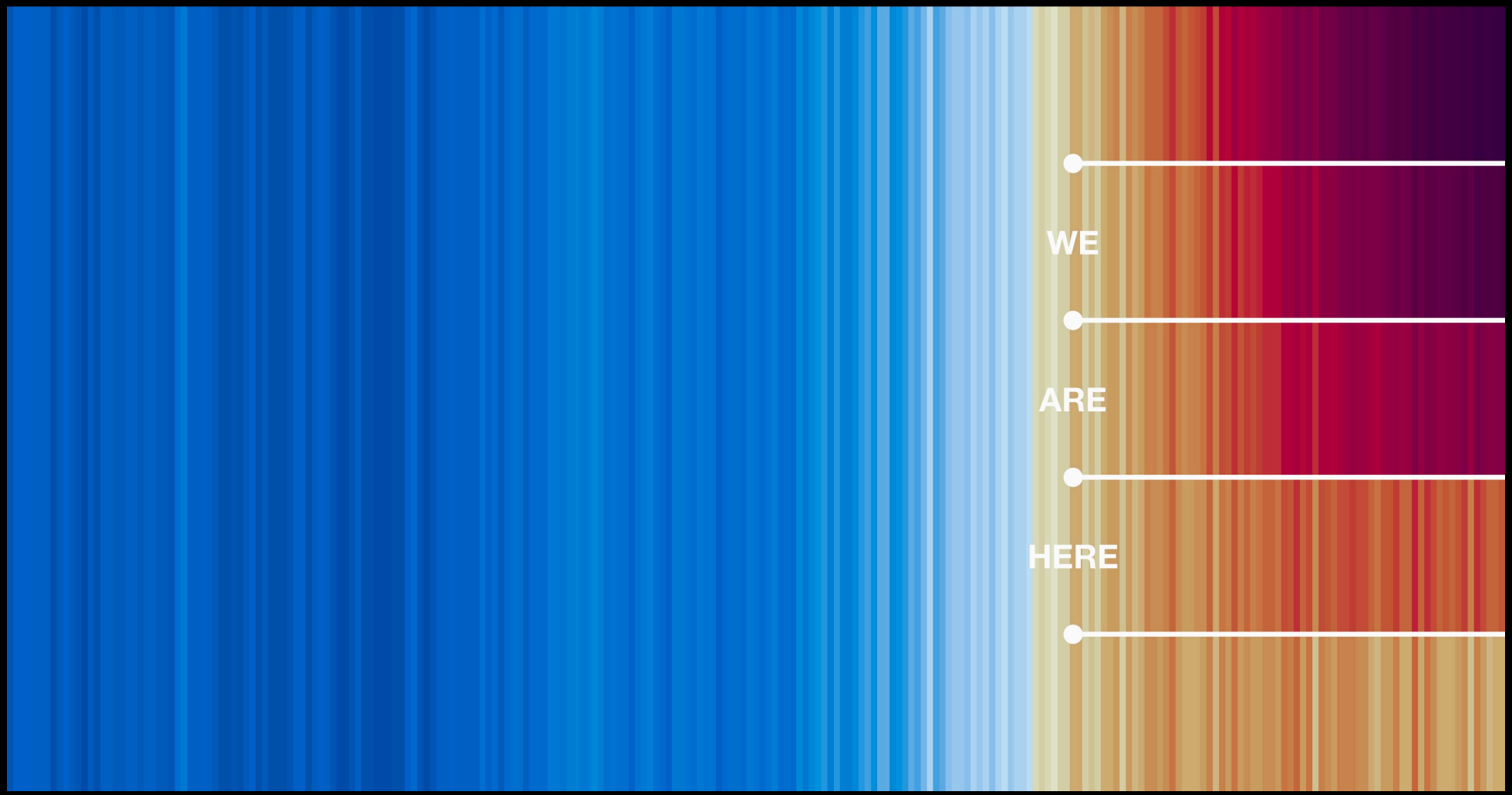
Deerfield Public Library
26 April 2023

What can *YOU* do about climate change? *A little*

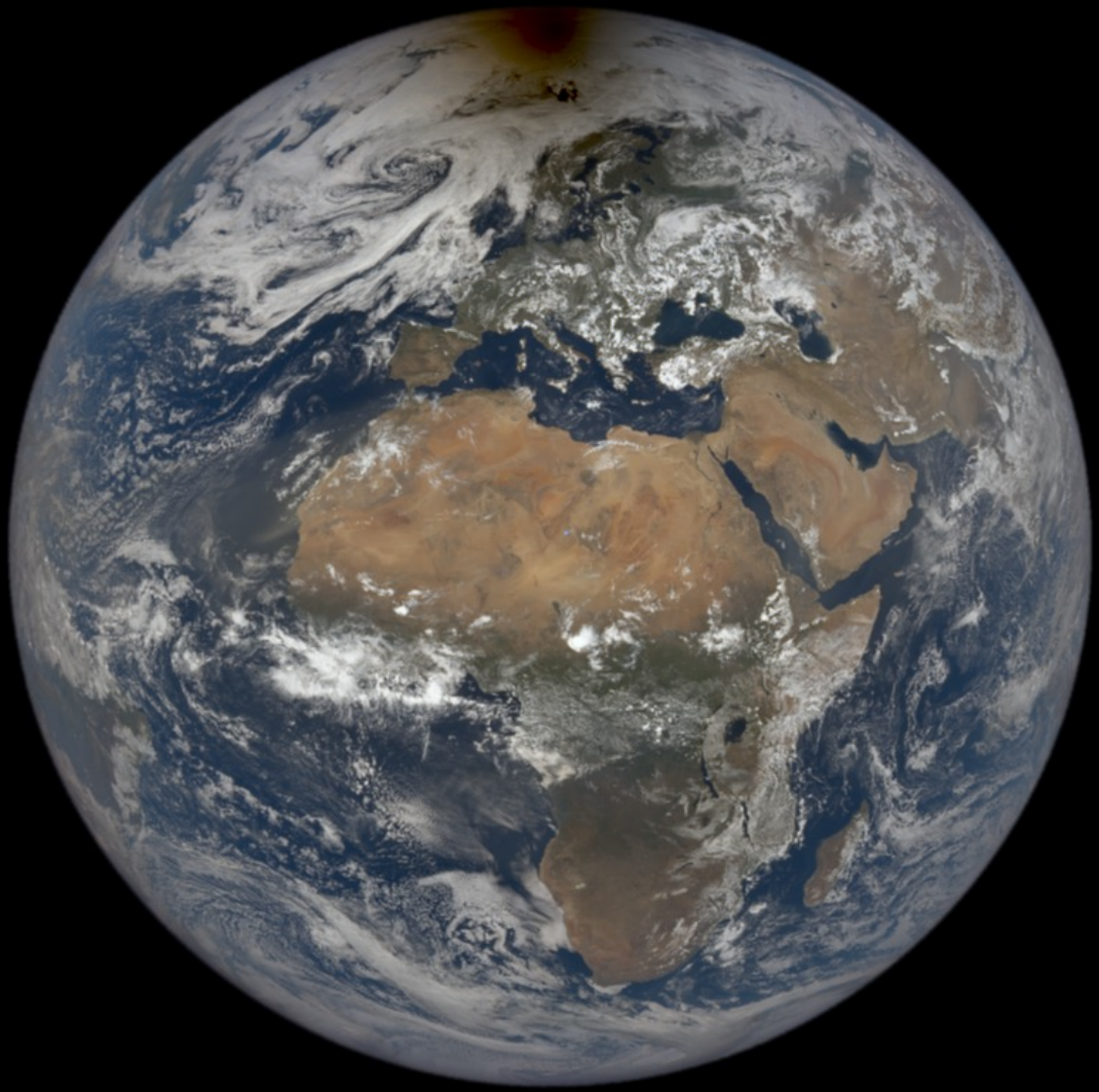


showyourstripes.info

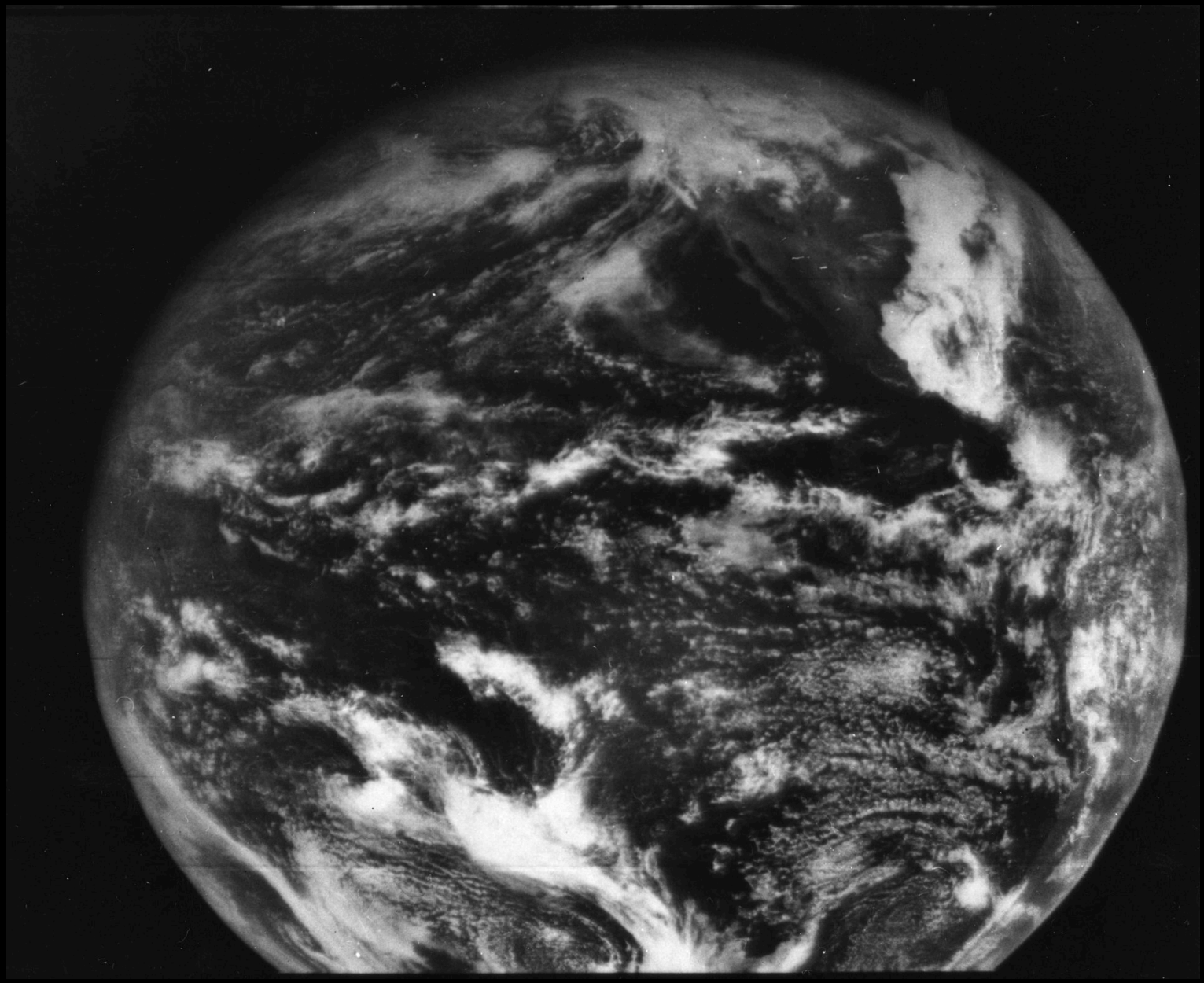
What can *WE* do about climate change? *A lot!*



From more than a million miles away...



NASA EPIC



ATS-1 1966

From 1970s to 2010s:

33% decline in ozone pollution

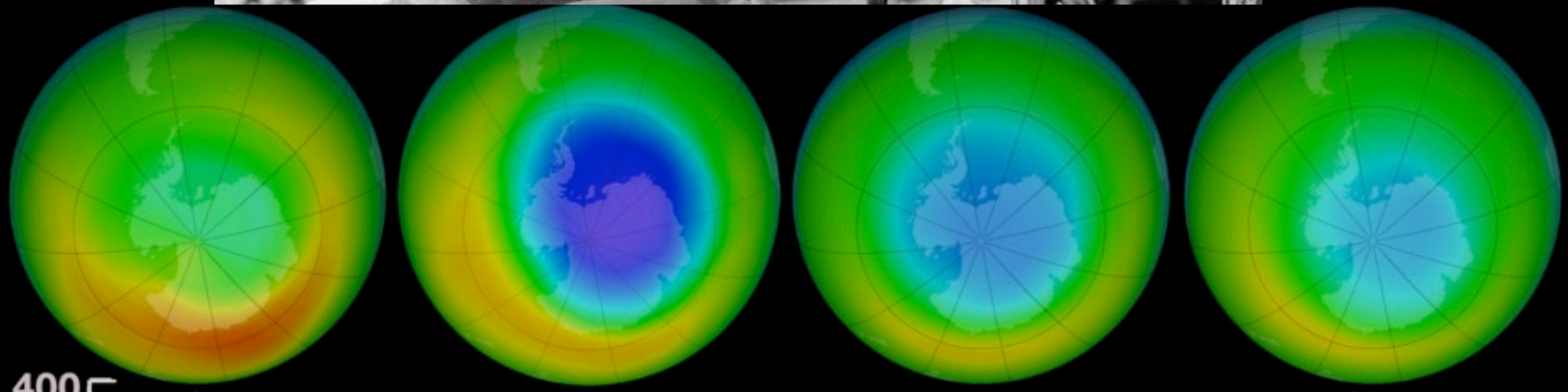
64% reduction in nitrates

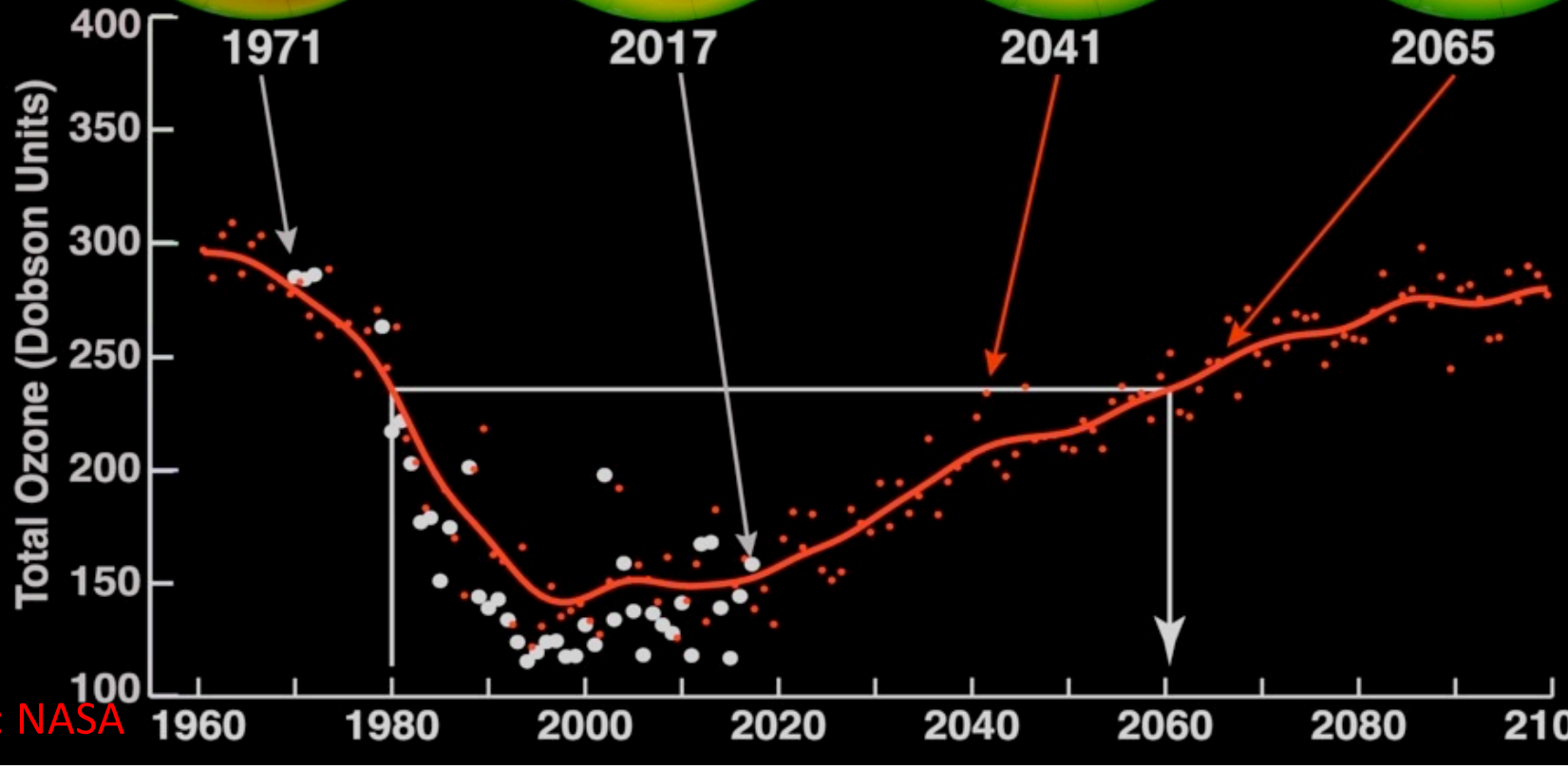
98% reduction in lead

Remember acid rain?

(US EPA)

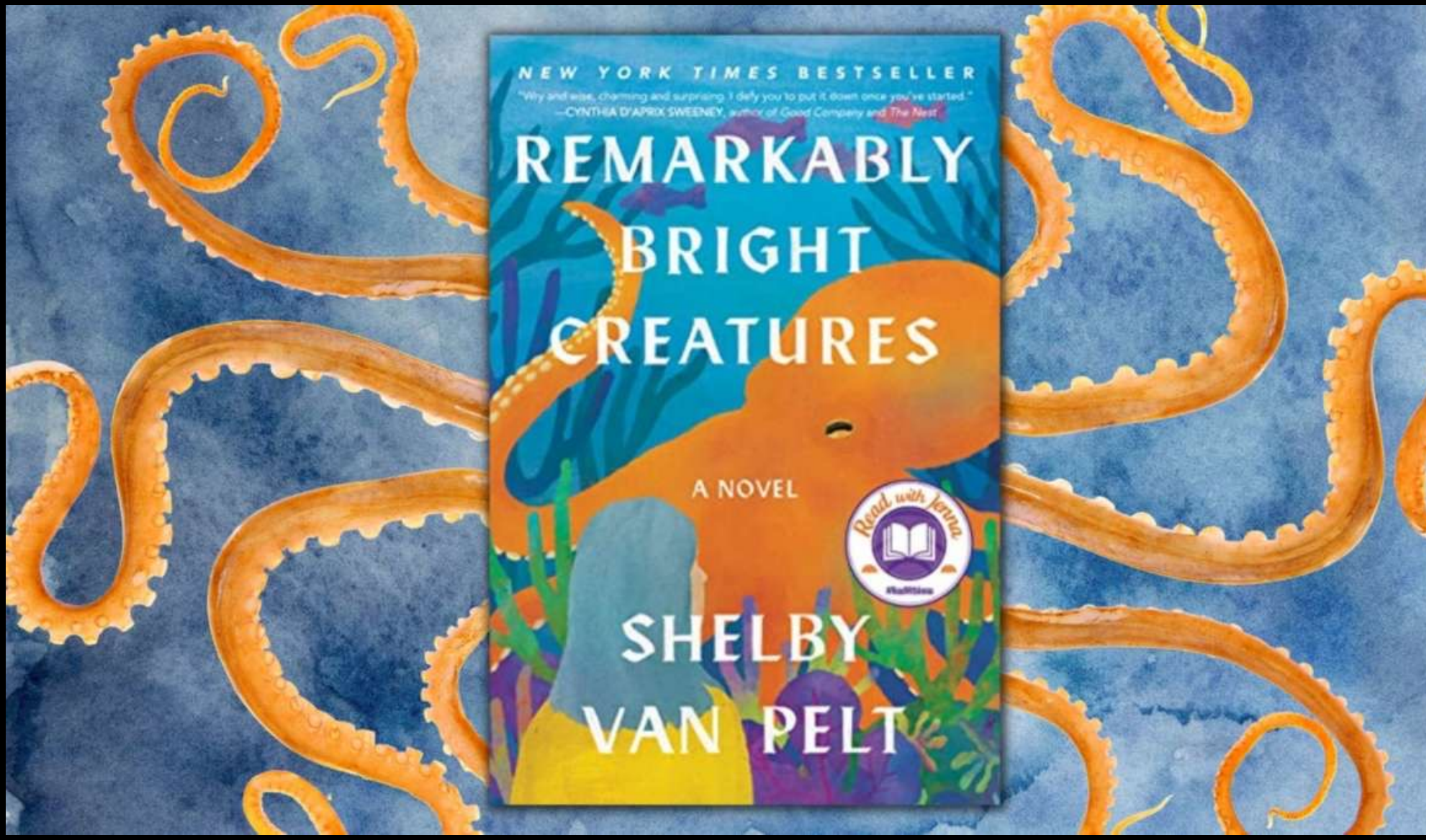
Credits: MI In the World, Wikimedia





Credits: NASA

Insideclimatenews.org



https://booktrib.com/2022/05/31/remarkably-bright-creatures-wraps-its-tentacles-around-your-heart/

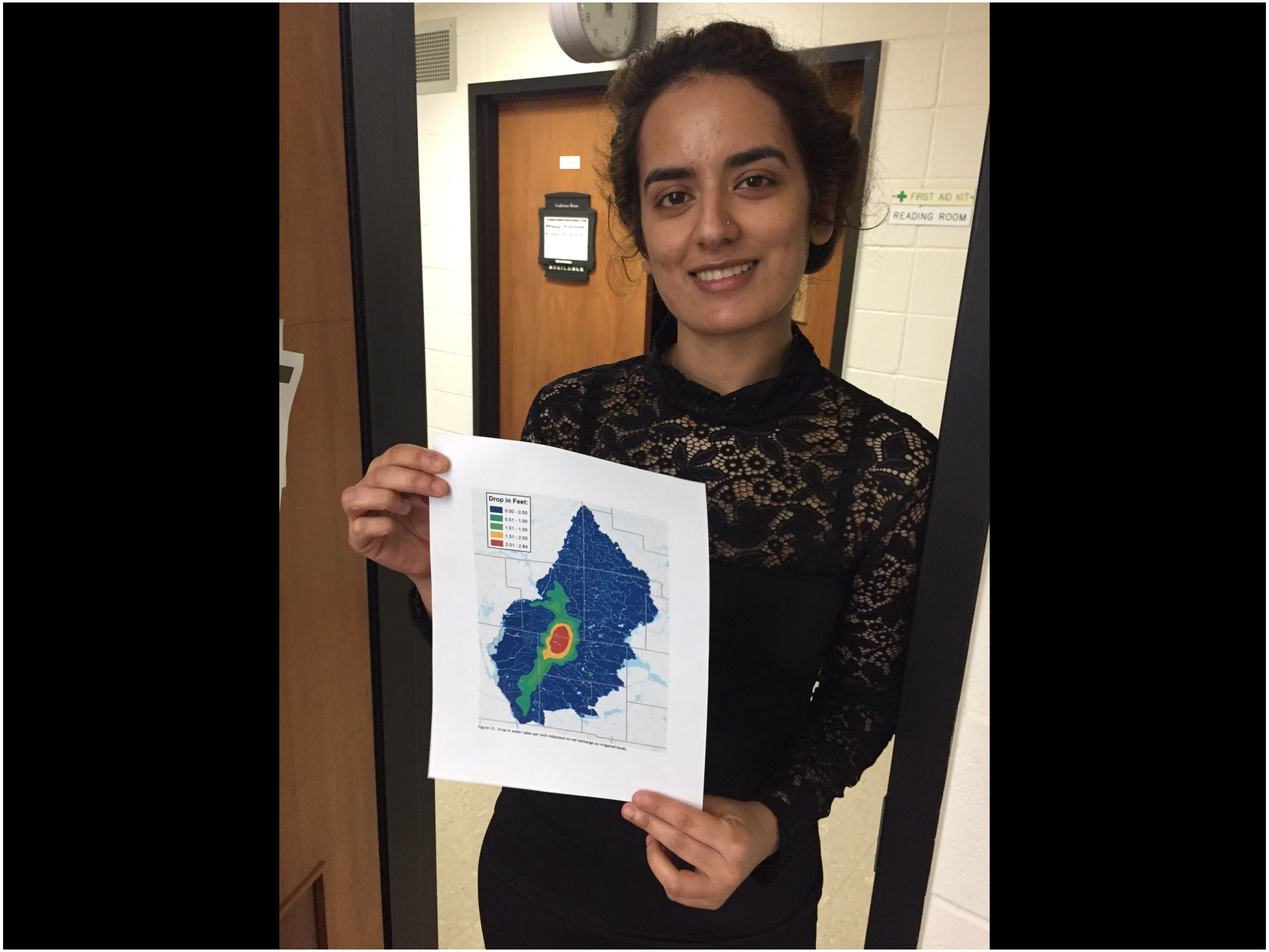
The Common Octopus May Stop Being Common Due to Climate Change

Authors: Ted Espinola, Kai Houston, Sean Kim, Sean Lee

The Brainy Octopus is a Quick Adapter to Climate Change, But the News is Not as Good as You May Think

LakesOfIndia May 21, 2022 Uncategorized

AP


Drop in Feet:
0.00 - 0.50
0.51 - 1.00
1.01 - 1.50
1.51 - 2.00
2.01 - 2.84
Figure 15. Drop in water table per inch reduction in net recharge on irrigated lands.
FIRST AID KIT
READING ROOM
AVAILABLE

University of Wisconsin-Madison

Department of Atmospheric and Oceanic Sciences

Who We Are

Since 1948 we have grown into one of the leading departments in our field of Atmospheric and Oceanic Sciences. We have strong graduate and undergraduate programs which are nationally recognized. We graduate about 15 Ph.D. and M.S. students each year; our graduates are active in research labs and universities around the world. We graduate approximately 20 B.S. students each year; they choose options allowing a focus on weather systems or general atmospheric science.

Our faculty of 15 has long maintained breadth and special strength in three areas:

- Climate systems, including the ocean
- Satellite and remote sensing
- Weather systems, including synoptic-dynamic

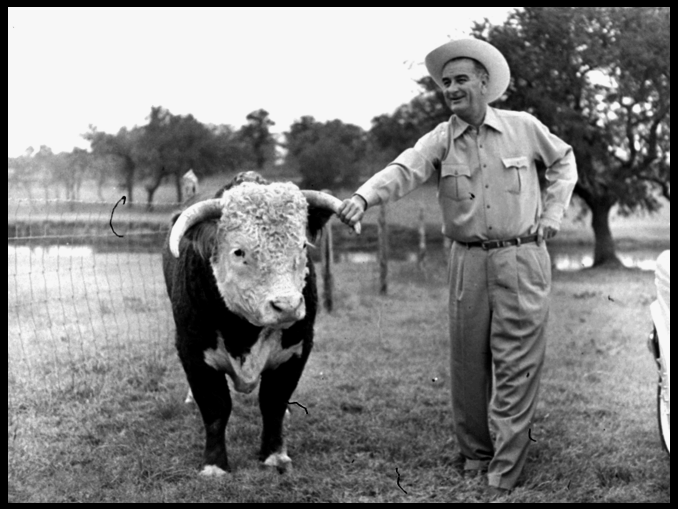
SSEC

Space Science and Engineering Center
University of Wisconsin-Madison

Center for Climatic Research
NELSON INSTITUTE
UNIVERSITY OF WISCONSIN-MADISON


STEAK & EGGS 14
SCRAMBLER 10
PLAIN OMELET 5
ORIENTAL CHICKEN OMELET W/ YANKS 10
CHILI CHEESE OMELET W/ YANKS 10
FRENCH TOAST 7
BUTTERMILK PANCAKES 7
BANANA NUT PANCAKES 8
GRIDDLE CAKES (OATMEAL, APPLE, RAISIN) 8
CHOCOLATE CHIP PANCAKES 8
STRAWBERRY PANCAKES 8
CAJUN CHICKEN SANDWICH 11
CHICKEN CLUB SANDWICH 12
STEAK SANDWICH 11
CAJUN STEAK SANDWICH 11
PHILLY CHEESESTEAK SANDWICH 12
LIVER & ONIONS 12
TUNA 4
B.L.T. 5
HOT DOG 3
HOMEMADE CORNED BEEF HASH 5
HAM, BACON OR SAUSAGE 4
CINNAMON ROLL 1.50
COFFEE CAKE 3
TOAST 1
ENGLISH MUFFIN OR BAGEL 1.50
HOMEMADE SOUP OR CHILI CUP 4 BOWL 5
GRILLED VEGGIES OR SIDE SALAD 4
CHEF SALAD OR CHICKEN SALAD 9
MILK 2% CHOCOLATE SM 1.50 LG 2.00
ROOTBEER FLOAT 3.50
SHAKES 5/MALTS 6
MADISON
EXIT
RESTROOM
SALT LAKE CITY

The continued release of CO_2 to the atmosphere from burning fossil fuels would "almost certainly cause significant changes" and "could be deleterious from the point of view of human beings [...] and marked changes in climate, not controllable through local or even national efforts.



U.S. President's Science Advisory to President Lyndon B. Johnson 1966

The Rodney & Otamatea Times
WAITEMATA & KAIPARA GAZETTE.
PRICE—10s per annum in advance
WARKWORTH, WEDNESDAY, AUGUST 14, 1912.
3d per Copy.

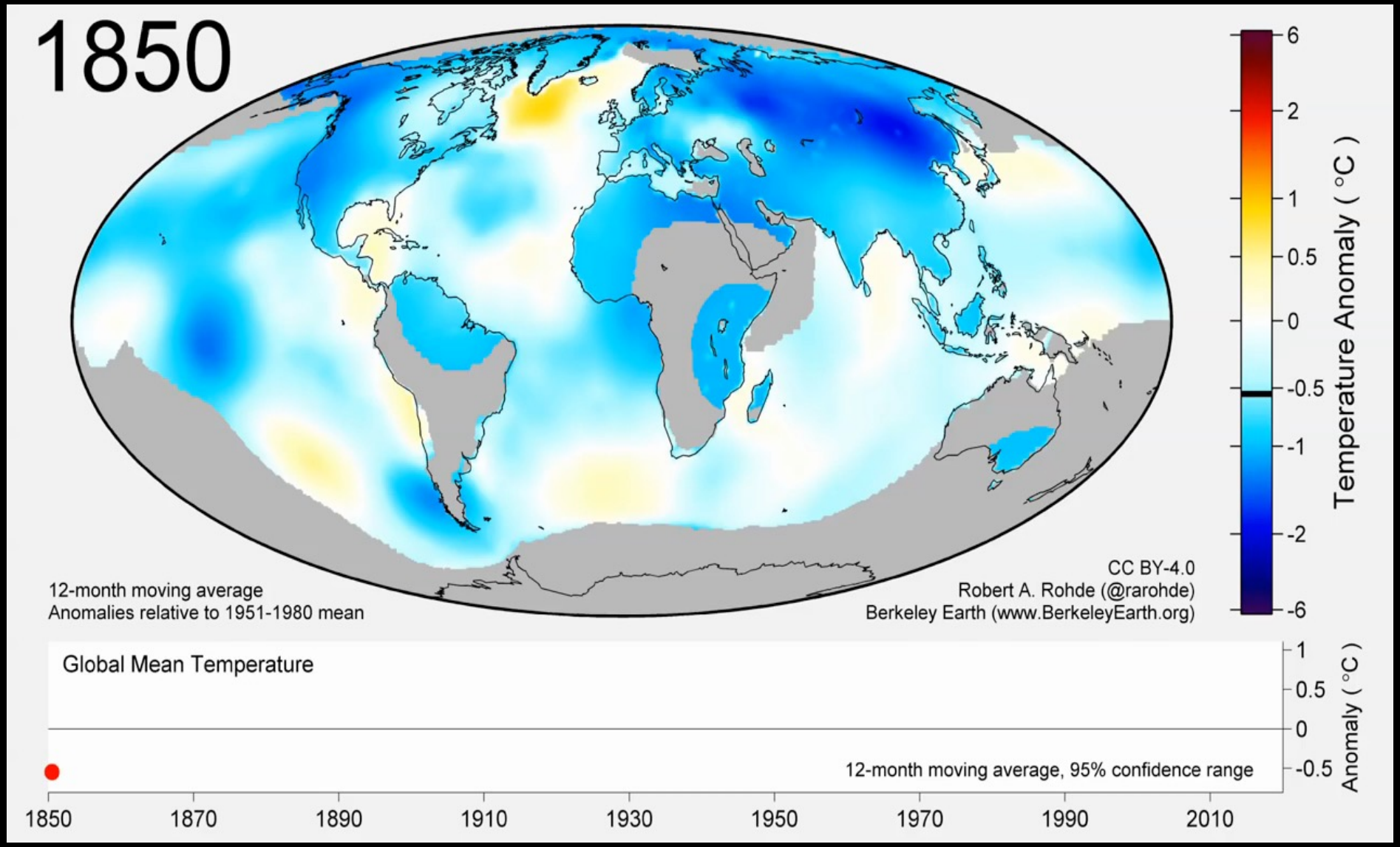
Science Notes and News.

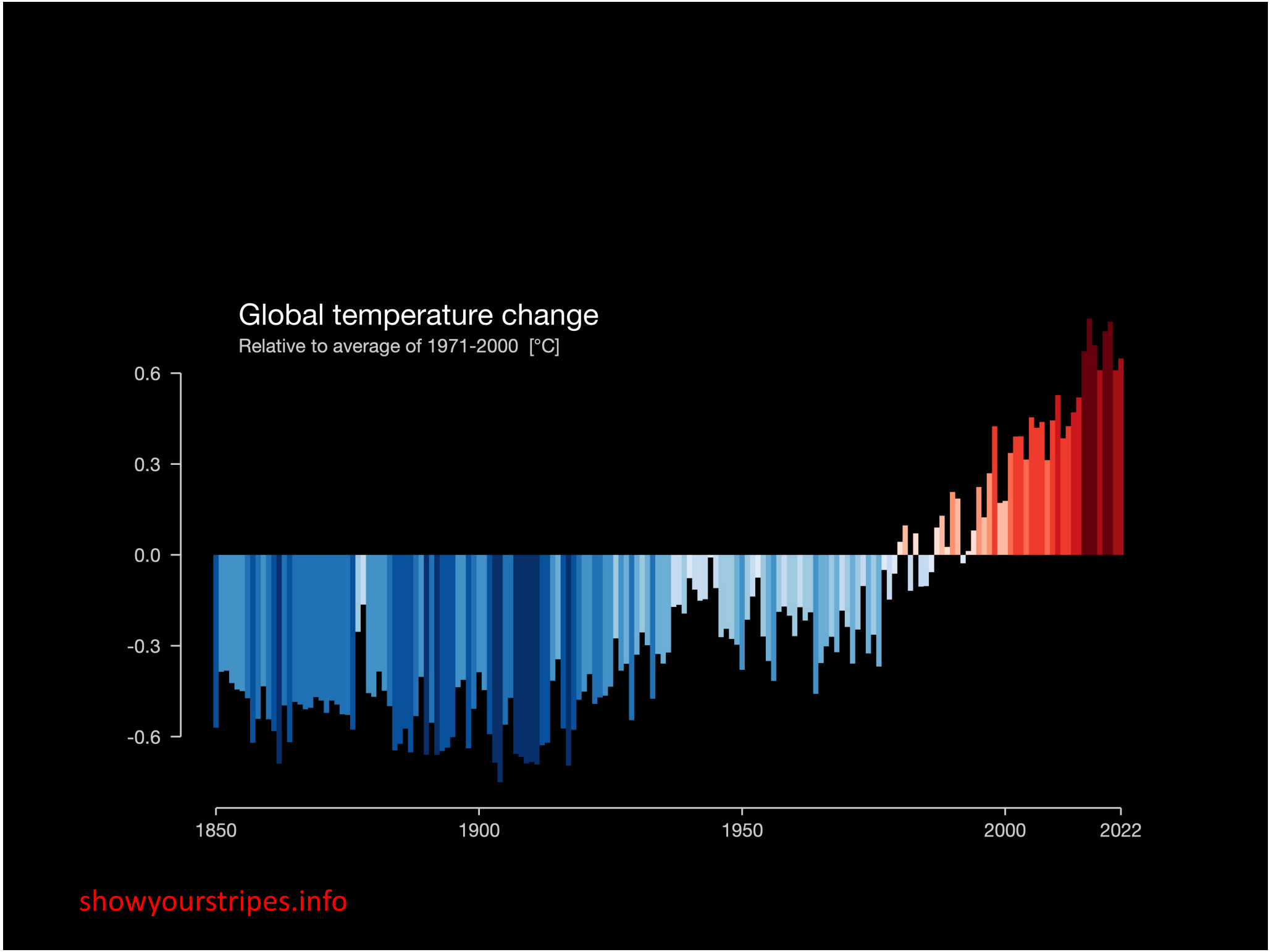
COAL CONSUMPTION AFFECTING CLIMATE.

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

Bottom Line

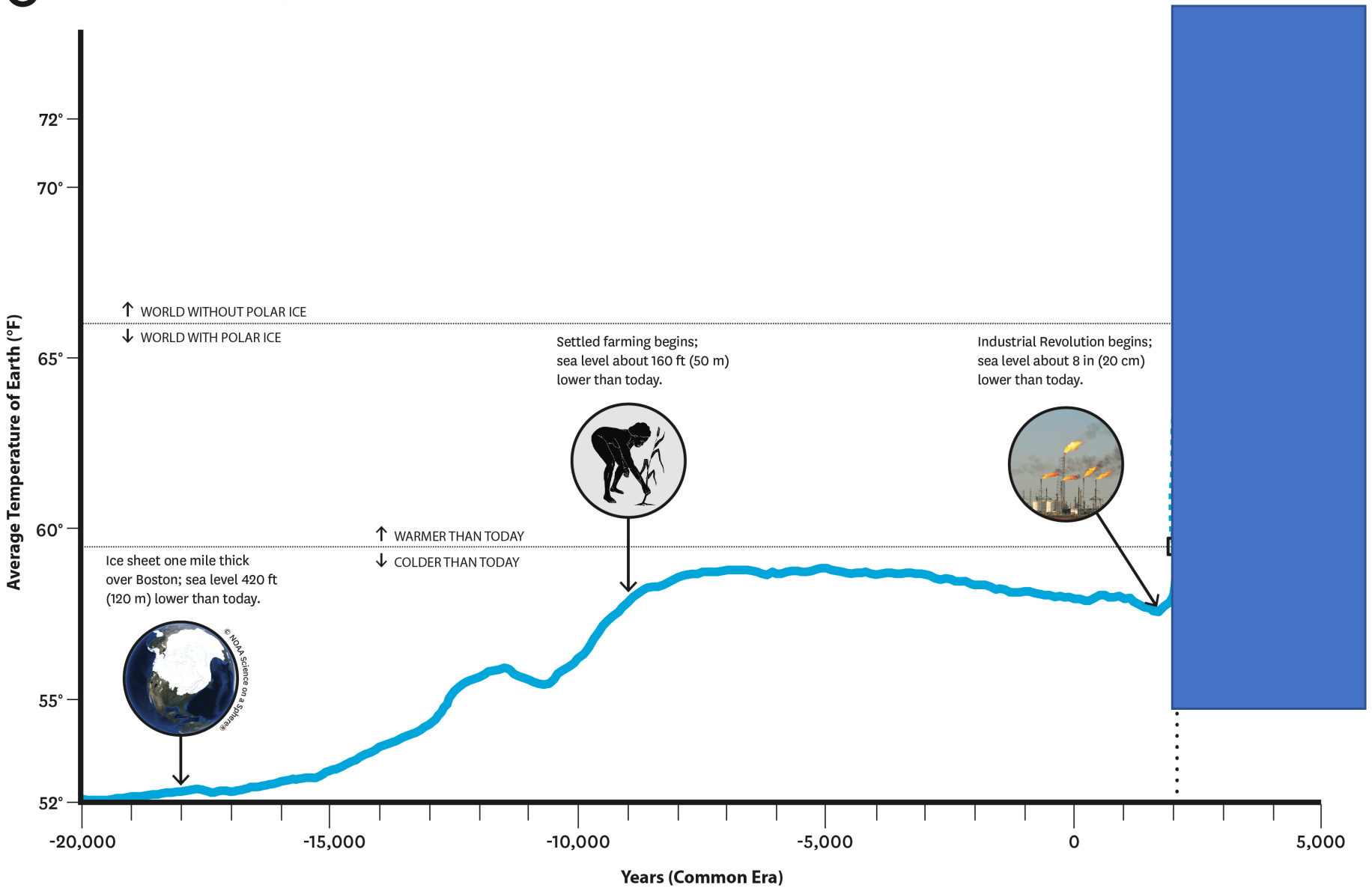
- Climate is warming and change is projected to **accelerate** in next century as a result of continued increases in fossil fuel emissions
- Vulnerable aspects of society and ecosystems are at **risk** from these changes without appropriate mitigation or adaptation measures
- The public increasingly **supports** action on climate change and is hungry for credible, legitimate, salient information on how to do so


1850
6
2
1
0.5
0
-0.5
-1
-2
-6
Temperature Anomaly (°C)
12-month moving average
Anomalies relative to 1951-1980 mean
CC BY-4.0
Robert A. Rohde (@rarohde)
Berkeley Earth (www.BerkeleyEarth.org)
Global Mean Temperature
1
0.5
0
-0.5
Anomaly (°C)
12-month moving average, 95% confidence range
1850
1870
1890
1910
1930
1950
1970
1990
2010

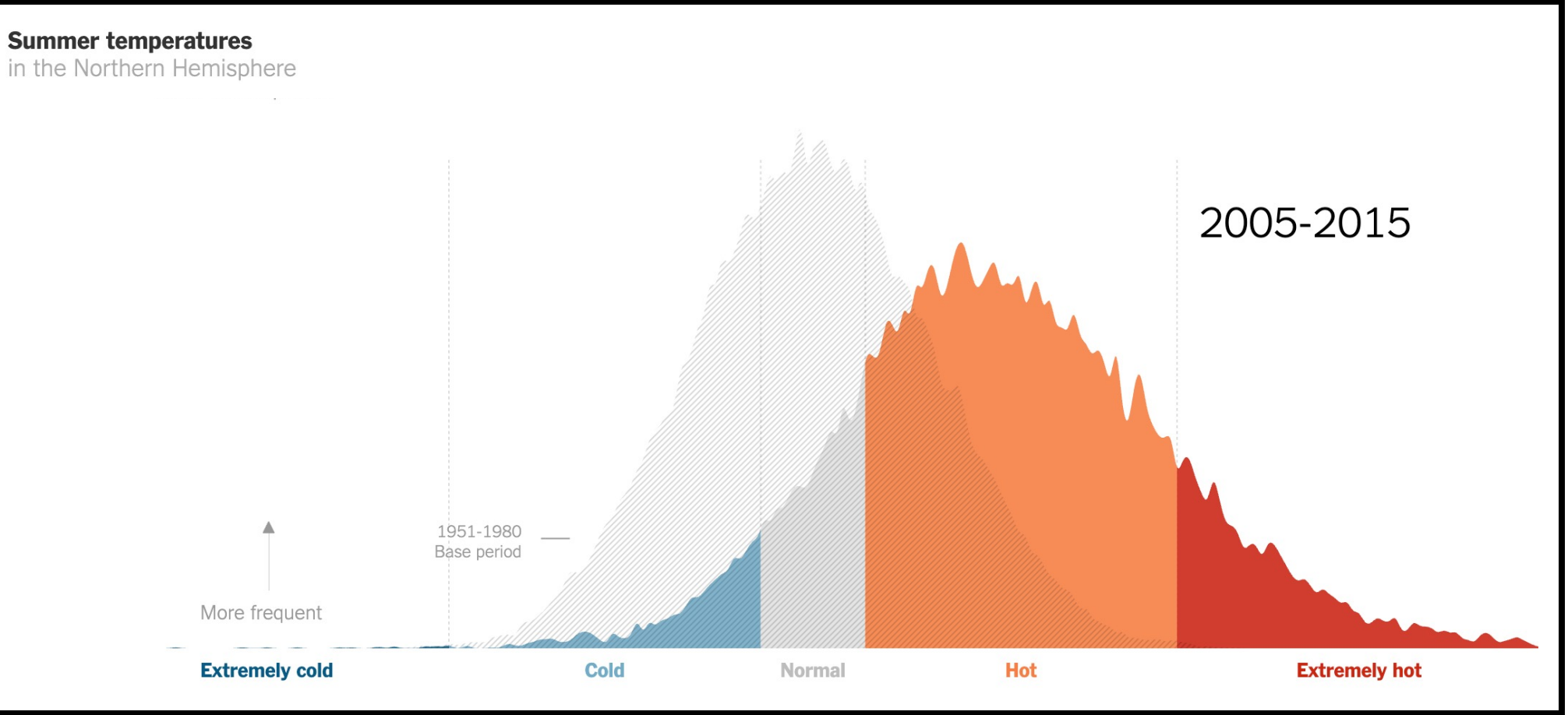

Global temperature change
Relative to average of 1971-2000 [°C]
0.6
0.3
0.0
-0.3
-0.6
1850
1900
1950
2000
2022
showyourstripes.info

Global Temperature

Since the Last Ice Age



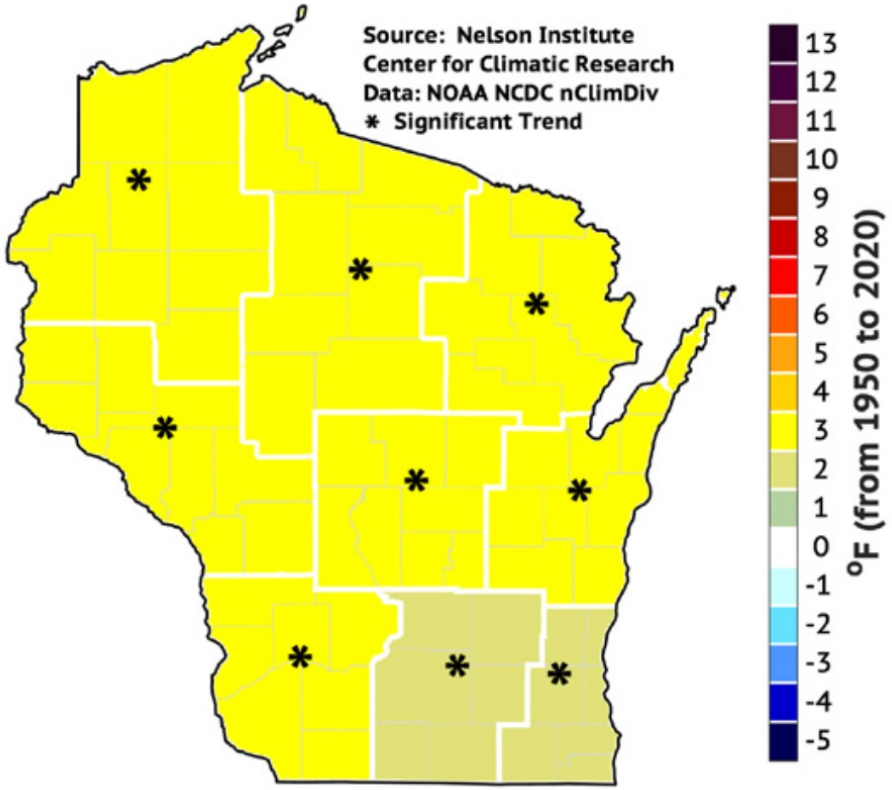
Credits: Smithsonian



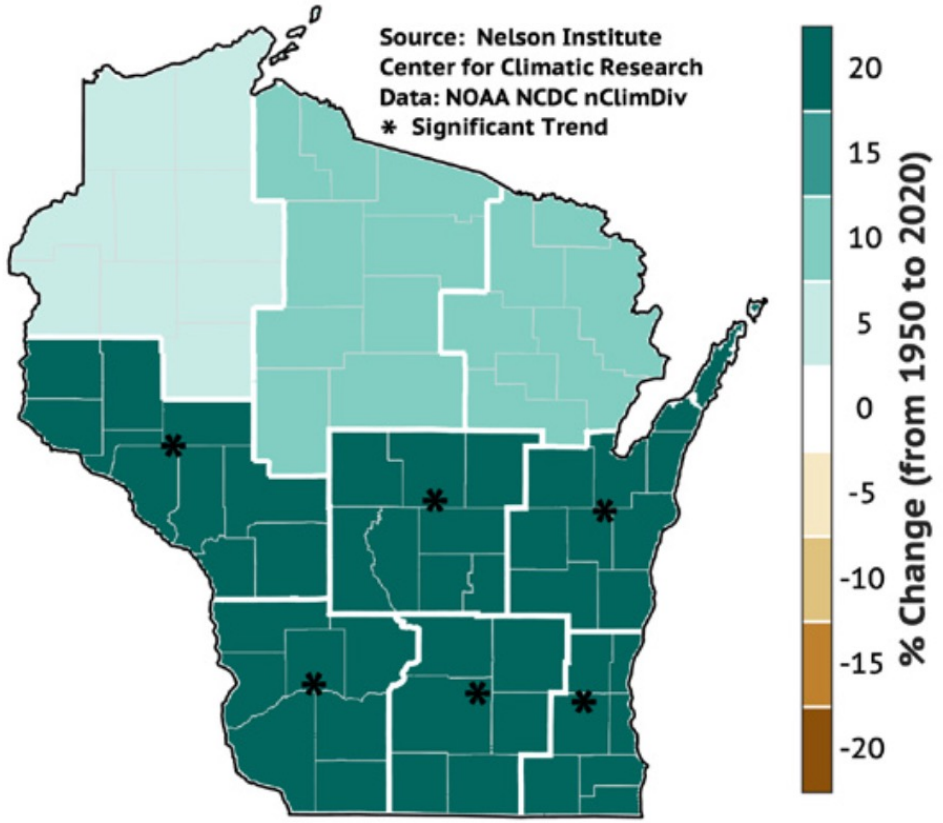
https://www.nytimes.com/interactive/2017/07/28/climate/more-frequent-extreme-summer-heat.html

https://wicci.wisc.edu/

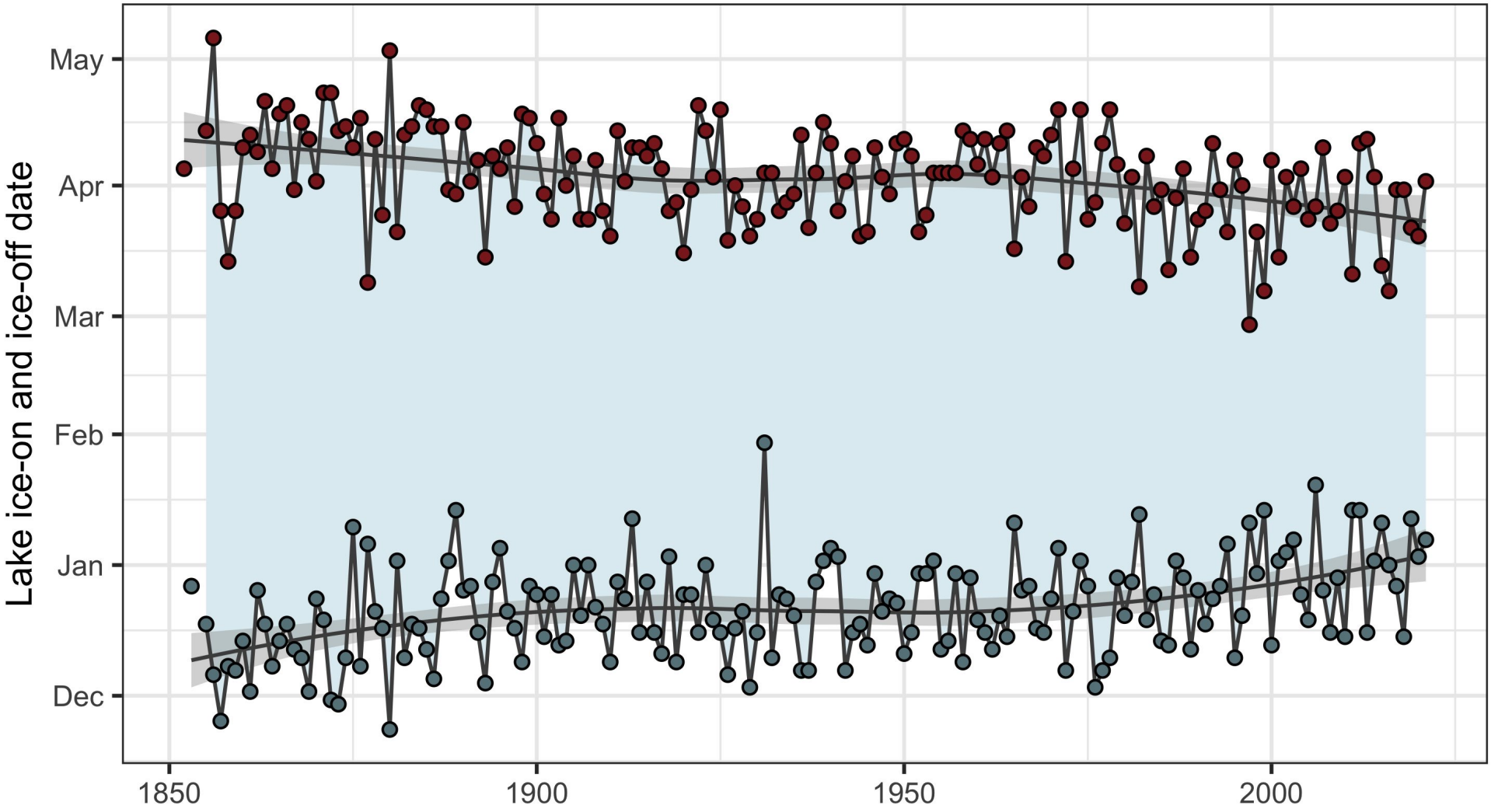
Historical Change in Annual Temperature from 1950 to 2020



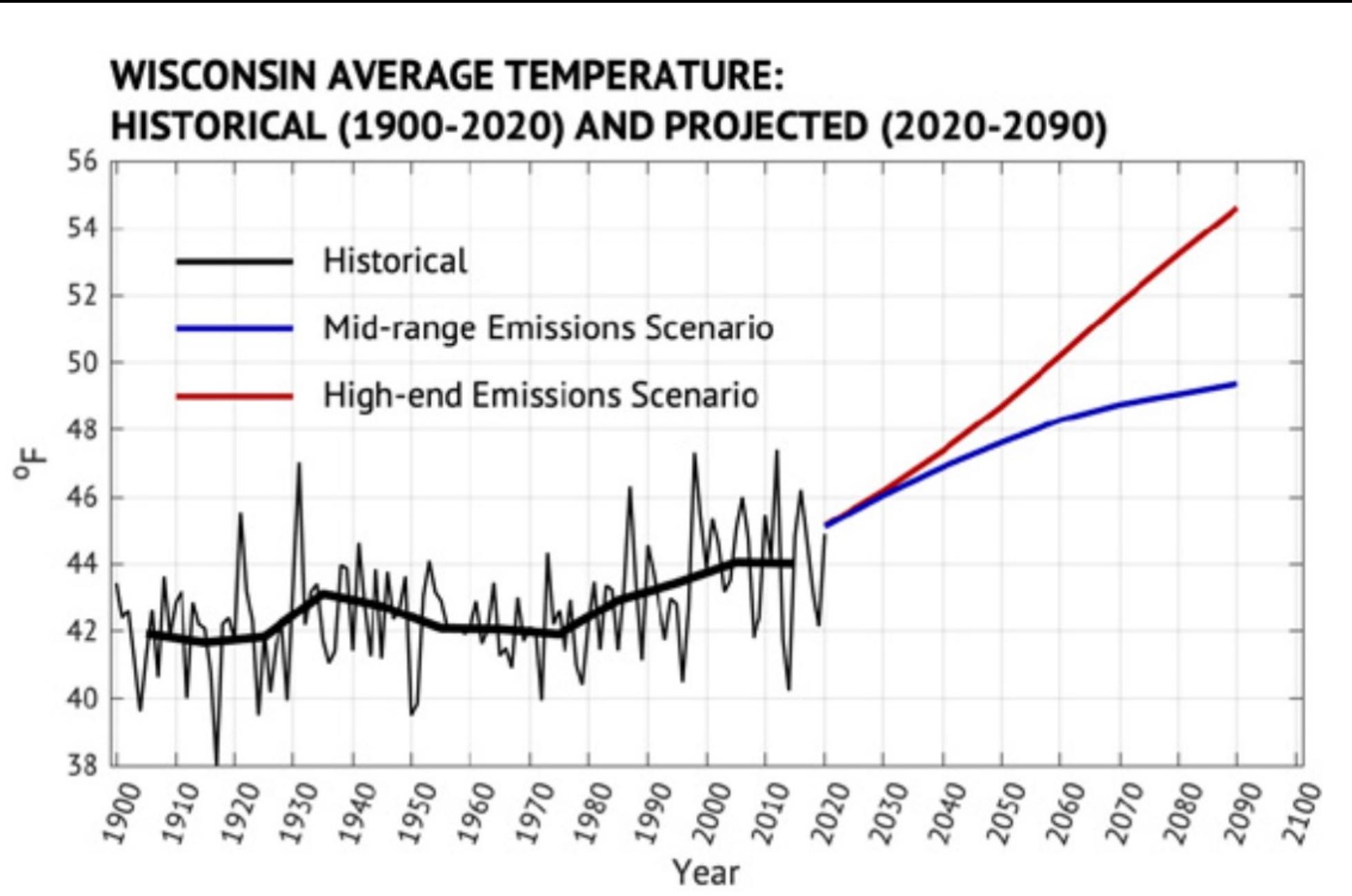
Historical Change in Annual Precipitation from 1950 to 2020



Ice Cover on Lake Mendota

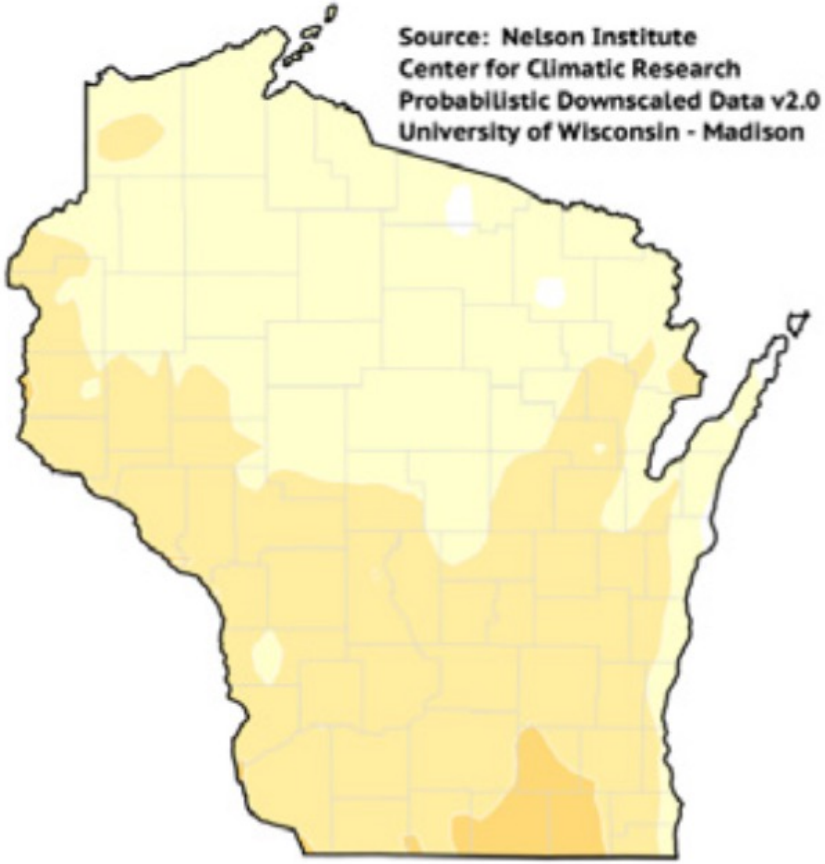


Datat from Wisconsin State Climatology Office

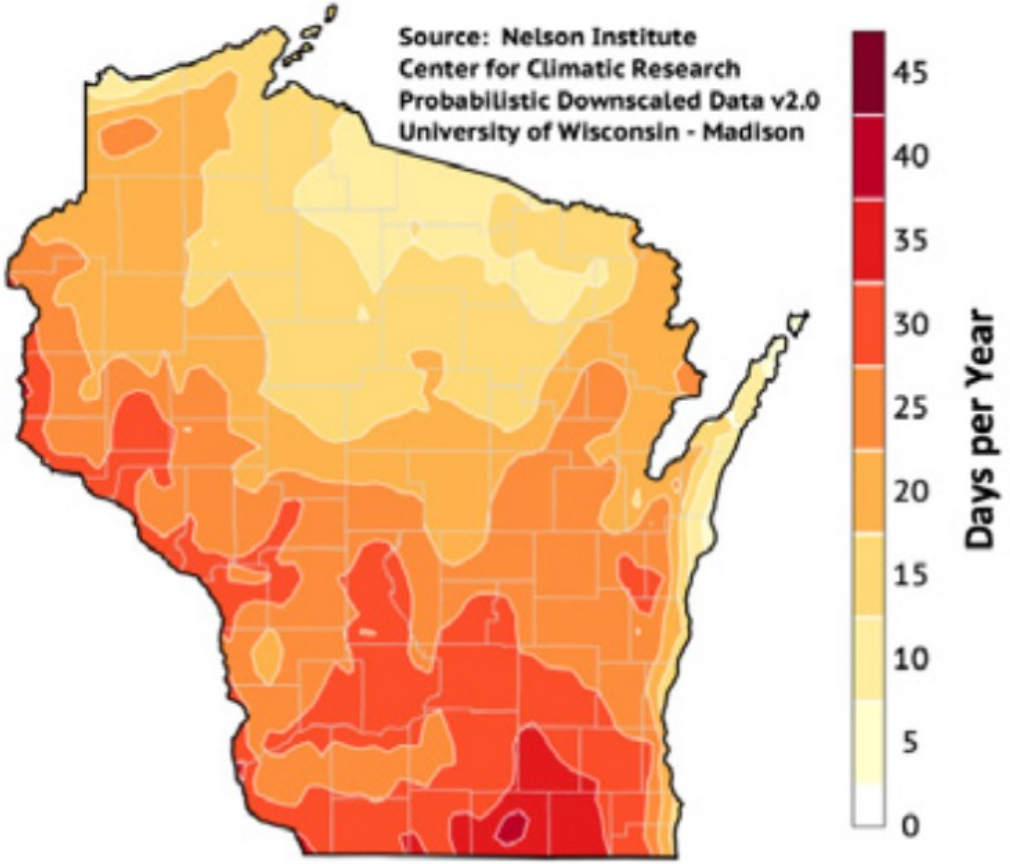

WISCONSIN AVERAGE TEMPERATURE:
HISTORICAL (1900-2020) AND PROJECTED (2020-2090)
Historical
Mid-range Emissions Scenario
High-end Emissions Scenario
°F
Year
56
54
52
50
48
46
44
42
40
38
1900
1910
1920
1930
1940
1950
1960
1970
1980
1990
2000
2010
2020
2030
2040
2050
2060
2070
2080
2090
2100

NUMBER OF EXTREMELY HOT DAYS PER YEAR

HISTORICAL

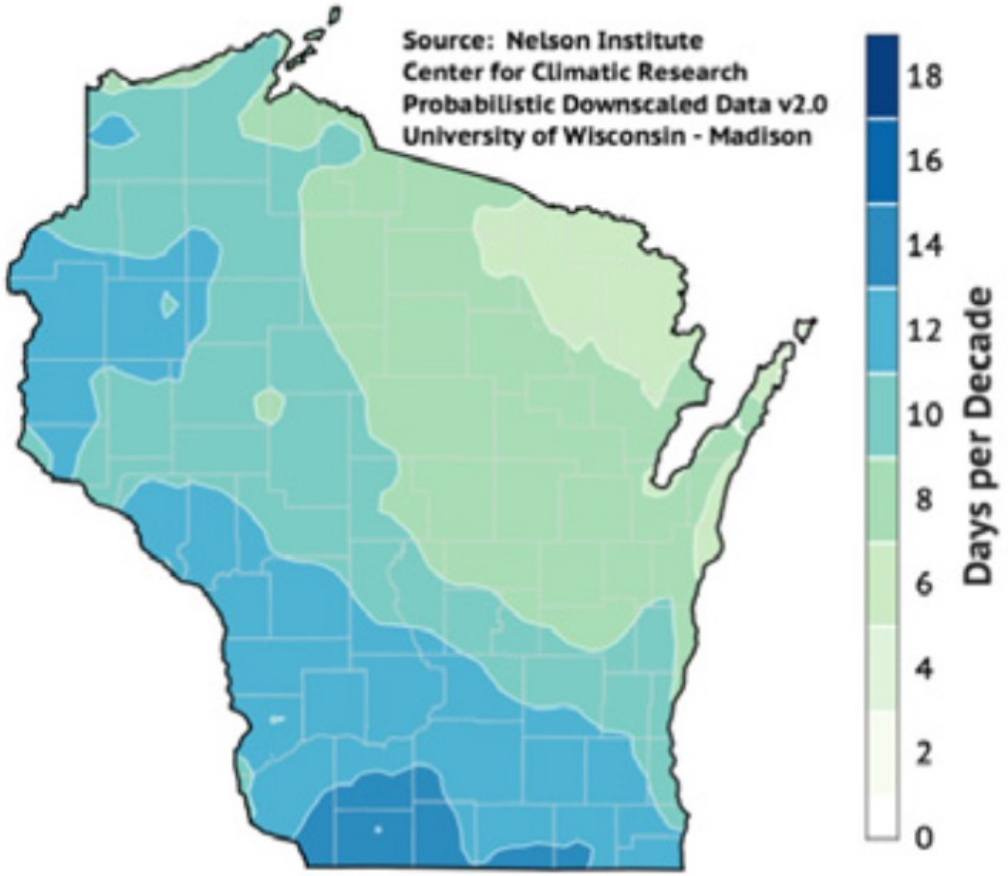


MID-CENTURY

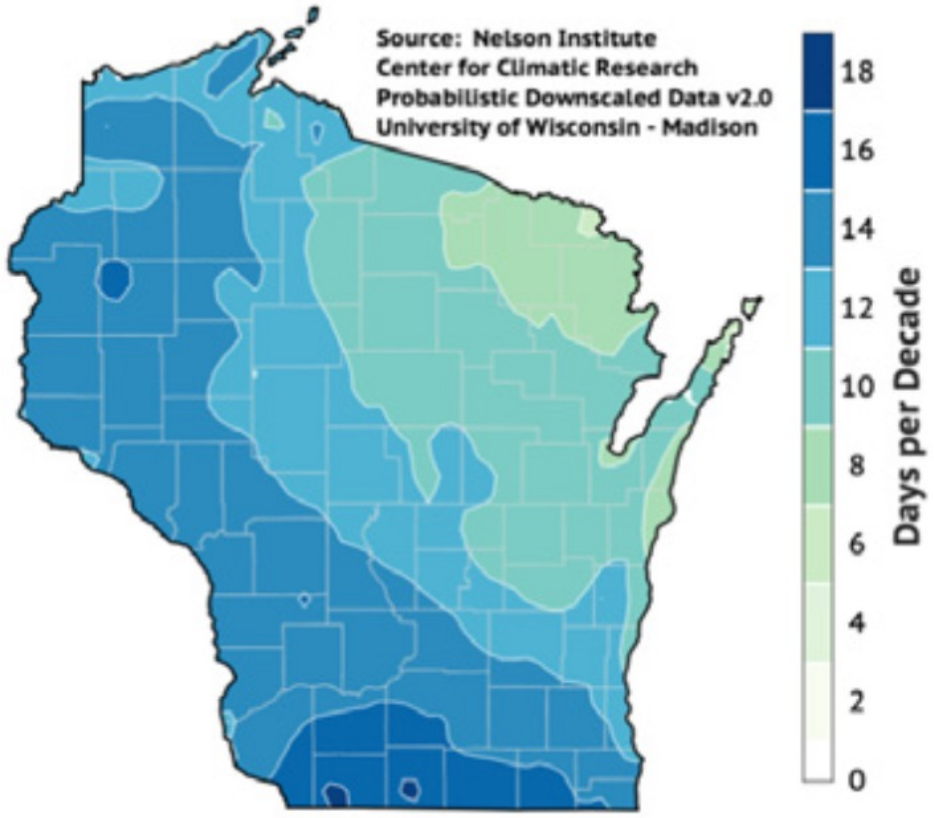


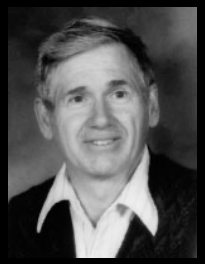
FREQUENCY OF EXTREME RAINFALL

HISTORICAL

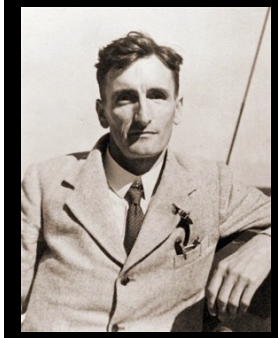


MID-CENTURY

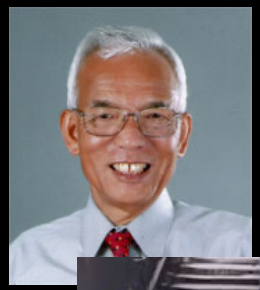




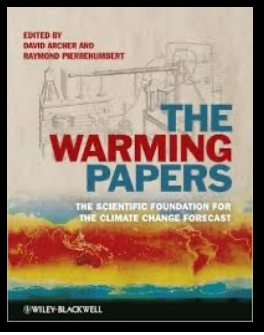
- Atmospheric CO_2 increasing ~ 2 ppm/yr from fossil fuel combustion, with 50% going into land and ocean sinks (Keeling 1960, Tans 1990)

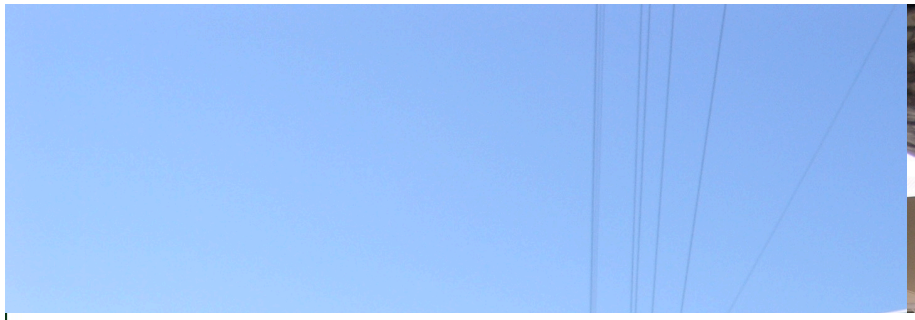


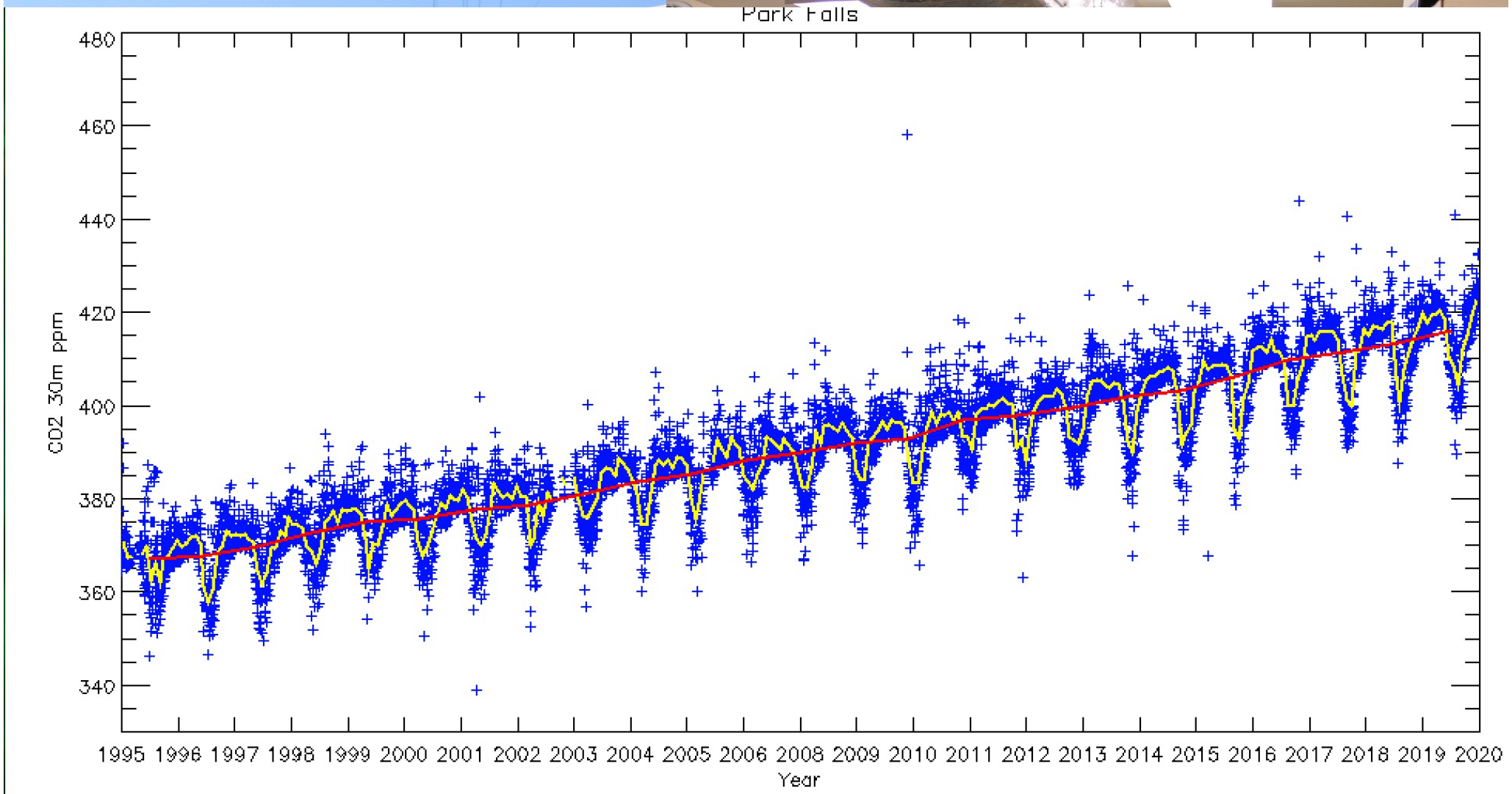
- Short and long term observed warming patterns are linked to greenhouse gases (Callendar 1938, Mann 1999)

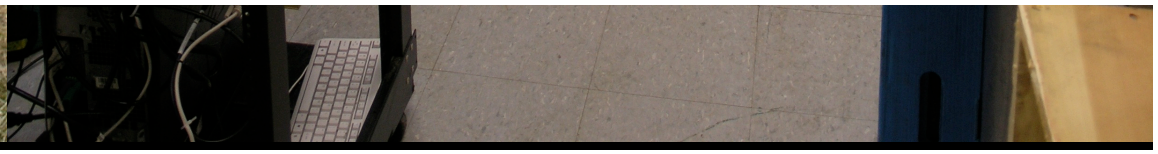


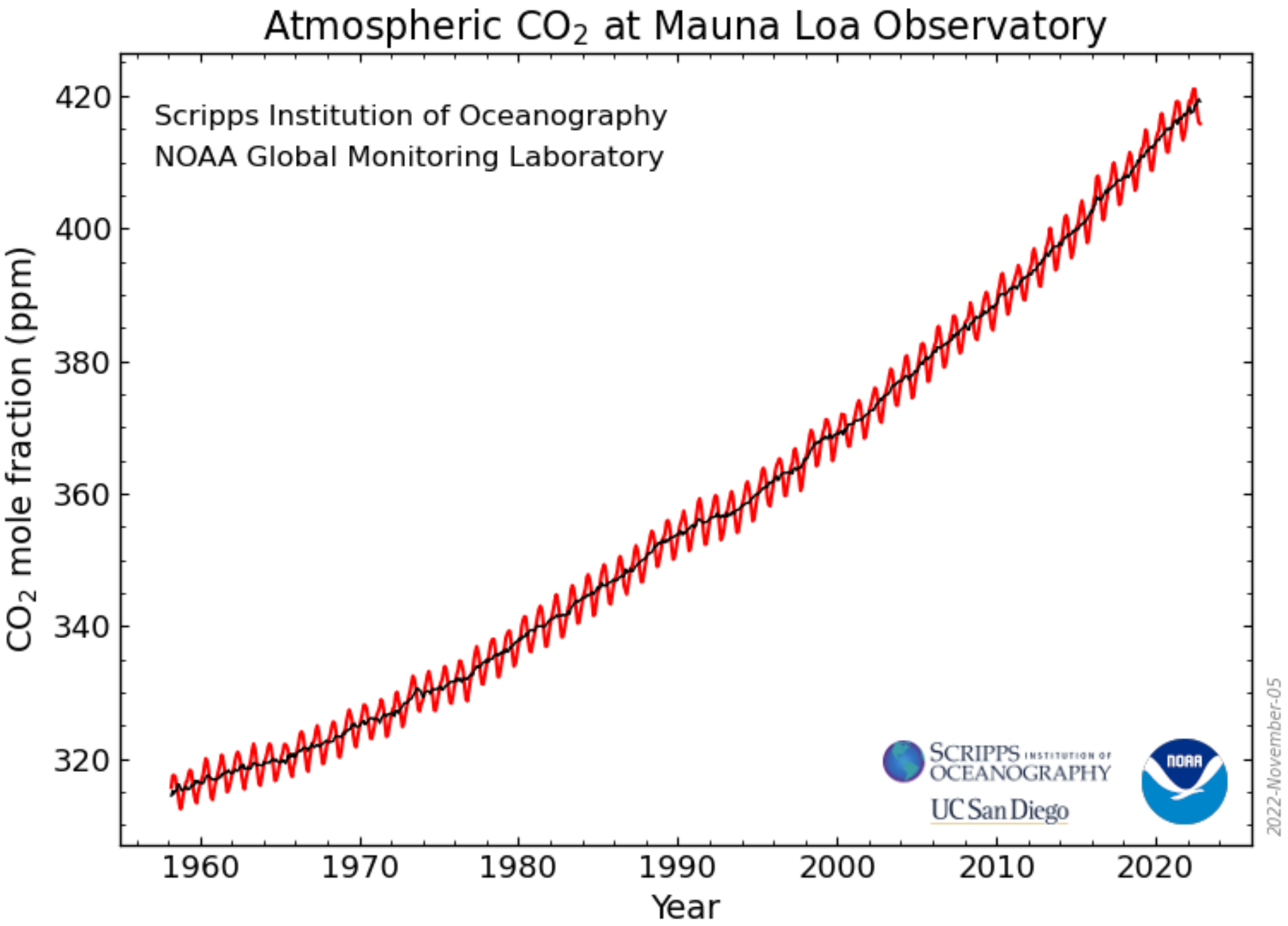
- Significant warming in the 20th century is mostly explained by atmospheric CO_2 (Manabe 1967, Hansen 1984)





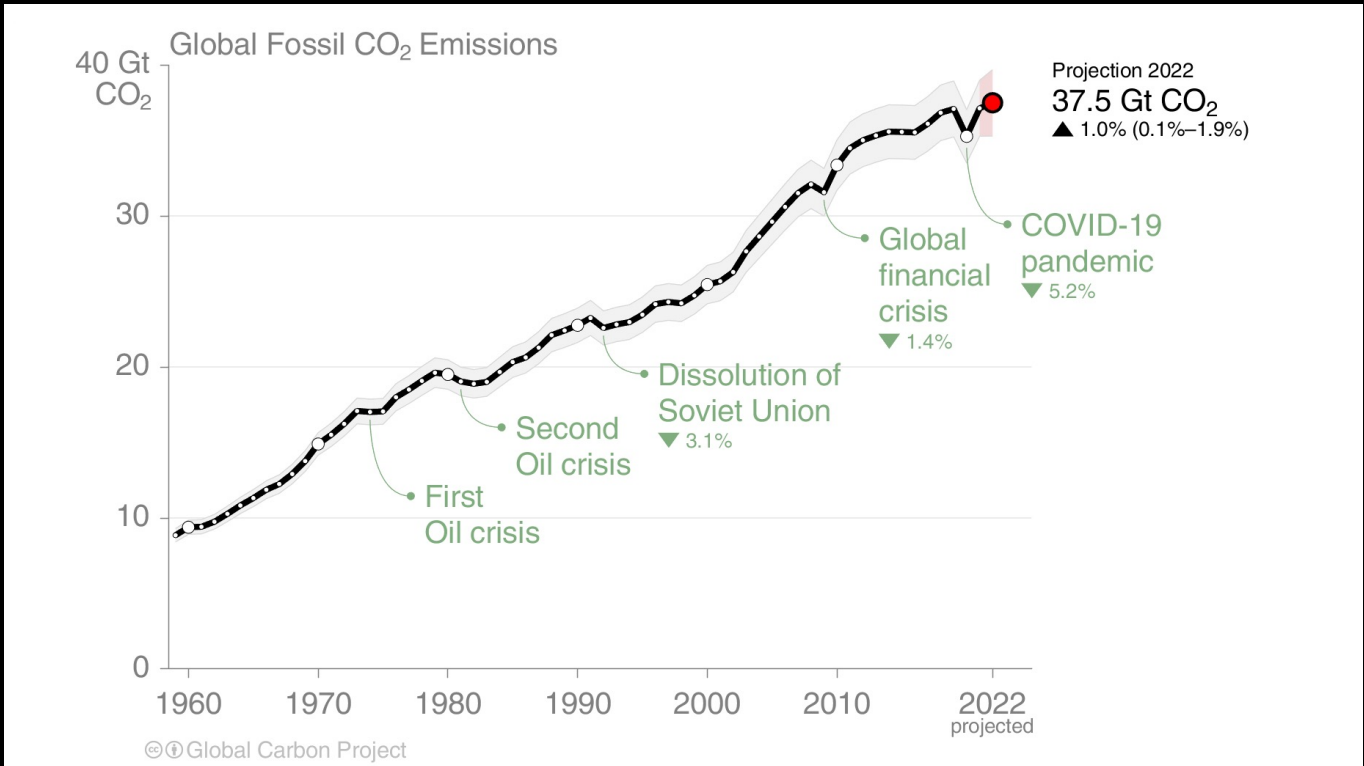

Park Falls
480
460
440
420
400
380
360
340
CO2 30m ppm
1995 1996 1997 1998 1999 2000 2001 2002 2003 2004 2005 2006 2008 2009 2010 2011 2012 2013 2014 2015 2016 2017 2018 2019 2020
Year




Atmospheric CO_2 at Mauna Loa Observatory
Scripps Institution of Oceanography
NOAA Global Monitoring Laboratory
CO_2 mole fraction (ppm)
420
400
380
360
340
320
1960
1970
1980
1990
2000
2010
2020
Year
SCRIPPS INSTITUTION OF OCEANOGRAPHY
UC San Diego
NOAA
2022-November-05

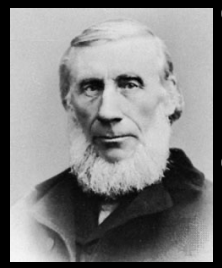
Global Fossil CO_2 Emissions

Global fossil CO_2 emissions have risen steadily over the last decades.
Emissions are set to grow again in 2022.



When including cement carbonation, the 2022 estimate is 36.6 ± 2 $GtCO_2$.
The 2022 projection is based on preliminary data and modelling.
Source: Friedlingstein et al 2022; Global Carbon Project 2022

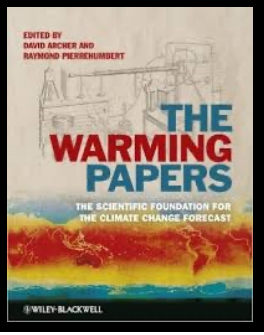


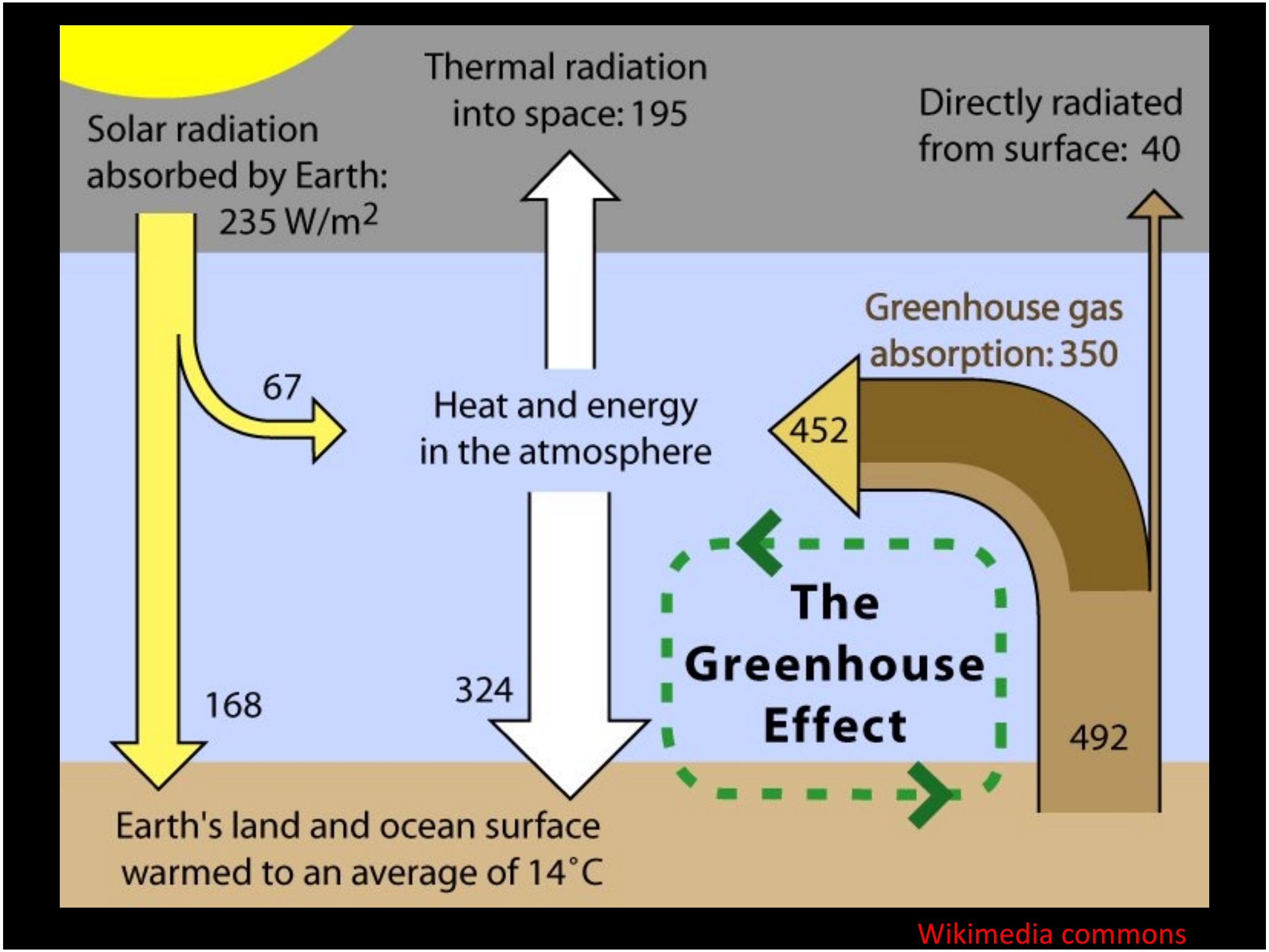


- Planetary (inc. Earth) temperature is determined by interaction of sunlight warming Earth's surface, and "greenhouse" gases that absorb infrared radiation (Fourier 1824, Tyndall 1861; Foote 1857)

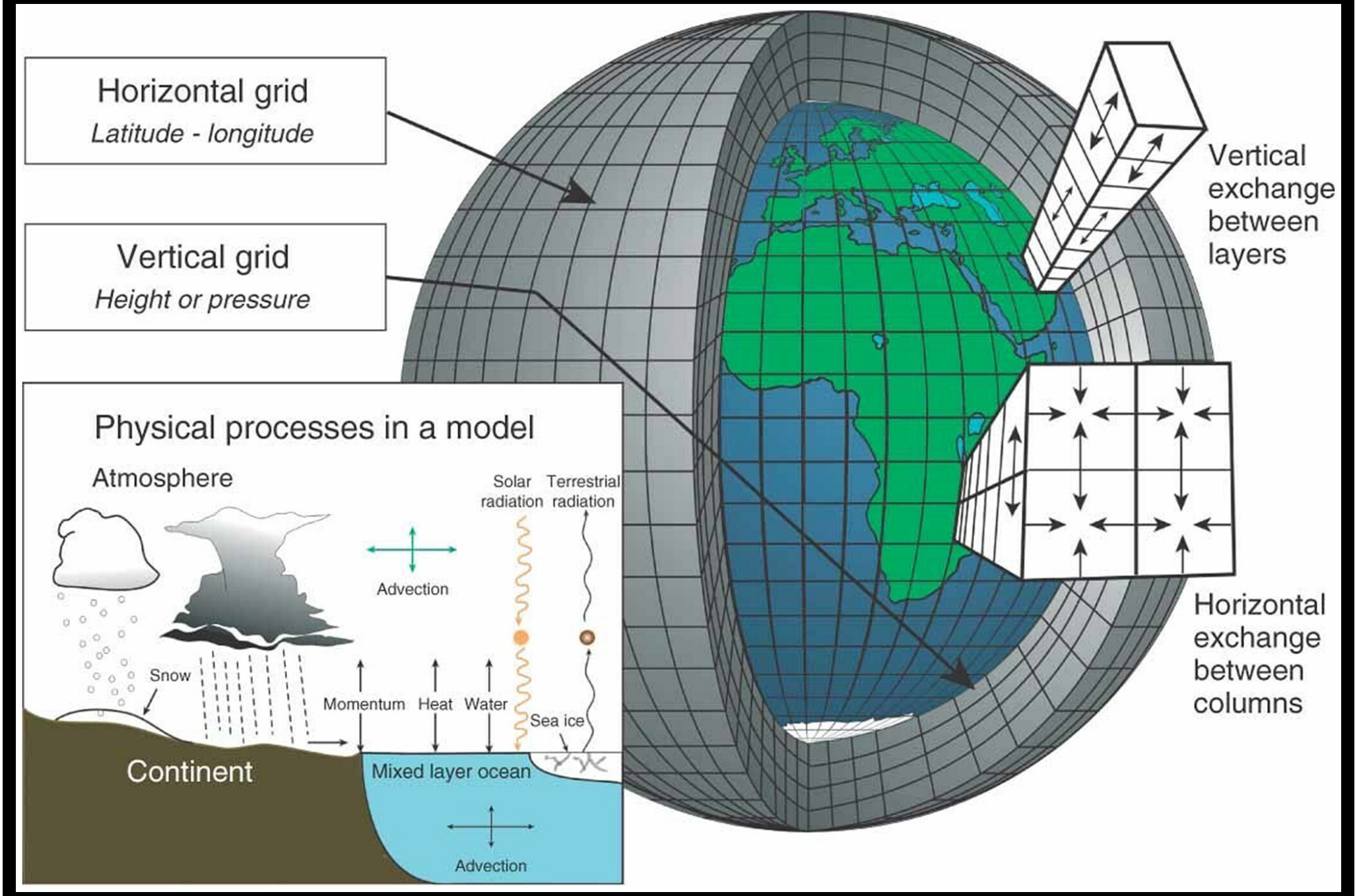
- CO_2 is a greenhouse warming gas and emitted from coal, oil, gas (Arrhenius 1896)

- Oceans can only take up a fraction of CO_2 produced by combustion (Revelle 1957)

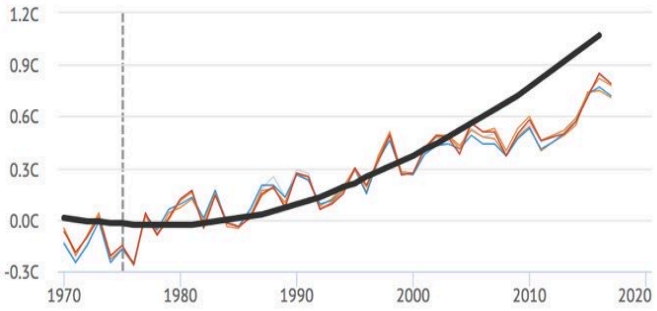




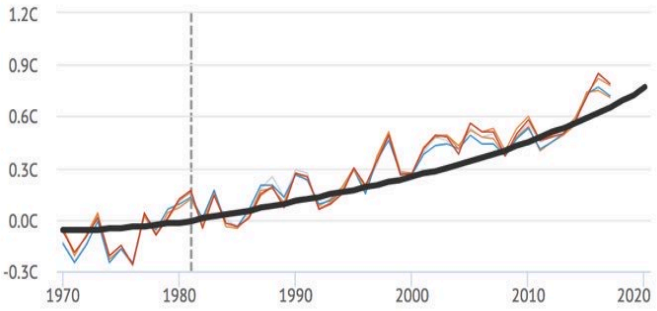
Wikimedia commons


Horizontal grid
Latitude - longitude
Vertical grid
Height or pressure
Physical processes in a model
Atmosphere
Solar radiation
Terrestrial radiation
Advection
Snow
Momentum
Heat
Water
Sea ice
Continent
Mixed layer ocean
Advection
Vertical exchange between layers
Horizontal exchange between columns

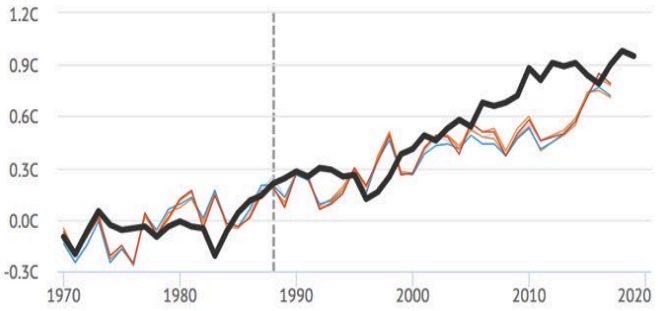
1975: Wally Broecker



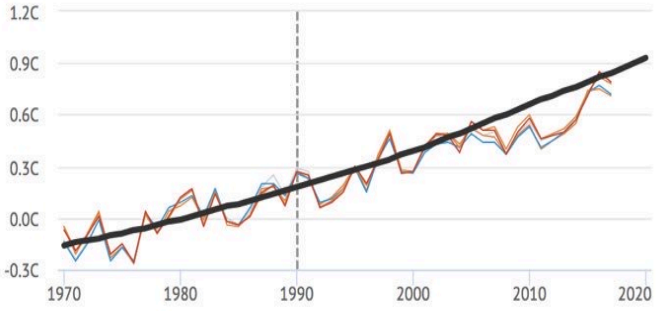
1981: Hansen et al



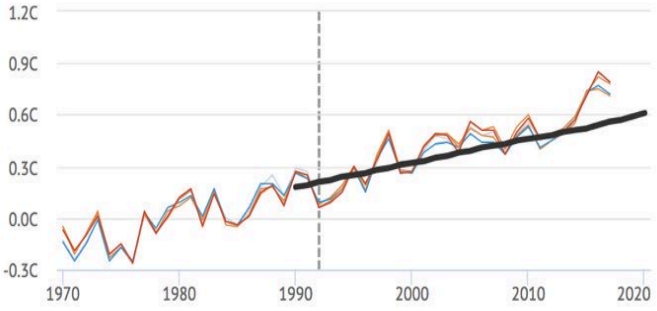
1988: Hansen et al



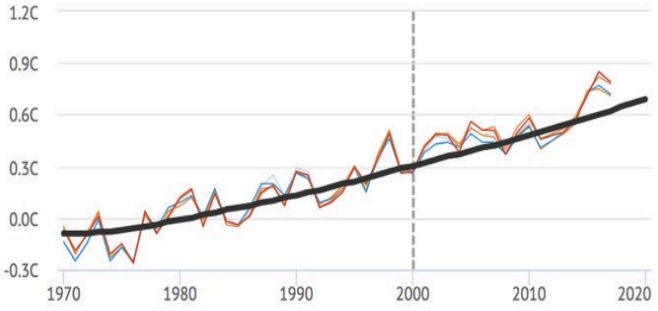
1990: IPCC First Assessment Report



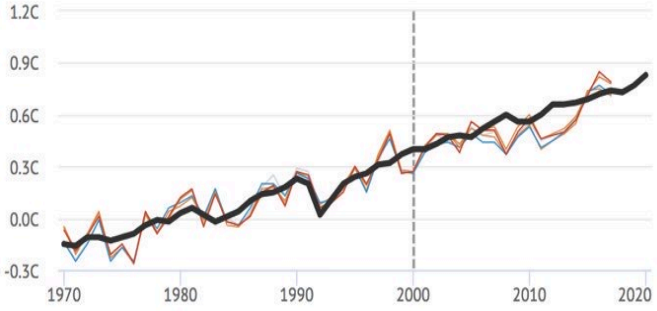
1995: IPCC Second Assessment Report



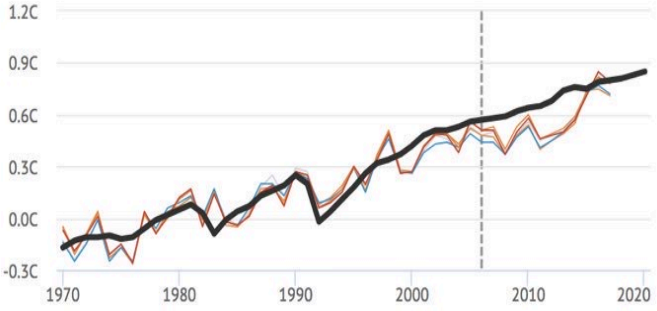
2001: IPCC Third Assessment Report



2007: IPCC Fourth Assessment Report



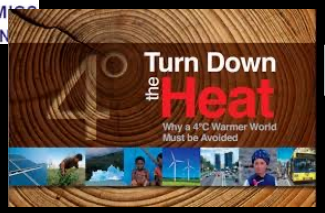
2013: IPCC Fifth Assessment Report



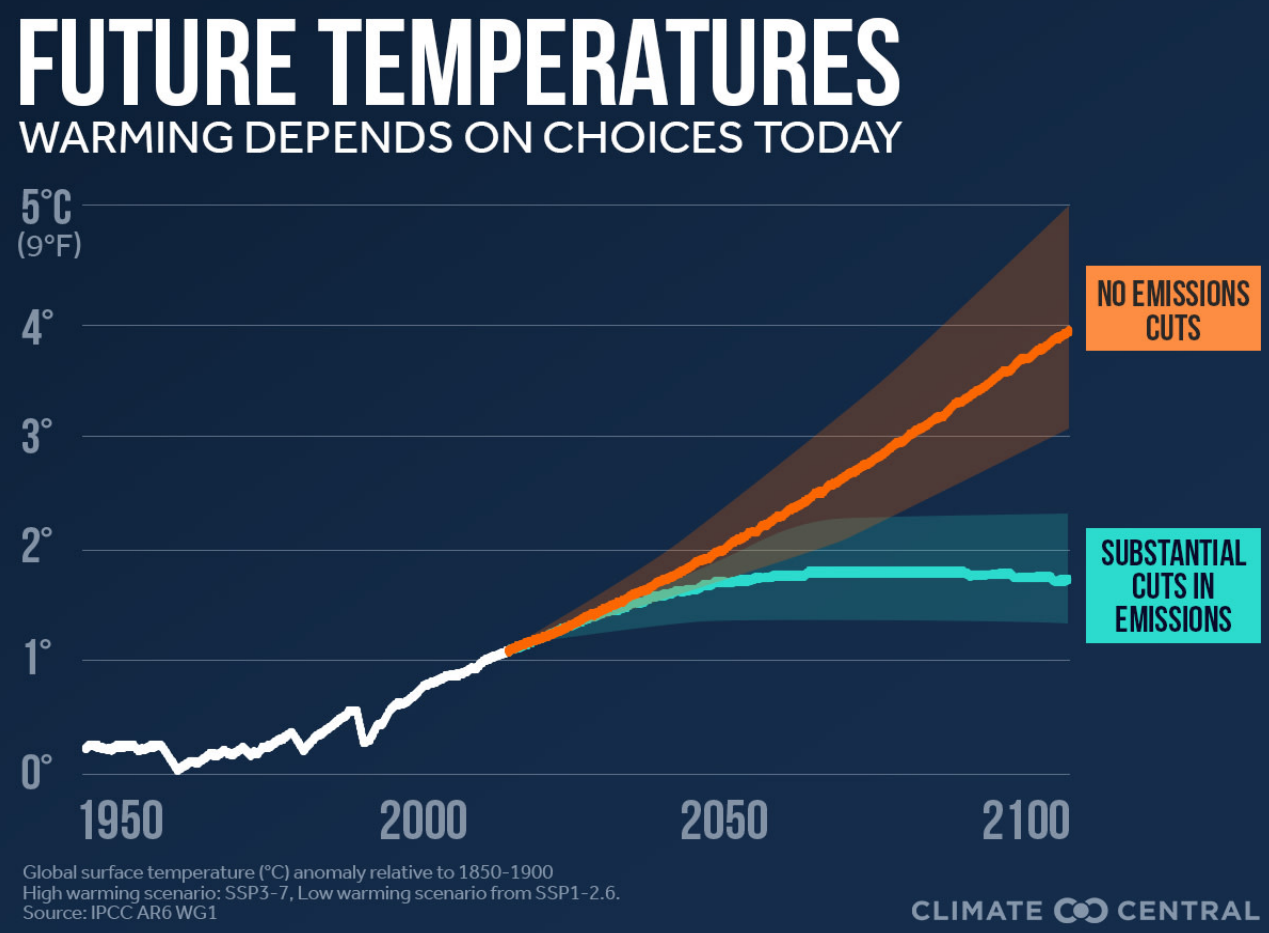
CB

"CO_2 is to climate what steroids was to baseball…" –Jason Samenow

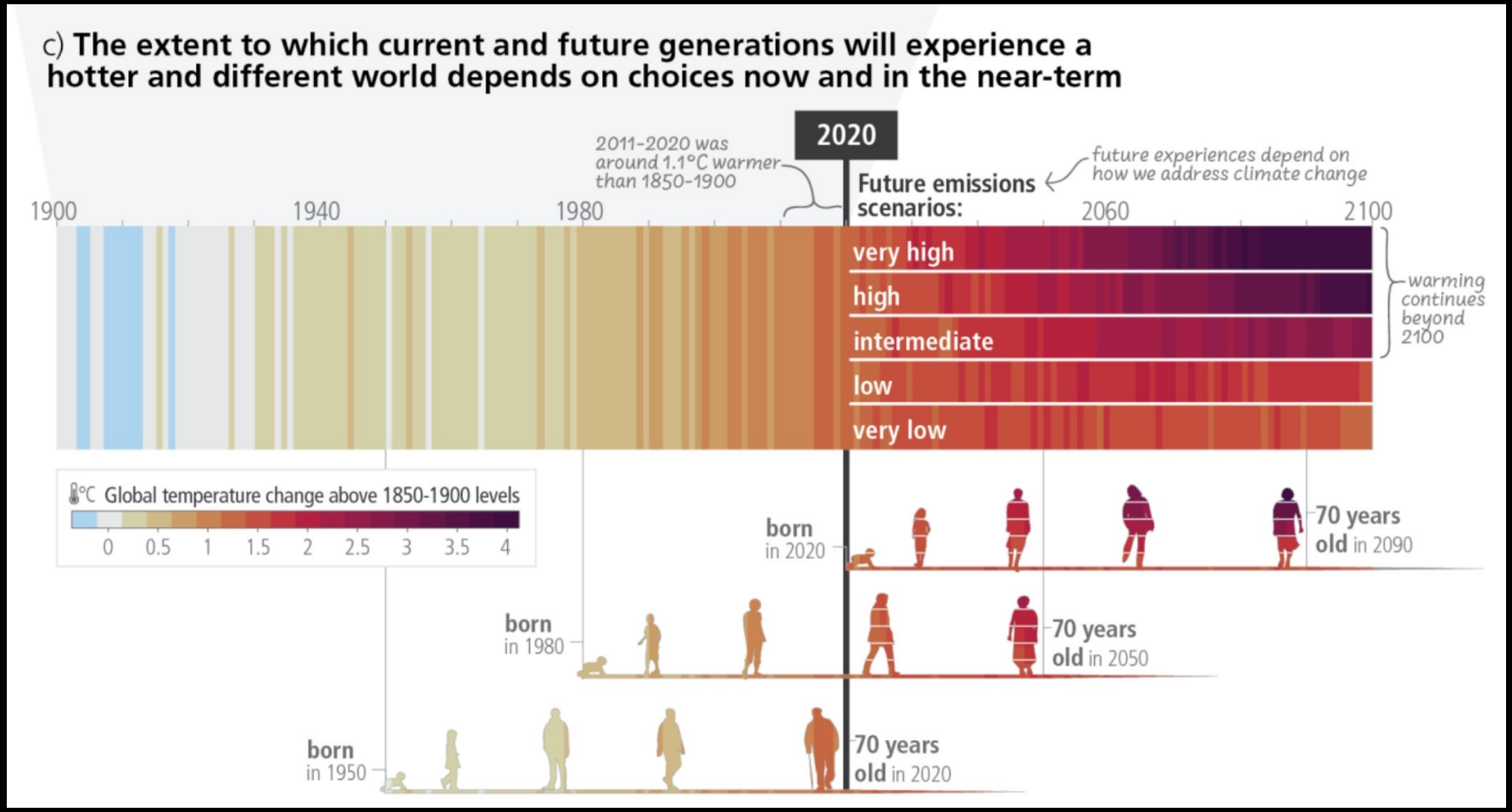
https://www.bloomberg.com/graphics/2015-whats-warming-the-world/



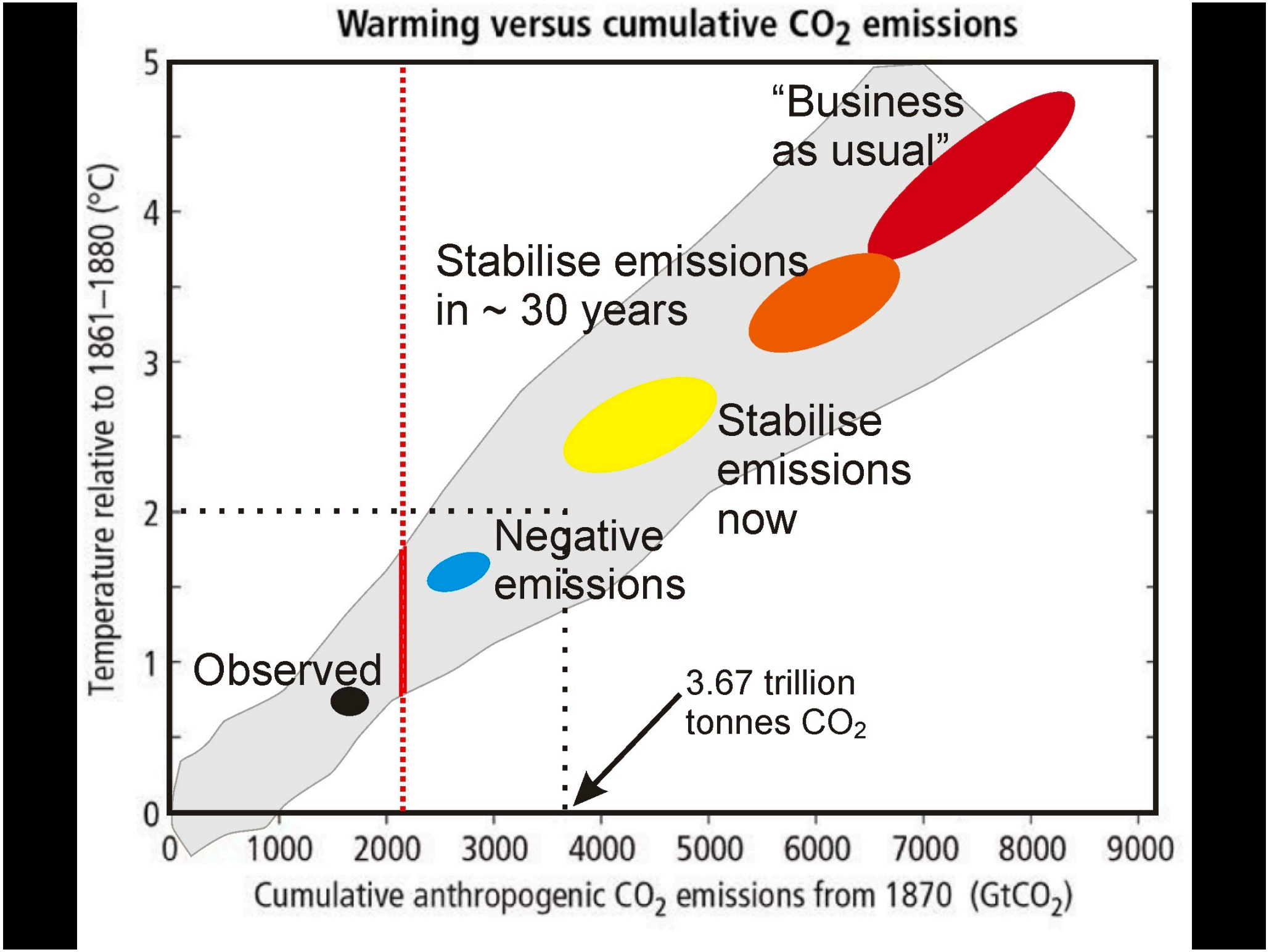
- US per capita fossil fuel emissions exceed most of the world (DOE, GCP). China total emissions now exceeds the US (IEA).
- Climate projections show a 3 C +/- 1.5 C response to doubling of CO_2 by 2100 with the primary uncertainty in range of emissions (IPCC 1990, 1995, 2001, 2007, 2013, 2022)
- Modest warming (0-2 C) creates both winners and losers; warming above 2C or 550 ppm, losers > winners; warming above 4C, mostly losers (WMO, ExxonMobil, Stern Review, World Bank, NCA, WICCI, DOD 1979-present)

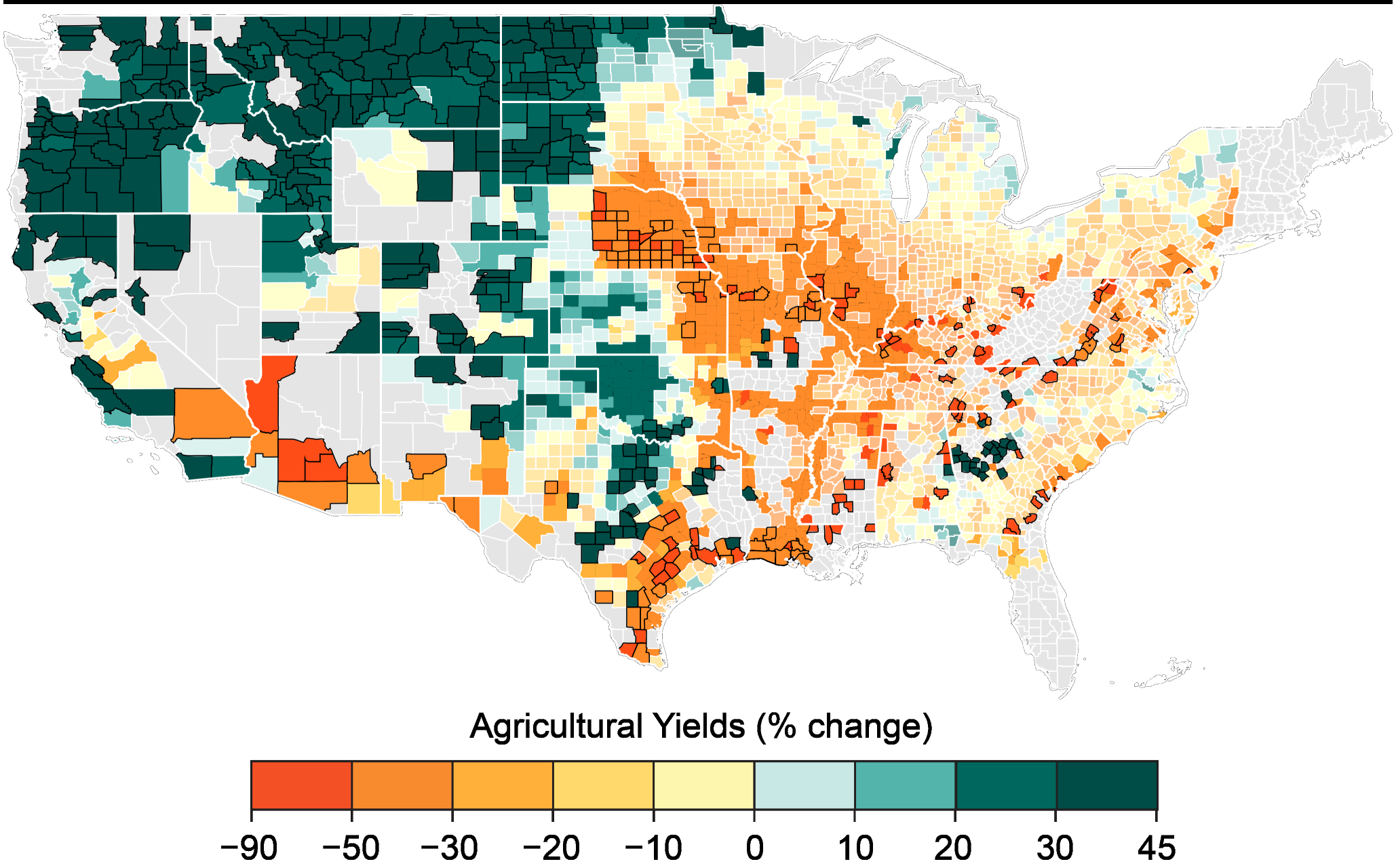


https://www.climatecentral.org/climate-matters/ipcc-6th-assessment-report-the-physical-science-basis



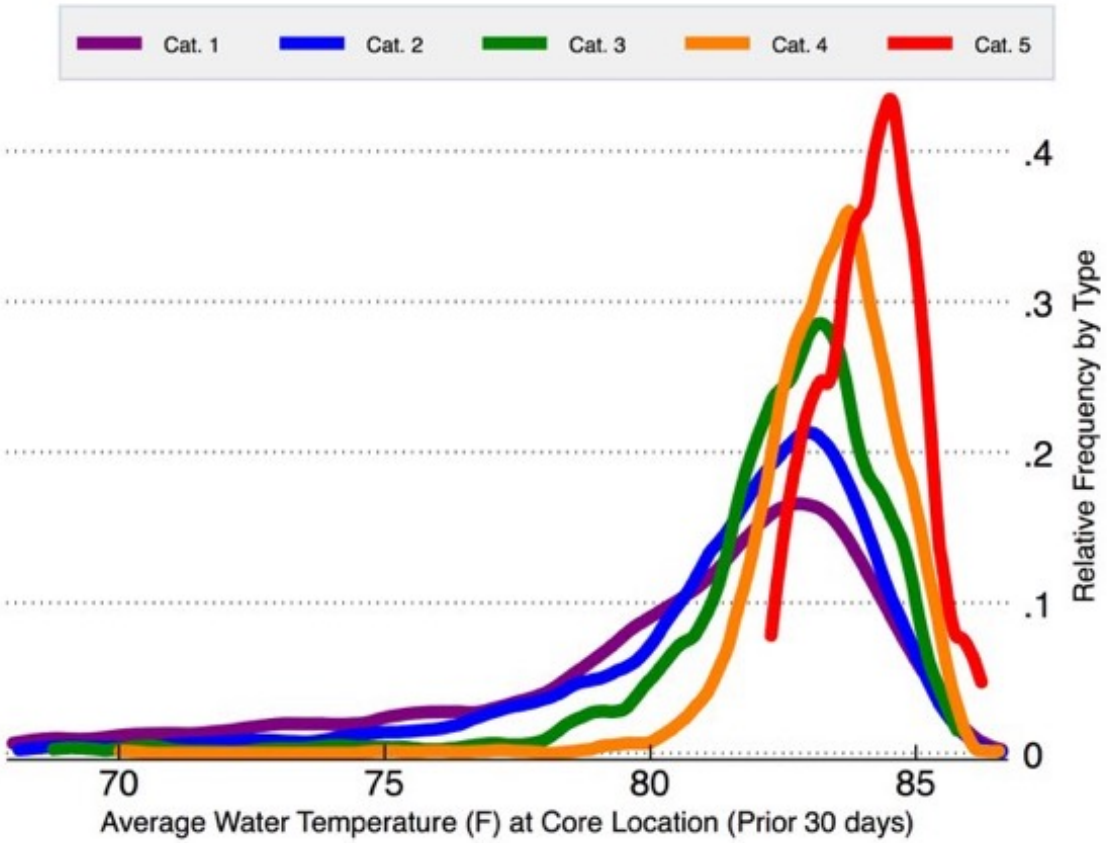
IPCC 6th assessment


Warming versus cumulative CO_2 emissions
"Business as usual"
Stabilise emissions in ~ 30 years
Stabilise emissions now
Negative emissions
Observed
3.67 trillion tonnes CO_2
Temperature relative to 1861–1880 (°C)
Cumulative anthropogenic CO_2 emissions from 1870 ($GtCO_2$)
0
1
2
3
4
5
0
1000
2000
3000
4000
5000
6000
7000
8000
9000



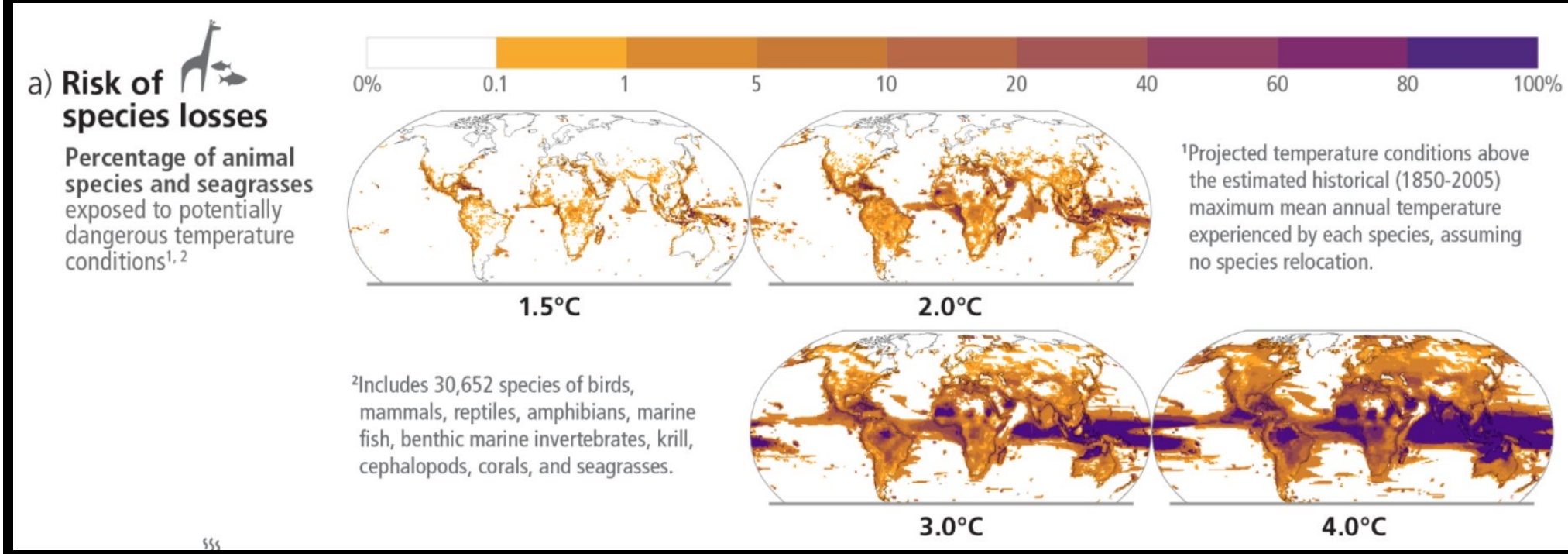
NCA, 2018

Hurricane Strength and Ocean Temperatures



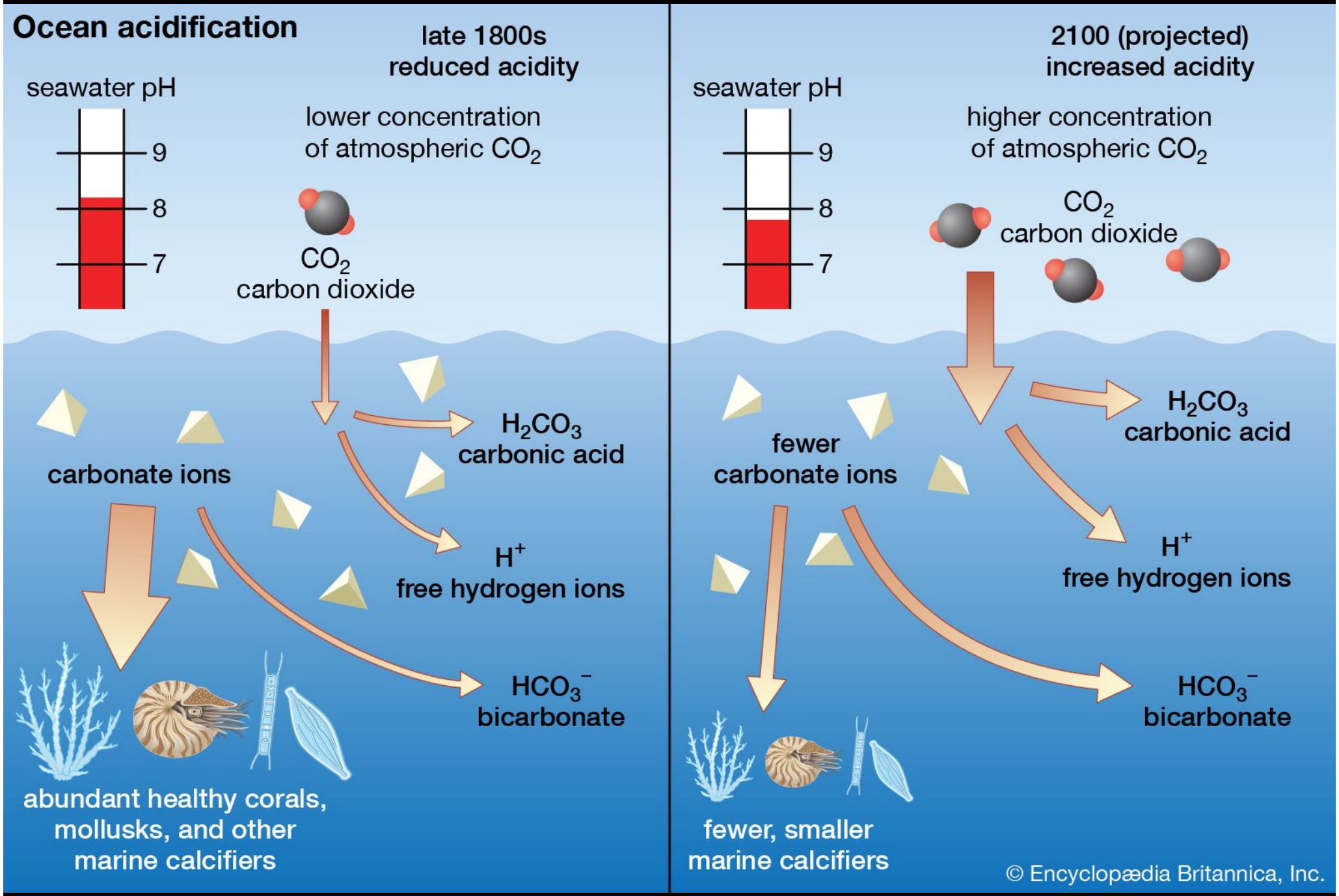
Kernal density functions of SSTs by hurricane category. Area under each curve represents 100% of hurricanes of that type. Hurricane wind speeds via HURDAT.


SALMON
OCTOPUS
OCEAN TROUT

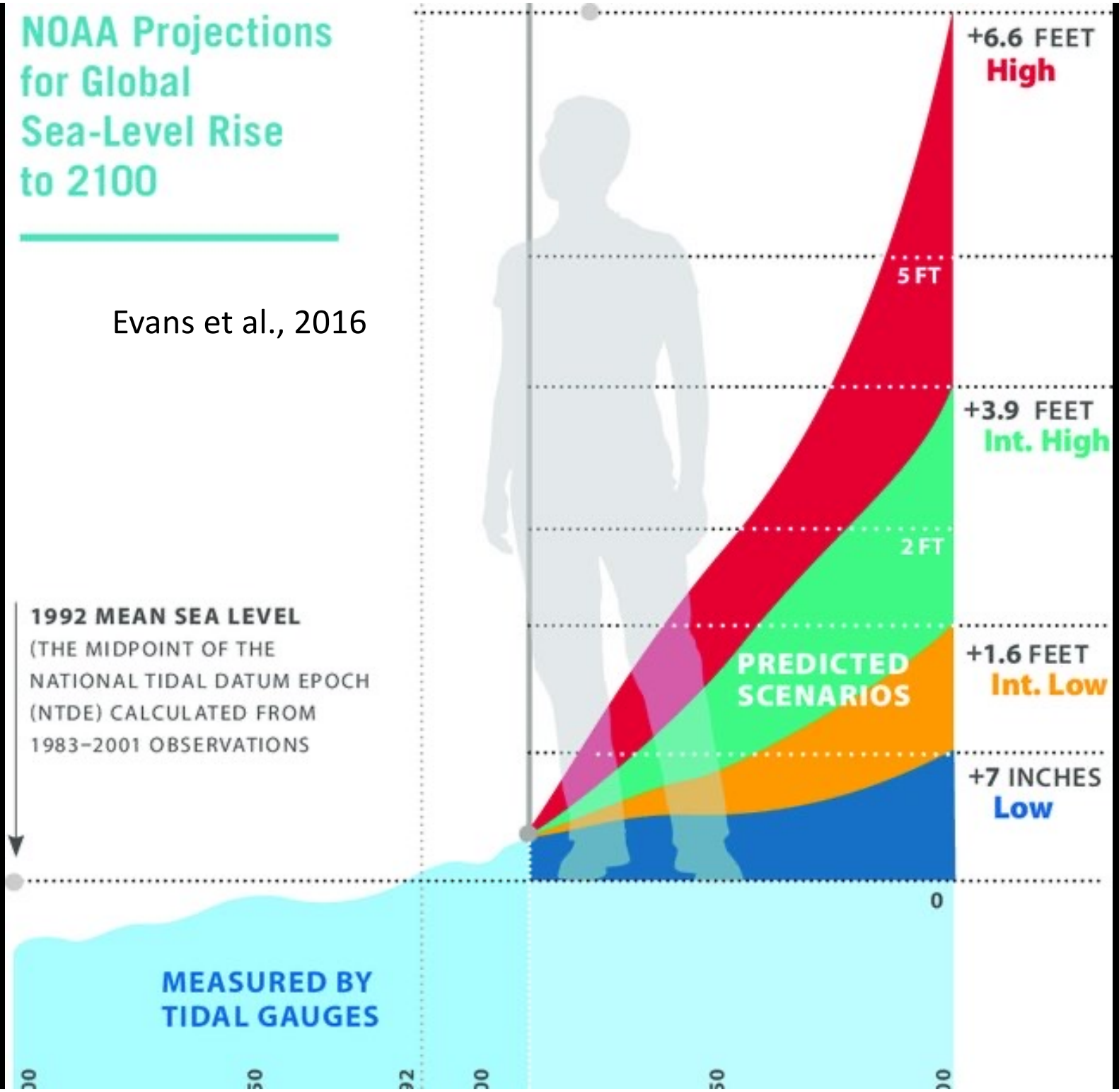


IPCC 6th assessment

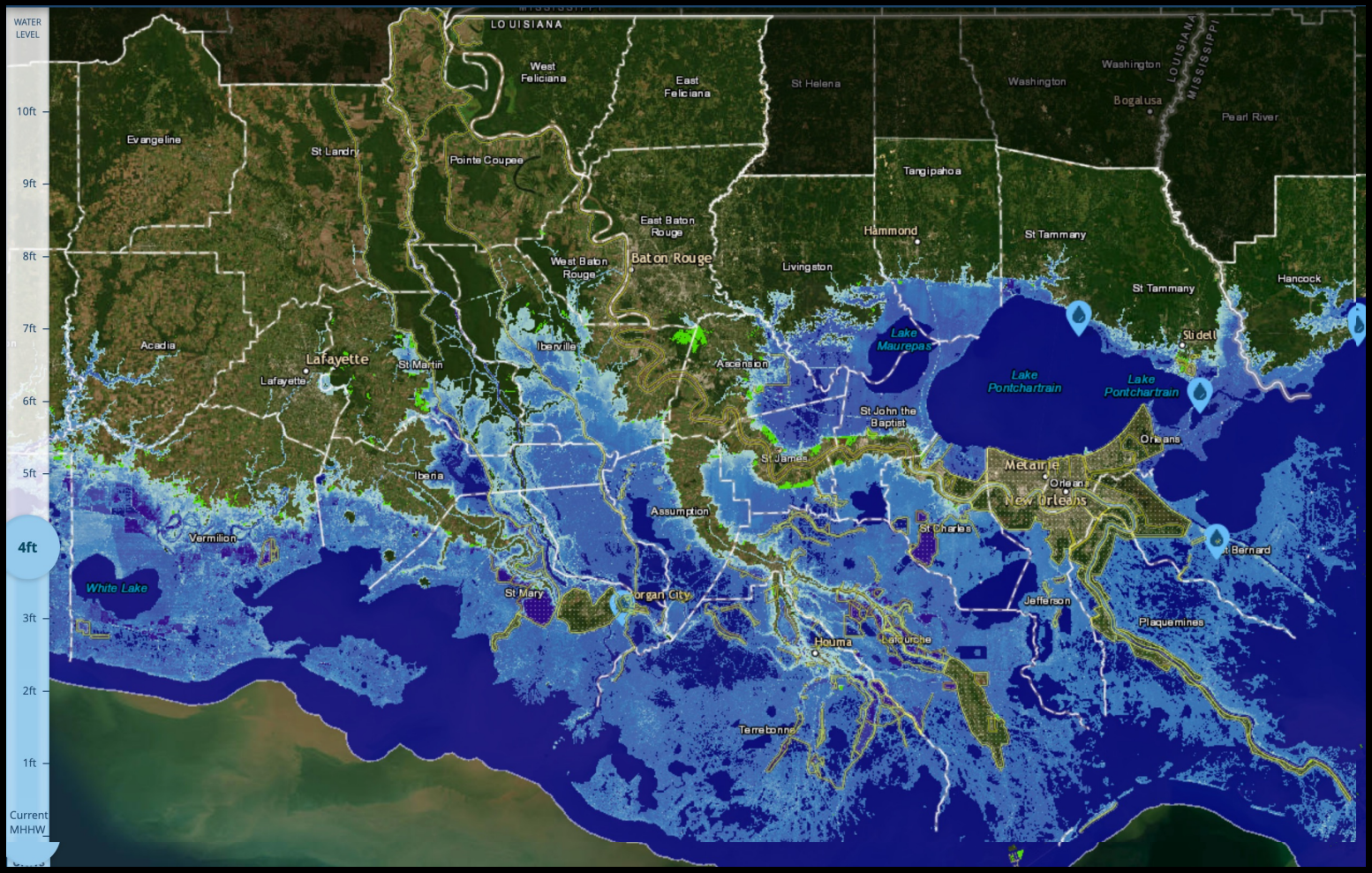
https://www.cbsnews.com/pictures/magnificent-microscopic-creatures-of-the-seas/2/


Ocean acidification
late 1800s
reduced acidity
seawater pH
9
8
7
lower concentration
of atmospheric CO_2
CO_2
carbon dioxide
H_2CO_3
carbonic acid
carbonate ions
H^+
free hydrogen ions
HCO_3^-
bicarbonate
abundant healthy corals,
mollusks, and other
marine calcifiers
2100 (projected)
increased acidity
seawater pH
9
8
7
higher concentration
of atmospheric CO_2
CO_2
carbon dioxide
H_2CO_3
carbonic acid
fewer
carbonate ions
H^+
free hydrogen ions
HCO_3^-
bicarbonate
fewer, smaller
marine calcifiers
© Encyclopædia Britannica, Inc.

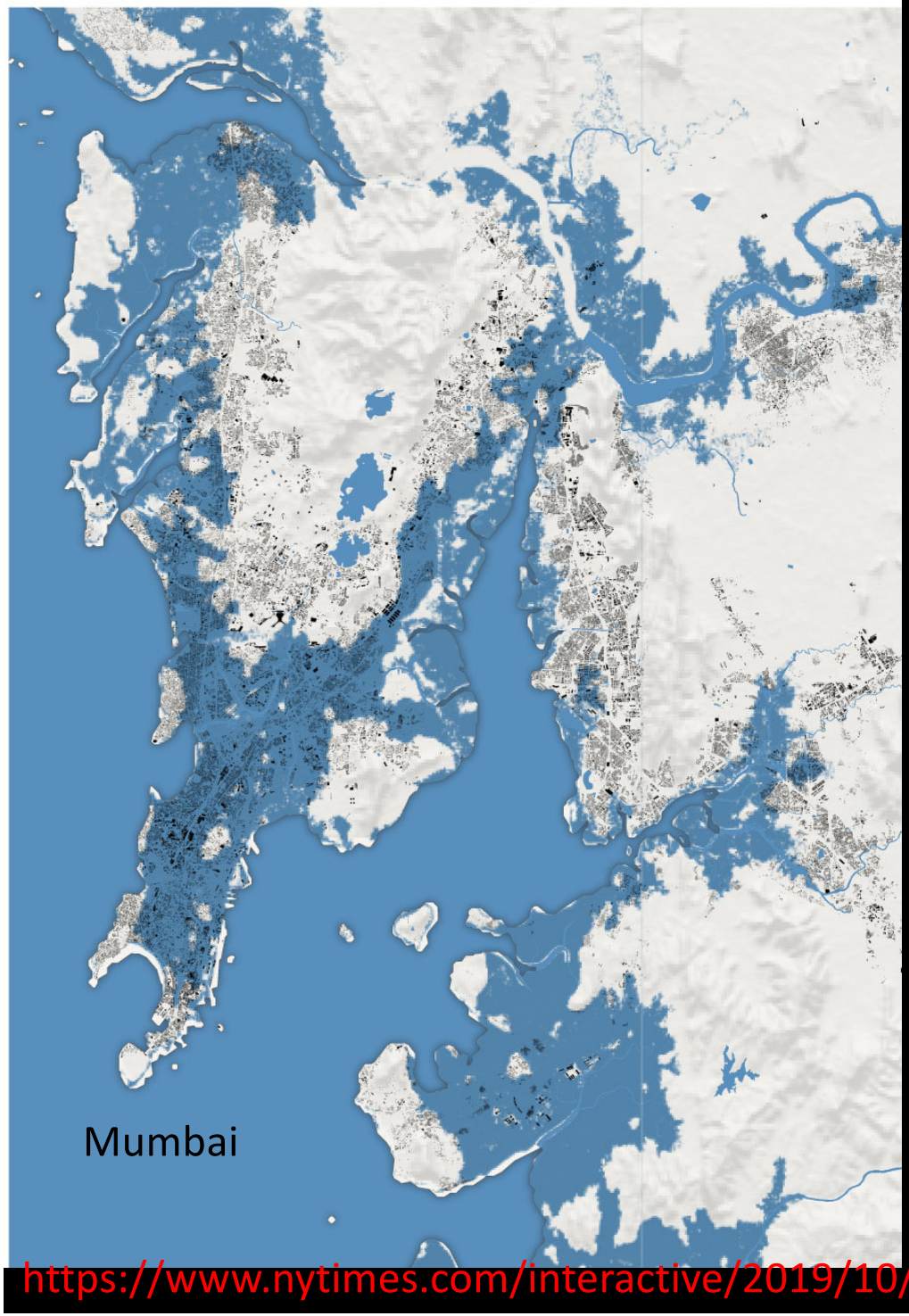
AP

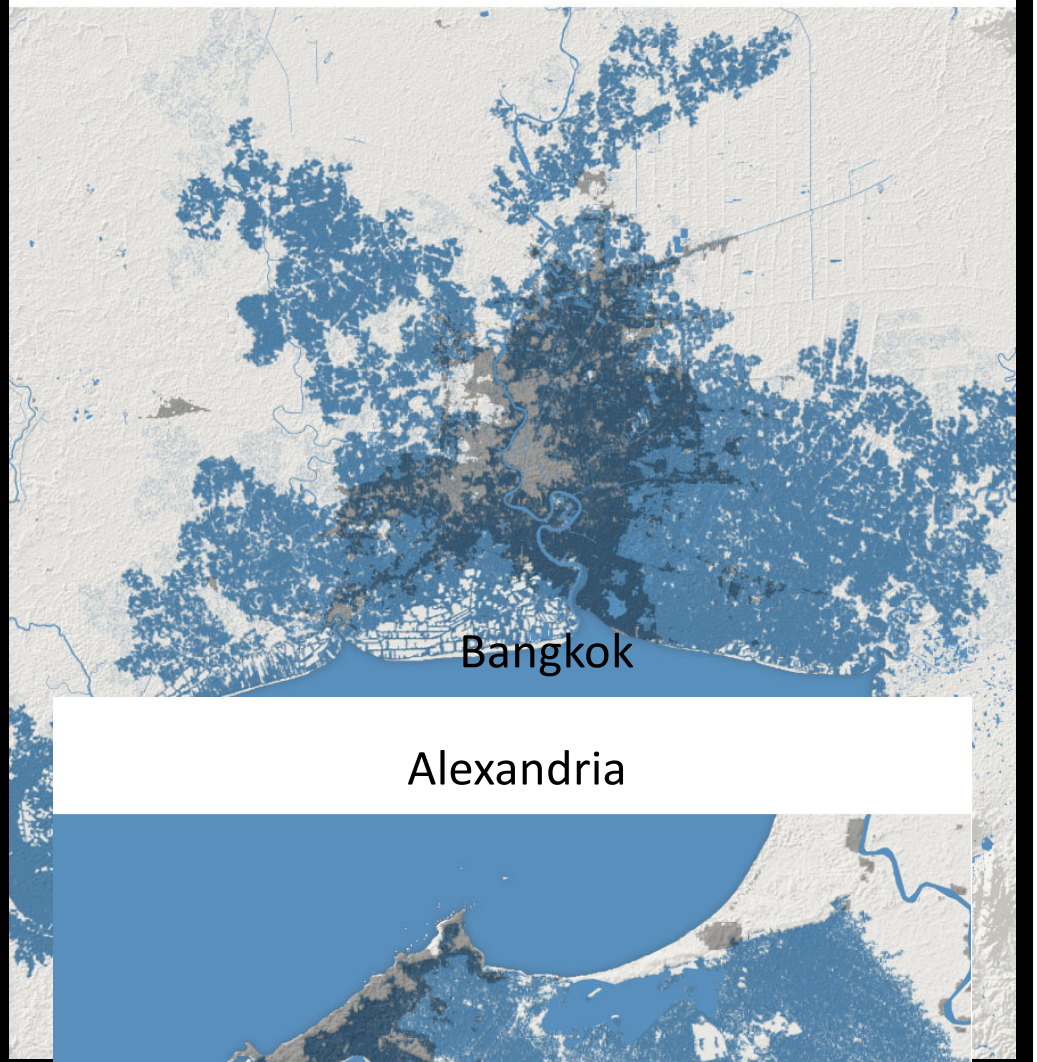

NOAA Projections for Global Sea-Level Rise to 2100
Evans et al., 2016
+6.6 FEET
High
5 FT
+3.9 FEET
Int. High
2 FT
PREDICTED SCENARIOS
+1.6 FEET
Int. Low
+7 INCHES
Low
0
1992 MEAN SEA LEVEL
(THE MIDPOINT OF THE NATIONAL TIDAL DATUM EPOCH (NTDE) CALCULATED FROM 1983–2001 OBSERVATIONS
MEASURED BY TIDAL GAUGES

https://coast.noaa.gov/slr/

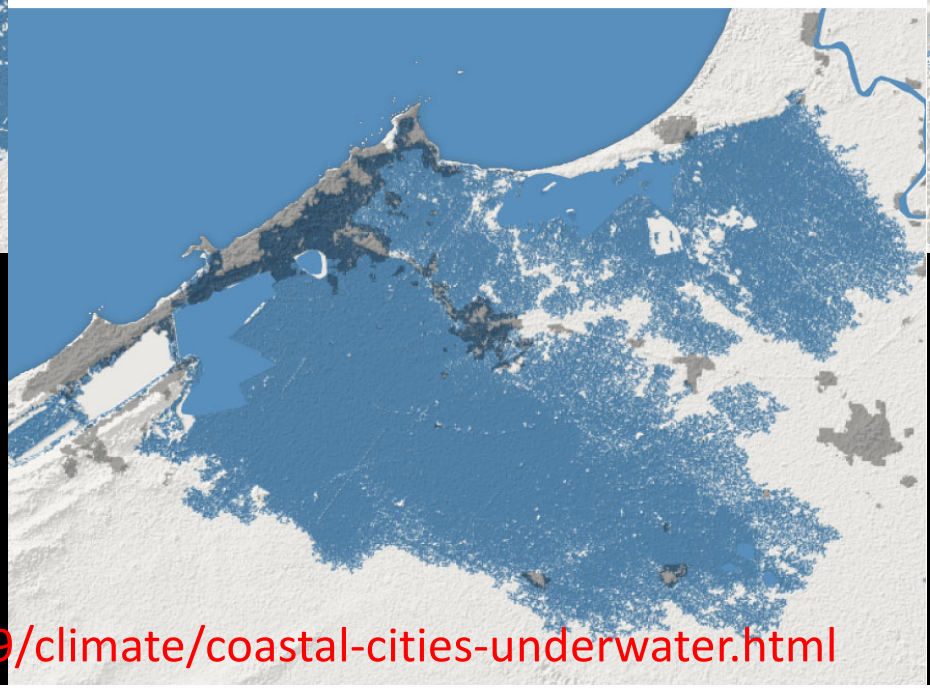



Wash Post





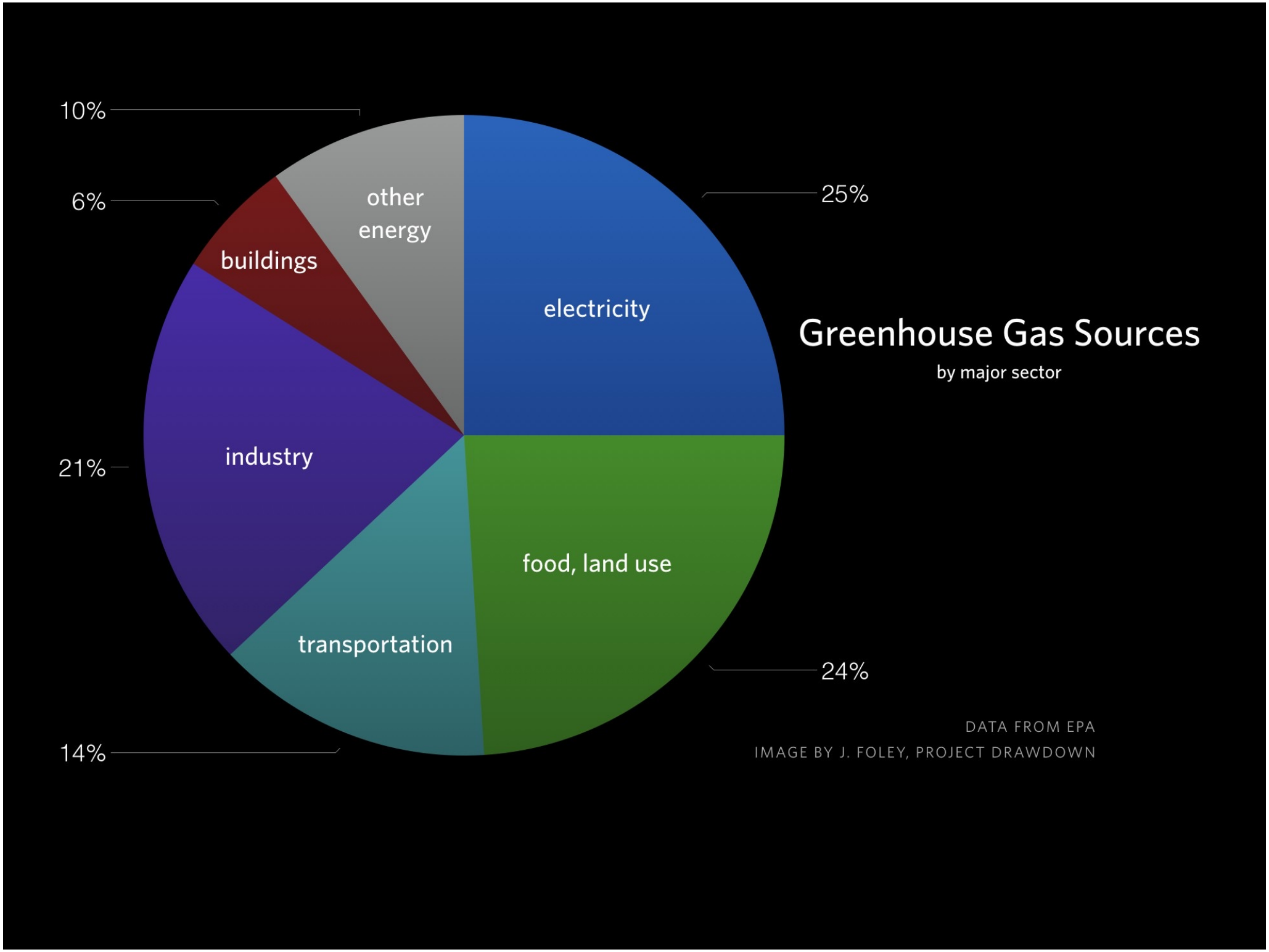
Alexandria

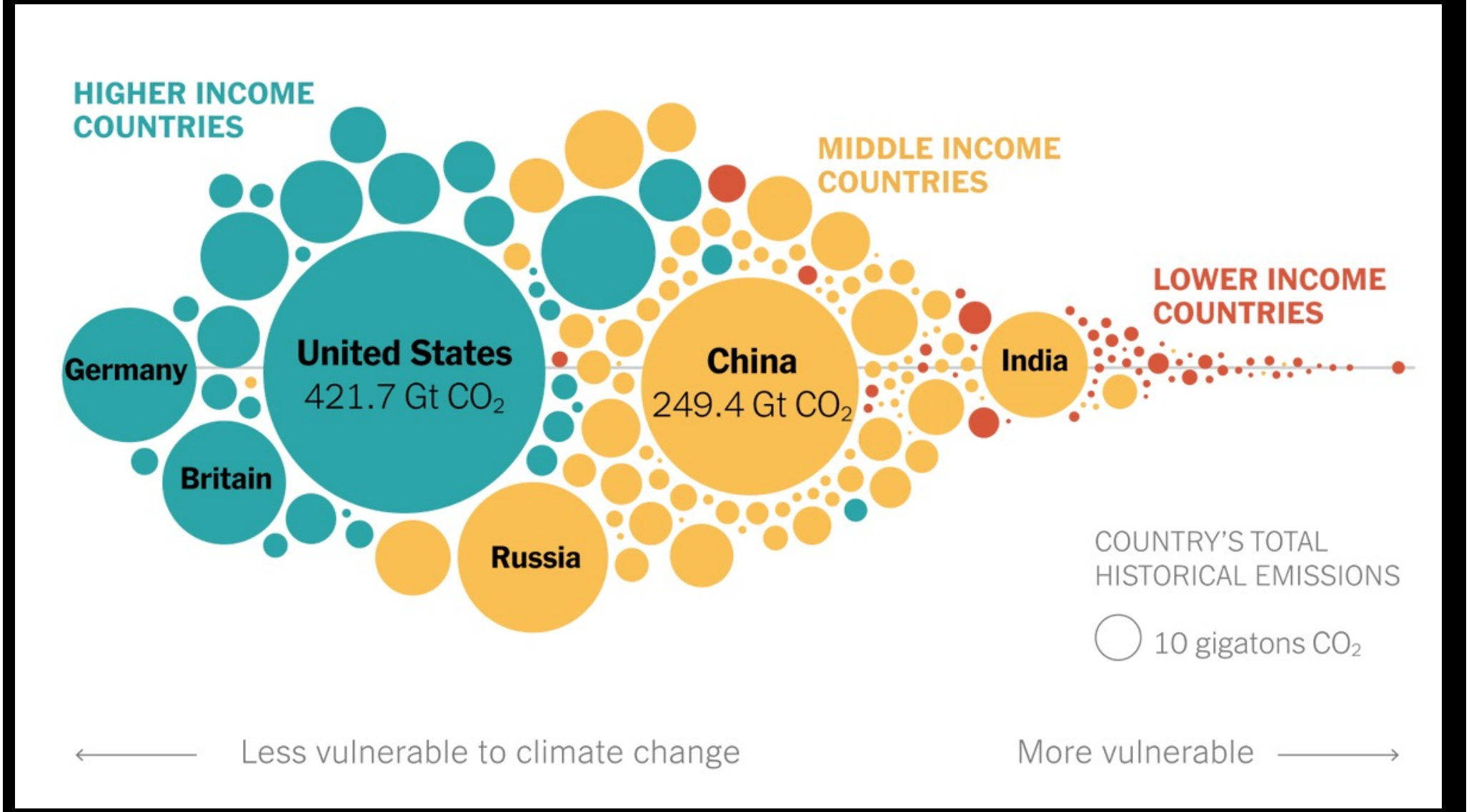


https://www.nytimes.com/interactive/2019/10/29/climate/coastal-cities-underwater.html


So what are *WE* going to do?
Jeff Miller UW-Communications

The worst effects of climate change will be primarily solved by reducing fossil fuel emissions and addressing the needs of the most vulnerable!

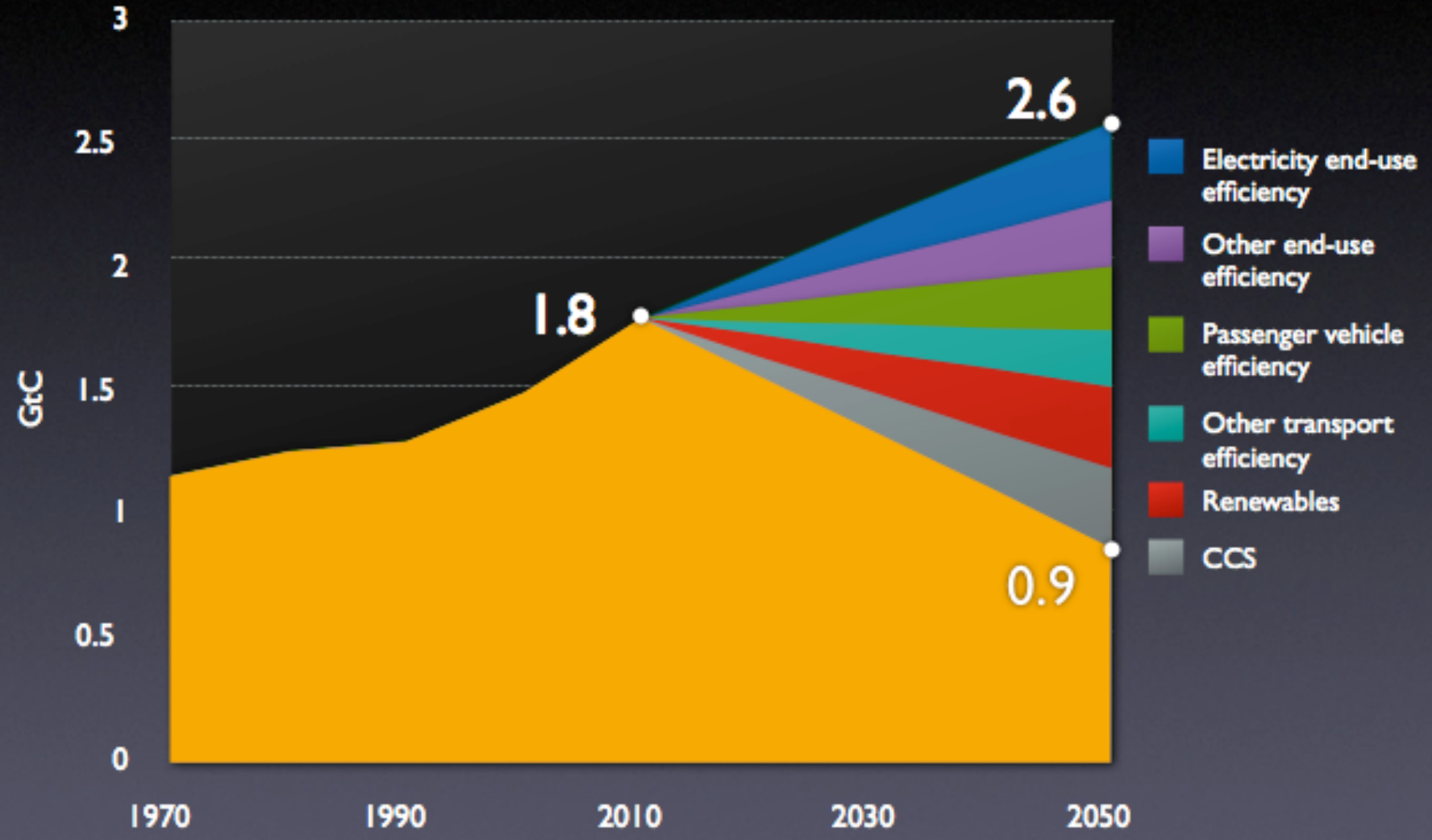

10%
6%
21%
14%
25%
24%
other energy
buildings
industry
transportation
electricity
food, land use
Greenhouse Gas Sources
by major sector
DATA FROM EPA
IMAGE BY J. FOLEY, PROJECT DRAWDOWN


HIGHER INCOME COUNTRIES
MIDDLE INCOME COUNTRIES
LOWER INCOME COUNTRIES
Germany
United States
421.7 Gt CO_2
Britain
Russia
China
249.4 Gt CO_2
India
COUNTRY'S TOTAL HISTORICAL EMISSIONS
10 gigatons CO_2
Less vulnerable to climate change
More vulnerable

U.S. Emissions

After Pacala and Socolow, 2004;
ARI CarBen3 Spreadsheet

- Carbon Capture & Storage



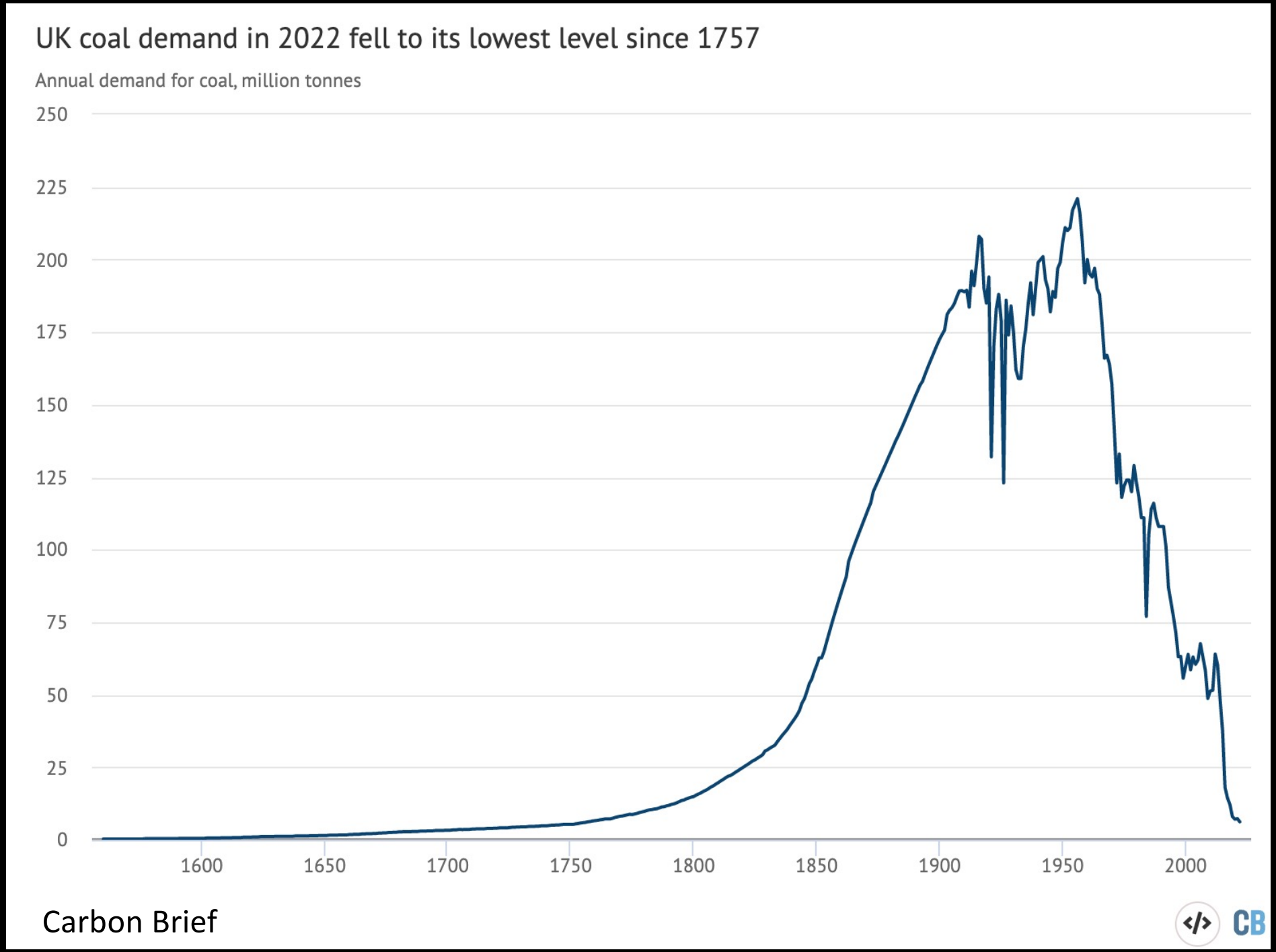
Solutions are abundant

- https://www.drawdown.org/solutions

Solutions by Rank

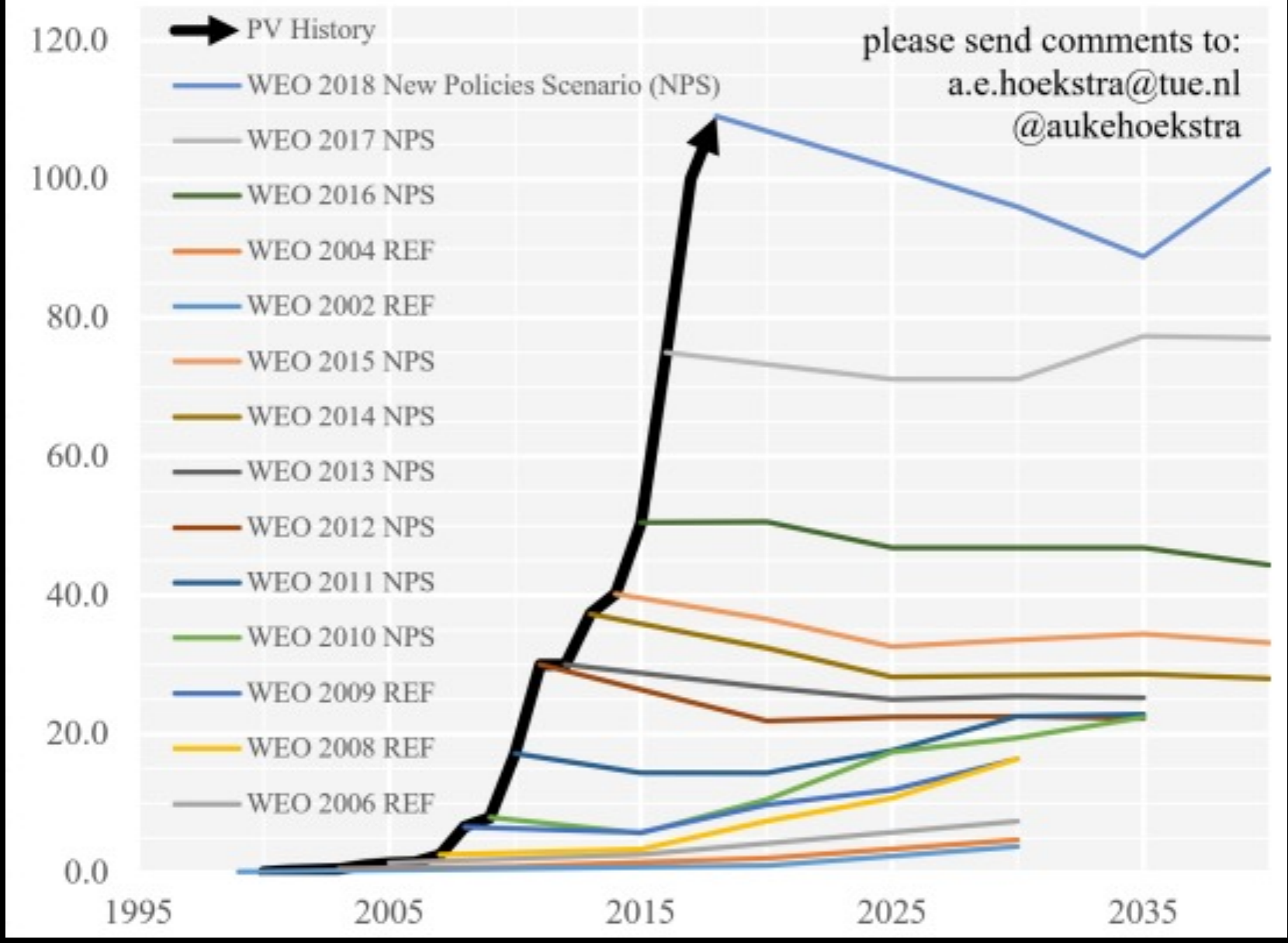
Rank	Solution	Sector	TOTAL ATMOSPHERIC CO2-EQ REDUCTION (GT)	NET COST (BILLIONS US $)	SAVINGS (BILLIONS US $)
1	Refrigerant Management	Materials	89.74	N/A	$-902.77
2	Wind Turbines (Onshore)	Electricity Generation	84.60	$1,225.37	$7,425.00
3	Reduced Food Waste	Food	70.53	N/A	N/A
4	Plant-Rich Diet	Food	66.11	N/A	N/A
5	Tropical Forests	Land Use	61.23	N/A	N/A
6	Educating Girls	Women and Girls	51.48	N/A	N/A
7	Family Planning	Women and Girls	51.48	N/A	N/A
8	Solar Farms	Electricity Generation	36.90	$-80.60	$5,023.84
9	Silvopasture	Food	31.19	$41.59	$699.37
10	Rooftop Solar	Electricity Generation	24.60	$453.14	$3,457.63

SEE ALL SOLUTIONS BY RANK


UK coal demand in 2022 fell to its lowest level since 1757
Annual demand for coal, million tonnes
250
225
200
175
150
125
100
75
50
25
0
1600
1650
1700
1750
1800
1850
1900
1950
2000
Carbon Brief
CB

Annual PV additions: historic data vs IEA WEO predictions

In GW of added capacity per year - source International Energy Agency - World Energy Outlook



Carbon Storage in Earth's Ecosystems

Achieving net-zero by 2050 depends on the Earth's natural carbon sinks.

Forests play a critical role in regulating the global climate. They absorb carbon from the atmosphere and then store it, acting as natural carbon sinks.

Where is Carbon Stored?

There are various carbon pools in a forest ecosystem.

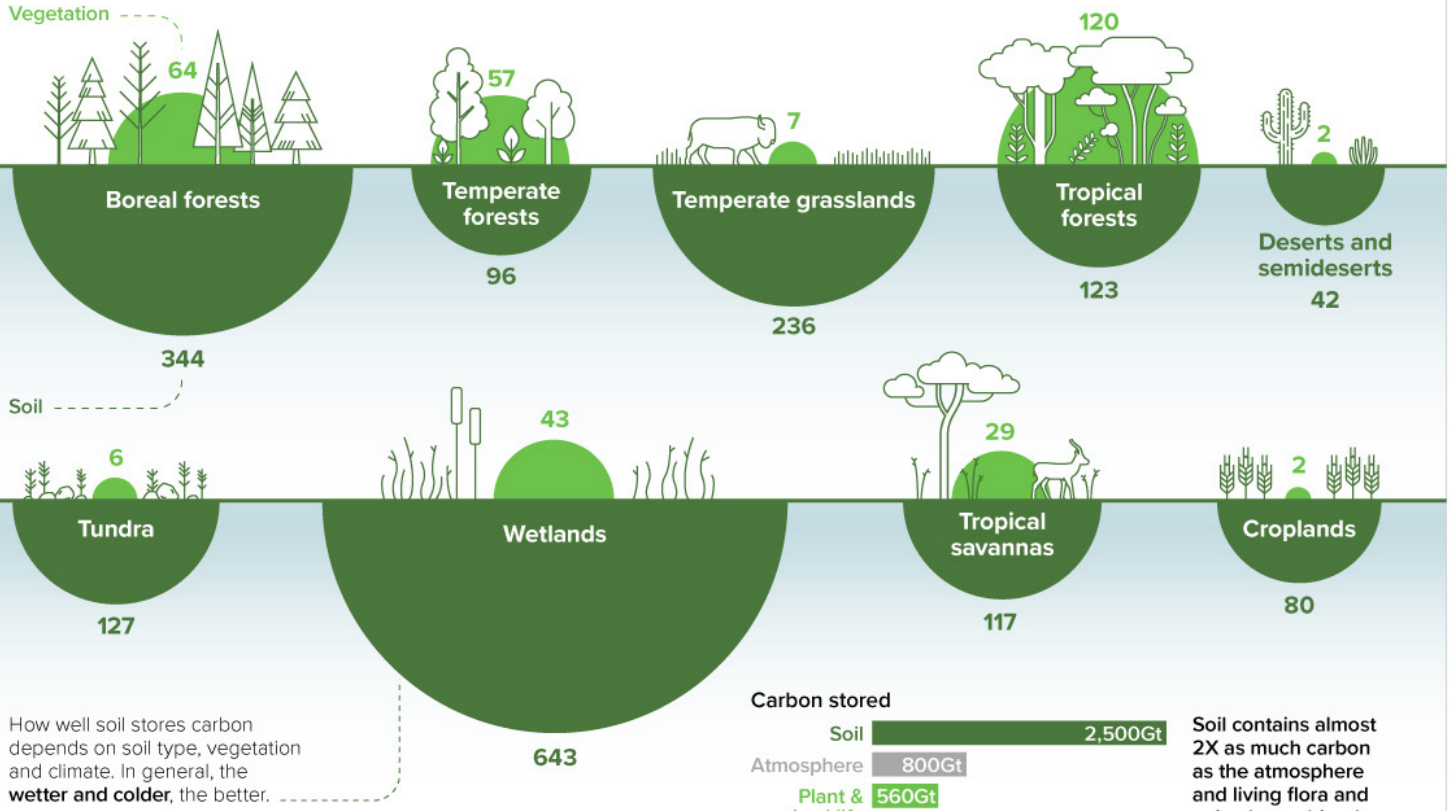
- **Living Biomass** — Leaves, twigs, roots of trees, trunk & branches
- **Dead Biomass** — Woody debris, leaf litter
- **Soil**

Carbon Storage

Tonnes of Carbon per Hectare*

The world's forests absorb around **15.6 gigatonnes** of CO_2 each year. That's around 3X the annual CO_2 emissions of the United States.

However, around **8.1 gigatonnes of CO_2 leaks back into the atmosphere** due to deforestation, fires and other disturbances.



How well soil stores carbon depends on soil type, vegetation and climate. In general, the **wetter and colder**, the better.

Carbon stored

Soil contains almost 2X as much carbon as the atmosphere and living flora and animals combined.

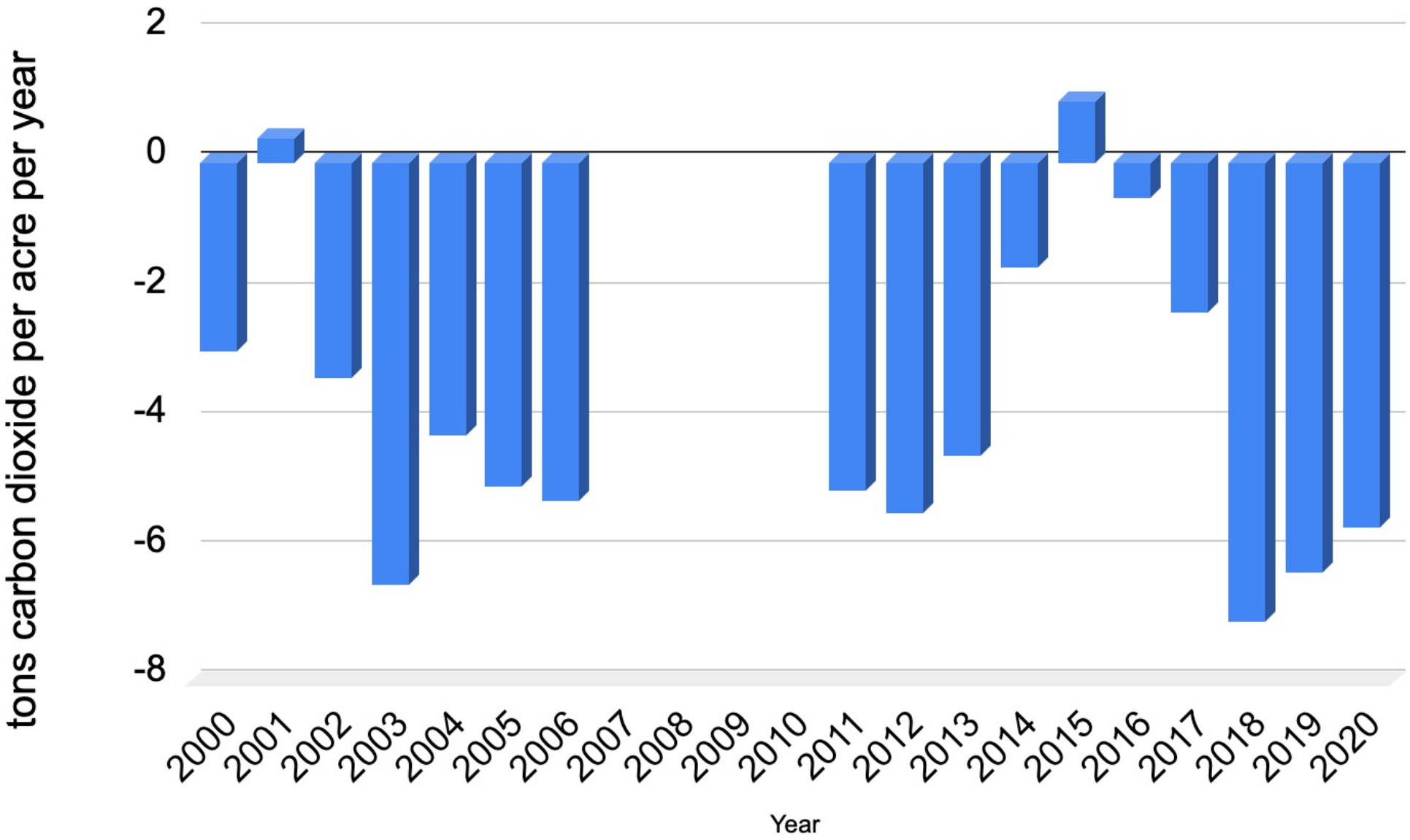
*At a ground depth of one meter

Sources: IPCC; NASA

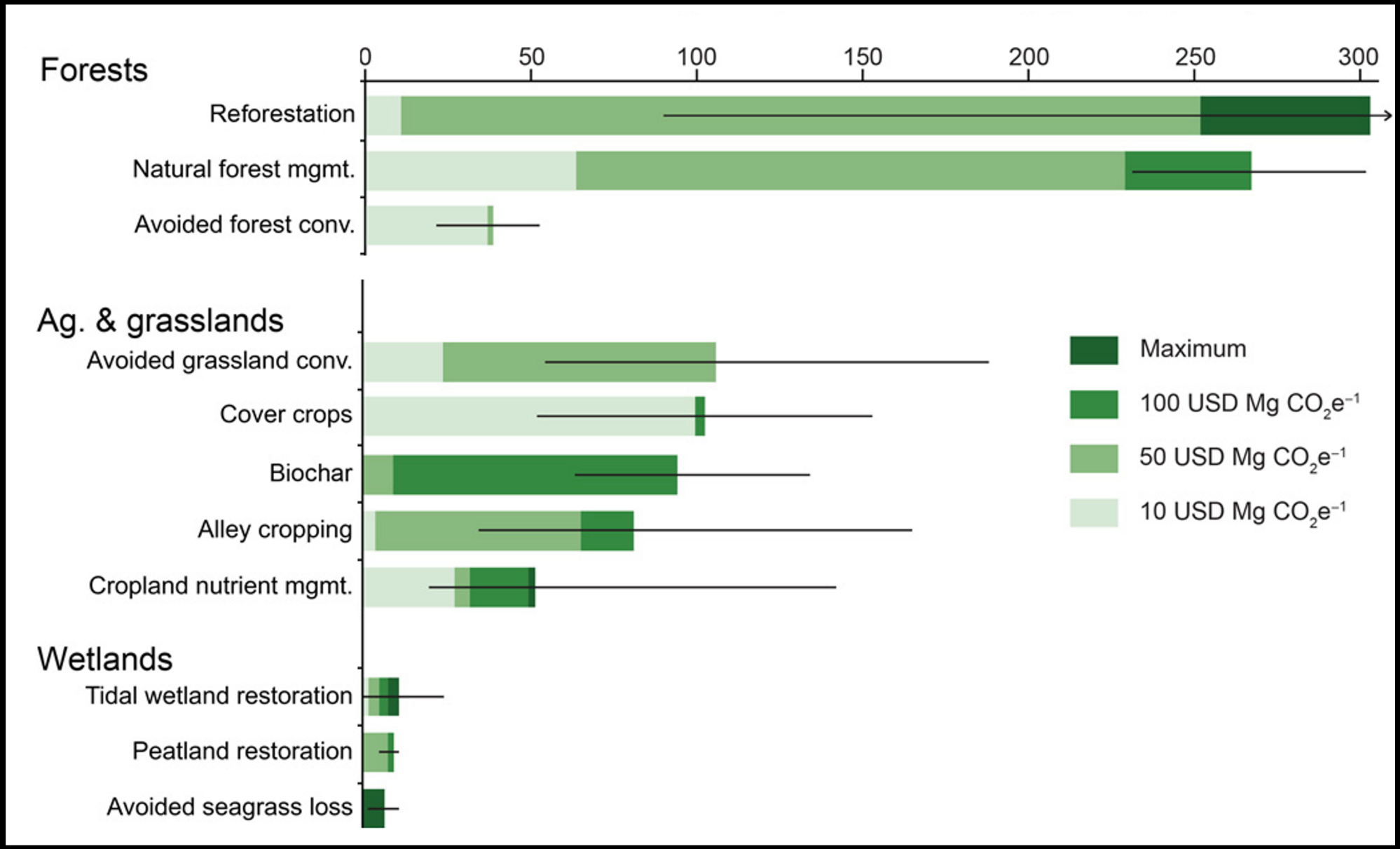
CHEESEHEAD 2019

Chequamegon Heterogeneous Ecosystem Energy-balance Study Enabled by a High-density Extensive Array of Detectors

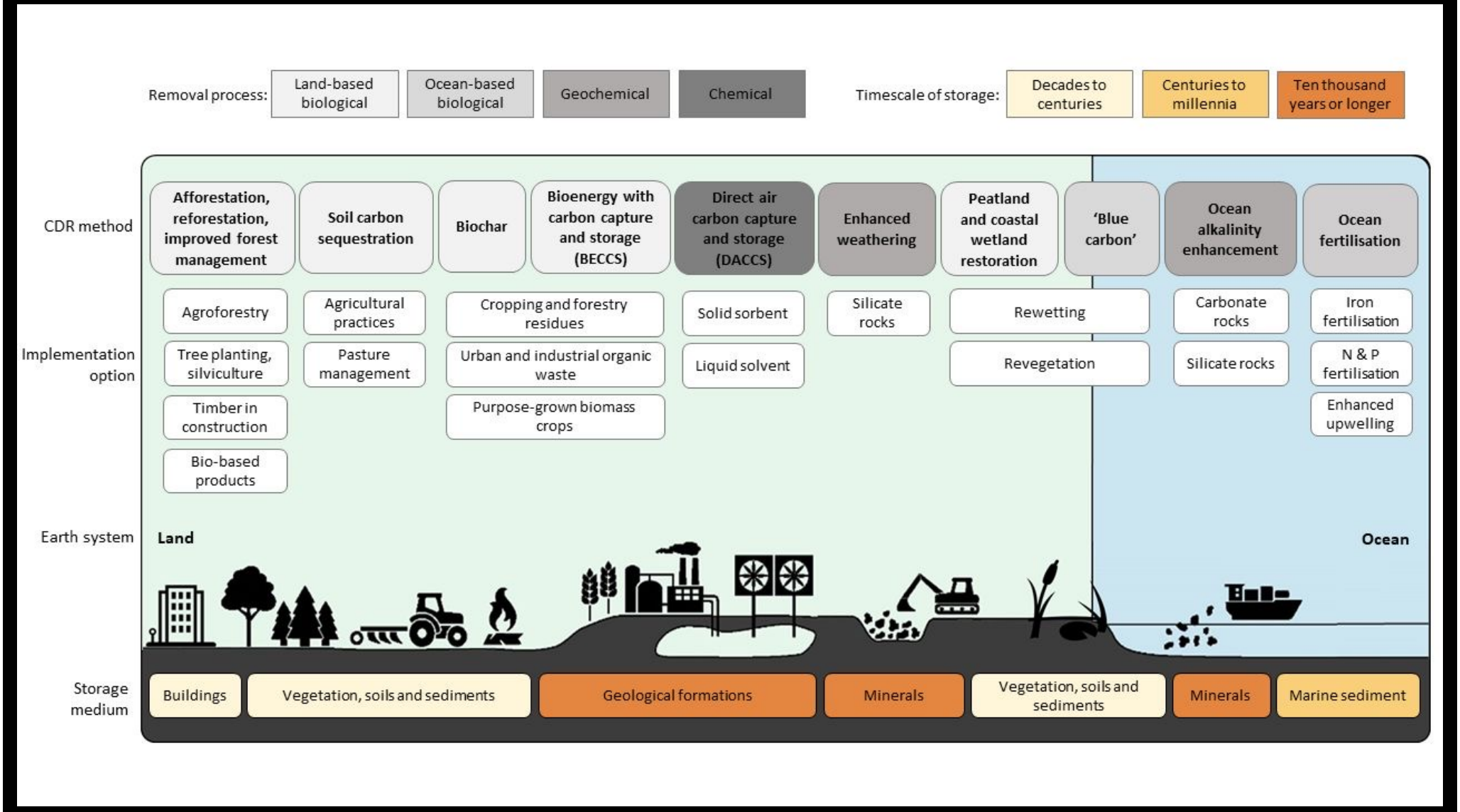
Negative number = taking carbon dioxide out of the air



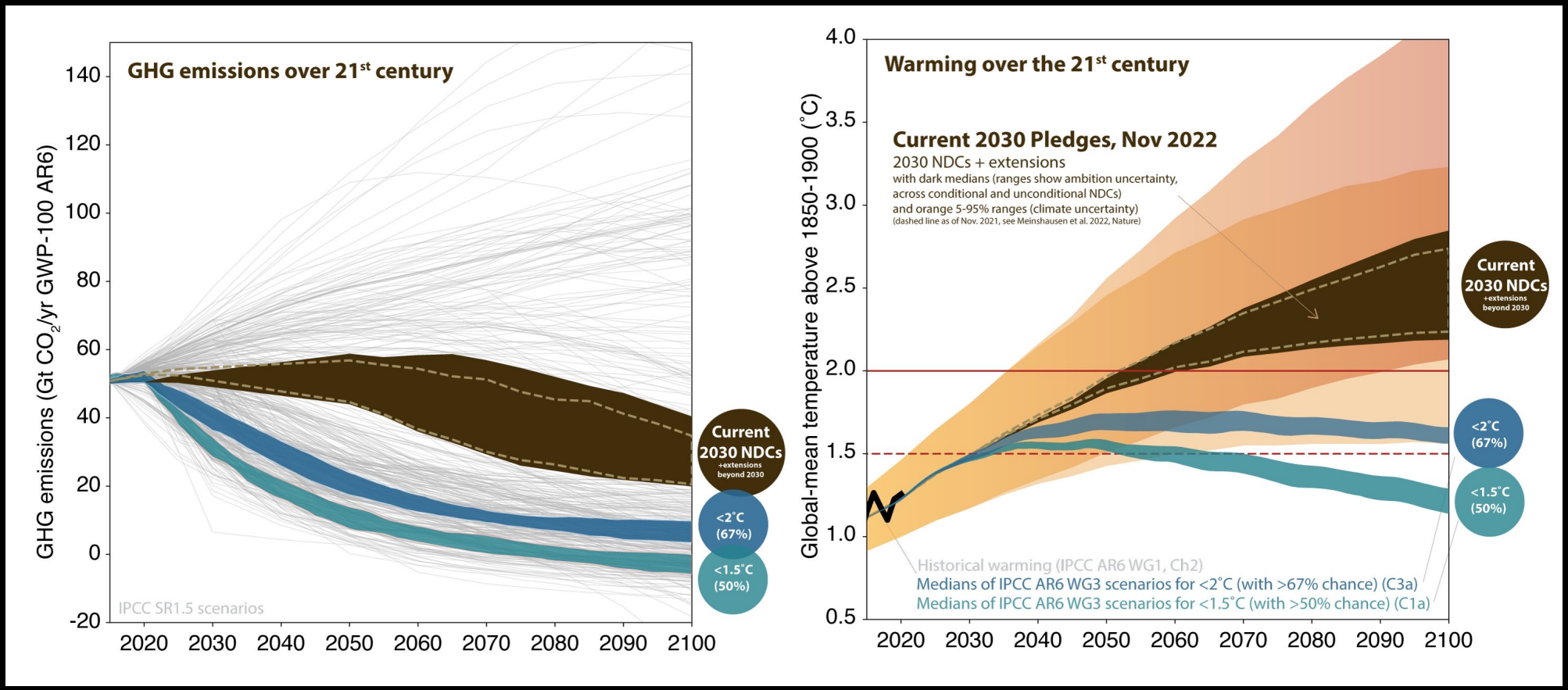
Nature-Based Climate Solutions



From Fargione et al. 2018



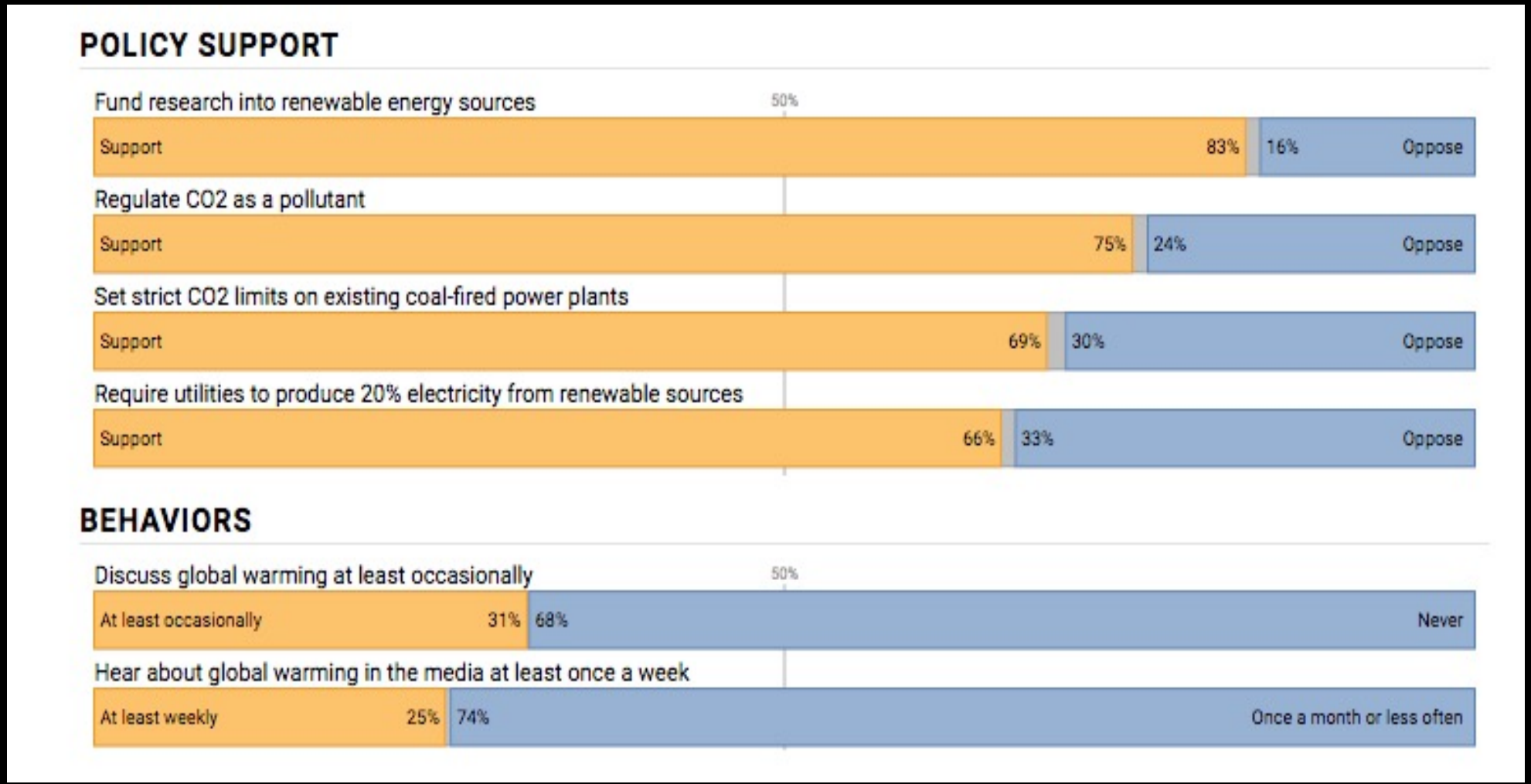
IPCC 6th assessment Working Group 1



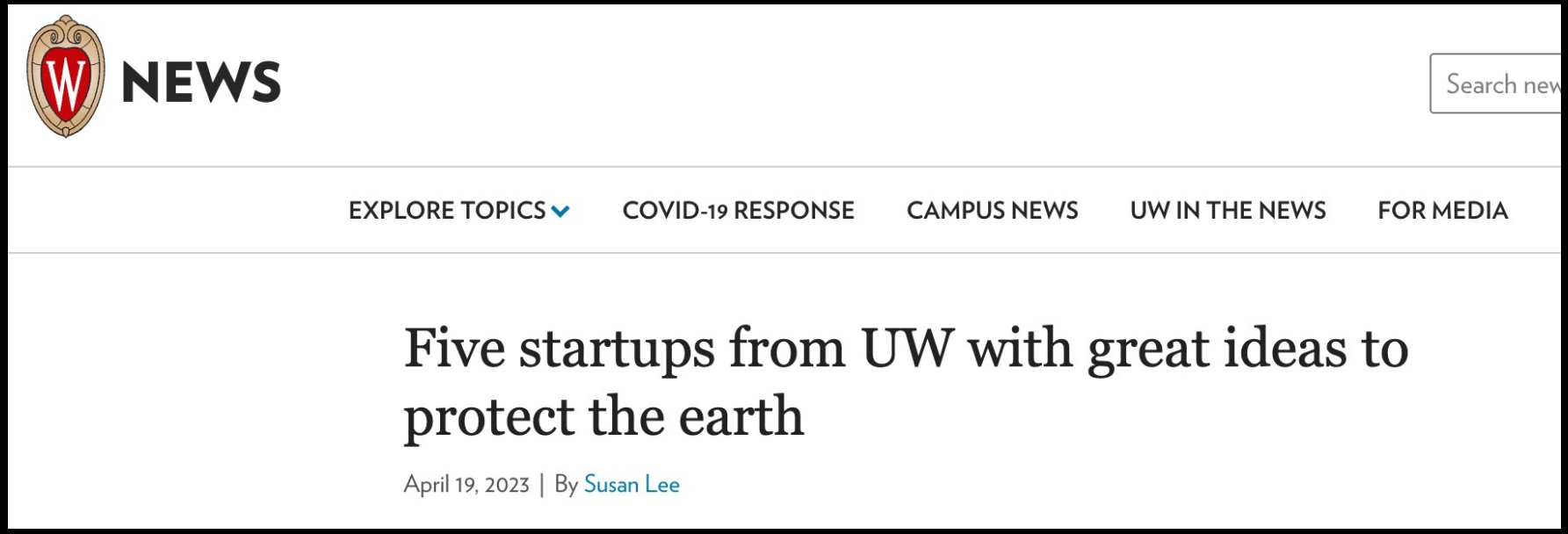
- AFP Getty

Throughout the landmark climate law, passed this month, is language written specifically to address the Supreme Court's justification for reining in the E.P.A., a ruling that was one of the court's most consequential of the term. The new law amends the Clean Air Act, the country's bedrock air-quality legislation, to define the carbon dioxide produced by the burning of fossil fuels as an "air pollutant."

There is support among Wisconsin residents



http://climatecommunication.yale.edu/visualizations-data/ycom-us-2016/



Removing salt from water
ChloBis Water, Inc.: Energy-efficient water desalination technology

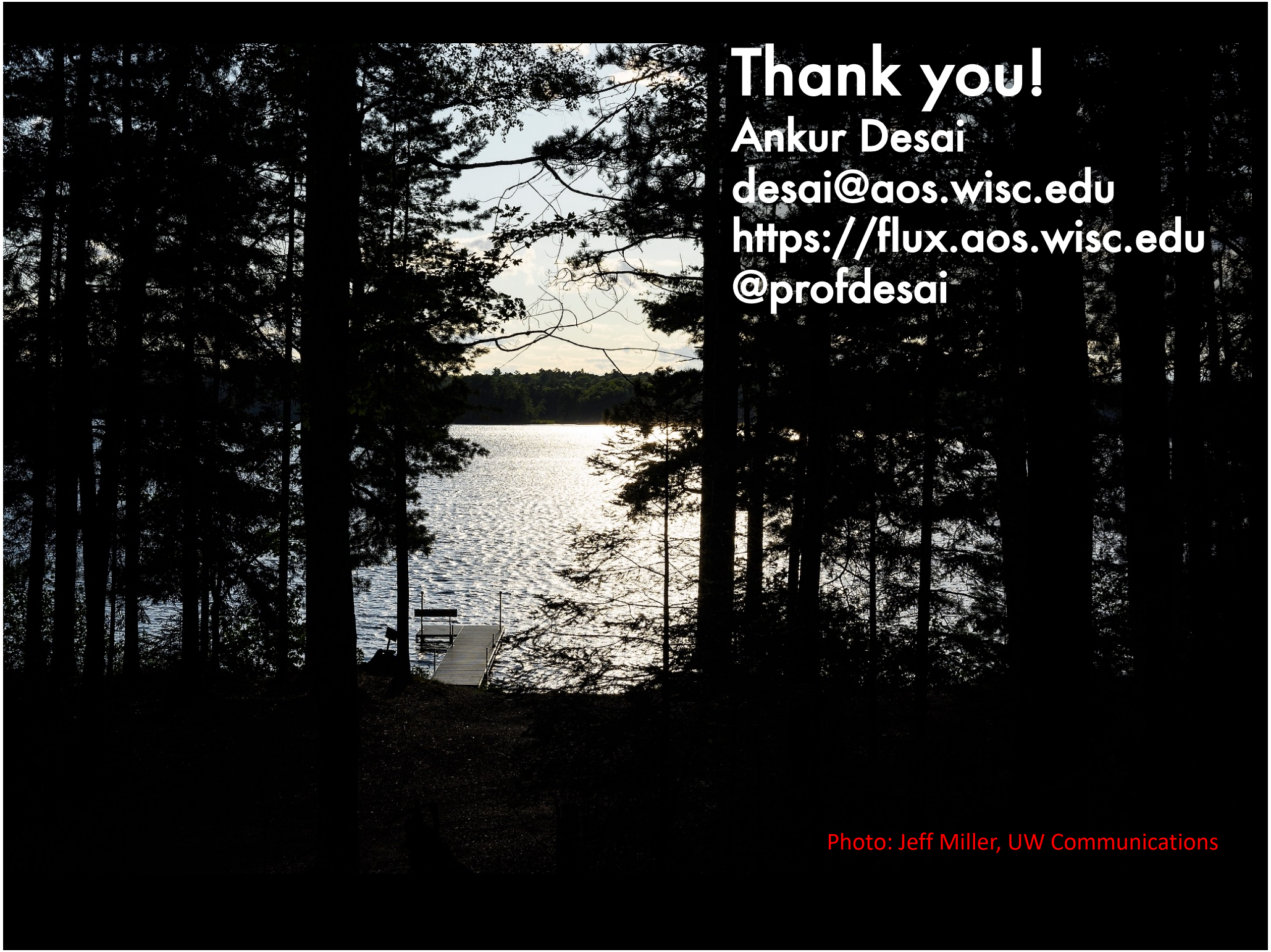
Capturing and storing carbon dioxide
Earth RepAIR, Inc.: Efficient carbon dioxide capture and upcycling

Building sustainable batteries
Flux XII: Renewable long-duration energy storage

Making feedstock into useful chemicals
Pyran: Renewable alternatives to petroleum-based chemicals

Fusion as an alternative source of heat
Realta Fusion: Industrial heat and power from fusion


NASA



Thank you!

Ankur Desai
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https://flux.aos.wisc.edu
@profdesai

Photo: Jeff Miller, UW Communications