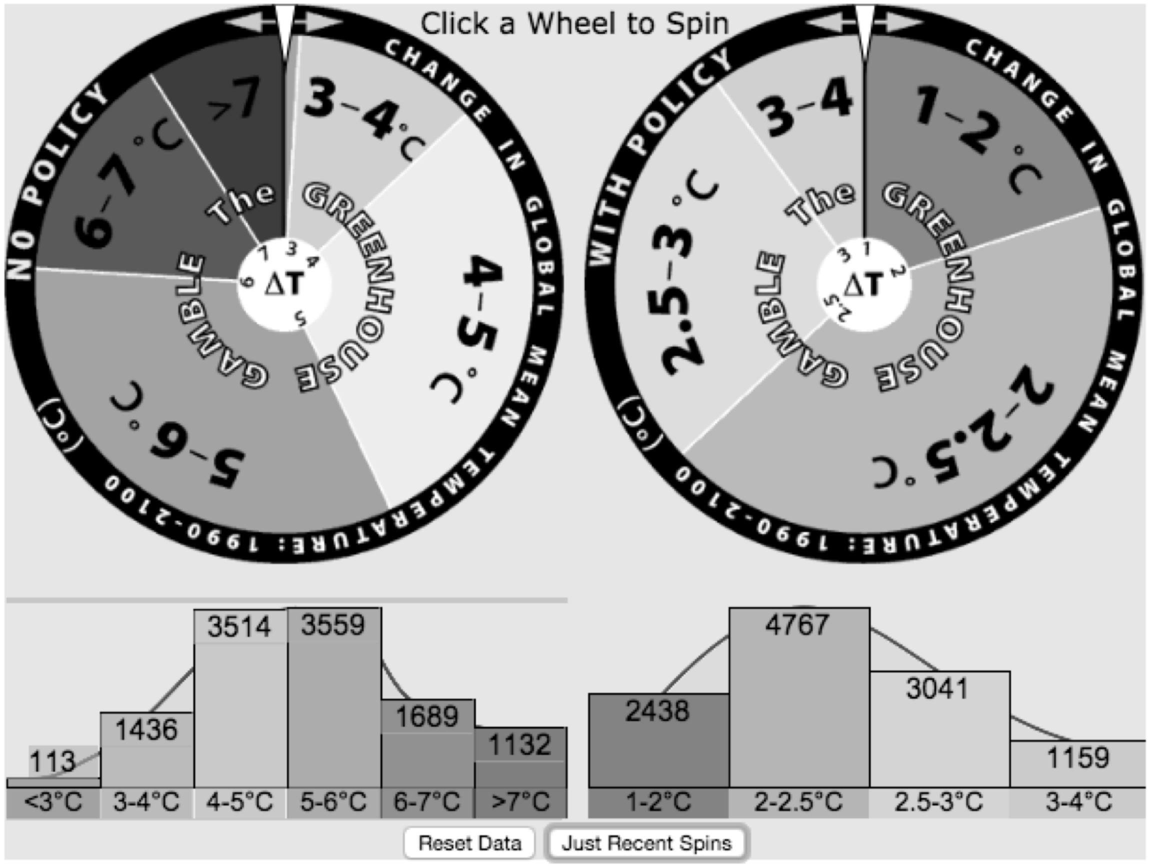
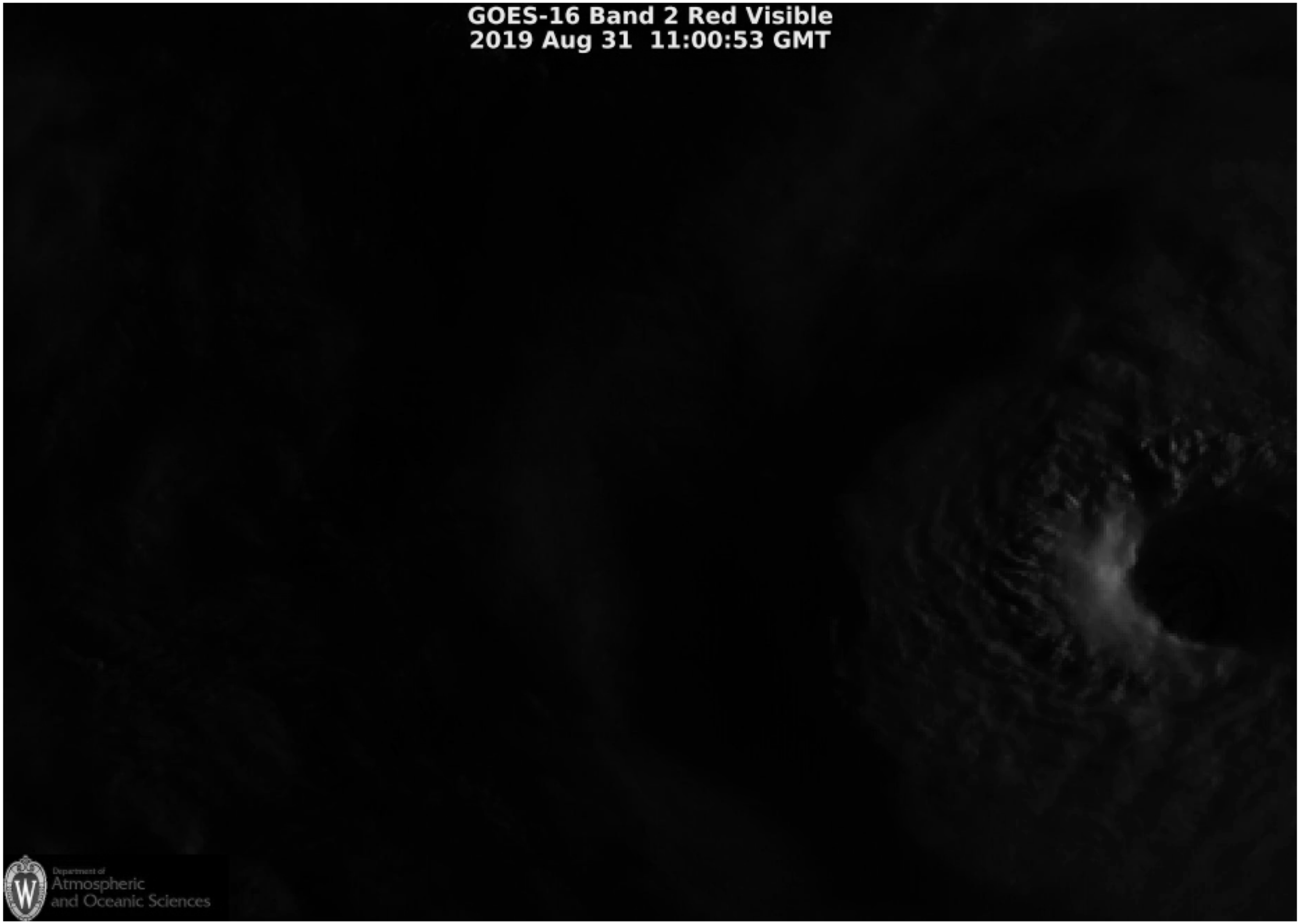
Risky business and the management of climate change

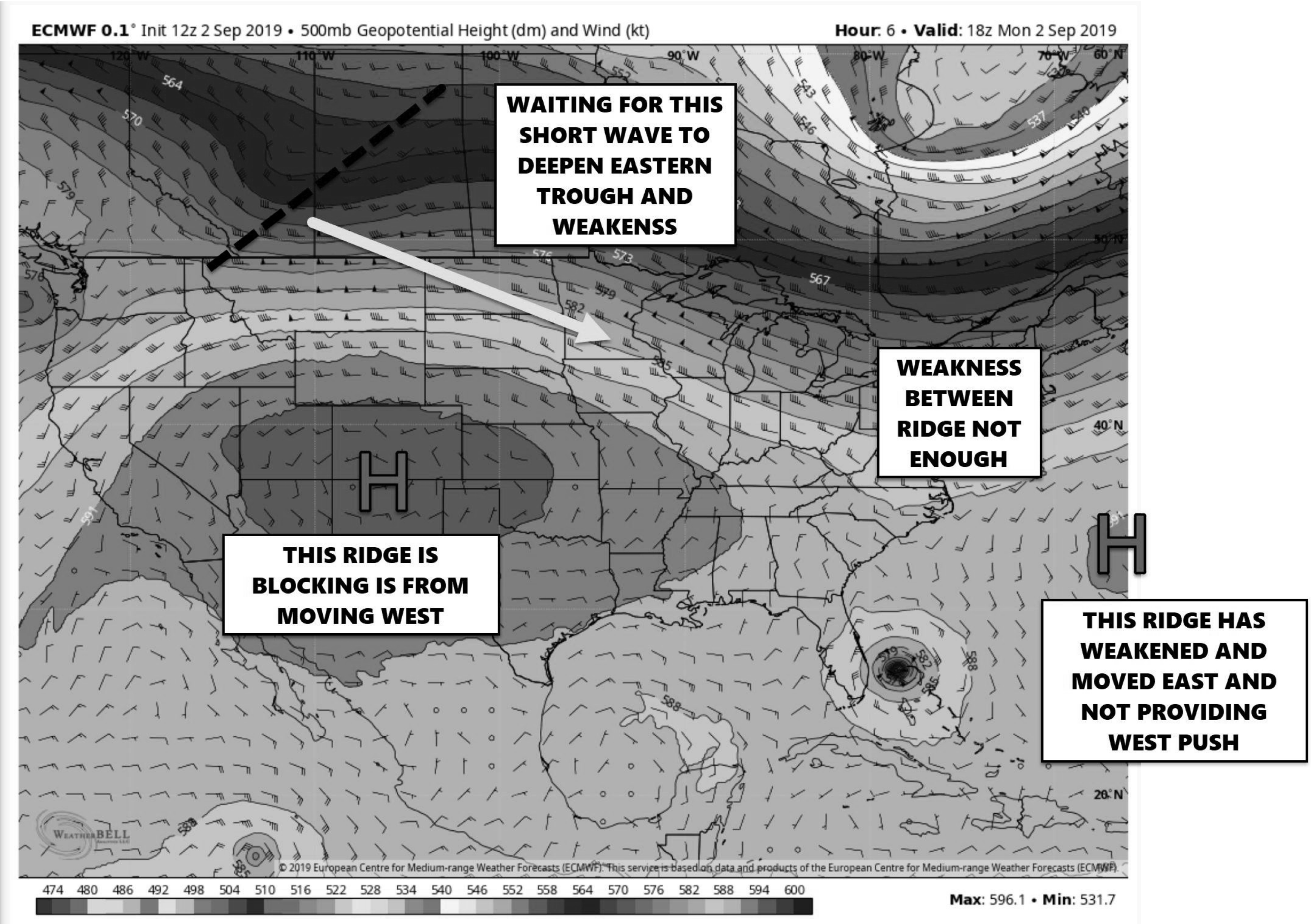


Ankur Desai
Dept of Atmospheric & Oceanic Sciences
University of Wisconsin-Madison

Oct 14, 2019 RMI 650



UW-Madison SSEC

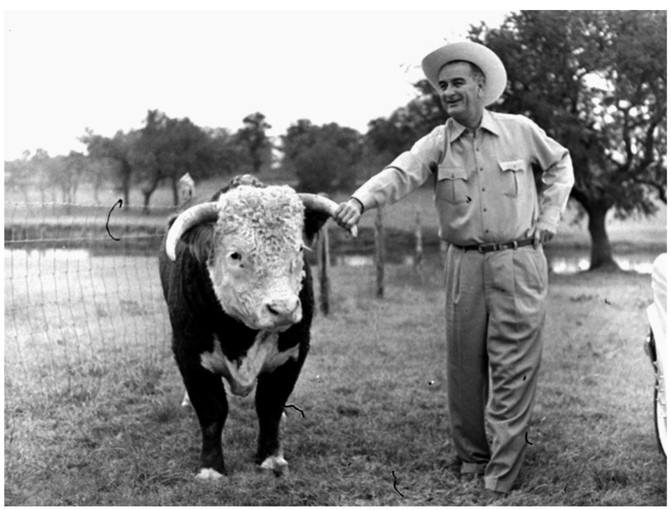

ECMWF 0.1° Init 12z 2 Sep 2019 • 500mb Geopotential Height (dm) and Wind (kt)
Hour: 6 • Valid: 18z Mon 2 Sep 2019
WAITING FOR THIS SHORT WAVE TO DEEPEN EASTERN TROUGH AND WEAKENSS
WEAKNESS BETWEEN RIDGE NOT ENOUGH
H
THIS RIDGE IS BLOCKING IS FROM MOVING WEST
H
THIS RIDGE HAS WEAKENED AND MOVED EAST AND NOT PROVIDING WEST PUSH
© 2019 European Centre for Medium-range Weather Forecasts (ECMWF). This service is based on data and products of the European Centre for Medium-range Weather Forecasts (ECMWF).
474 480 486 492 498 504 510 516 522 528 534 540 546 552 558 564 570 576 582 588 594 600
Max: 596.1 • Min: 531.7

Washington Post

Bottom Line

- Climate is warming and change is projected to **accelerate** in next century with 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

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.

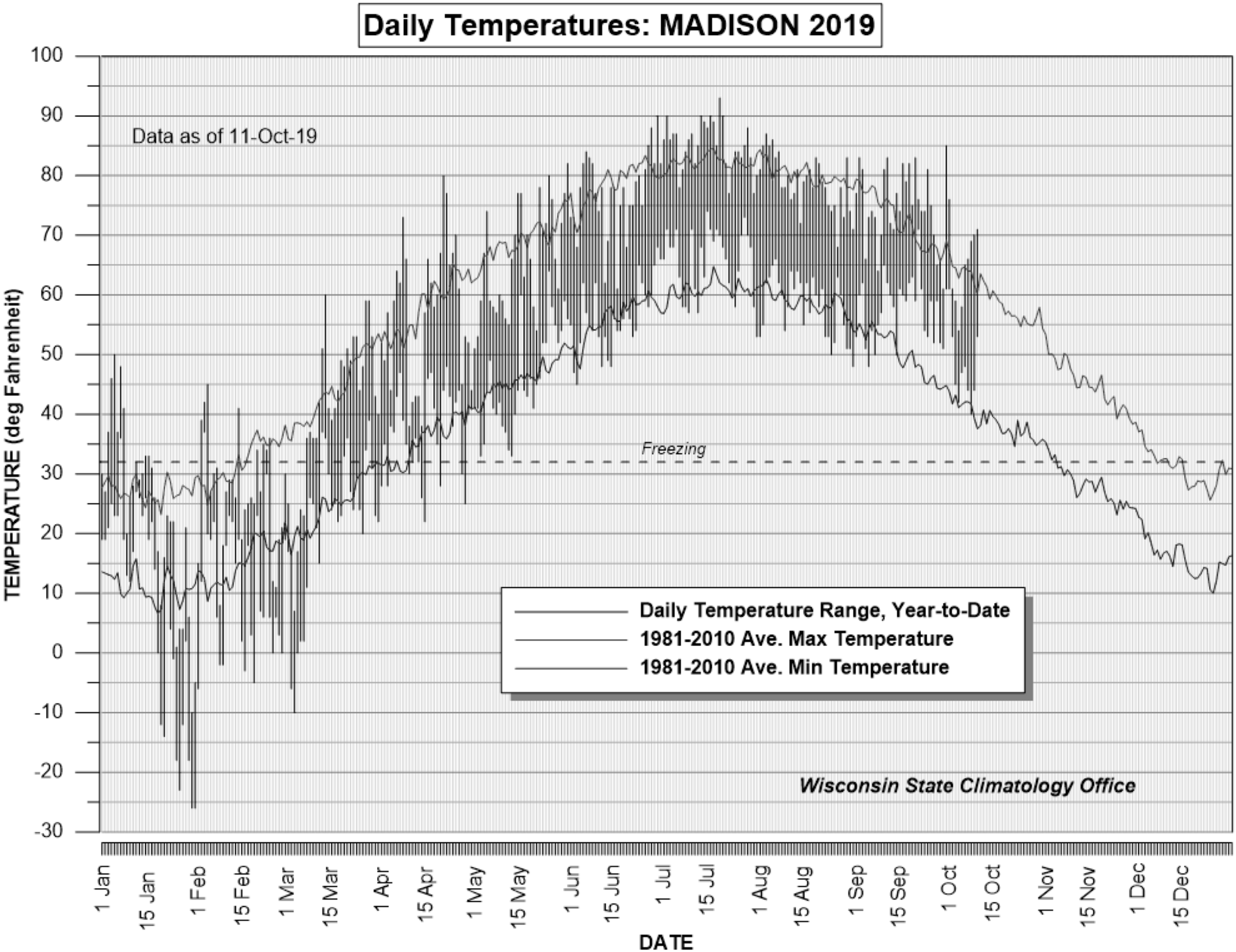
Science Notes and News.

COAL CONSUMPTION AFFECTING CLIMATE.

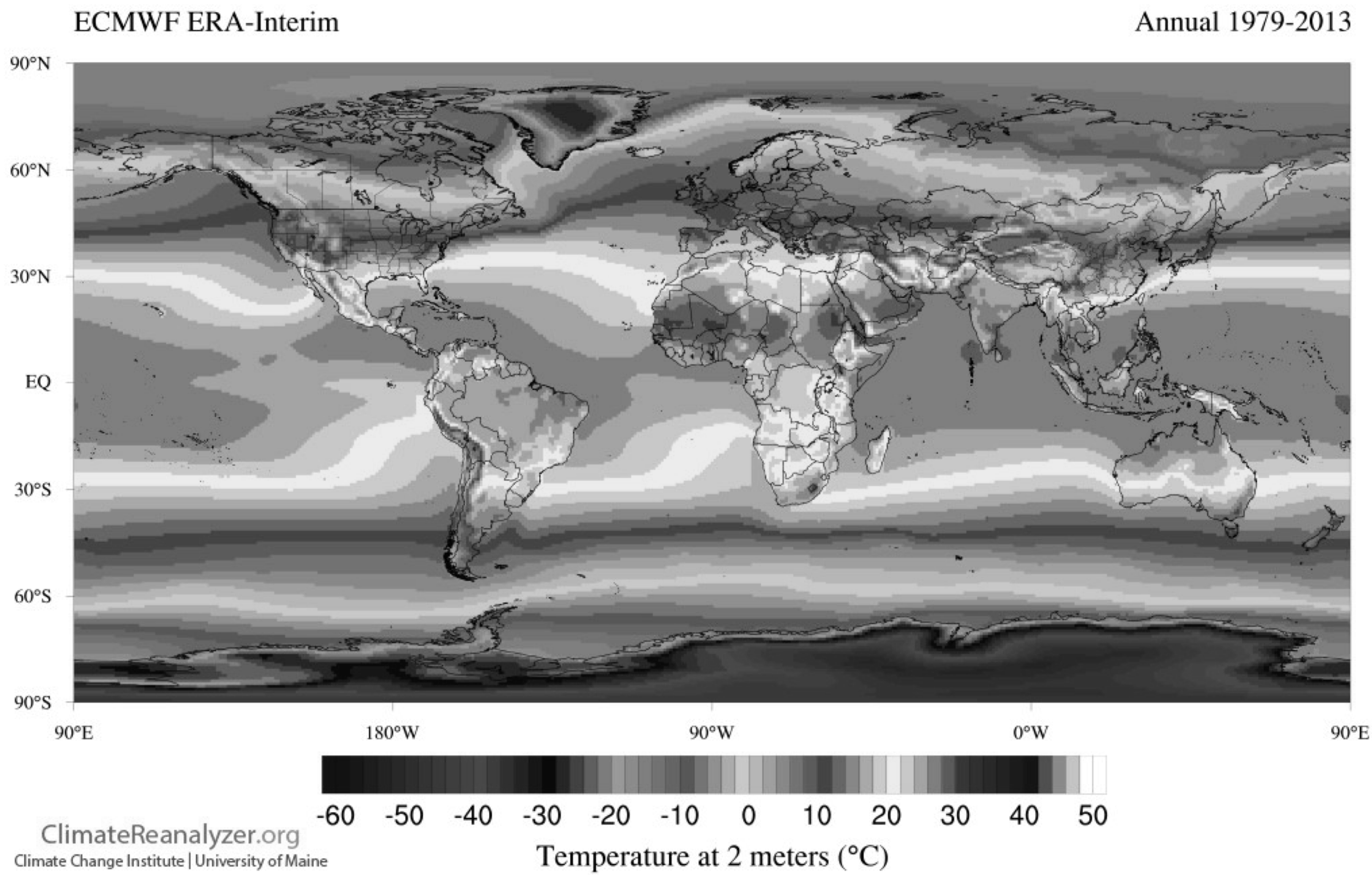
The furnaces of the world are now burning about 2,000,000,000 tons of coal a year. When this is burned, uniting with oxygen, it adds about 7,000,000,000 tons of carbon dioxide to the atmosphere yearly. This tends to make the air a more effective blanket for the earth and to raise its temperature. The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

What is Climate?

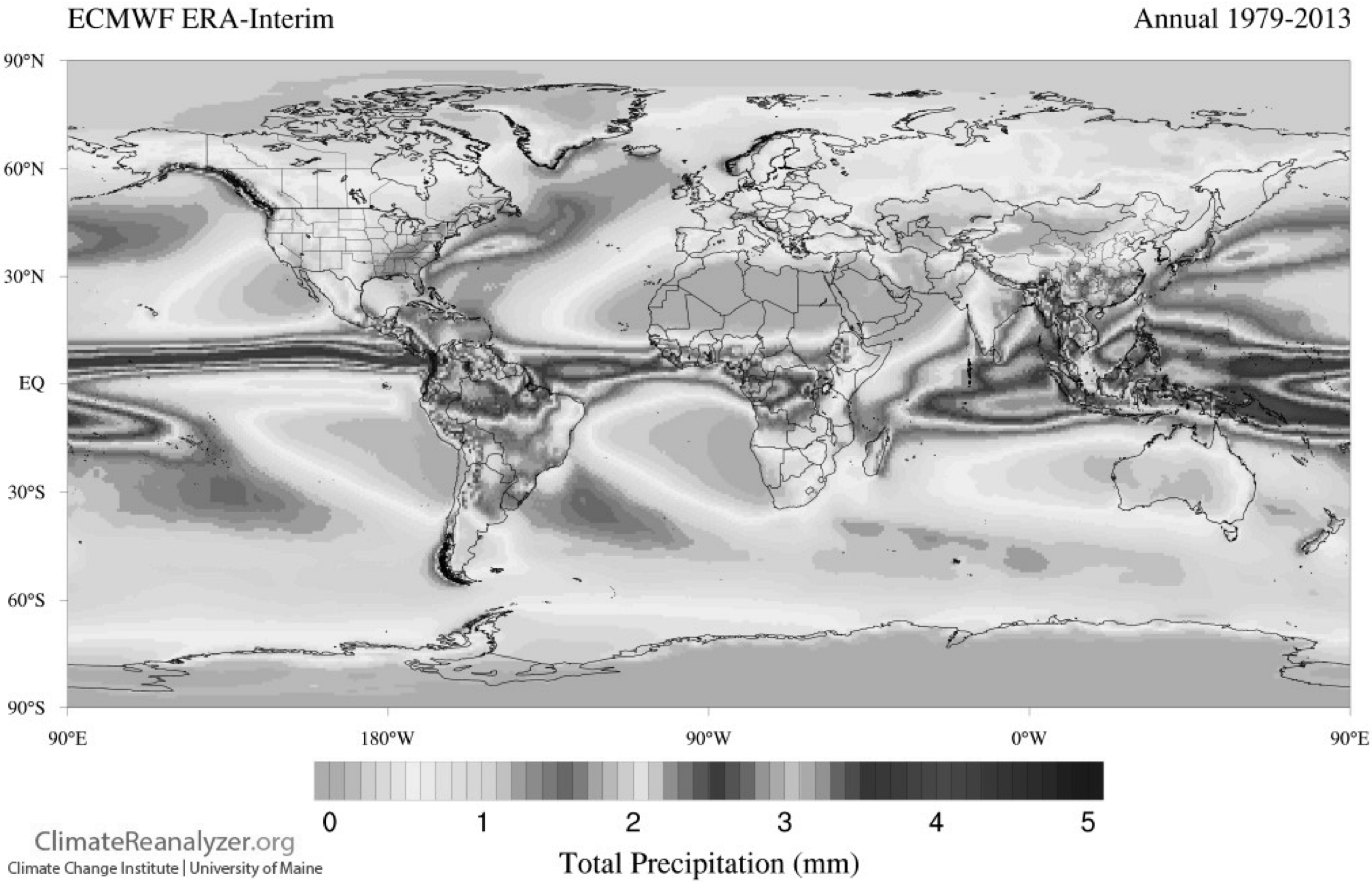
- Climate is the average of weather
  - “Climate is what you expect, weather is what you get” –Andrew John Herbertson
  - “Climate is your personality, weather is your mood” –Marshall Shepherd
- Climate changes naturally (over eons) and by humans (over centuries)



Daily Temperatures: MADISON 2019
Data as of 11-Oct-19
TEMPERATURE (deg Fahrenheit)
100
90
80
70
60
50
40
30
20
10
0
-10
-20
-30
Freezing
Daily Temperature Range, Year-to-Date
1981-2010 Ave. Max Temperature
1981-2010 Ave. Min Temperature
Wisconsin State Climatology Office
1 Jan
15 Jan
1 Feb
15 Feb
1 Mar
15 Mar
1 Apr
15 Apr
1 May
15 May
1 Jun
15 Jun
1 Jul
15 Jul
1 Aug
15 Aug
1 Sep
15 Sep
1 Oct
15 Oct
1 Nov
15 Nov
1 Dec
15 Dec
DATE

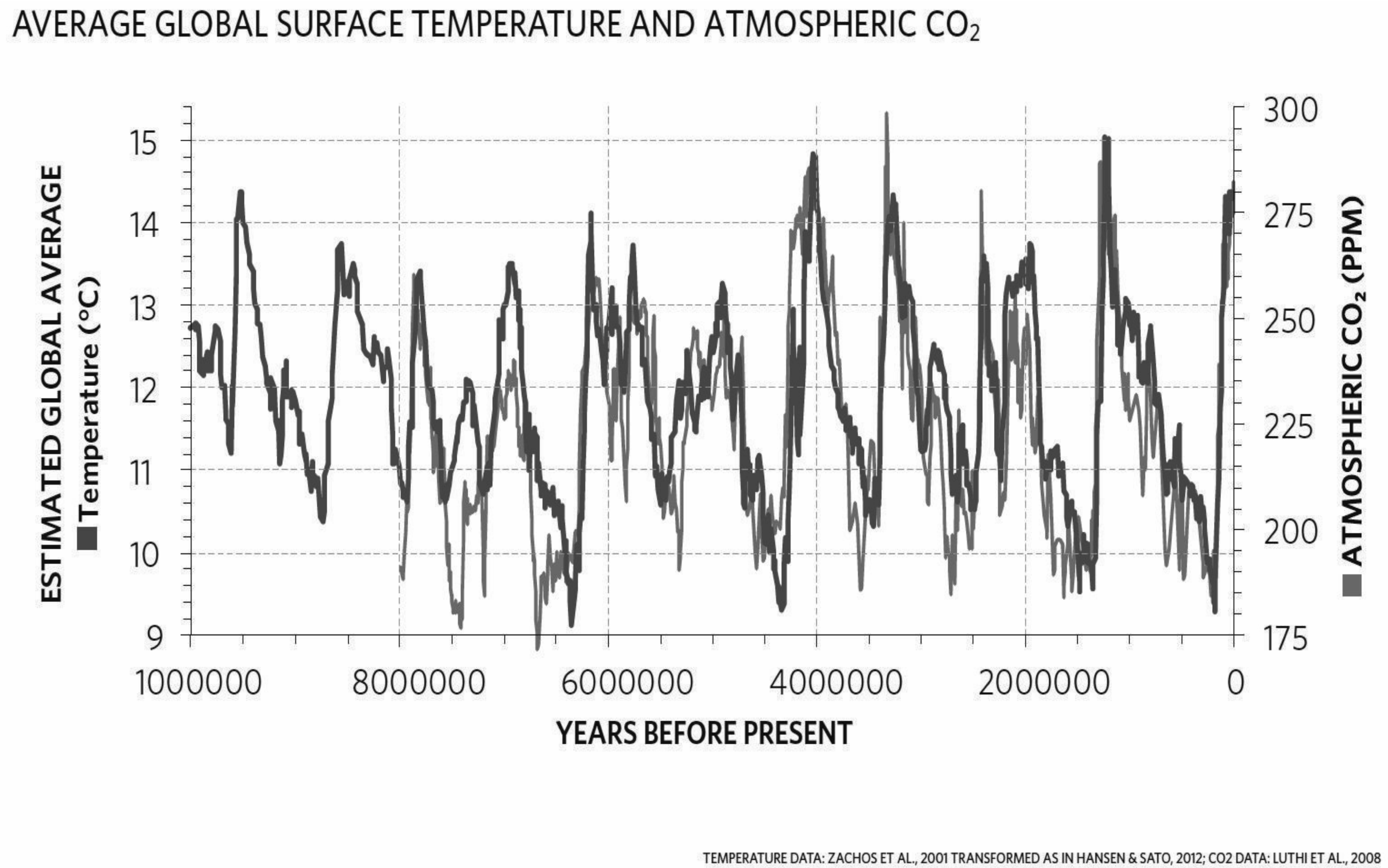


http://cci-reanalyzer.org/



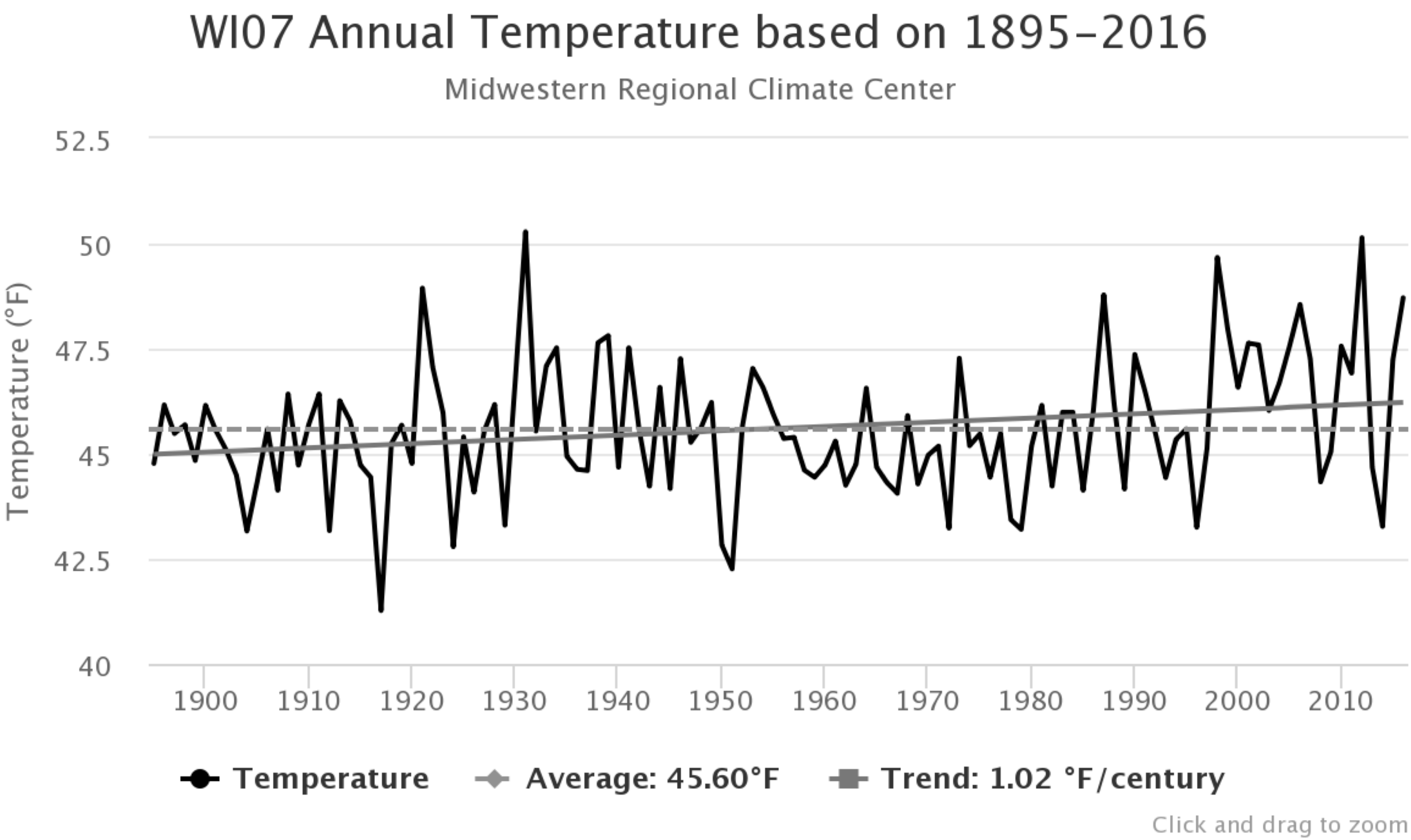
http://cci-reanalyzer.org/

Climate changes naturally AND by humans

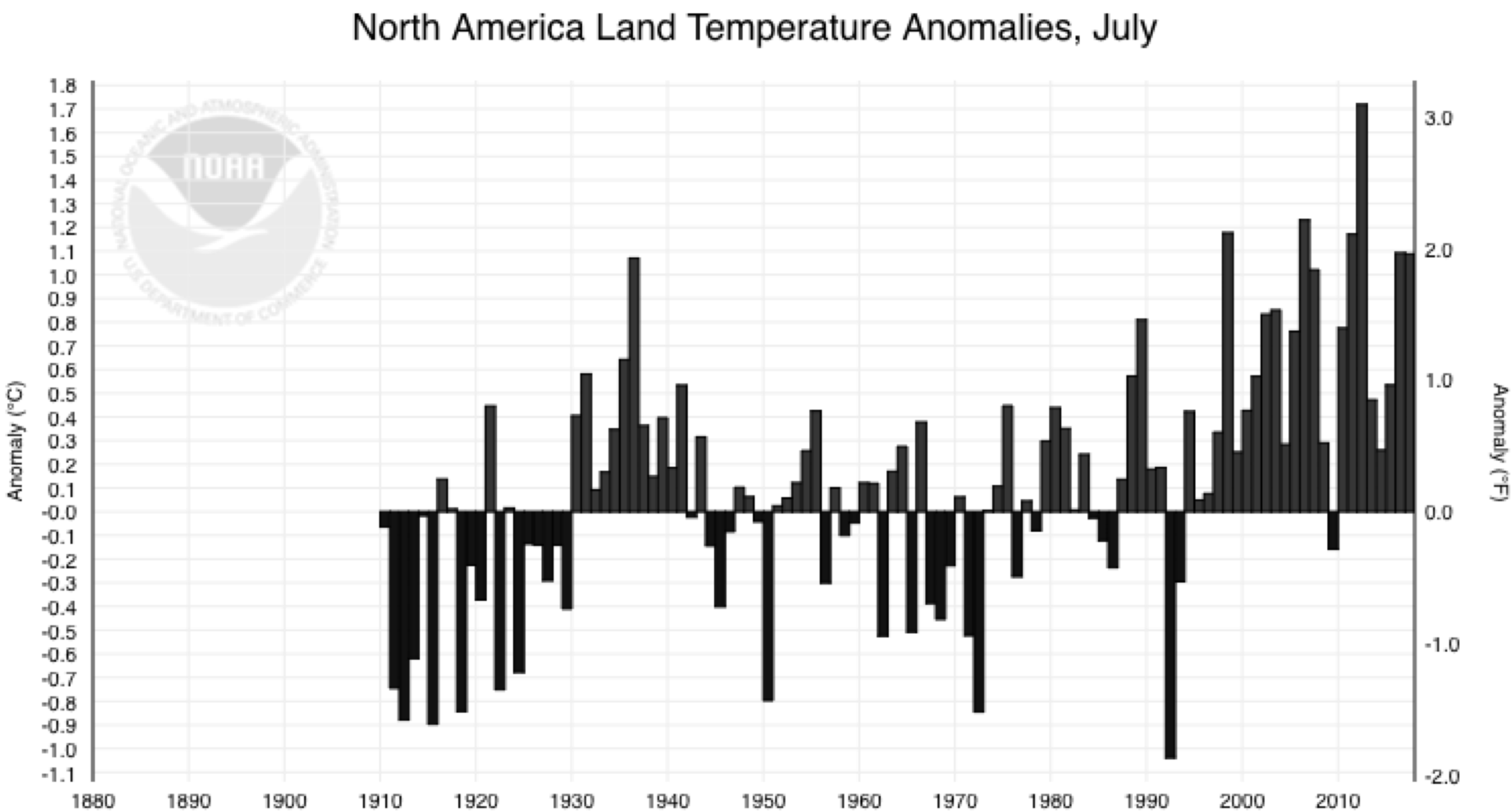


Mann et al., 2003, EOS

Southern Wisconsin



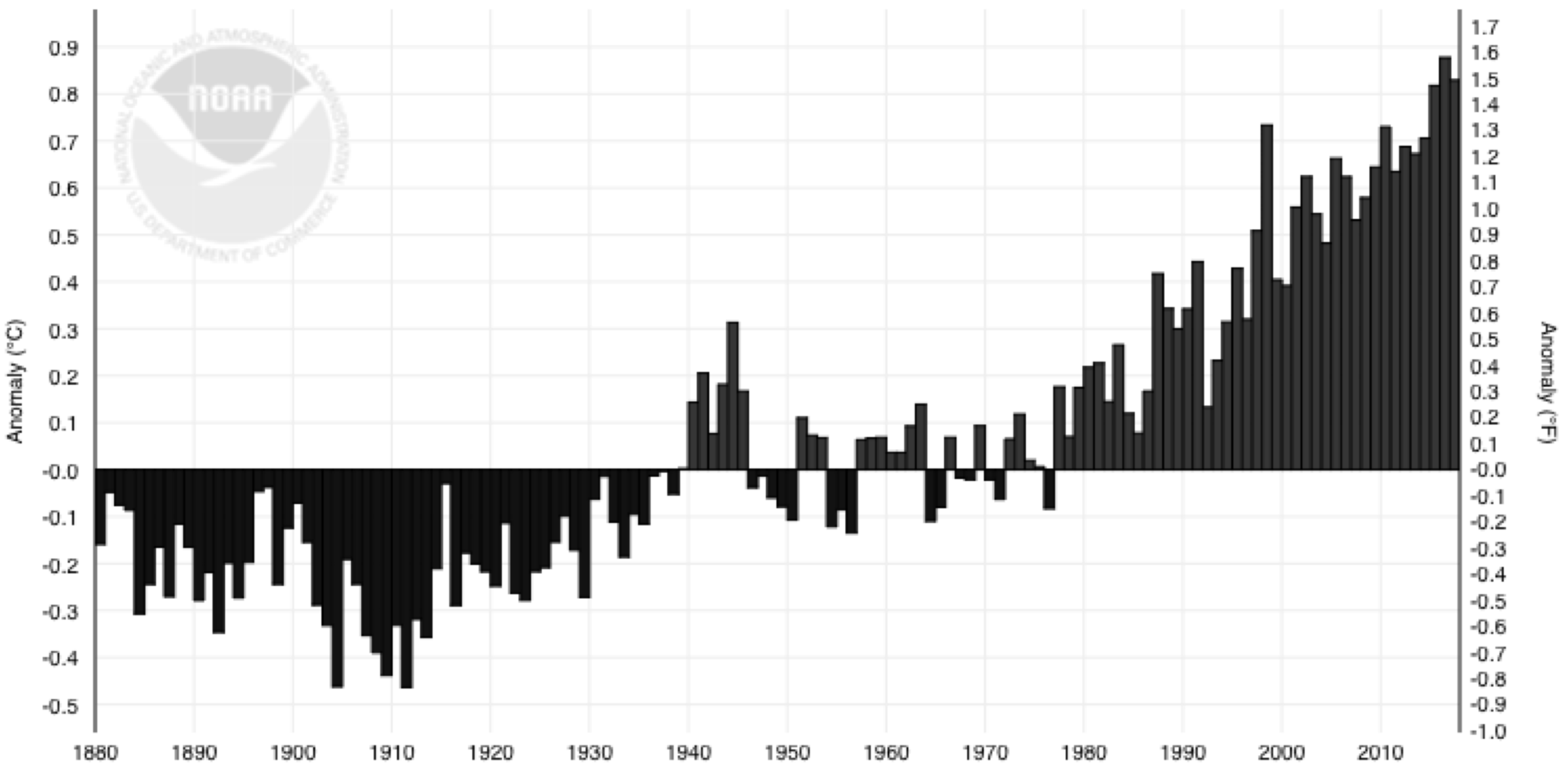
N America

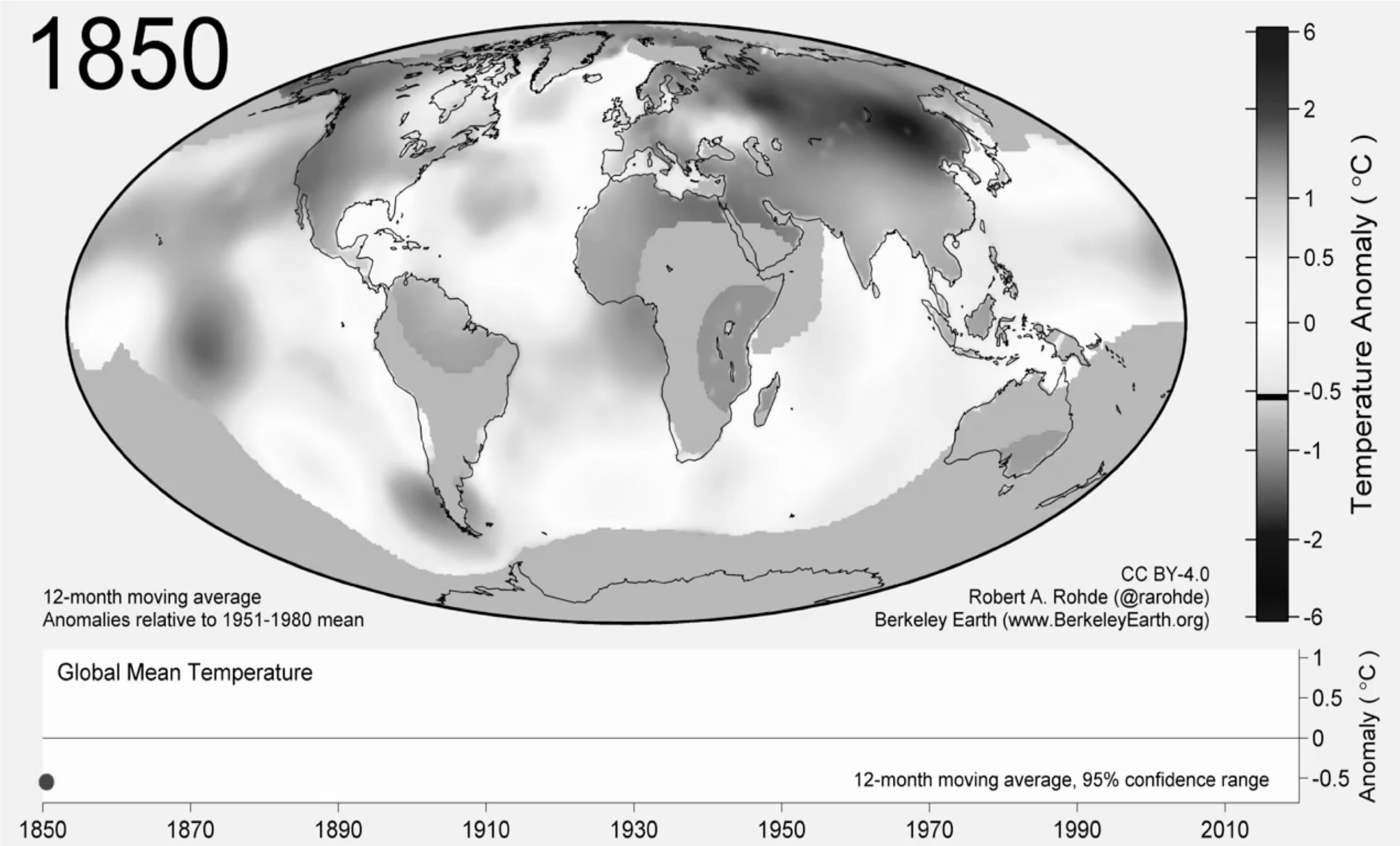


North America Land Temperature Anomalies, July
Anomaly (°C)
Anomaly (°F)
1880
1890
1900
1910
1920
1930
1940
1950
1960
1970
1980
1990
2000
2010

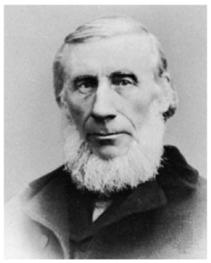
WORLD

Global Land and Ocean Temperature Anomalies, July




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
12-month moving average, 95% confidence range
1
0.5
0
-0.5
Anomaly (°C)
1850
1870
1890
1910
1930
1950
1970
1990
2010

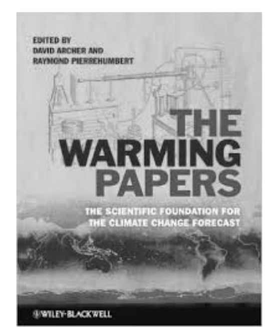
- The study of climate change is well-established. We know how climate changes and what is mostly causing current change

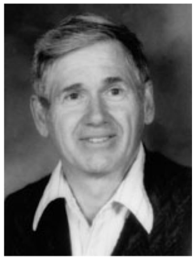



- Planetary (inc. Earth) temperature is determined by interaction of sunlight warming Earth's surface, and "greenhouse" gases that absorb infrared radiation (Fourier 1824, Tyndall 1861)

- 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)

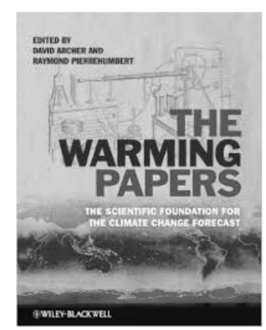




- Atmospheric CO_2 increasing ~ 2 ppm/yr from fossil fuel combustion, with 50% going into land and ocean sinks (Keeling 1960, Tans 1990)

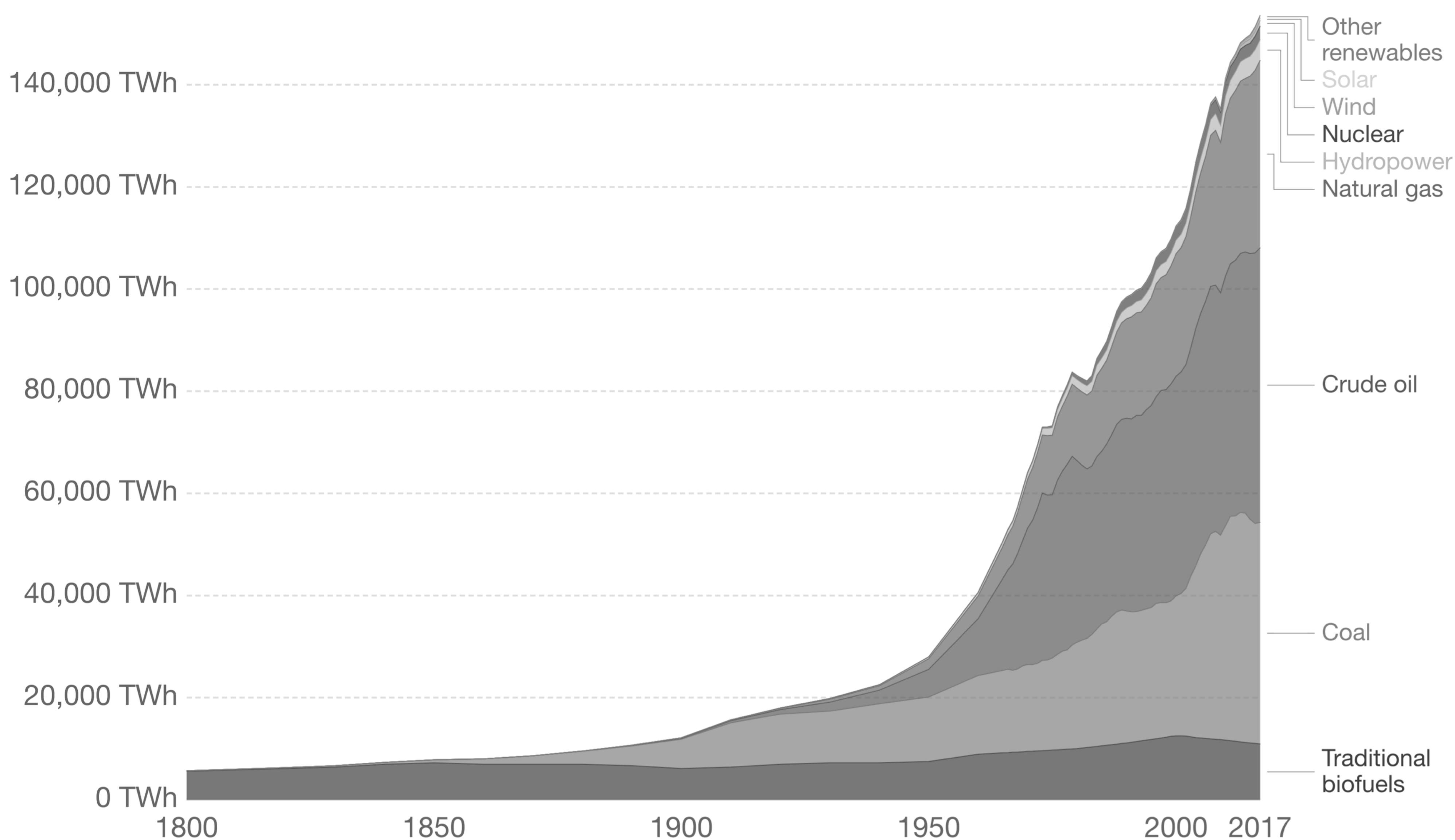
- Short and long term observed warming patterns are linked to greenhouse gases (Callendar 1938, Mann 1999)

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

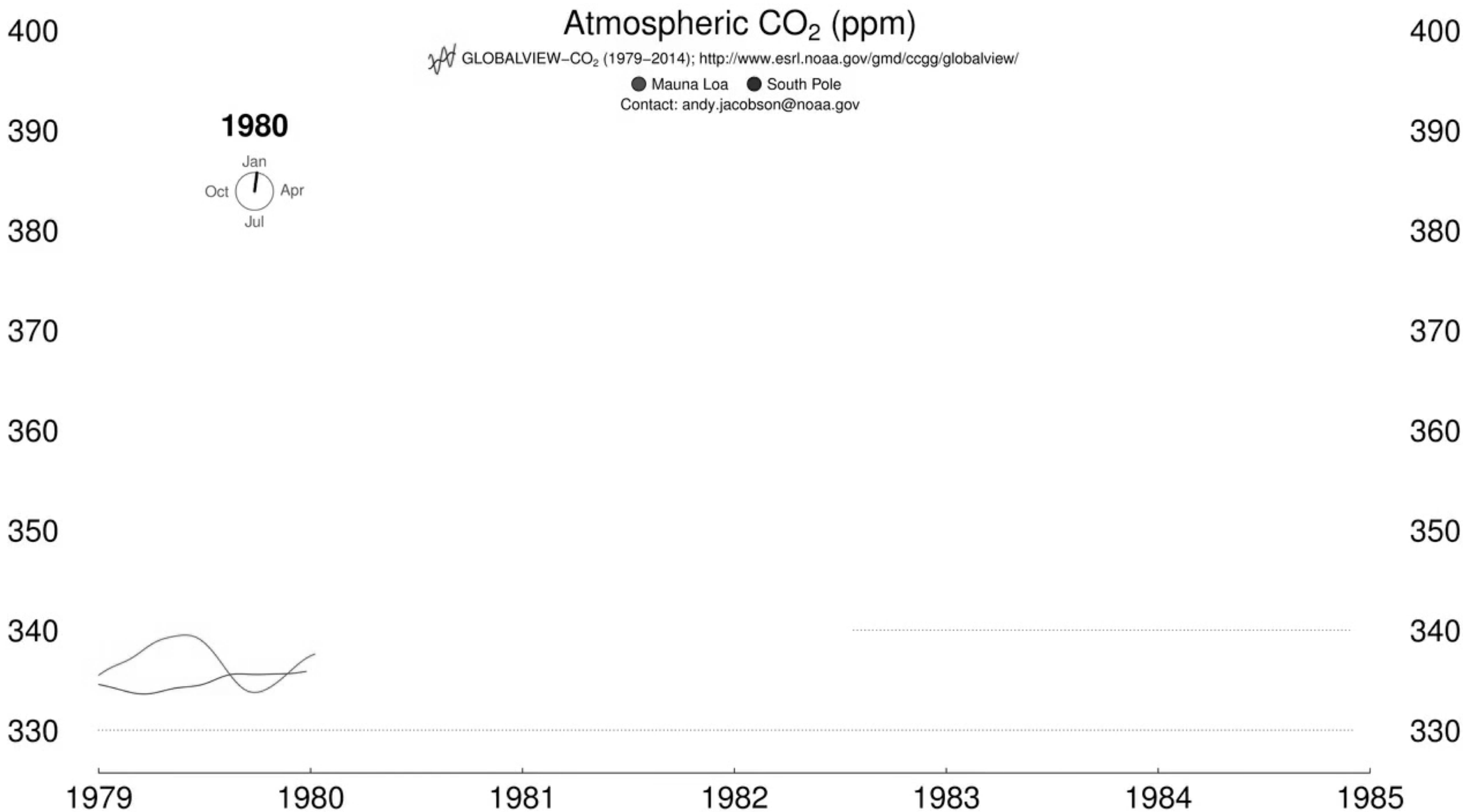


Global primary energy consumption

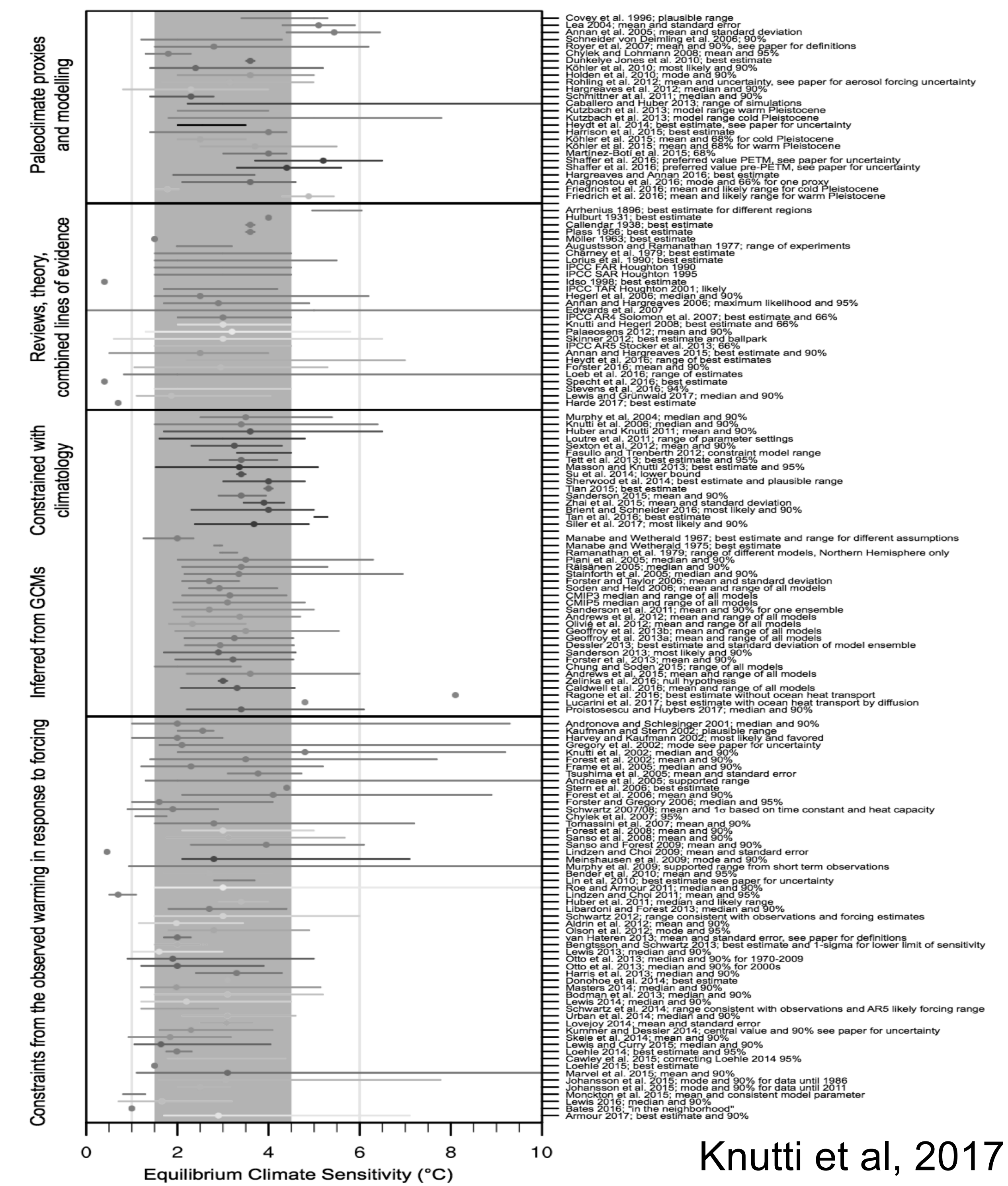
Global primary energy consumption, measured in terawatt-hours (TWh) per year. Here 'other renewables' are renewable technologies not including solar, wind, hydropower and traditional biofuels.



Source: Vaclav Smil (2017) and BP Statistical Review of World Energy



Other evidence: decreasing radiocarbon content of atmosphere, acidification of ocean, increased water use efficiency of plants, concentrations tracks emissions



Knutti et al, 2017

In mo… ature is determ… energy from th… e.

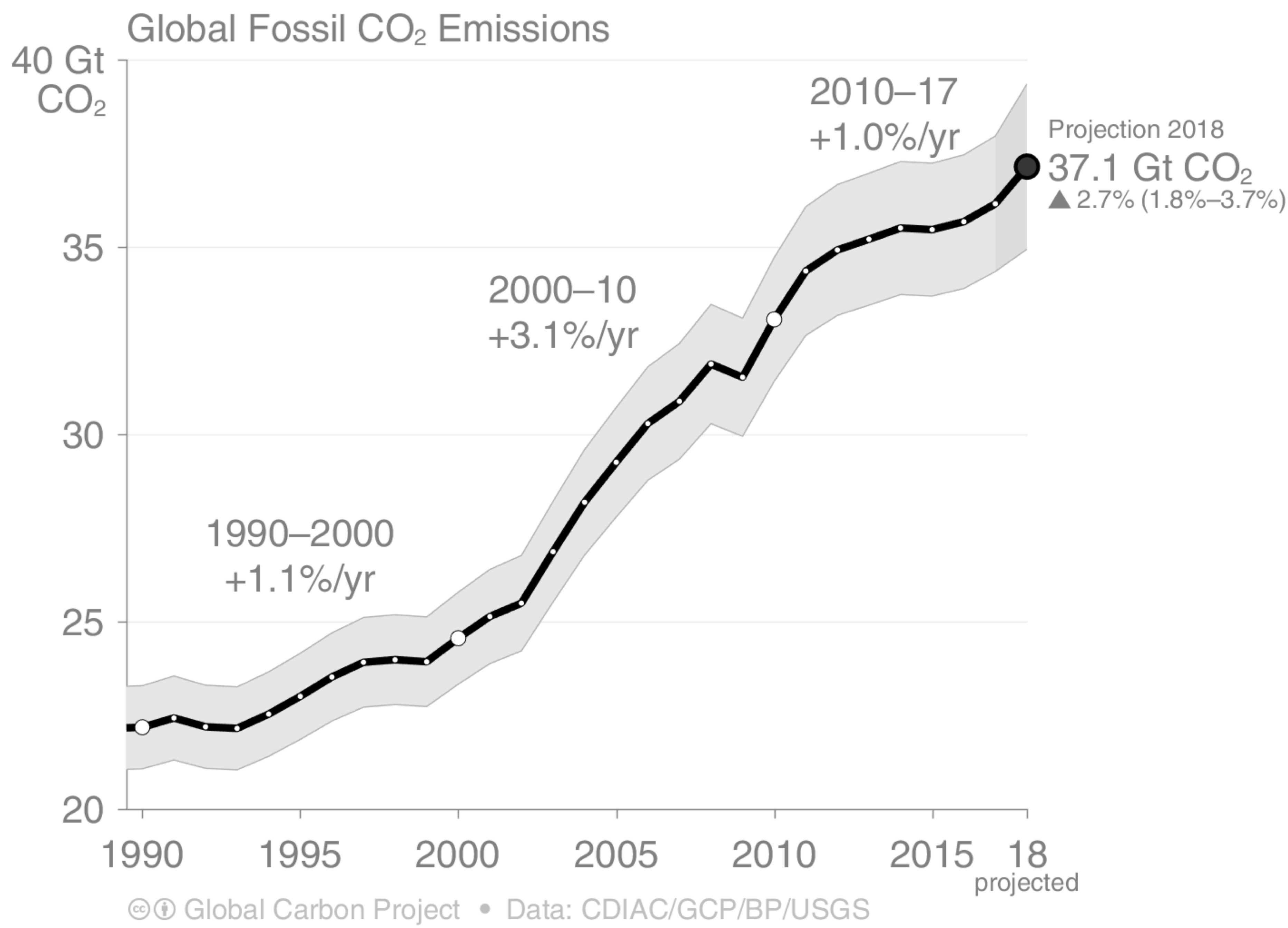
"*CO_2 is to climate what steroids was to baseball*…" –Jason Samenow

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

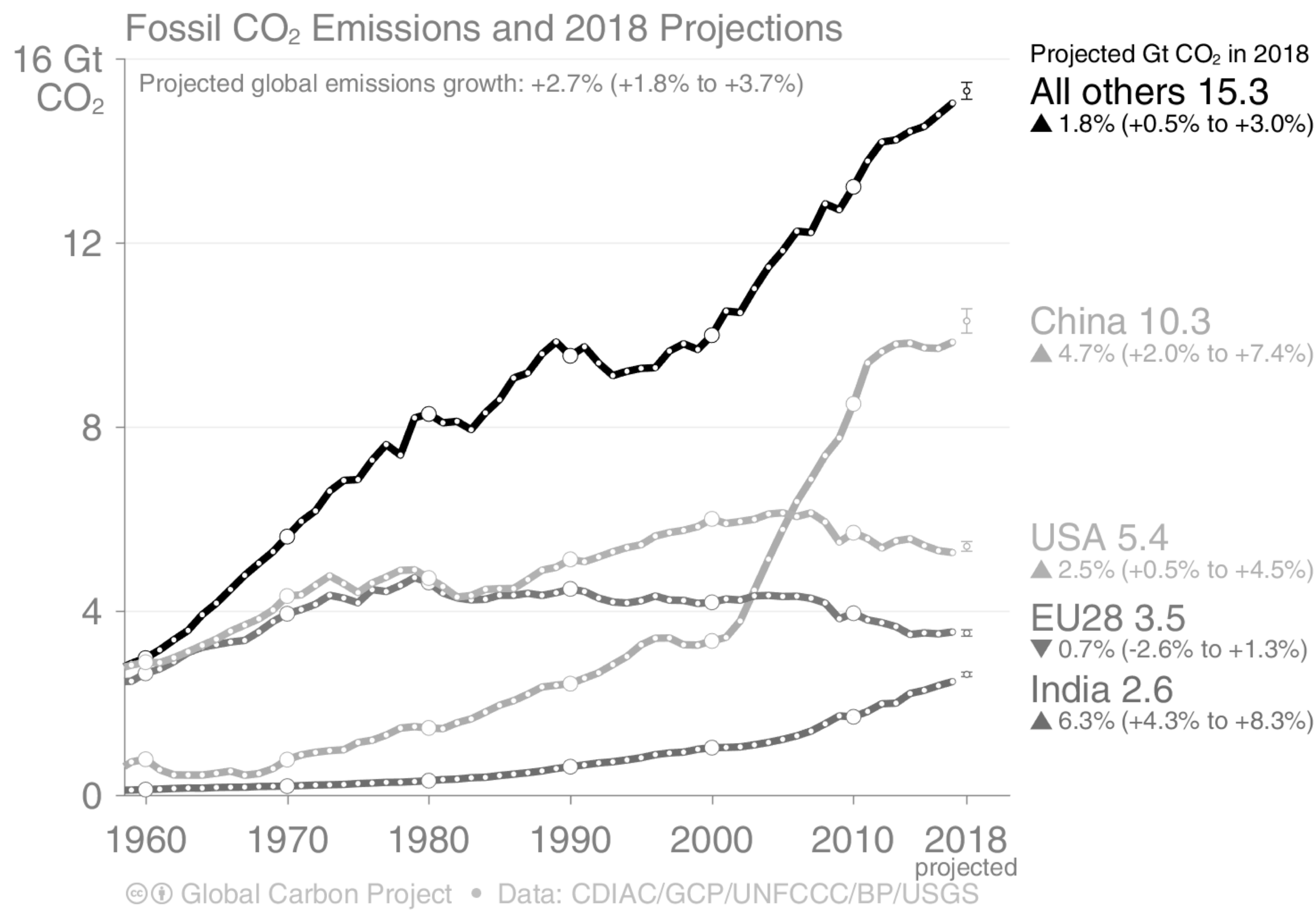
- US per capita fossil fuel emissions exceed most of the world (DOE, GCP). China total emissions now exceeds the US (IEA).

- 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)

- 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)

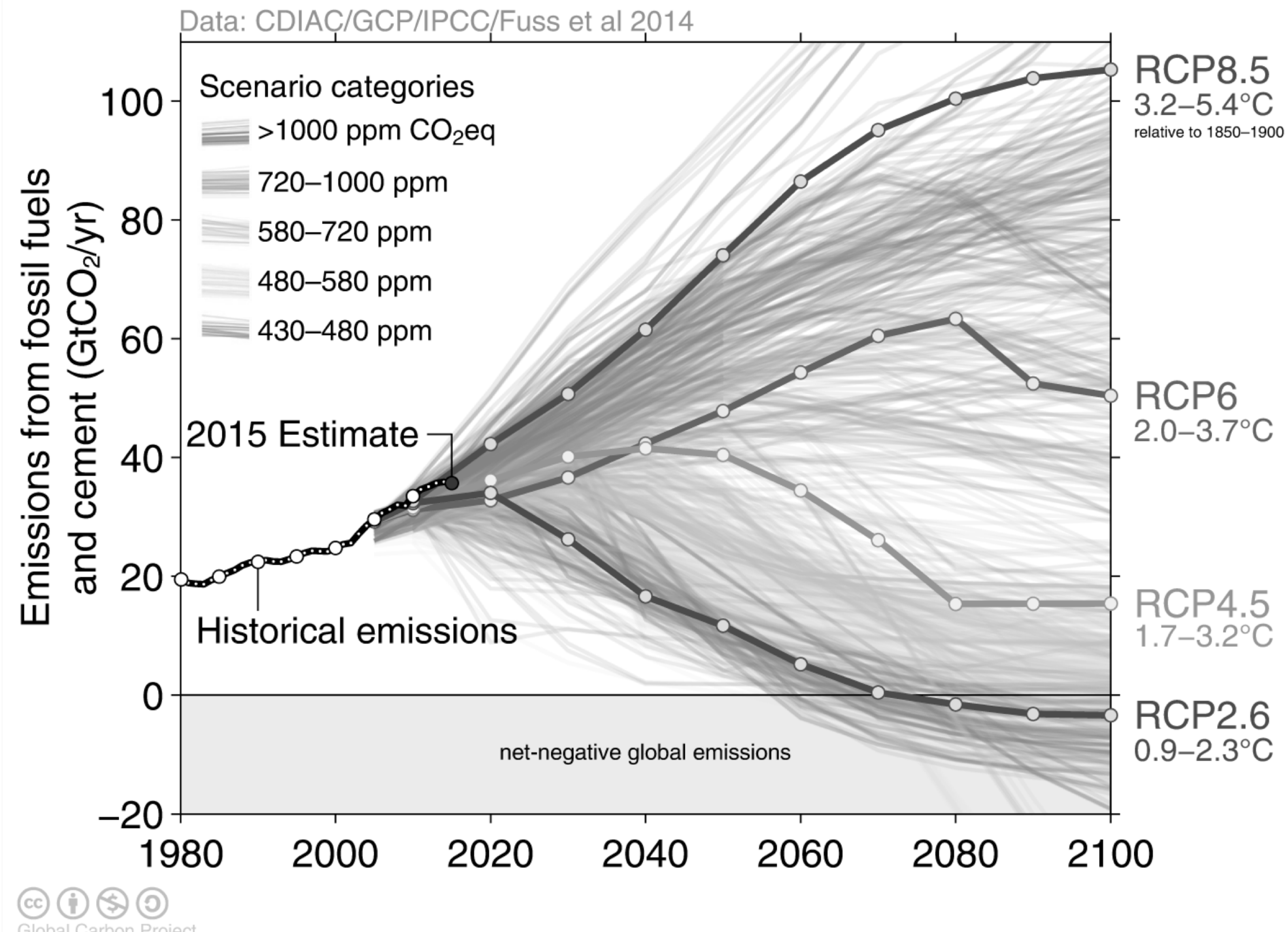


Global Fossil CO_2 Emissions
40 Gt CO_2
35
30
25
20
1990
1995
2000
2005
2010
2015
18
projected
1990–2000
+1.1%/yr
2000–10
+3.1%/yr
2010–17
+1.0%/yr
Projection 2018
37.1 Gt CO_2
▲ 2.7% (1.8%–3.7%)
Global Carbon Project • Data: CDIAC/GCP/BP/USGS


Fossil CO_2 Emissions and 2018 Projections
Projected global emissions growth: +2.7% (+1.8% to +3.7%)
16 Gt CO_2
12
8
4
0
1960
1970
1980
1990
2000
2010
2018 projected
Projected Gt CO_2 in 2018
All others 15.3
▲ 1.8% (+0.5% to +3.0%)
China 10.3
▲ 4.7% (+2.0% to +7.4%)
USA 5.4
▲ 2.5% (+0.5% to +4.5%)
EU28 3.5
▼ 0.7% (-2.6% to +1.3%)
India 2.6
▲ 6.3% (+4.3% to +8.3%)
Global Carbon Project • Data: CDIAC/GCP/UNFCCC/BP/USGS

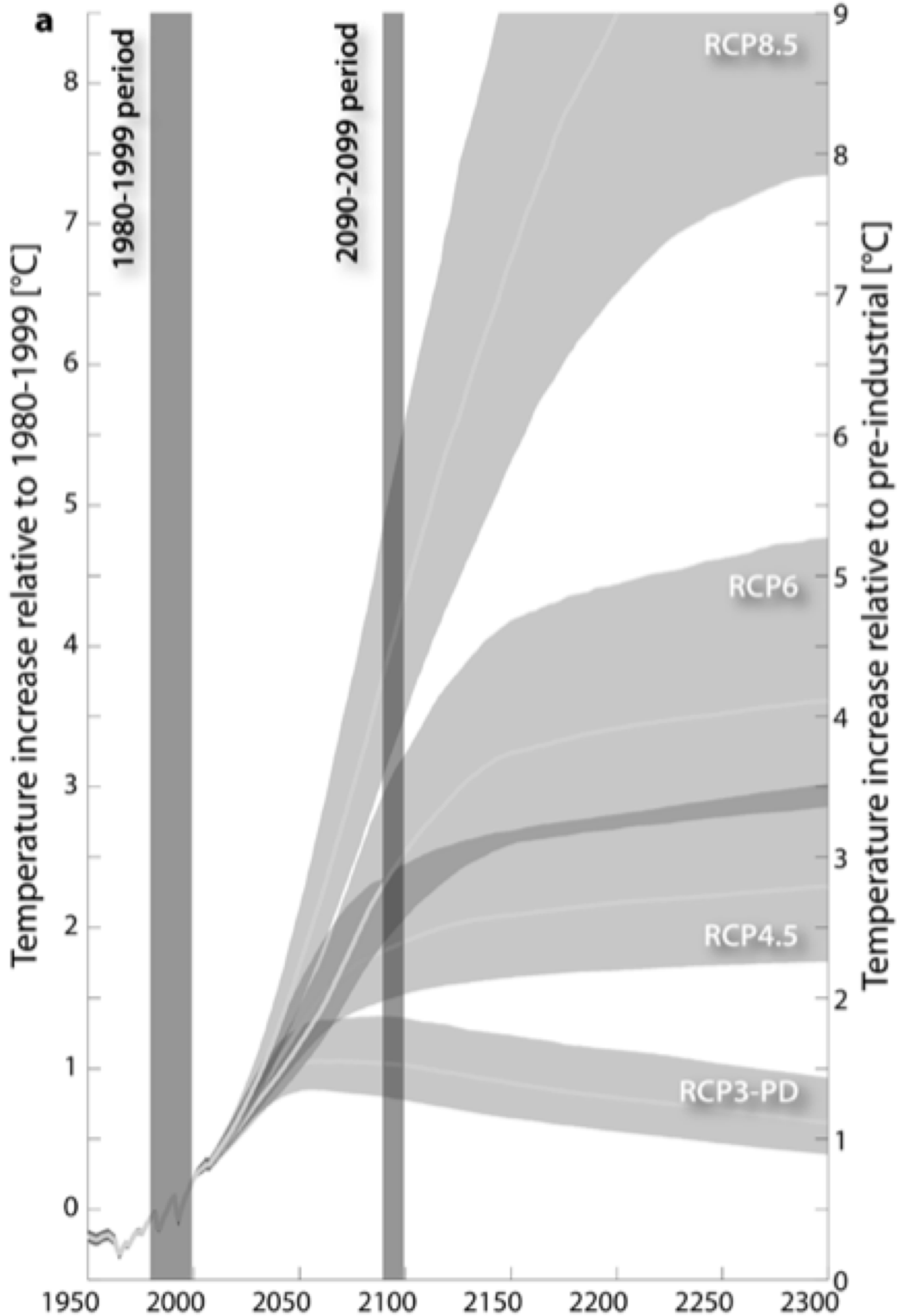
Observed emissions and emissions scenarios

The emission pledges submitted to the Paris climate summit avoid the worst effects of climate change (red), most studies suggest a likely temperature increase of about 3° C (brown)



Over 1000 scenarios from the IPCC Fifth Assessment Report are shown

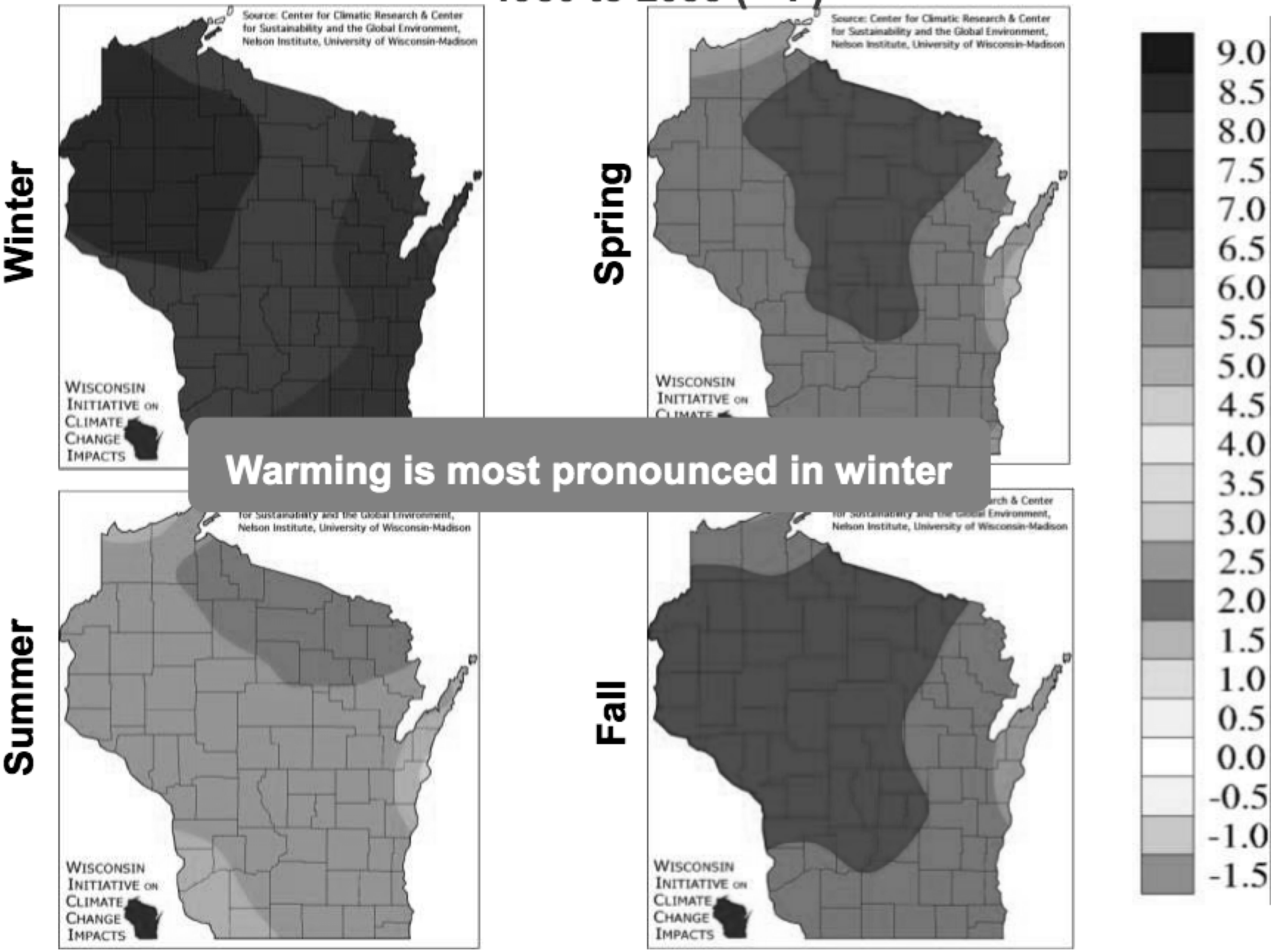
Source: Fuss et al 2014; CDIAC; Global Carbon Budget 2015



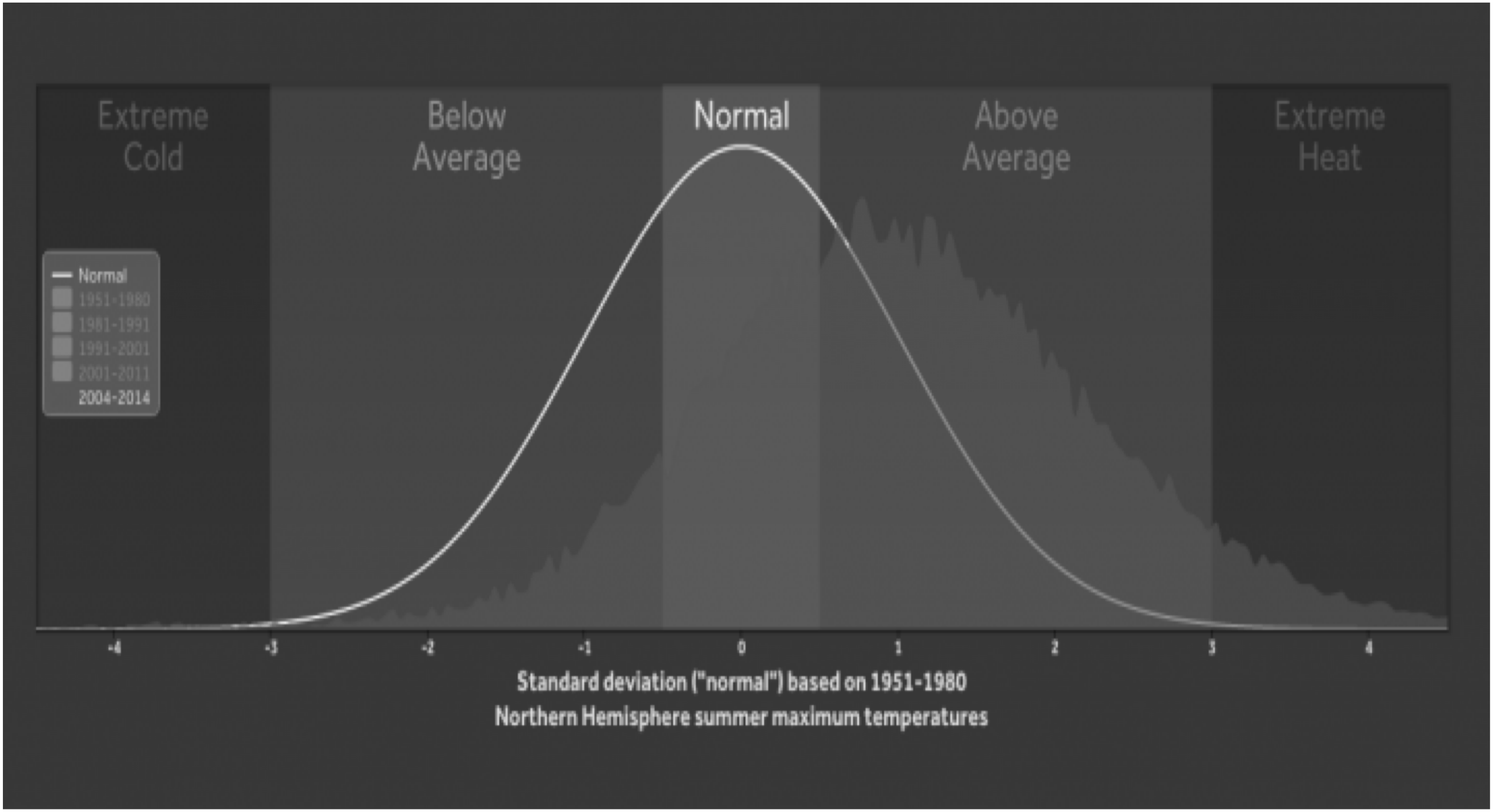
Source: Rogelj, Meinshausen et al. 2012

Projected Change in Seasonal Temperatures

1980 to 2055 (° F)



Warming is most pronounced in winter



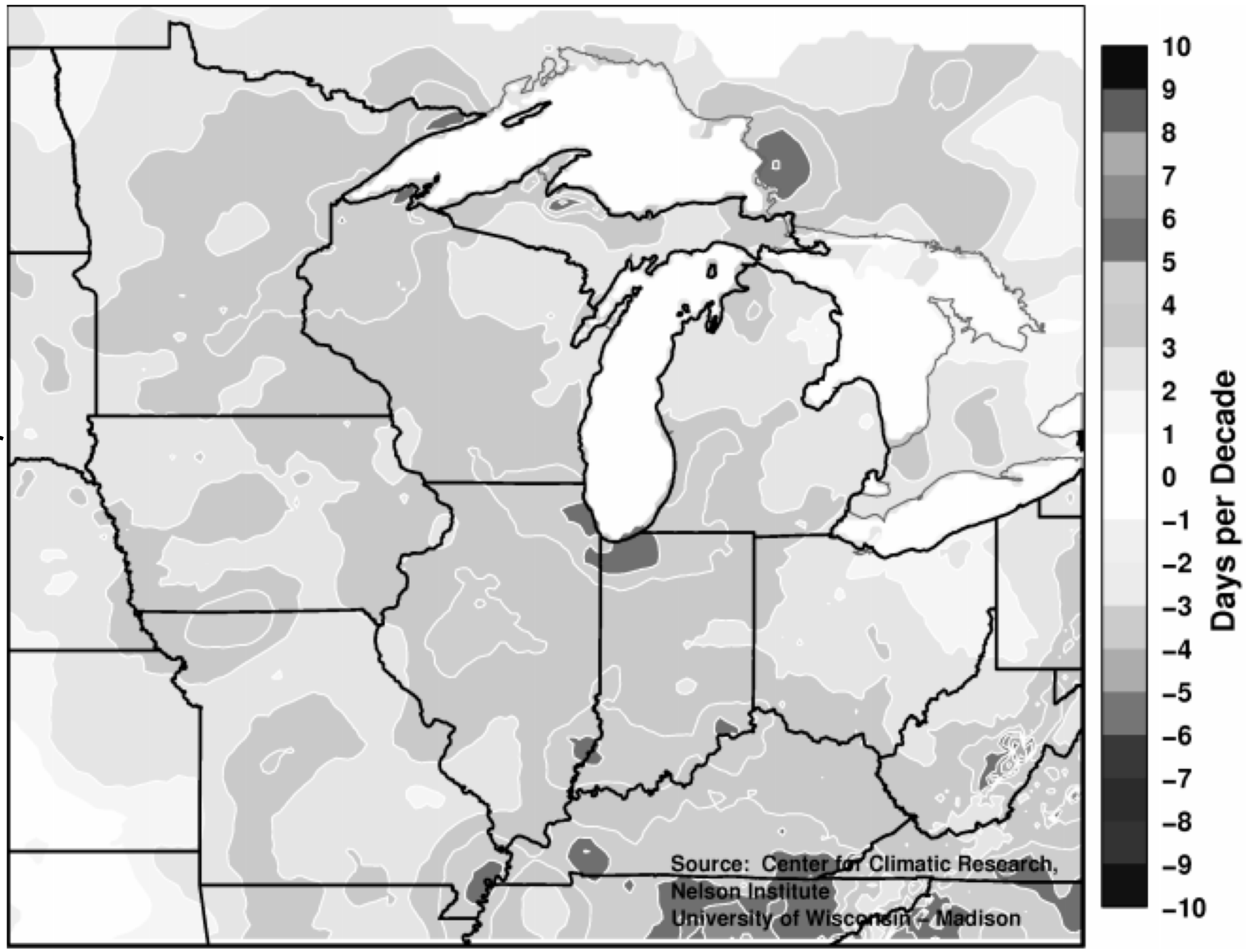
Extreme Cold
Below Average
Normal
Above Average
Extreme Heat
Normal
1951-1980
1981-1991
1991-2001
2001-2011
2004-2014
-4
-3
-2
-1
0
1
2
3
4
Standard deviation ("normal") based on 1951-1980
Northern Hemisphere summer maximum temperatures

So what’s the big deal?

https://nca2018.globalchange.gov/

Projected Heavy Rainfall

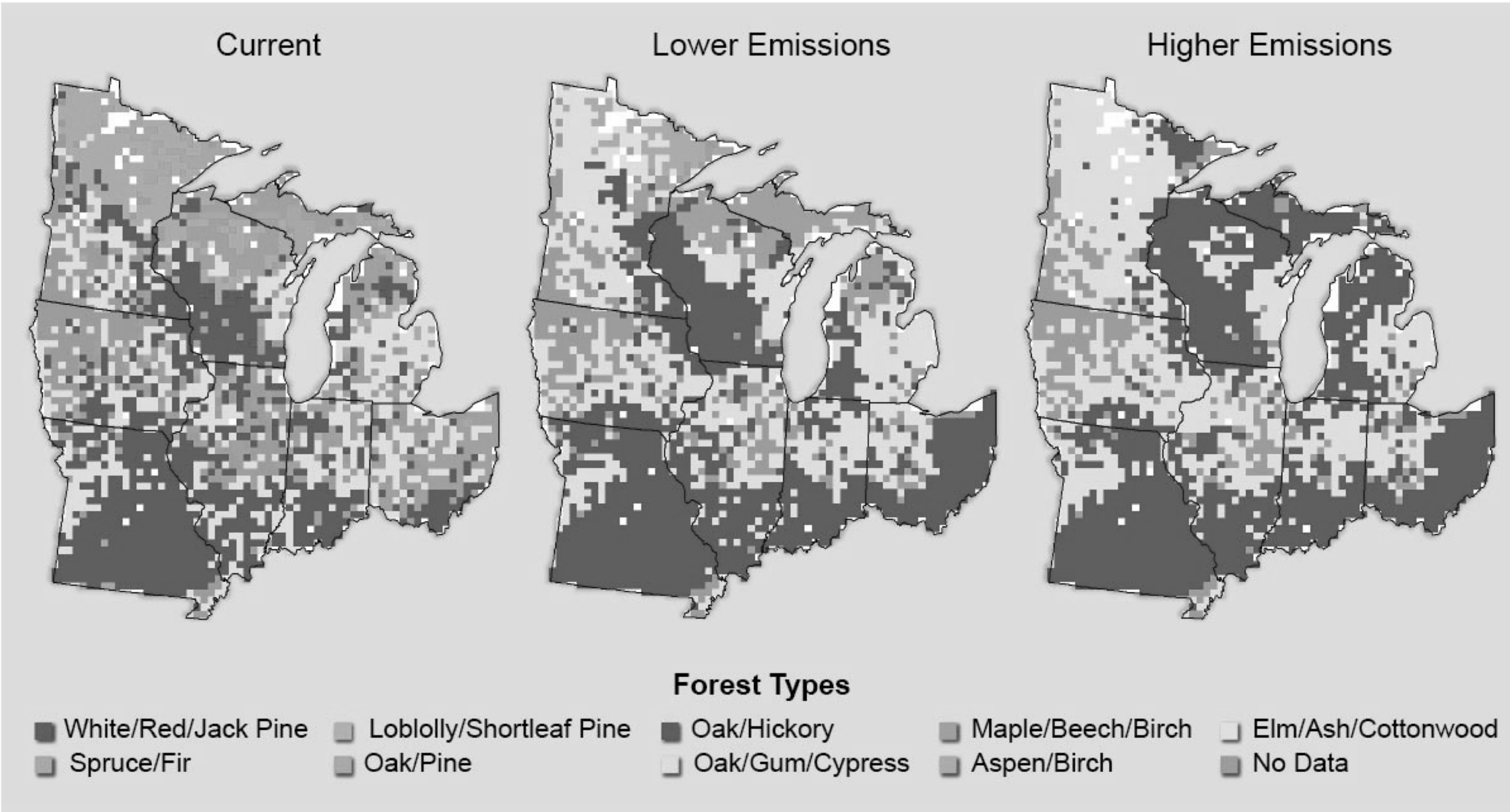
Change in 2”+ inches per 24 hr rain events:
Statistically downscaled GCM, 1980-2055 (SRES A1B)



2-5 days more per decade

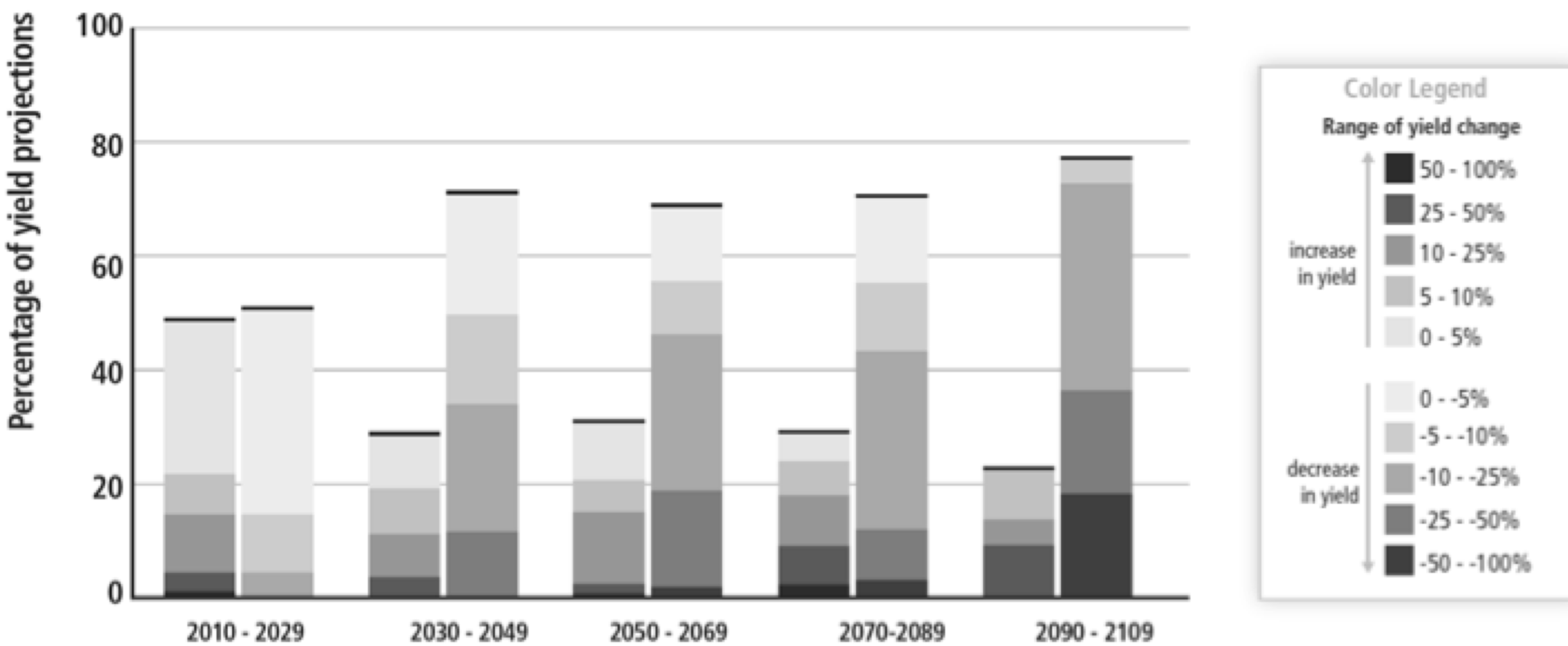
Source: UW-Madison
Nelson Institute
Center for Climatic Research

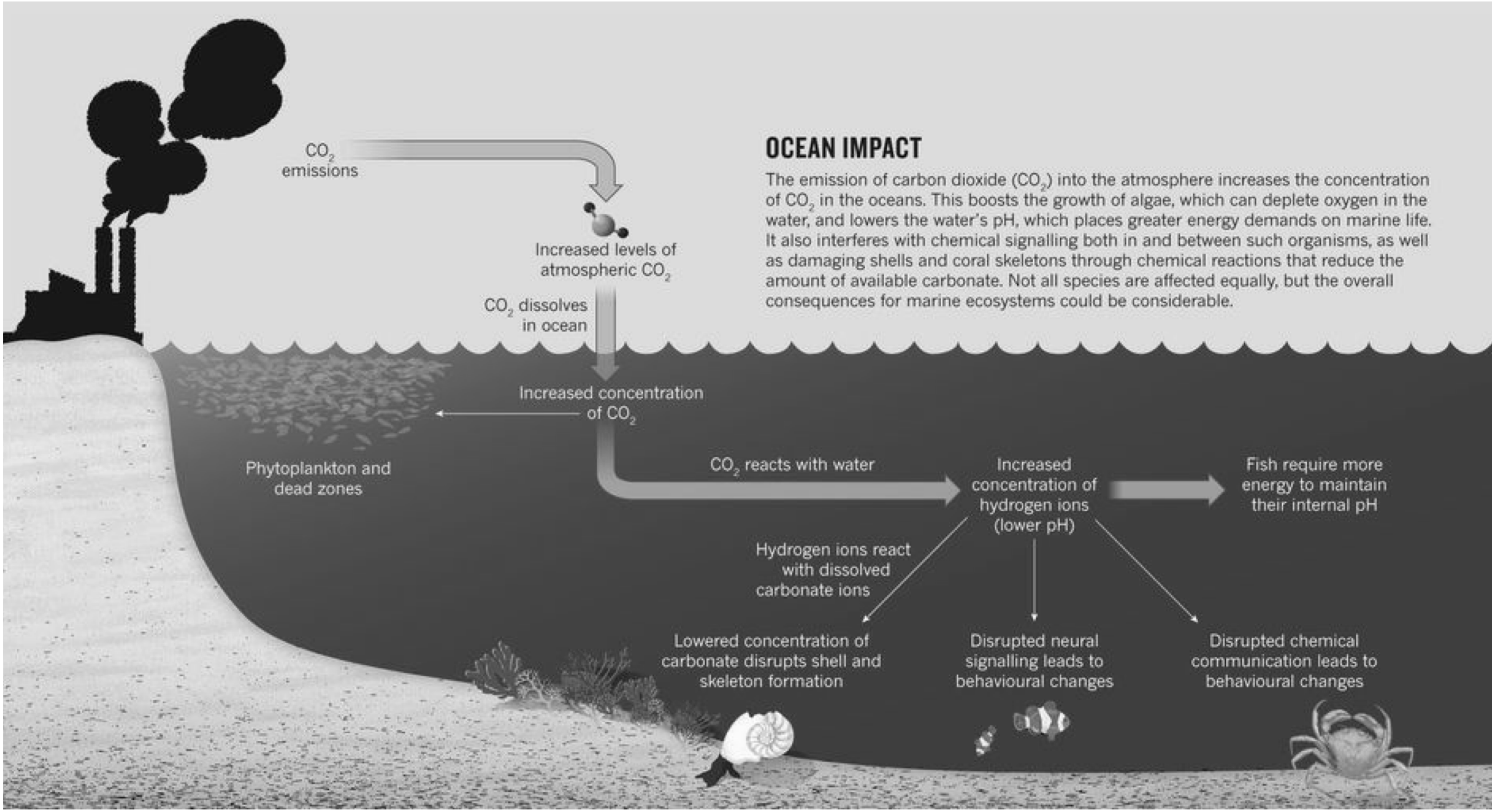
Forest Composition Shifts

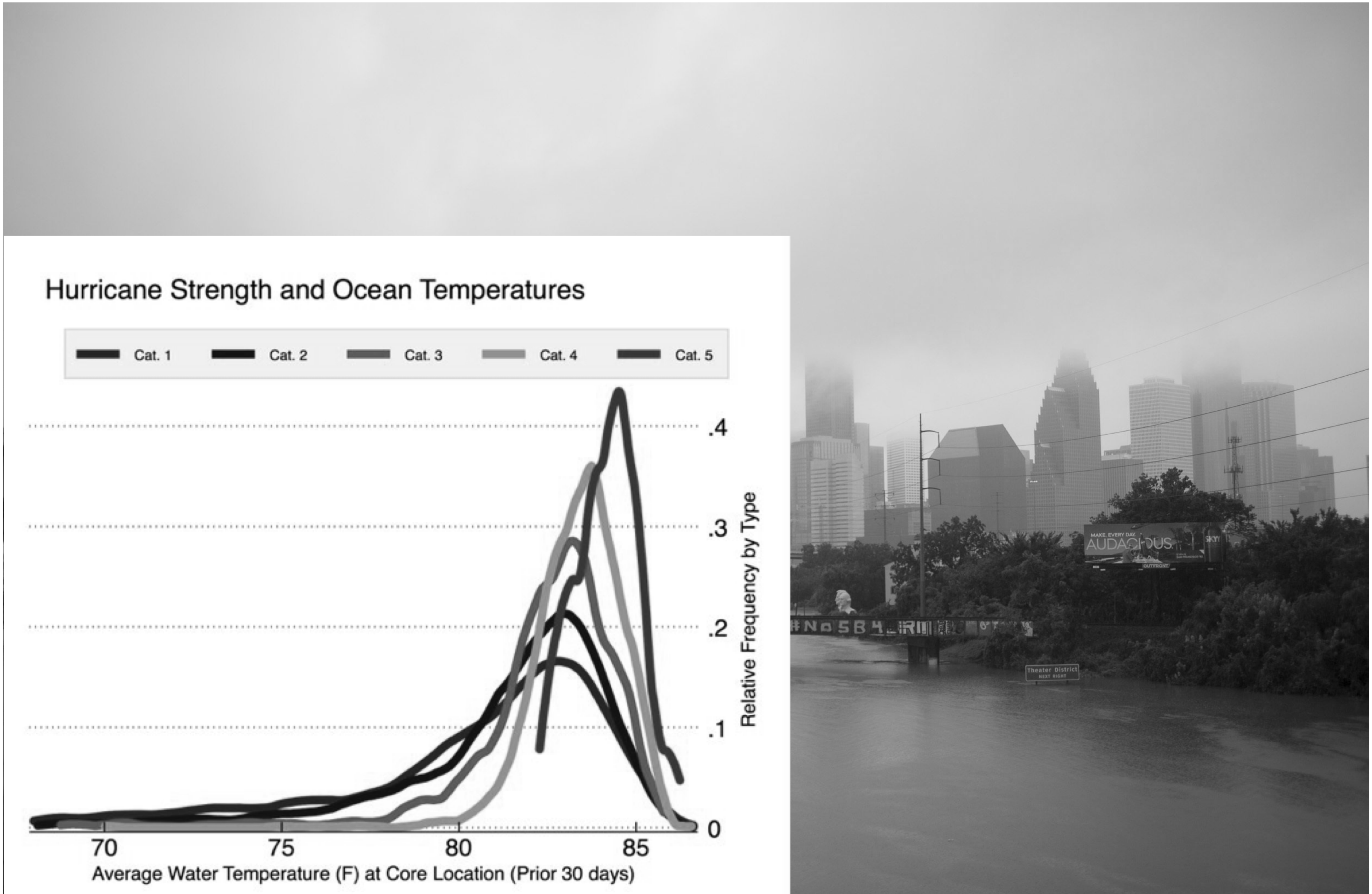


David Mladenoff, UW-Madison

Crop Yields Decline under Higher Temperatures



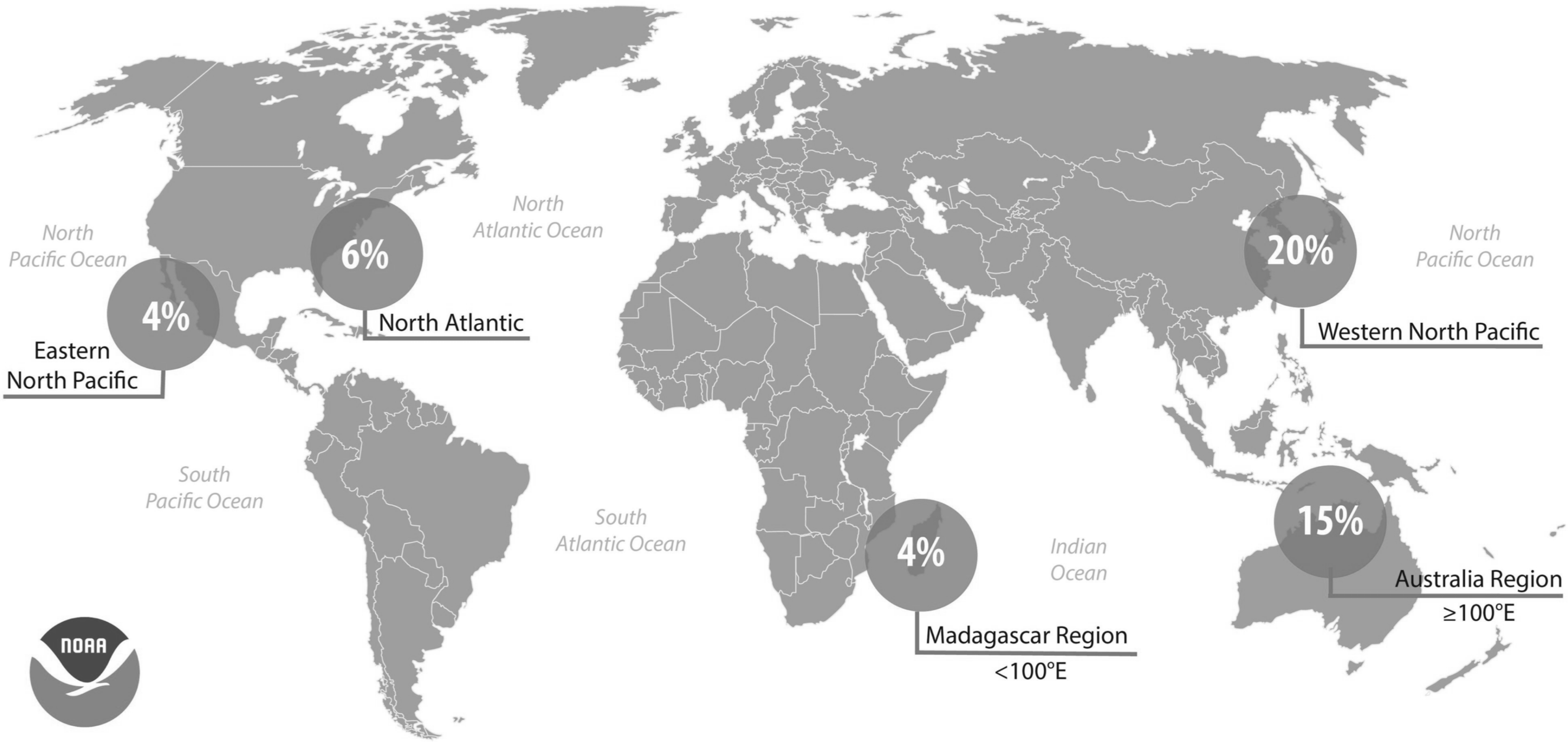

OCEAN IMPACT
The emission of carbon dioxide (CO_2) into the atmosphere increases the concentration of CO_2 in the oceans. This boosts the growth of algae, which can deplete oxygen in the water, and lowers the water's pH, which places greater energy demands on marine life. It also interferes with chemical signalling both in and between such organisms, as well as damaging shells and coral skeletons through chemical reactions that reduce the amount of available carbonate. Not all species are affected equally, but the overall consequences for marine ecosystems could be considerable.
CO_2 emissions
Increased levels of atmospheric CO_2
CO_2 dissolves in ocean
Increased concentration of CO_2
Phytoplankton and dead zones
CO_2 reacts with water
Increased concentration of hydrogen ions (lower pH)
Fish require more energy to maintain their internal pH
Hydrogen ions react with dissolved carbonate ions
Lowered concentration of carbonate disrupts shell and skeleton formation
Disrupted neural signalling leads to behavioural changes
Disrupted chemical communication leads to behavioural changes



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

Regional Slowdowns of Tropical Cyclone Movement

Between 1949 and 2016 over Land and Water



Adapted from "A Global Slowdown of Tropical Cyclone Translation Speed" by J.P. Kossin, published in *Nature* 2018

www.ncei.noaa.gov NOAA National Centers for Environmental Information #NOAANCEI

70 75 80 85

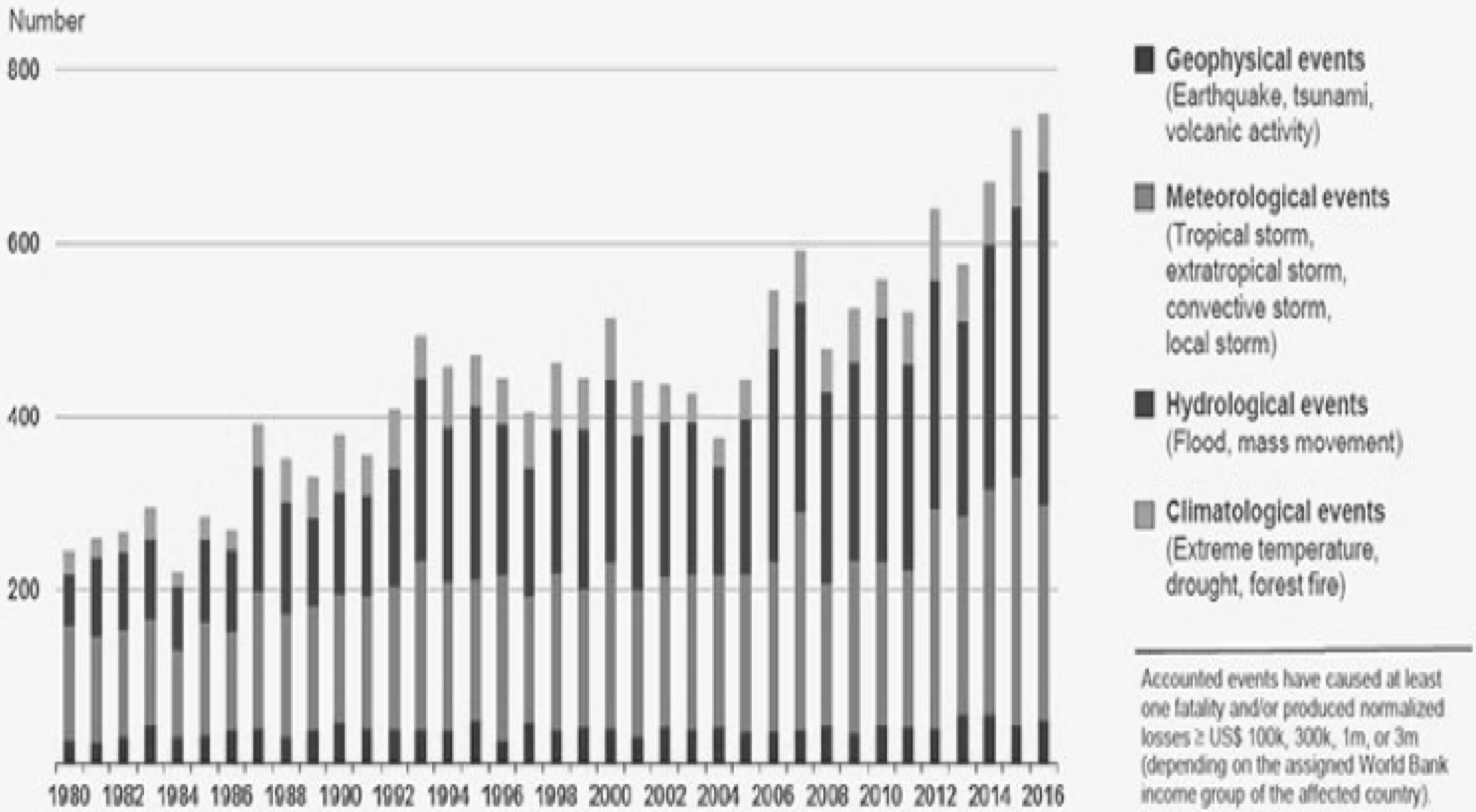
Average Water Temperature (F) at Core Location (Prior 30 days)

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

Number Of Natural Catastrophes

Global - 1980-2016

Source: Munich Re, Geo Risks Research



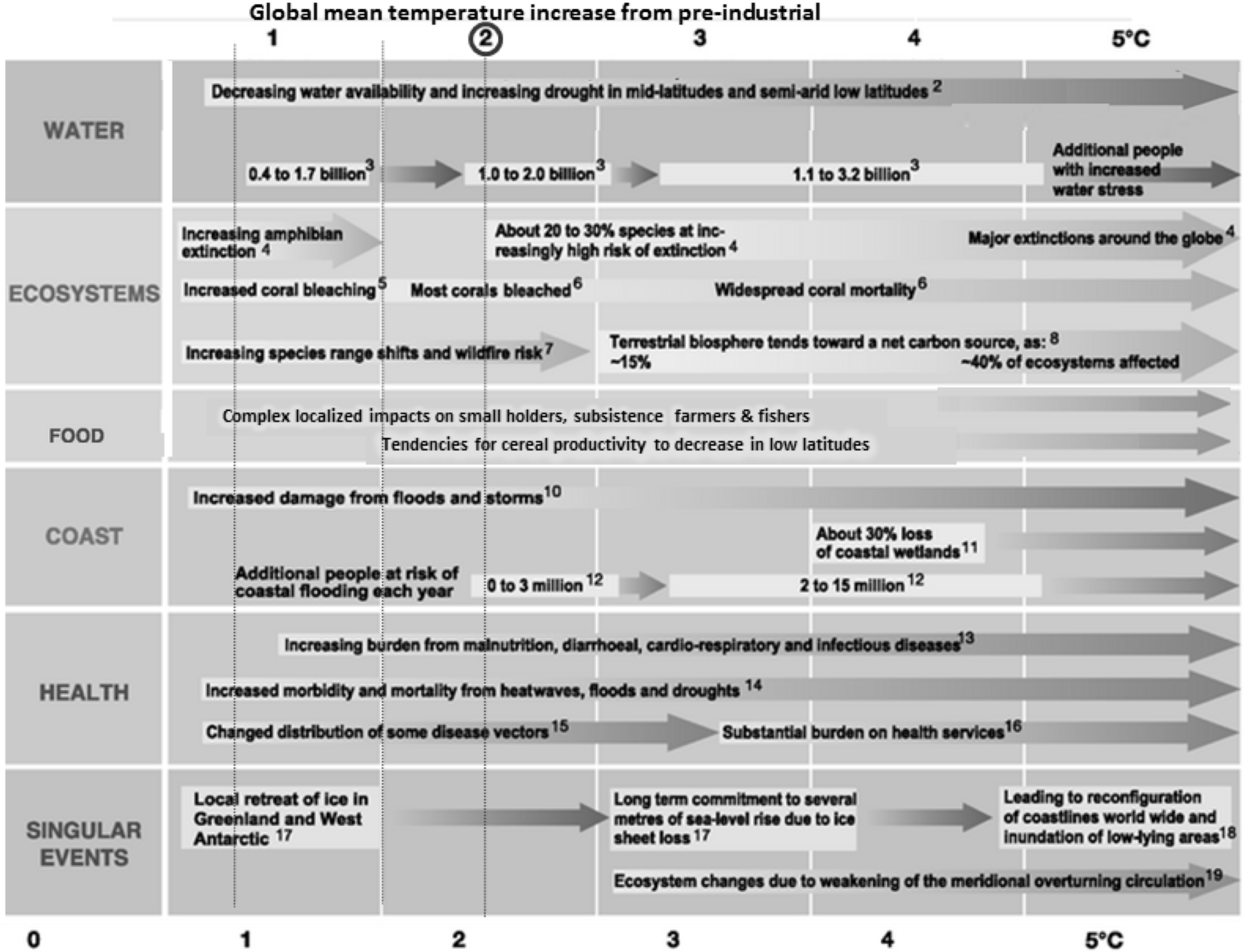
IPCC 2007 AR4 TS.4.3 Magnitudes of ADVERSE impacts for varying amounts of climate change

IPCC quotes in blue.
Impacts start where text box begins.
Edges of boxes and placing of text indicate the range of temperature change to which the impacts relate.

The impact chart omitted extreme weather events, that increase most impacts
The SPM impact chart was identical except it omitted the singular events

.

Estimates are for the 2020s, 2050s and 2080s, (used by he IPCC Data Distribution Centre) and for the 2090s.
Note that equilibrium temperatures would not be reached until decades or centuries after greenhouse gas stabilisation.



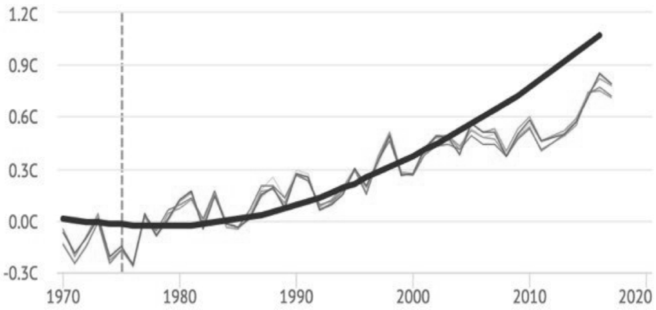
Peter Carter

UNFCCC objective quoted in AR4 …'prevent dangerous …interference with the climate system….within a time frame sufficient to allow ecosystems to adapt naturally to climate change, and to ensure that food production is not threatened'

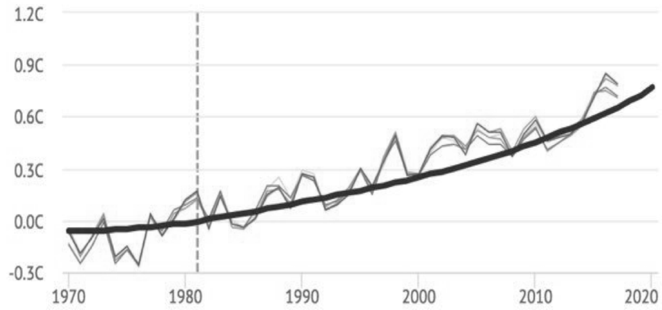
The IPCC *et al*

- Intergovernmental Panel on Climate Change (http://www.ipcc.ch/)
  - Established 1985 by UNEP and WMO
  - Provides review of science on causes of climate change (WG1), impacts of climate change (WG2), options of adaptation and mitigation (WG3)
  - Entirely volunteer run, with nomination process, support from UN trust fund
  - Assessment report ever ~4 yrs since 1990, a conservative estimate of state of science, in details and summary for policymakers
- Supports efforts of global climate change harm reduction under U.N. Framework Convention on Climate Change (UNFCCC), adopted 1992
  - Conference of Parties (165 signatories, 197 ratifiers) meets annually to update plans and form protocols for emissions reduction: Kyoto Protocol (1997, effective 2008-2012/2013-2020) and Paris Agreement (2015, effective 2016-)
- Has spurred many national and regional efforts on climate change assessment (National Academies, DOD, World Bank, WICCI), regulations (Clean Power Plan, Regional Greenhouse Gas Initiative, state level energy mandates), and industries (Tesla, BP carbon capture)

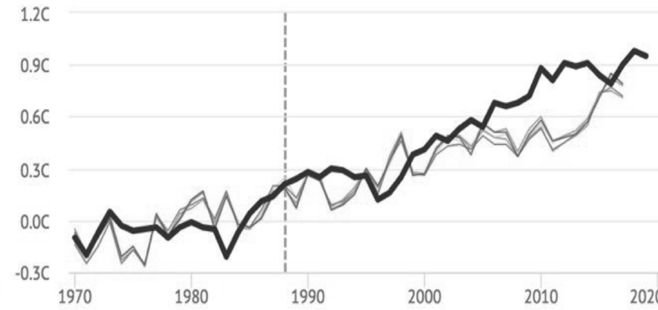
1975: Wally Broecker



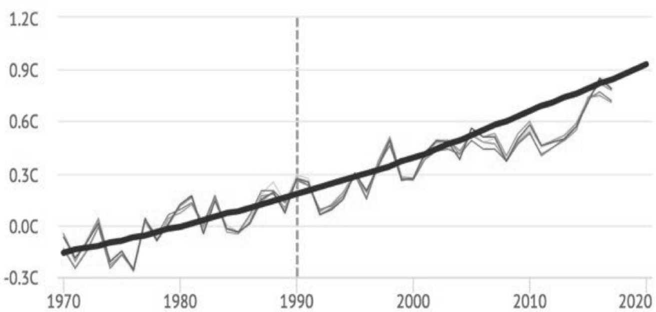
1981: Hansen et al



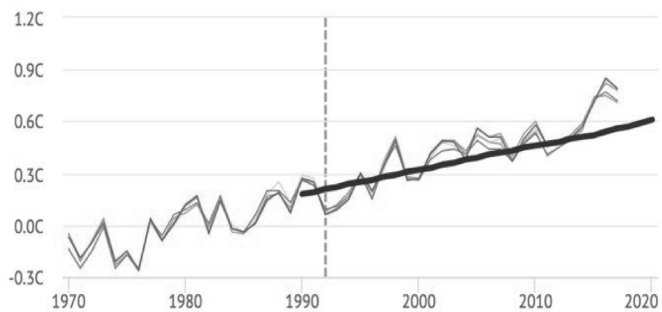
1988: Hansen et al



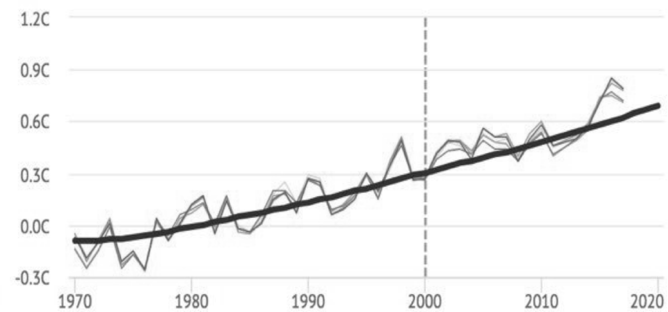
1990: IPCC First Assessment Report



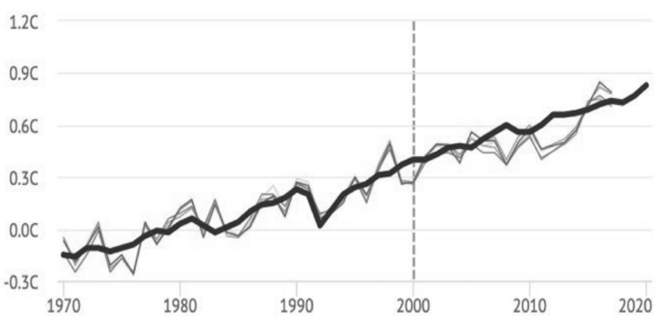
1995: IPCC Second Assessment Report



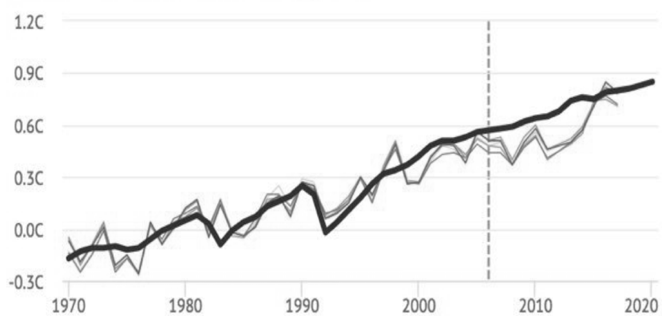
2001: IPCC Third Assessment Report



2007: IPCC Fourth Assessment Report



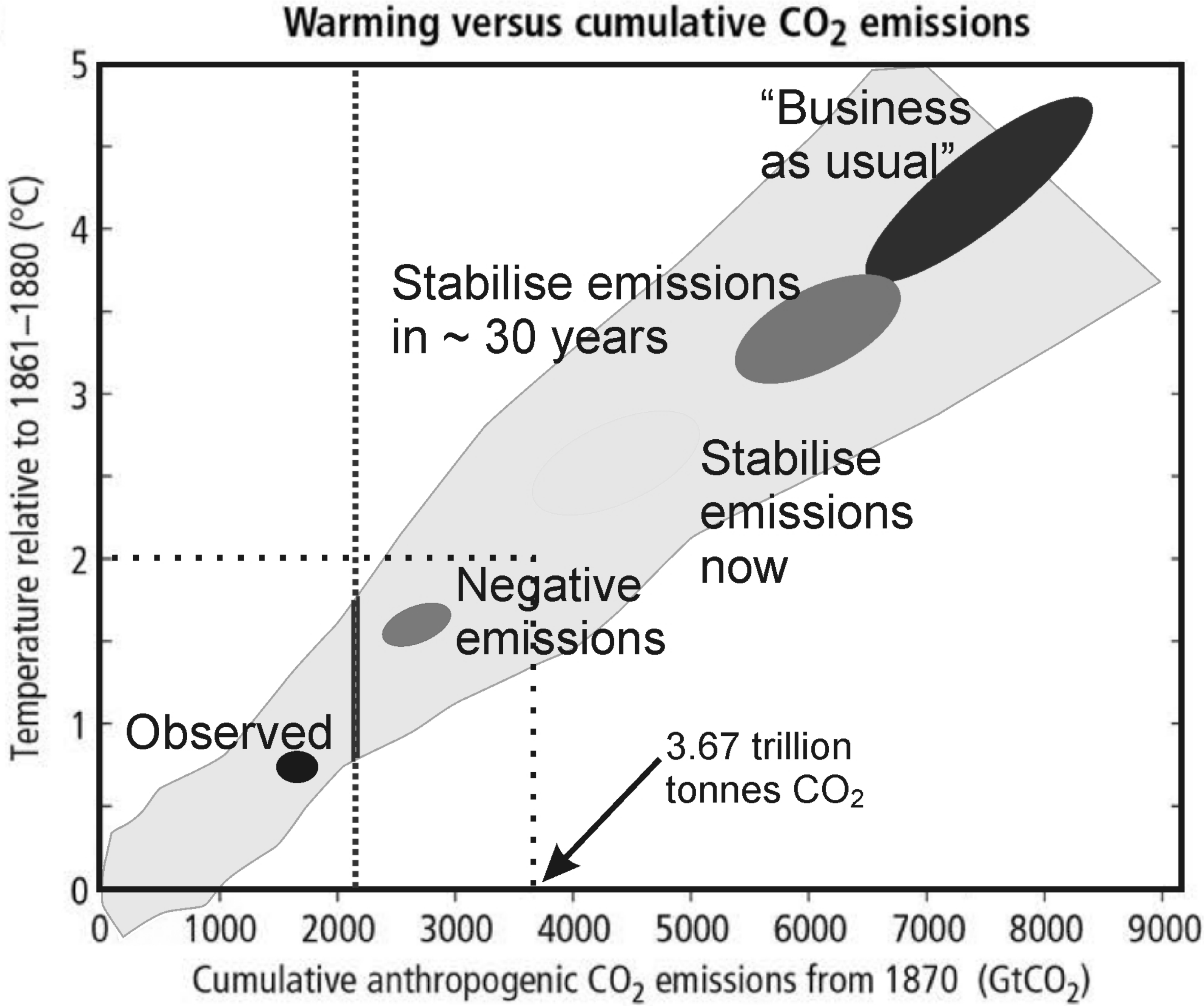
2013: IPCC Fifth Assessment Report



What Are The Options?

- Adaptation

- Mitigation


Warming versus cumulative CO_2 emissions
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
"Business as usual"
Stabilise emissions in ~ 30 years
Stabilise emissions now
Negative emissions
Observed
3.67 trillion tonnes CO_2

What Are The Options?

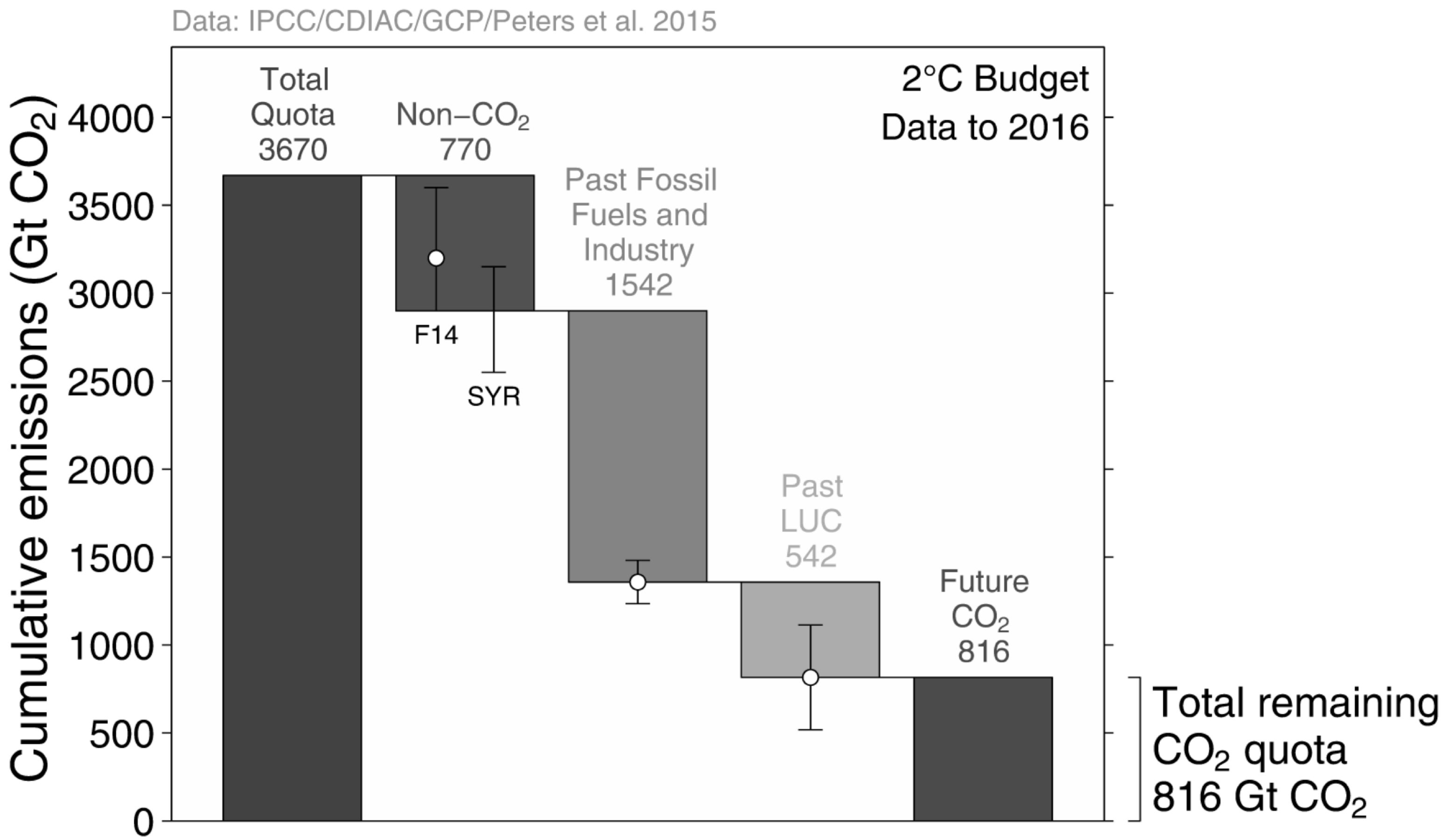
- Adaptation
  - Economic/political (relocation, tech transfer, payments for damages, reduce poverty, educate)
  - Technological (resilient tech, seawalls, genetic hybrids, cure malaria, colonize new planet)
- Mitigation

What Are The Options?

- Adaptation
  - Economic/political (relocation, tech transfer, payments for damages, reduce poverty, educate)
  - Technological (resilient tech, seawalls, genetic hybrids, cure malaria, colonize new planet)
- Mitigation
  - Economic (taxes, cap and trade, R&D)
  - Regulatory (treaties, bans, compacts, fuel/energy standards, public transit, voluntary agreements)
  - Societal (sustainable development, education)
  - Technological (CO_2 capture, geoengineering, green tech, alternative energy, energy efficiency)

Carbon quota for a 66% chance to keep below 2° C

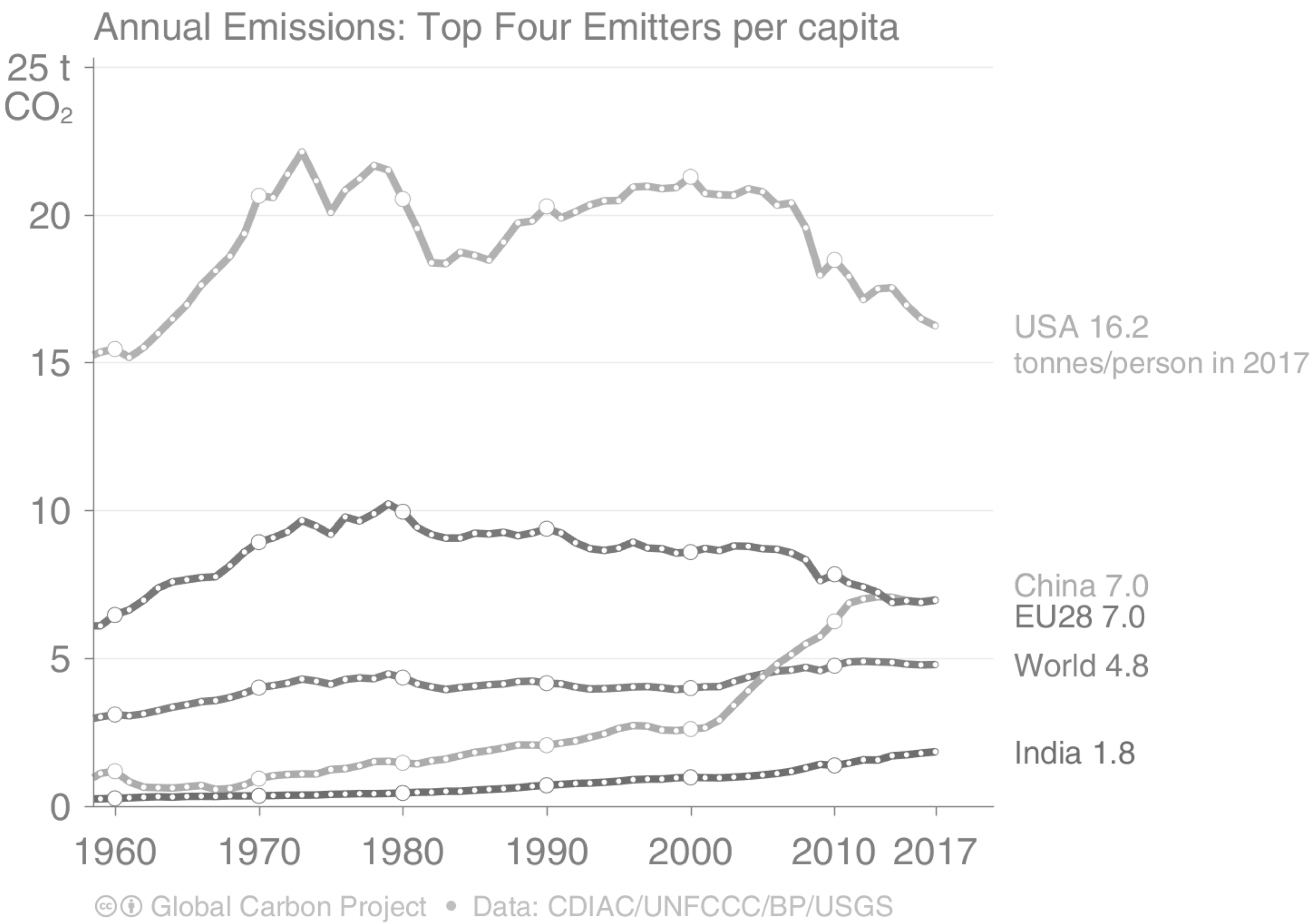
The total remaining emissions from 2017 to keep global average temperature below 2° C ($800GtCO_2$) will be used in around 20 years at current emission rates



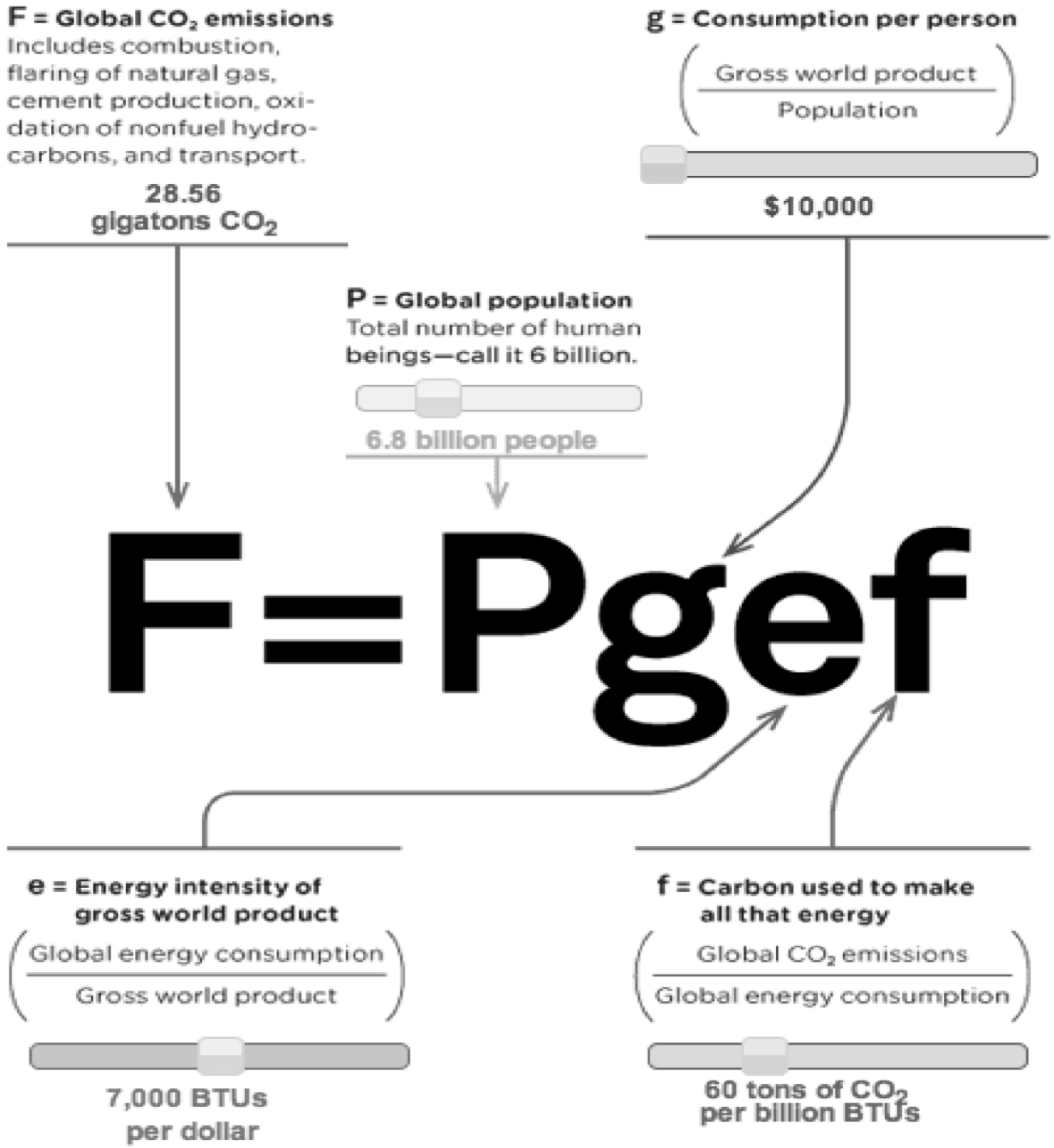
Grey: Total CO_2-only quota for 2° C with 66% chance. Green: Removed from CO_2 only quota. Blue: Remaining CO_2 quota.

The remaining quotas are indicative and vary depending on definition and methodology

Source: Peters et al 2015; Global Carbon Budget 2016

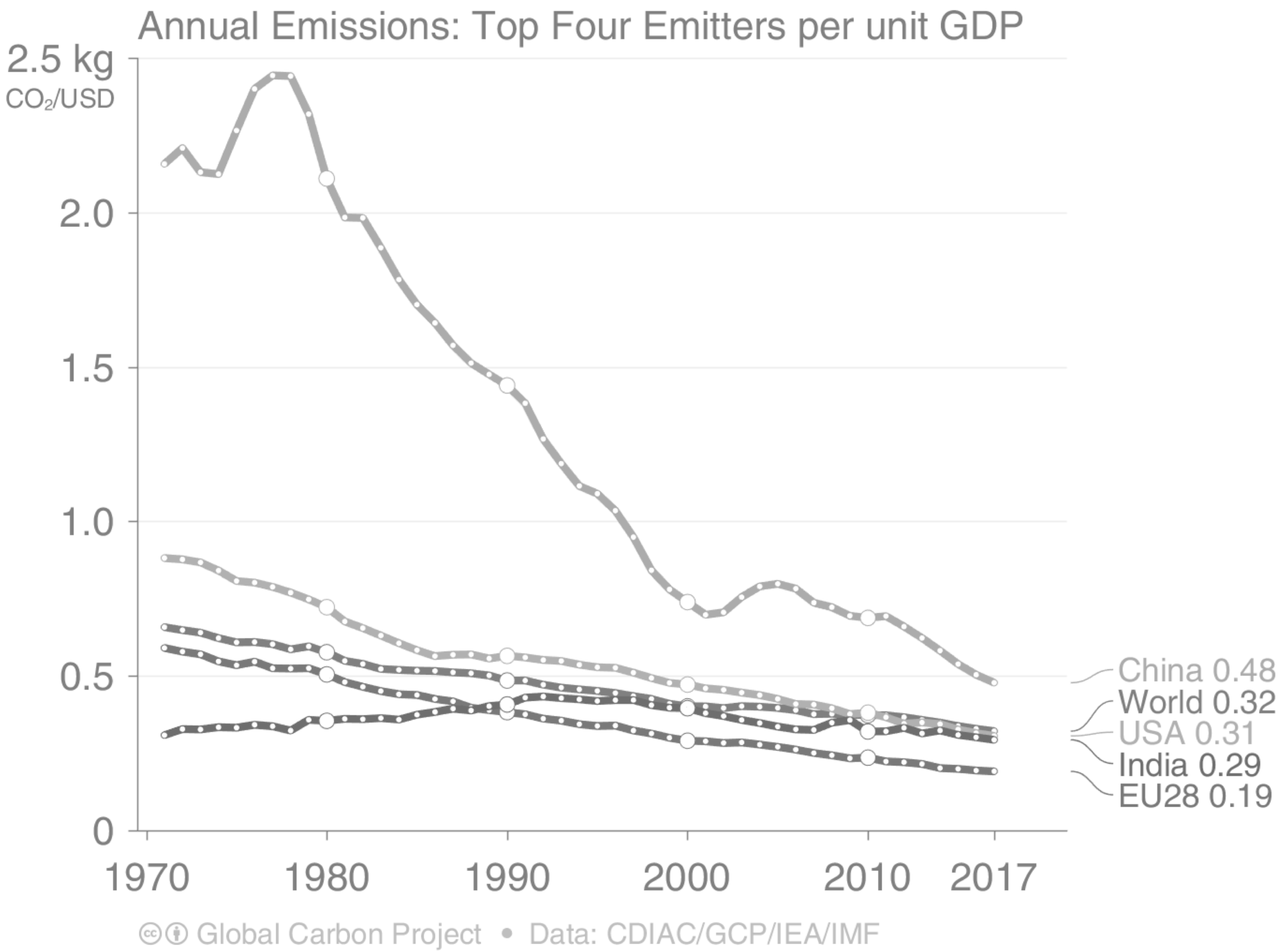


Annual Emissions: Top Four Emitters per capita
25 t
CO_2
20
15
10
5
0
1960
1970
1980
1990
2000
2010
2017
USA 16.2
tonnes/person in 2017
China 7.0
EU28 7.0
World 4.8
India 1.8
Global Carbon Project • Data: CDIAC/UNFCCC/BP/USGS

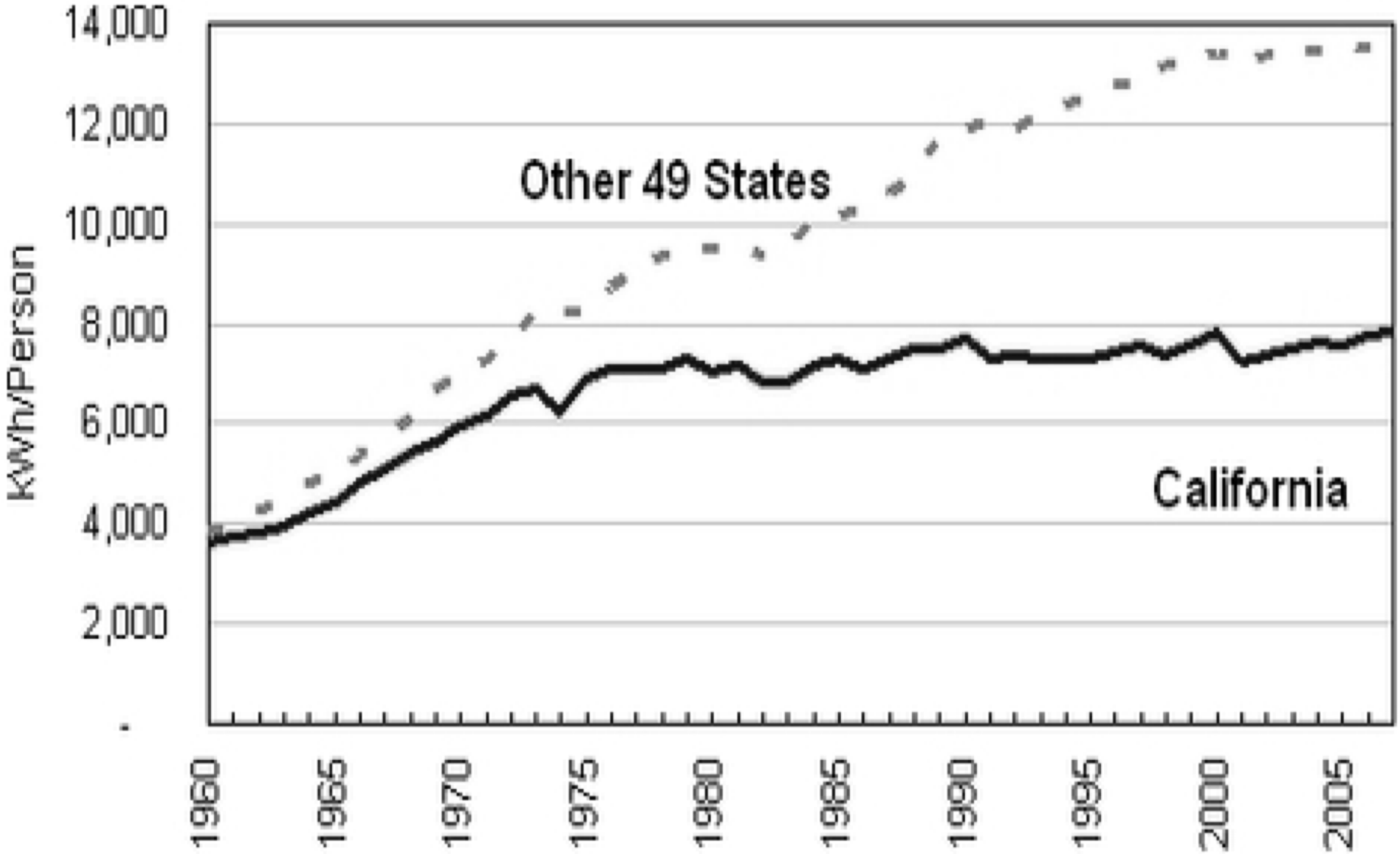


KAYA IDENTITY

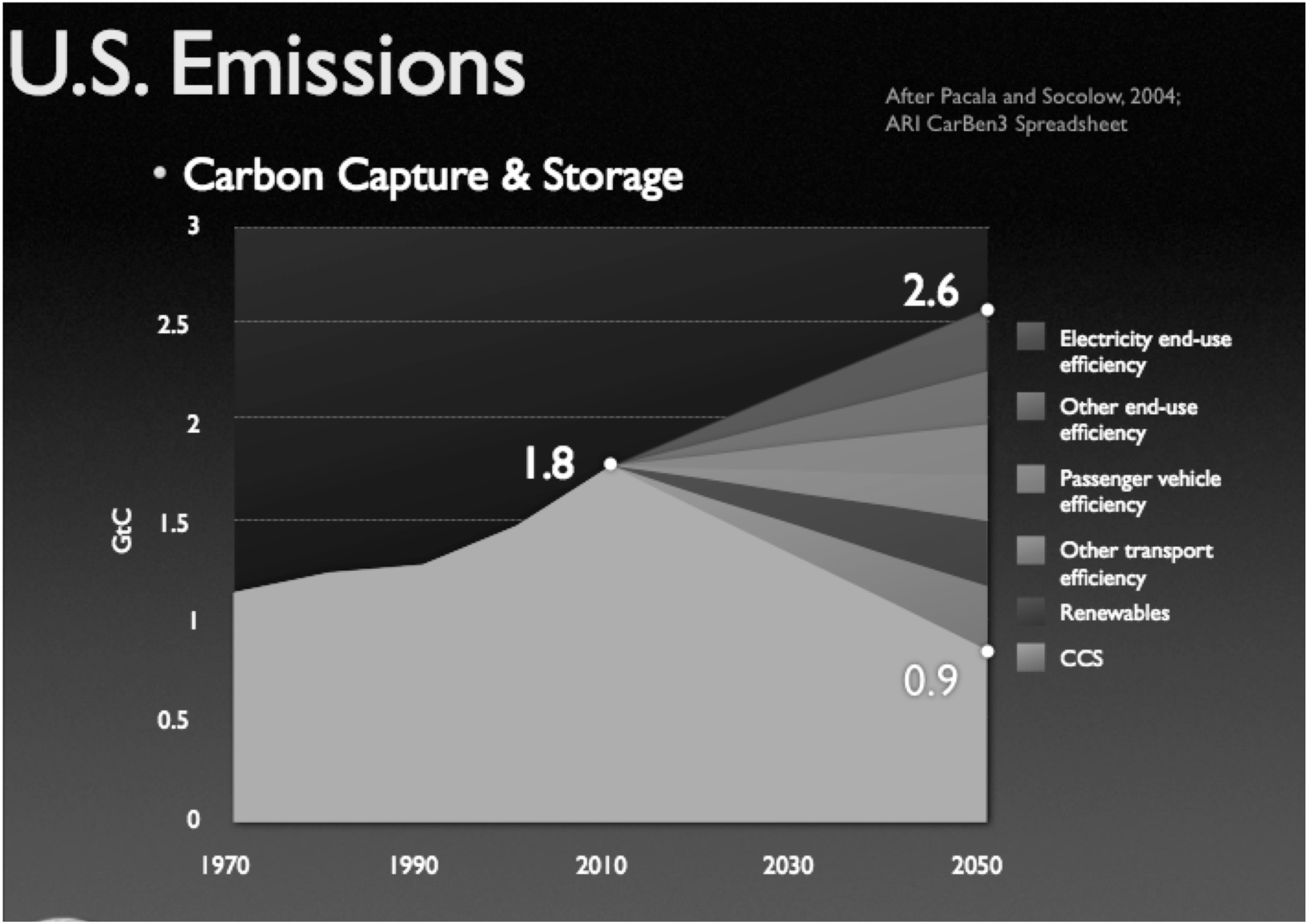
http://climatemodels.uchicago.edu/kaya/

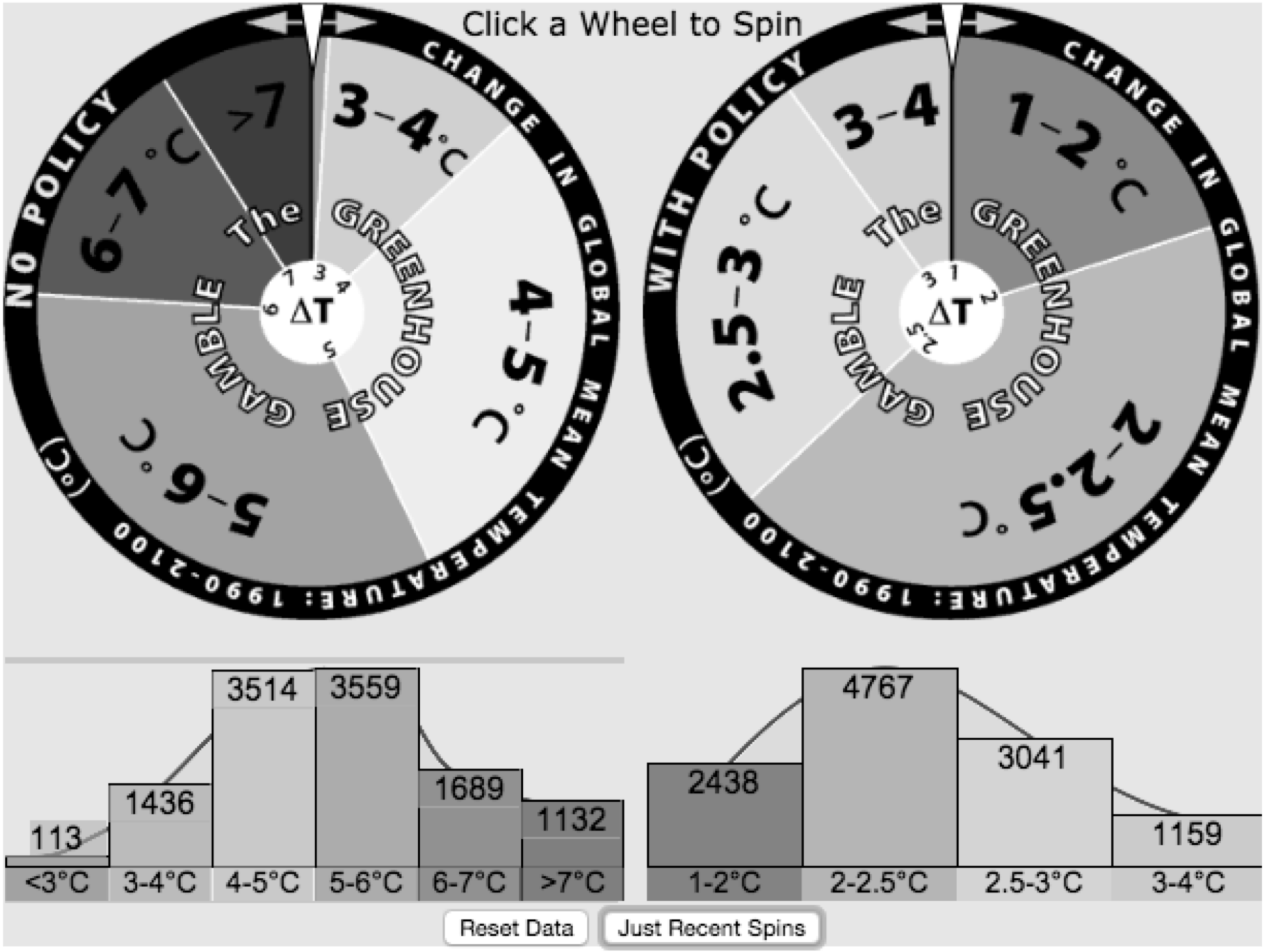


Annual Emissions: Top Four Emitters per unit GDP
2.5 kg
CO_2/USD
2.0
1.5
1.0
0.5
0
1970
1980
1990
2000
2010
2017
China 0.48
World 0.32
USA 0.31
India 0.29
EU28 0.19
Global Carbon Project • Data: CDIAC/GCP/IEA/IMF



14,000
12,000
10,000
8,000
6,000
4,000
2,000
-
KWh/Person
Other 49 States
California
1960
1965
1970
1975
1980
1985
1990
1995
2000
2005


U.S. Emissions
After Pacala and Socolow, 2004;
ARI CarBen3 Spreadsheet
• Carbon Capture & Storage
3
2.5
2
1.5
1
0.5
0
GtC
1970
1990
2010
2030
2050
2.6
1.8
0.9
Electricity end-use efficiency
Other end-use efficiency
Passenger vehicle efficiency
Other transport efficiency
Renewables
CCS



http://globalchange.mit.edu/focus-areas/uncertainty/gamble

Community standards do change

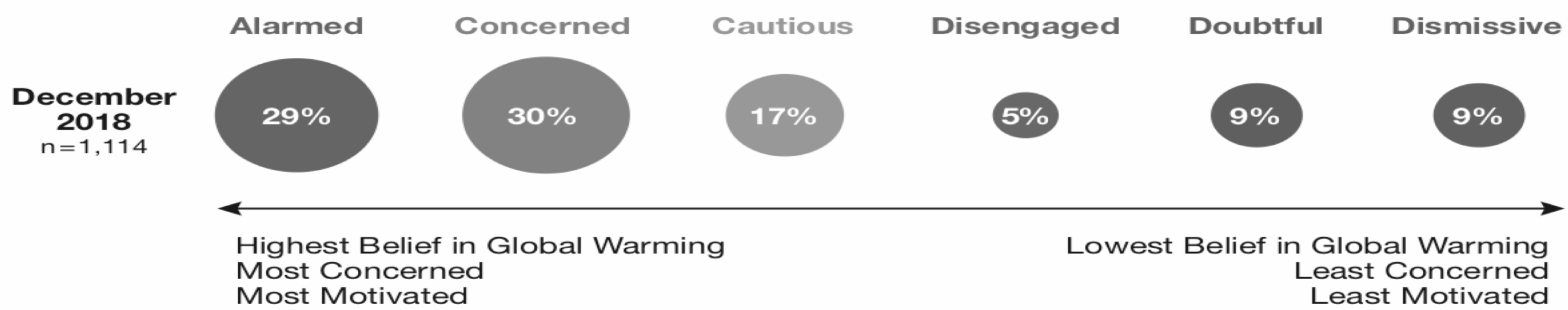
- Education and generational change
  - Recycling
- Innovation
  - The Ozone Hole
- Regulation
  - Acid rain

Global Treaties

- There is no international rules making body!
- Treaties are a game of incentives and disincentives to sign and to comply
- Individual countries weigh costs and benefits
- Compliance and monitoring are contentious issues

Paris

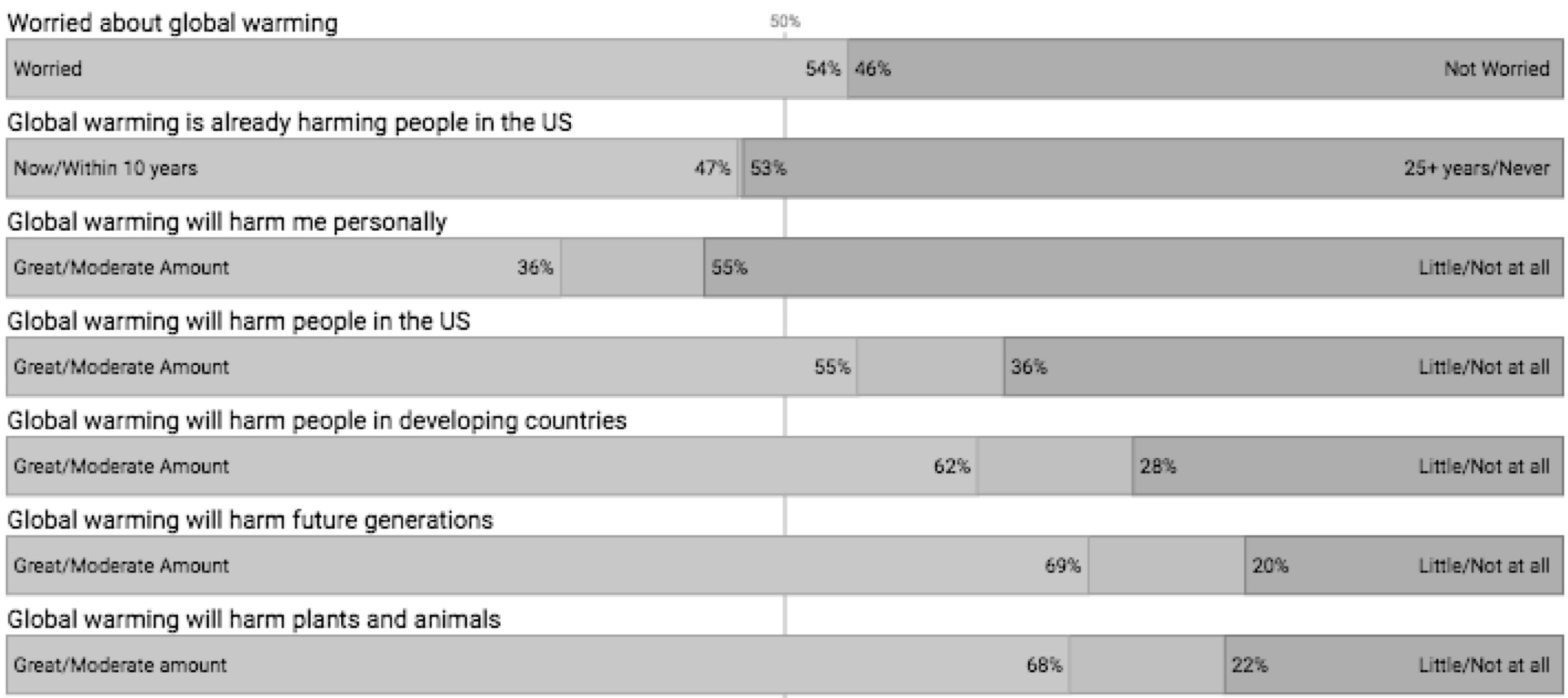
- Refocuses goal on temperature below 2 C limit (global emissions will need to peak in <20 years, sources must balance sinks by 2050)
- Lets countries determines their contribution
- $100 billion fund for developing countries
- Is set to be in force, now that > 55% of emissions included in ratified countries*
- Compliance and monitoring will be a key challenge



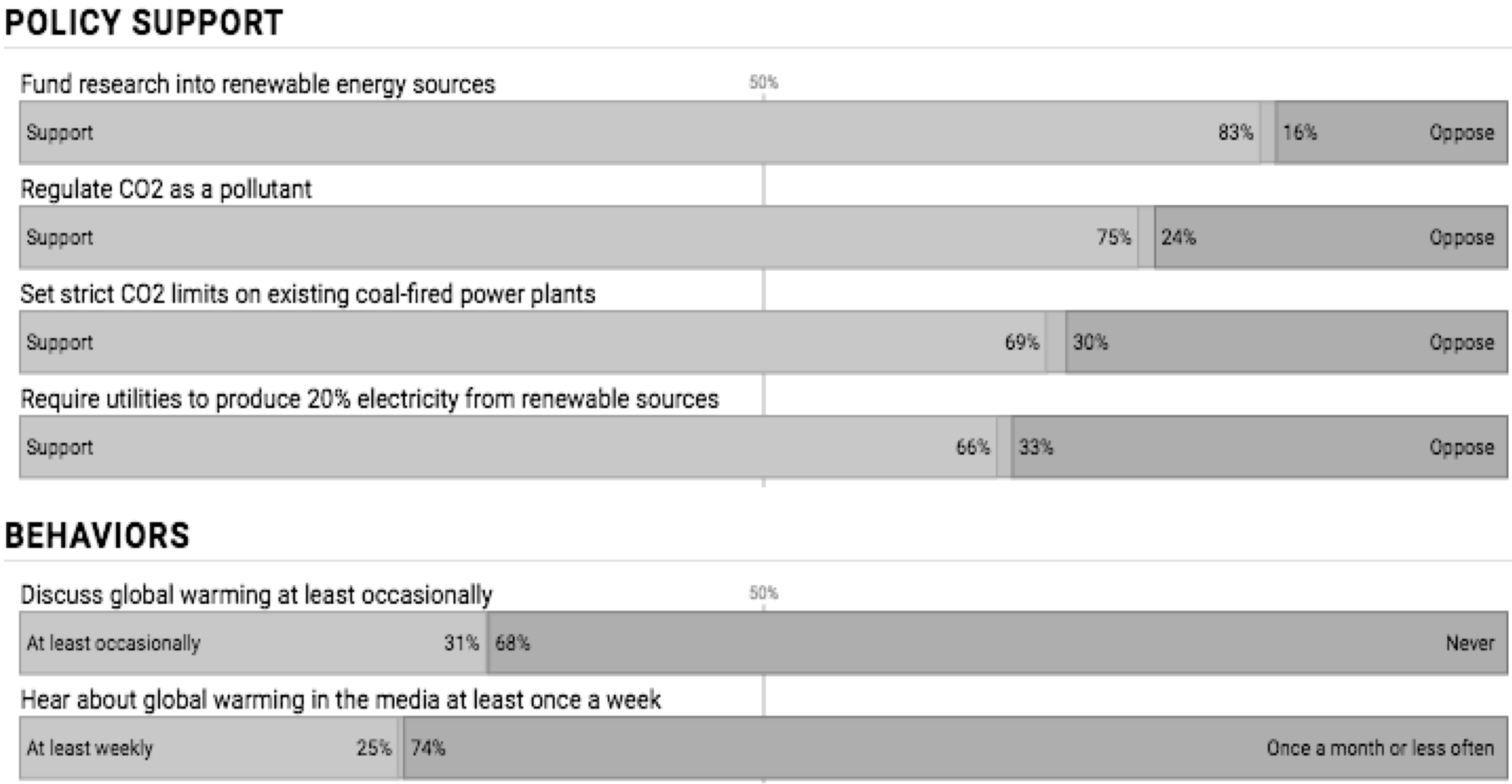
YALE PROGRAM ON Climate Change Communication

GEORGE MASON UNIVERSITY CENTER for CLIMATE CHANGE COMMUNICATION

RISK PERCEPTIONS



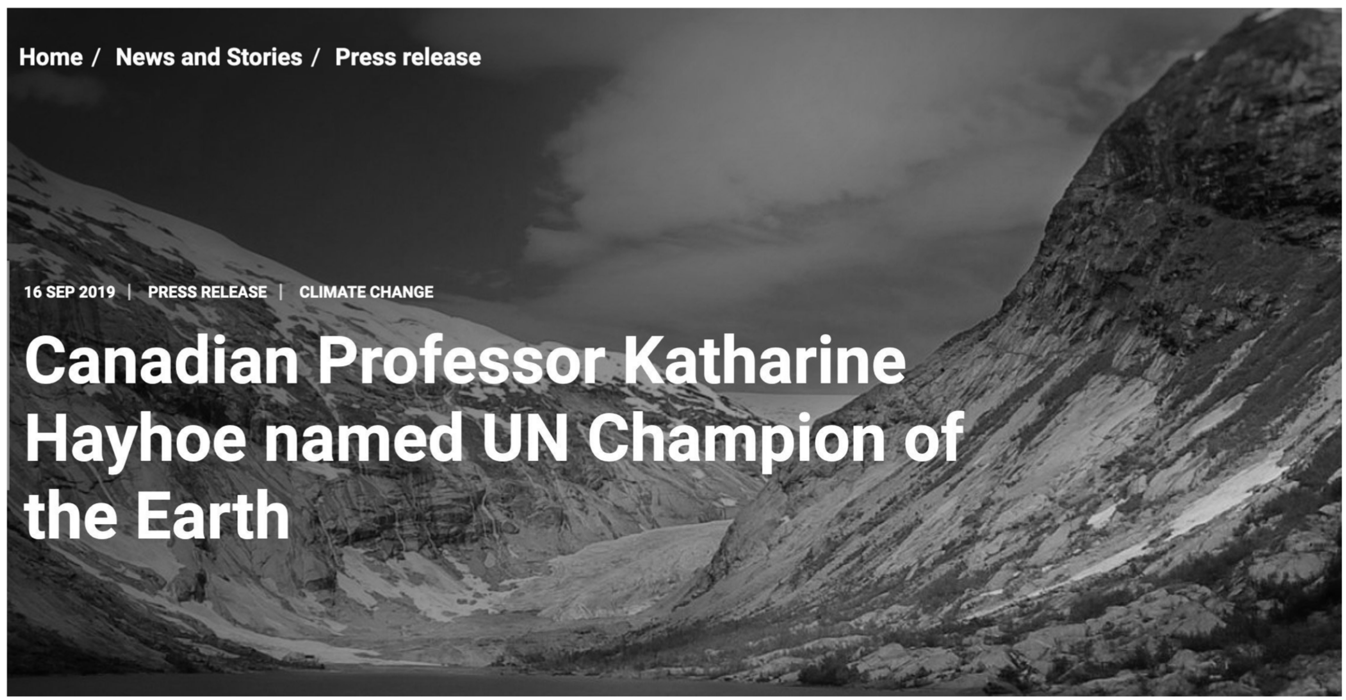
There is support among Wisconsin residents



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

http://katharinehayhoe.com

GLOBAL WEIRDING
YouTube Channel



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

https://globalclimatestrike.net/

The future?

- Climate scientists will continue to refine projections of future change and impacts in response to emissions and/or policy
- Global treaty progress will likely be slow, but there are successes in deforestation reduction, developing country support, and renewal energy infrastructure
- Bi- or Multi- lateral agreements (e.g., US-China) and within country “energy arms race” may end up having the biggest bang for buck
- Fossil fuel reserves are getting scarcer, but not running out anytime soon. Given lags in climate response, some level of adaptation is inevitable
- Risk Management as a field has to grapple with climate change

http://www.aos.wisc.edu/academics/profms/

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