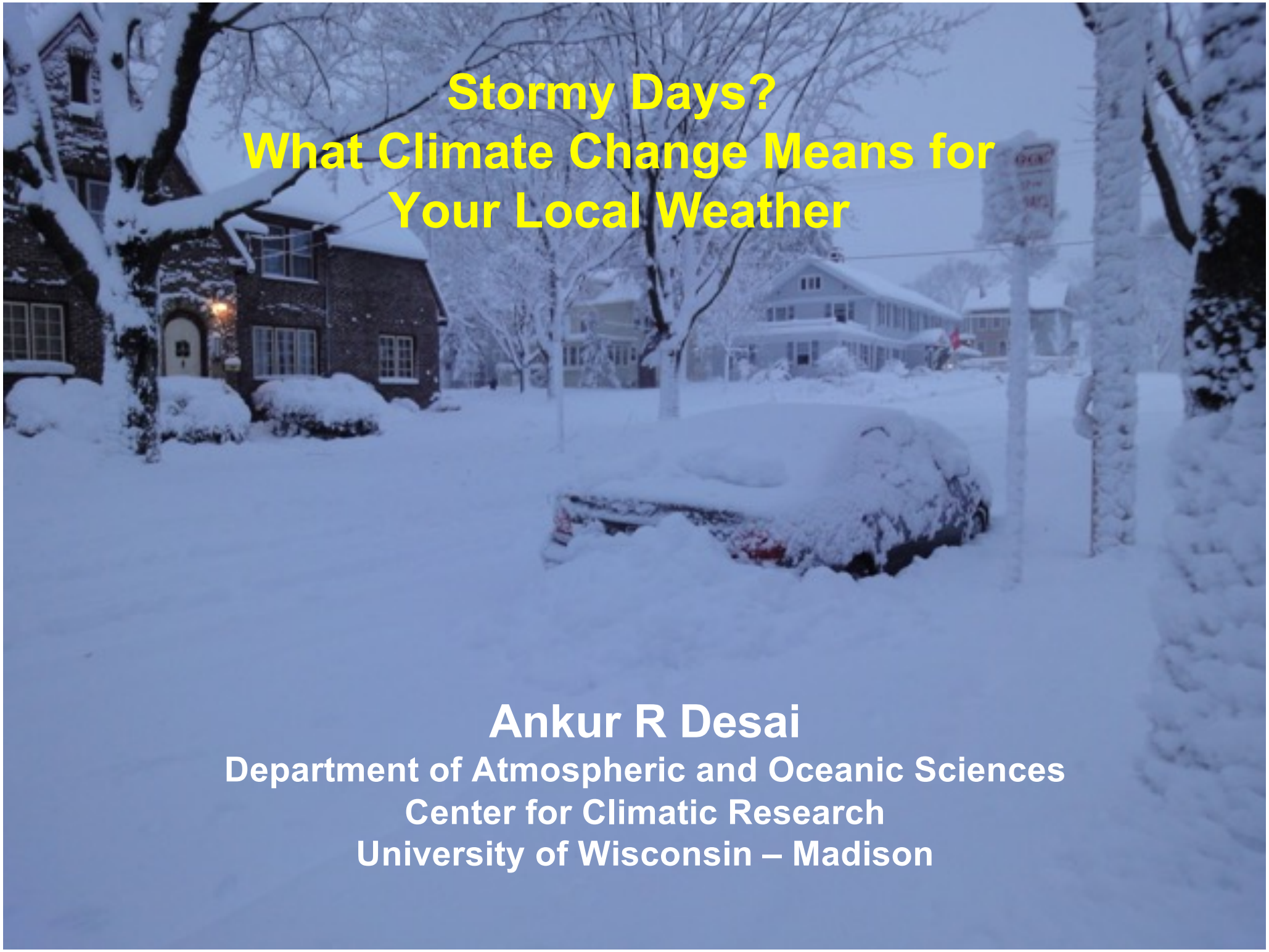


# Stormy Days?
# What Climate Change Means for Your Local Weather


**Ankur R Desai**

**Department of Atmospheric and Oceanic Sciences**

**Center for Climatic Research**

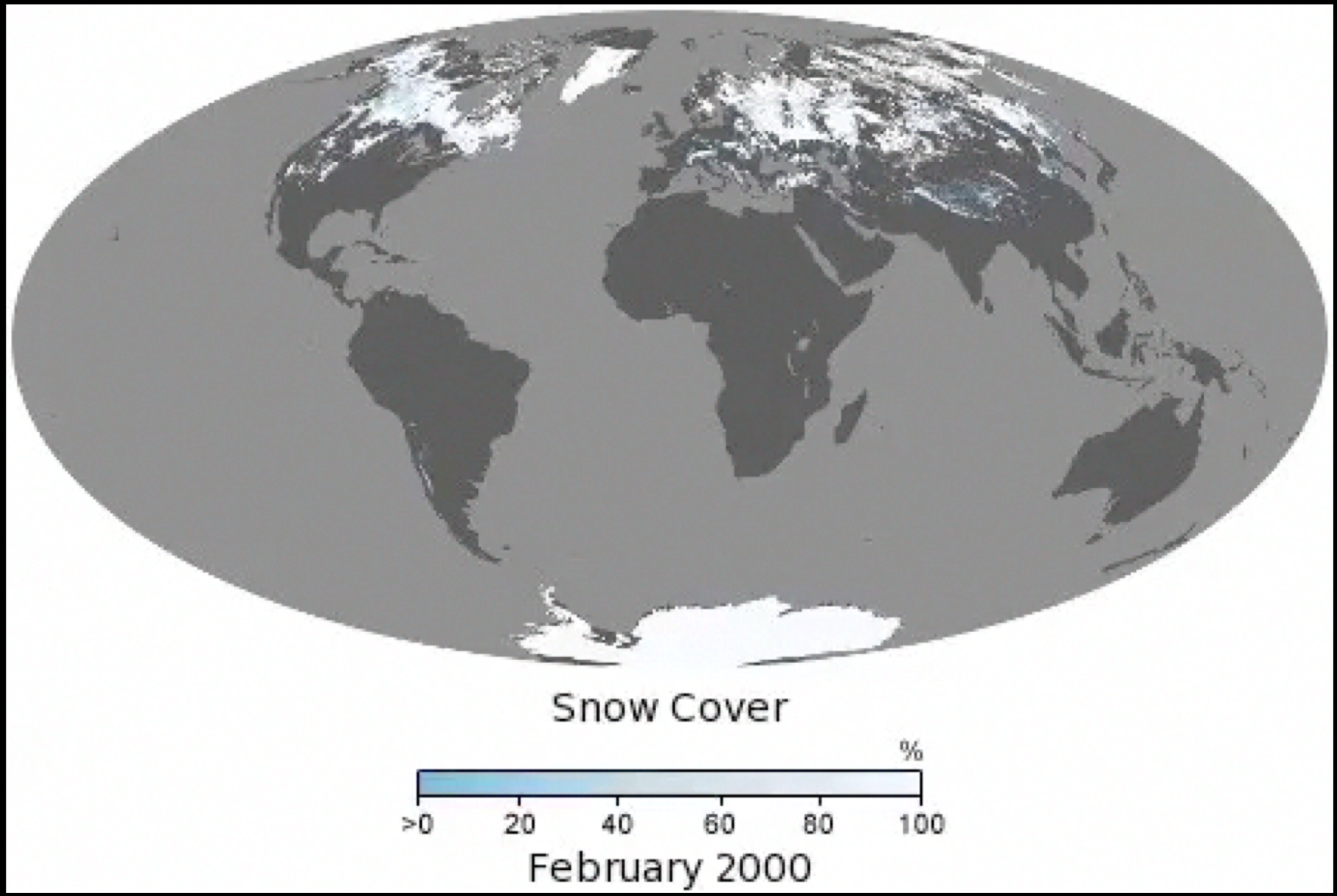
**University of Wisconsin – Madison**

https://www.nytimes.com/2020/01/10/world/australia/australia-wildfires-photos.html


NCA 2018

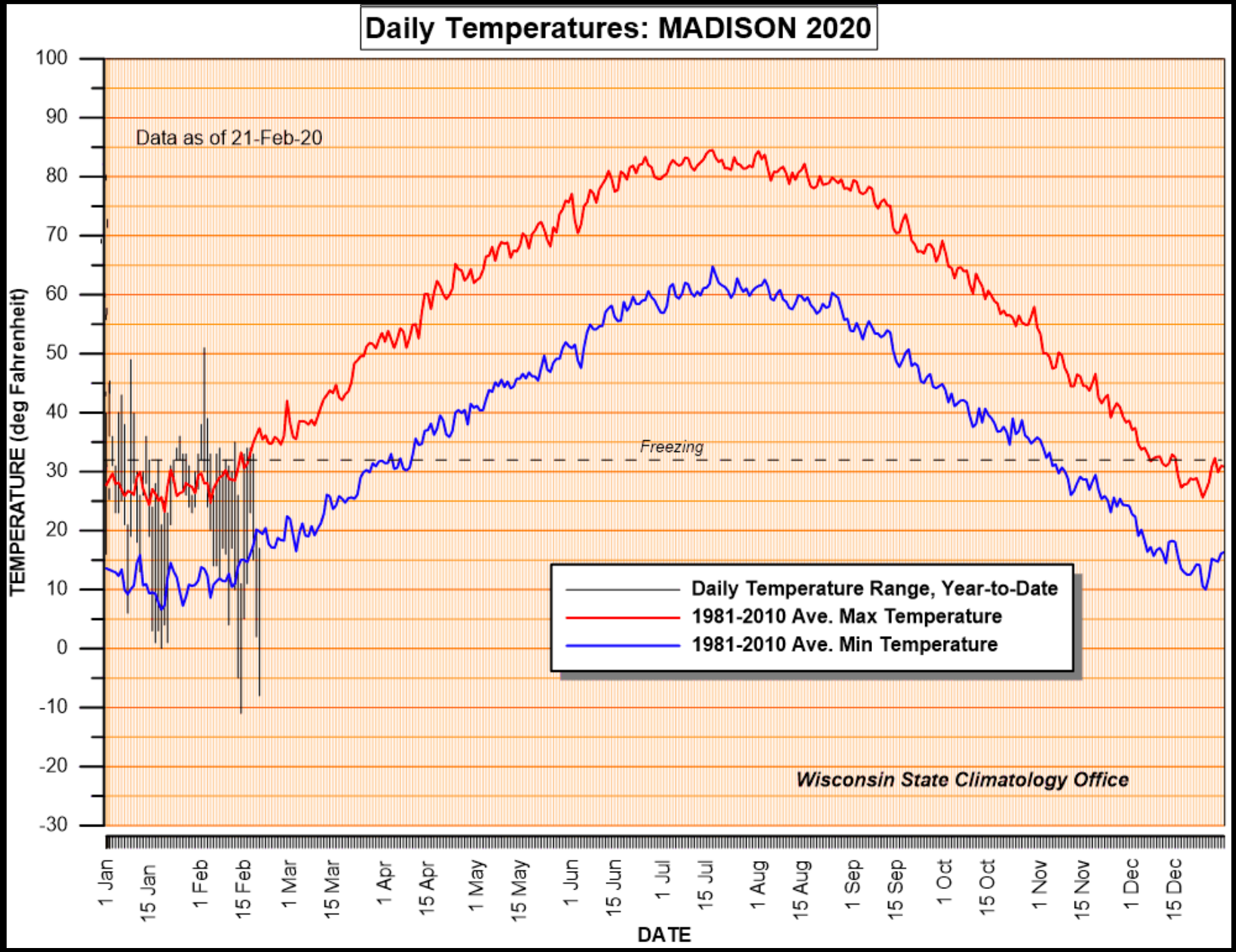
# Did climate change cause these extreme events?

- That's the wrong question!
- Better question: How much does a changing climate influence the likelihood or magnitude of an event?

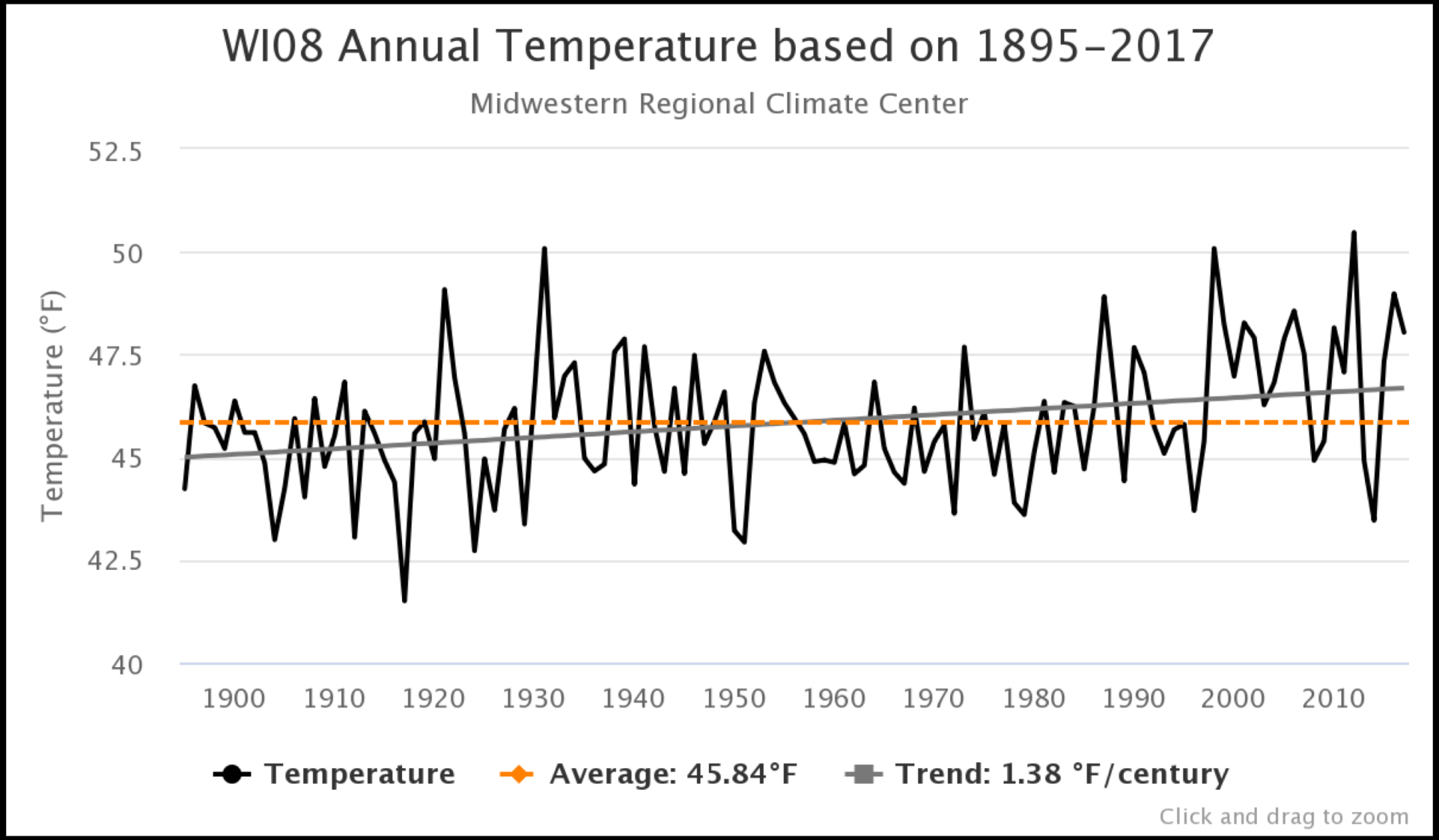

Snow Cover
%
>0
20
40
60
80
100
February 2000

# What is Climate?

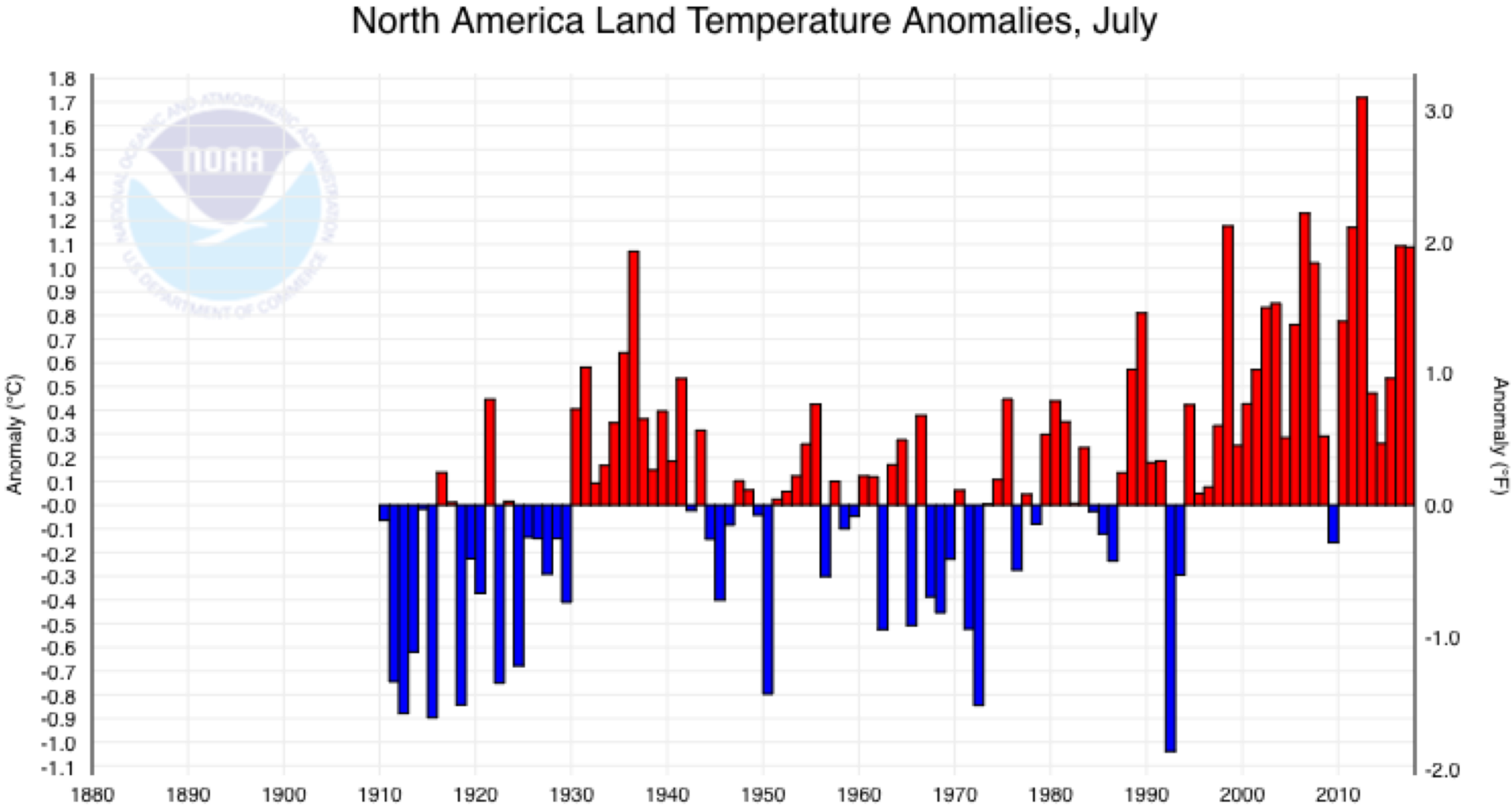
- Climate is the average of weather
  - "Climate is what you expect, weather is what you get" –Andrew John Herbertson
  - "Climate is your personality, weather is your mood" –Marshall Shepherd
- Climate changes naturally (over eons) and by humans (over centuries)

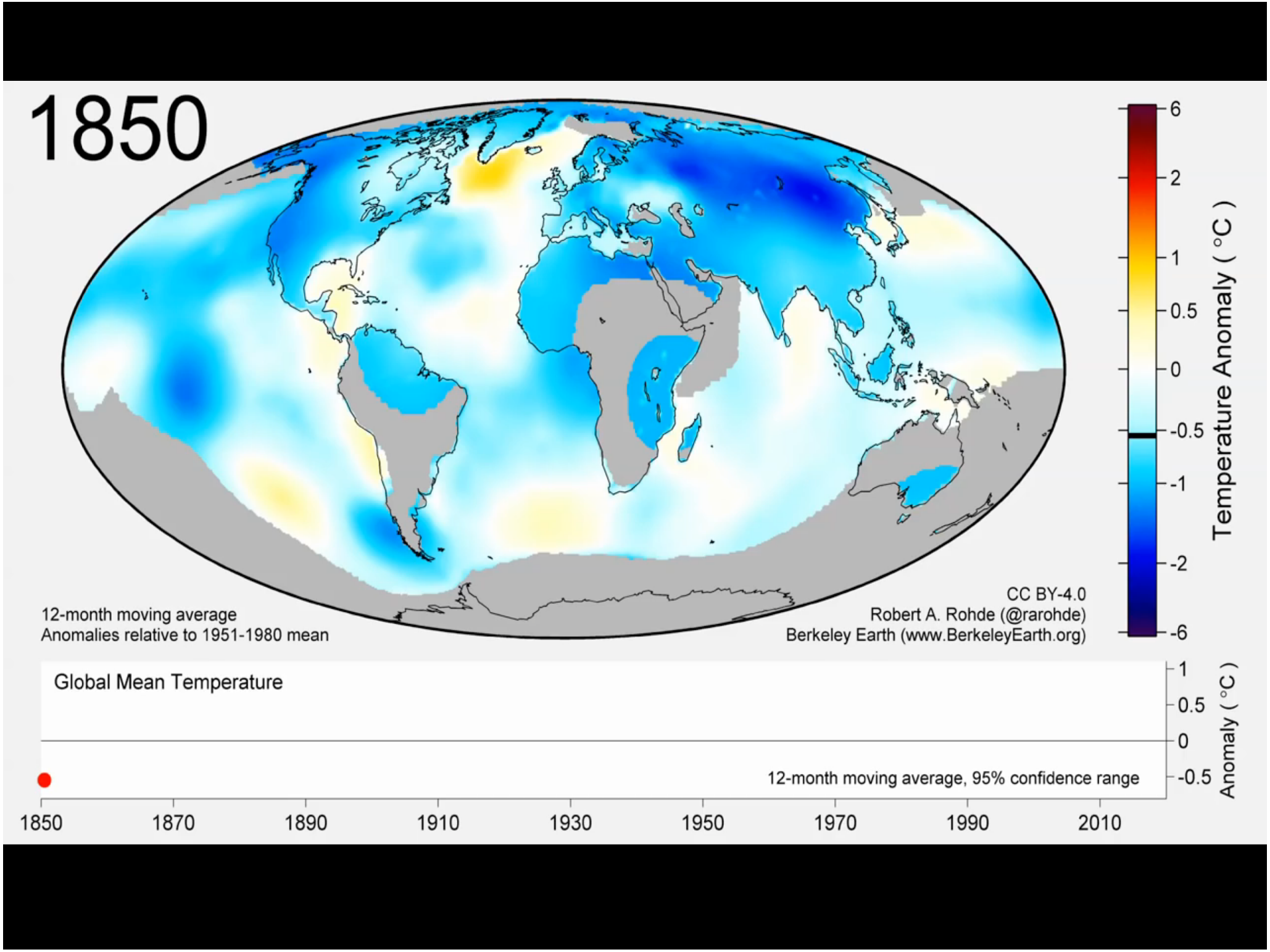

Daily Temperatures: MADISON 2020
Data as of 21-Feb-20
TEMPERATURE (deg Fahrenheit)
100
90
80
70
60
50
40
30
20
10
0
-10
-20
-30
Freezing
Daily Temperature Range, Year-to-Date
1981-2010 Ave. Max Temperature
1981-2010 Ave. Min Temperature
Wisconsin State Climatology Office
1 Jan
15 Jan
1 Feb
15 Feb
1 Mar
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

# Southern Wisconsin

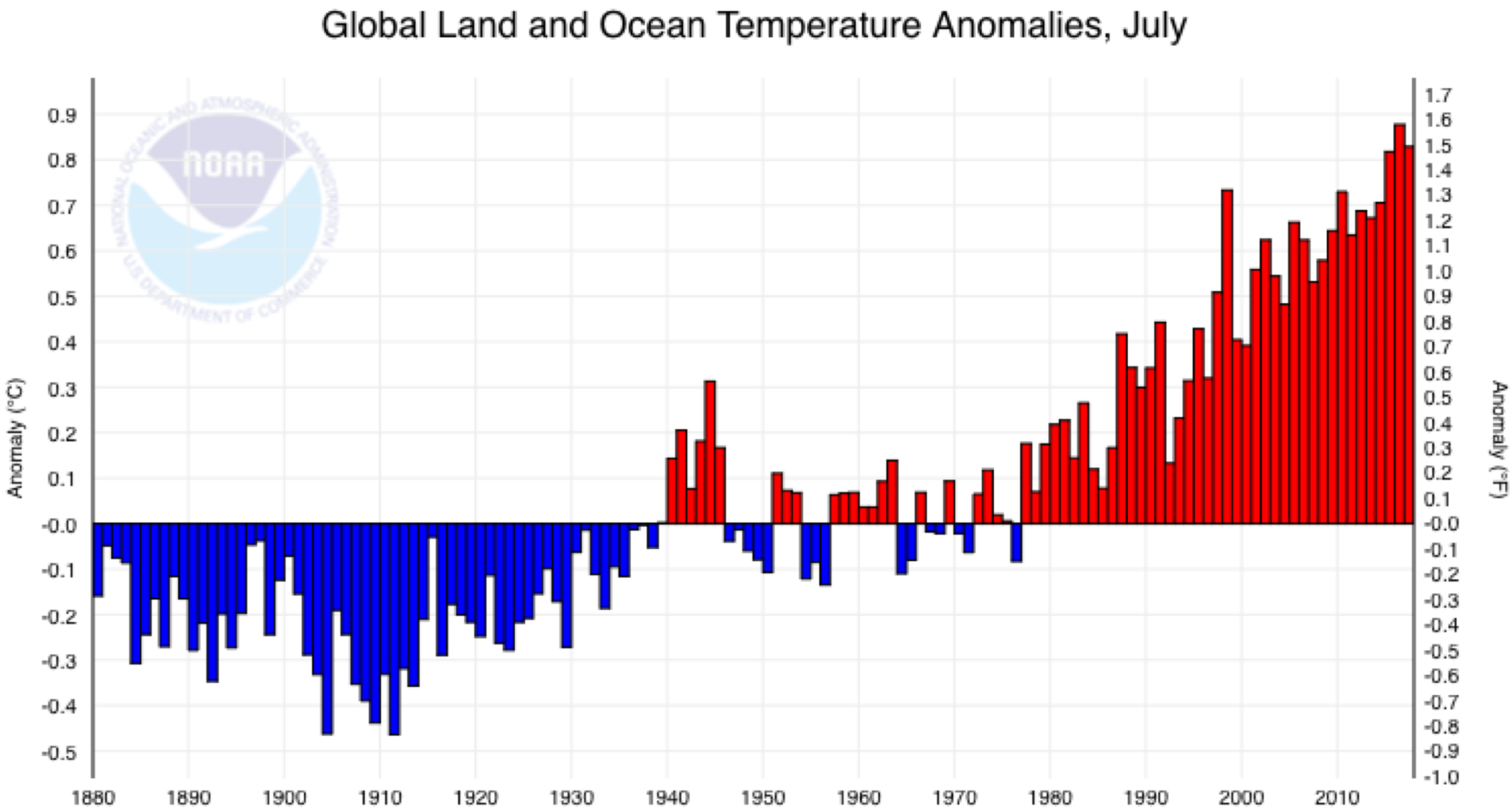


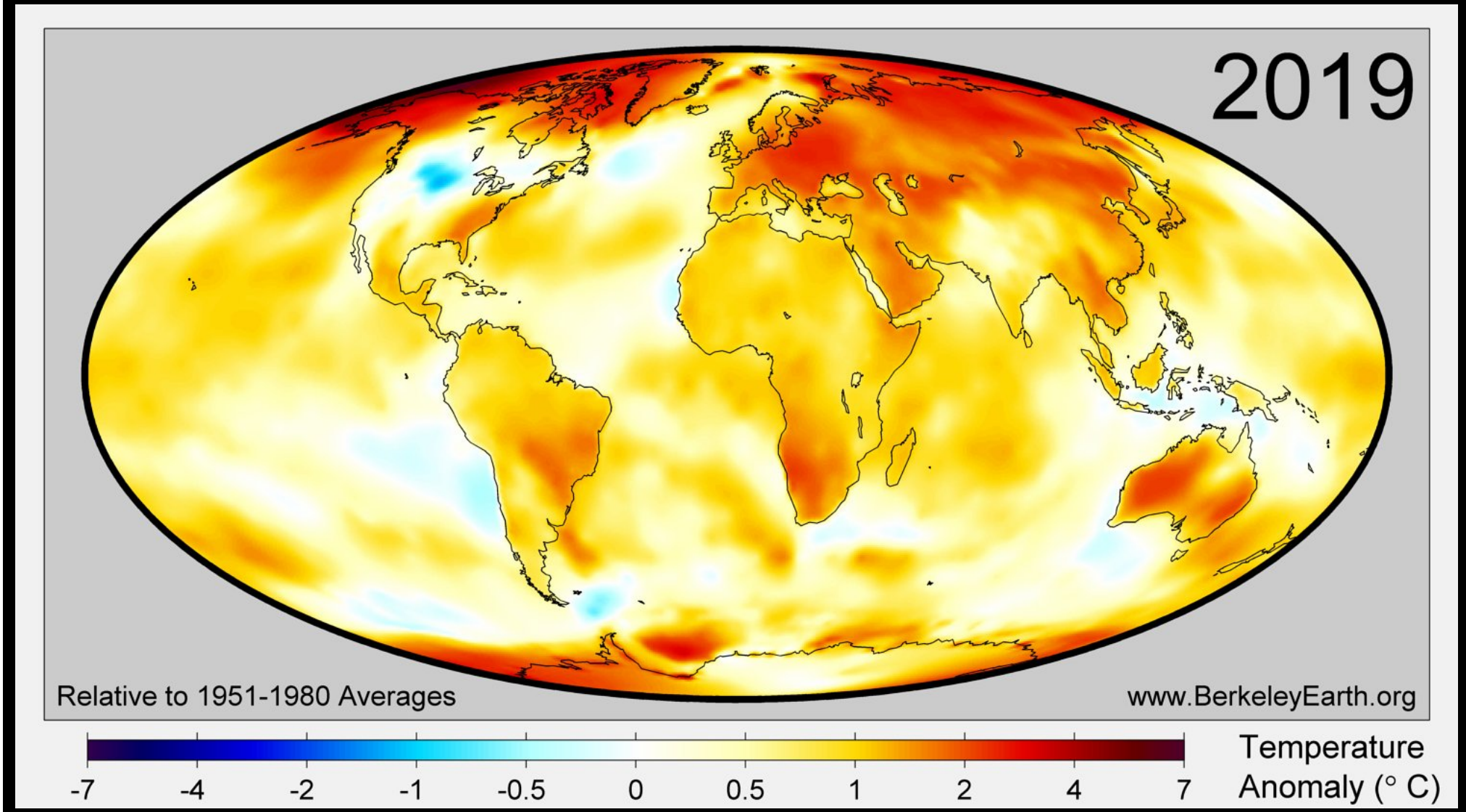
# N America


North America Land Temperature Anomalies, July
Anomaly (°C)
Anomaly (°F)
1.8
1.7
1.6
1.5
1.4
1.3
1.2
1.1
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
-0.0
-0.1
-0.2
-0.3
-0.4
-0.5
-0.6
-0.7
-0.8
-0.9
-1.0
-1.1
3.0
2.0
1.0
0.0
-1.0
-2.0
1880
1890
1900
1910
1920
1930
1940
1950
1960
1970
1980
1990
2000
2010


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

# WORLD


Global Land and Ocean Temperature Anomalies, July
Anomaly (°C)
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
-0.0
-0.1
-0.2
-0.3
-0.4
-0.5
1880
1890
1900
1910
1920
1930
1940
1950
1960
1970
1980
1990
2000
2010
Anomaly (°F)
1.7
1.6
1.5
1.4
1.3
1.2
1.1
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
-0.0
-0.1
-0.2
-0.3
-0.4
-0.5
-0.6
-0.7
-0.8
-0.9
-1.0




Robert Rhodes

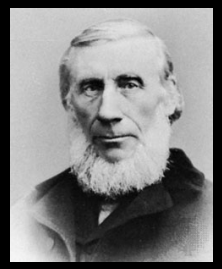
The Rodney & Otamatea Times
WAITEMATA & KAIPARA GAZETTE.
PRICE—10s per annum in advance
WARKWORTH, WEDNESDAY, AUGUST 14, 1912.
3d per Copy.

# 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.

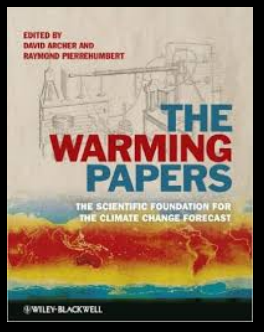




- Planetary (inc. Earth) temperature is determined by interaction of sunlight and “greenhouse” gases that absorb infrared radiation (Fourier 1824, Tyndall 1861; Foote 1857)

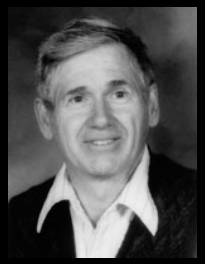
- $CO_2$ is a greenhouse warming gas and emitted from coal, oil, gas (Arrhenius 1896)

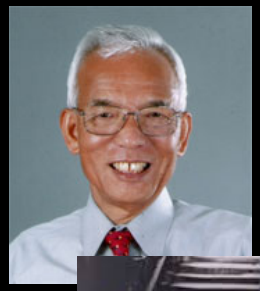
- Oceans can only take up a fraction of $CO_2$ (Revelle 1957)



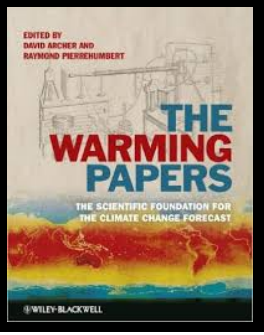
"$CO_2$ *is to climate what steroids was to baseball*…" –Jason Samenow

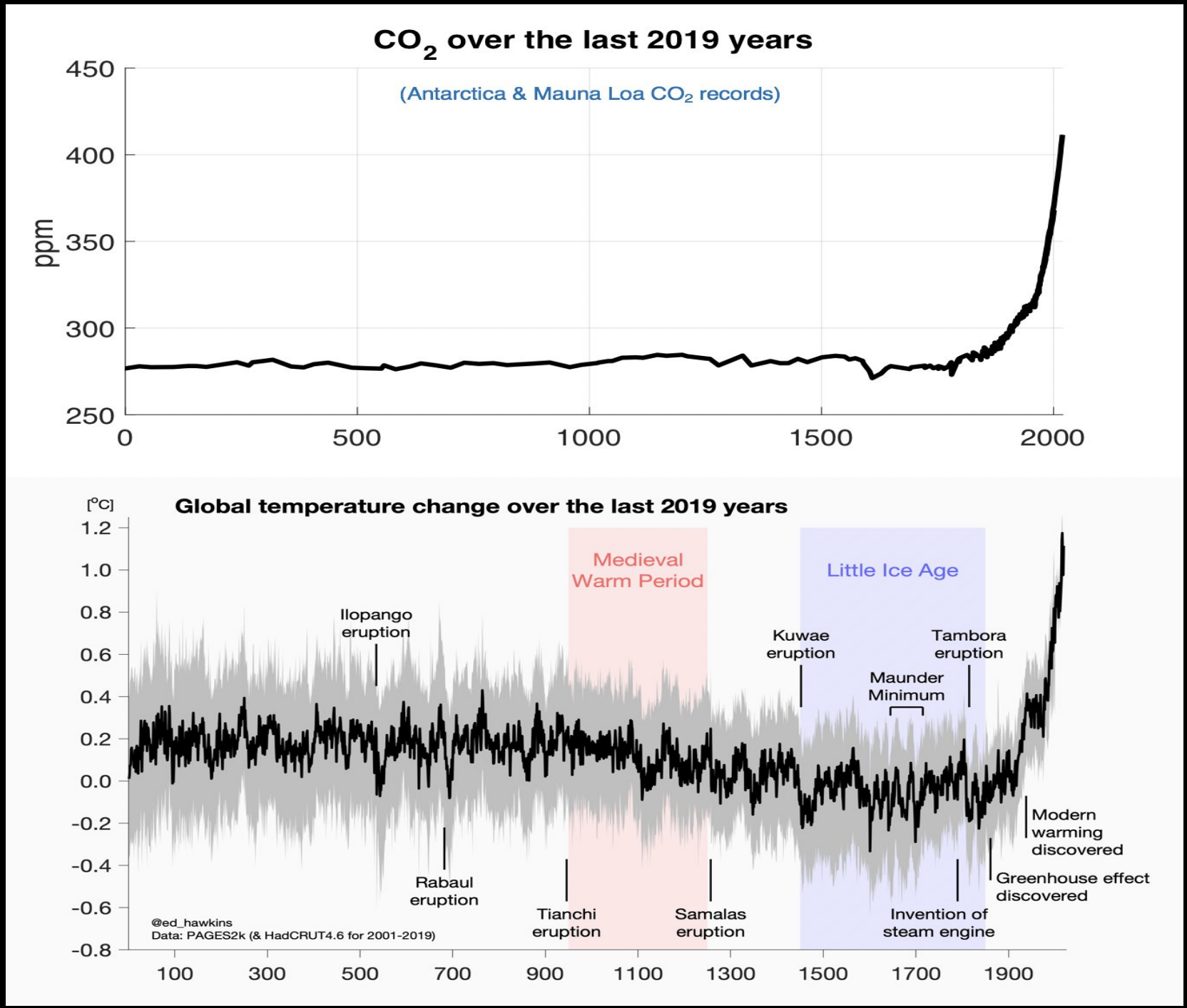

https://www.bloomberg.com/graphics/2015-whats-warming-the-world/





- Atmospheric $CO_2$ increasing 2 ppm/yr from fossil fuel use, half goes into land and ocean (Keeling 1960, Tans 1990)
- Observed warming patterns are linked to greenhouse gases (Callendar 1938, Mann 1999)
- $20^{th}$ century warming explained by atmospheric $CO_2$ and other gases and pollution (Manabe 1967, Hansen 1984)

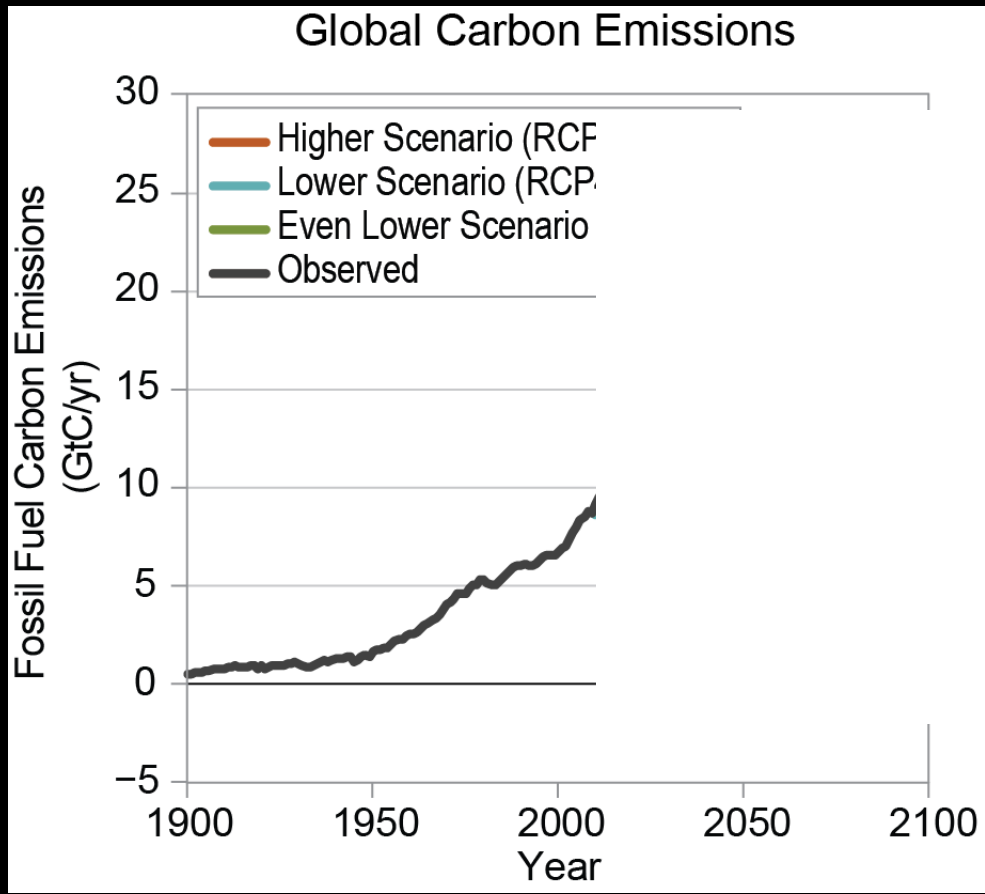


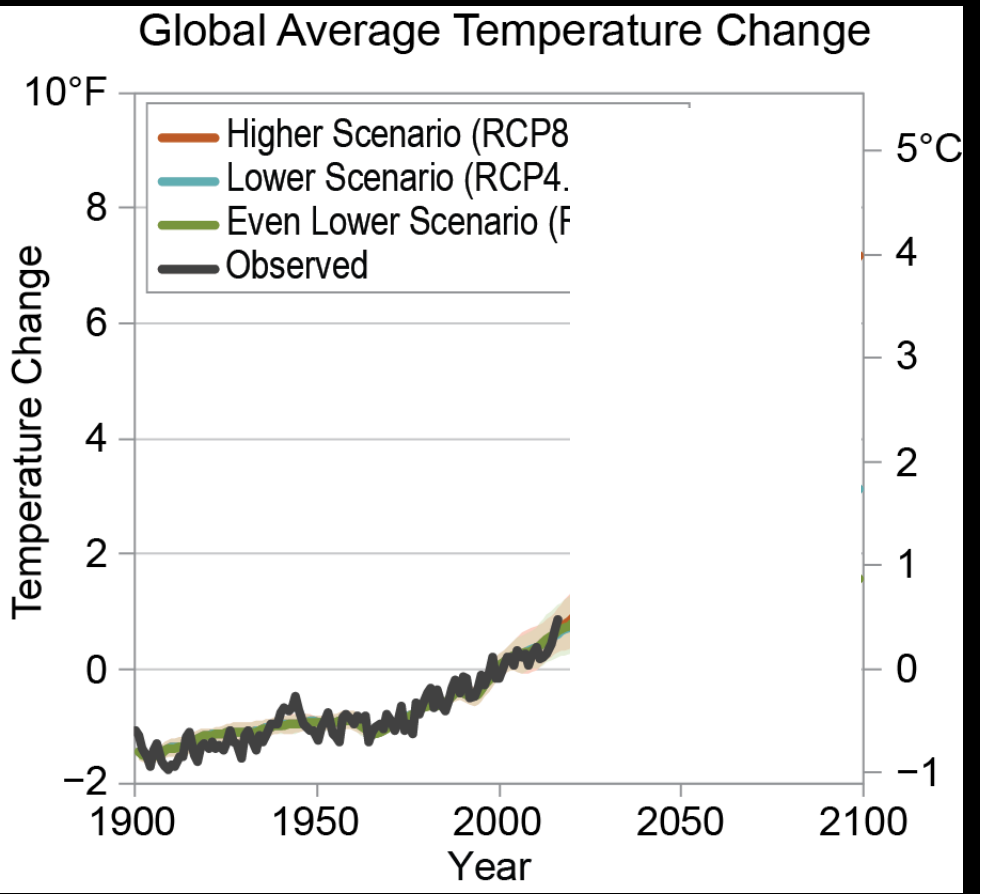

$CO_2$ over the last 2019 years
(Antarctica & Mauna Loa $CO_2$ records)
ppm
450
400
350
300
250
0
500
1000
1500
2000
Global temperature change over the last 2019 years
[°C]
1.2
1.0
0.8
0.6
0.4
0.2
0.0
-0.2
-0.4
-0.6
-0.8
Medieval Warm Period
Little Ice Age
Ilopango eruption
Kuwae eruption
Tambora eruption
Maunder Minimum
Rabaul eruption
Tianchi eruption
Samalas eruption
Invention of steam engine
Modern warming discovered
Greenhouse effect discovered
@ed_hawkins
Data: PAGES2k (& HadCRUT4.6 for 2001-2019)
100
300
500
700
900
1100
1300
1500
1700
1900

Ed Hawkins



- China total emissions now leads the world, but US tops per capita fossil fuel emissions (DOE,IEA).
- Climate projections show a 3 C +/- 1.5 C response to doubling of $CO_2$ by 2100. (IPCC 1990, 1995, 2001, 2007, 2013)
- Modest warming (0-2 C) creates both winners and losers around the world, while warming beyond this tends to be a net negative (WMO, ExxonMobil, Stern Review, World Bank, NCA, WICCI, DOD 1979-present)


Global Carbon Emissions
Fossil Fuel Carbon Emissions (GtC/yr)
30
25
20
15
10
5
0
−5
1900
1950
2000
2050
2100
Year
Higher Scenario (RCF
Lower Scenario (RCP
Even Lower Scenario
Observed


Global Average Temperature Change
Temperature Change
10°F
8
6
4
2
0
−2
5°C
4
3
2
1
0
−1
1900
1950
2000
2050
2100
Year
Higher Scenario (RCP8
Lower Scenario (RCP4.
Even Lower Scenario (F
Observed

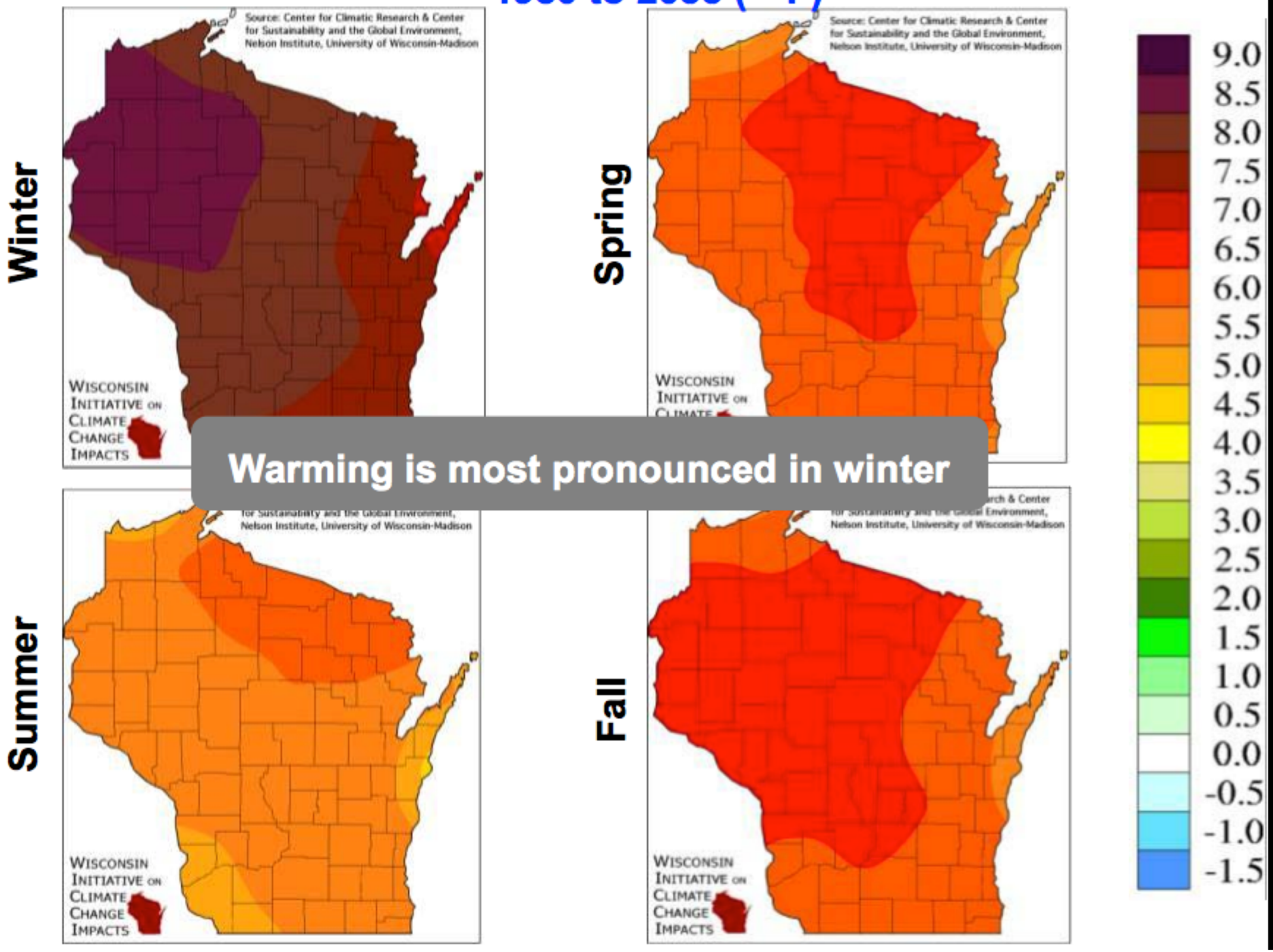
NCA 2018

So how does climate influence weather?

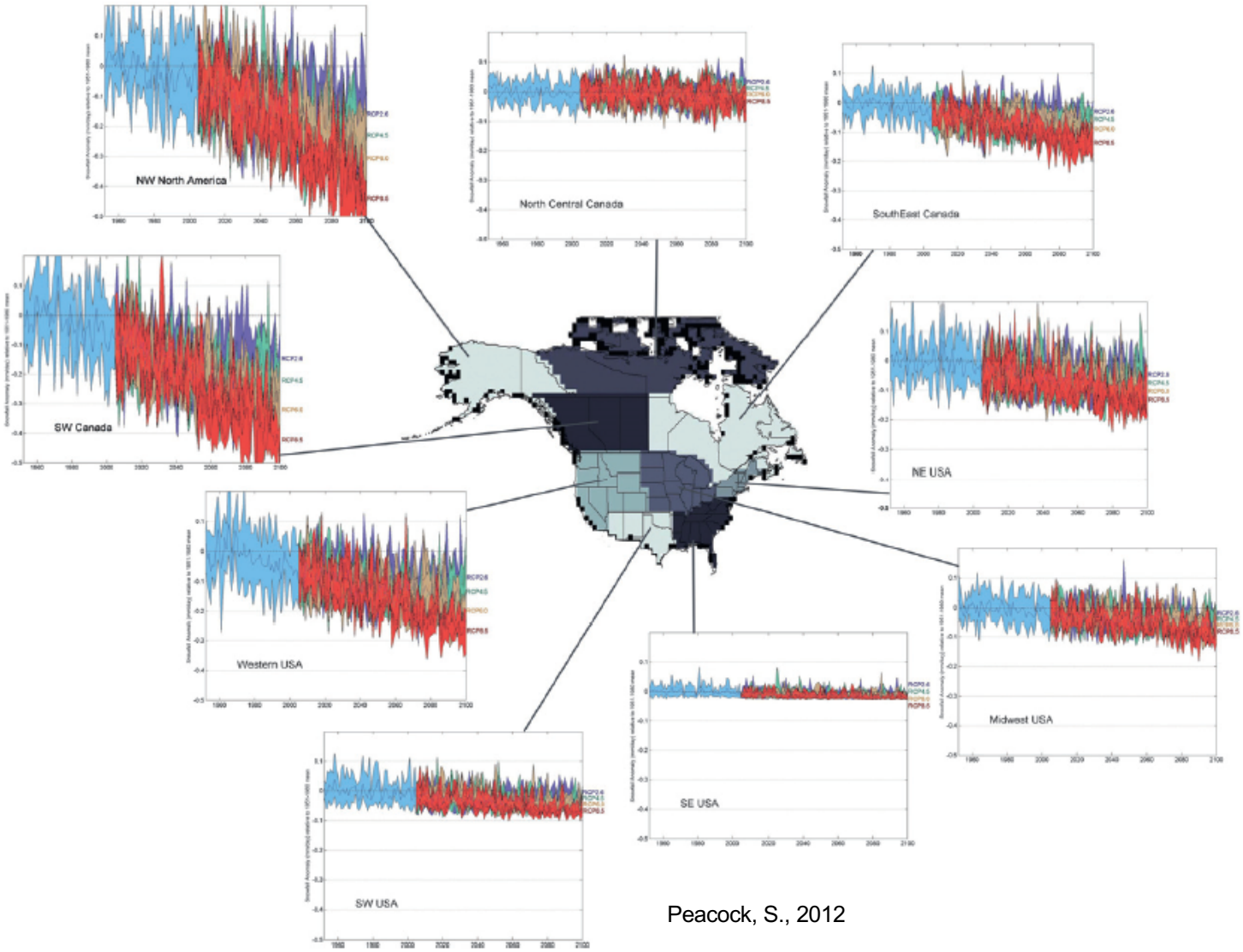


# Projected Change in Seasonal Temperatures

## 1980 to 2055 (° F)



# Snow cover is expected to decline

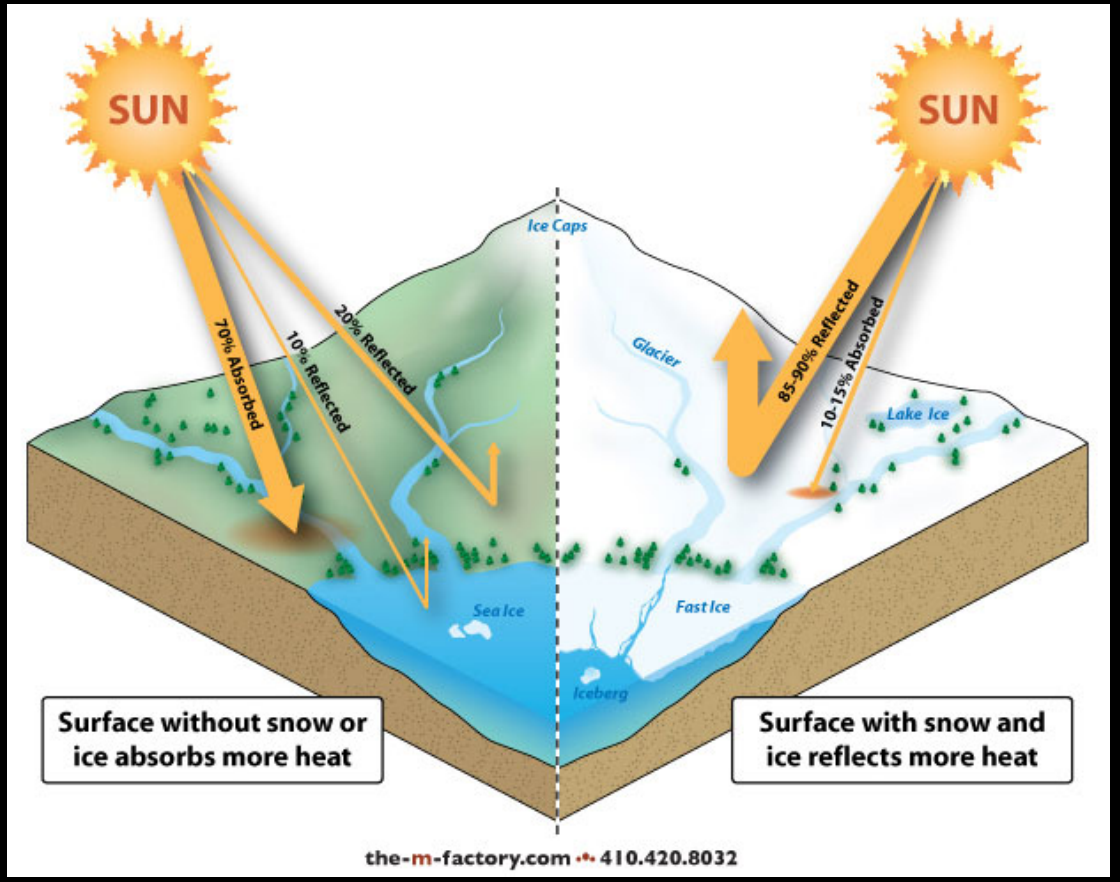



Peacock, S., 2012

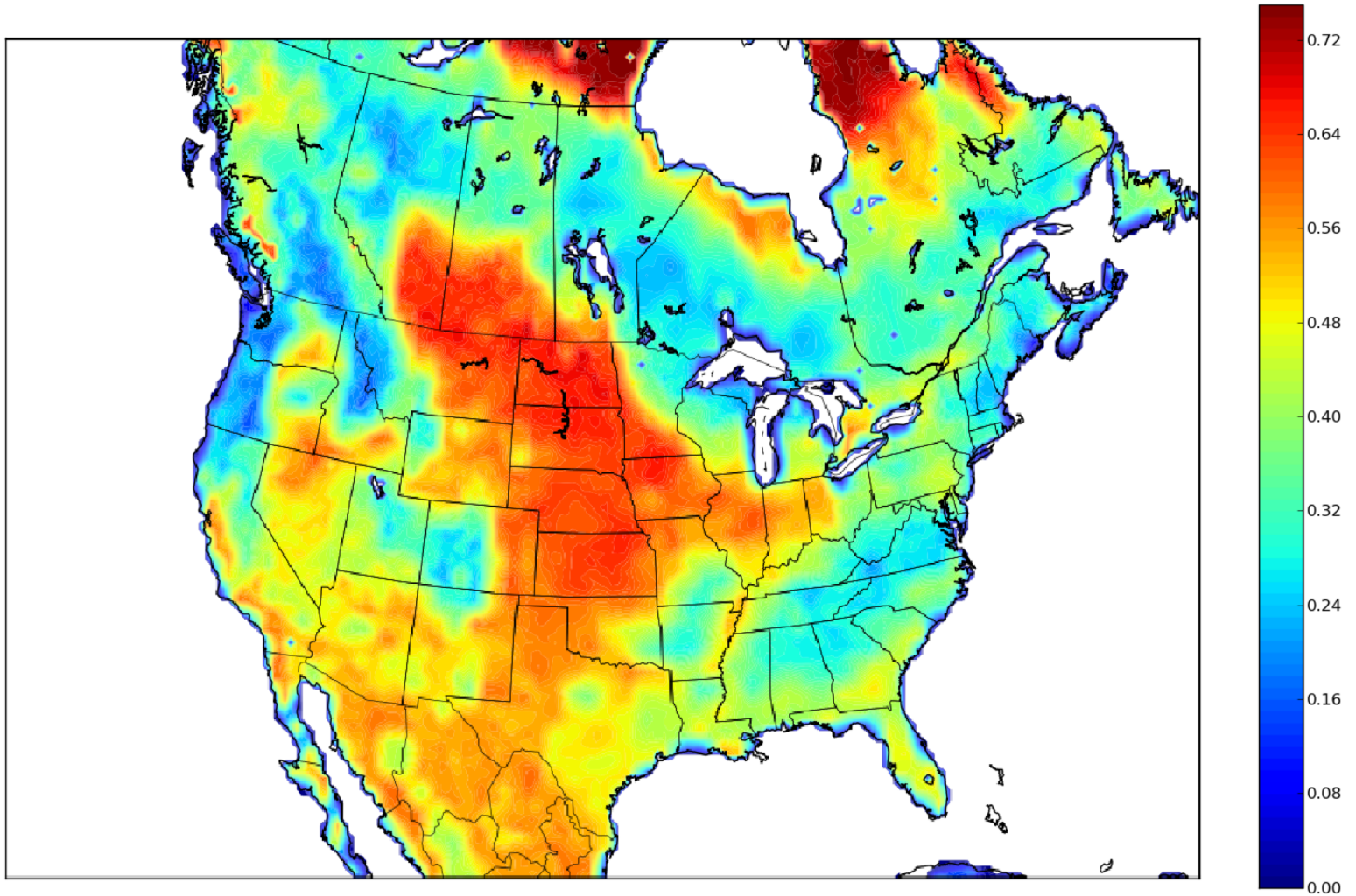
FIG. 21. Model spatially averaged ensemble mean snowfall anomalies (mm day$^{-1}$) relative to the 1951–80 mean values for each region for various regions of North America. Regions defined in Fig. 7. Model ensemble mean rainfall anomaly relative to the 1951–80 mean values for each region are shown by the thin lines. Shaded areas show the spread in the ensemble. Light blue shows the twentieth-century model results (1850–2005), purple from the RCP2.6 scenario, green from the RCP4.5 scenario, brown from the RCP6.0 scenario, and red from the RCP8.5 scenario. Snowfall anomalies are in mm day$^{-1}$.

# Snow changes “albedo”

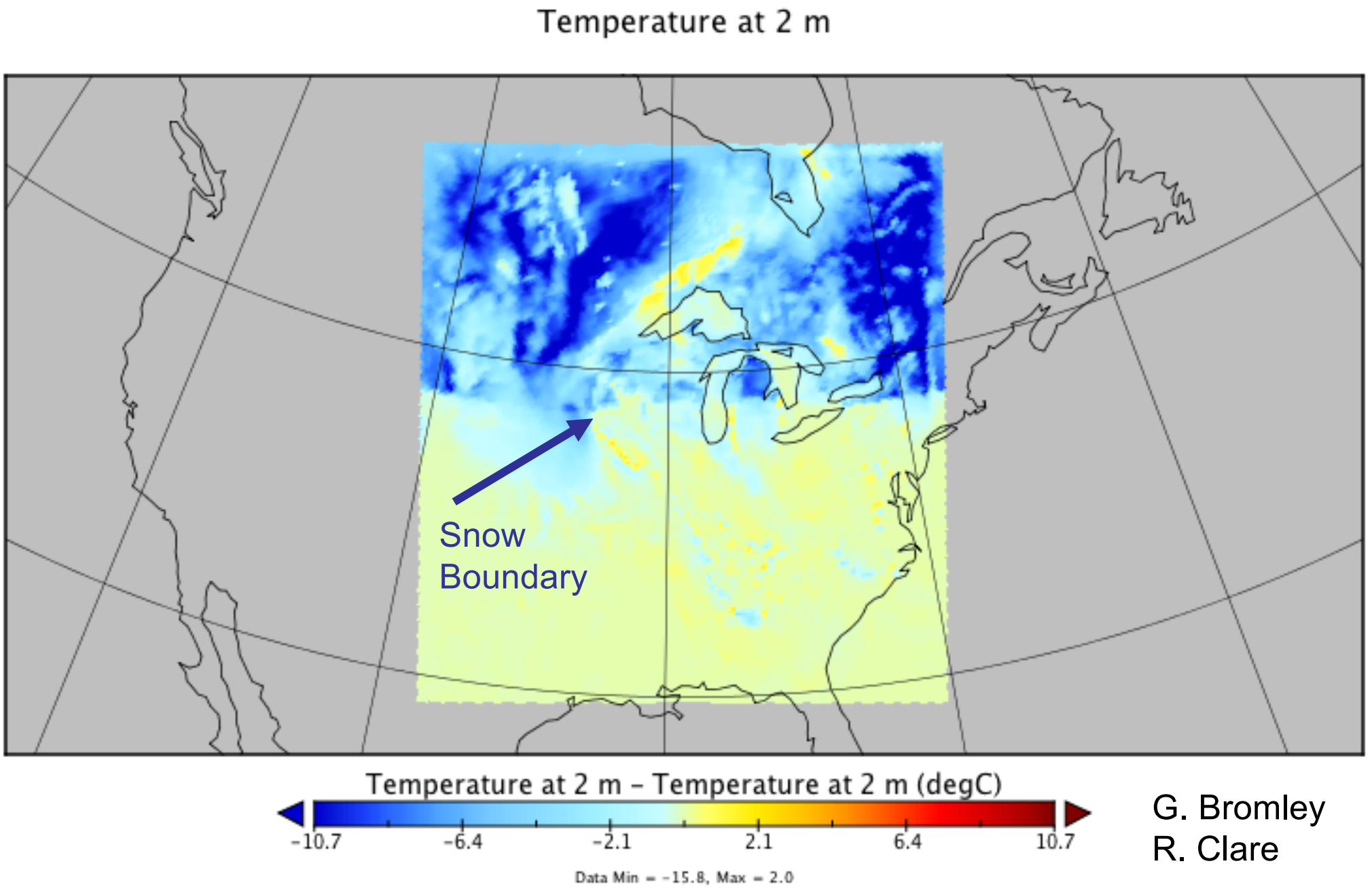
- 0% = dark, oceans, blacktop
- 100% = bright, mirror, ice
- Snow albedo exceeds 85%.
- Albedo gradients in winter exceeds 65% in winter.



# Especially in the central US

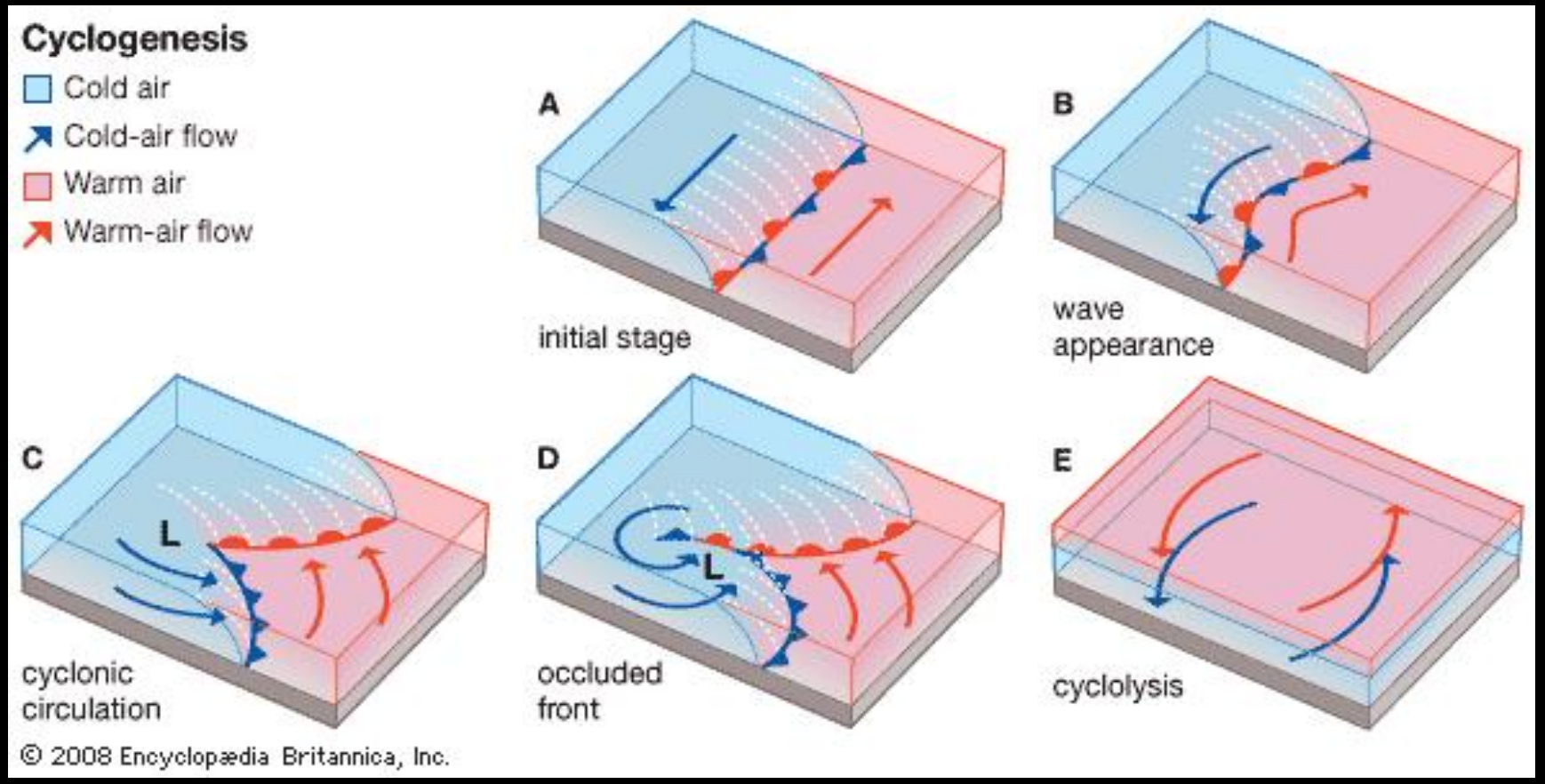


# Albedo influences surface temperature




G. Bromley
R. Clare

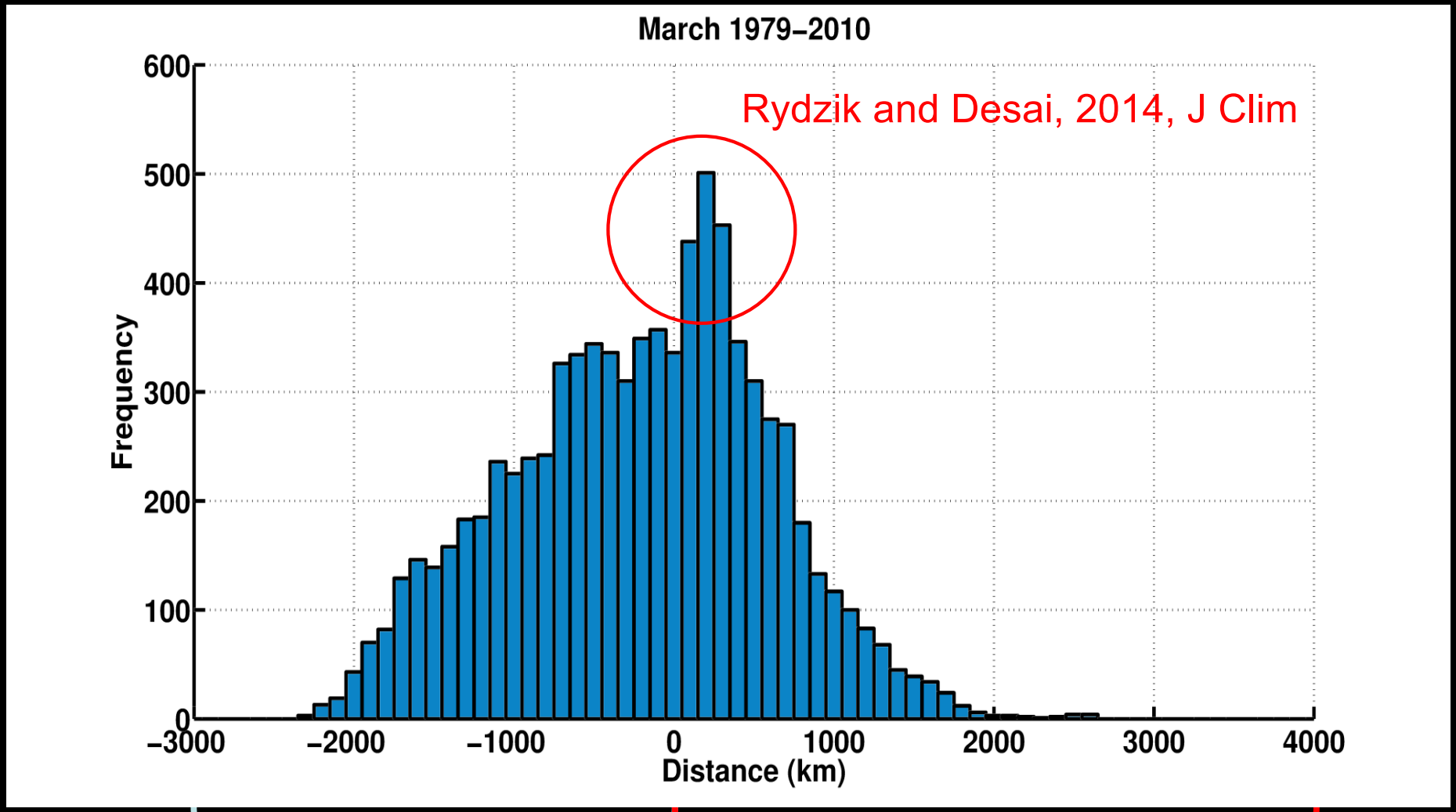
# Does it influence storms?




The Norwegian Model of
"Mid-Latitude Cyclones"

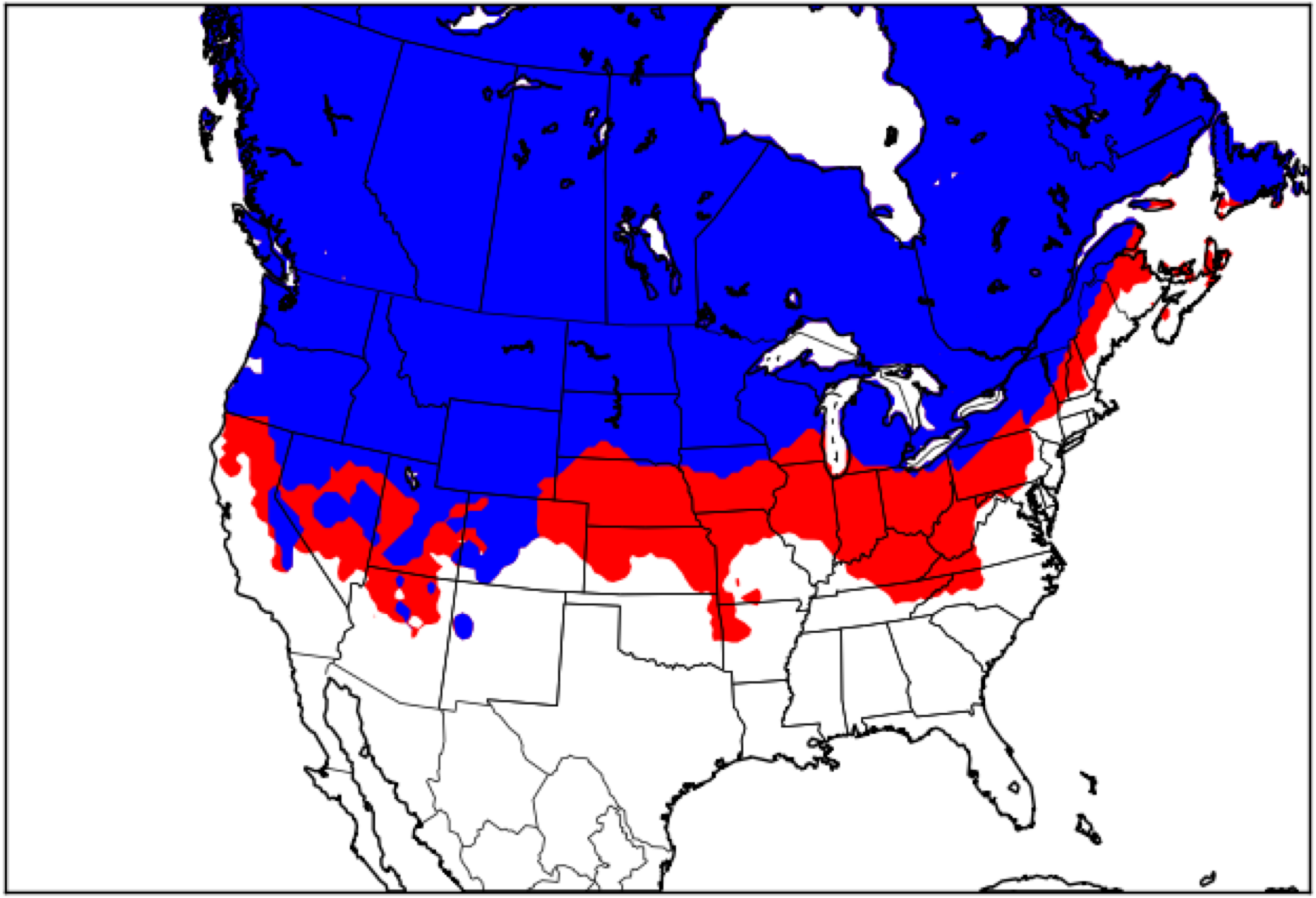
(Bjerknes and Solberg, 1922)

# Observations suggest it does



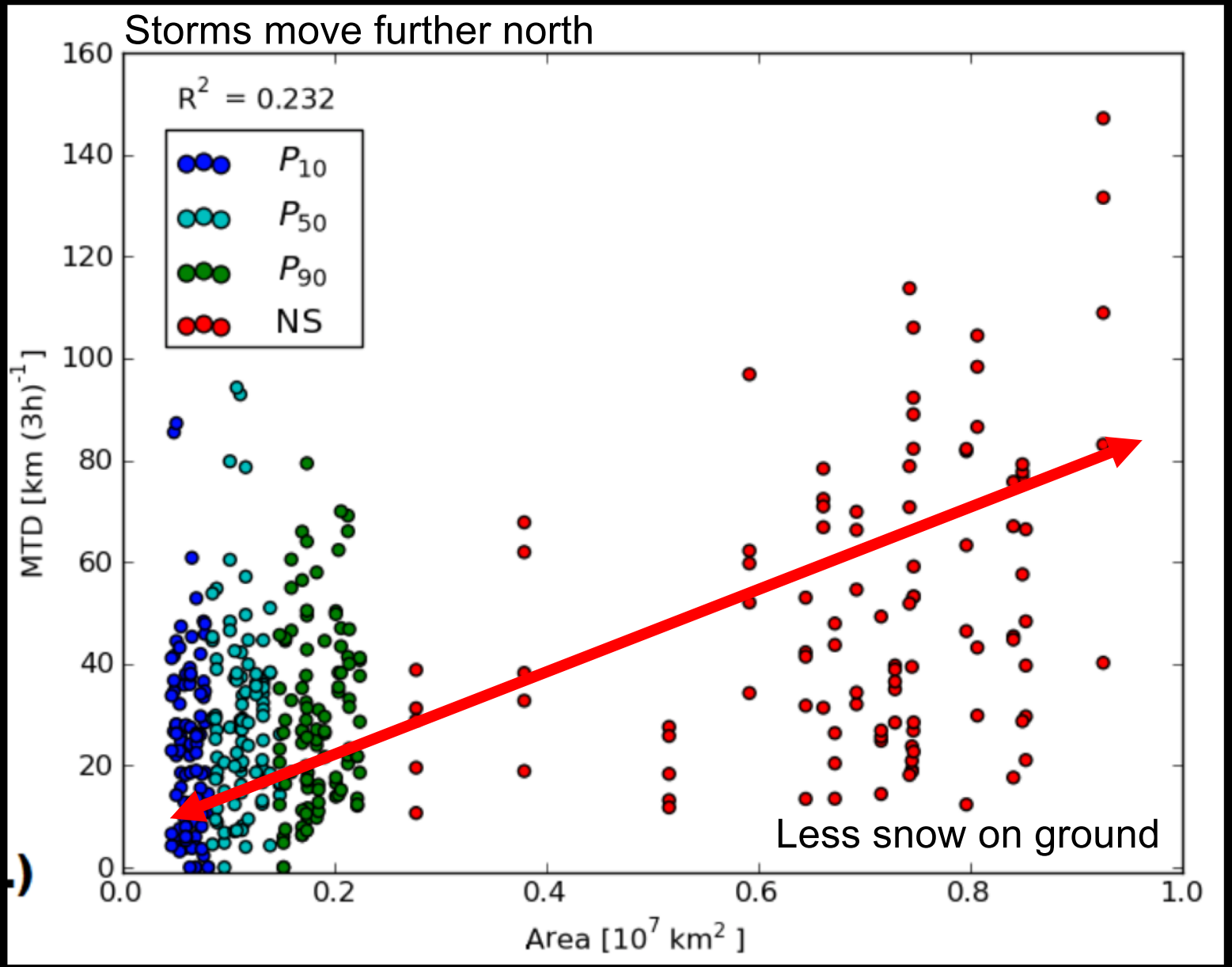
# A trip back to Jan 25, 1996

NWS LaCrosse



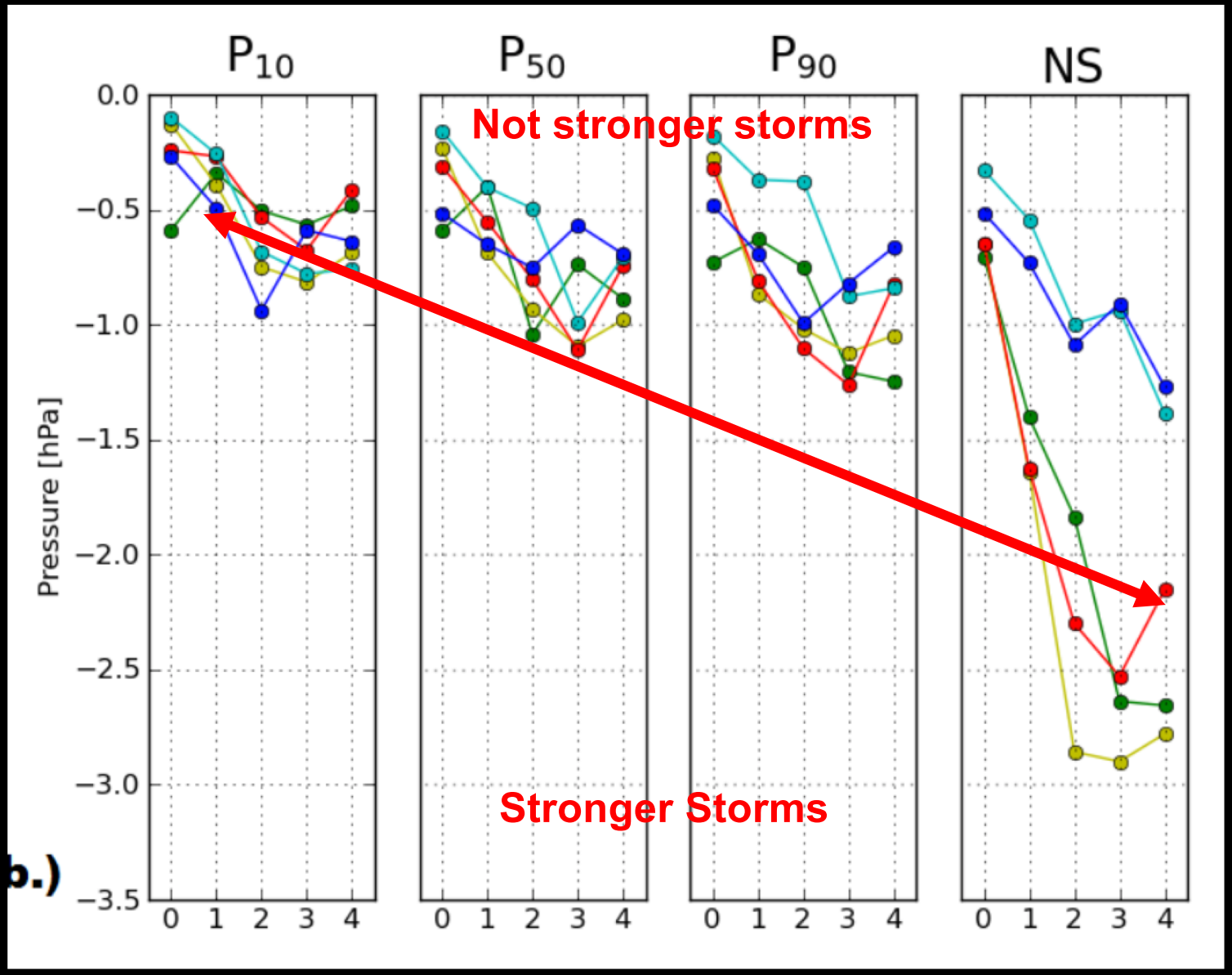
2100 25-01-1996

# Storms do follow snow cover, but only a little (~10 km per 10% reduction)

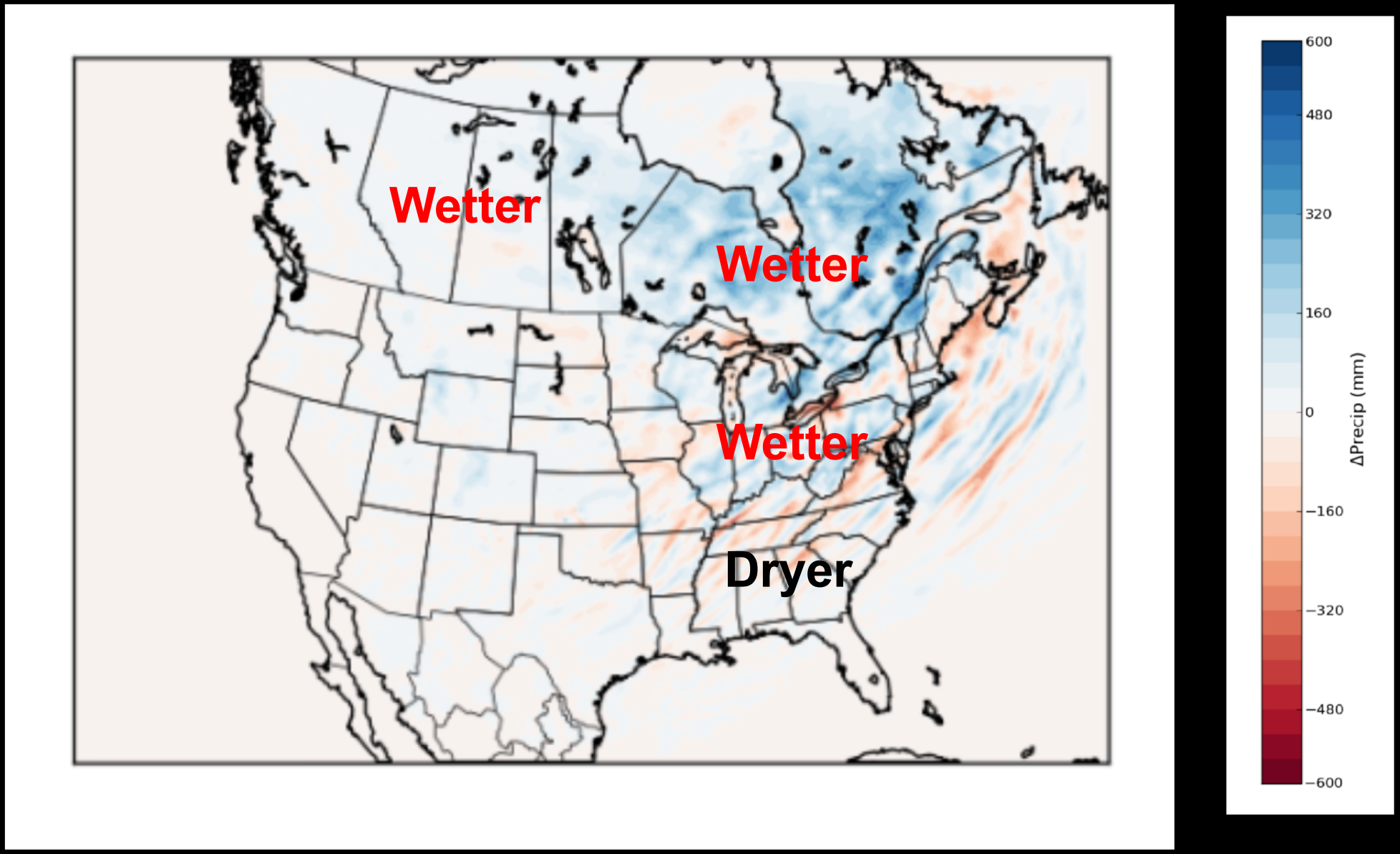


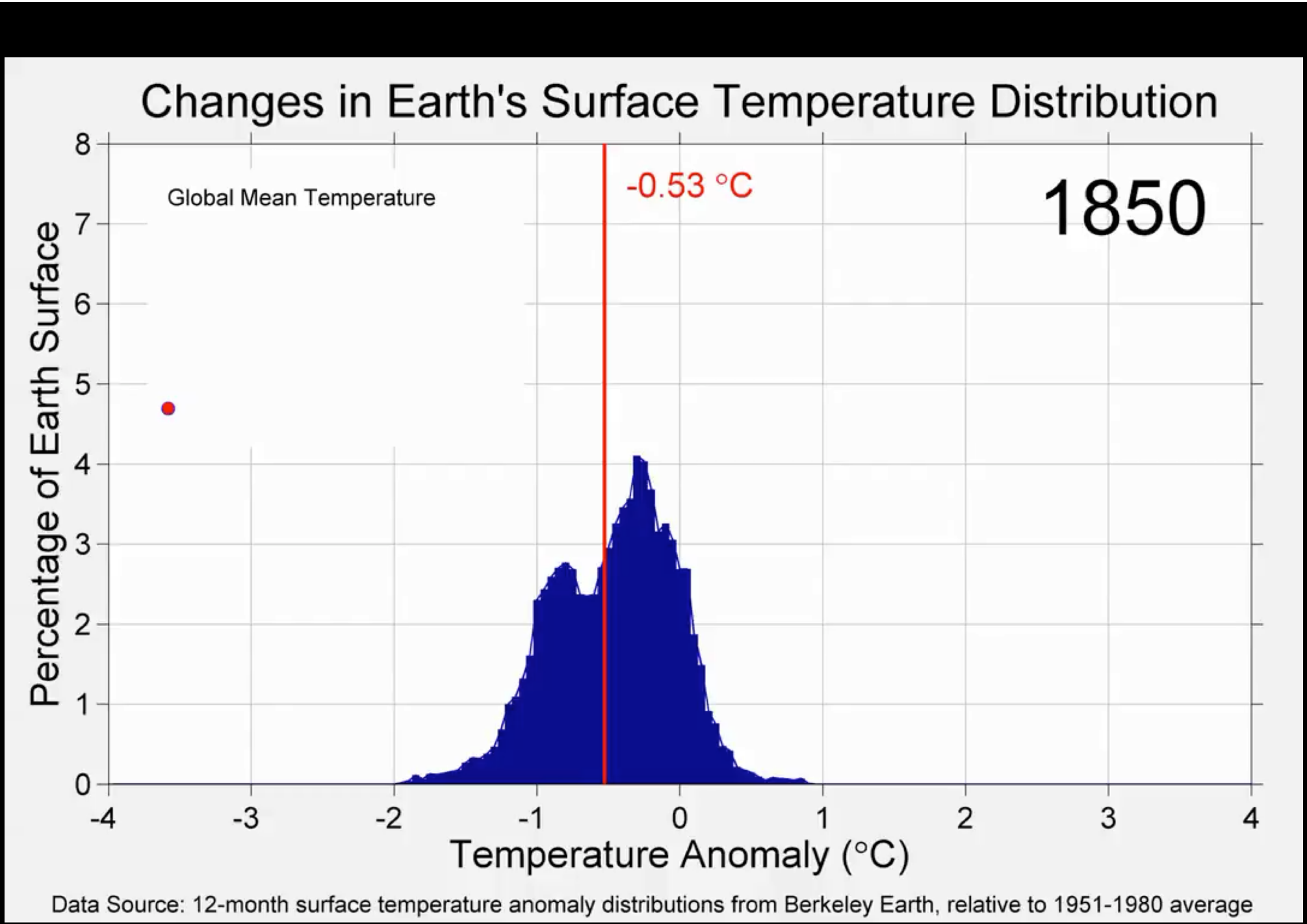
# A stronger response in storm intensity

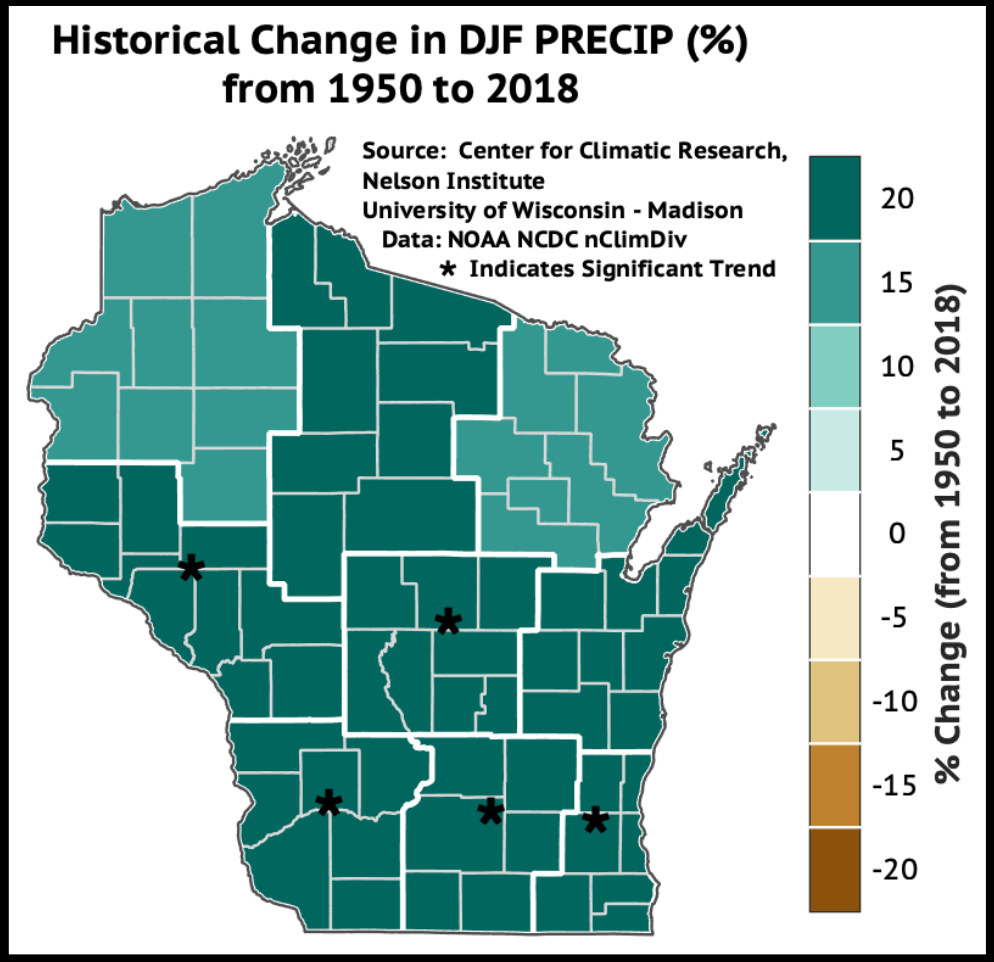
Less snow removed → All snow removed



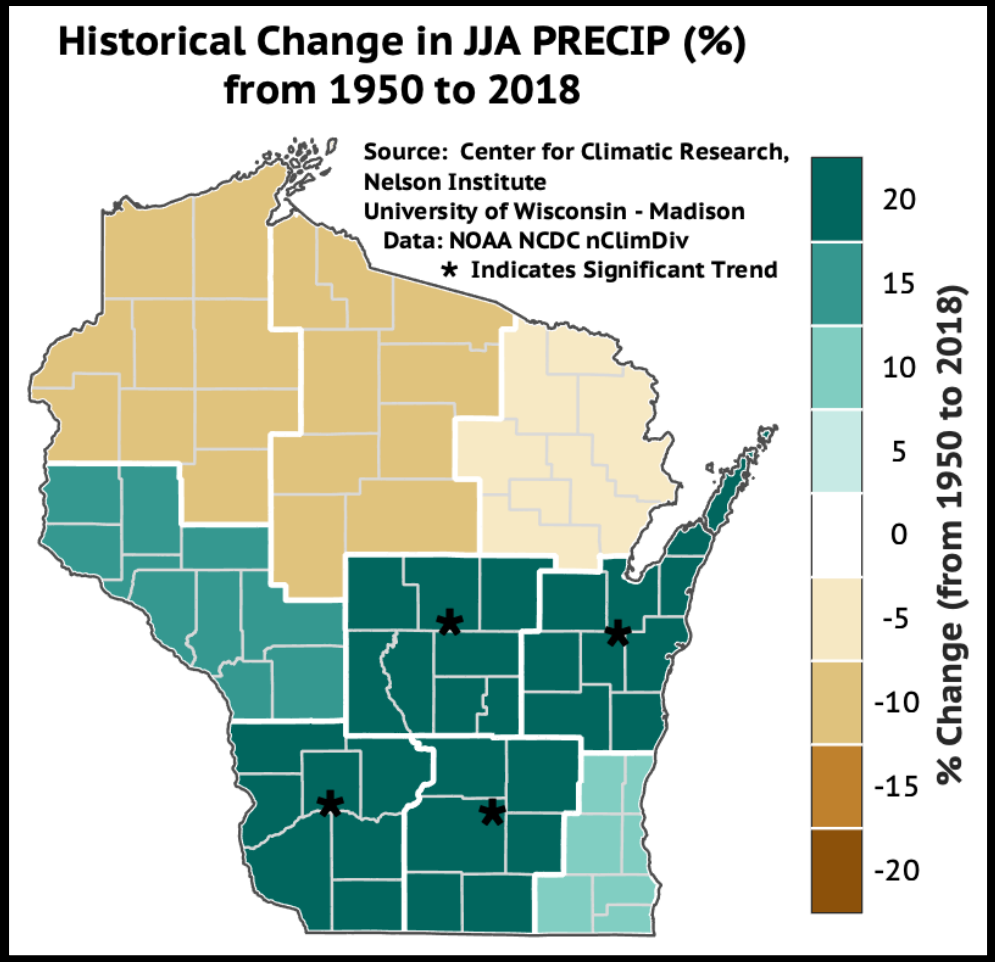
# In most places, it gets wetter and rainier




Changes in Earth's Surface Temperature Distribution
Global Mean Temperature
-0.53 °C
1850
Percentage of Earth Surface
0
1
2
3
4
5
6
7
8
-4
-3
-2
-1
0
1
2
3
4
Temperature Anomaly (°C)
Data Source: 12-month surface temperature anomaly distributions from Berkeley Earth, relative to 1951-1980 average



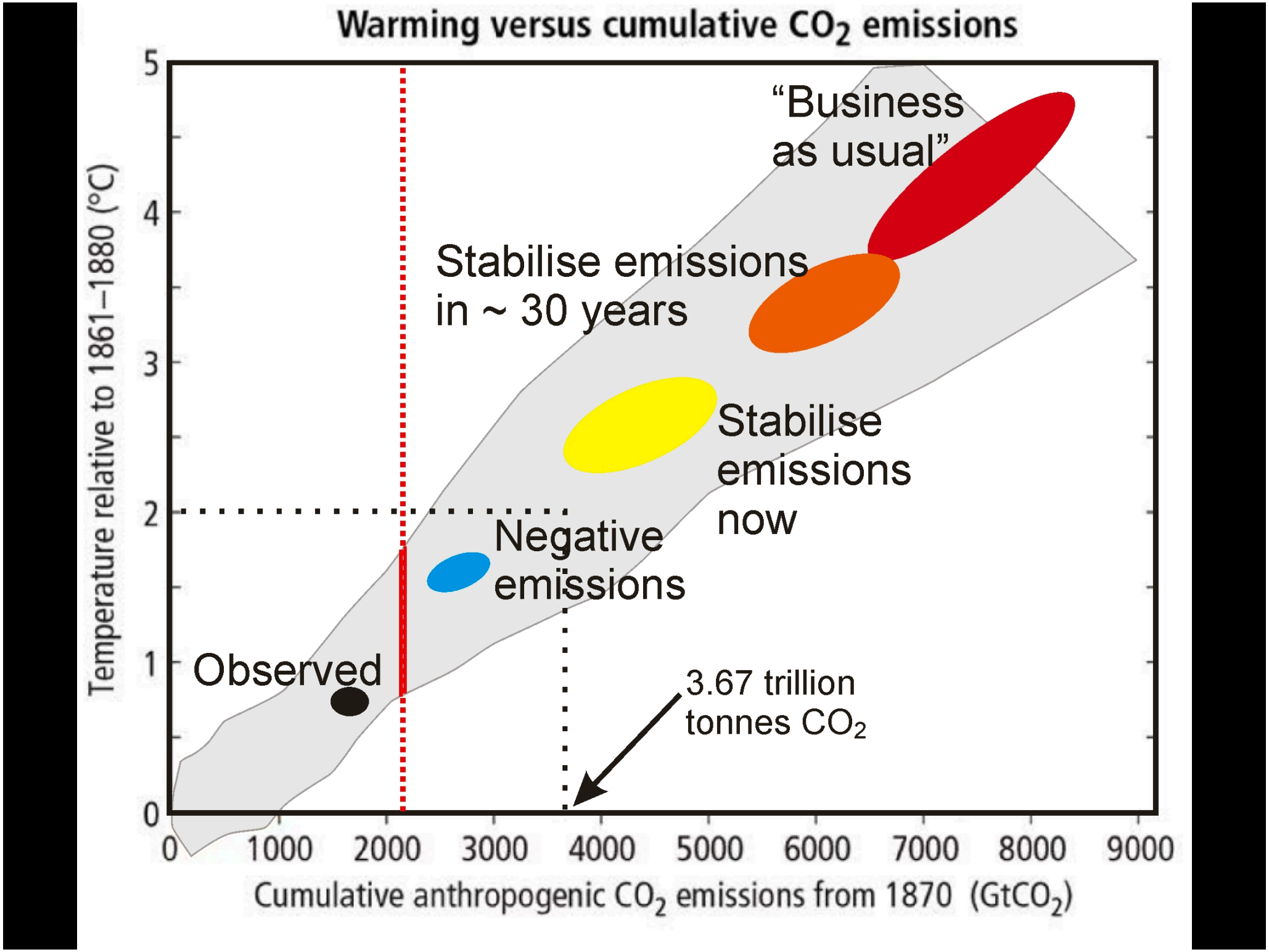

Winter




Summer

Dan Vimont, WI-Madison

Can policy address this?


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

# What Are The Options?

- Adaptation
  - Economic/political
  - Technological
- Mitigation


Wash Post


NCA, 2018

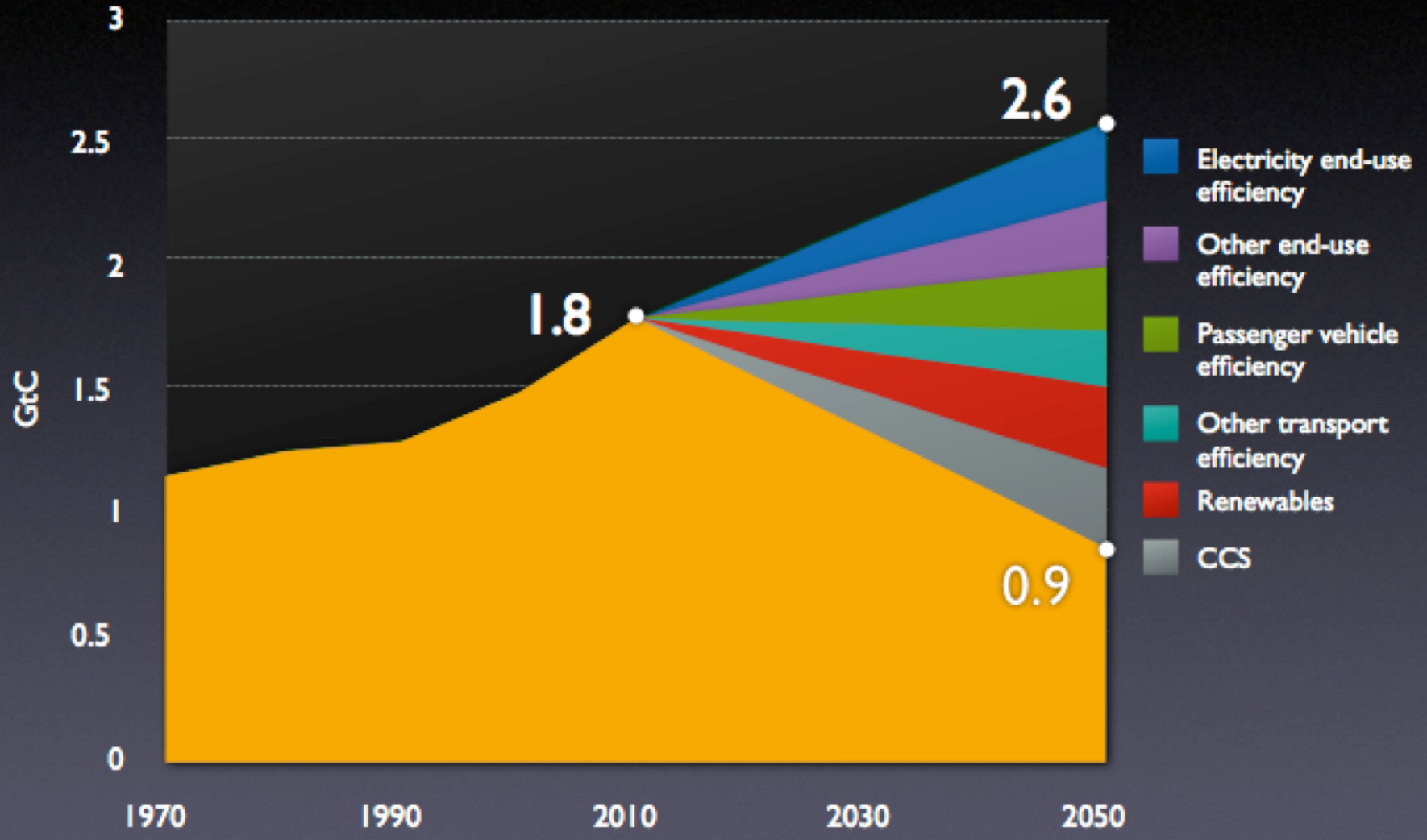
# What Are The Options?

- Adaptation
  - Economic/political
  - Technological
- Mitigation
  - Economic
  - Regulatory
  - Societal
  - Technological

# U.S. Emissions

After Pacala and Socolow, 2004;
ARI CarBen3 Spreadsheet

- Carbon Capture & Storage



# Solutions are abundant

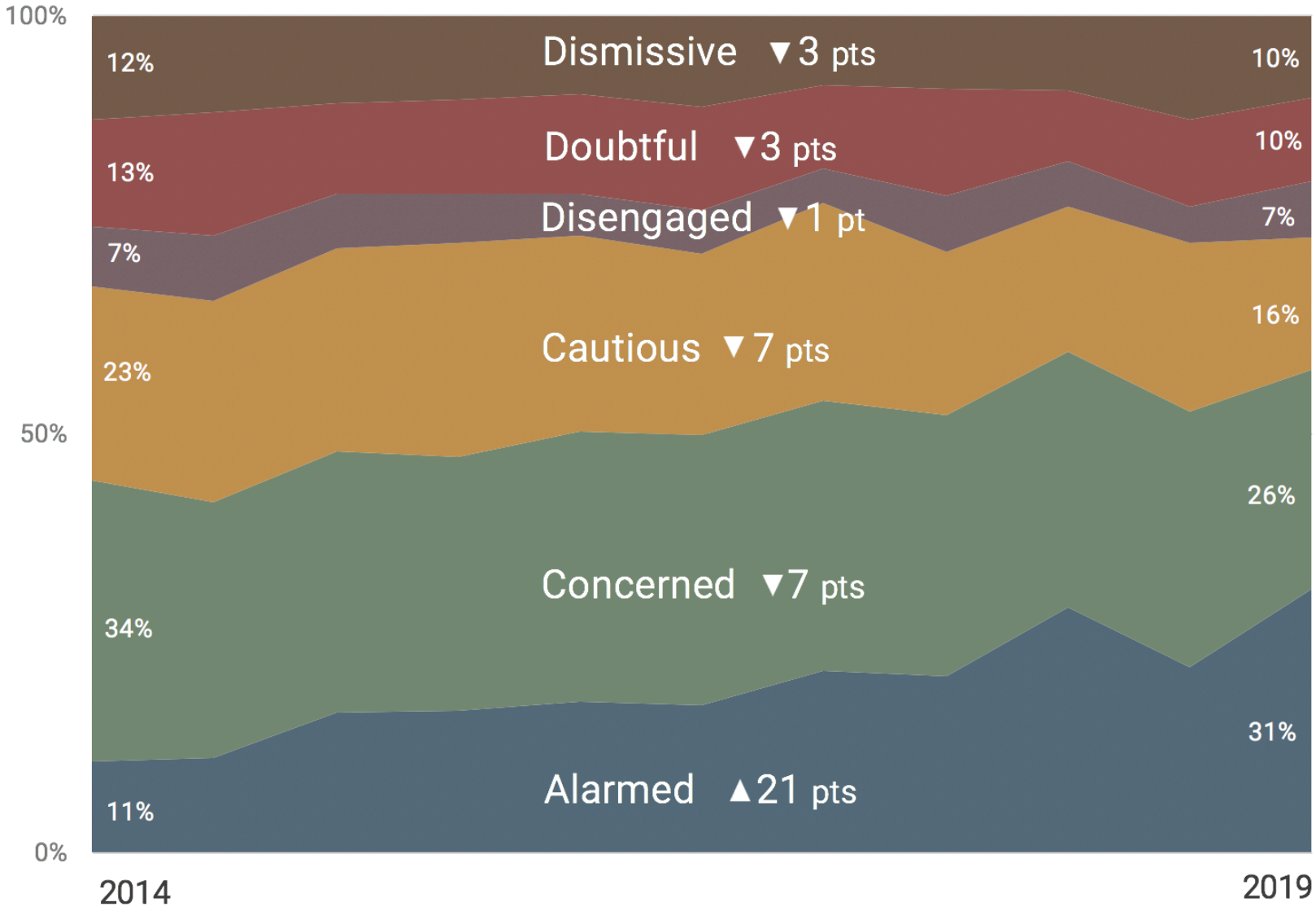
- https://www.drawdown.org/solutions

## 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

# Global Warming's Six Americas: Five-year Trend



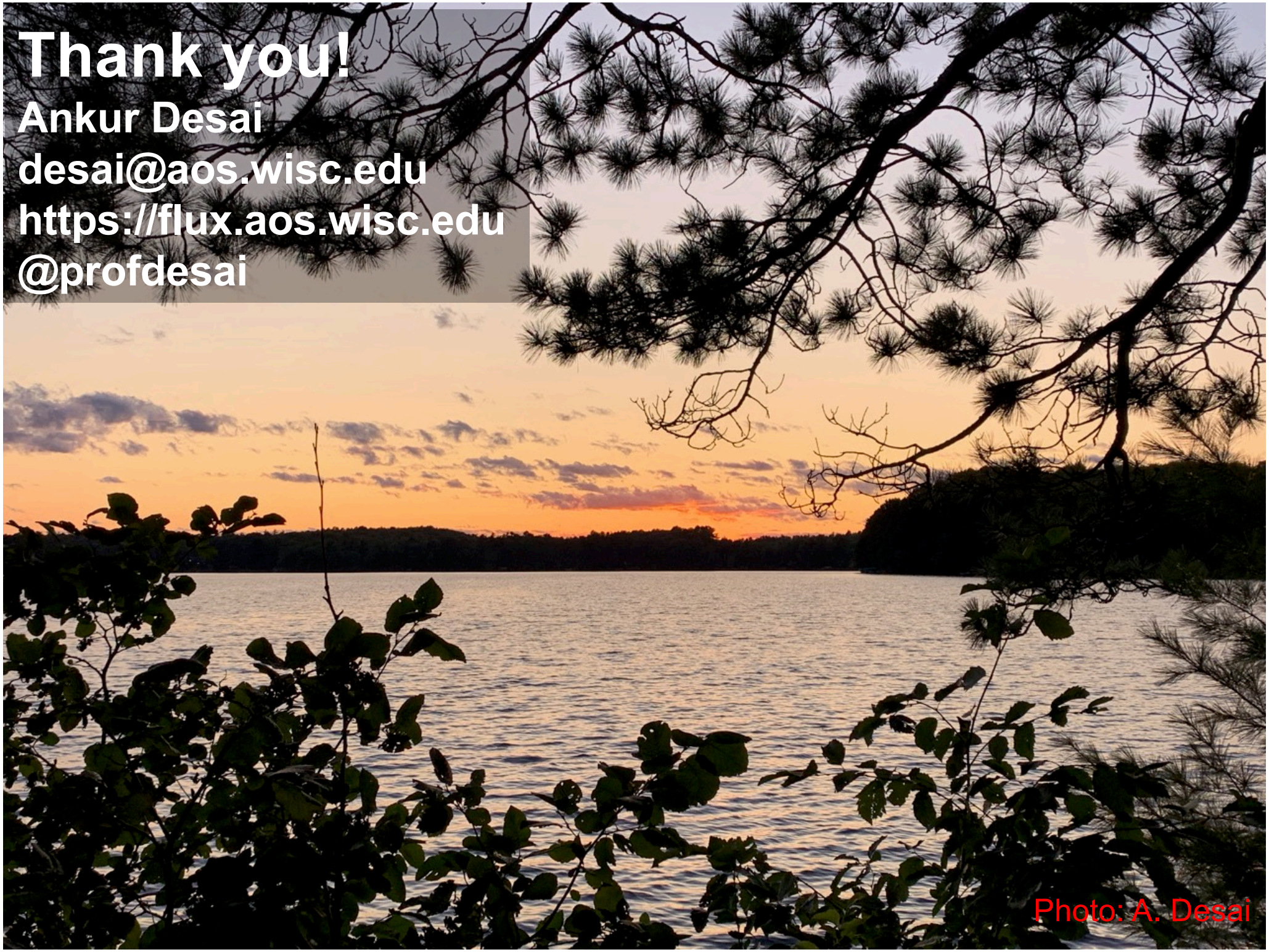

Data from 11 national surveys ($N$ = 13,854) from Oct. 2014 to Nov. 2019. Difference scores are calculated before rounding (example: 12.3%% - 9.7% = 2.6% which, after rounding, would appear in the figure as 12% - 10% = 3%).

YALE PROGRAM ON Climate Change Communication

GEORGE MASON UNIVERSITY CENTER *for* CLIMATE CHANGE COMMUNICATION


https://globalclimatestrike.net/

https://gfycat.com/oddballuniteddeviltasmanian-nature


Thank you!
Ankur Desai
desai@aos.wisc.edu
https://flux.aos.wisc.edu
@profdesai
Photo: A. Desai