Climate Change and Extreme Weather in Wisconsin




Steve Vavrus

Contributions from: Dan Vimont, Michael Notaro, David Lorenz

Wisconsin Initiative on Climate Change Impacts

Center for Climatic Research
NELSON INSTITUTE
UNIVERSITY OF WISCONSIN–MADISON

Lakes are Warming Globally

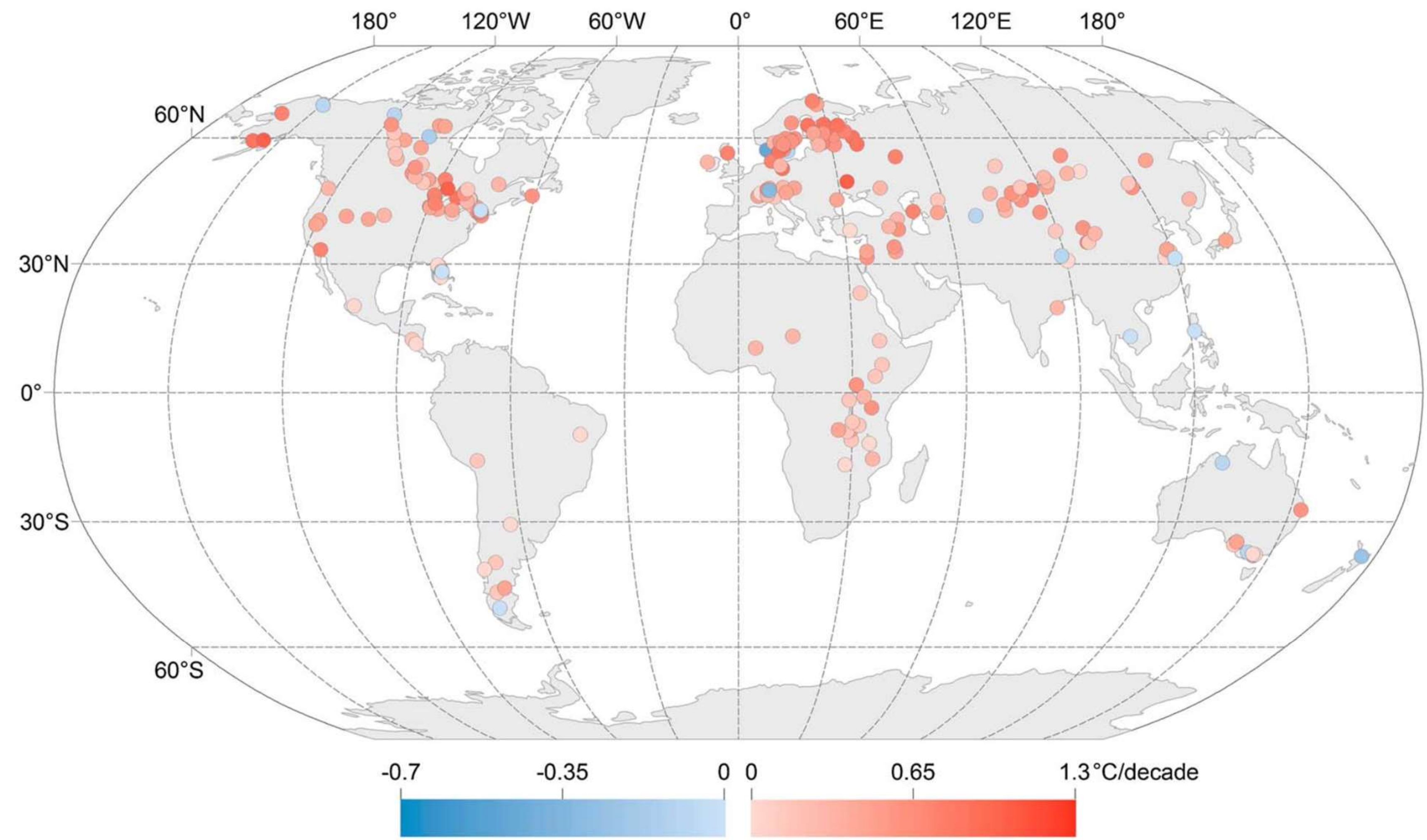
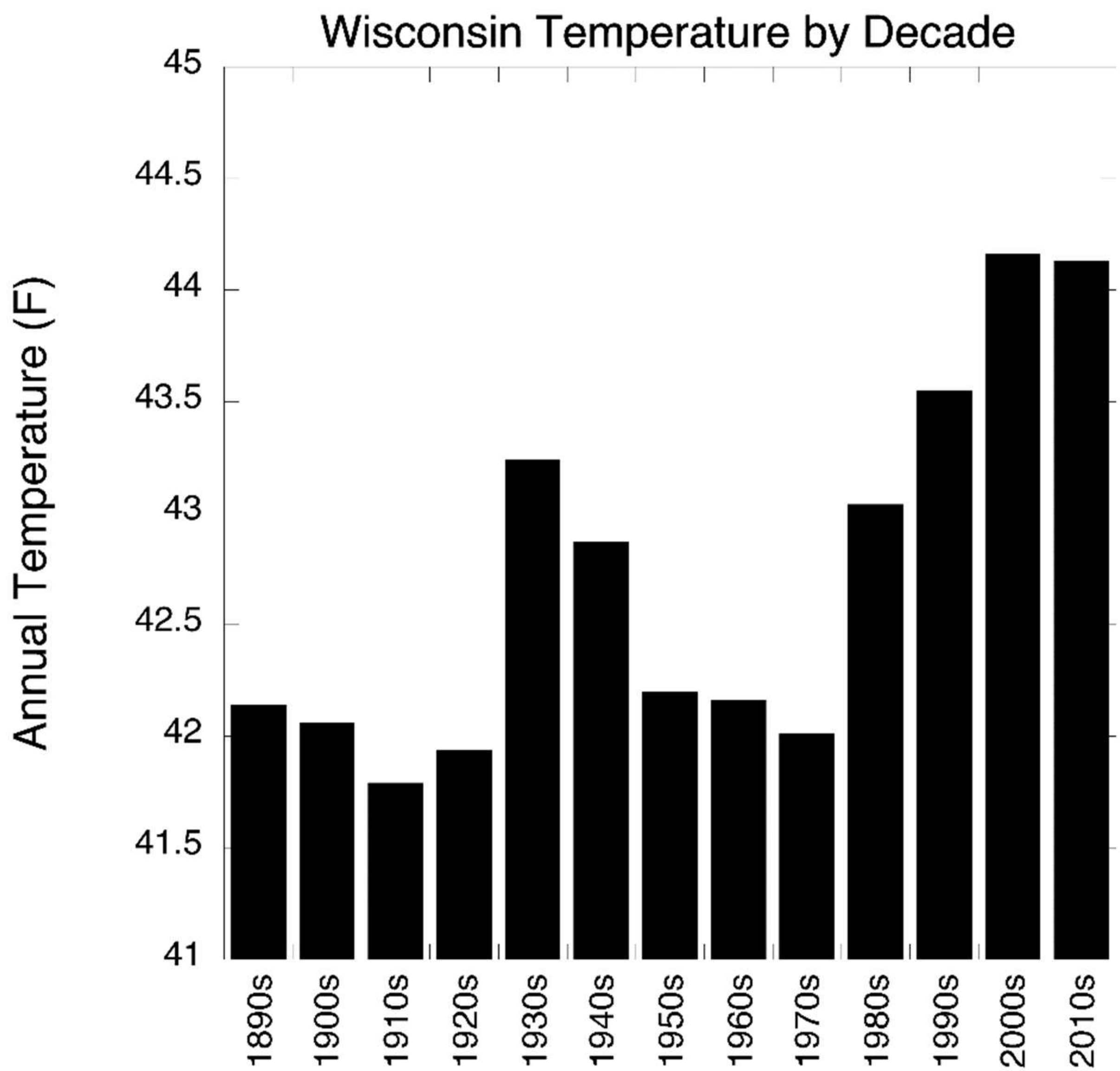


Figure 1. Map of trends in lake summer surface temperatures from 1985 to 2009. Most lakes are warming, and there is large spatial heterogeneity in lake trends. Note that the magnitudes of cooling and warming are not the same.

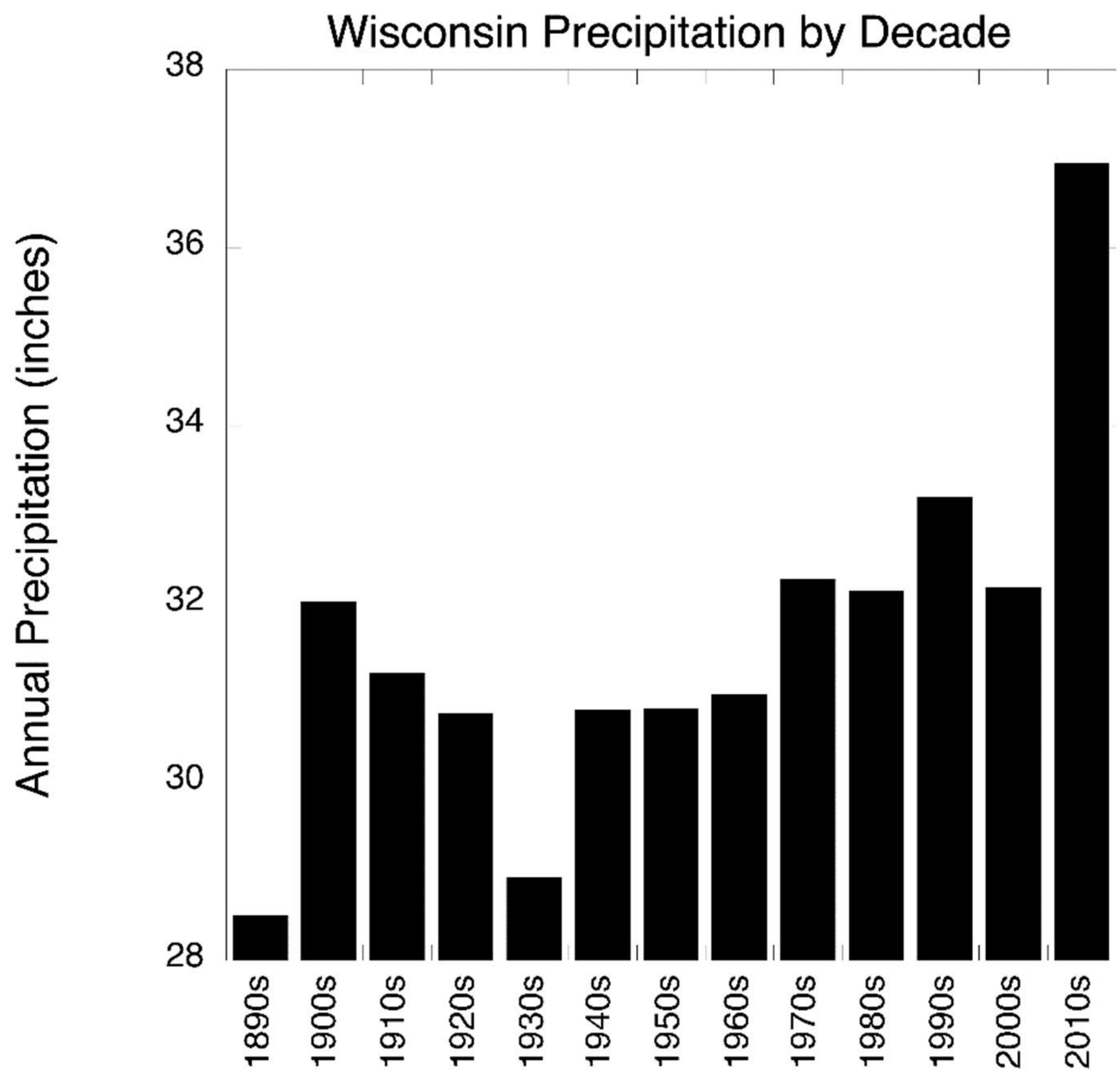
O'Reilly et al. 2015

Long-Term Annual Trends in Wisconsin (1895-2019)



Warmest two decades since turn of the century

Long-Term Annual Trends in Wisconsin (1895-2019)



2010s the wettest decade by far

2019 the wettest year

Long-Term Seasonal Trends in Wisconsin (1895-2019)

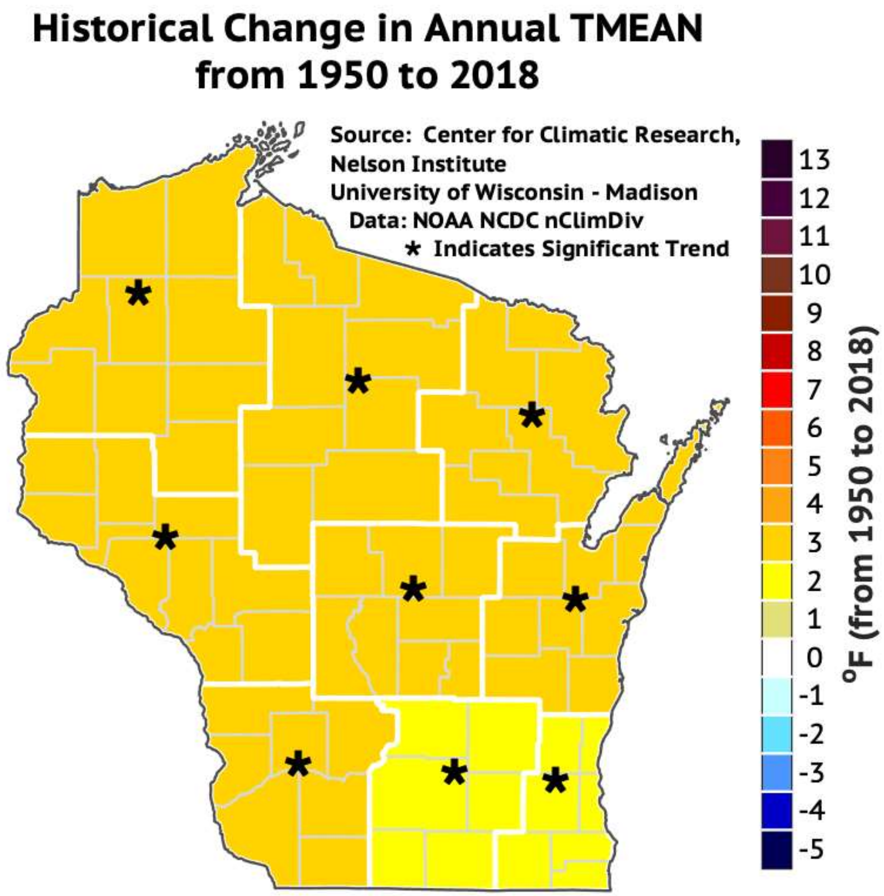
Statewide Temperature Trends (1895-2019) Degrees Fahrenheit	
Annual	2.07
Winter	4.11
Spring	1.97
Summer	0.87
Autumn	1.39

Long-Term Seasonal Trends in Wisconsin (1895-2019)

Statewide Temperature Trends (1895-2019) Degrees Fahrenheit	
Annual	2.07
Winter	4.11
Spring	1.97
Summer	0.87
Autumn	1.39

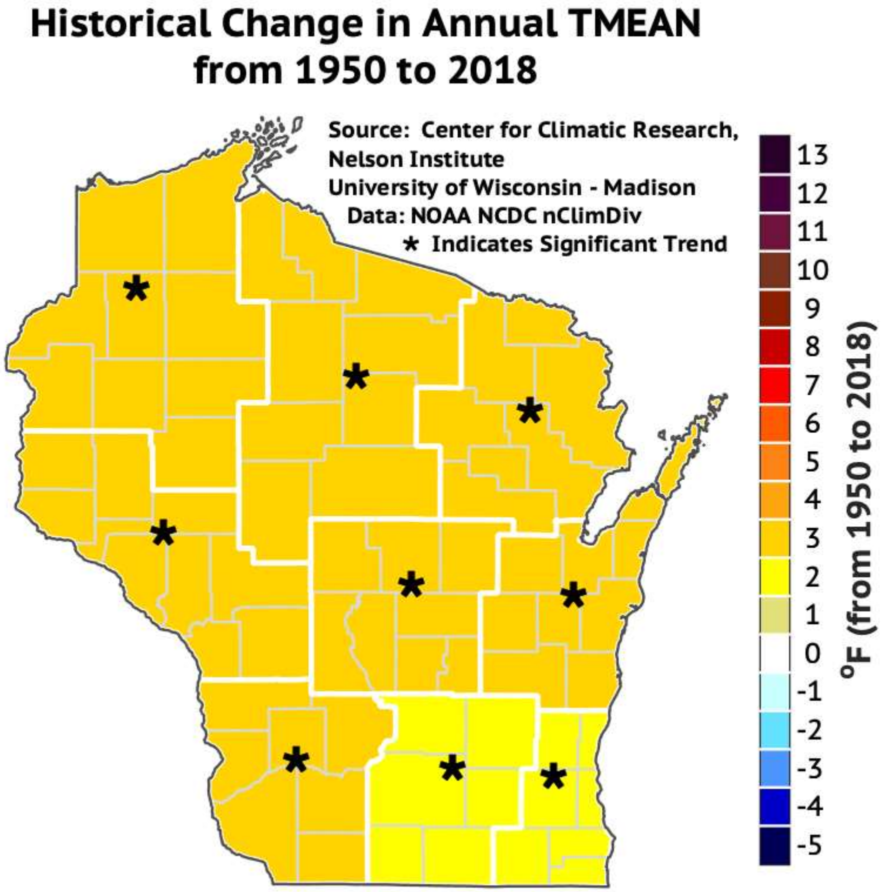
Statewide Precipitation Trends (1895-2019) Inches (%)	
Annual	4.51 *(14%)*
Winter	0.57 *(16%)*
Spring	1.29 *(16%)*
Summer	1.72 *(15%)*
Autumn	0.93 *(11%)*

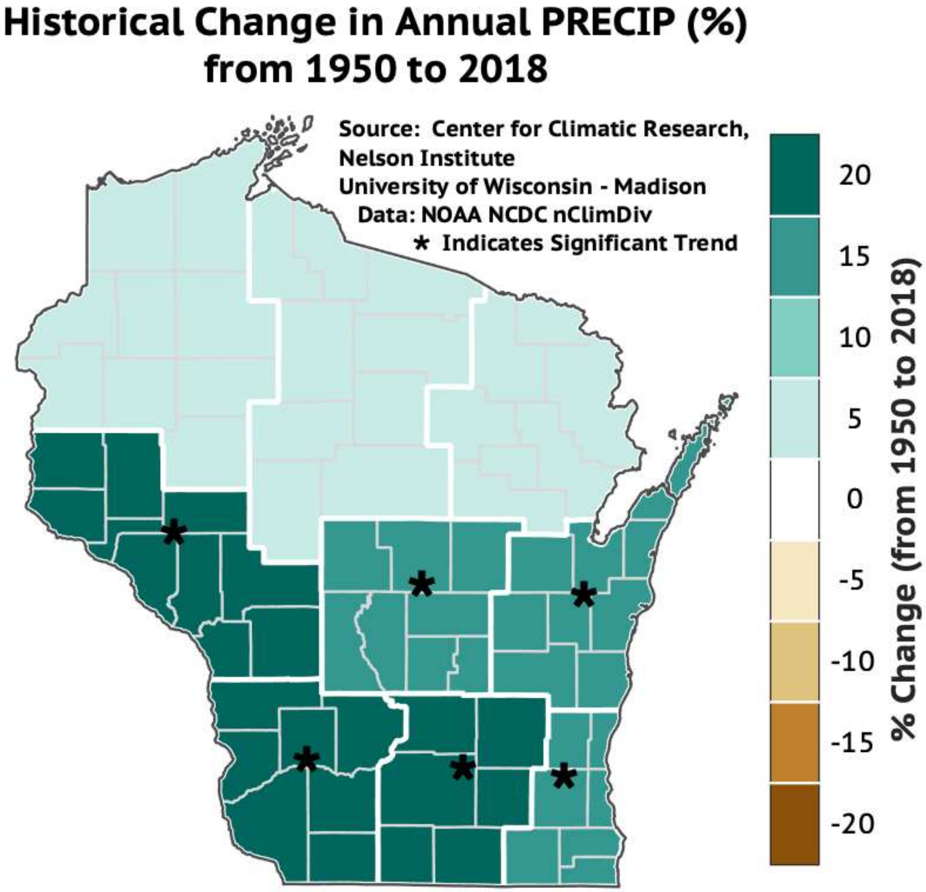
Annual Trends in Wisconsin since 1950



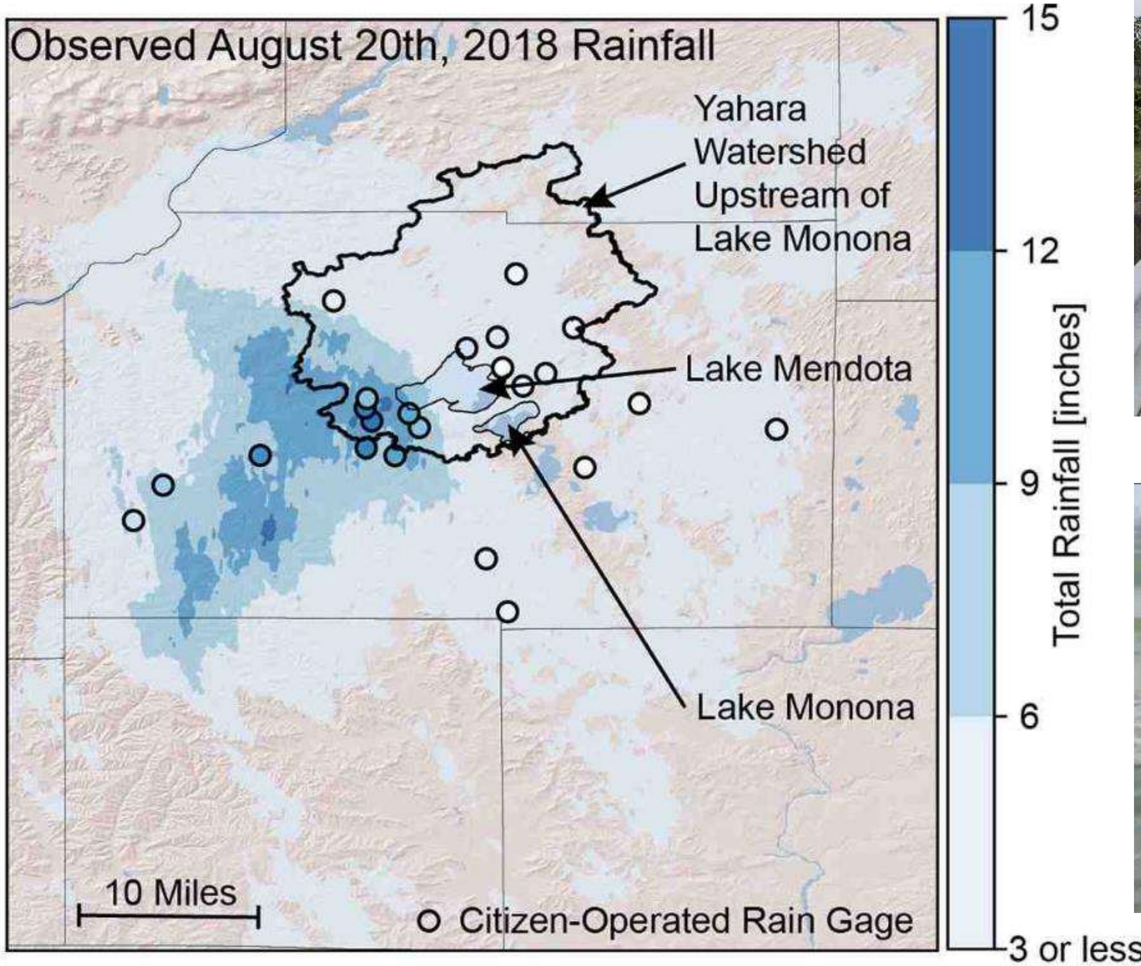
Dan Vimont

Annual Trends in Wisconsin <u>since 1950</u>





Madison, WI, Area Floods August 2018

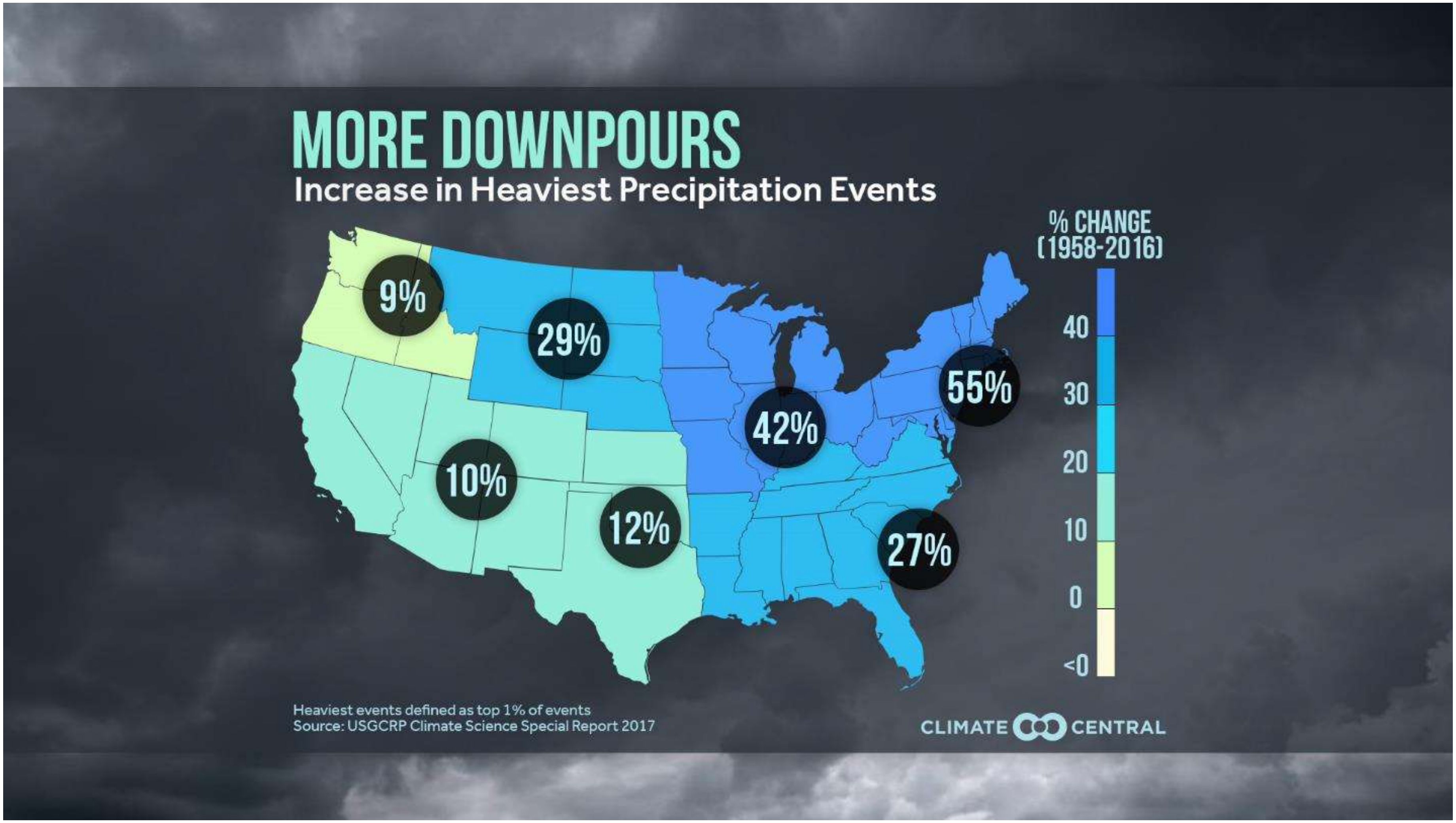


Dan Wright (UW), Bong-Chul Seo (U Iowa)

Unofficial Wisconsin record for heaviest 24-hour rainfall

Heavy Rainfalls Becoming More Common

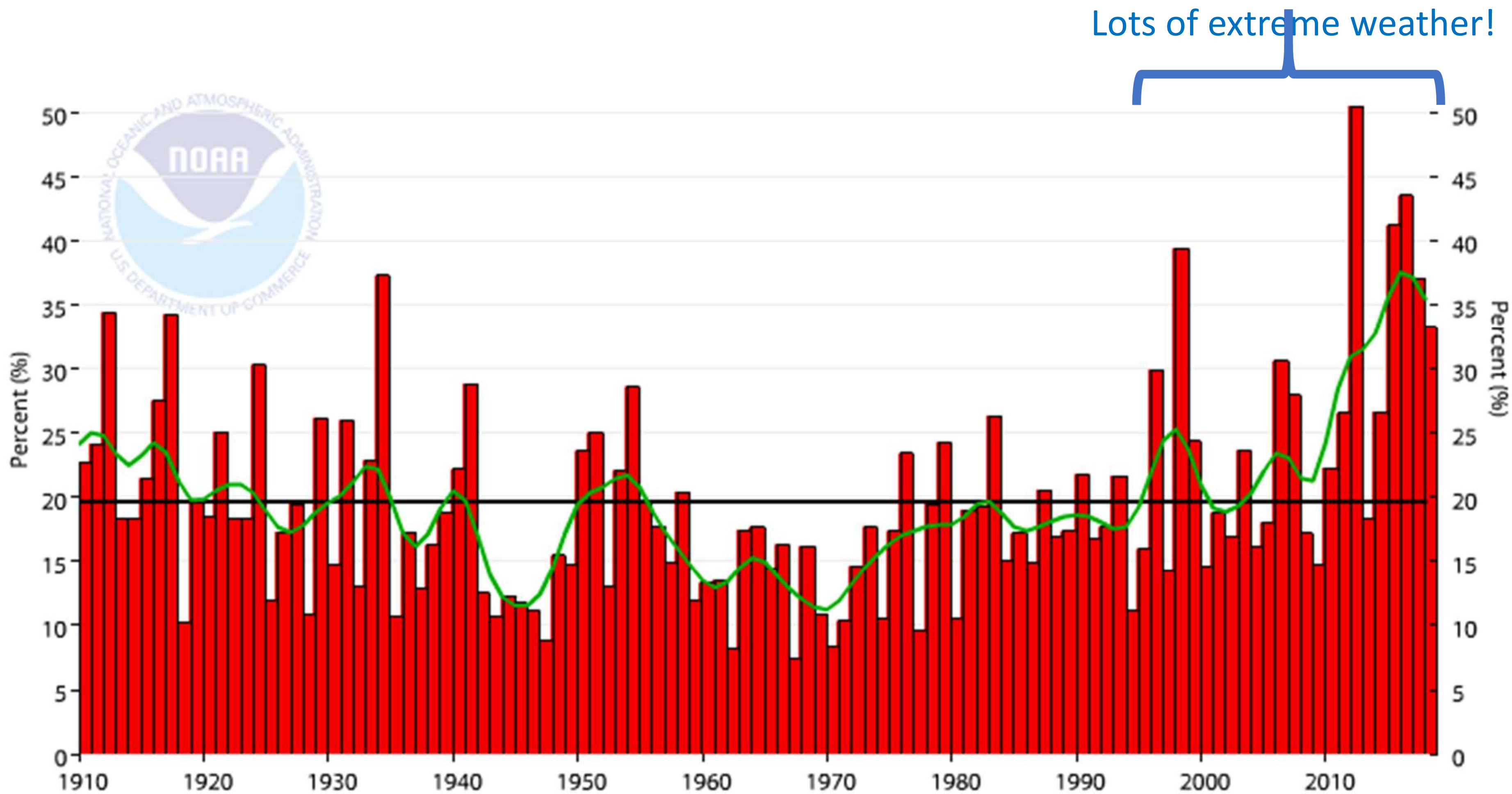
1958-2016



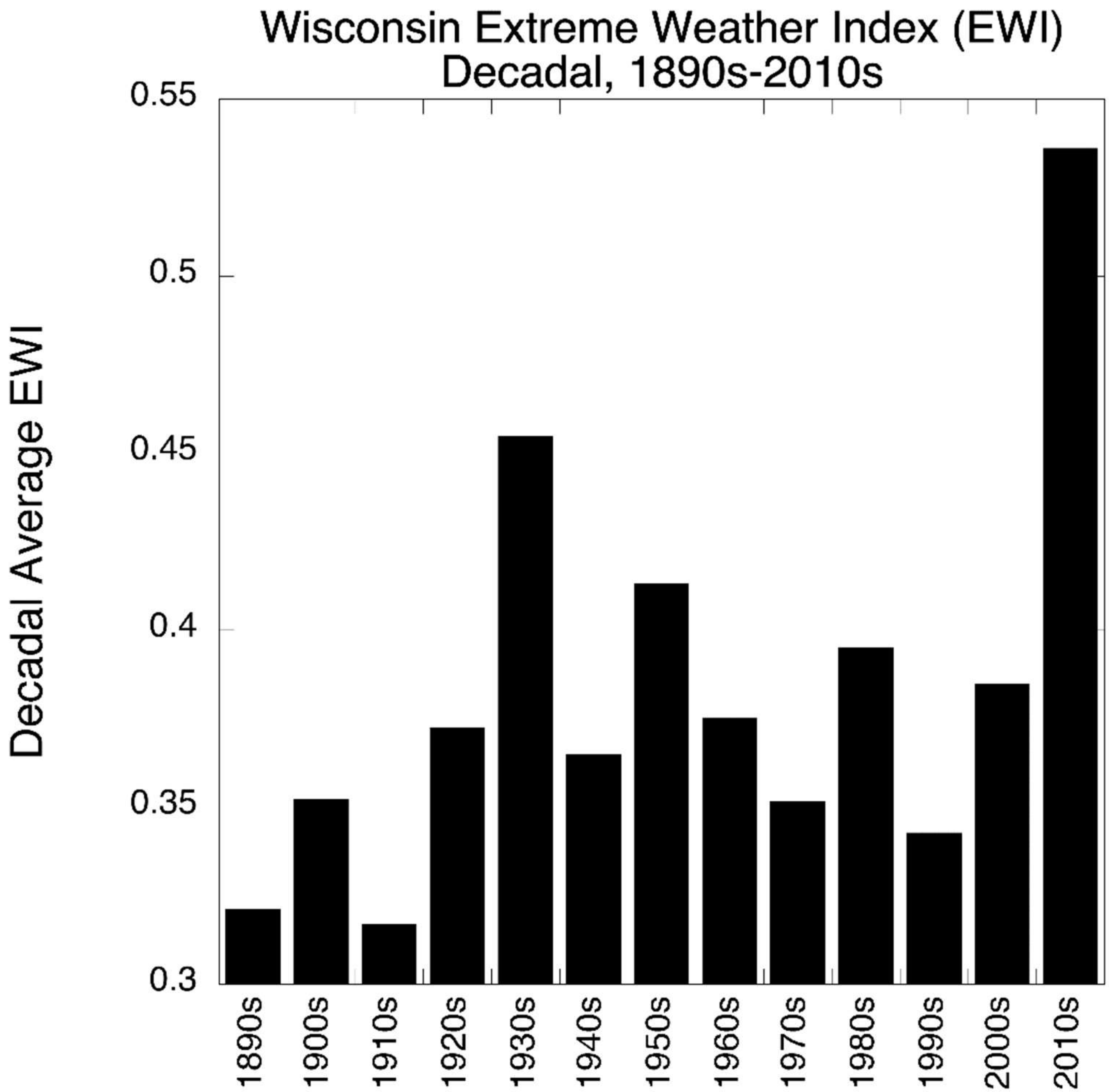
Recent increase in heavy precipitation, especially past 10-15 years

Increasing Trend of Extreme Weather

“Climate Extremes Index” (United States)

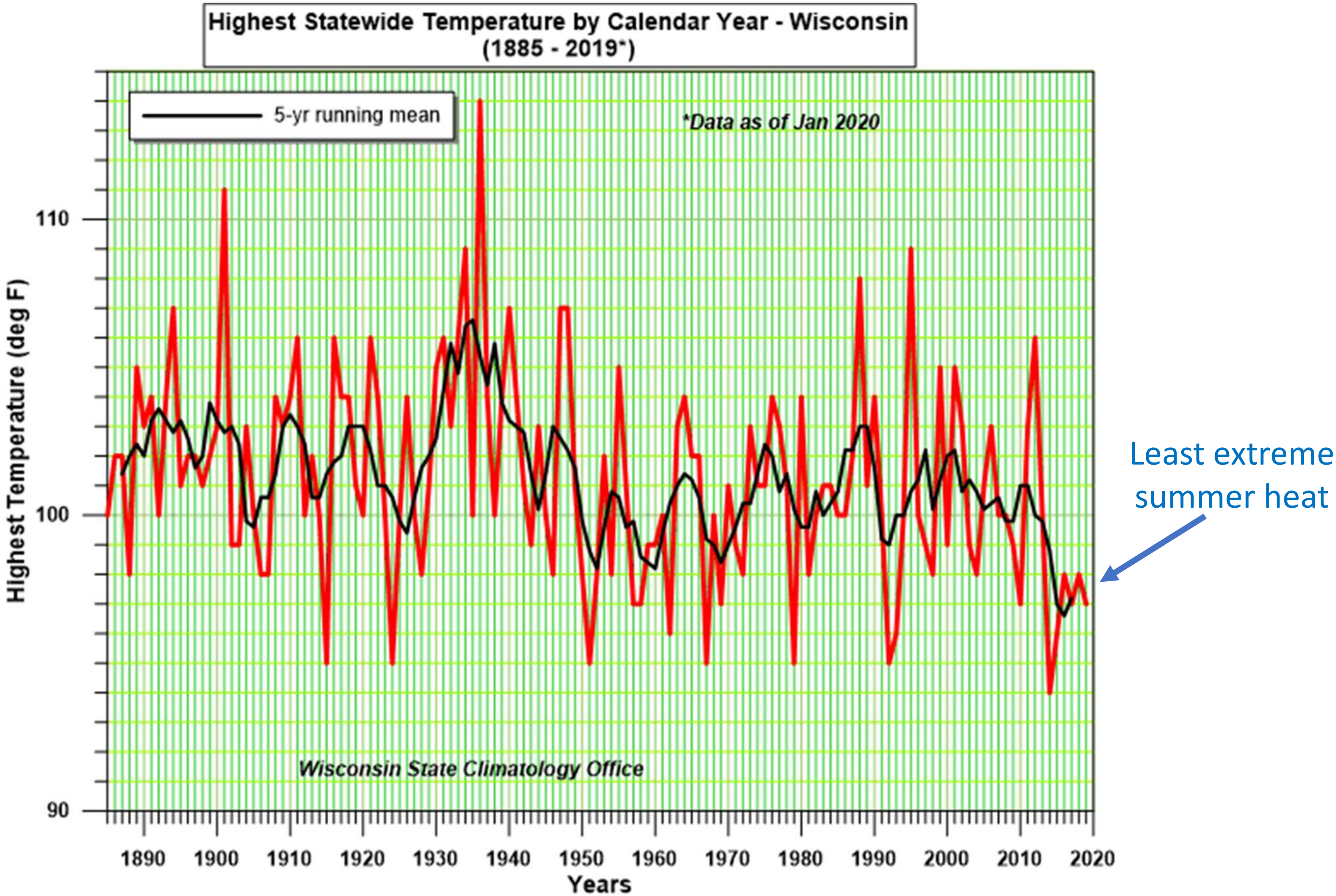


Recent increase in extreme weather: heavy precip, very warm nights



Wisconsin Extreme Weather Index (EWI)
Decadal, 1890s-2010s
Decadal Average EWI
0.55
0.5
0.45
0.4
0.35
0.3
1890s
1900s
1910s
1920s
1930s
1940s
1950s
1960s
1970s
1980s
1990s
2000s
2010s

Highest Annual Temperature in Wisconsin



Courtesy of Ed Hopkins

What about the future?

Downscaling

For adaptation & impacts, we need *high-resolution* climate projections.

Downscaling translates coarse information from global climate models (GCMs) to finer resolution. Two primary types: “statistical downscaling” and “dynamical downscaling”.

Michael Notaro

Downscaling

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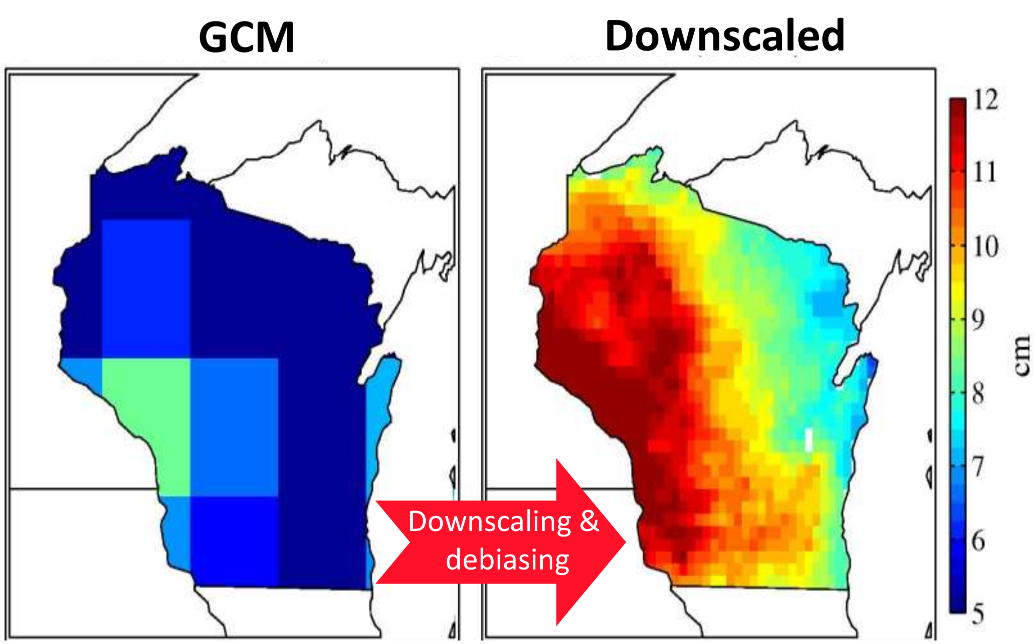
Statistical Downscaling:



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Downscaling

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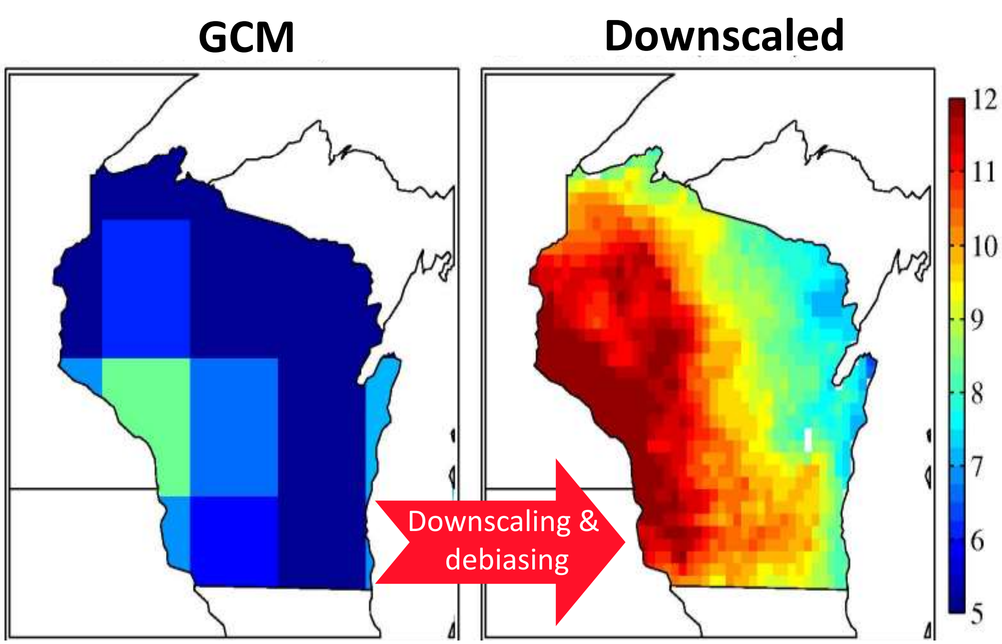
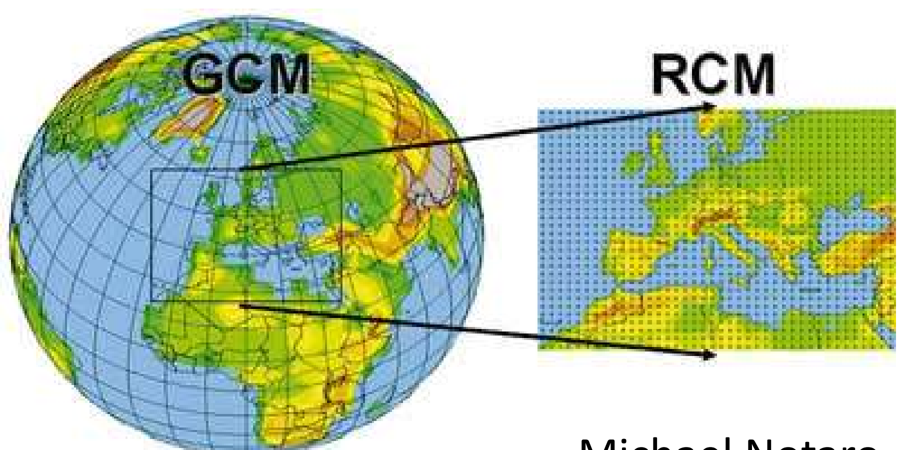
Downscaling translates coarse information from global climate models (GCMs) to finer resolution. Two primary types: “statistical downscaling” and “dynamical downscaling”.

Statistical Downscaling:



Dynamical Downscaling:

(Regional Climate Model, RCM)



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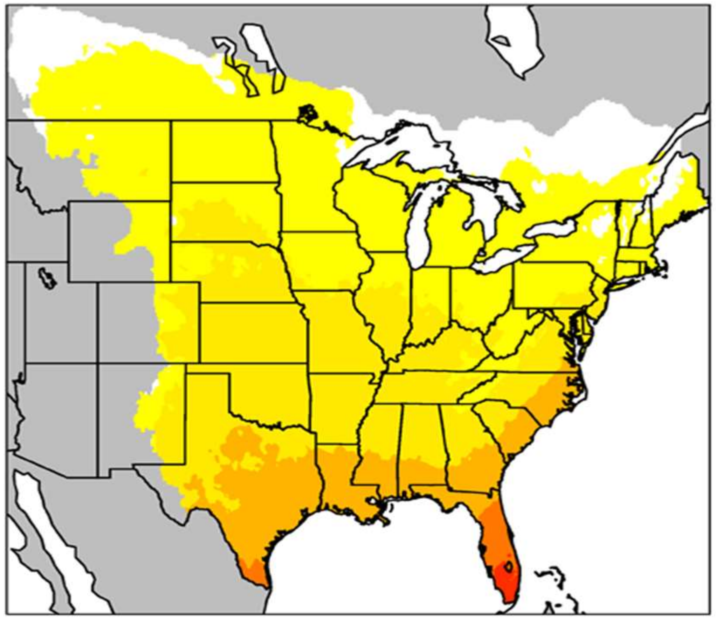
Domains used in Downscaling

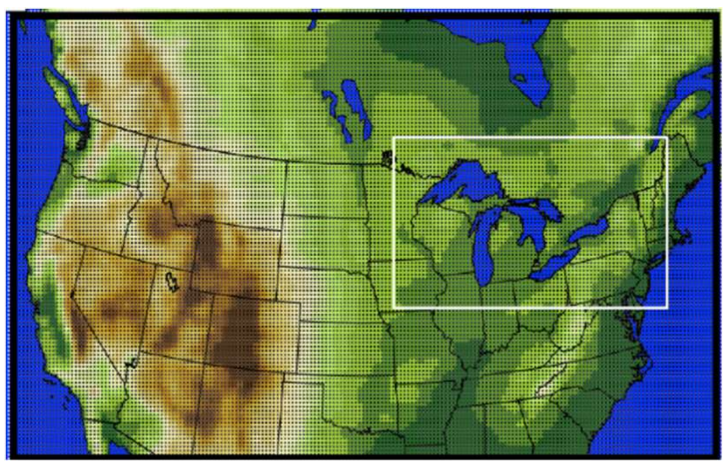
Statistical

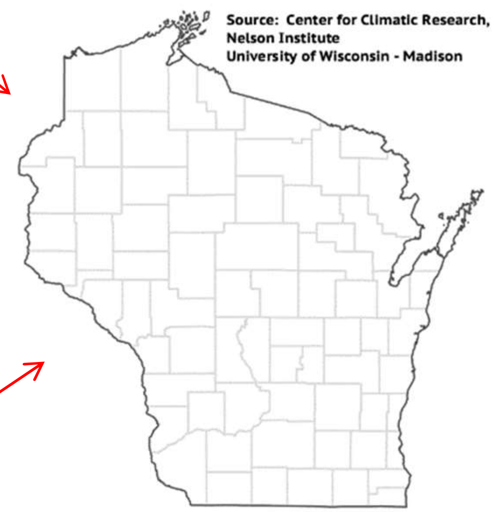
(24 models)



Dynamical

(6 models)





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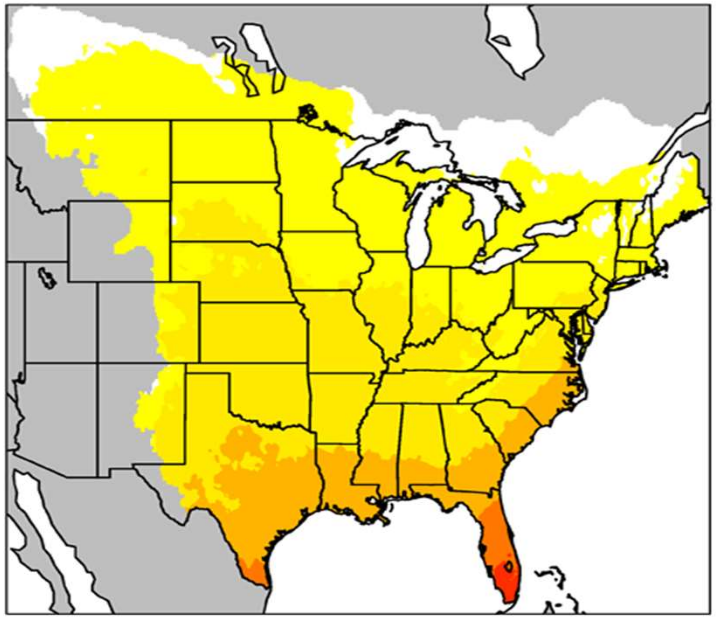
Domains used in Downscaling

Models driven by <u>high-end</u> RCP8.5 greenhouse gas emissions scenario

Statistical

(24 models)



Dynamical

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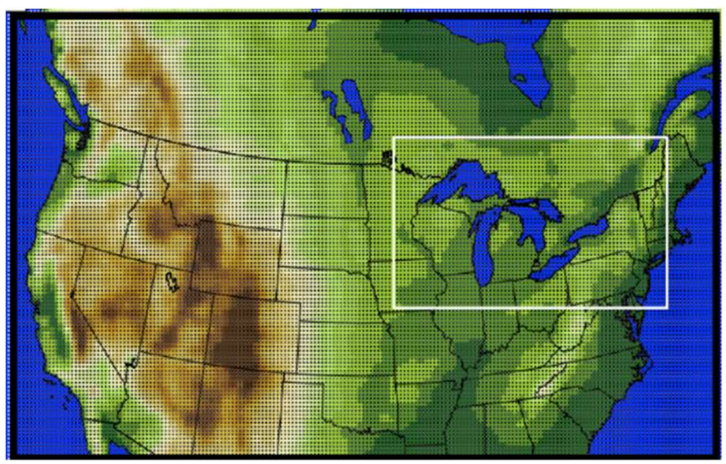

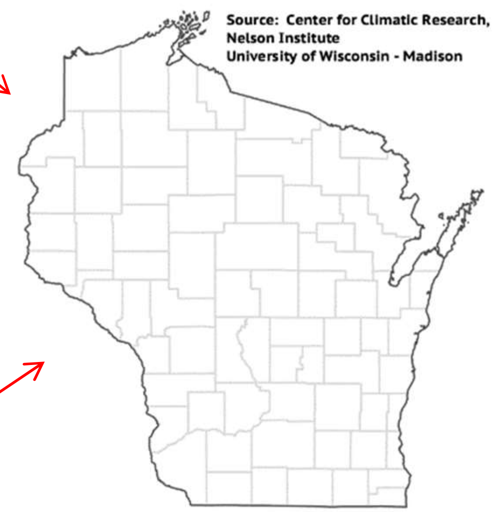

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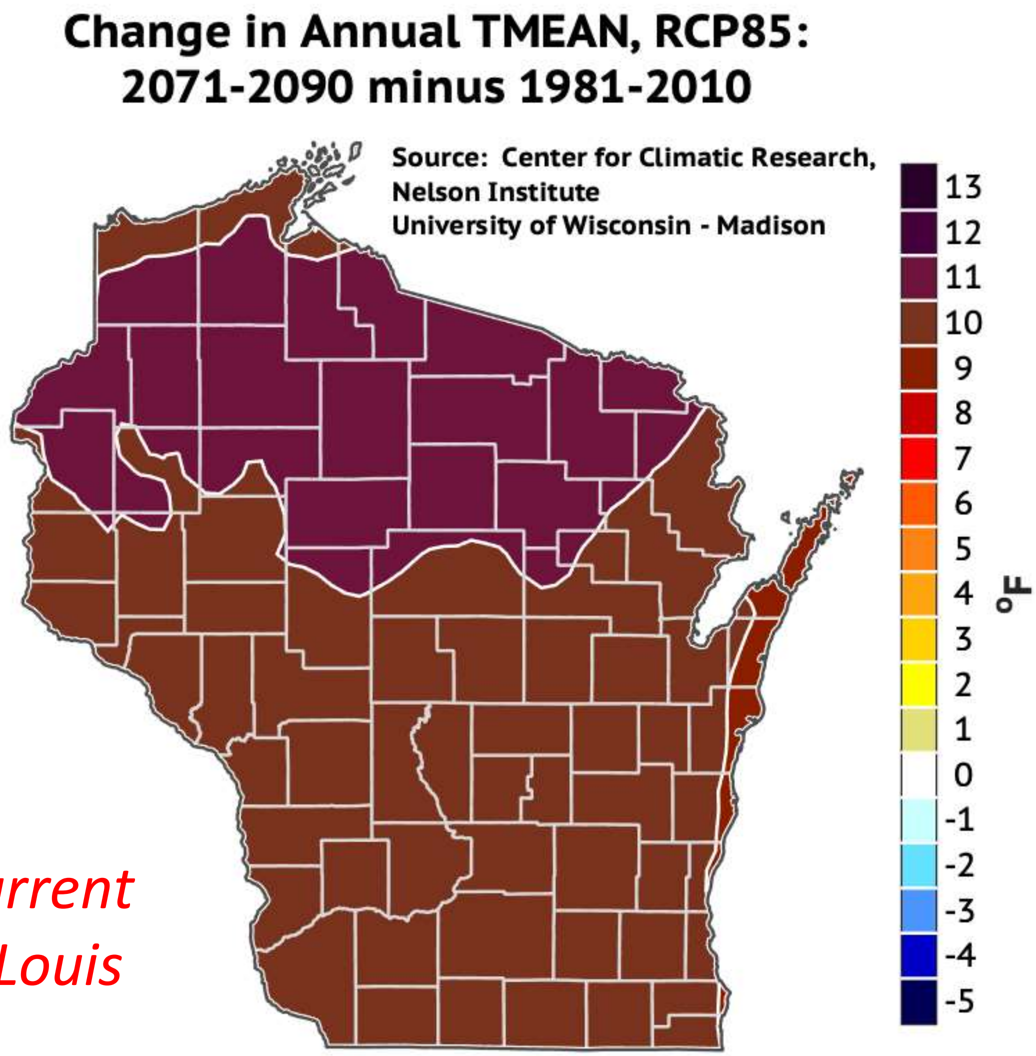
Projected Change in Annual Mean Temperature in Wisconsin

Statistical downscaling, RCP8.5



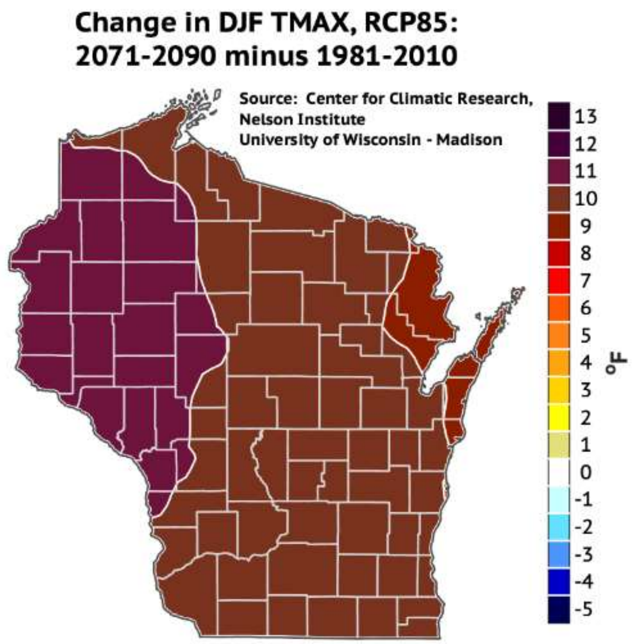
Warming of 10-11°F statewide

Close to the current climate of St. Louis

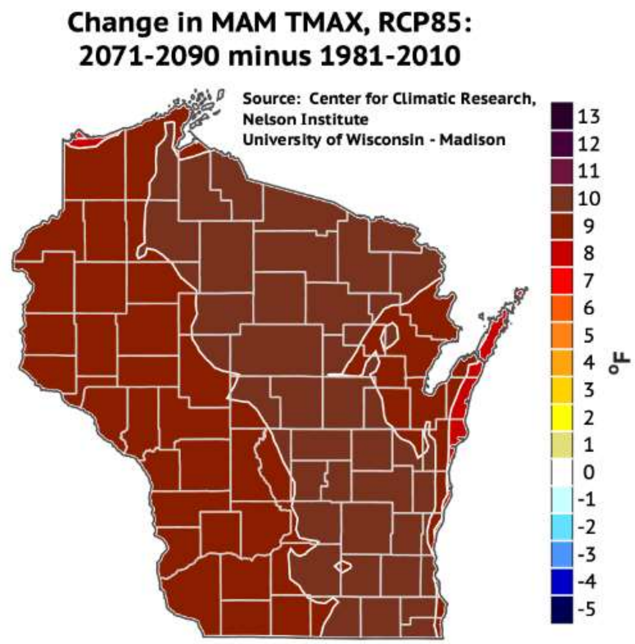
Projected Change in Mean Temperature in Wisconsin

Statistical Downscaling

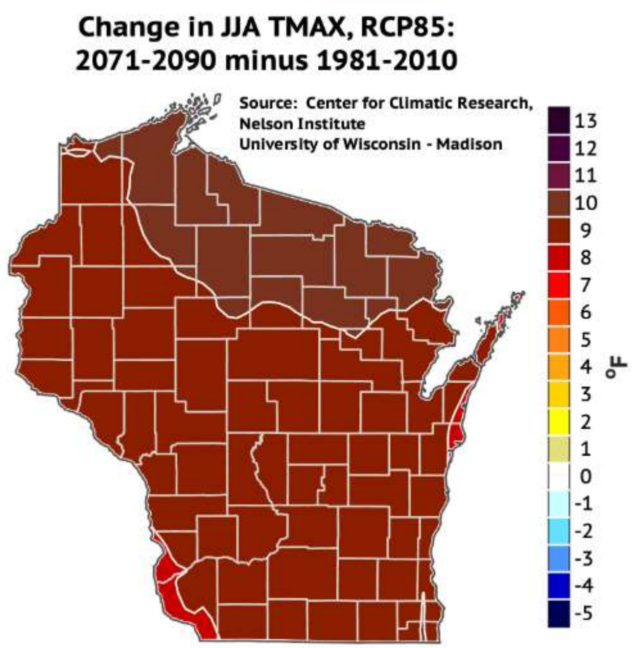
Winter



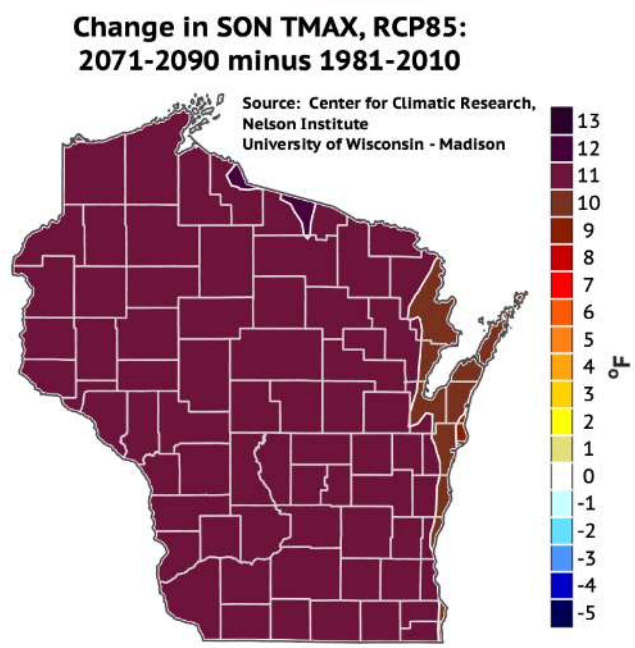
Spring



Summer



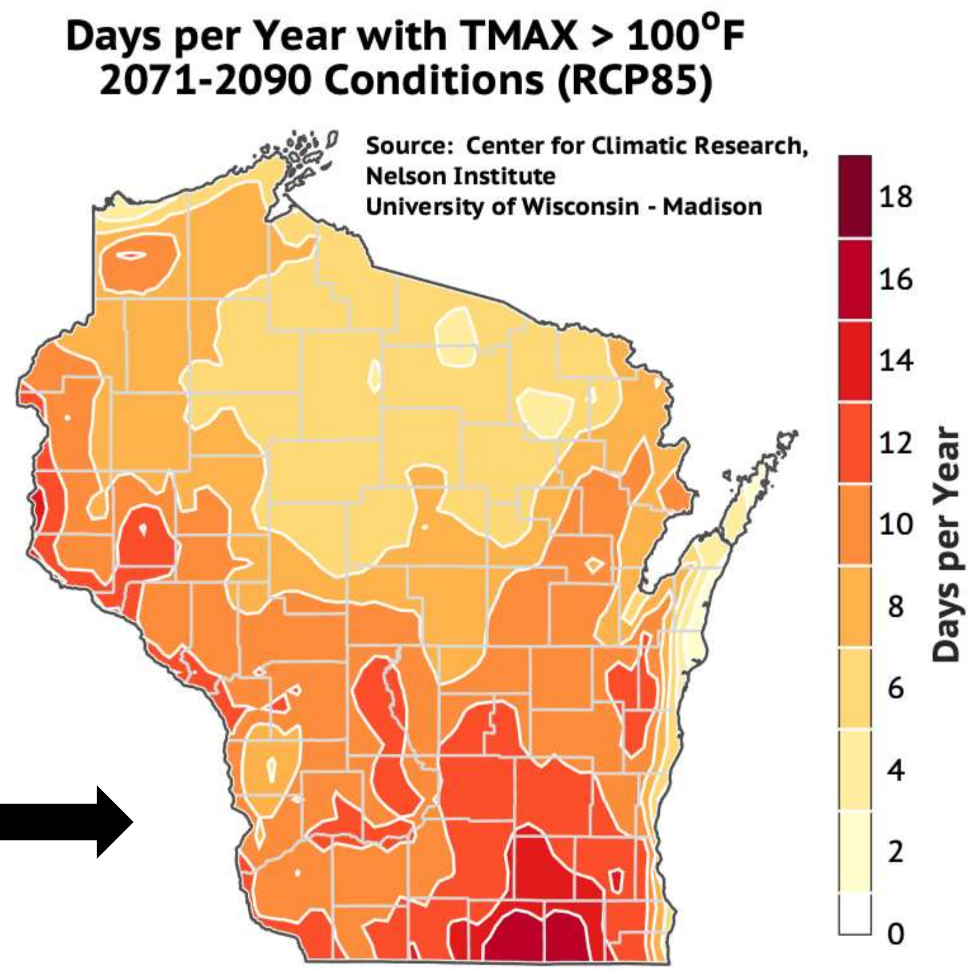
Autumn



Projected Change in Extreme Heat in Wisconsin

Statistical downscaling, RCP8.5

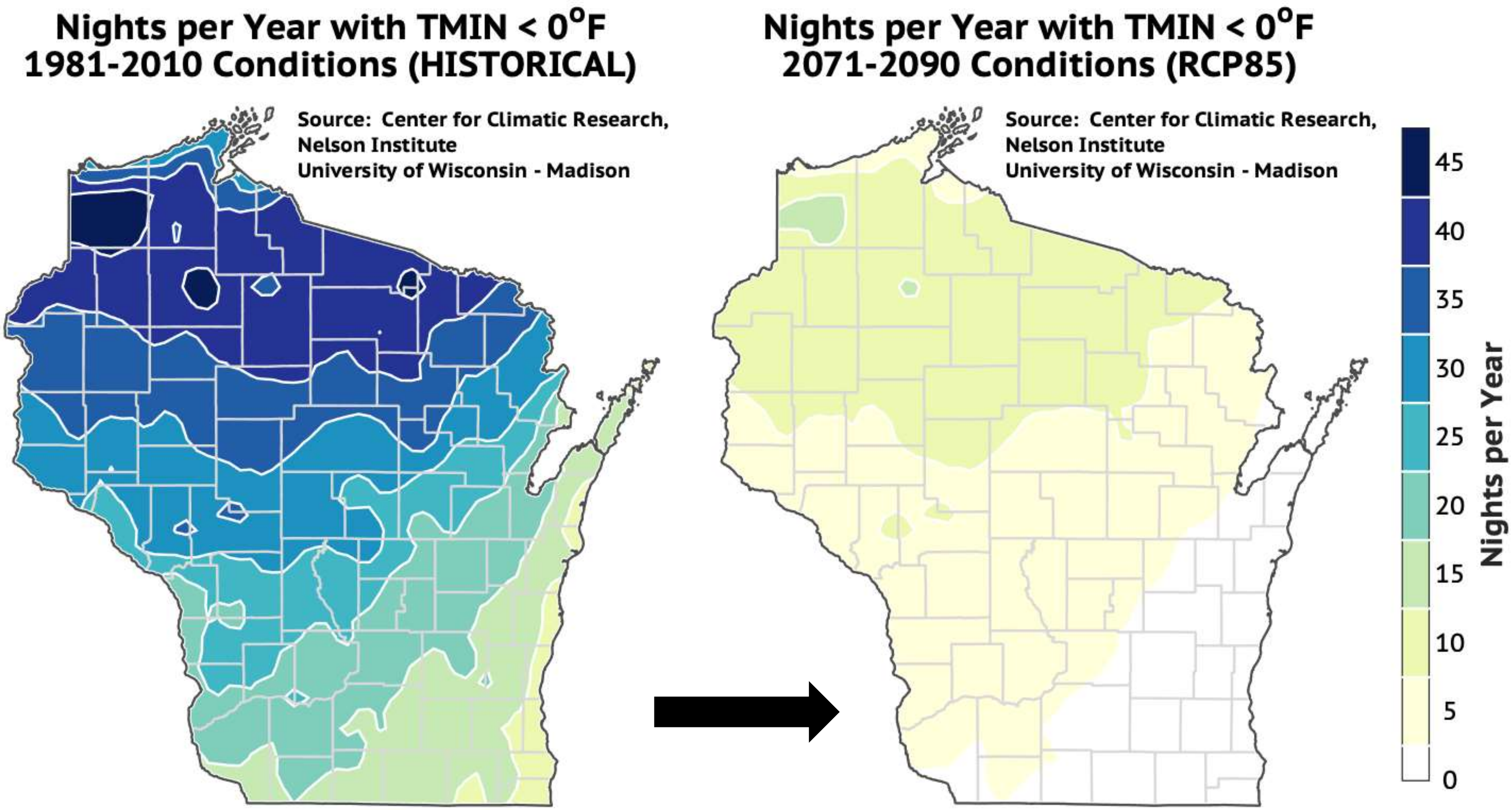
Past



Future

Projected Change in Extreme Cold in Wisconsin

<u>Statistical downscaling, RCP8.5</u>

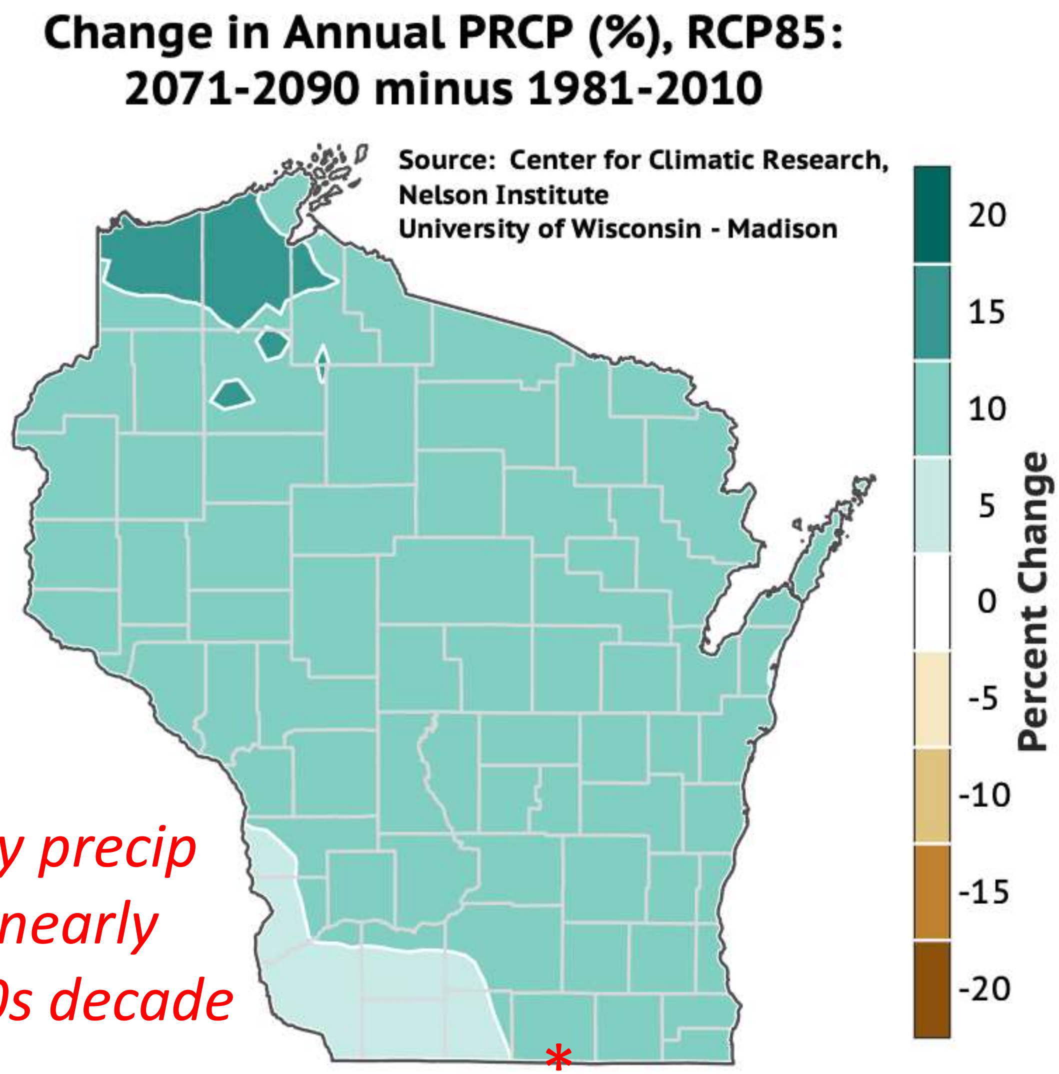


Past

Future

Projected Change in Annual Mean Precipitation in Wisconsin

<u>Statistical downscaling, RCP8.5</u>



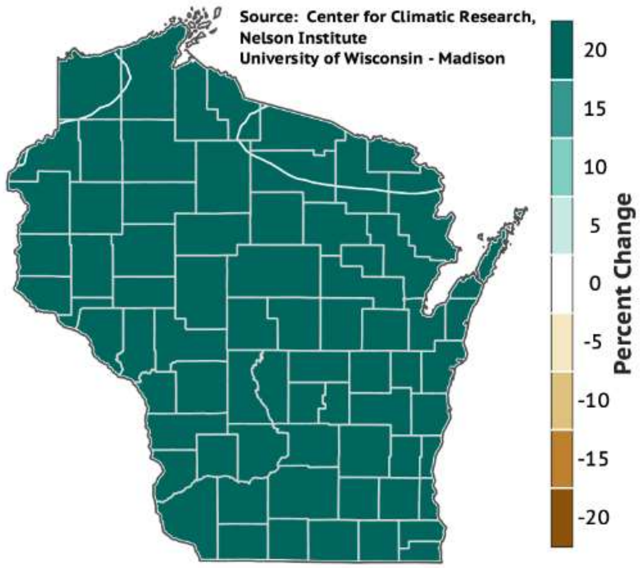
Like present-day precip in Beloit, and nearly equal to WI 2010s decade

Projected Change in Mean Precipitation in Wisconsin

Statistical Downscaling

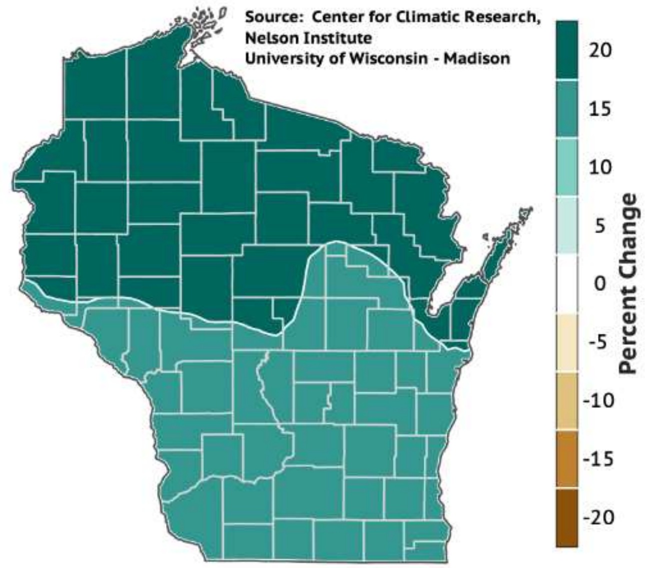
Change in DJF PRCP (%), RCP85:
2071-2090 minus 1981-2010

Winter



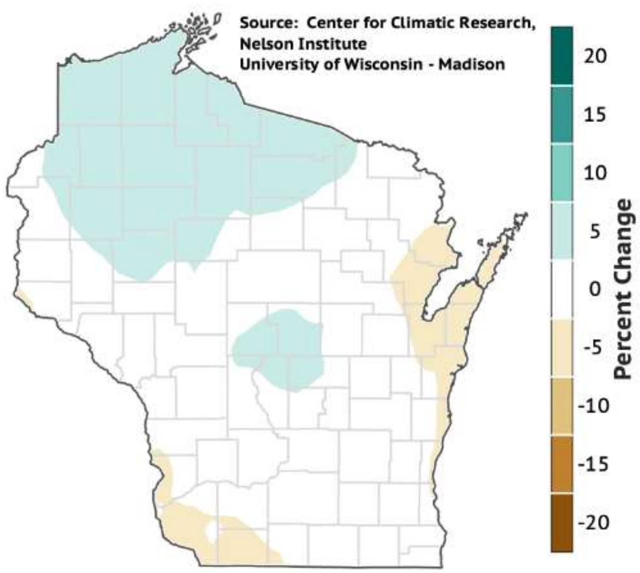
Change in MAM PRCP (%), RCP85:
2071-2090 minus 1981-2010

Spring



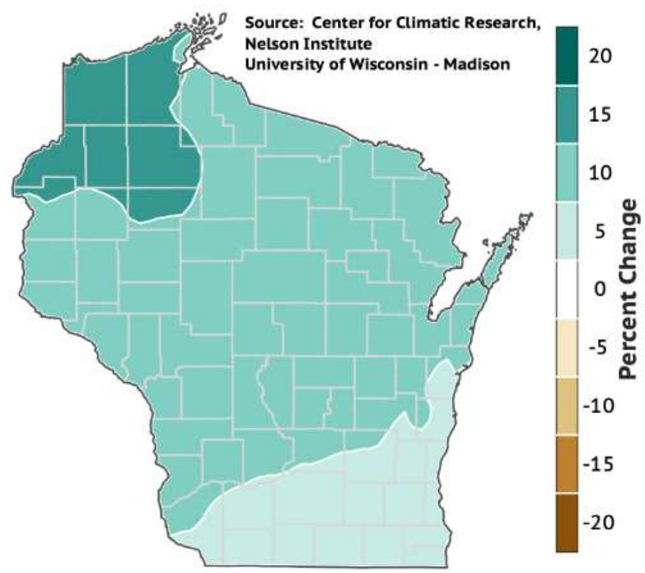
Change in JJA PRCP (%), RCP85:
2071-2090 minus 1981-2010

Summer

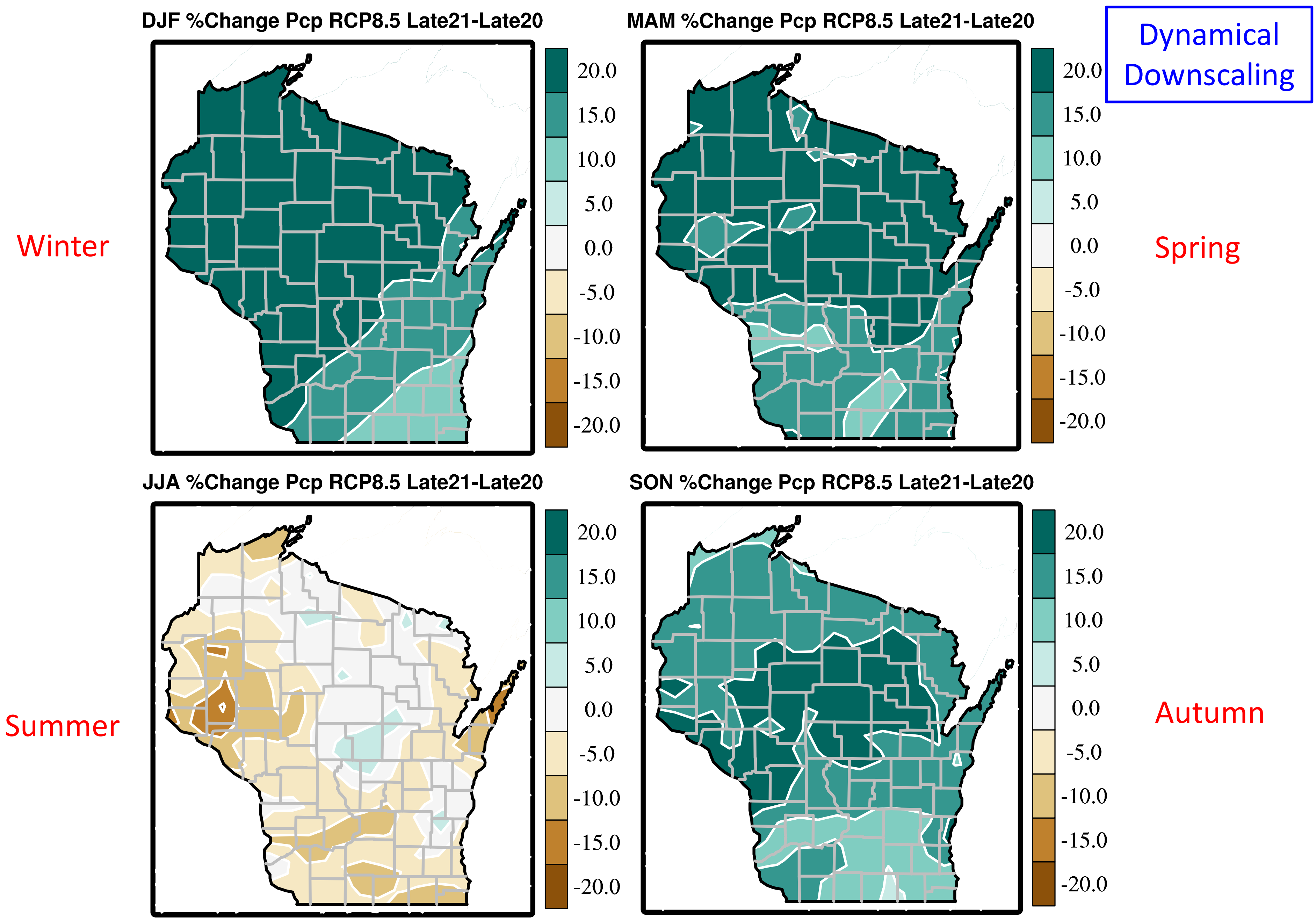


Change in SON PRCP (%), RCP85:
2071-2090 minus 1981-2010

Autumn



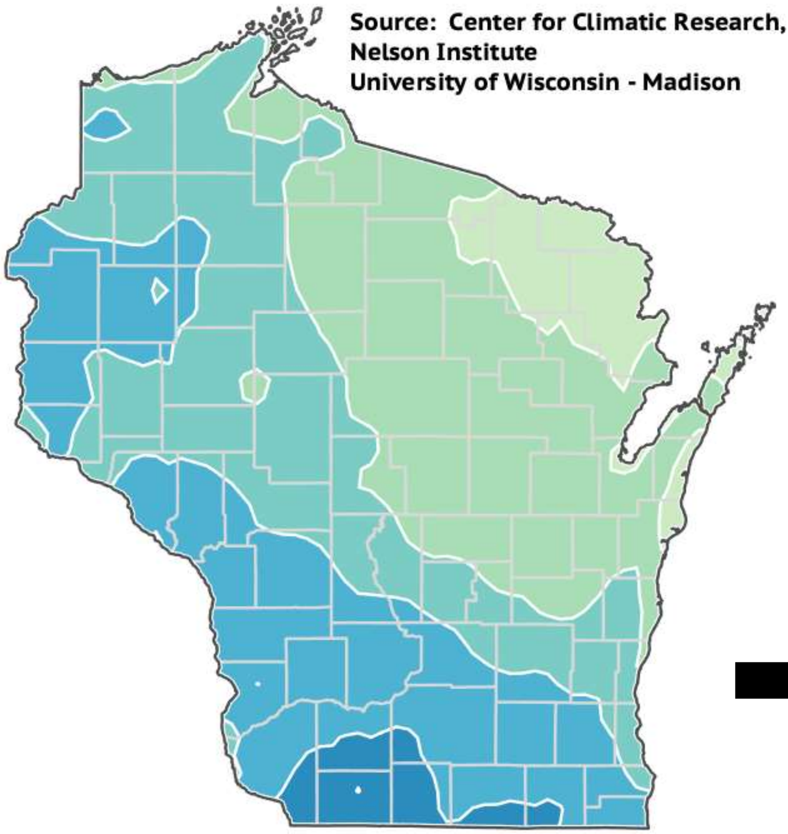
Projected Change in Mean Precipitation in Wisconsin



Projected Change in Extreme Precipitation in Wisconsin

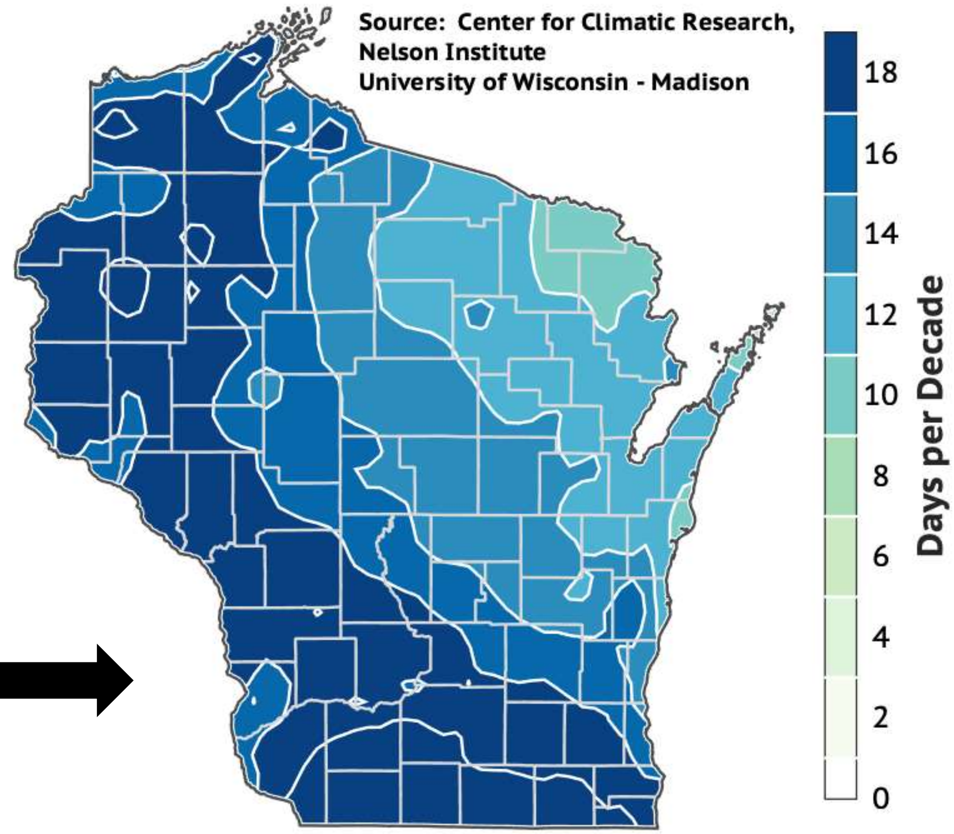
Statistical downscaling, RCP8.5

Days per Decade with PRCPDays > 2in
1981-2010 Conditions (HISTORICAL)



Past

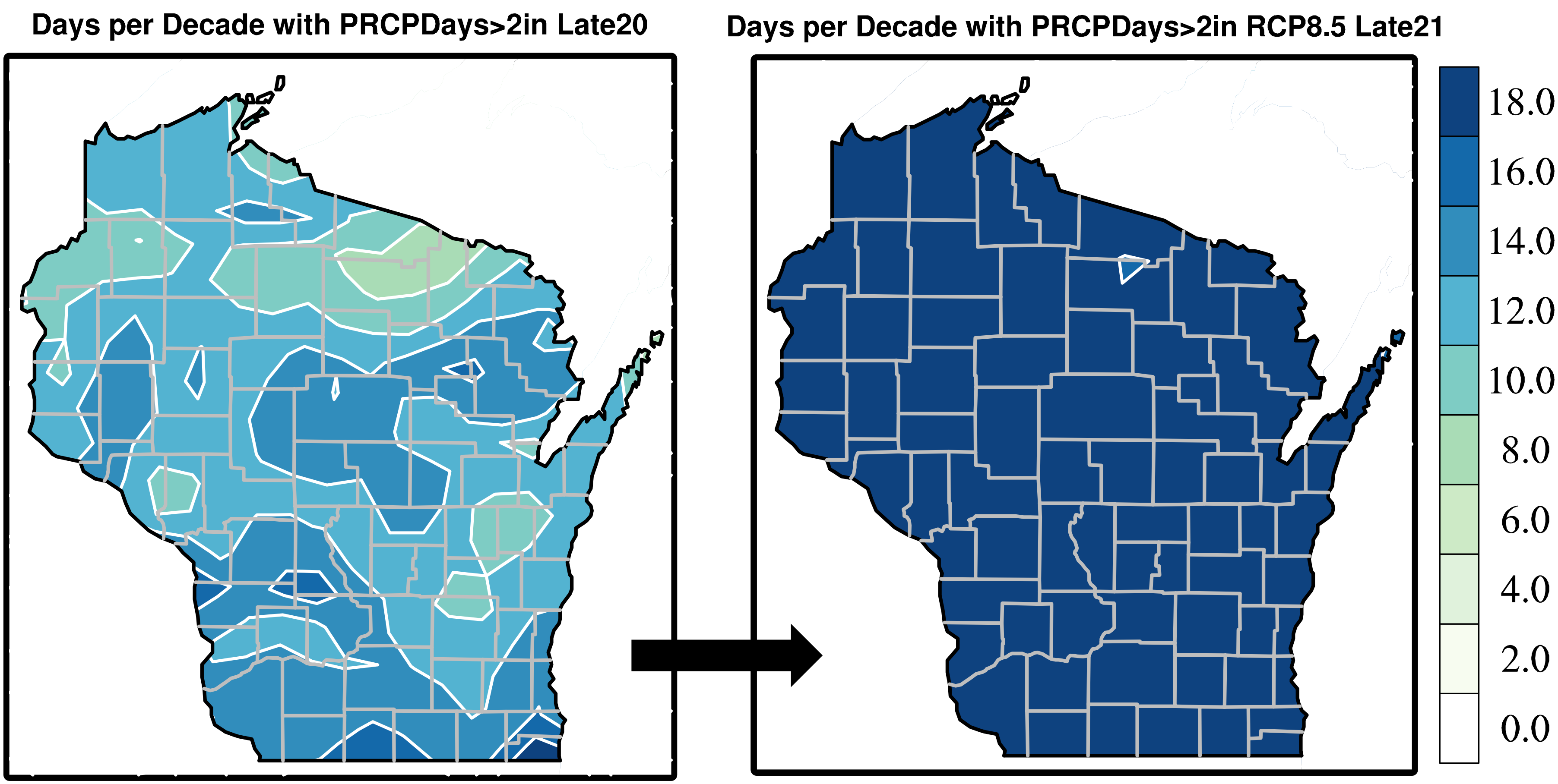
Days per Decade with PRCPDays > 2in
2071-2090 Conditions (RCP85)



Future

Projected Change in Extreme Precipitation in Wisconsin

Dynamical downscaling, RCP8.5



Past

Future

Michael Notaro

What are the impacts of these weather variations and climate changes?

- Lake ice
- Water quality
- Lake levels
- Fish species
- Invasives

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Stay tuned for Madeline Magee's presentation next!

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Water Quality

↑ precipitation → ↓ water clarity ↑ harmful algal blooms

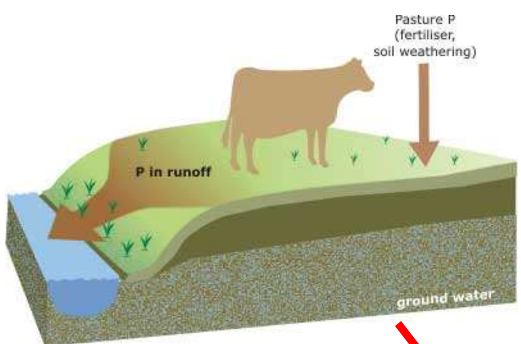
Slide from Madeline Magee

Consequences of Phosphorus and E. Coli Runoff to Lakes

Role of Rainfall in Phosphorus Inputs to Lakes

Steve Carpenter-led study:

- Precipitation and phosphorus loads to Lake Mendota are significantly correlated
- Highest phosphorus inputs occur in late <u>winter and spring</u> (manure spreading)
- <u>Just 29 days per year</u> account for ¾ of annual phosphorus load to Mendota



Why are Winter and Spring so Important for Runoff?

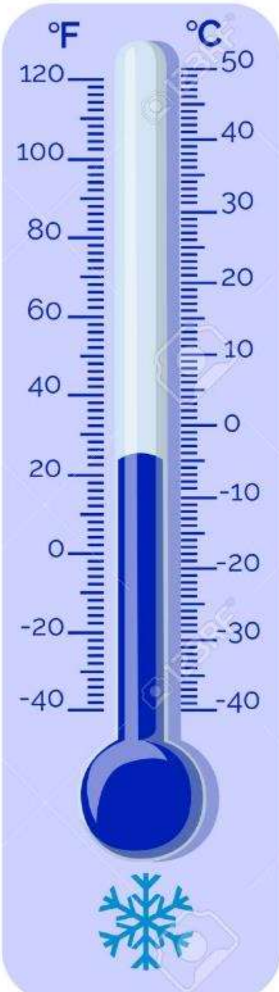
Snow Melt

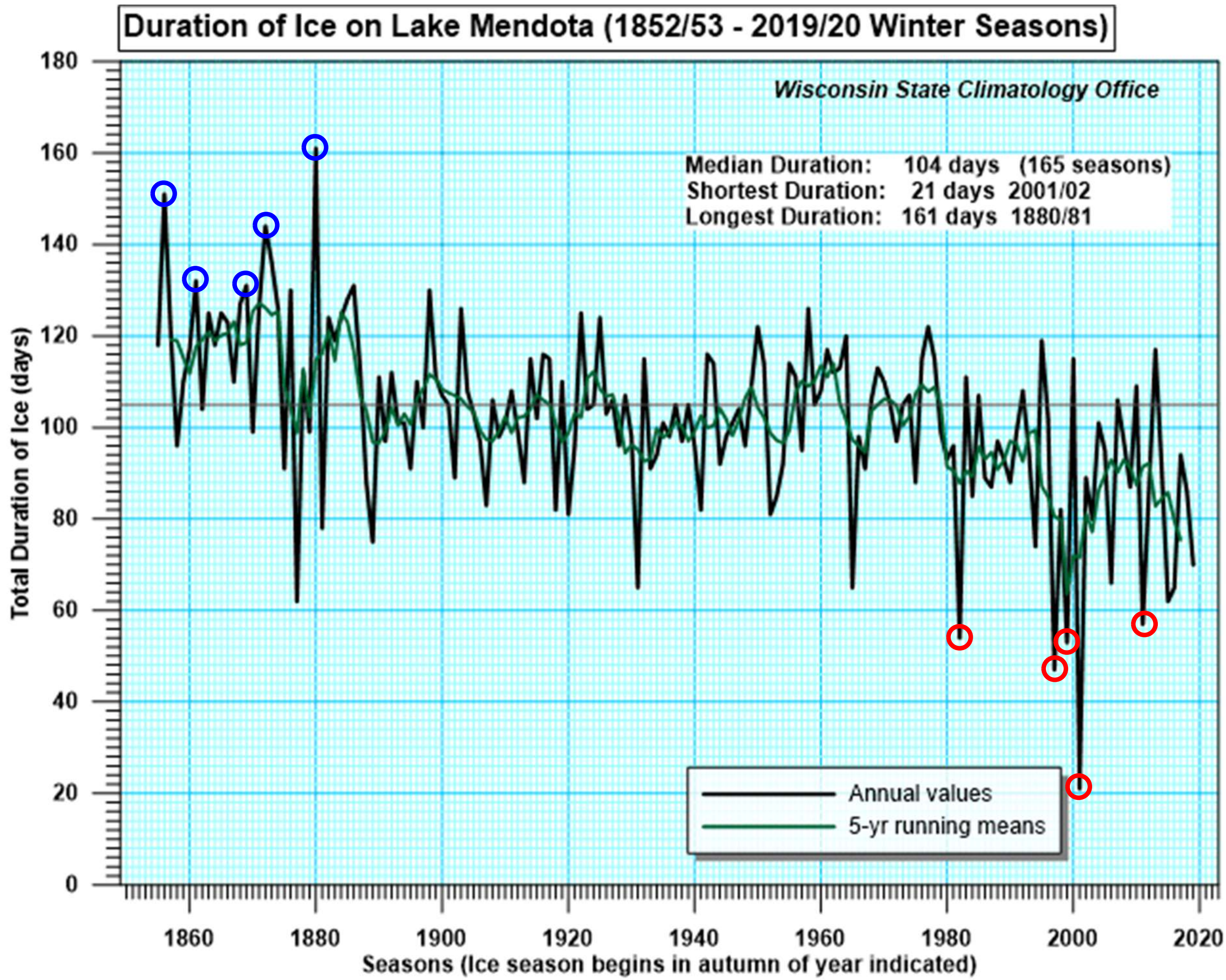
Frozen Ground

Manure on Fields

Wet Soils

Lake Ice as a "Climatometer"





Duration of Ice on Lake Mendota (1852/53 - 2019/20 Winter Seasons)
Wisconsin State Climatology Office
Median Duration: 104 days (165 seasons)
Shortest Duration: 21 days 2001/02
Longest Duration: 161 days 1880/81
Total Duration of Ice (days)
0
20
40
60
80
100
120
140
160
180
1860
1880
1900
1920
1940
1960
1980
2000
2020
Seasons (Ice season begins in autumn of year indicated)
Annual values
5-yr running means

Statistical Lake Ice Model

Based on thermodynamic equations and empirical relationships

Driven by a single variable: daily mean air temperature (T)

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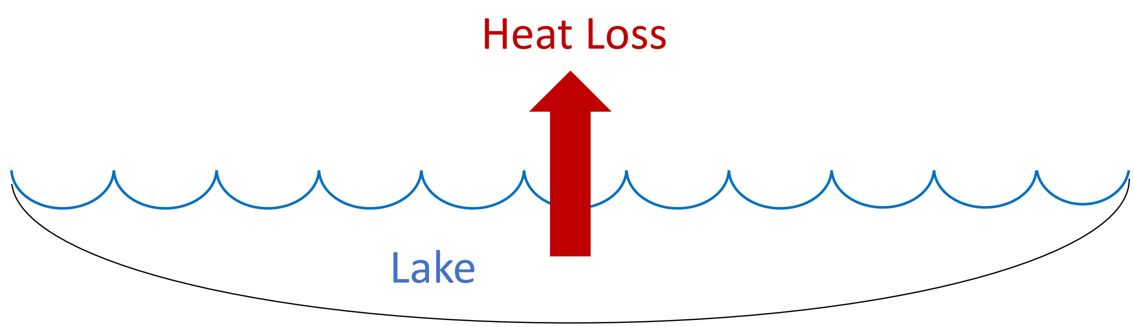

Freeze-up simulated when Accumulated Freezing Degree Days (AFDD) exceed an empirically determined value (273 AFDD for Lake Mendota)

FDD = Freezing-Degree Days (sum of 32°F minus T)

Statistical Lake Ice Model

Based on thermodynamic equations and empirical relationships

Driven by a single variable: daily mean air temperature (T)

Growth **Melt**

$$h = 0.7\sqrt{AFDD} - 0.12(ATDD)$$

h = ice thickness (inches)

AFDD = accumulated Freezing-Degree Days (sum of 32^{o}F minus T)

ATDD = accumulated Thawing-Degree Days (sum of T minus 32^{o}F)

Probability of Lake Mendota Freezing in a Winter

- *Lake model driven by daily mean air temperatures for Madison*
- *From 5 global climate models (statistically downscaled)*
- *Compare recent past to future*

Probability of Lake Mendota Freezing in a Winter

	Recent climate
Model	**1981-2000**
GFDL	100
GISS	100
CSIRO	100
CNRM	100
MIROC	100
Model Mean	100

Duration of Ice: *3 months*

Probability of Lake Mendota Freezing in a Winter

	Recent climate	3 to 4 decades from now
Model	**1981-2000**	**2046-2065**
GFDL	100	100
GISS	100	95
CSIRO	100	100
CNRM	100	100
MIROC	100	47
Model Mean	100	88
Duration of Ice:	*3 months*	*1.5 months*

Probability of Lake Mendota Freezing in a Winter

	Recent climate	3 to 4 decades from now	Late century
Model	**1981-2000**	**2046-2065**	**2081-2100**
GFDL	100	100	95
GISS	100	95	89
CSIRO	100	100	68
CNRM	100	100	63
MIROC	100	47	21
Model Mean	100	88	67
Duration of Ice:	*3 months*	*1.5 months*	*1.0 months*

1/3 of winters projected to be ice-free by end of this century

Conclusions

- “Warmer and wetter” observed trend in Wisconsin

  -- occurring in every season

  -- record precipitation lately

  -- not hotter but muggier

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  -- fairly consistent warming spatially and seasonally
  -- wetter especially during winter and spring (summer uncertain)
  -- emergence of more extreme heat likely

Conclusions

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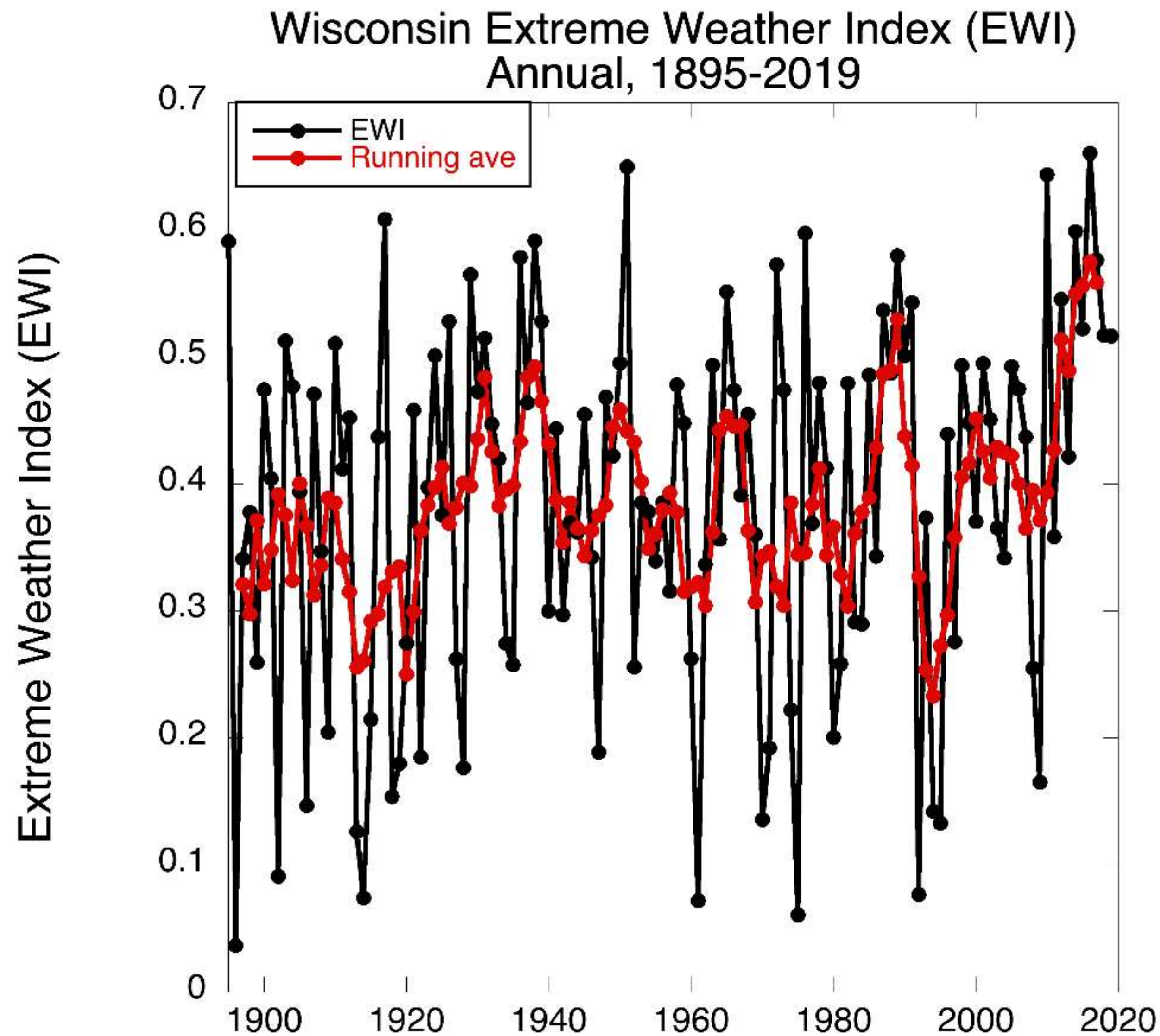
  -- record precipitation lately
  -- not hotter but muggier

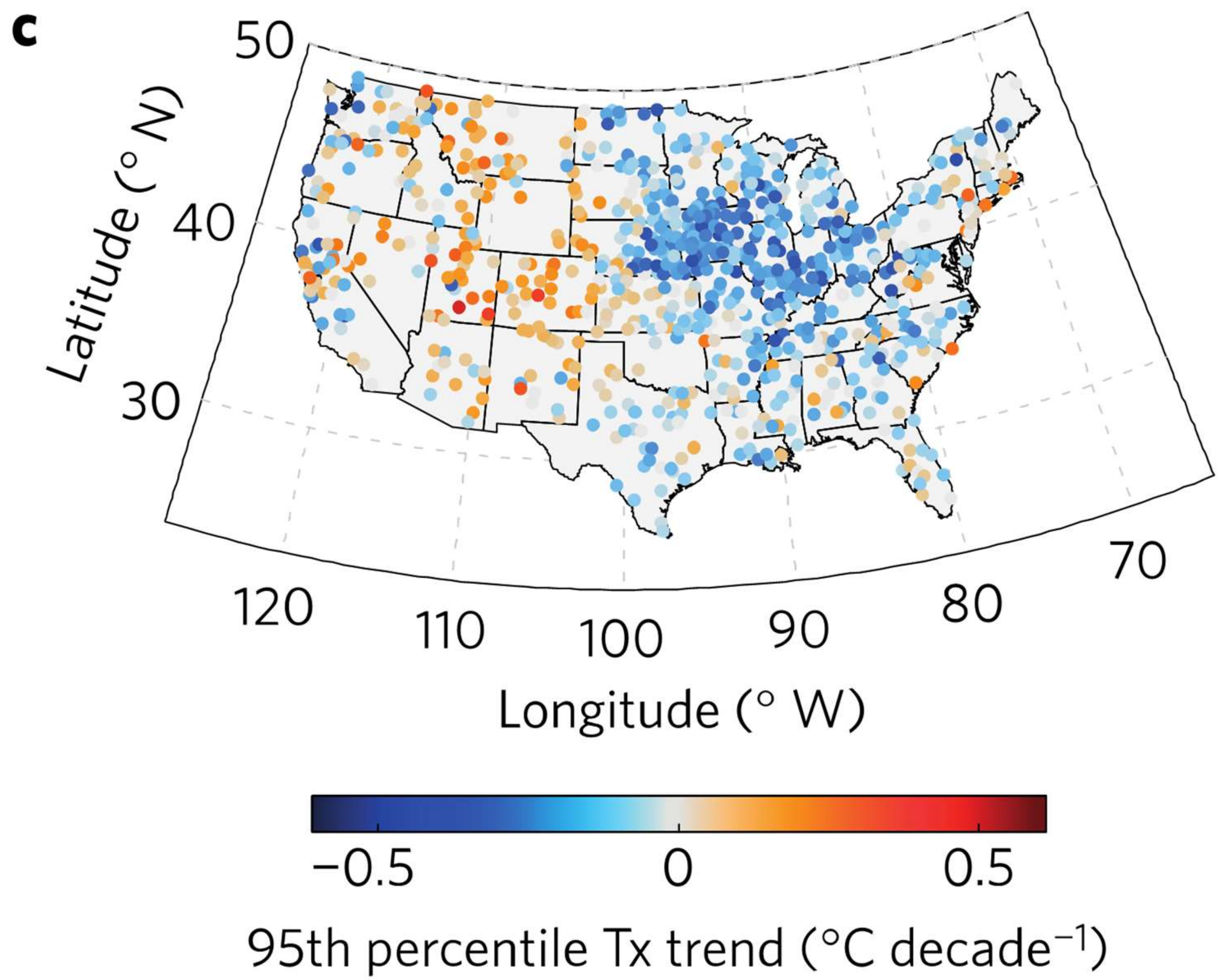
- Warmer and wetter trend projected to continue
  -- fairly consistent warming spatially and seasonally
  -- wetter especially during winter and spring (summer uncertain)
  -- emergence of more extreme heat likely

- Widespread impacts likely in Wisconsin’s lakes and streams
  -- enhanced runoff from heavier rainfalls an increasing threat
  -- greater runoff during wetter winters and springs
  -- significantly less lake ice in future

Extra slides


Wisconsin Extreme Weather Index (EWI)
Annual, 1895-2019
EWI
Running ave
Extreme Weather Index (EWI)
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
1900
1920
1940
1960
1980
2000
2020

Trend in Hottest 5% of Summer Days (1910-2014)



No trend toward more extreme heat in Midwest, at least during daytime

Mueller et al. (2015)