Climate Change in Wisconsin

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Thanks to…

The Wisconsin Initiative on Climate Change Impacts (WICCI)

especially David Lorenz, David Liebl, Megan Kirchmeier, Michael Notaro, Steve Vavrus, and more

Thanks to: **University of Wisconsin Cooperative Extension**

OVERVIEW

- **Atmospheric Physics 101**
- Climate Change: What we know and how we know it
- Climate Change in Wisconsin

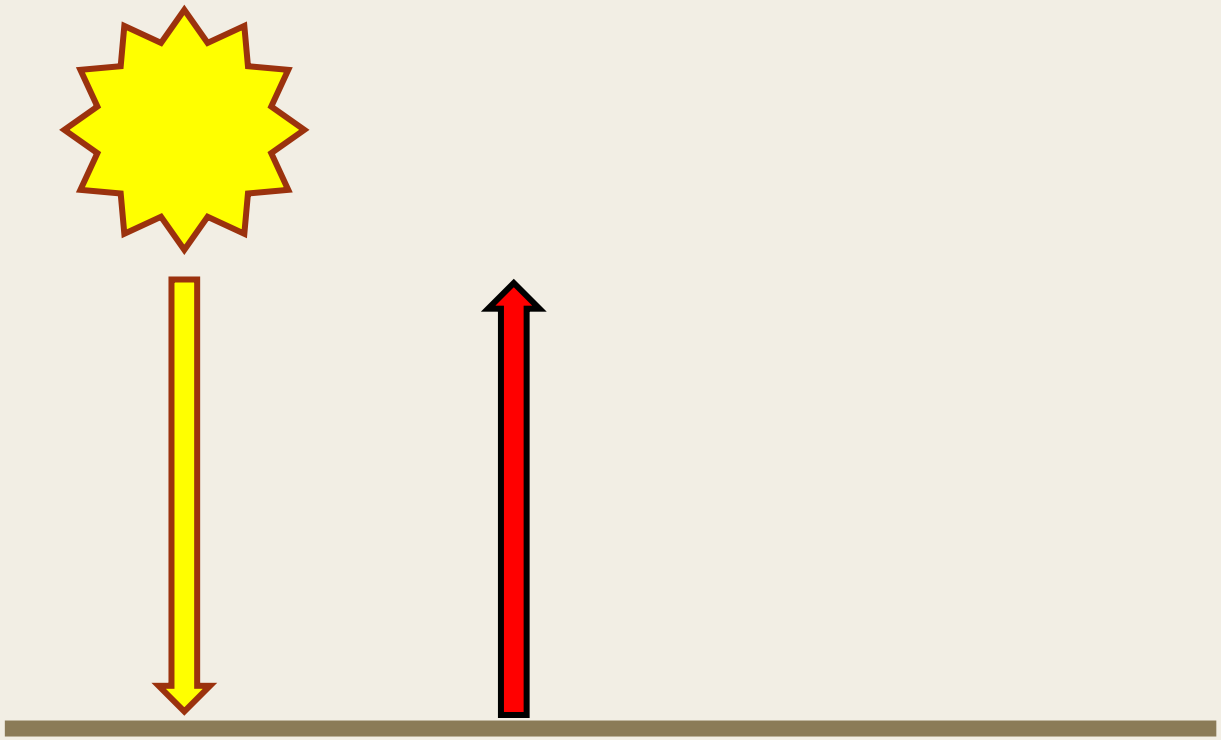
The Greenhouse Effect

Two Basic Laws of Physics:

Everything emits radiation.

Warmer objects emit more radiation than colder objects.

The Greenhouse Effect

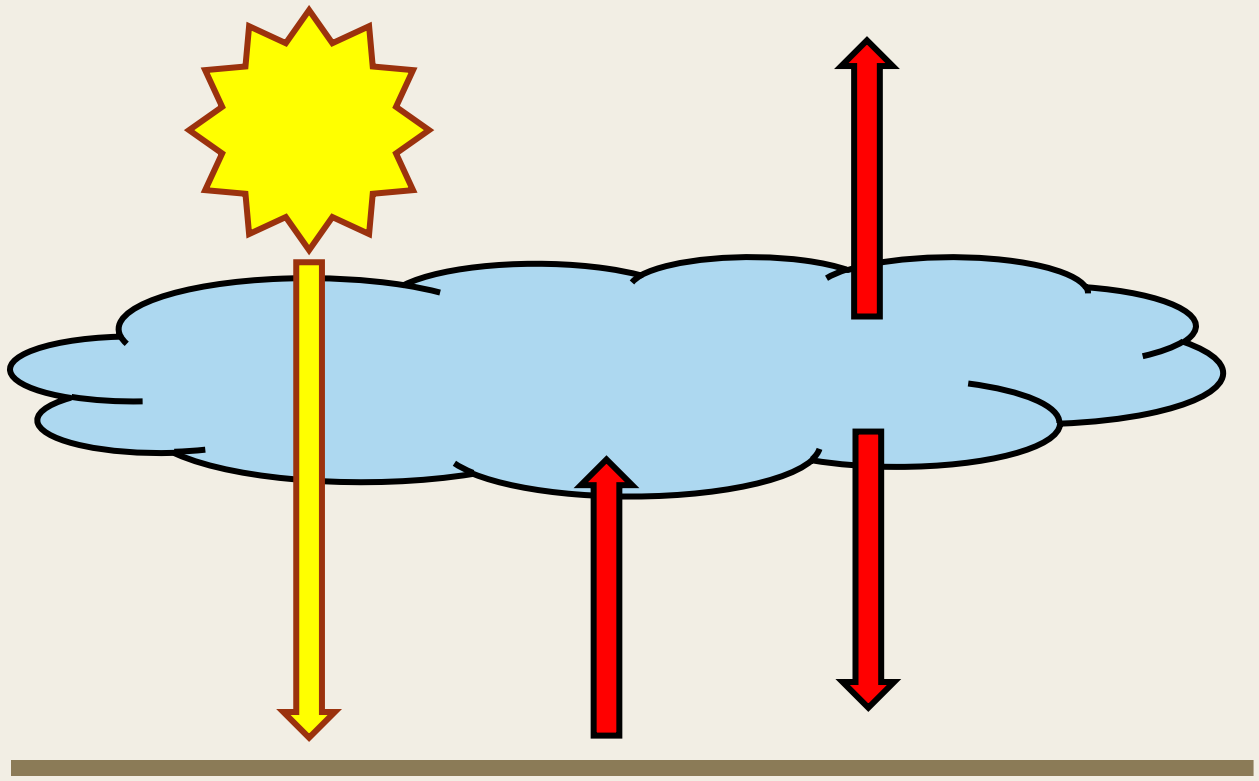


T = -18°C

Consider a planet with NO atmosphere:

As the planet absorbs radiation from the sun, it starts warming until it emits the same amount of radiation as it absorbs.

The Greenhouse Effect



T = +16°C

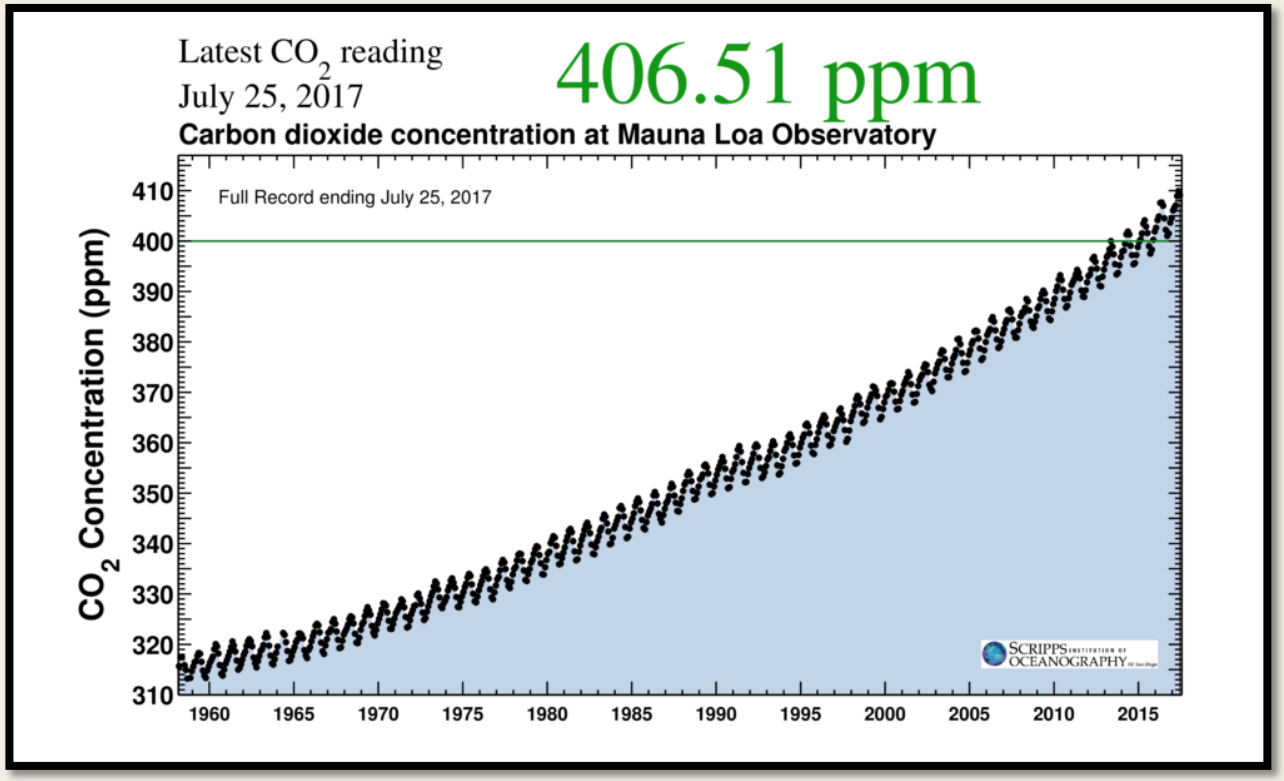
Add atmosphere with Greenhouse Gasses: Atmosphere warms, and emits radiation in both directions, which is an ***extra source of energy for the planet***

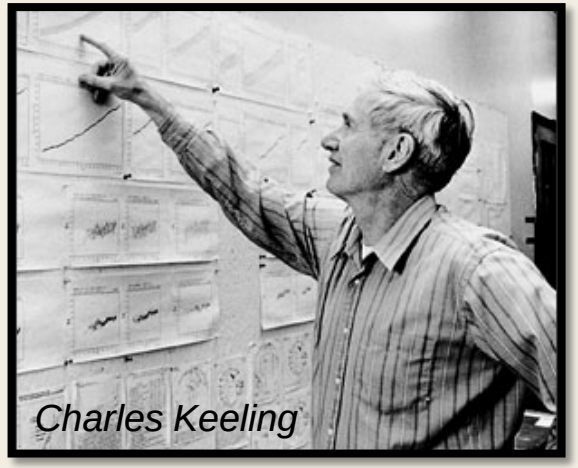
OVERVIEW

- Atmospheric Physics 101
- **Climate Change: What we know and how we know it**
- Climate Change in Wisconsin

Global Climate Change: What we know

Greenhouse gasses are increasing due to human emissions





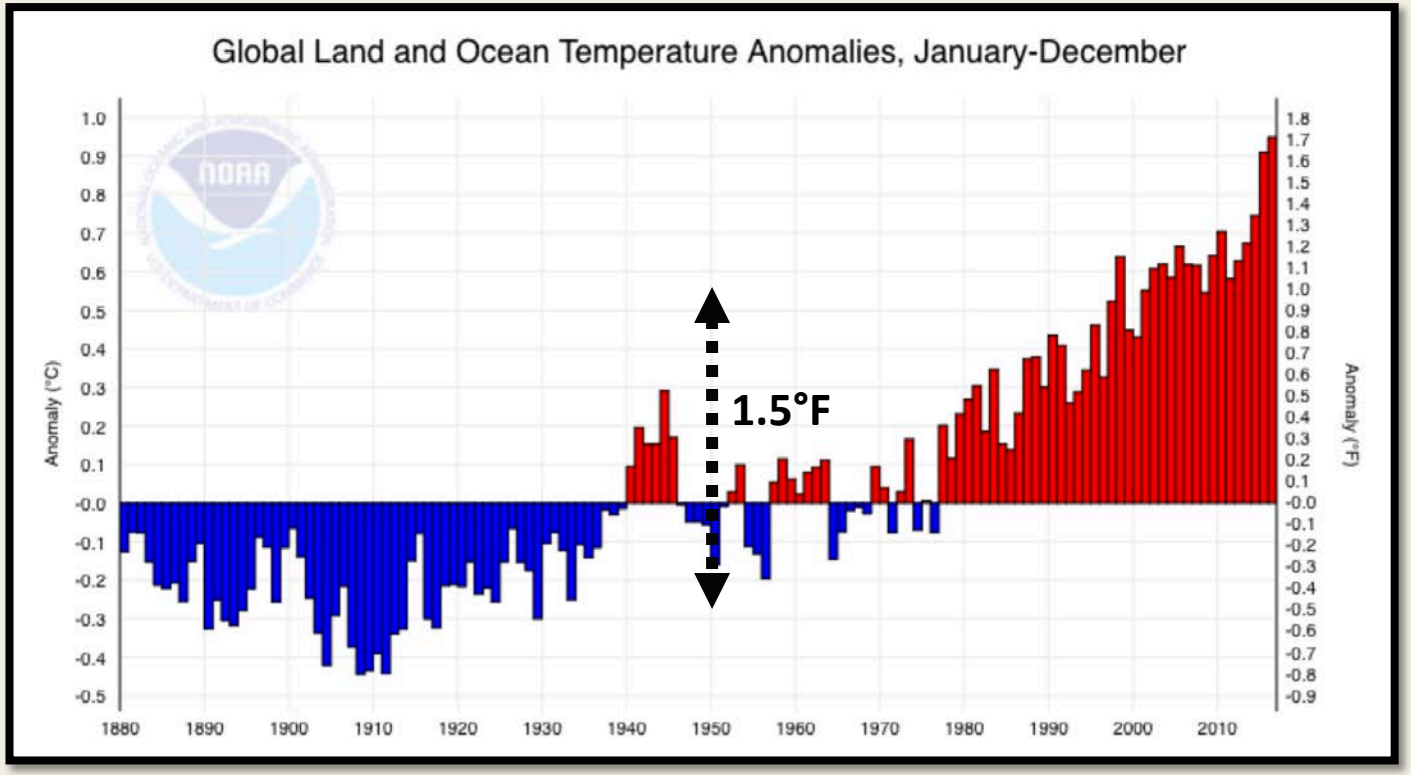
Greenhouse Gasses: "Trap" energy in lower atmosphere

Anthropogenic: Caused by human activity

Keeling Curve: https://scripps.ucsd.edu/programs/keelingcurve/

Global Climate Change: What we know

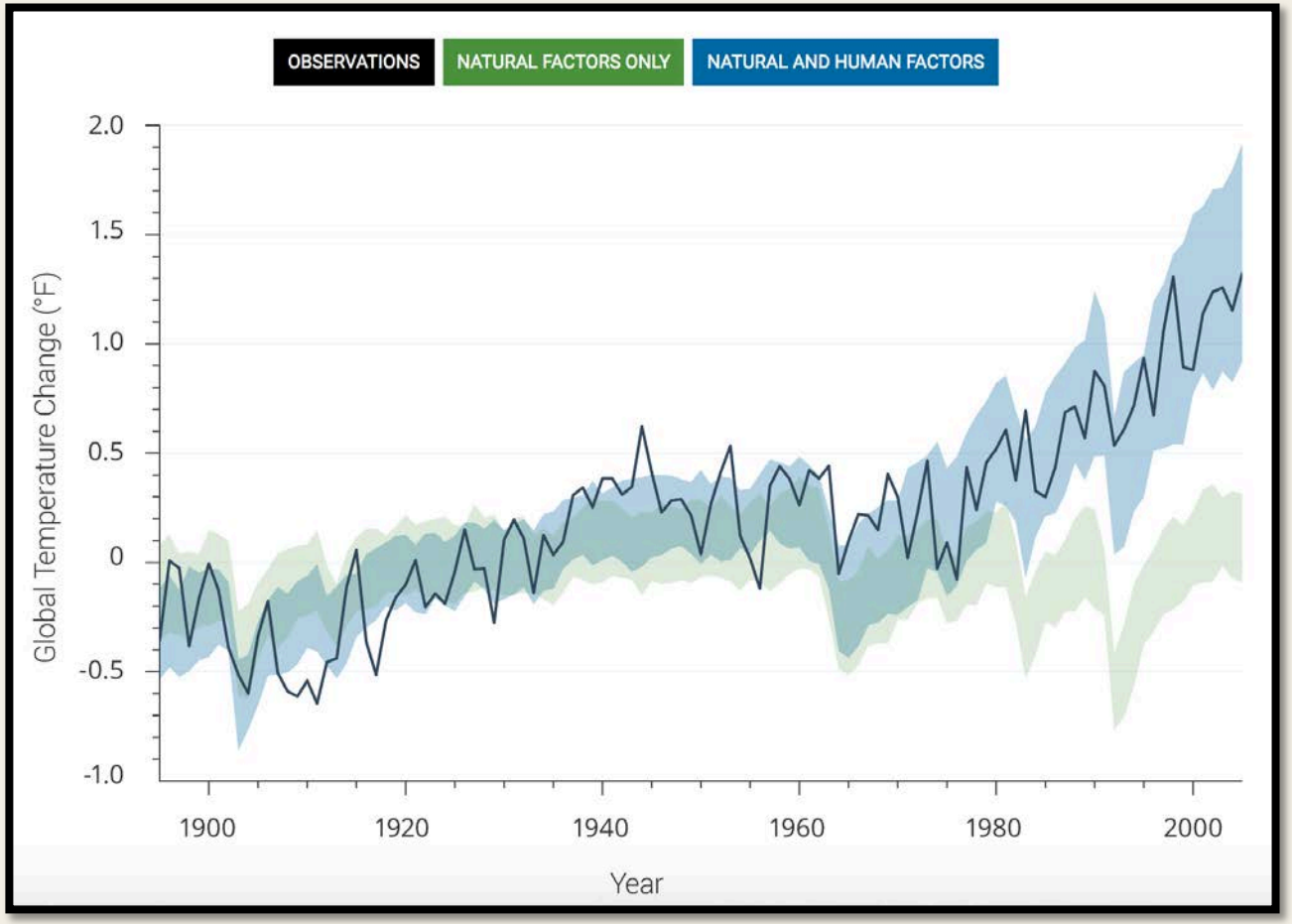
Global temperature is increasing (so is regional temperature)



Global temperature has warmed by about 1.5°F since 1900.

NOAA: https://www.ncdc.noaa.gov/cag/time-series/global/globe/land_ocean/ytd/12/1880-2016

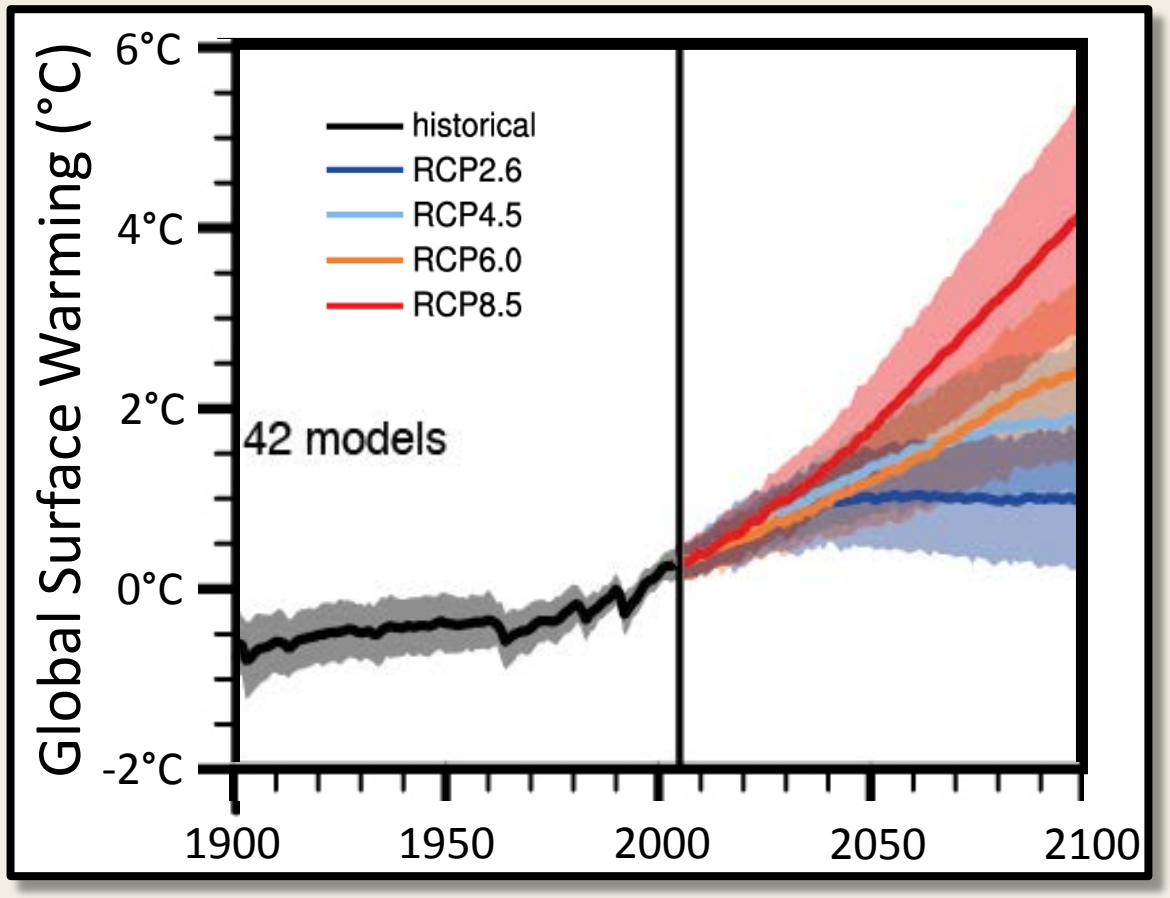
Global Climate Change: What we know



Without Anthropogenic greenhouse gasses, models cannot reproduce the warming since 1950.

Image: National Climate Assessment

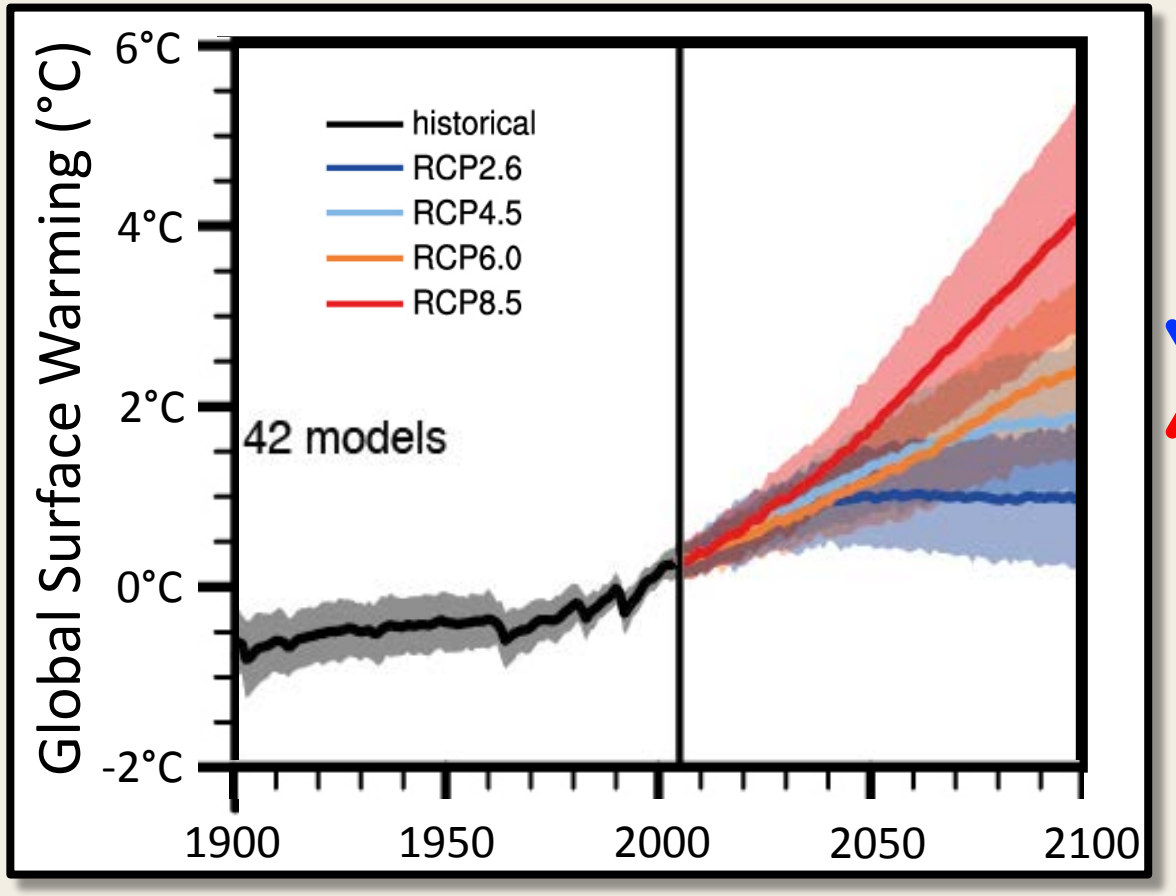
Global Climate Change: What's next



Global temperature will continue to warm by about 1.5°C (3°F) by 2050, 2°-4°C (3.5°-7.5°F) by 2100

Image: IPCC WGI, 5th Assessment Report

Global Climate Change: What's next



Mitigation:

Avoids "dangerous" amounts of climate change

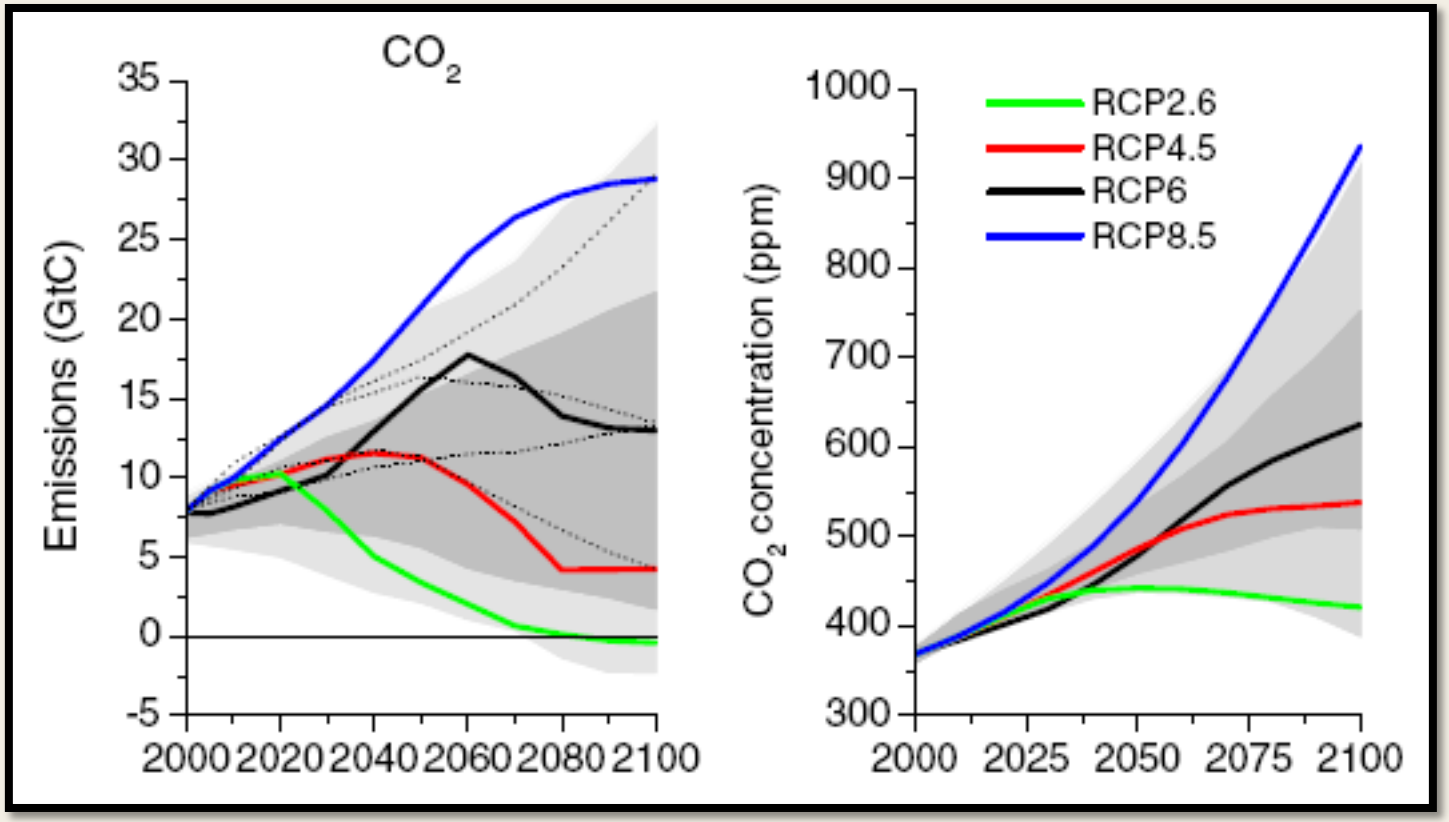
Adaptation:

Some climate change is inevitable

Adaptation needed to minimize impacts

Image: IPCC WGI, 5th Assessment Report

Emissions vs. Concentration



Stabilizing emissions results in continued global warming.

Reduction of emissions is necessary to stabilize CO_2 concentration.

EVEN THEN, Global Warming would continue for ~50yr.

Image from: https://www.climatechangeinaustralia.gov.au

Global Climate Change:
Q&A

OVERVIEW

- Atmospheric Physics 101
- What we know and how we know it
- **Climate Change in Wisconsin**

OVERVIEW

- Atmospheric Physics 101
- Climate Change: What we know and how we know it
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WICCI Overview

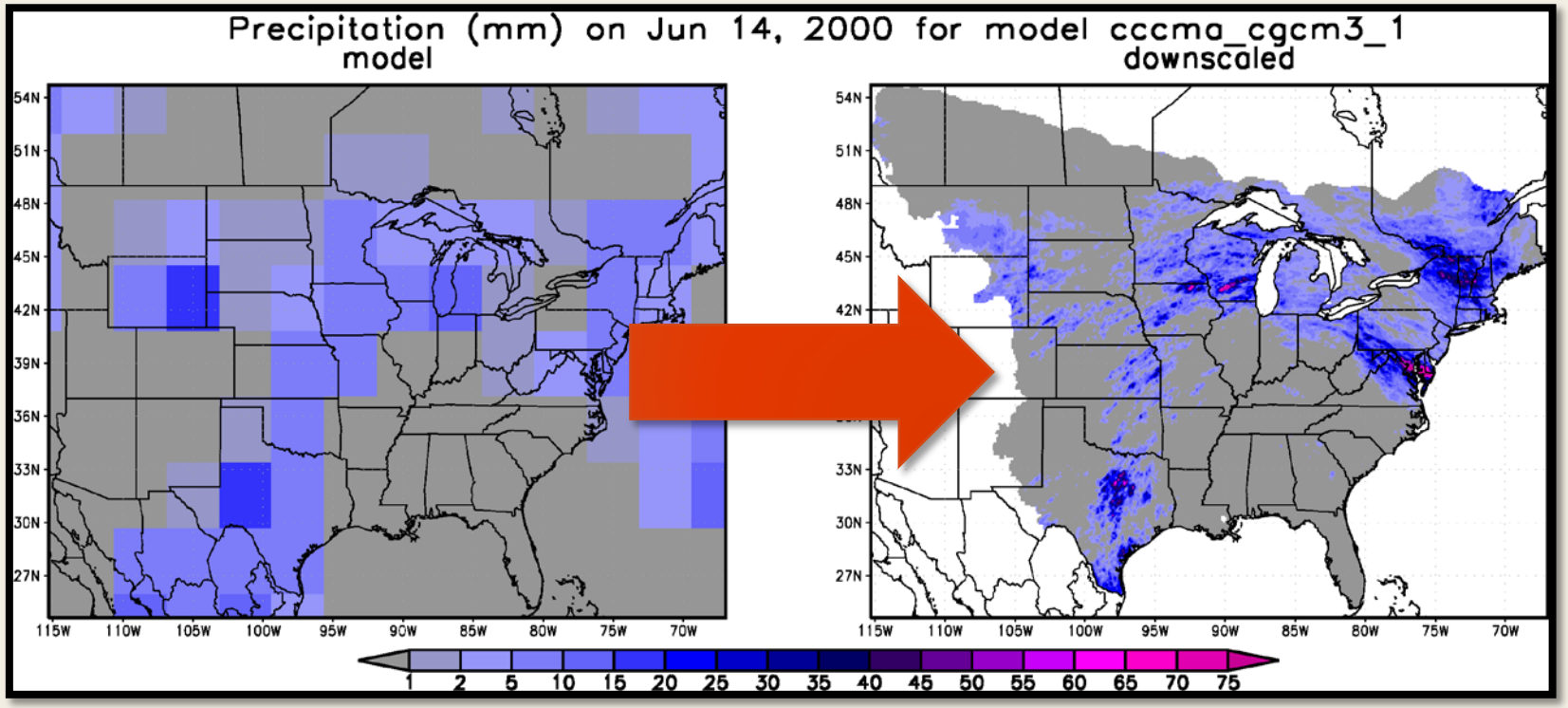
WICCI's mission is to generate and share information that can limit vulnerability to climate change in Wisconsin and the Upper Midwest.

http://www.wicci.wisc.edu

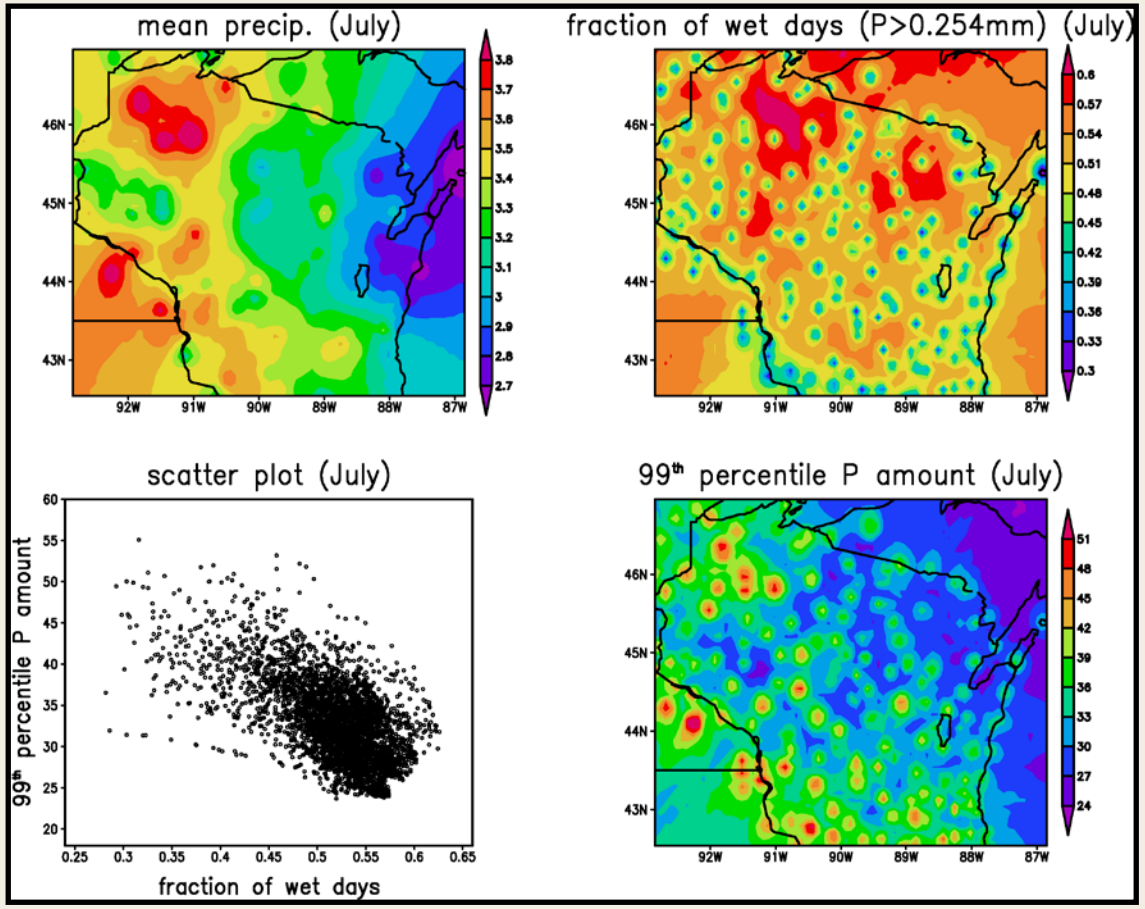
Global to Regional Projections

Problem: Climate models have coarse spatial resolution.

Downscaling: Focus global projections to a scale relevant to climate impacts.



Example: Deterministic Downscaling



Methodology Matters

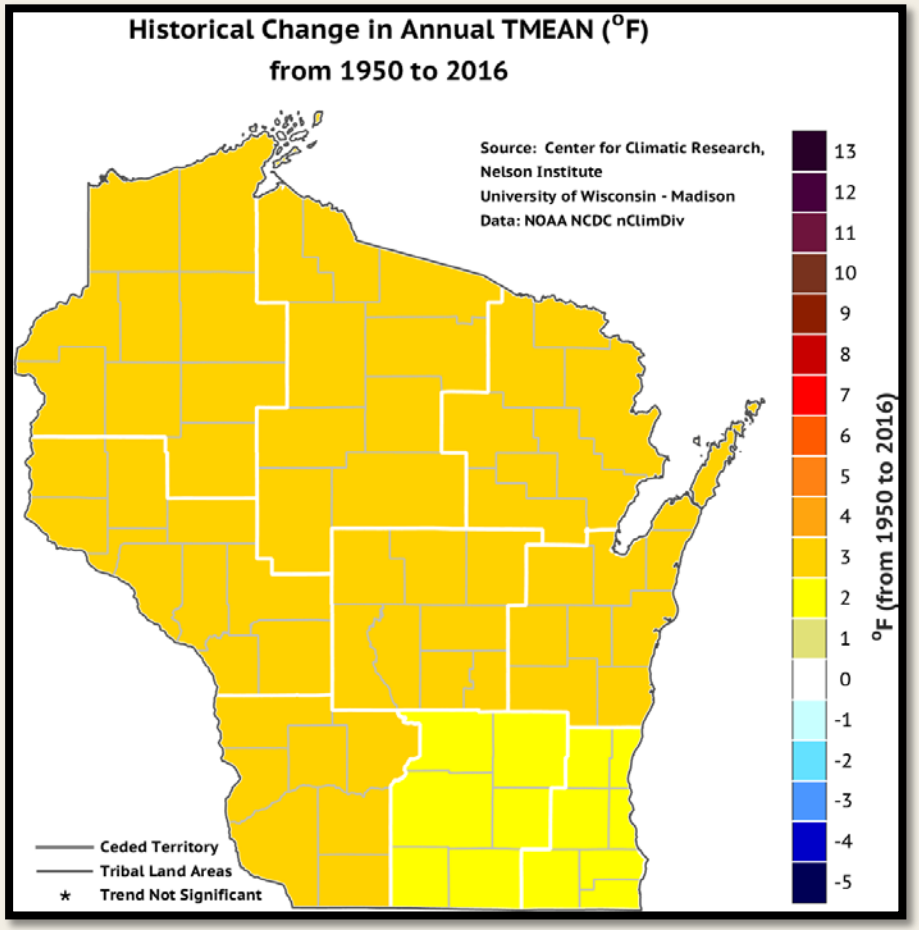
Problem:

- Standard regression-based statistical techniques tend to mute extremes
- Dynamical downscaling limits characterization of uncertainty

Solution:

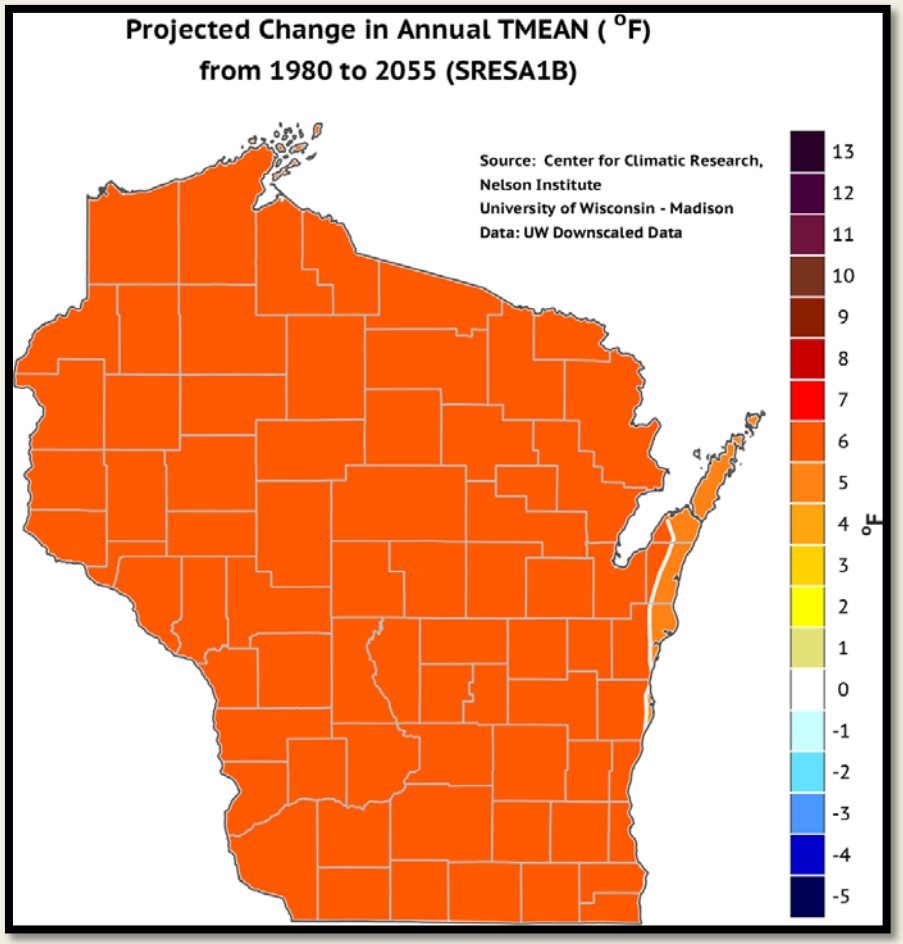
Probabilistic Downscaling

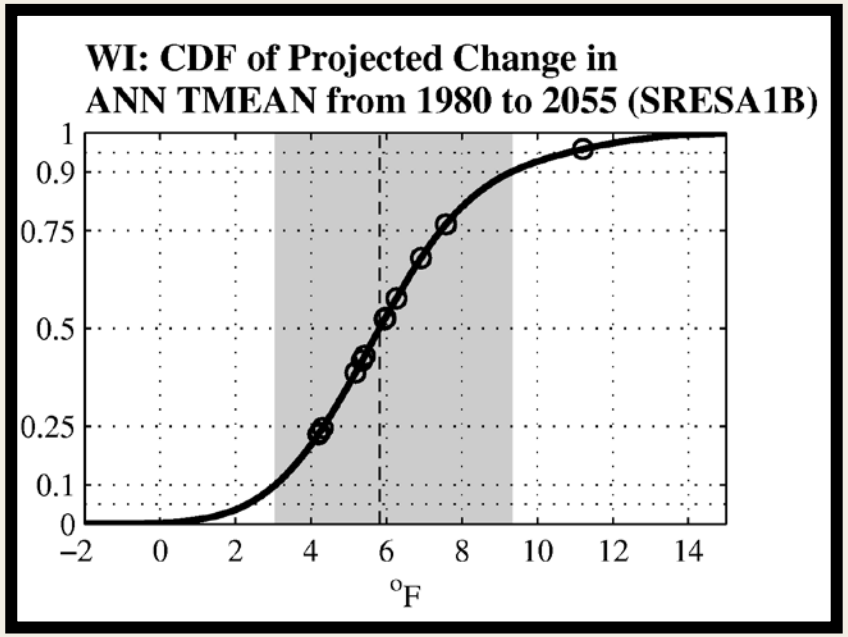
Average Temperature Change



Wisconsin has warmed by about 2°– 3°F since the mid 20th Century

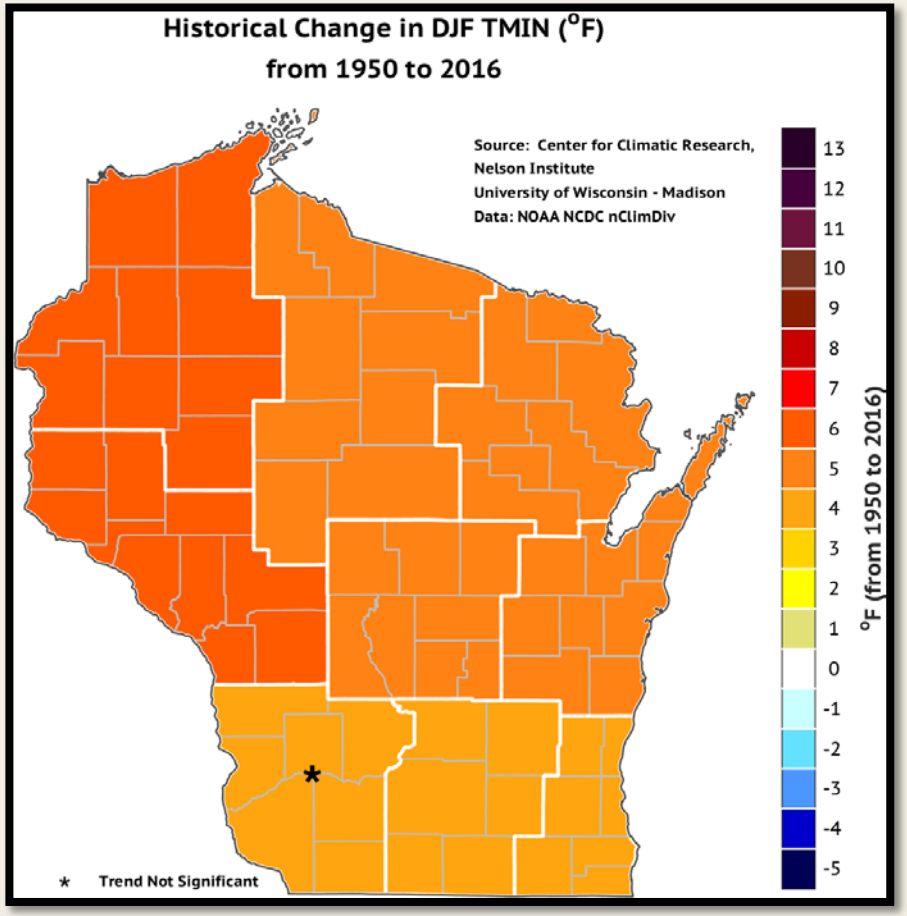
Annual Temperature in Wisconsin

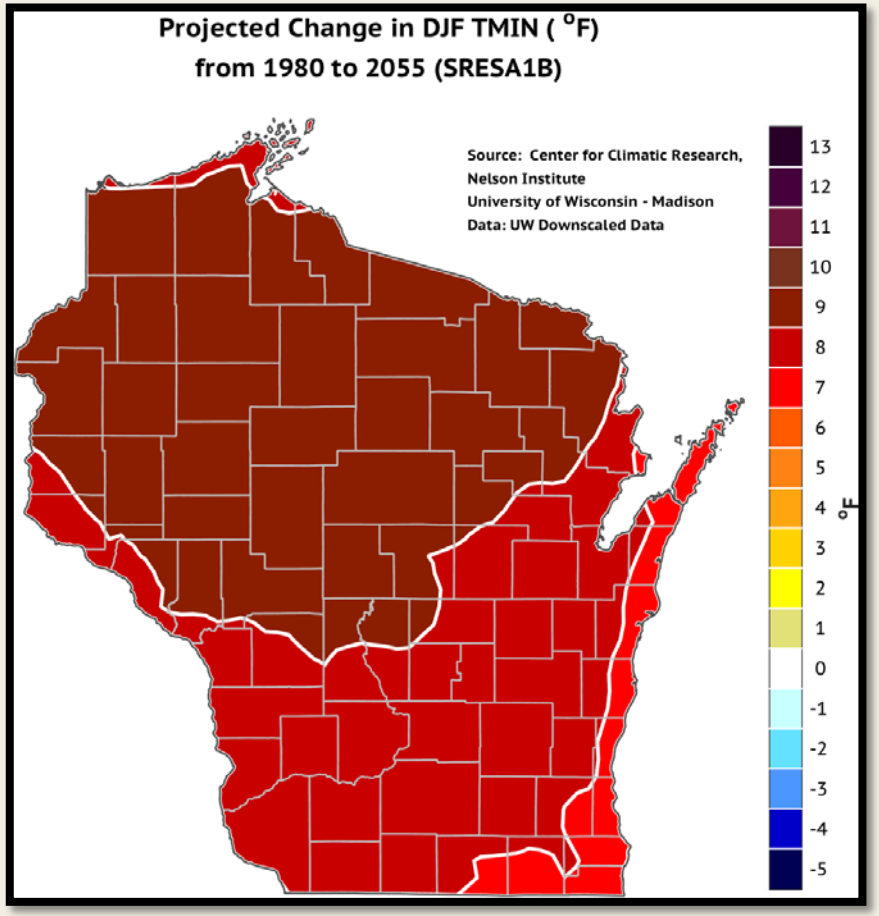




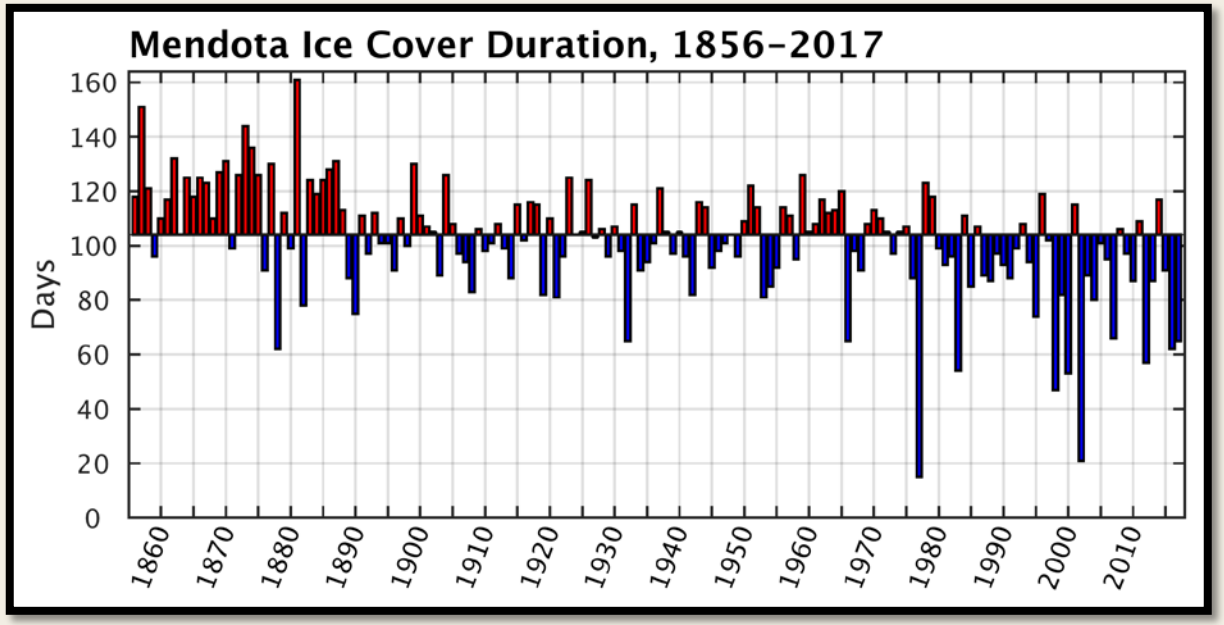
Wisconsin is expected to warm by 3°– 9°F by mid-21st century

Winter Temperature in Wisconsin



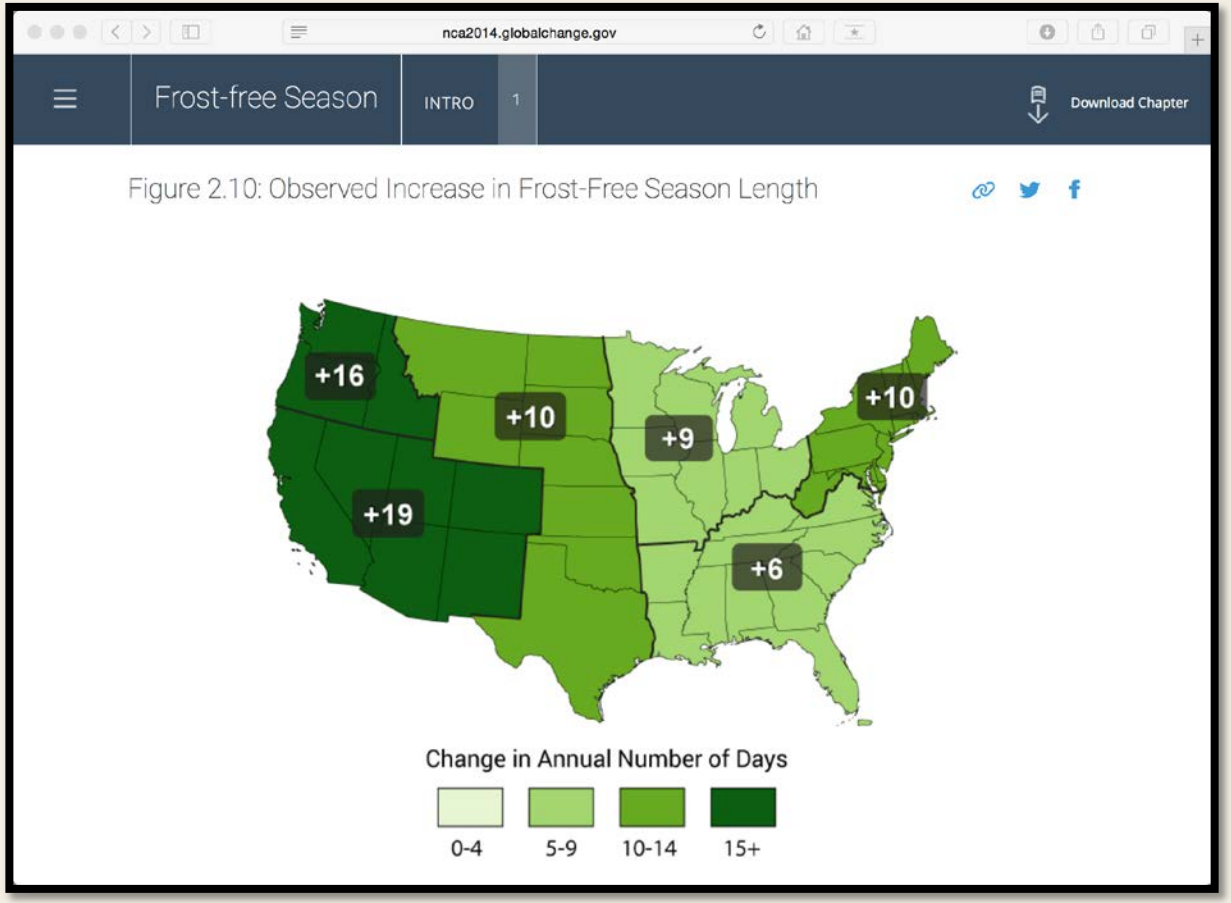


Winter Warming: What does it mean?



Warmer Winters → Shorter Ice Duration

Observed Change



The winter season is getting shorter.

Benefits: Longer growing season for Ag and forestry, less heating costs

Costs: Reduced winter tourism, invasive species, nutrient requirements increase for forests, habitat changes

Winter Warming: What does it mean?

Warmer Winters ⇒
Shorter snow season

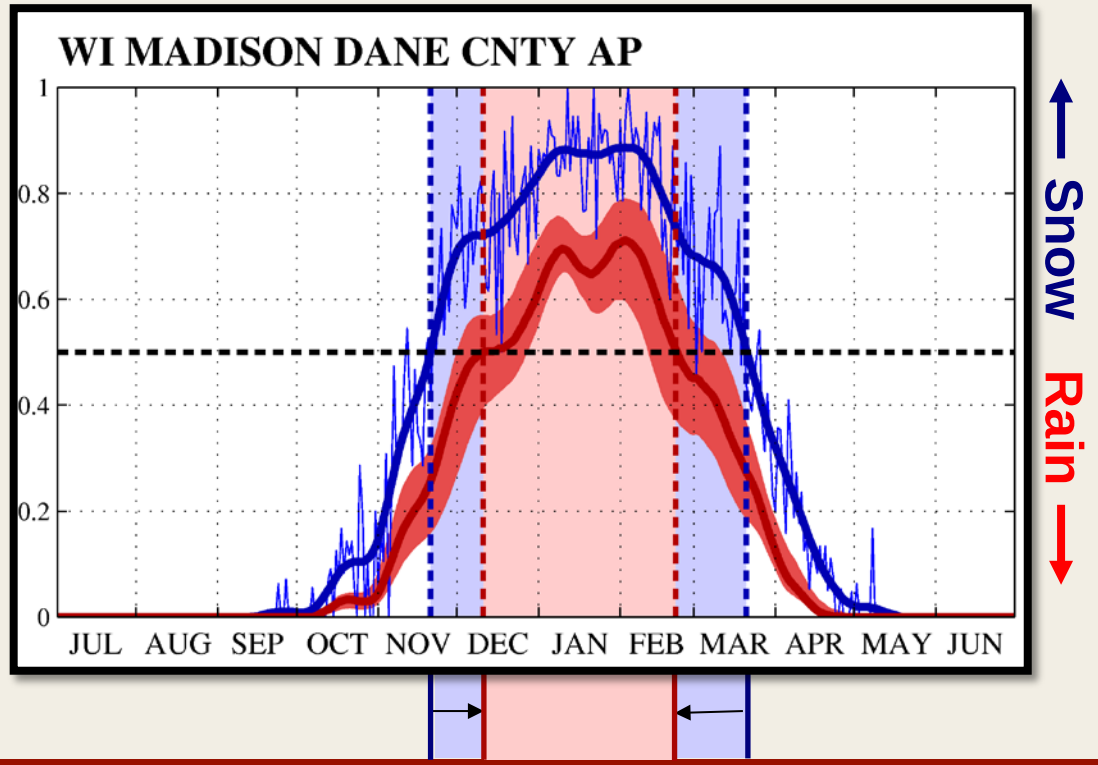
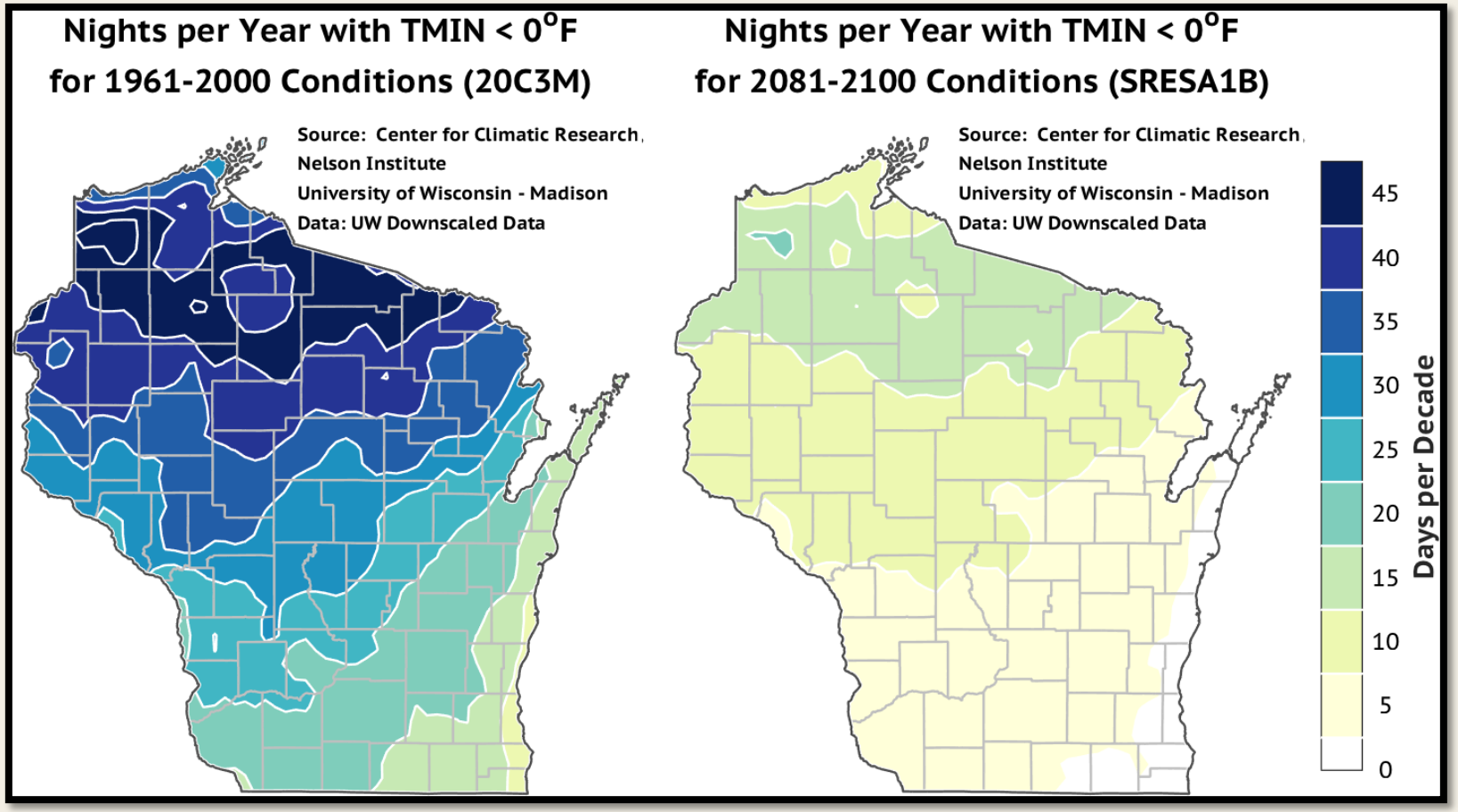


Image: Dane County Parks

Winter Warming



NOTE: WRONG PLOT –
This is for late century

Fewer extremely cold nights

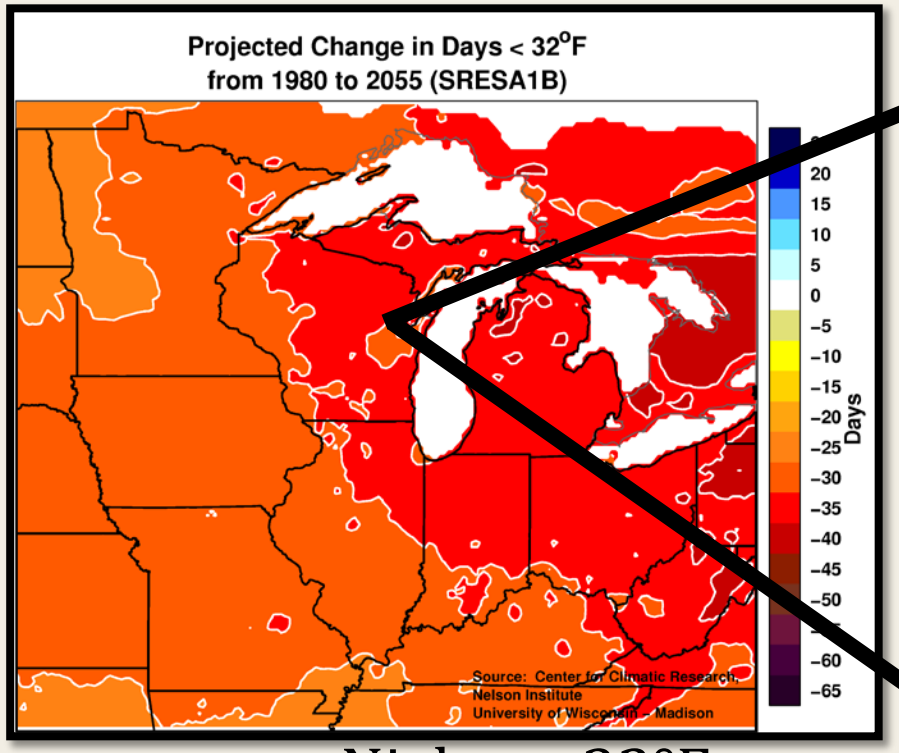
Winter Warming: What does it mean?

Changes in winter conditions impact forest management in north temperate forests

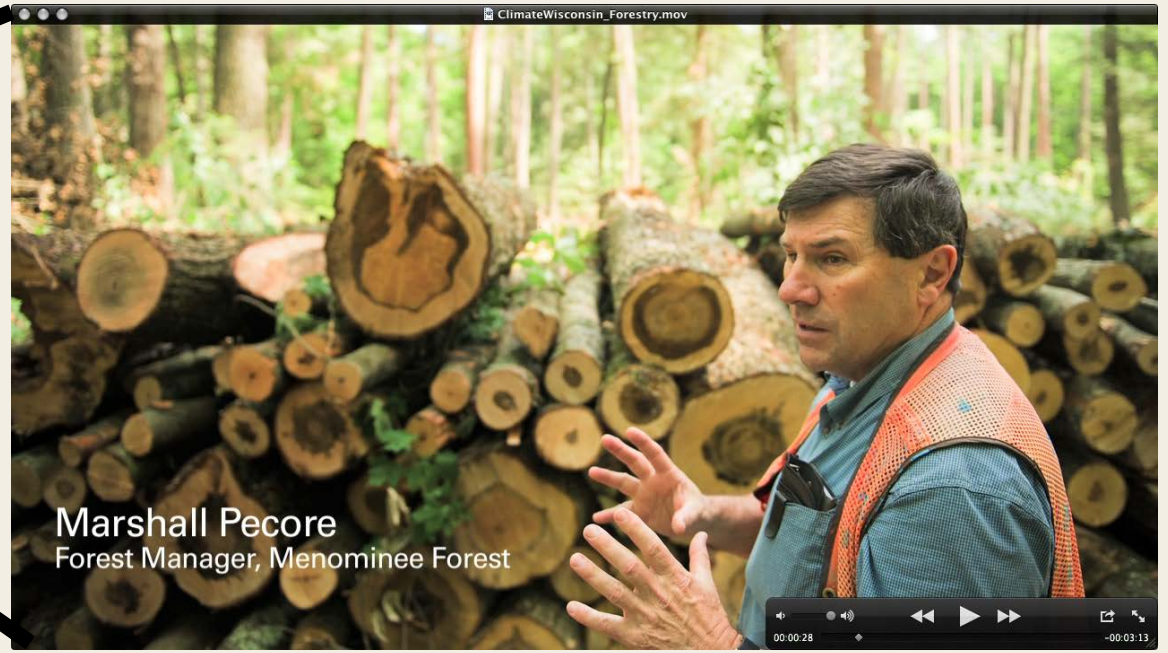
Chadwick D. Rittenhouse [a, b, *], Adena R. Rissman [a]

[a] Department of Forest and Wildlife Ecology, University of Wisconsin–Madison, 1630 Linden Drive, Madison, WI 53706, USA
[b] Wildlife and Fisheries Conservation Center, Department of Natural Resources and the Environment, University of Connecticut, 1376 Storrs Road Unit 4087, Storrs, CT 06269-4087, USA

Winter Warming: What does it mean?



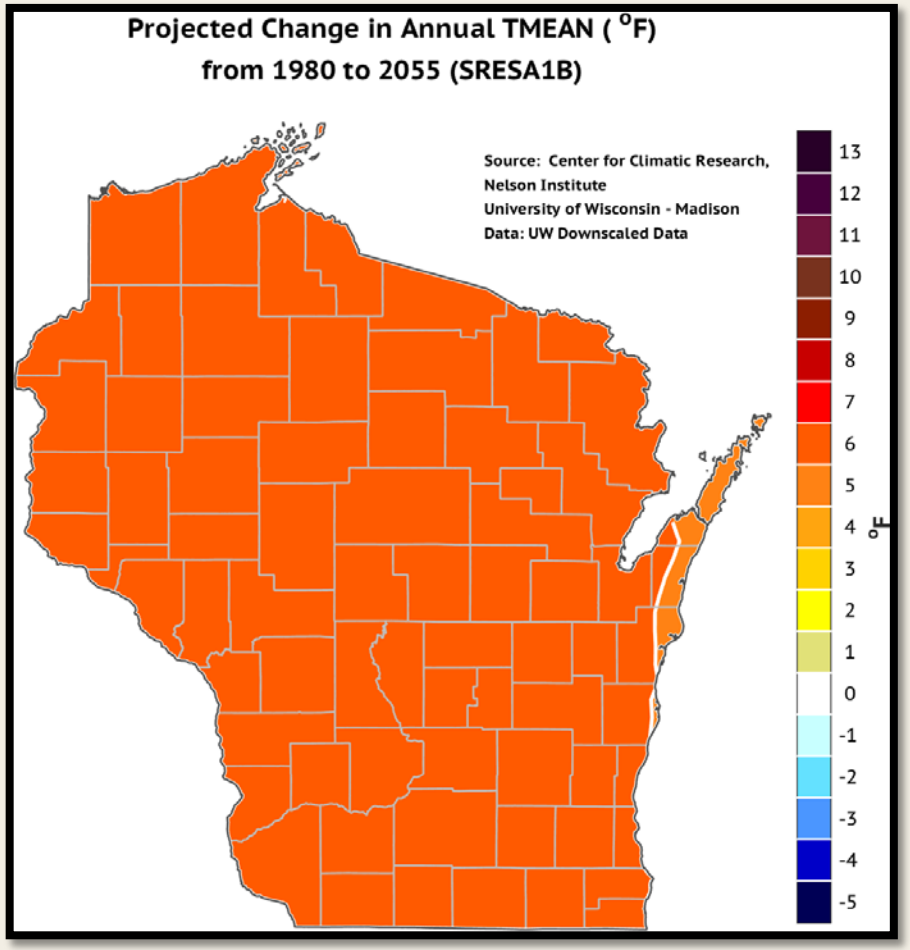
Nights < 32°F

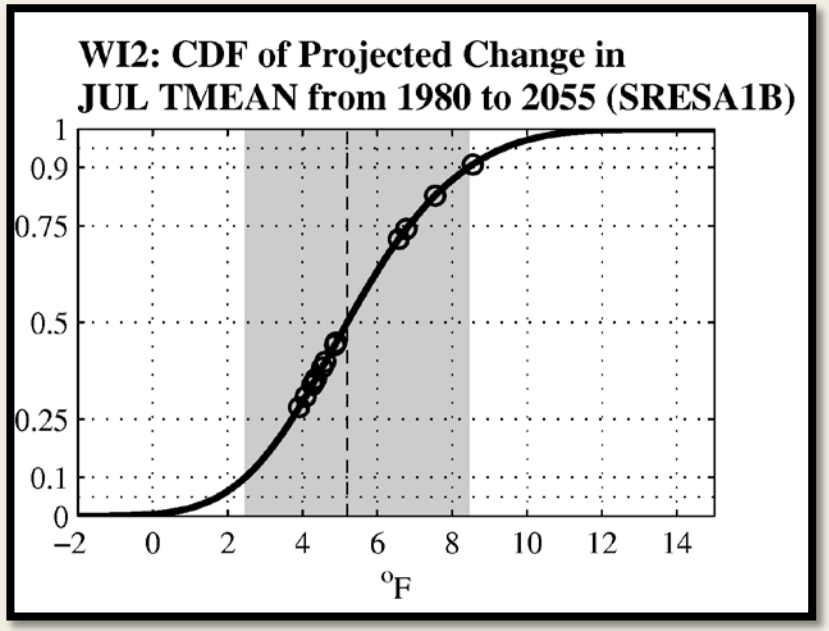


Source: http://climatewisconsin.org

Fewer cold / extremely cold nights

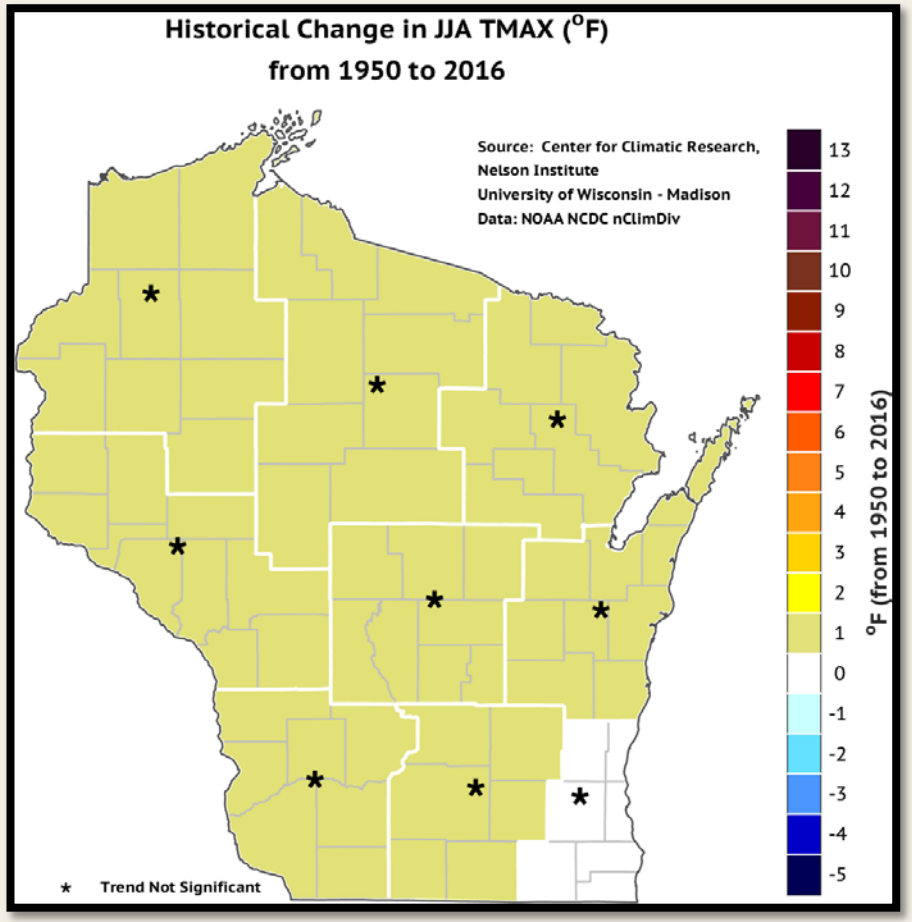
Summer Temperature in Wisconsin

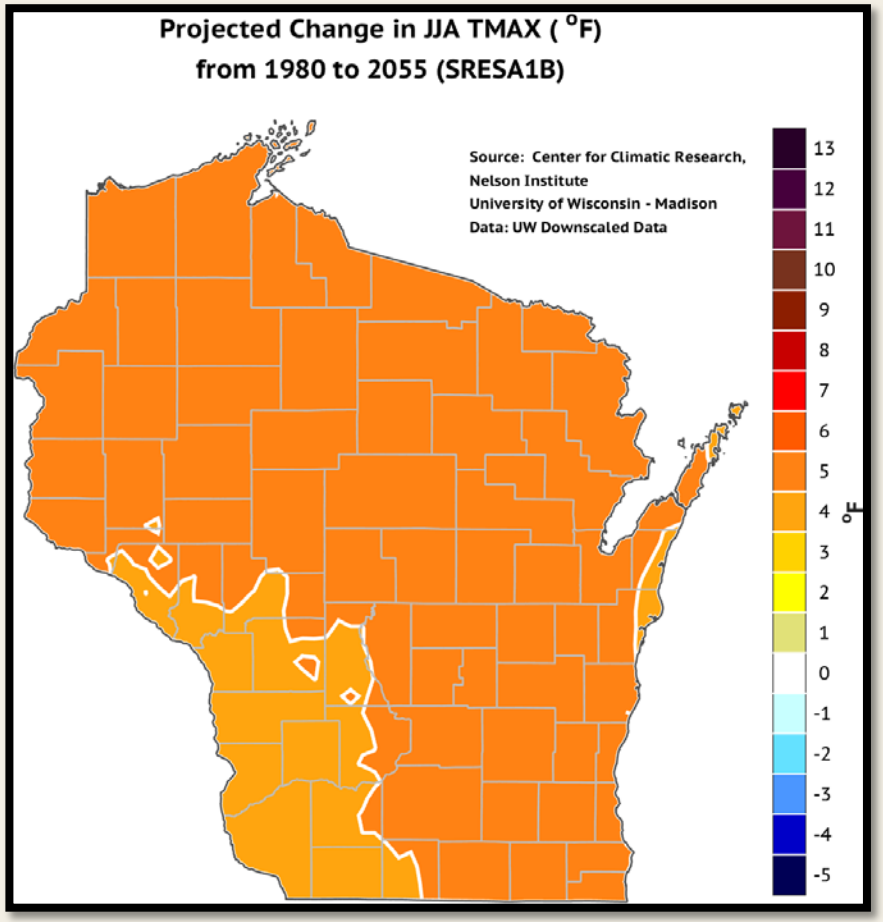




Wisconsin summers warm by 2°– 8°F by mid-21st century

Summer Temperature in Wisconsin



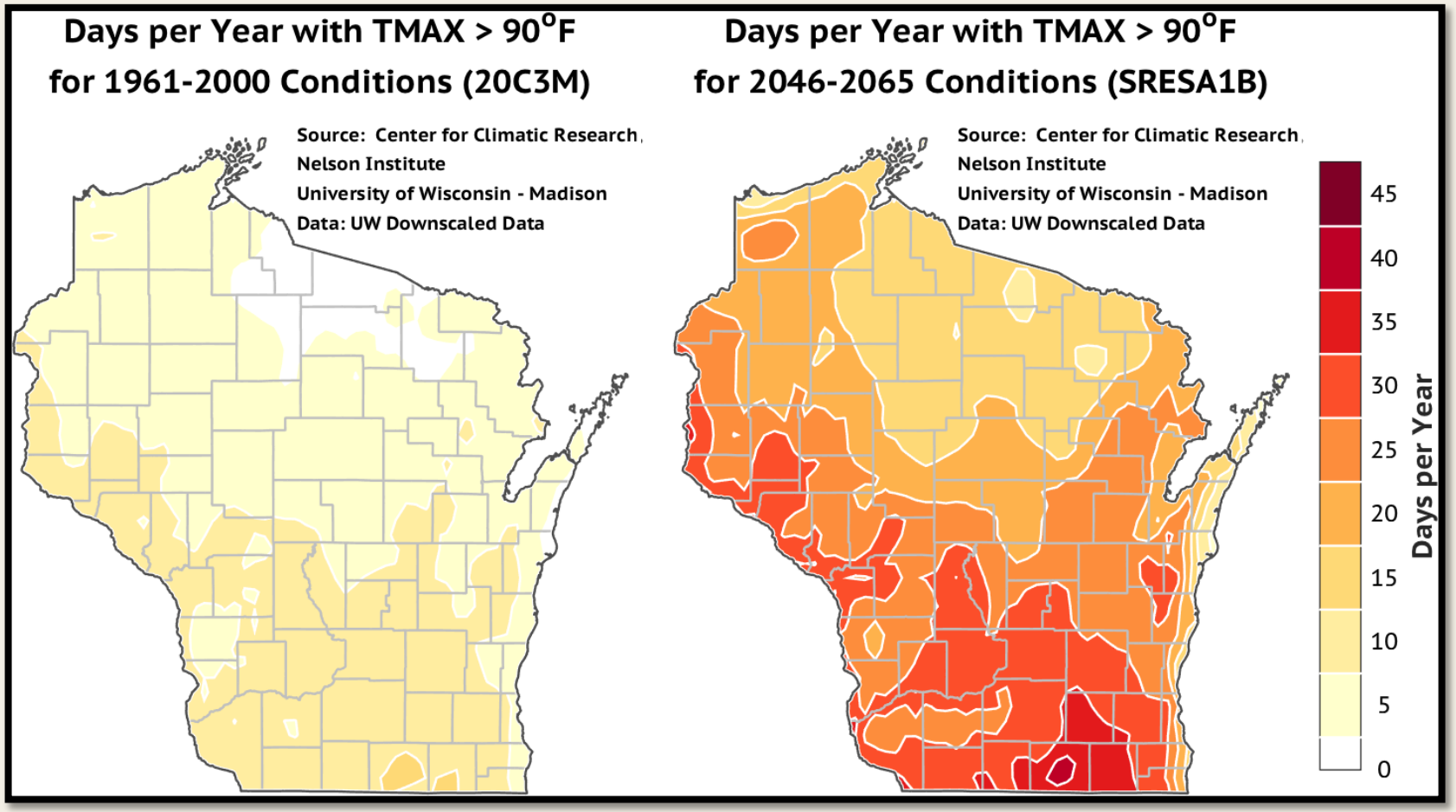


Summer Stream Temperatures

Photo: Matt Mitro

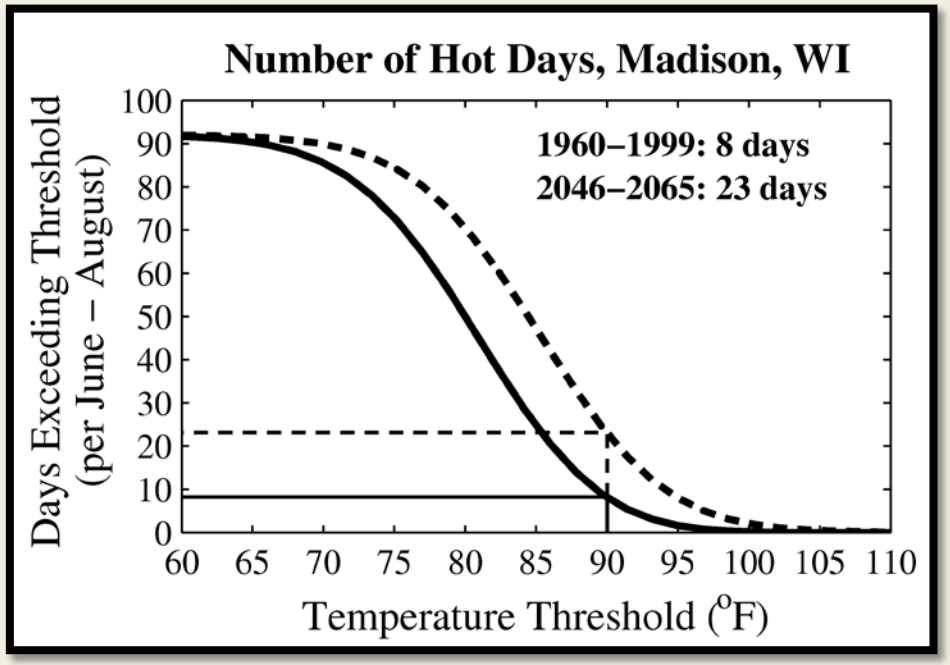
Warmer Summers → Reduced brook trout habitat

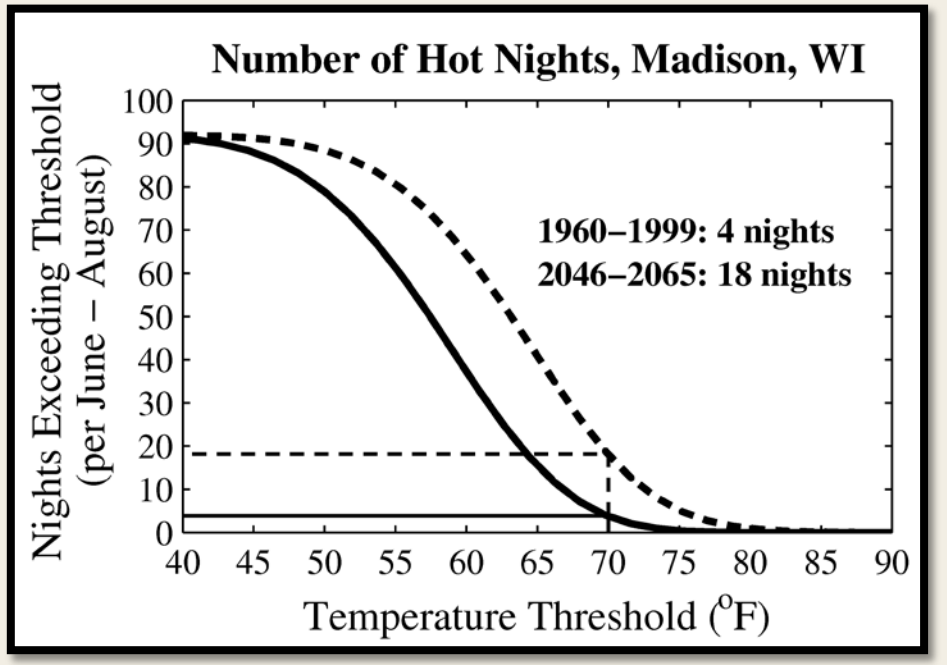
Summer Warming: What does it mean?



More "very hot" days

Extreme Heat in Wisconsin



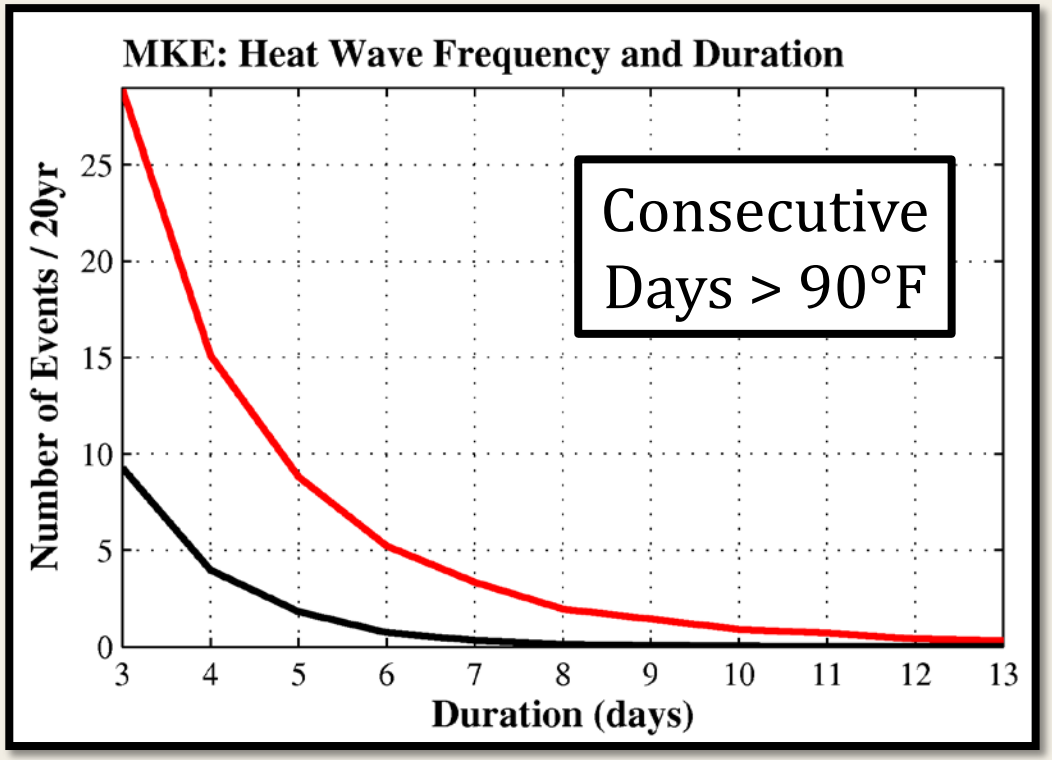


Days with extreme heat triple by mid-century

Extreme Heat: Multi-day heat waves

Heat waves: 3 to 5 times more frequent

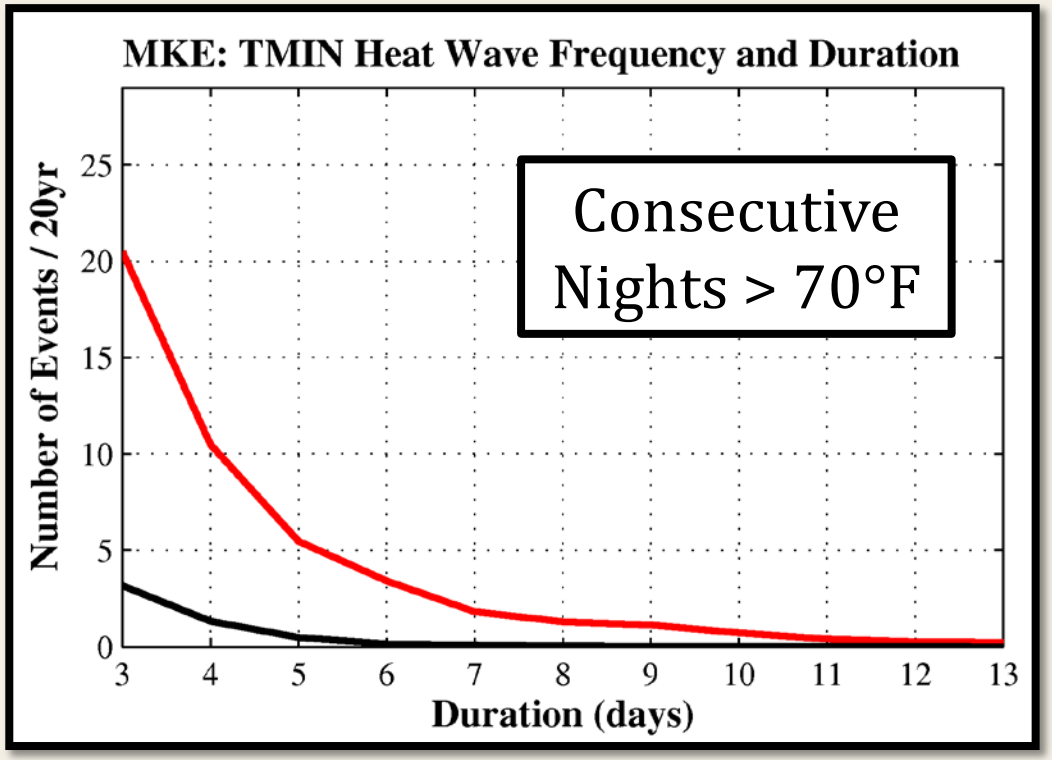
Increased Heat Wave Duration and Frequency



Extreme Heat: Multi-night heat waves

Nighttime Heat Waves:
5 times more frequent

Increased Heat Wave Duration and Frequency



“Dangerous” Heat

NOAA's National Weather Service

Heat Index

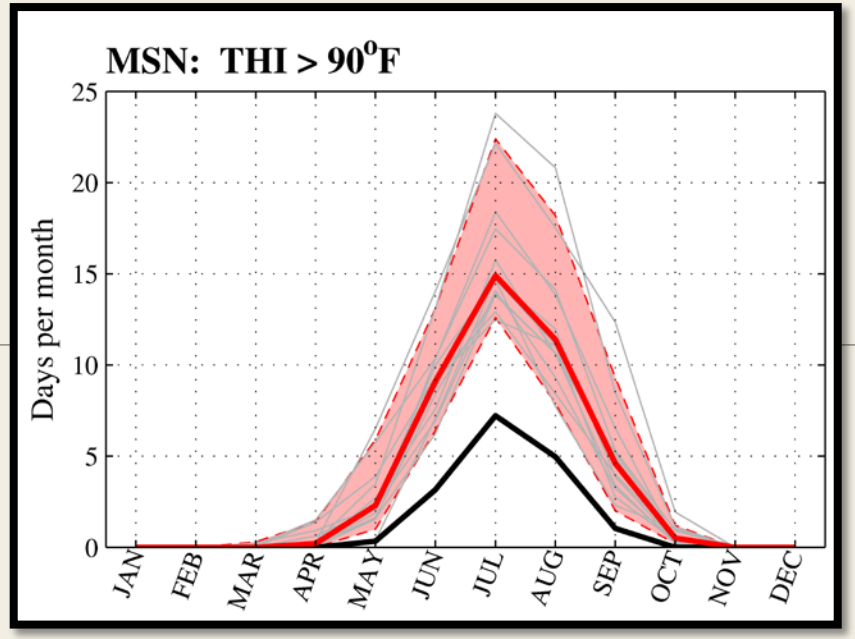
Temperature (°F)

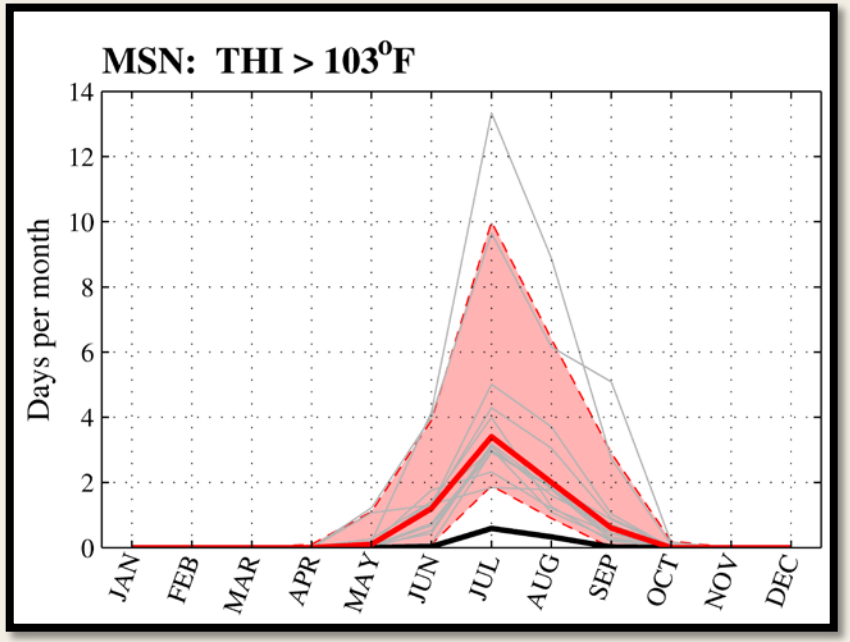
Relative Humidity (%)	80	82	84	86	88	90	92	94	96	98	100	102	104	106	108	110
40	80	81	83	85	88	91	94	97	101	105	109	114	119	124	130	136
45	80	82	84	87	89	93	96	100	104	109	114	119	124	130	137	
50	81	83	85	88	91	95	99	103	108	113	118	124	131	137		
55	81	84	86	89	93	97	101	106	112	117	124	130	137			
60	82	84	88	91	95	100	105	110	116	123	129	137				
65	82	85	89	93	98	103	108	114	121	128	136					
70	83	86	90	95	100	105	112	119	126	134						
75	84	88	92	97	103	109	116	124	132							
80	84	89	94	100	106	113	121	129								
85	85	90	96	102	110	117	126	135								
90	86	91	98	105	113	122	131									
95	86	93	100	108	117	127										
100	87	95	103	112	121	132										

Likelihood of Heat Disorders with Prolonged Exposure or Strenuous Activity

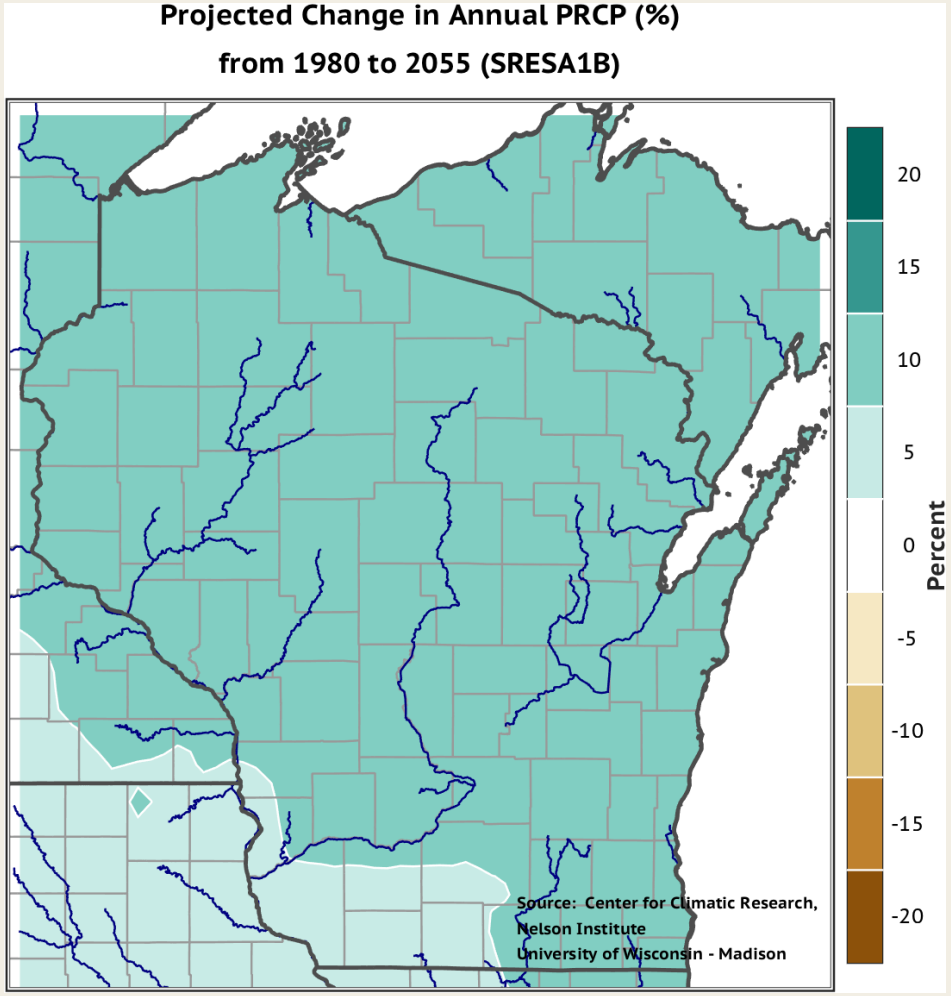
Caution | Extreme Caution | Danger | Extreme Danger

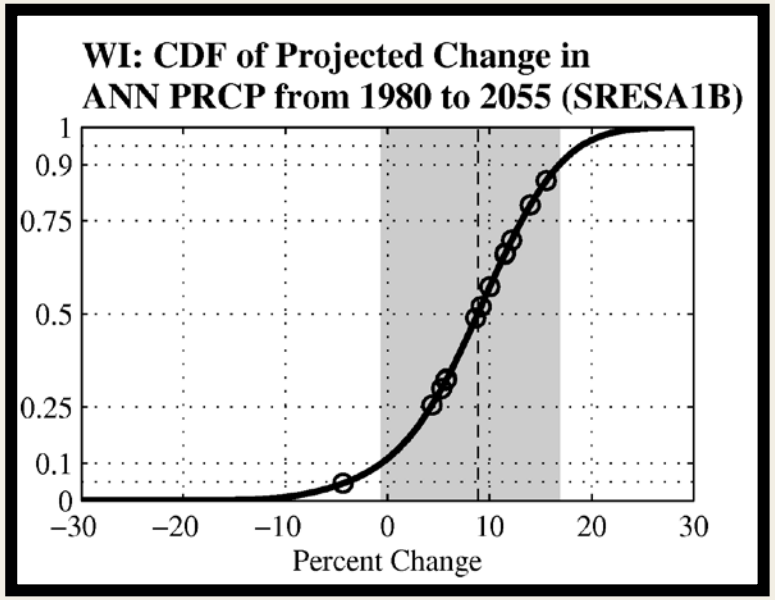
By mid-century, “Danger” heat index becomes a regular occurrence





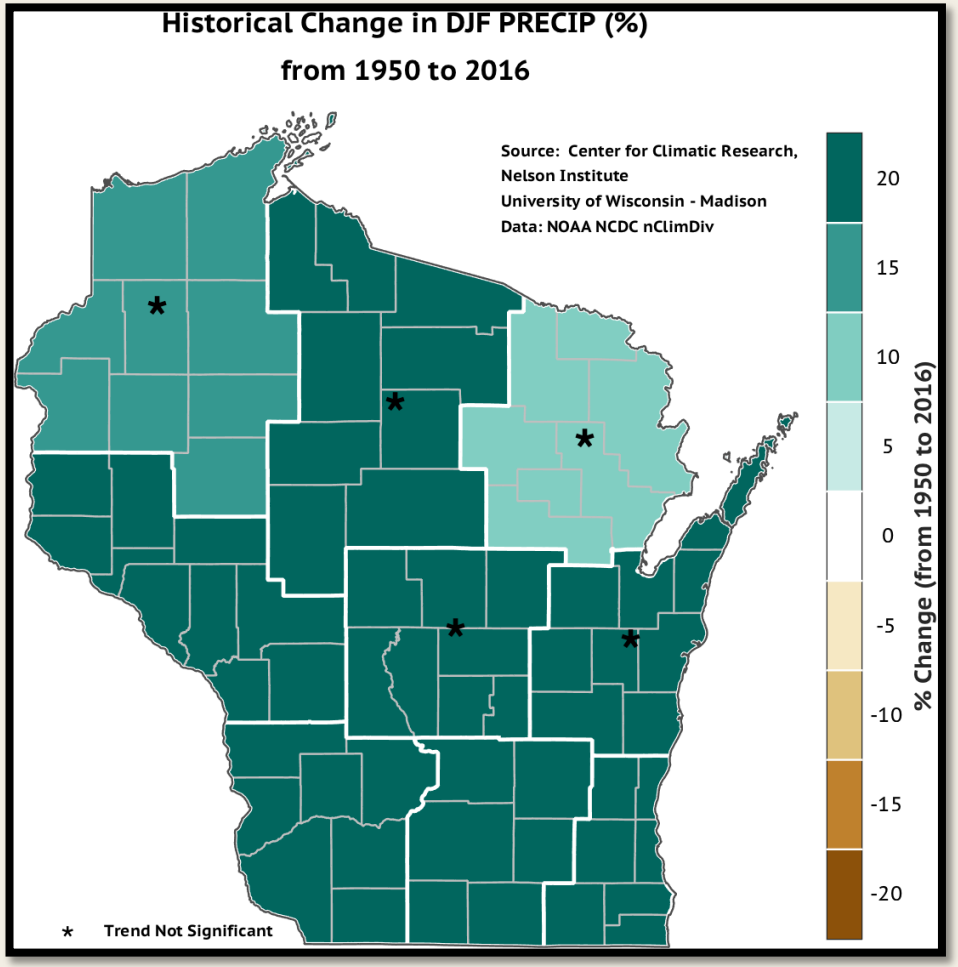
Annual Precipitation Change

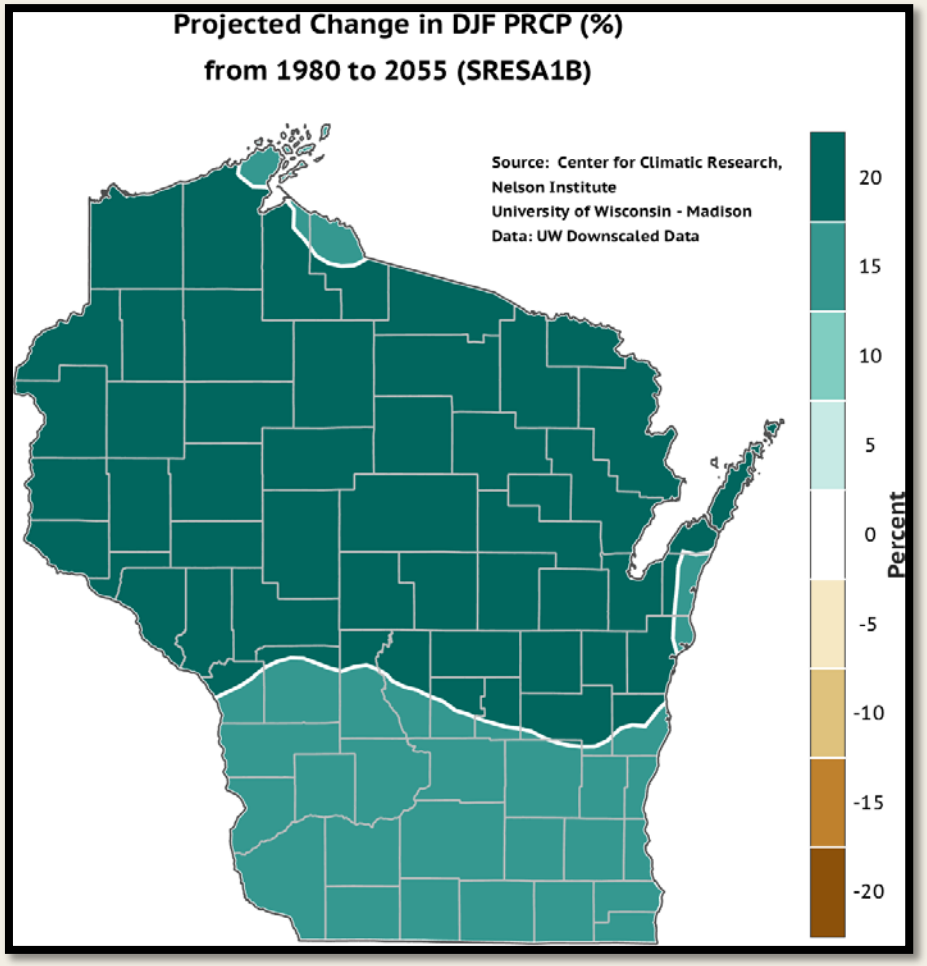




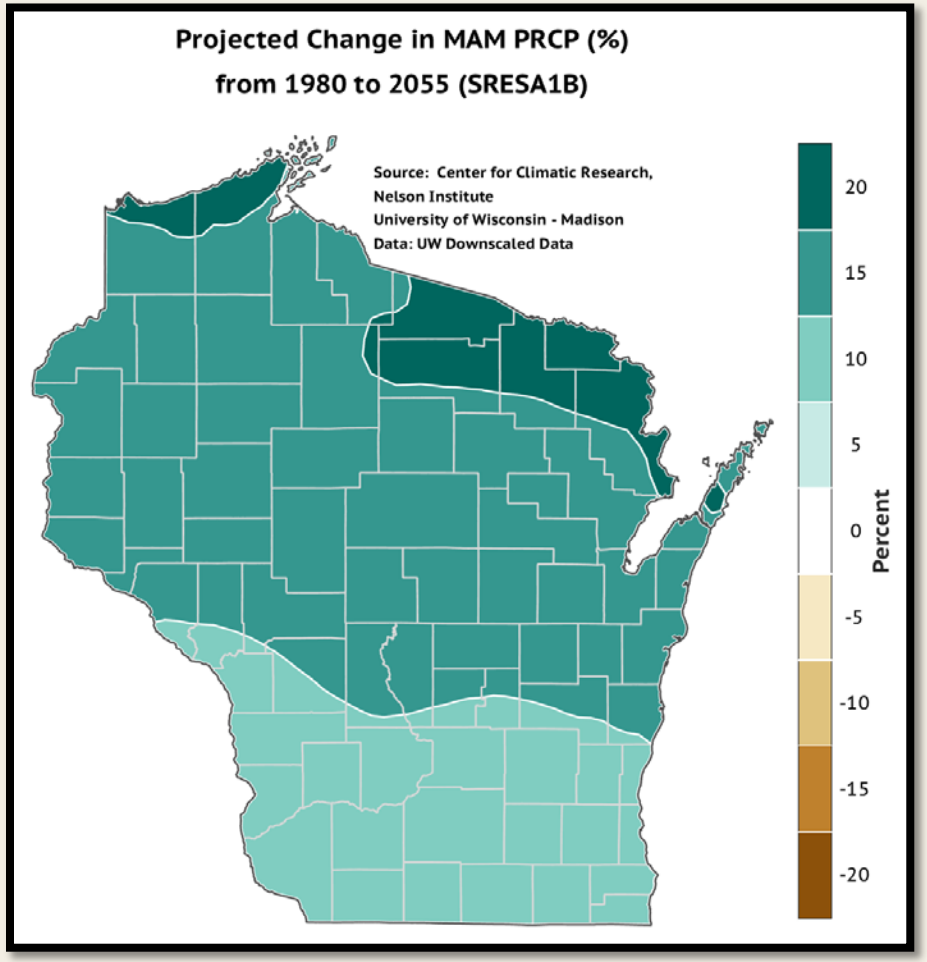
Wisconsin will get 0%–15% wetter by mid-21st century

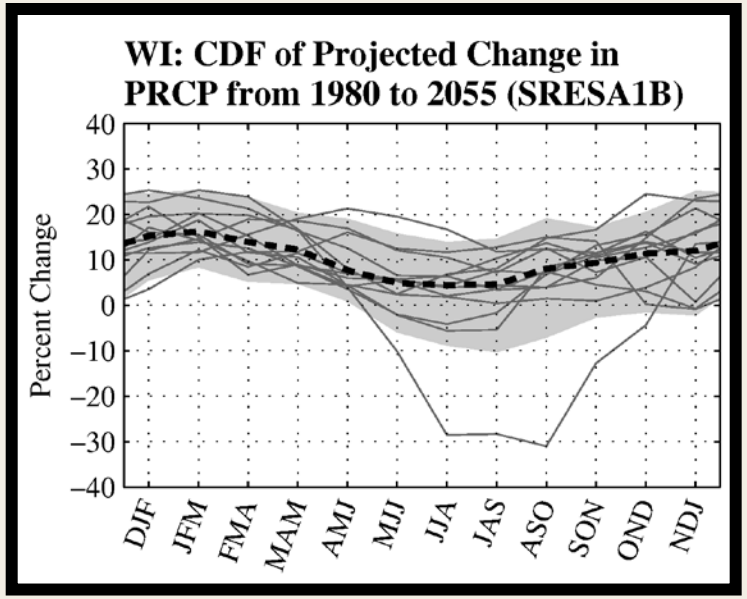
Winter Precipitation Change





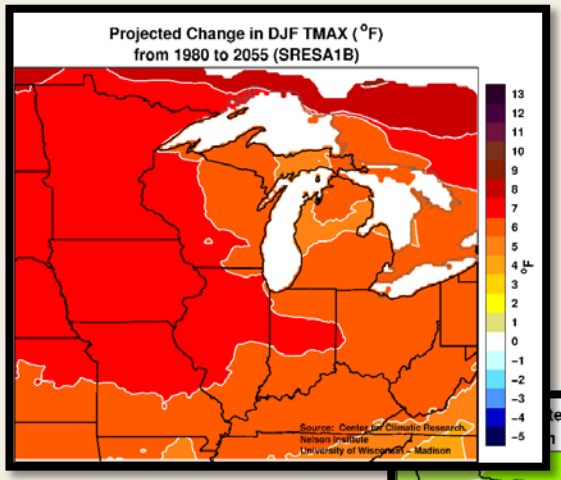
Winter Precipitation Change



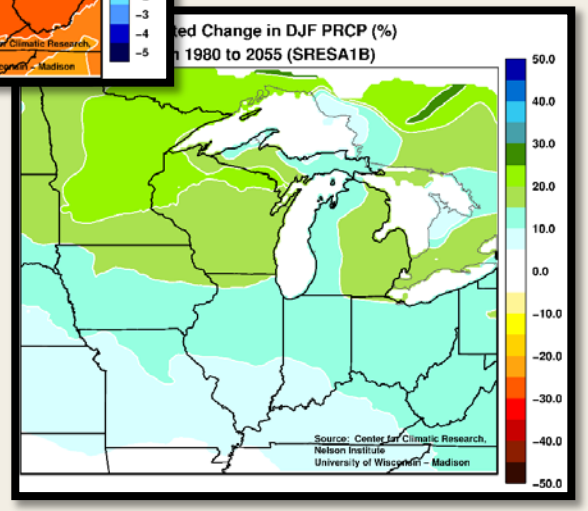


Robust increase in Precipitation during Winter and Spring

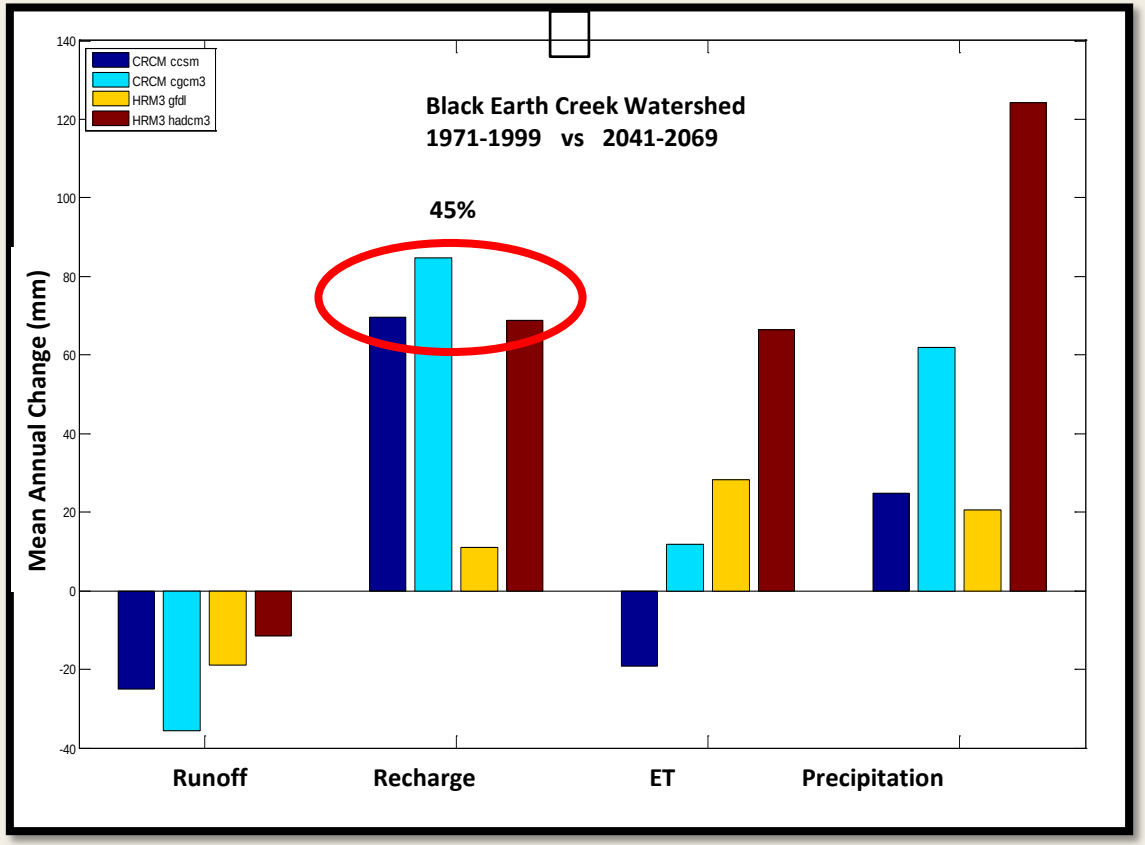
More winter/spring precipitation ➔ *Increased groundwater recharge*



Winter **+6-7°F**



Winter **+20-25%**

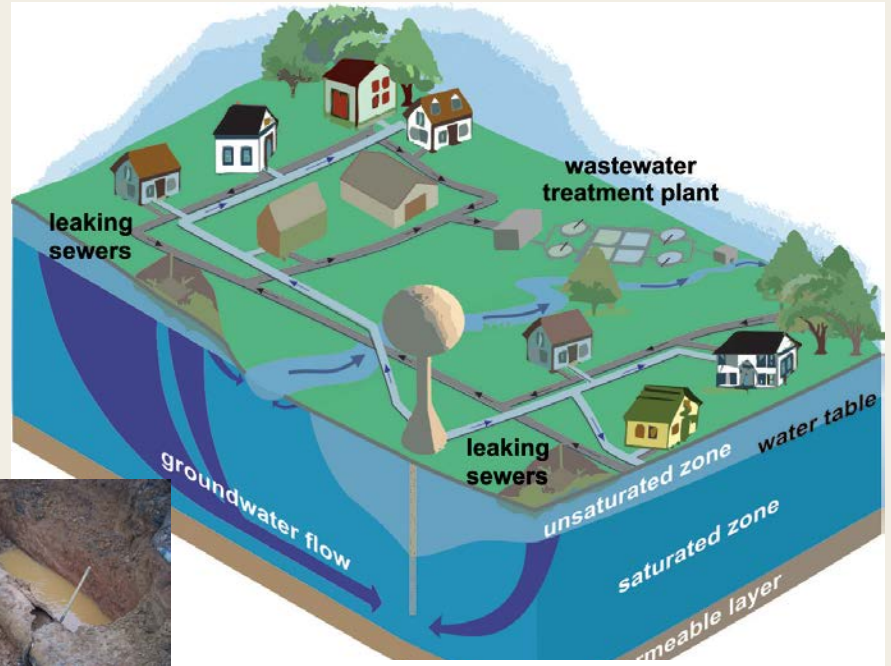


Evan Murdock

Increased recharge ➔ *Groundwater flooding*

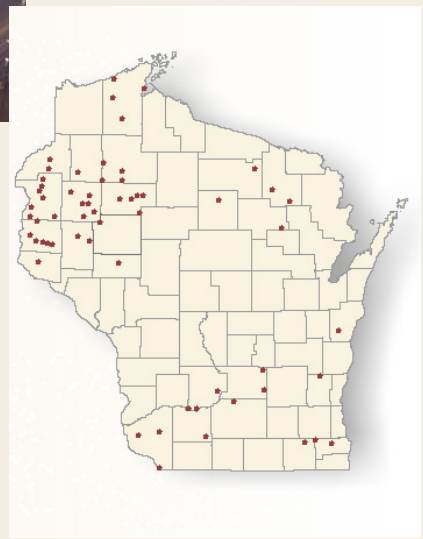
Spring Green - 2008

Rising water table can result in groundwater contamination

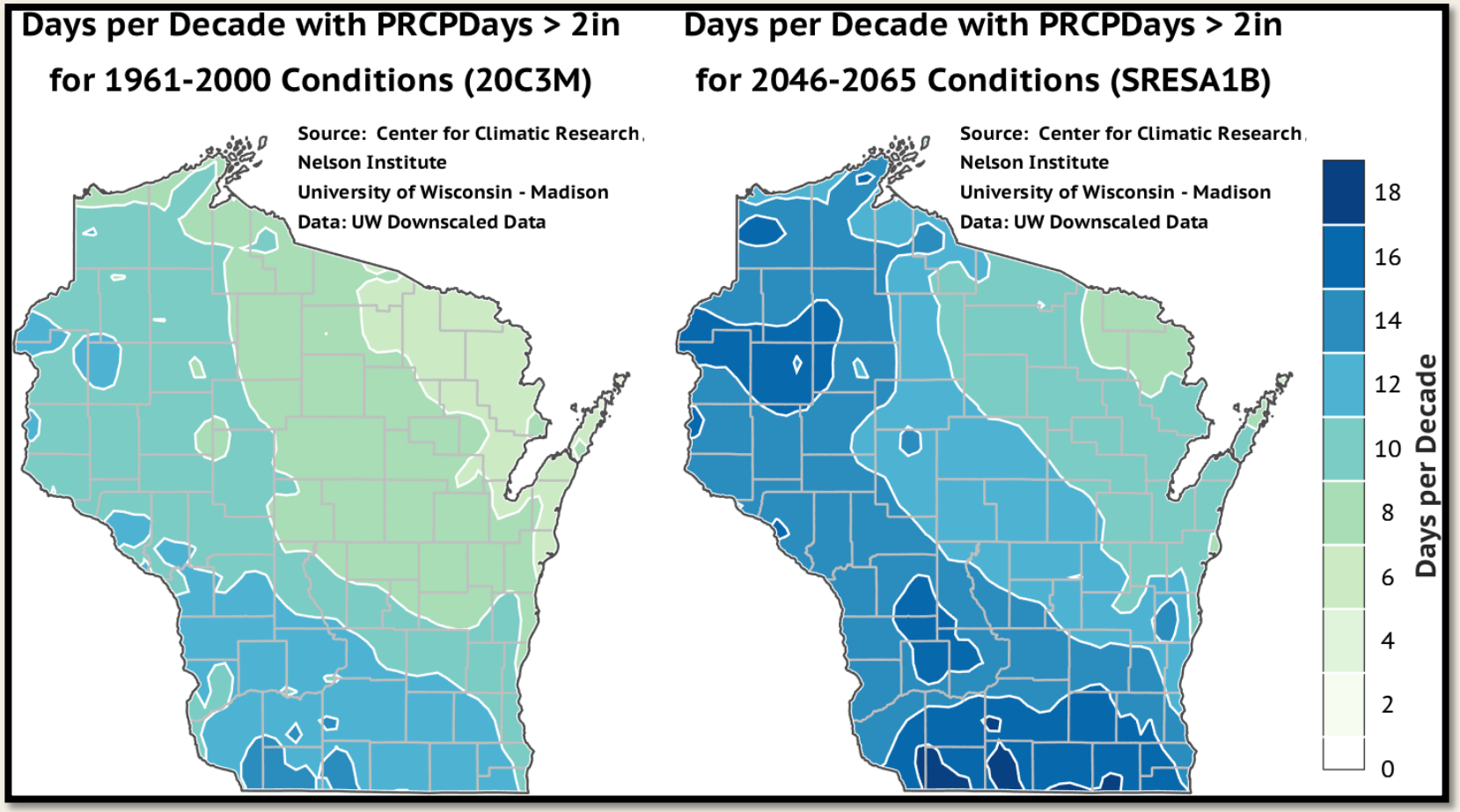


Gotkowitz & Liebl, 2013

Especially in communities that do not disinfect

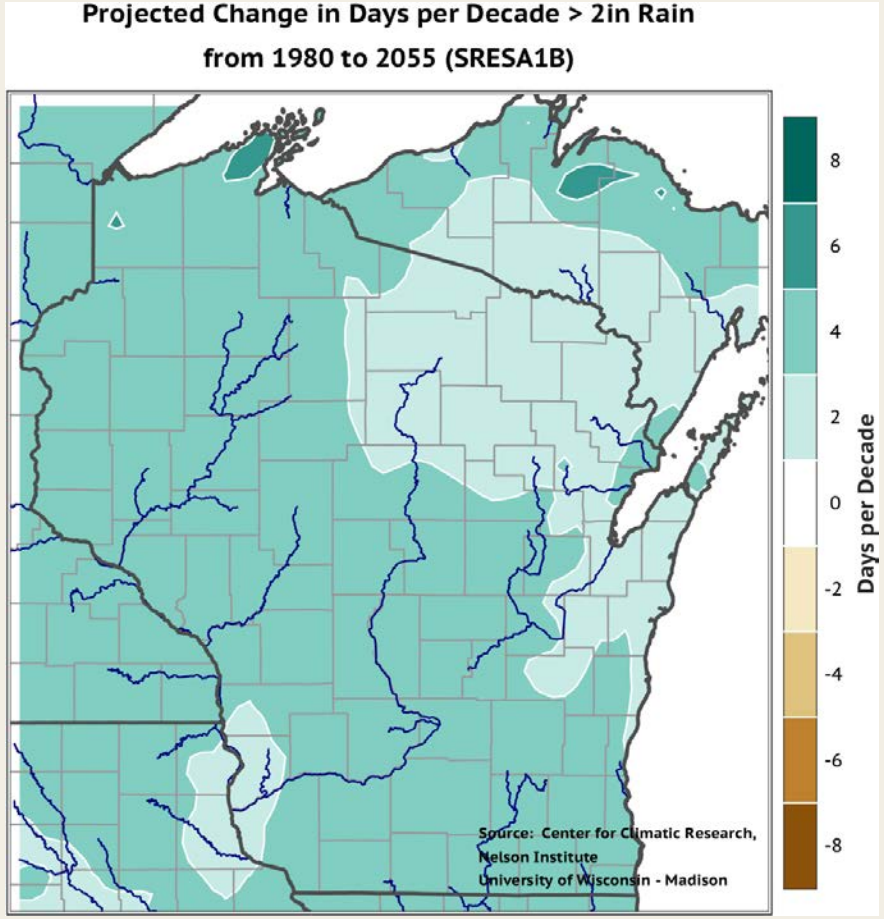


Large / Extreme Rainfall Events



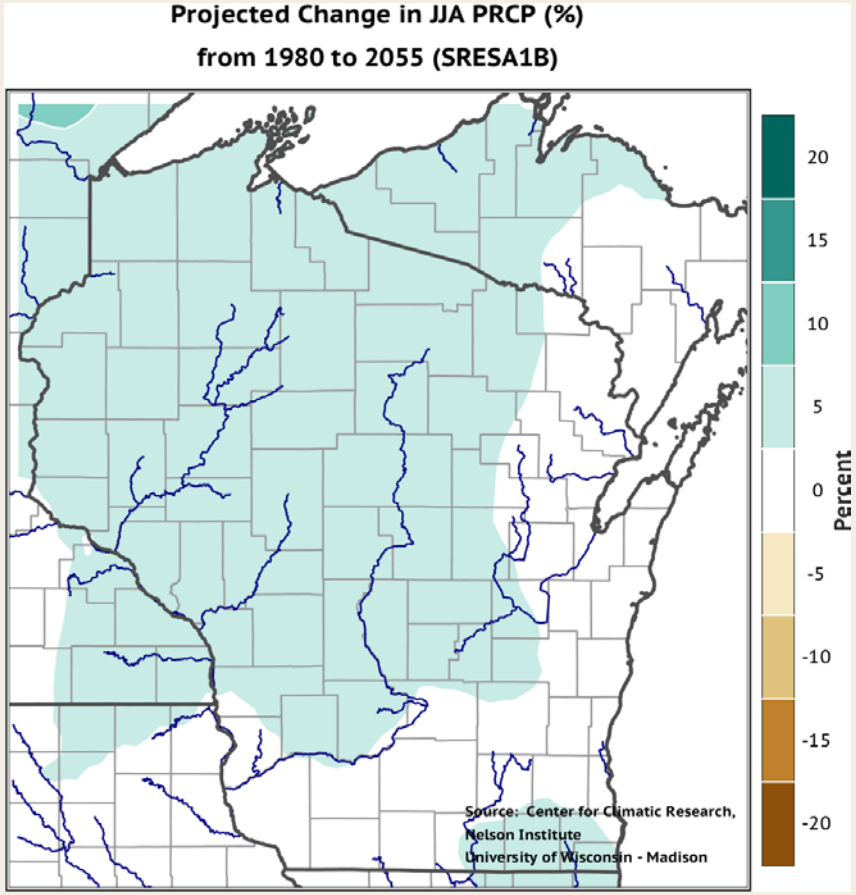
More extreme rainfall, especially during Spring

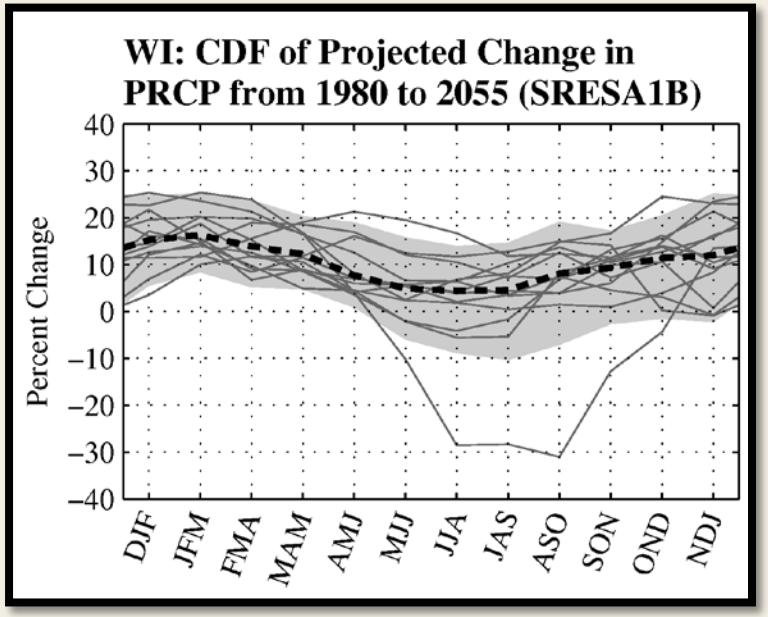
Large / Extreme Rainfall Events



Wisconsin could see a 30% increase in the number of large rainfall events

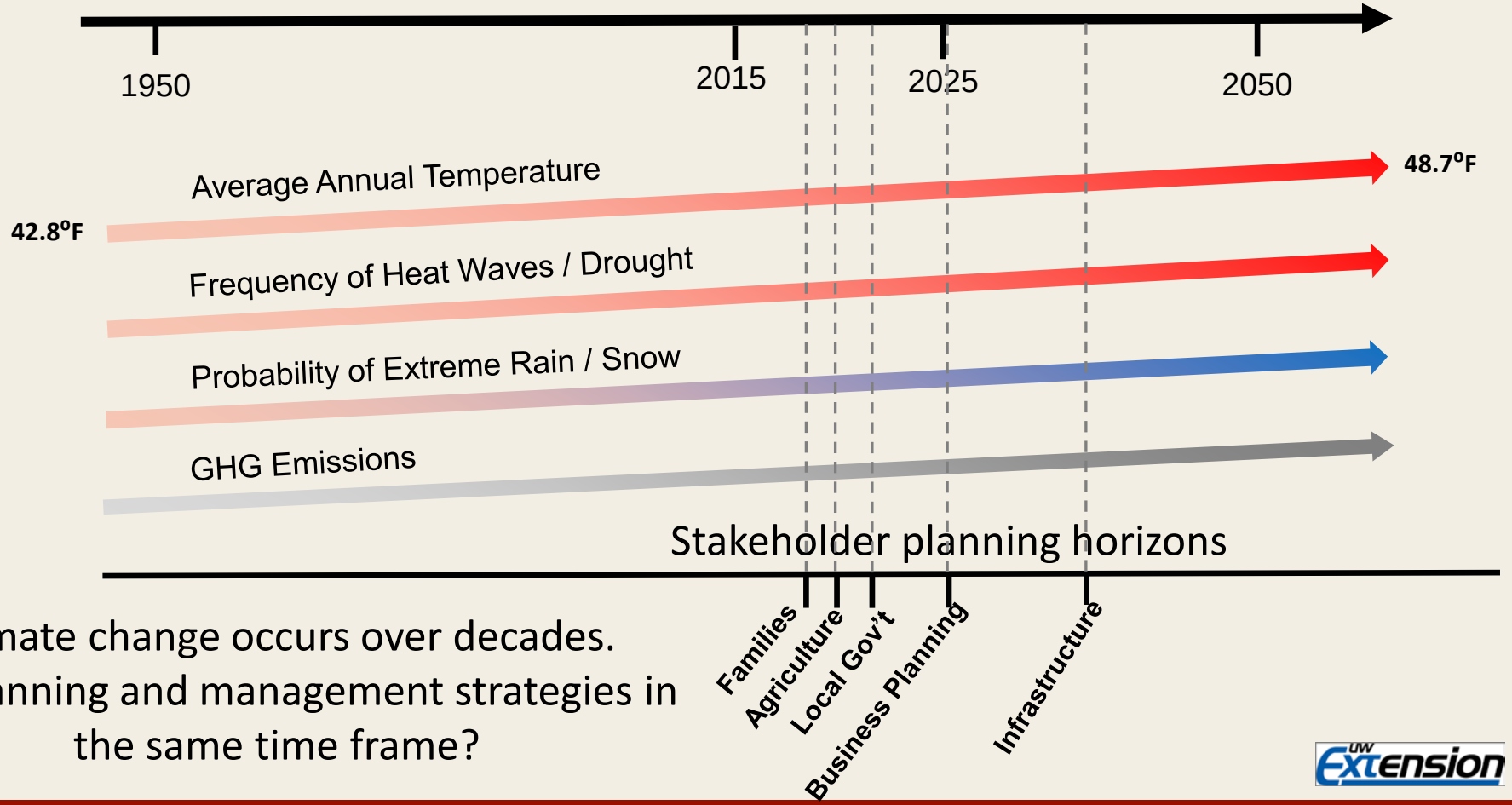
Summer Precipitation: No consensus





No consensus during Summer!

Long Planning Horizons

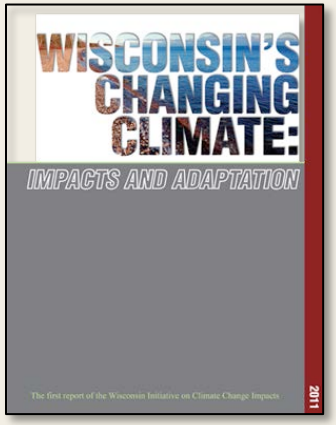


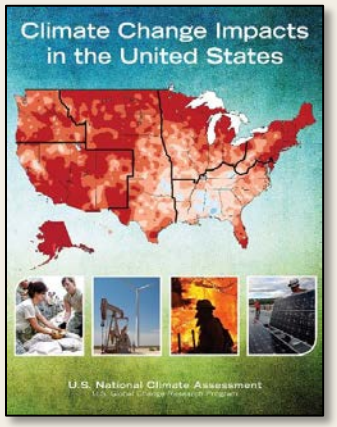
Climate change occurs over decades.
Are planning and management strategies in the same time frame?

SUMMARY

- **Global climate is changing** (a “science” issue)
  - Anthropogenic (human generated) greenhouse gasses are increasing in our atmosphere
  - Temperature is increasing, sea ice and land glaciers are receding, sea level is rising, extreme precipitation events are more common
  - The changing climate is already impacting our natural and built environment, and human health.
- **Adaptation and mitigation are both needed to avoid dangerous impacts** (what we do is a “policy” issue)

Resources:





Wisconsin Initiative on Climate Change Impacts:
http://www.wicci.wisc.edu

Center for Climatic Research Data Pages:
http://nelson.wisc.edu/ccr/resources/visualization-and-tools.php

National Climate Assessment (2014):
http://nca2014.globalchange.gov/

National Academies Climate Change:
http://nas-sites.org/americasclimatechoices/

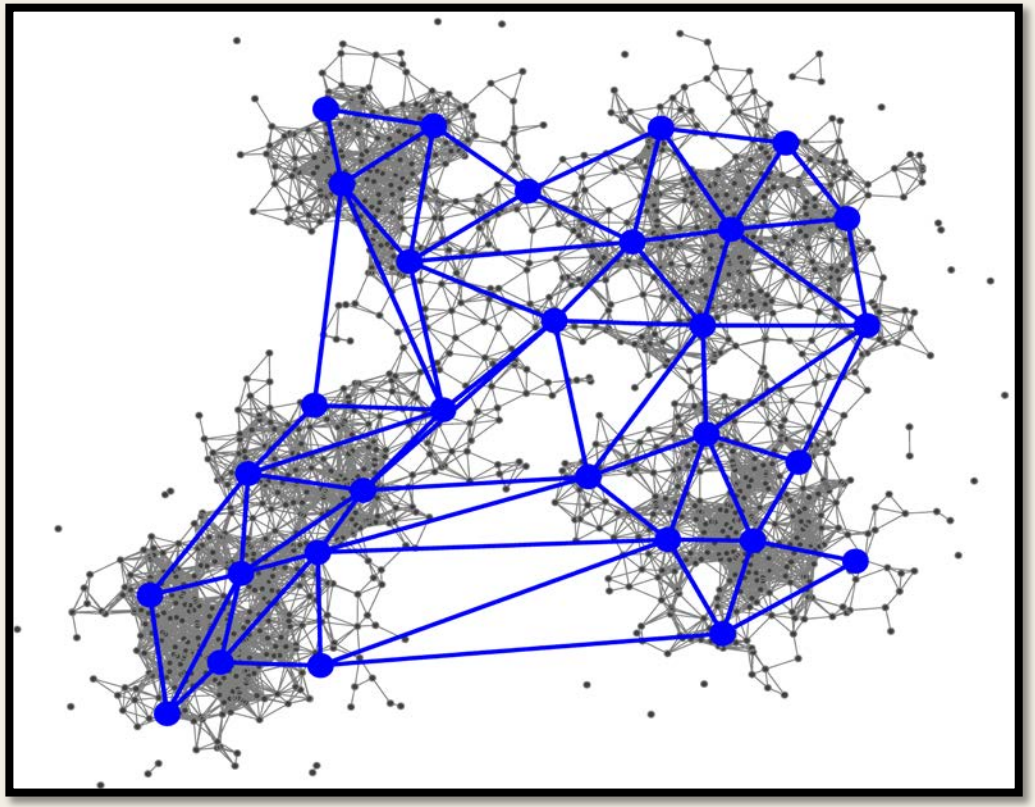
Risky Business: http://riskybusiness.org/

The Wisconsin Initiative on Climate Change Impacts

ENABLING CLIMATE ADAPTATION IN WISCONSIN AND THE UPPER MIDWEST

http://www.wicci.wisc.edu

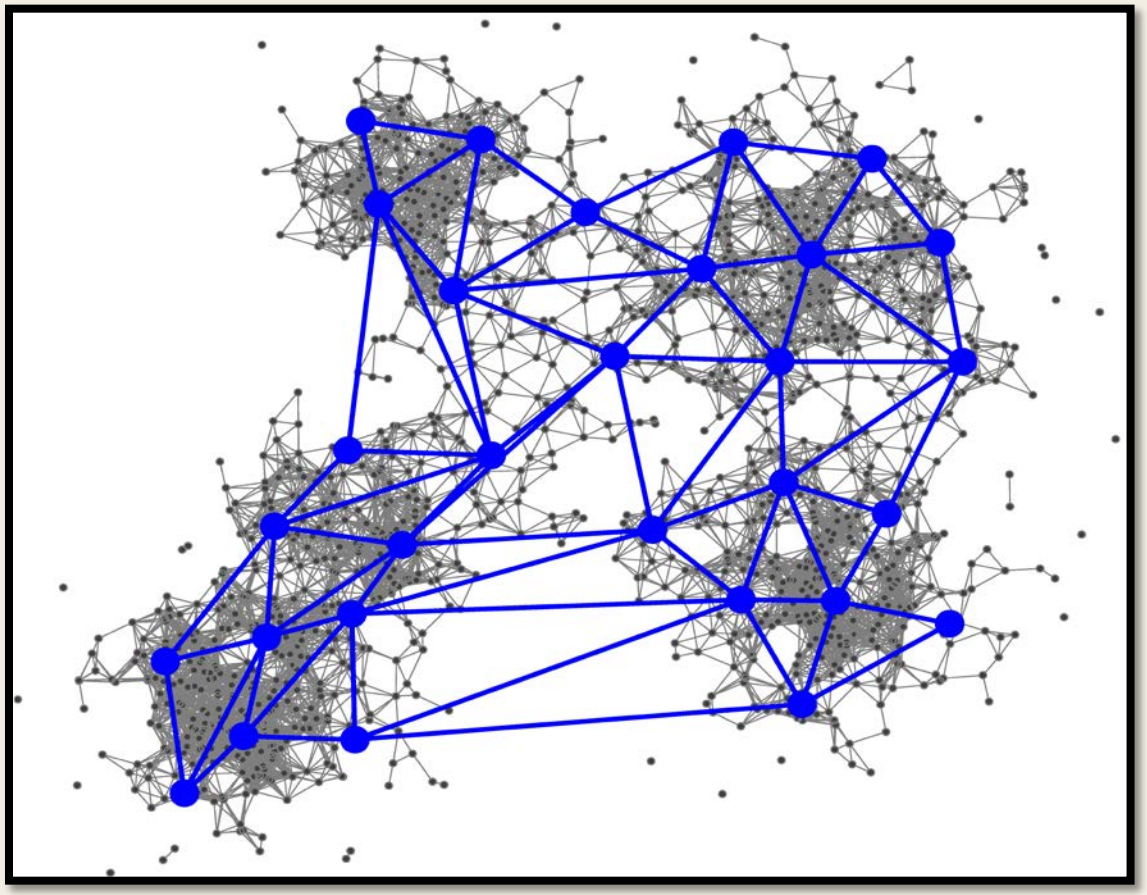
WICCI Overview



In [Complex Adaptive Systems], sustainable management comes close to initiating a "coevolutionary dialogue" where a continuous learning process is driven by the mutual and reciprocal interactions among the interlinked sub-systems and agents. Alongside this "dialogue", the ability to form new relations and new emerging properties enhances the chances of adaptive change and social–ecological resilience.

Rammel et al. (2007)

WICCI Overview



WICCI is:

An open, decentralized network

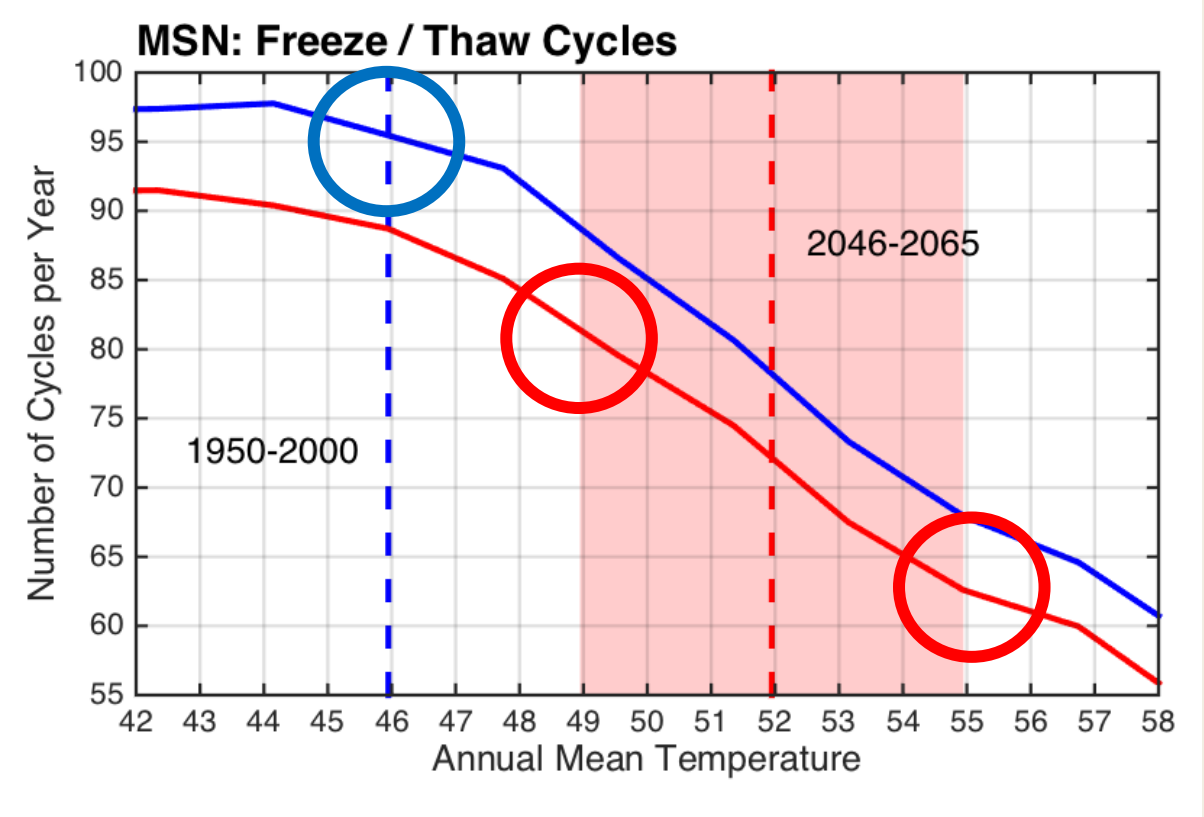
WICCI Engages:

Citizens, private and public decision-makers, scientists

WICCI Enables:

Planning, investment, other adaptation activities

Freeze / Thaw Cycles

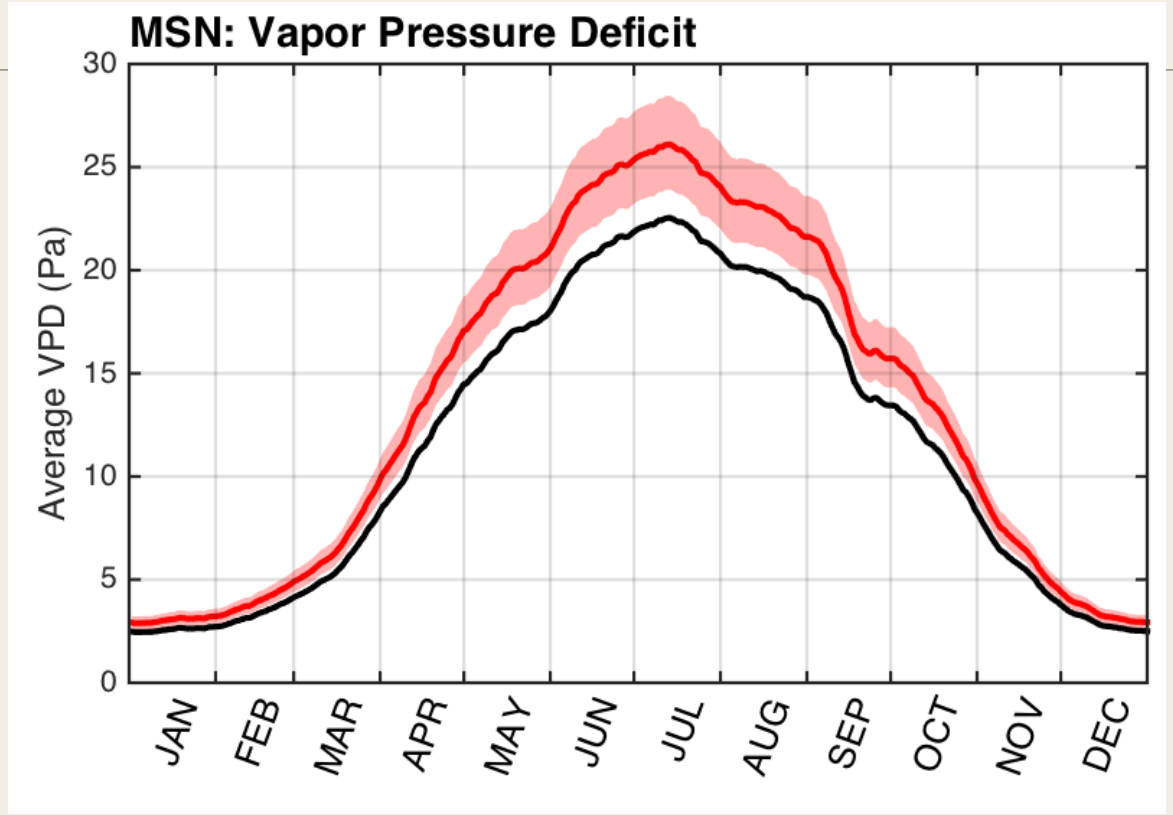


Fewer Freeze / Thaw Cycles per year

1950-2000: ~95 freeze / thaw cycles per year.

2046-2065: 60-85 freeze / thaw cycles per year: a decrease of about 15-30%

Vapor Pressure Deficit



Warmer temperatures, similar relative humidity ➔
Increased VPD by about 10%-25%

IPCC AR5 Attribution Statement:

It is *extremely likely* that more than half of the observed increase in global average surface temperature from 1951 to 2010 was caused by the anthropogenic increase in greenhouse gas concentrations and other anthropogenic forcings together.

IPCC AR5 Summary for Policy Makers

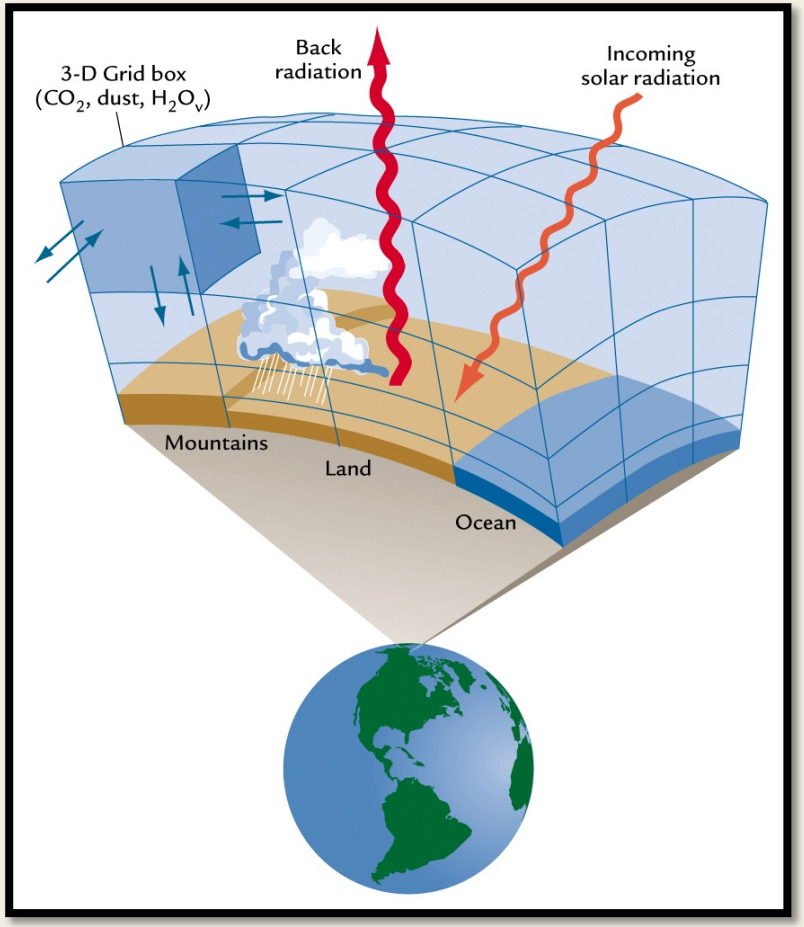
Global Climate Change

Future Climate Change: How do we project what will happen?

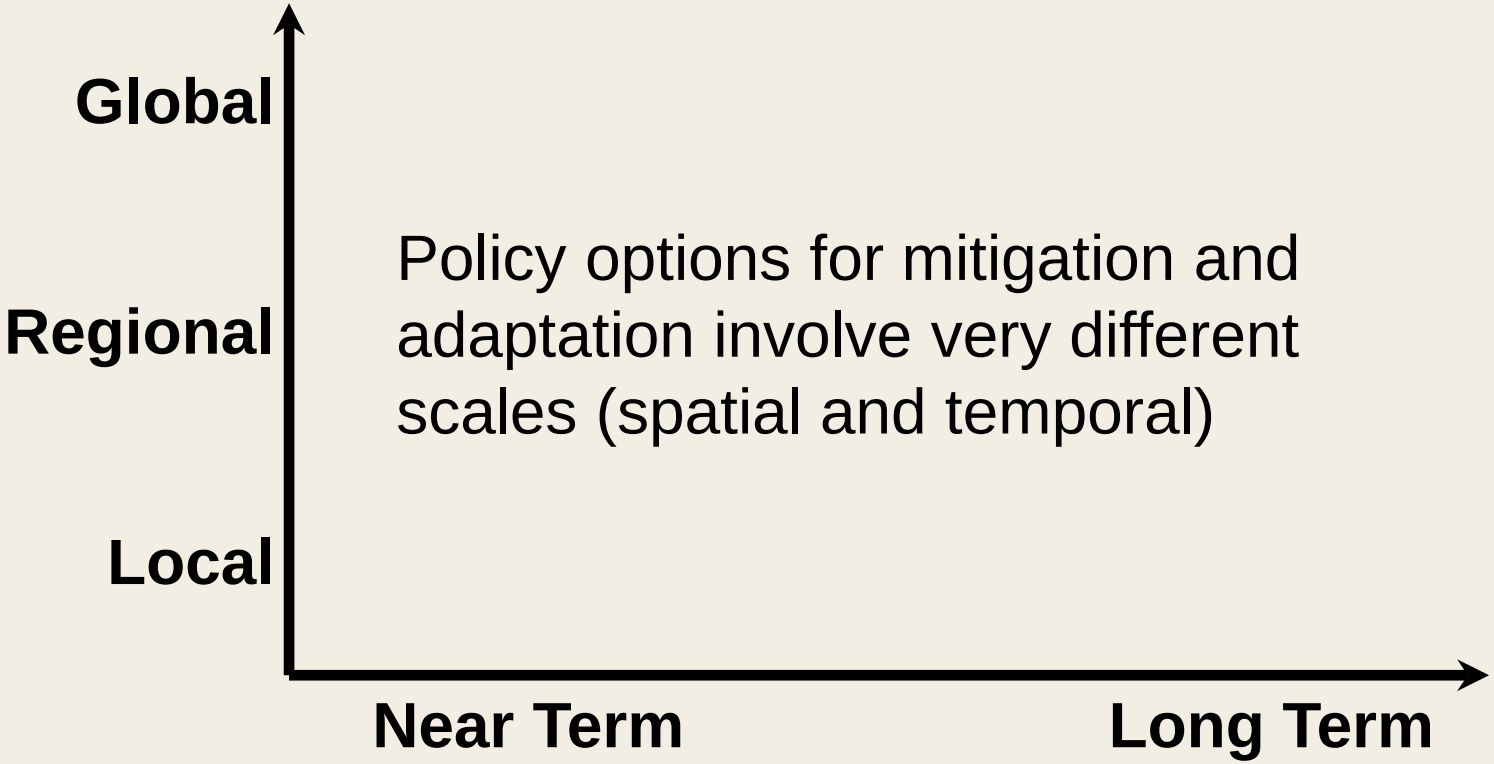
Global Climate Models

Divide the world into boxes, solve equations that govern weather / climate on a *discrete* grid.

Apply forcing based on a “storyline” of future emissions

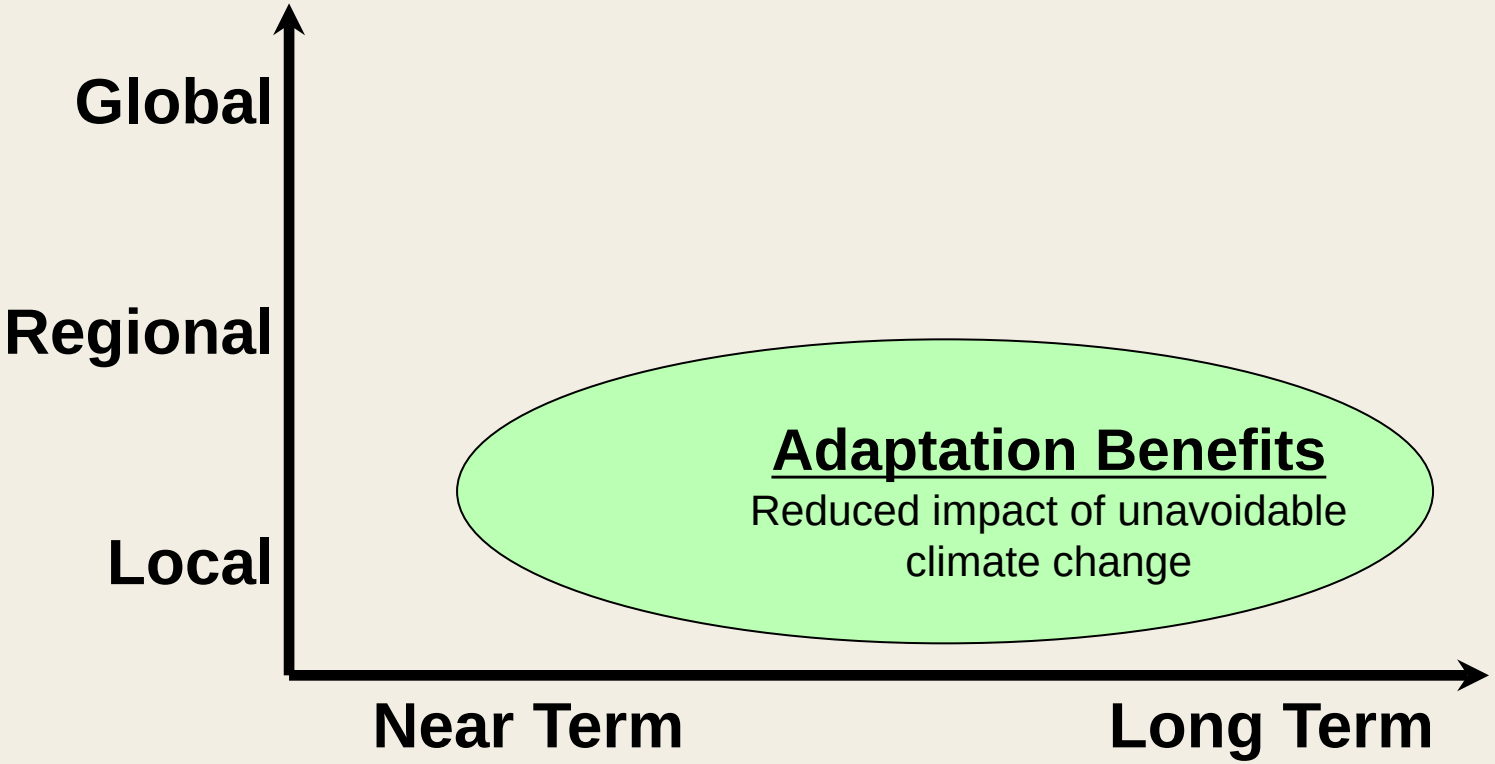


Climate Change and Risk:



Adapted from: Morgot and Agrawala: The Benefits of Climate Change Policies (Ch. 1)

Climate Change and Risk:



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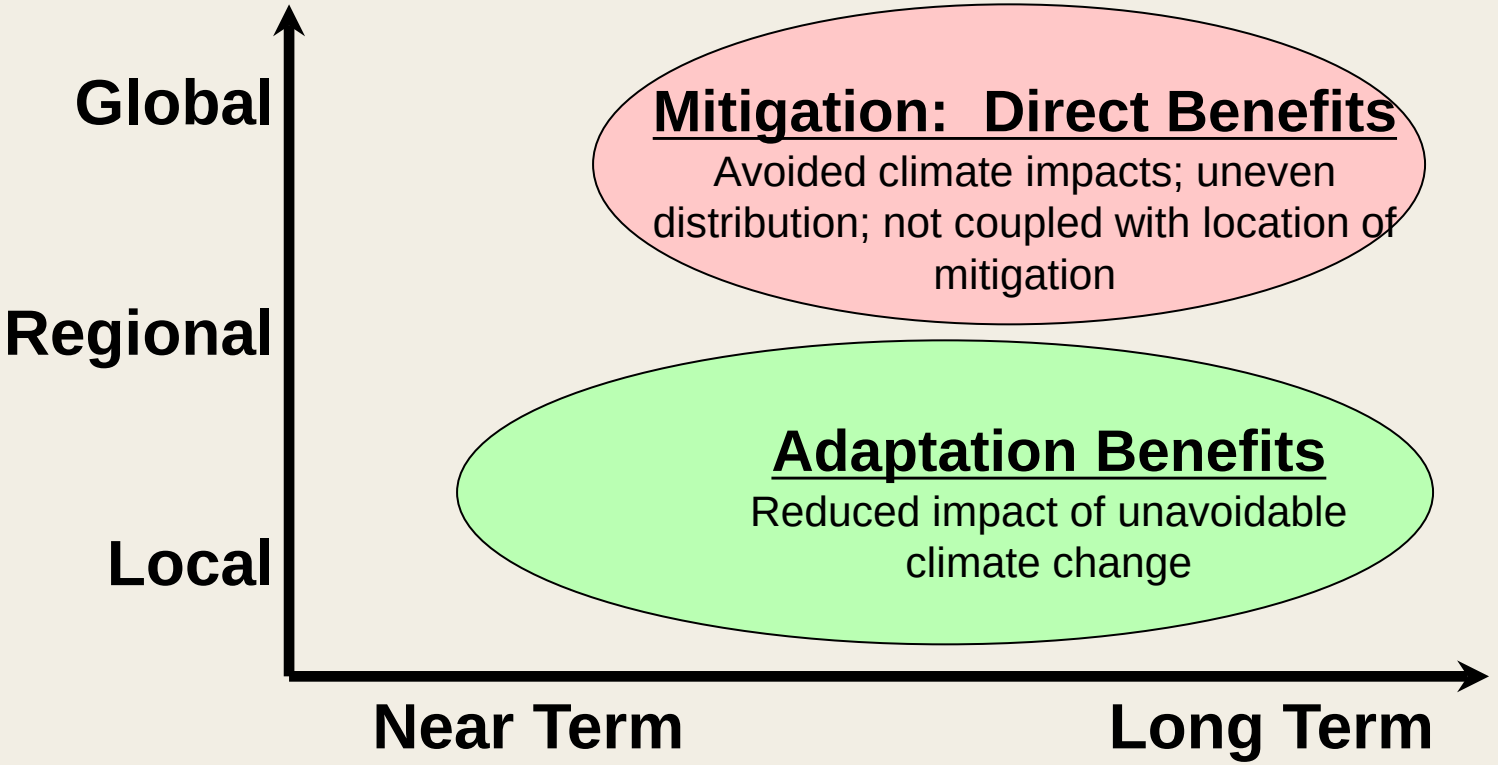
Climate Change and Risk:



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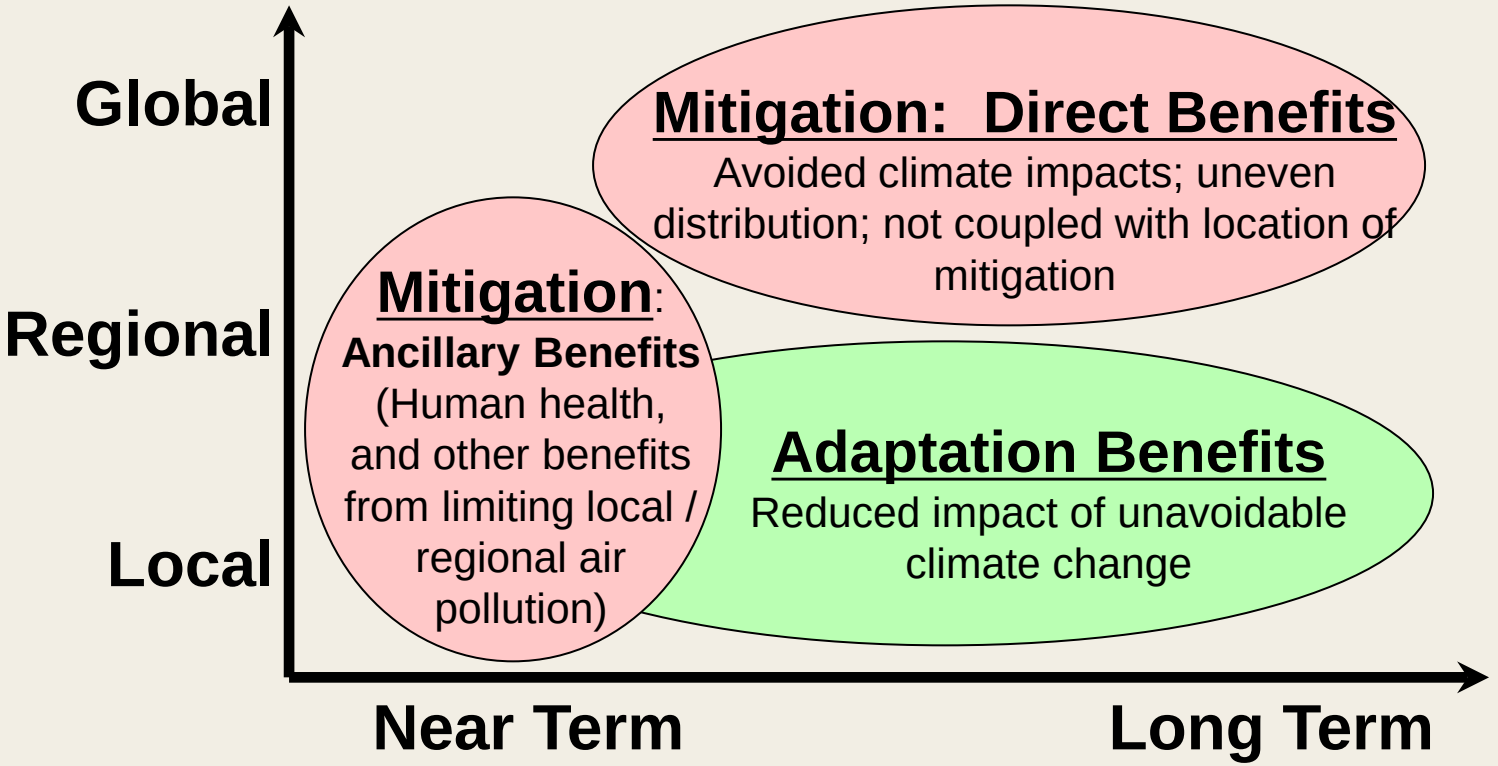
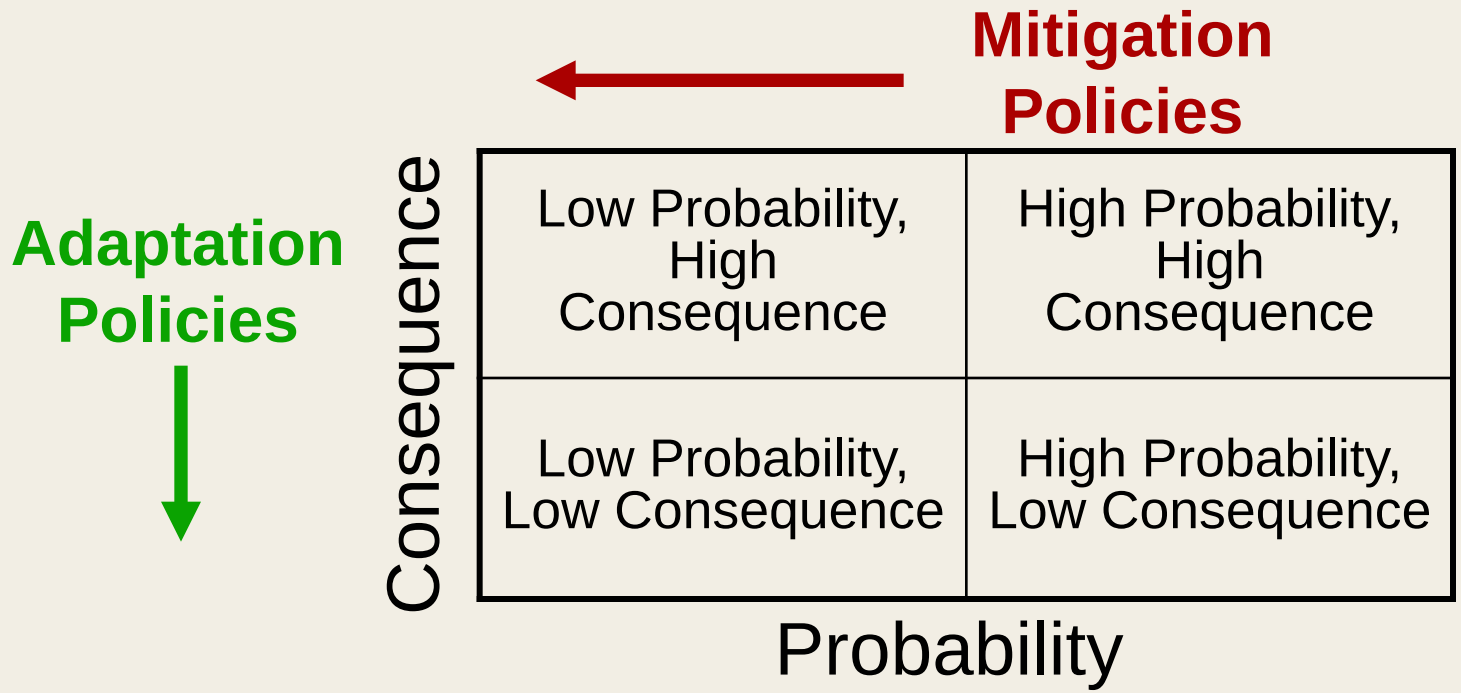
Climate Change and Risk:



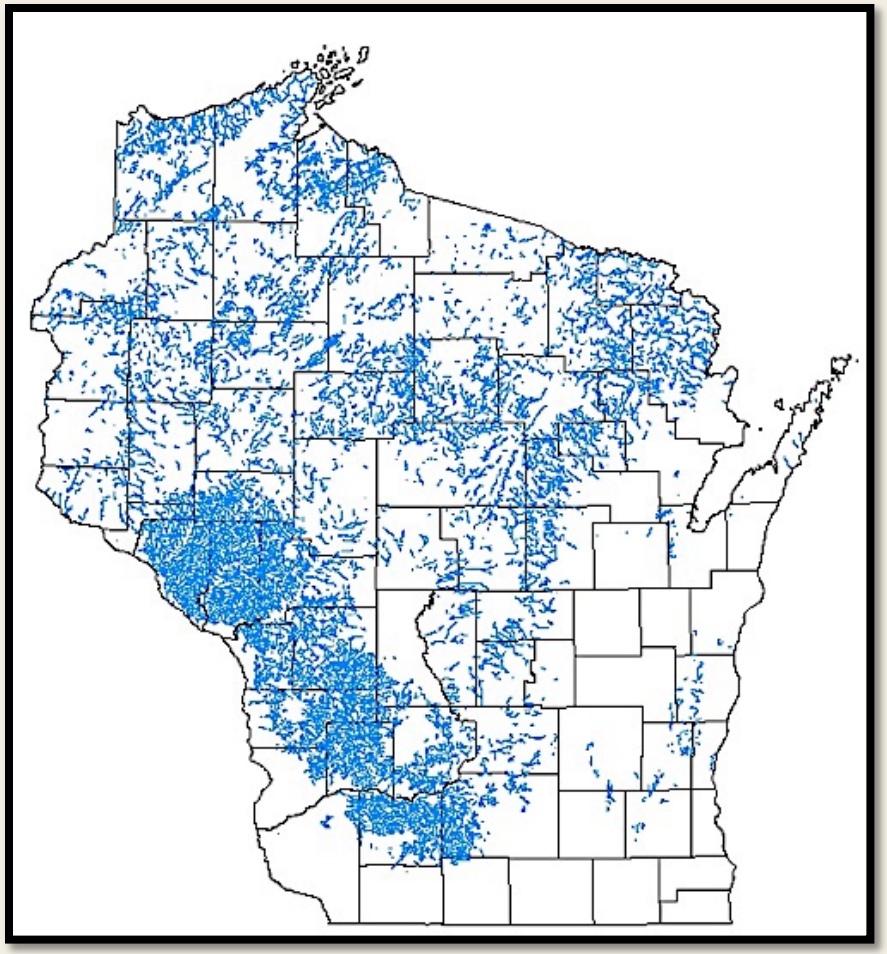
Adapted from: Morgot and Agrawala: The Benefits of Climate Change Policies (Ch. 1)

Climate Change and Risk:

Risk: *Probability of an event occurring times the consequence if it does occur*



Brook Trout Habitat (Current)

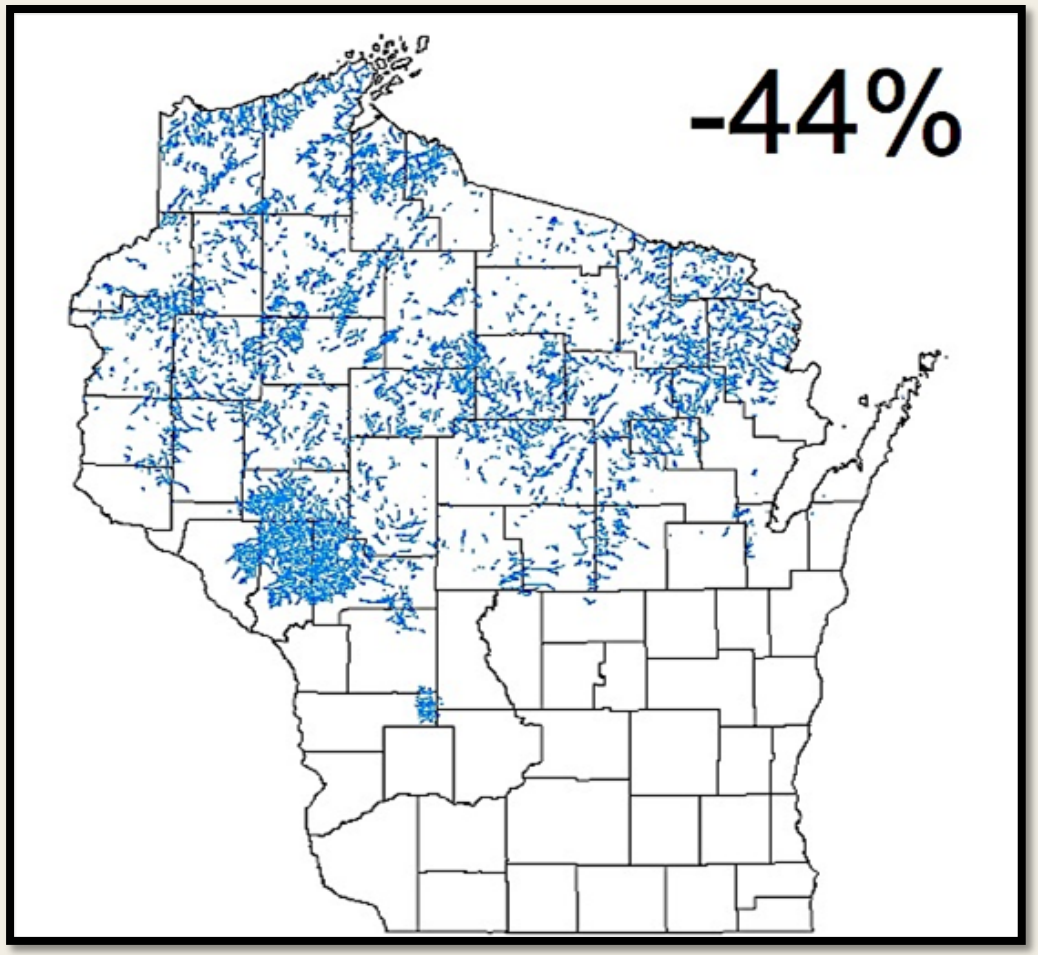


Low: +1°C Warming:

Med: +3°C Warming:

High: +5°C Warming

Brook Trout Habitat (2050)

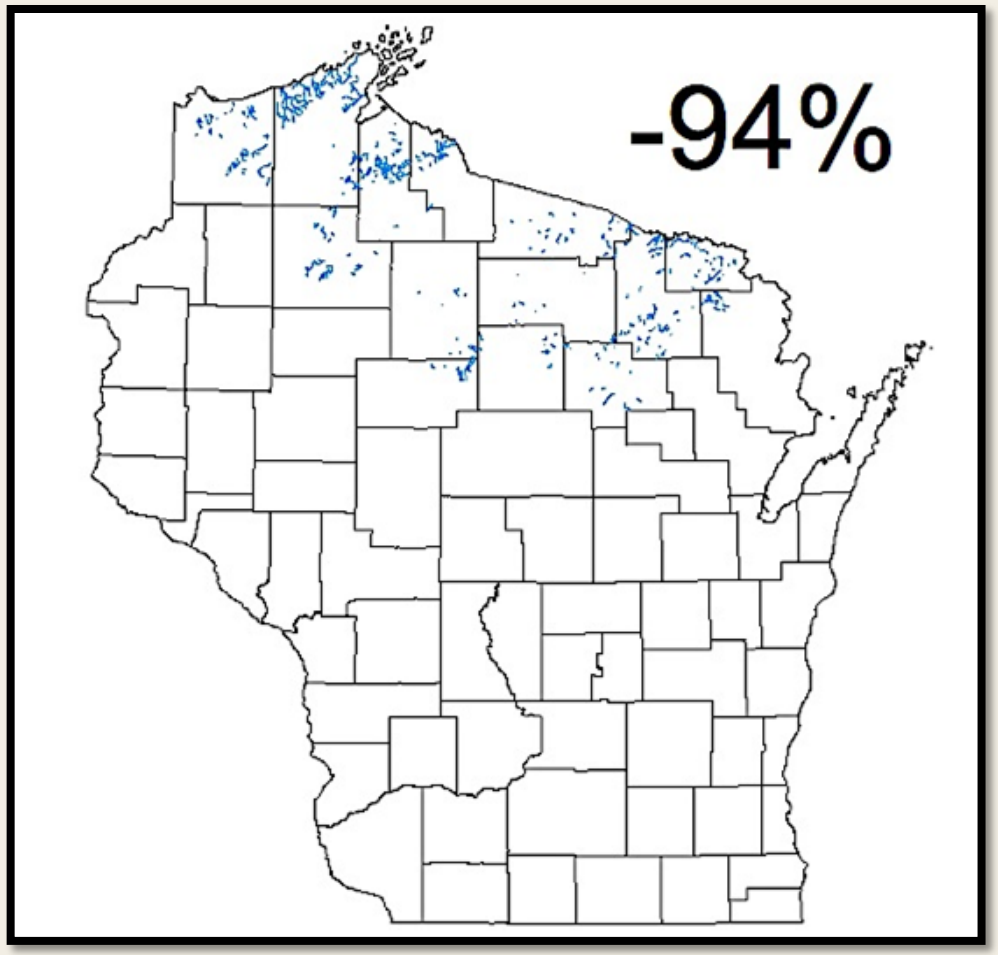


Low: +1°C Warming:

Med: +3°C Warming:

High: +5°C Warming

Brook Trout Habitat (2050)

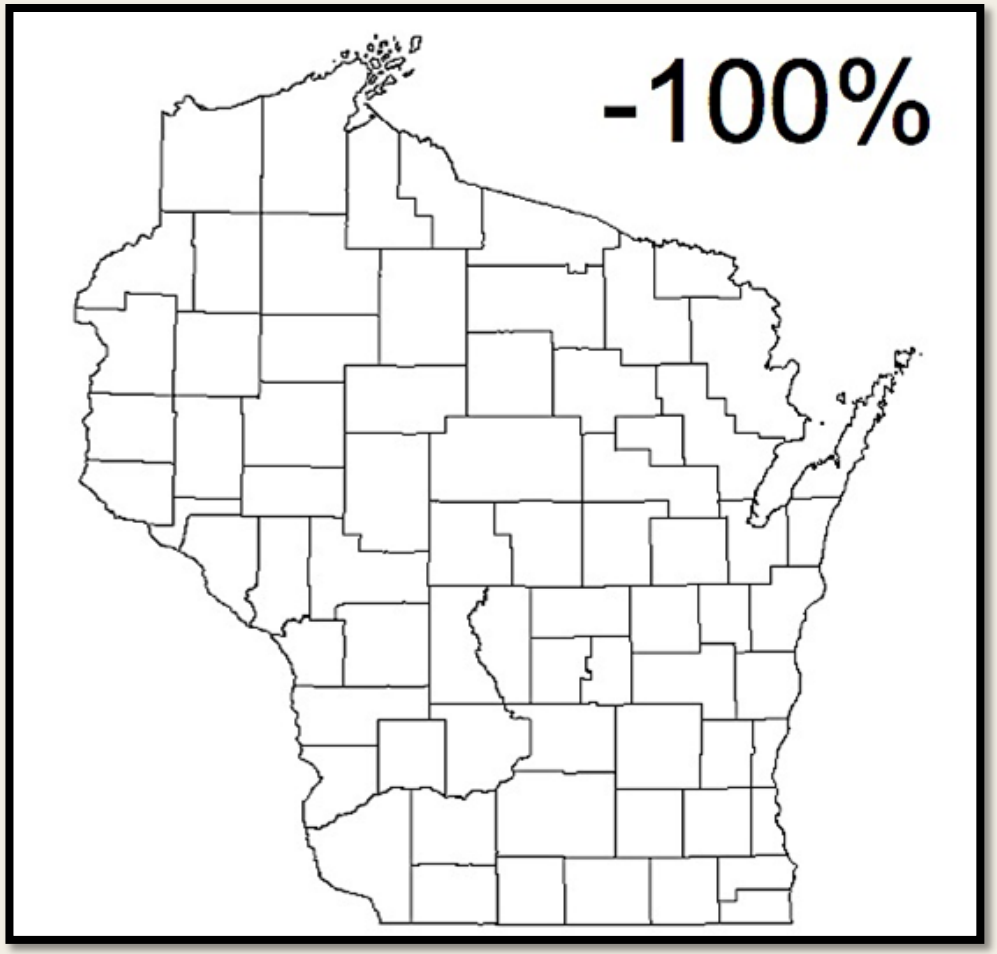


Low: +1°C Warming:

Med: +3°C Warming:

High: +5°C Warming

Brook Trout Habitat (2050)



Low: +1°C Warming:

Med: +3°C Warming:

High: +5°C Warming

The Wisconsin Department of Natural Resources used WICCI results to help ***prioritize management priorities*** for their Driftless Area Master Plan

The Driftless Area encompasses part or all of 23 counties in Wisconsin. To provide information at a meaningful scale, the Driftless Area is divided into eight Planning Regions that have similar types of aquatic and landscape features. Information for each Planning Region is presented by watershed and sub-watershed in a nested spatial structure. Sub-watersheds are comprised of catchments, which encompasses the land area that drains into each stream reach.

Information in this RPA ranges from fish abundance to habitat quality to human population density. In an effort to present the information simply and consistently, each watershed and sub-watershed is evaluated for how well it "performs" for a particular metric, relative to the other watersheds and sub-watersheds. These scores are then presented in a "report card" format.

Thus, the report card has "students," which are the watersheds (94) or sub-watersheds (441) and "subjects," which are habitat quality, the size and number of fish present, amount of public access, and the other topics being evaluated. The "students" are graded relative to the entire Driftless Area with A, B, C, D, and F's assigned. The maps in the RPA depict assessment grades at the finer sub-watershed scale, while the tabular report card is presented at the broader watershed scale.

The benefit of this approach is that it identifies the best or most pressing opportunities for future management and protection efforts. The downside is that in cases where all or most of the "students" perform well, grading on a curve gives the impression that some watersheds or sub-watersheds are poor or failing when in reality their performance is fine, but just not as high as the other "students." Similarly, in cases where few, if any, watersheds are functioning well, the best performers get high grades, despite poor performance.