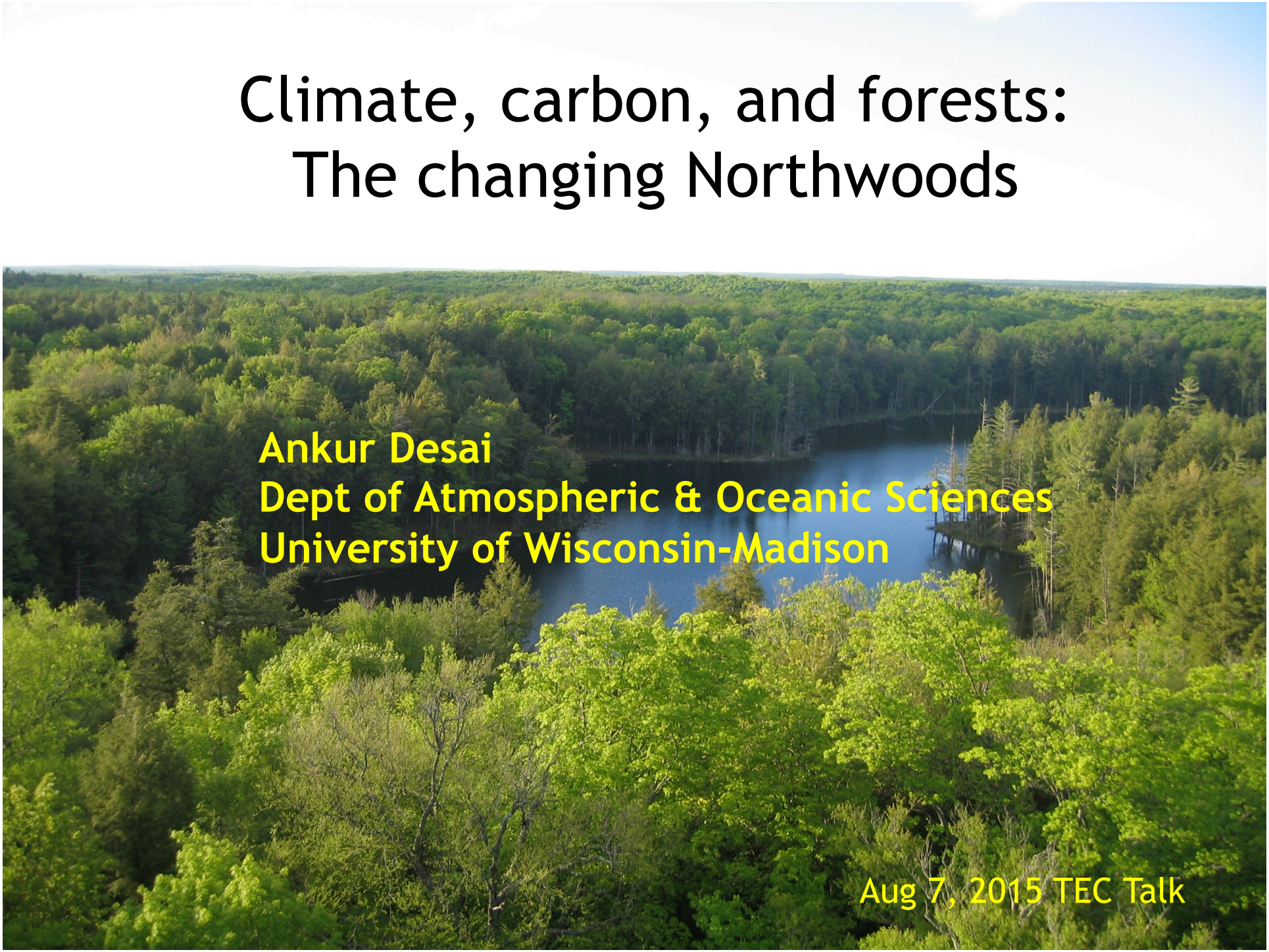
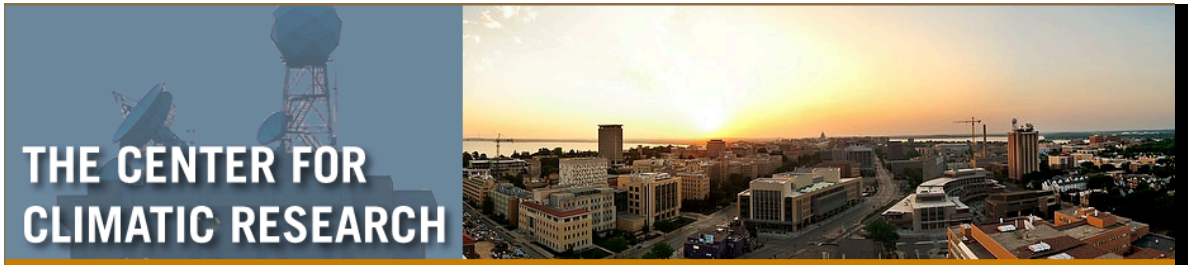
Climate, carbon, and forests: The changing Northwoods



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

Aug 7, 2015 TEC Talk



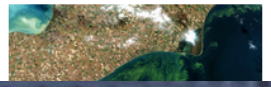
THE NELSON INSTITUTE FOR ENVIRONMENTAL STUDIES | UNIVERSITY OF WISCONSIN-MADISON

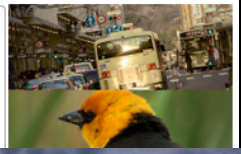
ABOUT CCR NEWS RESEARCH RESOURCES SUPPORT CC

Welcome to CCR

- Biogeochemistry

CCR researchers are investigating global and regional biogeochemistry, with a particular focus on the carbon cycle of the land biosphere a oceans and Great Lakes. Using data an elucidate natural carbon fluxes and the controlling them, and work to use this i improve predictive models.





- Climate Impacts
- Land Surface Processes
- Oceanography and Limnology
- Past Climates

Member of the US LTER Network

Welcome to NTL-LTER

North Temperate Lak
sites established by t
and changing land us
present, future).

Our primary study sit
their surrounding lan
Limnology at the Uni

University of Wisconsin-Madison

Department of Atmospheric and Oceanic Sciences

Who We Are

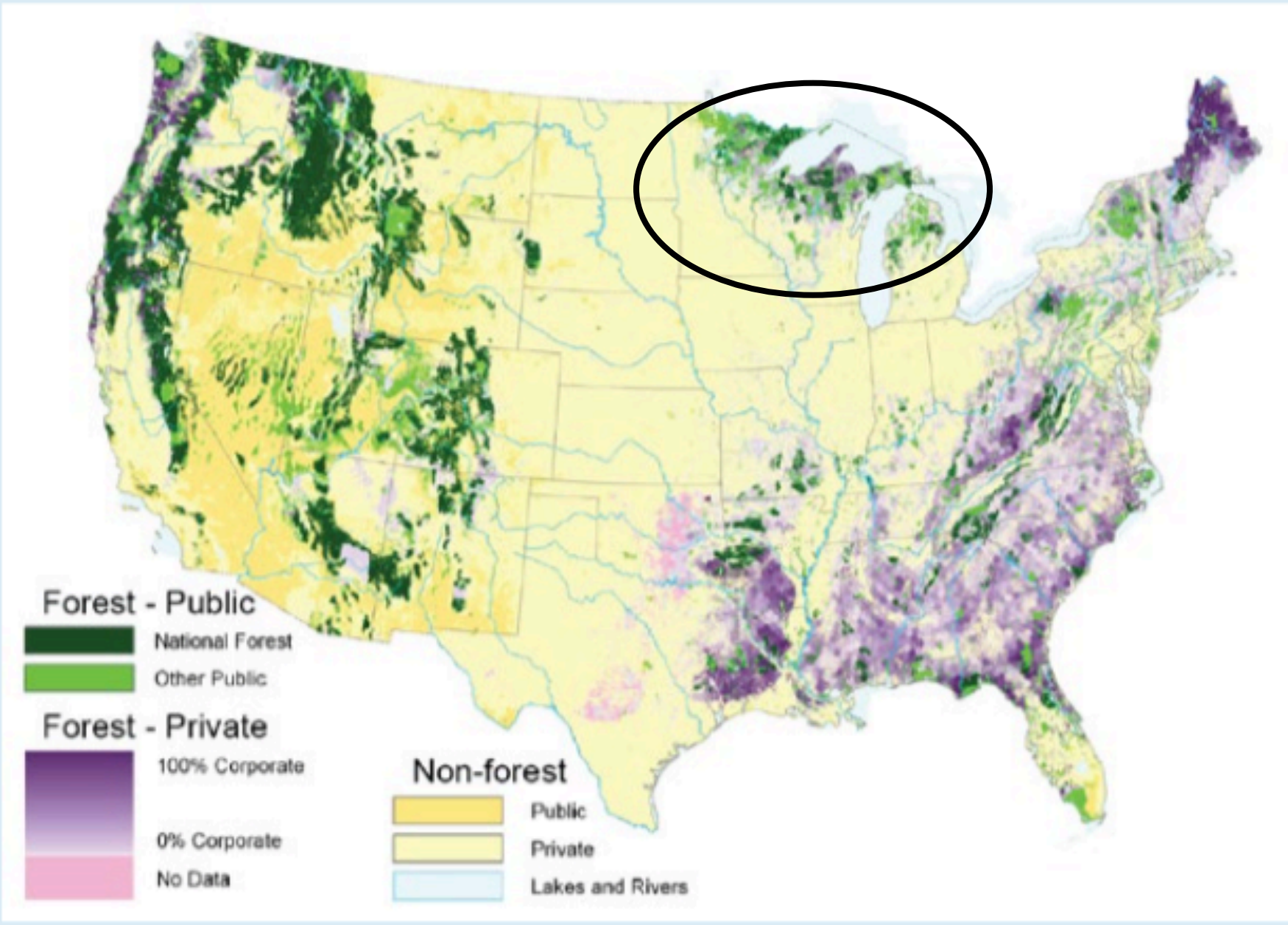
Since 1948 we have grown into one of the leading departments in our field of Atmospheric and Oceanic Sciences. We have strong graduate and undergraduate programs which are nationally recognized. We graduate about 15 Ph.D. and M.S. students each year; our graduates are active in research labs and universities 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.

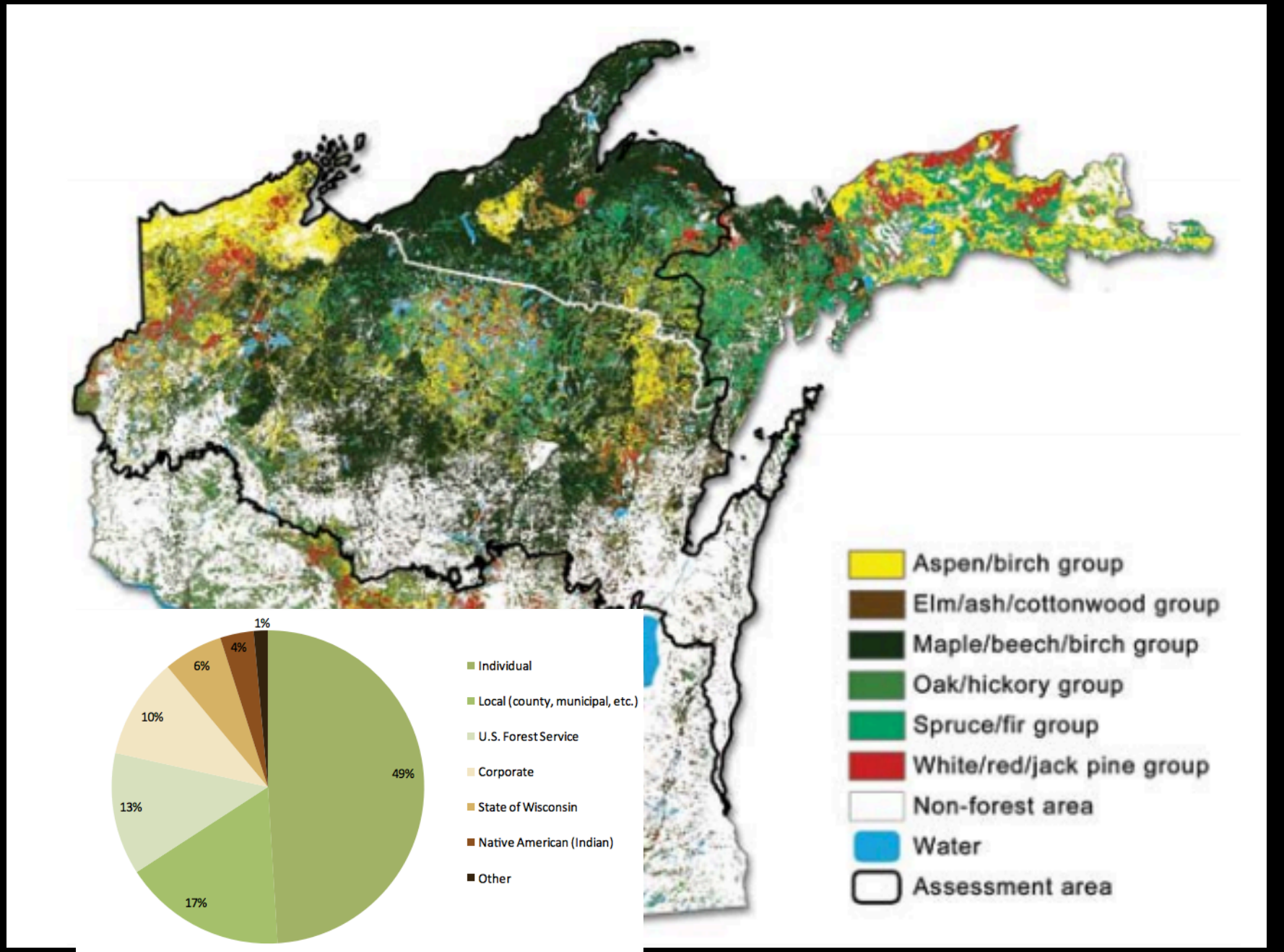
Our faculty of 15 has long maintained breadth and special strength in three areas:

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


THE END OF
THE ROAD

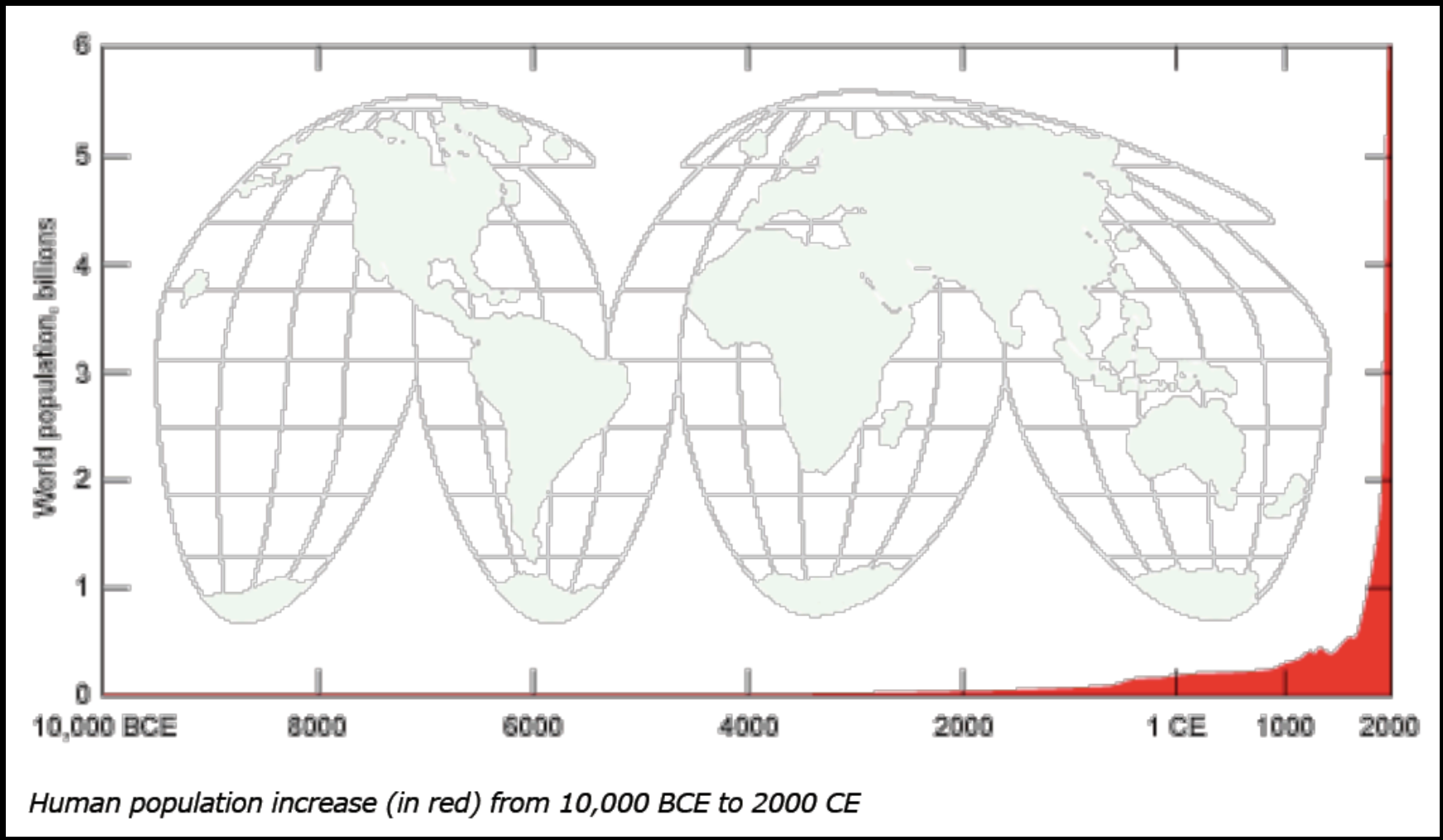
Public and Private Forestlands




Aspen/birch group
Elm/ash/cottonwood group
Maple/beech/birch group
Oak/hickory group
Spruce/fir group
White/red/jack pine group
Non-forest area
Water
Assessment area
49%
17%
13%
10%
6%
4%
1%
Individual
Local (county, municipal, etc.)
U.S. Forest Service
Corporate
State of Wisconsin
Native American (Indian)
Other

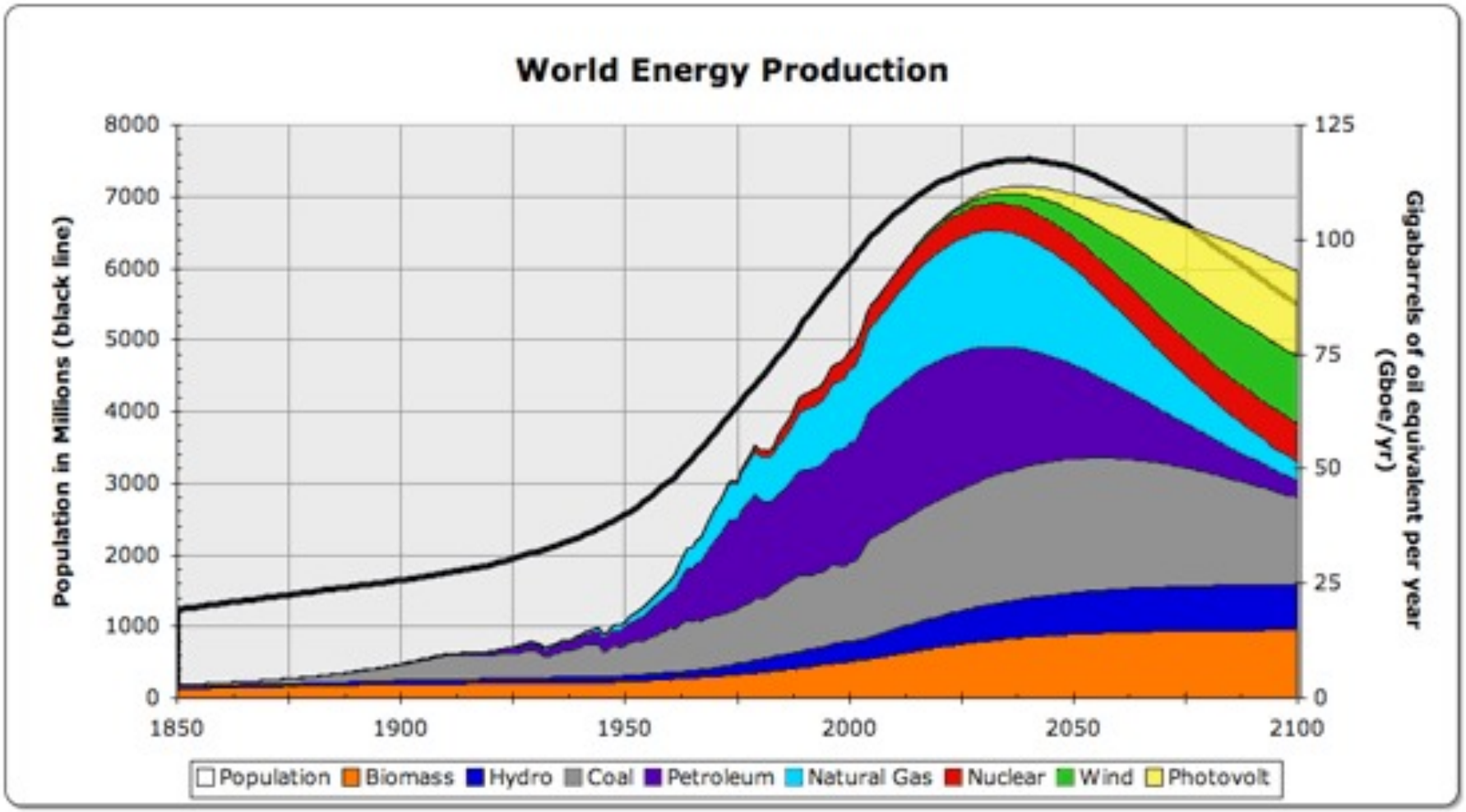

EDELRID


LGR
Los Gatos Research

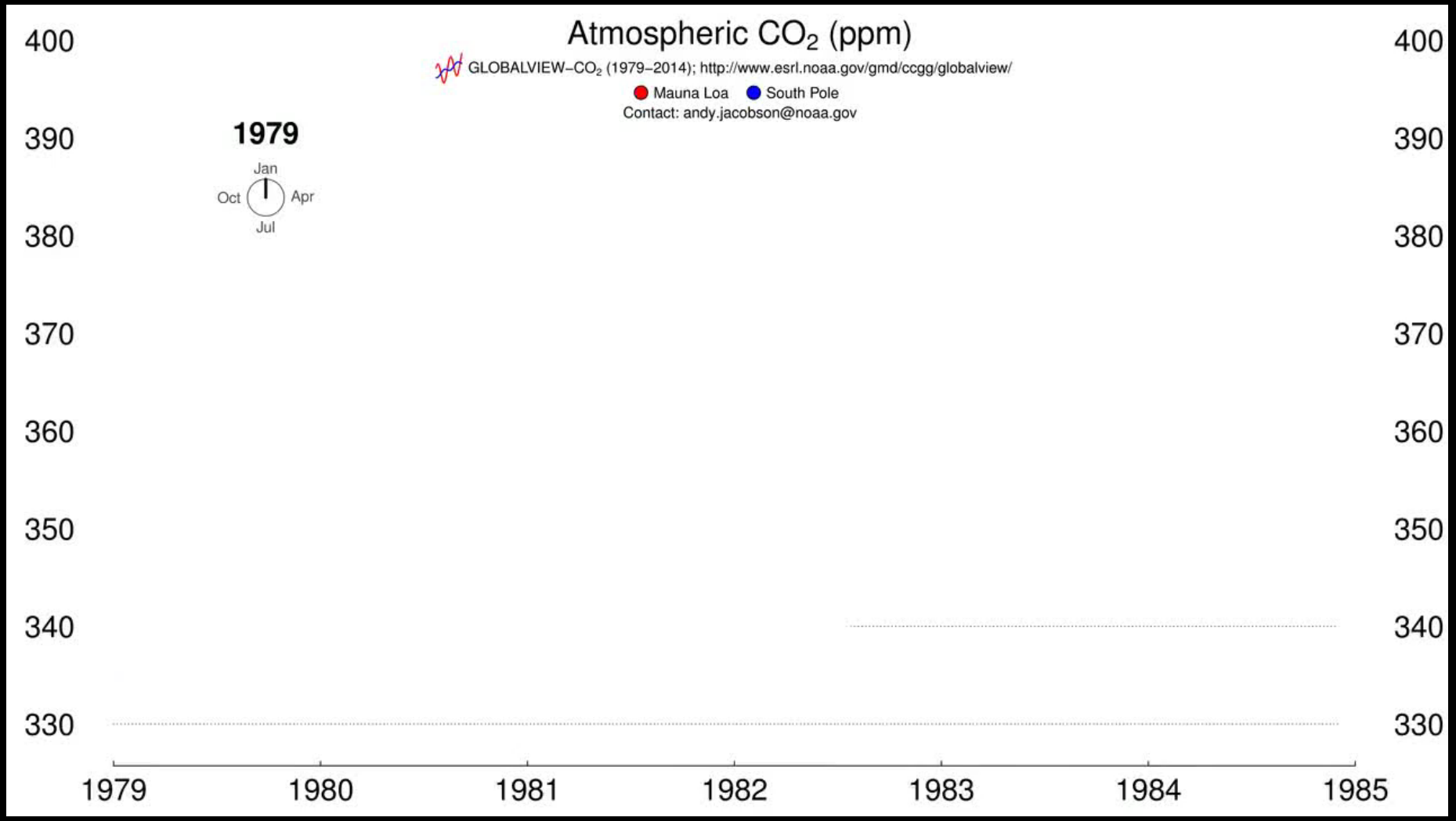


Human population increase (in red) from 10,000 BCE to 2000 CE

- Source: UCAR Quarterly, Summer 2007

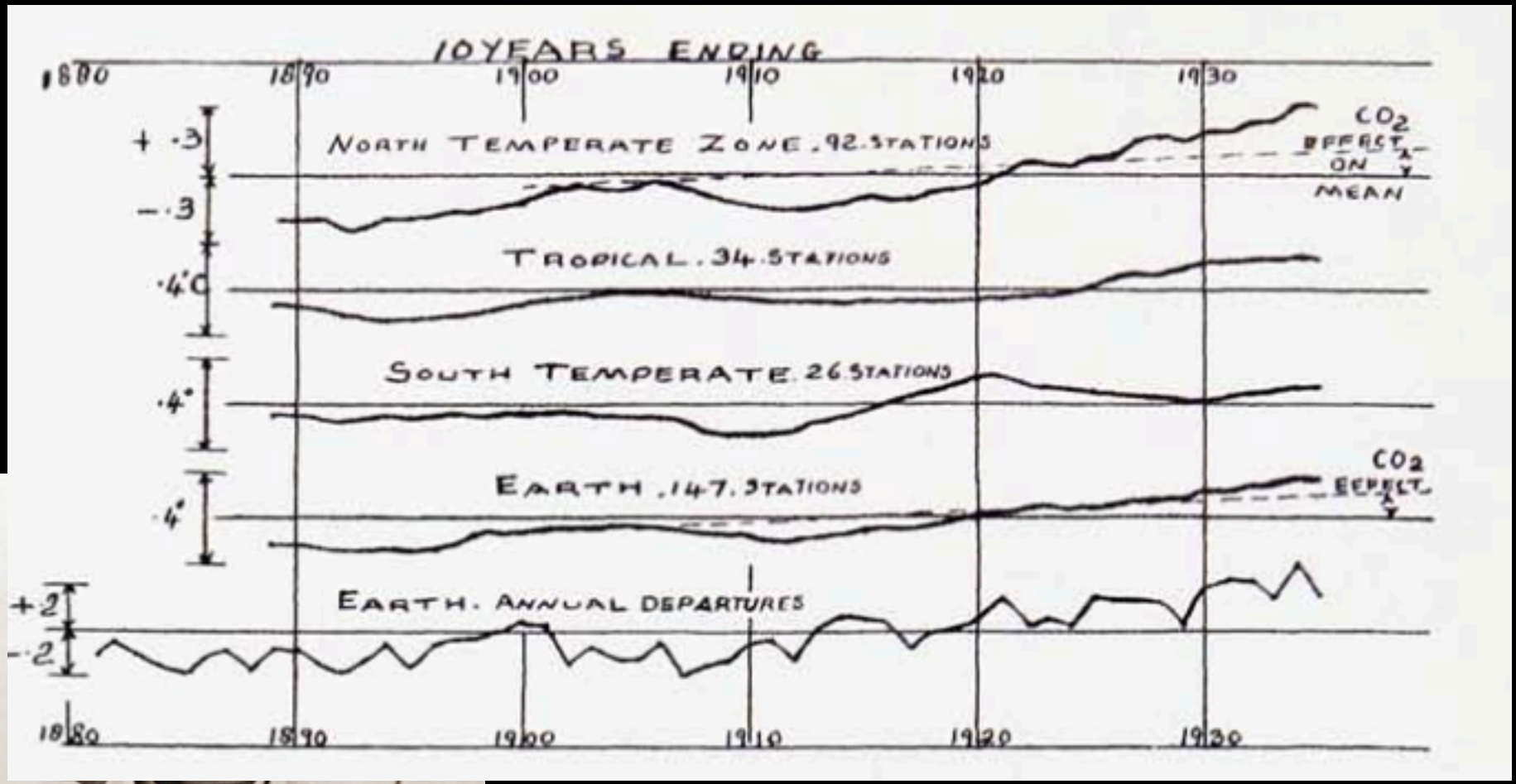


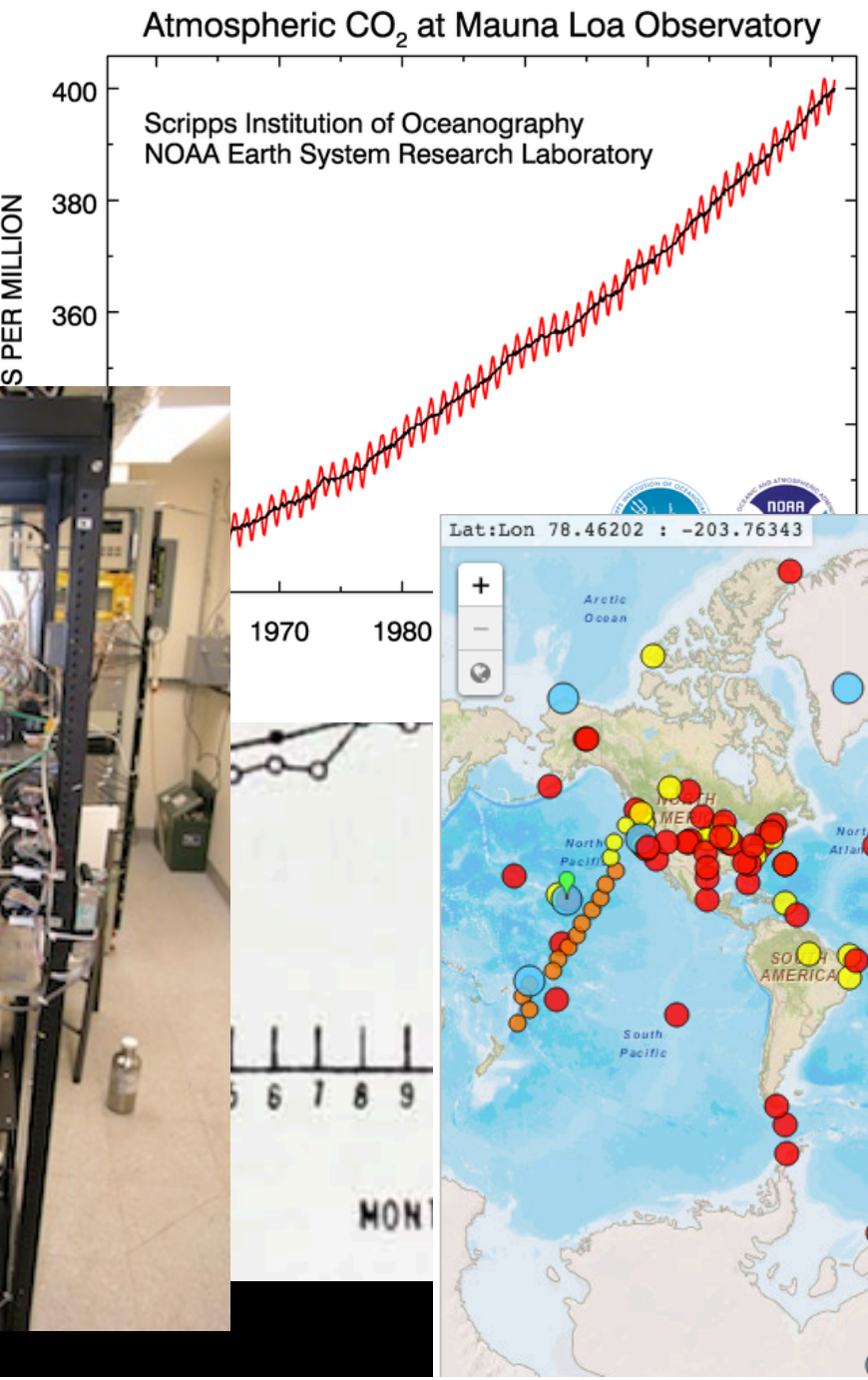
http://www.iceuls.com/_photo/b.jpg

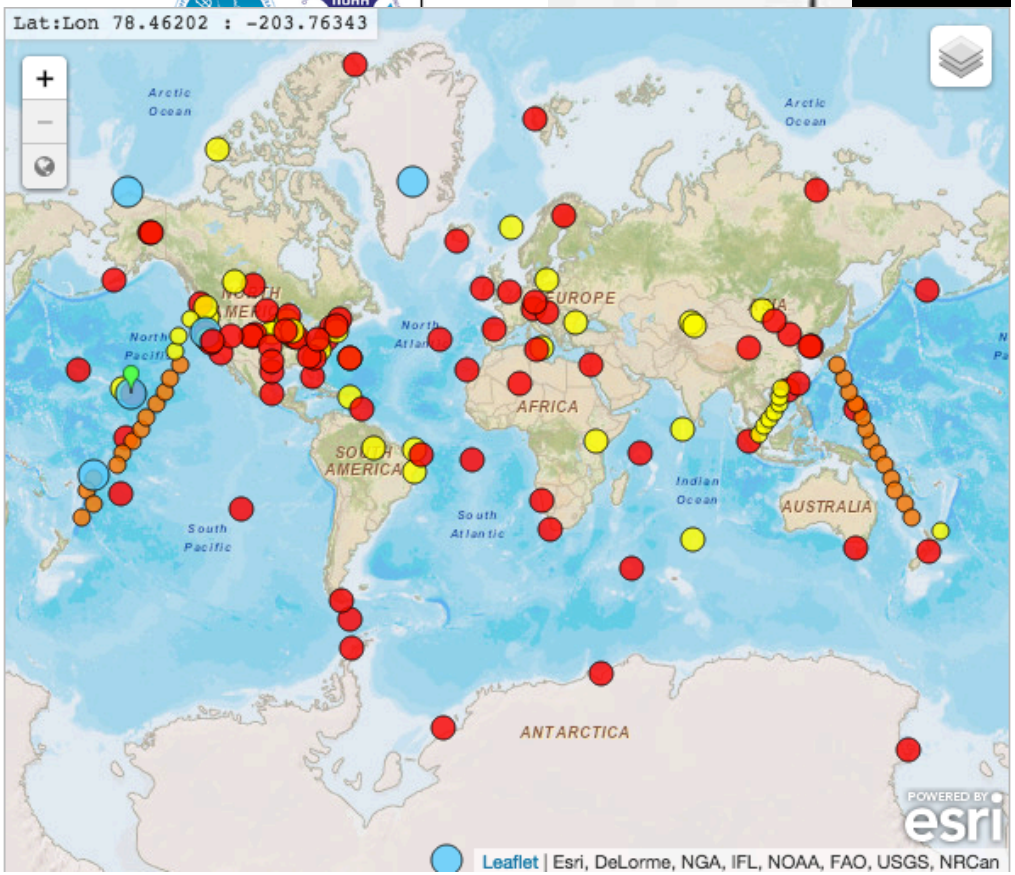

Atmospheric CO_2 (ppm)
GLOBALVIEW–CO_2 (1979–2014); http://www.esrl.noaa.gov/gmd/ccgg/globalview/
Mauna Loa
South Pole
Contact: andy.jacobson@noaa.gov
1979
Jan
Oct
Apr
Jul
400
390
380
370
360
350
340
330
1979
1980
1981
1982
1983
1984
1985

Since 1990

- Global annual CO_2 **emissions** grew 30% to
  33,000,000,000 tons of CO_2 per year
- CO_2 in the **atmosphere** grew 15% to
  2.9 trillion tons of CO_2 (400 ppm)
- At current rates, CO_2 is likely to **exceed**
  550 ppm sometime this century
- But: Rate of atmospheric CO_2 increase is about half the rate of emissions increase. **Why?**


10 YEARS ENDING
1880
1890
1900
1910
1920
1930
+ ·3
− ·3
NORTH TEMPERATE ZONE. 92. STATIONS
CO_2 EFFECT ON MEAN
·4°C
TROPICAL. 34. STATIONS
·4°
SOUTH TEMPERATE. 26 STATIONS
·4°
EARTH. 147. STATIONS
CO_2 EFFECT
+2
−2
EARTH. ANNUAL DEPARTURES


Atmospheric CO_2 at Mauna Loa Observatory
Scripps Institution of Oceanography
NOAA Earth System Research Laboratory
S PER MILLION
400
380
360
1970
1980
MON


Lat:Lon 78.46202 : -203.76343
Arctic Ocean
EUROPE
AFRICA
AUSTRALIA
ANTARCTICA
Indian Ocean
South Pacific
South Atlantic
Leaflet | Esri, DeLorme, NGA, IFL, NOAA, FAO, USGS, NRCan

Global Carbon Budget

The cumulative contributions to the Global Carbon Budget from 1870
Contributions are shown in parts per million (ppm)

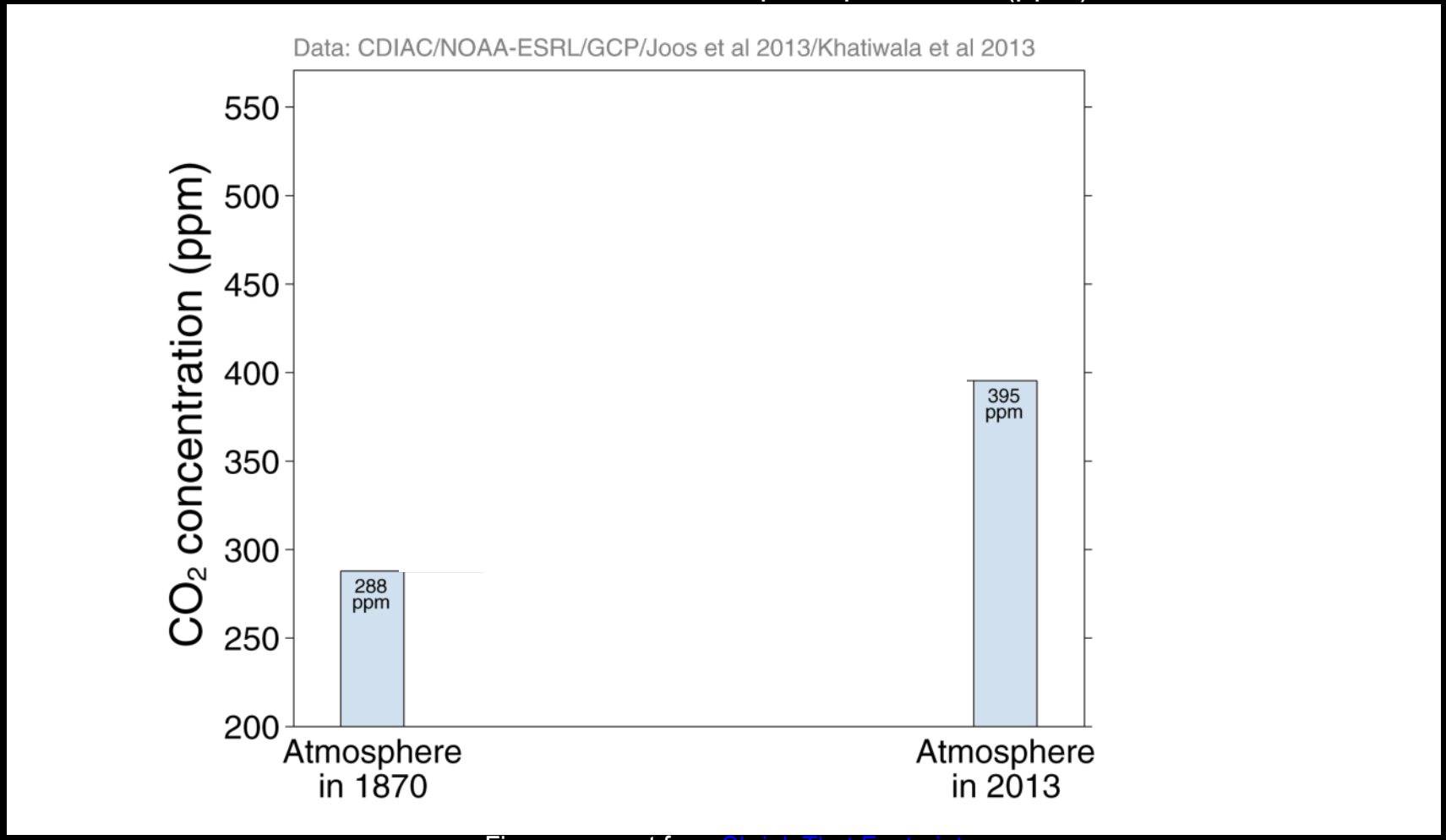
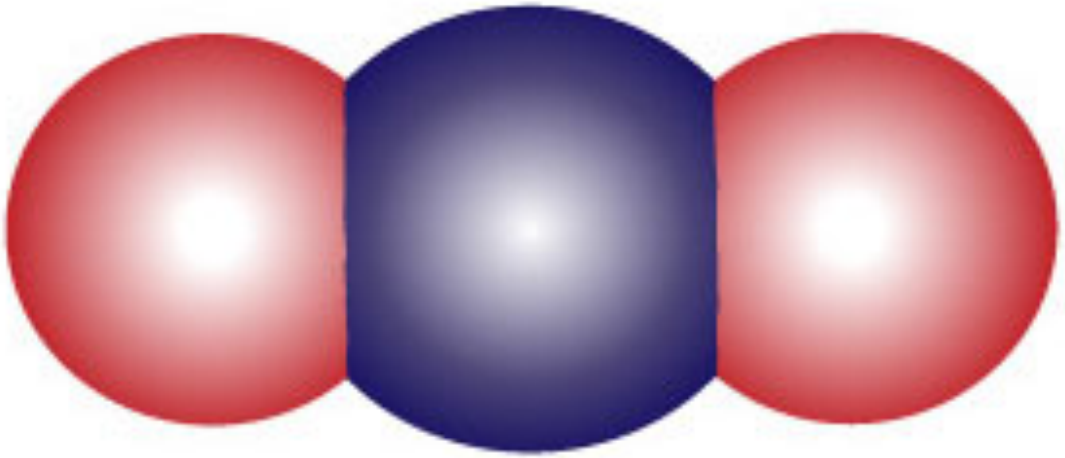
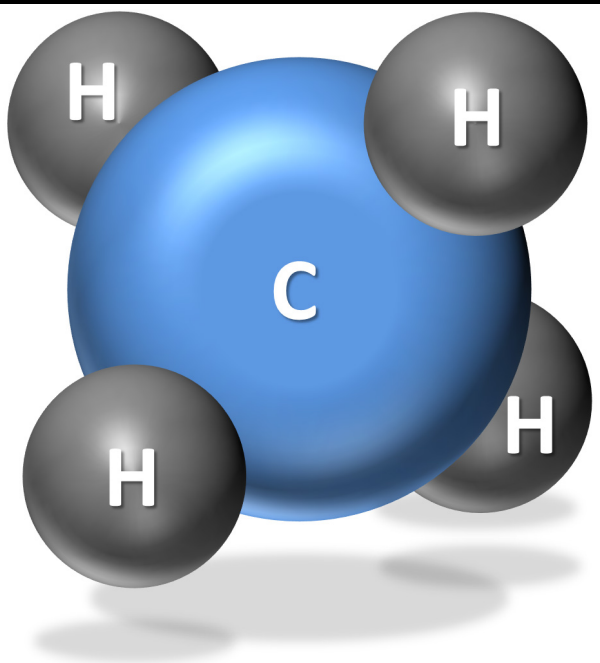


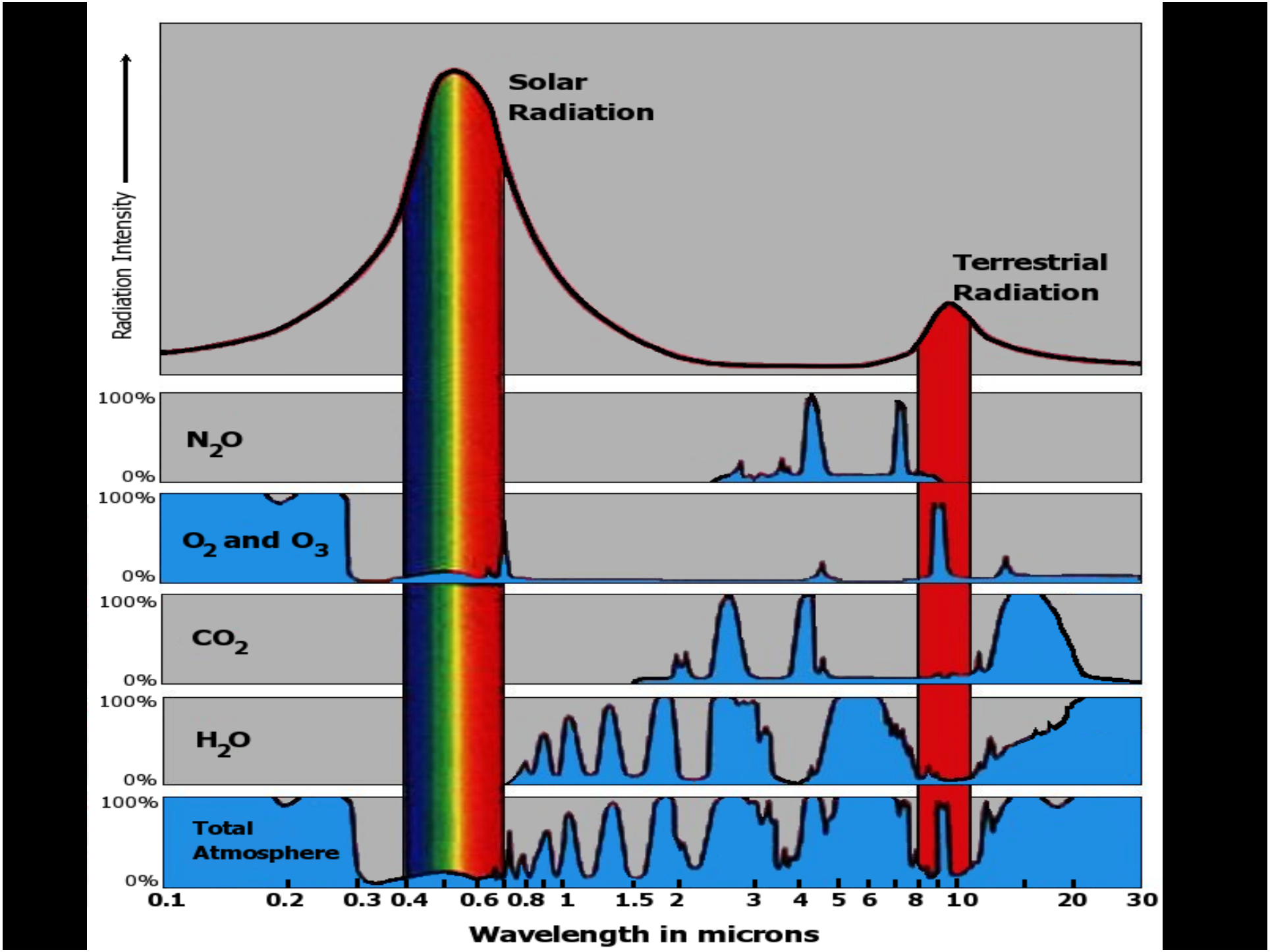
Figure concept from Shrink That Footprint

Source: CDIAC; NOAA-ESRL; Houghton et al 2012; Giglio et al 2013; Joos et al 2013; Khatiwala et al 2013; Le Quéré et al 2014; Global Carbon Budget 2014



O=C=O




Radiation Intensity
Solar Radiation
Terrestrial Radiation
100%
N_2O
0%
100%
O_2 and O_3
0%
100%
CO_2
0%
100%
H_2O
0%
100%
Total Atmosphere
0%
0.1
0.2
0.3
0.4
0.6
0.8
1
1.5
2
3
4
5
6
8
10
20
30
Wavelength in microns

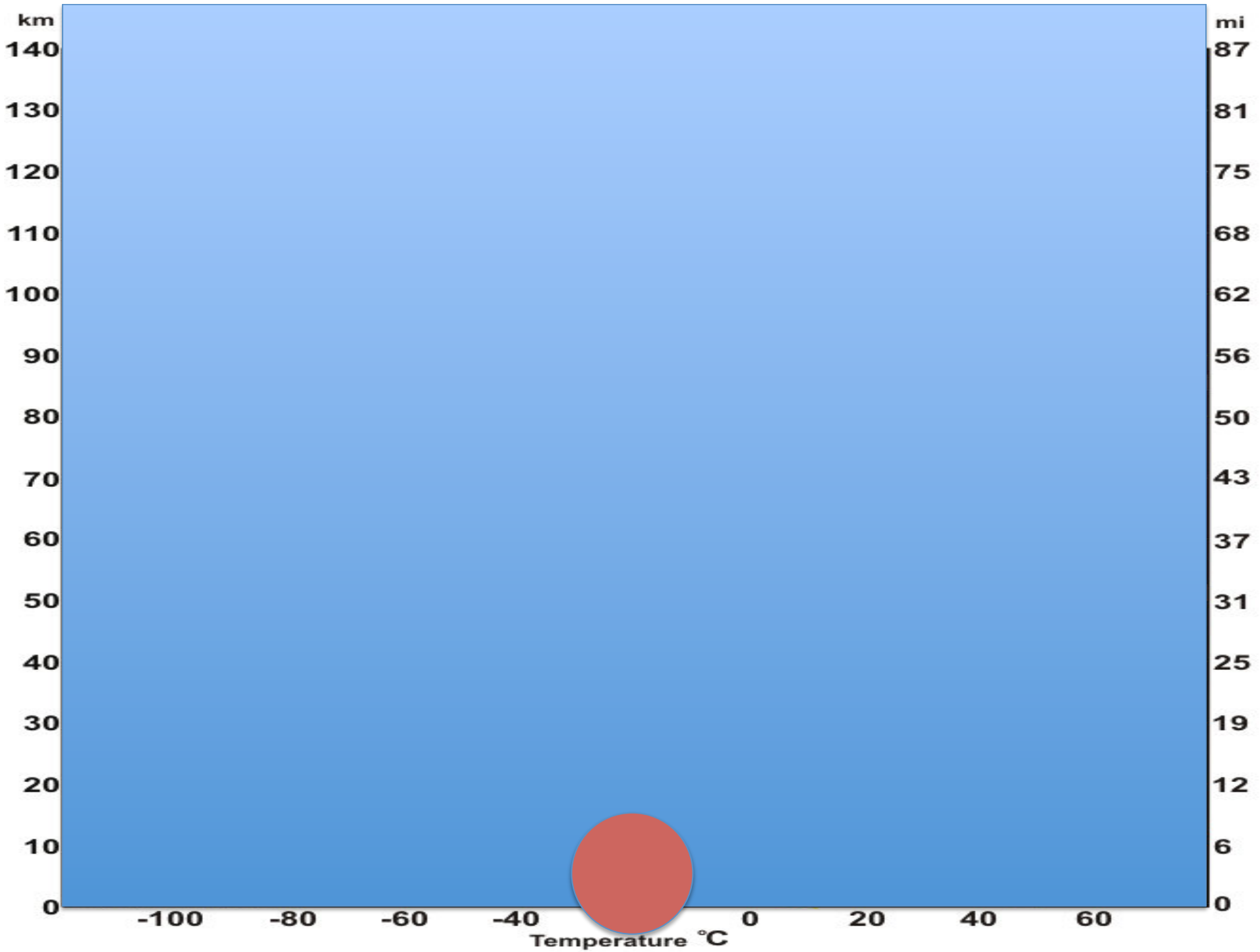
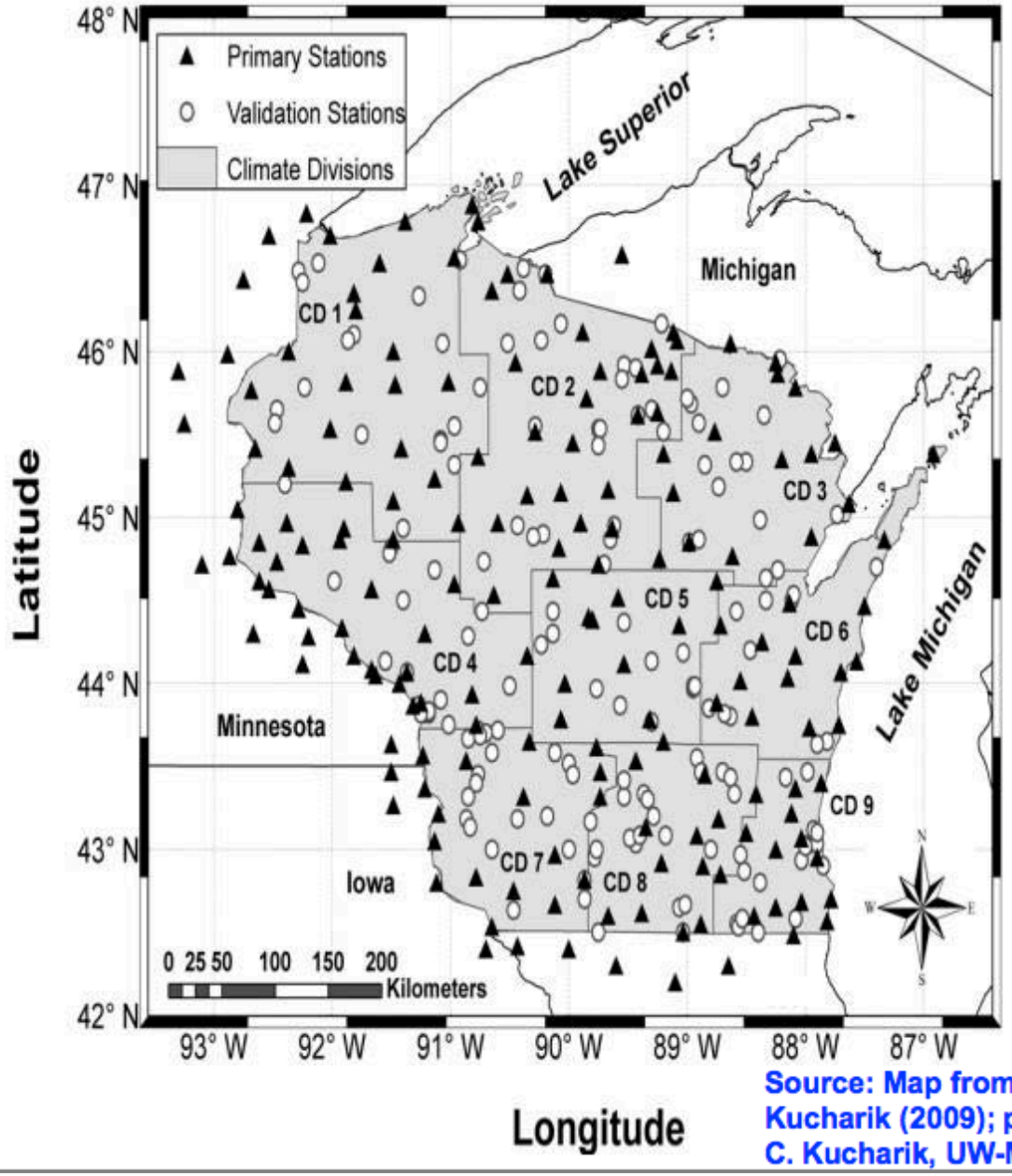

km
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
mi
87
81
75
68
62
56
50
43
37
31
25
19
12
6
0
-100
-80
-60
-40
0
20
40
60
Temperature °C

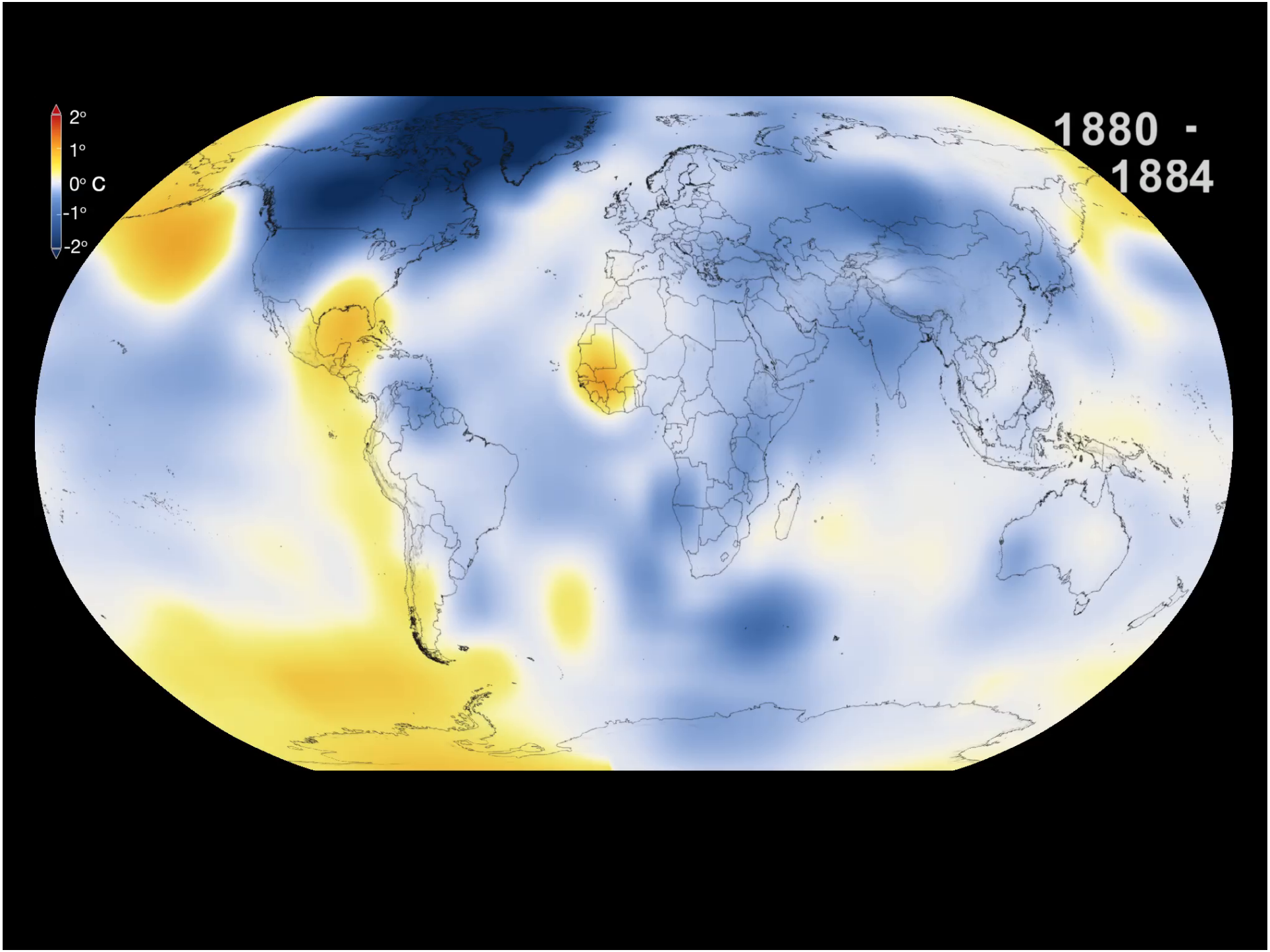
Photo credit: NOAA

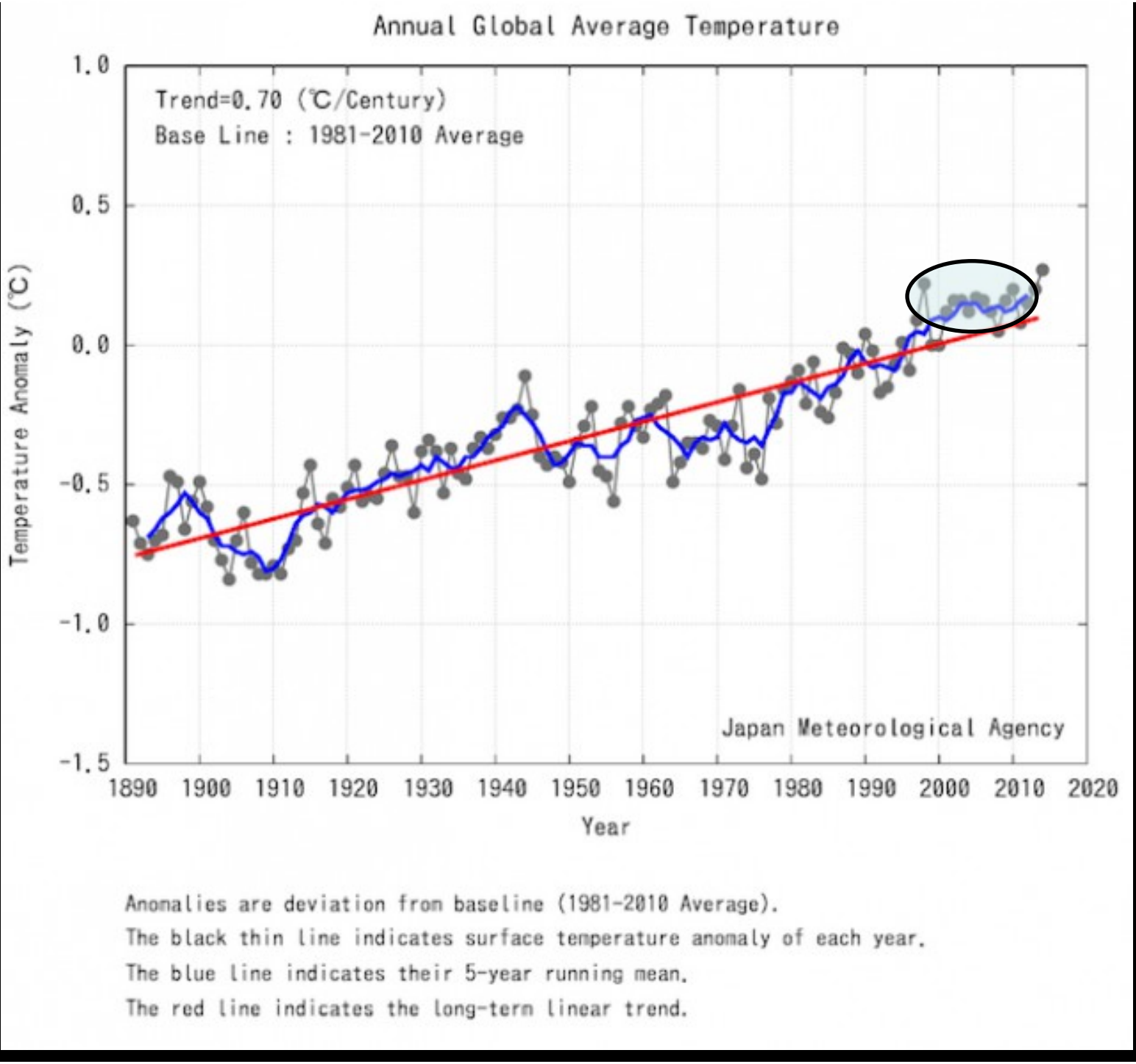
Weather Station Network for Wisconsin

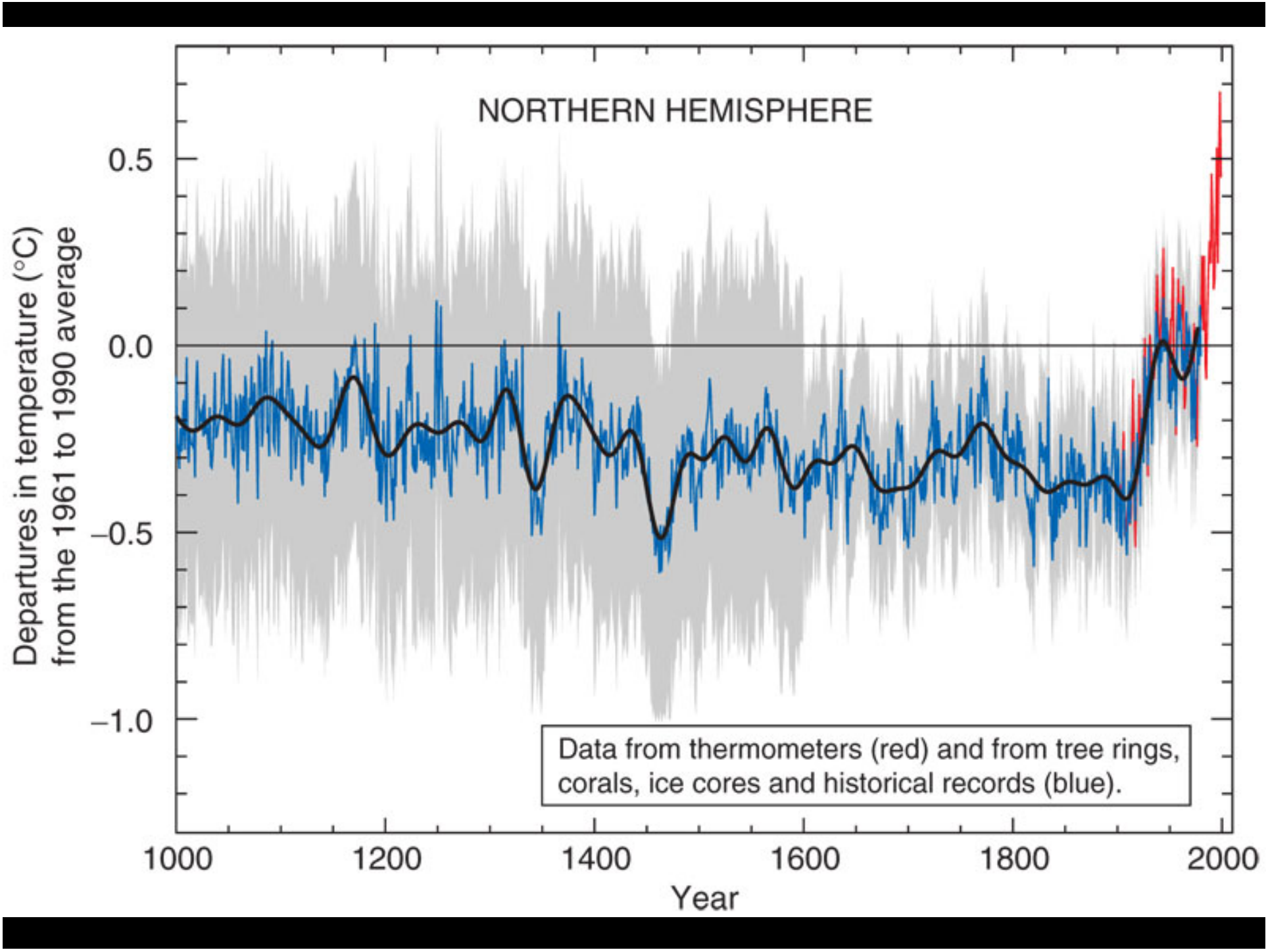
(Daily temperature and precipitation data since 1950)

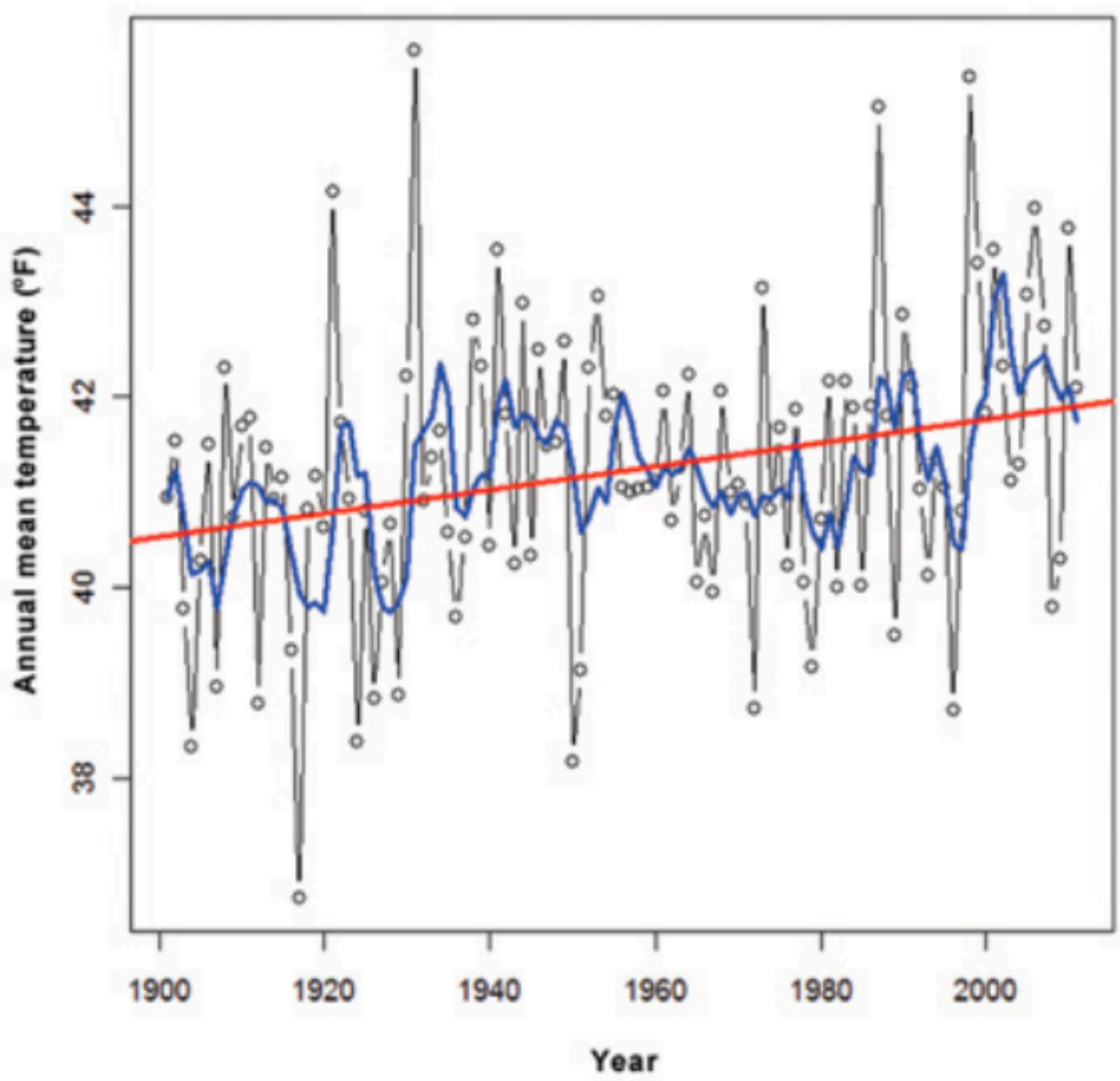


Source: Map from Serbin and Kucharik (2009); photos from C. Kucharik, UW-Madison

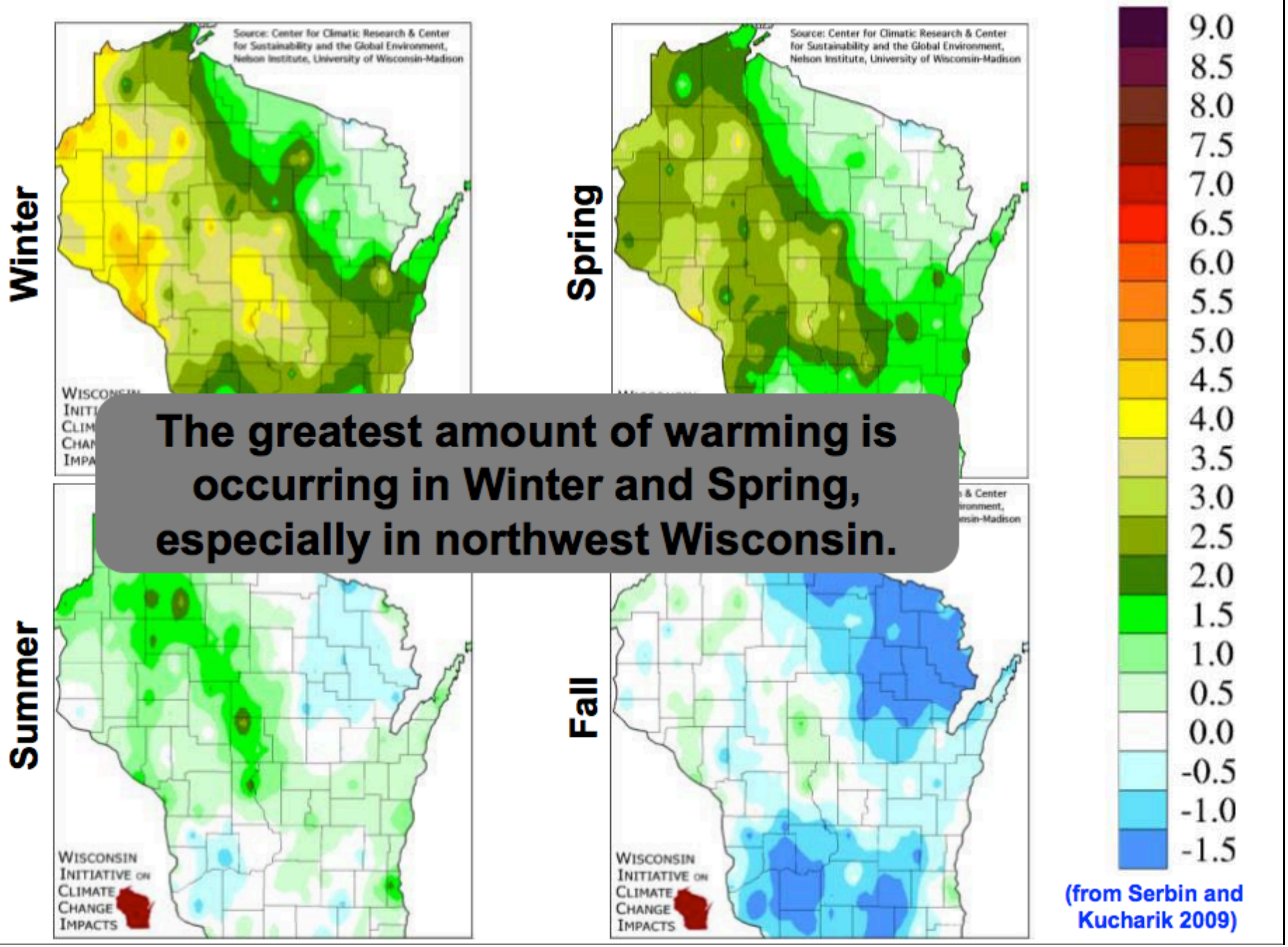

2°
1°
0° C
-1°
-2°
1880 -
1884


Annual Global Average Temperature
Trend=0.70 (℃/Century)
Base Line : 1981-2010 Average
Temperature Anomaly (℃)
1.0
0.5
0.0
-0.5
-1.0
-1.5
1890
1900
1910
1920
1930
1940
1950
1960
1970
1980
1990
2000
2010
2020
Year
Japan Meteorological Agency
Anonalies are deviation fron baseline (1981-2010 Average).
The black thin line indicates surface temperature anomaly of each year.
The blue line indicates their 5-year running mean.
The red line indicates the long-tern linear trend.


NORTHERN HEMISPHERE
Departures in temperature (°C)
from the 1961 to 1990 average
0.5
0.0
−0.5
−1.0
1000
1200
1400
1600
1800
2000
Year
Data from thermometers (red) and from tree rings,
corals, ice cores and historical records (blue).

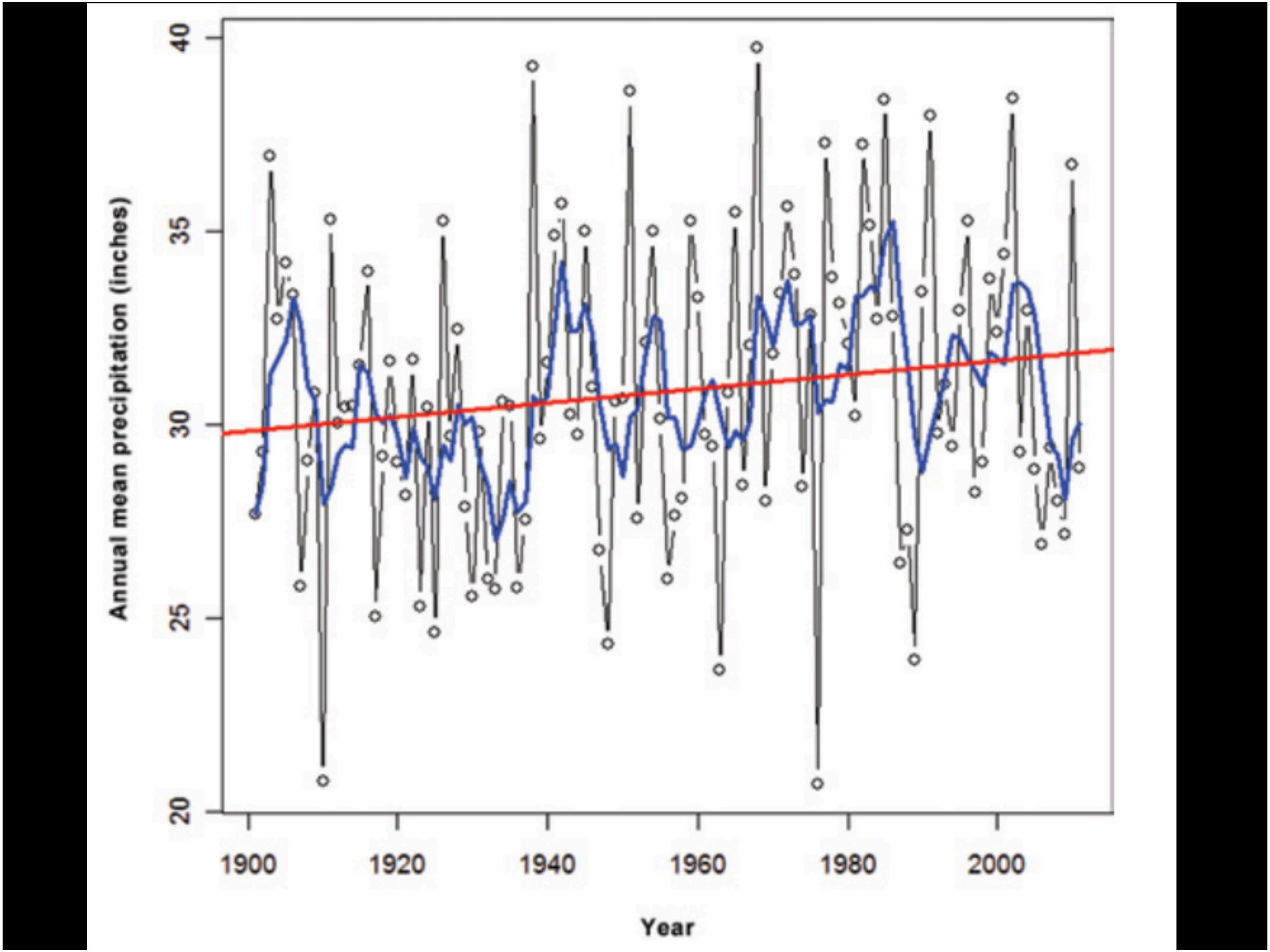

Annual mean temperature (°F)
38
40
42
44
1900
1920
1940
1960
1980
2000
Year

Change in Average Temperature (° F) from 1950 to 2006

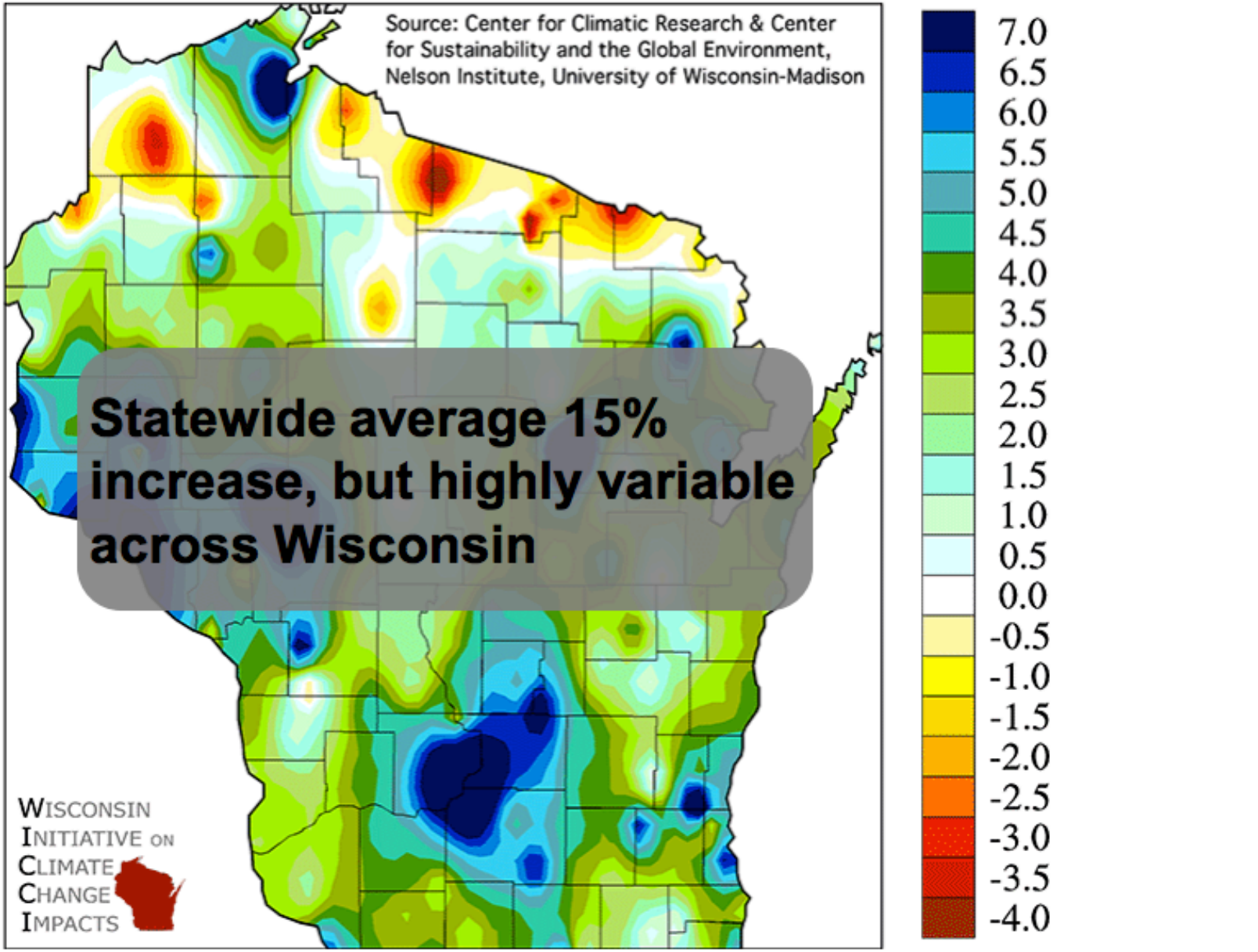


The greatest amount of warming is occurring in Winter and Spring, especially in northwest Wisconsin.

(from Serbin and Kucharik 2009)

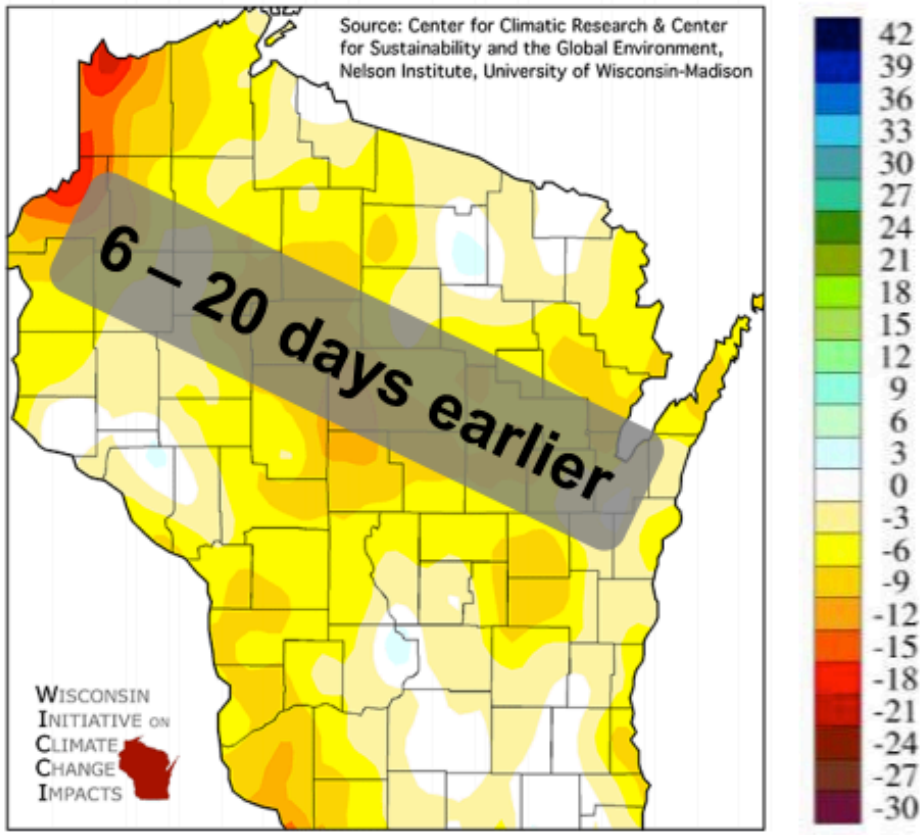

Annual mean precipitation (inches)
20
25
30
35
40
1900
1920
1940
1960
1980
2000
Year

Change in Annual Average Precipitation (inches) from 1950 to 2006

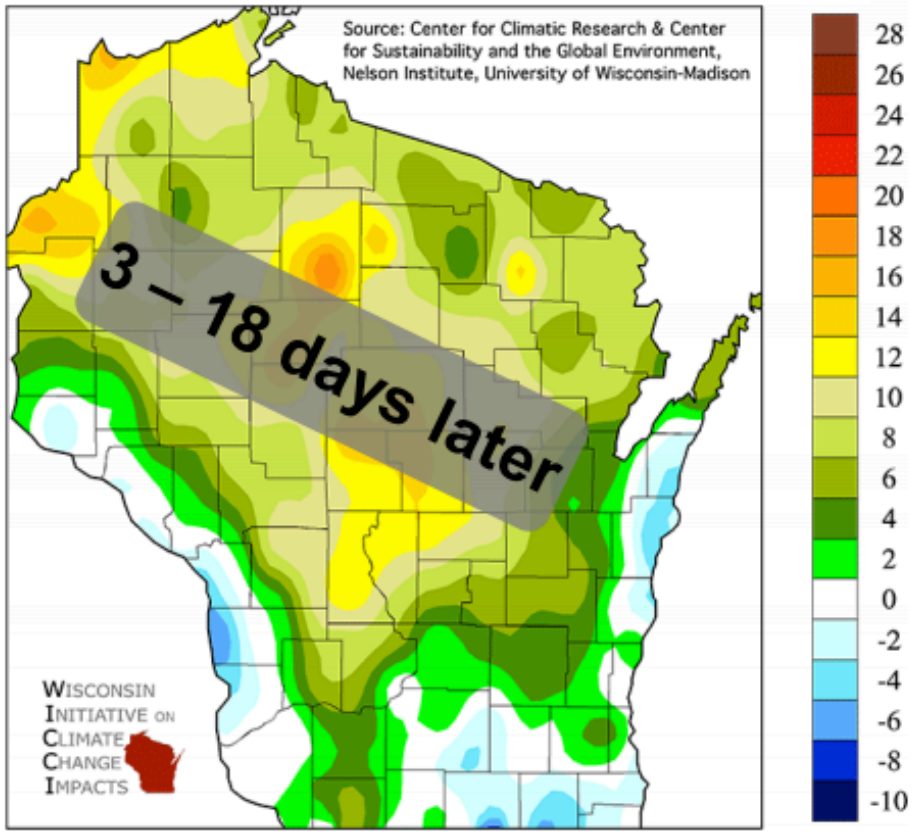


(from Serbin and Kucharik 2009)

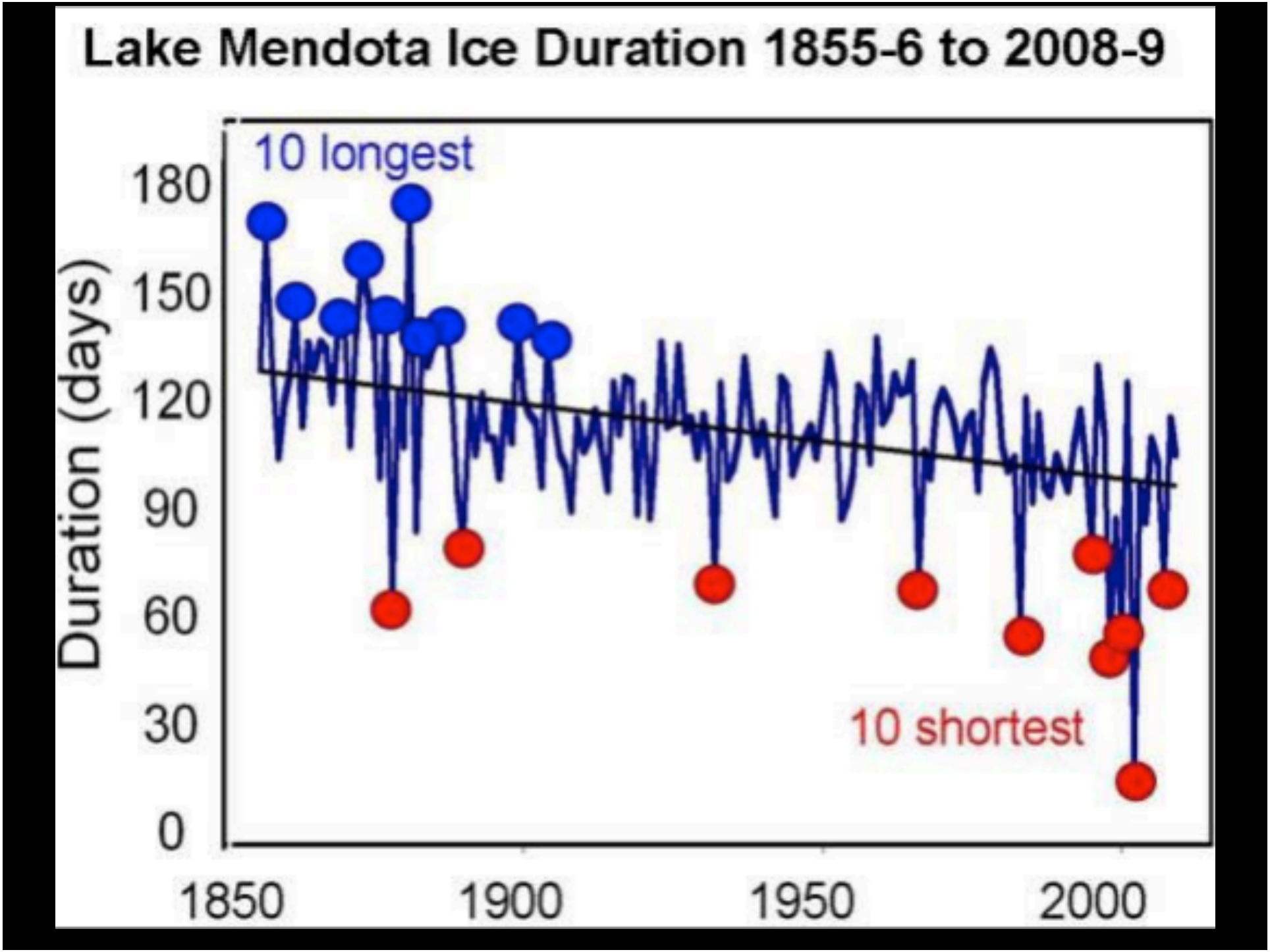
Change in Date of Last Spring Freeze from 1950 to 2006

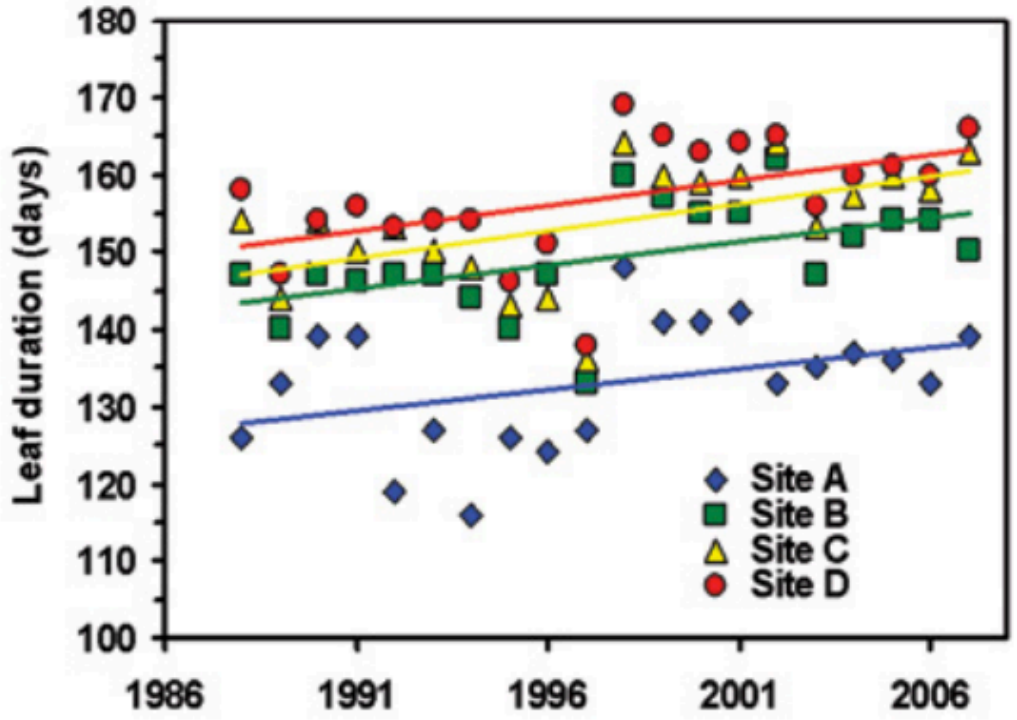


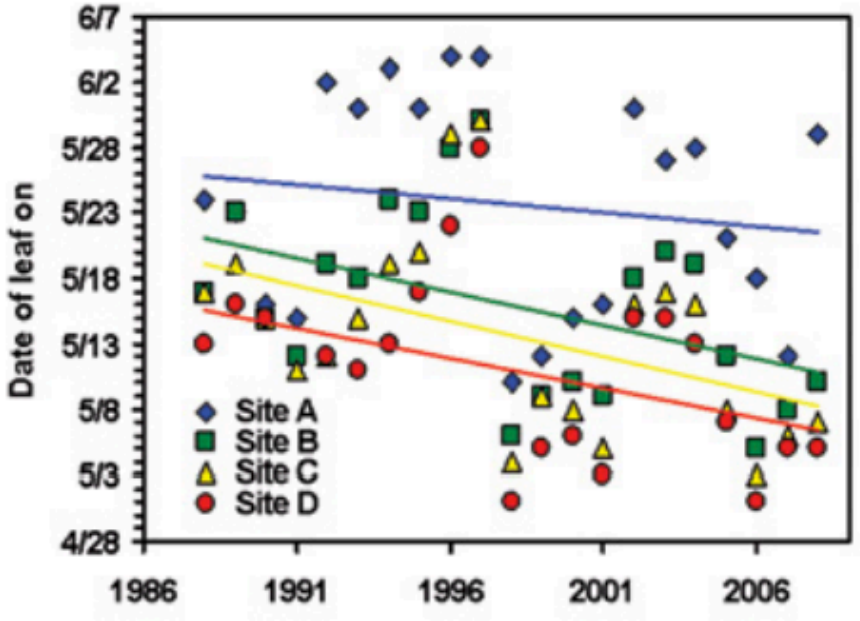
Change in Date of First Fall Freeze from 1950 to 2006

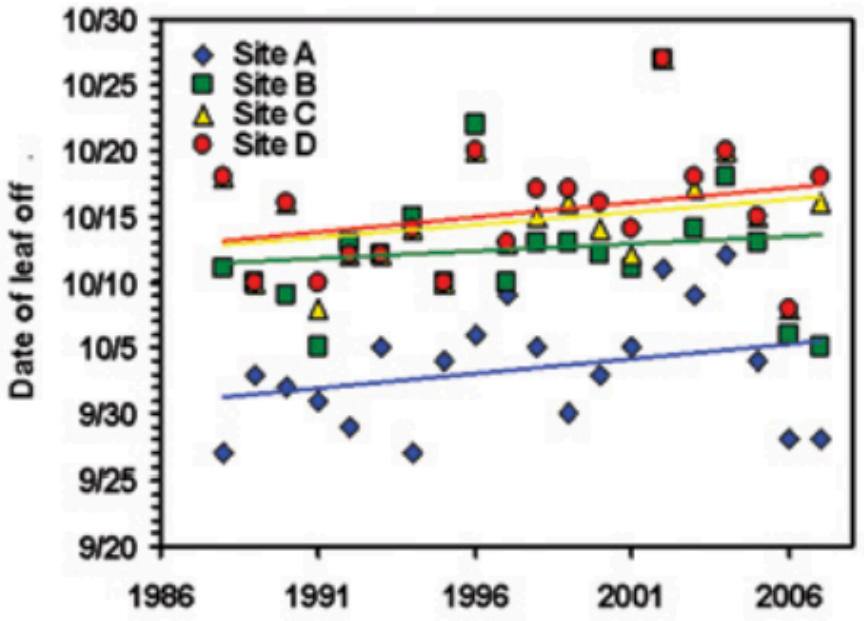


(from Serbin and Kucharik 2009)


Lake Mendota Ice Duration 1855-6 to 2008-9
10 longest
10 shortest
Duration (days)
180
150
120
90
60
30
0
1850
1900
1950
2000


Leaf duration (days)
180
170
160
150
140
130
120
110
100
1986
1991
1996
2001
2006
Site A
Site B
Site C
Site D


Date of leaf on
6/7
6/2
5/28
5/23
5/18
5/13
5/8
5/3
4/28
1986
1991
1996
2001
2006
Site A
Site B
Site C
Site D


Date of leaf off
10/30
10/25
10/20
10/15
10/10
10/5
9/30
9/25
9/20
1986
1991
1996
2001
2006
Site A
Site B
Site C
Site D

Earlier arrival of spring in Wisconsin

Bird migration	Vegetation
Geese Arrival: 29 days	*Baptista* first bloom: 18 days
Cardinal first song: 22 days	*Butterfly weed* first bloom: 18 days
Robin arrival: 9 days	*Marsh milkweed* first bloom: 13 days

Nina Leopold Bradley

Photo: Jeffrey Phelps, Milw. Journal Sentinel

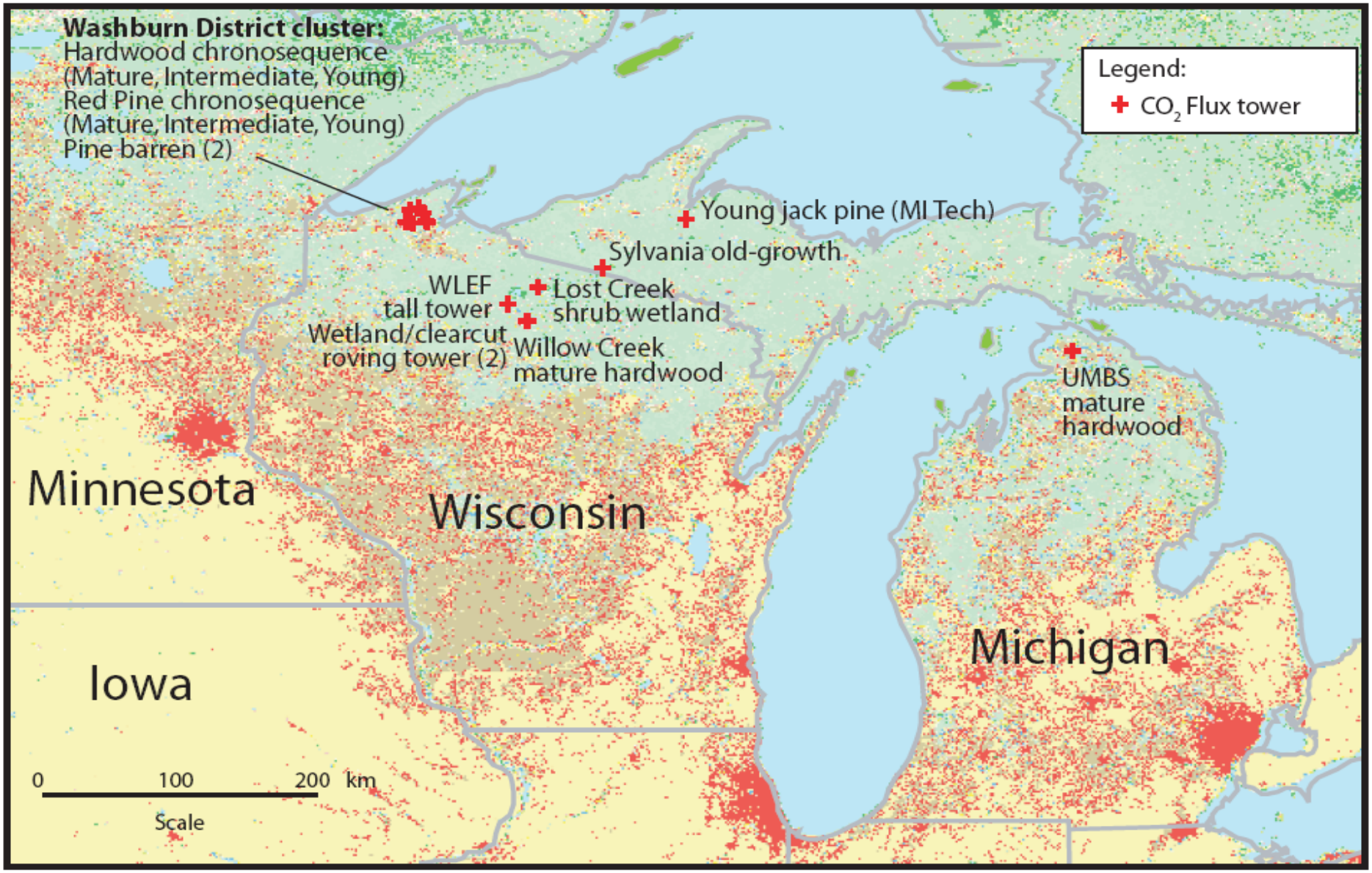
Leopold Shack

Photo: Aldo Leopold Foundation

55 ecological indicators of spring occurred on average 1.2 days earlier per decade from 1936 to 1998.

Source: Bradley et al., 1999. Phenological changes reflect climate change in Wisconsin. Proc. Natl. Acad. Sci., 96: 9701-9704.

Slide adapted from C. Kucharik, UW-Madison

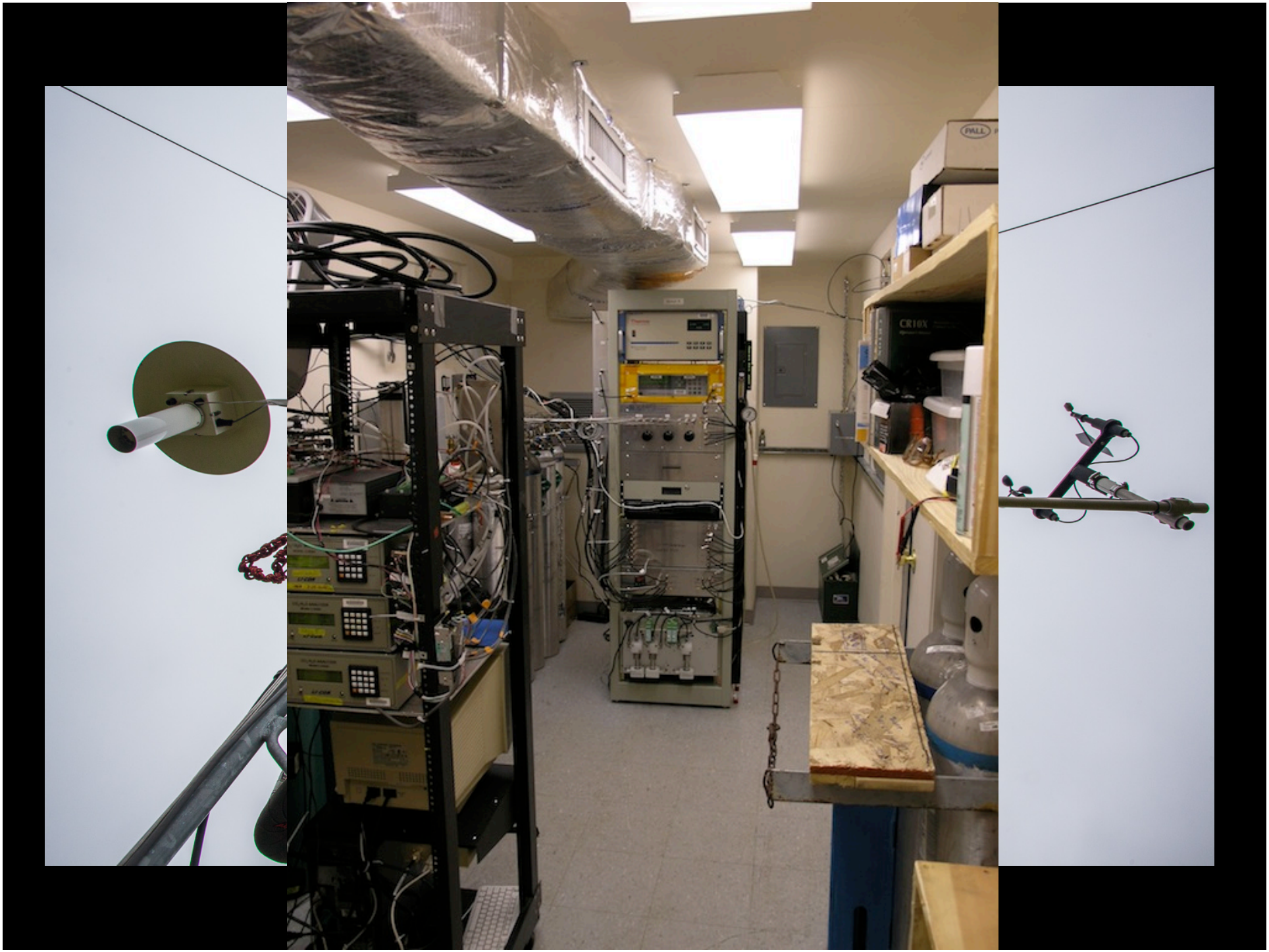

Washburn District cluster:
Hardwood chronosequence
(Mature, Intermediate, Young)
Red Pine chronosequence
(Mature, Intermediate, Young)
Pine barren (2)
Legend:
CO2 Flux tower
Young jack pine (MI Tech)
Sylvania old-growth
WLEF
tall tower
Lost Creek
shrub wetland
Wetland/clearcut
roving tower (2)
Willow Creek
mature hardwood
UMBS
mature
hardwood
Minnesota
Wisconsin
Michigan
Iowa
0
100
200 km
Scale

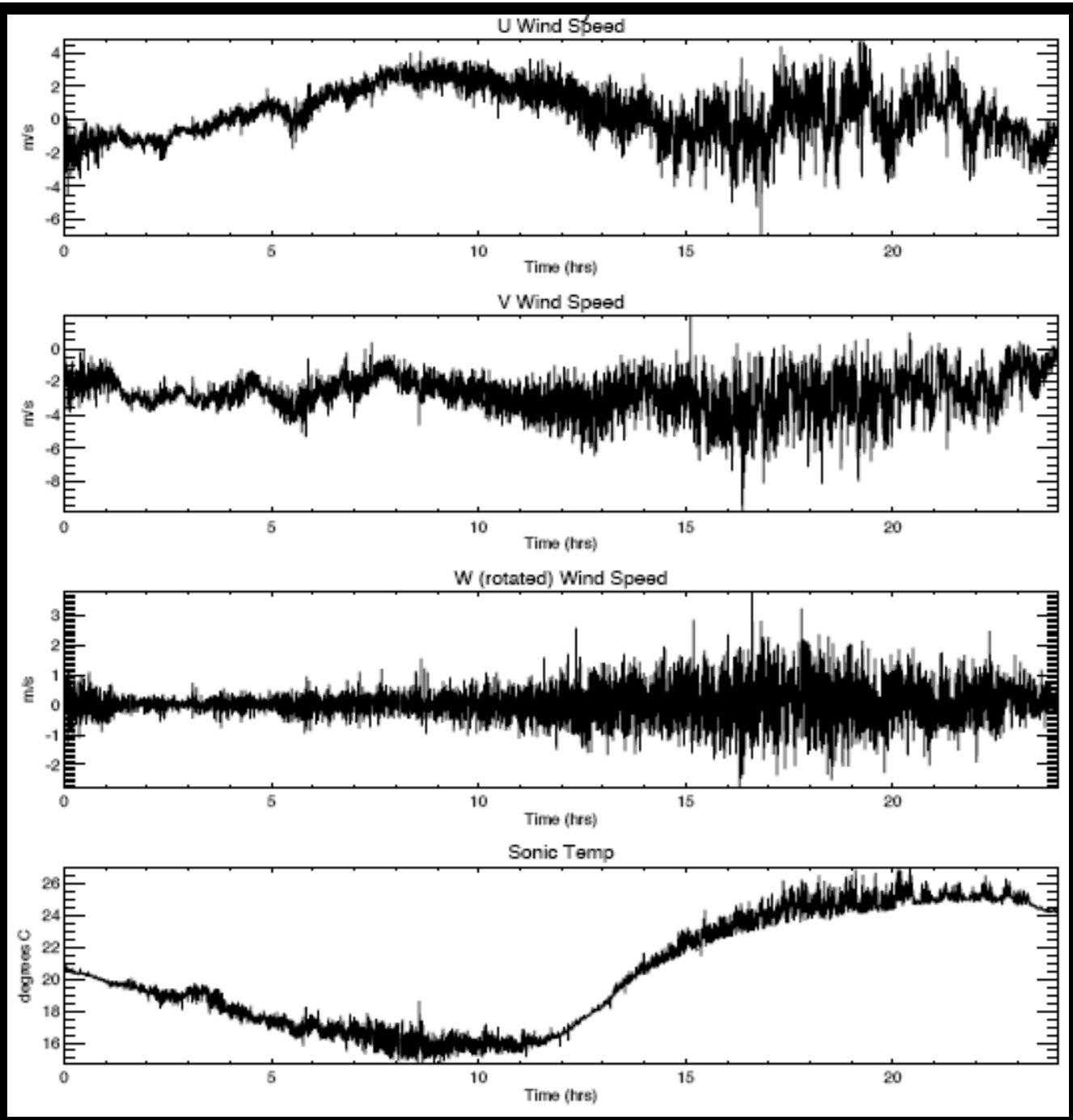

Clear-cut

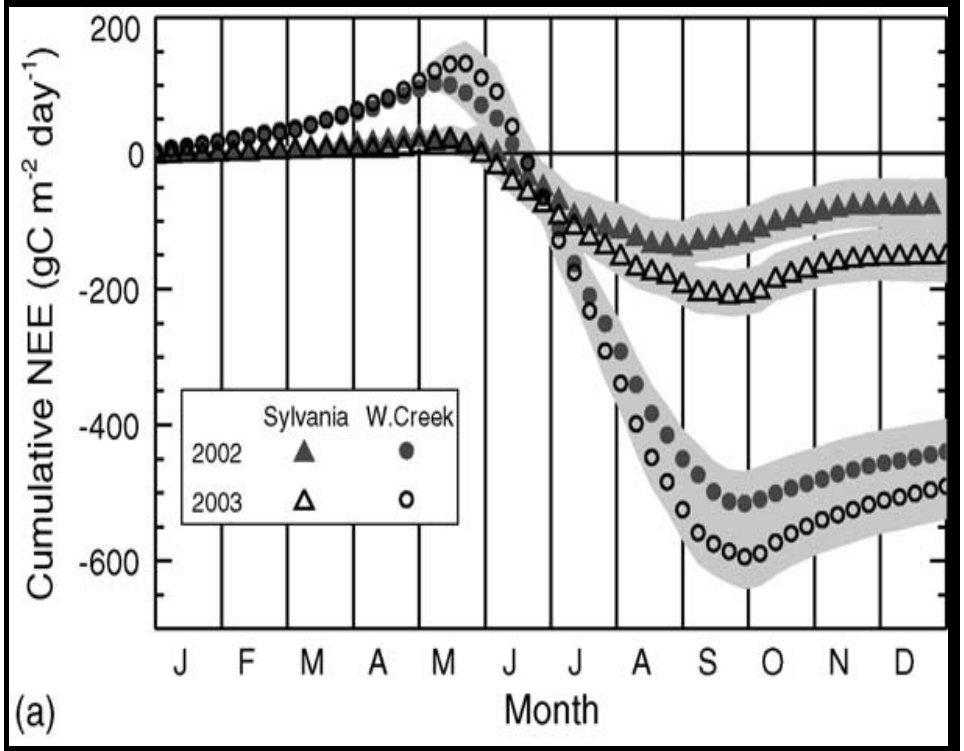

Young

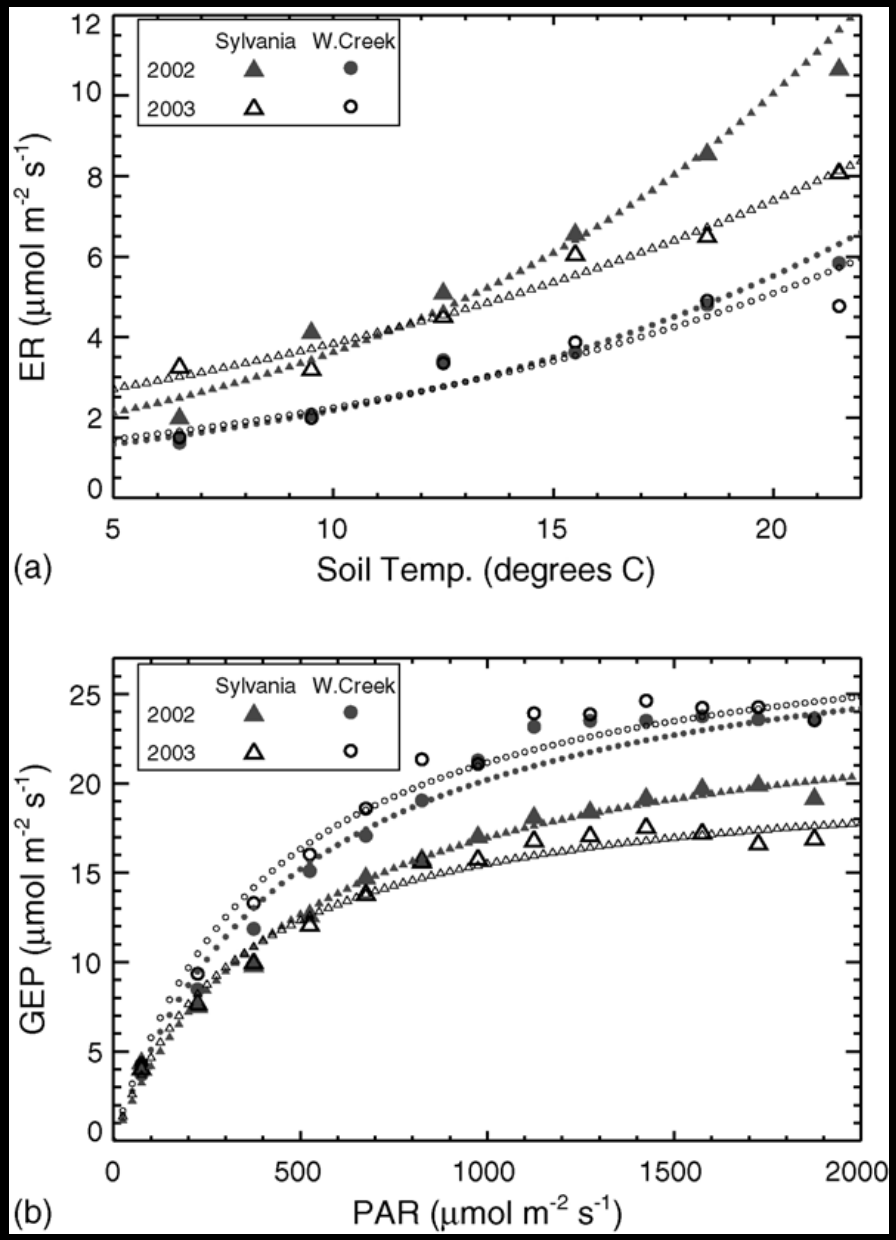

Mature


Old-growth

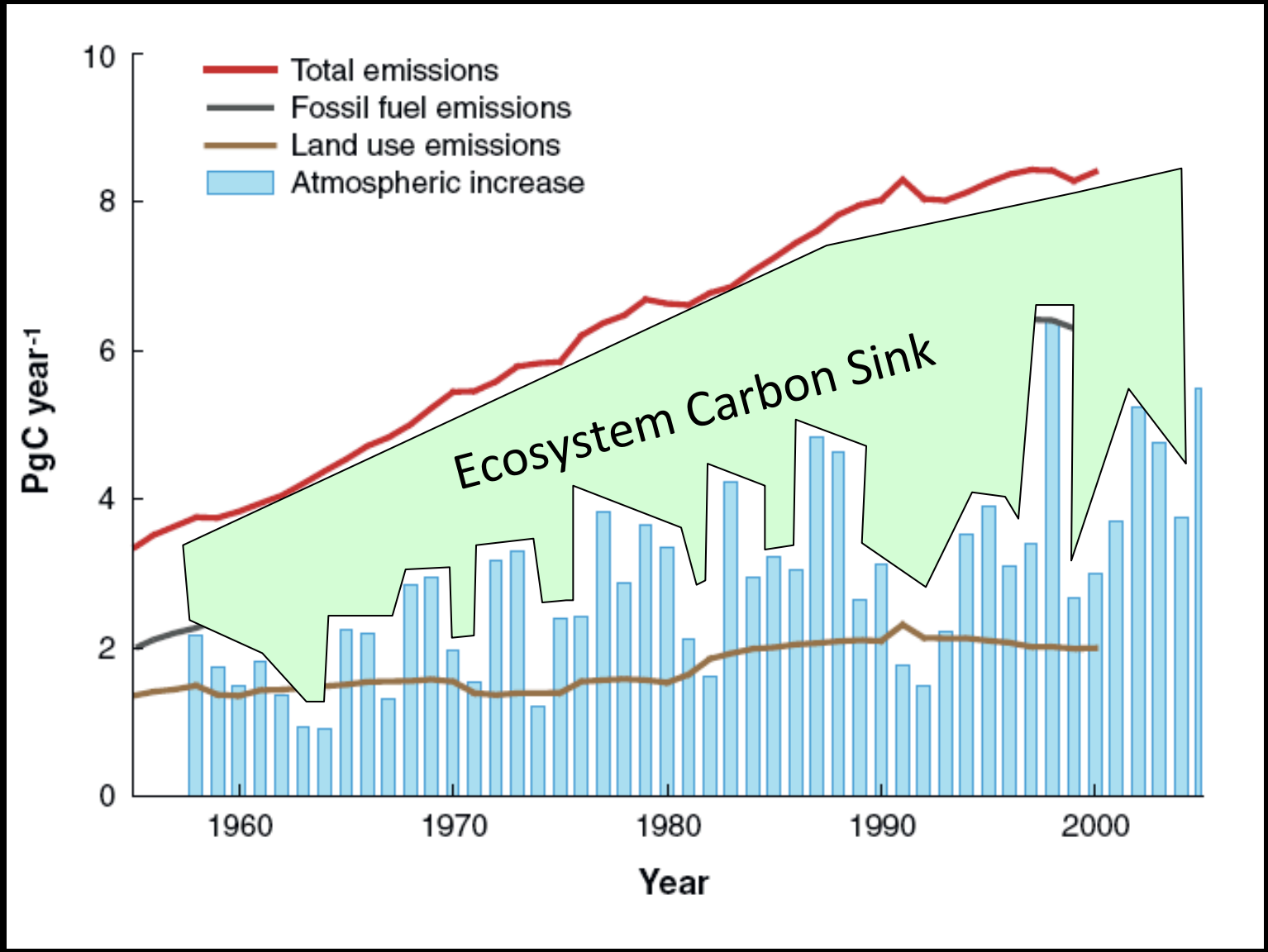

CR10X


U Wind Speed
m/s
Time (hrs)
V Wind Speed
m/s
Time (hrs)
W (rotated) Wind Speed
m/s
Time (hrs)
Sonic Temp
degrees C
Time (hrs)

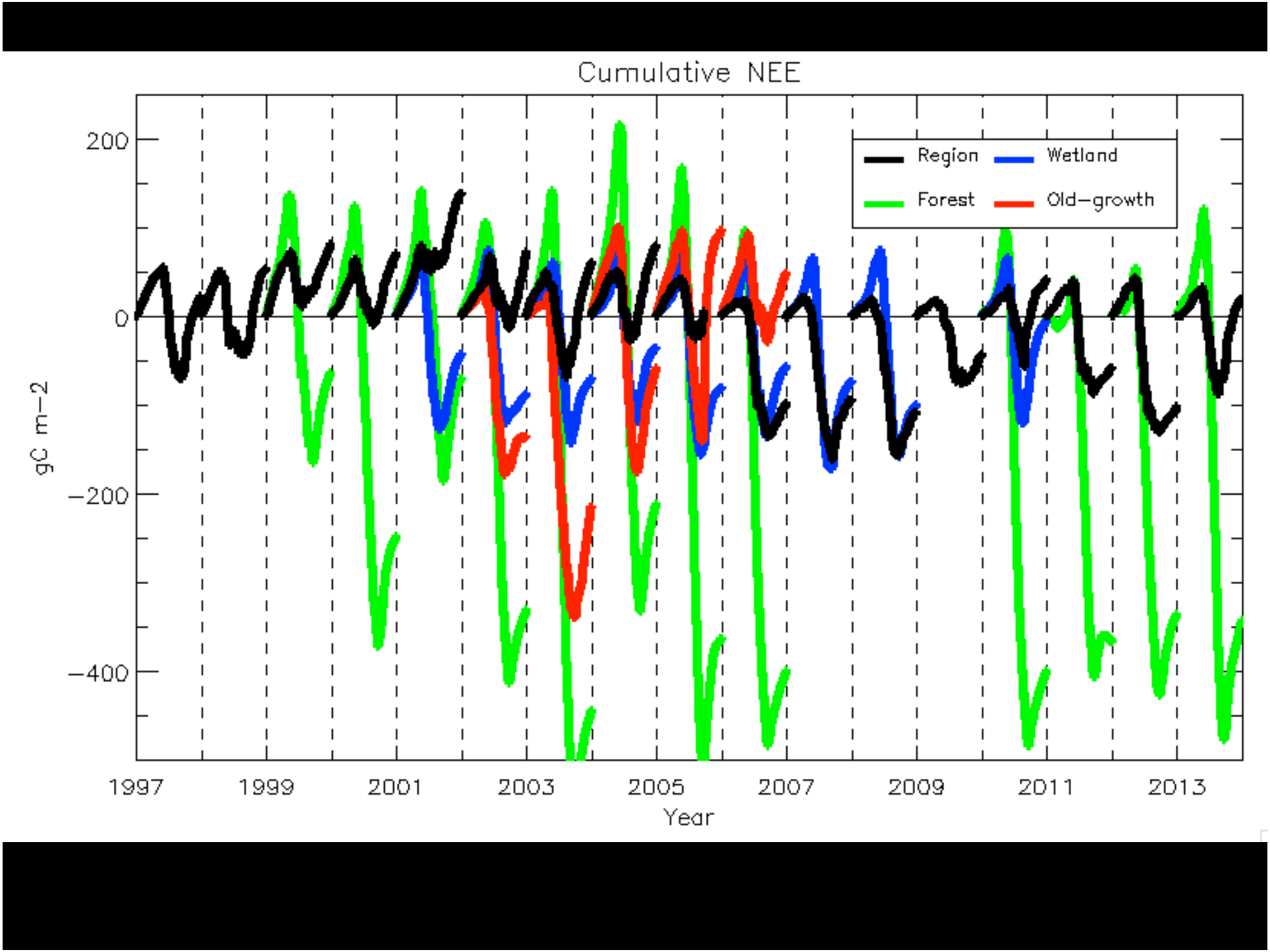


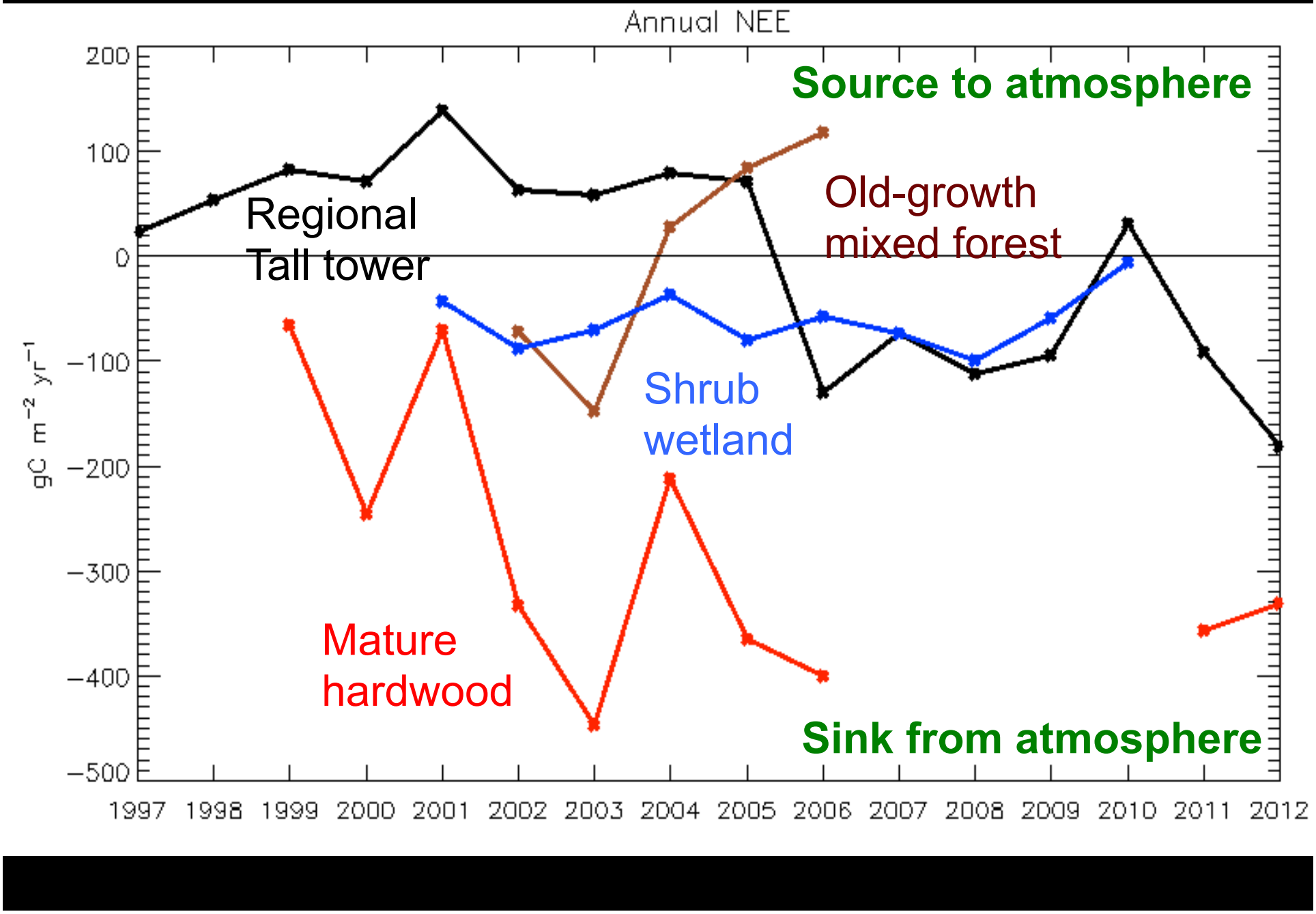


Desai et al., 2005



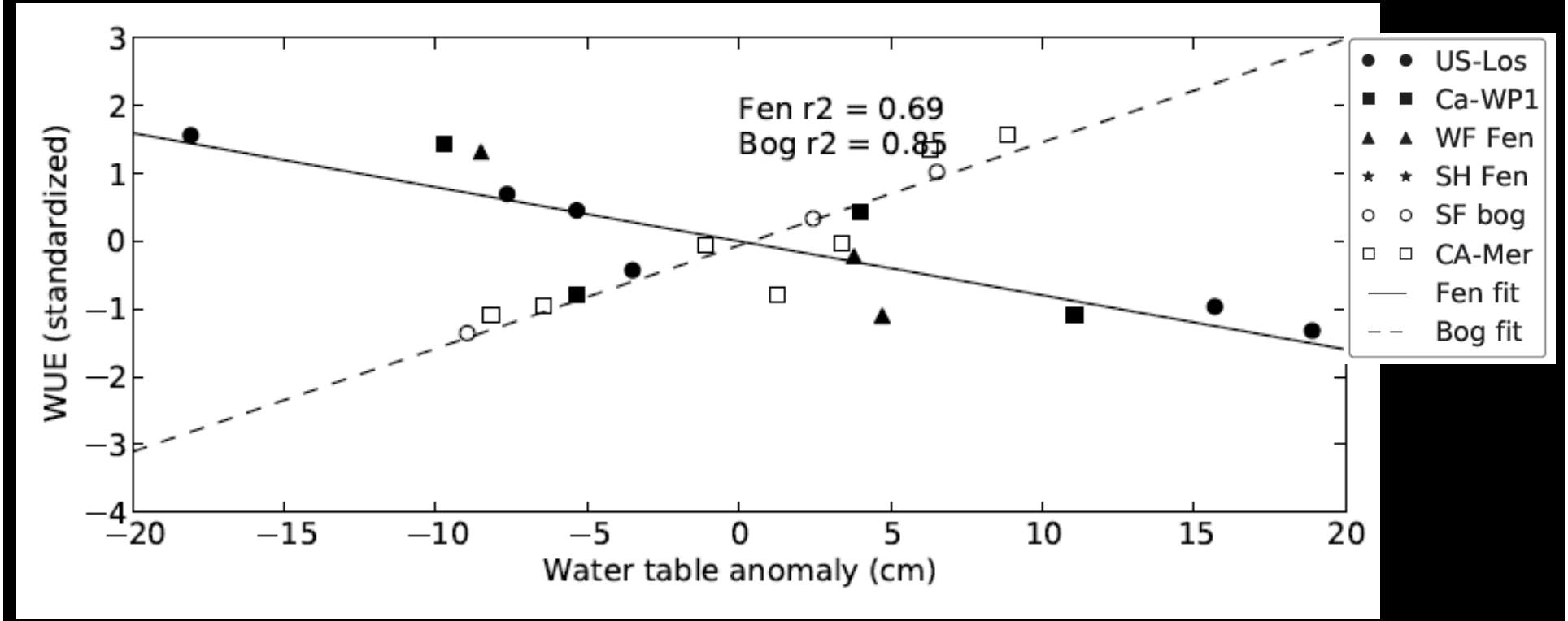
Houghton et al. (2007)


Cumulative NEE
Region
Wetland
Forest
Old−growth
200
0
−200
−400
gC m−2
1997
1999
2001
2003
2005
2007
2009
2011
2013
Year


Annual NEE
Source to atmosphere
Regional
Tall tower
Old-growth
mixed forest
Shrub
wetland
Mature
hardwood
Sink from atmosphere
gC m^{-2} yr^{-1}
200
100
0
−100
−200
−300
−400
−500
1997
1998
1999
2000
2001
2002
2003
2004
2005
2006
2007
2008
2009
2010
2011
2012

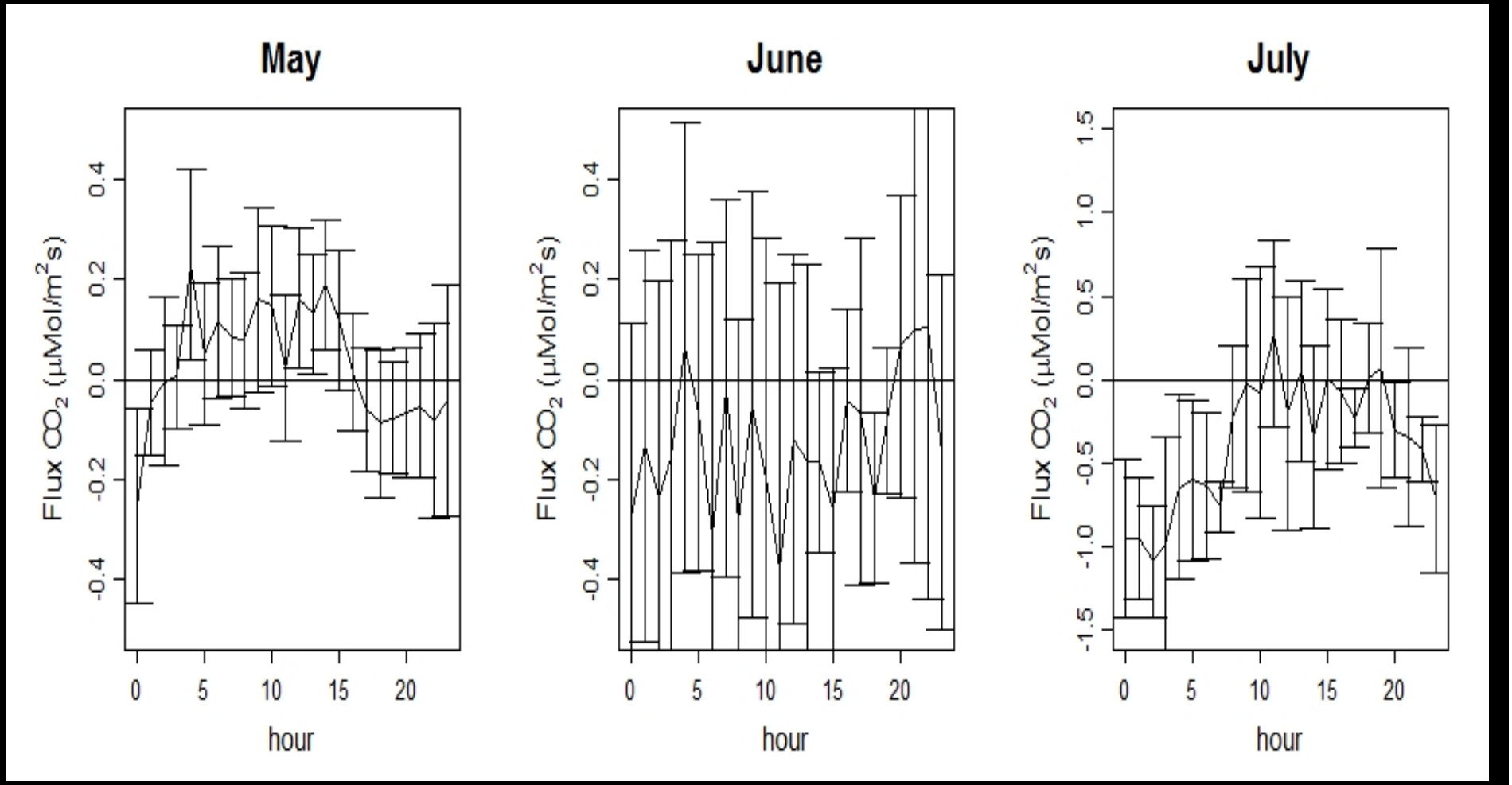
Wetlands are interesting…

- Adaptation of plants to drying conditions leads to increases in water use efficiency, especially for fens

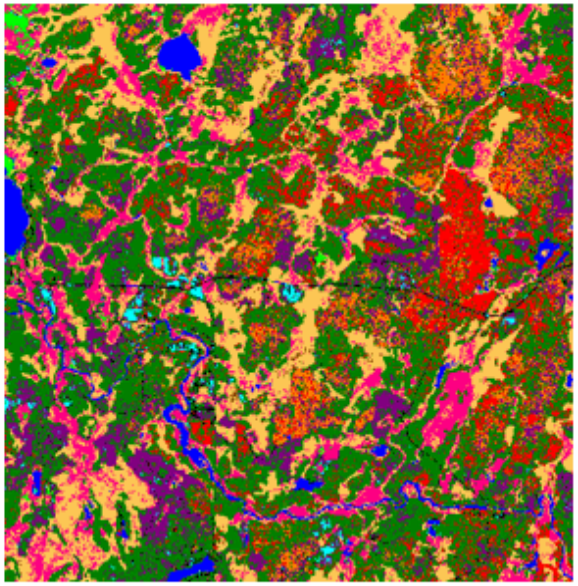
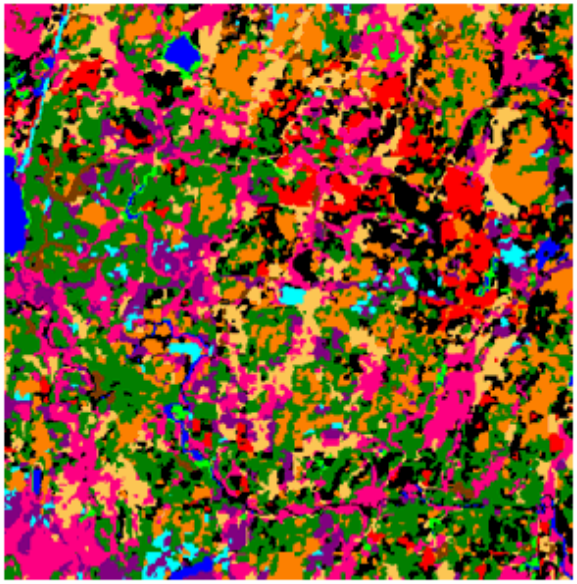
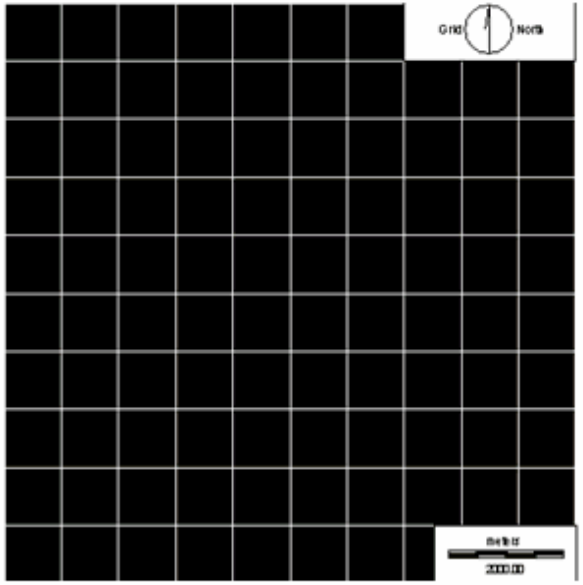


Sulman et al. (in prep)

Trout Lake



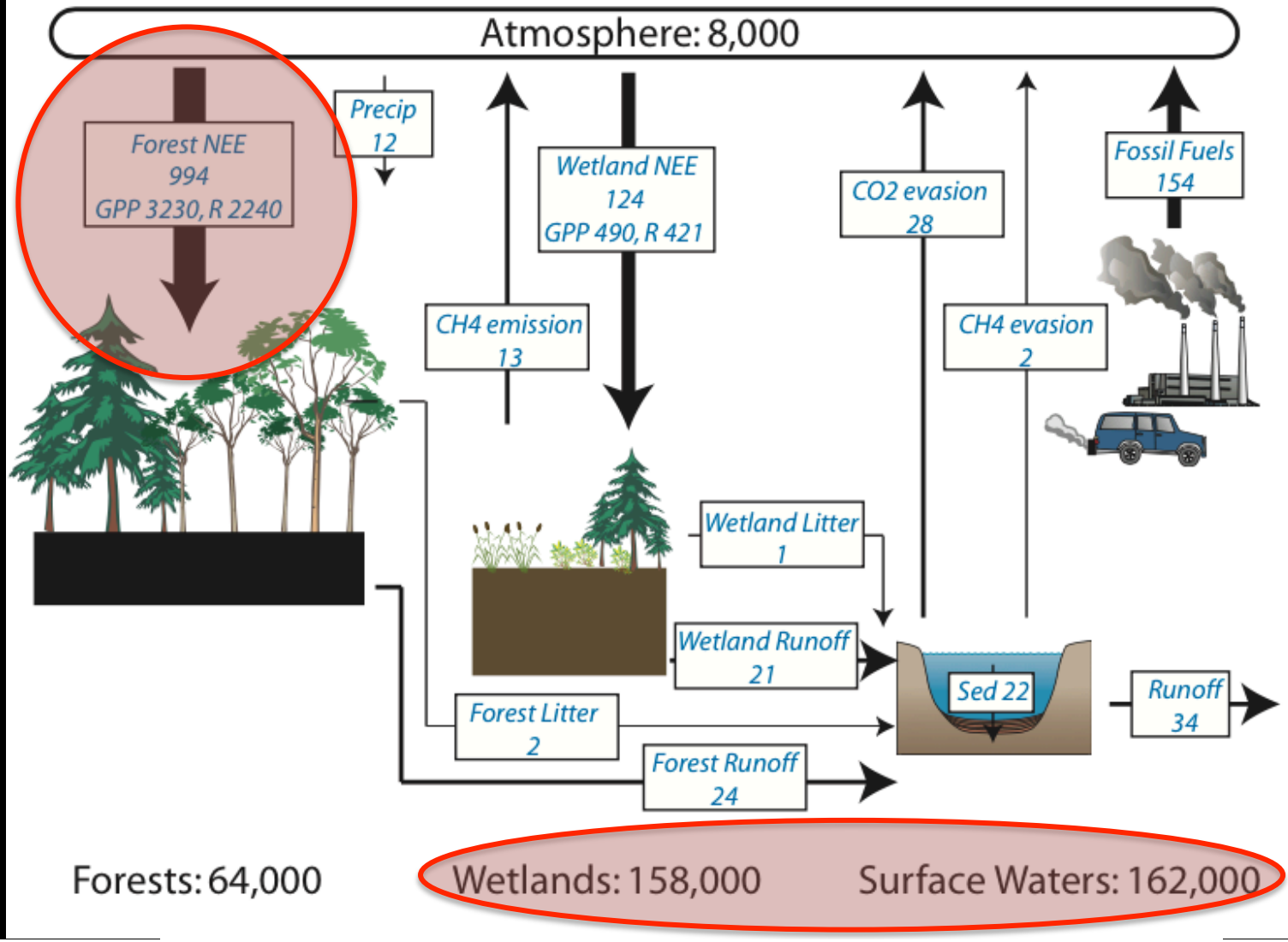
M. Balliett, UW

a) IKONOS.	b) WISCLAND.	c) MODIS-UMD and IGBP.
		
— Mixed Forest 13.3% Upland Conifer 34.8% Aspen-Birch 5.7% Upland Hardwood 12.0% Upland Opening/Shrub 0.9% Grassland 17.8% Lowland Conifer 0.7% Lowland Deciduous 10.6% Lowland Shrub 0.6% Wet Meadow 2.6% Open Water 1.0% Road	7.1% Mixed Forest 13.0% Upland Conifer 25.3% Aspen-Birch 14.6% Upland Hardwood 6.8% Upland Opening/Shrub 1.8% Grassland 10.7% Lowland Conifer 1.9% Lowland Deciduous 16.3% Lowland Shrub 1.0% Wet Meadow 1.6% Open Water — Road	100% Mixed Forest

Buffam et al., 2011, GCB

Flux rates in Gg-C yr-1

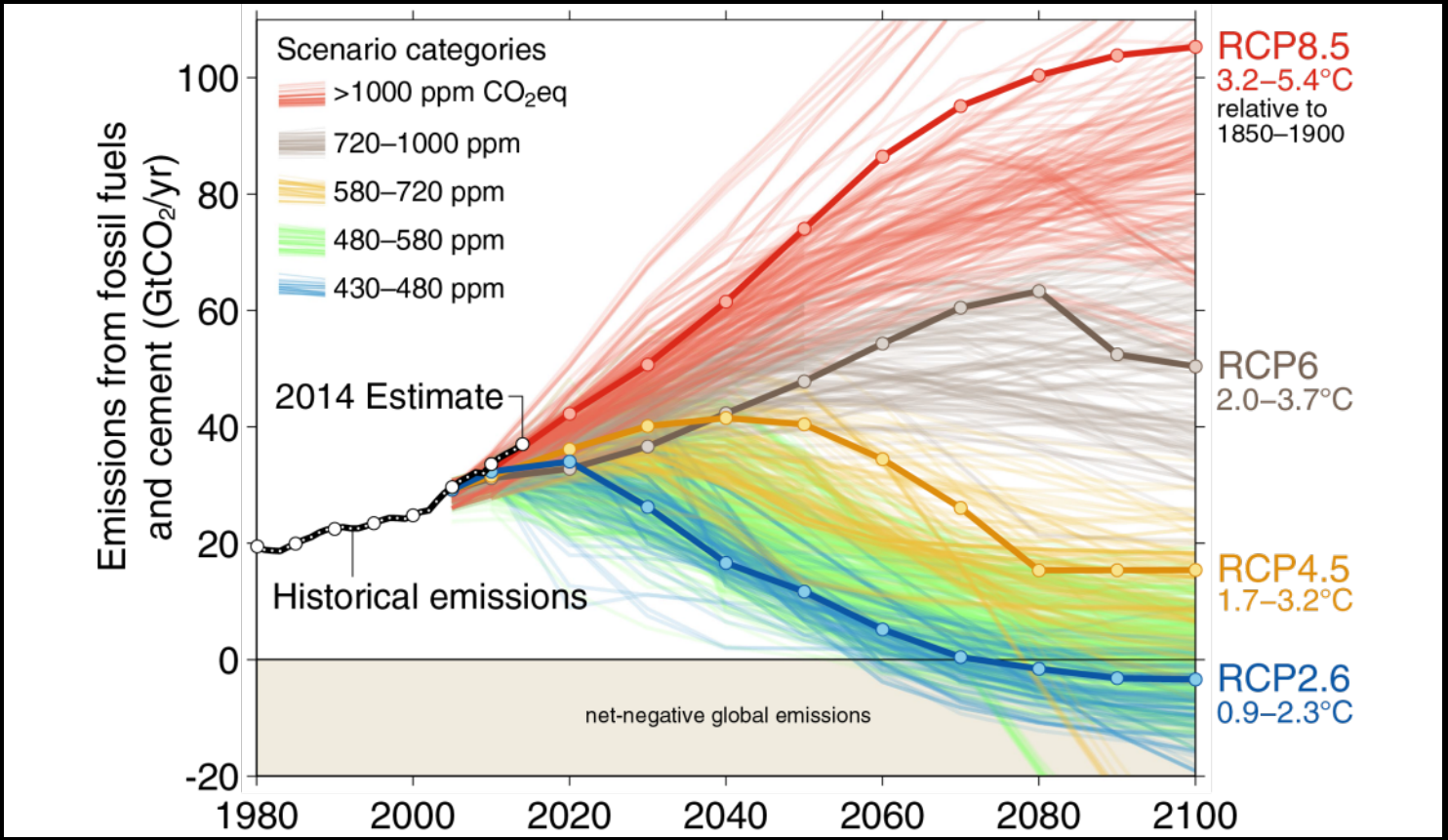
Pool sizes in Gg-C



Observed Emissions and Emissions Scenarios

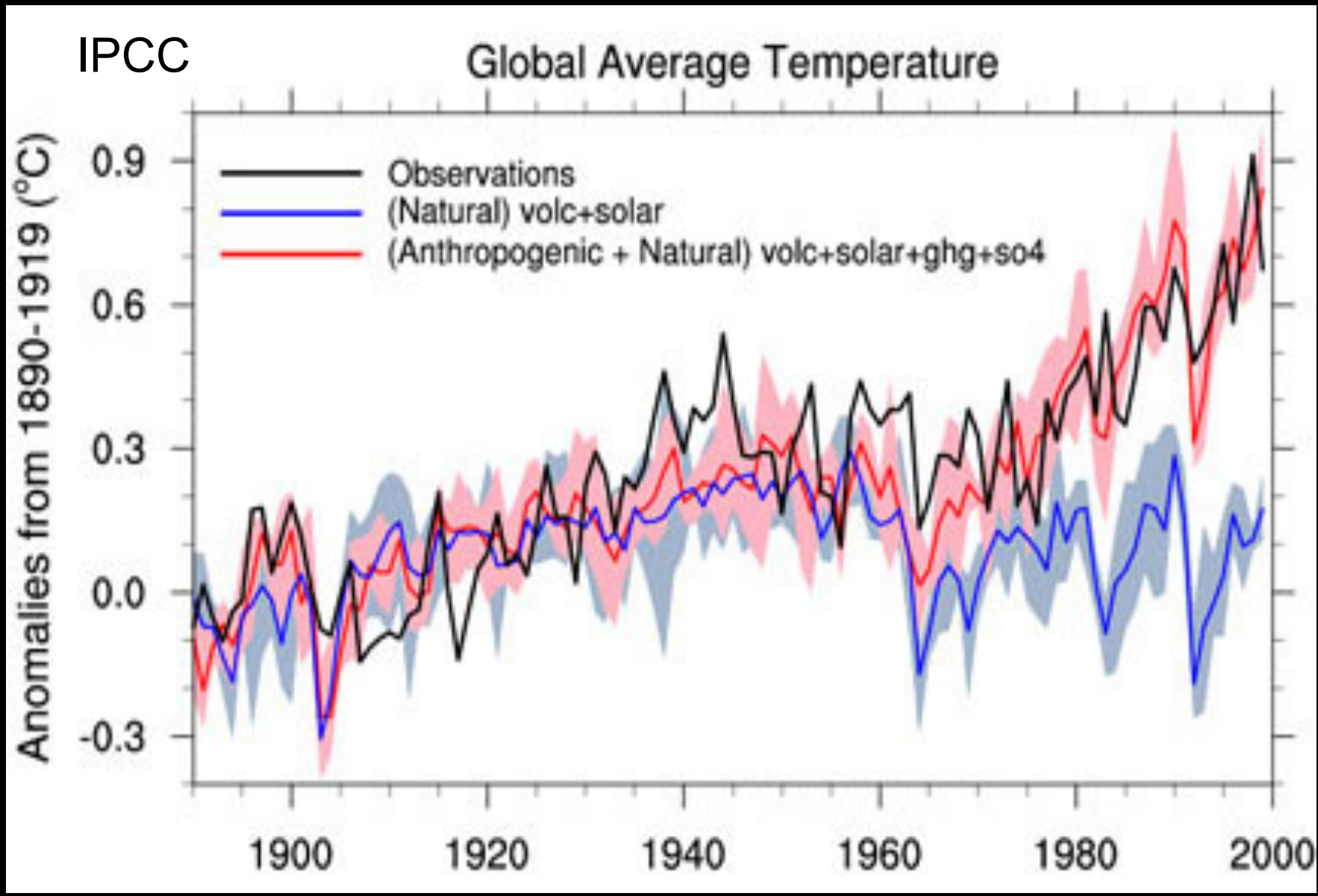
Emissions are on track for 3.2–5.4ºC "likely" increase in temperature above pre-industrial
Large and sustained mitigation is required to keep below 2ºC

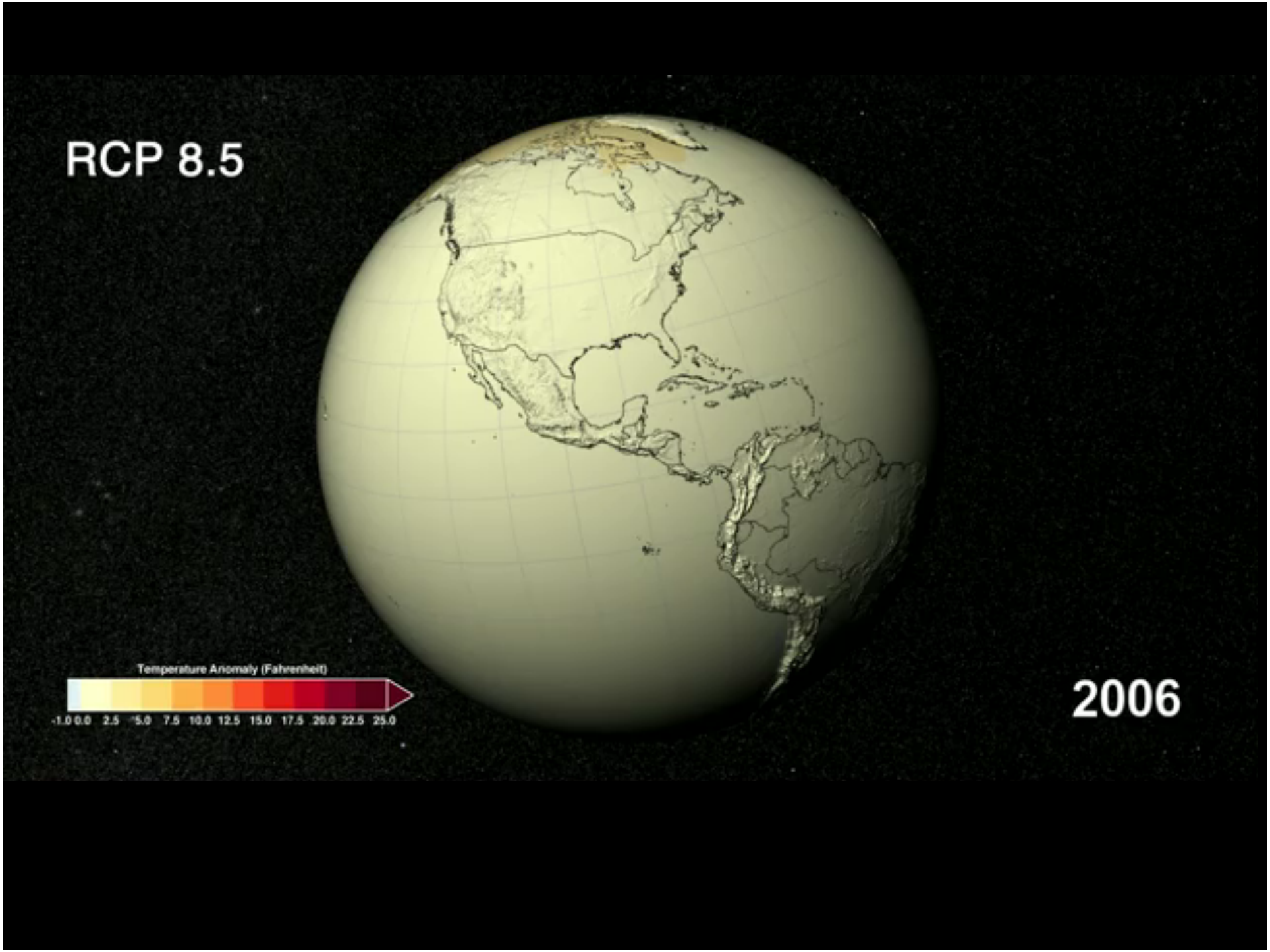
Data: CDIAC/GCP/IPCC/Fuss et al 2014

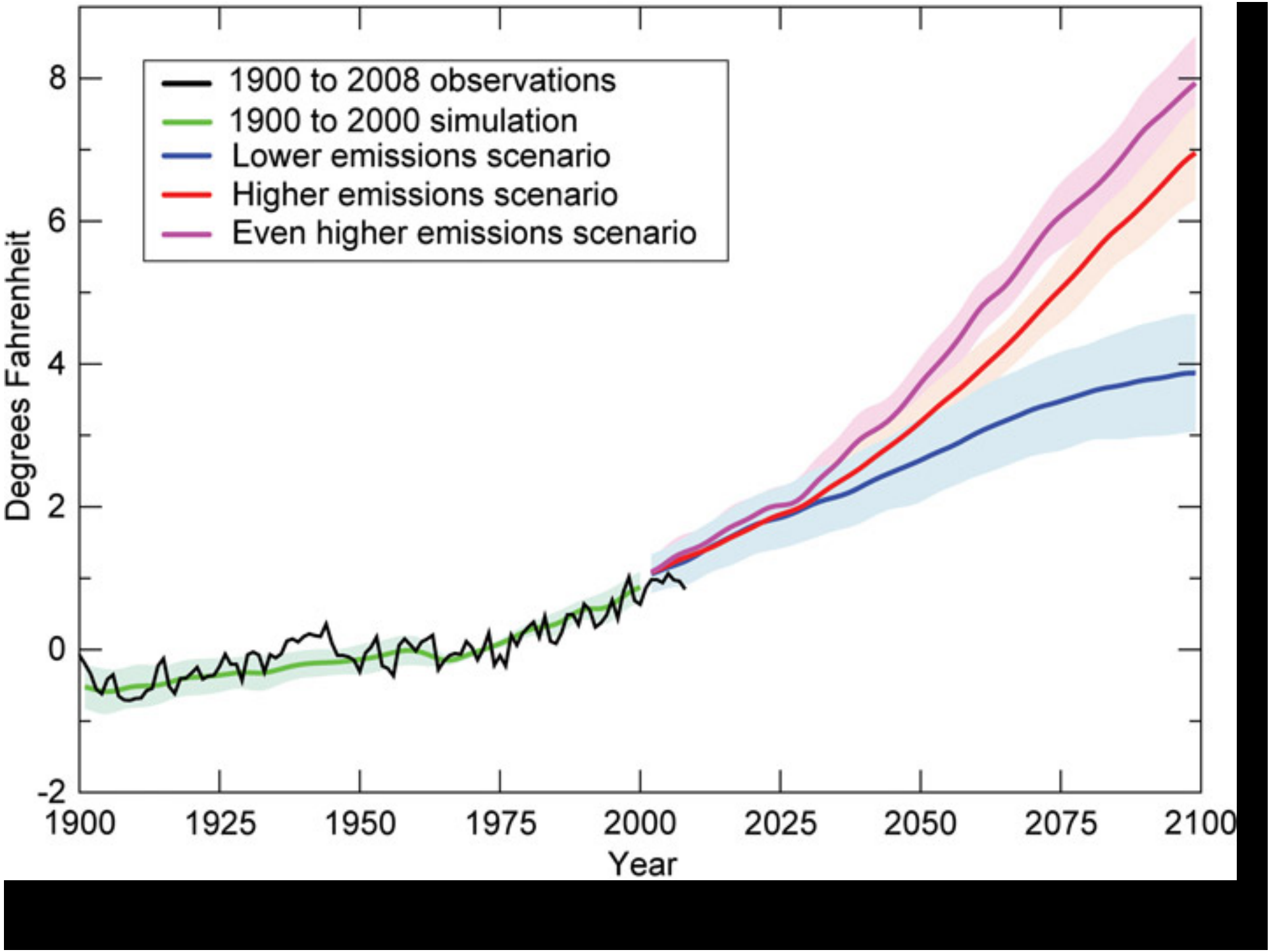


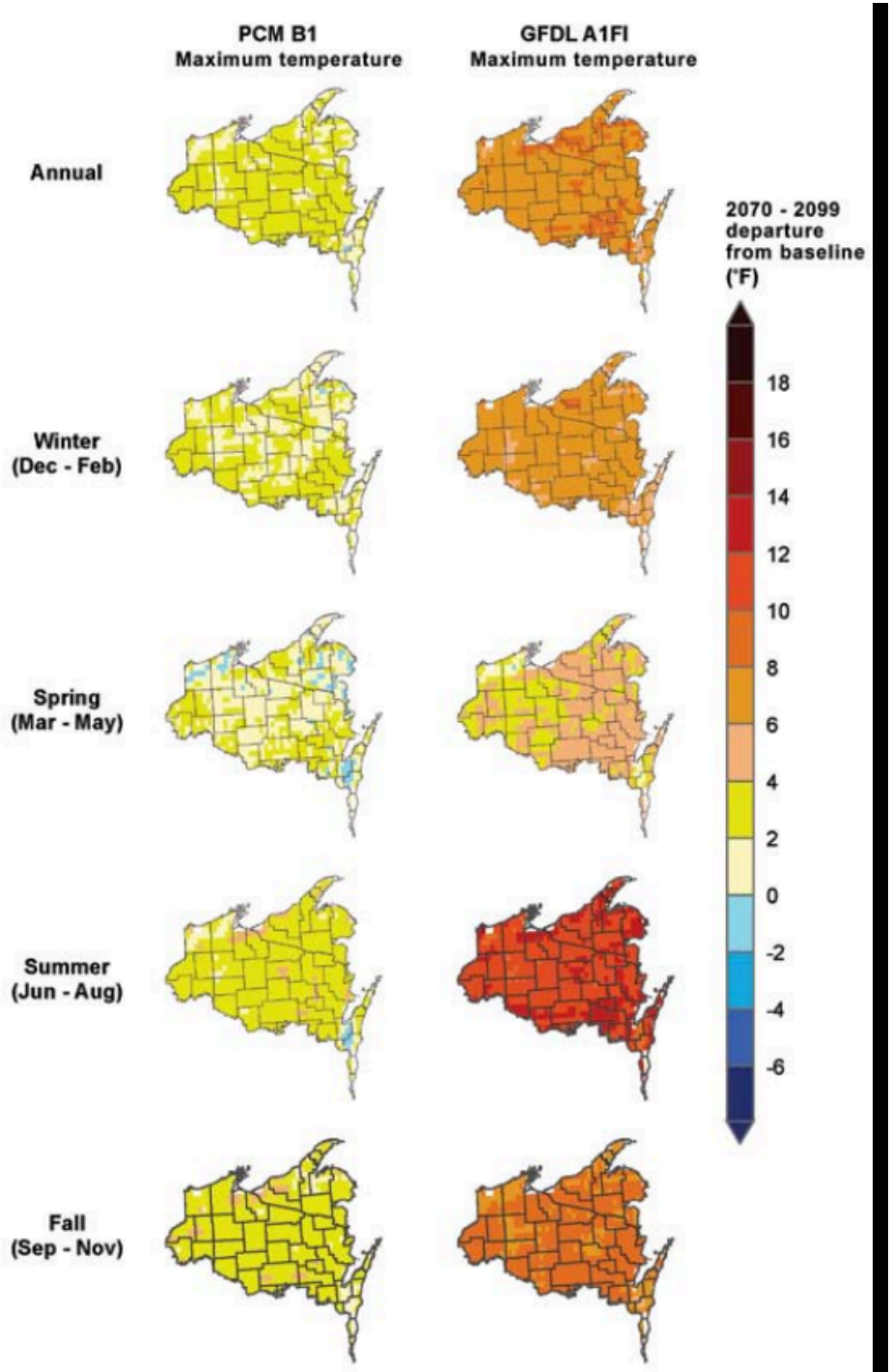
Over 1000 scenarios from the IPCC Fifth Assessment Report are shown

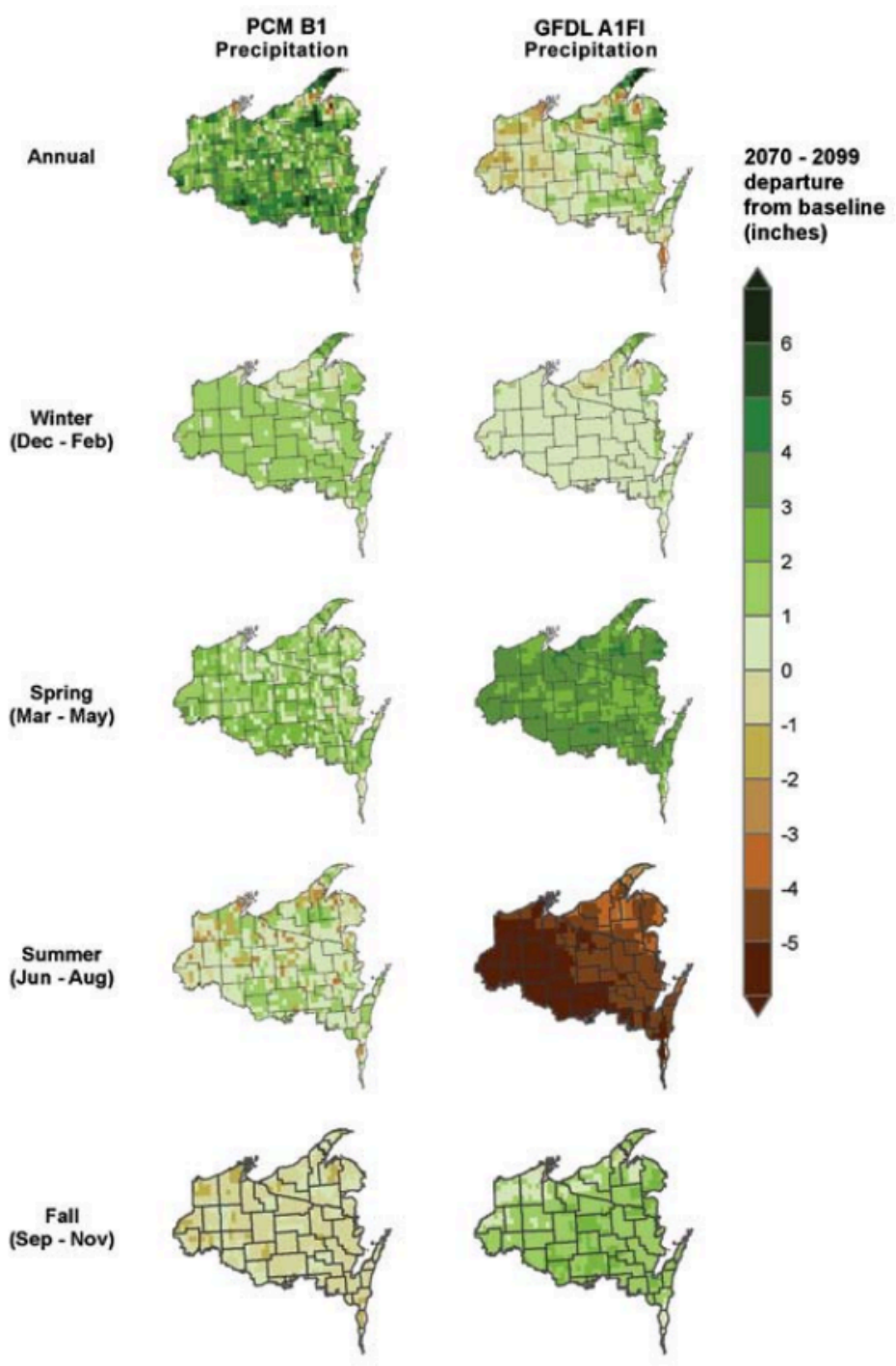
Source: Fuss et al 2014; CDIAC; Global Carbon Budget 2014


IPCC
Global Average Temperature
Anomalies from 1890-1919 (°C)
0.9
0.6
0.3
0.0
-0.3
Observations
(Natural) volc+solar
(Anthropogenic + Natural) volc+solar+ghg+so4
1900
1920
1940
1960
1980
2000


RCP 8.5
Temperature Anomaly (Fahrenheit)
-1.0 0.0 2.5 5.0 7.5 10.0 12.5 15.0 17.5 20.0 22.5 25.0
2006

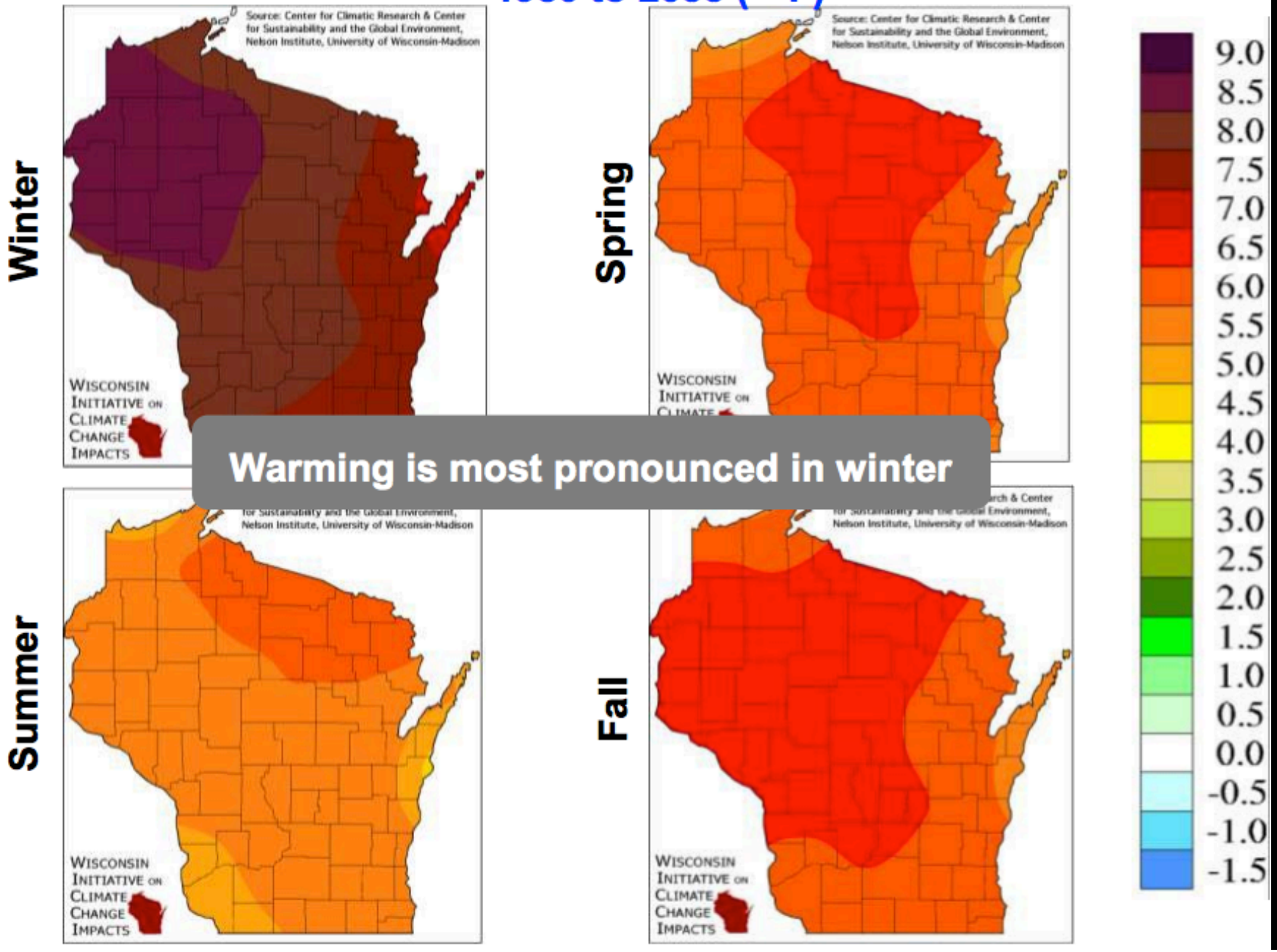

1900 to 2008 observations
1900 to 2000 simulation
Lower emissions scenario
Higher emissions scenario
Even higher emissions scenario
Degrees Fahrenheit
8
6
4
2
0
-2
1900
1925
1950
1975
2000
2025
2050
2075
2100
Year


PCM B1
Maximum temperature
GFDL A1FI
Maximum temperature
Annual
Winter
(Dec - Feb)
Spring
(Mar - May)
Summer
(Jun - Aug)
Fall
(Sep - Nov)
2070 - 2099
departure
from baseline
(°F)
18
16
14
12
10
8
6
4
2
0
-2
-4
-6


PCM B1
Precipitation
GFDL A1FI
Precipitation
Annual
Winter
(Dec - Feb)
Spring
(Mar - May)
Summer
(Jun - Aug)
Fall
(Sep - Nov)
2070 - 2099
departure
from baseline
(inches)
6
5
4
3
2
1
0
-1
-2
-3
-4
-5

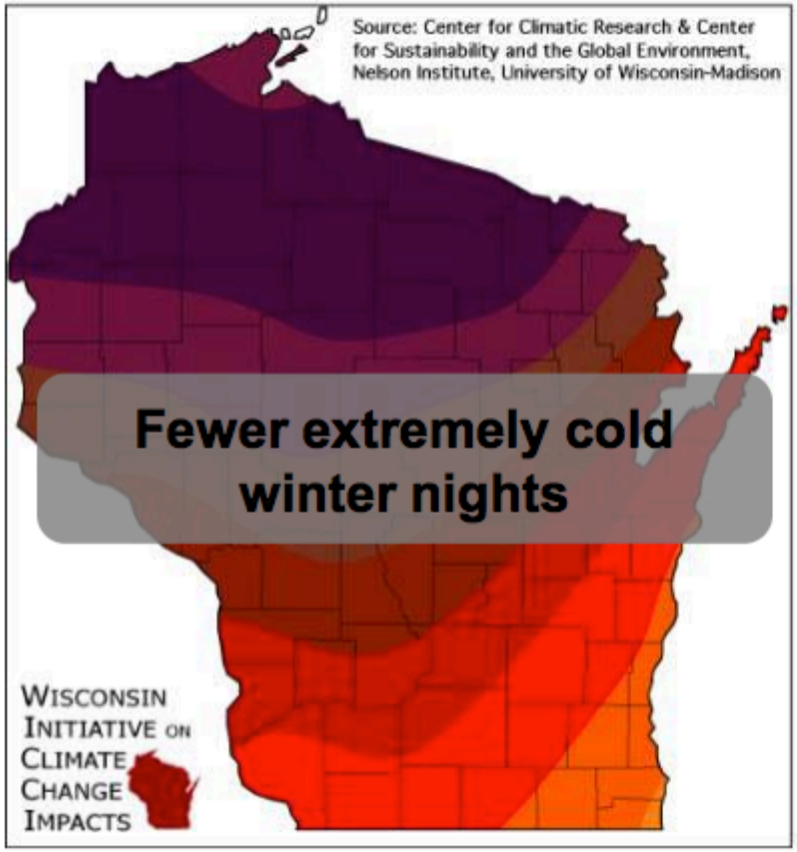
Projected Change in Seasonal Temperatures

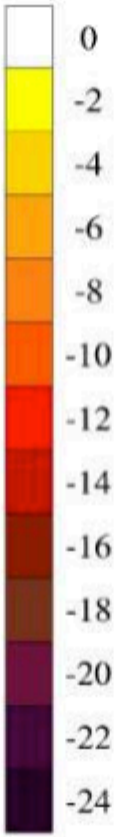
1980 to 2055 (° F)



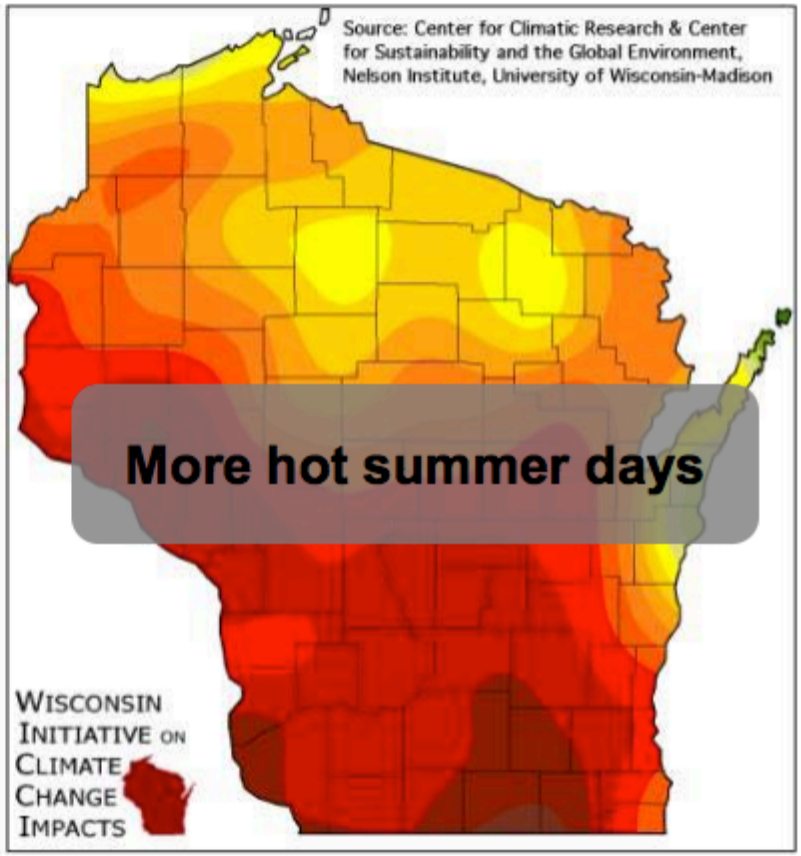
Warming is most pronounced in winter

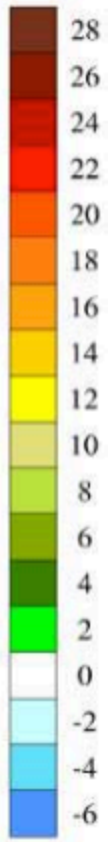
Projected change in the frequency of <0° F nights per year from 1980 to 2055



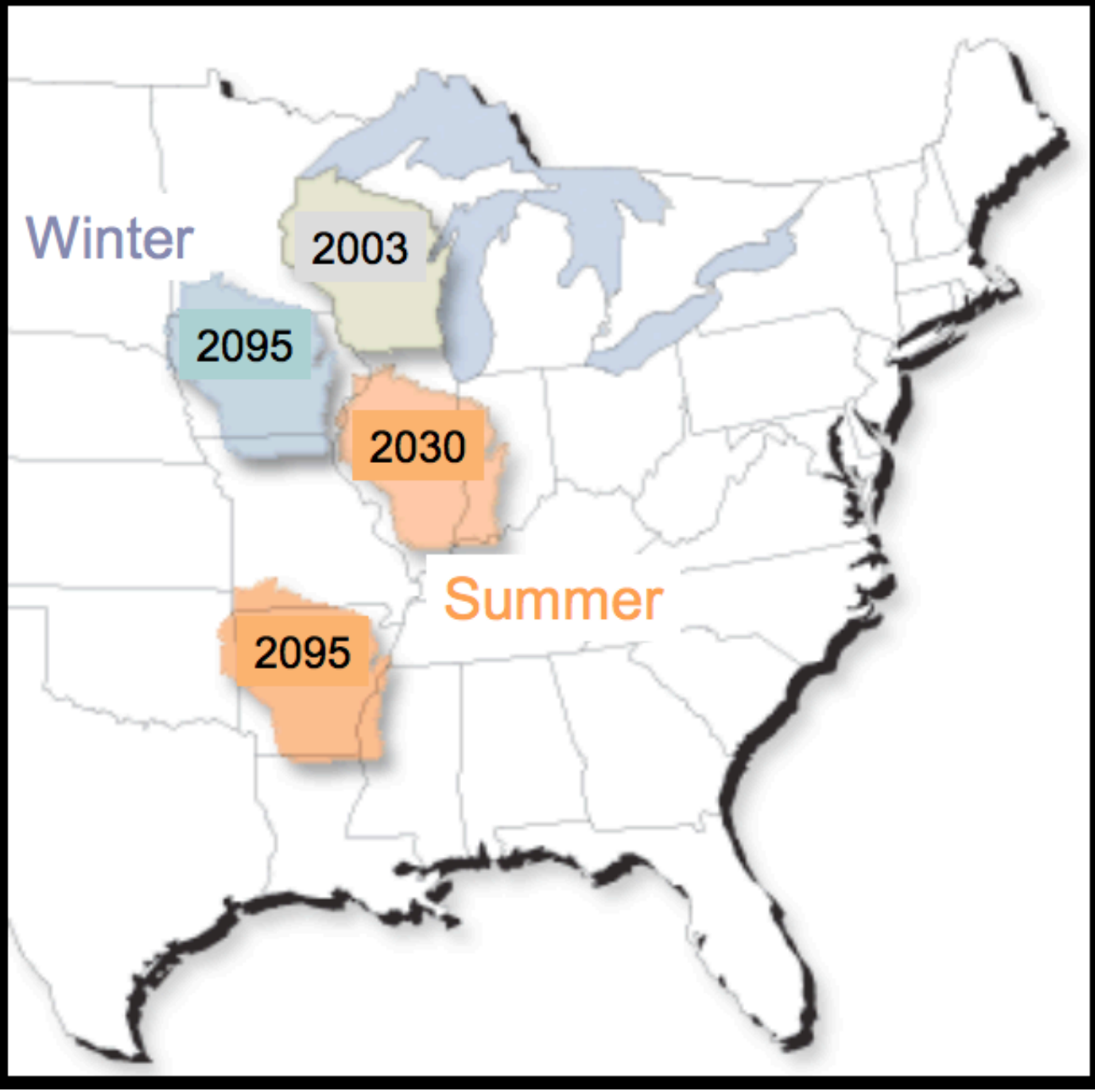


Projected change in the frequency of ≥90° F days per year from 1980 to 2055



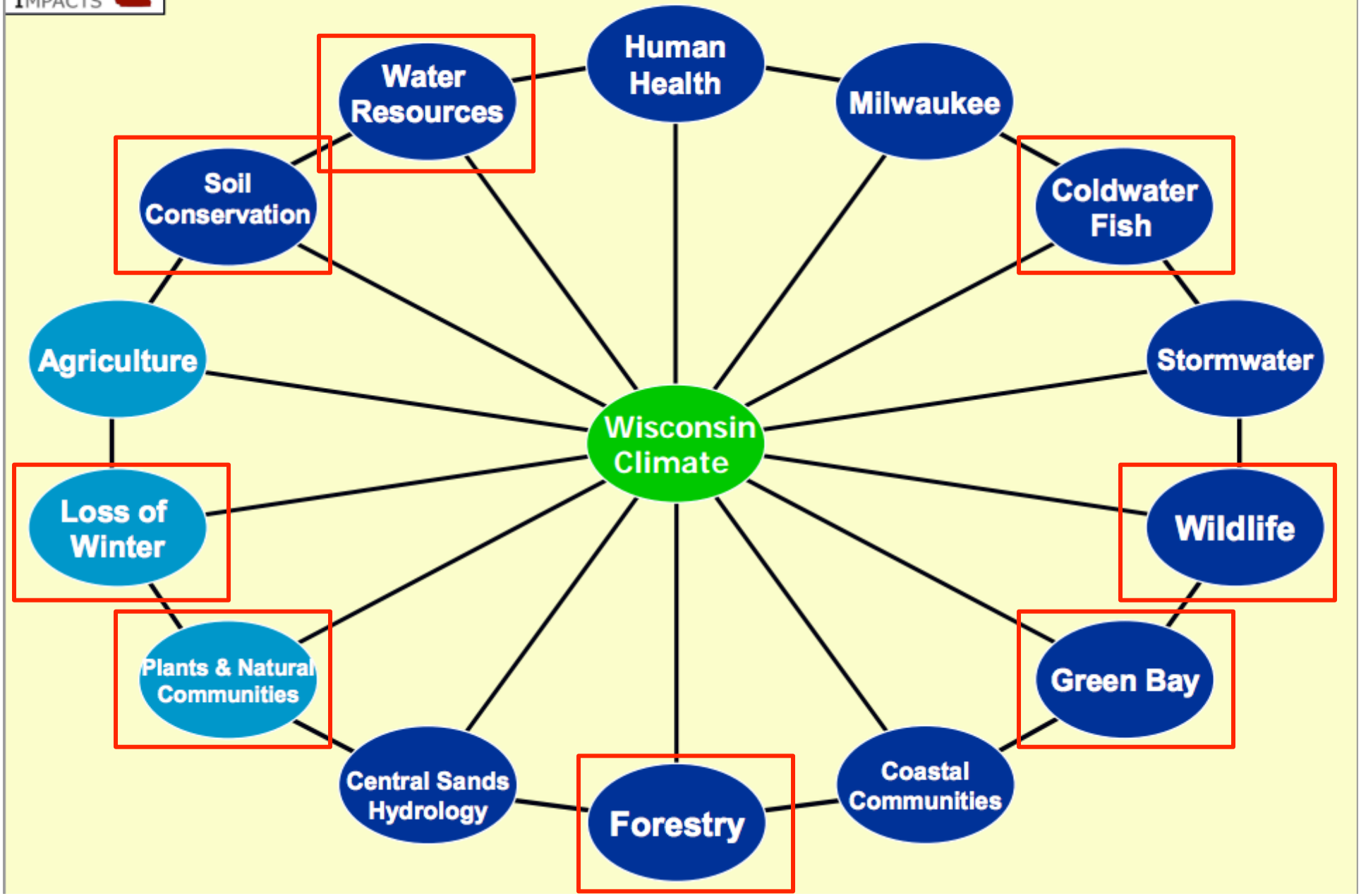


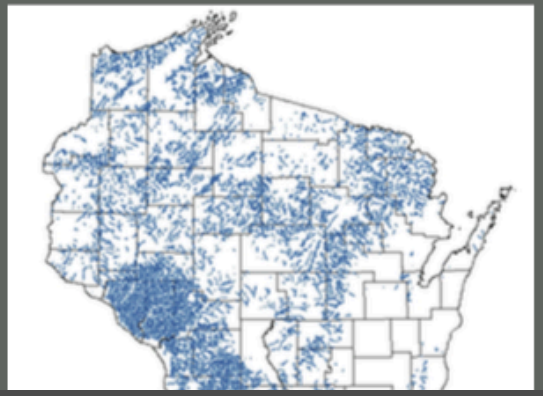
Wisconsin Migrating Climate

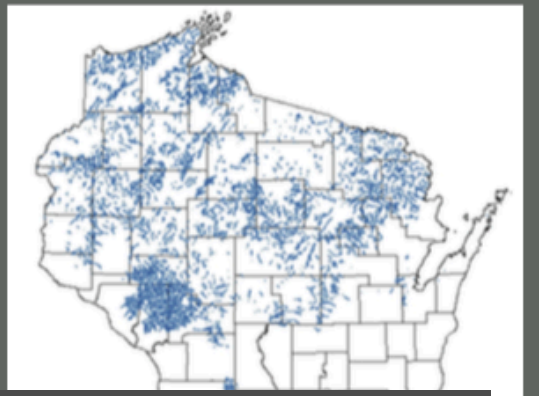


WISCONSIN INITIATIVE ON CLIMATE CHANGE IMPACTS

Current & Developing Working Groups







Coldwater Brown Trout
losing about 33,000 km of habitat (-88 percent)

Brook Trout
losing about 29,000 km (-100 percent)

Coolwater Northern Pike
losing 11,000 km (-72 percent)

Walleye
losing 4,000 km (-88 percent)

Whereas:

Warmwater Channel Catfish
gaining 1,600 km (+32 percent)

Largemouth Bass
gaining 7,000 km (+34 percent)

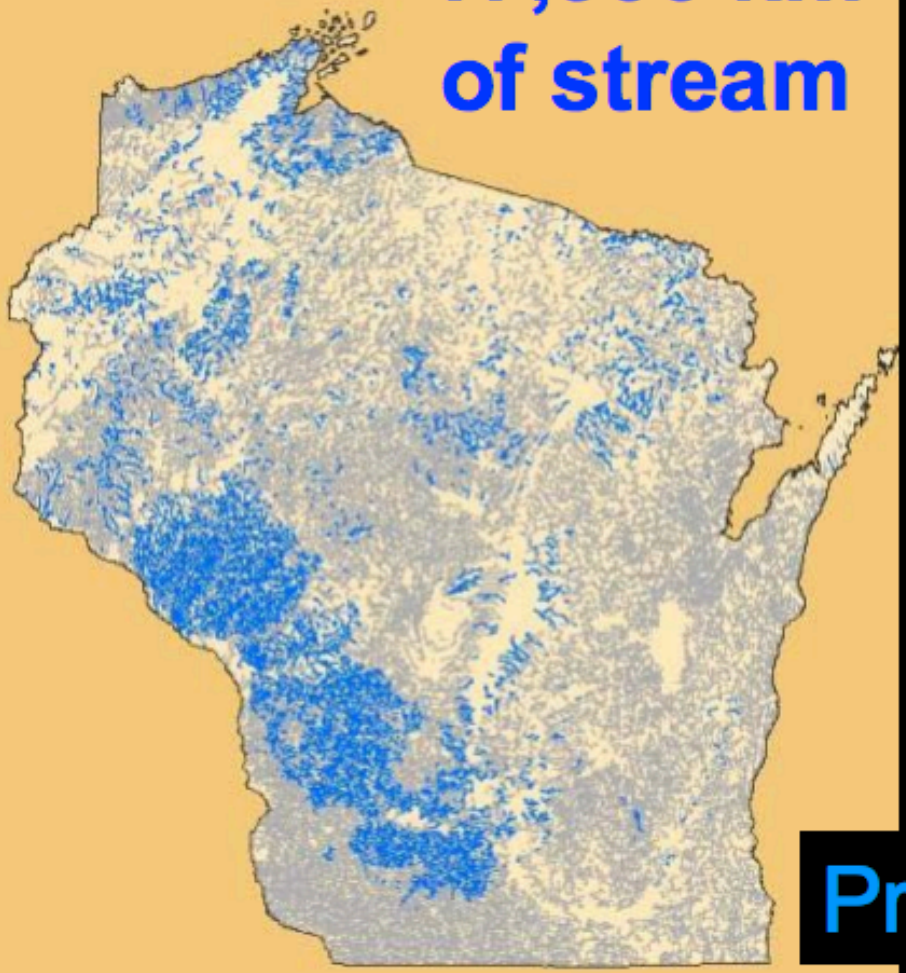
+4.3°F = 94% loss

+7.2°F = total loss

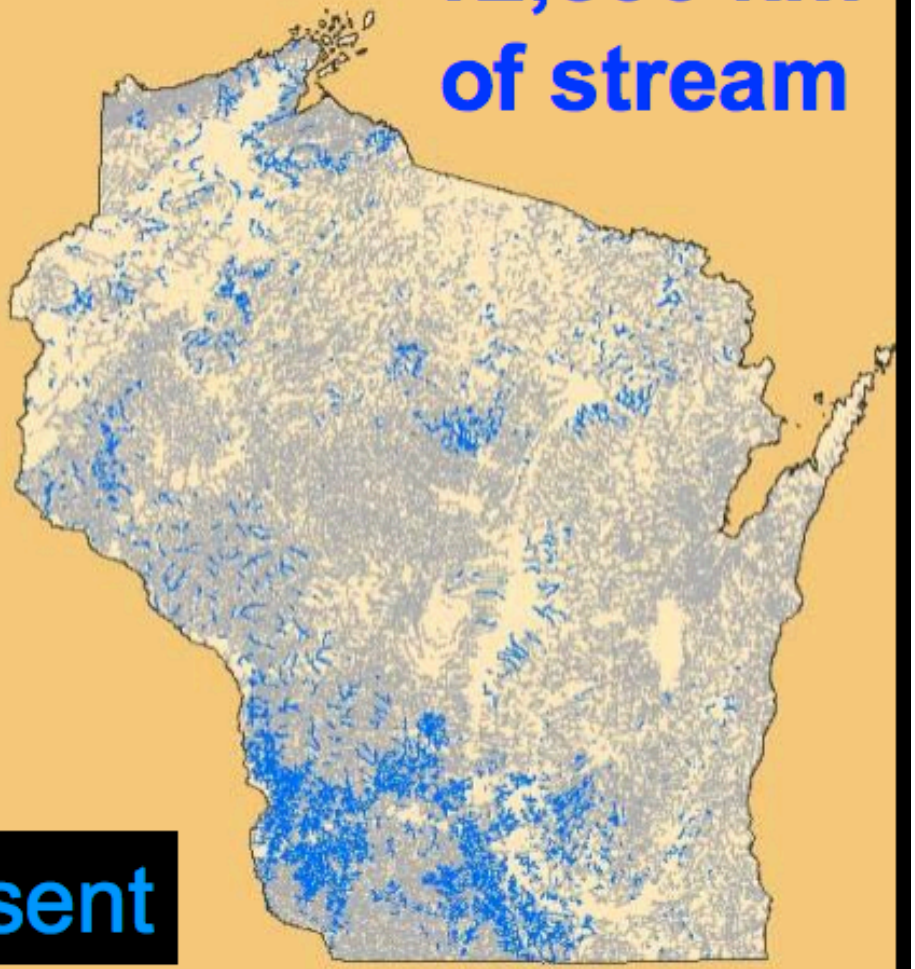
Predicted distribution of brook trout in Wisconsin streams under current climate conditions and predicted losses under three climate-warming scenarios for Wisconsin by mid-century.

NOW

17,900 km of stream



12,500 km of stream

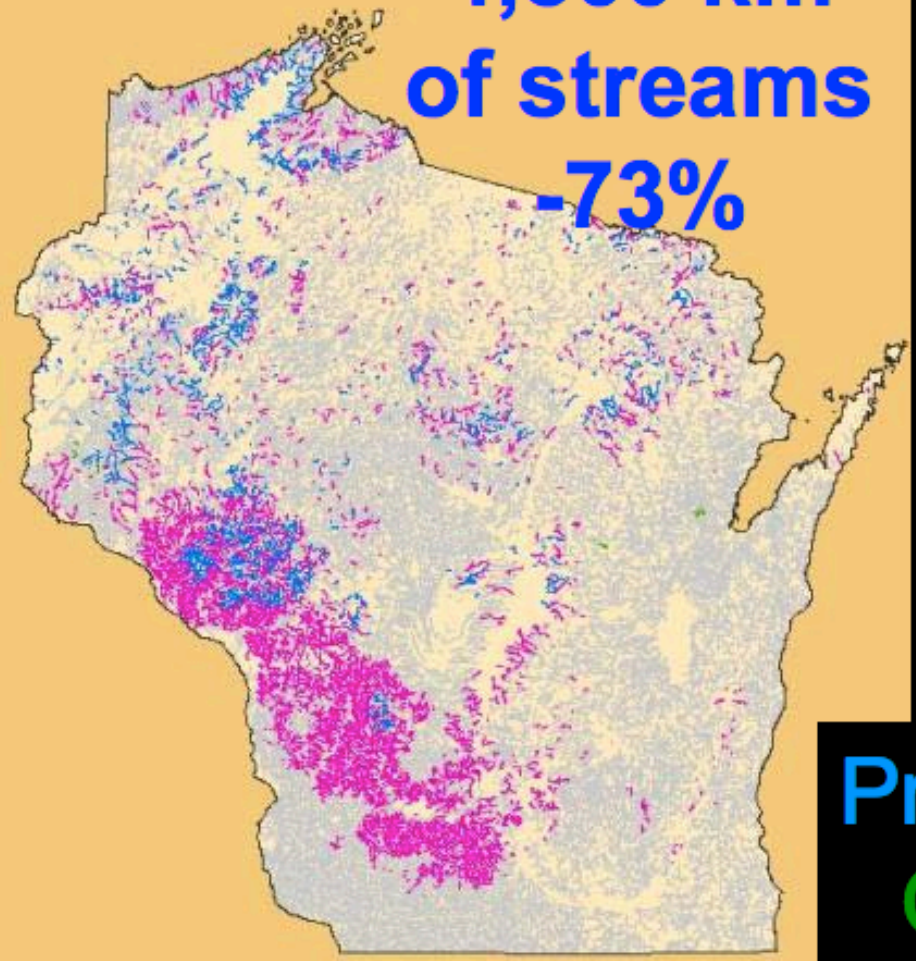


Present

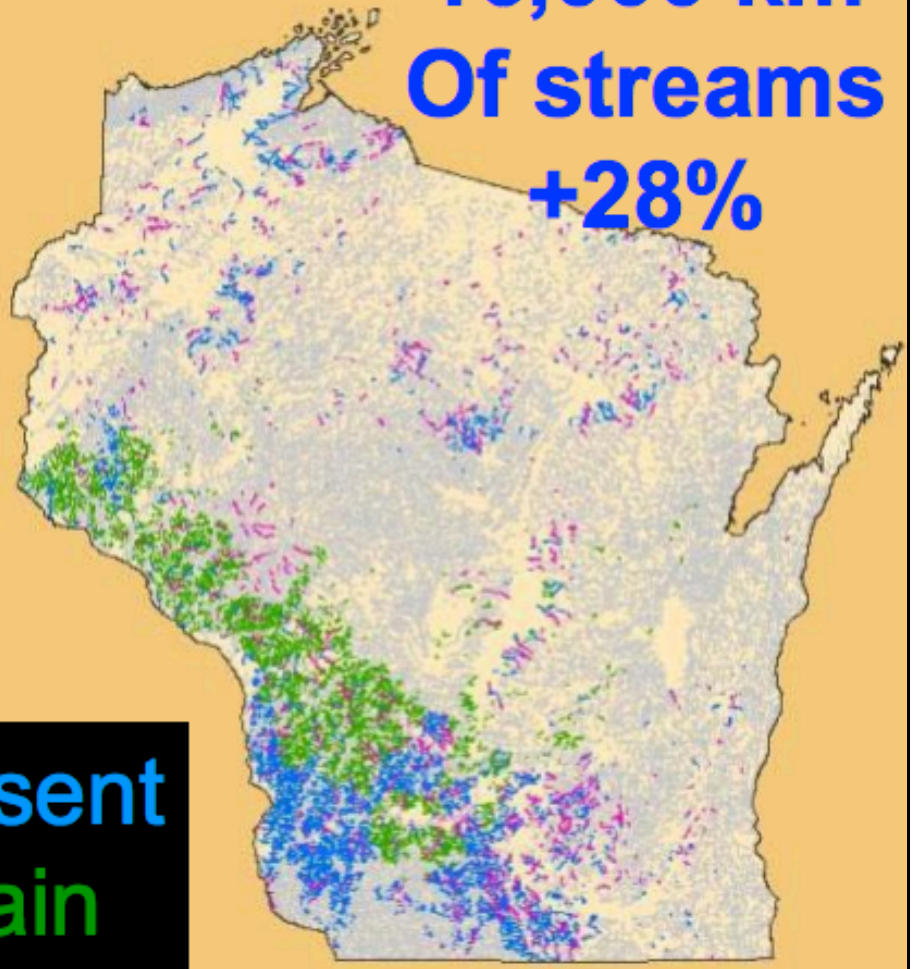
Matt Mitro & John Lyons WDNR

+1° C

4,800 km
of streams
-73%



16,000 km
Of streams
+28%

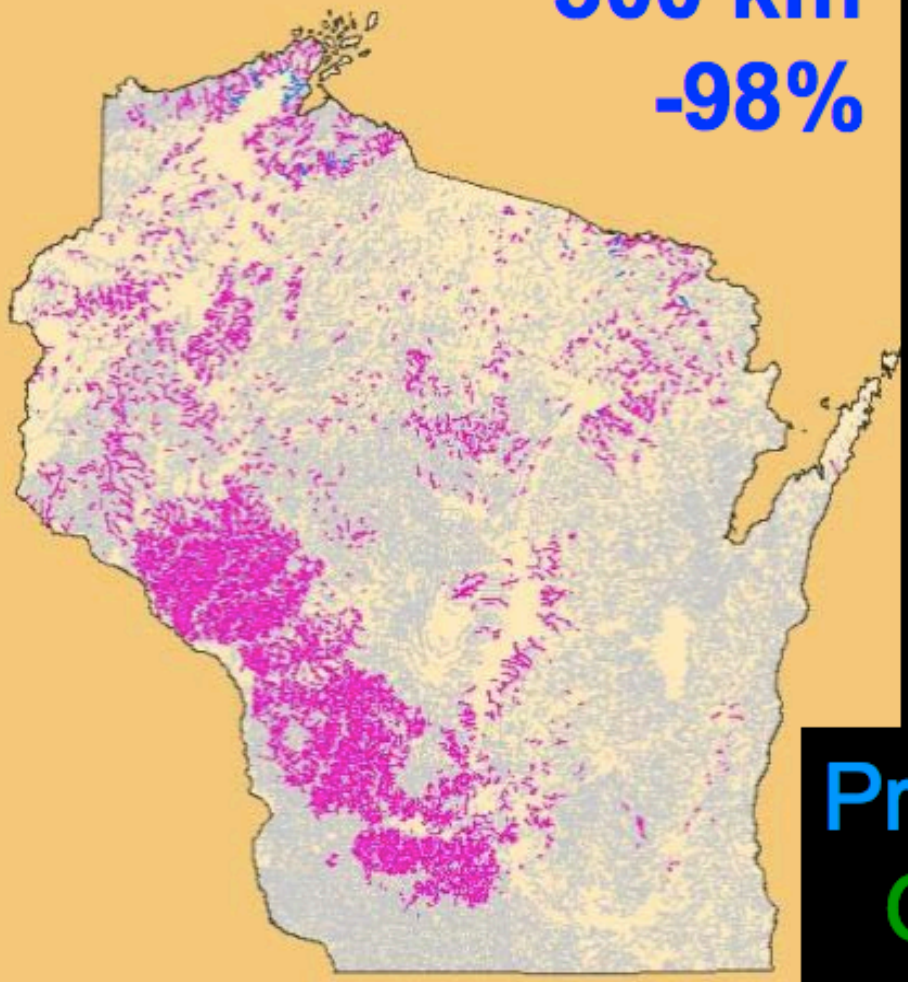


Present
Gain
Loss

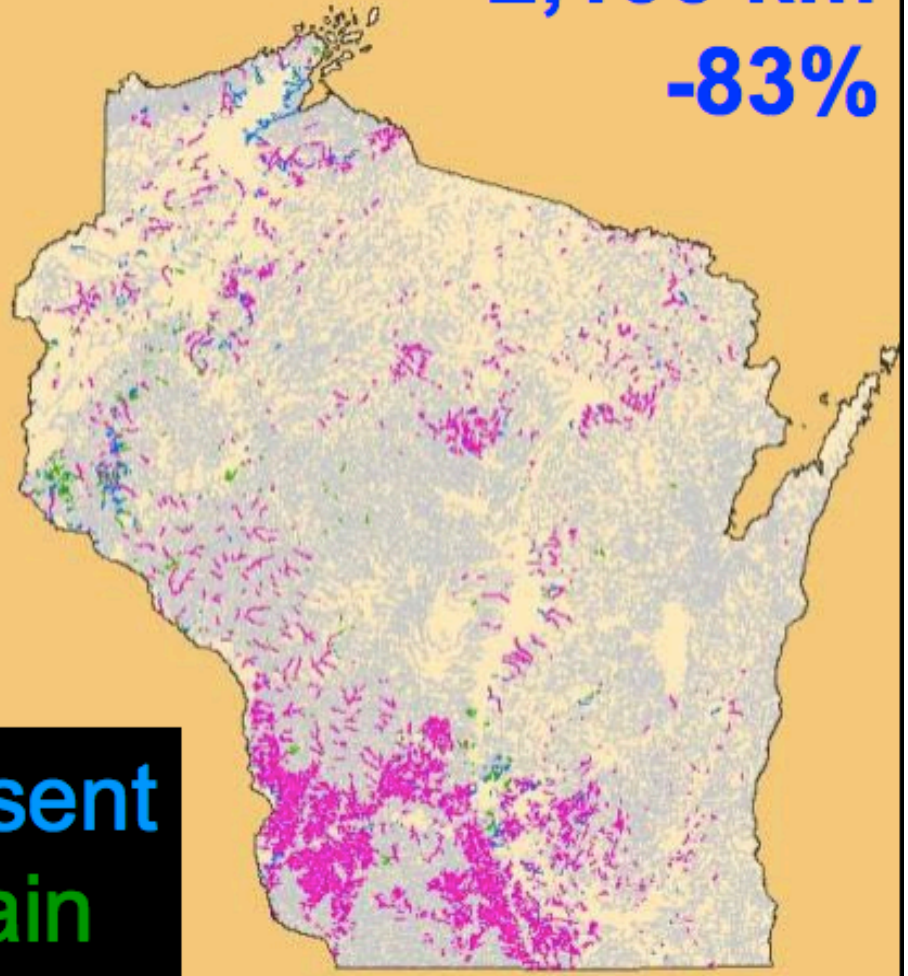
Matt Mitro & John Lyons WDNR

+3° C

300 km
-98%

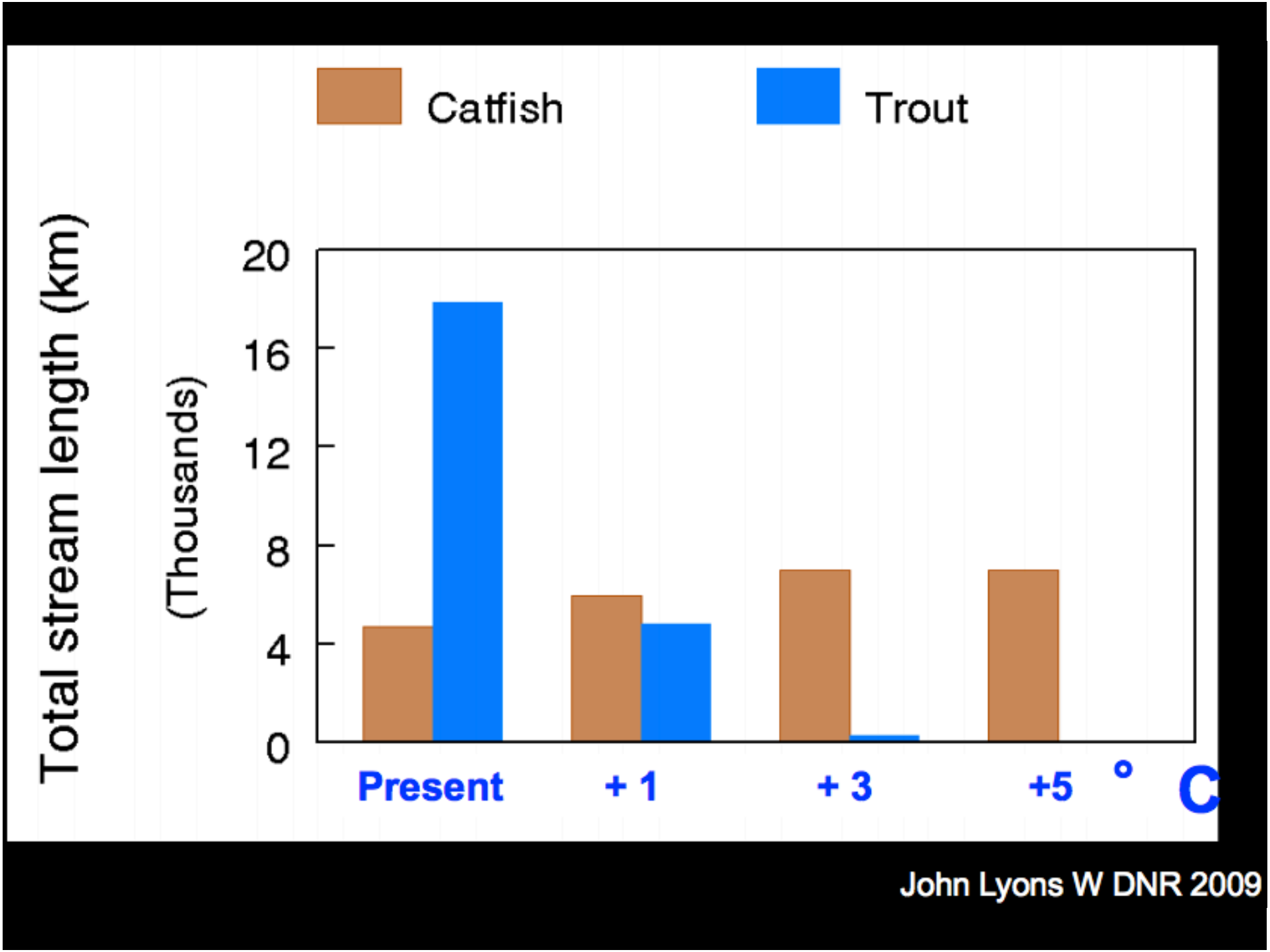


2,100 km
-83%



Present
Gain
Loss

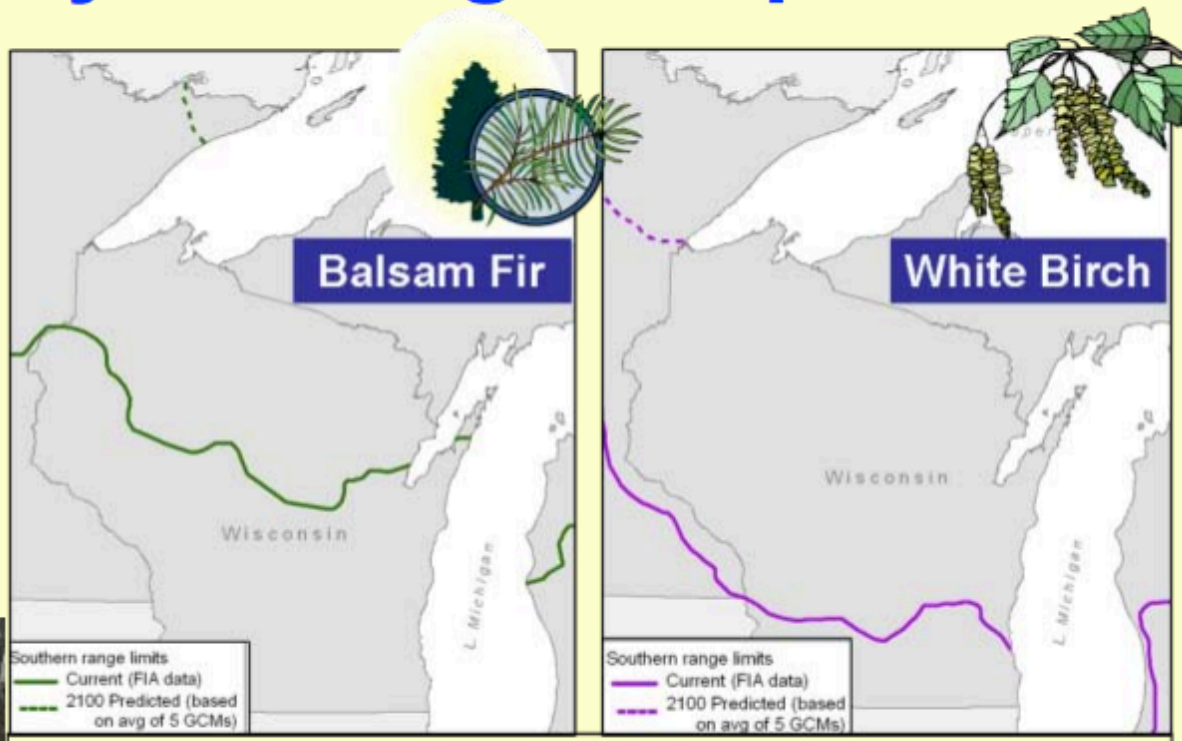
Matt Mitro & John Lyons WDNR


Catfish
Trout
Total stream length (km)
(Thousands)
20
16
12
8
4
0
Present
+ 1
+ 3
+5
°
C
John Lyons W DNR 2009

WISCONSIN INITIATIVE ON CLIMATE CHANGE IMPACTS

Forestry Working Group

Loss of Northern Tree Species

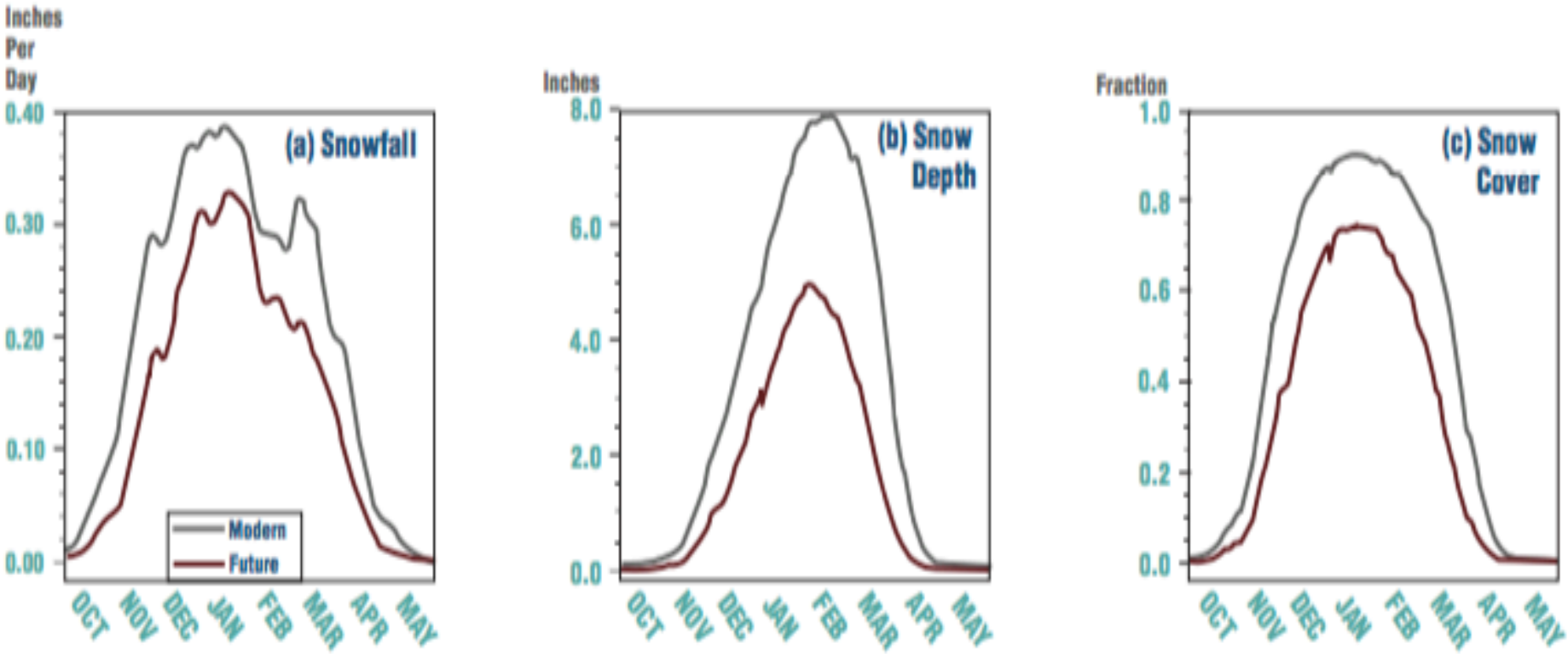


Source: D. Mladenoff, UW-Madison; adapted from Prasad, A.M. and L.R. Iverson. 1999-ongoing. http://www.fs.fed.us/ne/delaware/atlas/index.html

Photo: Karin Fassnacht, WDNR

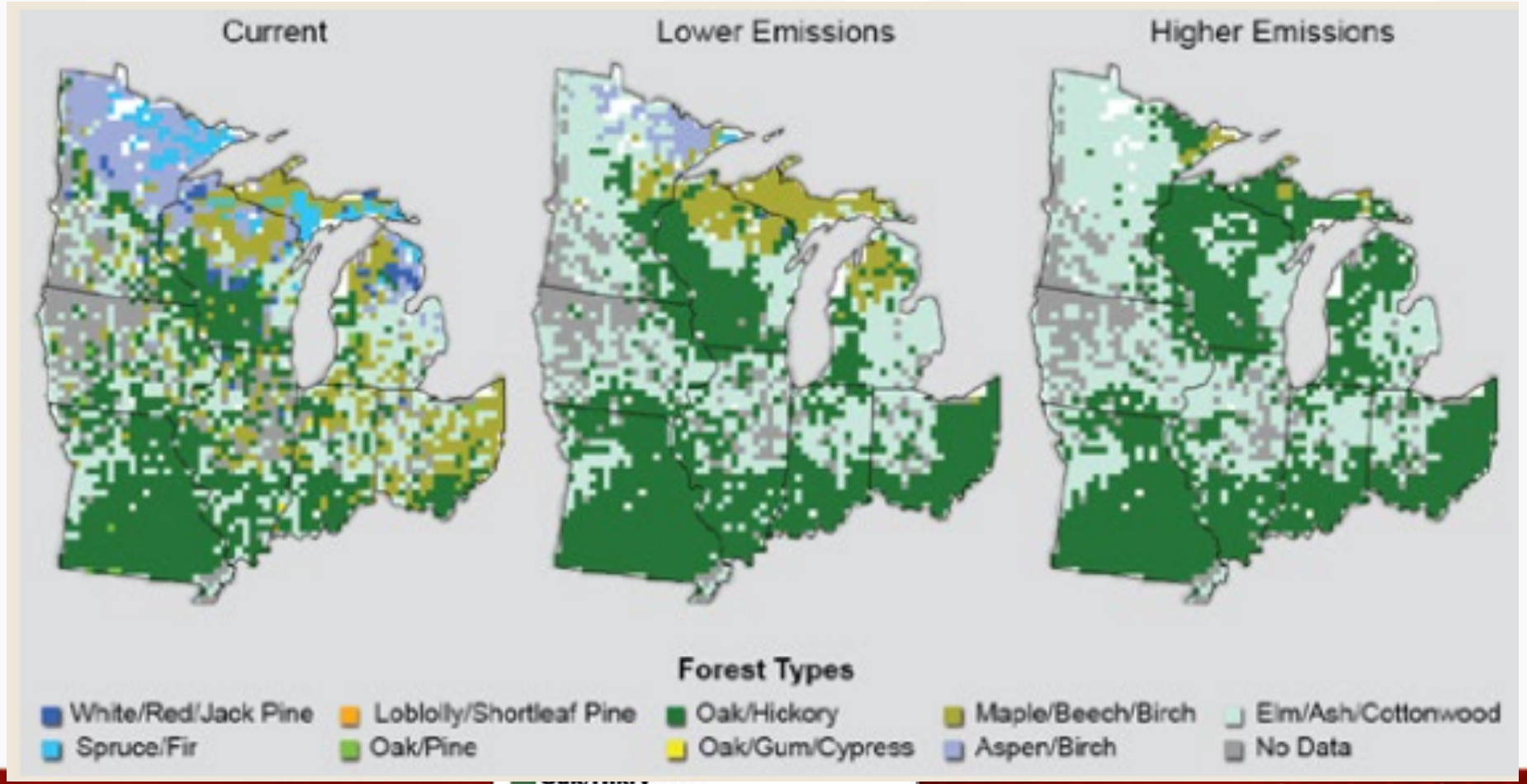
Impacts of Warmer Winters on Logging

PROJECTED SNOW

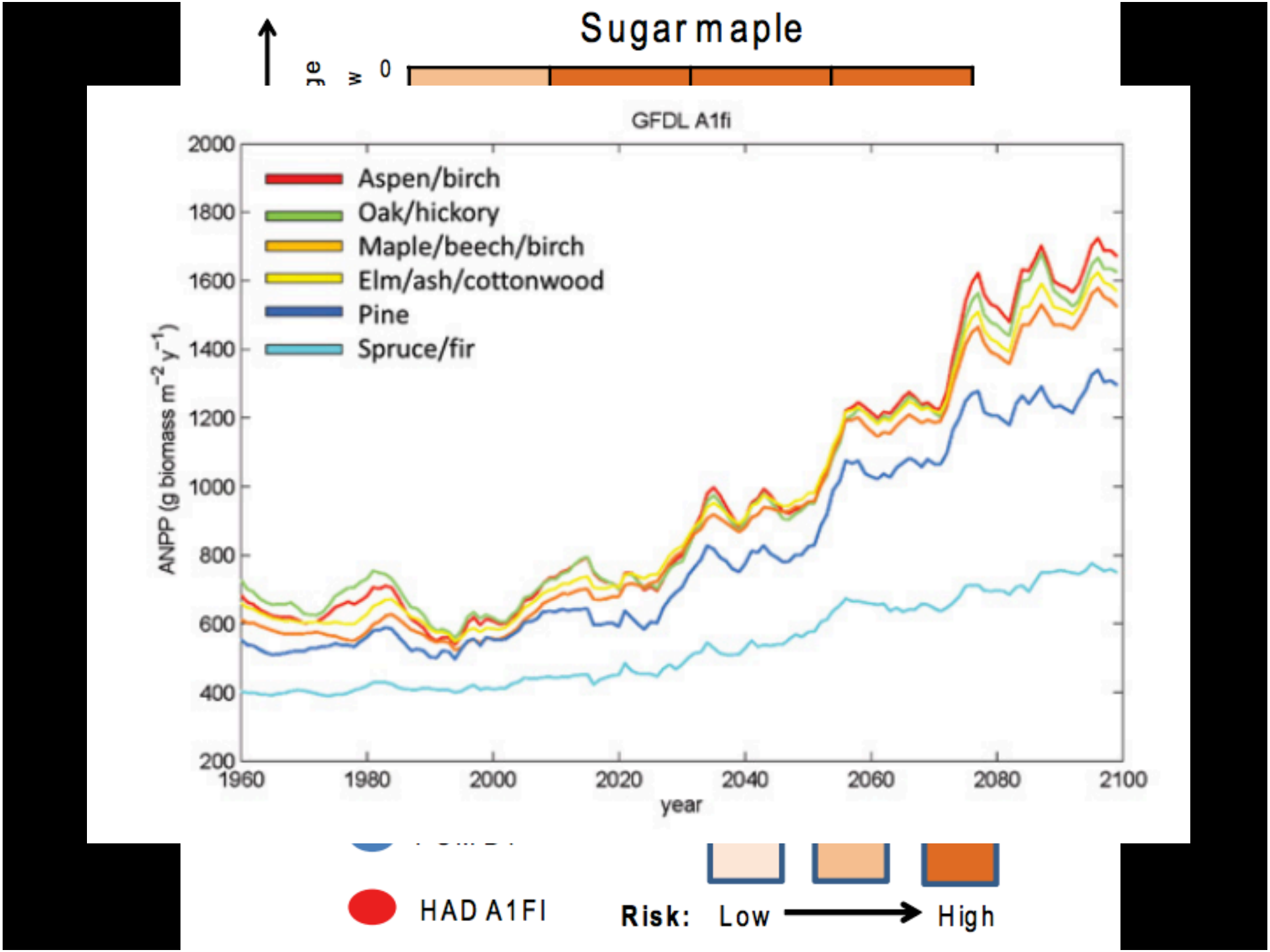


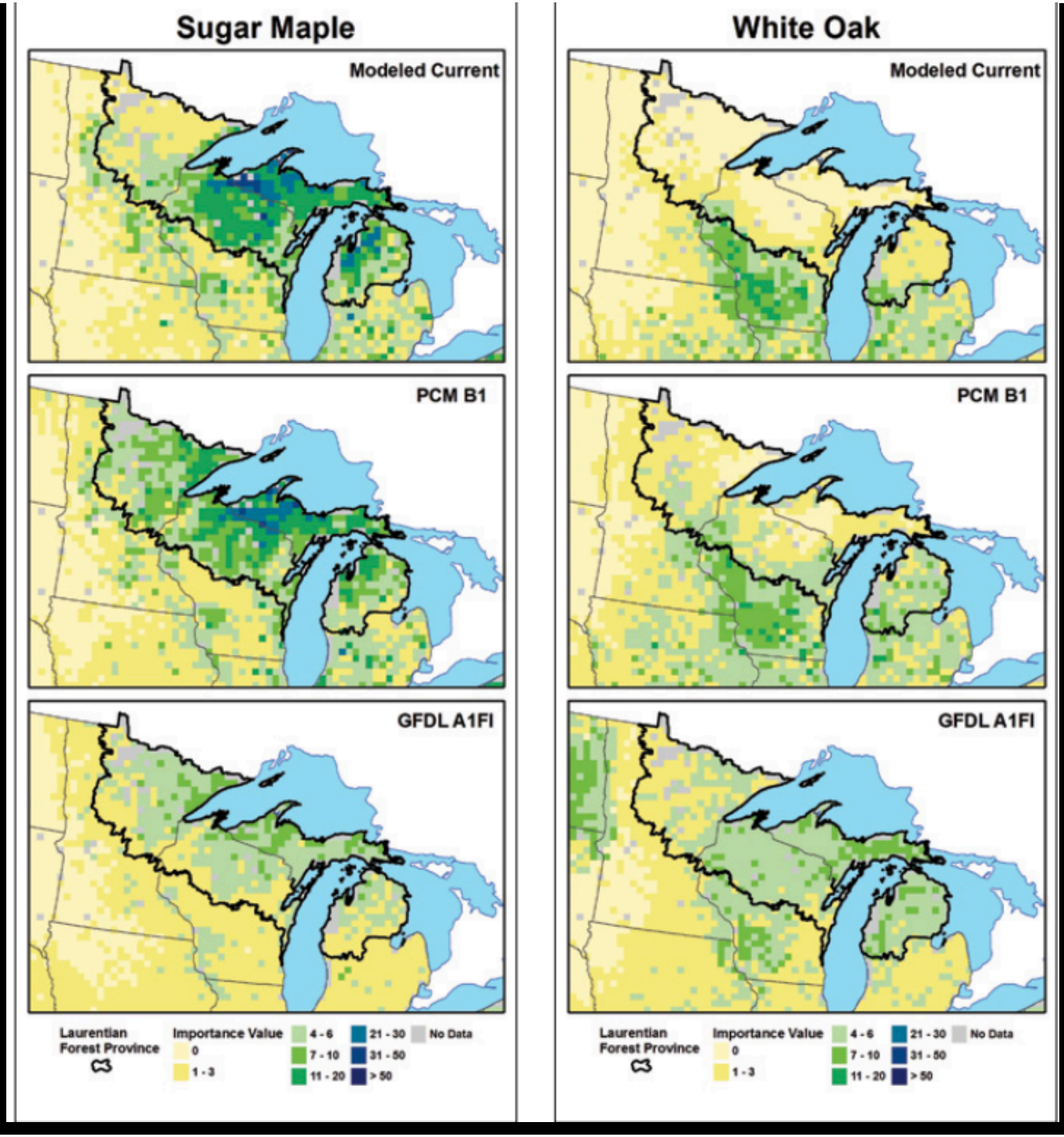
Source: Notaro, M., D. Lorenz, D. Vimont, S. Vavrus, C. Kucharik, and K. Franz, 2010: 21st century Wisconsin snow projections based on an operational snow model driven by statistically downscaled climate data. International Journal of Climatology, DOI: 10.1002/joc.2179.

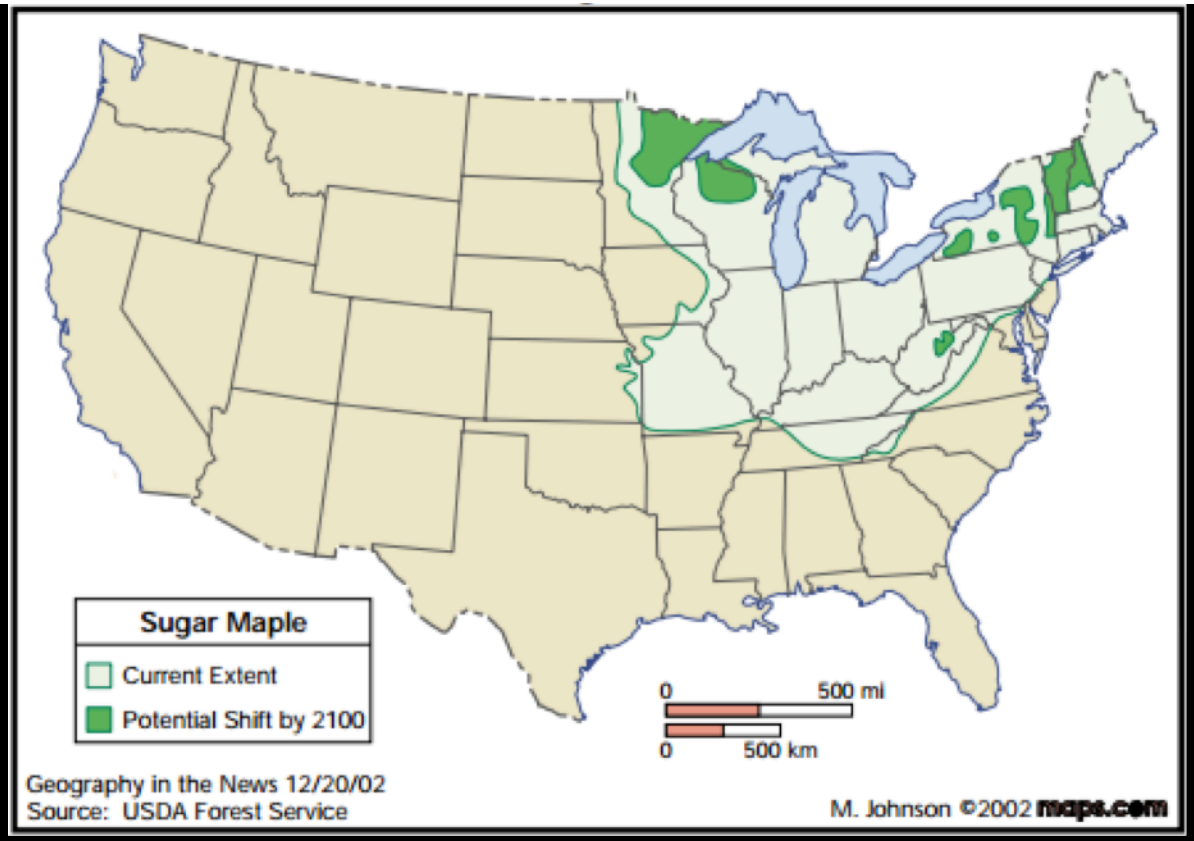
Species range shifts:

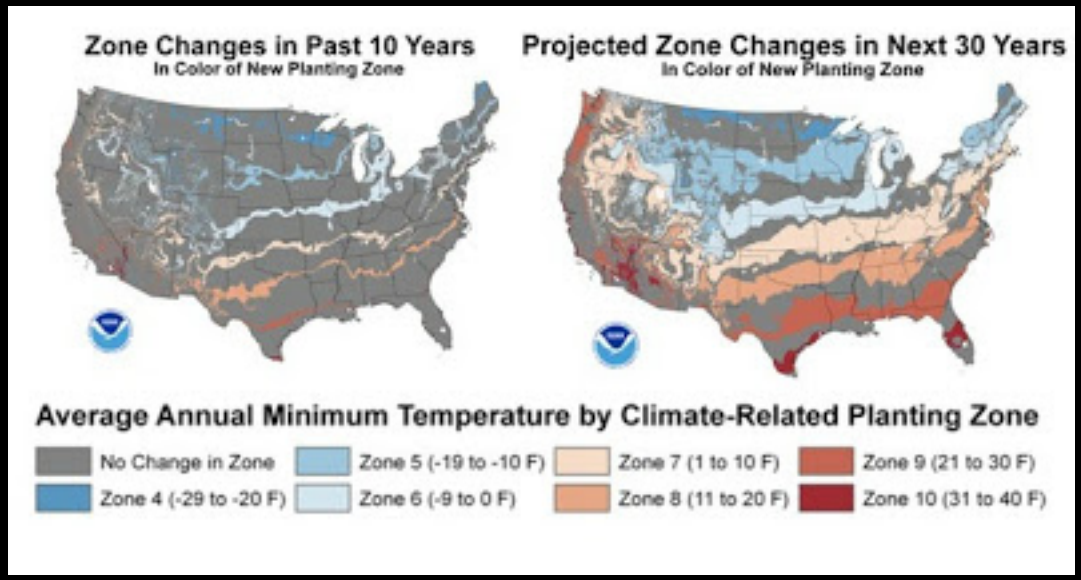


Iverson et al. 2008


Sugar maple
0
GFDL A1fi
Aspen/birch
Oak/hickory
Maple/beech/birch
Elm/ash/cottonwood
Pine
Spruce/fir
ANPP (g biomass m^{-2} y^{-1})
2000
1800
1600
1400
1200
1000
800
600
400
200
1960
1980
2000
2020
2040
2060
2080
2100
year
HAD A1FI
Risk: Low
High


Sugar Maple
Modeled Current
PCM B1
GFDL A1FI
White Oak
Modeled Current
PCM B1
GFDL A1FI
Laurentian Forest Province
Importance Value
0
1 - 3
4 - 6
7 - 10
11 - 20
21 - 30
31 - 50
> 50
No Data


Sugar Maple
Current Extent
Potential Shift by 2100
0
500 mi
0
500 km
Geography in the News 12/20/02
Source: USDA Forest Service
M. Johnson ©2002 maps.com


Zone Changes in Past 10 Years
In Color of New Planting Zone
Projected Zone Changes in Next 30 Years
In Color of New Planting Zone
Average Annual Minimum Temperature by Climate-Related Planting Zone
No Change in Zone
Zone 4 (-29 to -20 F)
Zone 5 (-19 to -10 F)
Zone 6 (-9 to 0 F)
Zone 7 (1 to 10 F)
Zone 8 (11 to 20 F)
Zone 9 (21 to 30 F)
Zone 10 (31 to 40 F)

WISCONSIN INITIATIVE ON CLIMATE CHANGE IMPACTS

Stormwater Working Group

Damage to communities and transportation systems from extreme storm events

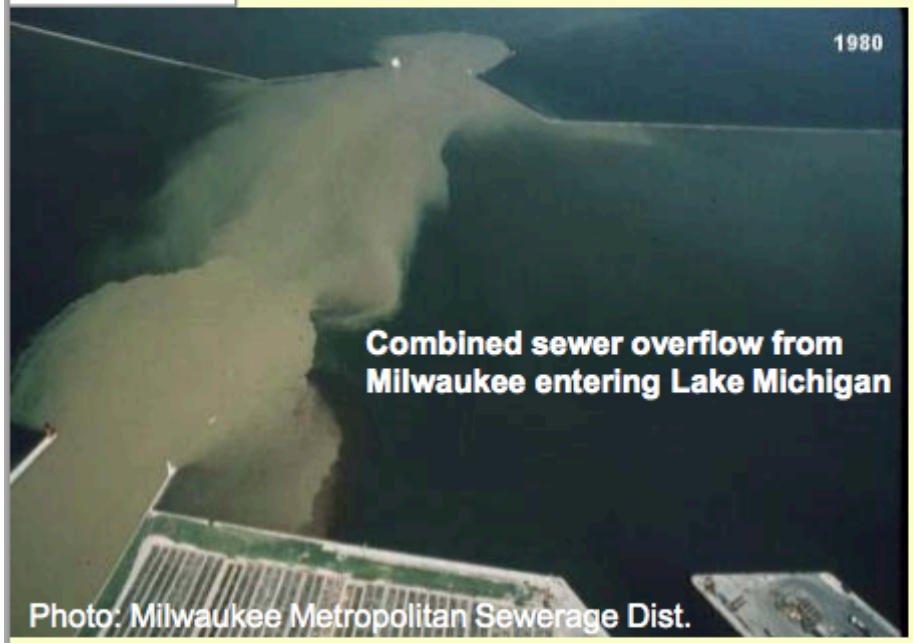
Rock Springs, WI, June 2008
Photo: Michael Kienitz


Madison, WI, July 2006
Photo: Gordy Stephenson


Jamie McCartney
HWY 60 near Excelsior, WI
August 20, 2007

WISCONSIN INITIATIVE ON CLIMATE CHANGE IMPACTS

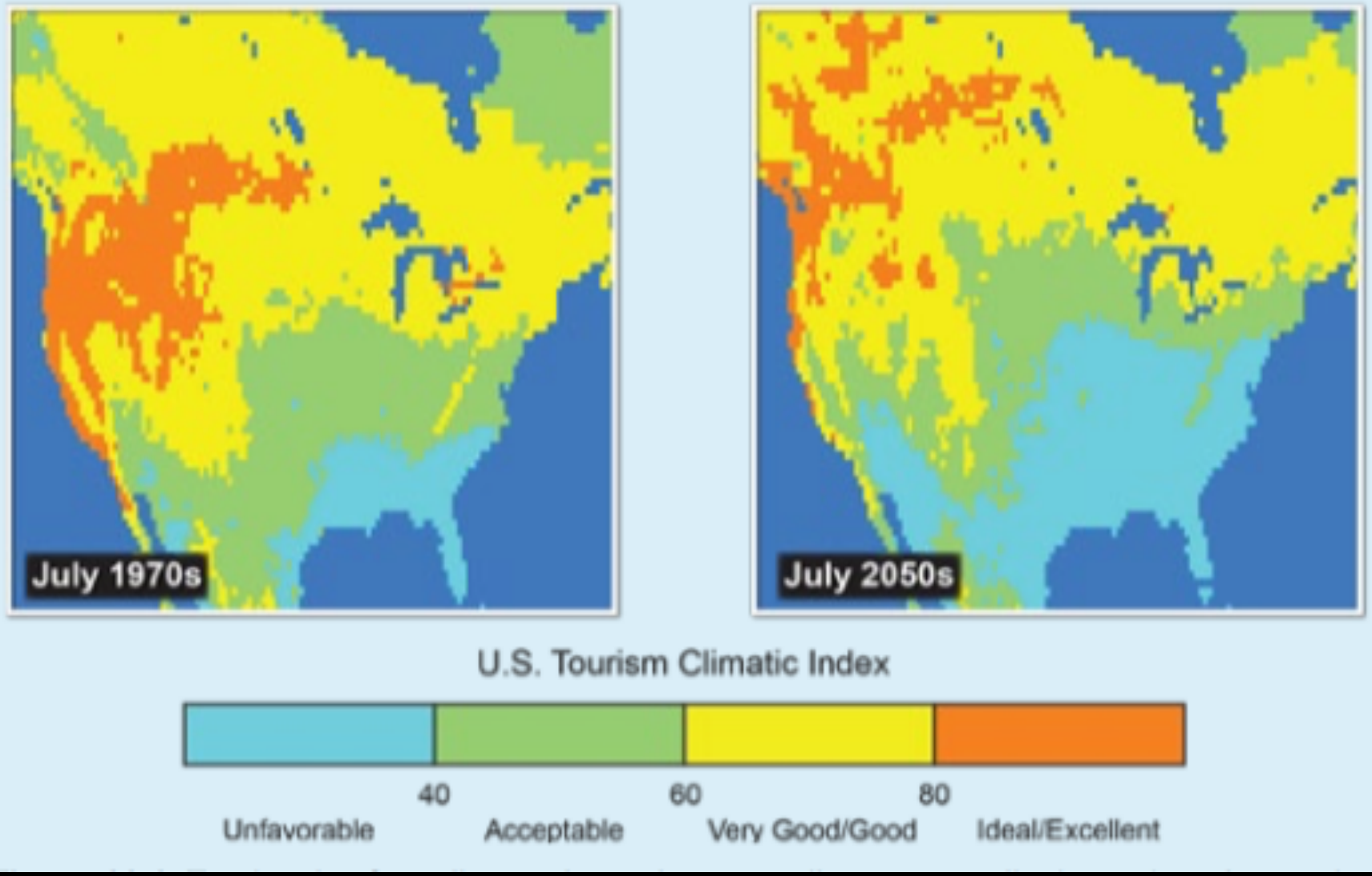
Human Health Working Group



Increase in waterborne infectious diseases from more intense storms

Increase in respiratory health problems from air pollution and climate change

Climate Change Impacts on Summertime Tourism



1990

SO, THIS CLIMATE CHANGE THING COULD BE A PROBLEM...

1995

CLIMATE CHANGE: DEFINITELY A PROBLEM.

2001

YEP, WE SHOULD REALLY BE GETTING ON WITH SORTING THIS OUT PRETTY SOON...

2007

LOOK, SORRY TO SOUND LIKE A BROKEN RECORD HERE...

2013

WE REALLY HAVE CHECKED AND WE'RE NOT MAKING THIS UP.

2019

IS THIS THING ON?

TAP TAP TAP

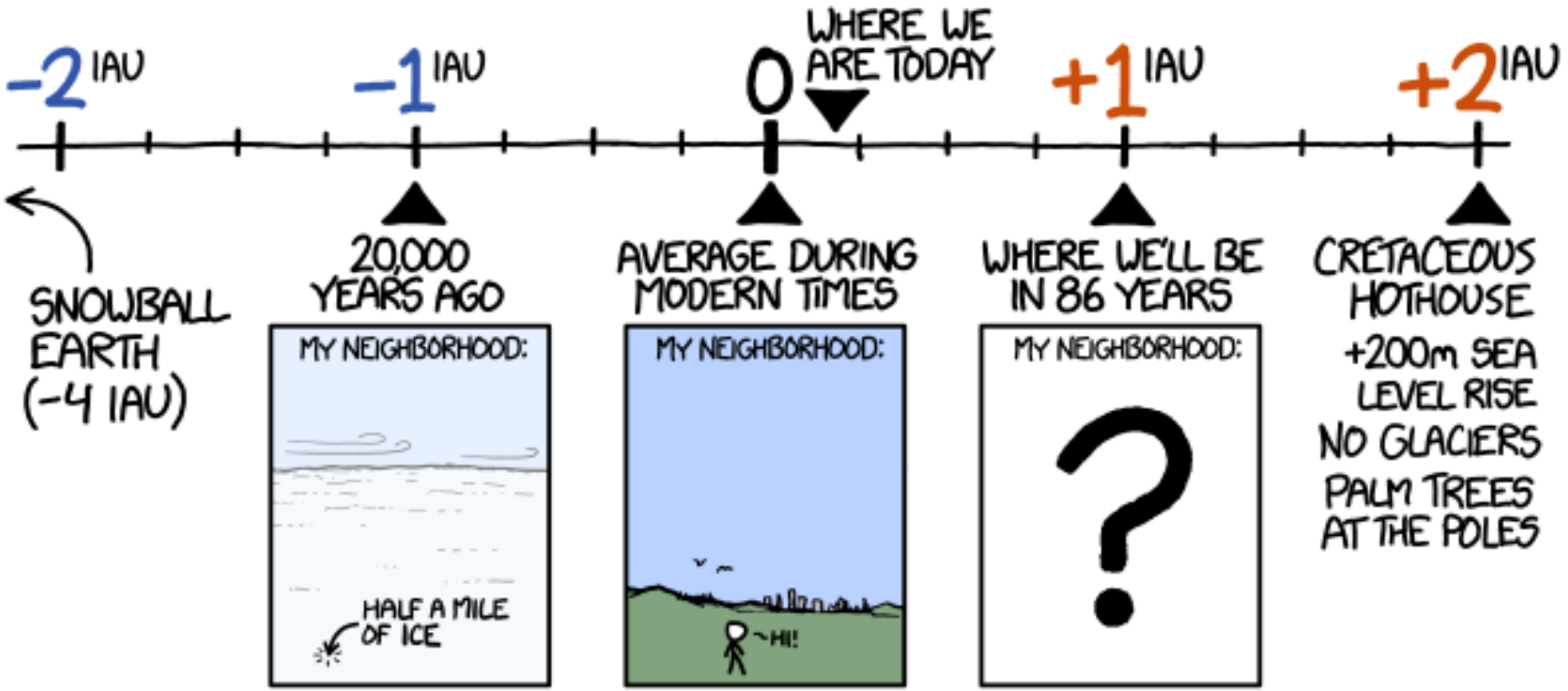
KUDELKA. 28/9/13

WITHOUT PROMPT, AGGRESSIVE LIMITS ON CO_2 EMISSIONS, THE EARTH WILL LIKELY WARM BY AN AVERAGE OF 4°-5°C BY THE CENTURY'S END.

HOW BIG A CHANGE IS THAT?

IN THE COLDEST PART OF THE LAST ICE AGE, EARTH'S AVERAGE TEMPERATURE WAS 4.5°C BELOW THE 20TH CENTURY NORM.

LET'S CALL A 4.5°C DIFFERENCE ONE "ICE AGE UNIT."



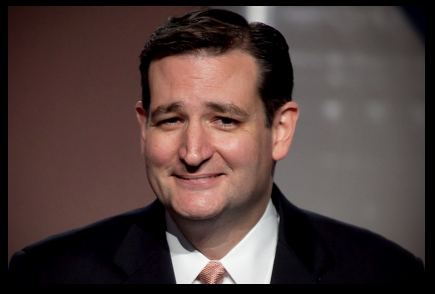
- “I am not a scientist myself, but my best assessment of the data is that the world is getting warmer, that human activity contributes to that warming, and that policymakers should therefore consider the risk of negative consequences.”
  – Sept. 2012

http://www.sciencedebate.org/debate12/

- “Higher temperatures and less-predictable weather would hurt poor farmers, most of whom live on the edge and can be devastated by a single bad crop. […] It would be a terrible injustice to let climate change undo any of the past half-century’s progress against poverty and disease—and doubly unfair because the people who will be hurt the most are the ones doing the least to cause the problem.”

Linkedin.com

- “If you look at global warming alarmists, they don't like to look at the actual facts and the data. The satellite data demonstrate that there has been no significant warming whatsoever for 17 years. […] I read this morning a Newsweek article from the 1970s talking about global cooling. And it said the science is clear, it is overwhelming, we are in a major cooling period... Now, the data proved to be not backing up that theory. So then all the advocates of global cooling suddenly shifted to global warming […] and the **solution interestingly enough was the exact same solution -- government control of the energy sector and every aspect of our lives.**”

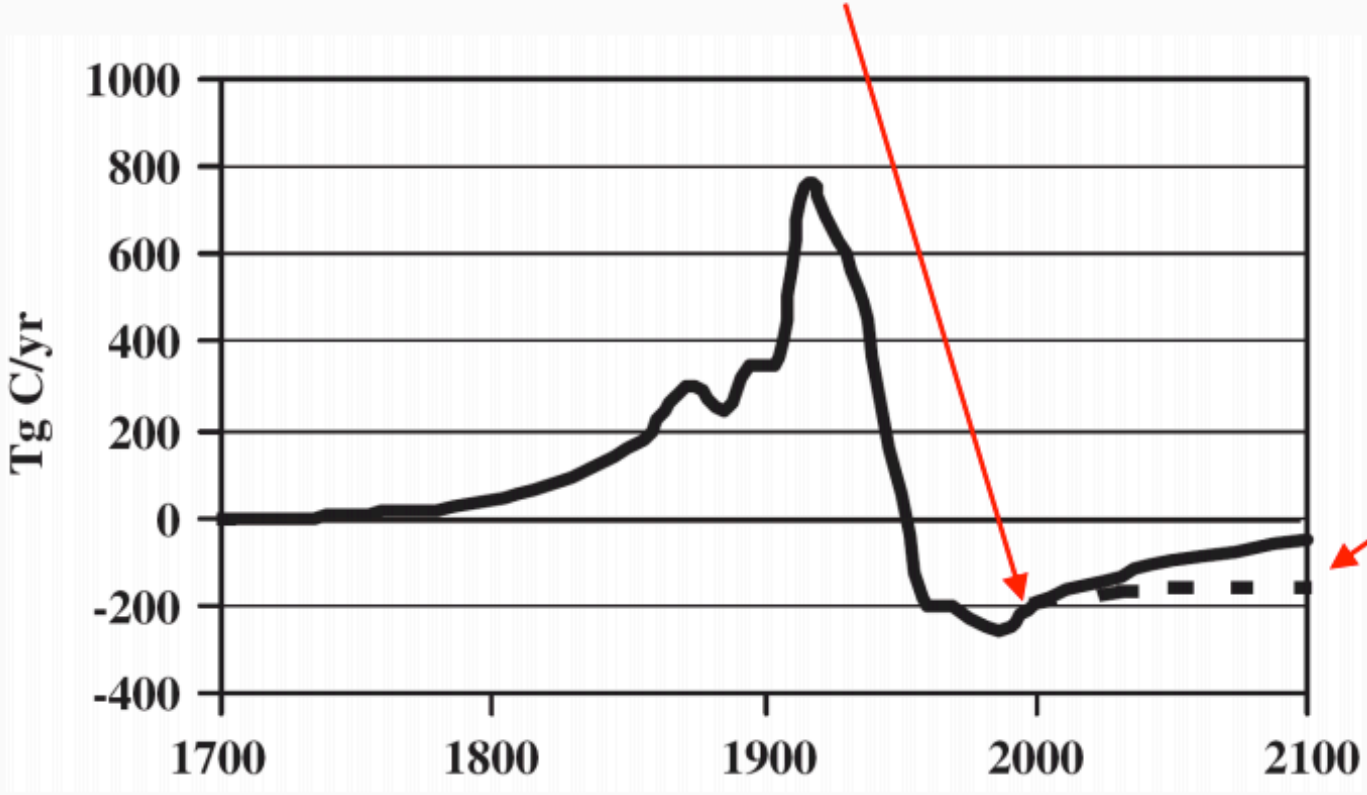


Washington Post, 2 Aug 2015

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)
  - Political (treaties, bans, compacts, fuel/energy standards, public transit, voluntary agreements)
  - Societal (sustainable development)
  - Technological (CO_2 capture, geoengineering, green tech, alternative energy, energy efficiency)

US forests annually sequester the equivalent of 10% of US carbon dioxide emissions from burning fossil fuels



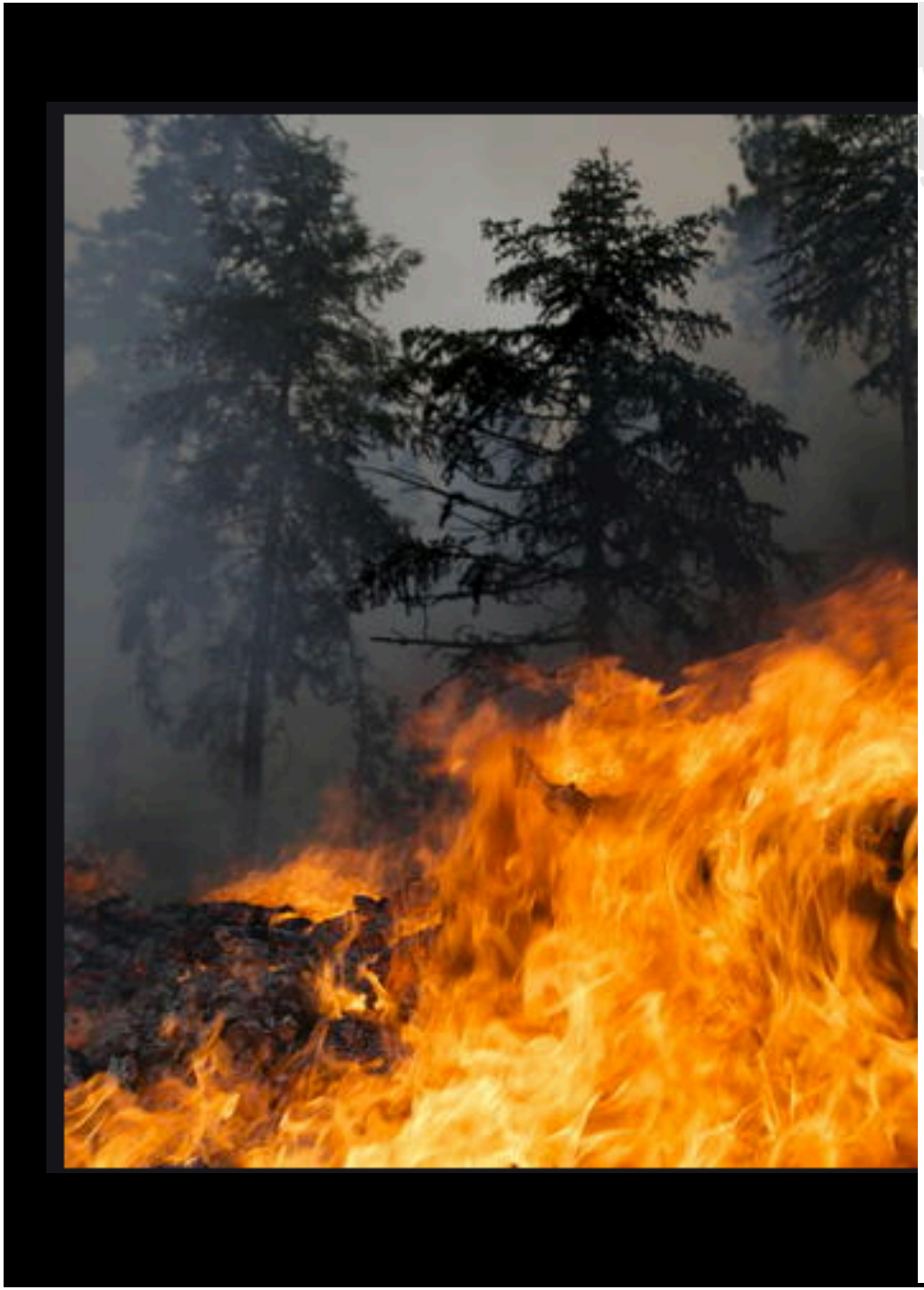
Forestry activities could remove another 100 to 200 Tg C/yr

Smith and Heath 2004, EPA 2005, Birdsey et al. 2006

Life of Wood and Paper Products:

End use	Half-life of carbon (years)
Single-family homes (pre-1980)	80
Single-family homes (post-1980)	100
Multifamily homes	70
Mobile homes	20
Nonresidential construction	67
Pallets	6
Manufacturing	12
Furniture	30
Railroad ties	30
Paper (free sheet)	6
Paper (all other)	1

Skog and Nicholson 2000



WILDFIRES PLAGUE WESTERN STATES

Active fires
Continuing fires
Fire weather watch
Red flag warning
WASH.
Seattle
MONT.
Portland
ORE.
IDAHO
Boise
WYO.
Reno
NEV.
UTAH
Sacramento
San Francisco
CALIF.
ARIZ.
Los Angeles
Phoenix

Note: as of 8 a.m. ET Aug. 3

SOURCES: Wildlandfire.com, National Weather Service

Janet Loehrke, USA TODAY

USA TODAY

- “Power plants are the single biggest source of harmful carbon pollution that contributes to climate change. Until now, there have been no federal limits to the amount of carbon pollution plants dump in the air.”

CNN

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"The Wisconsin Idea"

Lake States Aspen-Birch:

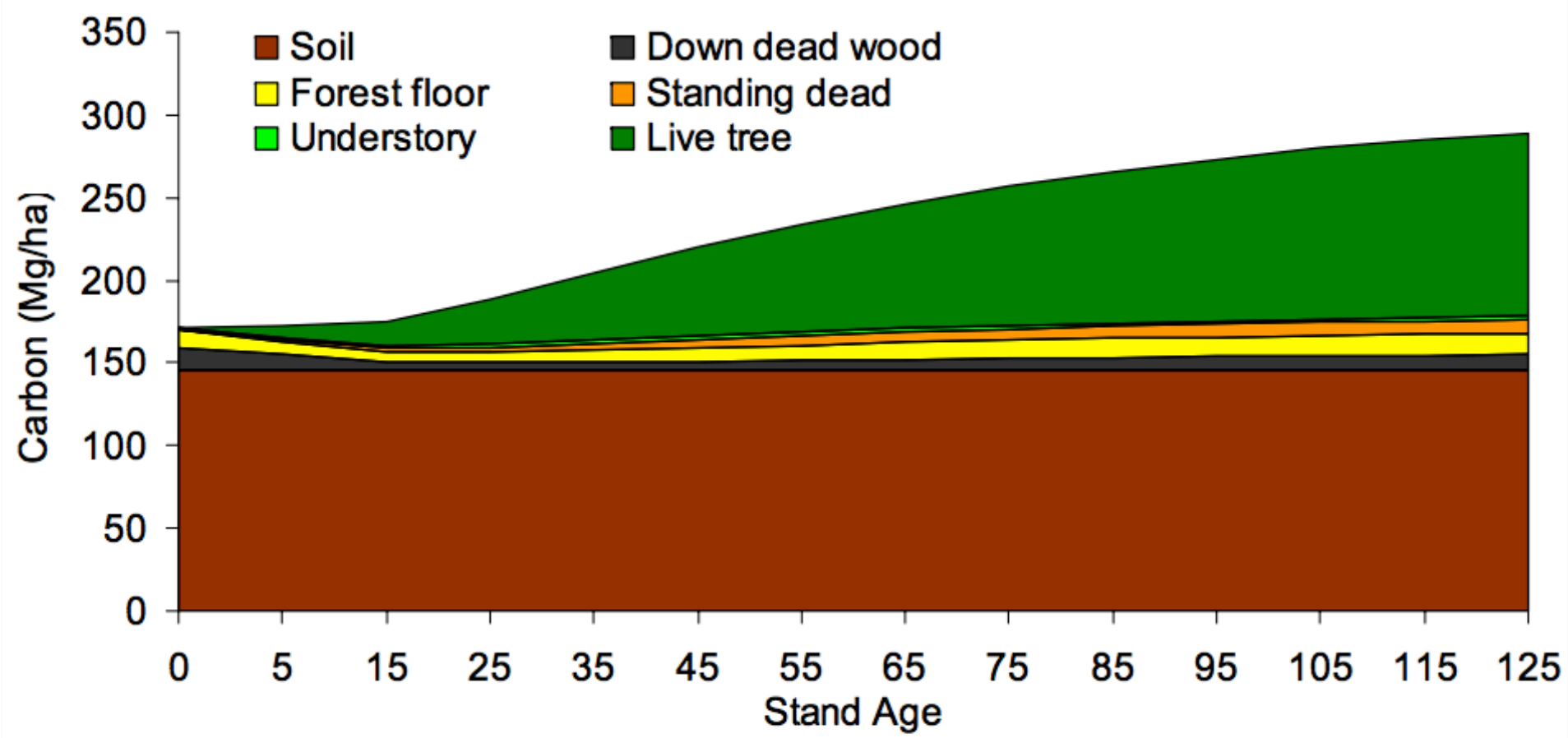
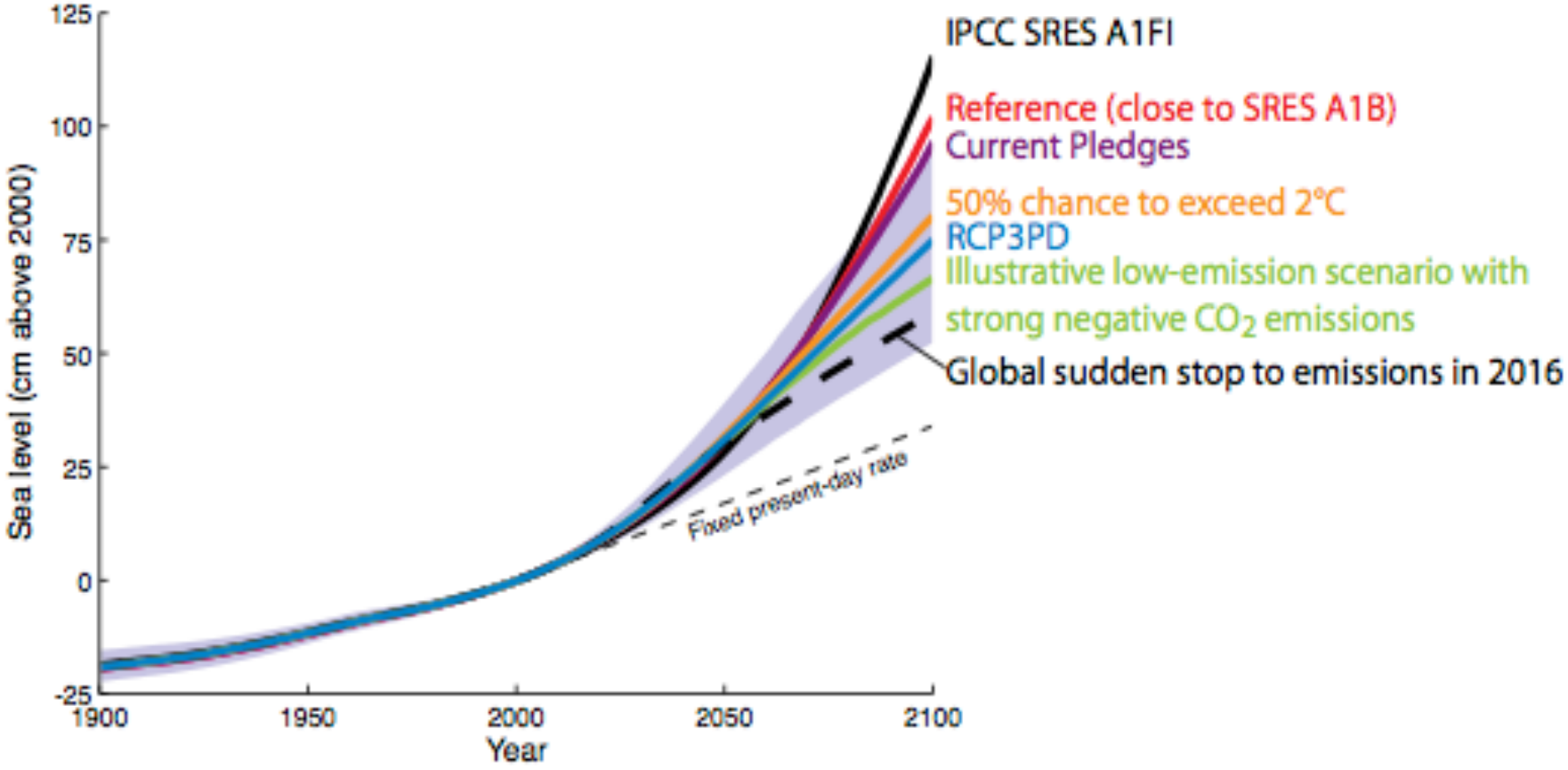


Figure data: Smith et al. 2005


125
100
75
50
25
0
-25
Sea level (cm above 2000)
1900
1950
2000
2050
2100
Year
IPCC SRES A1FI
Reference (close to SRES A1B)
Current Pledges
50% chance to exceed 2°C
RCP3PD
Illustrative low-emission scenario with
strong negative CO_2 emissions
Global sudden stop to emissions in 2016
Fixed present-day rate