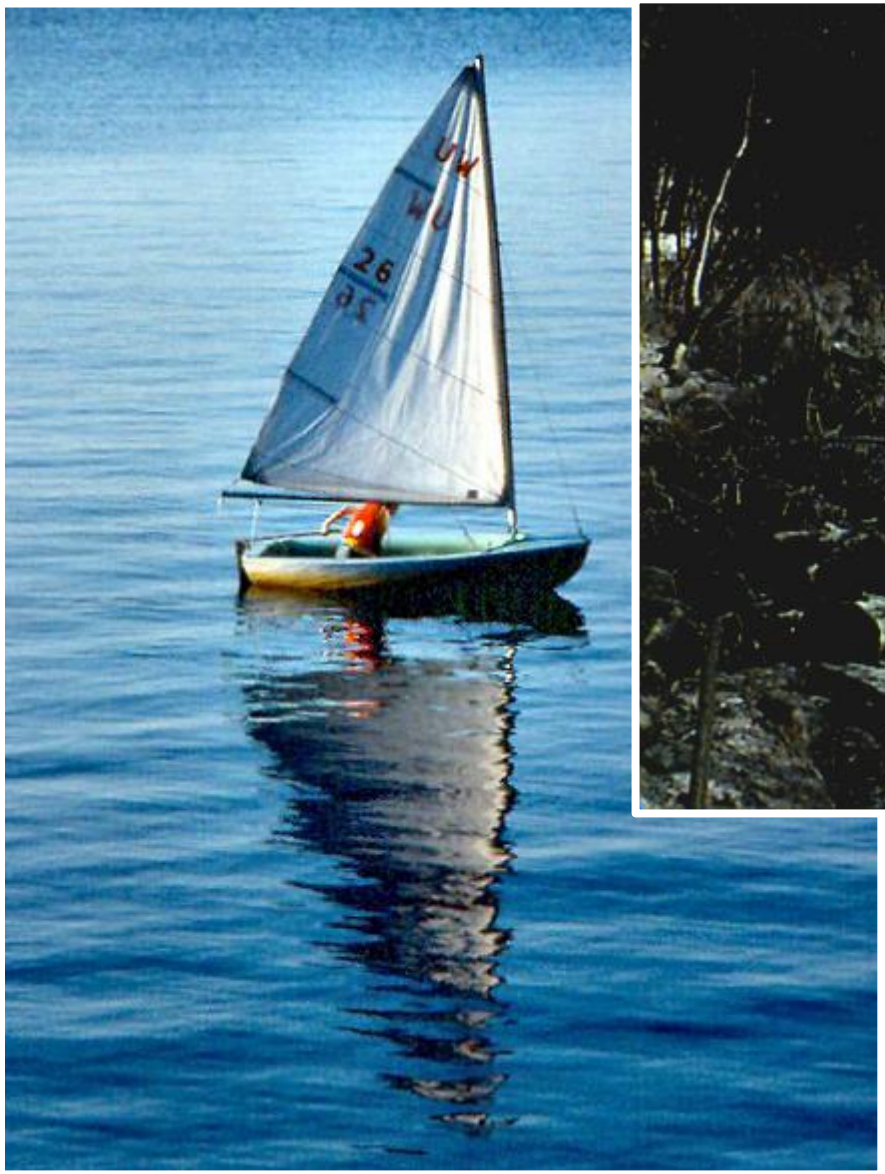
Lake Ice - the Invisible Present & Place: Years to Centuries Wisconsin to Northern Hemisphere

Wisconsin Lakes & Rivers Convention
Stevens Point, WI
April 3, 2020 Remotely

John J. Magnuson
Center for Limnology
University of Wisconsin-Madison

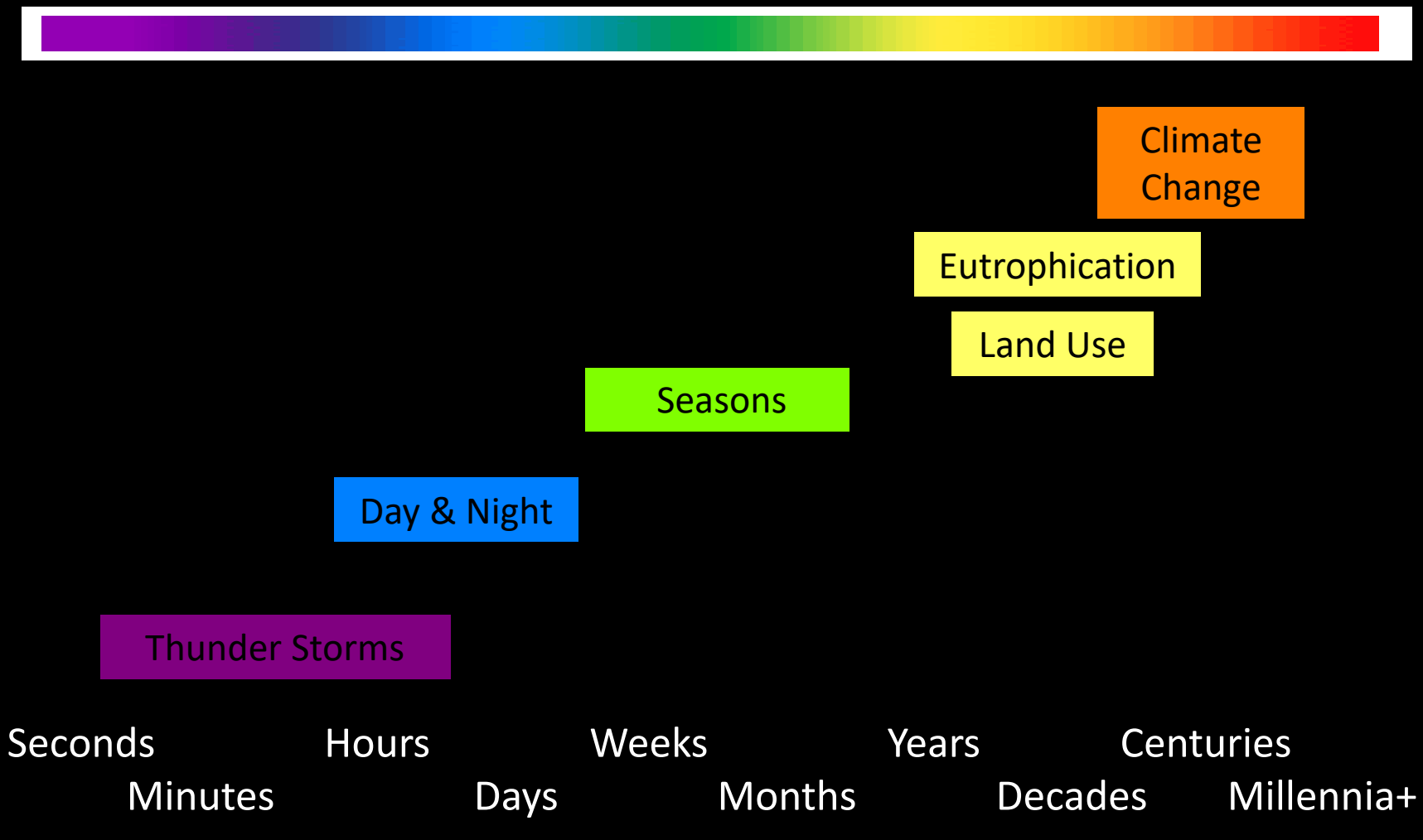
Lake Mendota WI, Magnuson 2010

How Do We Deal With Change?



Magnuson Photos

Changes Occur Quickly and Slowly



Time Scales of Changes

Magnuson 2009

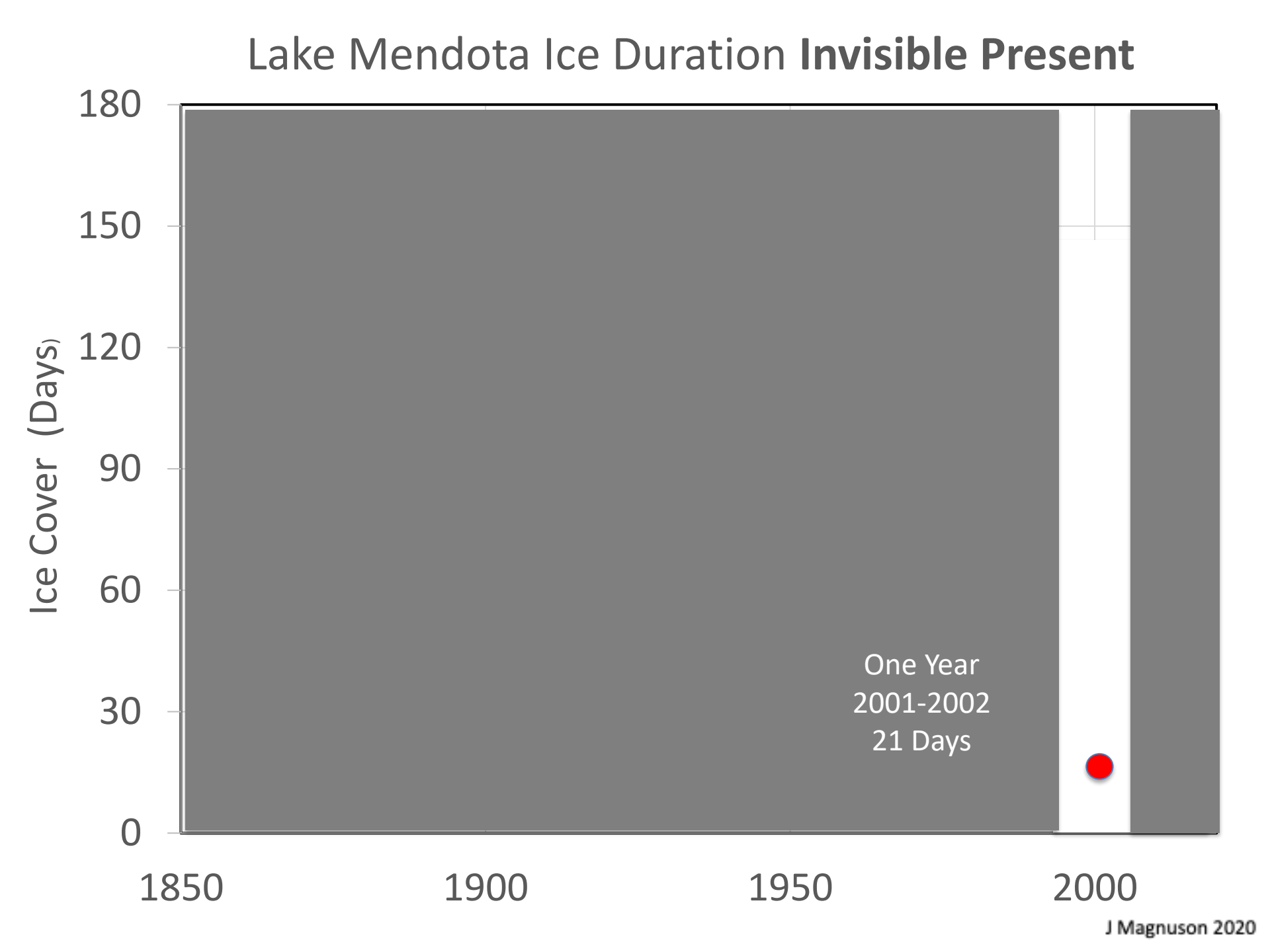
The Invisible Present

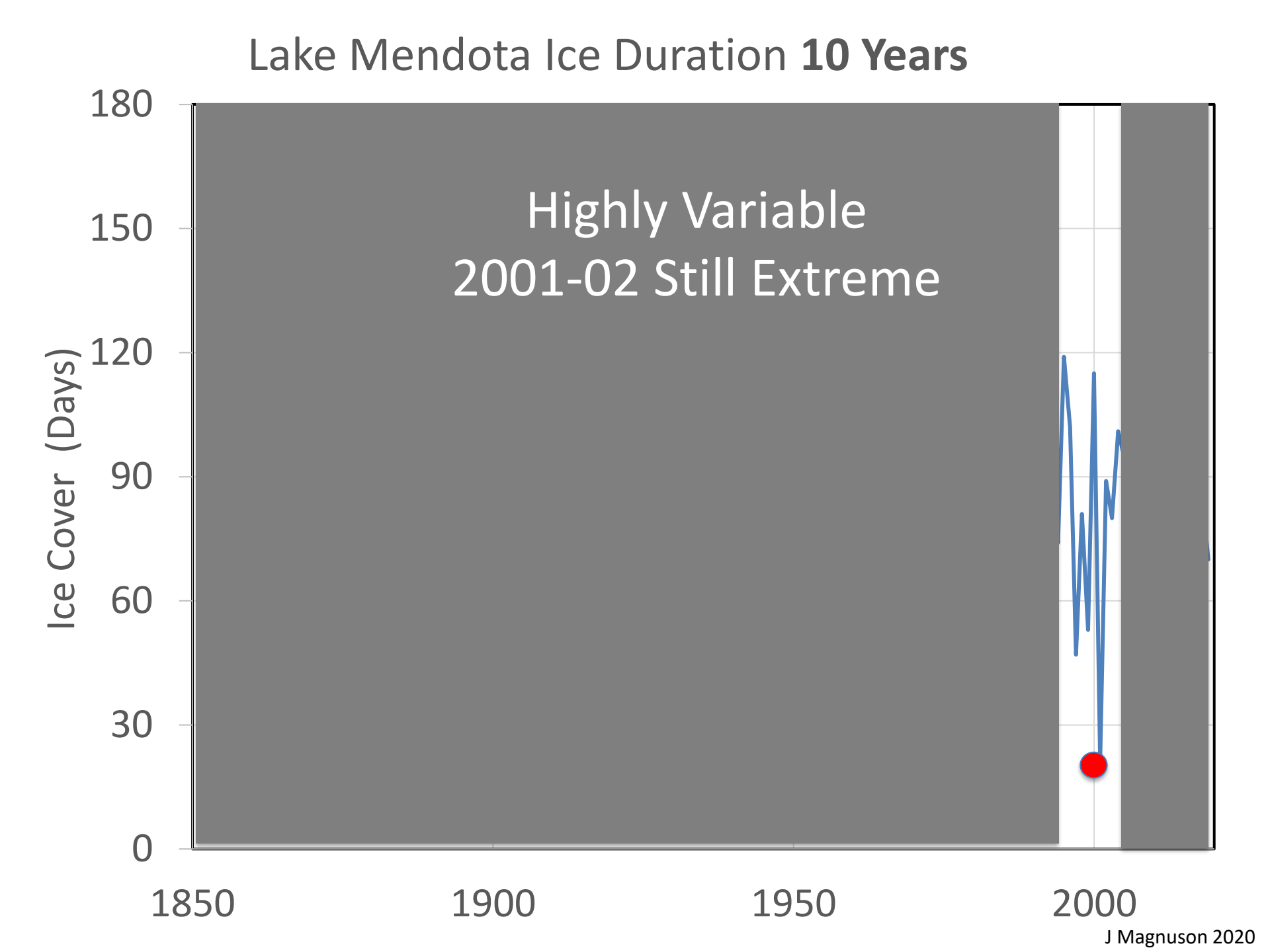
Magnuson 2006

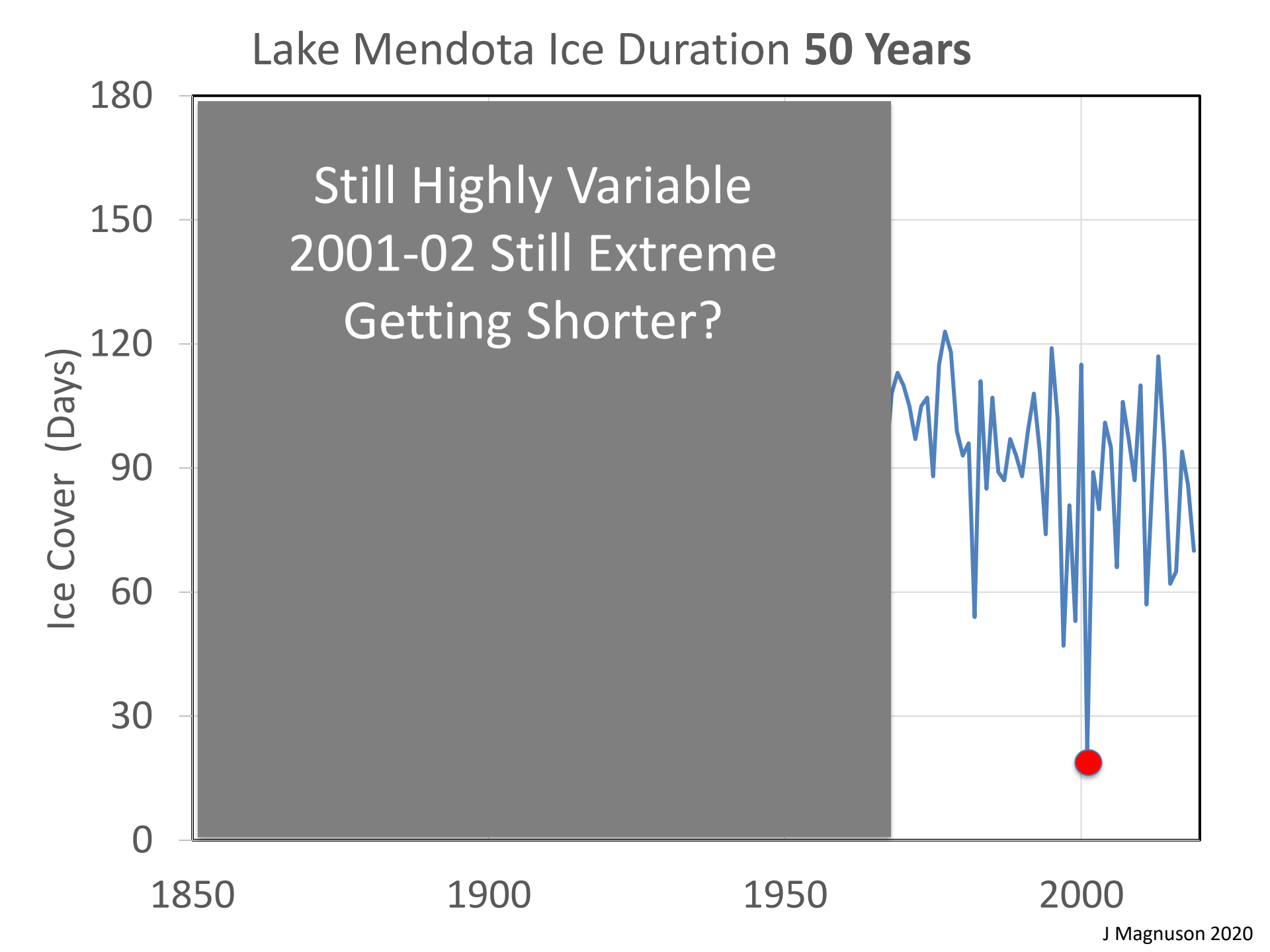
An early quote about time

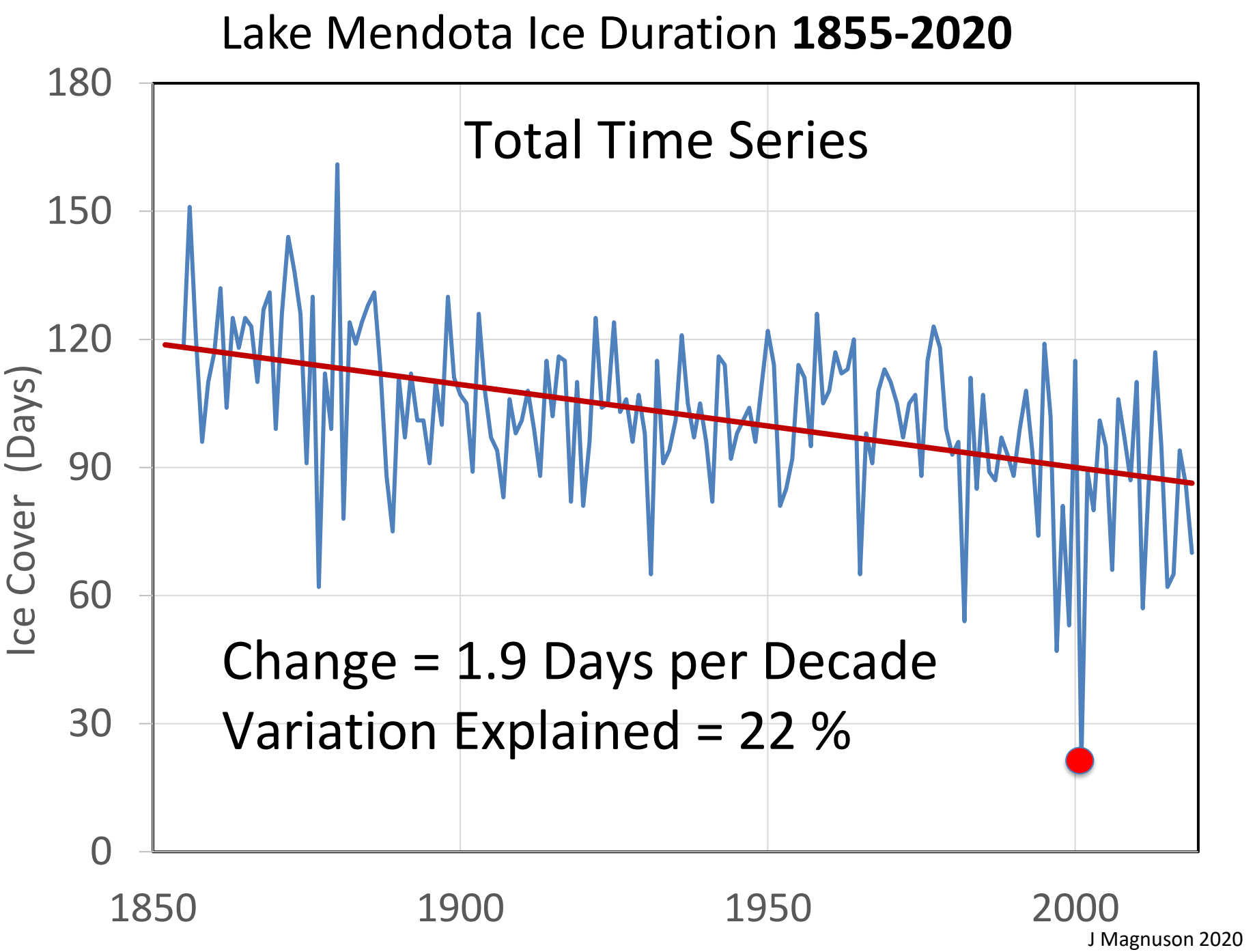
Marcus Auraelius Antonius,
Roman Emperor

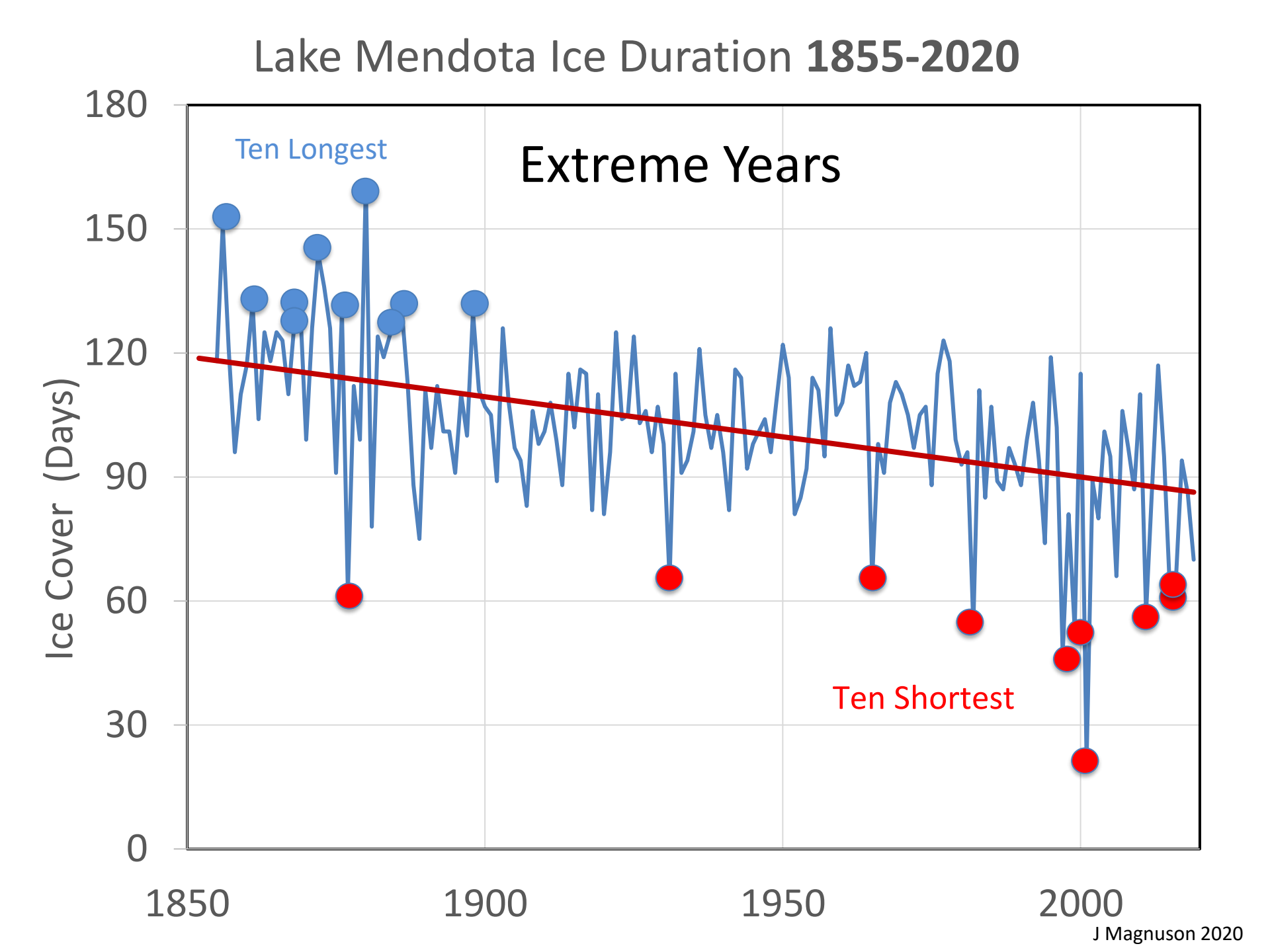
Time is sort of a river of passing events, and strong is its current;
no sooner is a thing brought to sight than it is swept by
and another takes its place, and this too will be swept away. (ca. 170)

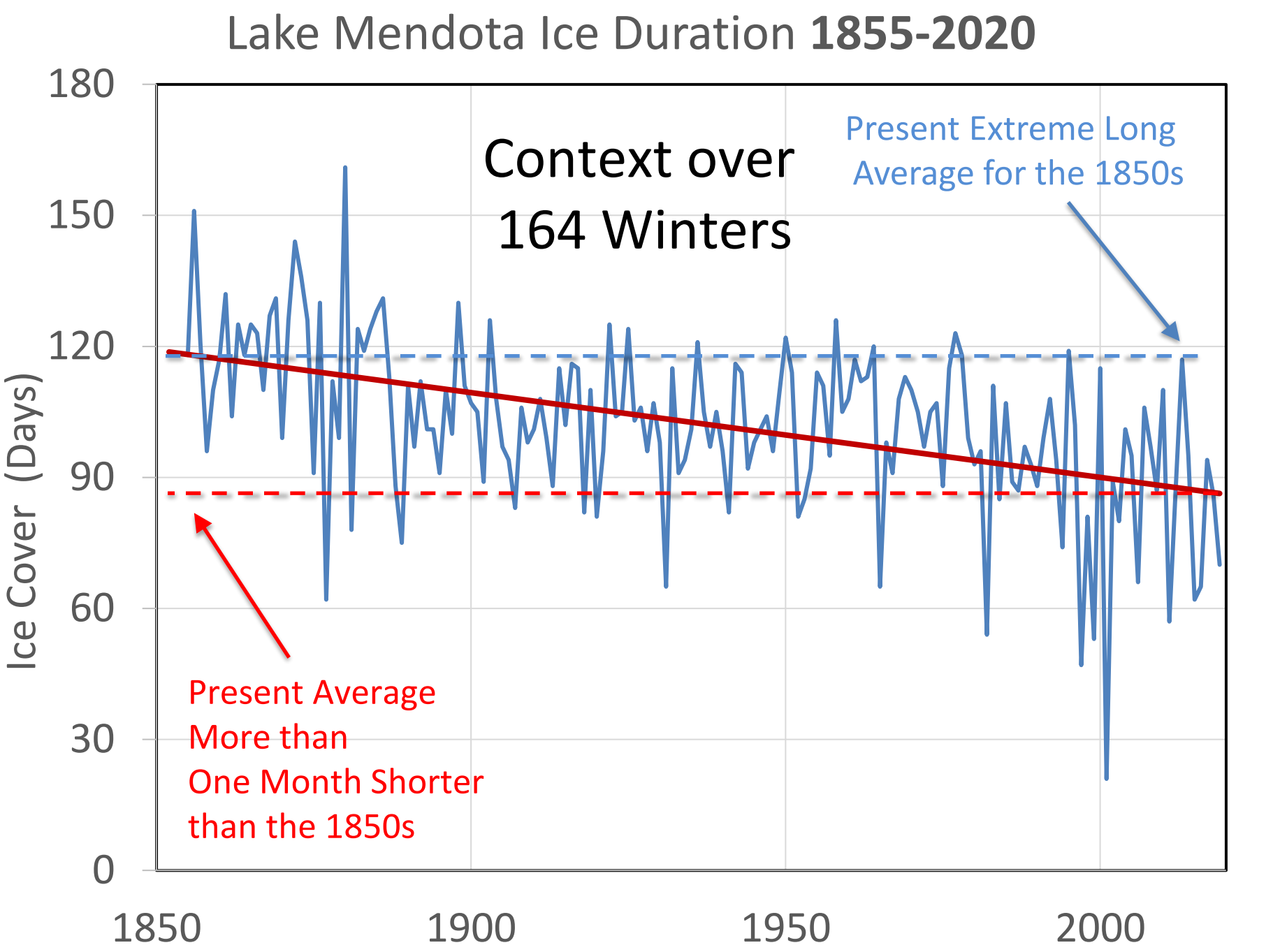

Lake Mendota Ice Duration **Invisible Present**
Ice Cover (Days)
180
150
120
90
60
30
0
1850
1900
1950
2000
One Year
2001-2002
21 Days
J Magnuson 2020


Lake Mendota Ice Duration **10 Years**
Highly Variable
2001-02 Still Extreme
Ice Cover (Days)
180
150
120
90
60
30
0
1850
1900
1950
2000
J Magnuson 2020

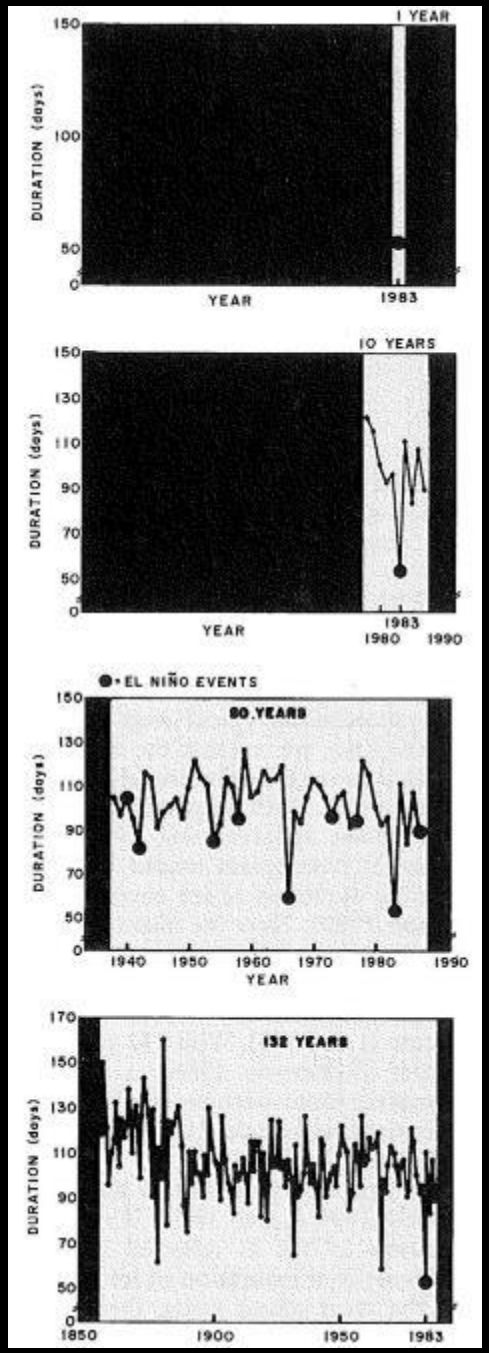

Lake Mendota Ice Duration **50 Years**
Still Highly Variable
2001-02 Still Extreme
Getting Shorter?
Ice Cover (Days)
180
150
120
90
60
30
0
1850
1900
1950
2000
J Magnuson 2020


Lake Mendota Ice Duration **1855-2020**
Total Time Series
Ice Cover (Days)
180
150
120
90
60
30
0
1850
1900
1950
2000
Change = 1.9 Days per Decade
Variation Explained = 22 %
J Magnuson 2020


Lake Mendota Ice Duration 1855-2020
Extreme Years
Ten Longest
Ten Shortest
Ice Cover (Days)
180
150
120
90
60
30
0
1850
1900
1950
2000
J Magnuson 2020


Lake Mendota Ice Duration 1855-2020
Context over
164 Winters
Present Extreme Long
Average for the 1850s
Present Average
More than
One Month Shorter
than the 1850s
Ice Cover (Days)
180
150
120
90
60
30
0
1850
1900
1950
2000
J Magnuson 2020


Lake Mendota Ice-on Day, January 20, 2007
Peter W. Schmitz

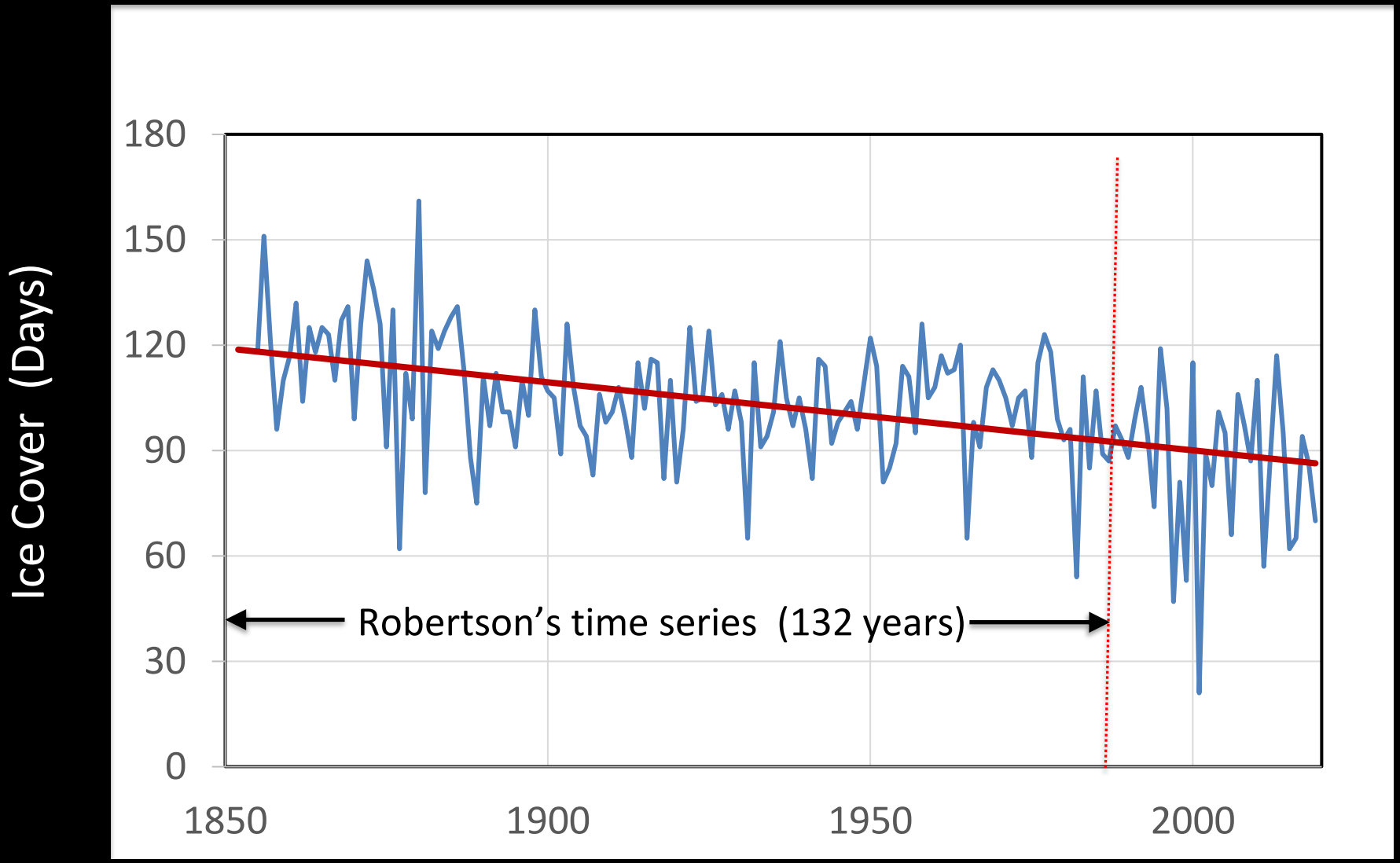


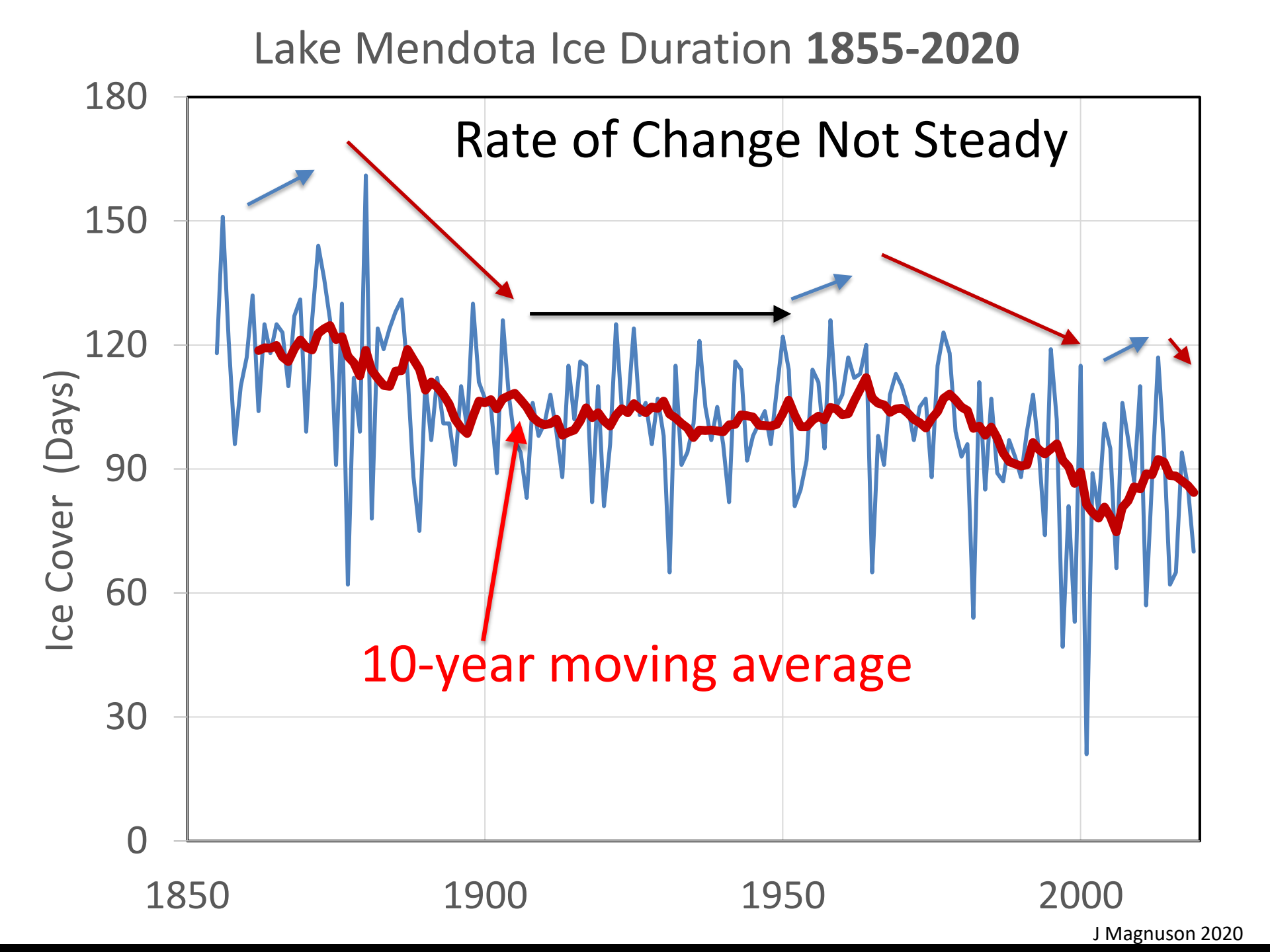
Invisible Present BioScience Magnuson 1990

From
Dale Robertson
Ph.D. thesis
1989

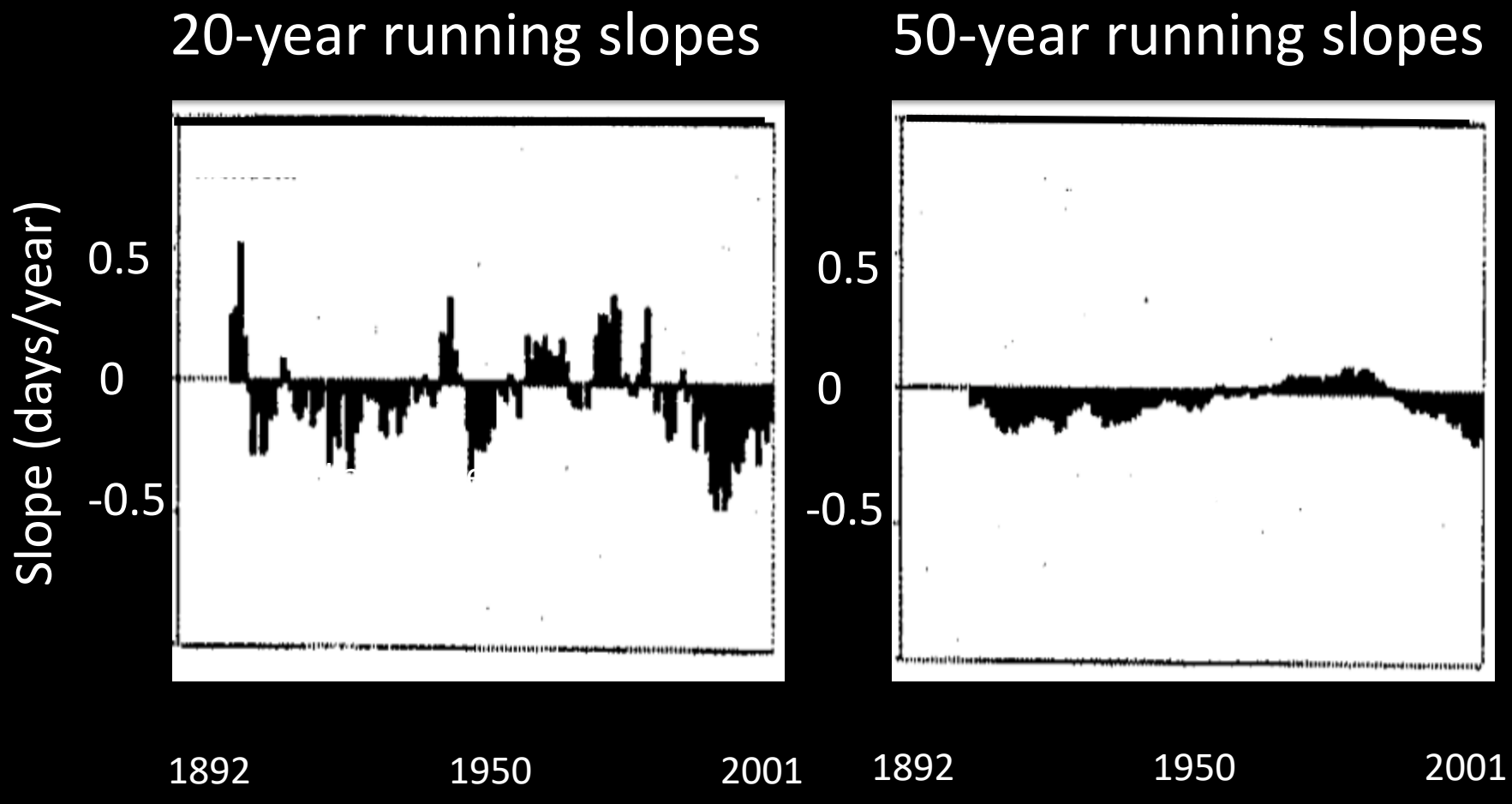
132 Years of
Serendipitous
data

Lake Mendota Ice Duration **1855-2020**




Lake Mendota Ice Duration 1855-2020
Rate of Change Not Steady
10-year moving average
Ice Cover (Days)
180
150
120
90
60
30
0
1850
1900
1950
2000
J Magnuson 2020

20- or even 50-years of ice breakup dates are needed to detect the direction of long-term trends.



Wynne 2001, Magnuson 2002

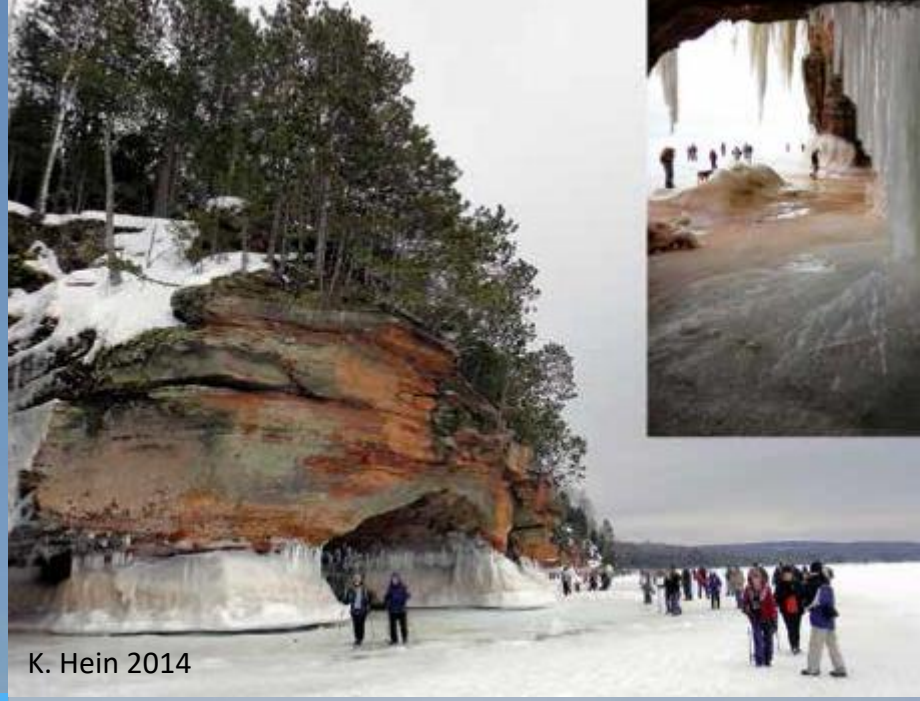
The Invisible Place

Magnuson 2006

An early quote about space

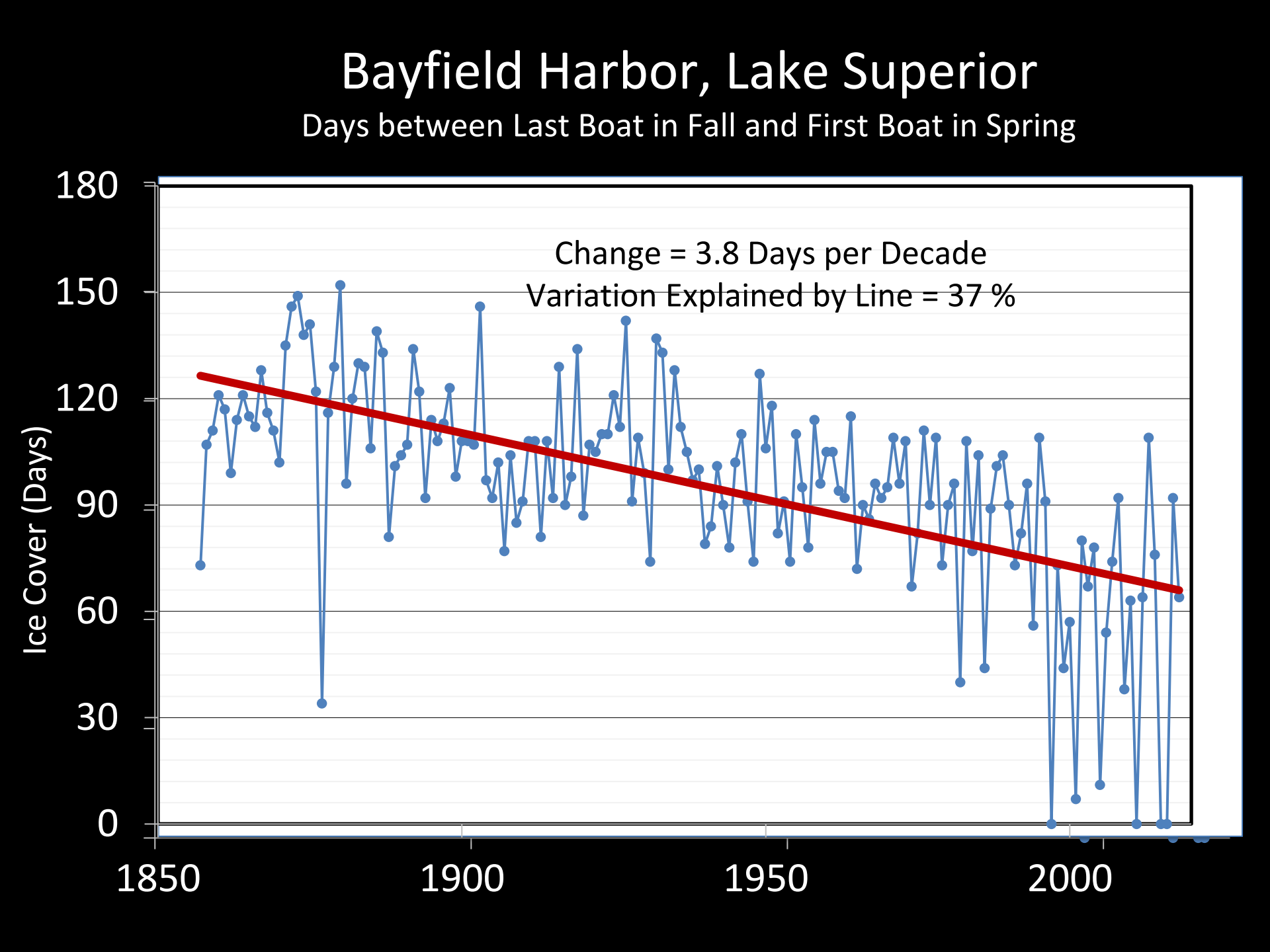
John Heywood (mid 1500s)

Not being able to see the forest for the trees.
You cannot see the wood for the trees.



K. Hein 2014

Apostle Island National Lakeshore


Bayfield Harbor, Lake Superior
Days between Last Boat in Fall and First Boat in Spring
Change = 3.8 Days per Decade
Variation Explained by Line = 37 %
Ice Cover (Days)
180
150
120
90
60
30
0
1850
1900
1950
2000

Ice Road from Madeline Island to Bayfield, Wisconsin

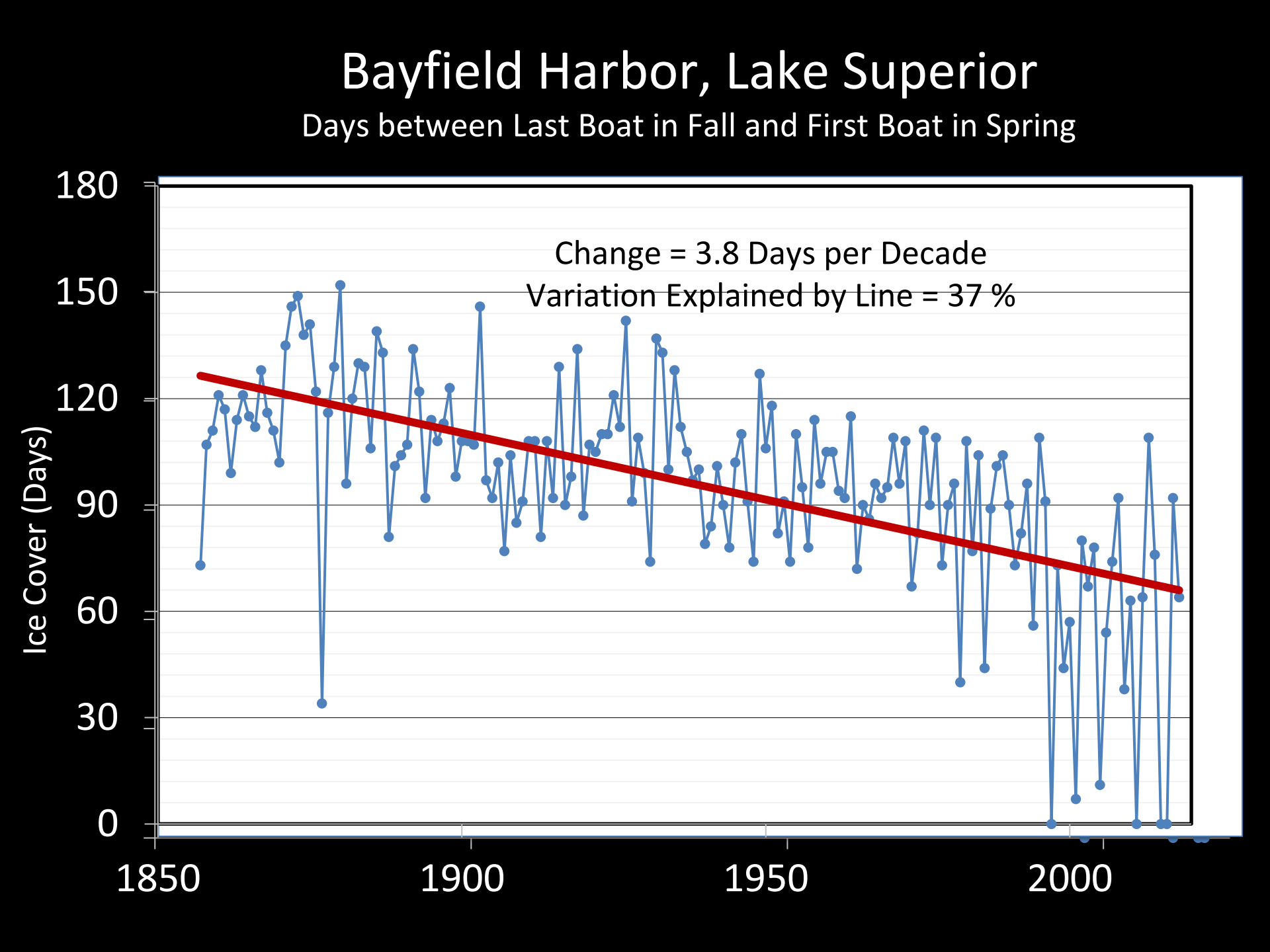
Sources: Bob Hanson
https://www.youtube.com/watch?v=d_tDfye6Ffc

How much longer can a good thing last?

Taken from an Article in Diane Daulton's Water Column (ddaulton@centurytel.net)

The Madeline Island Ferry was still running in February 2016.
Ice Cover = 0 days
The ferry can break through about 6 inches of ice.
Boats may not have been as able to break ice as well in the early years.

Photo courtesy of Jon Armstrong www.apostlerentals.com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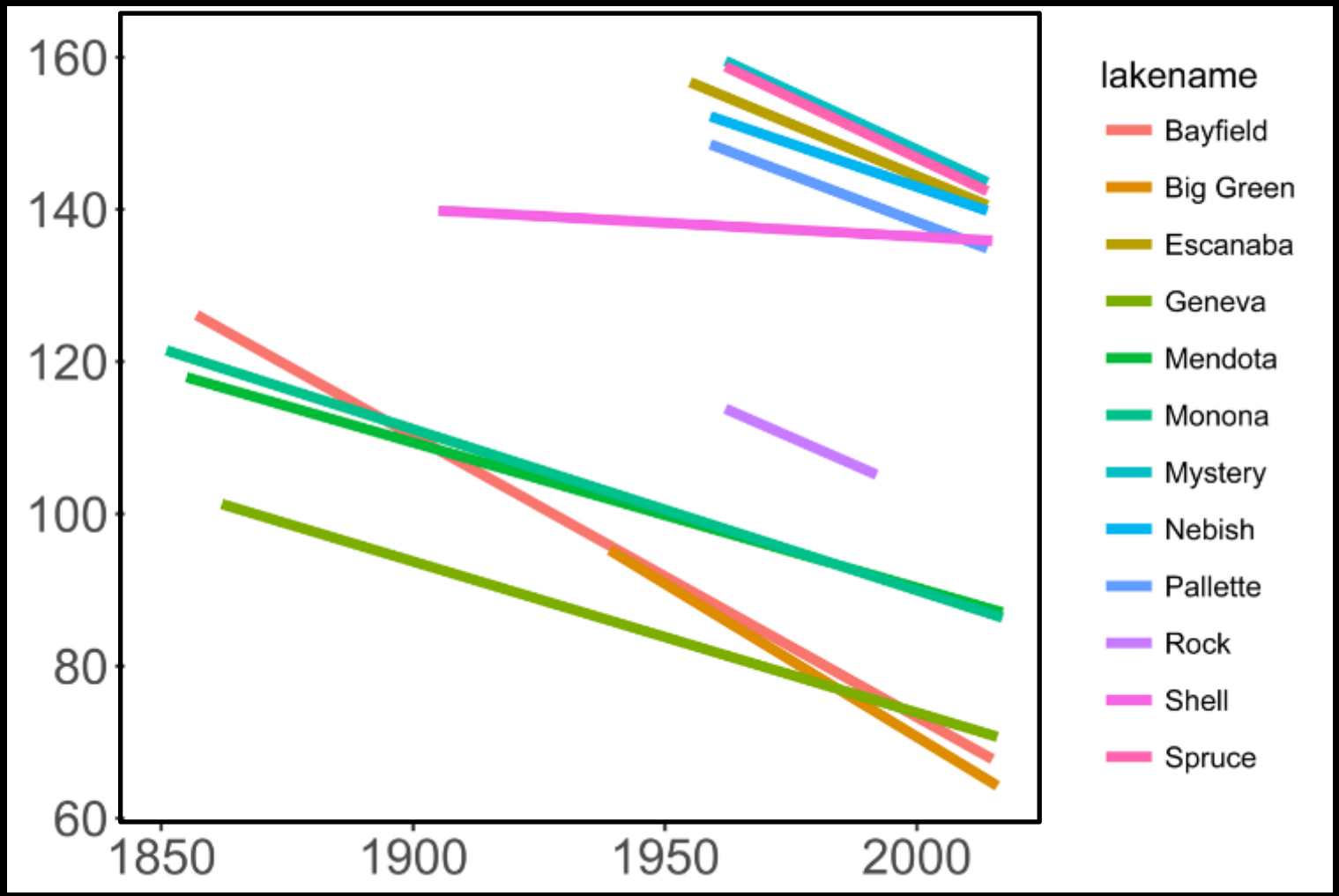
Ice Cover (Days)
180
150
120
90
60
30
0
1850
1900
1950
2000

Location of a few of the 46 Wisconsin lakes with ice cover observations

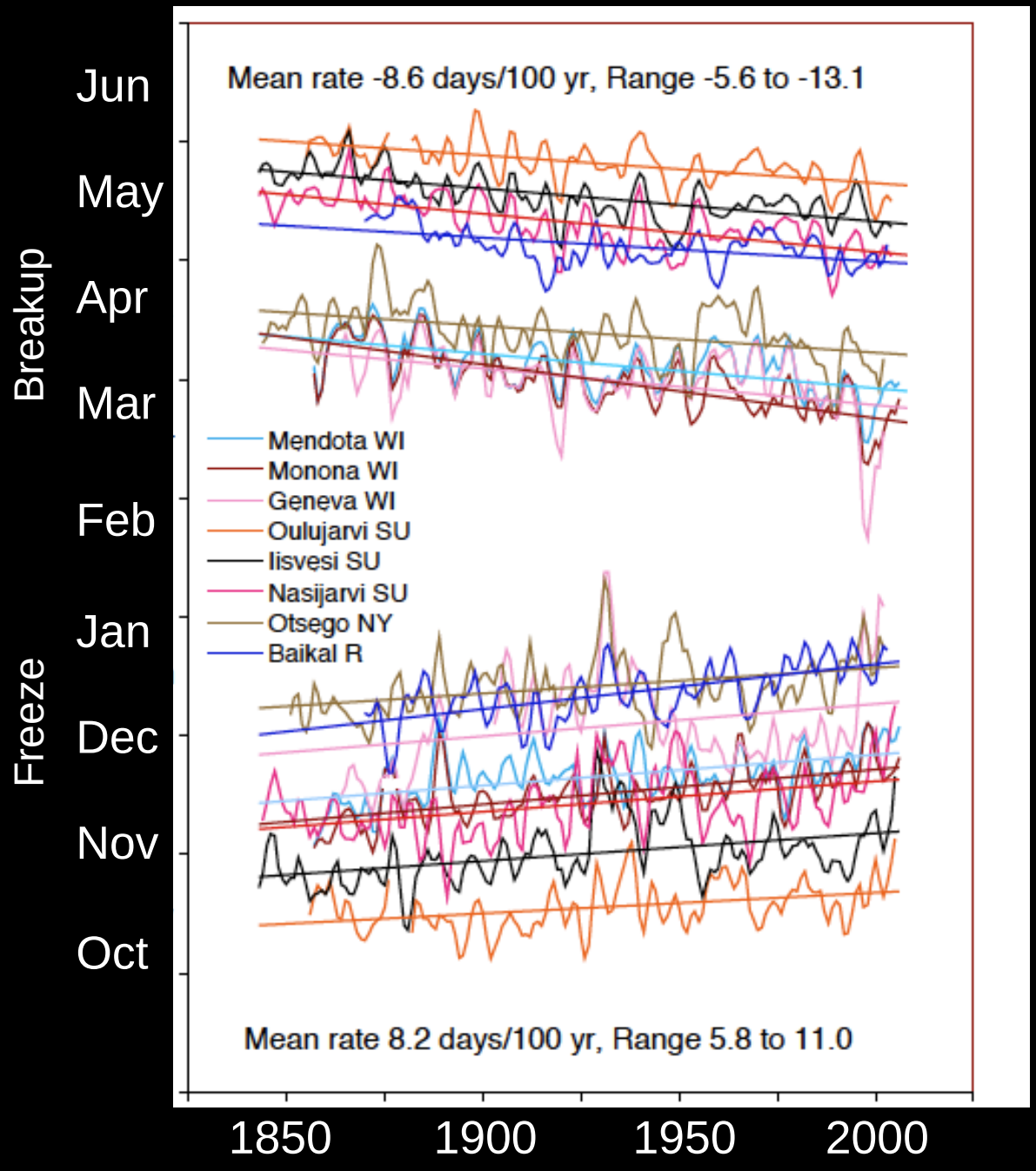
Ice cover duration on a few of the 46 Wisconsin lakes with ice observations



International Lake Ice Analysis Group 1996 at Trout Lake, WI

Changes in Freeze and Breakup Dates

winters
1843-4 to 2008-9
(8 lakes)

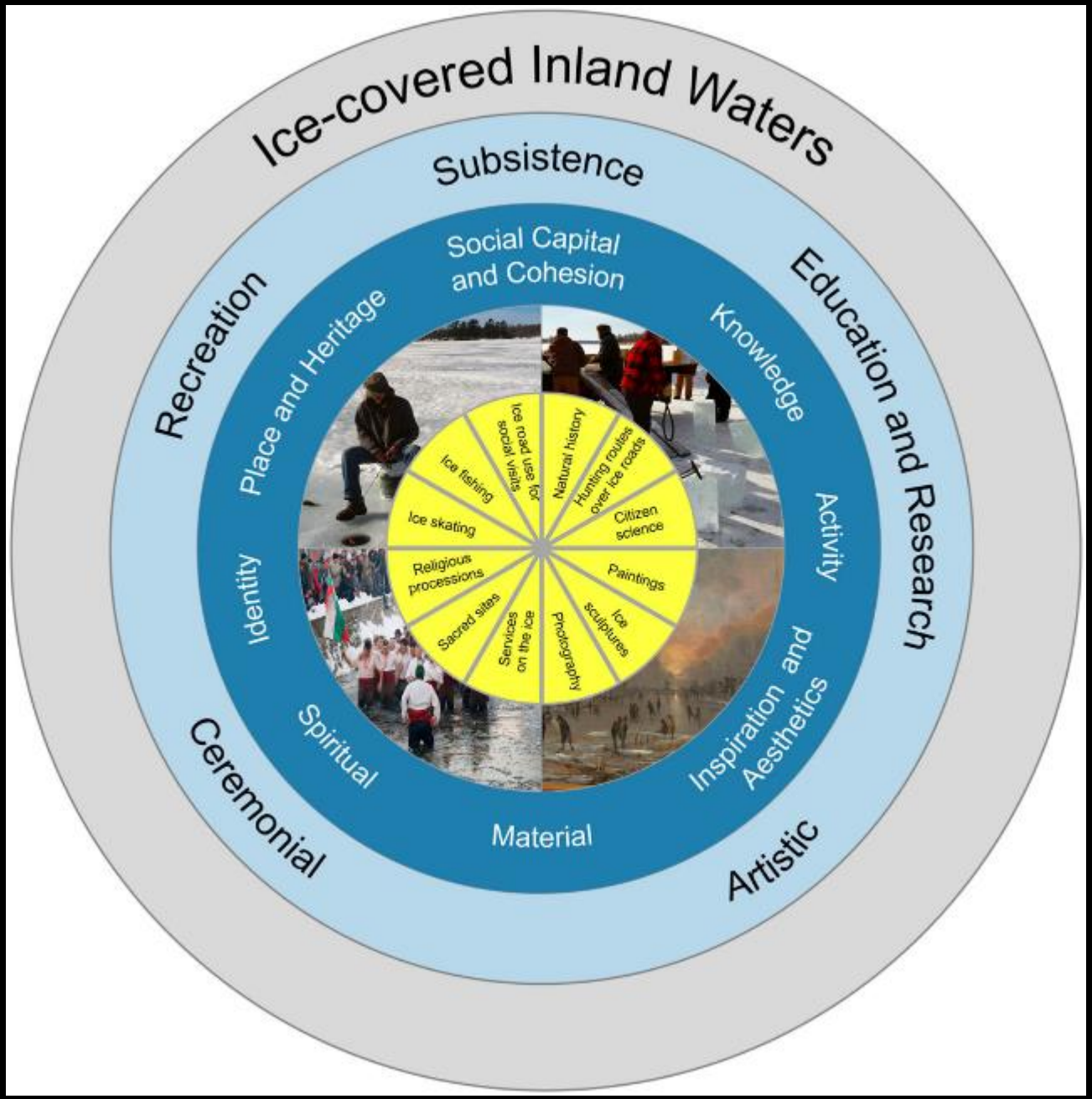


Magnuson et al. Science 2000


Lake Ice:
a Miner's Canary
for Climate Change
Magnuson photo
Mystery Lake , mid 19

Influence of Declining Lake Ice on People

Consequences of lake & river ice loss on cultural ecosystem services.



Knoll et al 2019

Recreational Values Are Being Lost

Ice Services to us Declining with Warming

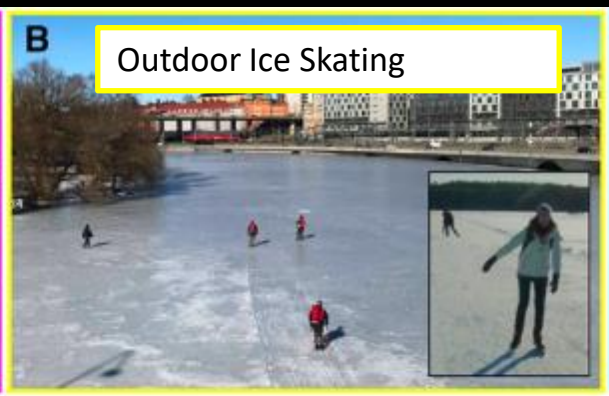


Photo Legend:

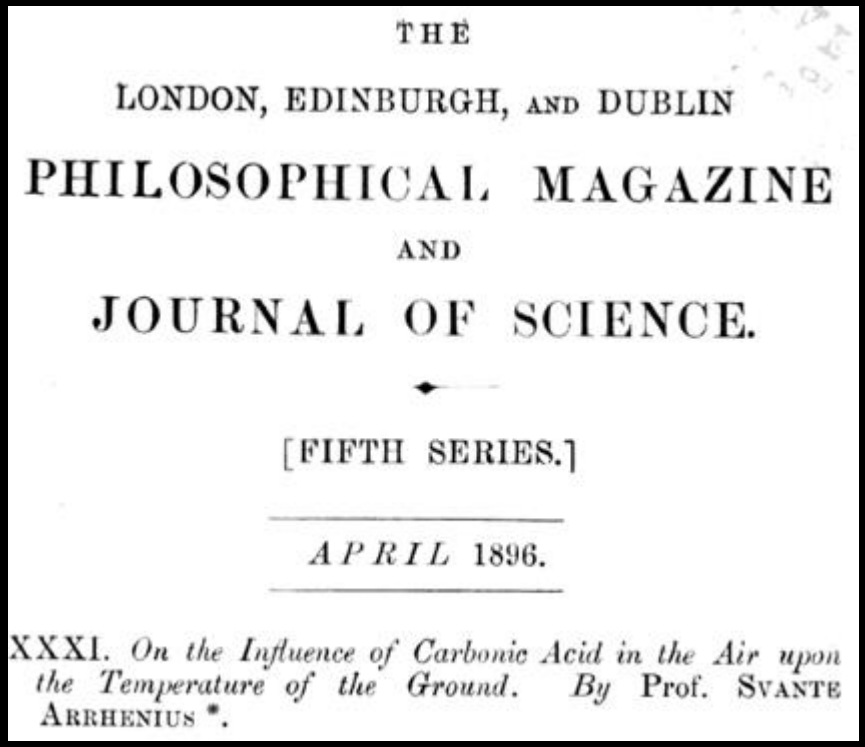
(A) **Stable Ice Road** (Ontario, Canada). *Insert:* **Truck Through Ice** (Manitoba, Canada).
(B) **Ice Skating Race** (Lake Mälaren, Sweden). *Insert:* **Ice Skater** (Lake Fjälnora, Sweden).
(C) **Shinto Ritual** (Lake Suwa, Japan)
(D) **International Eelpout Ice Fishing Festival** (Leech Lake, Minnesota, USA).
(E) **Seegfrörne Procession** (Lake Constance, Germany/Switzerland/Austria).

Knoll et al. 2019

How Long Has Science Recognized the Importance of CO_2 in Warming the Atmosphere?

At least from 1896 through the works of Svante Arrhenius, a Swedish Chemist

Quote:
"if the carbon dioxide is increased by 2.5 to 3 times its present value, the temperature in the arctic regions must rise 8 to 9ºC. and produce a climate as mild as that of the Eocene period."



THE

LONDON, EDINBURGH, AND DUBLIN

PHILOSOPHICAL MAGAZINE

AND

JOURNAL OF SCIENCE.

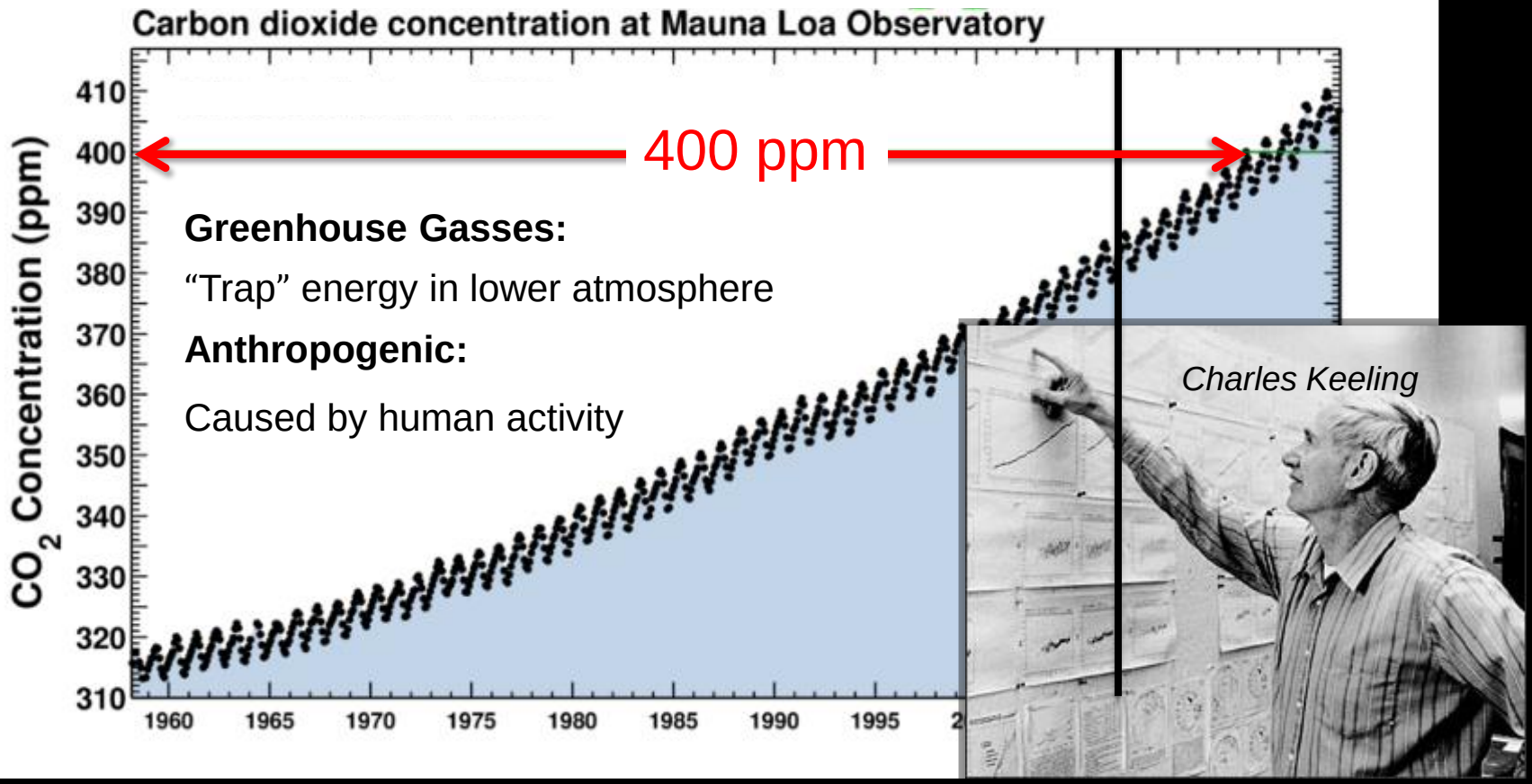
[FIFTH SERIES.]

APRIL 1896.

XXXI. *On the Influence of Carbonic Acid in the Air upon the Temperature of the Ground.* *By* Prof. SVANTE ARRHENIUS *.

Greenhouse gasses are increasing owing to burning fossil fuels

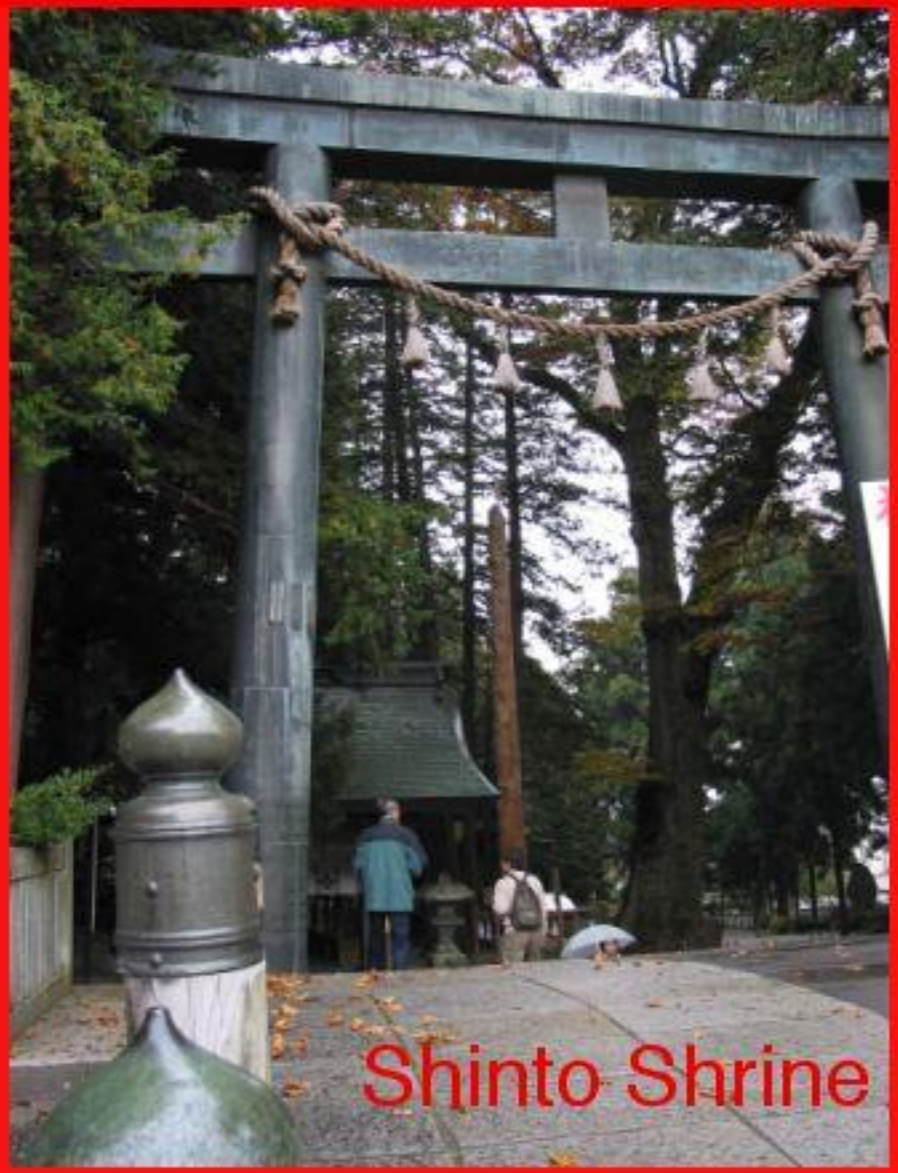
CO_2 reading on Jan 15, 2018: 407.8 ppm



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

The Longest Lake Ice Record

Suwa Ko, Japan



Magnuson Photos

Shinto Ceremony at Omiwatari on Suwa Ko

Shrine Photo

From Shinto tradition to data and analysis

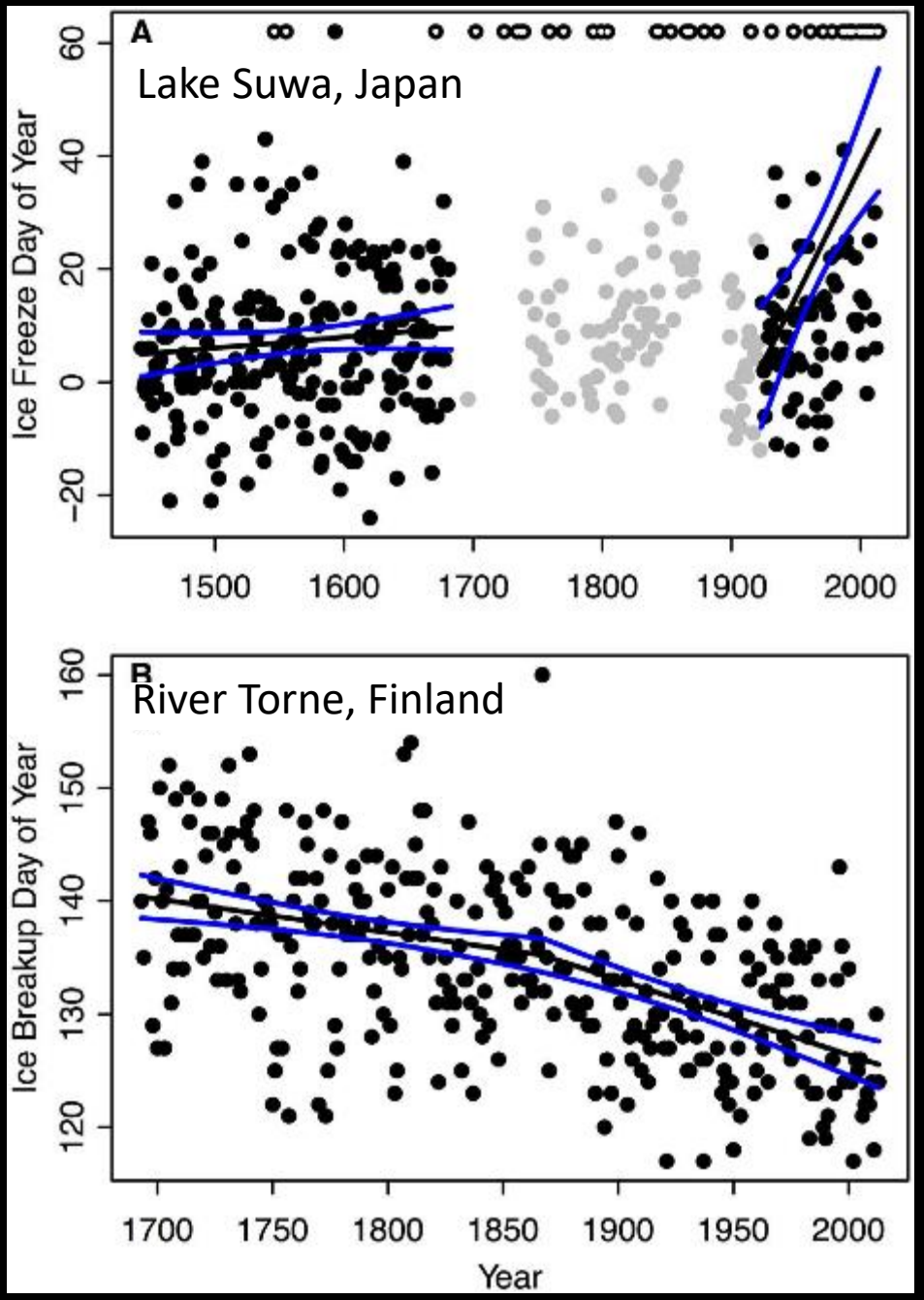
Shinto Ceremony on Lake Suwa, Japan

These long records include dates before & after the start of the Industrial Revolution.

Ice-on date
(Lake Suwa, Japan)

Ice-off date
(River Torne, Finland)

google: Lake Suwa ice & climate change



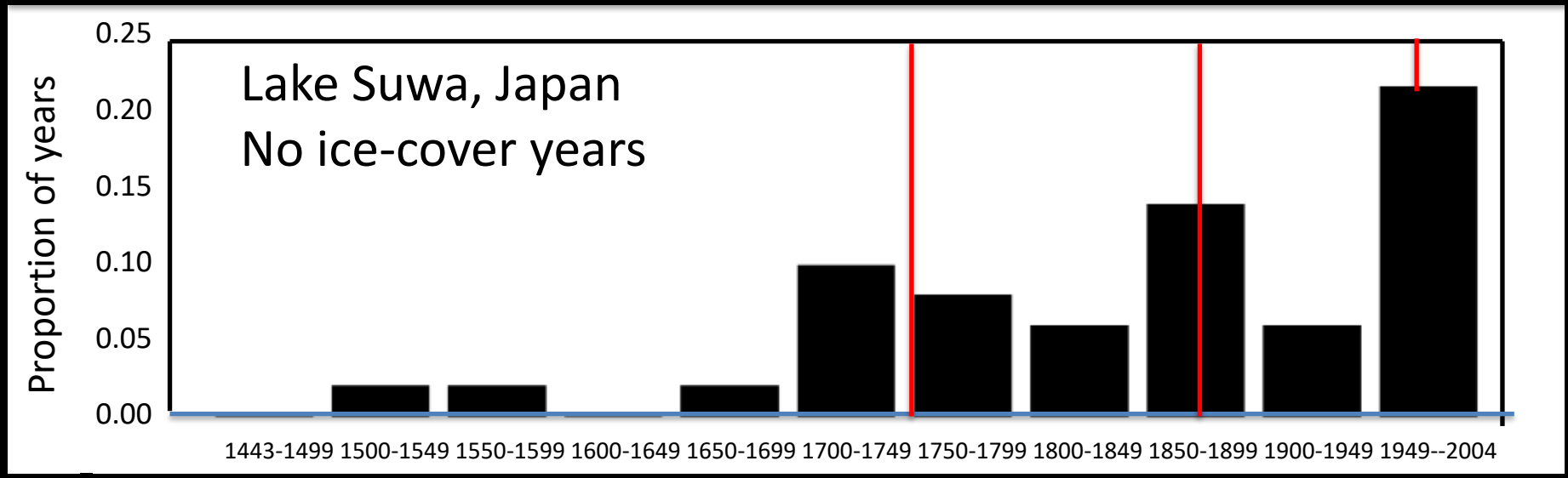
Sharma, Magnuson, et al. 2016

Change in ice dates before & after the start of the Industrial Revolution (Days per Decade)

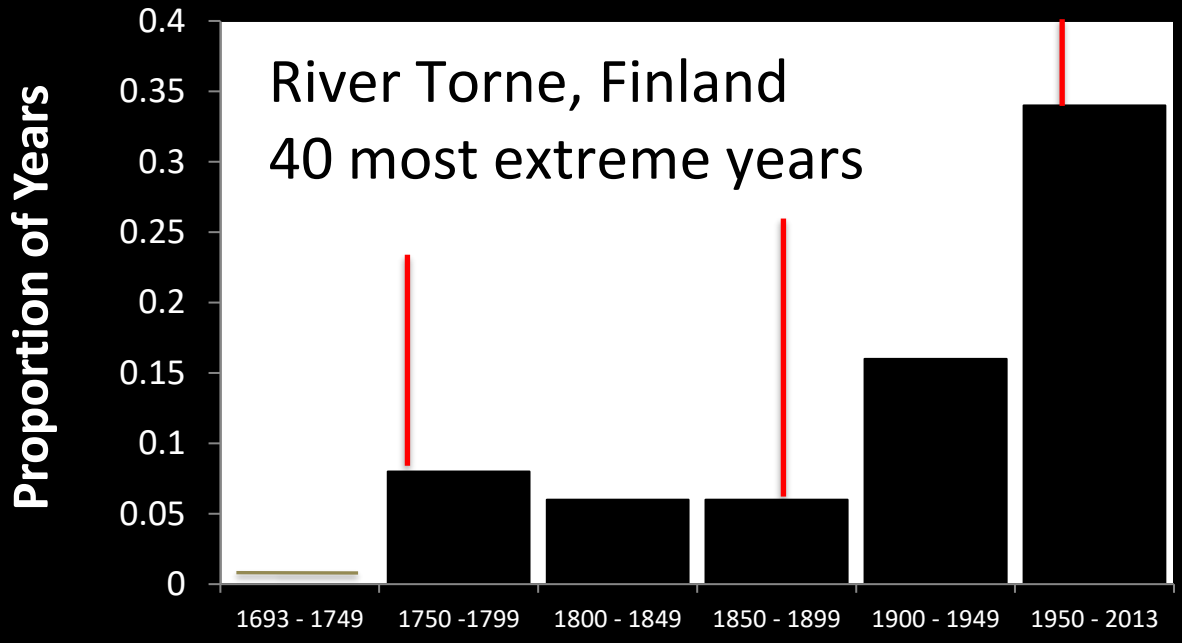
Water Body	Ice Data	Before	After
	Lake Suwa	1443-1683	1923-2014
	River Torne	1693-1866	1867-2013
Lake Suwa (Japan)	**Ice on**	**0.2**	**4.6**
River Torne (Finland)	**Ice off**	**-0.3**	**-0.7**

Sharma, Magnuson, et al. 2016

Really Long Term - Warm Extremes are Becoming More Common

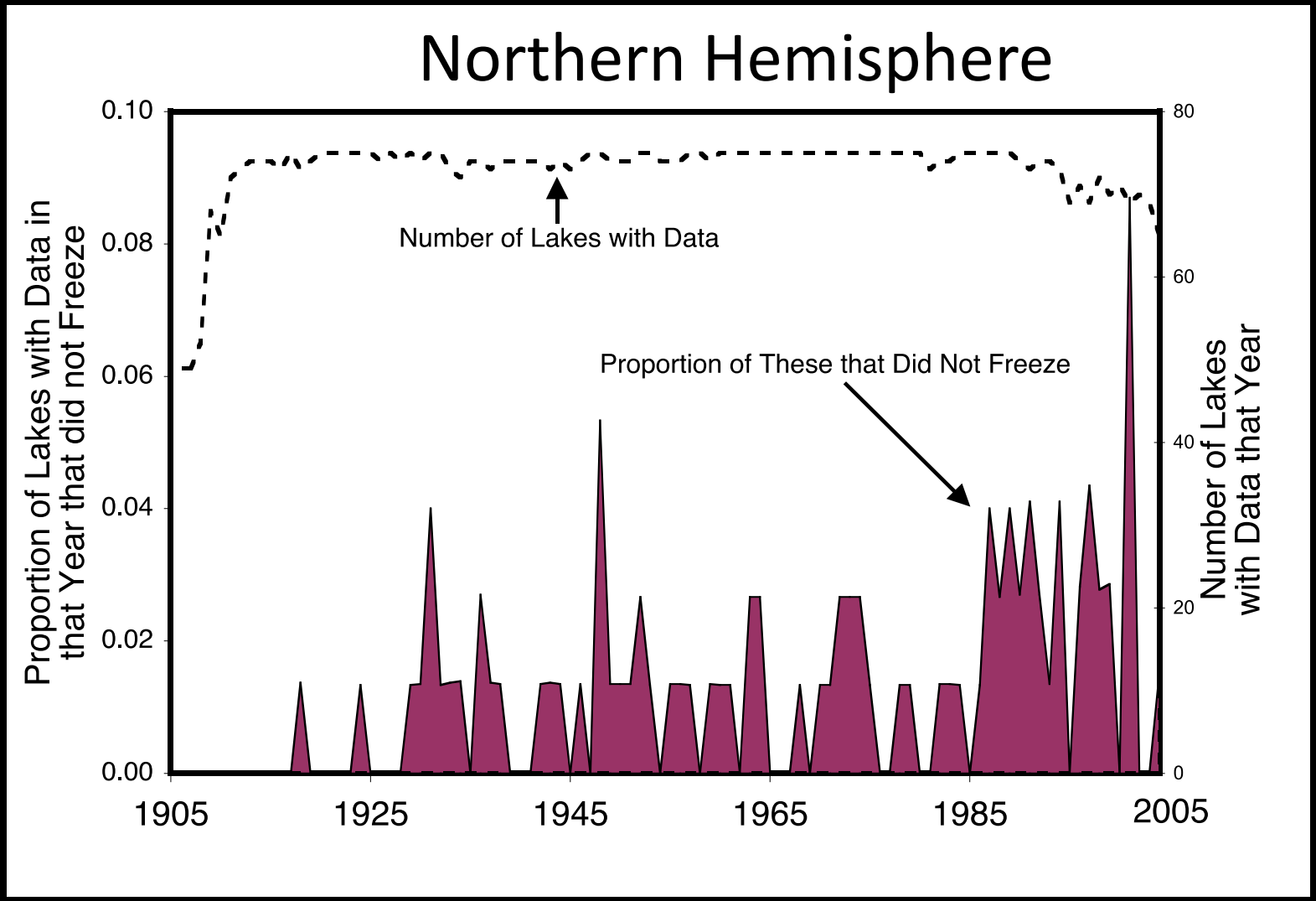


Industrial Revolutions Vertical Red lines



Sharma, Magnuson, et al. 2016

Increase in the Extreme Event of Lakes Not Freezing



Benson, Magnuson, Jensen, et al. 2012

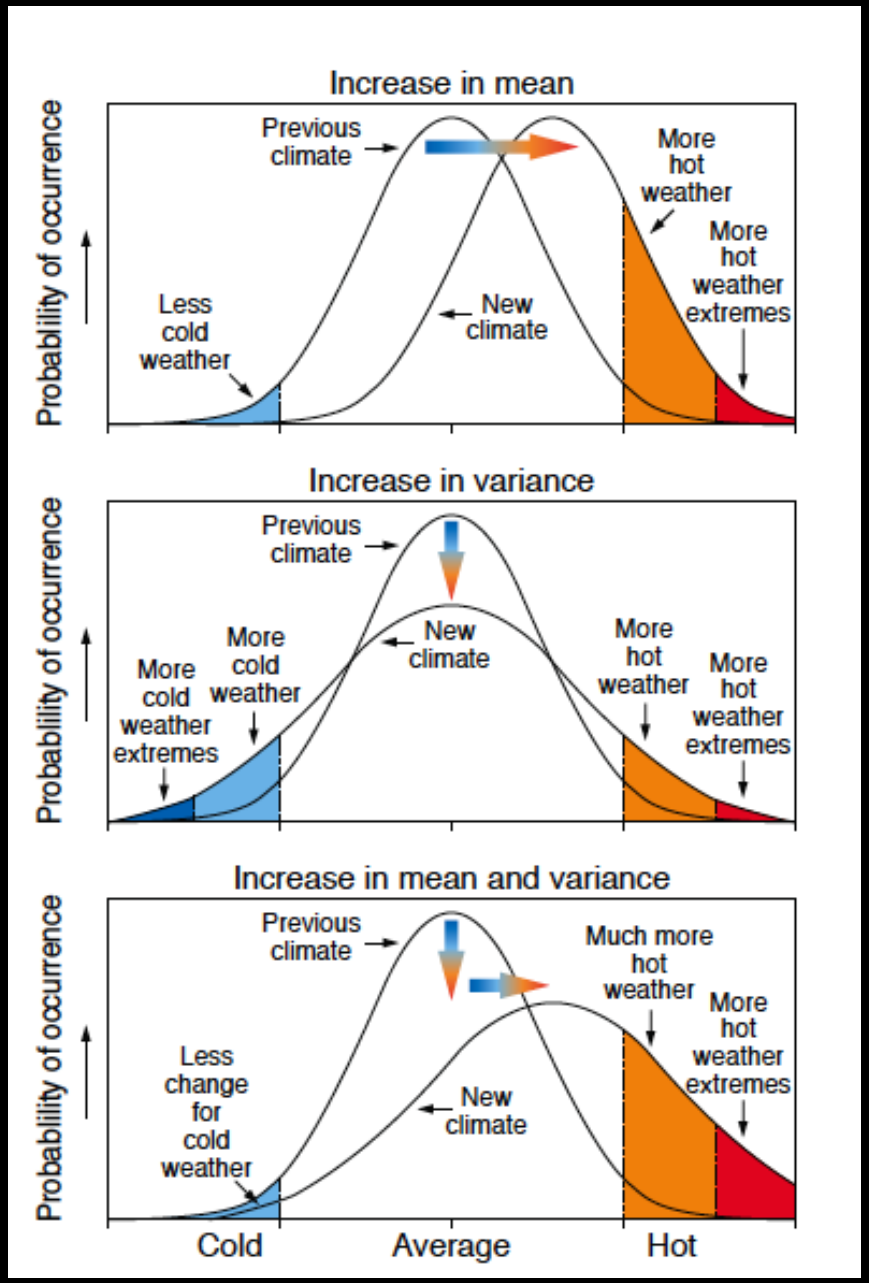
Expectations:

Extremes can occur from

A change in the mean →

An increase in the variability →

Both →



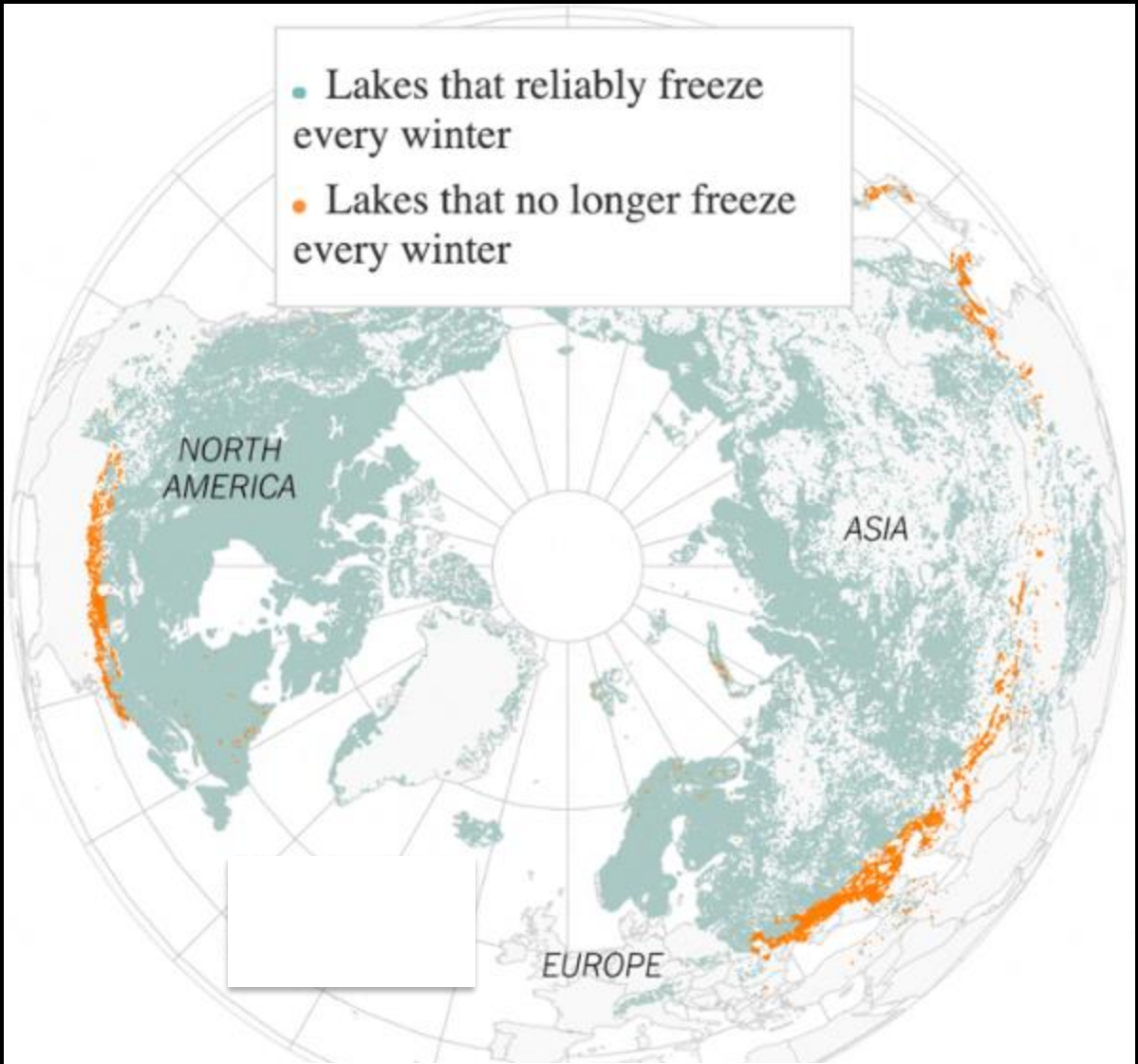
Modified from IPCC Working Group 1, 2001

Lakes would begin to have winters without complete ice cover

When

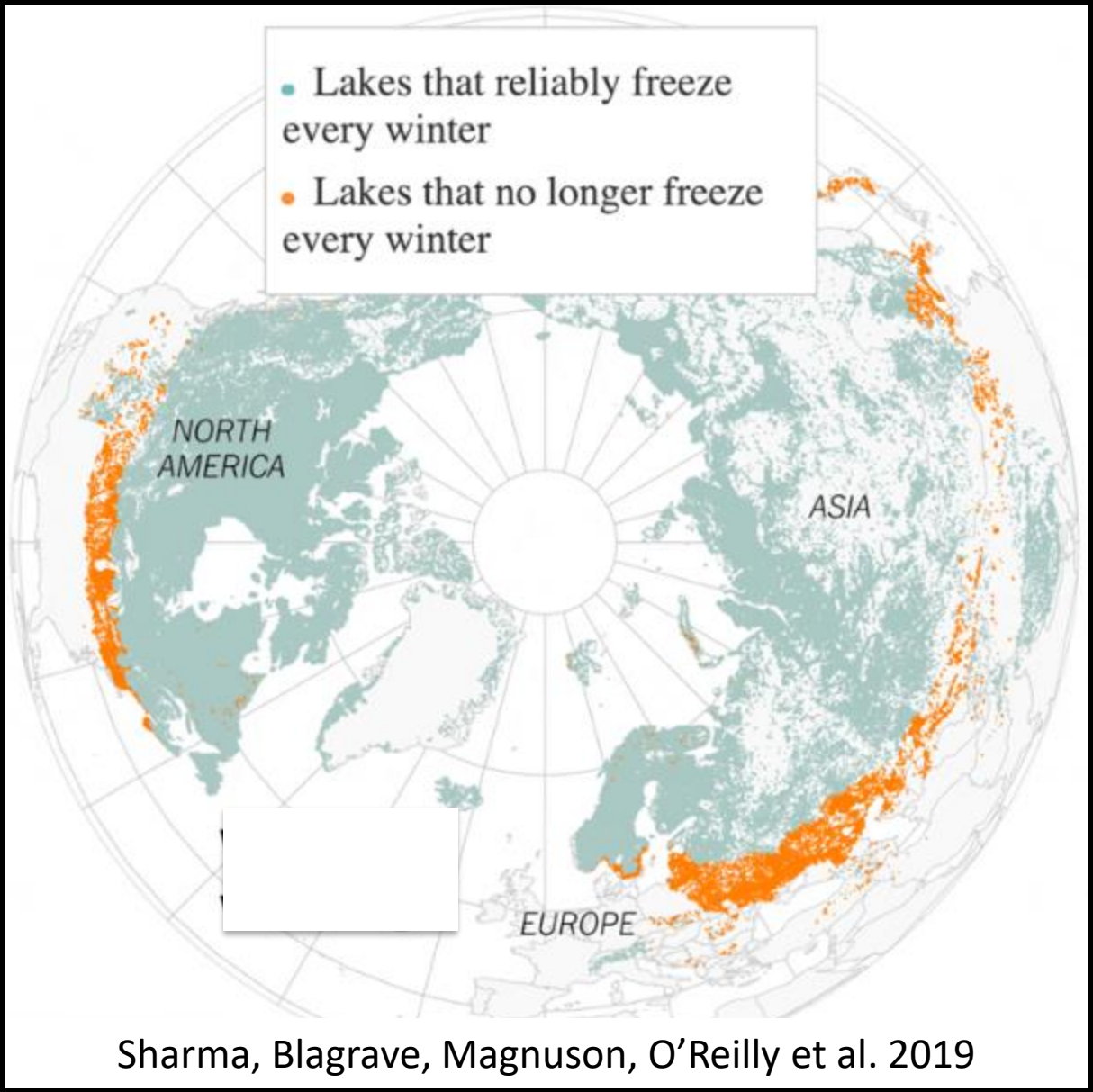
1. Annual mean air temperatures are equal or greater than $8.4^{o}C$
2. Or when mean depth is greater than 24 meters
3. And elevation is less than 270 meters
4. Shoreline complexity is low (i.e. closer to being round)

Current Conditions



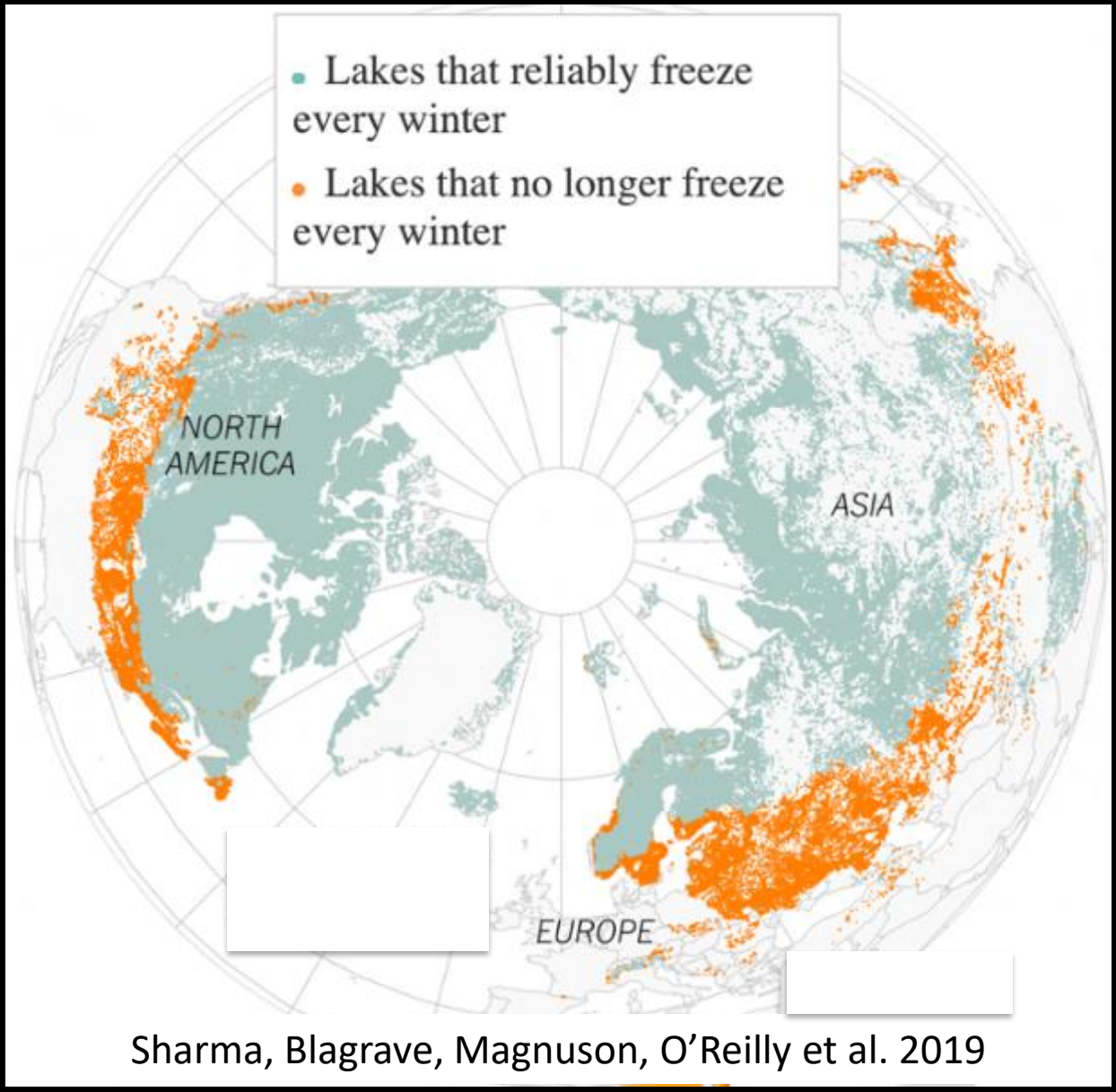
Sharma, Blagrave, Magnuson, O'Reilly et al. 2019

2°C Warming



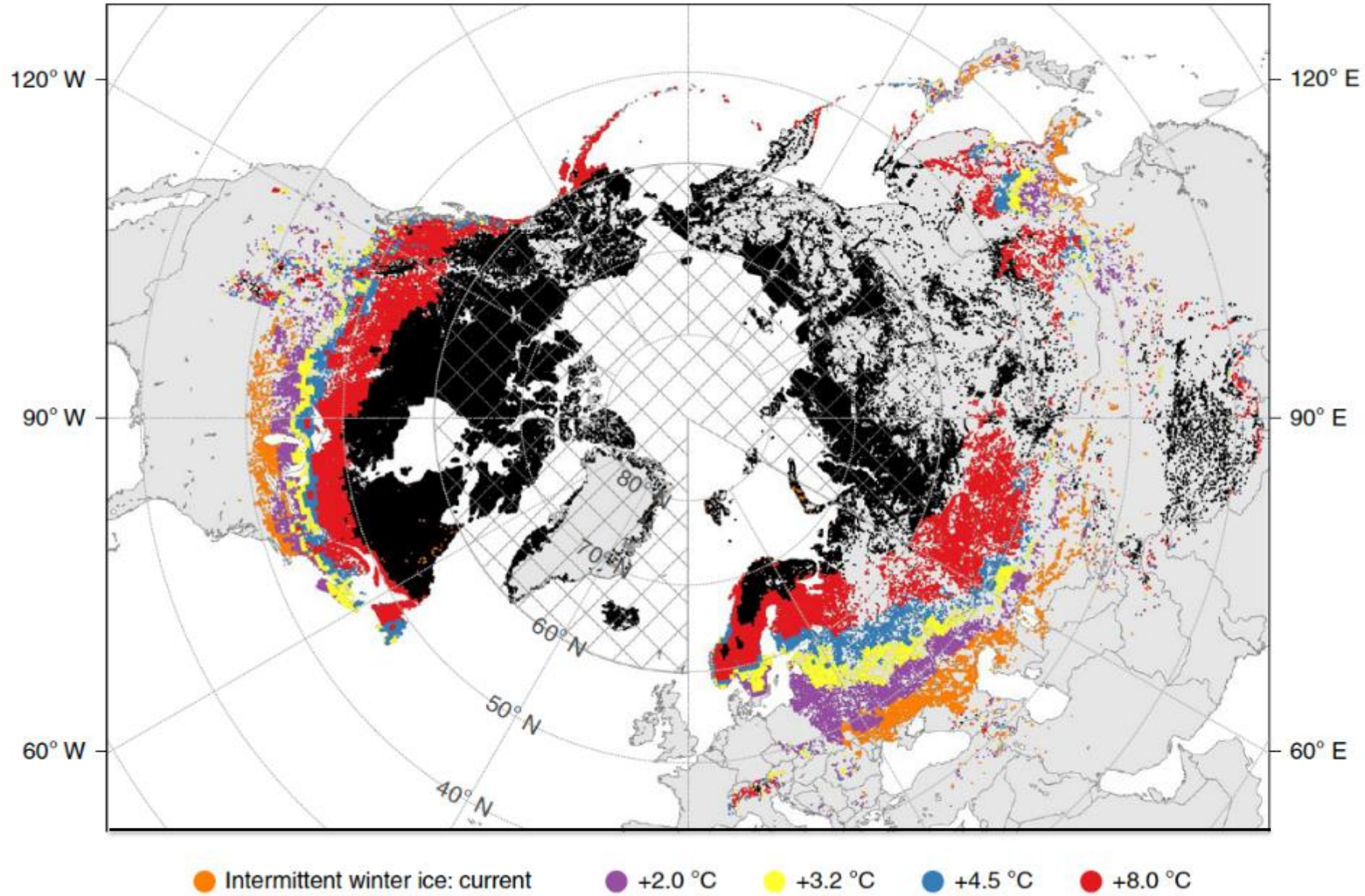
Sharma, Blagrave, Magnuson, O'Reilly et al. 2019

4.5°C Warming



Sharma, Blagrave, Magnuson, O'Reilly et al. 2019

Northward movement of lakes with intermittent ice



Sharma, Blagrave, Magnuson, O'Reilly et al. 2019

Number of lakes, countries, or people affected by the shift of lakes from annual to intermittent winter ice cover.

Temperature Increase	Current Conditions	2°C *	4.5°C **
Number of lakes with intermittent Ice	14,800	35,300	90,200
Number of countries with intermittent ice	30	41	47
Number of people within grid cell of intermittent lake	248,000,000	394,000,000	562,000,000

* Goal of Paris Accord

** Expected warming without any mitigation

Sharma, Blagrave, Magnuson, O'Reilly et al. 2019

When would Wisconsin lakes likely start having intermittent ice?

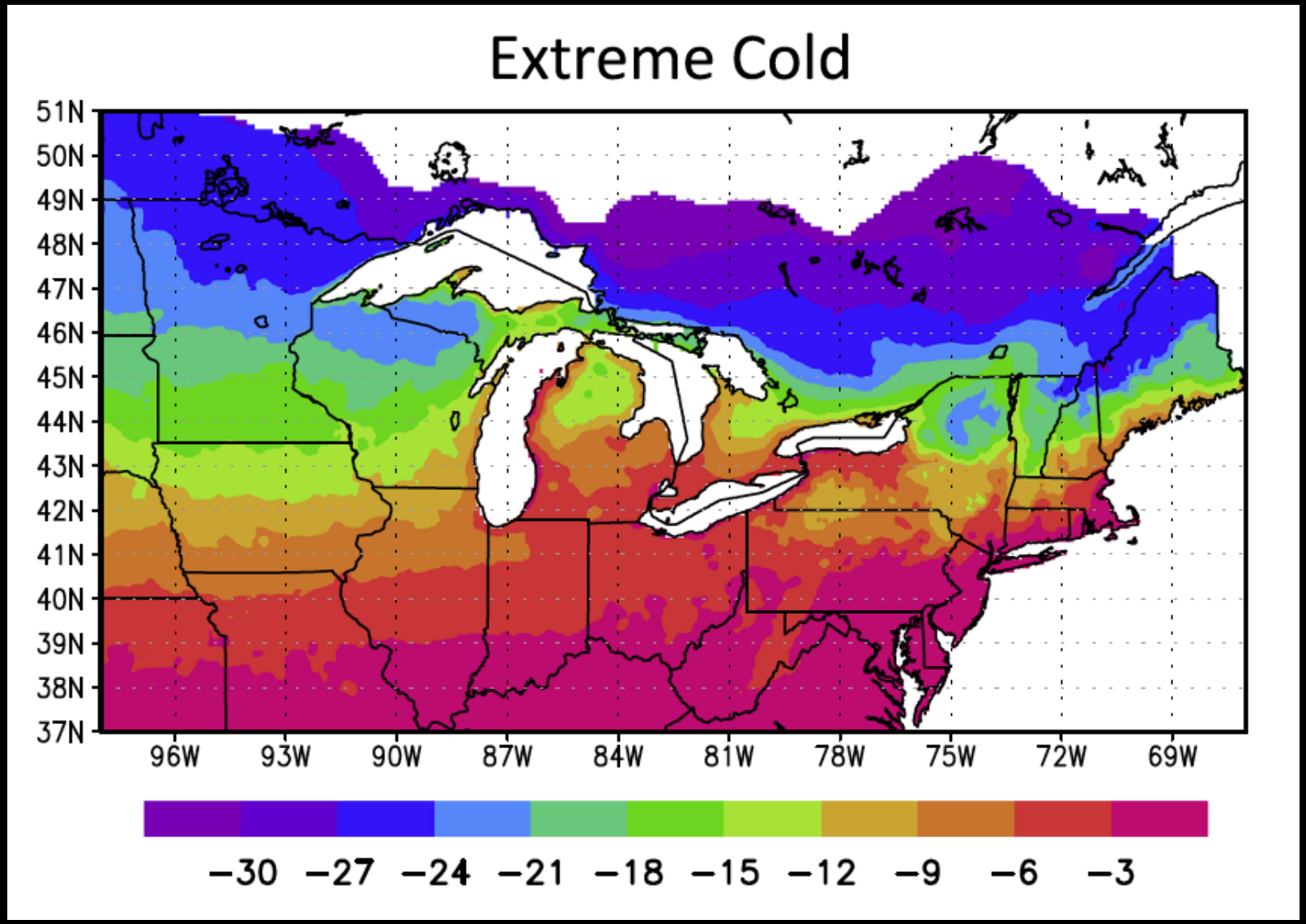
Lake	When
Lake Geneva southeastern corner	Already occurring
Lake Mendota southcentral	By 2040
Trout Lake northcentral	2100

Two More Questions for Today

Are the declines in lake ice cover likely to continue?

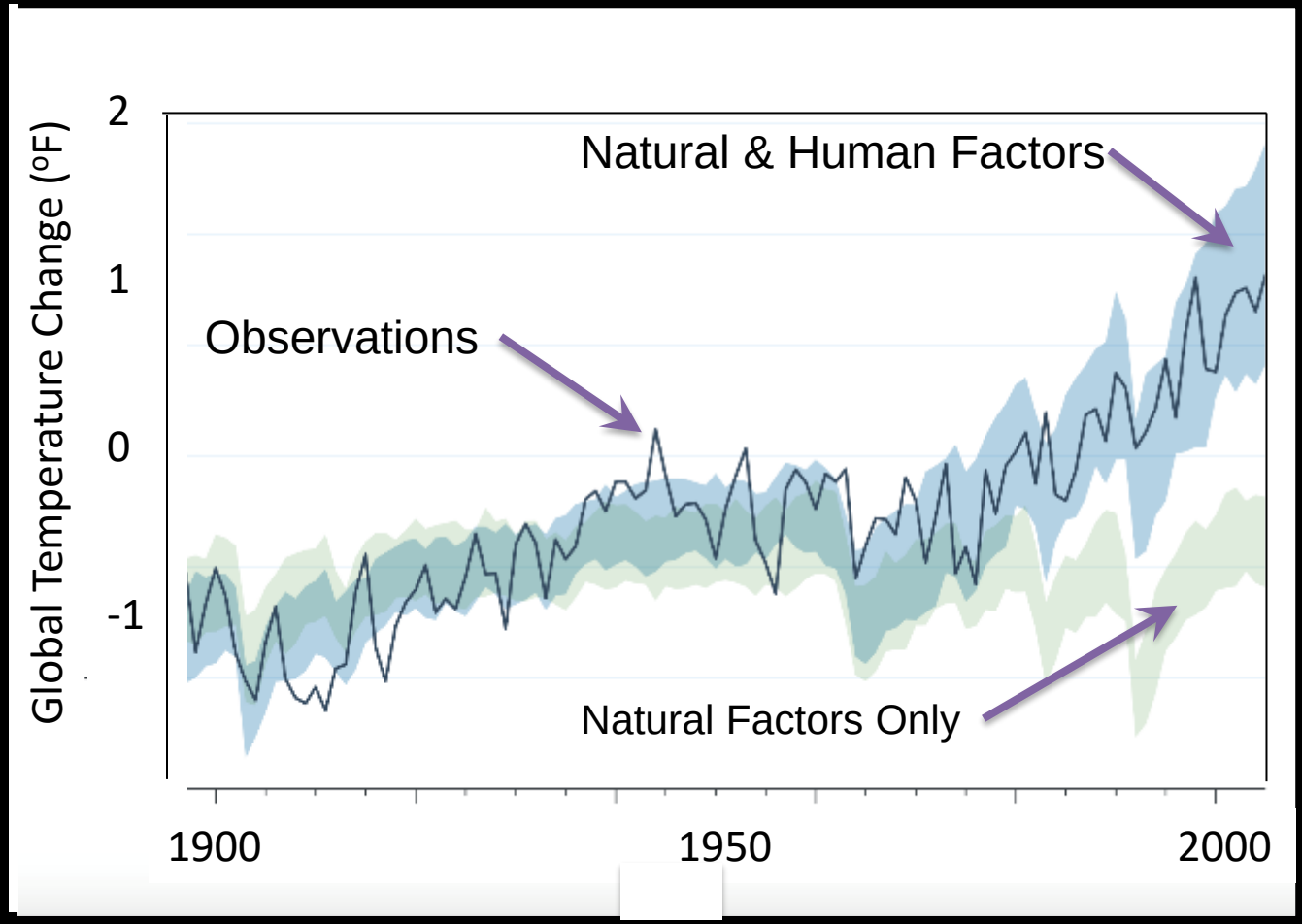
What causes all the variability around the trend lines?

Projected Decrease in Extreme Cold Days (<0°F) from 1961-2000 to 2046-2065



Vavrus, Notaro, & Lorenz 2015

Evidence for the Effect of Greenhouse Gases

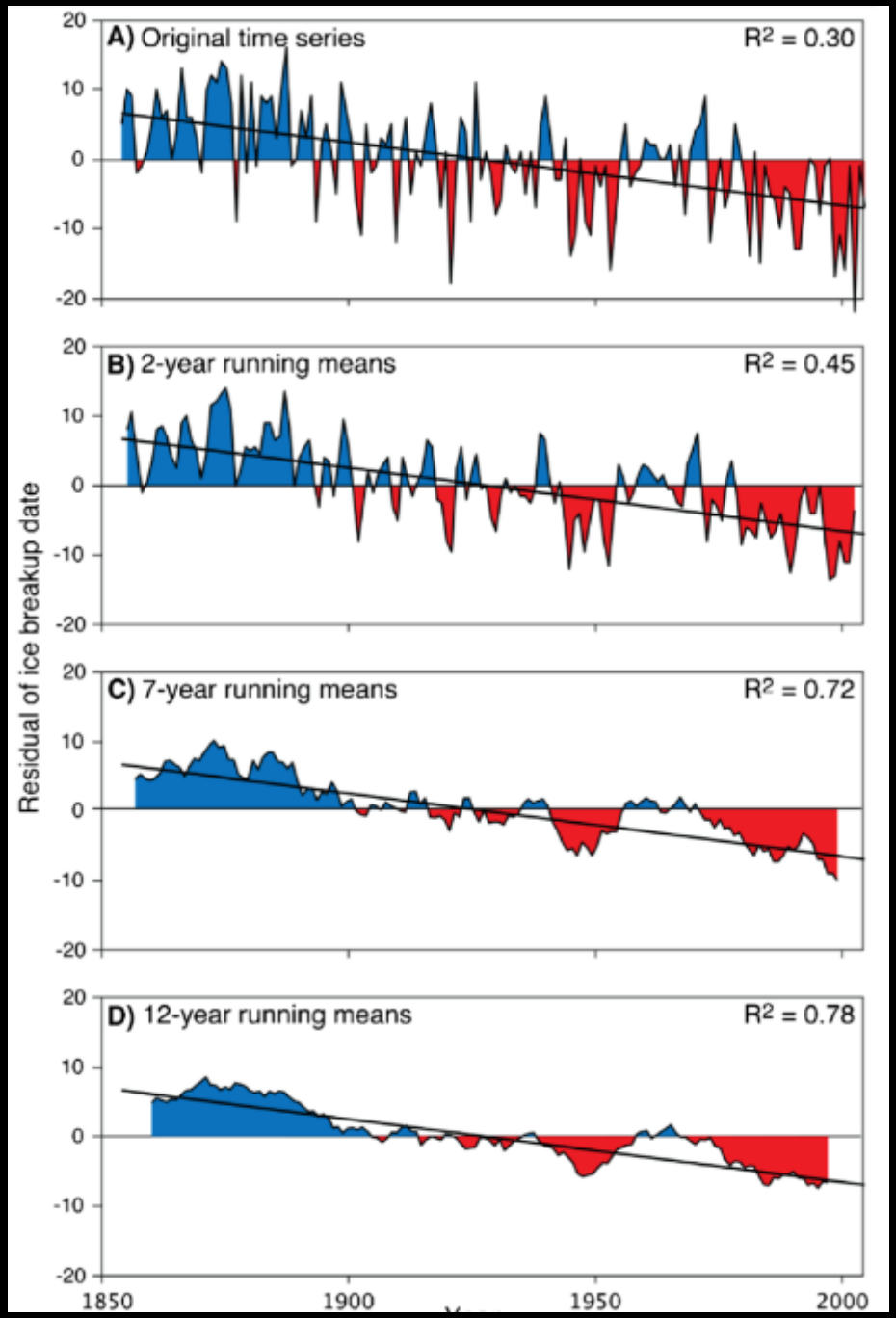


Without including anthropogenic greenhouse gasses, models cannot reproduce the warming that has occurred since 1950.

Daniel Vimont & Colleagues

Image: National Climate Assessment

What causes all the variability around the trend lines?



Oscillatory dynamics do not mask the long-term trends of ice breakup in 150-year time series on 13 lakes in Europe & North America.

Sharma & Magnuson 2014

Review Sources of Variation

long-term trend of climate change (7 to 30%)

Quasi Biennial Oscillation (9%)

El Nino/La Nina Oscillation (8%)

10-year solar cycle (2%)

multidecadal oscillations of 20 to 67 years (4%)

longer than 67 years (3%)

weather (16 to 24%)

unexplained (ca. 50%)

Various sources: Sharma, Benson, Magnuson, & others

1.Lake ice is a sensitive bellwether of climate change & variability.

2. In a short-term view, high variability masks the longer trends of climate change & truth is lost in the Invisible Present.

3. Analyzing lake ice can help us discriminate between climate change & shorter-term climate variability & weather.

4. In long-term records, climate trends are visible even with the high short-term variability.

5. The loss of lake ice is also the loss of an under-valued resource that is a part of our sense of place.*

*google: Magnuson & Lathrop 2014, Lakeline

Changes Occur Quickly and Slowly

Climate Change

Eutrophication

Land Use

Seasons

Day & Night

Thunder Storms

Seconds Hours Weeks Year Decades Millennia+

Minutes Days Months Years Centuries

Time Scales of Changes

Magnuson 2009

So be aware & use
what we looked at today
to understand long-term change

Do not fall victims to living in:

The Invisible Present
The Invisible Place

WISCONSIN

Magnuson 2006

Mendota's ice ridges mirror the complex variability

We are losing winter as we knew it.

We are degrading our “sense of place.”

If you see something, do something.

What do you think we should do?