First,
How Do We Deal With Change?
Changes Occur Quickly and Slowly

Time Scales of Changes

Magnuson 2009
An early quote about time

Marcus Aurelius Antonius, Roman Emperor & Philosopher

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)
The Invisible Present
Lake Mendota Ice-on Day, January 20, 2007
Lake Mendota Ice Duration **Invisible Present**

- One Year 2001-2002
- 21 Days

*J Magnuson 2020*
Lake Mendota Ice Duration 10 Years

Highly Variable
2001-02 Still Extreme
Lake Mendota Ice Duration 50 Years

Ice Cover (Days)
Lake Mendota Ice Duration 1855-2020

Total Time Series

Change = 1.9 Days per Decade
Variation Explained = 22 %
Lake Mendota Ice Duration 1855-2020

Ten Longest

Ten Shortest

J Magnuson 2020
The Invisible Place
Quotes about Space

Ralph Waldo Emerson
Essays IX Circles (1841)

The field can not be well seen from within the field.

Albert Arnold (Al) Gore

It is helpful to stand at some distance from any large pattern we are trying to comprehend.

John Heywood (mid1500s)

Not being able to see the forest for the trees.
You cannot see the wood for the trees.
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.
Longest Ice Records from Northern Wisconsin
(Shell L. & L. Superior at Bayfield)

Ice Cover Duration on Northern Wisconsin Lakes (1855-2015)

- Shell Lake: 1.2 days shorter / decade (7% of variation)
- Lake Superior at Bayfield: 3.7 days shorter / decade (36% of variation)
Projected Decrease in Extreme Cold Days (<0°F) from 1961-2000 to 2046-2065

Vavrus, Notaro, & Lorenz 2015
Changes in Freeze and Breakup Dates for winters 1843-4 to 2008-9 (8 lakes)

Mean rate 8.2 days/100 yr, Range 5.8 to 11.0

Magnuson et al. Science 2000
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 9° C. and produce a climate as mild as that of the Eocene period.”
Greenhouse gases are increasing owing to burning fossil fuels

CO₂ reading on Jan 15, 2018: 407.8 ppm

Greenhouse Gasses:
“Trap” energy in lower atmosphere

Anthropogenic:
Caused by human activity

Keeling Curve: https://scripps.ucsd.edu/programs/keelingcurve/
CLIMATE CHANGE 2007
THE PHYSICAL SCIENCE BASIS

Working Group I Contribution to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change
Lakes that do not freeze every winter (Projection)

- Lakes that reliably freeze every winter
- Lakes that no longer freeze every winter

Sharma, Blagrave, Magnuson, O’Reilly, et al. 2019
Lakes that do not freeze every winter (Projection)

Current Condition

Warming 2 Degrees C

Warming 4.5 Degrees C

Warming 8 Degrees C
Lake Ice: a Miner’s Canary for Climate Change
Winter is a part of our “Sense of Place.”
Let's consider the Impacts of Climate Change on the Waters of Wisconsin. Variability and Extreme Events are being lost. Ice services to us are declining with warming.

Ice Services to us Declining with Warming

Knoll et al. 2019
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?
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.
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 %
Winter is a part of our “Sense of Place.”
Increased winter drownings on ice-covered lakes regions with warmer winters

We analyzed of 4,000 winter drownings in 10 countries

About 20% of total drownings

48% of drownings are explained by winter temperatures

Sharma, et. al. 2020.
Changes Occur Quickly and Slowly

- Seconds
- Minutes
- Hours
- Days
- Weeks
- Months
- Years
- Decades
- Centuries
- Millennia+

Time Scales of Changes

Magnuson 2009
Lake Mendota’s ice ridges mirror the complex interannual variability.
Do not fall victims to living in:

The Invisible Present
The Invisible Place

So be aware & use what we learned today to help understand long-term change
Think Ahead!
Climate Change
Adaptation & Mitigation