Climate Change Impacts on Water in Great Lakes National Parks

Brenda Moraska Lafrancois

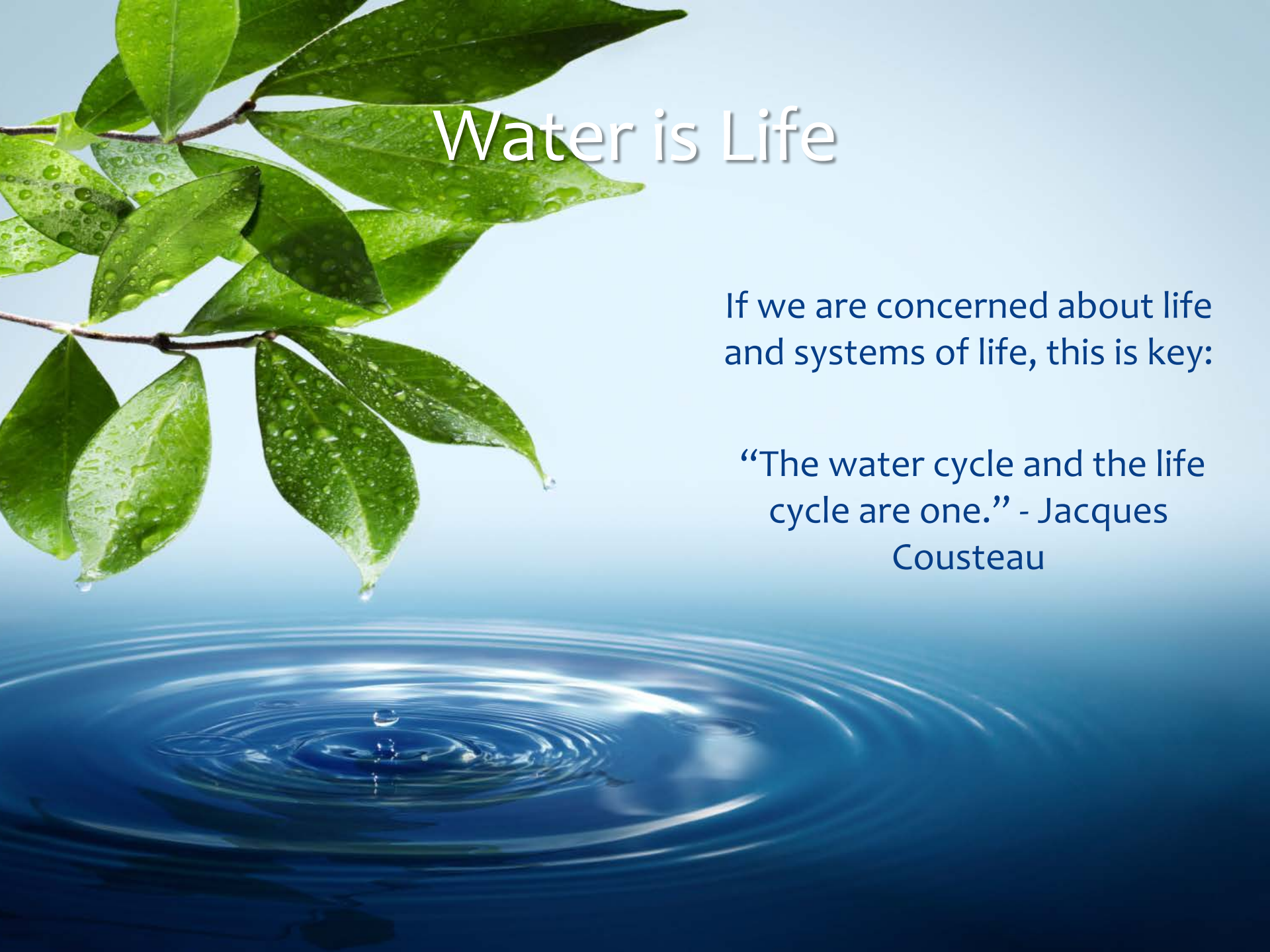
2016 G-WOW "Hear the Water Speak" Institute

July 20, 2016

U.S. National Park Service
Midwest Region
Water Resources Division

The Water Lens

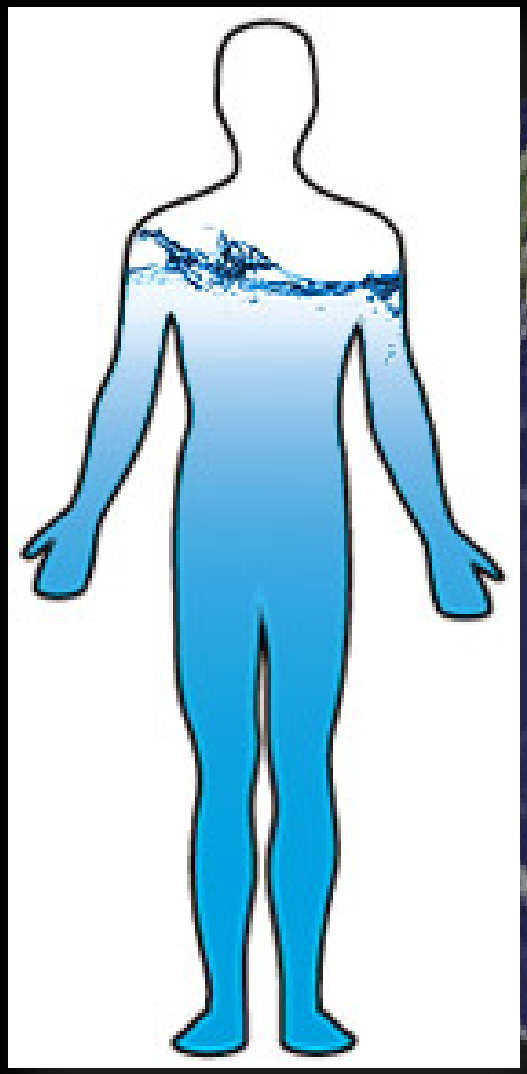
Randy Scott Slavin



Water is Life

If we are concerned about life and systems of life, this is key:

"The water cycle and the life cycle are one." - Jacques Cousteau



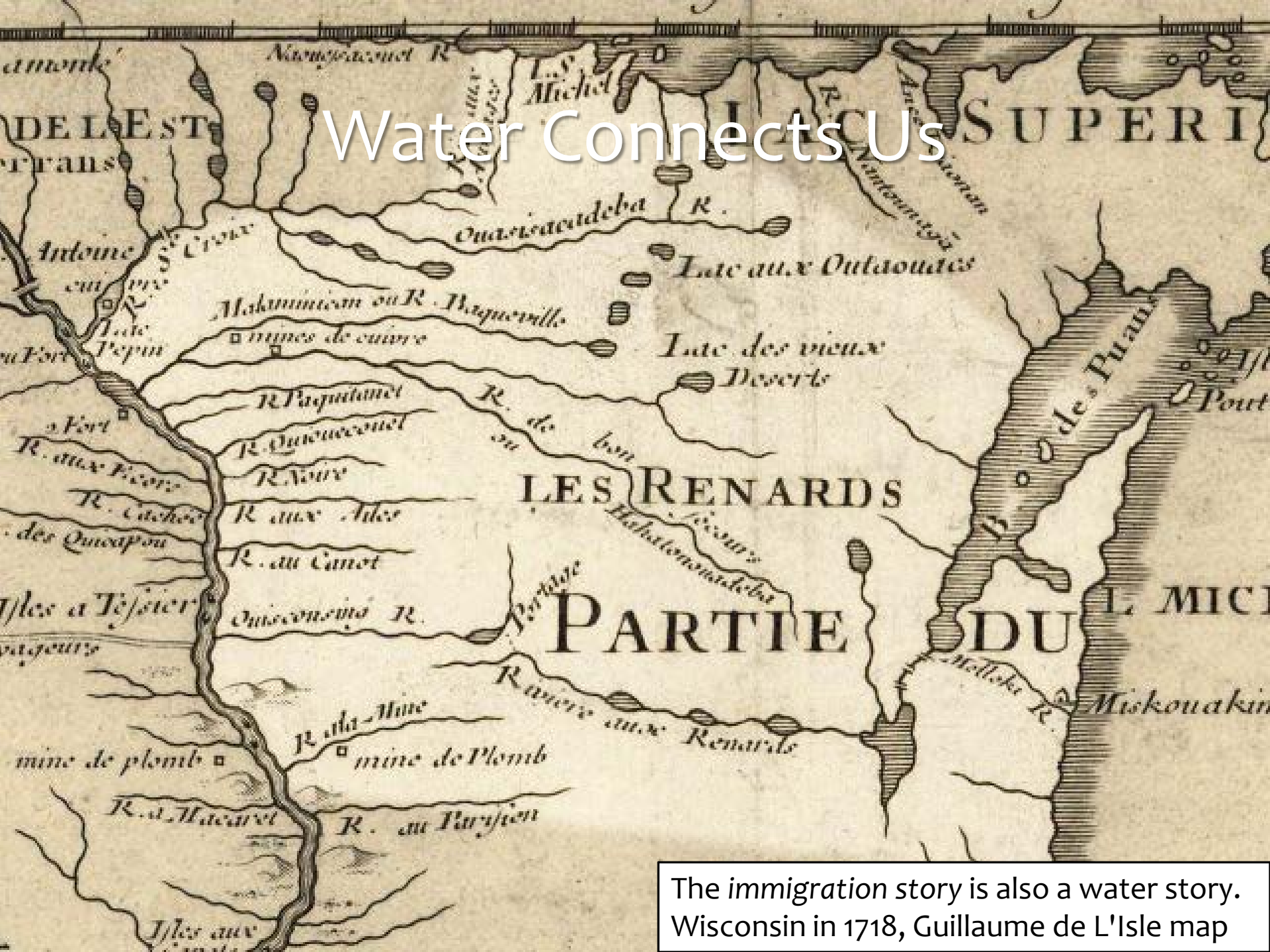
"No water, no life.
No blue, no green."
– Sylvia Earle

Water Connects Us

To landscapes and each other

The Ojibwe migration route traced water.
The *migration story* is partly a water story.

Water Connects Us

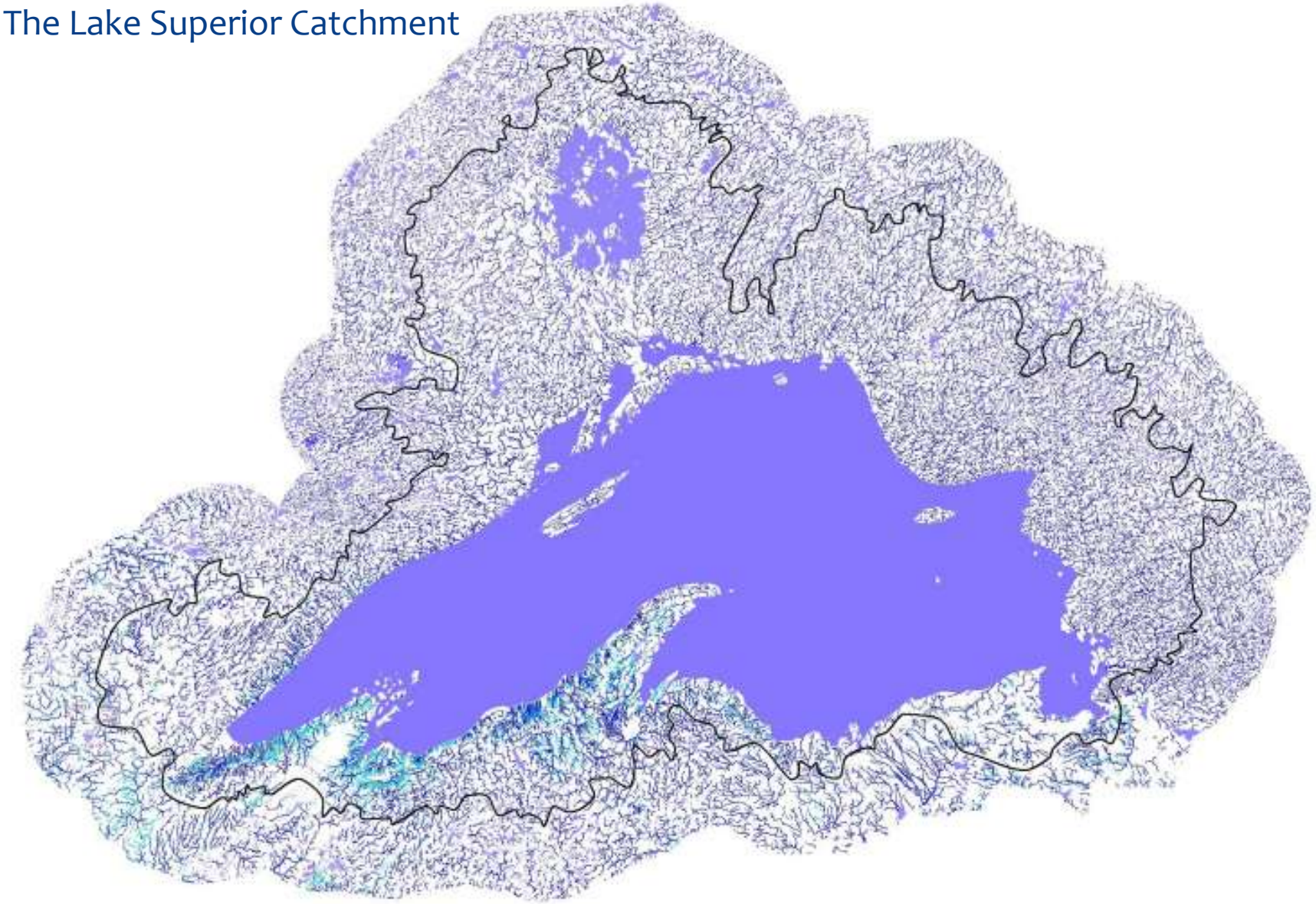


The *immigration story* is also a water story.
Wisconsin in 1718, Guillaume de L'Isle map

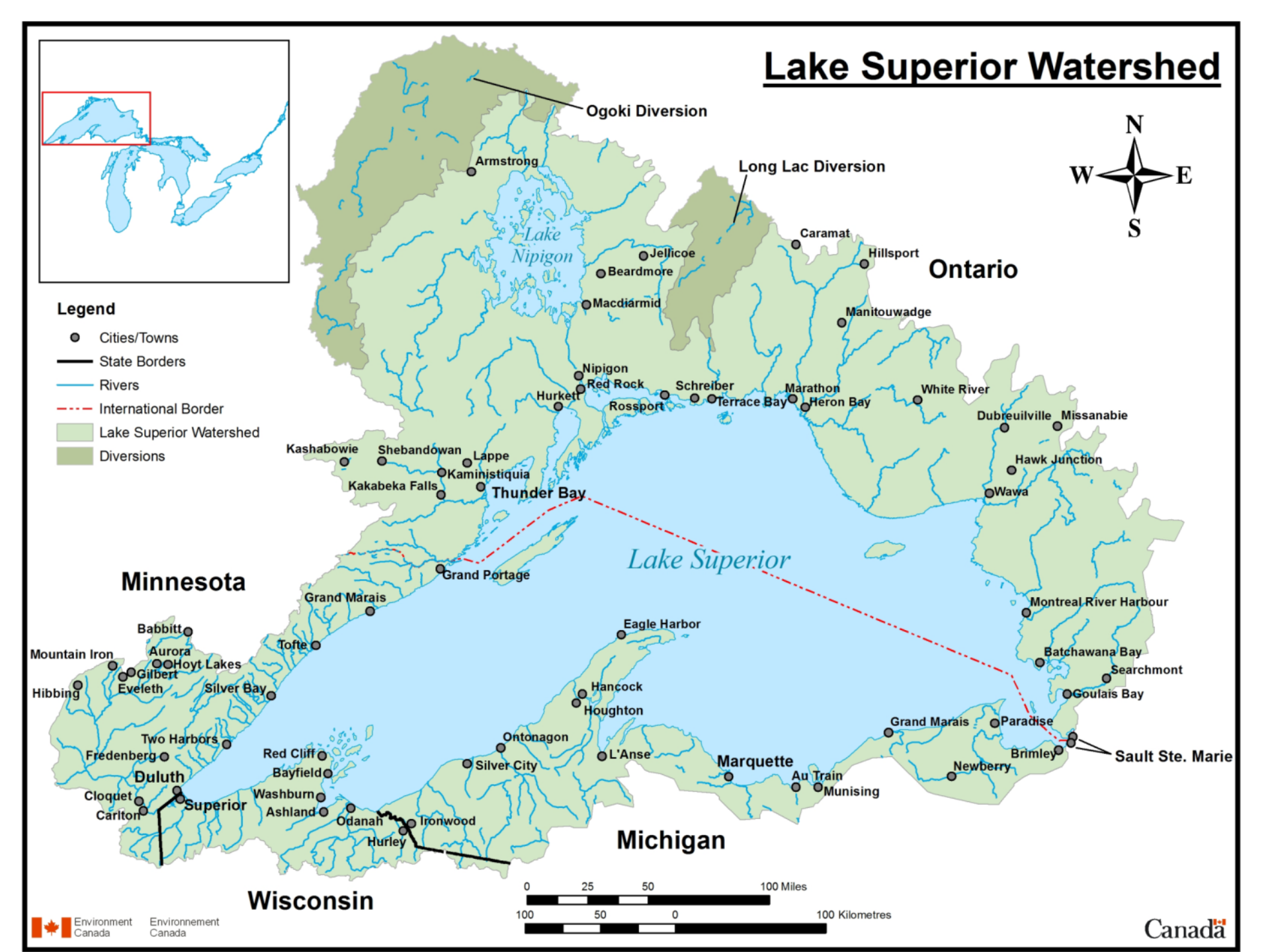
Water Integrates

* Everything we do, make, and dispose of is reflected in our watersheds and receiving waters.
* “Catchments.” They catch things. Good recorders of change.

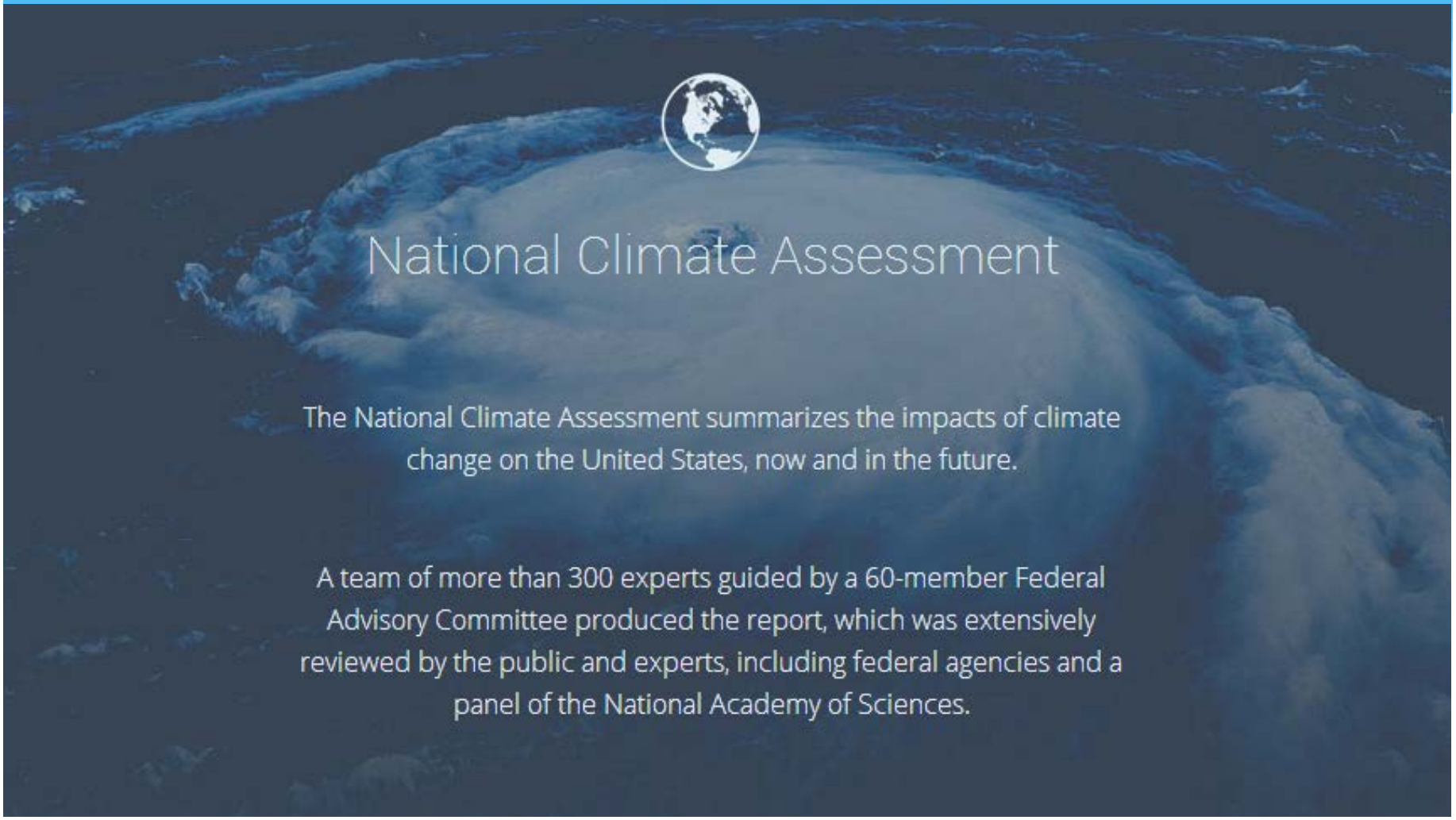
The Lake Superior Catchment



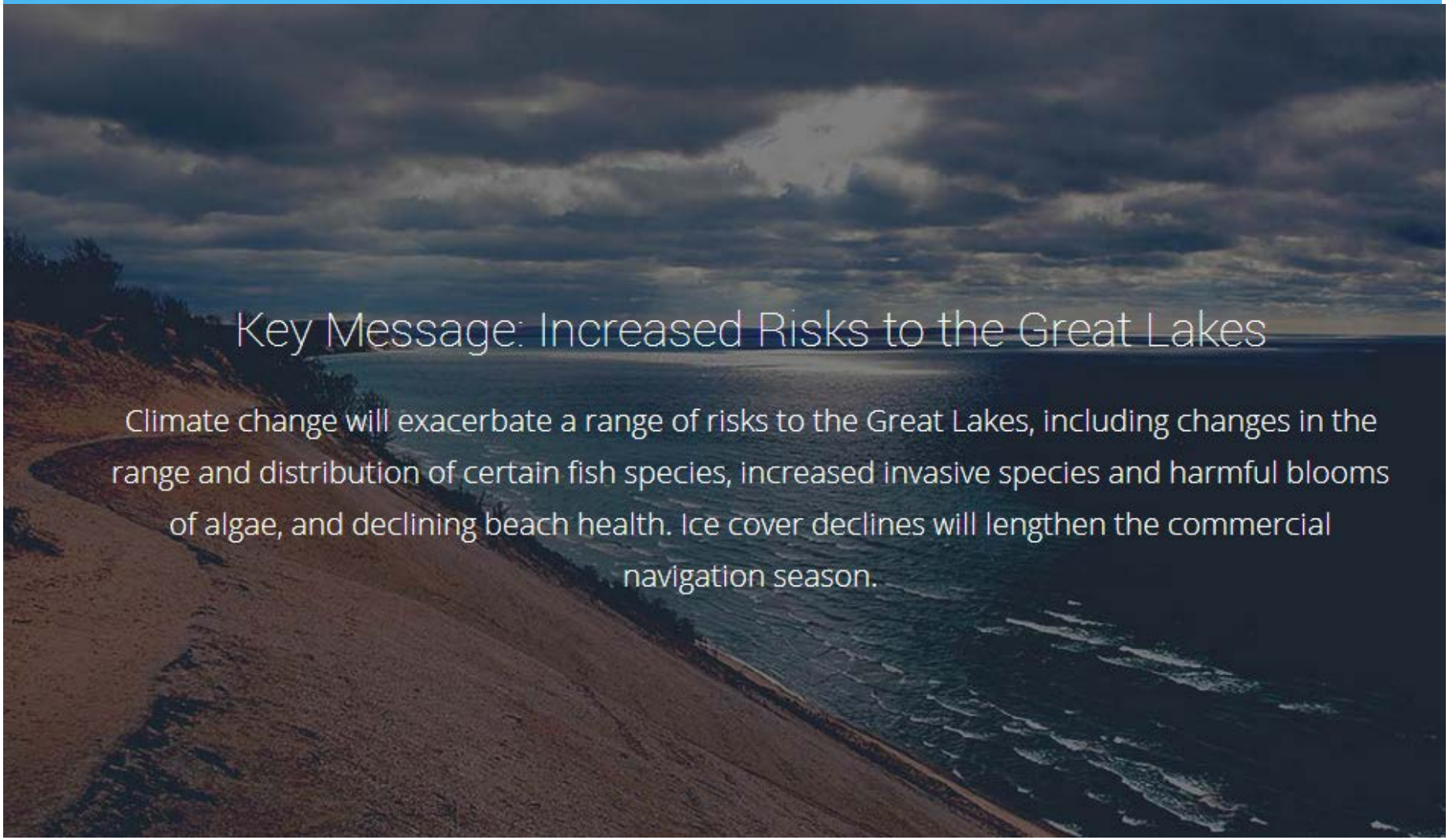
A vast network of tributaries.
A circulatory system.


Lake Superior Watershed
Ogoki Diversion
Long Lac Diversion
Armstrong
Lake Nipigon
Caramat
Hillsport
Jellicoe
Beardmore
Ontario
Macdiarmid
Manitouwadge
Nipigon
Red Rock
Schreiber
Hurkett
Rossport
Terrace Bay
Marathon
Heron Bay
White River
Dubreuilville
Missanabie
Hawk Junction
Wawa
Kashabowie
Shebandowan
Lappe
Kaministiquia
Kakabeka Falls
Thunder Bay
Lake Superior
Grand Portage
Minnesota
Grand Marais
Montreal River Harbour
Eagle Harbor
Babbitt
Tofte
Mountain Iron
Aurora
Hoyt Lakes
Gilbert
Eveleth
Hibbing
Silver Bay
Batchawana Bay
Searchmont
Goulais Bay
Hancock
Houghton
Grand Marais
Paradise
Two Harbors
Fredenberg
Ontonagon
Red Cliff
Bayfield
Duluth
Silver City
L'Anse
Marquette
Brimley
Sault Ste. Marie
Newberry
Au Train
Munising
Cloquet
Carlton
Superior
Washburn
Ashland
Odanah
Ironwood
Hurley
Michigan
Wisconsin
Legend
Cities/Towns
State Borders
Rivers
International Border
Lake Superior Watershed
Diversions
N
W
E
S
0 25 50 100 Miles
100 50 0 100 Kilometres
Environment Canada
Environnement Canada
Canada

New Climate Expectations



New Climate Expectations



Climate Change Projections for the Great Lakes

* Warmer, drier summers
* Warmer winters
* Shorter cold season
* More winter precipitation as rain
* Later freeze-up, earlier ice-out
* More evaporation from lakes
* **Warmer water**
* **Less ice**
* **Lower lake levels**
* **Irregular, higher intensity storms**
* **More flooding**, esp. in spring

Outer Island, Apostle Islands National Lakeshore

Overview

* Climate projections and observed impacts
* Unexpected climate cascades

Warmer Water

Lake Superior States Are Warming Fast

Rank #2,3, and 4 in Temperature Change Per Decade

The Heat Is On

U.S. Temperature Trends

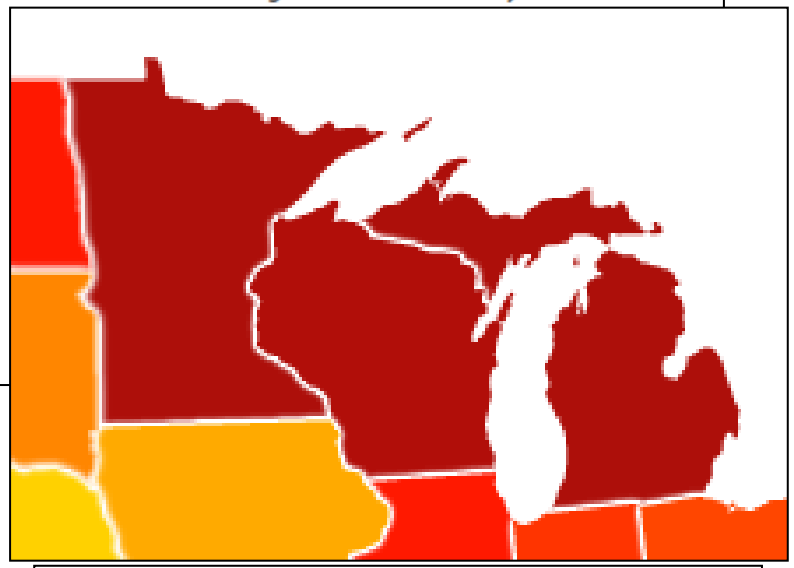
[Average Daily Temperatures]

Every State Has Warmed Since 1970

Table 2. Since 1970, every state has experienced a warming and the rates of warming were faster than they were over the past 100 years.

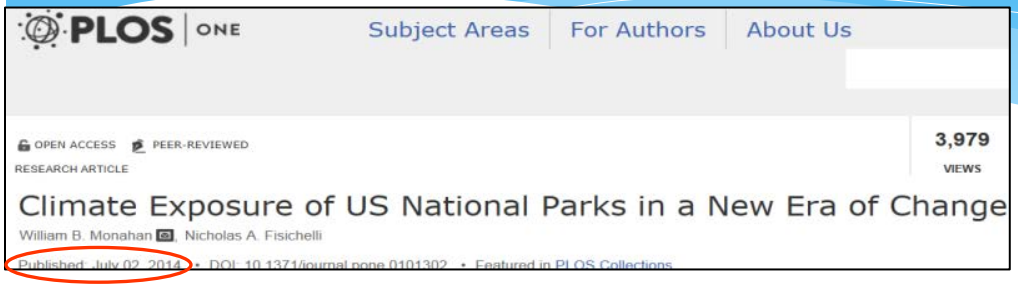
Rank	State	Temperature Change (°F per decade)
1	Arizona	0.639
2	Michigan	0.622
3	Minnesota	0.620
4	Wisconsin	0.616

CLIMATE CENTRAL

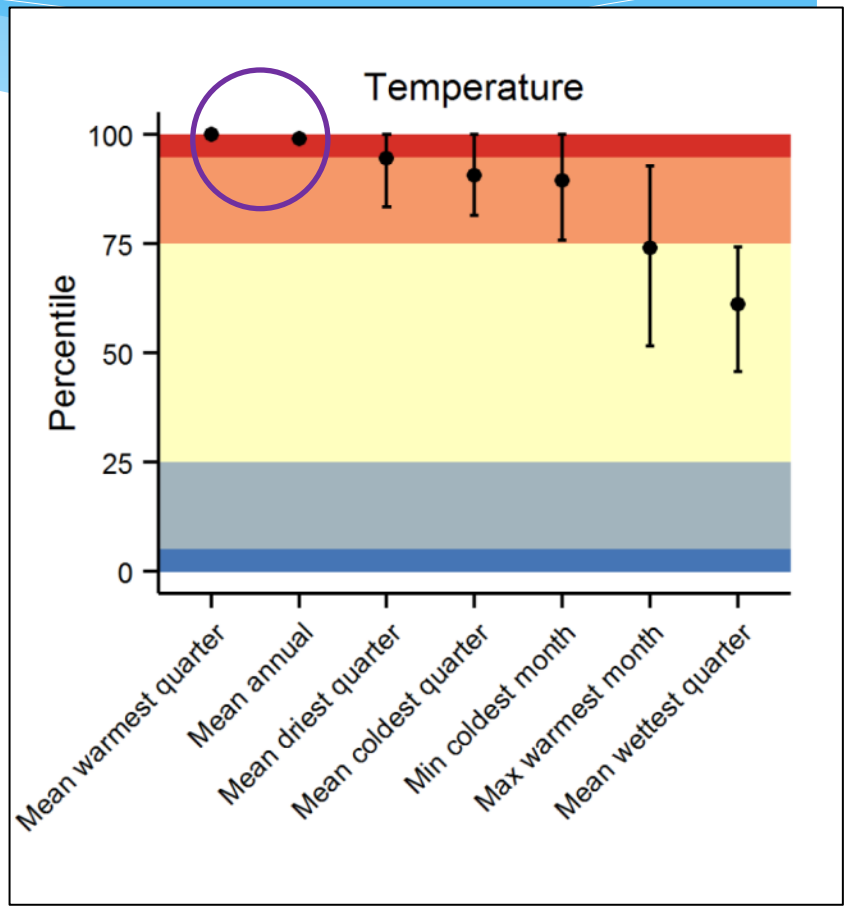


http://www.climatecentral.org/news/the-heat-is-on

The Apostle Islands Are Warming

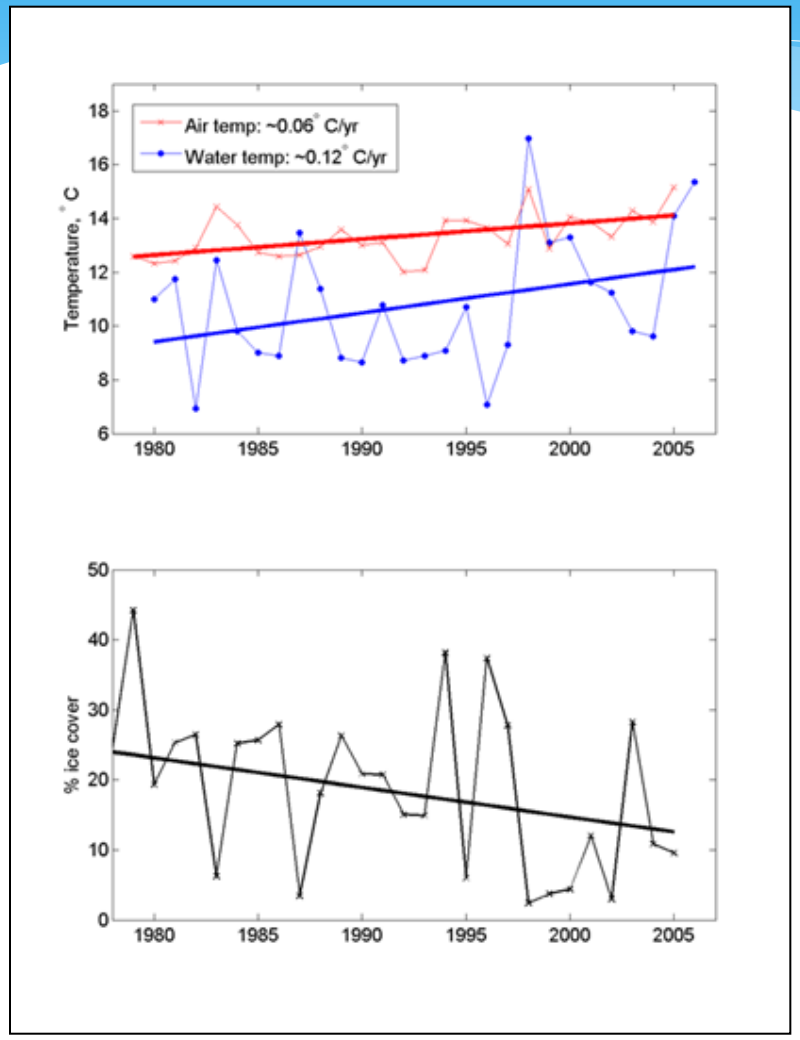


* "The recent average temperature of summer months at Apostle Islands … is at the highest point measured over the last 112 years (1901-2012); any continued increase in temperature will push the park's summer temperatures higher than it has experienced since 1901."



http://www.plosone.org/article/info%3Adoi%2F10.1371%2Fjournal.pone.0101302

Lake Superior Temps Are Rising Fast(er!)



* Lake Superior water temperature is rising at twice the rate of air temperature since 1980.
* This correlates with decreasing ice cover over the same period.
* A similar pattern has been noted in Lake Baikal (Russia).

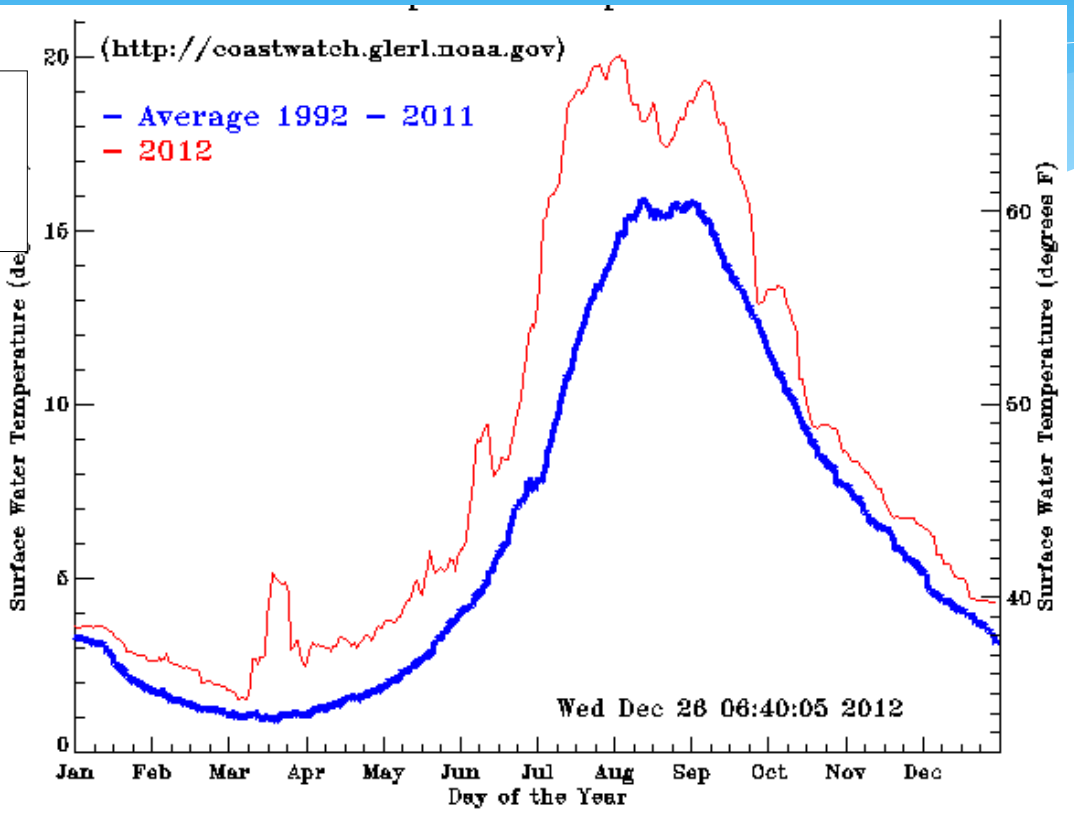
From http://www.d.umn.edu/~jaustin/ICE.html
(Austin and Colman, 2007
From http://www.planetark.org/dailynewsstory.cfm?newsid=48179,
http://minnesota.publicradio.org/collections/special/columns/statewide/archive/2011/06/lake-superior-warming-is-global-trend.shtml

Surface Waters Are Reaching Record Temps

Swimming anyone? Lake Superior water temps warmest in a century

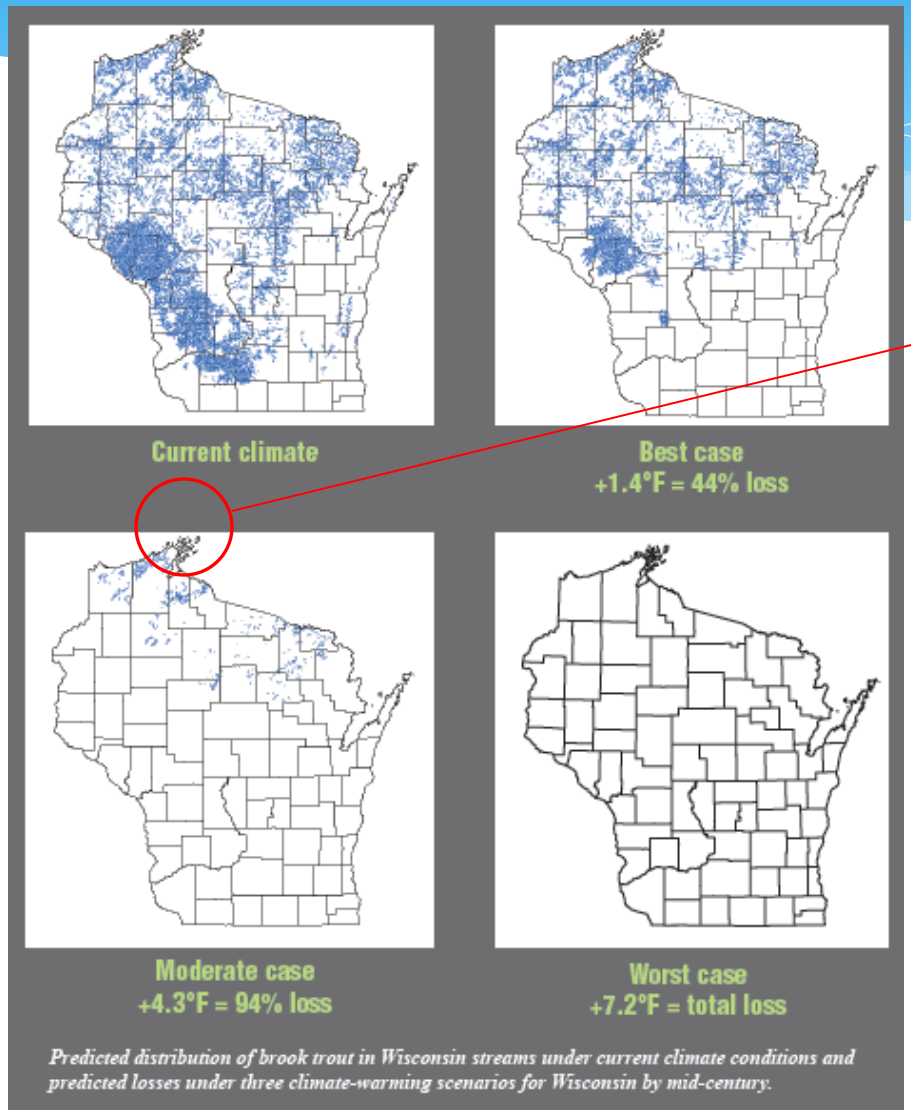
Posted at 9:11 AM on July 25, 2012 by Paul Huttner (3 Comments)
Filed under: Climate change, Lake Superior

- Temps in early summer 2012 were 15-20°F above normal – because they were a month early!
- Warm lake in summer increases chances of lake effect snow the next winter … > 50" after April 1, 2013!



http://coastwatch.glerl.noaa.gov/statistic/gif/avgtemps-s_1992-2011.gif
http://minnesota.publicradio.org/collections/special/columns/updraft/archive/2012/07/balmy_70s_2012_lake_superior_w.shtmlfrom
http://www.climatecentral.org/news/great-lakes-water-temperatures-at-record-levels

Water Temp Side Effect – Brook Trout Habitat 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.

Several Lake Superior tributaries prioritized for restoration and adaptation

WICCI 2011

Water Temp Side Effect – A Windier Lake

Stronger winds over a large lake in response to weakening air-to-lake temperature gradient

Ankur R. Desai[1]*, Jay A. Austin[2], Val Bennington[1] an

The impacts of climate change on the world's large lakes are a cause for concern[1–4]. For example, over the past decades, mean surface water temperatures in Lake Superior, North America, have warmed faster than air temperature during the thermally stratified summer season, because decreasing ice cover has led to increased heat input[2,5]. However, the effects of this change on large lakes have not been studied extensively[6]. Here we analyse observations from buoys and satellites as well as model reanalyses for Lake Superior, and find that increasing temperatures in both air and surface water, and a reduction in the temperature gradient between air and water are destabilizing the atmospheric surface layer above the lake. As a result, surface wind speeds above the lake are increasing by nearly 5% per decade, exceeding trends in wind speed over land. A numerical model of the lake circulation suggests that the increasing wind speeds lead to increases in current speeds, and long-term warming causes the surface mixed layer to shoal and the season of stratification to lengthen. We conclude that climate change will profoundly affect the biogeochemical cycles of large lakes, the mesoscale atmospheric circulation at lake–land boundaries and the transport of airborne pollutants in regions that are rich in lakes.

Since 1970, global average temperatures have increased at 0.2 °C decade^{-1}, largely, it is hypothesized, owing to anthropogenic emissions of greenhouse gases[1]. Temperate mid-continent regions such as the Midwest United States of America, not insulated by the buffering effects of ocean heat capacity or tropical moisture, have warmed even faster, and impacts on ecosystems and large lakes are starting to be felt[2]. Lakes, and especially large lakes, are known to be an important component of regional and possibly global biogeochemical cycles[3,4]. Yet, little is known about the impact of climatic warming on large lake physical and biological environments.

The Laurentian Great Lakes contain over 20% of the world's non-frozen fresh water, and Lake Superior, is the largest freshwater lake in the world by area[5]. The impact of warming temperatures on the dynamics of Lake Superior is poorly understood. One

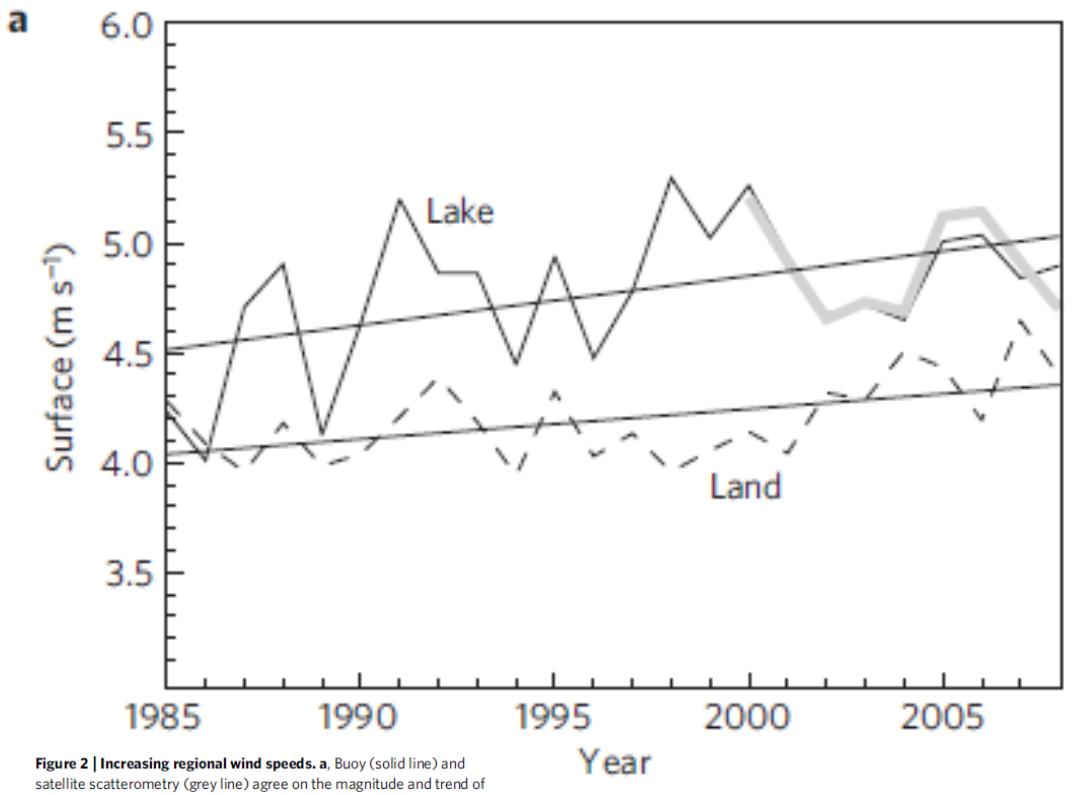


Figure 2 | Increasing regional wind speeds. a, Buoy (solid line) and satellite scatterometry (grey line) agree on the magnitude and trend of wind speed (0.22 ± 0.09 m s^{-1} decade^{-1}) since 1985. This increase is 64% faster than reanalysis wind speed trends (0.14 ± 0.05 m s^{-1} decade^{-1}) over land within a 3.75° latitude by 9° longitude area surrounding Lake Superior, suggesting that lake destabilization is causing the change in lake wind speeds. **b**, The wind speed trend (0.15 ± 0.17 m s^{-1} decade^{-1}) in the free troposphere at 850 hPa is similar to the land trend, strengthening arguments for surface-based forcing.

Wind and Shoreline Change – Outer Lagoon Breach

Less Lake Ice

Lake Temps Affect Lake Ice

Lake Temps Affect Lake Ice

The Importance of Spring and Autumn Atmospheric Conditions for the Evaporation Regime of Lake Superior

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P. D. Blanken

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School of Natural Resources, University of Nebraska–Lincoln, Lincoln, Nebraska

N. Hedstrom

Environment Canada, Saskatoon, Saskatchewan, Canada

Abstract

Feedbacks between ice extent and evaporation have long been suspected to be important for Lake Superior evaporation because it is during autumn and winter when latent heat fluxes are highest. Recent direct measurements of evaporation made at the Stannard Rock Lighthouse have provided new information on the physical controls on Lake Superior evaporation, in particular that evaporation can react within hours to days to a change in synoptic conditions. However, the large heat capacity of the lake creates a strong seasonal cycle of energy storage and release. There is a complex interaction among heat storage, evaporation, and ice cover that is highly dependent on atmospheric conditions in the spring and autumn "shoulder seasons." Small changes in conditions in November and March caused by synoptic-scale events can have profound impacts on annual evaporation, the extent of ice cover, and the length of the ice-covered period. Early winter air temperatures in November and December dictate the nature of ice formation and much of the winter evaporative flux. Decreased ice cover, by itself, does not necessarily lead to enhanced annual evaporation losses. Rather, a combination of low ice cover and warm spring air temperatures, leading to an early breakup, can significantly lengthen the next evaporation season and cause greater cumulative water loss the subsequent year. The influence of individual synoptic events on annual evaporation is notable enough that the research community should ensure that their role is properly captured in numerical models to provide sound predictions of future Laurentian Great Lakes evaporation regimes.

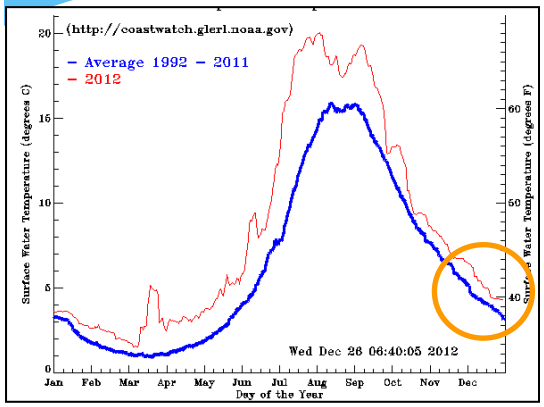
Keywords: North America, Energy budget/balance, Evaporation, Hydrometeorology, Ice loss/growth, Radiative fluxes

Received: November 26, 2012; Final Form: June 6, 2013

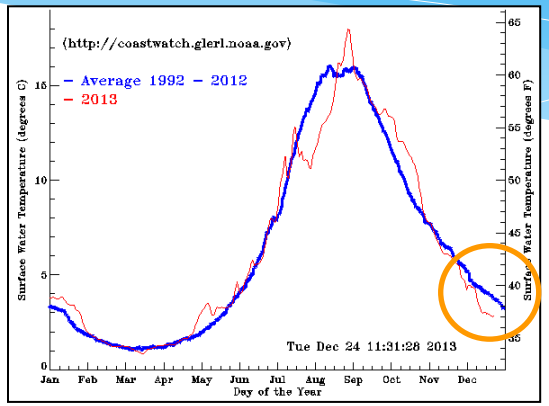
* "Small changes in conditions in November and March caused by synoptic-scale events can have profound impacts on annual evaporation, the extent of ice cover, and the length of the ice-covered period. **Early winter air temperatures in November and December dictate the nature of ice formation** and much of the winter evaporative flux."

Lake Temps Affect Lake Ice

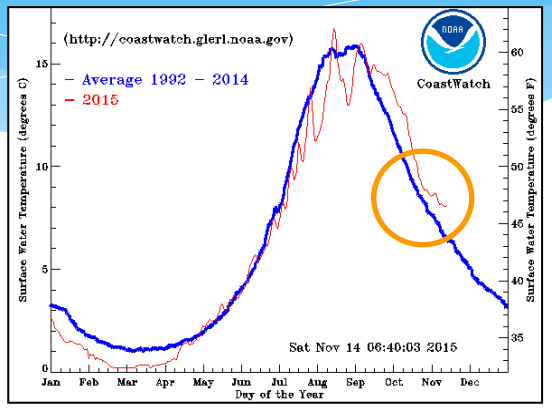
Water Temp 2012



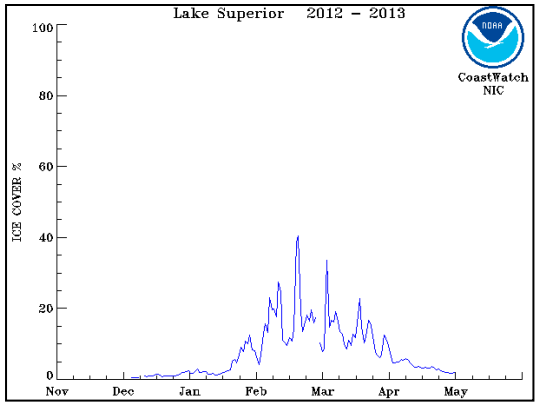
Water Temp 2013



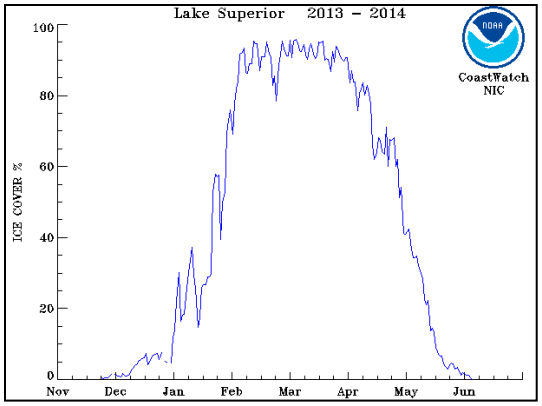
Water Temp 2015



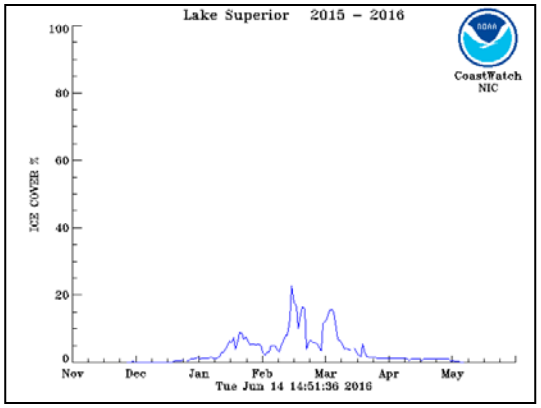
Ice Cover 2012-2013



Ice Cover 2013-2014



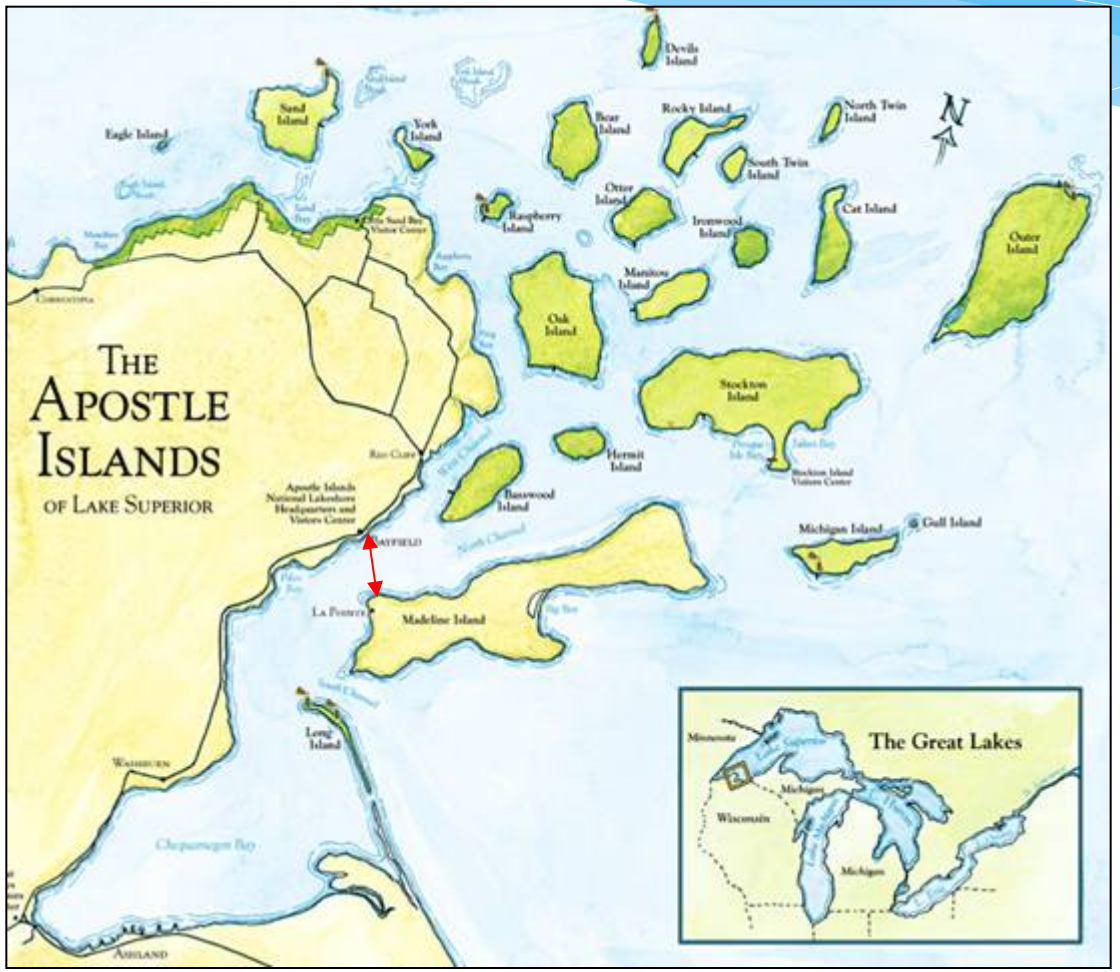
Ice Cover 2015-2016



Ice cover is lower in years with warmer than average fall water temps

Lake Temps Affect Lake Ice

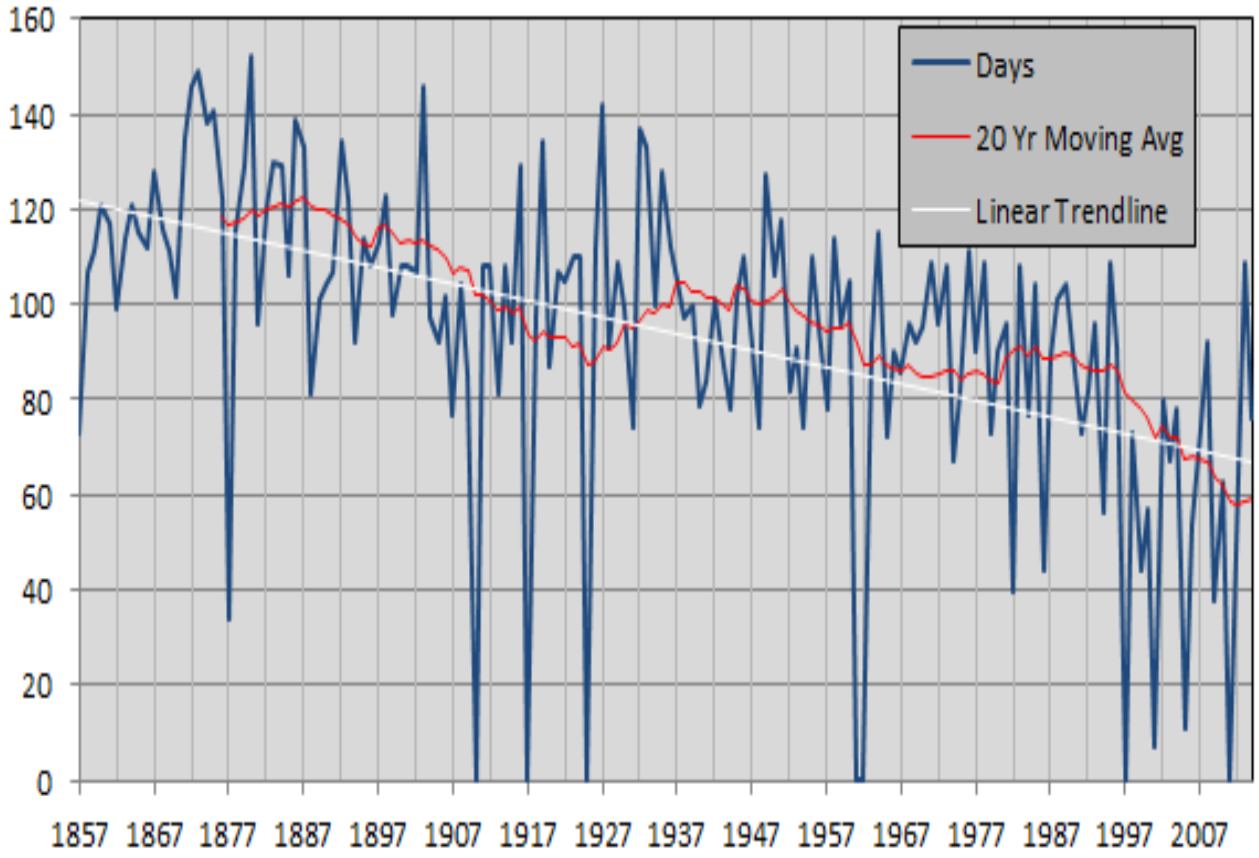
Madeline Island Ice Road, Lake Superior



Lake Temps Affect Lake Ice

Madeline Island Ice Road, Lake Superior

Days Without Boat Navigation



Ice duration *HERE* has declined:

3.4 days/decade since 1857

14.7 days/decade since 1975

From Howk, 2009
Changes in ice cover at Bayfield, Wisconsin. Journal of Great Lakes Research
35(1):159-162

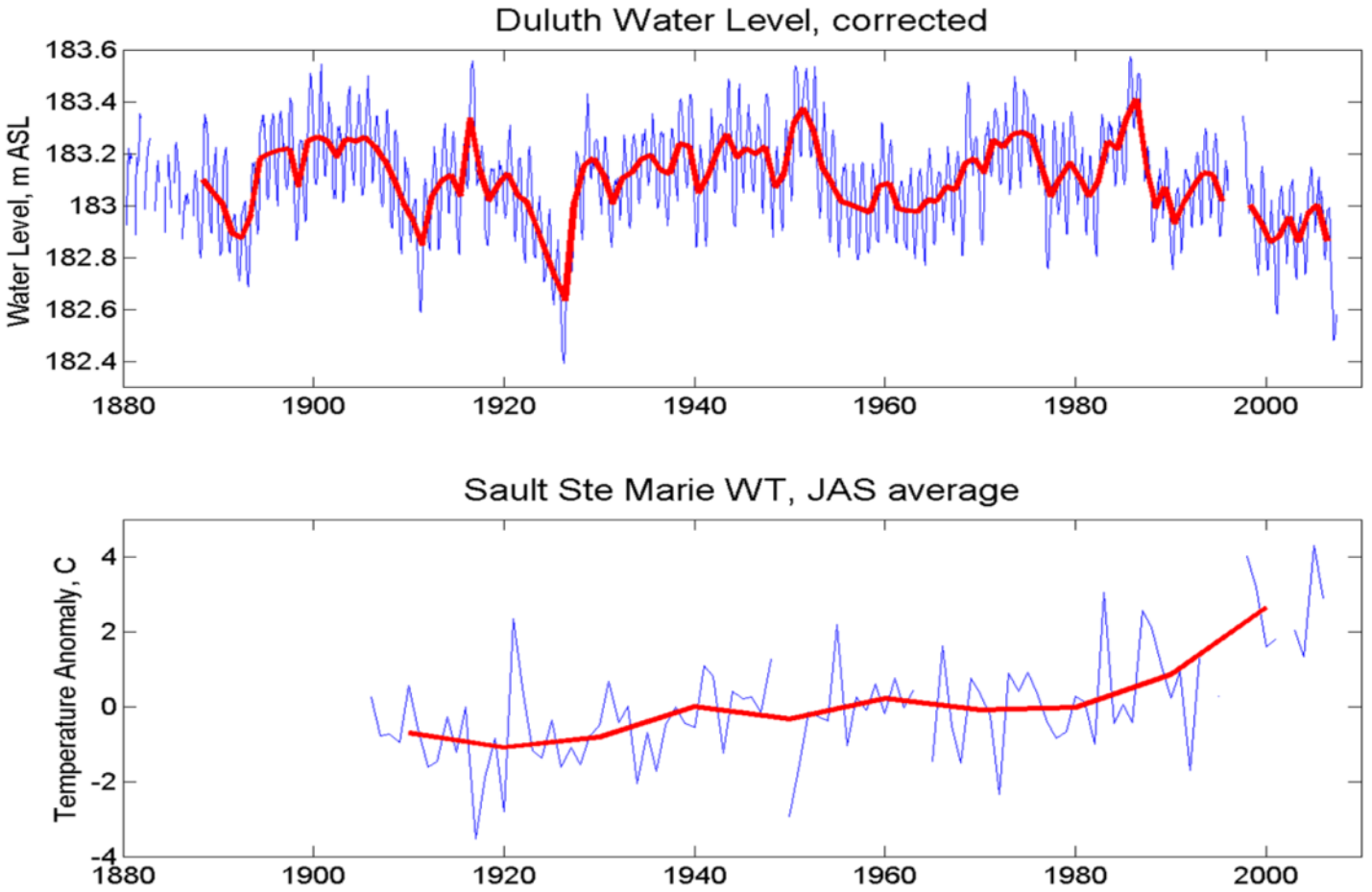
Chart updated since 2009 by NPS staff

Van Cleave et al., 2014

Lower Lake Levels

Lake Superior Water Level is Declining

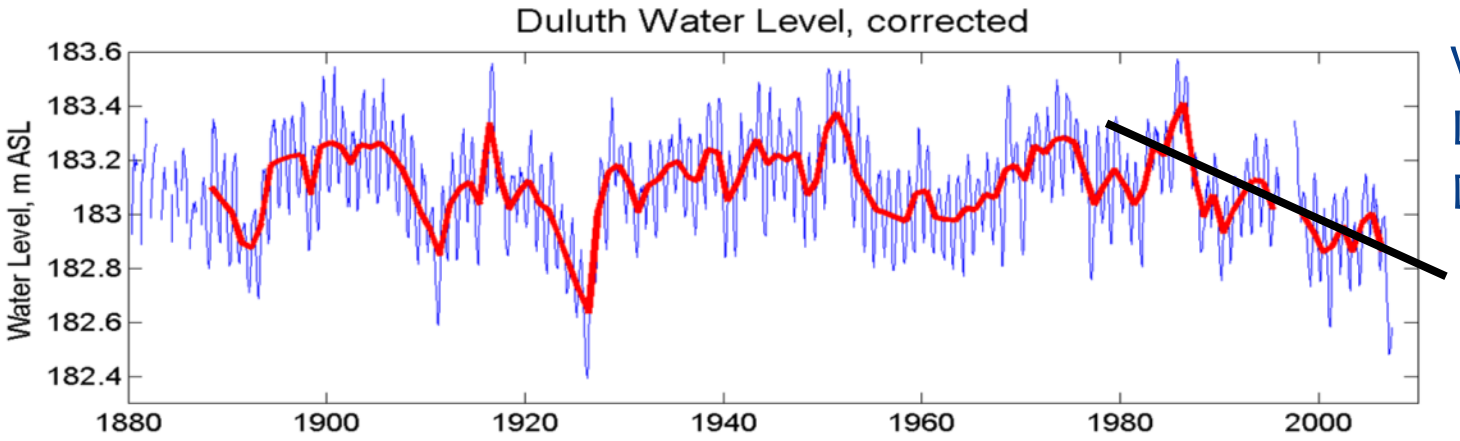
As Temperature Has Increased Since ~ 1970s



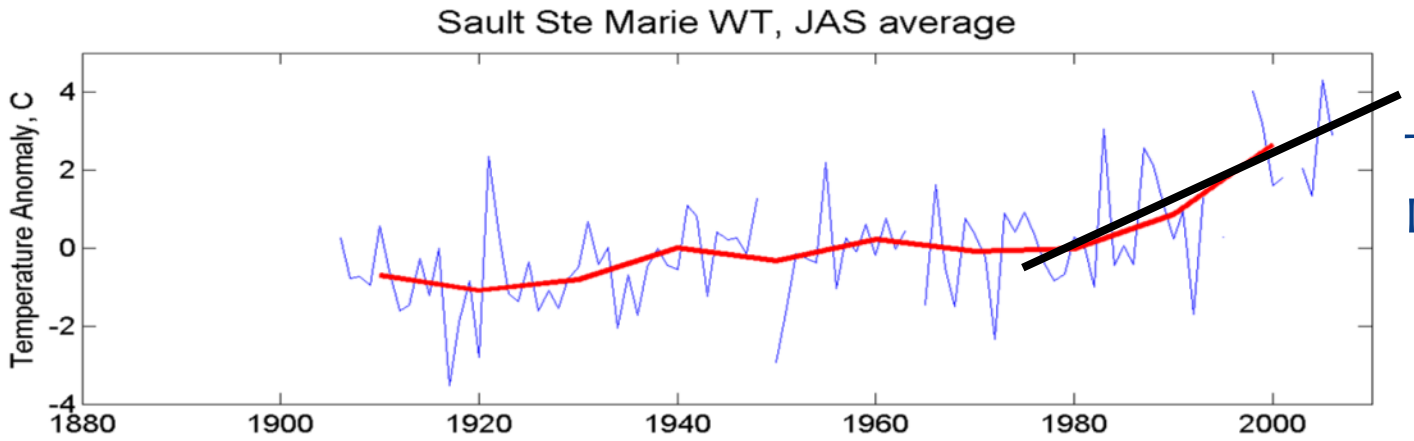
Slide from Jay Austin presentation at Apostle Islands National Lakeshore Climate Friendly Parks Meeting (17 July 2007)

Lake Superior Water Level is Declining

As Temperature Has Increased Since ~ 1970s



Water Level Decreases



Temperature Increases

Slide from Jay Austin presentation at Apostle Islands National Lakeshore Climate Friendly Parks Meeting (17 July 2007)


Pre - 2006

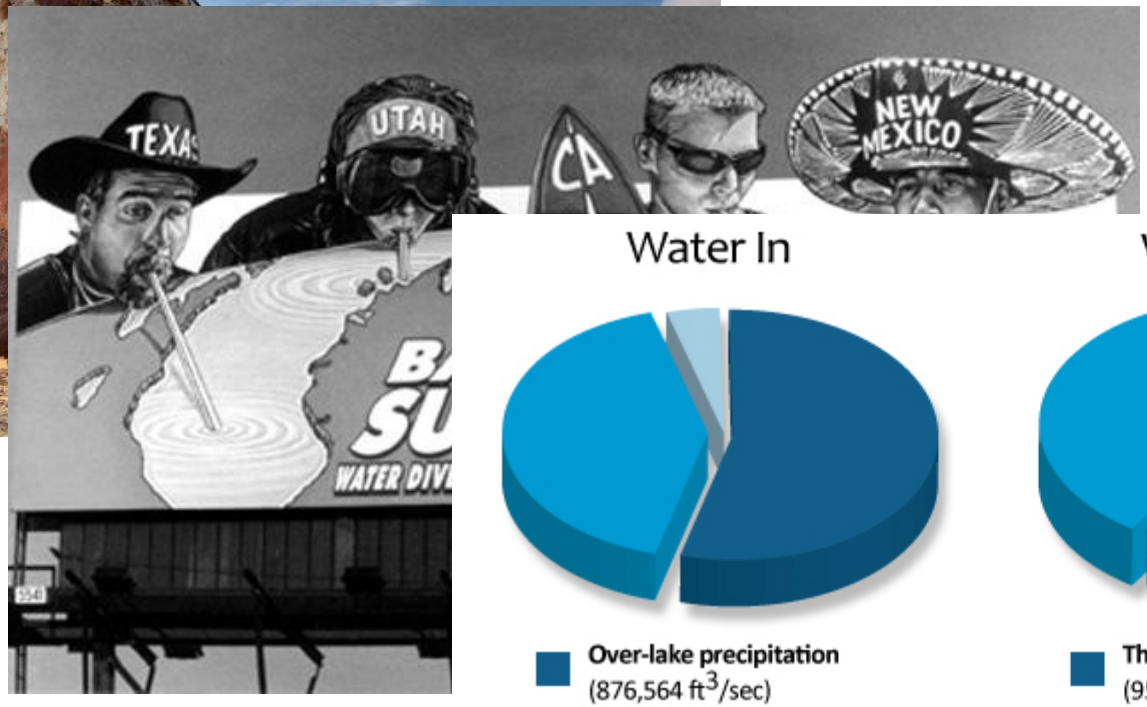

Winter 2006-7

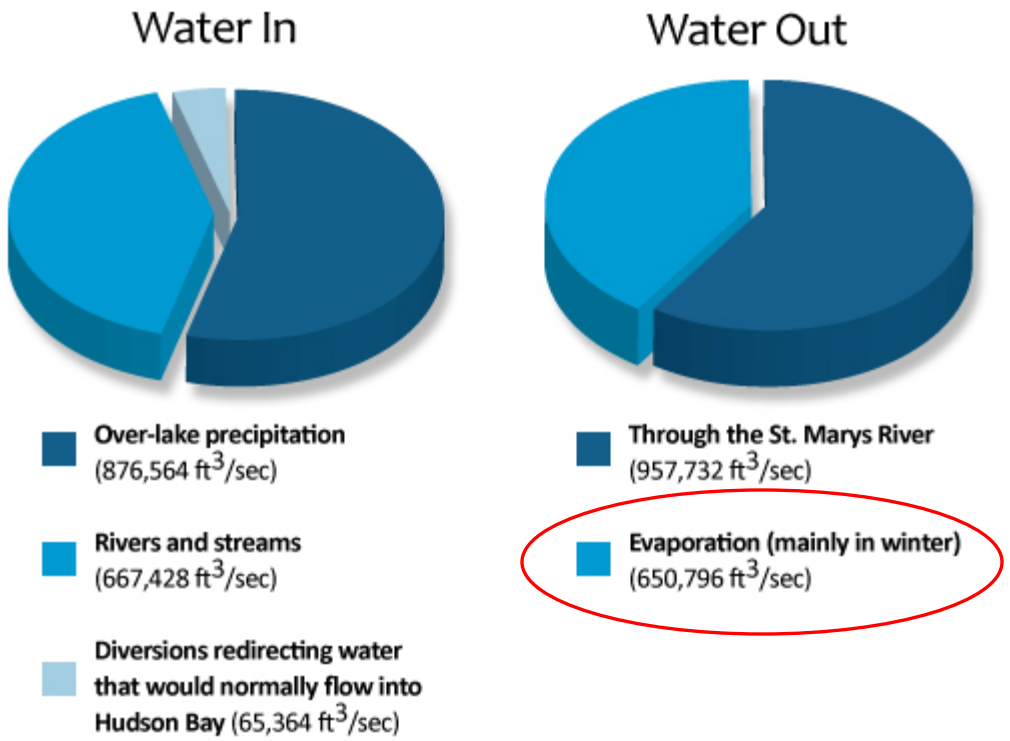

Summer 2007


Winter 2007-8

Winter 2014

Photo credit: Joel Trick

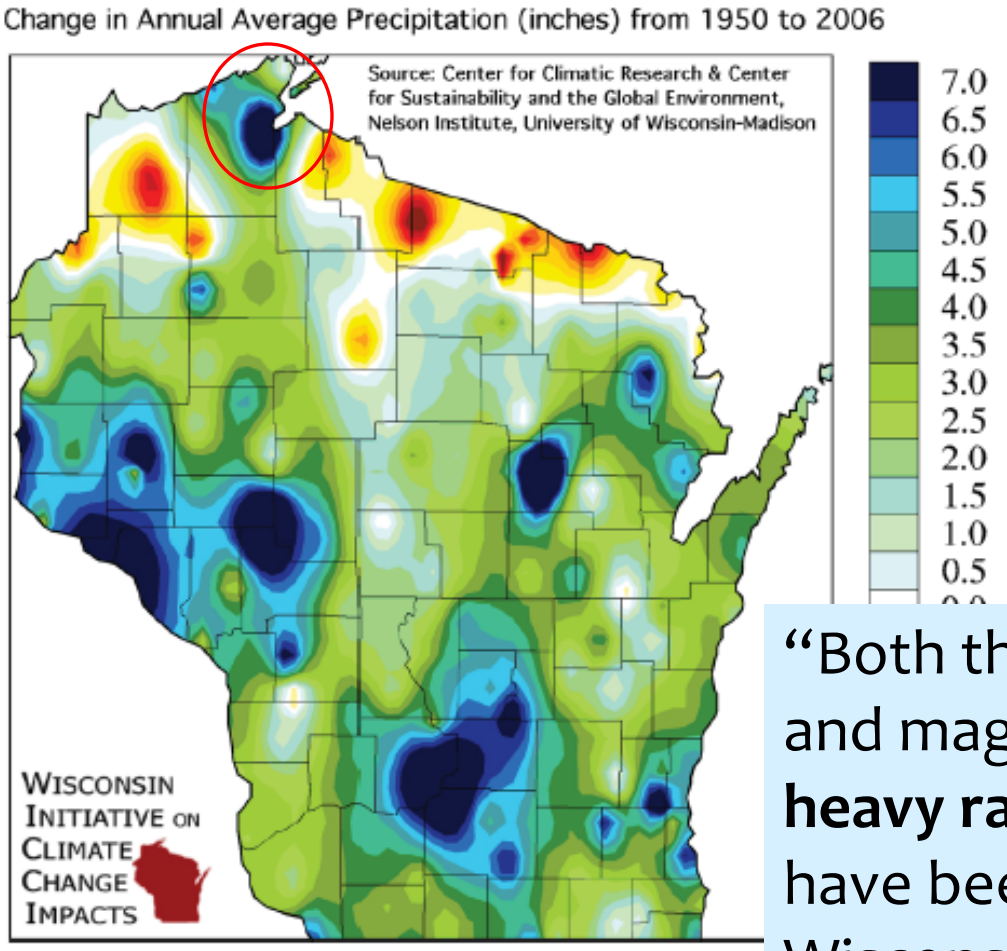




http://www.seagrant.umn.edu/superior/facts

Precipitation Changes

Precipitation Has Increased

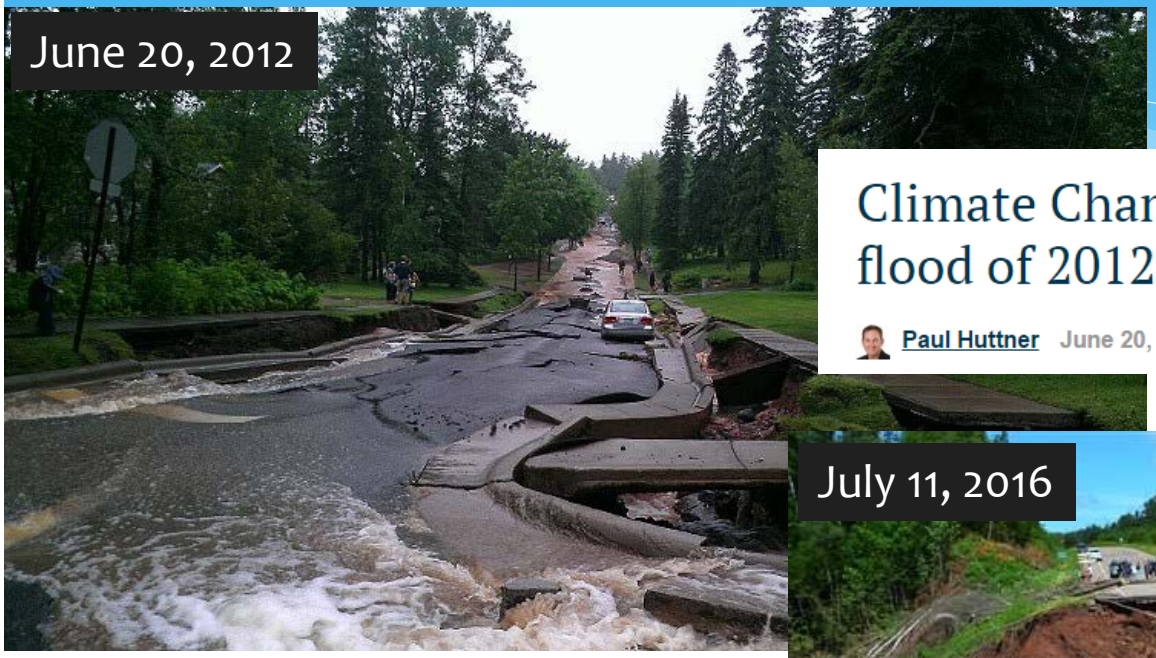


From 1950 to 2006, Wisconsin as a whole has become wetter, with an increase in inches. This observed increase in annual precipitation has primarily occurred Wisconsin, while northern Wisconsin has experienced some drying.

"Both the frequency and magnitude of **heavy rainfall events** have been increasing in Wisconsin." (WICCI 2011)

Frequency of Intense Storms Has Increased

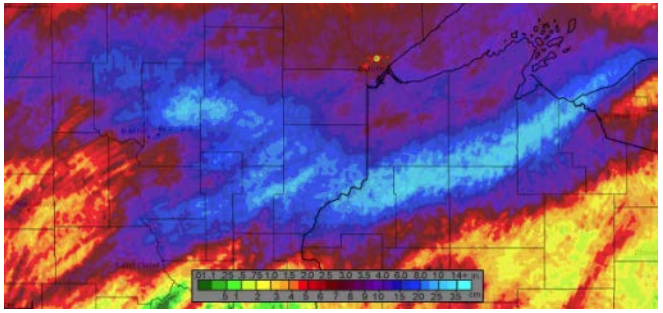
June 20, 2012



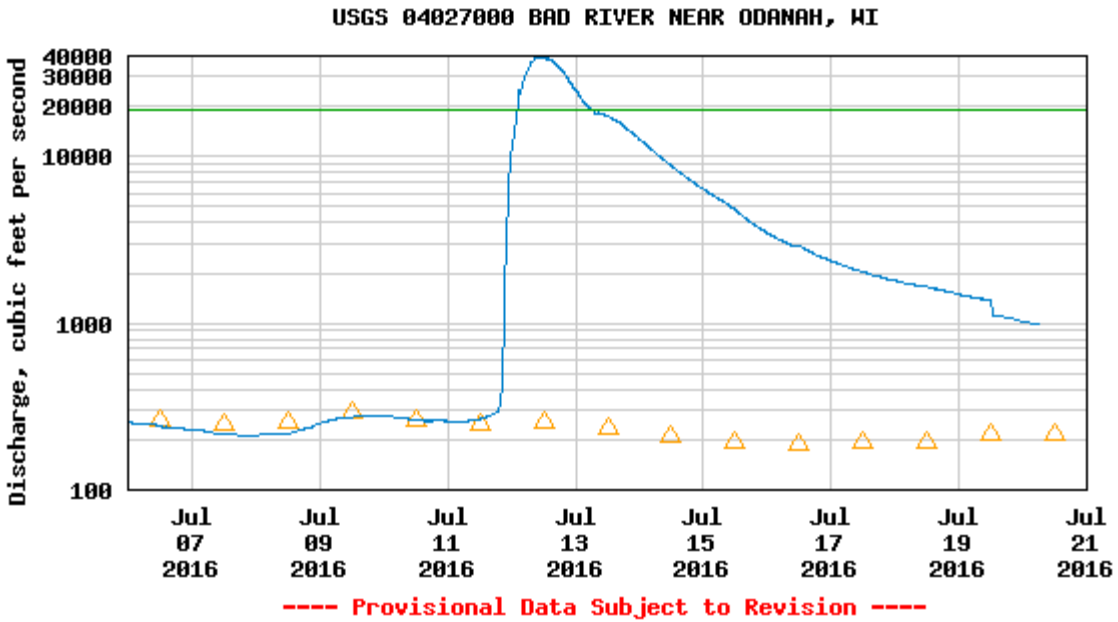
Climate Change likely 'juiced' Duluth flood of 2012

Paul Huttner June 20, 2013, 10:00 AM 0 Comments

July 11, 2016

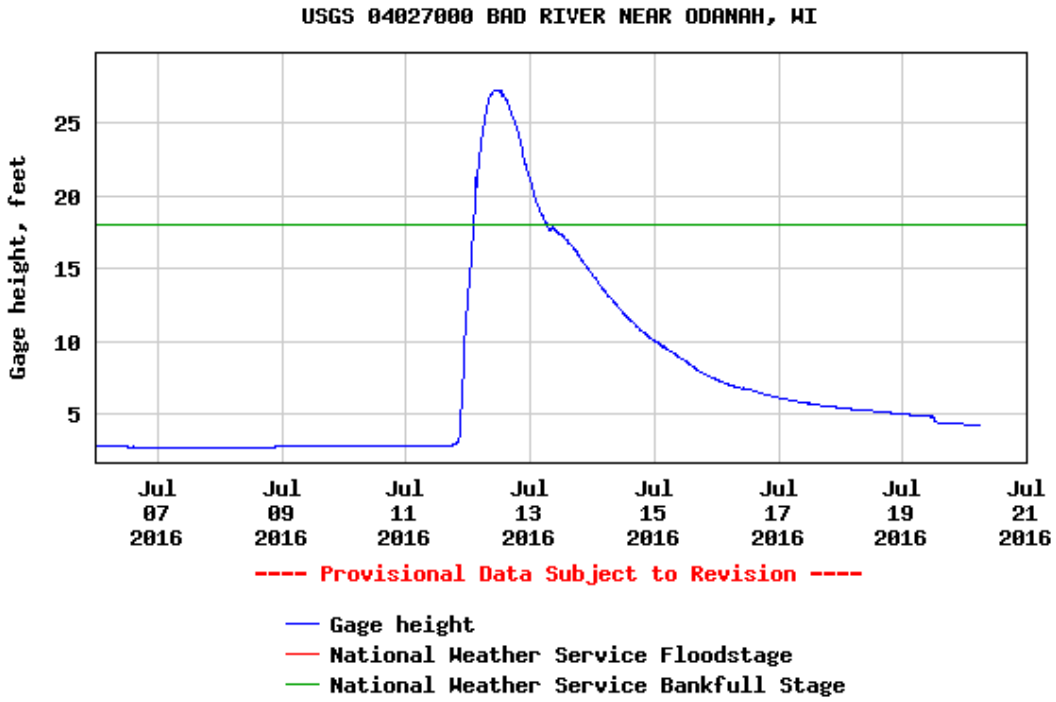


10+ inches in <24 hours ⟶



Flow climbed from ~200 cfs (on par with long-term average for this date) to 40,000 cfs – increased 200x overnight!

Water rose on the gage from <5 ft to over 25 ft



Climate Cascade #1

Altered landscape

+

Increased precipitation/flow

=

Increased nutrient and sediment loading

+

Warmer Waters

Increased algal blooms
Decreased water clarity


Gina LaLiberte, Wisconsin DNR

June 21, 2012 – 1 day after 2012 flood event

June 30, 2012 – 10 days after 2012 flood event

Algal bloom detected

BAYFIELD, WI - July 25, 2012
"… Samples of a **'green scum'** reported by visitors to Lake Superior beaches from Cornucopia to Little Sand Bay on July 14-15 were confirmed to contain a species of bluegreen algae …"

July 14, 2012 – **3 ½ weeks after** 2012 flood event

Algal bloom detected

"… Bluegreen algae blooms are **extremely unusual** in Lake Superior because the water is generally very low in nutrients and cold. However, the **floods in June flushed nutrients** and sediment from the land into the lake… Combined with the **warm weather**, conditions may have been just right for the algae to multiply."

July 14, 2012 – **3 ½ weeks after** 2012 flood event


July 19, 2016

Mouth of the Brule, July 17, 2016

Capturing the plume: tracking currents, water clarity, water quality continuously

Periodically sampling along plume transects

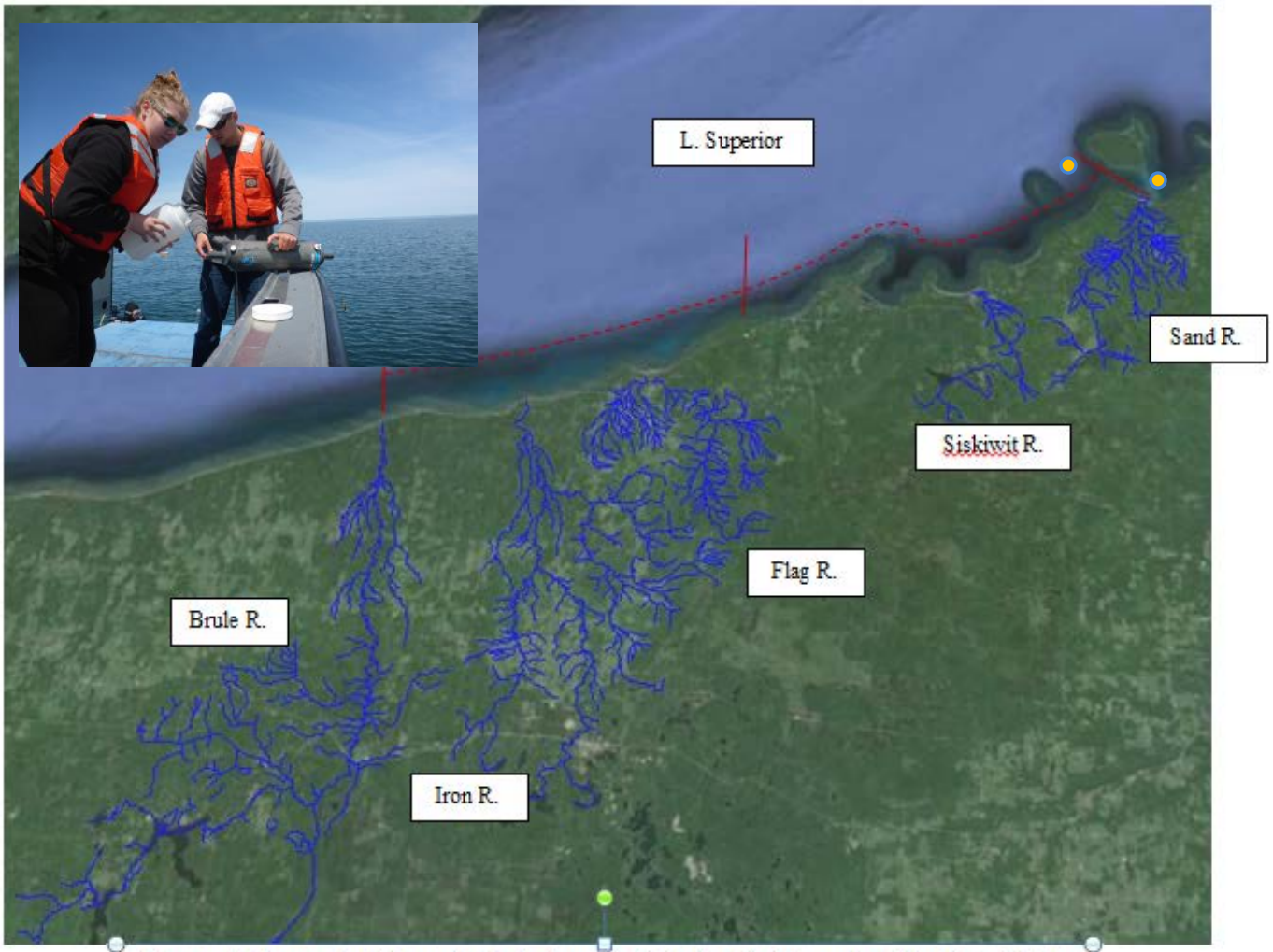


Figure 4: Proposed study area in Lake Superior depicting the five major tributaries (Brule, Iron, Flag, Siskiwit, and Sand; shown in blue) and the cross-shore transects (solid red line) as well as the alongshore transect (dotted red line).

- = continuous nearshore monitoring stations

Like Lake Erie here? Not anytime soon.

But perception that Lake Superior is totally immune has waned.

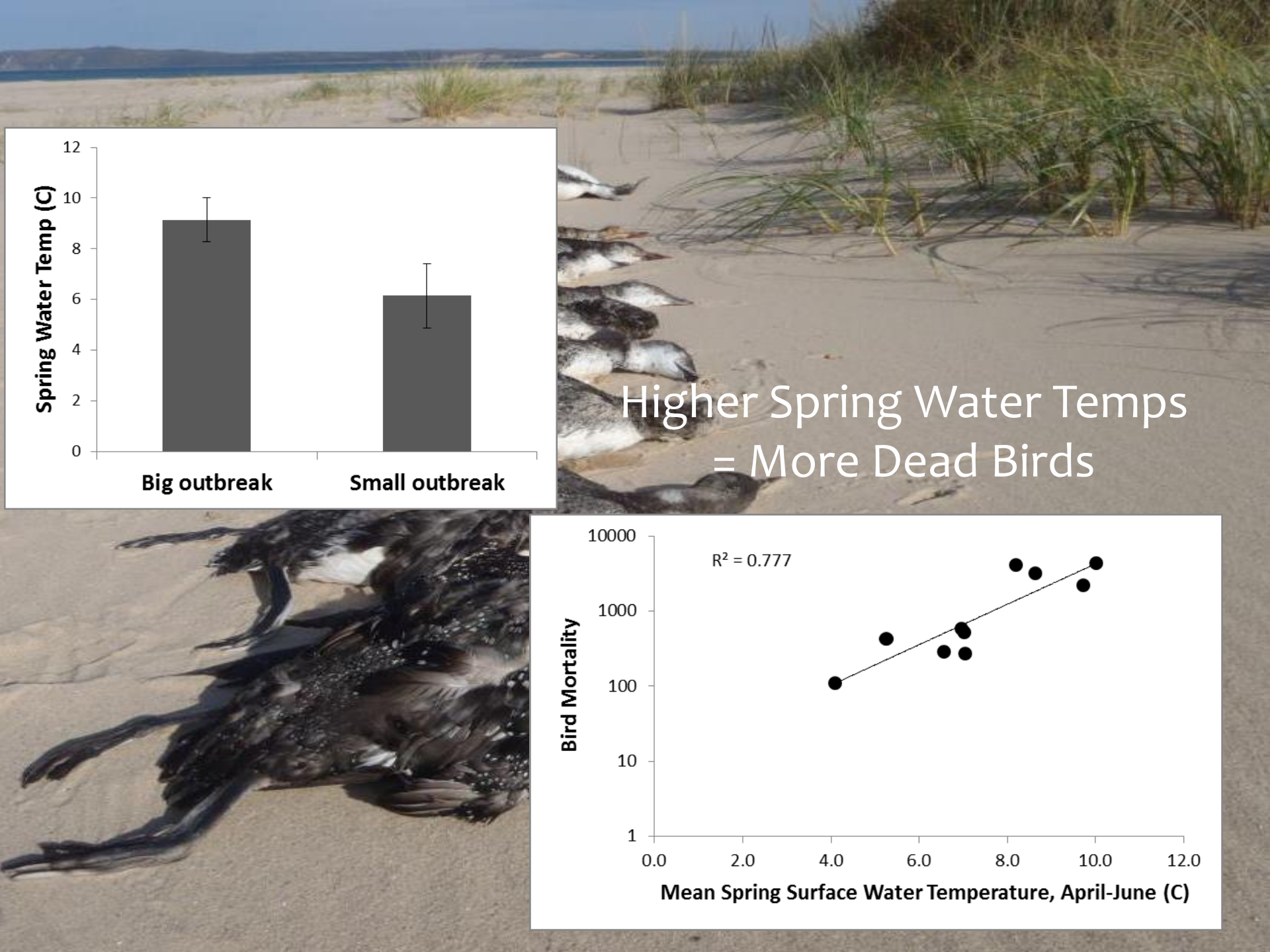
Continued attention needed.

Climate Cascade #2

- Zebra and Quagga Mussels
  → Increase water clarity; move nutrients to bottom
  → Increase growth of algae on bottom

- Algae slough and decompose
  → Create anoxic conditions
  → Facilitate growth of Clostridium botulinum; toxin production

- Toxin makes its way through food web to birds
  → Massive bird die-offs



Higher Spring Water Temps = More Dead Birds

Existing stressors (land use change, species invasions, etc.) can interact with climate change in unexpected ways.

Take-Home Points

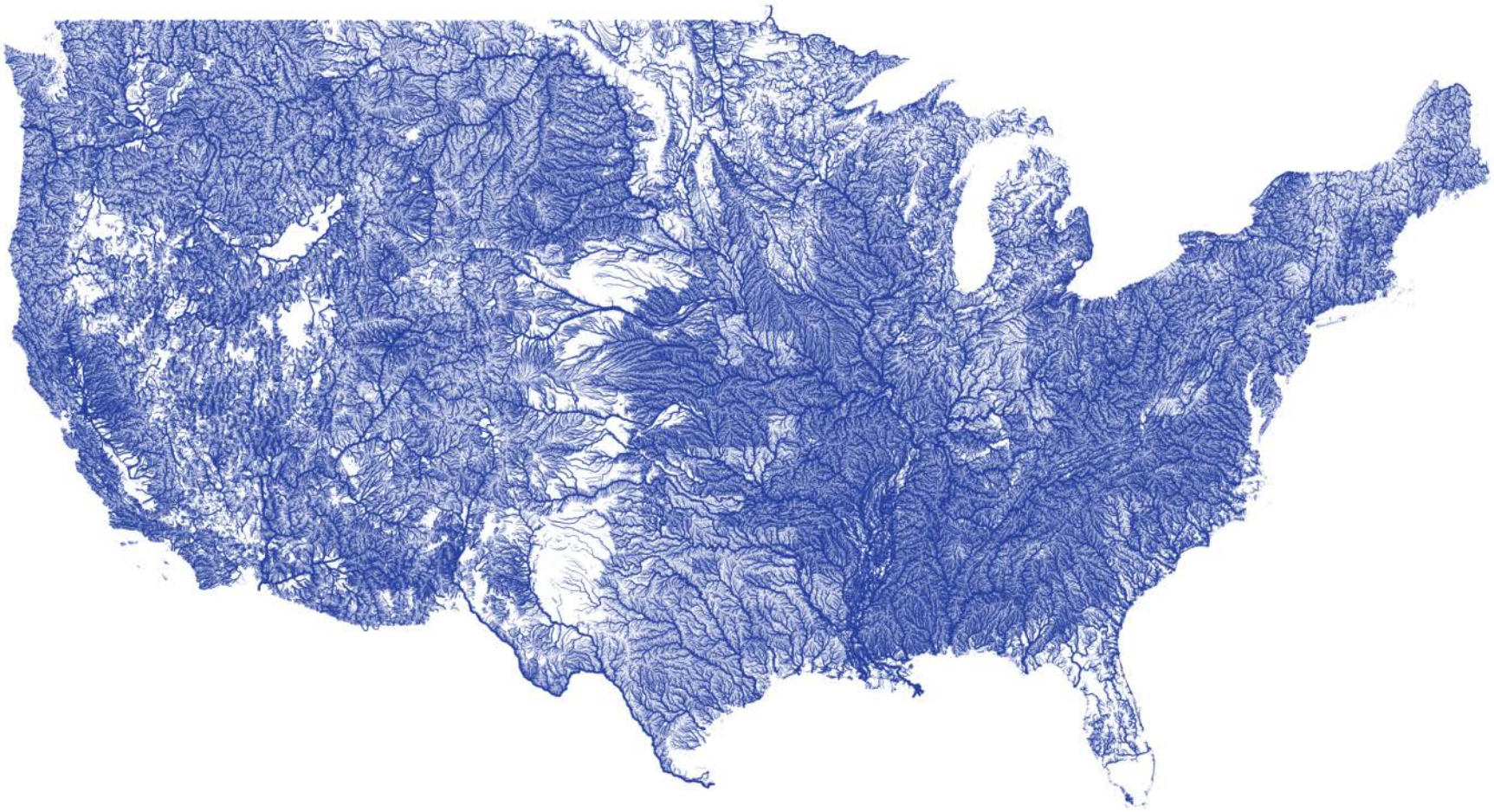
* Climate change is real
* It's affecting waters in Apostle Islands and other parks *right now*
* Some effects are expected/easily anticipated
* Others are complex, interactive, and hard to anticipate

All hands on deck…

… or on shore


… or in the river
And they can be tiny hands, or middle school hands, or college kid hands.

Follow the Drop



22.29°N 127.83°W

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