Climate Change Impacts on Water in Great Lakes National Parks

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2016 G-WOW “Hear the Water Speak” Institute
July 20, 2016

U.S. National Park Service
Midwest Region
Water Resources Division
The Water Lens
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
The Ojibwe migration route traced water. The migration story is partly a water story.
The immigration story is also a water story. Wisconsin in 1718, Guillaume de L'Isle map
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.
New Climate Expectations

National Climate Assessment

The National Climate Assessment summarizes the impacts of climate change on the United States, now and in the future.

A team of more than 300 experts guided by a 60-member Federal Advisory Committee produced the report, which was extensively reviewed by the public and experts, including federal agencies and a panel of the National Academy of Sciences.
Key Message: Increased Risks to the Great Lakes

Climate change will exacerbate a range of risks to the Great Lakes, including changes in the range and distribution of certain fish species, increased invasive species and harmful blooms of algae, and declining beach health. Ice cover declines will lengthen the commercial navigation season.
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

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.

<table>
<thead>
<tr>
<th>Rank</th>
<th>State</th>
<th>Temperature Change (°F per decade)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Arizona</td>
<td>0.639</td>
</tr>
<tr>
<td>2</td>
<td>Michigan</td>
<td>0.622</td>
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<tr>
<td>3</td>
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<td>0.620</td>
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<tr>
<td>4</td>
<td>Wisconsin</td>
<td>0.616</td>
</tr>
</tbody>
</table>

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


Surface Waters Are Reaching Record Temps

- 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://minnesota.publicradio.org/collections/special/columns/updraft/archive/2012/07/balmy_70s_2012_lake_superior_w.shtml
Water Temp Side Effect – Brook Trout Habitat Loss

Several Lake Superior tributaries prioritized for restoration and adaptation

*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.*
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, Jay A. Austin, Val Bennington

The impacts of climate change on the world’s large lakes are a cause for concern. 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. However, the effects of this change on large lakes have not been studied extensively. 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. 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. Lakes, and especially large lakes, are known to be an important component of regional and possibly global biogeochemical cycles. 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 area². The impact of warming temperatures on the dynamics of Lake Superior is poorly understood. One explanation is that the lake is warming faster than its atmosphere. This increase in water temperature can increase evaporation, which could lead to more intense winds and precipitation. The increased winds, in turn, could further warm the lake, creating a positive feedback loop. This feedback could be significant because it could amplify the warming of the lake and atmosphere, leading to more intense winds and precipitation, which could further warm the lake, and so on. This could have a significant impact on the lake’s ecosystem, as well as on the surrounding region. The increased winds could also lead to more intense storms, which could have a significant impact on the lake’s ecosystem, as well as on the surrounding region. The increased winds could also lead to more intense storms, which could have a significant impact on the lake’s ecosystem, as well as on the surrounding region.

Figure 2 | Increasing regional wind speeds. a. Buoys (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

300-400 year old lagoon

Storm-related breach; September 10, 2014
Less Lake Ice
Lake Temps Affect Lake Ice
“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
Lake Superior Water Level is Declining
As Temperature Has Increased Since ~ 1970s

Duluth Water Level, corrected

Sault Ste Marie WT, JAS average

Water Level Decreases
Temperature Increases

Slide from Jay Austin presentation at Apostle Islands National Lakeshore Climate Friendly Parks Meeting (17 July 2007)
http://www.seagrant.umn.edu/superior/facts
Precipitation Changes
Precipitation Has Increased

“Both the frequency and magnitude of heavy rainfall events have been increasing in Wisconsin.” (WICCI 2011)
Frequency of Intense Storms Has Increased

Climate Change likely ‘juiced’ Duluth flood of 2012

Paul Huttner  June 20, 2013, 10:00 AM

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

\[\downarrow\]

Increased algal blooms
Decreased water clarity
June 21, 2012 – 1 day after 2012 flood event
June 30, 2012 – 10 days after 2012 flood event
July 14, 2012 – 3 ½ **weeks after** 2012 flood event

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 – 3½ weeks after 2012 flood event

“...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.”
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.
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
For slides and climate smarts – Bob Krumenaker, Neil Howk, Randy Lehr, and others

For ongoing nearshore monitoring – Great Lakes Restoration Initiative, many staff and scientists from NPS, USGS, UWM, and partner universities

For inspiration – NPS interpretive staff, G-WOW organizers, you all...