# Climate Change in the Great Lakes Region

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| Average Temperature | Frost-free Season | Total Precipitation | Heavy Precipitation Events |
|---|---|---|---|
|  |  |  |  |
| **2.3°F** | **16 Days** | **14%** | **35%** |
| 1951-2017 | 1951-2017 | 1951-2017 | 1951-2017 |

## Temperature

- Since 1951, annual average air temperatures have increased by 2.3°F (1.3°C) in the U.S. Great Lakes region.
- By mid-century (2050), average air temperatures are projected to increase by 3°F to 6°F (1.7°C to 3.3°C).
- By end of century (2100), average air temperatures are projected to increase by 6°F to 11°F (3.3°C to 6.1°C).

## Precipitation

- Since 1951, total annual precipitation has increased by 14% in the U.S. Great Lakes region.
- Future projections suggest more precipitation on average, but not necessarily during all seasons (summer to be drier) and not for all locations depending on which model is used.
- Reduced lake ice cover and enhanced evaporation may lead to increased lake-effect snowfall in the near-term, but rising temperatures will cause more winter precipitation to fall as rain as opposed to snow across the region by late century.

## Snow, Ice Cover and Lake Temperature

- Summer lake surface temperatures have been increasing faster than the surrounding air temperatures, with Lake Superior increasing by 4.5°F between 1979 and 2006.
- Annual average ice cover on the Great Lakes underwent a shift from higher amounts prior to the 1990s to lower amounts in recent decades. There remains strong year-to-year variability, and high ice years are still possible.
- Lake-effect snowfall has increased in northern areas and may continue to increase through mid-century.

## Extreme Weather

- The frequency and intensity of severe storms has increased. This trend will likely continue as the effects of climate change become more pronounced.
- The amount of precipitation falling in the heaviest 1% of storms increased by 35% in the U.S. Great Lakes region from 1951 through 2017.
- More severe storms may have a negative economic impact due to resulting damages and increased costs of preparation, clean up, and business disruption.

## Water Quality and Stormwater Management

- Projected increases in droughts, severe storms, and flooding events may amplify the risk of erosion, sewage overflow, interference with transportation, and flood damage.
- Future changes in land use could have a far greater impact on water quality than climate change. The coupling of climate change and land use change could therefore result in even stronger effects in some areas.

## Lake Levels

- Water level fluctuations on the Great Lakes are mainly driven by precipitation, evaporation, and runoff, which make up the lakes' net basin supply.
- After a period of low lake levels lasting from the 1990s to the mid-2010s, the lakes have risen at an unprecedented rate since 2014. This contributed to record high levels on Lake Ontario, which caused widespread flooding in 2017.
- Modeling of future lake levels is continually being updated and improved. Currently, the strongest evidence indicates increasing variability in lake level fluctuations.

GLISA-info@umich.edu
UNIVERSITY OF MICHIGAN
MICHIGAN STATE UNIVERSITY
glisa.umich.edu

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## Algal Blooms

- Warmer surface water temperatures increase stratification of the lakes and decrease vertical mixing.
- Stronger storms and the use of impervious surfaces increase runoff and nutrient loading to the Great Lakes.
- Combined sewer overflows and agricultural fertilizers are major contributors to high nutrient loads.
- Stronger storms, warmer temperatures, and nutrient loading contribute to the formation of harmful algal blooms and hypoxic dead zones.

## Fish and Wildlife

- The rate of warming may outpace the rate at which ecosystems are able to migrate and adapt.
- Wildlife populations better adapted to cold temperatures will continue to decline as competing species migrate into the region with rising temperatures.
- Lake stratification and hypoxic conditions will further stress biomass productivity in lakes and wetlands.
- Increased evaporation rates and sustained levels of high or low water levels may change wetland areas in the region.

## Water Availability

- Despite increasing precipitation, land surfaces in the Great Lakes region are expected to become drier overall due to increasing temperatures and evaporation rates.
- More frequent summer droughts could affect soil moisture, surface waters, and groundwater supply.
- The seasonal distribution of the water cycle will likely change. Warmer temperatures may lead to more winter rain and earlier peak streamflows.

## Forests

- As temperatures rise, the distribution and composition of tree species will change and shift northward.
- With warmer temperatures and increasing $CO_2$, forest productivity will likely increase until other impacts of climate change, such as increased drought, fire, and invasive species present additional stressors to forests.

## Energy and Industry

- Reduced summer water availability may interfere with some industrial operations (i.e., hydropower, thermoelectric and nuclear plant cooling).
- Warmer temperatures and more frequent heat waves will likely increase electricity demands, particularly in urban areas and during summer months.

## Agriculture

- The frost-free season lengthened by 16 days in the Great Lakes region from 1951-2017, and may extend up to 50 days longer by 2100.
- In the near-term, a longer growing season and higher $CO_2$ concentrations will likely have a positive effect on crop yields.
- In the long-term, the negative effects of increasing storm activity, flooding, extreme heat, summer drought risks, and pests may outweigh the benefits of warmer climates.

## Transportation

- More extreme heat may increase the risk of heat damage to pavement and railroads.
- More extreme precipitation may compromise transportation routes and damage infrastructure.
- Shipping lanes will likely be open earlier and longer due to reduced ice cover on the Great Lakes.
- Low lake levels can affect navigation channels and reduce the maximum loads carried by vessels, which amount to substantial monetary losses per transit.

## Public Health

- Increased risk of heat waves and increased humidity may amplify the number of heat-related deaths and illnesses.
- More storm activity and flooding will likely increase the risk of watershed contamination and water-borne illnesses, while warmer surface waters amplify the risk of toxic algal blooms and fish contamination.

## Tourism and Recreation

- Winter recreation and tourism are likely to suffer due to reduced snow cover and shorter winters.
- Increased lake contamination from algal blooms may degrade shoreline water quality and coastal ecosystem health, but increasing summer temperatures and a longer summer season may increase demand for beaches.
- Overall, summer tourism may grow before temperature rise becomes unfavorable for many recreational activities.
- Many coldwater species of fish important to recreation (i.e., whitefish and lake trout) are likely to decline while populations of warm water species are likely to grow.

**Further explanation and references for reported trends and statements are available at:**
**glisa.umich.edu/gl-climate-factsheet-refs**

# Climate Change in the Great Lakes


# Great Lakes Integrated Sciences & Assessments

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GREAT LAKES INTEGRATED SCIENCES + ASSESSMENTS

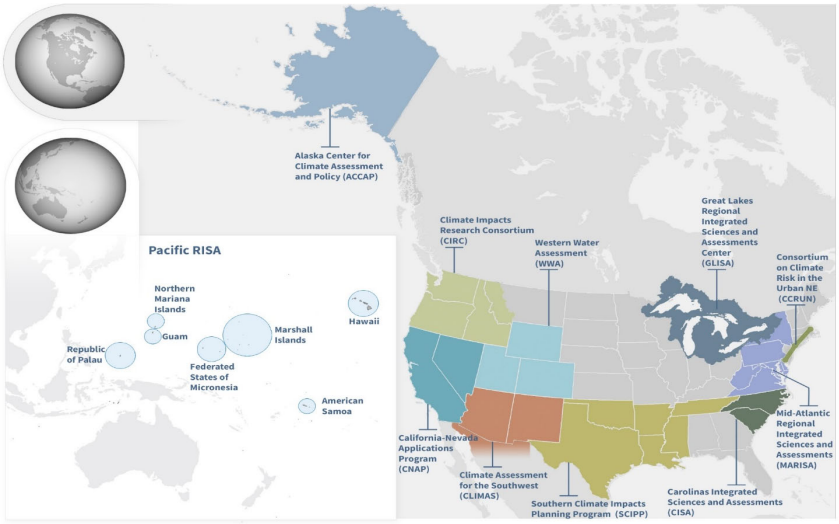
UNIVERSITY OF MICHIGAN

NOAA NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION U.S. DEPARTMENT OF COMMERCE

MICHIGAN STATE UNIVERSITY

# NOAA Regional Integrated Sciences and Assessments (RISA)

Regional teams that help the nation to prepare for and adapt to climate variability and change

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# GLISA's Approach

**Research**

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**Integration**
**Collaboration**
**Extension**

**Service**

- Interpret *existing* information and data for stakeholders
- Provide *locally* relevant climate synthesis:
  - What has happened?
  - What could happen?
  - What are the impacts?

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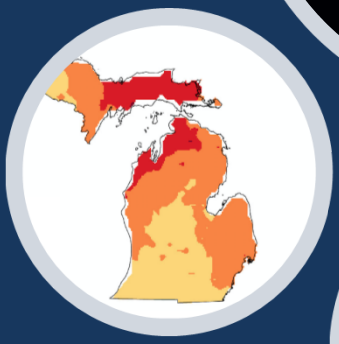
# Global | Regional | Local

- There are multiple ways of looking at climate change:
  - Global
  - Regional
  - Local

- Local factors can drastically alter the magnitude of climate change impacts, but can also be adapted to more readily.



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# Global | Regional | Local

Photo credit: http://www.noaa.gov/resource-collections/great-lakes-eco-region

## Rising Temperatures


Source: GLISA and Univ. of Wisc. Nelson Institute

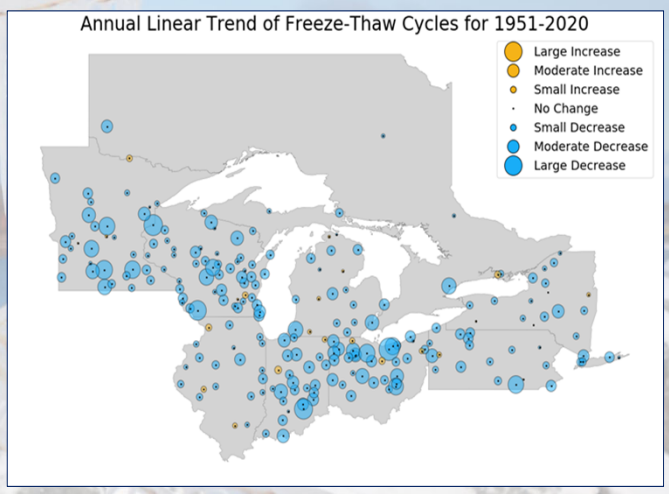
## Winters are Warming Faster


Source: GLISA & National Centers for Environmental Information

Photo: Dan Brown

# Freeze-Thaw Cycles

**The number of freeze-thaw cycles are decreasing regionwide**

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# A Longer Frost-free Season

**Observed**

**16 Days**
**Longer**
**1951-2020**

**Future**

**35 to 54 Days**
**Longer**
**2070-2099**

Observed changes due mostly to **earlier last winter freeze**

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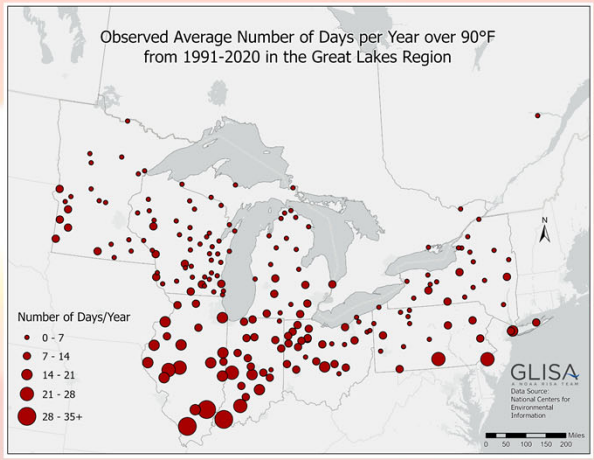
Source: GLISA and Univ. of Wisc. Nelson Institute

# Extreme Heat

**Average Number of Days over 90°F in the Great Lakes region has increased by:**

**7.7 Days**

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Source: National Centers for Environmental Information

# Extreme Heat

**By mid-century, models project the region could see:**

**90°F Days**
**9 to 37 more days per year**

**100°F Days**
**3 to 19 more days per year**

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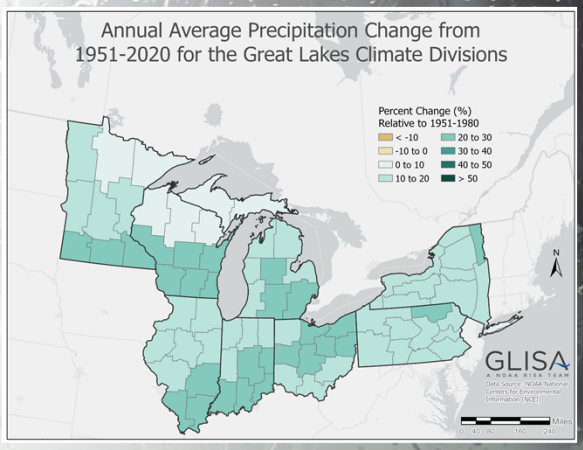
Source: GLISA and Univ. of Wisc. Nelson Institute

# More Precipitation

**Total annual precipitation in the Great Lakes region has increased by:**

**17%**




**Uneven changes across the Region**

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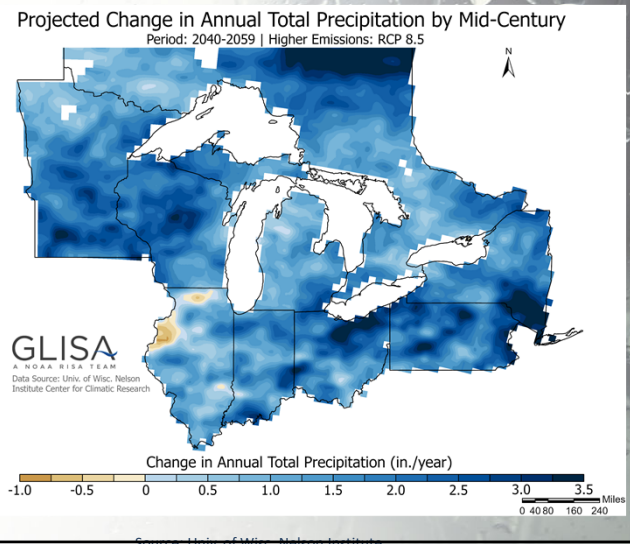
Percent change are calculated relative to the period of 1951-1980 historical reference period.

Source: National Centers for Environmental Information

# Future Precipitation

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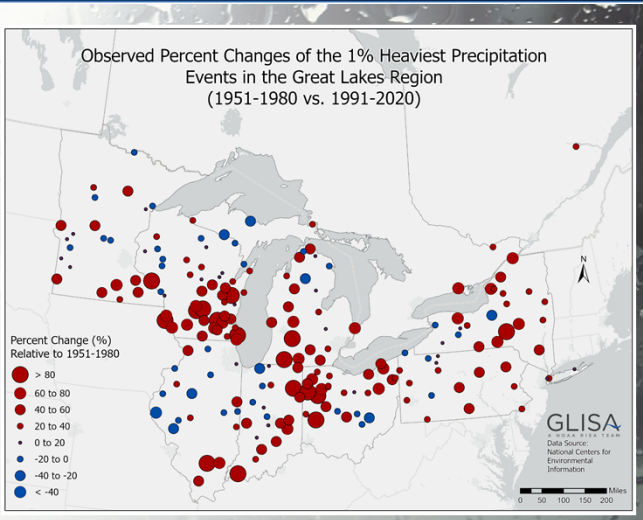
Source: Univ. of Wisc. Nelson Institute

# More Extreme Precipitation

**1% Heaviest Precipitation Events:**

**24%**

**Nuisance flooding and minor damages are reported more frequently after these events**




Source: National Centers for Environmental Information

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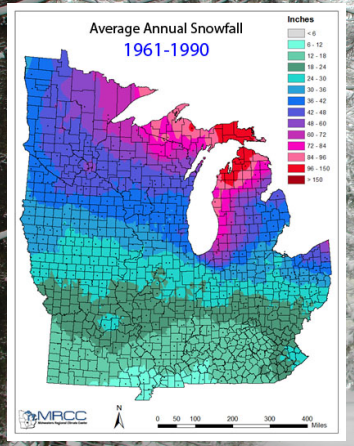
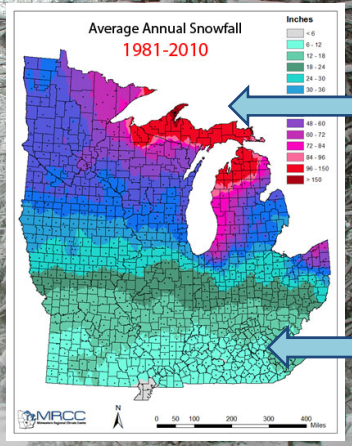
# Change in Snowfall




**Snowfall has increased in lake-effect areas**

**Snowfall has remained stable or decreased throughout southern parts of the region**

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Photo: Kim Channell

# Impacts


# Algal Blooms and Water Quality

More/Stronger Storms

More Runoff from Agriculture

Greater Nutrient Loading

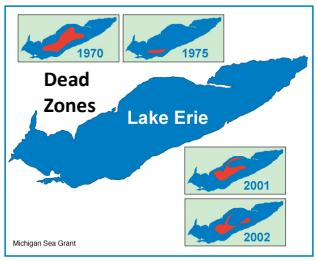
Warmer Lake Temperatures

Changed Lake Dynamics

Algal Blooms

Dead Zones

NOAA




MI SeaGrant

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# Plants and Wildlife

- Forest ecosystems forced northward
  - Maple-Beech-Birch forest displaced
- Amplified stressors on biodiversity
  - Declining Coldwater fish populations, species migrating northward
- Agriculture
  - Longer growing season
  - Water availability, warm spells, spring freezes, flooding, and drought will reduce crop yields
  - Drier conditions affecting water supply

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# Lake Levels

Main drivers of water supply on the lakes are:

- Precipitation - Evaporation + Runoff
- All three drivers are affected by regional climate change

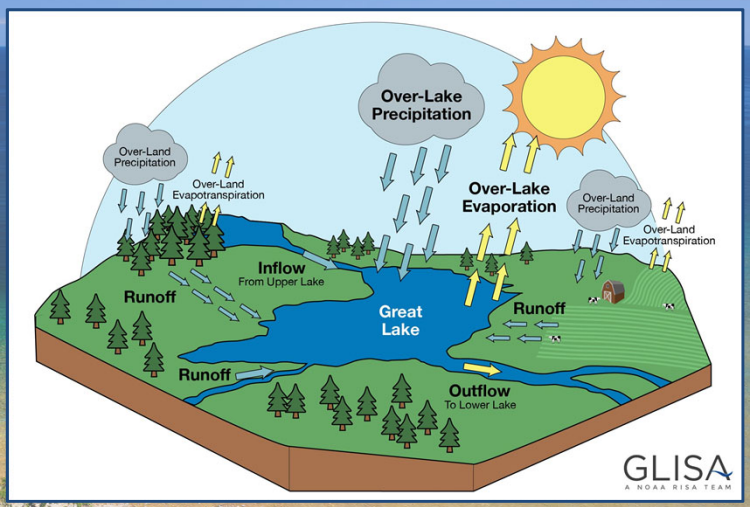


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Photo: Dan Brown

# Future Lake Levels

- Future water level changes will depend on whether precipitation or evaporation dominate
- Short-term variability with periods of high and low lake levels are still anticipated

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Photo: Dan Brown

# Impacts of Lake Levels

- Boating and recreation
- Shipping and navigation
- Hydropower
- Property
- Fisheries and wetlands

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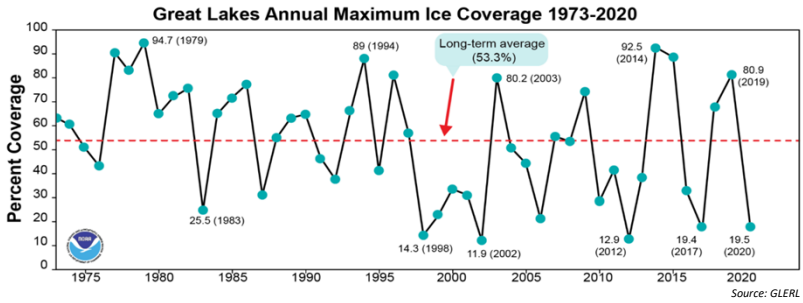
Photos: Kim Channell

# Impacts of Variable Great Lakes Ice Cover




- **Fishing Industry:** Ice cover protects whitefish spawning areas. Great Lakes commercial fishing is $4 billion industry.
- **Coastal Zone:** In nearshore areas, ice provides stable platform for recreation and protects wetland areas from erosion.
- **Water Levels and Navigation:** Heavy ice cover can reduce evaporation and contribute to higher water levels in the following seasons—good news for shipping.

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# Potential Impacts on Shipping

Every lost inch of water depth:

- Reduces cargo capacity 50-270 tons
- Costs $10k-30k per transit.

…but less lake ice cover allows for a longer shipping season

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# Great Lake Shoreline Flooding and Erosion

- High wind and waves accelerate erosion
  - Winter events can lead to ice shoves and further shoreline and infrastructure erosion
- Many instances of flooding from high lake levels in recent years
  - Ontario 2017 & 2019
  - Superior 2019
  - Michigan-Huron 2020

**2017 Flooding & Erosion on Lake Ontario, NY.**

*Photo credits: Coastal Flooding Survey Project, Cornell University and New York Sea Grant*

# Stormwater Impacts

- Intense, flashy runoff amplify flooding risks.
- Road and infrastructure damage
  - Transportation
  - Emergency services
- Erosion
- Sewage overflow
  - Water quality
  - Public health
- Ground saturation is a factor

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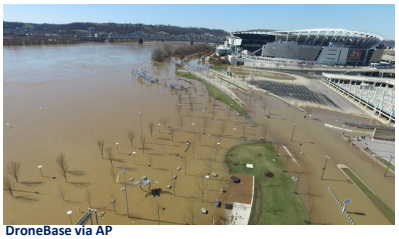
David Archambeau

**2018 flood damage in Houghton, MI**



DroneBase via AP

**2018 Ohio River flooding in Cincinnati, OH**

# Stormwater Adaptation

- Stormwater drainage systems designed for historic conditions
  - Don't have capacity to handle increasing amounts of extreme precipitation
- Adaptation will require evaluating stormwater systems and pursuing green infrastructure

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"The annual cost of adapting urban stormwater systems to more frequent and severe storms is projected to exceed $500 million for the Midwest by the end of the century"
– 4th National Climate Assessment