GLISA
A NOAA CAP TEAM

Summary of Climate Change in the Great Lakes Region

The climate system in the Great Lakes region is dynamic and will continue to change rapidly due to climate change. Changing atmospheric conditions and warming temperatures are fueling extreme weather, increased precipitation, and frequent downpours. Additionally, heat, drought, and other climate changes are increasingly impacting the region.

Climate change also poses evolving challenges, priorities, and risks that will affect all sectors. Importantly, climate and weather conditions will not change to a new set of static conditions. This means long-term planning efforts should regularly assess climate changes and be as flexible and adaptable as possible. Understanding past and future climate changes is a first step toward this goal.

This document summarizes historic trends and future projections across the Great Lakes region. Some parts of the region may have different rates of change than the regional average, therefore local data should be used where available.

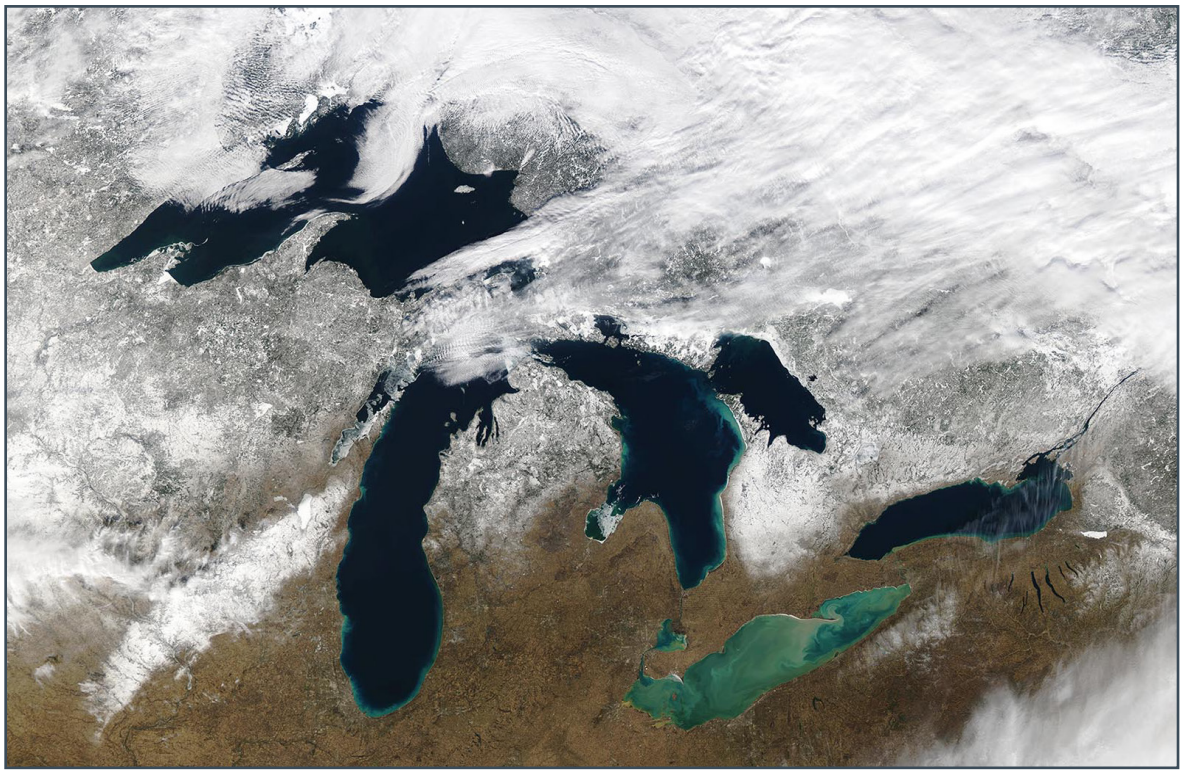


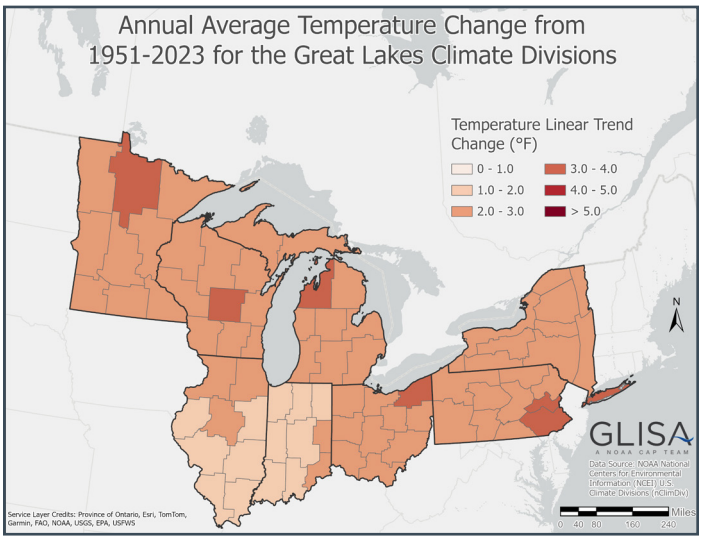
Photo: Satellite image of the Great Lakes.

Historic trends and values listed in this summary refer to average trends across the U.S. Great Lakes region from 1951 to 2023. **Future** trends and values refer to average projected changes for mid-century (2040–2059) and late-century (2080–2099) compared to the late 20th century (1980–1999). Future trends capture changes across the entire U.S. and Canadian Great Lakes region, which includes the U.S. Great Lakes states and the province of Ontario in Canada. Maps of projected regional changes are available on the GLISA website.

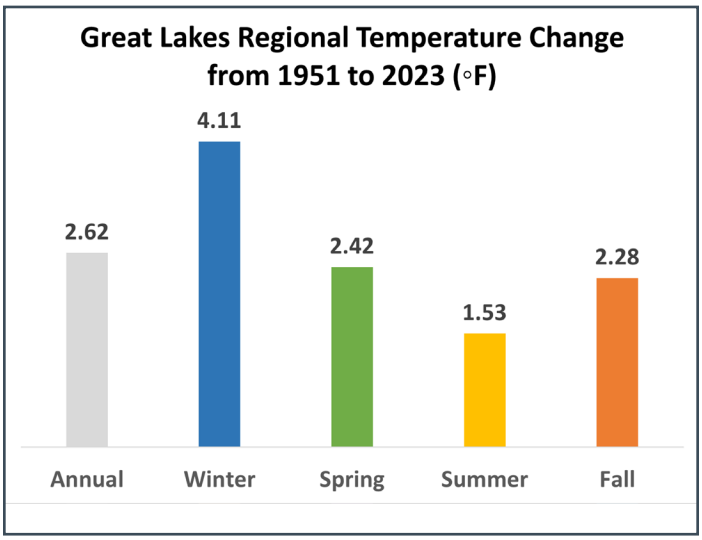
Temperature Trends

Past

- Between 1951 and 2023, average annual air temperatures increased by 2.6°F (1.4°C).
- Most of this warming has been observed during the early winter and late spring.
- Warming has also been observed in overnight low temperatures.



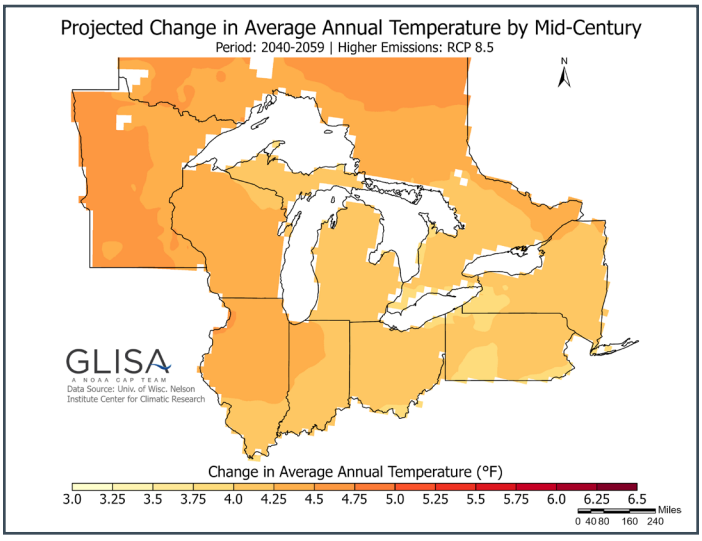
Observed annual temperature changes for climate divisions in the Great Lakes Region. Darker colors correspond to greater increases.



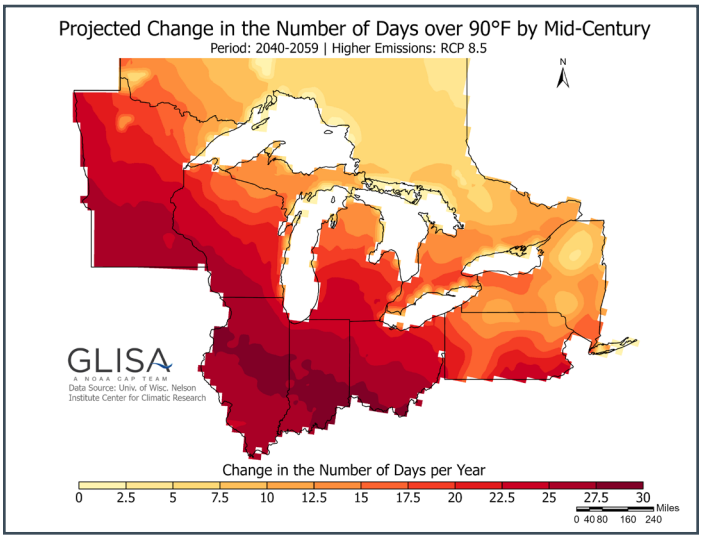
Changes in annual and seasonal temperature for the Great Lakes Region from 1951–2023. Seasons are warming at different rates.

Future

- Temperatures will continue to warm at a pace near or faster than the current rate.
- Average air temperature is projected to rise by 3°F to 6°F (1.7 to 3.3°C) by mid-century, and by 6°F to 11°F (3.3°C to 6.1°C) by late-century.
- By late-century, the number of extreme heat days will increase, with projections indicating 9 to 37 more days over 90°(32°C) by mid-century and 27 to 66 more days by end-century in an average year.
- Northern parts of the region will likely experience the greatest temperature increases.



Projected annual temperature changes for the Great Lakes Region. Darker colors correspond to greater increases.

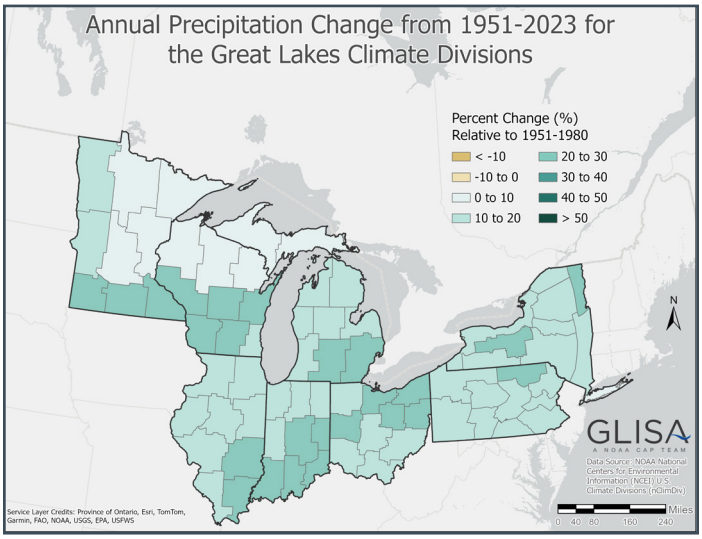


Projected change in the number of days per year over 90°F for the Great Lakes Region. Darker colors correspond to greater increases.

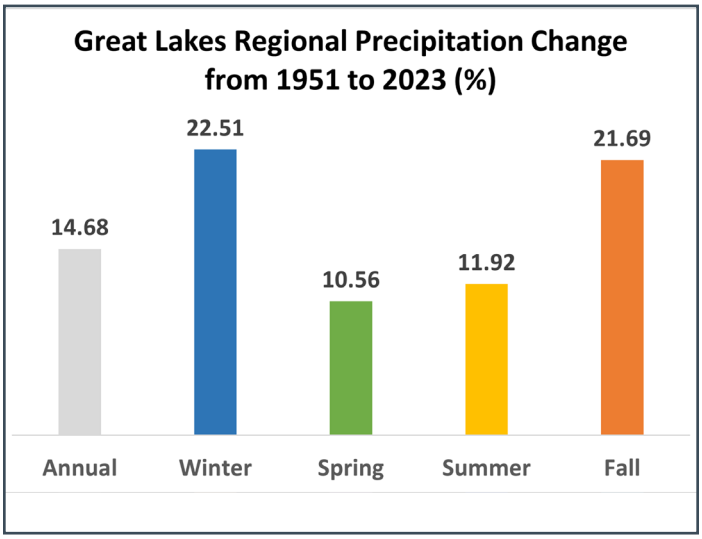
Precipitation Trends

Past

- Between 1951 and 2023, total annual precipitation has increased by an average of 14%, with significant variation across the region.
- The greatest precipitation increases have been observed in winter and fall.
- The amount of rain falling in extreme events (heaviest 1% of storms) has increased by 34% and these events have generally become more frequent between the periods of 1951–1980 and 1991–2020.
- Due to warmer winter temperatures, winter precipitation is increasingly falling as rain or sleet, rather than snow.
- Snowfall has decreased, except in lake-effect zones, where warmer lakes and declining ice cover contribute to increased lake-effect snowfall.



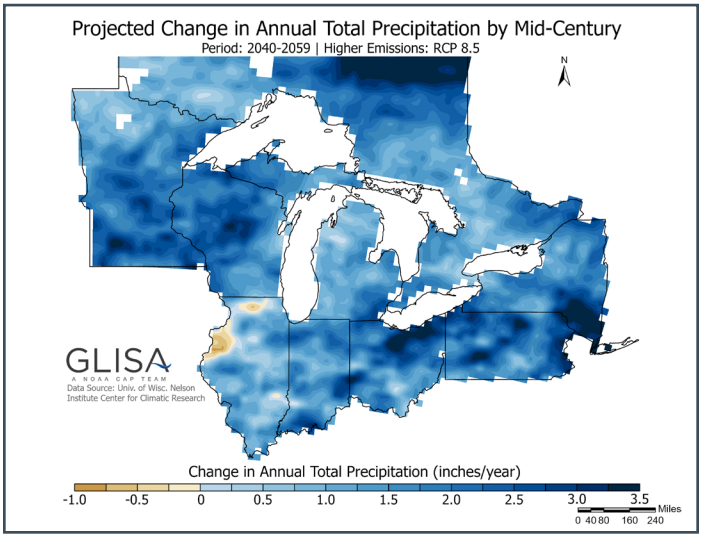
Observed annual precipitation changes for climate divisions in the Great Lakes Region. Darker colors correspond to greater increases.



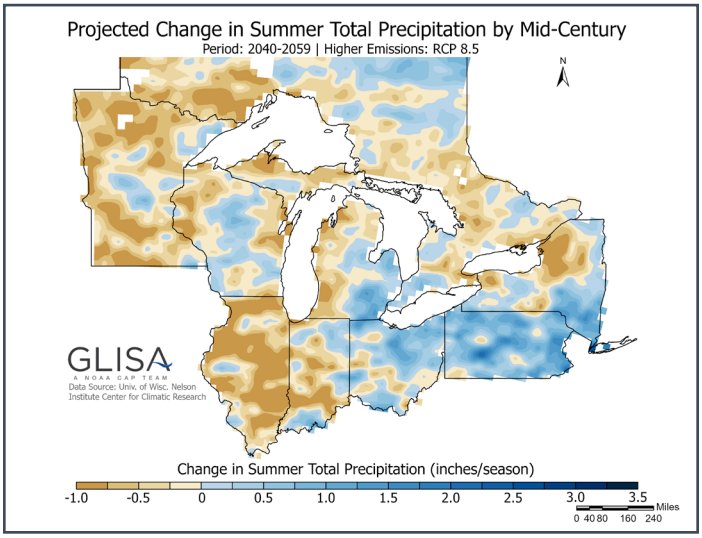
Changes in annual and seasonal precipitation for the Great Lakes Region from 1951–2023. Seasons are changing at different rates.

Future

- Total annual rainfall is projected to change by –0.3 to 4.2 inches (–6.4 to 107.7 mm) by mid-century, and increase by 1 to 6 inches (25.4 to 152.4 mm) by late-century.
- Despite overall increases in annual rainfall, summer drought and the number of consecutive dry days will likely increase, interspersed with periods of increased rainfall.
- Warmer winters will continue to cause more winter precipitation to fall as rain rather than snow, leading to declines in overall snowfall in the future, even in lake-effect zones that have observed increased snowfall in the recent past.



Projected annual precipitation changes for the Great Lakes Region. Most of the region is projected to experience increases (blue).



Projected summertime precipitation changes for the Great Lakes Region. Large swaths of the region are projected to decrease (brown).

Extreme Weather

- With warmer conditions, the atmosphere can hold more water vapor. This increase in moisture, combined with rising temperatures, contributes to storm formation.
- This climate phenomenon has led to more frequent and intense storms and will likely continue to produce more intense storms into the future.

Lake Levels

- Great Lakes water level fluctuations are mainly driven by the competing balance of precipitation, evaporation, and runoff. Climate change is amplifying these factors and causing lake levels to fluctuate more rapidly and to greater extremes.
- For example, after a period of low lake levels during the 1990s to the mid-2010s, the lakes rose at an unprecedented rate between 2014 to 2020. This contributed to record high lake levels across the basin, widespread flooding, and severe shoreline erosion in some areas. Since this period, lake levels have fallen back to near-average as of 2024.
- Modeling to project future lake levels is continually being updated and improved. Currently, recent studies and modeling efforts indicate that lake levels will continue to see increasing fluctuations and variability into the future.

Ice Cover & Lake Temperature

- In recent decades, less annual average ice cover has been observed on the Great Lakes, compared to decades prior to the 1990s. However, with strong year-to-year variability, years with high ice coverage are still possible.
- Due to lake ice melting earlier in the season, the surface of the lakes are open to absorb heat from the sun earlier and longer. This has contributed to increases in summer lake surface temperatures, with Lake Superior increasing the most by 4.5°F (2.5°C) between 1979 and 2006.

Future Climate Hazards in the Great Lakes Region

The table below summarizes extreme climate hazards in the Great Lakes region and how they are expected to change in the future. The number and direction of arrows indicate the projected trends for mid-century (2040-2059) and late-century (2080-2099) compared to the late 20th century (1980-1999). For example, a single arrow indicates a moderate change, and two arrows indicate a substantial change.

Climate Hazards in the Great Lakes Region

Risk	By Mid Century	By End of Century	Summary
Flood Hazards	↑↑	↑↑	Stronger and more extreme precipitation events will be more likely to overwhelm stormwater infrastructure.
Dam Failures	↑	↑↑	Stronger and more extreme precipitation events coupled with aging dam infrastructure will increase the probability of dam failure.
Convective Weather (Severe Winds, Lightning, Tornadoes, Hail)	↑	↑	Warmer temperatures and additional moisture increase the potential for severe weather (e.g., tornadoes and hail) and allow for a longer severe weather season.
Severe Winter Weather (Ice/Sleet Storms, Snow Storms)	↑	↑	Warmer, shorter winters will reduce winter-related impacts, though lake-effect snow will continue increasing in the near future. Due to natural variability, cold air outbreaks are still possible and can lead to ice, sleet, freezing rain, and wet snow.
Extreme Heat	↑	↑↑	The number of extremely hot days (over 95°F and 100°F) will likely increase. Overnight lows have warmed faster than daytime highs, which may lessen opportunities for relief during heat waves. Increased heatwaves and humid conditions elevate the risk of heat-related deaths and illnesses.
Extreme Cold	↓	↓↓	The number of extremely cold days (i.e., days below 10°F) have decreased in the region and are projected to decrease even more in the future. However, cold air outbreaks are still possible due to natural varibility.
Drought	↑	↑↑	Summer drought and the number of consecutive dry days will likely increase, interspersed with periods of increased rainfall.
Wildfires	↑	↑	Increased summer drought and the number of consecutive dry days will increase the risk of wildfires, particularly in the northern portions of the region.

The arrows in this table reflect a qualitative assessment made by the GLISA team based on analysis in the Fourth National Climate Assessment. These trends represent an average across the Great Lakes region, and will vary by location due to the localized nature of extremes.

Data Sources

Historical Observations: National Oceanic and Atmospheric Administration National Centers for Environmental Information Global Historical Climatology Network daily (GHCNd) Station Observations. https://www.ncei.noaa.gov/products/land-based-station/global-historical-climatology-network-daily

Future Projections: Nelson Institute Center for Climatic Research at the University of Wisconsin-Madison. Regional Climate Model version 4 (RegCM4). Dynamical Downscaling for the Midwest and Great Lakes Basin. https://ccr.nelson.wisc.edu/dynamical-downscaling/index.php

Additional Resources

- Climate Change in the Great Lakes Region 2-page fact sheet
- Great Lakes Climatologies (local and subregional information)
- Great Lakes Regional Climate Change Projection Maps
- Tools and Resources for City Adaptation
- Climate Hazard and Mitigation Planning (CHaMP) Tool
- Annual Great Lakes Climate Summary

How to Cite This Resource

GLISA. Summary of Climate Change in the Great Lakes Region, October 2024, glisa.umich.edu.

About GLISA

This summary was produced by GLISA. GLISA is the Great Lakes CAP team and is part of NOAA's Climate Adaptation Partnerships (CAP) network, formerly known as RISA. GLISA was established in 2010 and is a collaboration between the University of Michigan, Michigan State University, The College of Menominee Nation, and the University of Wisconsin. GLISA works at the boundary between climate science and decision-makers, striving to enhance Great Lakes communities' capacity to understand, plan for, and respond to climate impacts now and in the future.

Learn more: glisa.umich.edu

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