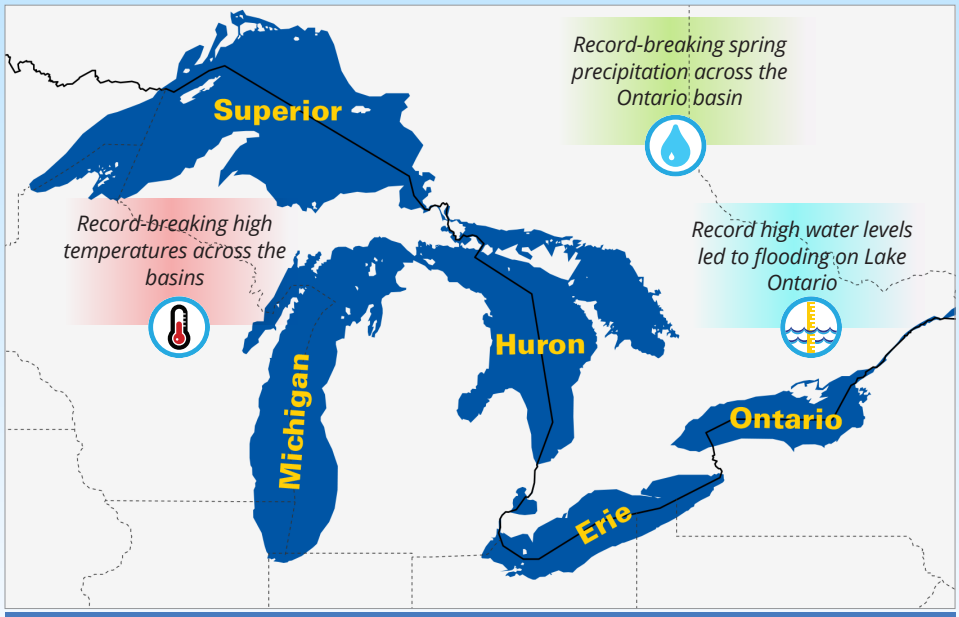
2017 ANNUAL CLIMATE TRENDS AND IMPACTS SUMMARY FOR THE GREAT LAKES BASIN

During the 2017 reporting period, several notable events and trends were observed across the Great Lakes basin including higher than average seasonal temperature and precipitation, flooding, and low ice cover. The majority of the region experienced a wet spring with persistent heavy rain and snowfall. Water levels in the five Great Lakes were above average, continuing a similar trend during the past several years. Due primarily to high spring rainfall, Lake Ontario reached its highest ever recorded water level in May 2017 resulting in shoreline flooding in New York and Ontario. Winter and fall warm spells led to record warm temperatures in parts of the basin. At just 15% areal coverage, Great Lakes maximum ice cover for the year was 40% below the long-term average.



2017 Highlights: Record Breaking Year

High Precipitation

The entire basin experienced a wet winter and spring with portions of Ontario experiencing more than twice the normal amount of precipitation in April and May. Fall was wet in the central Great Lakes, with Michigan experiencing record October rainfall.

High Water Levels

Heavy winter and spring precipitation led to a record rise in Lake Ontario water levels from January to June. This caused major flooding on the shoreline of Lake Ontario and the St. Lawrence River in May 2017. The floods caused property damage, road and park closures, shoreline erosion, and untreated sewage dispersal.

High Temperatures

The winter of 2017 saw record-breaking warmth across the basin, with winter average temperatures 1 to 5°C above the long-term average. Fall warm spells in September and October also set temperature records in some eastern areas of the region.

Photo: *Greece, NY. Coastal Flooding Survey Project, Cornell University and New York Sea Grant*

Photo: *Kingston, ON. Environment and Climate Change Canada (ECCC), Wendy Leger*

2017 ANNUAL CLIMATE TRENDS AND IMPACTS SUMMARY FOR THE GREAT LAKES BASIN

Climate Overview: December 2016 - November 2017

The December 2016 – November 2017 reporting period was overall warmer and wetter than normal, though there was substantial spatial and temporal variation across the region *(Figure 1)*. Mean annual temperatures were -1 to +2 °C below/above average across the region, with the largest departures from average temperature during the winter months. Precipitation was significantly greater than normal (10 to 50%), as seen by the green areas on the map, with some areas of the region setting new monthly and annual precipitation records. Given milder than normal temperatures during the cold season months, snow accumulations and snow cover duration were less than normal. Air temperatures over land in the basin were milder than normal, as were water temperatures.

Given heavy precipitation during much of the reporting period, basin-wide precipitation, runoff, and evaporation totals were also greater than normal. These numbers are generally consistent with observed long-term trends. Over the period from 1981-2010 across the region, air temperature (+0.26°C/decade), precipitation (+23.4mm/decade), evaporation (+19.9mm/decade), and water temperatures (+0.53°C/decade) have all increased. Runoff (-16.8mm/decade) has declined over the same time period. Highlights and links to additional data are given in the sections below.

**This report utilizes climatological seasons, which includes December from the previous year as part of the winter season.*

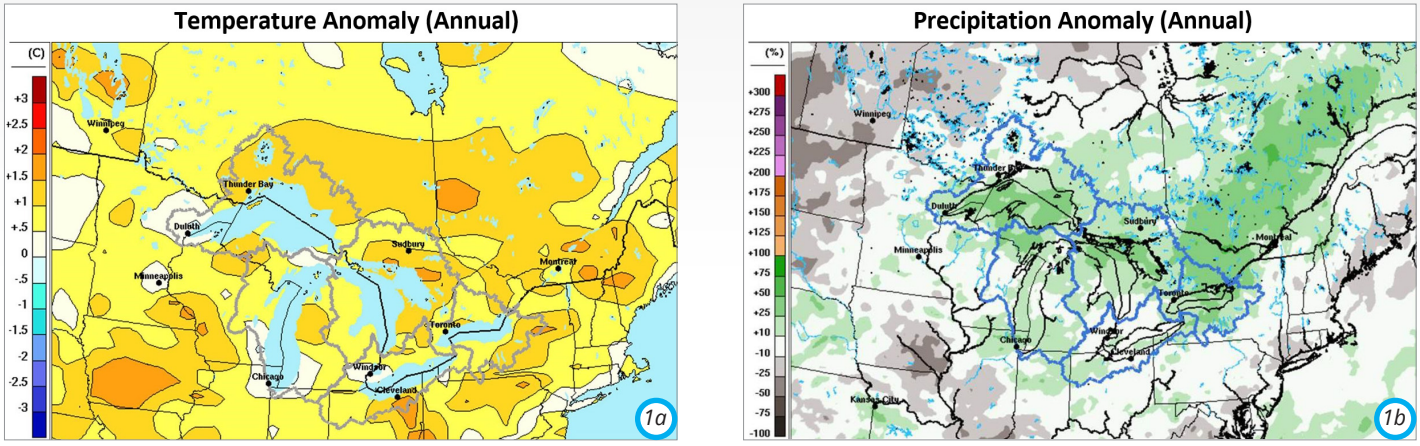


Figure 1. Maps displaying annual anomalies for temperature (1a) and total precipitation accumulation (1b) in the Great Lakes region. Anomalies for temperature are departures from the 1981-2010 mean. Anomalies for precipitation are % departure from the 2002-2016 mean. Data for temperature are from ECCC model output and precipitation data is a merged dataset containing ECCC model and Numerical Weather Prediction (NWP) model data. Figures created by ECCC.

		Superior		Michigan		Huron		Erie		Ontario	
		2017	LTA	2017	LTA	2017	LTA	2017	LTA	2017	LTA
Water Temps (C°)	Max	16.4	16.0	21.5	21.3	21.1	19.9	24.0	23.9	23.2	22.2
	Min	1.3	1.0	2.4	1.5	1.1	0.9	0.7	1.1	2.7	1.8
	Avg	7.0	6.4	10.5	9.5	9.7	8.8	12.0	11.4	11.2	10.1
Ice Cover (%)	Max	18.7	48.6	18.2	28.8	35.4	51.7	35.5	70.1	6.8	20.5

		Superior		Michigan-Huron*		Erie		Ontario	
		2017	LTA	2017	LTA	2017	LTA	2017	LTA
Water Levels (meters)	Max	183.8	183.5	177.0	176.6	174.8	174.3	75.8	75.0
	Min	183.4	183.2	176.5	176.3	174.2	174.0	74.5	74.5
	Avg	183.6	183.4	176.7	176.4	174.6	174.1	75.1	74.8
Precipitation (mm)	Ann Sum	1032.8	711.6	883.6	794.4	963.0	842.4	1258.9	859.2
Evaporation (mm)	Ann Sum	764.8	556.8	843.9	504.0	972.5	896.4	745.0	650.4

Table 1: *Summary of hydro-climate variables by lake. **Long Term Average (LTA)** changes depending on variable: **Water Temps (°C)** - 2017: December 2016 through November 2017, LTA: 1992-2016; **Ice Cover (%)** – 2017: December 2016 through April 2017, LTA: 1973-2016; **Water Levels (meters)** - 2017: December 2016 through November 2017, LTA: Period of Record (1918-2016); **Precipitation (mm)** - 2017: December 2016 through November 2017, LTA: 1981-2010; **Evaporation (mm)** - 2017: December 2016 through November 2017, LTA: 1981-2010*

**Lakes Michigan and Huron are treated as one unit for water-levels, precipitation, and evaporation since there is no physical separation between the two lake bodies.*

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2017 ANNUAL CLIMATE TRENDS AND IMPACTS SUMMARY FOR THE GREAT LAKES BASIN

Temperature Highlights: Very warm both in February and September

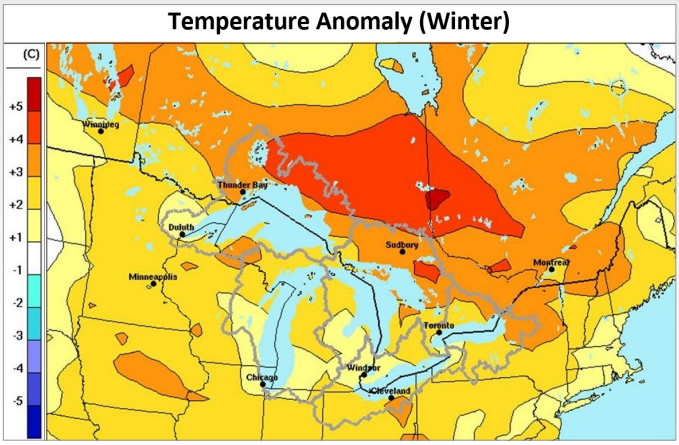

Figure 2. Temperature anomalies (vs. 1981-2010 mean) for winter (December, January, February) 2016-2017. Figure created by ECCC.

Winter temperatures averaged 1 to 5°C above normal *(Figure 2)*, with a below to near average December and very warm January and February. September and October were much above average, with record warmth in some eastern areas of the region.

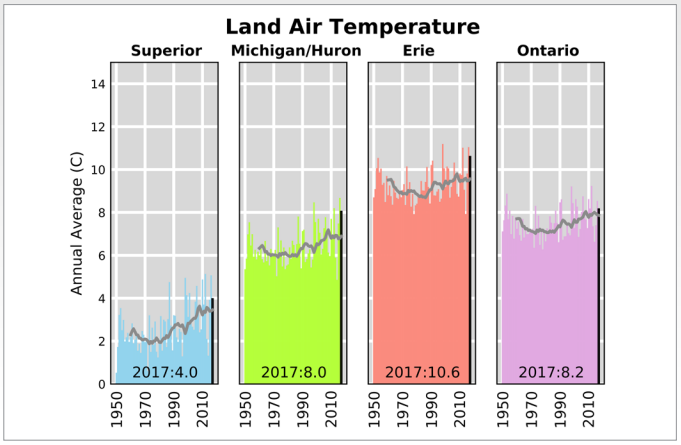

Figure 3. Time series of over-land air temperatures by lake basin 1950-2017. The gray line is a 10 year moving average and the black line is the 2017 average.

Annual air temperatures over land from December 2016 – November 2017 were above the historical long-term mean *(Figure 3)* and are consistent with the observed long-term increasing trend of air temperature, particularly in northern areas.

Hydrologic Highlights: Record Lake Levels on Ontario and Warm Water Temperatures

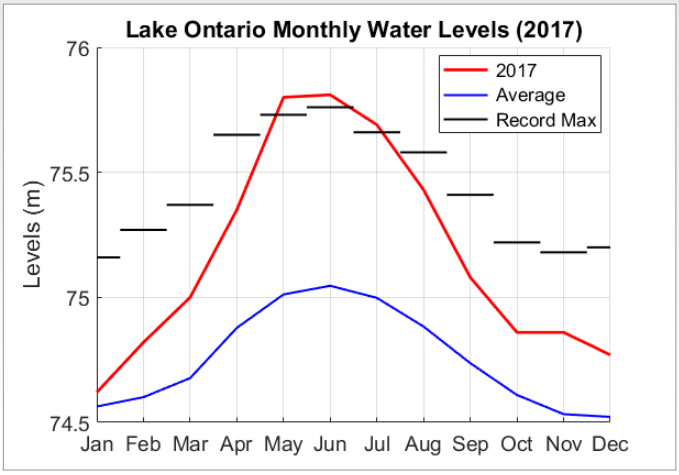

Figure 4. 2017, historical average, and record lake levels for Lake Ontario. Average levels based on 1918-2016 mean.

In 2017, water levels on all 5 of the Great Lakes were higher than the long-term average. Record high water levels were observed on Lake Ontario in May, June, and July *(Figure 4)*.

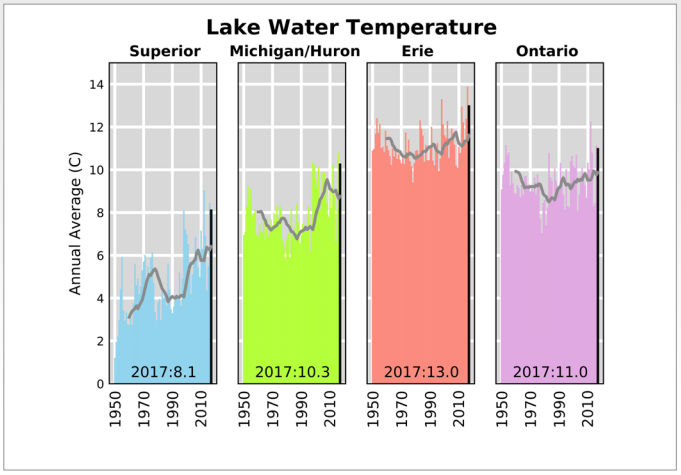

Figure 5. Time series of water temperatures by lake basin 1950-2017. The grey line is a 10 year moving average and the black line is the 2017 average.

Water temperatures on all of the Great Lakes were above average in 2017 and continuing an upward trend in surface water temperatures *(Figure 5)*, that has been particularly notable on the upper Great Lakes.

2017 ANNUAL CLIMATE TRENDS AND IMPACTS SUMMARY FOR THE GREAT LAKES BASIN

Precipitation Highlights: Wet Spring and Variable Summer Across the Basin

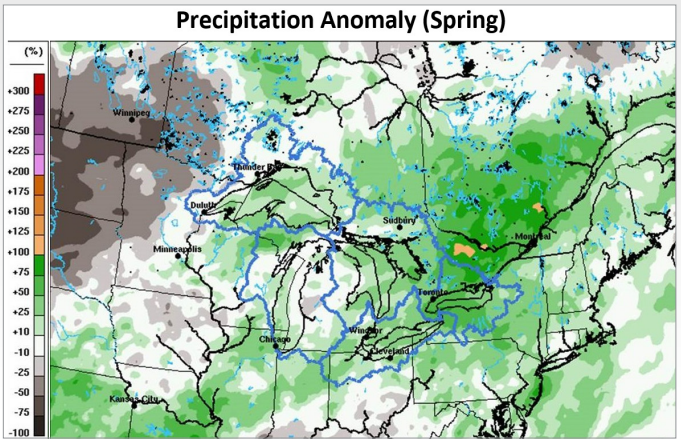

Figure 6. Spring 2017 (March, April, May) precipitation anomalies (% departure 2002-2016 mean). Figure created by ECCC.

In spring, much of the region experienced above average precipitation both over lake and over land, as seen by the green areas of the map *(Figure 6)*. Some areas in eastern Ontario and western Quebec saw more than twice the normal amount for this period, as seen by the gold areas on the map. Summer and fall precipitation was more varied across the region.

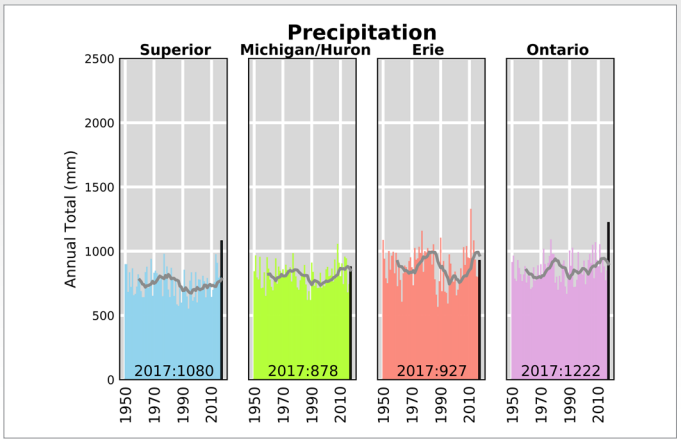

Figure 7. Time series of precipitation by lake basin 1950-2017. The grey line is a 10 year moving average and the black line is the 2017 average.

Annual precipitation accumulation for 2017 was above average (10% to 50%) for the region and continued a general upward trend observed in recent years *(Figure 7)*, though substantial inter-annual variability is common.

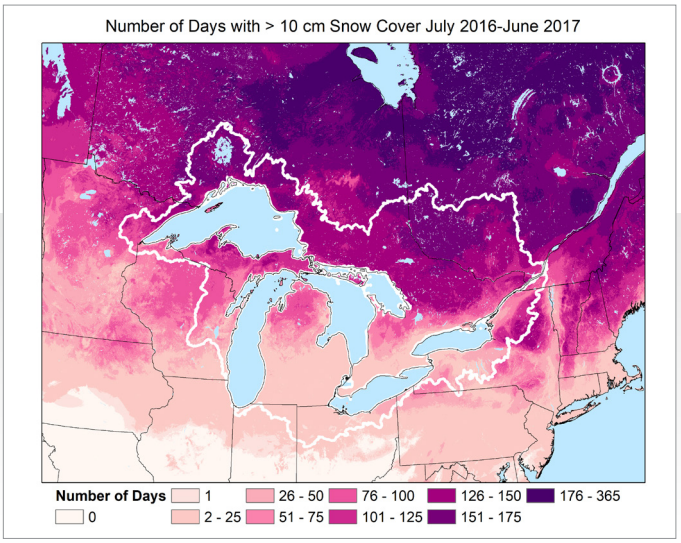

Figure 8. Days with > 10 cm snow cover July 2016-June 2017. Estimated from the National Oceanic and Atmospheric Administration's National Operational Hydrologic Remote Sensing Center (NOAA NOHRSC) model output.

Days with more than 10 cm of snow depth across the region ranged from 1 day in the extreme southern areas of the basin to more than 150 days in the northern reaches *(Figure 8)*. 2016-2017 was below the 2012-2017 average for all basins except the St. Lawrence, which experienced 6 more days of snow cover than average. The Lake Michigan basin experienced the largest departure of 16 fewer days of snow cover than average.

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2017 ANNUAL CLIMATE TRENDS AND IMPACTS SUMMARY FOR THE GREAT LAKES BASIN

Major Climatic Events

Winter 2016-2017

- Entire Great Lakes basin experienced near-record to record-breaking warmth in January and February.
- Great Lakes only reached a maximum ice cover of 15% compared to the long-term average of 55%.
- Reduced ice cover forced existing ice near shores to erode coastlines in areas such as Erie, Pennsylvania.

Spring 2017

- Record-breaking or near-record precipitation during the spring caused significant flooding.
- Water levels on Lake Ontario experienced a record rise in spring, with May seeing the highest water levels recorded since records began in 1918.
- Widespread flooding and erosion occurred across New York, Ontario, and downstream in Quebec. Severe flooding closed Toronto Island Park from May 4th to July 30th.
- Freezing temperatures May 7-10 caused damage to vulnerable vegetation.

Photo: Toronto Island Park. ©Toronto and Region Conservation (TRCA)

Summer 2017

- Lake Ontario set new record-high monthly average water levels in June and July.
- High water levels and heavy precipitation resulted in several flash flood events across the basin.
- Flooding and cooler temperatures caused many issues for farmers.
- Western Lake Erie's harmful algal bloom was larger than average due to excessive spring and summer rain.
- In the western basin first freezes occurred more than a month before the median first freeze dates.

Photo: Ellisburg, NY. Coastal Flooding Survey Project, Cornell University and New York Sea Grant

Autumn 2017

- Late season heat wave impacted the basin in late September, with many areas getting above 35°C (95°F).
- Record precipitation in portions of the Great Lakes region during October.
- A rapid transition from above-normal to below-normal precipitation led to harvesting difficulties in November.
- Cold conditions in early November broke records in southern Ontario, Pennsylvania, and New York.
- Lake Ontario had the highest decline in water levels on record for the month of September due to a dry August and September.
- Near-record high monthly water levels for Lake Superior in October and November
- November saw the highest wave ever recorded on Lake Superior at 8.8m (28.8ft)

Photo: Hamlin, NY. Coastal Flooding Survey Project, Cornell University and New York Sea Grant

2017 ANNUAL CLIMATE TRENDS AND IMPACTS SUMMARY FOR THE GREAT LAKES BASIN

New Research, Applications, and Activities

This section highlights research findings from across the region from the previous year. Findings from these efforts have implications for a wide range of sectors across the region, improve the understanding of regional climate, and show promise for informing planning efforts and policy implementation in the Great Lakes.

Regional Modeling

- Production of statistically downscaled temperature and precipitation datasets for the region based on Climate Model Intercomparison Project Phase 5 (CMIP5) global simulations *(Byun and Hamlet 2017).*
- Development of an ensemble forecasting system driven by CMIP5 scenarios by the U.S. Army Corps of Engineers and NOAA Great Lakes Environmental Research Lab to meet the needs of power generation authorities.
- Examination of regional and global precipitation projections under high emissions scenarios found general increases, concentrated in heavy rain events in the spring *(Basile et al. 2017).*
- Wind speed changes may be as critical as air temperature changes when determining the impact of climate change on water temperatures and stratification *(Magee and Wu 2017).*
- Improved methodologies developed for linking dynamical models of the lakes and atmosphere *(Xue et al. 2017).*
- Results of dynamically downscaling future climate scenarios in the Great Lakes basin *(Wang et al. 2017).*

Natural Resources

- Review of previous research regarding responses of fish to climate change finding that if food supplies are adequate, fish growth rates will increase with warming *(Collingsworth et al. 2017).*
- Historically observed shift toward diatom types with smaller cell sizes may be due to warming water *(Bramburger et al. 2017).*
- Projected future climate trends lead to higher fire weather indices (i.e., greater risk of wildfires) in the Great Lakes region and northeastern U.S. *(Kerr et al. 2017).*
- Die-offs of water birds due to botulism occur episodically and are associated with warm water with low levels *(Princé et al. 2017).*
- Of migratory birds in the basin, eastern meadowlark and wood thrush are quite vulnerable to climate change, while the hooded warbler is less vulnerable *(Rempel and Hornseth 2017).*

Planning and Engagement

- The United States Fourth National Climate Assessment held a regional engagement workshop in March 2017 for the Midwest region to provide stakeholders an opportunity to give input to and exchange ideas with the chapter author teams *(USGCRP 2017).*
- Under the Canada-Ontario Agreement Respecting the Great Lakes, the Ontario Ministry of Environment and Climate Change supported the Great Lakes Climate Change Adaptation Project 2016-18, led by ICLEI Canada. The project targeted municipal learning on climate change adaptation for 28 Ontario municipalities throughout the watershed. *(ICLEI Canada)*
- Strategies for introducing climate adaptation schemes in areas where political resistance may arise, using the Great Lakes region as a case study *(Rasmussen et al. 2017).*
- Public poll to find differences among communities in their attitude toward the threat of climate change based on their location *(Feltman et al. 2017).*
- Evaluation of potential financial consequences of climate change for hydropower producers and how to reduce risk, primarily those doing their generation on the Niagara River *(Meyer et al. 2017).*

For additional figures, information, and sources visit:
glisa.umich.edu/resources/annual-climate-summary

About This Document

Coordinated by a partnership between climate services organizations in the U.S. and Canada, this product provides a synthesis report summarizing the previous years' climate trends, events, new research, assessments, and related activities in the Great Lakes Region. This product is a contribution to the U.S.-Canada Great Lakes Water Quality Agreement, through Annex 9 on Climate Change Impacts, and to the national climate assessment processes in the U.S. and Canada. It should be cited as: Environment and Climate Change Canada and the U.S. National Oceanic and Atmospheric Administration. 2017 Annual Climate Trends and Impacts Summary for the Great Lakes Basin. 2018. Available at binational.net.

Contributing Partners

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canada.ca/en/environment-climate-change

Great Lakes Environmental Research Laboratory
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Great Lakes Integrated Sciences and Assessments
glisa.umich.edu

Great Lakes Water Quality Agreement
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