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 positive seasonal temperature and precipitation anomalies, flooding, and low ice cover. Winter and fall warm spells led to record warm temperatures in parts of the basin, while 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. At just 15.3% areal coverage, Great Lakes maximum ice cover for the year was 40% below the long-term average.

Major Climatic Events

Winter 2016-2017

1. Reduced ice cover, forced existing ice near shores to erode coastlines near Erie, Pennsylvania.
2. The rise in water levels for Lake Ontario in February was the 3rd largest on record for this time of year.

- Entire Great Lakes basin experienced near-record to record-breaking warmth in February.
- Great Lakes only reached a maximum ice cover of 15% compared to the long-term average of 55%.

Spring 2017

3. At the end of May, the water level on Lake Ontario was the highest it's been since records began in 1918.
4. In order to mitigate flooding, untreated water was released into Lake Ontario, resulting in contamination.

- Record-breaking or near-record precipitation during the spring, causing significant flooding.
- Freezing temperatures from May 7-10 caused damage to vulnerable vegetation.

Summer 2017

5. Lake Ontario set new record-high monthly average water levels in June and July.
6. Watertown and Avon (New York) experienced their wettest summers on record.
7. Western Lake Erie harmful algal bloom was larger than average due to excessive spring and summer rain.
8. In the western basin first freezes occurred more than a month before the median first freeze dates.

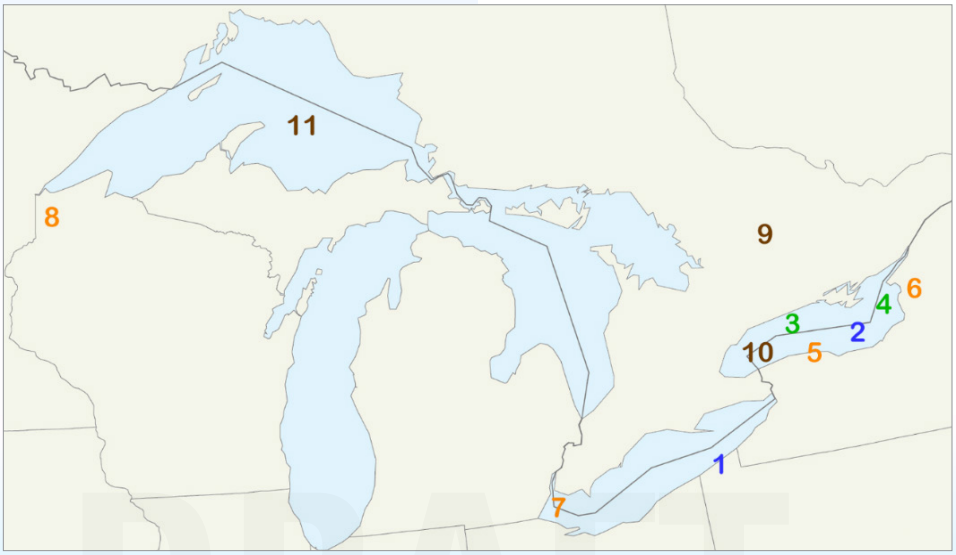
- High water levels and heavy precipitation resulted in several flash flood events across the basin.
- Flooding and cooler temperatures caused many issues for farmers.

Autumn 2017

9. Cold conditions in early November broke records in southern Ontario, Pennsylvania, and New York.
10. Lake Ontario had the highest decline in water levels on record for the month of September.
11. Near-record high monthly water levels for Lake Superior in October and November.

- A rapid transition from above-normal to below-normal precipitation led to harvesting difficulties.
- 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.

***Note:** Bullets refer to basin-wide events and numbers correspond to specific location (see map)*



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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 warmer across the region, with the largest departures during the winter months. Precipitation was significantly greater than normal (10 to 50 %), 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.

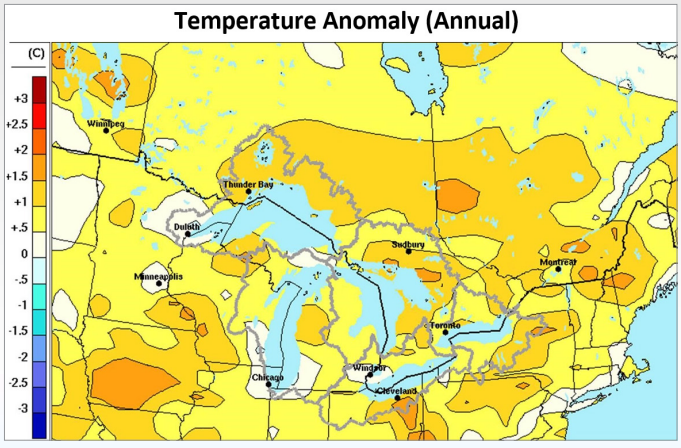
Given heavy precipitation during much of the reporting period, basin-wide precipitation, runoff, and evaporation totals were also greater than normal. These numbers are generally consistent with observed long-term trends. Long-term trends (units/decade) from 1981-2010 include: +0.26°C for air temperature, +23.4 mm for precipitation, +19.9 mm for evaporation, -16.8 mm for runoff, +0.53°C for water temperatures. Highlights and links to additional data are given in the sections below.

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

**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.*

		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 Sum	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



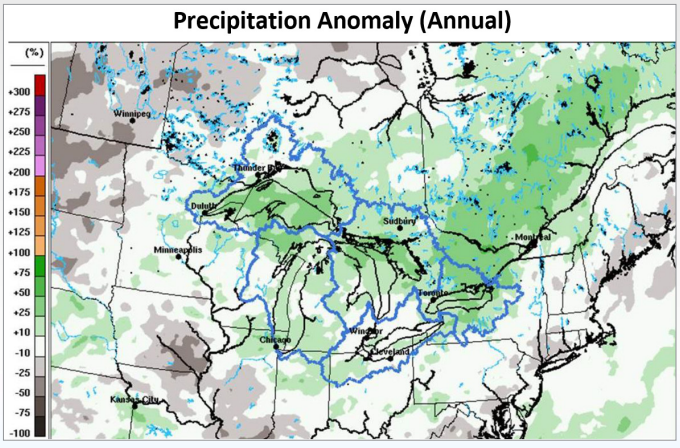


Figure 1. Maps displaying annual anomalies for temperature (1a) and total precipitation accumulation (1b) in the Great Lakes region. Anomalies for temperature are departures from the 1981-2010 mean. Anomalies for precipitation are % departure from the 2002-2016 mean. Data for temperature are from ECCC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

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Temperature Highlights: Very warm both in February and September

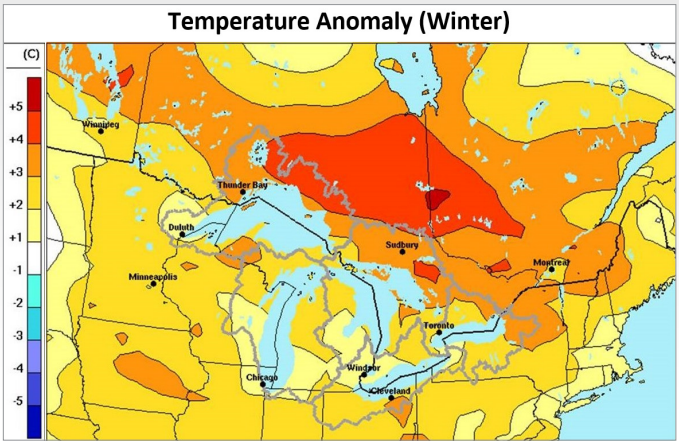

Figure 2. Temperature anomalies (vs. 1981-2010 mean) for winter (December, January, February) 2016-2017. Figure created by ECCC.

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.

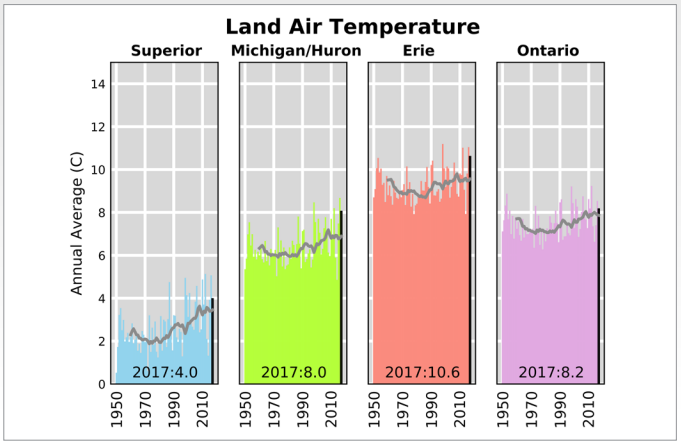

Figure 3. Time series of over-land air temperatures by lake basin 1950-2017. The gray line is a 10 year moving average and the black line is the 2017 average.

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

Hydrologic Highlights: Record Lake Levels on Ontario and Warm Temperatures

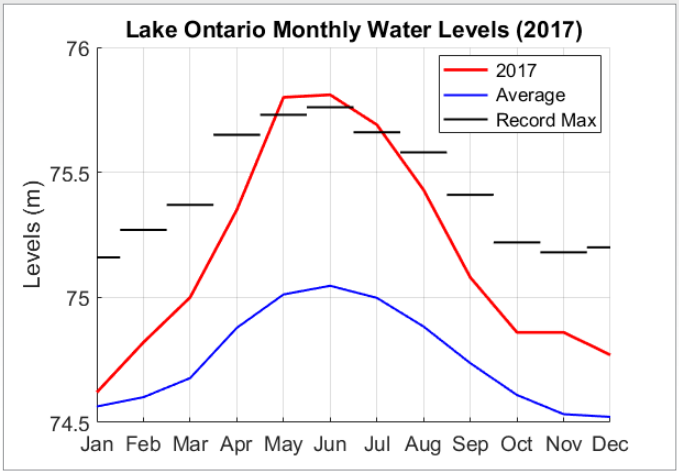

Figure 4. 2017, historical, and record lake levels for Lake Ontario. Average levels based on 1981-2016 mean.

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

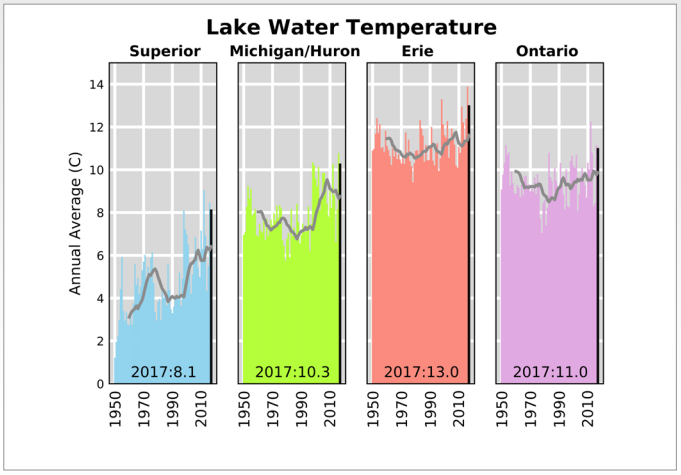

Figure 5. Time series of water temperatures by lake basin 1950-2017. The grey line is a 10 year moving average and the black line is the 2017 average.

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.

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Precipitation Highlights: Wet Spring and Variable Summer Across the Basin

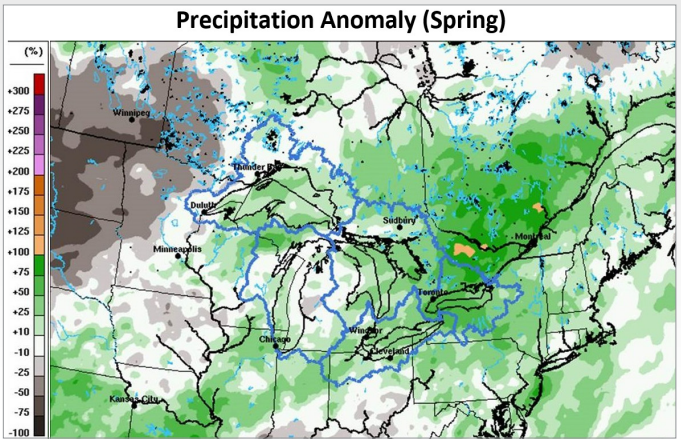

Figure 6. Spring 2017 (March, April, May) precipitation anomalies (% departure 2002-2016 mean). Figure created by ECCC.

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

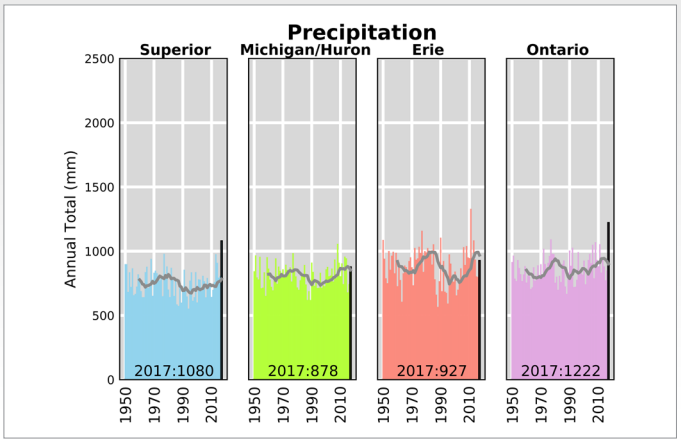

Figure 7. Time series of precipitation by lake basin 1950-2017. The grey line is a 10 year moving average and the black line is the 2017 average.

Annual 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.

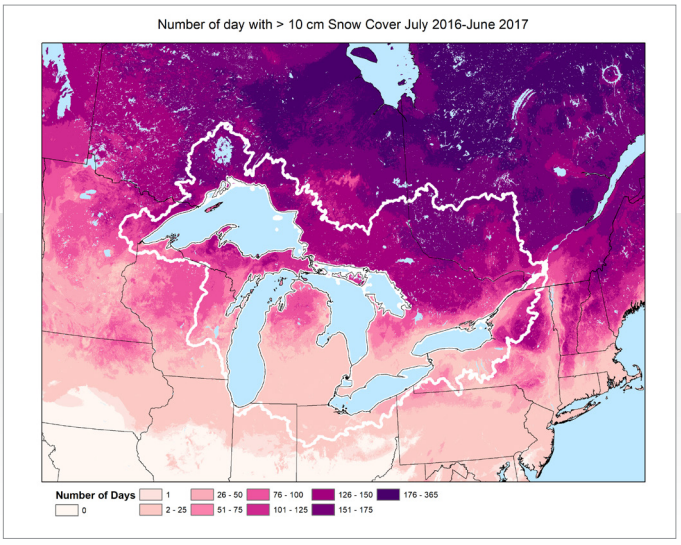

Figure 8. Days with > 10 cm snow cover July 2016-June 2017. Estimated from NOAA NOHRSC model output.

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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New Research, Applications, and Activities

Regional Modeling

- Examination of precipitation projections by regional and global climate models under high carbon dioxide concentration scenarios found general increases, particularly concentrated in heavy rain events during the spring *(Basile et al. 2017)*.
- Results of dynamically downscaling future climate scenarios in the Great Lakes basin *(Wang et al. 2017)*.
- Production of statistically downscaled temperature and precipitation datasets for the Midwestern US and Great Lakes region based on Climate Model Intercomparison Project Phase 5 (CMIP5) global simulations *(Byun and Hamlet 2017)*.
- Improved methodologies developed for linking dynamical models of the lakes and atmosphere *(Xue et al. 2017)*.

Natural Resources

- Trade-off identified between future soil moisture conditions and human-generated nitrogen deposition in the soil with regard to sugar maples in Michigan *(Ibáñez et al. 2018)*.
- Review of previous research regarding responses of fish to climate change. One finding is that, if food supplies are adequate, fish growth rates will increase with warming, but the question of whether food supplies will be adequate remains unanswered *(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 US *(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)*.
- Evaluation of climate risks for three species of migratory birds that frequent the Great Lakes basin found that the eastern meadowlark and wood thrush are quite vulnerable, while the hooded warbler is less vulnerable *(Rempel and Hornseth 2017)*.

Planning and Engagement

- The Detroit Climate Action Plan, the City's first, was released in October 2017 by the Detroit Climate Action Collaborative. The Collaborative is an initiative of Detroiters Working for Environmental Justice, composed of 27 partner organizations working together to improve public health and address environmental justice issues.
- The United States Fourth National Climate Assessment is currently in development and held a regional engagement workshop on March 1, 2017 for the Midwest region to ensure the assessment is informed by and useful to stakeholders. The hub meeting in Chicago and nine satellite meetings across the region provided stakeholders an opportunity to provide input to and exchange ideas with the chapter author teams.
- 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, primarily those doing their generation on the Niagara River, and examined ways of reducing risk *(Meyer et al. 2017)*.

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

Environment and Climate Change Canada
canada.ca/en/environment-climate-change

Great Lakes Environmental Research Laboratory
glerl.noaa.gov

Great Lakes Integrated Sciences and Assessments
glisa.umich.edu

Great Lakes Water Quality Agreement
binational.net

Midwestern Regional Climate Center
mrcc.isws.illinois.edu

National Oceanic and Atmospheric Administration
noaa.gov

Contact Information

Contact for NOAA:

Meredith Muth
meredith.f.muth@noaa.gov

Contact for ECCC:
ec.enviroinfo.ec@canada.ca