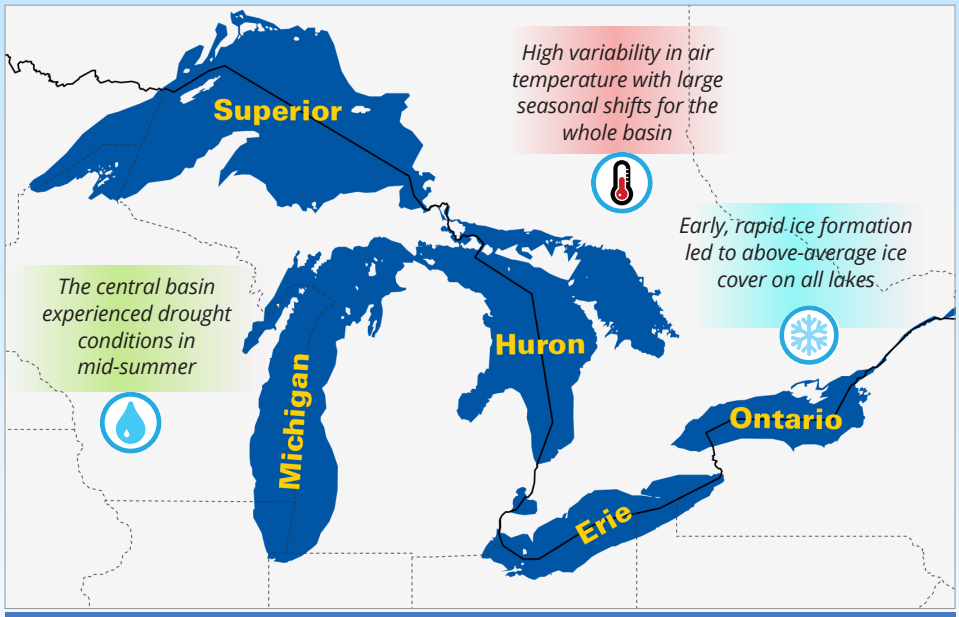
2018 ANNUAL CLIMATE TRENDS AND IMPACTS SUMMARY FOR THE GREAT LAKES BASIN

During the 2018 reporting period, several notable events and trends were observed across the Great Lakes basin, including rapid shifts in both temperature and precipitation. Some areas saw record-breaking cold and record-breaking warmth within a matter of weeks. The basin also experienced localized flooding, drought, and high ice cover. Water levels in the five Great Lakes continued to be above average, following the trend observed during the past several years. There was an early onset of ice cover due to extreme cold conditions in late December 2017 and early January 2018. At 69% areal coverage, Great Lakes maximum ice cover for the year was 14% above the long-term average.



*Arrows indicate how 2018 average values compare to long-term average:

Above Below Variable

Air Temperature	Basin Precipitation	Water Temperature	Ice Cover	Water Levels
↕	↕	↕	↑	↑

2018 Highlights: Variability and Extremes

Temperatures

Large swings in temperature characterized much of the Great Lakes Basin in 2018. Record or near-record breaking cold conditions were observed in many locations in early winter (December/January) that caused early, rapid ice formation on the lakes. By February, temperatures had climbed to above average. In the spring, there was a rapid shift from very cold to very warm conditions, with some areas seeing their coldest April on record followed by their warmest May. Fall also saw a rapid temperature swing, with above-average conditions falling to below-average conditions in a matter of weeks during the month of October.

Photo: Great Lakes ice cover in February, 2018 (NASA Visible Earth)

Precipitation

In 2018, periods of drought conditions, in addition to record-breaking annual precipitation, occurred in multiple parts of the basin. Dry conditions began to develop in early summer and intensify through July. Despite drought conditions during part of the summer, many stations, particularly along and west of Lake Michigan, experienced their wettest years on record. Flooding occurred in different parts of the basin throughout the year due to periodic heavy rainfall.

Photo: Flood damage in Houghton, MI (Credit: David Archambeau)

Environment and Climate Change Canada
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2018 ANNUAL CLIMATE TRENDS AND IMPACTS SUMMARY FOR THE GREAT LAKES BASIN

Climate Overview: December 2017 - November 2018

The December 2017 – November 2018 period was characterized by high variability in temperature and precipitation. Much of this variability balanced out in the annual averages for the region, resulting in near-average annual anomalies (Figure 1a). Mean annual temperatures were near average to slightly below average by -0.5 to -1.5 °C across the region. Annual precipitation totals were above average (10 to 50%) in some southern areas of the basin, with the rest of the basin remaining near-average (Figure 1b). Parts of the Great Lakes region experienced record-breaking precipitation and drought, as well as both record-high and record-low monthly temperatures. After cold and snowy conditions in late December and early January subsided, the majority of the region experienced snowfall deficits for the winter. Annual water temperatures for all of the Great Lakes (except Superior) were near or above their long-term averages. Annual evaporation totals were also above normal for the basin in 2018.

The observed values for all variables considered (Table 1) are generally consistent with 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. 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.*

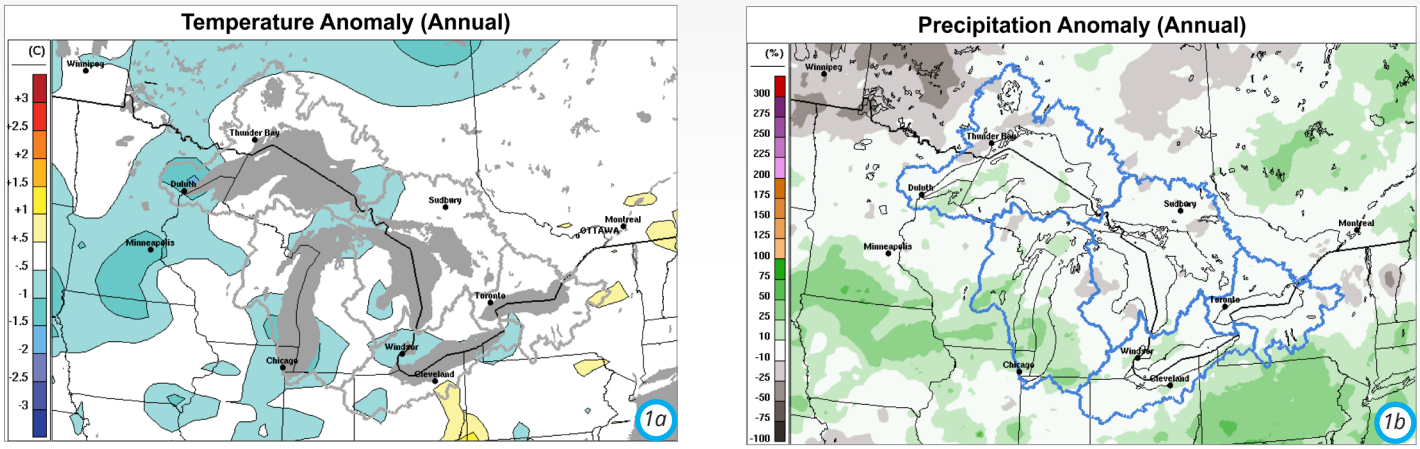

Figure 1. Maps displaying annual anomalies for temperature (1a) and total precipitation accumulation (1b) in the Great Lakes region. Anomalies for temperature are departures from the 1981-2010 mean. Anomalies for precipitation are % departure from the 2002-2017 mean. Gray/blue outlines depict the individual lake basins. Data for temperature are from ECCC model output and precipitation is a merged dataset containing ECCC model and Numerical Weather Prediction (NWP) model data. Figures created by ECCC.

		Superior		Michigan		Huron		Erie		Ontario	
		2018	LTA	2018	LTA	2018	LTA	2018	LTA	2018	LTA
Water Temps (°C)	Max	16.98	17.65	22.66	22.52	22.69	21.32	25.64	24.94	24.39	23.43
	Min	0.23	0.62	1.11	1.24	0.38	0.60	0.20	0.33	1.71	1.25
	Avg	5.84	6.57	9.92	9.70	8.80	8.88	11.59	11.35	10.62	10.27
Ice Cover (%)	Max	77.2	60.5	51.3	39.4	81.4	64.2	95.1	81.9	25.7	29.9

**LTA: Long Term Average*

		Superior		Michigan-Huron		Erie		Ontario	
		2018	LTA	2018	LTA	2018	LTA	2018	LTA
Water Levels (meters)	Max	183.77	183.57	176.98	176.59	174.89	174.37	75.26	75.09
	Min	183.47	183.22	176.73	176.22	174.38	173.88	74.62	74.41
	Avg	183.63	183.40	176.86	176.42	174.65	174.15	74.91	74.76
Precipitation (mm)	Ann Sum	910.5	711.6	805.3	794.4	872.6	842.4	1097.1	859.2
Evaporation (mm)	Ann Sum	704.4	556.8	701.5	504.0	949.5	896.4	746.4	650.4

Table 1: Summary of hydro-climate variables by lake. Long Term Average (LTA) changes depending on variable: Water Temps (°C) - 2018: December 2017 through November 2018, LTA: 1992-2017; Ice Cover (%) – 2018: December 2017 through May 2018, LTA: 1973-2017; Water Levels (meters) - 2018: December 2017 through November 2018, LTA: Period of Record (1918-2017); Precipitation (mm) - 2018: December 2017 through November 2018, LTA: 1981-2010; Evaporation (mm) - 2018: December 2017 through November 2018, LTA: 1981-2010. Estimated from NOAA Great Lakes Surface Environmental Analysis (water temps), NOAA GLERL CoastWatch (ice cover), NOAA GLERL Great Lakes Dashboard (lake levels), NOAA GLERL Great Lakes Hydrologic Data (precipitation and evaporation).

**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.*

**LTAs here are not comparable to those in the 2017 summary report, because a different averaging method was used to calculate LTAs in this 2018 version.*

2018 ANNUAL CLIMATE TRENDS AND IMPACTS SUMMARY FOR THE GREAT LAKES BASIN

Historical Trends

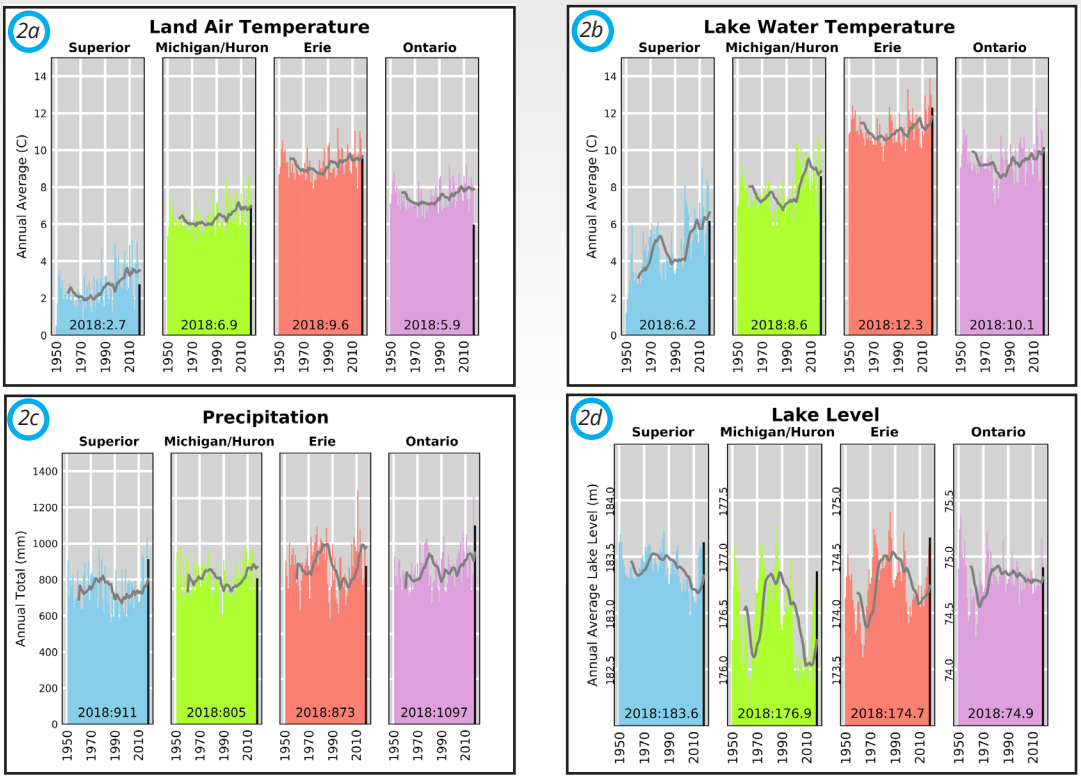

Figure 2. Time series of air temperatures (2a), water temperatures (2b), precipitation (2c), and water levels (2d) by lake basin from 1950-2018. The grey line is a 10-year moving average and the black line is the 2018 average. Estimated from GLERL Great Lakes Monthly Hydrologic Data, and Coordinating Committee on Great Lakes Basin Hydraulic and Hydrologic Data.

Air (Figure 2a) and water temperatures (Figure 2b) were near the 10-year average in 2018. There has been an upward trend in both air and water temperatures in recent years that is particularly notable in the upper Great Lakes and their basins. Annual precipitation accumulation (Figure 2c) in 2018 was above the 10-year average for the Superior and Ontario basins and near the 10-year average for the Michigan/Huron and Erie basins. This follows a general upward trend observed in recent years, though substantial inter-annual variability is common. Water levels remained above the 10-year average on all of the Great Lakes in 2018 (Figure 2d). Lake levels have risen since 2014 after a period of low lake levels lasting from the 1990s to the mid-2000s.

Temperature Highlights: Extremes and Variability Throughout the Seasons

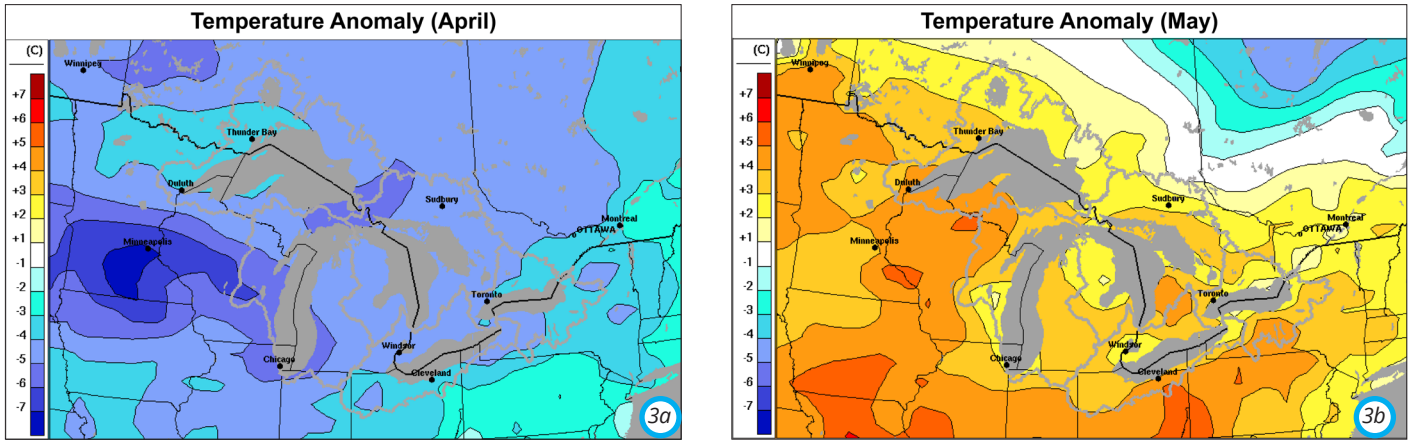

Figure 3. Temperature anomalies (vs. 1981-2010 mean) for April (3a) and May (3b). Gray outline depicts the individual lake basins Figures created by ECCC.

The spring of 2018 saw a large, rapid swing from cold to warm temperatures between April (Figure 3a) and May (Figure 3b) throughout much of the basin. Some areas experienced their coldest April and warmest May on record during this time (e.g., Waterloo, ON). Though cold conditions in April delayed crop seeding and emergence, the 2018 growing season became one of the warmest on record after this temperature shift. Prior to spring, record low temperatures also occurred in late December and early January, followed by unseasonably warm conditions in February. Fall of 2018 saw a similar, but opposite, swing from warm to cold temperature that happened very rapidly and led to an early start to the winter season in November across the basin.

Precipitation Highlights: Drought and Record Highs

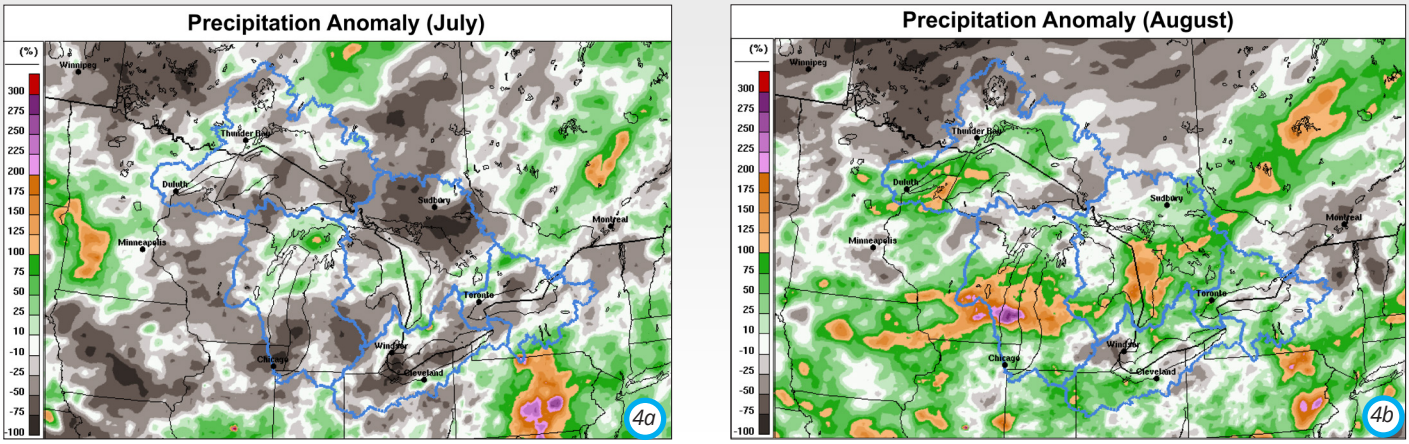

Figure 4. Precipitation anomalies (% departure from 2002-2017 mean) for July (4a) and August (4b). Blue outline depicts the individual lake basins. Figures created by ECCC.

Drought conditions developed rapidly in parts of the basin during the summer, as seen by negative July precipitaiton anomalies (Figure 4a). Despite the drought, some stations along Lake Michigan set records for high annual precipitation, in part due to significantly wetter conditions that developed in August (Figure 4b). Several areas experienced flooding as a result of heavy rainfall throughout the year, including the central basin (Indiana, Illinois, Michigan) in February, Houghton, MI in June, Toronto, ON in August, and Duluth, MN in October.

Snow and Ice

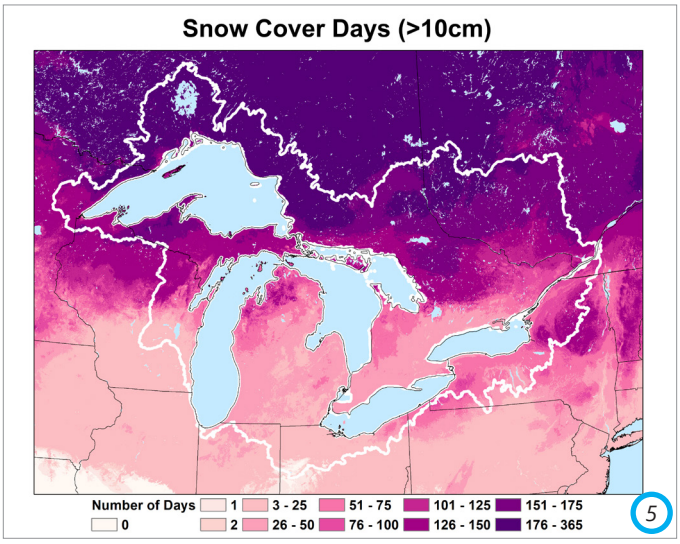

Figure 5. Days with > 10 cm snow cover July 2017-June 2018. White outline depicts the Great Lakes-Ottawa River basin. Estimated from the NOAA National Operational Hydrologic Remote Sensing Center (NOAA NOHRSC) model output.

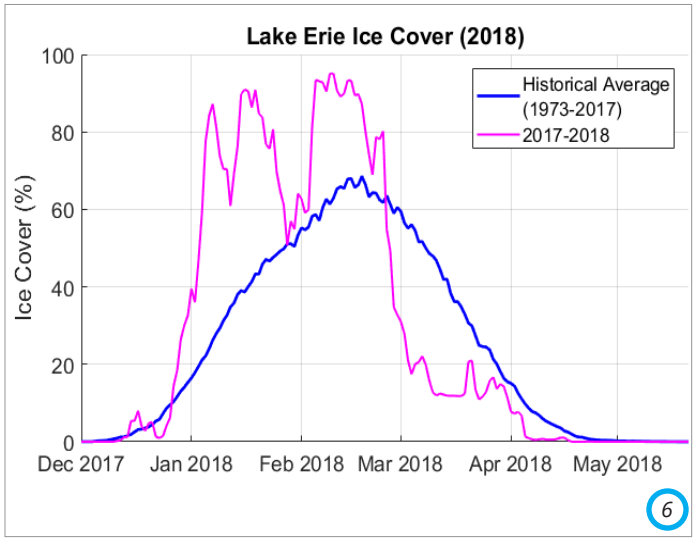

Figure 6. Daily 2018 and historical average ice cover concentrations for Lake Erie. Estimated from NOAA GLERL Great Lakes CoastWatch.

Days with substantial snow cover (> 10 cm) across the region ranged from 1 day in the extreme southern portions of the basin to more than 175 days in the northern reaches of the basin (Figure 5). Much of the region saw more days with snow depth during the period from July 2017-June 2018 when compared to July 2016-June 2017, especially the areas around Lake Superior. Exceptions to this occurred in portions of the north-central lower peninsula of Michigan, eastern Wisconsin, and south-eastern Ontario, which experienced fewer days with substantial snow cover over the same period.

Due to extreme cold temperatures, Great Lakes ice cover grew rapidly in the month of December, causing issues for the shipping industry. Basin-wide ice cover had 2 peaks during the 2017-2018 ice season, one in mid-January and one in mid-February, seen most prominently in Lake Erie (Figure 6). All of the lakes saw near- or above-average ice concentrations in January. Despite a declining ice cover trend over the past several decades, there remains strong year-to-year variability, with the possibility of individual years still experiencing high ice cover.

2018 ANNUAL CLIMATE TRENDS AND IMPACTS SUMMARY FOR THE GREAT LAKES BASIN

Major Climatic Events

Winter 2017-2018

Rapid ice formation in late December, due to below-normal temperatures and strong winds, impacted the coastline of rivers and lakes across the Great Lakes basin. This caused a sudden slow-down in shipping capabilities throughout the basin and additional ice breakers had to be utilized to open shipping lanes.

Strong winds and cold conditions forced large amounts of ice from Lake Erie onshore in late December, resulting in the formation of ice shoves that caused coastal damage.

By January 1st, the Great Lakes were already 20% covered in ice (compared to 2% the previous winter).

In late February, continuous, heavy rainfall caused widespread flooding across the southern and central basin, forcing counties to declare a state of emergency and call for evacuations.

Unseasonably warm temperatures in late February broke records for many locations across the basin.

Photo: Ice shove on Lake Erie (©The Blade, Jeremy Wadsworth)

Spring 2018

Four nor'easters in a three-week period in March brought above average snowfall to much of the eastern basin.

In mid-April, a rapid drop in air temperature led to the formation of new ice in Lake Superior.

Anomalously cold conditions in March and April delayed the seeding and emergence of many crops, while above-normal temperatures in May made up for the delayed start.

Summer 2018

Agriculture around the Great Lakes experienced quick development during the early summer months as a result of above-normal temperatures.

Dry conditions began to develop and intensify through mid-to-late summer, primarily in eastern portions of the basin, resulting in increased stress on crops and livestock.

Heavy rain up to 18cm (7in) over a few hours led to severe flooding and road damage across the Keweenaw Peninsula of Northern Michigan. Areas of Northwest Wisconsin received up to 38cm (15in) of rainfall from this same storm system.

Photo: Michigan corn showing drought stress in July 2018. (Jeff Krohn/ Northern Thumb Crop Consulting)

Sediment runoff from this severe storm (previous bullet) contributed to a rare algal bloom on Lake Superior in August.

At the end of August, all of the Great Lakes had water levels above average for the time of year.

Autumn 2018

Excessive rainfall across the Lake Superior basin from October 8-11 caused water levels to rise during a time of year when levels typically decrease.

A strong October storm with high winds on Lake Superior caused coastal erosion, localized flooding, and damage to popular tourist spots that amounted to over $18.4 million in damages.

Crop harvest in the Great Lakes region was slow due to wet conditions in October and early-season snow in November that delayed the ability to harvest crops.

The Harmful Algal Bloom (HAB) that occurred on Lake Erie this year ended earlier than normal in the first week of October, and had a much weaker severity index than what was originally forecasted.

Cold conditions in late November led to an early start to the winter season across the basin.

Photo: October 10th Lake Superior Storm (Derek Montgomery/ derekmontgomery.com)

**See 'Quarterly Climate Impacts and Outlook' for the Great Lakes Region on binational.net for more details.*

2018 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 & Natural Resources

- Shoreline flooding on Lake Ontario occurs during the summer due to the natural seasonal cycle and can be preconditioned by already high lake levels and La Niña conditions during the preceding cold season (Carter and Steinschneider 2018).
- An overall vision is proposed for modeling and research on the lake-land-atmosphere system of the Great Lakes region, along with impacts on natural and human systems in the region (Sharma et al. 2018).
- Dynamically downscaled regional climate models show that interactions between large-scale horizontal fluxes of water vapor and more localized processes determine regional precipitation responses to climate change (Peltier et al. 2018).
- A strong sensitivity for wind speed was found in formulas tested for calculating exchange of heat between the lake and the atmosphere (Charusombat et al. 2018).
- Heat waves are shown to cluster in the eastern Great Lakes, and the frequency of these heat waves is more sensitive to climate change than other clusters in the Great Plains (Lopez et al. 2018).
- The flow of nitrogen and phosphorus nutrients from land (especially agricultural land) into the Great Lakes is expected to increase due to increased overall precipitation and extreme storms (Wang et al. 2018).

Adaptation & Resilience

- The 2018 Fourth U.S. National Climate Assessment Midwest Chapter notably incorporates new key messages on ecosystem benefits and community vulnerability (Angel et al. 2018).
- The NOAA U.S. Climate Resilience Toolkit has a new Great Lakes web portal with region-specific information about resilience tools and case studies (toolkit.climate.gov).
- A binational literature review of 22 recent climate change vulnerability assessments (VA) in the basin, outlines methods, best practices, and limitations in conducting a VA (Pereaux et al. 2018).
- A Collaborative Strategy for the Great Lakes and St. Lawrence (GLSL) River was launched in 2018 to provide recommendations on new and innovative ways to approach GLSL protection (westbrookpa.com/glslcollab).
- The 2018 update to the Cleveland Climate Action Plan focuses on improving outcomes in health, access to green jobs, climate resiliency, and equity (sustainablecleveland.org/climate_action).
- Identification of climate science knowledge gaps from engagement with Great Lakes Water Quality Agreement Annex leads (Milner et al. 2018).
- The City of Toronto developed a resilient food system plan to provide residents adequate and equitable access to food within walking distance after extreme weather events (Zeuli et al. 2018).
- Community members of the Chequamegon Bay Region collaborated with experts to identify vulnerabilities to climate change and existing adaptive capacity practices (Kemkes et al. 2018).

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. 2018 Annual Climate Trends and Impacts Summary for the Great Lakes Basin. 2019. 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

Ontario Climate Consortium
climateconnections.ca

Contact Information

Contact for NOAA:

glisa-info@umich.edu

Contact for ECCC:

ec.enviroinfo.ec@canada.ca

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

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