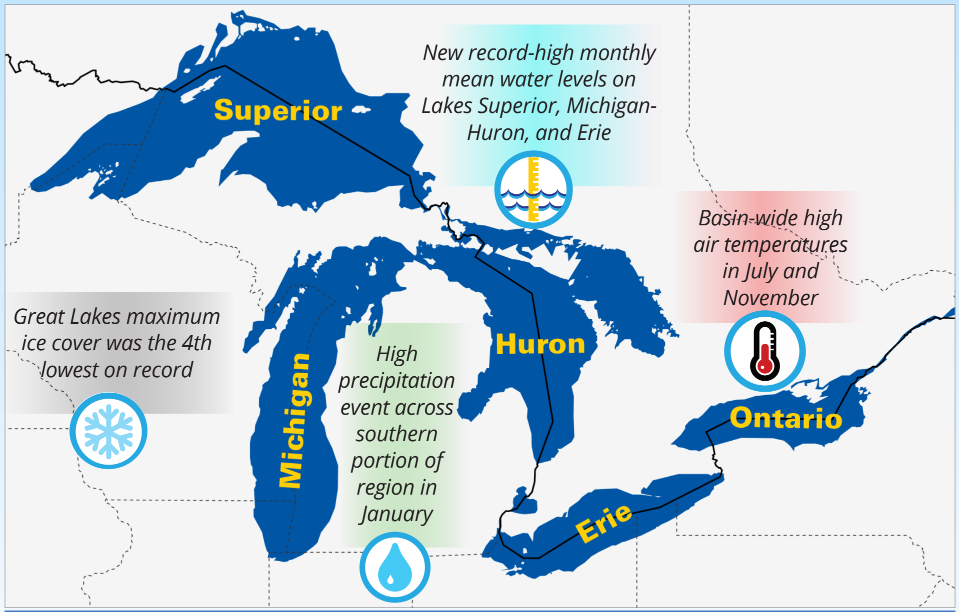
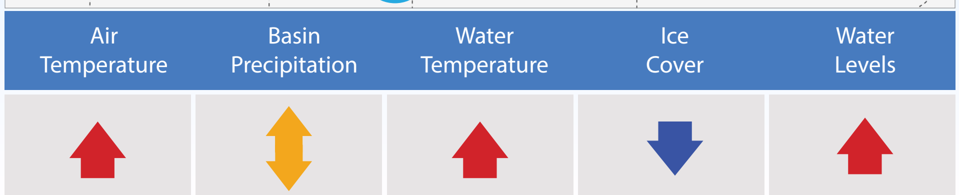
2020 ANNUAL CLIMATE TRENDS AND IMPACTS SUMMARY FOR THE GREAT LAKES BASIN

During the 2020 reporting period, several notable events and trends were observed across the Great Lakes basin, including periods of very high temperatures in summer and fall, and extreme rainfall events that led to flooding in the winter and spring. Water levels on the Great Lakes continued to be very high, with Lake Superior, Lake Michigan-Huron, and Lake Erie reaching new record-high monthly mean levels multiple times. Locations around the basin experienced coastal flooding and erosion due to high water levels and low ice cover. Despite near-average precipitation in 2020, multiple years of above-average precipitation in the basin have cumulatively contributed to high water level conditions on the Great Lakes in recent years. At 19.5% areal coverage, Great Lakes maximum ice cover in 2020 was the 4th lowest on record.



**Arrows indicate how 2020 average values compare to long-term average:*

Above *Below* *Variable*



2020 Highlights

High Water Levels

Although annual precipitation for much of the basin was generally near or below average in 2020, the past five years of above-average precipitation continue to have an impact on the Great Lakes water supply. Current high water conditions, including new monthly high records set on Lakes Superior, Michigan-Huron, and Erie, are largely inherited from the cumulative precipitation trends from the wettest 5-year period on record (2015-2019). During these years, water levels have been dominated more by precipitation patterns than by evaporation.

Low Ice Cover

In 2020, the Great Lakes reached a maximum ice cover of only 19.5% areal coverage, with very little ice formed in the middle parts of the lakes. This is the 4th lowest maximum on record, with a long-term average maximum of 54%. This can be partially attributed to above-average air and water temperatures in the basin.

Coastal Erosion

Erosion events in the Great Lakes were prominent in 2020. The lack of ice cover to protect coastal areas, along with high water conditions, particularly in winter months, contributed to these events. Many areas experienced accelerated coastal erosion and infrastructure damage due to strong storms that brought high winds and waves.

Photo: No auger needed to drill through ice on Tawas Bay, Lake Huron, December 22, 2019 (Credit: Amy Sacka / Huffington Post)

Photo: Lake Michigan shoreline flooding, South Haven, MI, March 6, 2020 (Credit: Joel Bissell / MLive)

2020 ANNUAL CLIMATE TRENDS AND IMPACTS SUMMARY FOR THE GREAT LAKES BASIN

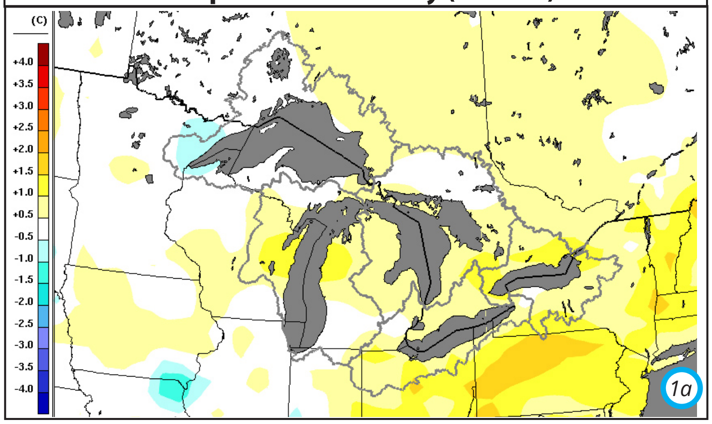
Climate Overview: December 2019 - November 2020

During the December 2019 – November 2020 reporting period*, mean annual air temperatures across the Great Lakes region were near average to slightly above average by +0.5 to +1.5 °C (Figure 1a). The highest anomalies, above +1°C, were recorded in the Mid-Lake Michigan basin and on the northern and western shores of Lake Ontario. On a monthly scale, cool periods across the basin in April-May and September-October were offset by long periods that greatly exceeded average air temperatures in July and November. Annual precipitation totals were near normal across the basin, with some variability between individual lake basins (Figure 1b), with the exception of the northwest, where below-normal precipitation was recorded for every season in 2020, and the Lake Ontario basin. Warm and wet conditions characterized the winter for much of the basin, with the southeast experiencing extremely high rainfall in January. These conditions gave way to cooler and drier conditions in the spring, with some exceptions for heavy rainfall events.

Annual water temperatures for all of the Great Lakes were above their long-term averages. Basin-wide runoff totals were near or below average in 2020, and evaporation totals were near or above normal. Over the period from 1991-2020 across the region, air temperature (+0.14 °C/decade), precipitation (+11.5mm/decade), evaporation (+17.4mm/decade), water temperatures (+0.43 °C/ decade), and runoff (+20.1mm/decade) have all increased.

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

Temperature Anomaly (Annual)



Precipitation Anomaly (Annual)

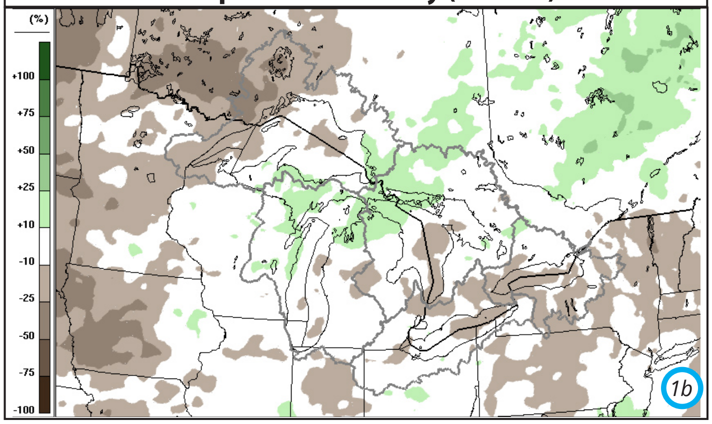


Figure 1. Maps displaying annual anomalies for temperature (1a) and total precipitation accumulation (1b) in the Great Lakes region. Anomalies for temperature are departures from the 1981-2010 mean. Anomalies for precipitation are % departure from the 2002-2019 mean. Gray outlines depict the individual lake basins. Data for temperature are from ECCC and NOAA surface observations and precipitation is a merged dataset containing ECCC model and Numerical Weather Prediction model data. Figures created by ECCC.

		SUPERIOR		MICHIGAN		HURON		ERIE		ONTARIO	
		2020	**LTA**	**2020**	**LTA**	**2020**	**LTA**	**2020**	**LTA**	**2020**	**LTA**
Surface Water Temps (°C)	Max	18.29	17.58	23.84	22.54	22.24	21.34	26.27	24.97	24.96	23.46
	Min	1.15	0.59	2.25	1.22	1.11	0.57	1.00	0.32	2.51	1.26
	Avg	6.69	6.52	10.18	9.69	9.35	8.85	11.99	11.36	11.18	10.27
Ice Cover (%)	Max	22.56	62.23	17.23	40.46	32.15	65.23	15.90	82.64	10.67	30.22

		SUPERIOR		MICHIGAN-HURON**		ERIE		ONTARIO	
		2020	**LTA**	**2020**	**LTA**	**2020**	**LTA**	**2020**	**LTA**
Water Levels (meters)	Max	183.81	183.57	177.46	176.60	175.10	174.39	75.36	75.10
	Min	183.57	183.23	177.20	176.24	174.65	173.89	74.60	74.42
	Avg	183.70	183.41	177.32	176.43	174.90	174.16	75.06	74.76
Precipitation (mm)	Ann Sum	930.6	780.5	959.3	794.7	934.9	973.9	874.0	930.7
Evaporation (mm)	Ann Sum	649.8	556.8	646.0	504.0	943.6	896.4	696.2	650.4

*Table 1: Summary of hydro-climate variables by lake. Long Term Average (LTA) changes depending on variable: **Surface Water Temps (°C)** - 2020: December 2019 through November 2020, LTA: 1995-2019; **Ice Cover (%)** – 2020: December 2019 through May 2020, LTA: 1973-2019; **Water Levels (meters)** - 2020: December 2019 through November 2020, LTA: Period of Record (1918-2019); **Precipitation (mm)** - 2020: December 2019 through November 2020, LTA: 1981-2010; **Evaporation (mm)** - 2020: December 2019 through November 2020, LTA: 1981-2010. Estimated from NOAA Great Lakes Surface Environmental Analysis (surface water temps), NOAA GLERL CoastWatch (ice cover), US Army Corps of Engineers (water 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 lake bodies.*

2020 ANNUAL CLIMATE TRENDS AND IMPACTS SUMMARY FOR THE GREAT LAKES BASIN

Historical Trends

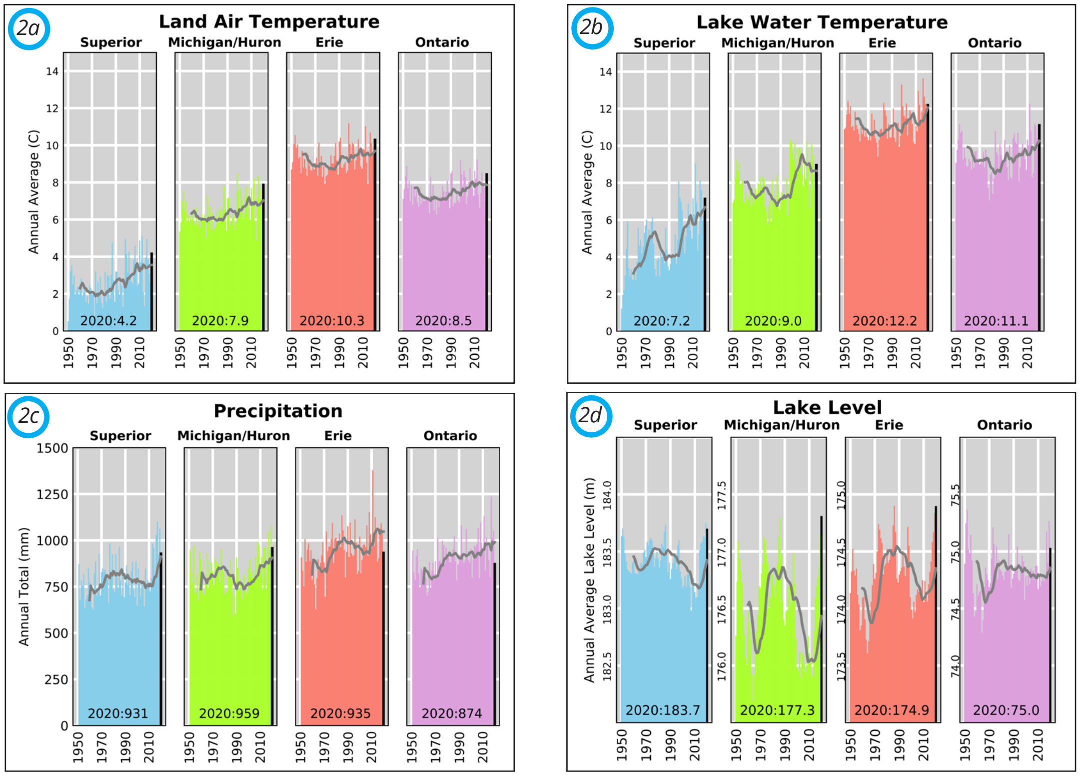


Figure 2. Time series of air temperatures (2a), water temperatures (2b), precipitation (2c), and water levels (2d) by lake basin from 1950-2020. The grey line is a 10-year moving average and the black line is the 2020 average. Estimated from GLERL Great Lakes Monthly Hydrologic Data, and Coordinating Committee on Great Lakes Basin Hydraulic and Hydrologic Data.

Air (Figure 2a) and surface water temperatures (Figure 2b) were above the 10-year average for each lake basin in 2020. There has been an upward trend in both air and water temperatures in recent years. Annual precipitation accumulation (Figure 2c) in 2020 was above the 10-year average for the upper Great Lakes of Superior, Michigan, and Huron, and below the 10-year average for the lower Great Lakes of Erie and Ontario. There has been a general upward trend in precipitation observed on all lakes in recent years, though substantial interannual variability is common. Water levels (Figure 2d) remained above the 10-year average on all of the Great Lakes in 2020, with Lake Michigan-Huron and Lake Erie levels being exceptionally high. Lake levels have risen since 2013, following a period of low lake levels lasting from the 1990s to the mid-2000s.

Precipitation

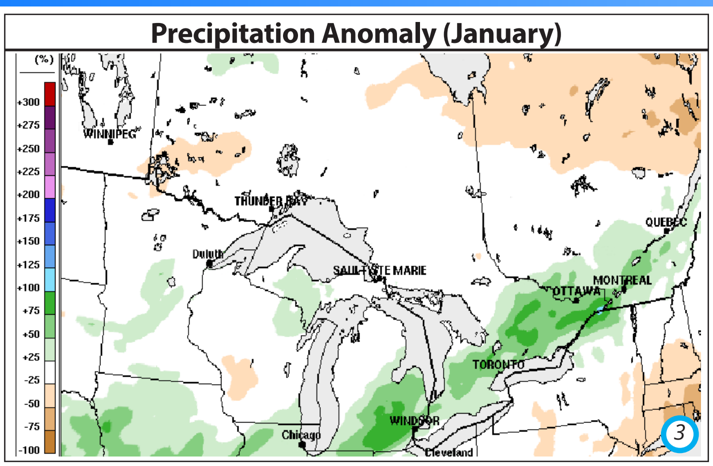


Figure 3. January 2020 precipitation anomaly (% departure from 2002-2019 mean). Figure created by ECCC.

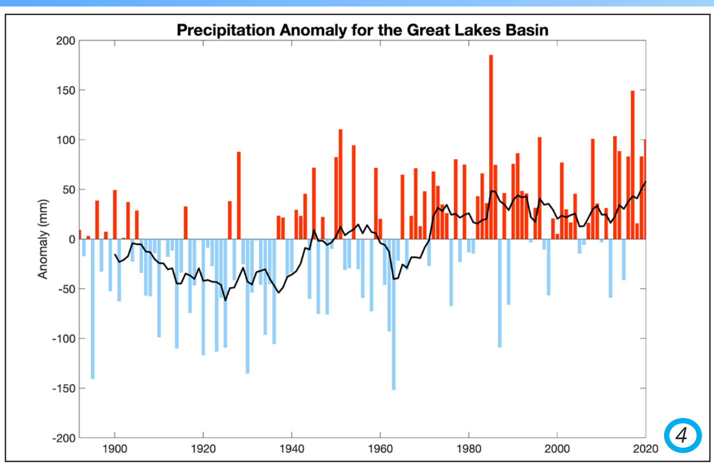


Figure 4. Precipitation anomaly (mm) for the Great Lakes basin based on the departure from the 1892-2019 mean, with a 9-year running average (black line). Estimated from GPCC Global Precipitation Climatology Centre (1982-2019) and Canadian Precipitation Analysis (2020)

Though annual precipitation totals were near normal across the basin, there were still periods of extreme precipitation. January 2020 precipitation totals were well above average (Figure 3), driven largely by one extreme precipitation event from January 9th-10th. This event brought heavy rainfall and flooding to southern Michigan and southern Ontario, with over 70mm of rain recorded in a 2-day period in many areas. Monroe, MI, observed 107mm of rainfall during this period. Precipitation totals and heavy precipitation events are both increasing in wintertime.

Much of the current wet conditions in the basin, particularly in high lake levels and soil moisture, are inherited from cumulative precipitation trends from the past several years. The last 5 years (2015-2019) were cumulatively the wettest 5-year period on record for the basin (Figure 4). This continues to contribute to shoreline flooding and erosion from high lake levels and surface flooding from highly saturated soil.

Lake Levels

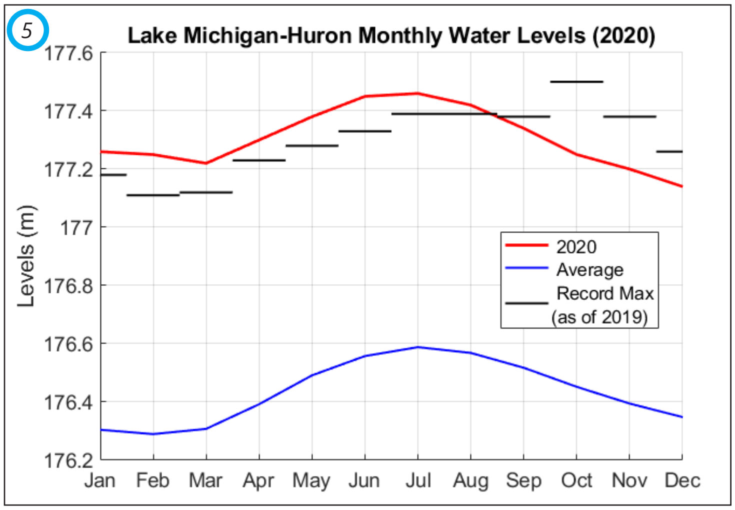


Figure 5. 2020, historical average, and record lake levels for Lake Michigan-Huron. Average levels based on 1918-2019 mean. Estimated from US Army Corps of Engineers Data.

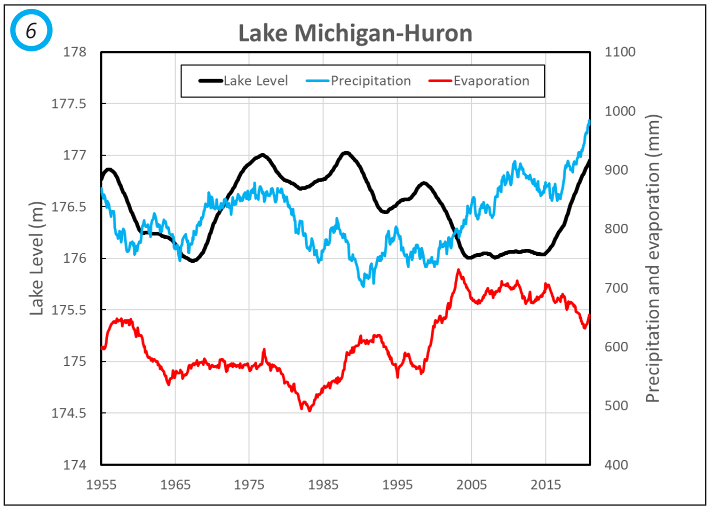


Figure 6. Lake Michigan-Huron 5-year running average of lake levels, precipitation, and evaporation. Estimated from NOAA GLERL Great Lakes Hydrologic Data.

In 2020, water levels on all five of the Great Lakes remained above their long-term average. New monthly mean water levels records were set on Lakes Superior, Michigan-Huron (Figure 5), and Erie. Lower-than-average runoff from dry conditions in the spring contributed to a larger-than-average seasonal decline in water levels for the second half of the year. By the fall, most lakes were below their 2019 levels, but still above average. The high lake levels in winter and spring contributed to significant flooding, coastal erosion, and infrastructure damage. The shipping season was delayed several weeks in early spring to release higher outflows from Lake Ontario into the St. Lawrence River.

High water levels in 2020 followed an increasing trend in the lakes' net total water supply (NTS: the sum of precipitation, runoff, and upstream inflow into the lake minus evaporation from the lake), which is a shift from the previous decade of below-average NTS and lower lake levels. The main drivers of these water level trends are precipitation and evaporation (Figure 6). Lake level conditions on all of the Great Lakes generally followed precipitation trends until around 1998, when the effects of high evaporation began to dominate, contributing to a long period of below-average lake levels. Since around 2014, higher precipitation has been the dominant lake level driver again, contributing to the high lake level conditions observed in recent years.

Snow and Ice

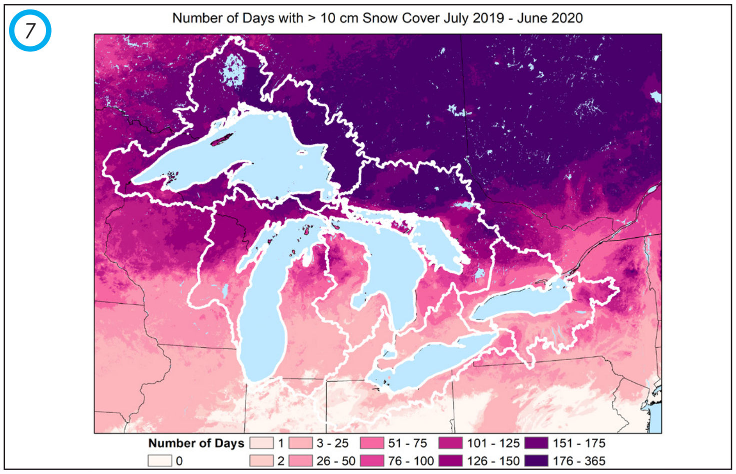


Figure 7. Days with > 10 cm snow cover July 2019-June 2020. White outlines depict the individual lake basins. Estimated from the NOAA National Operational Hydrologic Remote Sensing Center (NOAA NOHRSC) model output.

Days with substantial snow cover (> 10 cm) across the region ranged from 1-25 days in the southernmost portions of the basin (same or fewer than 2019) to more than 176 days in the northern reaches of the basin (more than 2019) (Figure 7).

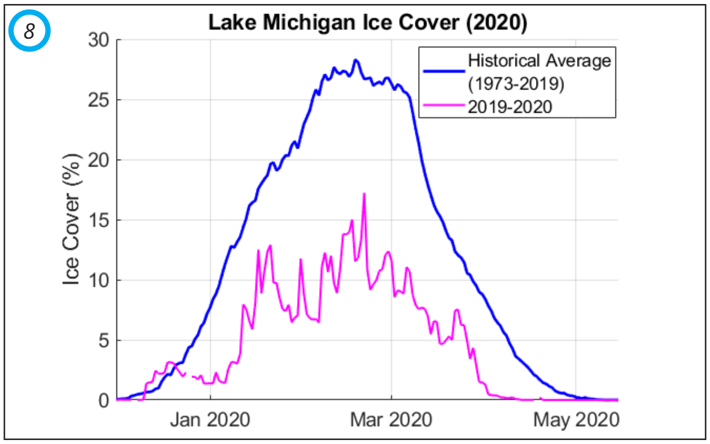


Figure 8. Daily 2020 and historical average ice cover concentrations for Lake Michigan. Estimated from NOAA GLERL Great Lakes CoastWatch.

Above-average air and water temperatures in the basin contributed to below-average lake ice cover for the majority of the winter (Figure 8). Most of the ice cover that did form was near the coasts, with very little ice formation in the middle parts of the lakes. There has been a declining ice cover trend over the past several decades, though there remains strong year-to-year variability.

2020 ANNUAL CLIMATE TRENDS AND IMPACTS SUMMARY FOR THE GREAT LAKES BASIN

Major Climatic Events

Winter 2019-2020

The last week of December was exceptionally warm across much of the basin, with many record-high maximum and minimum temperatures observed.

The basin's fourth lowest maximum ice cover was set at 19.5% on Feb. 21, 2020 (the long-term average of annual max ice is 54%).

Most of the Great Lakes states had one of their top 10 warmest winters on record.

Five monthly records for mean high water level were broken and one tied. The high lake levels contributed to significant coastal erosion, flooding, and infrastructure damage.

Photo: Lakefront Trail in Chicago, IL, January 2020 (Credit: Lloyd Degrane).

Spring 2020

In March, Erie, PA, and Watertown, NY, set or tied their records for least snowy March with only a trace of snow, in part due to warmer-than-normal air temperatures.

Early May was much colder than normal, resulting in a late-season damaging freeze event for many specialty crops. In contrast, late May was extremely warm, especially in the eastern half of the basin.

Detroit, MI, received at least a trace of snow each day from May 8-12, which is the longest snowfall streak for the month of May for the city, while Toronto-Pearson, ON, had its snowiest May on record.

Heavy rain from May 17-20 led to historic river and shoreline flooding along the Tittabawassee and Saginaw Rivers in Michigan that led to dam failures. This event also contributed to Chicago, IL, recording its record wettest May.

In March, April, and May, monthly mean water level records were set on Lakes Michigan-Huron and Erie as impacts related to coastal erosion, shipping, and recreation remained across the basin.

Summer 2020

July was the all-time hottest month on record for Syracuse and Buffalo, NY. Buffalo also recorded its all-time longest streak of days with a high air temperature of at least 32°C for eight days in a row.

Average surface water temperatures in early July on Lakes Erie and Ontario were more than 3°C warmer than normal. On July 10, the average surface temperature on Lake Ontario was around 25°C, resulting in some of the hottest water temperatures reported for this early in the season.

Summer was, overall, very warm across the basin, with air temperatures remaining quite high overnight and offering little relief from hot daytime conditions. Several locations reported one of their top 10 warmest summers for minimum (nighttime) temperature.

Abnormally hot and dry conditions in some areas of the basin had negative impacts, from slow growth of corn and soybeans in New York to smaller peaches in Michigan.

Lake Michigan-Huron set new monthly mean high water level records in June, July, and August. Flooding, erosion and infrastructure damage continued throughout the summer.

Photo: Waterspouts on Lake Erie, October 1, 2020 (Credit: David Piano).

Autumn 2020

Strong winds in early September contributed to a sudden end of Lake Erie's Harmful Algal Bloom season, which was much less severe than initially forecasted.

From September 28 through October 4, 232 waterspouts were observed on the lakes, setting a record for the largest outbreak ever recorded on the Great Lakes.

Record-setting warmth in the first half of November set many daily temperature records across the basin. Chicago, IL, set a record for having seven days in November with high temperatures of at least 21°C.

On November 15, wind gusts of 95-141 km/h produced widespread wind damage and numerous power outages across the eastern Great Lakes and southern Ontario. A 2m storm surge and 5m waves were observed across Lake Erie, resulting in flooding.

Compared to events in the Fall of 2019, temperature and precipitation conditions were relatively normal throughout the fall, resulting in a fairly good fall crop harvest.

2020 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

- A study used the fully integrated surface-subsurface model HydroGeoSphere to assess potential watershed response to changing climate conditions in southwestern Ontario. Simulation outputs were compared to assess the potential influence of changing climate on groundwater hydraulic head, surface discharge, and net fluid exchange between surface and subsurface domains (Persaud et al. 2020).
- Researchers examined how climate change could affect sea lamprey in the Great Lakes in the future by calculating larval survival in rivers, growth and maturation in lakes, phenology and the spawning migration as adults return to rivers, and the overall abundance and distribution of sea lamprey in the Great Lakes (Lennox et al. 2020).
- Studying the effects of climate, lake morphology, and invasive dreissenid mussels on changes in water quality over the past 40 years, researchers found that precipitation, air temperature, and morphology explained 73.1% of the variation in water quality trends for the Great Lakes, whereas precipitation, temperature, morphology, and occurrence of mussels explained 45.6% of the variation for smaller inland lakes (Mahdiyan et al. 2020).
- A study characterized uncertainty from both climate models and hydrologic models in predicting riverine discharge and nutrient loading in order to assess hydrology and nutrient loadings for mid-century in the Maumee River Watershed, the largest watershed draining to the Great Lakes (Kujawa et al. 2020).
- Photogrammetric surveys were used to create four high resolution (10 cm) digital elevation models in order to determine sediment quantity loss from erosion of a Lake Michigan bluff. The study compared the elevation models to evaluate variations in sediment loss to modeled time series of wave data, atmospheric temperature and lake levels (Volpano et al. 2020).
- A surface water-ground water model was created to account for hydrologic seasonality for the Great Lakes basin and calculcated the annual average rates of direct groundwater discharge to all the lakes, demonstrating how this affects total net basin supply spatially and seasonally (Xu et al. 2020).
- Aquanty Inc developed a new real-time hydrologic forecasting platform for watersheds in southern Ontario, giving users access to streamflow, groundwater, satellite imagery, and statistical simulations (Aquanty Inc).

Adaptation, Policy & Resilience

- The Great Lakes Integrated Sciences and Assessments (GLISA) team developed a suite of climate model consumer-report-style documents to help climate information consumers make decisions (Briley et al. 2020).
- Researchers used a water-restricted multi-regional input–output model to evaluate the economic impacts of water supply reductions in the Canadian Great Lakes Basin, and investigated the impacts of two climate change scenarios on water security and the economy, with and without additional food and energy security restrictions for the Great Lakes (Garcia-Hernandez et al. 2020).
- The American Society of Adaptation Professionals (ASAP), in partnership with GLISA, designed a knowledge and skill-building workshop to better understand for-profit providers' practices and needs and support integration of existing public-sector climate data and information into their products, services, and strategies (ASAP 2020).
- The Ontario Climate Consortium developed a guidance document as part of updated climate projections for Durham Region. The document provides information to municipalities and Conservation Authorities on how to undertake their own climate modeling studies, while supporting consistency in the climate modeling approaches used across Ontario municipalities (Delaney et al. 2020).
- Zuzek Inc. issued a report highlighting climate change adaptation case studies within the Canadian basin of the Great Lakes. This project advances the knowledge base and will enhance the adaptive capacity of practitioners managing the coastal zone in the Great Lakes basin (Zuzek Inc. 2020).

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. 2020 Annual Climate Trends and Impacts Summary for the Great Lakes Basin. 2021. Available at https://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

Illinois-Indiana Sea Grant
iiseagrant.org

Midwestern Regional Climate Center
mrcc.isws.illinois.edu

National Oceanic and Atmospheric Administration
noaa.gov

Northeast Regional Climate Center
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For additional figures, information, and sources visit:
glisa.umich.edu/summary-climate-information/annual-climate-trends