Seasonal Summary

Great Lakes

Winter 2017-2018

By the North American Ice Service

Summary for the Great Lakes

The 2017-2018 winter in the Great Lakes region was characterized by an above average ice coverage that was driven primarily by a below normal temperature regime. As is often the case, intra-seasonal variability led to substantial changes in lake ice cover. Rapid accelerations in ice growth were followed by significant decreases during periods of otherwise expected continued gains in ice thickness and spread. However, the total accumulated ice coverage (TAC) for this past season (for the historic weeks of 4 December to 21 May) was 20.14%, in the 60th percentile of historic cases of TAC from 1972-1973 to present day. This TAC was a notable rebound from the previous ice season, more than tripling the TAC of 5.97% observed in 2016-2017.

A quick start to ice development was observed in late November 2017 in the northern bays of Lake Superior. This earlier than normal ice presence would also soon manifest in other shallow and isolated bodies of water throughout the Great Lakes. By Christmas 2017, ice had spread from the margins of the shore in the North Channel, Green Bay, Saginaw Bay and the Western Basin of Lake Erie. Deep cold had settled across the Great Lakes, with surface air temperature anomalies of over 5°C below normal during the second half of December (Figure 1). Record cold temperatures for the final week of December were established in upstate New York and southern Ontario, setting the stage for explosive ice growth in early 2018. Continued colder than normal temperatures (Figure 2) pushed ice coverage to an early season peak of 34.08% by mid-January, with anomalous growth of ice observed in all the Great Lakes. Lake Erie in particular was well ahead of the climatology with respect to ice coverage at this point, with a widespread appearance of thin and medium lake ice. Another indication of the anomalous cold weather was the early establishment of fast ice in the isolated sections of the Great Lakes. Green Bay, Saginaw Bay and Lake St. Clair all saw earlier than normal development of fast ice by mid-month.

A reprieve from the harsh winter arrived in late January 2018. A quick reversal in the surface temperature anomaly developed and warmer than normal temperatures dominated the region (Figure 3). Western Lakes Michigan and Superior were over 5°C above the climatological normal surface air temperature during this timeframe. Accordingly, ice coverage diminished in response and retreated to 21.30 % of the lake surface by the end of January. Appreciable losses of ice in western Lake Erie, southern

Lake Huron, southern Lake Michigan and eastern Lake Ontario contributed heavily to this decline.

This period of warmth was short-lived however as February would again bring a return of below seasonal temperatures to the Great Lakes. Of interest was the spatial orientation of the anomaly, as the largest anomalies were located over the western half of the region (Figure 4). This distribution of the anomalies correlated well with the areas that underwent the most notably episodes of ice growth, namely Superior, Huron and Michigan. The first two weeks of the month saw ice cover triple to a peak value of 64.25% by 12 February 2018, well above the median peak value of 39.81%. Preconditioned waters in the lakes were optimally positioned to undergo extensive ice expansion during this phase, and the accompanying colder than normal air temperatures that arrived in early February facilitated the recording of the maximum seasonal ice cover. This peak was reached one month earlier than the climatological normal as well. Thicker than normal ice was analyzed in eastern Lake Erie, Georgian Bay and Whitefish Bay also.

After this peak period of ice cover and development, a gradual decline was observed for the remainder of the season. The decay of the ice was driven by first an additional warmer than normal period from mid-February to mid-March (Figure 5) and then a cooler than normal spring that delayed and slowed the ice destruction (Figure 6). The anomalously warm phase during the typical peak ice period for the Great Lakes saw the rapid disappearance of ice from southern Lake Michigan, western Lake Erie and Lake Huron. Lower than climatologically normal ice concentrations were now visible by mid-March across the Great Lakes excluding Lake Superior, Green Bay and the North Channel.

This warmer than normal atmospheric pattern was then displaced by a one final colder than normal period of surface air temperatures from mid-March to the end of the ice season over the northern Great Lakes. Maximum daytime highs were now consistently above freezing for the lower Great Lakes, maintaining the steady destruction of the last remaining traces of ice. Average temperatures for the northern portions of the lakes remained below freezing and below normal, stalling the ice melt and leading to above normal ice concentrations in Green Bay, the North Channel, St. Mary's River and much of Lake Superior. The last remaining ice cleared from the Great Lakes near mid-May, first in the North Channel and then days later in the northern bays of Lake Superior. Whitefish Bay was the last area to fully clear with ice free and open water conditions prevailing by 21 May throughout the Great Lakes. Ice lingered three weeks

to a month longer than normal in Whitefish Bay and the North Channel due to the colder than normal spring in these regions.

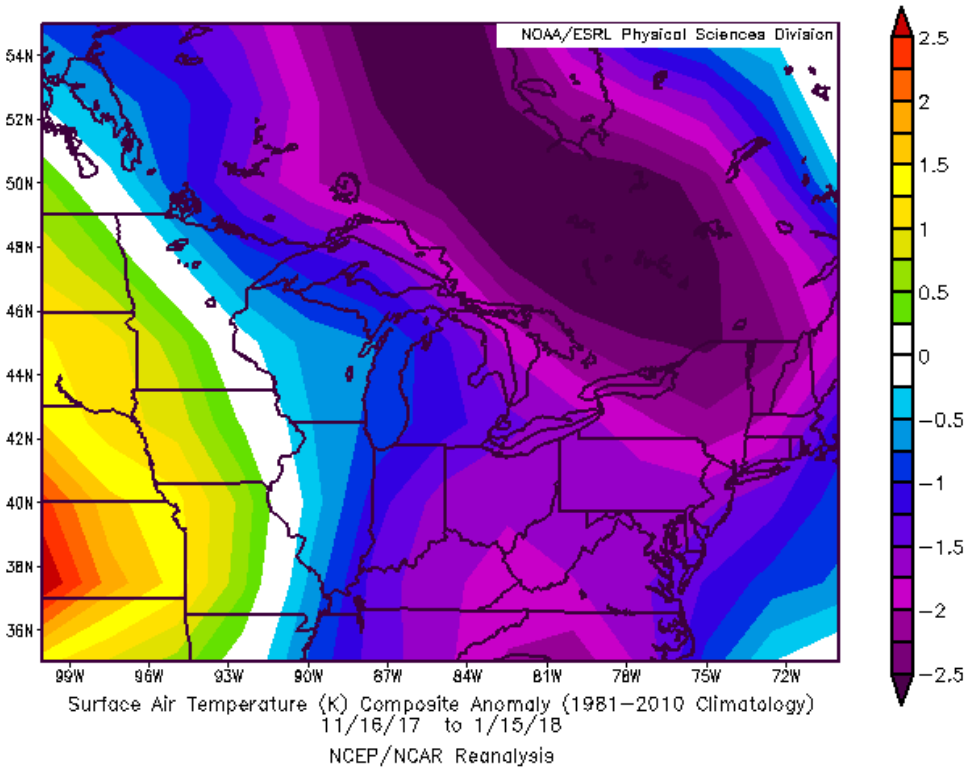

Figure 1: Surface Air Temperature Anomaly for the Great Lakes, 16 November 2017 to 15 January 2018.

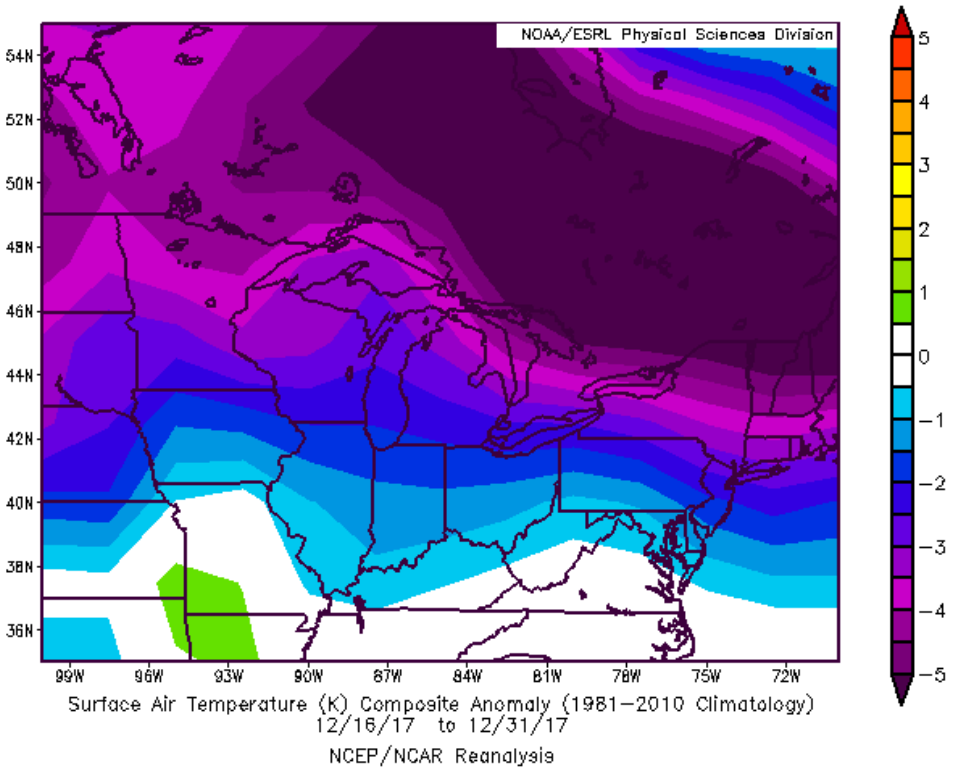

Figure 2: Surface Air Temperature Anomaly for the Great Lakes, 16 to 31 December 2017.

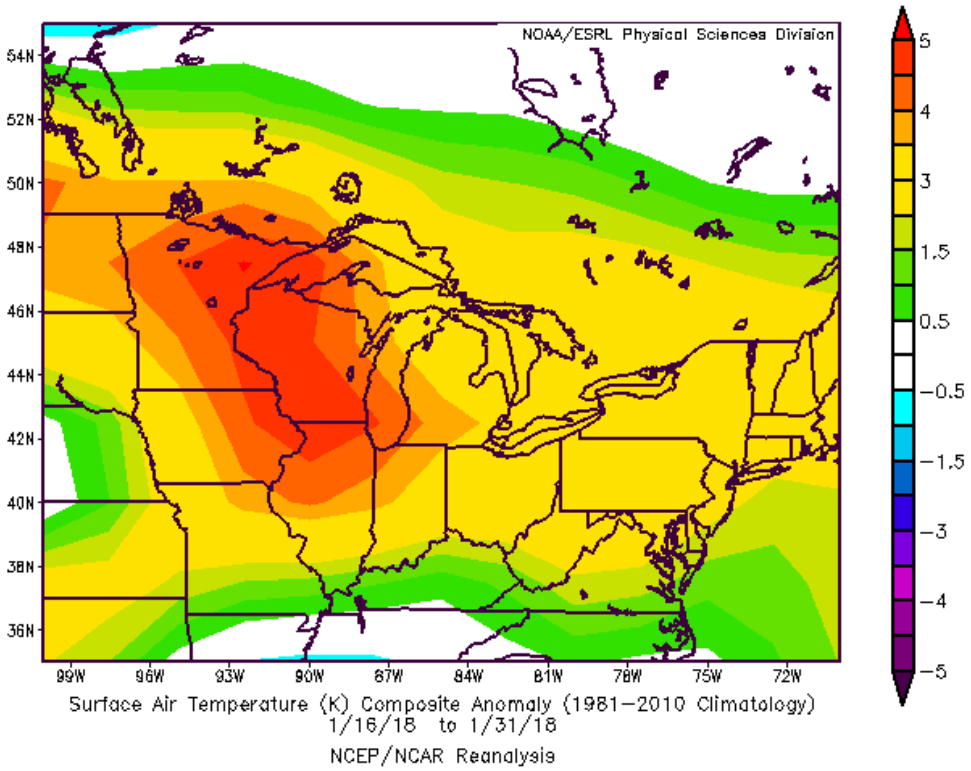

Figure 3: Surface Air Temperature Anomaly for the Great Lakes, 16 to 31 January 2018.

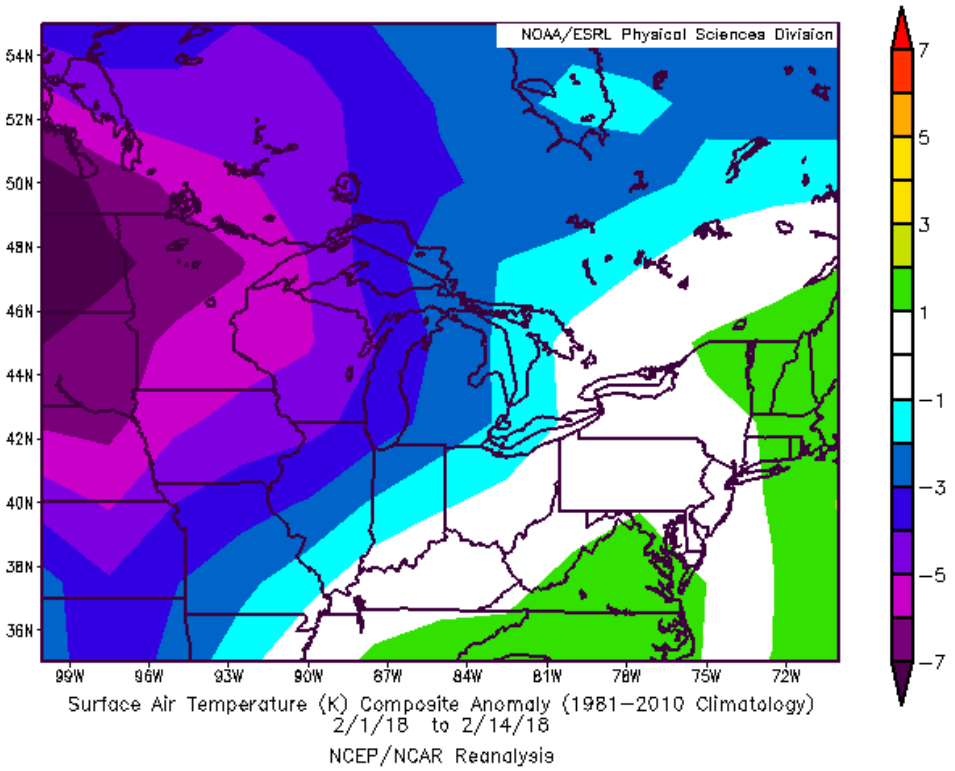

Figure 4: Surface Air Temperature Anomaly for the Great Lakes, 1 to 14 February 2018.

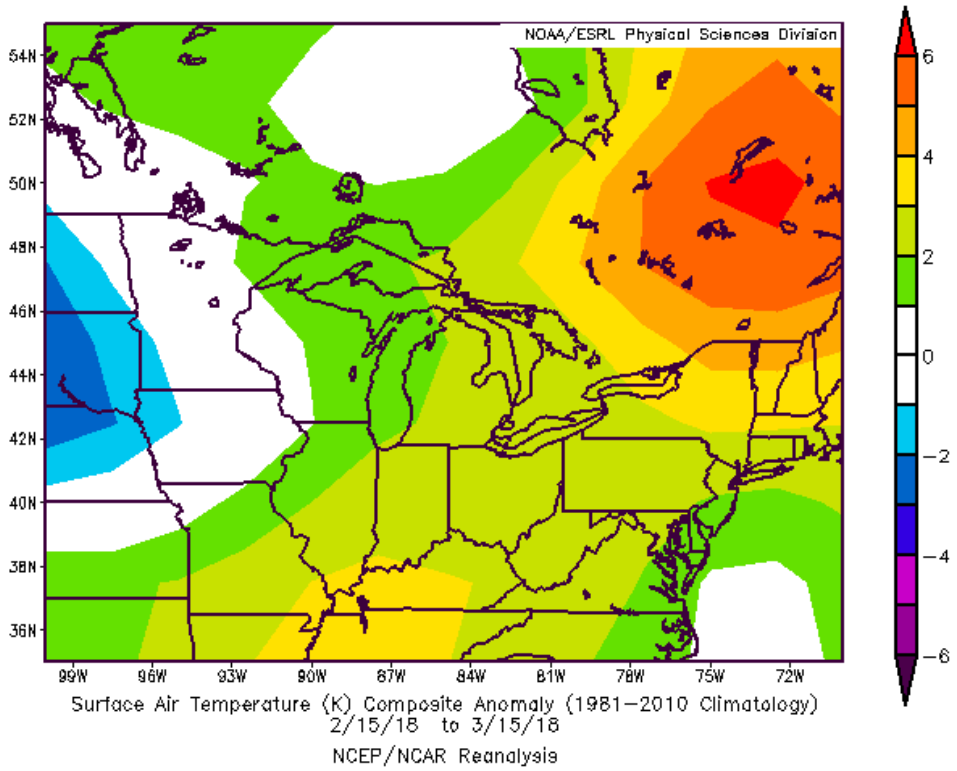

Figure 5: Surface Air Temperature Anomaly for the Great Lakes, 15 February to 15 March 2018.

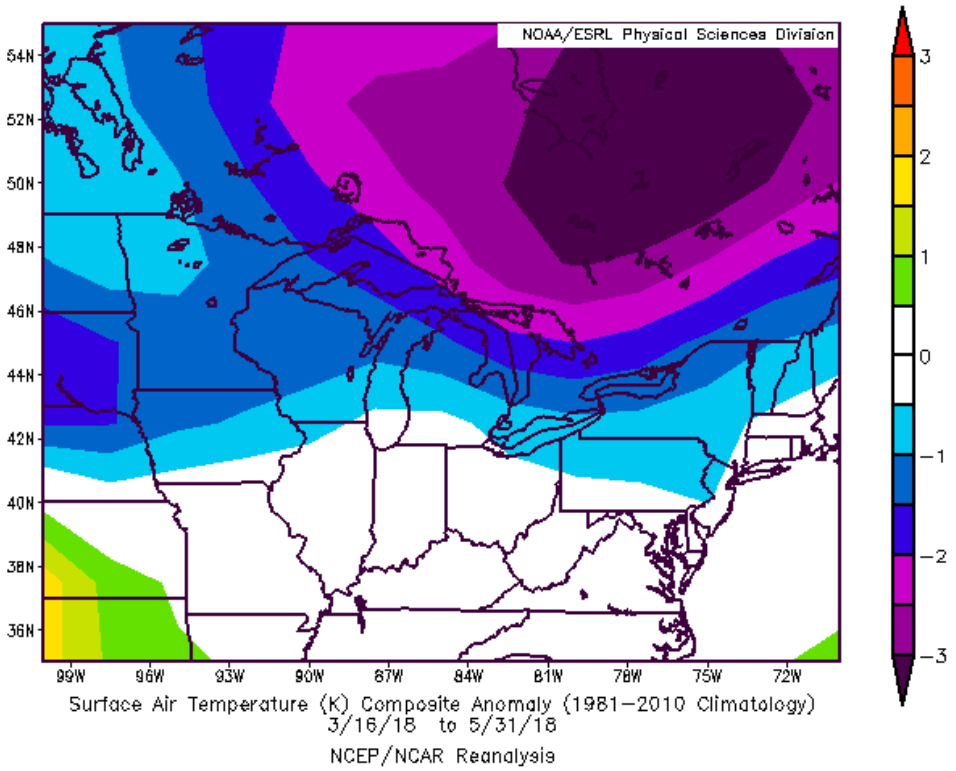

Figure 6: Surface Air Temperature Anomaly for the Great Lakes, 16 March to 31 May 2018.

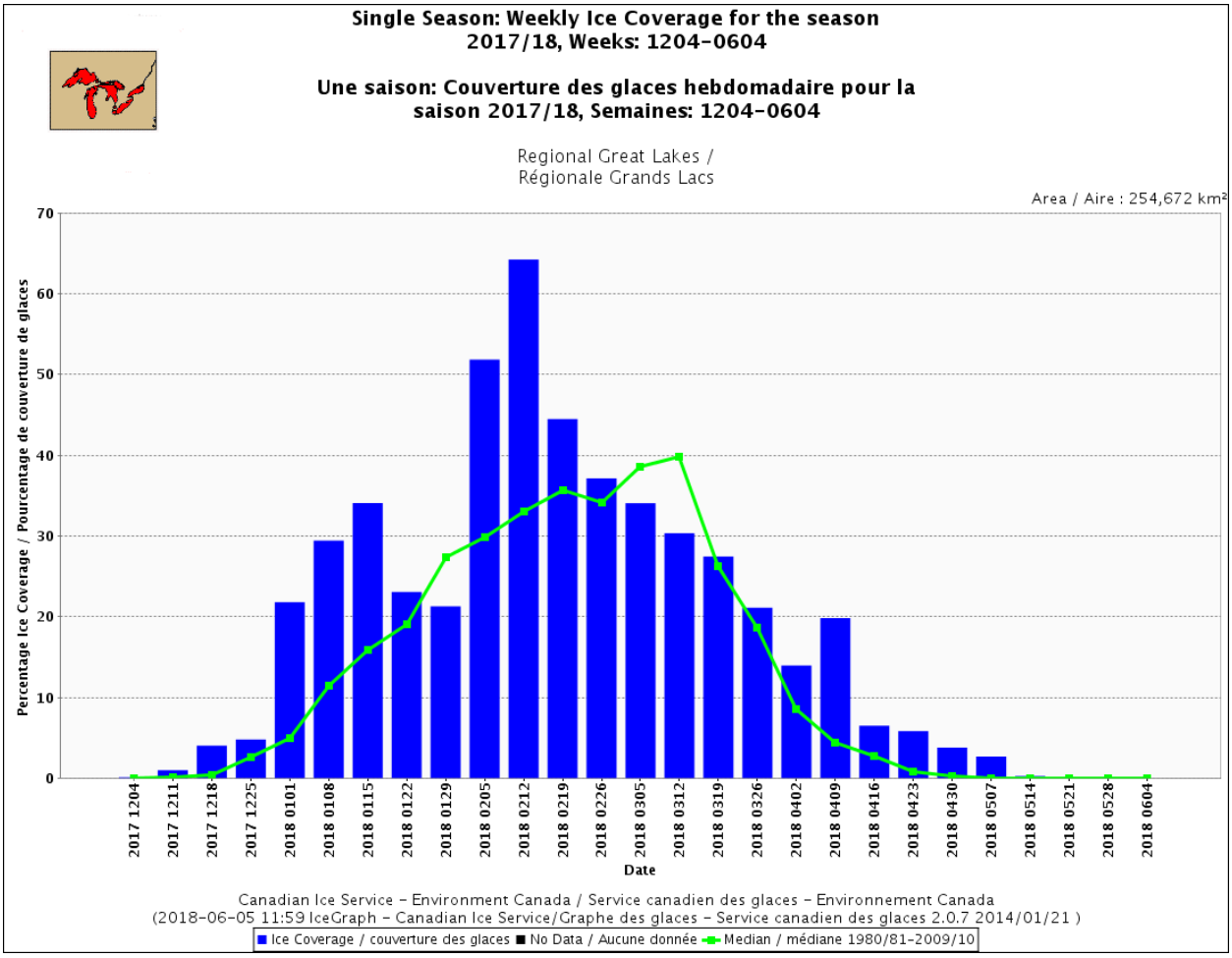

Figure 7: Weekly ice coverage for the Great Lakes, winter 2017-2018.

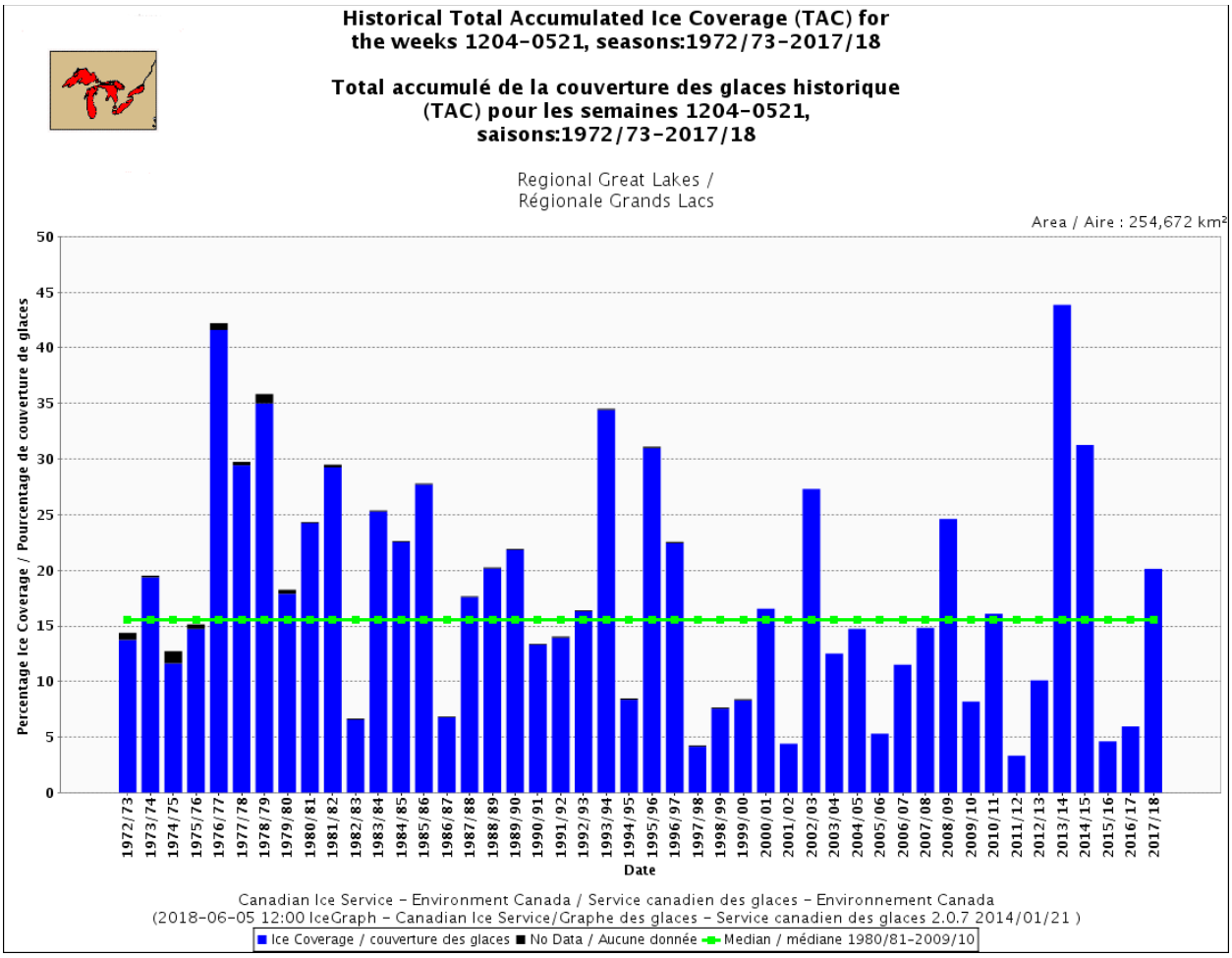

Figure 8: Historical Total Accumulated Ice Coverage on the Great Lakes, 1972-1973 to 2017-2018.

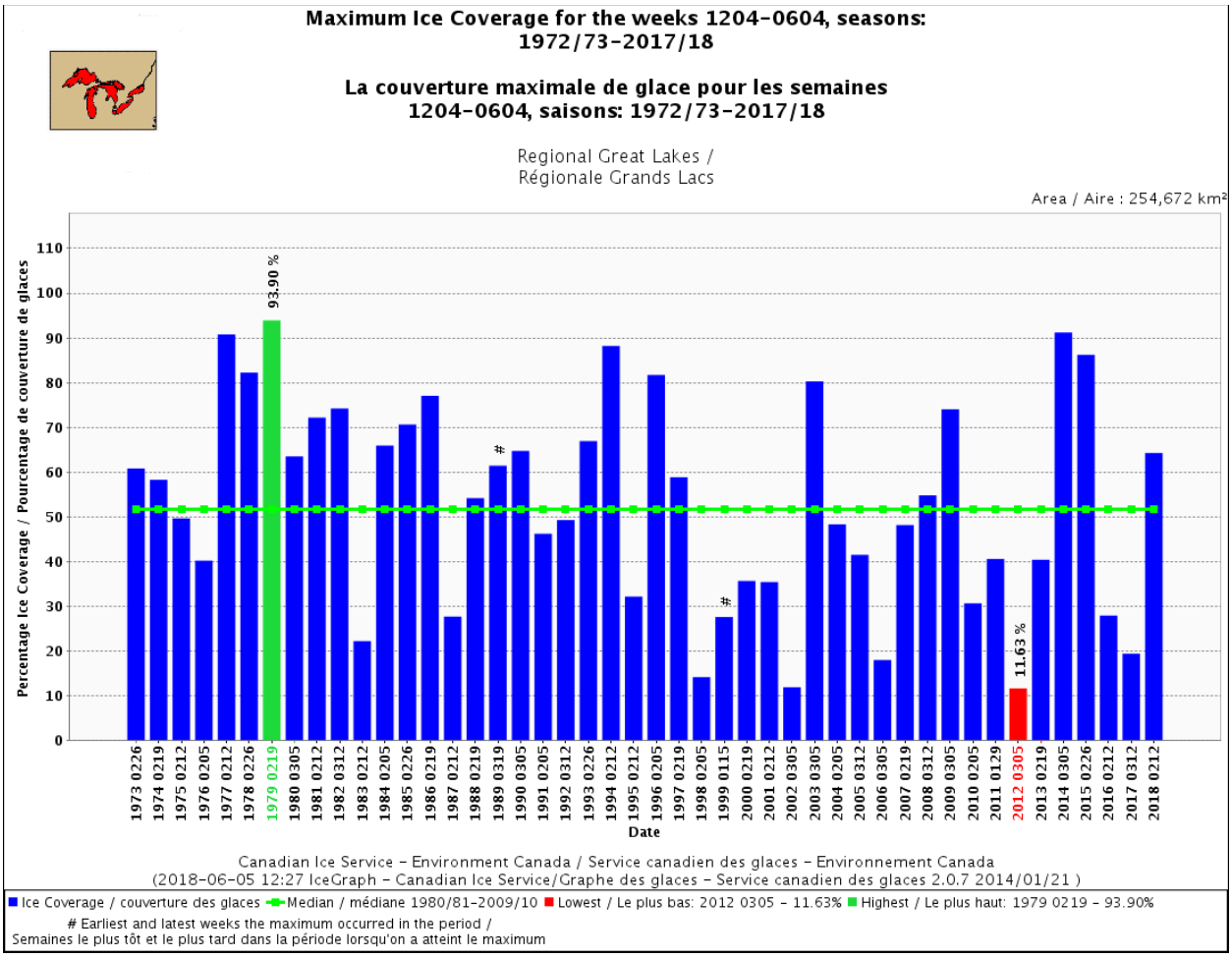

Figure 9: Maximum weekly ice coverage for the Great Lakes, 1973 to 2018.

Lake Superior

2017-2018 Season temperatures:

Surface air temperatures across Lake Superior were below the climate normal as the 2018-2018 ice season started. Anomalies ranged from 0.5°C to 2.0°C below normal from mid-November 2017 to mid-January 2018, with a period of enhanced cold anomalies of 2.5°C to 4.5°C below normal in the second half of December. A reversal in the atmospheric pattern after mid-January 2018 led to warm surface air temperature anomalies from 2.5°C to 5.5°C above the climate normal until the end of the month, the largest above normal anomalies in all the Great Lakes during this timeframe. The arrival of February 2018 brought back colder than normal air temperatures and again the largest anomalies affected Lake Superior, ranging between 2°C and 6°C below normal. The variability

in seasonal temperatures continued in the second half of February, as temperatures 1°C to 3°C above the normal were observed. A final colder than normal period overtook the region until the end of the season, with air temperatures approximately 1°C to 3°C below the seasonal values.

2017-2018 Ice conditions:

New and thin lake ice were first noted in Black and Nipigon Bay in late November 2017 and remained the only notable ice development throughout the Great Lakes system for the remainder of the month. In the second week of December, many isolated bays and inlets experienced new and thin ice growth and medium lake ice was present in Black Bay and Nipigon Bay. Minor growth continued along the shorelines of the lake during December and consolidated medium lake ice was established in Chequamegon, Nipigon and Black bays. Ice extents and concentrations were relatively near normal in the basin.

The pace of ice growth accelerated in the first half of January after the previously noted period of deep cold that affected the Great Lakes in late December 2017. Above normal ice concentrations were observed along the southern shore of the lake and in Whitefish Bay, with significant amounts of thin and medium lake ice extending approximately 20 nautical miles from the shore. Additional higher than normal ice concentrations developed from Grand Marais, MN to Marathon, ON, and the first areas of consolidated thick lake ice were analyzed in isolated bays.

The recent gains in ice cover were diminished in the second half of January 2018. A return of unseasonal warmth to Lake Superior led to the destruction of much of the fragile new and thin lake ice. Ice cover fell below 10% for the lake after reaching 22.92% in mid-January as the offshore lake ice was destroyed, yet the ice protected in isolated bays remained intact in general.

Intense cold quickly returned to Lake Superior in early February and ice growth resumed, rapidly reaching the seasonal maximum ice coverage by 12 February 2018. The ice coverage peaked at 73.19%, well above the maximum median value of 49.65% from the 1981-2010 climatology. This peak was also achieved one month ahead of the typical date of the climatological maximum. The pattern of above normal ice coverage and thickness was maintained through the rest of the season over Lake Superior unlike the rest of the Great Lakes. The noted period of above normal surface air temperatures from mid-February to mid-March 2018 was not as pronounced near Superior, as the anomaly in air temperature was

weakest over the western extent of the Great Lakes. Modest declines in TAC were noted in the month following the 12 February peak in ice cover, but values oscillated between 55% and 70% and stayed well above the normal climatological ice coverages. Thick lake ice expanded across the lake near the western shore of the Keweenaw Peninsula in the second half of February, and eventually was analyzed east of the peninsula along the southern shore in late March. An expansion of thin and medium lake ice was documented in the central section of the lake as well in late February and early March, sustaining the high ice cover values.

Steady ice losses began in late March but ice coverage remained above normal through to the end of the ice season. Consolidated very thick lake ice was predominant in Black and Nipigon Bays by early April and was detected within Chequamegon Bay, Thunder Bay and Whitefish Bay at this time. A substantial increase in cover occurred in the second week of April as a broad ridge of high pressure sustained a brief period of colder than normal temperatures over Lake Superior. Ice cover climbed to nearly 50%, approximately 10 times the median value for this time of year. The ice that appeared during this episode however was predominantly new lake ice, and was quickly destroyed in a few days as temperatures warmed and stronger winds prevailed. Anomalous amounts of lake ice remained generally along the southern shore of the lake east of the Keweenaw Peninsula and within Whitefish Bay. This thick lake ice lingered well beyond the typical seasonal normal, roughly three to four weeks late with respect to the clearing of all lake ice. Additional areas of late ice clear-out were noted in Black, Nipigon, Thunder and Chequamegon bays, all approximately one to two weeks slower than usual. Final TAC for the season was 26.13%, up from the 2016-2017 value of 3.97% and above the median of 16.22%.

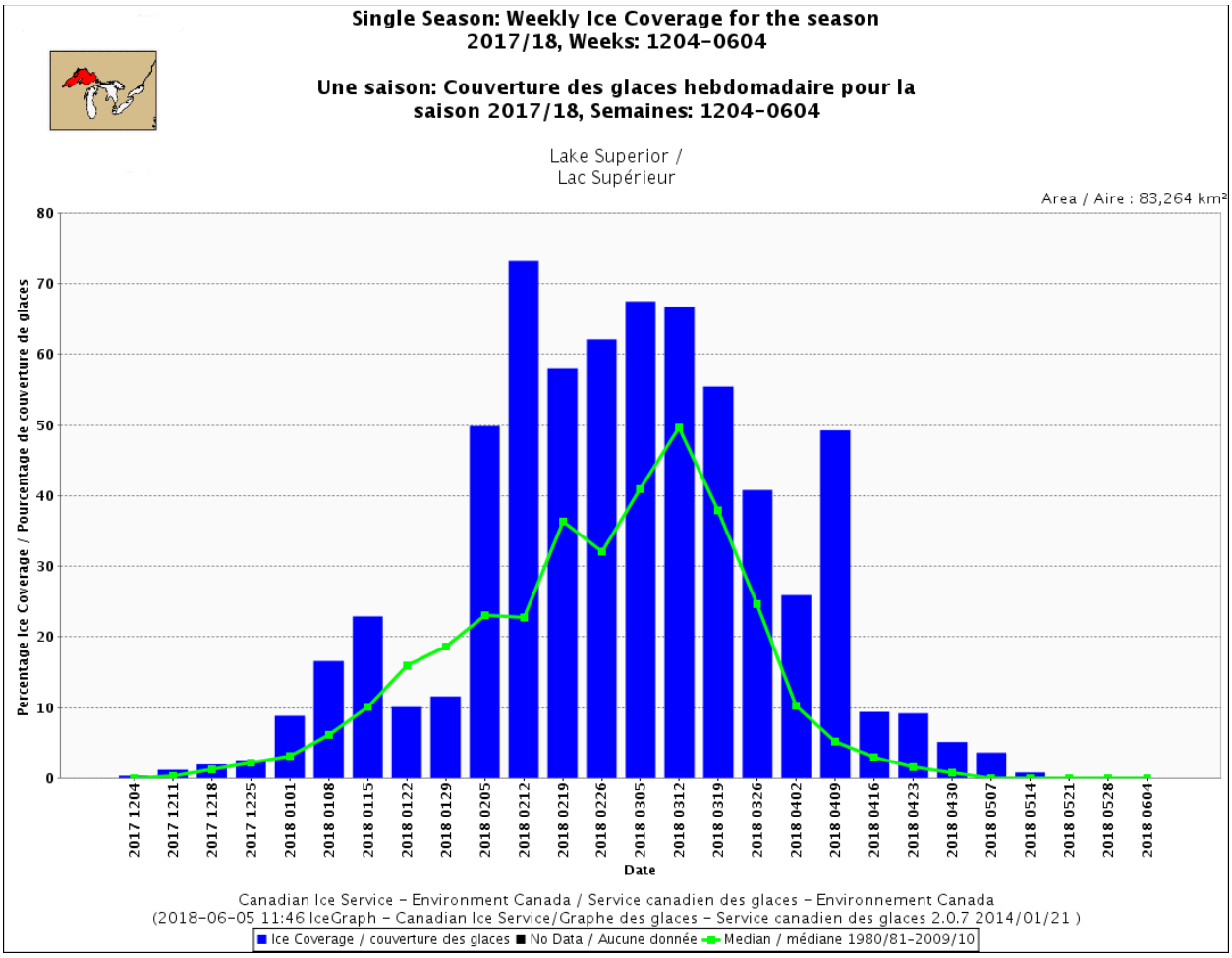

Figure 10: Weekly Ice Coverage in Lake Superior for winter 2017-18.

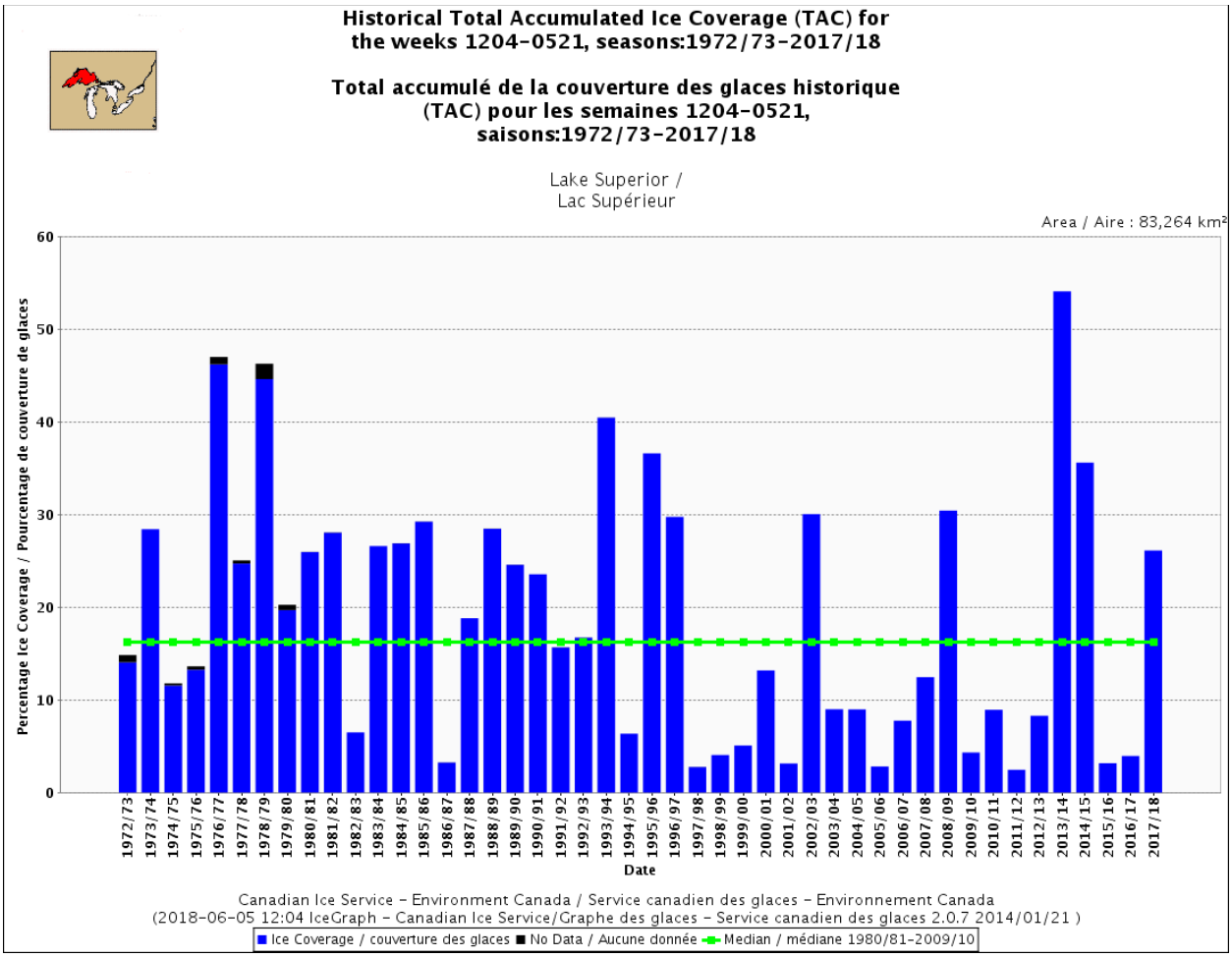

Figure 11: Historical Total Accumulated Ice Coverage in Lake Superior by season, 1972-2018.

Lake Michigan

2017-2018 Season temperatures:

Colder than normal surface air temperatures at the end of autumn over Lake Michigan were observed, ranging from 0.5°C to 1.5°C below normal. This continued through mid-January 2018, until a major shift in the pattern occurred and warmer than normal temperatures arrived. This period from mid-January to the end of the month saw temperatures range from 2°C to 5°C above the normal. This short reprieve was then replaced by a colder than normal regime once again, with the largest anomalous cold period (2°C to 4°C below climate normal) becoming established in the first half of February. This phase was then displaced by another warming trend, with modest anomalies of 1°C to 2°C above normal for the mid-February to mid-March 2018 timeframe. A final colder than normal period

was noted at the end of the 2017-2018 ice season in Lake Michigan, with cold anomalies of up to 2°C below the climatological average.

2017-2018 Ice conditions:

Lake Michigan's ice season commenced earlier than usual with the first new lake ice forming in Green Bay near the middle of December 2017. Ice quickly thickened in the southern and northern extremes of Green Bay to the medium lake ice stage near the end of the month, and ice lined the northern shore of the lake. A very rapid period of ice growth began in the last week of December and lasted until mid-January 2018. Ice cover quadrupled in the last week of December, as Green Bay was filled in its entirety with thin and medium lake ice and the northeastern portion near the Straits of Mackinac was fully covered with new, thin and some medium lake ice. New lake ice extended along the shores of the southern section of the lake as well at this point, and rapidly thickened to thin and medium along the eastern shore due to prevailing winds compressing the ice.

A drop in the ice cover was experienced during the second half of January 2018, with approximately half of the analyzed lake ice disappearing from the system. This was most observable in the southern section of the lake where ice vulnerable to destruction was destroyed along the shores. But this reduction of ice coverage was only temporary and February would lead to a massive rebound in ice concentrations.

The first half of February 2018 marked the period of peak ice coverage for Lake Michigan. The maximum ice cover of 38.10% was reached on 12 February, a week earlier than the typical median peak ice according to the 1981 to 2010 climatology. The distribution of ice was confined to Green Bay, the northeastern section of the lake and the near-shore environment in the southern section. Consolidated thick lake ice was the predominant ice type in southern Green Bay and the Bays de Noc, whereas consolidated medium lake ice was predominantly found in central Green Bay and east of Beaver Island to the Straits of Mackinac. Concentrations of lake ice were anomalous in the southern section and the northeastern section west of Beaver Island as well.

Ice coverage typically declines as late February approaches and 2018 was no exception to this pattern. Ice in the southern portion quickly melted by the last week of February, as a warmer than normal pattern overtook Lake Michigan. The ice west of Beaver Island also receded rapidly, while the consolidated ice at the entrance to Green Bay became mobile. Coverage of lake ice fell below normal in the second half of

February until mid-March. With the removal of much of the ice in less sheltered environments, the remaining ice was well situated to persist beyond the climatic normal.

A cooler than normal spring period developed in the Great Lakes basin and lake ice in the isolated sections of Lake Michigan resisted the spring break-up. By mid-April ice left in southern Green Bay and the Bays de Noc was lasting beyond the climate normal significantly, as open water conditions are expected in all of Green Bay shortly after mid-April. The final remnants of ice melted from the region by early May, approximately two to three weeks later than normal. Seasonal ice cover was overall near normal as expressed by the TAC as 2017-2018 reached 10.55%, close to the median of 9.23%.

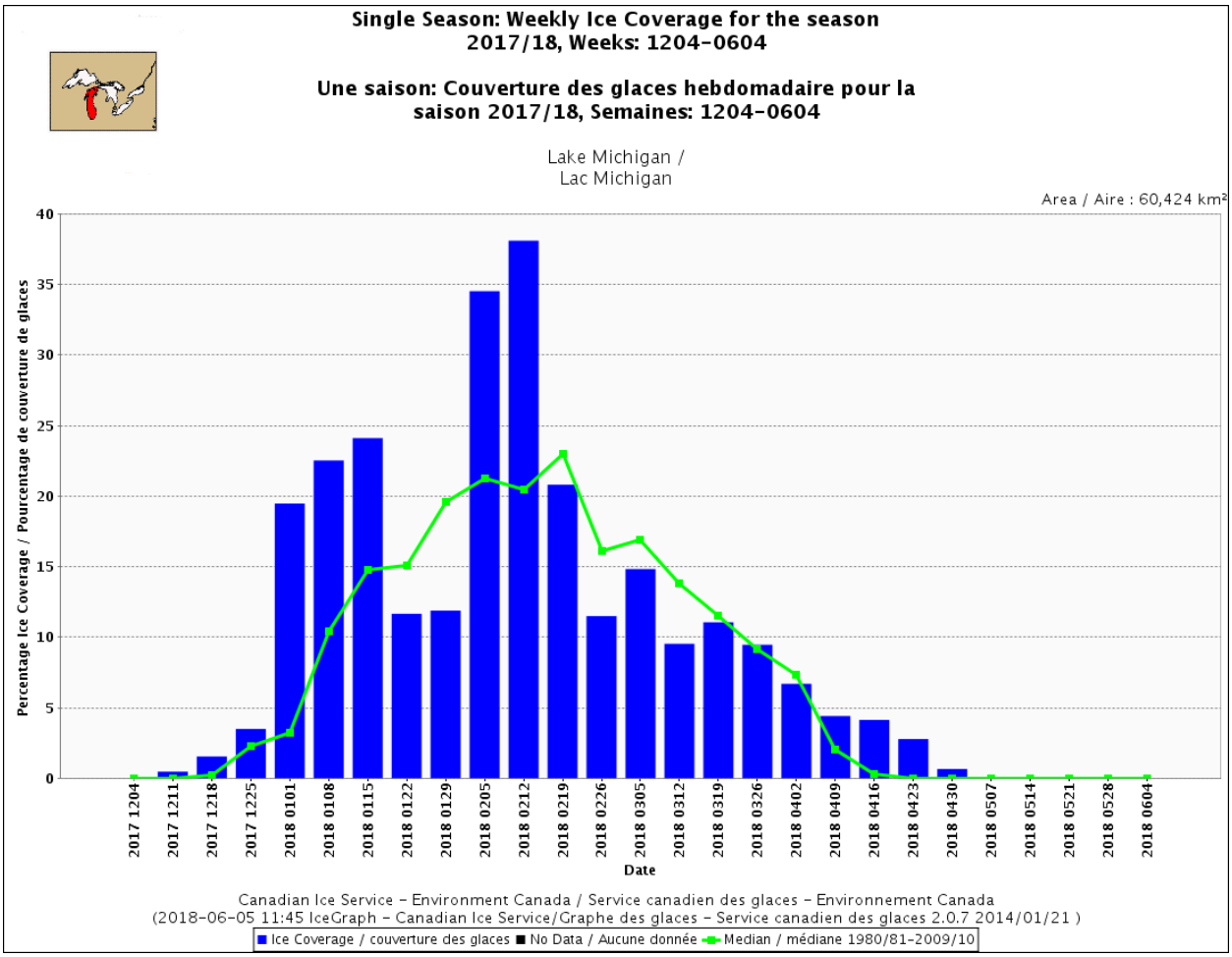

Figure 12: Weekly Ice Coverage in Lake Michigan for winter 2017-18.

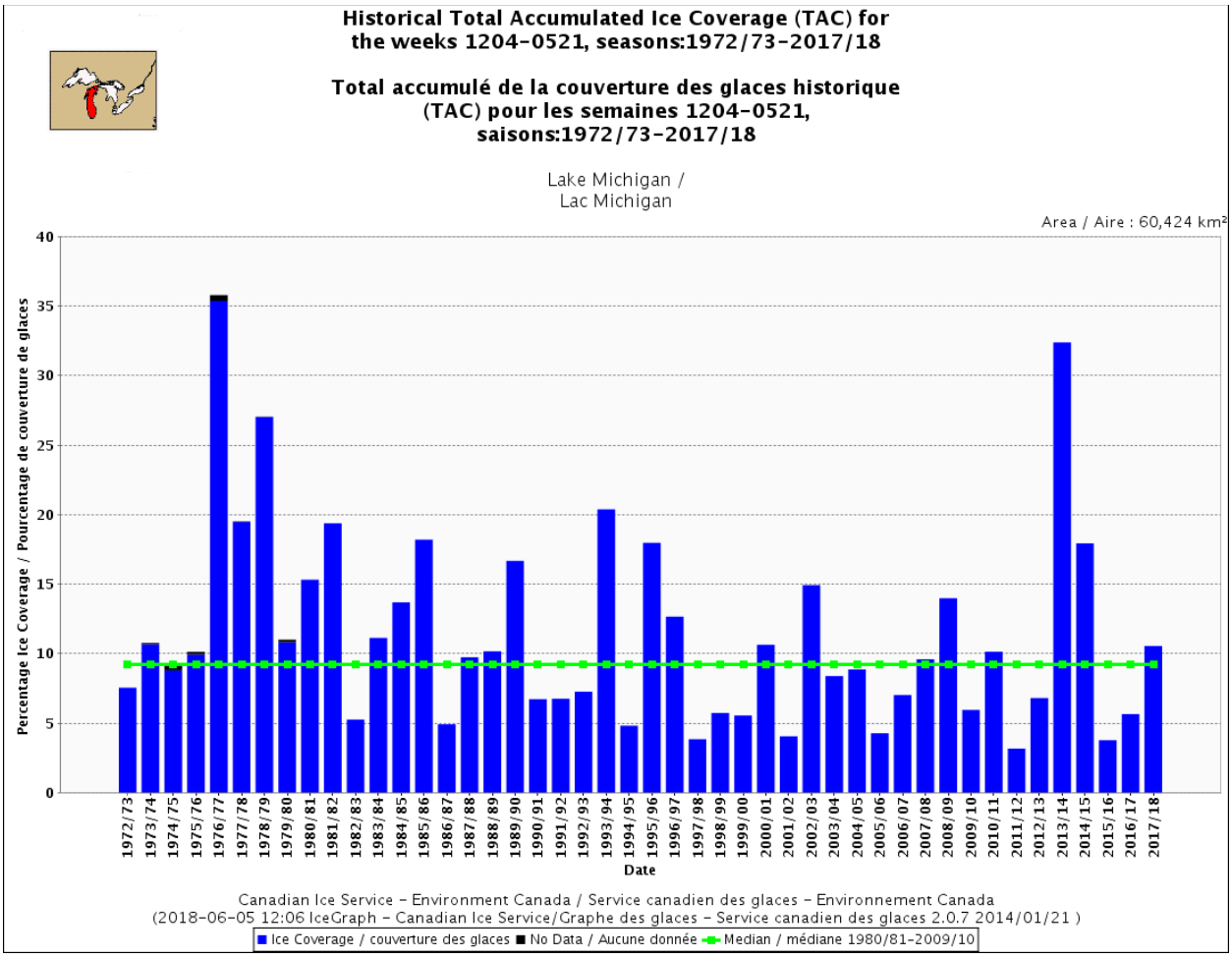

Figure 13: Historical Total Accumulated Ice Coverage in Lake Michigan by season, 1972-2018.

Lake Huron

2017-2018 Season temperatures:

Anomalously cold surface air temperatures affected Lake Huron at the outset of the ice season, falling between 1°C to 2.5°C below normal. Lake Huron experienced some of the most extreme cold in the Great Lakes region with anomalies of 3°C to 5.5°C under the seasonal values for the second half of December 2018. This continued until mid-January when a trend of warmer than normal temperatures disrupted the cold outbreak. Anomalies from mid-January to the end of the month were recorded to be 2.5°C to 3.5°C over the lake. A near normal to colder than normal period was reestablished by February and lasted until mid-month, with a maximum cold anomaly of -3.0°C in the northwestern section of the lake. A reversal of the cold anomaly followed from mid-February and endured to mid-March,

with average temperatures 2.0°C to 3.0°C above normal. A final cold phase ushered out the last remaining ice in the Lake Huron basin, with surface air temperatures 1.5°C to 3.0°C below normal from mid-March to May 2018.

2017-2018 Ice conditions:

Ice development commenced in the St. Mary's River, North Channel and Saginaw Bay in the second week of December, and steadily progressed through the rest of the month at a slightly faster than normal rate. A notable departure from normal occurred in early January 2018 as anomalous ice growth in Saginaw Bay, the North Channel, northern Georgian Bay and along the shores of Lake Huron took place. Medium mobile and fast ice was already analyzed in Saginaw Bay, as well as the St. Mary's River and eastern end of the North Channel. Ice conditions would remain in a relative steady state until early February as warmer than normal temperatures slowed the ice growth in the second half of January 2018.

Lake Huron's seasonal peak in ice cover was reached in the next period, as ice development accelerated quickly and coverage more than doubled. The maximum coverage of 80.47% was attained on 12 February, one week earlier than normal and well above the normal maximum of 46.84%. Consolidated thick lake ice was prevalent in Saginaw Bay, the North Channel, eastern and northern Georgian Bay, and the St. Mary's River. Medium and thin lake ice with some thick lake ice was widespread over Lake Huron and Georgian Bay in general, with only the central section of the lake remaining as open water. The third week of February saw a precipitous decline in ice cover to a near normal extent as ice thinned rapidly in much of the western section of Lake Huron and was destroyed over southern Georgian Bay.

From this point a steady decline ensued and ice cover fell below normal over much of the lake. Glaring absences of ice were observed in southern and western Lake Huron and most of Georgian Bay. Fast ice in Saginaw Bay proved to be no match for the warmer than normal period of temperatures for mid-February to mid-March and was quickly eroded until no ice was left in late March 2018. Ice that had collected in the southeastern portion of the lake was eventually destroyed by late March as well. Stubborn areas of ice would remain intact though, due to their isolated nature and an oncoming colder than normal temperature phase for Spring 2018.

Slow ice destruction would unfold in the North Channel and St. Mary's River for the duration of April and May 2018. By late April the ice in these locations was now present in concentrations much larger than usual relative to the climatology. Consolidated ice gradually became mobile by the first week of May, two to three weeks later than normal. The delays continued through the month as final clearing of all ice took place in the second week of May 2018. Even with the anomalous presence of ice at the end of the season, TAC was well within the normal range as it measured 21.30% for this winter whereas the median is 21.27% for the same period.

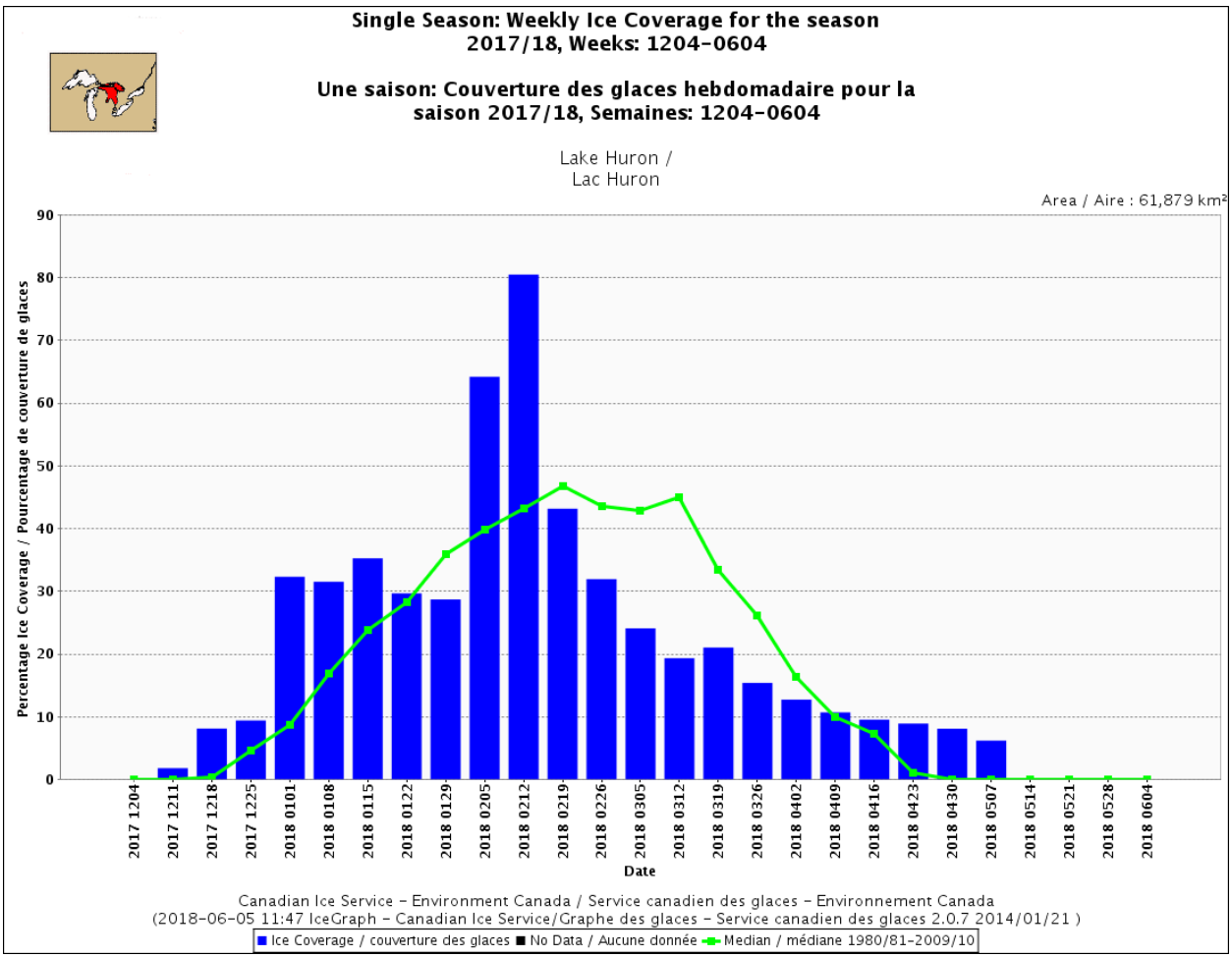

Figure 14: Weekly Ice Coverage in Lake Huron for winter 2017-18.

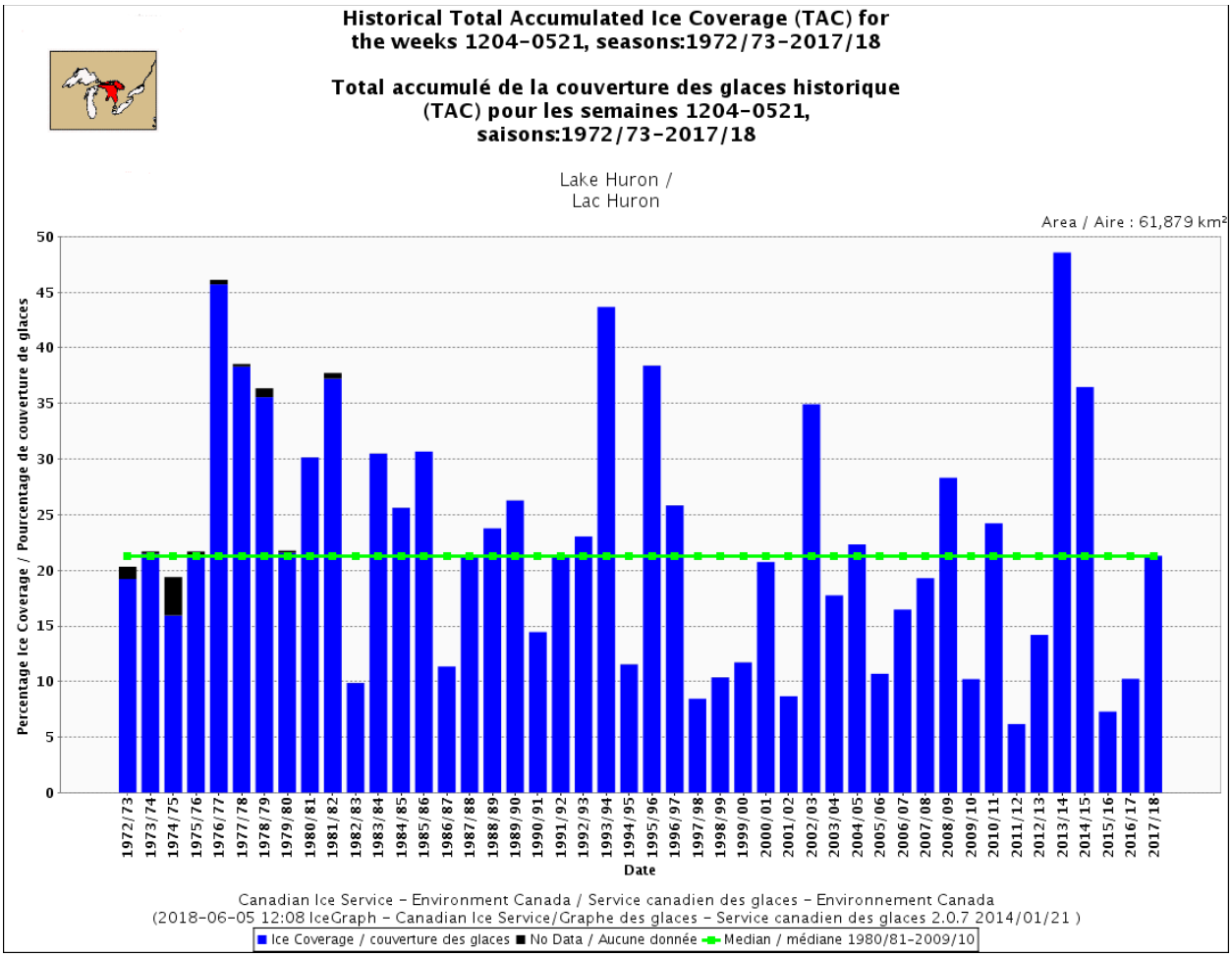

Figure 15: Historical Total Accumulated Ice Coverage in Lake Huron by season, 1972-2018.

Lake Erie

2017-2018 Season temperatures:

Lake St. Clair and Lake Erie demonstrated a colder than usual temperature pattern for the start of the winter, with anomalies of -1°C to -2°C across the region. This was amplified during the second half of December 2017, with anomalies reaching -1.5°C to -3°C during this timeframe. As was the case broadly across the Great Lakes, a warm up followed in the second half of January 2018 and anomalies approached 2°C to 3.5°C above normal. The southeastern sector of the Great Lakes then exhibited a pattern that was significantly different from the rest of the basin, as a near normal temperature regime was installed for the first half of February. A milder trend of temperatures was ushered in for the mid-February to mid-March period, ranging from 2°C to 3°C greater than the

climatology. A final phase of colder than normal air temperatures terminated the ice season for Lake Erie, with anomalous values of -0.5°C to -1°C.

2017-2018 Ice conditions:

Ice growth in the Lake St. Clair and Lake Erie system was observed earlier than climatologically usual, as new and thin lake ice was analyzed along the shores of Lake St. Clair, in the Western Basin of Lake Erie and in Long Point Bay. As intense cold arrived in the Great Lakes region for the second half of December, ice growth rapidly increased in Lake Erie. By the first week of January 2018, the Western Basin and Lake St. Clair were covered with thin and medium lake ice. This event constituted ice formation that was one to two weeks faster than normal. Prolonged anomalous cold led to extensive ice formation by mid-January 2018, development that is often reserved for early February. The basin was 92.24% covered with lake ice at this point, nearly four times the median amount of ice detected in mid-January according to the 1981-2010 climatology. Consolidated medium and thick lake ice was prevalent in Lake St. Clair, a progression only unusual in terms of ice stage of development.

A moderating trend of warmer than normal surface air temperatures from mid-January to February 2018 slowed ice growth and facilitated some ice destruction. Observations showed an area of ice cover reduction north of Cleveland, OH that gradually brought coverage back to the median climatological value. Ice thickness however continued to be augmented via compression and compaction, and thick lake ice was detected throughout Lake St. Clair, the Western Basin and eastern Lake Erie.

A dramatic rebound in ice coverage took place in early February as colder than normal air temperatures returned to the region. Peak ice cover was achieved one week earlier than normal and hit 95.33%, slightly above the median maximum ice cover of 87.33%. Thick lake ice composed the majority of the ice across the eastern section of Lake Erie and in Lake St. Clair by mid-February.

The decline of ice cover happened quickly beginning in the final week of February 2018. Ice coverage fell to approximately 50% at this stage as the western section of Lake Erie cleared of ice due to strong southerly winds and anomalously warm temperatures. Lake St. Clair emptied of ice by the first week of March, further enhancing the drastic drop in ice cover. Well below normal ice cover was now established in Lake Erie, roughly one third of the median value for the start of March. Declines slowed by mid-

March with the support of colder than normal temperatures until the end of the ice season. Resilient thick lake ice remained over the southeastern portion of the basin until the end of April, resisting destructive forces as it stayed compressed along the southern shore from Buffalo, NY to Erie, PA. This last ice was anomalous in duration despite the otherwise early clear-out of ice in the rest of the system. The TAC for the winter 2017-18 season was near normal despite the high degree of variability within the season, ending at 30.35%.

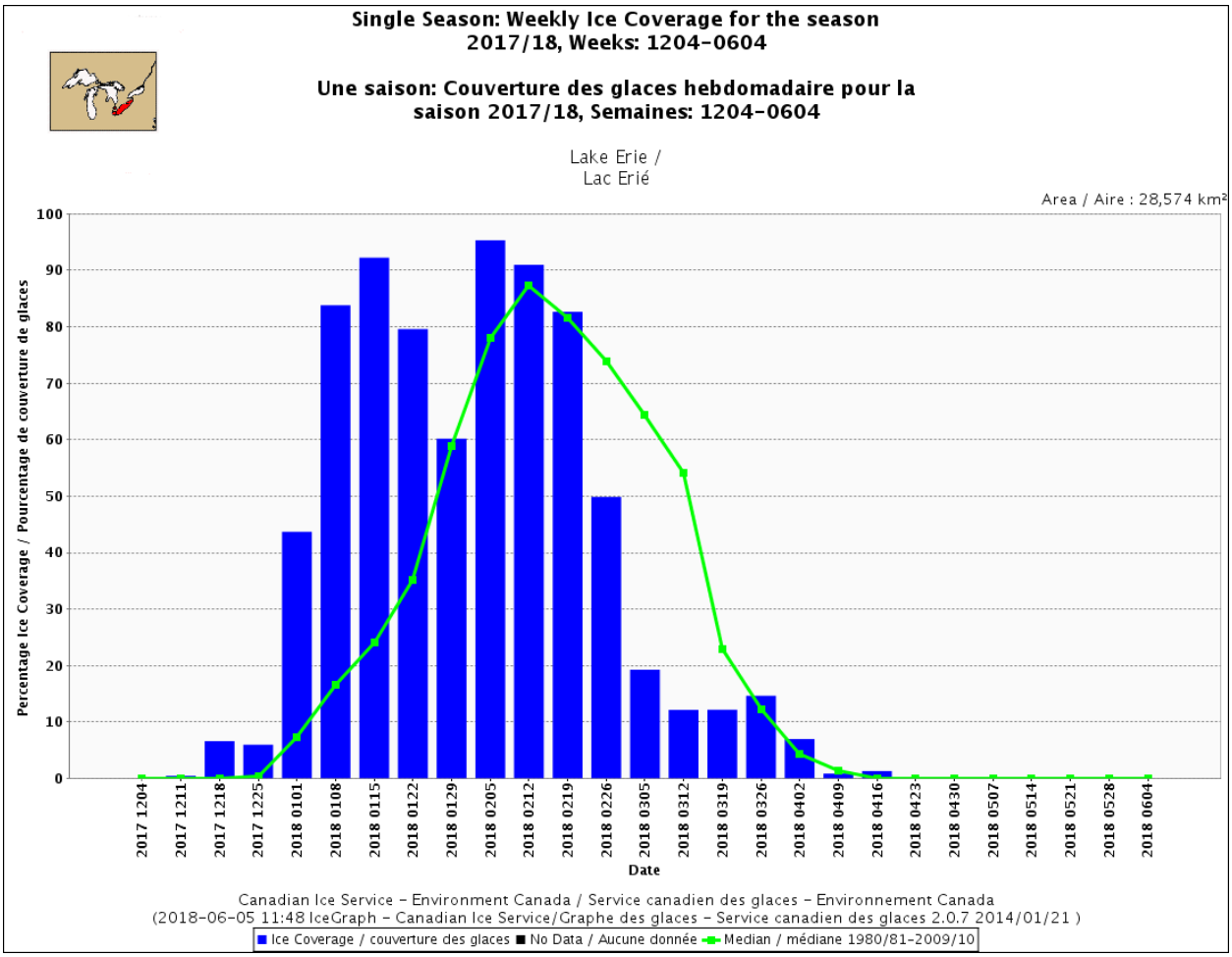

Figure 16: Weekly Ice Coverage in Lake Erie for winter 2017-18.

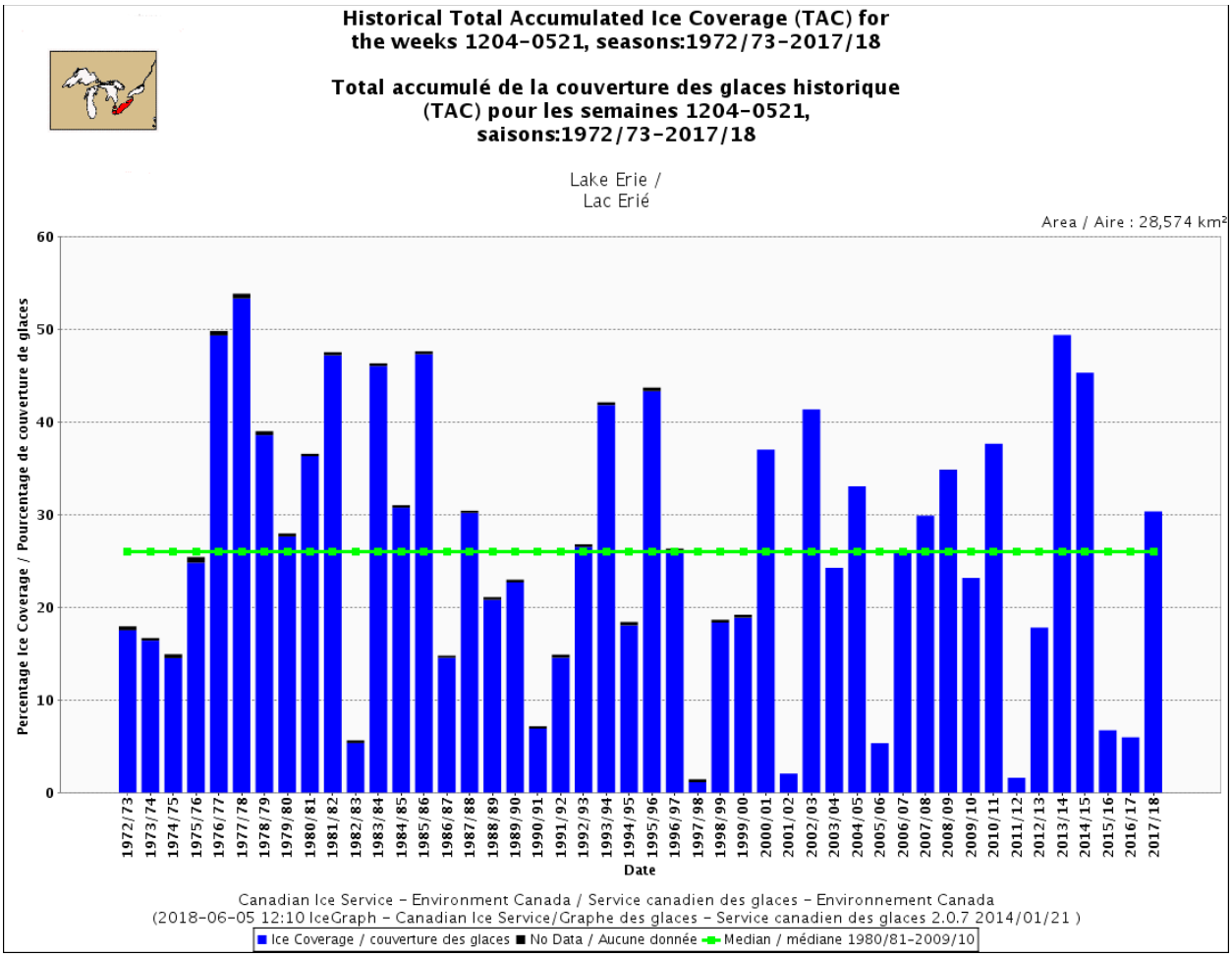

Figure 17: Historical Total Accumulated Ice Coverage in Lake Erie by season, 1972-2018.

Lake Ontario

2017-2018 Season temperatures:

A colder than normal pattern commenced over Lake Ontario in Fall 2017 and lasted through January 2018, with temperatures on average 1.5°C to 2.5°C below normal. The most significant cold during this period was experienced in the second half of December, dropping to 3.0°C to 4.5°C under the seasonal average. Warmth in the second part of January 2018 was in stark contrast to the previous colder than normal phase, as values of surface air temperature were 2.0°C to 4.0°C above the climatology.

Lake Ontario entered a neutral phase in the first half of February and near-normal temperatures were noted across the region. A return to the

regime of the second half of January was then observed from mid-February to mid-March 2018, as temperatures reached values 2.0°C to 4.0°C greater than normal. A reversal of the warming trend closed the ice season and surface temperatures dropped 1°C to 2°C below the seasonal average.

2017-2018 Ice conditions:

A quick start to the freeze-up took place in northeastern Lake Ontario, with ice lining the shores of Prince Edward County, the St. Lawrence River and eastern Lake Ontario shortly after mid-December 2017. Intense cold settled over the region during this period and anomalous ice growth spread along all the shores of the lake by early January 2018. Consolidated thin lake ice was noted in the Bay of Quinte, a relatively normal occurrence according to the 1981-2010 climatology. New and thin lake ice was well established in the St. Lawrence River, while new ice was analyzed along the northwestern and southern shores, a relatively rare event for this time of year. By mid-January this explosive and unusual ice growth led to the seasonal peak in ice coverage at 23.04%. The peak was remarkable for the timing, occurring six weeks earlier than normal, and for its magnitude, covering nearly 10% more of the lake than typical at the climatological maximum. Medium lake ice was predominant over the northeastern section by the second week of January and fast ice in the Bay of Quinte began to transition to thick lake ice.

A steep reduction in lake ice was felt in the basin during the second half of January, as coverage dropped to less than 10% from the previous high. This ice loss was mainly attributed to ice destruction along the southern shore and a retraction of the ice edge in the northeastern section. Recovery of ice cover was slow and a secondary maximum in coverage was documented in mid-February. Even during the diminishment of ice, thickening continued as thick lake ice appeared in the pack beginning in late January and was the predominant ice type in the consolidated ice in the Bay of Quinte by early February.

The second half of the ice season from the end of February to final ice melt in April was marked by significantly lower ice coverage than normal. Ice was confined to the northeastern section of the lake from the start of this period to the end of March, after which lake ice melted from the remaining isolated sections in the Bay of Quinte and St. Lawrence River. Break-up in the river and Bay of Quinte were approximately one month faster than the climate normal. With the early melt and destruction coupled with rapid freeze-up of the lake, a near-normal TAC was registered for the

season despite the high degree of variability. TAC measured 5.79%, marginally higher than the median value of 5.68% from the 30-year climatology.

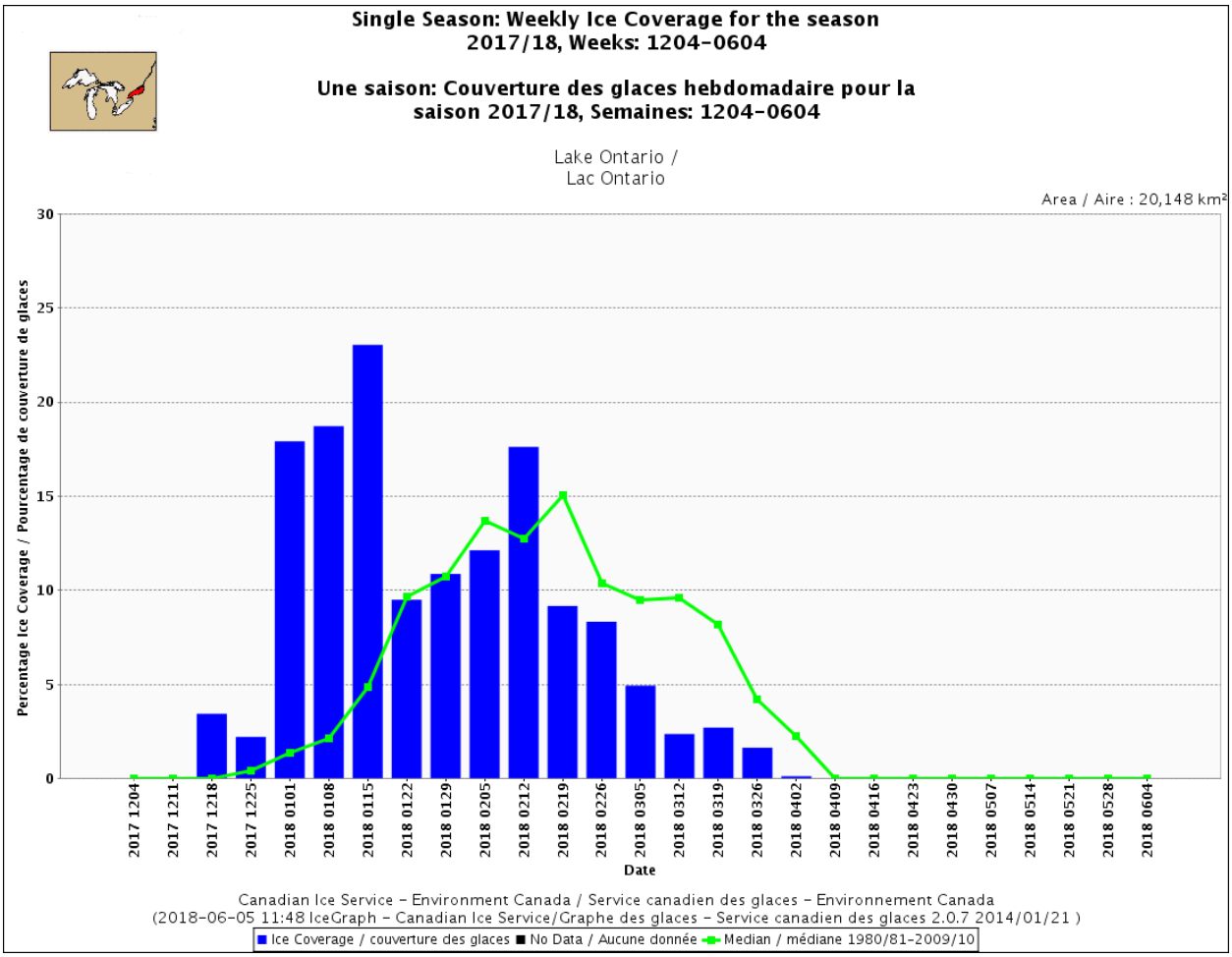

Figure 18: Weekly Ice Coverage in Lake Ontario for winter 2017-18.

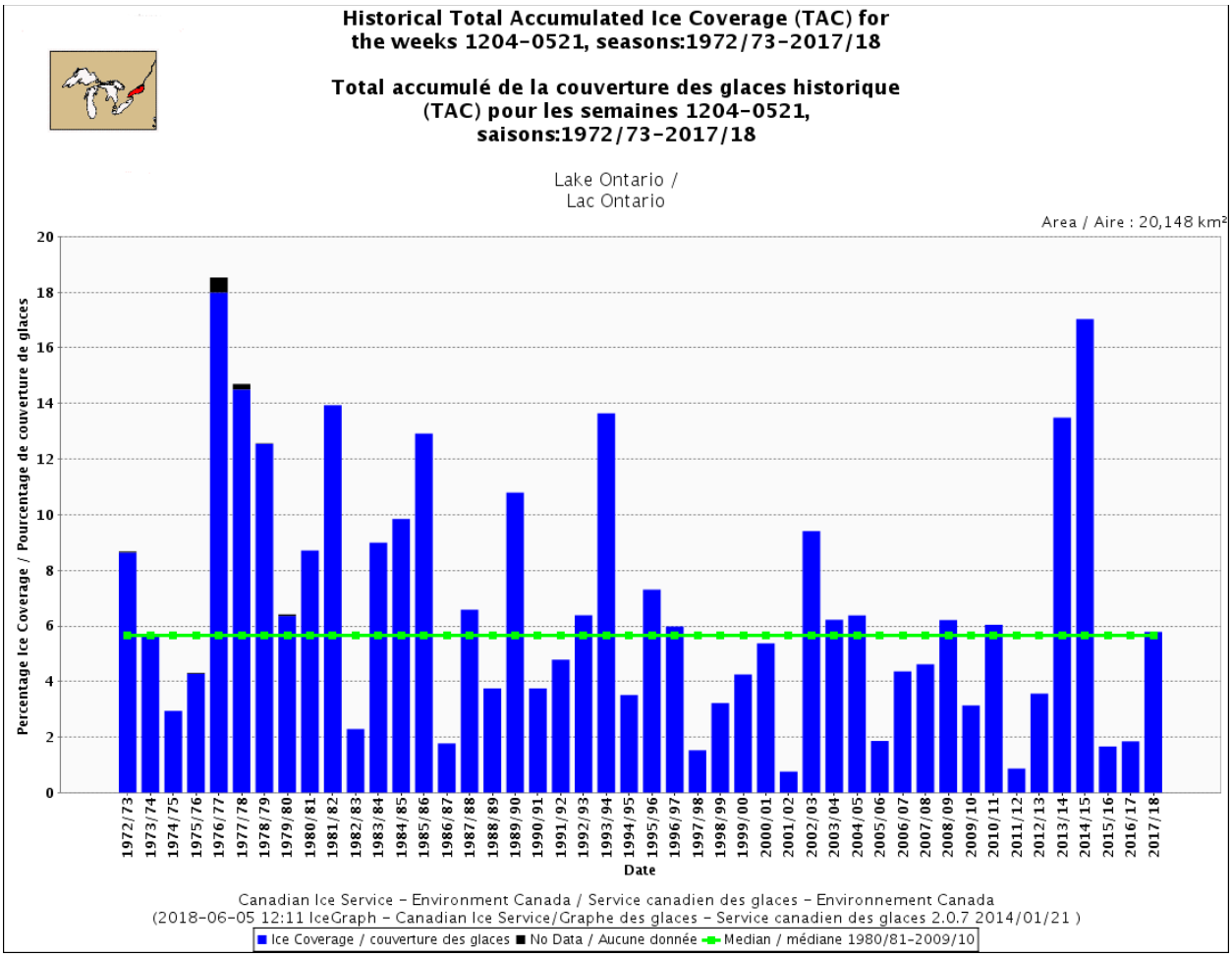

Figure 19: Historical Total Accumulated Ice Coverage in Lake Ontario by season, 1972-2018.