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GREAT LAKES ICE COVER, FIRST ICE, LAST ICE, AND ICE DURATION: WINTERS 1973-2002

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Great Lakes Ice Cover, First Ice, Last ice, and Ice Duration: Winters 1973-2002

Raymond A. Assel

ABSTRACT. A 30-winter digital ice cover data set consisting of 1210 ice charts was established for the Great Lakes. The data set is an update of a 28-winter data set given in Assel et al. (2002). The temporal and spatial distribution patterns of the dates of first ice, dates of last ice, and ice duration over the 30-winter base period are analyzed for the combined Great Lakes and for each Great Lake over the 30-winter period. Average and the composite extremes over the 30 winters are presented. Analysis methods are described, and results are summarized in a series of plots, charts, and tables. The complete data set is available as part of an official National Oceanic and Atmospheric Administration Atlas (Assel, 2003).

1. INTRODUCTION

This cryosphere is an important indicator of climate and climate change (Fitzharris et al., 1996, Magnuson et al., 2000), and lake ice is a sensitive index of regional winter climate (Assel and Robertson, 1995). Therefore, the availability of improved information on Great Lakes ice is timely. This is the first of a series of reports presenting various aspects of an analysis of a 30-year digital ice cover data set, updated from Assel et al, (2002). In this report, the results of an analysis of the dates of first ice, dates of last ice, and ice duration over a 30-winter base period are presented. The data is described, analysis methods are documented, and results are presented. Temporal and spatial trends are briefly discussed within the context of lake bathymetry (Fig. 1a), which is a proxy for lake heat storage, and winter air temperature (Fig. 1b), which is a proxy for heat loss at the lakes surface. Place names are given in Figure 1c. This report and data in Assel (2003) provides a baseline of Great Lakes ice cover and ice cover variation during the late 20th and early 21st centuries and supersedes Assel et al., 1983. The information given here and in Assel (2003) has applications to research, education, engineering, and operational planning and activities. Recent studies in which Great Lakes ice was a factor considered include climate (Lofgren et al., 2002), fish recruitment (Brown et al., 1993), and the winter aquatic system (Nicholls, 1998; Magnuson et al., 1997).

2. BASIC DATA AND ANALYSIS METHODS

The data used in this analysis is ice concentration, that is the fraction of a unit of lake surface area that is completely covered with ice. The ice concentration is contained in a grid matrix of 510 rows x 516 columns, making a total of 263,160 grid cells; each grid cell has a nominal resolution of 2.5 km x 2.5 km (Assel et al., 2002). There are 38,203 over-water cells and 224,957 land cells. There are a total of 1210 grids over the 30-winter seasons. These data were partitioned by winter season (Table 1) and an analysis for threshold ice concentration values of dates of first/last ice each winter, and ice duration (the difference between these dates) was made for each winter season. The original ice charts had ice concentration recorded to the nearest 10%. A preliminary analysis using discrete 10% values or ranges, on the date ice was first observed produced incoherent spatial patterns and was therefore not used. Instead, the analysis was made on nine overlapping threshold ice concentration values in 10% increments starting from ice concentration ≥10%, and ending at ice concentrations ≥90% (≥10%, ≥20%, ≥30%, ≥40%, ≥50%, ≥60%, ≥70%, ≥80%, ≥90%). These threshold values corresponding to ranges of ice concentration as shown in the box below. This approach produced spatially coherent patterns. If one wanted to examine the 10% ice concentration pattern (for dates of first/last ice or ice duration) it could be done by taking the differences between the ≥10% and ≥20% ice concentration. This same is true of any other adjacent ice concentration range. The dates of observed first/last ice may not be the **actual** date that ice **first formed** and **actual last date** of ice because this analysis is limited by the dates of the first and last ice charts of each winter. However, it is likely that for most of the lake's surface area that the actual date of first ice occurred somewhere between the date of the first ice chart, and the ice chart that has the observed threshold value of ice concentration. This is true because on the date of the first ice chart, most of the Great Lakes are usually open water. A similar comment is true for the date of last ice cover. The dates of first/last ice reports each winter and the percent ice cover on the date of first/last

ice reports are given in Table 1. The lake-averaged percentage of ice cover on the first and last ice chart is under 5% for most winters, and the number of days between ice charts each winter varied from 2 to 7 days (Assel et al., 2003). The estimates for date of first/last ice each winter is, in general, representative for most threshold ice concentrations for most of the surface area of the Great Lakes within these limits.

Range	Threshold
0% to 9%	none
10% to 100%	≥10%
20% to 100%	≥20%
30% to 100%	≥30%
40% to 100%	≥40%
50% to 100%	≥50%
60% to 100%	≥60%
70% to 100%	≥70%
80% to 100%	≥80%
90% to 100%	≥90%

2.1 Averages and Extremes Over the 30-Winters

The average date of first/last ice and average days of ice duration and the composite maximum and minimum of these variables were calculated from the 30 annual grids respectively. If less than 14 winters met the threshold ice concentration value for a given grid cell, then that grid cell was not included in the calculation of the 30-winter average. The composite maximum date of first ice cover is an observed climatic limit for the latest date of first ice cover, and the composite minimum is an observed climatic limit for the earliest date of first ice cover at each grid cell. In a similar fashion, the composite maximum for the last date of ice cover for a given ice concentration threshold value is an observed climatic limit of the latest date of last ice cover concentration for a given ice concentration threshold value, and the minimum for the last date of ice cover is the climatic limit for the earliest date of last ice cover. The composite maximum and minimum duration are the observed limits of ice cover duration over the 30-winter period.

2.2 Spatial Averages for Specific Depth Ranges

The dates of first/last ice and ice duration for the ≥90% ice concentration threshold and for the ≥10% ice concentration threshold were related to lake bathymetry by a grid of water depths that is coincident with the ice cover grid. The spatial average ice concentration for each winter season was calculated for the following depth ranges: >0 m and ≤20 m, >20 m and ≤50 m, >50 m to ≤100 m, >100 m to ≤200 m, and >200 m. The ≥90% (Table 2) and the ≥10% (Table 3) ice concentration threshold values were chosen for analysis here because they bracket the entire range of possible dates of first/last ice and days of ice cover duration. The ≥10% ice concentration threshold represents the ice edge boundary, concentrations below10% are defined as "open water" (World Meteorological Organization, 1970). The ≥90% ice concentration threshold is an upper limit of ice concentrations, corresponds to the WMO definitions for very closed pack (>90% but <100% ice concentration) and consolidated pack ice (pack ice that is 100% ice concentration), (World Meteorological Organization, 1970). These two extremes have obvious implications for winter navigation in the Great Lakes. The values of all other ice concentration threshold values are between these two extremes.

In making the calculation of the depth range spatial average (date: first/last ice or days ice duration) over all grid cells for a given depth range if the ice concentration for a grid cell in that depth range was below the threshold ice concentration value it was not included in the calculation. Including grid cells below the ice concentration threshold values would result in an underestimation of the area averaged value (earlier for first/last ice and shorter for ice duration) for that ice concentration threshold and depth range. However doing the calculations without these cells makes it difficult to compare values for different years because the number of grid cells, and thus the area meeting the threshold ice concentration for a given depth range, is different each year. Therefore in order to help interpret the significance of the depth averages (dates of first/last ice and ice duration) the number of cells for the >0 m and ≤20 m depth range (Fig. 2a) and for the >100 m and ≤200 m depth range (Fig. 2b) for which the ice concentration threshold value (for the ≥90% and ≥10% ice thresholds) is observed each winter for the combined area of the Great Lakes is given as a percent of the total number of grid cells for each depth range. Similar plots were produced for Lakes Superior (Fig. 2c, 2d), Michigan (Fig. 2e, 2f), Huron (Fig. 2g, 2h), Erie, (Fig 2i, 2j), and Ontario (Fig. 2k, 2l).

3. PRESENTATION OF RESULTS AND DISCUSSION

3.1 Analysis Results

The complete analysis results are available in Assel (2003). That data set is given as fixed formatted ASCII grids and as ice chart graphics that portray spatial pattern of first/last ice dates and ice duration for each ice concentration threshold value for each winter season, and are not given here for the sake of brevity. Here we present selected results from that publication and we present the results of the bathymetry and lake averaged analysis that is not given in Assel (2003). Table 2.1 to Table 2.6 and Table 3.1 to Table 3.6 can be used to identify inter-annual variations, the extremes, and typical values of the dates of first/last ice and ice duration for selected combinations of depth range and ice concentration threshold value for the ≥90% (Tables 2) and the ≥10% (Tables 3) threshold values, for the combined Great Lakes (Table 2.1 and Table 3.1) and for each Great Lake (Tables 2.2-2.6 and Tables 3.2-3.6). Thus, using Fig. 2, Table 2, and Table 3 one can evaluate the severity of any given winter season (in this data set or other winters) relative to dates of first/last ice and ice duration and place it into historical context.

Here we use charts and line graphs of the ≥90% and the ≥10% threshold values in the discussion of the spatial and temporal distribution patterns of first/last ice and ice duration. The spatial pattern for other ice concentration threshold values is similar to these two thresholds. The discussion below is limited to temporal and spatial patterns of first/last ice dates and ice duration for the >0 and ≤20 depth range, which is representative of the shore area of the Great Lakes and depths representative of the deeper mid-lake areas of the Great Lakes (different for each Great Lake). Those readers who wish to examine values for other discrete depth ranges noted above are referred to Tables 2 and Tables 3.

3.2 Long-Term Average and Trends of First Ice Dates

The spatial pattern of the 30-winter average date of first reported ice cover is portrayed in Fig. 3a. Mid-lake areas of Lakes Superior (Table 2.2, 101-200 m), Huron (Table 2.4, 101-200 m), and the northern section of Michigan (Table 2.3, 101-200 m) form ice cover ≥90% during February. However, on the long-term average ≥10% threshold plot of dates of first ice (not shown but similar to Fig. 3a), there are areas in Lakes Michigan, Huron, and Ontario that are open water. These open water areas are largest for Lakes Michigan and Ontario where they cover virtually the entire mid lake area. This pattern is attributed to the combination of lake bathymetry (Fig. 1a), and winter air temperatures (Fig. 1b). Lake Michigan has a large north to south extent, and air temperatures are usually milder in the southern end of that lake. Only during winters when much-below average air temperatures extend to the southern end of that lake for much of the winter will Lake Michigan form extensive mid lake ice cover (Assel and Quinn, 1979). Lake Ontario is the eastern most and second southern most of the Great Lakes, so that winter air masses approaching from the north and west are moderated by movement over the open waters of Lakes Superior, Huron, and Michigan, and this, in combination with the large mean depth of Lake Ontario (86 m), results in less extensive ice cover most winters (Assel et al., 2003). The perimeter of the Great Lakes, and all of Lake Erie because it is so shallow, develop ice cover ≥90% during January (Tables 2.1-2.6, 0-20 m). The shallow bay areas north of about 43.5^{0}N form ice covers ≥90% in December (Fig 3a).

The 30-winter average date of first ice for the Great Lakes as a whole varies from February 9 for mid lake (depths 101-200 m) to January 14 for shallow areas (depths ≤20 m). The maximum and minimum dates of first ice are January 29 and December 24 for the shore area and February 26 and January 17 for mid lake area (Fig. 3b, similar plots for each Great Lake are given as Fig. 3b-1 to Fig. 3b-5). The minimum date is somewhat misleading in that in extremely mild winters such as 1998 (Assel et al., 2000 and 2002) (Assel and Norton, 2002) the mid lake areas are virtually ice-free.

A linear regression analysis of the area (number of grid cells) for specific depth ranges given in Fig. 2a and Fig. 2b for the ≥90% ice threshold show that the area of ice cover expressed as a percent for both the shore and mid-lake depth ranges has a decreasing trend over the 30 winters, annual rate of decrease is 0.65% for the shore area

and 1.31% for the mid lake area. The regression coefficients were significant at the 95% level. A similar analysis for the annual dates of first ice (Fig. 3b) did not have significant regression coefficients. So, the date of first ice has not changed significantly, but the area of ice on that date for a given depth range, particularly for mid-lake areas has decreased. This is also true for amounts of ice for the dates of last ice since the areas where dates of first ice did not meet the threshold ice cover values are also the same for the dates of last ice.

3.3 Extreme Dates of First Ice

Winter 1977 provides an example of the spatial distribution pattern of dates of first ice when ice formed earlier than average (Fig. 3c). During that winter, dates of first ice in the mid lake area was January 22 and the shore areas it was December 26, both of these dates are about 3 weeks earlier than their respective 30-winter averages. The mid lake area of ice at the ≥90% threshold value was also much large than average (Fig 2b). Other winters for which the area of ice at the ≥90% threshold value for water depths between 100 m and 200 m was also much larger than average include 1978, 1979, and 1994. The average date of first reported mid-lake ice for these three winters is February 15, February 3, and January 27, respectively (Table 2.1). Winters in which the shallow lake areas (0-20 m) reported first ice, at the ≥10% threshold, earlier than the long-term average date over the Great Lakes as a whole includes winter 1977 (December 22) and winter 1990 (December 20) see Table 3.1.

The composite minimum (earliest) date of first ice at the ≥10% threshold (Fig. 3d) shows that ice formed in the shallows of the Great Lakes in December. However, the composite over the 30 winters for mid-lake areas was a no-ice condition, that is these areas were open water during one or more of the 30-winter base period.

Winter 1998 provides an example of the spatial distribution pattern of dates of first ice during a winter when ice formed later than average (Fig. 3e). Mid lake areas were open water, and ice formed in bays and the Straits of Mackinaw during January. This pattern is remarkably similar to Fig. 3d, the composite minimum over the 30-winters, but in 1998 it occurred a month later. Other winters with much-below average areas of mid-lake ice formation for the Great Lakes as a whole (Fig. 2b) include the winters of 1983, 1987, 1999, 2000, and 2002. Thus, the dates in Tables 2.1 and Table 3.1 for these winters are not important because the mid-lake areas, and to a lesser degree the shore areas, were primarily ice-free those winters. Other winters with relatively low mid-lake ice covers include winters 1975, 1976, 1995, and 2001. The extreme (climatic composite) latest date of first ice, for winters in which ice formed (Fig. 3f, ice ≥10%), occurred primarily in February and March with ice in small sporadic areas in April. The latest dates of first ice occur in January in the west end of Lake Erie, all of Lake St. Clair, and the shallow areas of Lakes Superior, Huron, and Michigan (Lake Huron -- Saginaw Bay, east shore areas of Georgian Bay and North Channel; Lake Michigan -- Green Bay; Lake Superior -- shore areas of Whitefish Bay, the Apostle Islands, and Thunder, Black, and Nipigon Bays along the north central shore.

3.4 Long-Term Average and Trends Of Last Ice Dates

Ice loss (last reports of ice) is primarily a function of the energy balance at the lakes surface, which is relatively uniform; while the date of ice formation is affected by temperature decline of the entire water column, which is influenced by lake bathymetry. This is reflected in a smaller difference in the average date of last reported ice between the shore area and mid-lake areas (March 15, March 7, respectively, Table 2.1) relative to the average dates of first reported ice for the shore and mid-lake areas (January 14, February 9, respectively, Table 2.1). Thus, for Lakes Superior and Huron, the spatial pattern of the average date of last ice cover (Fig. 4a) does not correspond to patterns of lake bathymetry (Fig. 1a) as well as the 30-winter average date of first ice (Fig. 3a).

The average dates of last reported ice occur during the month of March over most of Lakes Superior, Huron, and Erie with some shore areas losing their ice during April (Lake Superior -- the Apostle Islands, and Thunder, Black, Nipigon, Whitefish, and Keweenaw bays; Lake Michigan -- the north tip and south half of Green Bay; Lake Huron -- the Straits of Mackinaw, North Channel, east shore of Georgian Bay; Lake Erie -- the extreme eastern end of the lake). The average date of last ice ≥90% along the shores of the southern two thirds of Lake Michigan occurs in February due in part to more moderate air temperatures going southward (Fig. 1b)

The inter-annual variations in averaged dates of last reported ice for the shore and mid-lake area (Fig. 4b)[1] and percent of depth range with ice (Fig. 2b) have two prominent features: the occurrence of local minima during some strong El Nino winters (1983, 1987, and 1998) and the dramatic shift to earlier dates during the last five winters of the period of record. The shift to earlier dates during the winters 1998-2002 is in agreement with two recent studies of annual maximum ice cover, which indicates the average of the annual maximum ice covers of those 5 winters is the lowest 5-winter average in four decades (Assel and Norton, 2002; Assel et al., 2003). This suggests a change in the average dates of last ice cover may be occurring in mid lake regions of the Great Lakes. However, several more years of observations are needed to confirm that a regime change to earlier dates of last ice is indeed taking place.

3.5 Extreme Dates of Last Ice

Winter 1994 provides an example of the spatial distribution pattern of dates of last ice during a severe winter (Fig. 4c). During that winter, dates of last ice ≥90% in mid-lake areas and shore areas averaged March 19 and March 31 respectively, about 2 weeks later than their respective 30-winter averages (Table 2.1). Virtually all of the mid-lake area (>100 m and ≤200 m) was covered by ice at the ≥90% threshold value that winter (Fig 2b). Dates of last ice at the ≥90% threshold value were in April over the southern two-thirds of Lake Superior, most of Green Bay, Grand Traverse Bay, the Straits of Mackinaw in Lake Michigan, North Channel, Georgian Bay, Saginaw Bay and the eastern portion of the lake in Lake Huron, the eastern half of Lake Erie, and the extreme east tip of Lake Ontario. Last dates of ice in much of the rest of the Great Lakes occurred in March. Winters with similarly late average dates of last mid lake ice include 1979, 1996, and 1997 (March 25, March 31, and March 25, respectively, Table 2.1).

The 30-winter composite maximum (latest) date of last reported ice (Fig. 4d, ≥10% threshold) shows that Lake Superior is in a class by itself with last dates of ice in May over the western half of the lake and out from the south and southeast shore, and dates of last ice in April over the rest of that lake. This is due to lower air temperatures in the vicinity of Lake Superior relative to the other Great Lakes. Composite latest last dates of ice also occur in May in the northern tip of Green Bay, portions of the Straits of Mackinaw, North Channel, the eastern shores of Georgian Bay and the Bruce Peninsula, and in the eastern tip of Lake Erie. Much of the rest of Lakes Huron and Erie, northern Michigan, and the east end of Lake Ontario have latest last dates of ice in April. The composite maximum (latest) dates of last ice occur in March on the southern half of Lake Michigan and in March and February on Lake Ontario.

Winter 1998 (Fig. 4e) is representative of the set of extremely mild winters noted earlier in section 3.3 (winters 1983, 1987, 1999, 2000, and 2002). During such winters mid-lake areas are virtually ice-free, and less than half the shore area have ice cover (Fig. 2a) so that the dates of last ice (Table 2.1, Table 3.1) represent only a small portion of areas associated with the given depth ranges. This is true to a lesser degree for mid-lake areas in winters 1975, 1976, 1995, and 2001 (Fig. 2b). In winter 1998, the last dates of ice ranged from January through April and are spatially sporadic (Fig. 4e). Lake Erie is virtually ice-free; the last dates of ice in Sandusky Bay in western Lake Erie occur in January. Last ice in bays and shallow areas in Lakes Superior, Huron, and Michigan occur primarily in February and March and on northern Lake Superior (Black and Nipigon Bays) into April. Winters 1998 and 2002 are remarkable in their similarity to the composite minimum (earliest) date of last ice (Fig. 4f). Winter 1998 set new low records for annual maximum ice extent (Assel et al., 2000) and it and winter 2002 influenced the composite minimum disproportionately. Composite minimum (earliest) last reported ice (Fig. 4f) occurs in February and March in bays, shallow lake areas, and in a discontinuous narrow ban along the perimeter of the lakes.

3.6 Long-Term Average and Trends of Ice Duration

The spatial distribution pattern of average duration for ice cover ≥90%, the difference in days between Fig. 3a and Fig. 4a, is portrayed in Fig. 5a. Ice duration is 90 days or more in the shallow shore areas of the Great Lakes

[1]Similar plots for each Great Lakes are given as Fig. 4b-1 to Fig. 4b-5.

(Lake Superior -- Duluth Harbor, the Apostle Islands, Thunder, Nipigon, Black, and Keweenaw bays, and the shallow area of Whitefish Bay; Lake Michigan -- Green Bay; Lake Huron -- the St. Marys River, North Channel, and the eastern shores of Georgian Bay and Saginaw Bay). Long-term average ice duration of more than 45 days but less than 90 days occurs lake-ward of these bay areas and over most of Lake Erie. Ice duration less than 45 days occurs in the deepest areas of Lakes Superior, Huron, Michigan, and Ontario. The 30-winter statistics for depth-averaged ice duration for the entire Great Lakes is given as Table 2.1, summaries for each Great Lake are given in Table 2.2 through Table 2.6. The mid-lake areas average 27 days of ice, while shore areas average[2] 61 days. The inter-annual range (minimum to maximum) of the spatial average durations[2] is 33-89 days for the shore area and 2-56 days in the mid-lake area (Table 2.1, Fig. 5b). The lower than average ice duration in the last 5 winters (Fig. 5b) is due primarily to earlier dates of last ice. Plots similar to 5b for each Great Lake, Fig. 5b-1 to Fig. 5b-5, show that the lower than average ice duration during the last 5 winters is most pronounced on Lakes Superior (Fig. 5b-1). Average mid-lake ice duration[2] from lowest to highest (ice cover ≥90%) is as follows: Lake Michigan 10, Lake Ontario 11, Lake Huron 20, Lake Superior 31, and Lake Erie 43 (Fig. 5b-1 to Fig. 5b-5, Table 2.2 through Table 2.6). Thus, Lake Erie, the most southern of the Great Lakes and exposed to the mildest winter temperatures (Fig. 1b), ironically has the highest ice cover duration, likely due to its shallow depth. Average duration[2] (for ice cover ≥90%) in the shore region of each Great Lake in order from greatest to least is: Lake Huron = 72, Lake Superior = 67, Lake Michigan = 56, Lake Erie = 48, and Lake Ontario = 42. Thus the northern Great Lakes (Superior, Huron, and to a lesser degree Michigan) have the greatest duration of shore region ice cover, likely because of longer duration of lower air temperatures.

3.7 Extreme Ice Duration

Winter 1994 (Fig. 5c) is an example of a spatial pattern of ice cover duration for very severe winter. In 1994 mid-lake duration (Table 2.1) averaged 52 days, while the shore area ice cover duration averaged 86 days (both are about 3½ weeks more than the long-term averages of 27 and 61 days, respectively). Winters similar to 1994 for mid lake ice duration[2] include 1977, 1979, and 1996 with 55, 54, and 56 days of mid-lake ice duration (Table 2.1). Winters similar to 1994 shore ice duration[2] include 1977, 1978, 1979, 1984, 1990, and 1996 with 86, 80, 81, 82, and 89 days of ice duration, respectively. The composite maximum ice duration for ≥10% ice cover (Fig. 5d) is shown for comparison. The composite maximum ice duration is between 135 and 180 days in bays and shoal areas of Lake Superior -- Thunder, Black, Nipigon, Keweenaw, and Whitefish bays, the Apostle Islands, and the southeast shore in the vicinity of Marquette Michigan; Lake Michigan -- north and south ends of Green Bay; Lake Huron -- St. Marys River, North Channel, east shore of Georgian Bay, St. Martins Bay in the Straits of Mackinaw, and the southern end of the lake in the vicinity of Port Huron; Lake Erie -- the extreme eastern tip of that lake. Lake areas with composite maximum durations of 90-135 days include in general all but the deepest lake areas (Lake Superior -- the west half and the perimeter of the eastern basin; Lake Michigan -- Green Bay and north of a line from the northern entrance of Green Bay to Traverse City then in a band along the eastern shore to Muskegon; Lake Huron -- most of Georgian Bay and the perimeter of the main lake extending 5-50 km. Composite maximum ice duration of 45-90 days occurs in the remaining mid-lake areas of the Great Lakes with the exception of Lake Ontario where maximum ice duration in the rest of its mid lake area is 1-45 days.

Winters with average ice duration less than 1 week (for ≥90% ice cover), are the shortest ice cover duration winters for the mid-lake area (100-200 m depth range). These winters include 1987 (3 days), 1998 (2 days), 2000 (5 days), and 2002 (3 days). Winter 1998 (Fig. 5e) provides an example of this type of extremely mild winter. Winters when the mid-lake ice duration ranged between 1 and 2 weeks are also noteworthy and include the winters of 1973 (14 days), 1976 (14 days), 1983 (9 days), 1995 (8 days), and 1999 (8 days). In the shore area (less than 20 m depth) winters with average ice duration between 30 and 45 days, the lower extreme of minimum ice cover, include 1973 (44), 1975 (43), 1983 (32 days), 1987 (34 days), 1995 (45+ days), 1998 (39 days), 2000 (38 days), and 2002 (45). Thus, the winters 1983, 1987, 1998, 2000, and 2002 have extremely low ice duration in both shore and mid-lake regions of the Great Lakes. These are the winters that likely contributed most to the composite minimum ice duration pattern (Fig. 5f).

[2]Rounded to the nearest whole day.

The composite minimum duration exceeds 90 days in Nipigon and Black Bays (Lake Superior), and it exceeds 75 days in portions of Lake Superior -- Apostle Islands, shallow areas of Whitefish Bay; Lake Huron -- the St. Marys River, North Channel, east shore of Georgian Bay, and east shore of Saginaw Bay; Lake Michigan -- the north and southern tips of Green Bay. Lake-ward of the these areas ice cover is limited to shallows of the Great Lakes where its duration in most cases does not exceed 30 days, exceptions include the Straits of Mackinaw and discrete areas of the previously mentioned bays where the duration is up to 60 days. Thus, ice duration is virtually nil over most of the open waters of the Great Lakes on the composite minimum ice duration chart (Fig. 5f).

4. SUMMARY AND OBSERVATIONS

The analysis given in this report provides a climatic baseline of the dates of first/last ice and ice duration for each of 30 winters for discrete depth ranges and ice concentration threshold values for the Great Lakes as a whole (Table 2.1 and Table 3.1) and for individual Great Lakes (Table 2.2 through 2.6 and Table 3.2 through 3.6). The objective is to provide ice cover information in the public, government, and private sectors for research, education, engineering, and operational applications. This report documents analysis methods and supplements the analysis products on the dates of first ice, last ice, and ice duration given in Assel (2003). That data, which is available as computer ASCII grid files and plot files, consist of nine threshold values of ice concentration for each winter, the 30-winter average, the composite maximum, and composite minimum.

4.1 Lake Bathymetry

The spatial patterns of dates of first ice are related to lake bathymetry, the shallower areas form ice first as shown in Fig. 3, Tables 2.1, and Tables 3.1. Average date of first ice in shallow waters (up to 20 m depth) is January 8 and January 14 (for the ≥10% and ≥90% ice concentration threshold values, respectively), while it occurs about 4 weeks later (February 5 and February 9 for the ≥10% and ≥90% ice threshold values respectively) for the deeper mid lake waters (>100 to 200 m). A representative variation about these average dates over the 30-winter period is provided by the 25% and 75% quartiles for January 8 (January 2, January 13), January 14 (January 8, January 21), February 5 (January 29, February 9), and February 9 (February 4, February 16), respectively. Similar observations can be made for each Great Lake from the data given in Tables 2.2 through 2.6 (≥90% ice threshold) and Tables 3.2 through 3.6 (≥ 10% ice threshold).

The spatial patterns of dates of last ice are not as well related to lake bathymetry, Fig. 4, as dates of first ice because ice ablation is primarily a function of the energy balance at the lakes surface, existing ice cover, and ice movement by winds and currents. The average date of last ice varies from March 22 to March 15 in the shallow depth regime, and from March 14 to March 7 in the mid lake depth regime, for the ≥10% and ≥90% ice threshold values, respectively. Typical variations of these averages over the 30-winter base period as indicated from the 25% and 75% quartiles are as follows: for March 22 (March 16, March 31), for March 15 (March 10, March 23), for March 14 (March 4, March 25) and for March 7 (March 1, March 17), respectively. Similar observations can be made for each Great Lake from the data given in Tables 2.2 through 2.6 (≥90% ice threshold) and Tables 3.2 through 3.6 (≥10% ice threshold).

The 30-winter average duration[3] of the ice cover, is about twice as long in the shallow depth regime (74 days and 61 days for the ≥10% and the ≥90% ice threshold values, respectively) as it is for the mid-lake depth regime (38 and 27 days, respectively). The 25% and 75% quartiles of these long-term averages are as follows: for 74 days (63, 88 days), for 61 days (47, 73 days), for 38 days (22, 53 days) , and 27 days (14, 40 days), respectively. Similar observations can be made for each Great Lake from the data given in Tables 2.2 through 2.6 (≥90% ice threshold) and Tables 3.2 through 3.6 (≥10% ice threshold).

[3]Rounded to the nearest whole day.

4.2 Temporal Trends

A regression analysis of the annual values (winters 1973 through 2002) of the percent ice covered area for the Great Lakes surface area bounded by the shore and the 20 depth contour (shore regime), and for that part of the lake surface bounded by the 100 and 200 m depth contour (mid-lake regime) for the dates of first reported ice cover show average annual declines of 0.65% and 1.31% respectively, over the period of record. The last reported dates of ice for the Great Lakes (Fig. 4b) show two prominent features: (1) earlier dates of ice loss during the extremely strong El Nino events of 1983, 1987, and 1998, and (2) a trend for earlier than average ice loss dates during the last five winters of record. However, a linear analysis of the dates of first ice, last ice, and the magnitude of ice cover duration do not have significant coefficients at the 95% level. Thus, while the percent (amount) of ice covered area in the shore regime and mid-lake regime is decreasing the date of occurrence apparently is not. The likely reason for this is that ice formation is a discrete event (ice or no ice). If the precursor processes needed for ice formation do not occur (the cooling of the entire water column to the temperature of maximum density in late fall and early winter, followed by the further cooling of surface mixing layer to the freezing point, followed by the loss of the heat of crystallization at the water's surface) ice formation will not occur.

4.3. Future Ice Cover

It is likely that the annual time series of dates of first ice cover will have a higher frequency of a "no ice" condition in the future if global warming continues (Lofgren et al., 2002). This will occur first in the deeper areas of the Great Lakes because of their greater heat storage and because of the action of strong winds, which can retard or prevent ice formation. In fact, the deeper portions of the Great Lakes do not form ice every winter under the current climate as evidenced by winters during the last 30 years in which ice concentration was <10%[4], see : Lakes Michigan and Huron (Table 3.3 and Table 3.4 for depths >200 m) and Lakes Erie and Ontario (Table 3.5 and Table 3.6 for depths >50 m).

The record of freeze-up at Grand Traverse Bay on Lake Michigan provides evidence this is also occurring in some of the deeper bays of the Great Lakes over the past 30 winters relative to the past 150 winters. The frequency of occurrence of winters without freeze-up at the west arm of Grand Traverse Bay is over three times as great during the 30-winters 1973-2002 compared to the four consecutive 30 winter periods prior to it (Table 4). And freeze-up has only occurred 3 times during the last (1993-2002) 10 winters in Grand Traverse Bay. Thus, instead of a smooth linear decline the time series of annual date of first ice might show a "step change" from a" ice" to a "no ice" condition. The date of last ice for mid lake regions also provides evidence for a possible "step change" to earlier last ice dates (Fig. 4b). However, more data, at least another decade of observations, is needed to see if that pattern will continue. If it does winters with virtually no mid lake ice formation and only sporadic shore ice formation such as 1998 and 2002 will become more frequent and perhaps more intense in the 21st Century.

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[4]Ice <10% is considered open water and is indicated by "NA" in Tables 3.2 through 3.6.

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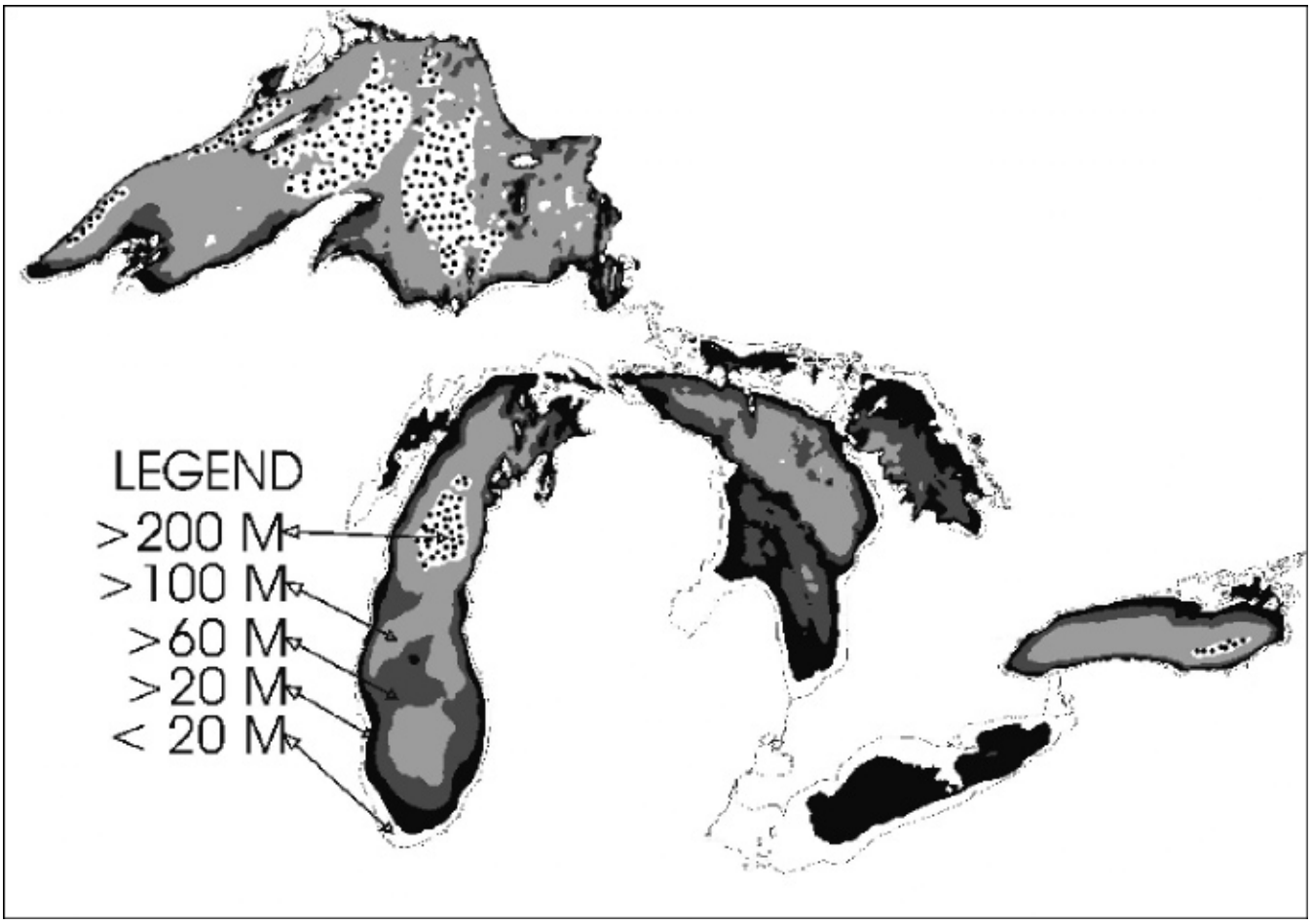

Figure 1a. Lake Bathymetry.

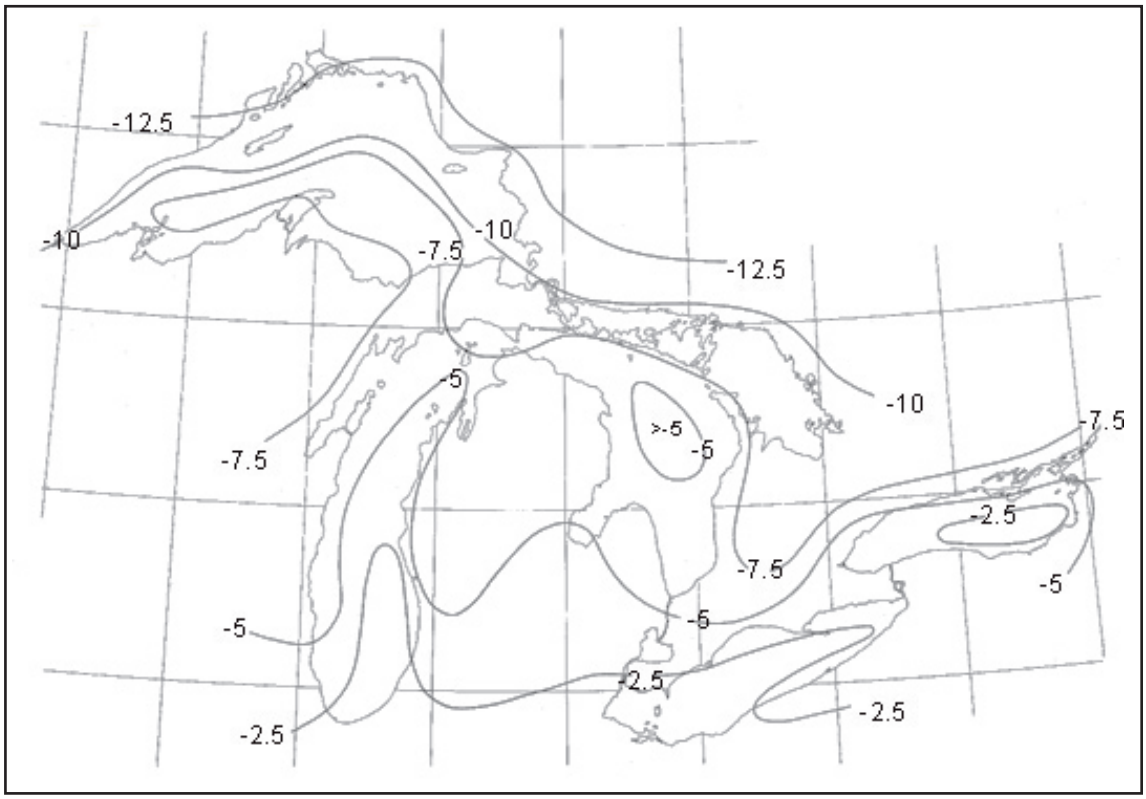

Figure 1b. Average February air temperatures (oC).

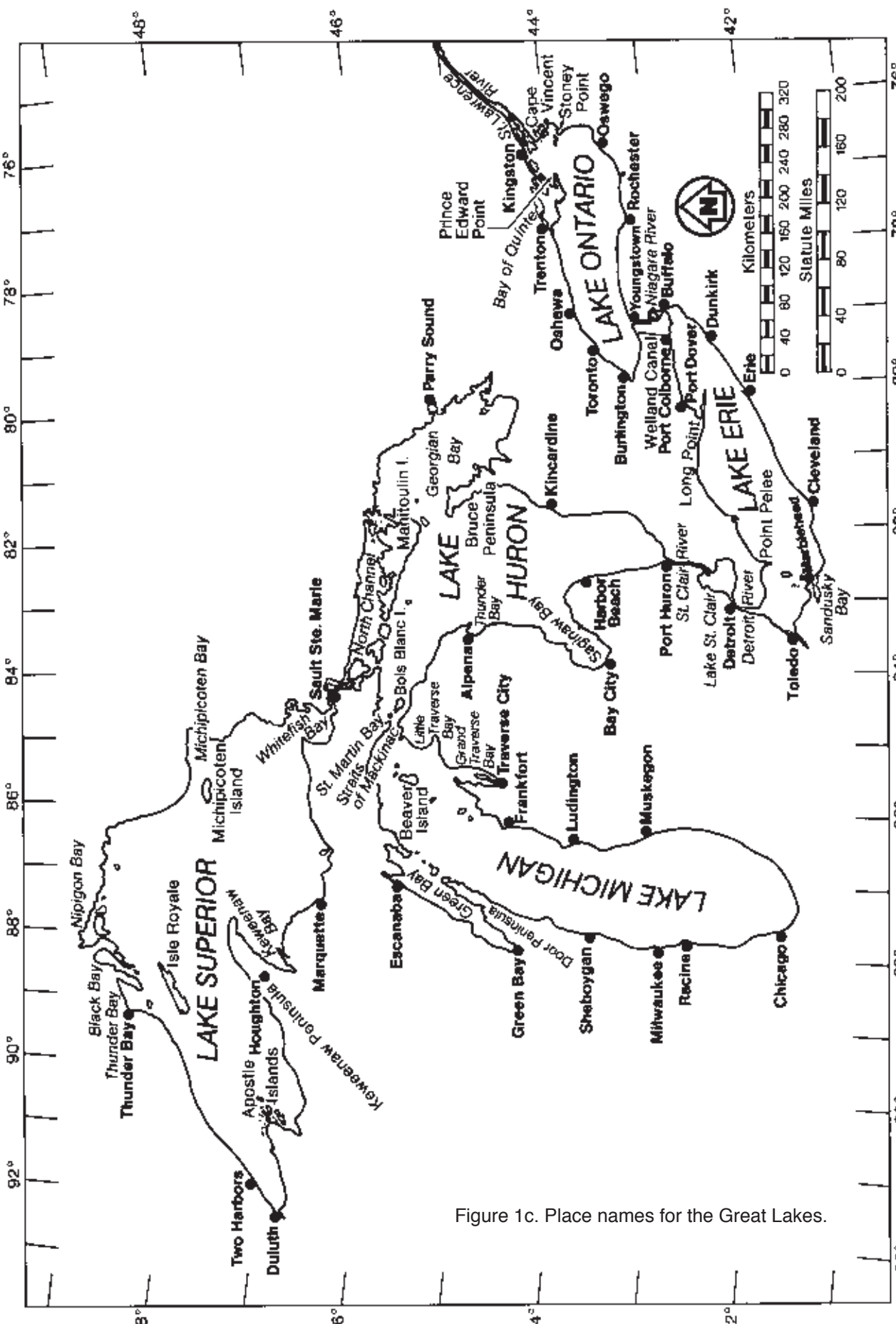

Figure 1c. Place names for the Great Lakes.

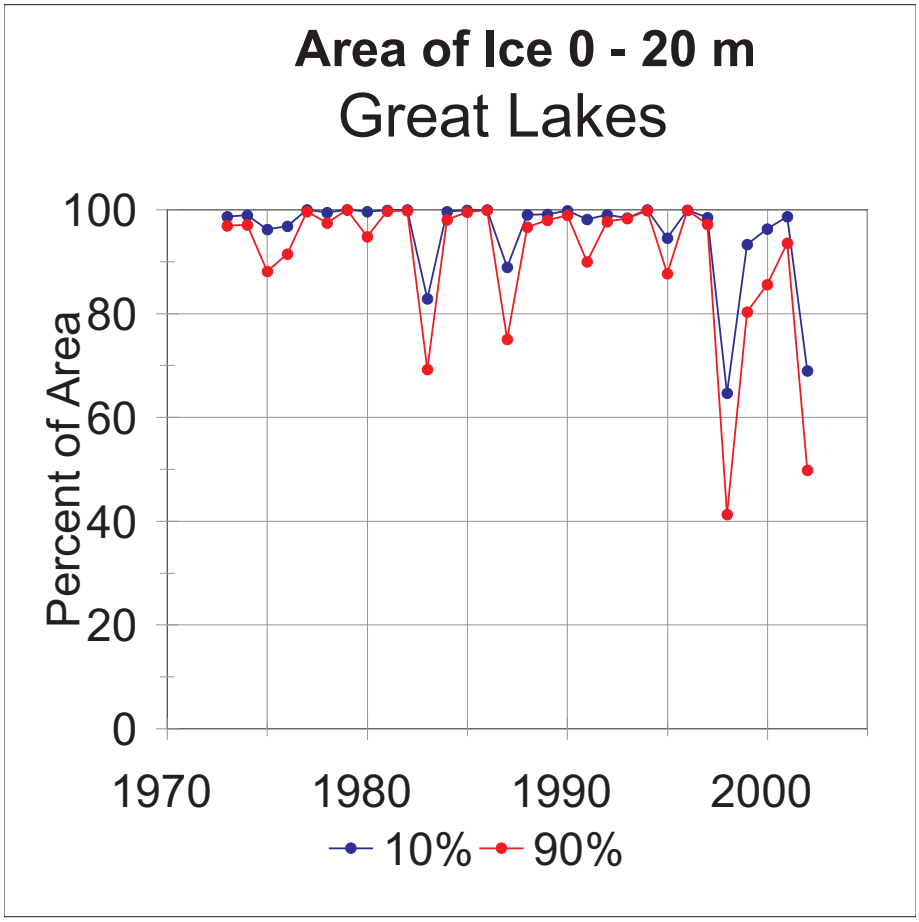

Figure 2a. Combined Great Lakes inter-annual variations in the percent of depth range (≤ 20m) with ice at the ≥ 90% and with ice at the ≥ 10% ice concentration threshold values.

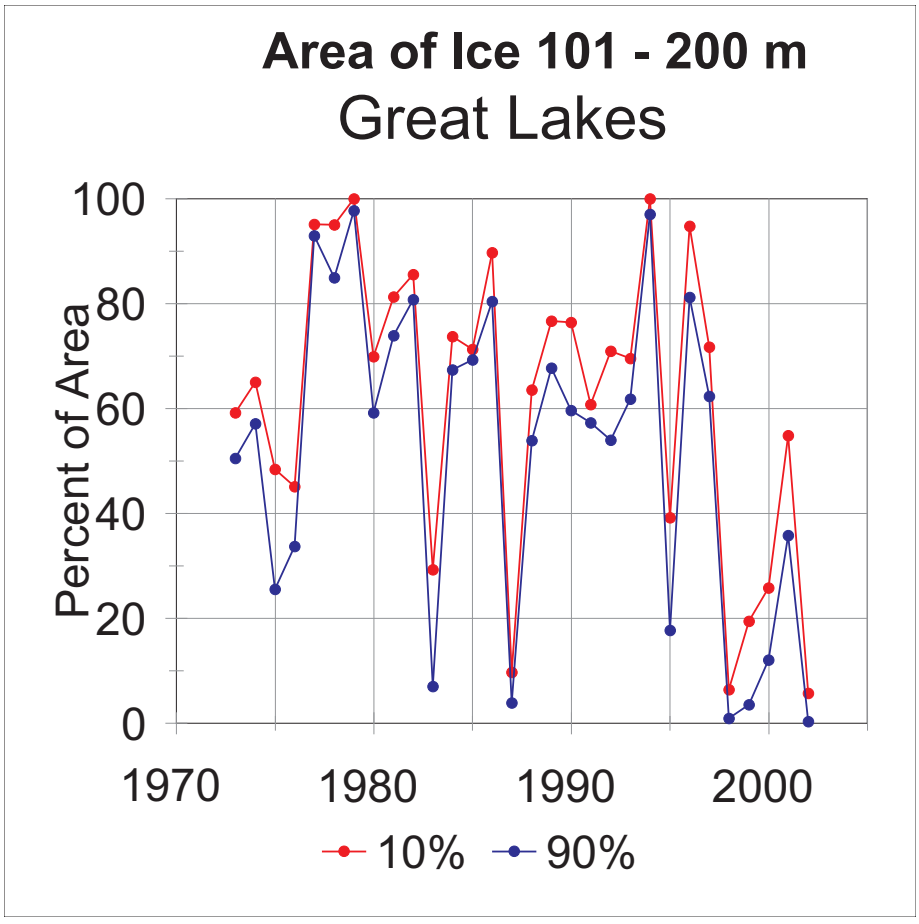

Figure 2b. Combined Great Lakes inter-annual variations in the percent of representative mid-lake depth range with ice at the ≥ 90% and the ≥ 10% ice concentration threshold values.

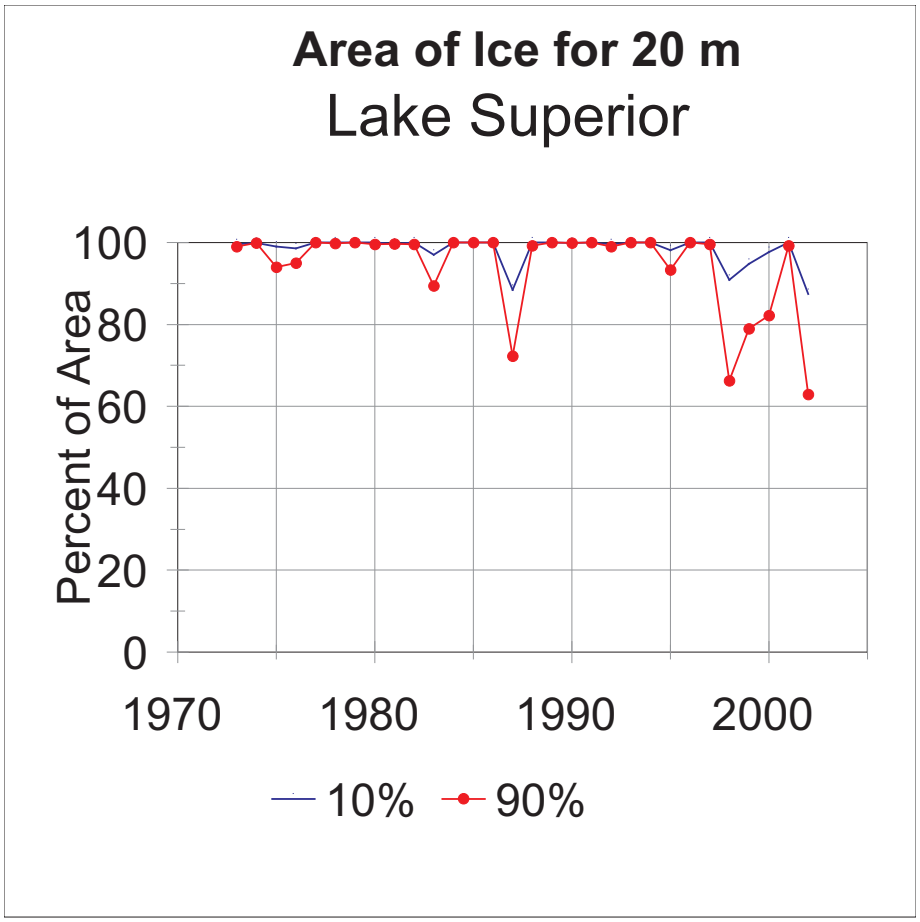

Figure 2c.Same as 2a but for Lake Superior.

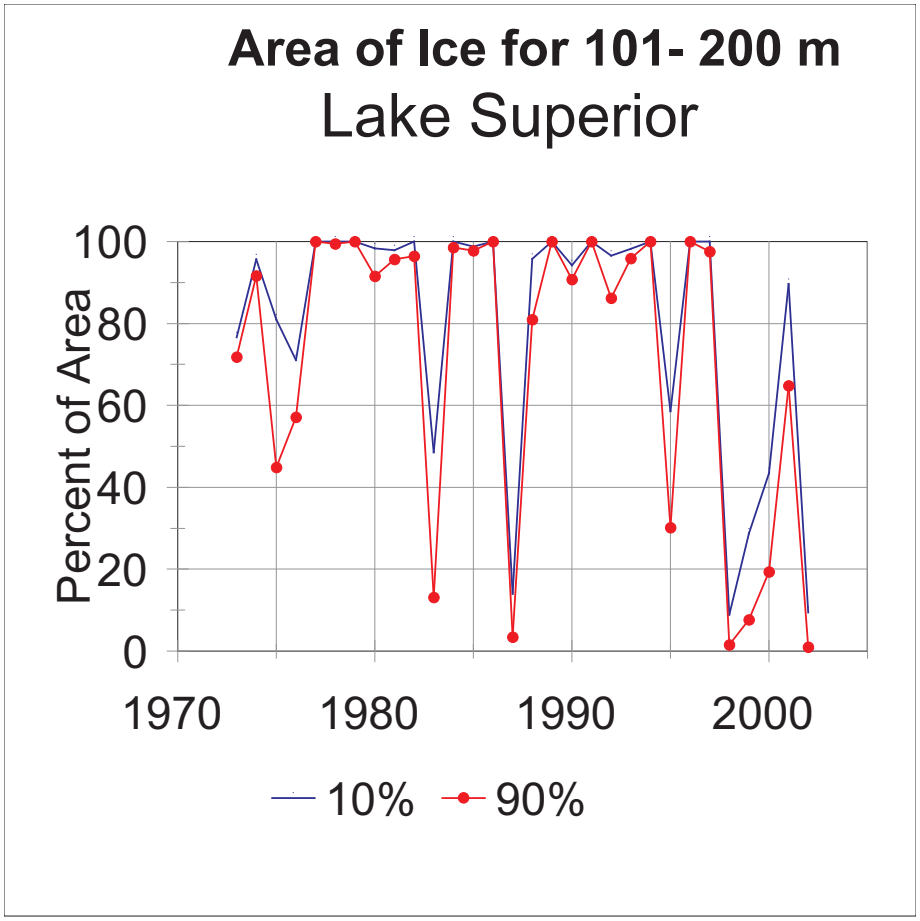

Figure 2d. Same as 2b but for Lake Superior.

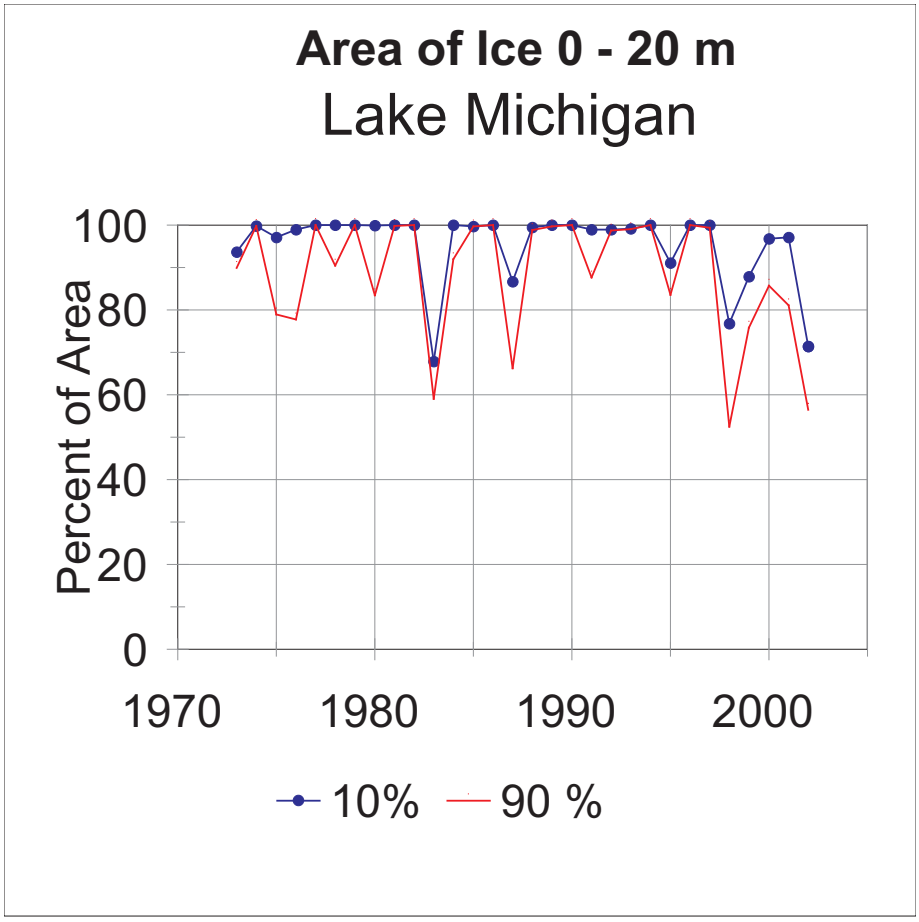

Figure 2e. Same as 2a but for Lake Michigan.

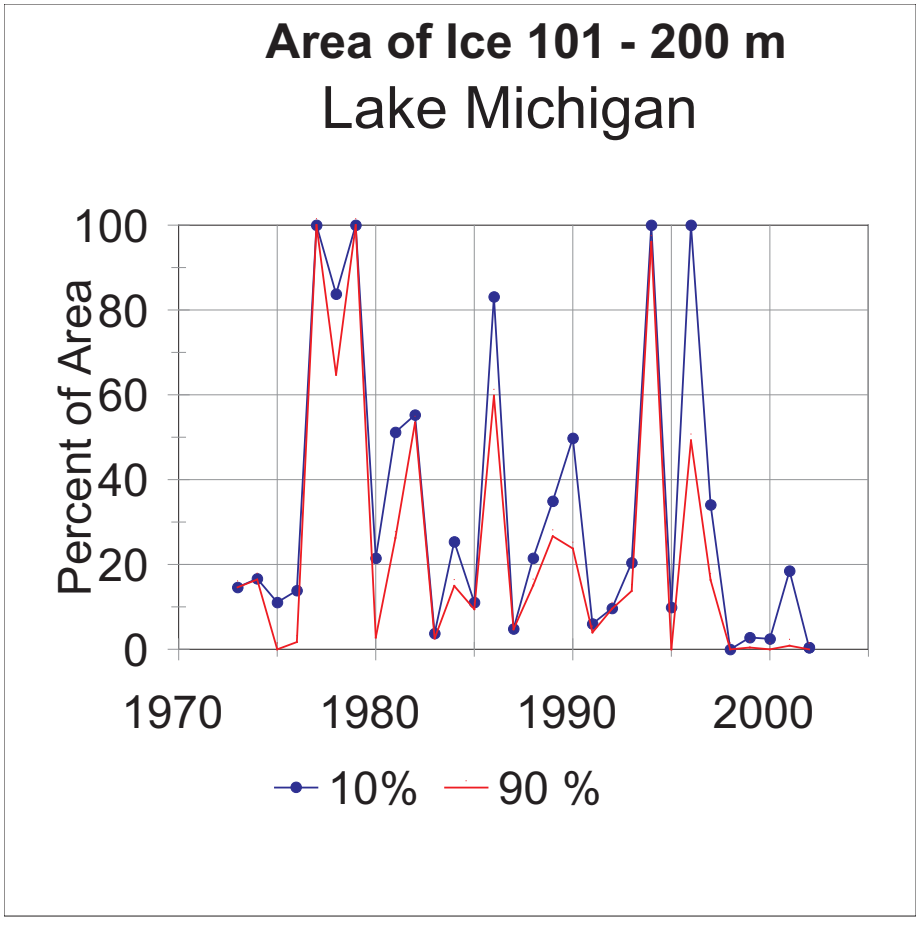

Figure 2f. Same as 2b but for Lake Michigan.

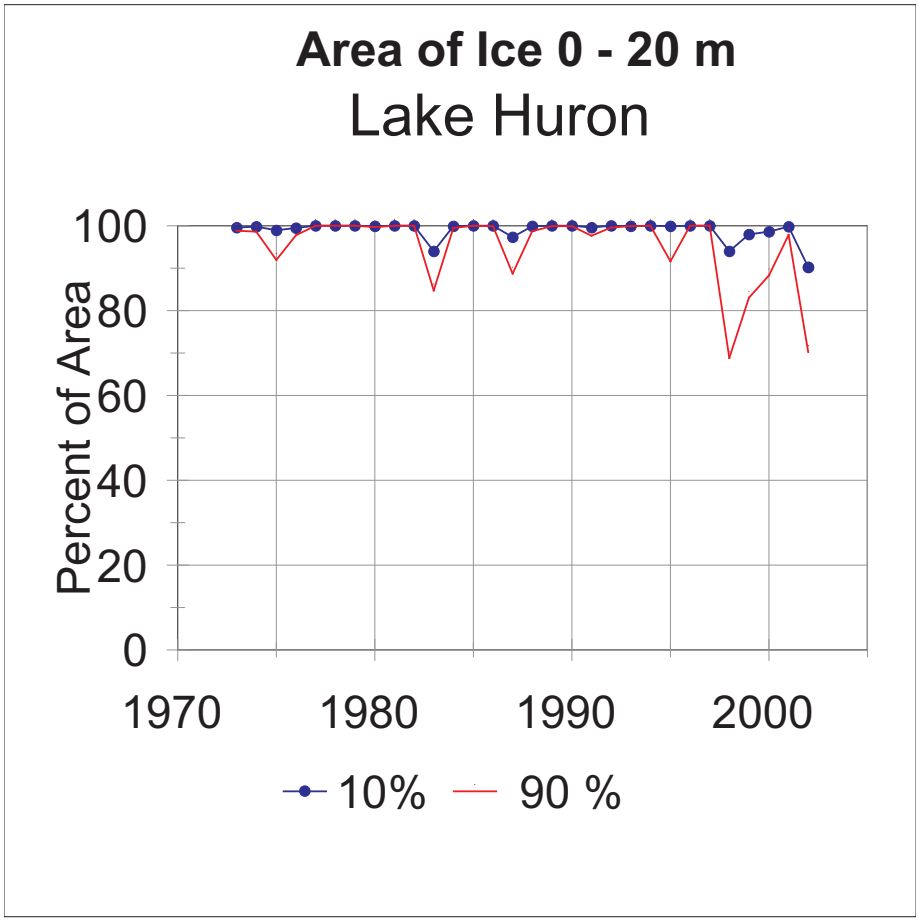

Figure 2g. Same as 2a but for Lake Huron.

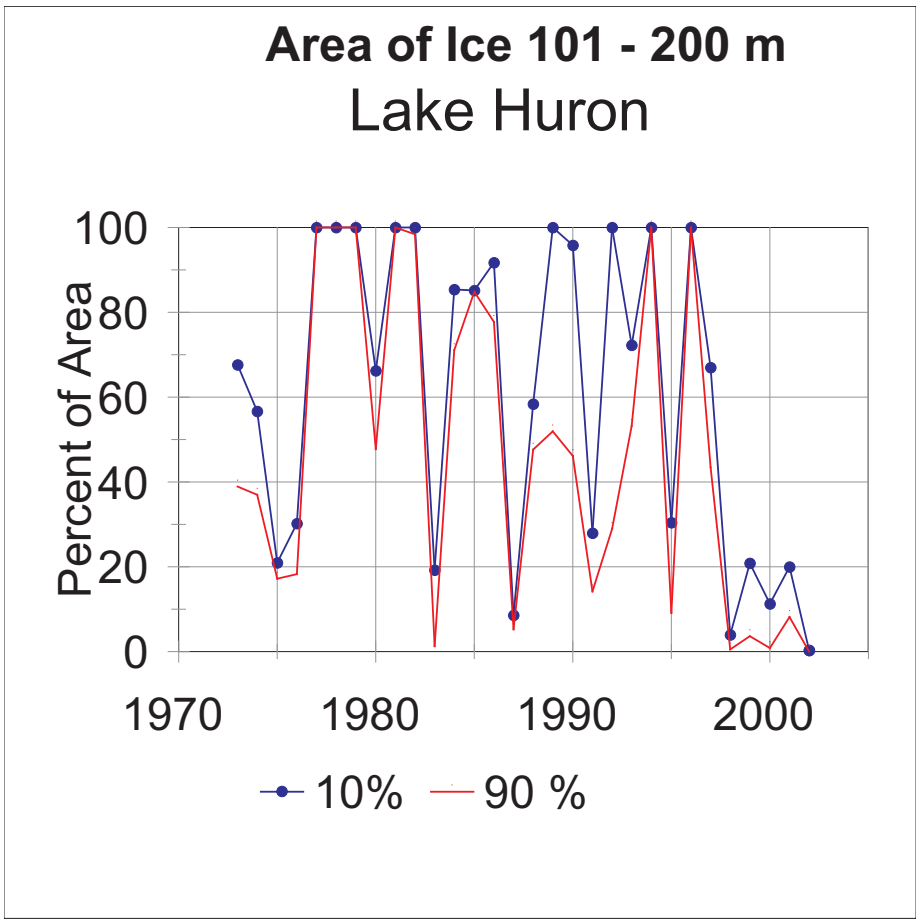

Figure 2h. Same as 2b but for Lake Huron.

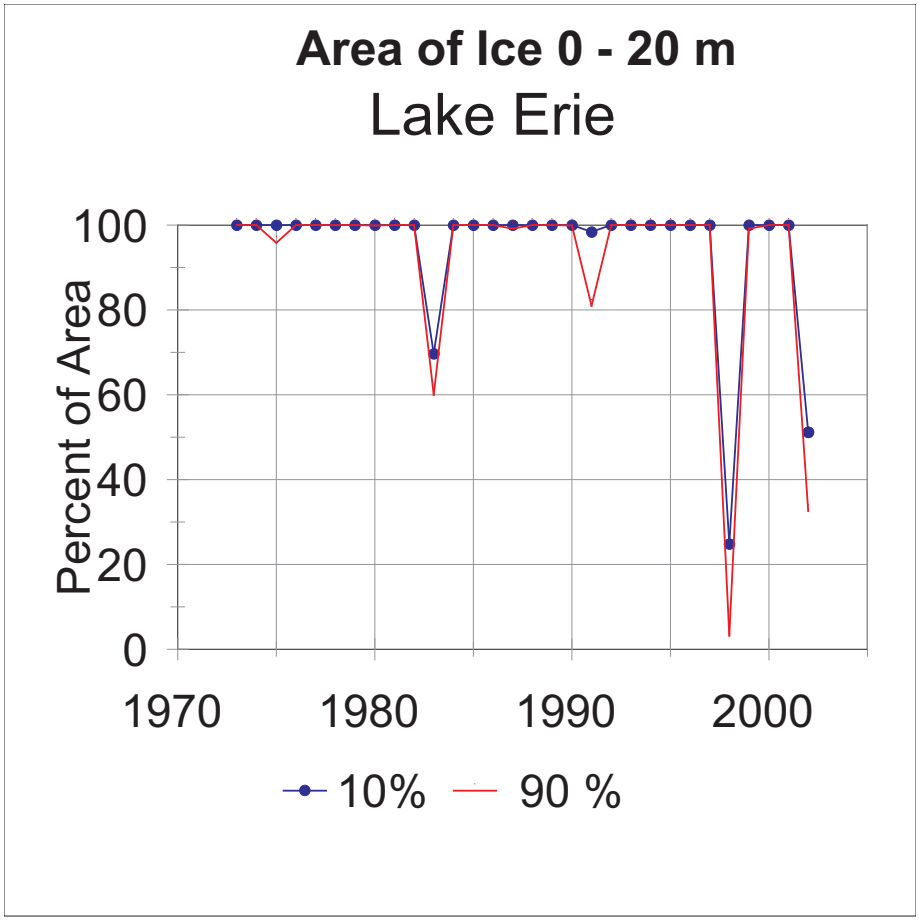

Figure 2i. Same as 2a but for Lake Erie.

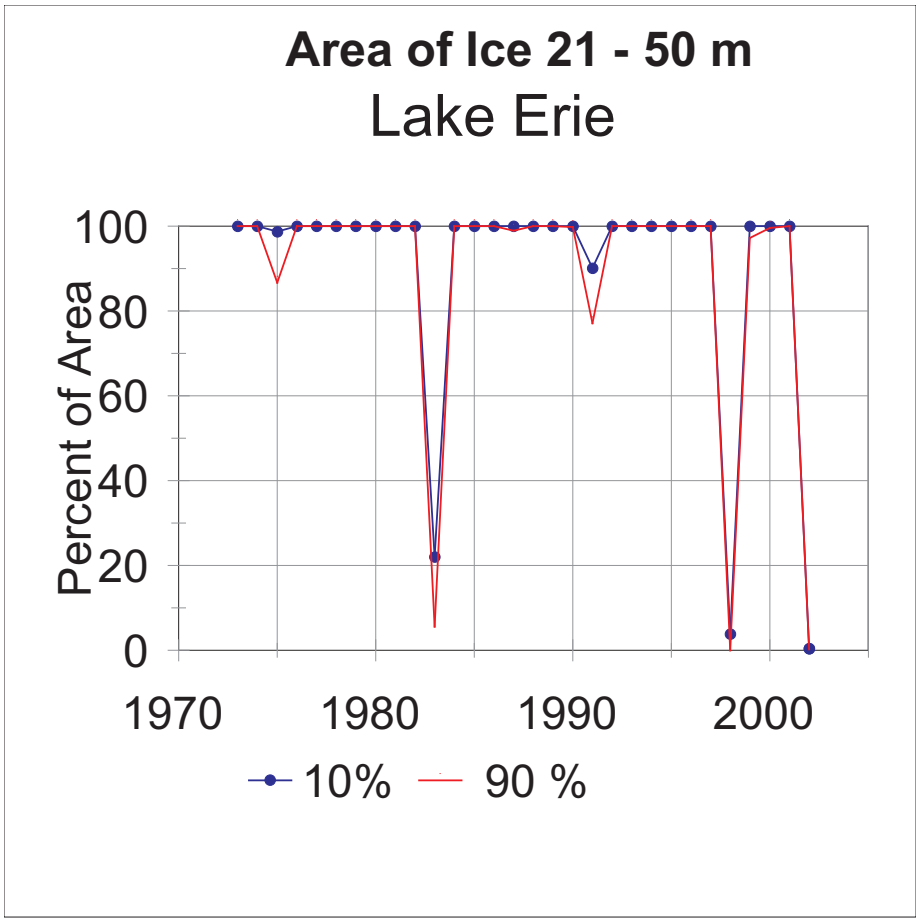

Figure 2j. Same as 2b but for Lake Erie.

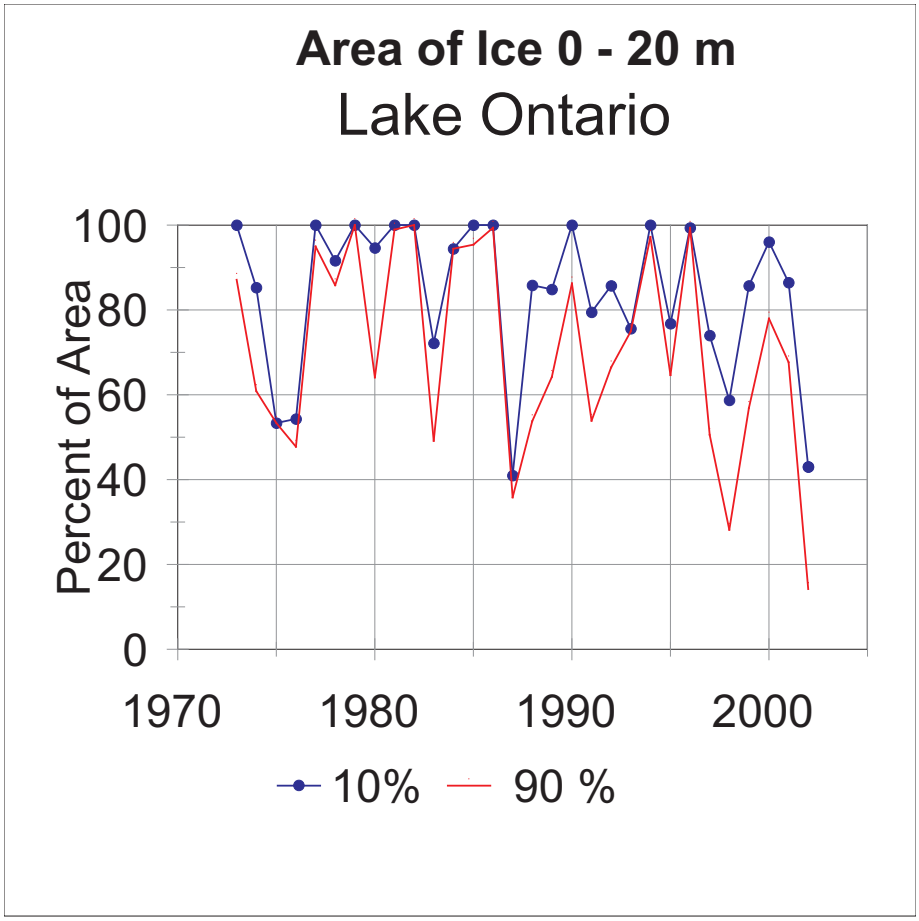

Figure 2k. Same as 2a but for Lake Ontario.

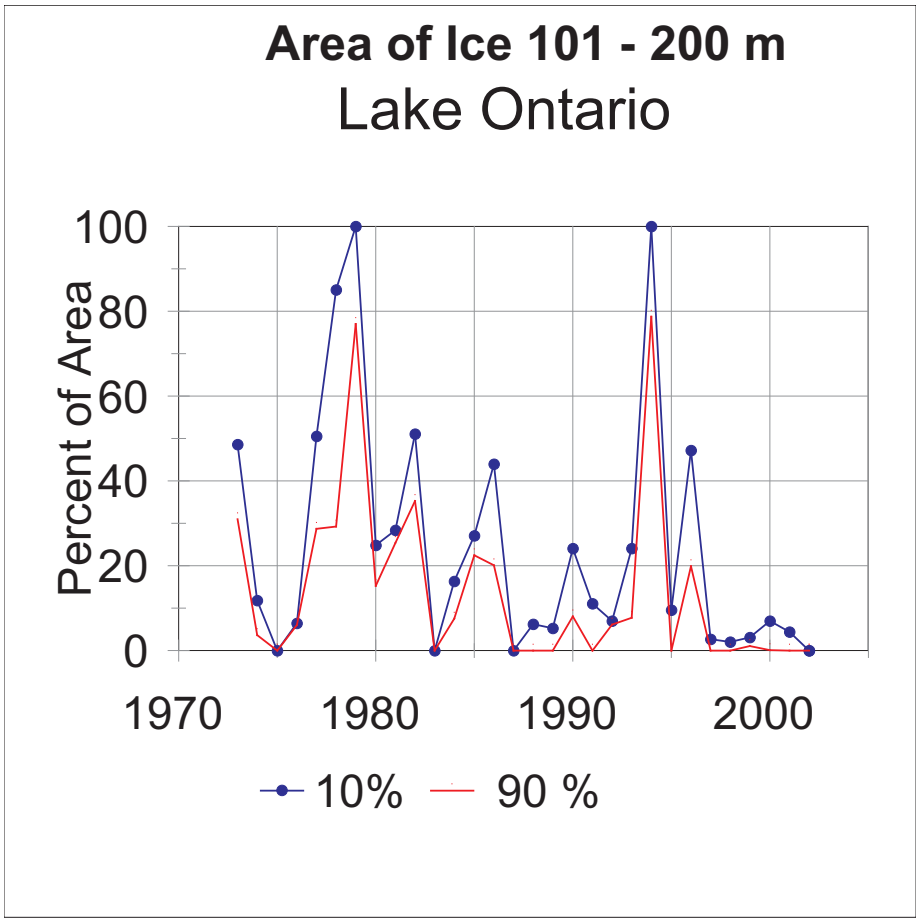

Figure 2l. Same as 2b but for Lake Ontario.

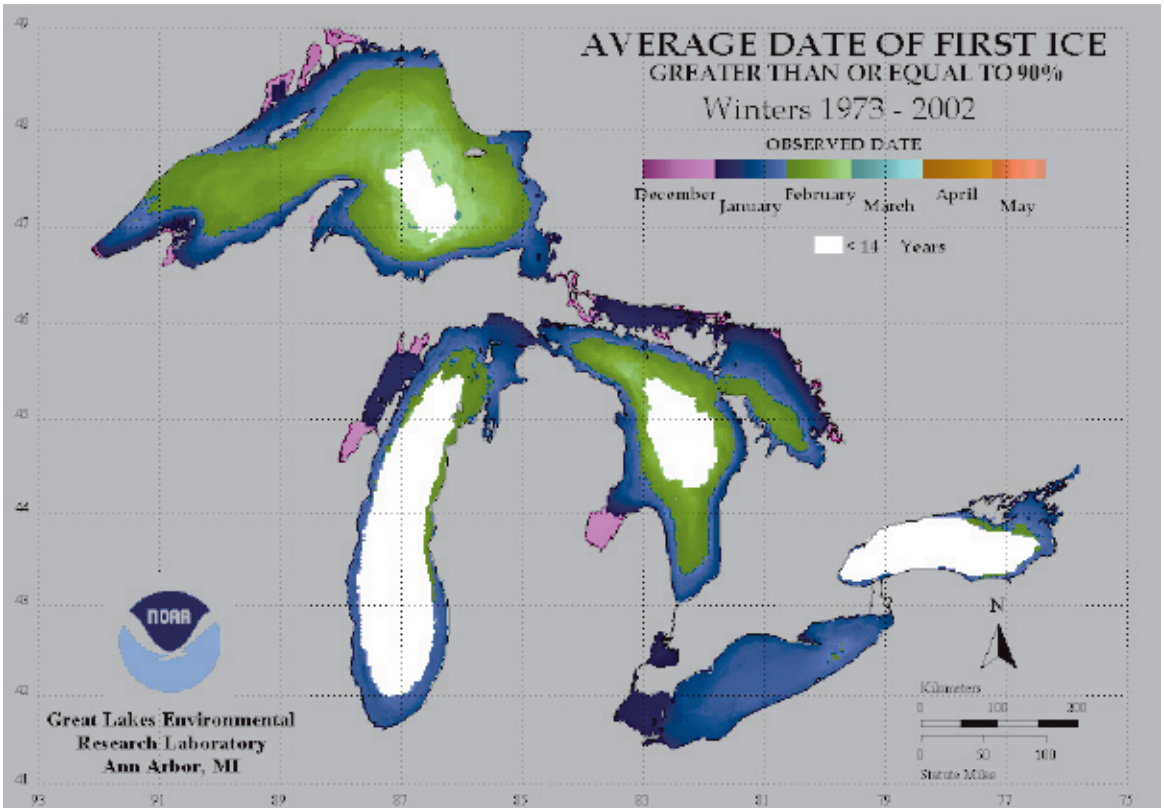

Figure 3a. Thirty-winter average dates of first reported ice at the ≥ 90% threshold value.

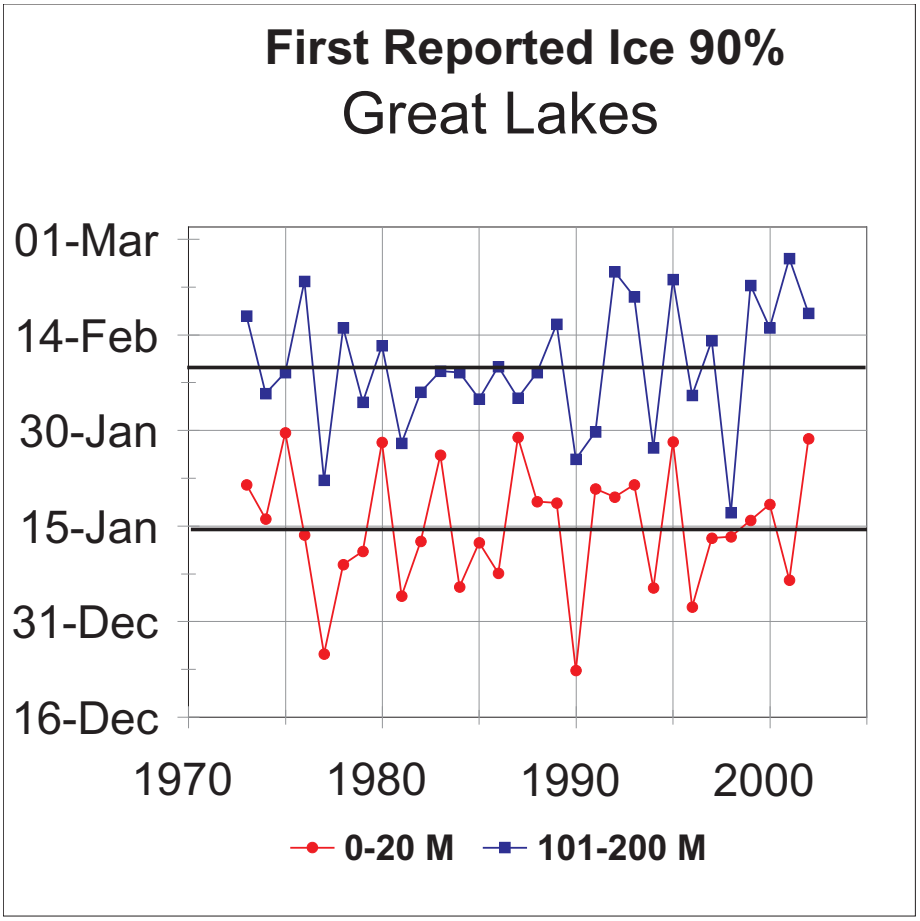

Figure 3b. Spatial averaged dates of first ice for the shore area (0-20 m depth range) and mid lake area (101-200 m depth range). The horizontal black lines are the 30-winter averages.

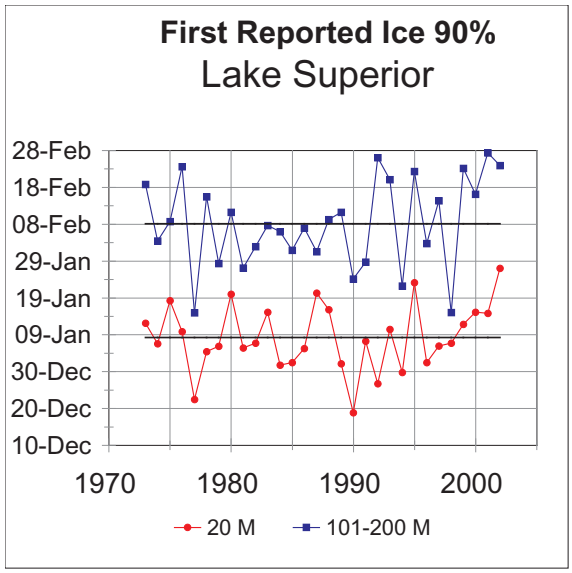

Figure 3b-1.Same as 3b but for Lake Superior.

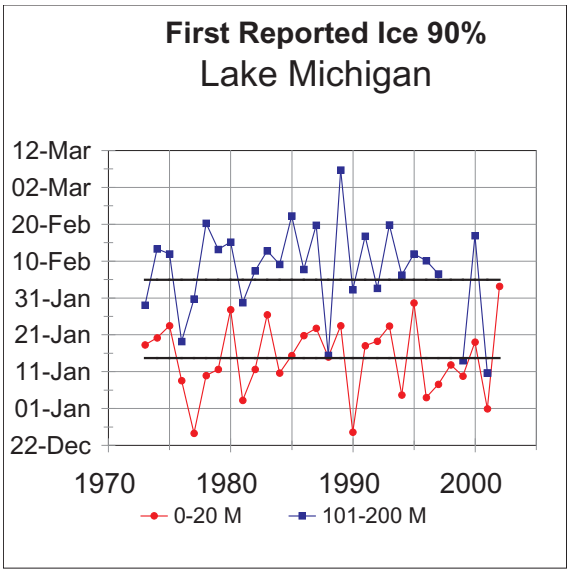

Figure 3b-2. Same as 3b but for Lake Michigan.

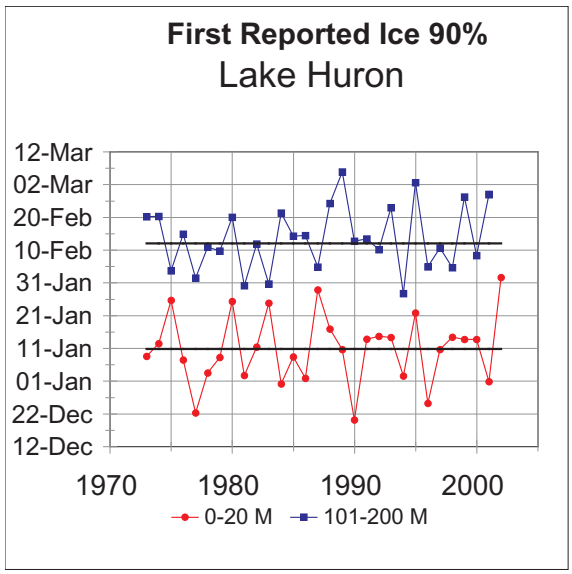

Figure 3b-3.Same as 3b but for Lake Huron.

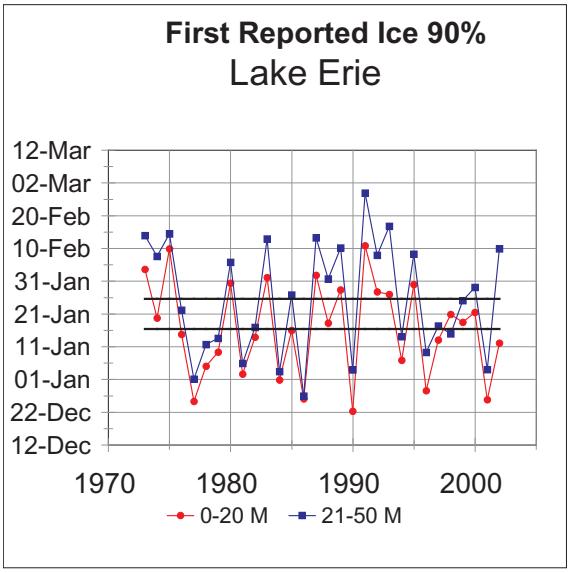

Figure 3b-4. Same as 3b but for Lake Erie.

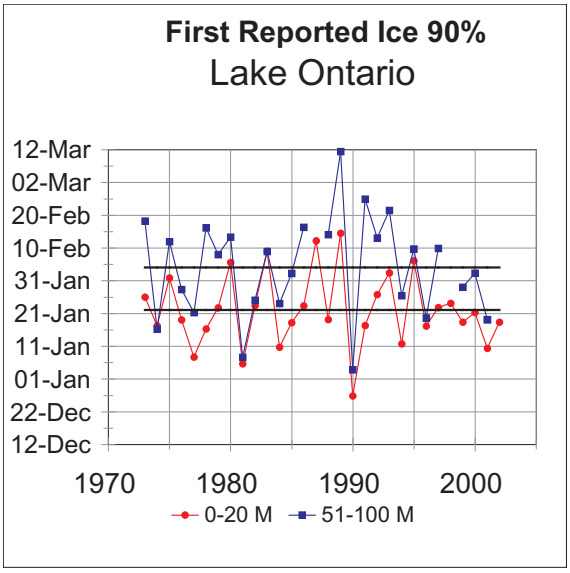

Figure 3b-5. Same as 3b but for Lake Ontario.

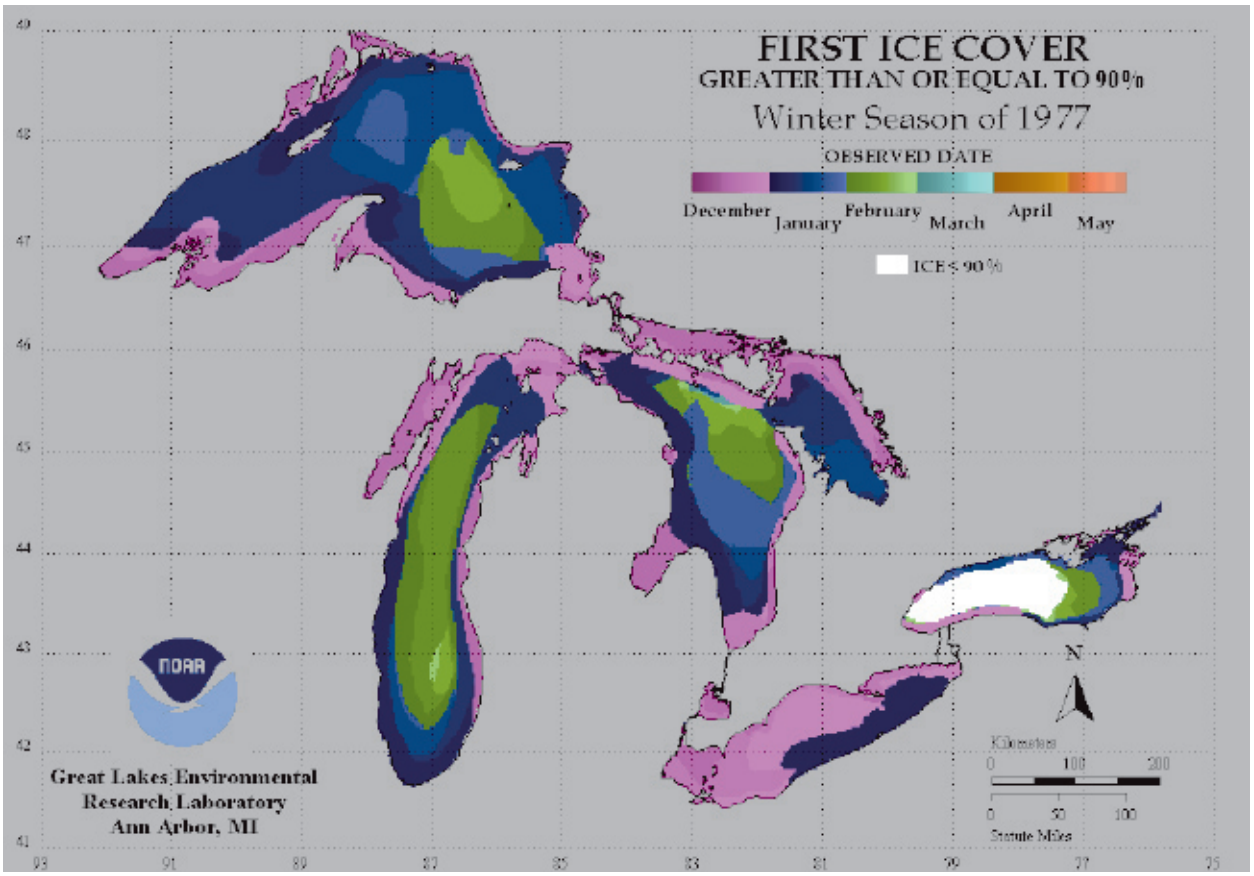

Figure 3c. Winter 1977 spatial distribution of dates of first reported ice at the ≥ 90% ice threshold.

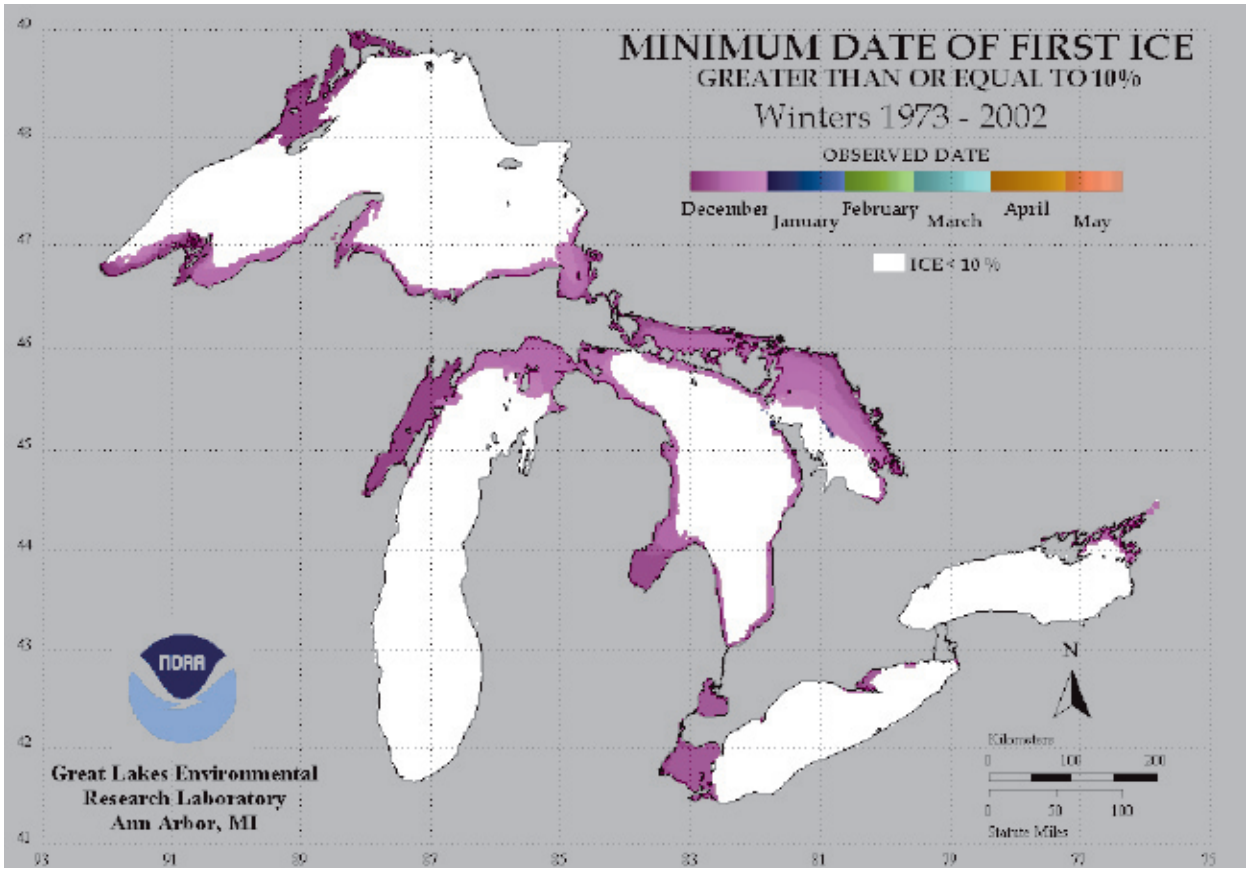

Figure 3d.Thirty-winter composite minimum (earliest) dates of first reported ice at the ≥ 10% ice threshold.

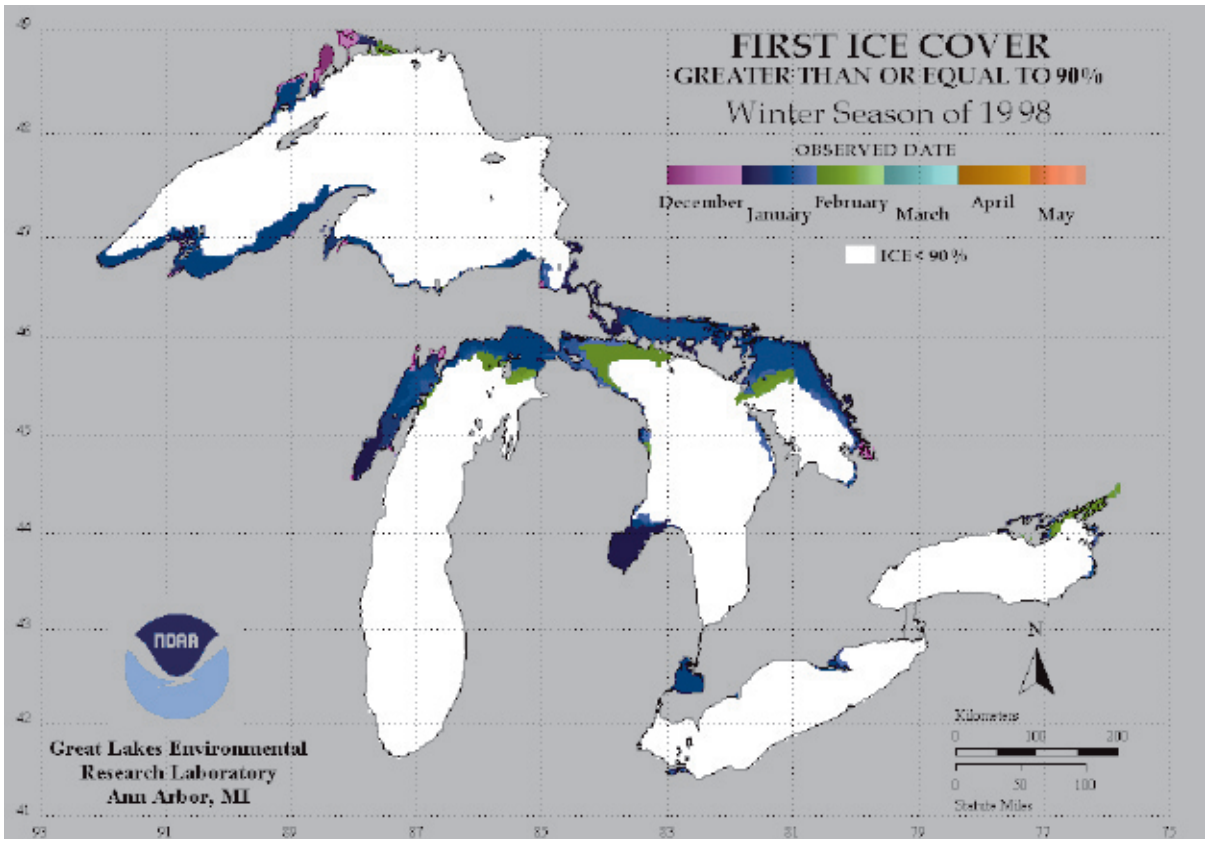

Figure 3e. Winter 1998 spatial distribution of dates of first reported ice at the ≥ 90% ice threshold.

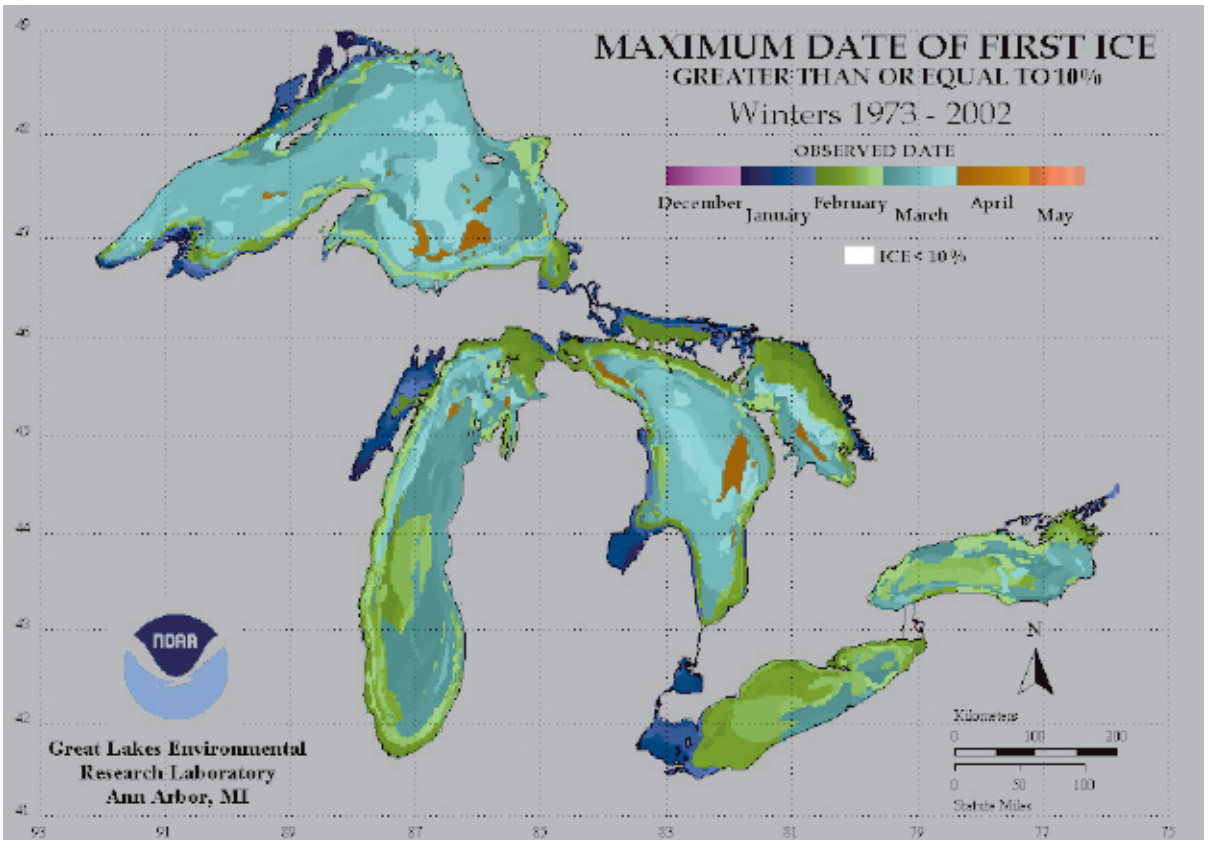

Figure 3f. Thirty-winter composite maximum (latest) dates of first reported ice at the ≥ 10% ice threshold.

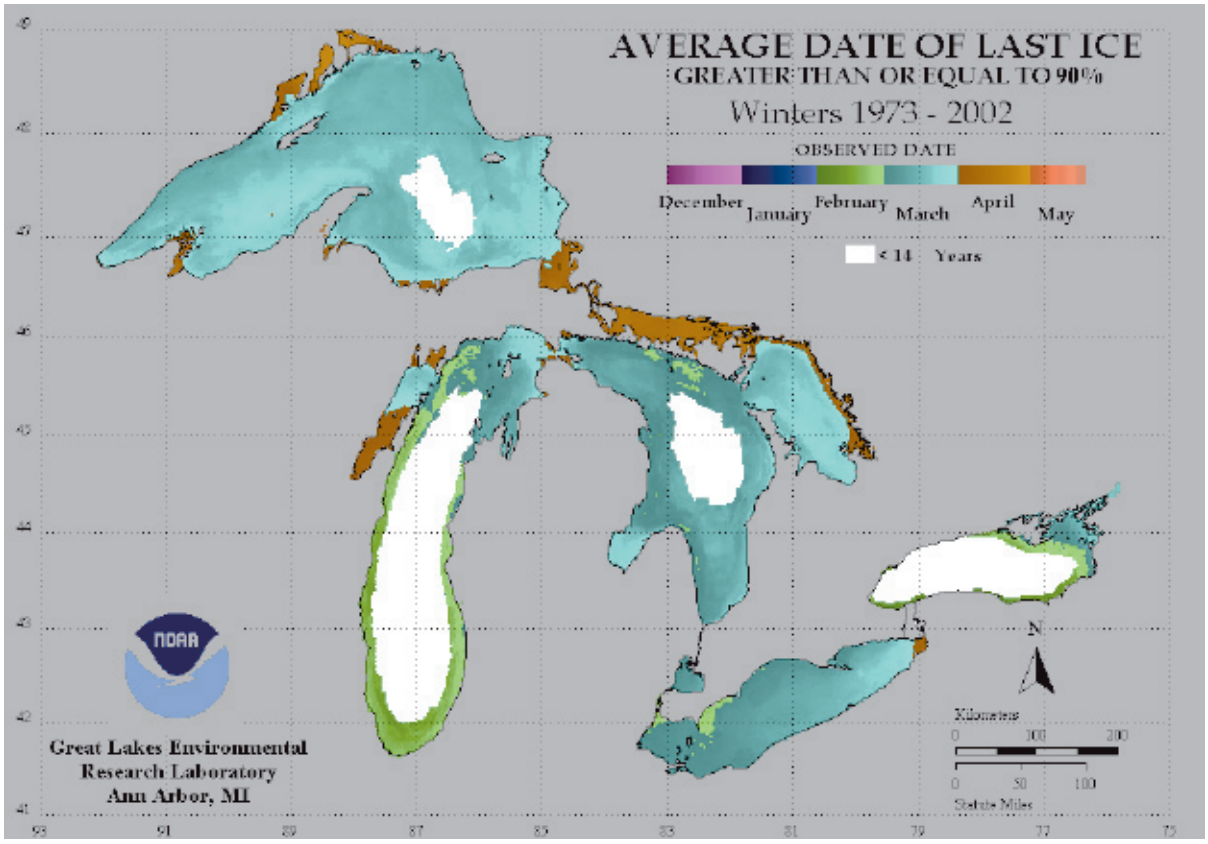

Figure 4a. Thirty-winter average dates of last reported ice at the ≥ 90% threshold value.

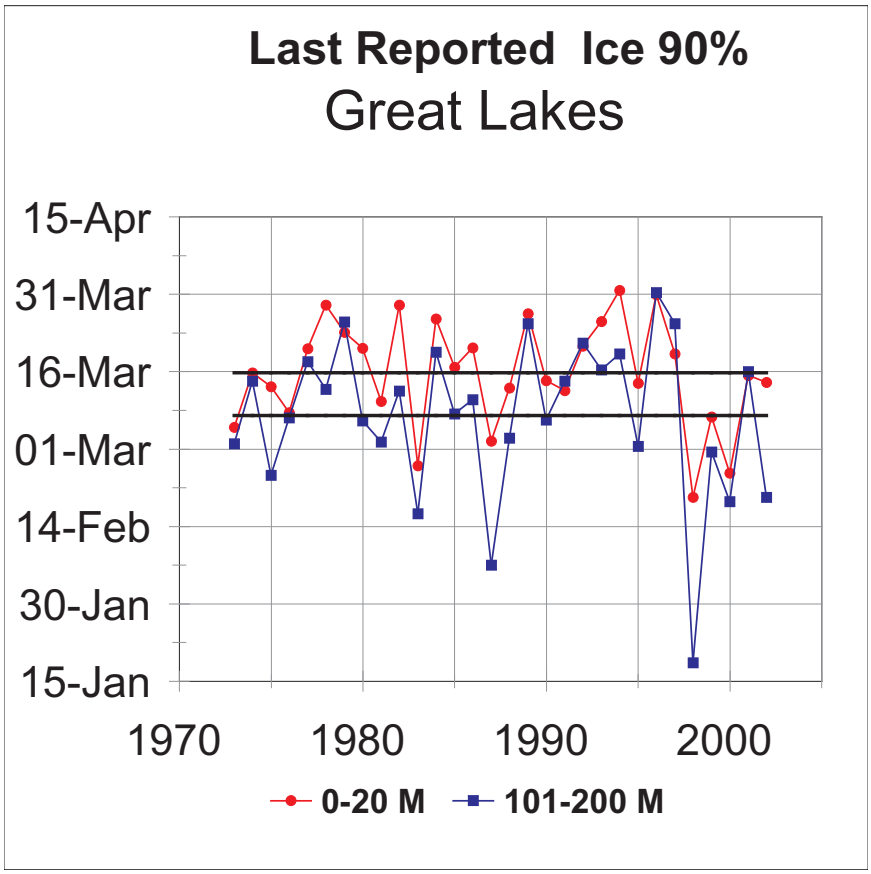

Figure 4b. Spatial averaged dates of last ice for the shore area (0-20 m depth range) and mid lake area (101-200 m depth range). The horizontal black lines are the 30-winter averages.

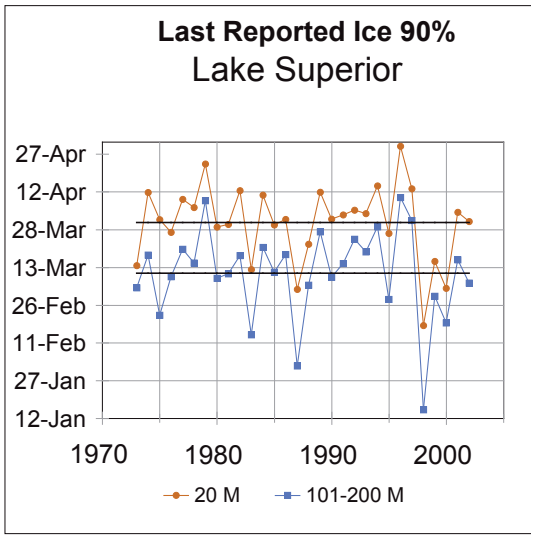

Figure 4b-1.Same as 4b but for Lake Superior.

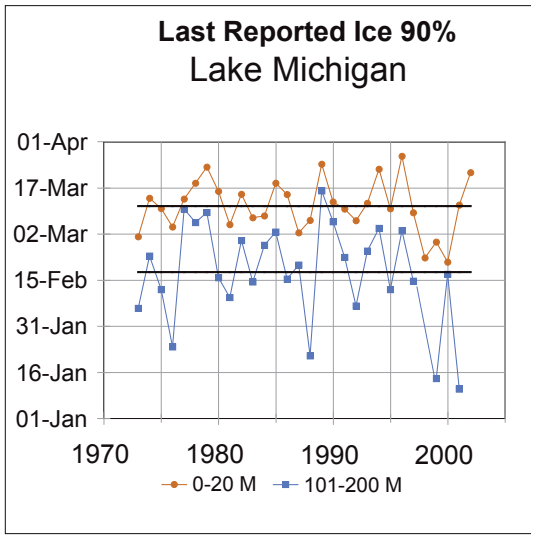

Figure 4b-2.Same as 4b but for Lake Michigan.

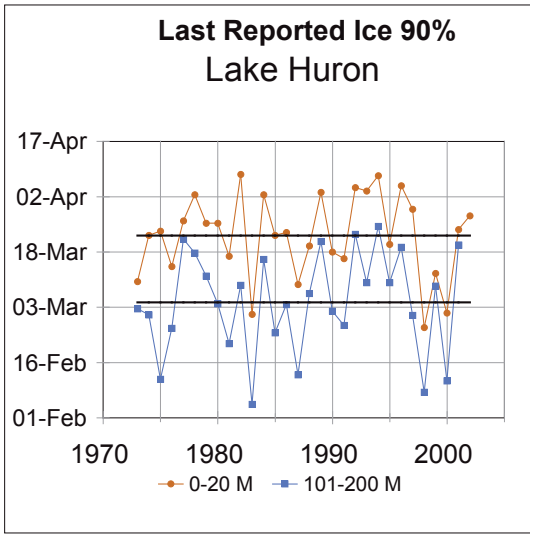

Figure 4b-3.Same as 4b but for Lake Huron.

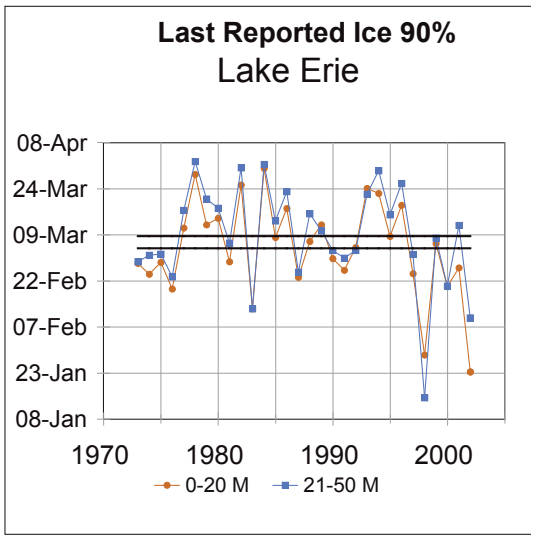

Figure 4b-4.Same as 4b but for Lake Erie.

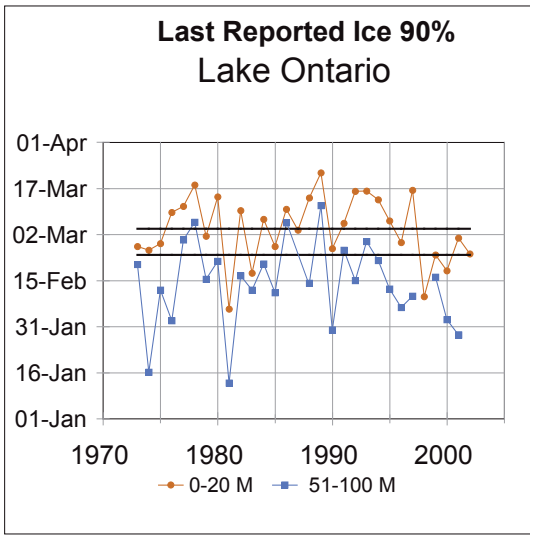

Figure 4b-5.Same as 4b but for Lake Ontario.

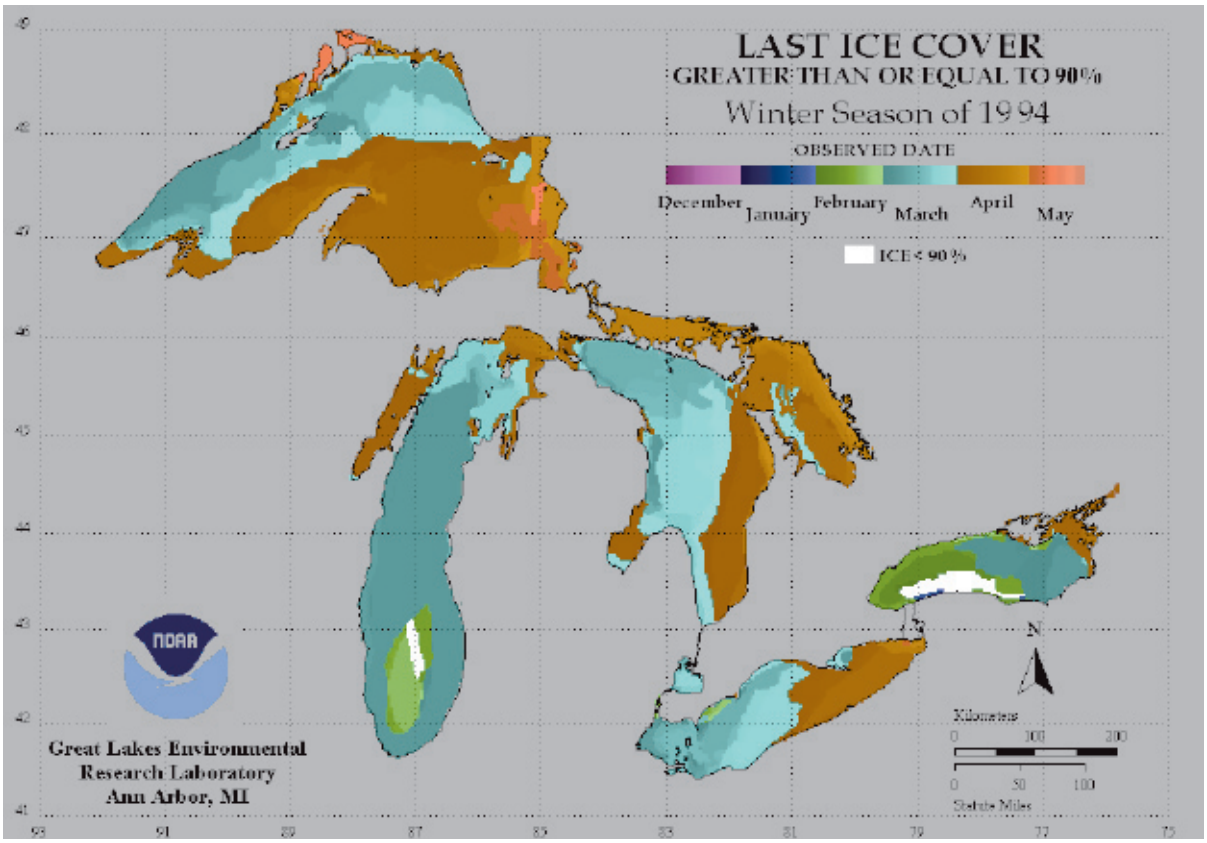

Figure 4c. Winter 1994 spatial distribution pattern of dates last reported ice at the ≥ 90% ice threshold.

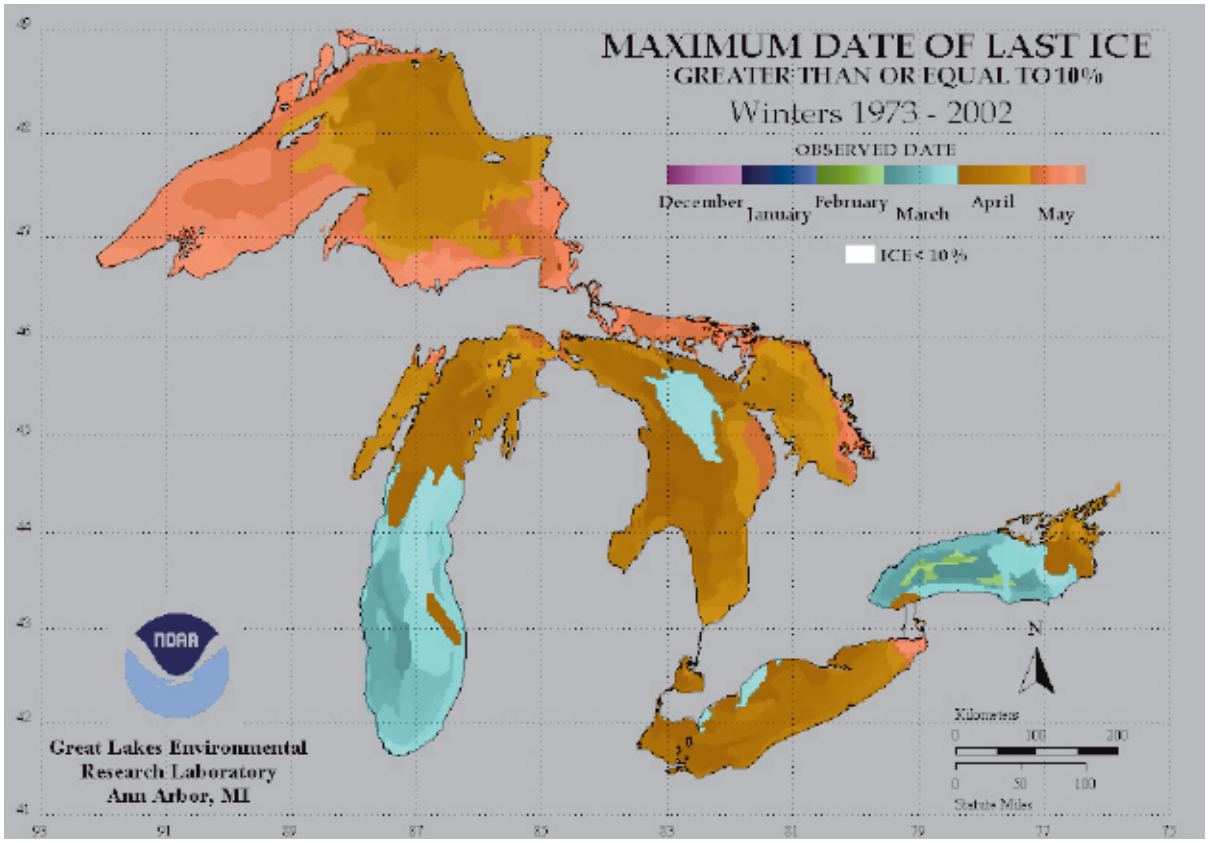

Figure 4d. Thirty-winter composite maximum (latest) dates of last reported ice at the ≥ 10% ice threshold.

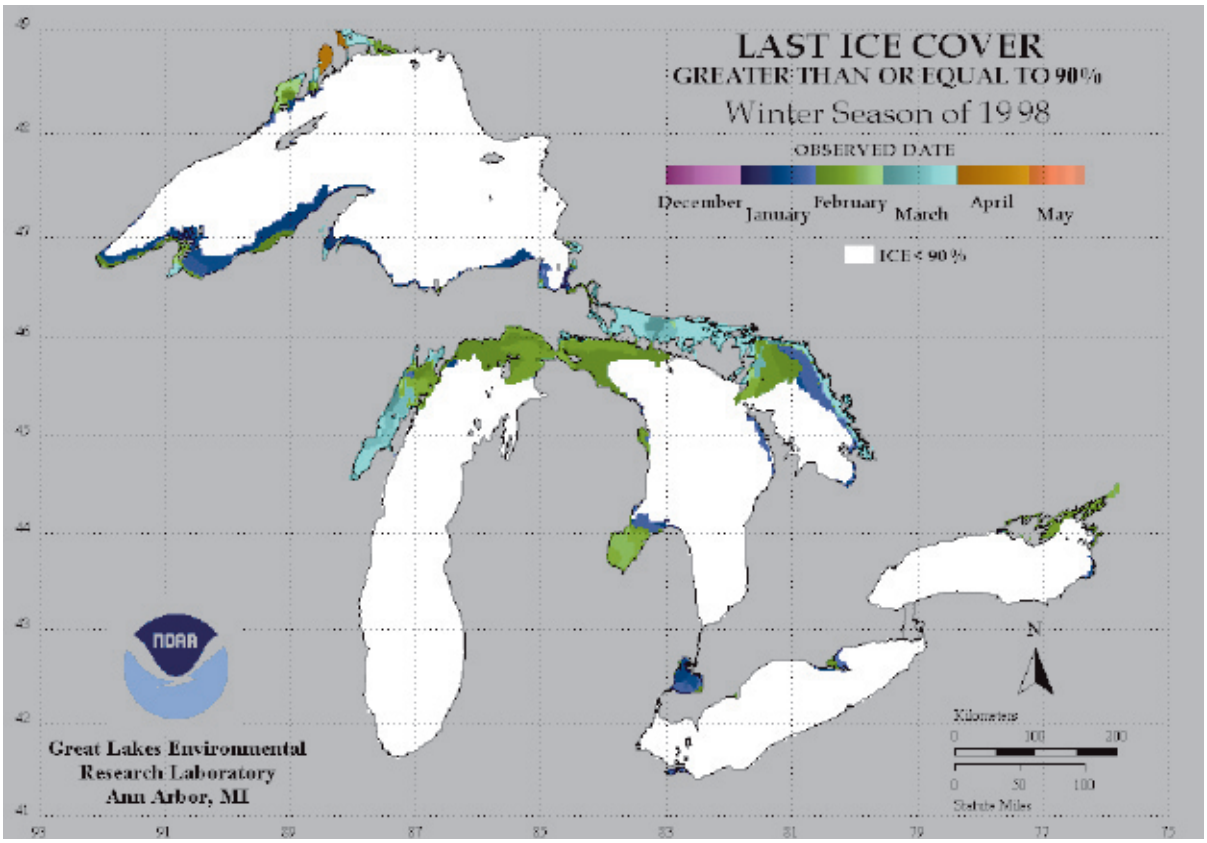

Figure 4e. Winter 1998 spatial distribution pattern of dates last reported ice at the ≥ 90% ice threshold.

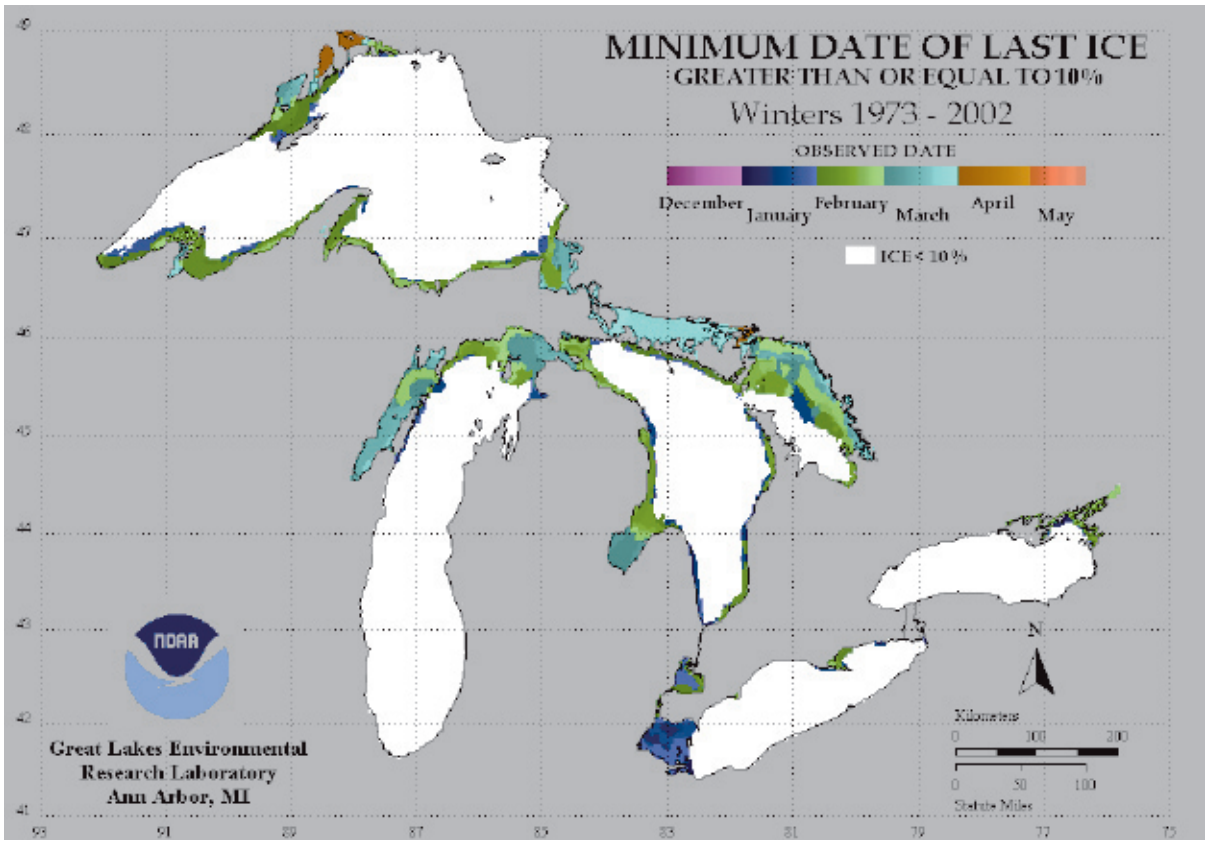

Figure 4f. Thirty-winter composite minimum (earliest) dates of last reported ice at the ≥ 10% ice threshold.

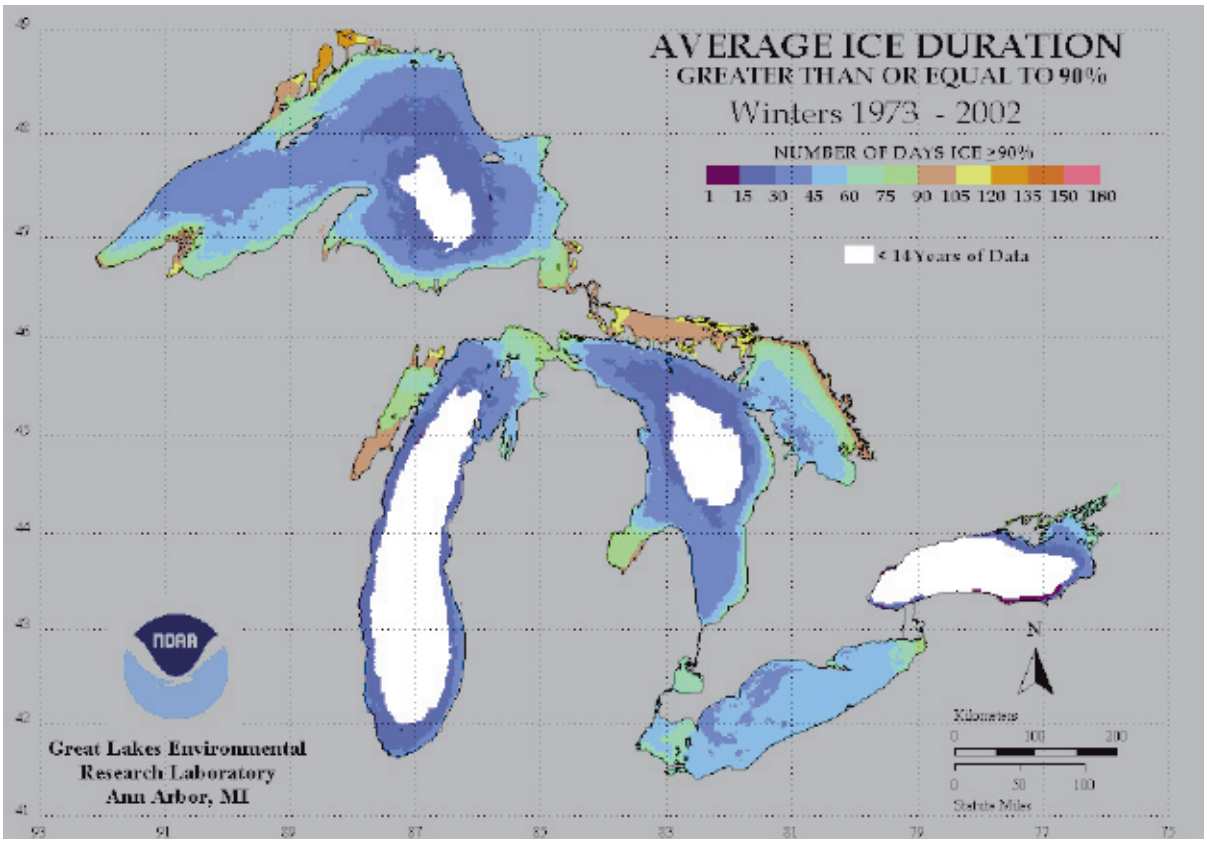

Figure 5a. Thirty-winter average ice duration at the ≥ 90% threshold value.

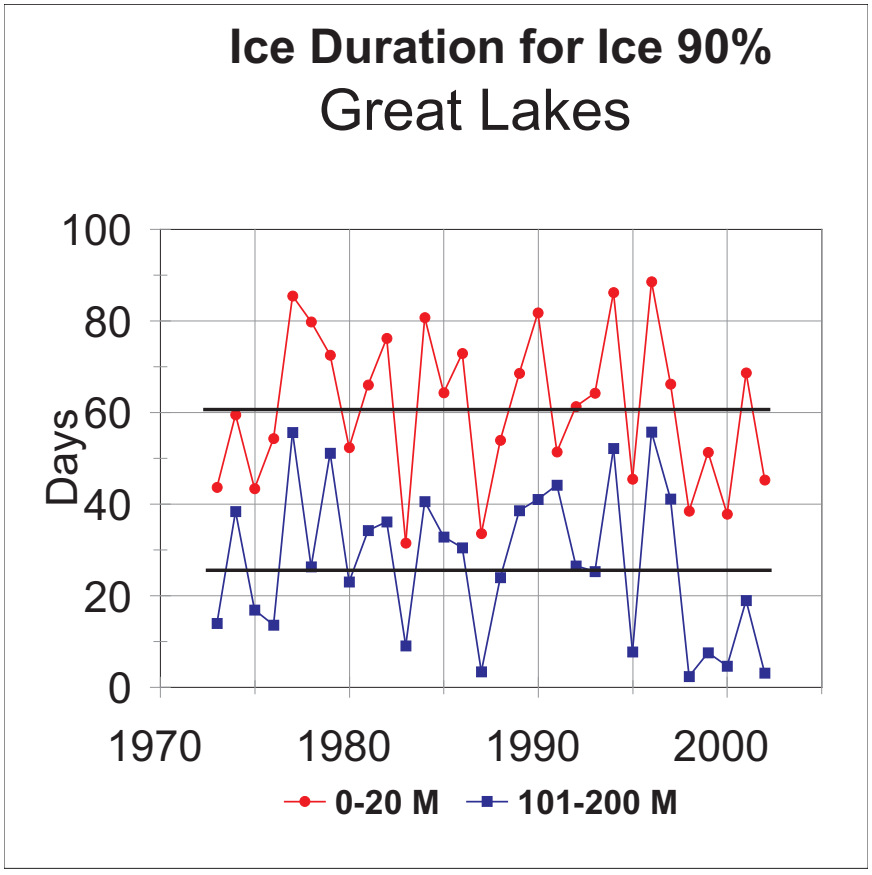

Figure 5b. Spatial averaged ice duration for the shore area (0-20 m depth range) and mid lake area (101-200 m depth range). The horizontal black lines are the 30-winter averages.

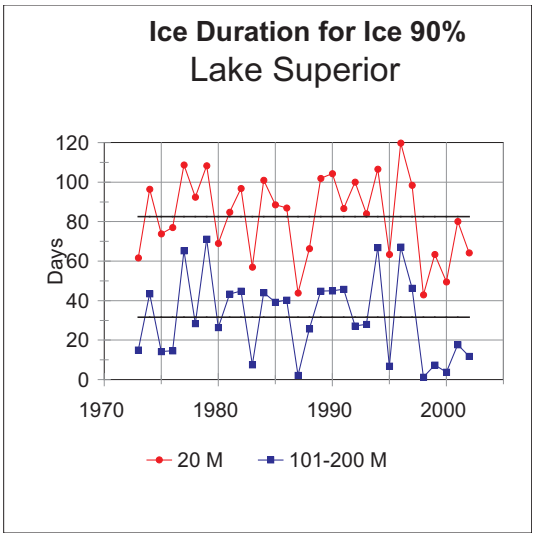

Figure 5b-1.Same as 5b but for Lake Superior.

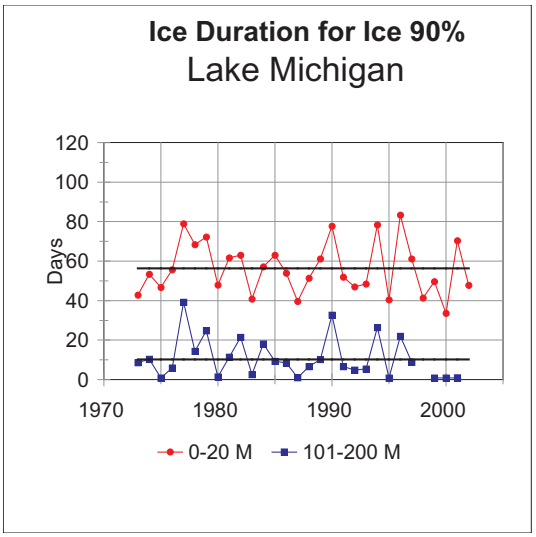

Figure 5b-2.Same as 5b but for Lake Michigan.

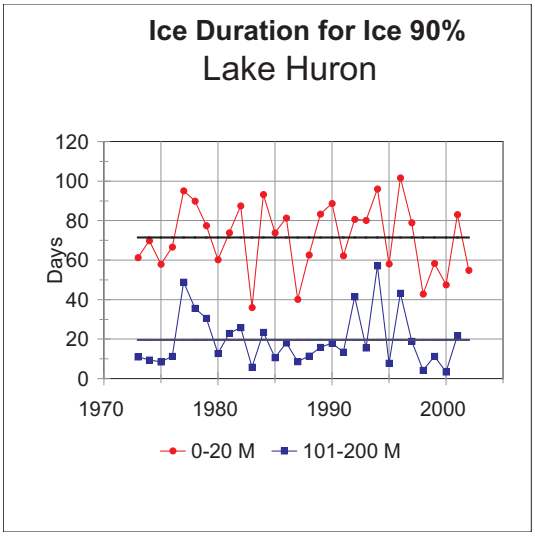

Figure 5b-3.Same as 5b but for Lake Huron.

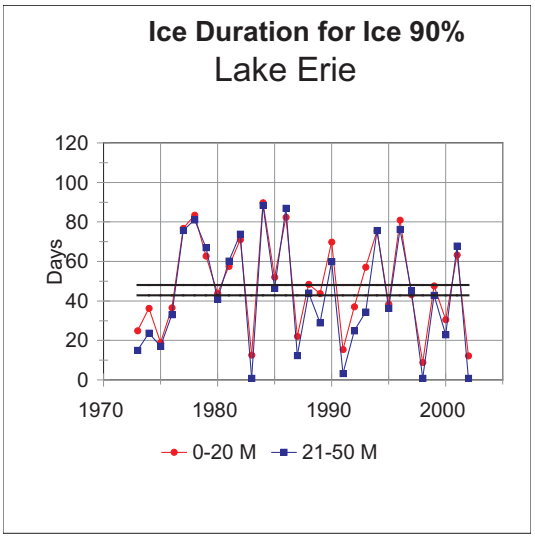

Figure 5b-4.Same as 5b but for Lake Erie.

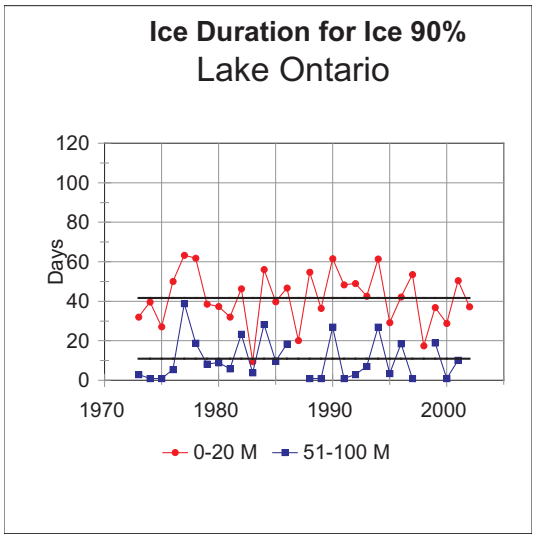

Figure 5b-5.Same as 5b but for Lake Ontario.

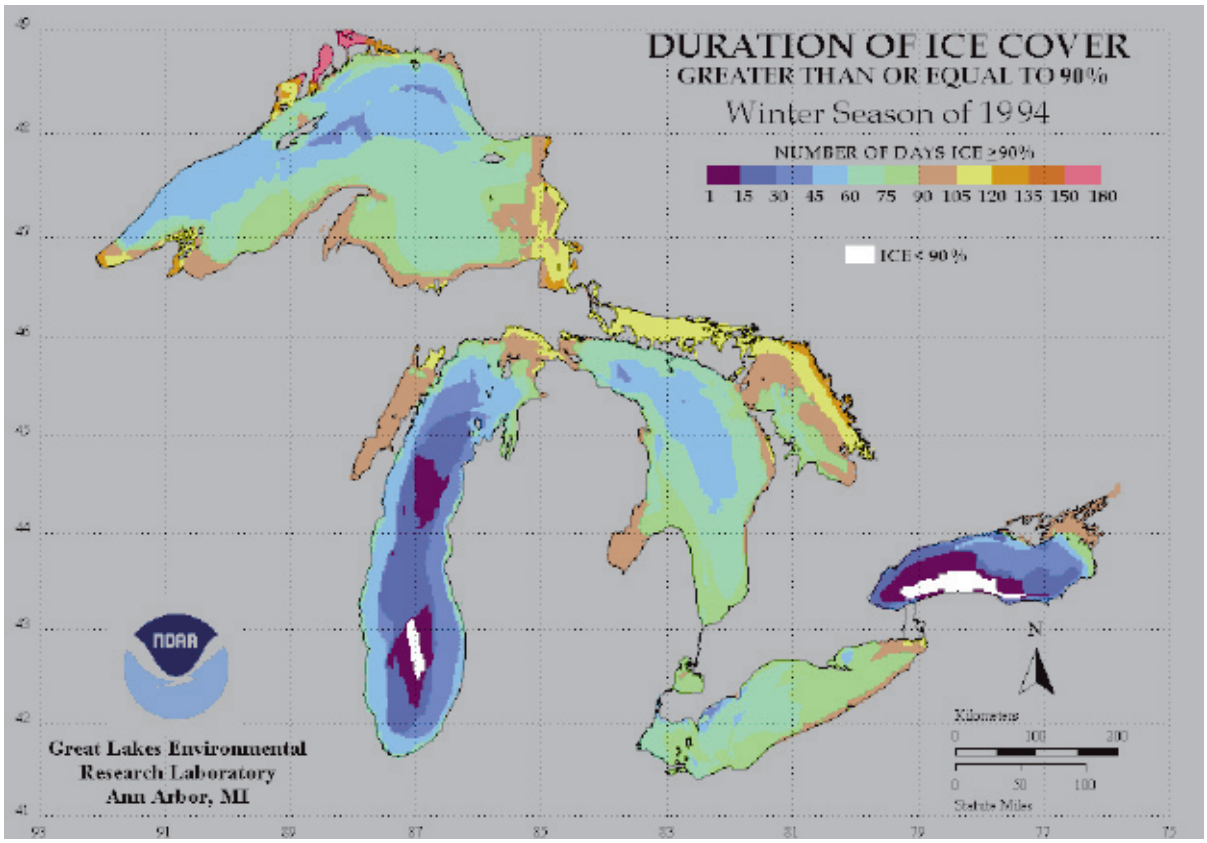

Figure 5c.Winter 1997 spatial distribution pattern of ice duration at the ≥ 90% threshold.

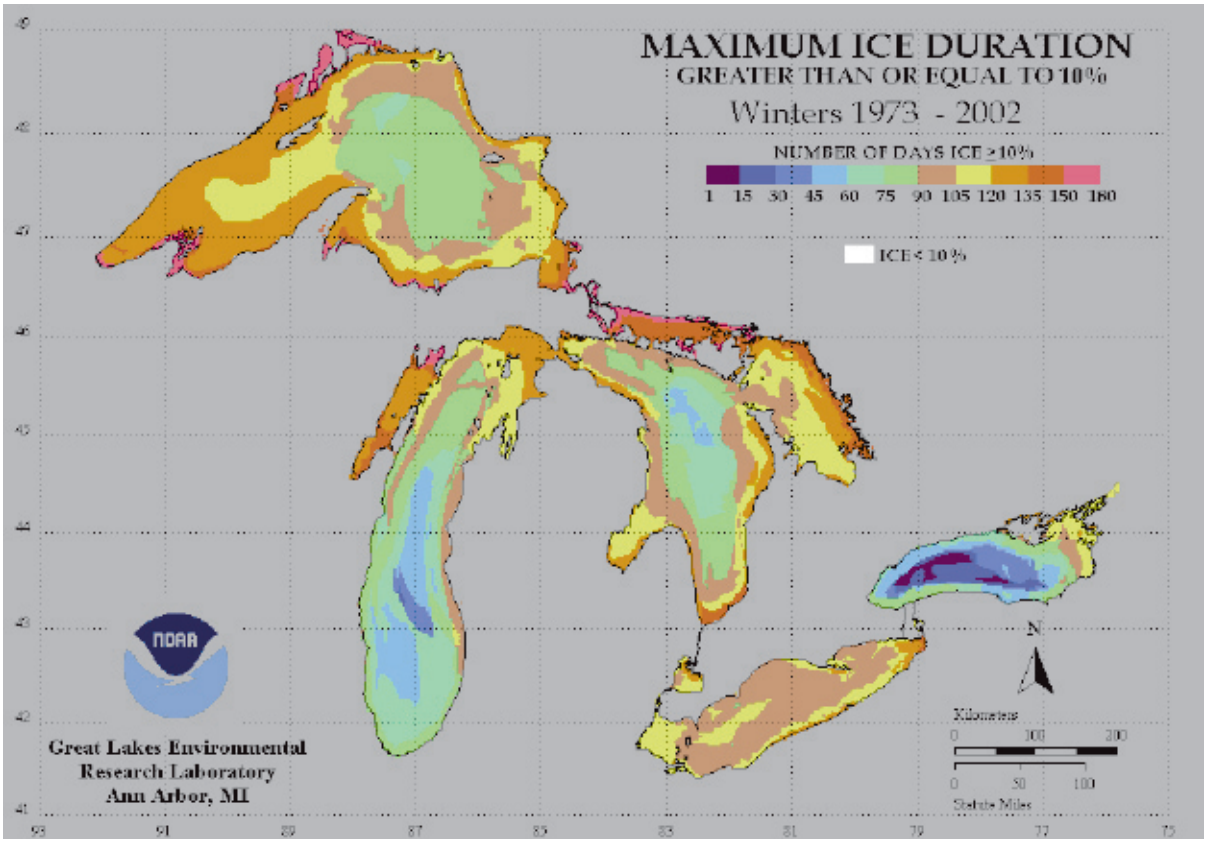

Figure 5d. Thirty-winter composite maximum ice duration at the ≥ 10% ice threshold.

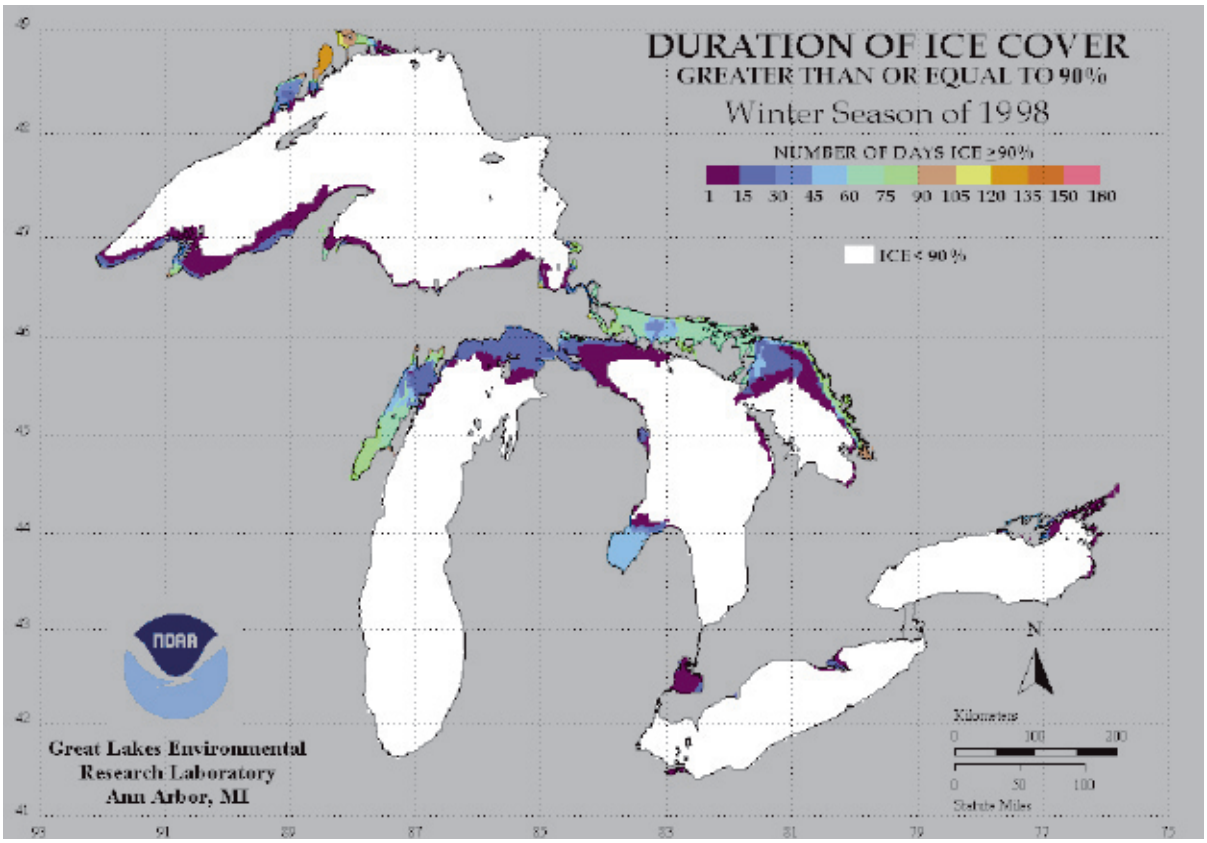

Figure 5e. Winter 1998 spatial distribution pattern of ice duration at the ≥ 90% threshold.

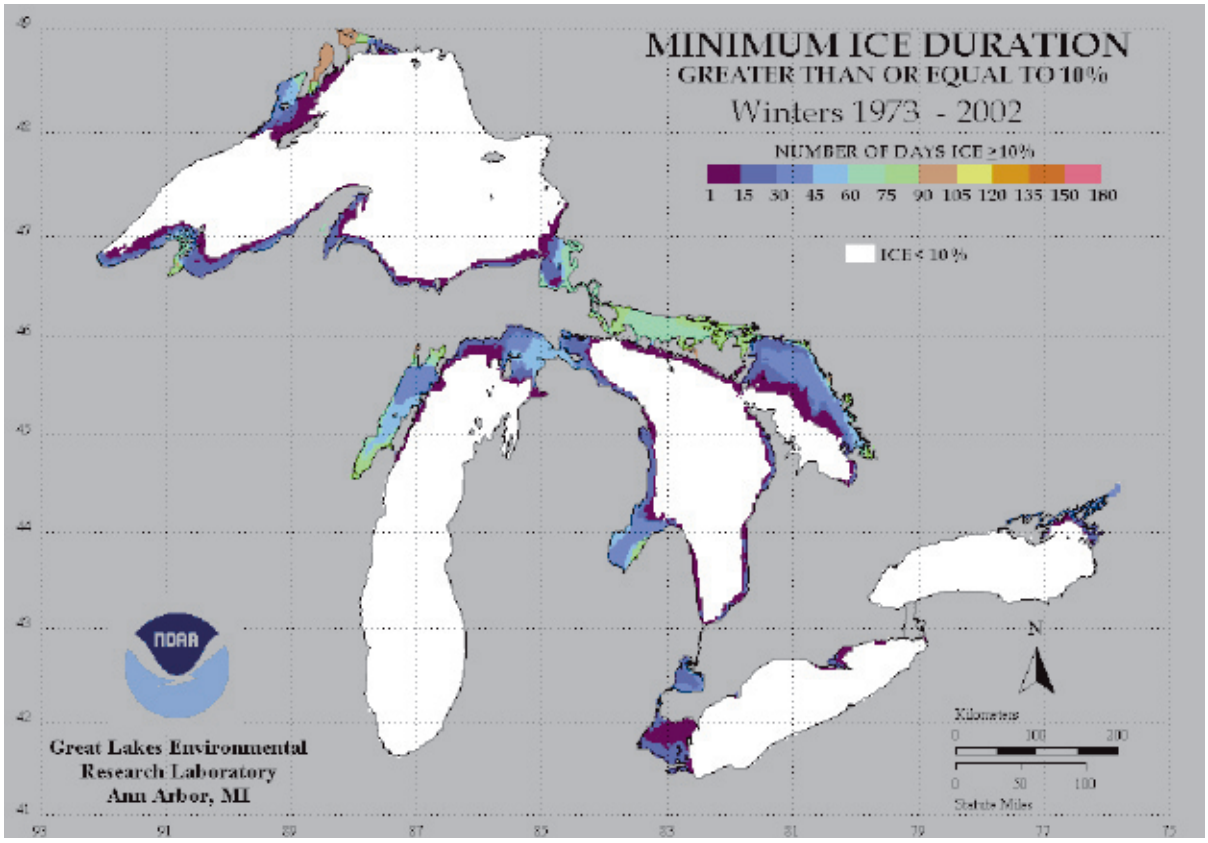

Figure 5f. Thirty-winter composite minimum ice duration at the ≥ 10% ice threshold.

Table 1. Distribution of Ice Charts by Winter Season.

		First Ice Chart			Last Ice Chart		
Winter	No.	Month	Day	% Ice	Month	Day	% Ice
1973	16	12	20	10.5	4	6	2.1
1974	18	12	31	5.5	5	2	1.5
1975	17	1	2	1.6	4	24	4.0
1976	18	12	23	10.0	4	20	1.5
1977	21	12	16	17.5	5	4	0.8
1978	20	12	21	3.6	5	3	1.5
1979	23	12	18	2.8	5	14	2.9
1980	16	1	2	6.0	4	16	3.1
1981	16	12	24	9.3	4	15	2.6
1982	22	12	21	0.9	5	17	0.1
1983	20	12	21	0.5	5	3	0.3
1984	22	12	20	8.2	5	3	0.1
1985	19	12	22	0.7	4	27	0.5
1986	20	12	14	3.4	4	23	0.3
1987	15	12	27	1.8	4	5	2.2
1988	16	1	3	2.6	4	17	1.4
1989	82	12	14	3.2	5	8	0.2
1990	78	12	13	3.9	4	27	0.3
1991	71	12	28	1.2	5	1	0.1
1992	91	12	6	4.0	5	11	0.0
1993	82	12	14	0.3	5	5	0.2
1994	85	12	3	0.5	5	16	0.2
1995	90	12	5	0.0	5	22	0.0
1996	75	11	17	0.2	5	31	< 0.1
1997	49	11	26	0.3	5	13	0.1
1998	42	12	2	0.1	4	24	0.1
1999	36	12	15	0.1	5	4	0.1
2000	42	12	3	0.1	4	28	0.1
2001	43	12	1	0.1	5	3	0.0
2002	45	12	3	0.3	5	9	0.0

No. = number of ice charts for a given winter season.
% Ice = the lake averaged ice cover concentration.

Table 2.1 Great Lakes statistics for discrete depth ranges for ice cover concentration ≥ 90%.

Winter Season	a) Average date of First Ice					b) Average date of Last Ice					c) Average Duration (days)				
	Depth Range (m)					Depth Range (m)					Depth Range (m)				
	0-20	21-50	51-100	101-200	>200	0-20	21-50	51-100	101-200	>200	0-20	21-50	51-100	101-200	>200
1973	21-Jan	29-Jan	08-Feb	17-Feb	21-Feb	05-Mar	01-Mar	02-Mar	02-Mar	01-Mar	43.7	31.8	22.5	14.0	9.0
1974	16-Jan	26-Jan	30-Jan	04-Feb	12-Feb	15-Mar	10-Mar	09-Mar	14-Mar	16-Mar	59.6	44.5	38.5	38.4	33.0
1975	29-Jan	03-Feb	08-Feb	08-Feb	07-Feb	13-Mar	08-Mar	06-Mar	24-Feb	23-Feb	43.4	33.7	26.8	16.9	16.8
1976	13-Jan	18-Jan	29-Jan	22-Feb	03-Mar	08-Mar	02-Mar	28-Feb	07-Mar	08-Mar	54.4	44.2	31.3	13.6	6.3
1977	26-Dec	01-Jan	14-Jan	22-Jan	24-Jan	20-Mar	19-Mar	16-Mar	18-Mar	19-Mar	85.5	77.6	61.9	55.7	54.9
1978	09-Jan	16-Jan	02-Feb	15-Feb	20-Feb	29-Mar	24-Mar	16-Mar	12-Mar	12-Mar	79.9	68.0	43.1	26.4	21.1
1979	11-Jan	18-Jan	30-Jan	03-Feb	07-Feb	23-Mar	20-Mar	16-Mar	25-Mar	01-Apr	72.6	62.6	46.4	51.2	53.7
1980	28-Jan	04-Feb	12-Feb	12-Feb	14-Feb	20-Mar	17-Mar	11-Mar	06-Mar	01-Mar	52.4	41.5	27.9	23.1	15.7
1981	04-Jan	08-Jan	16-Jan	28-Jan	03-Feb	10-Mar	04-Mar	24-Feb	02-Mar	07-Mar	66.1	56.1	39.9	34.3	33.9
1982	12-Jan	17-Jan	26-Jan	05-Feb	07-Feb	29-Mar	22-Mar	13-Mar	12-Mar	09-Mar	76.3	65.1	47.3	36.2	30.8
1983	26-Jan	28-Jan	02-Feb	08-Feb	07-Feb	25-Feb	24-Feb	17-Feb	16-Feb	03-Mar	31.6	28.9	15.9	9.1	24.2
1984	05-Jan	12-Jan	29-Jan	08-Feb	12-Feb	26-Mar	22-Mar	17-Mar	19-Mar	19-Mar	80.8	70.5	48.5	40.6	36.0
1985	12-Jan	21-Jan	01-Feb	04-Feb	08-Feb	16-Mar	12-Mar	07-Mar	07-Mar	07-Mar	64.4	50.1	34.8	32.9	28.5
1986	07-Jan	16-Jan	05-Feb	09-Feb	18-Feb	20-Mar	16-Mar	10-Mar	10-Mar	15-Mar	73.0	59.2	34.3	30.5	26.3
1987	29-Jan	05-Feb	07-Feb	04-Feb	16-Jan	02-Mar	27-Feb	19-Feb	06-Feb	21-Jan	33.6	23.1	12.7	3.4	6.5
1988	18-Jan	27-Jan	04-Feb	08-Feb	14-Feb	12-Mar	11-Mar	04-Mar	03-Mar	07-Mar	54.0	43.7	28.6	24.0	22.7
1989	18-Jan	01-Feb	11-Feb	15-Feb	24-Feb	27-Mar	23-Mar	25-Mar	25-Mar	26-Mar	68.6	51.7	42.9	38.6	30.3
1990	24-Dec	01-Jan	15-Jan	25-Jan	04-Feb	14-Mar	06-Mar	03-Mar	06-Mar	06-Mar	81.8	65.3	48.5	41.1	31.2
1991	20-Jan	28-Jan	31-Jan	29-Jan	01-Feb	12-Mar	07-Mar	07-Mar	14-Mar	12-Mar	51.5	39.3	36.0	44.2	40.0
1992	19-Jan	27-Jan	04-Feb	24-Feb	06-Mar	21-Mar	13-Mar	16-Mar	21-Mar	22-Mar	61.4	46.3	41.8	26.6	17.1
1993	21-Jan	03-Feb	13-Feb	20-Feb	24-Feb	25-Mar	19-Mar	15-Mar	16-Mar	20-Mar	64.3	44.7	31.5	25.3	24.9
1994	05-Jan	11-Jan	20-Jan	27-Jan	31-Jan	31-Mar	27-Mar	19-Mar	19-Mar	24-Mar	86.3	76.3	59.1	52.2	53.2
1995	28-Jan	06-Feb	17-Feb	22-Feb	25-Feb	13-Mar	10-Mar	04-Mar	01-Mar	07-Mar	45.5	33.4	15.3	7.8	10.7
1996	02-Jan	12-Jan	26-Jan	04-Feb	09-Feb	31-Mar	26-Mar	22-Mar	31-Mar	04-Apr	88.6	74.1	55.7	55.8	55.8
1997	13-Jan	20-Jan	03-Feb	13-Feb	23-Feb	19-Mar	13-Mar	14-Mar	25-Mar	27-Mar	66.3	52.7	40.0	41.2	32.7
1998	13-Jan	20-Jan	23-Jan	17-Jan	15-Jan	19-Feb	14-Feb	31-Jan	18-Jan	15-Jan	38.5	26.4	8.7	2.4	1.0
1999	16-Jan	23-Jan	12-Feb	21-Feb	19-Feb	07-Mar	05-Mar	27-Feb	28-Feb	23-Feb	51.4	42.3	16.0	7.6	5.7
2000	18-Jan	26-Jan	05-Feb	15-Feb	17-Feb	24-Feb	21-Feb	17-Feb	18-Feb	18-Feb	37.9	26.3	13.1	4.7	2.5
2001	06-Jan	12-Jan	01-Feb	26-Feb	28-Feb	15-Mar	10-Mar	02-Mar	16-Mar	14-Mar	68.7	57.4	29.5	19.0	14.6
2002	28-Jan	13-Feb	25-Feb	17-Feb	28-Feb	14-Mar	24-Mar	19-Mar	19-Feb	12-Mar	45.3	39.4	23.7	3.2	13.3
Maximum	29-Jan	13-Feb	25-Feb	26-Feb	06-Mar	31-Mar	27-Mar	25-Mar	31-Mar	04-Apr	88.6	77.6	61.9	55.8	55.8
Minimum	24-Dec	01-Jan	14-Jan	17-Jan	15-Jan	19-Feb	14-Feb	31-Jan	18-Jan	15-Jan	31.6	23.1	8.7	2.4	1.0
Average	14-Jan	22-Jan	02-Feb	09-Feb	13-Feb	15-Mar	11-Mar	07-Mar	07-Mar	09-Mar	60.9	49.2	34.1	27.3	25.1
Median	14-Jan	22-Jan	02-Feb	08-Feb	13-Feb	15-Mar	11-Mar	08-Mar	09-Mar	10-Mar	62.8	45.5	34.6	26.5	24.6
25% of pdf	08-Jan	16-Jan	29-Jan	04-Feb	07-Feb	10-Mar	06-Mar	02-Mar	01-Mar	04-Mar	46.9	39.3	24.5	13.7	13.6
75% of pdf	21-Jan	29-Jan	08-Feb	16-Feb	23-Feb	23-Mar	20-Mar	16-Mar	17-Mar	19-Mar	72.9	61.8	43.0	40.1	33.0

pdf = probability density function of the cumulative frequency distribution.

Table 2.2. Lake Superior statistics for discrete depth ranges for ice cover concentration ≥ 90%.

Winter Season	a) Average date of First Ice					b) Average date of Last Ice					c) Average Duration (days)				
	Depth Range (m)					Depth Range (m)					Depth Range (m)				
	0-20	21-50	51-100	101-200	>200	0-20	21-50	51-100	101-200	>200	0-20	21-50	51-100	101-200	>200
1973	12-Jan	23-Jan	02-Feb	18-Feb	21-Feb	13-Mar	09-Mar	08-Mar	05-Mar	01-Mar	61.8	46.3	34.6	15.2	8.5
1974	06-Jan	12-Jan	20-Jan	03-Feb	12-Feb	12-Apr	04-Apr	24-Mar	18-Mar	17-Mar	96.5	82.4	63.9	43.6	34.2
1975	18-Jan	28-Jan	04-Feb	08-Feb	05-Feb	01-Apr	18-Mar	08-Mar	22-Feb	25-Feb	73.9	50.0	33.5	14.4	20.7
1976	09-Jan	20-Jan	05-Feb	23-Feb	05-Mar	27-Mar	16-Mar	09-Mar	09-Mar	12-Mar	77.2	55.8	32.9	14.8	7.9
1977	23-Dec	27-Dec	02-Jan	15-Jan	24-Jan	09-Apr	04-Apr	28-Mar	20-Mar	21-Mar	108.8	100.1	85.4	65.4	56.9
1978	04-Jan	15-Jan	31-Jan	15-Feb	20-Feb	06-Apr	25-Mar	19-Mar	14-Mar	13-Mar	92.6	70.2	47.4	28.5	22.2
1979	05-Jan	12-Jan	18-Jan	28-Jan	06-Feb	23-Apr	19-Apr	11-Apr	08-Apr	03-Apr	108.4	97.8	83.9	71.3	56.5
1980	20-Jan	30-Jan	08-Feb	11-Feb	13-Feb	29-Mar	20-Mar	14-Mar	08-Mar	02-Mar	69.1	49.6	34.7	26.5	17.4
1981	05-Jan	11-Jan	17-Jan	27-Jan	02-Feb	30-Mar	22-Mar	16-Mar	10-Mar	08-Mar	84.9	71.5	59.4	43.5	35.1
1982	06-Jan	13-Jan	21-Jan	02-Feb	09-Feb	12-Apr	29-Mar	21-Mar	17-Mar	11-Mar	96.9	76.0	59.9	45.0	31.6
1983	15-Jan	26-Jan	01-Feb	07-Feb	08-Feb	12-Mar	22-Feb	16-Feb	14-Feb	03-Mar	57.1	28.5	16.0	7.7	23.9
1984	31-Dec	10-Jan	21-Jan	06-Feb	14-Feb	10-Apr	05-Apr	28-Mar	21-Mar	20-Mar	101.1	86.0	66.6	44.2	34.8
1985	01-Jan	07-Jan	17-Jan	01-Feb	10-Feb	30-Mar	21-Mar	16-Mar	11-Mar	08-Mar	88.6	73.8	59.2	39.3	27.4
1986	05-Jan	15-Jan	26-Jan	07-Feb	20-Feb	01-Apr	25-Mar	22-Mar	18-Mar	16-Mar	87.0	70.5	56.1	40.4	24.9
1987	20-Jan	28-Jan	30-Jan	31-Jan	19-Jan	04-Mar	14-Feb	08-Feb	02-Feb	19-Jan	44.0	18.4	9.9	2.3	1.0
1988	15-Jan	21-Jan	28-Jan	09-Feb	13-Feb	22-Mar	14-Mar	07-Mar	06-Mar	08-Mar	66.5	52.6	39.1	25.8	23.4
1989	01-Jan	10-Jan	22-Jan	11-Feb	25-Feb	12-Apr	07-Apr	02-Apr	27-Mar	27-Mar	102.0	88.2	70.6	45.0	31.0
1990	19-Dec	24-Dec	01-Jan	24-Jan	04-Feb	01-Apr	23-Mar	14-Mar	09-Mar	06-Mar	104.4	91.1	73.1	45.1	31.0
1991	07-Jan	15-Jan	21-Jan	28-Jan	03-Feb	03-Apr	25-Mar	16-Mar	14-Mar	12-Mar	86.8	69.9	55.3	45.9	37.3
1992	27-Dec	12-Jan	02-Feb	26-Feb	07-Mar	04-Apr	29-Mar	24-Mar	24-Mar	22-Mar	100.1	77.0	51.3	27.3	16.5
1993	10-Jan	22-Jan	06-Feb	20-Feb	24-Feb	03-Apr	22-Mar	19-Mar	19-Mar	21-Mar	84.1	60.6	41.4	28.1	26.1
1994	30-Dec	07-Jan	15-Jan	22-Jan	28-Jan	14-Apr	09-Apr	03-Apr	29-Mar	28-Mar	106.7	92.4	79.1	67.0	59.8
1995	23-Jan	06-Feb	18-Feb	22-Feb	25-Feb	26-Mar	14-Mar	05-Mar	28-Feb	06-Mar	63.5	36.9	16.3	7.0	10.1
1996	01-Jan	15-Jan	25-Jan	02-Feb	09-Feb	30-Apr	23-Apr	17-Apr	10-Apr	06-Apr	119.9	99.2	82.5	67.3	57.7
1997	06-Jan	19-Jan	31-Jan	14-Feb	25-Feb	13-Apr	07-Apr	03-Apr	31-Mar	27-Mar	98.5	79.0	62.8	46.4	31.3
1998	06-Jan	14-Jan	15-Jan	15-Jan	15-Jan	18-Feb	26-Jan	19-Jan	15-Jan	15-Jan	43.1	13.0	5.0	1.4	1.0
1999	11-Jan	22-Jan	11-Feb	23-Feb	26-Feb	15-Mar	27-Feb	01-Mar	01-Mar	28-Feb	63.6	37.4	19.8	7.5	3.2
2000	15-Jan	29-Jan	09-Feb	16-Feb	15-Feb	04-Mar	22-Feb	19-Feb	19-Feb	17-Feb	49.7	24.7	10.7	4.0	3.6
2001	14-Jan	29-Jan	13-Feb	27-Feb	01-Mar	04-Apr	24-Mar	18-Mar	16-Mar	15-Mar	80.2	55.5	34.6	17.8	15.2
2002	27-Jan	19-Feb	26-Feb	24-Feb	14-Feb	31-Mar	23-Mar	25-Mar	07-Mar	23-Feb	64.3	33.1	28.3	12.0	9.6
Maximum	27-Jan	19-Feb	26-Feb	27-Feb	07-Mar	30-Apr	23-Apr	17-Apr	10-Apr	06-Apr	119.9	100.1	85.4	71.3	59.8
Minimum	19-Dec	24-Dec	01-Jan	15-Jan	15-Jan	18-Feb	26-Jan	19-Jan	15-Jan	15-Jan	43.1	13.0	5.0	1.4	1.0
Average	08-Jan	18-Jan	28-Jan	08-Feb	13-Feb	30-Mar	21-Mar	15-Mar	10-Mar	09-Mar	82.7	62.9	47.1	31.7	25.3
Median	06-Jan	15-Jan	29-Jan	08-Feb	13-Feb	01-Apr	23-Mar	17-Mar	13-Mar	11-Mar	85.9	70.1	49.4	28.3	24.4
25% of pdf	02-Jan	12-Jan	20-Jan	31-Jan	05-Feb	26-Mar	14-Mar	08-Mar	05-Mar	02-Mar	64.9	47.1	33.1	14.5	11.4
75% of pdf	15-Jan	25-Jan	05-Feb	18-Feb	24-Feb	10-Apr	02-Apr	25-Mar	20-Mar	21-Mar	99.7	81.6	63.6	45.0	33.6

pdf = probability density function of the cumulative frequency distribution.

Table 2.3. Lake Michigan statistics for discrete depth ranges for ice cover concentration ≥ 90%.

Winter Season	a) Average date of First Ice					b) Average date of Last Ice					c) Average Duration (days)				
	Depth Range (m)					Depth Range (m)					Depth Range (m)				
	0-20	21-50	51-100	101-200	>200	0-20	21-50	51-100	101-200	>200	0-20	21-50	51-100	101-200	>200
1973	18-Jan	20-Jan	28-Jan	29-Jan	NA	01-Mar	19-Feb	20-Feb	05-Feb	NA	42.9	30.8	30.8	8.8	NA
1974	20-Jan	25-Jan	07-Feb	13-Feb	NA	13-Mar	01-Mar	24-Feb	22-Feb	NA	53.5	35.7	35.7	10.5	NA
1975	23-Jan	27-Jan	06-Feb	12-Feb	NA	10-Mar	06-Mar	15-Feb	12-Feb	NA	46.9	38.5	38.5	1.0	NA
1976	08-Jan	18-Jan	30-Jan	19-Jan	NA	04-Mar	27-Feb	10-Feb	24-Jan	NA	55.8	41.4	41.4	6.1	NA
1977	26-Dec	30-Dec	18-Jan	30-Jan	06-Feb	13-Mar	11-Mar	05-Mar	10-Mar	08-Mar	79.1	72.1	72.1	39.3	31.0
1978	10-Jan	19-Jan	09-Feb	20-Feb	02-Mar	18-Mar	16-Mar	08-Mar	05-Mar	07-Mar	68.5	56.2	56.2	14.5	5.6
1979	11-Jan	18-Jan	03-Feb	13-Feb	15-Feb	23-Mar	17-Mar	08-Mar	09-Mar	12-Mar	72.3	59.7	59.7	24.9	25.8
1980	27-Jan	06-Feb	18-Feb	15-Feb	NA	16-Mar	09-Mar	27-Feb	15-Feb	NA	48.1	32.2	32.2	1.6	NA
1981	03-Jan	09-Jan	16-Jan	29-Jan	10-Feb	05-Mar	24-Feb	09-Feb	09-Feb	10-Feb	61.8	47.6	47.6	11.6	1.0
1982	11-Jan	15-Jan	25-Jan	07-Feb	09-Feb	15-Mar	07-Mar	26-Feb	28-Feb	15-Feb	63.2	51.2	51.2	21.6	6.9
1983	26-Jan	29-Jan	10-Feb	12-Feb	NA	07-Mar	26-Feb	17-Feb	14-Feb	NA	40.9	28.3	28.3	2.7	NA
1984	10-Jan	19-Jan	01-Feb	09-Feb	NA	08-Mar	28-Feb	17-Feb	26-Feb	NA	57.3	41.8	41.8	18.2	NA
1985	15-Jan	27-Jan	13-Feb	22-Feb	NA	18-Mar	12-Mar	03-Mar	02-Mar	NA	63.2	44.6	44.6	9.4	NA
1986	20-Jan	29-Jan	05-Feb	07-Feb	21-Feb	14-Mar	07-Mar	20-Feb	15-Feb	22-Feb	54.1	38.8	38.8	8.6	1.8
1987	22-Jan	31-Jan	14-Feb	19-Feb	NA	02-Mar	03-Mar	20-Feb	20-Feb	NA	39.7	31.3	31.3	1.2	NA
1988	15-Jan	20-Jan	19-Jan	15-Jan	NA	06-Mar	25-Feb	05-Feb	21-Jan	NA	51.5	37.9	37.9	6.8	NA
1989	23-Jan	02-Feb	20-Feb	06-Mar	18-Mar	24-Mar	20-Mar	16-Mar	16-Mar	18-Mar	61.3	47.0	47.0	10.3	1.0
1990	26-Dec	04-Jan	18-Jan	02-Feb	NA	12-Mar	02-Mar	20-Feb	06-Mar	NA	77.9	58.5	58.5	32.8	NA
1991	18-Jan	18-Jan	06-Feb	16-Feb	NA	10-Mar	08-Mar	02-Mar	22-Feb	NA	52.1	49.7	49.7	6.8	NA
1992	19-Jan	26-Jan	29-Jan	02-Feb	02-Feb	06-Mar	24-Feb	11-Feb	06-Feb	02-Feb	47.1	30.1	30.1	5.0	1.0
1993	23-Jan	01-Feb	14-Feb	19-Feb	NA	12-Mar	03-Mar	26-Feb	24-Feb	NA	48.6	31.0	31.0	5.6	NA
1994	04-Jan	14-Jan	28-Jan	06-Feb	20-Feb	23-Mar	16-Mar	07-Mar	03-Mar	06-Mar	78.5	62.3	62.3	26.5	14.2
1995	29-Jan	08-Feb	16-Feb	12-Feb	NA	10-Mar	03-Mar	22-Feb	12-Feb	NA	40.6	24.2	24.2	1.0	NA
1996	04-Jan	16-Jan	02-Feb	10-Feb	05-Mar	27-Mar	17-Mar	02-Mar	03-Mar	07-Mar	83.4	61.3	61.3	22.1	2.2
1997	07-Jan	18-Jan	28-Jan	06-Feb	13-Feb	09-Mar	02-Mar	18-Feb	14-Feb	13-Feb	61.3	43.9	43.9	9.0	1.0
1998	12-Jan	21-Jan	07-Feb	NA	NA	22-Feb	20-Feb	07-Feb	NA	NA	41.5	31.2	31.2	NA	NA
1999	09-Jan	14-Jan	25-Jan	14-Jan	NA	27-Feb	26-Feb	26-Jan	14-Jan	NA	49.8	44.2	44.2	1.0	NA
2000	19-Jan	23-Jan	02-Feb	17-Feb	NA	20-Feb	23-Feb	13-Feb	17-Feb	NA	33.8	32.1	32.1	1.0	NA
2001	01-Jan	07-Jan	14-Jan	10-Jan	NA	11-Mar	27-Feb	23-Jan	10-Jan	NA	70.5	51.8	51.8	1.0	NA
2002	03-Feb	09-Feb	17-Feb	NA	NA	22-Mar	22-Mar	20-Feb	NA	NA	47.9	42.4	42.4	NA	NA
Maximum	03-Feb	09-Feb	20-Feb	06-Mar	18-Mar	27-Mar	22-Mar	16-Mar	16-Mar	18-Mar	83.4	72.1	72.1	39.3	31.0
Minimum	26-Dec	30-Dec	14-Jan	10-Jan	02-Feb	20-Feb	19-Feb	23-Jan	10-Jan	02-Feb	33.8	24.2	24.2	0.0	1.0
Average	14-Jan	21-Jan	02-Feb	05-Feb	19-Feb	11-Mar	05-Mar	20-Feb	17-Feb	26-Feb	56.4	43.3	43.3	10.3	8.3
Median	15-Jan	20-Jan	02-Feb	09-Feb	15-Feb	10-Mar	03-Mar	20-Feb	18-Feb	06-Mar	53.8	42.1	42.1	8.7	2.2
25% of pdf	08-Jan	16-Jan	28-Jan	30-Jan	09-Feb	06-Mar	26-Feb	13-Feb	11-Feb	14-Feb	47.3	32.1	32.1	1.3	1.0
75% of pdf	22-Jan	28-Jan	09-Feb	14-Feb	26-Feb	15-Mar	11-Mar	01-Mar	02-Mar	07-Mar	63.2	50.8	50.8	13.8	10.6

pdf = probability density function of the cumulative frequency distribution.
NA = no data meeting threshold ice concentration.

Table 2.4. Lake Huron statistics for discrete depth ranges for ice cover concentration ≥ 90%.

Winter Season	a) Average date of First Ice					b) Average date of Last Ice					c) Average Duration (days)				
	Depth Range (m)					Depth Range (m)					Depth Range (m)				
	0-20	21-50	51-100	101-200	>200	0-20	21-50	51-100	101-200	>200	0-20	21-50	51-100	101-200	>200
1973	08-Jan	26-Jan	14-Feb	20-Feb	19-Feb	10-Mar	06-Mar	02-Mar	02-Mar	19-Feb	61.4	40.4	17.2	11.2	1.0
1974	12-Jan	22-Jan	06-Feb	20-Feb	27-Feb	22-Mar	14-Mar	06-Mar	01-Mar	27-Feb	70.0	51.8	28.4	9.6	1.0
1975	25-Jan	02-Feb	16-Feb	03-Feb	05-Feb	23-Mar	13-Mar	08-Mar	11-Feb	05-Feb	58.1	39.9	21.7	8.6	1.0
1976	07-Jan	13-Jan	25-Jan	14-Feb	02-Mar	14-Mar	05-Mar	28-Feb	25-Feb	02-Mar	66.7	52.0	34.8	11.4	1.0
1977	23-Dec	02-Jan	15-Jan	01-Feb	09-Feb	26-Mar	21-Mar	20-Mar	21-Mar	22-Mar	95.2	79.1	64.7	49.0	41.7
1978	03-Jan	15-Jan	27-Jan	11-Feb	10-Feb	02-Apr	27-Mar	20-Mar	17-Mar	14-Mar	90.0	71.9	52.5	35.7	32.2
1979	08-Jan	19-Jan	31-Jan	09-Feb	11-Feb	25-Mar	17-Mar	14-Mar	11-Mar	07-Mar	77.6	57.1	43.5	30.7	24.5
1980	25-Jan	05-Feb	14-Feb	20-Feb	05-Feb	25-Mar	22-Mar	14-Mar	04-Mar	05-Feb	60.4	45.6	28.9	12.9	1.0
1981	02-Jan	07-Jan	17-Jan	30-Jan	03-Feb	16-Mar	07-Mar	27-Feb	21-Feb	18-Feb	74.0	59.2	42.3	23.0	16.3
1982	11-Jan	19-Jan	28-Jan	11-Feb	23-Feb	08-Apr	30-Mar	21-Mar	09-Mar	08-Mar	87.6	71.4	53.6	26.0	13.4
1983	24-Jan	27-Jan	30-Jan	30-Jan	NA	01-Mar	24-Feb	15-Feb	04-Feb	NA	36.2	28.2	17.0	6.0	NA
1984	31-Dec	12-Jan	01-Feb	21-Feb	07-Feb	02-Apr	27-Mar	24-Mar	16-Mar	07-Mar	93.4	75.9	51.5	23.6	29.7
1985	08-Jan	19-Jan	05-Feb	14-Feb	13-Feb	22-Mar	12-Mar	06-Mar	24-Feb	22-Feb	74.0	53.5	29.9	10.8	9.3
1986	01-Jan	18-Jan	08-Feb	14-Feb	23-Feb	23-Mar	15-Mar	14-Mar	03-Mar	28-Feb	81.5	56.8	35.2	18.3	5.7
1987	28-Jan	03-Feb	09-Feb	04-Feb	NA	09-Mar	04-Mar	23-Feb	12-Feb	NA	40.3	29.6	15.4	8.8	NA
1988	17-Jan	01-Feb	16-Feb	24-Feb	06-Mar	19-Mar	16-Mar	12-Mar	06-Mar	06-Mar	62.7	44.4	24.7	11.5	1.0
1989	10-Jan	30-Jan	20-Feb	05-Mar	09-Mar	03-Apr	28-Mar	24-Mar	20-Mar	15-Mar	83.5	58.2	33.0	16.0	7.7
1990	21-Dec	01-Jan	23-Jan	12-Feb	NA	18-Mar	08-Mar	06-Mar	02-Mar	NA	88.8	67.4	42.6	18.1	NA
1991	13-Jan	21-Jan	07-Feb	13-Feb	NA	16-Mar	04-Mar	26-Feb	26-Feb	NA	62.3	43.4	20.3	13.5	NA
1992	14-Jan	23-Jan	08-Feb	10-Feb	NA	04-Apr	25-Mar	26-Mar	22-Mar	NA	80.8	62.2	47.1	41.6	NA
1993	14-Jan	28-Jan	16-Feb	23-Feb	27-Feb	03-Apr	27-Mar	19-Mar	09-Mar	27-Feb	80.3	58.2	31.9	15.7	1.0
1994	02-Jan	08-Jan	16-Jan	27-Jan	28-Jan	07-Apr	03-Apr	28-Mar	25-Mar	24-Mar	96.1	85.7	71.7	57.2	55.6
1995	21-Jan	05-Feb	19-Feb	02-Mar	NA	20-Mar	10-Mar	04-Mar	09-Mar	NA	58.2	33.8	13.1	8.0	NA
1996	26-Dec	08-Jan	24-Jan	05-Feb	12-Feb	05-Apr	29-Mar	24-Mar	19-Mar	17-Mar	101.8	80.9	59.6	43.4	34.7
1997	10-Jan	24-Jan	07-Feb	10-Feb	18-Feb	29-Mar	19-Mar	12-Mar	28-Feb	24-Feb	79.0	55.0	34.4	19.1	6.5
1998	14-Jan	23-Jan	01-Feb	04-Feb	NA	25-Feb	19-Feb	13-Feb	08-Feb	NA	43.0	28.6	13.3	4.3	NA
1999	13-Jan	28-Jan	18-Feb	26-Feb	NA	12-Mar	10-Mar	05-Mar	08-Mar	NA	58.4	42.6	15.8	11.4	NA
2000	13-Jan	24-Jan	03-Feb	08-Feb	NA	01-Mar	21-Feb	16-Feb	11-Feb	NA	47.6	28.7	14.2	3.6	NA
2001	31-Dec	16-Jan	05-Feb	27-Feb	NA	24-Mar	11-Mar	06-Mar	19-Mar	NA	83.2	55.7	29.4	21.8	NA
2002	01-Feb	17-Feb	01-Mar	NA	NA	27-Mar	26-Mar	29-Mar	NA	NA	55.0	37.7	28.9	NA	NA
Maximum	01-Feb	17-Feb	01-Mar	05-Mar	09-Mar	08-Apr	03-Apr	29-Mar	25-Mar	24-Mar	101.8	85.7	71.7	57.2	55.6
Minimum	21-Dec	01-Jan	15-Jan	27-Jan	28-Jan	25-Feb	19-Feb	13-Feb	04-Feb	05-Feb	36.2	28.2	13.1	3.6	0.0
Average	10-Jan	22-Jan	05-Feb	12-Feb	16-Feb	22-Mar	15-Mar	10-Mar	04-Mar	02-Mar	71.6	53.2	33.9	19.7	13.5
Median	11-Jan	22-Jan	06-Feb	12-Feb	13-Feb	23-Mar	14-Mar	10-Mar	04-Mar	02-Mar	74.0	54.3	30.9	15.7	7.7
25% of pdf	03-Jan	15-Jan	28-Jan	04-Feb	08-Feb	16-Mar	07-Mar	03-Mar	25-Feb	23-Feb	58.9	41.0	20.7	10.8	1.0
75% of pdf	14-Jan	28-Jan	14-Feb	20-Feb	24-Feb	01-Apr	26-Mar	20-Mar	16-Mar	11-Mar	83.4	61.5	43.3	23.6	24.5

pdf = probability density function of the cumulative frequency distribution.
NA = no data meeting threshold ice concentration.

Table 2.5. Lake Erie statistics for discrete depth ranges for ice cover concentration ≥ 90%.

Winter Season	a) Average date of First Ice					b) Average date of Last Ice					c) Average Duration (days)				
	Depth Range (m)					Depth Range (m)					Depth Range (m)				
	0-20	21-50	51-100	101-200	>200	0-20	21-50	51-100	101-200	>200	0-20	21-50	51-100	101-200	>200
1973	03-Feb	14-Feb	22-Feb	NA	NA	27-Feb	28-Feb	27-Feb	NA	NA	25.1	15.2	6.4	NA	NA
1974	19-Jan	07-Feb	23-Jan	NA	NA	24-Feb	02-Mar	12-Mar	NA	NA	36.4	23.8	48.6	NA	NA
1975	10-Feb	14-Feb	26-Feb	NA	NA	28-Feb	02-Mar	26-Feb	NA	NA	19.1	17.2	1.0	NA	NA
1976	14-Jan	22-Jan	25-Jan	NA	NA	19-Feb	23-Feb	02-Mar	NA	NA	36.7	33.2	36.1	NA	NA
1977	26-Dec	01-Jan	04-Jan	NA	NA	11-Mar	17-Mar	22-Mar	NA	NA	76.9	75.8	77.8	NA	NA
1978	05-Jan	11-Jan	15-Jan	NA	NA	28-Mar	01-Apr	03-Apr	NA	NA	83.6	81.2	79.1	NA	NA
1979	09-Jan	13-Jan	19-Jan	NA	NA	12-Mar	20-Mar	21-Mar	NA	NA	62.9	67.2	62.3	NA	NA
1980	30-Jan	05-Feb	07-Feb	NA	NA	14-Mar	17-Mar	23-Mar	NA	NA	44.0	40.9	45.1	NA	NA
1981	02-Jan	06-Jan	06-Jan	NA	NA	28-Feb	06-Mar	27-Mar	NA	NA	57.6	60.4	81.6	NA	NA
1982	14-Jan	17-Jan	17-Jan	NA	NA	25-Mar	30-Mar	11-Apr	NA	NA	71.2	73.9	85.1	NA	NA
1983	01-Feb	13-Feb	NA	NA	NA	13-Feb	13-Feb	NA	NA	NA	12.7	1.0	NA	NA	NA
1984	31-Dec	03-Jan	10-Jan	NA	NA	30-Mar	01-Apr	08-Apr	NA	NA	89.8	88.5	89.1	NA	NA
1985	16-Jan	26-Jan	01-Feb	NA	NA	08-Mar	13-Mar	28-Mar	NA	NA	52.2	46.7	56.4	NA	NA
1986	27-Dec	27-Dec	27-Dec	NA	NA	17-Mar	23-Mar	29-Mar	NA	NA	82.5	87.1	93.4	NA	NA
1987	01-Feb	13-Feb	18-Feb	NA	NA	23-Feb	24-Feb	27-Feb	NA	NA	22.3	12.5	9.4	NA	NA
1988	18-Jan	31-Jan	07-Feb	NA	NA	06-Mar	15-Mar	30-Mar	NA	NA	48.6	44.1	52.1	NA	NA
1989	28-Jan	10-Feb	13-Feb	NA	NA	12-Mar	10-Mar	09-Mar	NA	NA	43.9	29.0	24.2	NA	NA
1990	23-Dec	04-Jan	03-Jan	NA	NA	01-Mar	04-Mar	12-Mar	NA	NA	69.9	60.0	68.9	NA	NA
1991	10-Feb	27-Feb	27-Feb	NA	NA	25-Feb	01-Mar	28-Feb	NA	NA	15.6	3.4	2.5	NA	NA
1992	27-Jan	08-Feb	10-Feb	NA	NA	04-Mar	04-Mar	03-Mar	NA	NA	37.2	25.1	22.5	NA	NA
1993	27-Jan	16-Feb	18-Feb	NA	NA	24-Mar	22-Mar	21-Mar	NA	NA	57.2	34.5	31.8	NA	NA
1994	06-Jan	14-Jan	15-Jan	NA	NA	22-Mar	29-Mar	09-Apr	NA	NA	75.6	75.8	84.9	NA	NA
1995	30-Jan	08-Feb	11-Feb	NA	NA	08-Mar	15-Mar	17-Mar	NA	NA	38.5	36.4	34.7	NA	NA
1996	29-Dec	09-Jan	13-Jan	NA	NA	18-Mar	25-Mar	26-Mar	NA	NA	81.1	76.4	72.3	NA	NA
1997	13-Jan	17-Jan	26-Jan	NA	NA	24-Feb	02-Mar	20-Mar	NA	NA	43.3	45.3	53.9	NA	NA
1998	20-Jan	15-Jan	NA	NA	NA	28-Jan	15-Jan	NA	NA	NA	9.0	1.0	NA	NA	NA
1999	18-Jan	25-Jan	08-Mar	NA	NA	06-Mar	08-Mar	09-Mar	NA	NA	47.8	42.9	1.7	NA	NA
2000	21-Jan	29-Jan	31-Jan	NA	NA	20-Feb	20-Feb	04-Feb	NA	NA	30.7	23.1	4.9	NA	NA
2001	26-Dec	04-Jan	19-Jan	NA	NA	26-Feb	12-Mar	07-Apr	NA	NA	63.4	68.0	79.1	NA	NA
2002	12-Jan	10-Feb	NA	NA	NA	23-Jan	10-Feb	NA	NA	NA	12.3	1.0	NA	NA	NA
Maximum	10-Feb	27-Feb	08-Mar	NA	NA	30-Mar	01-Apr	11-Apr	NA	NA	89.8	88.5	93.4	NA	NA
Minimum	23-Dec	27-Dec	27-Dec	NA	NA	23-Jan	15-Jan	04-Feb	NA	NA	9.0	1.0	1.0	NA	NA
Average	16-Jan	25-Jan	29-Jan	NA	NA	04-Mar	08-Mar	18-Mar	NA	NA	48.2	43.0	48.3	NA	NA
Median	17-Jan	26-Jan	27-Jan	NA	NA	05-Mar	09-Mar	21-Mar	NA	NA	45.9	41.9	52.1	NA	NA
25% of pdf	05-Jan	12-Jan	15-Jan	NA	NA	24-Feb	01-Mar	06-Mar	NA	NA	32.1	23.3	23.4	NA	NA
75% of pdf	28-Jan	09-Feb	12-Feb	NA	NA	13-Mar	19-Mar	28-Mar	NA	NA	68.3	67.8	78.5	NA	NA

pdf = probability density function of the cumulative frequency distribution.
NA = no data meeting threshold ice concentration.

Table 2.6. Lake Ontario statistics for discrete depth ranges for ice cover concentration ≥ 90%.

Winter Season	a) Average date of First Ice					b) Average date of Last Ice					c) Average Duration (days)				
	Depth Range (m)					Depth Range (m)					Depth Range (m)				
	0-20	21-50	51-100	101-200	>200	0-20	21-50	51-100	101-200	>200	0-20	21-50	51-100	101-200	>200
1973	26-Jan	04-Feb	18-Feb	19-Feb	NA	26-Feb	23-Feb	20-Feb	19-Feb	NA	32.2	20.3	3.0	1.0	NA
1974	17-Jan	31-Jan	16-Jan	09-Jan	NA	25-Feb	16-Feb	16-Jan	09-Jan	NA	39.7	16.8	1.0	1.0	NA
1975	31-Jan	11-Feb	12-Feb	NA	NA	27-Feb	12-Feb	12-Feb	NA	NA	27.2	1.8	1.0	NA	NA
1976	19-Jan	01-Feb	28-Jan	01-Feb	NA	09-Mar	20-Feb	02-Feb	02-Feb	NA	50.2	20.0	5.6	1.6	NA
1977	07-Jan	13-Jan	21-Jan	03-Feb	08-Feb	11-Mar	09-Mar	28-Feb	27-Feb	22-Feb	63.4	55.7	39.0	25.0	15.4
1978	16-Jan	26-Jan	16-Feb	18-Feb	14-Feb	18-Mar	11-Mar	06-Mar	26-Feb	17-Feb	61.9	44.7	18.9	8.5	4.6
1979	22-Jan	31-Jan	08-Feb	12-Feb	11-Feb	01-Mar	21-Feb	15-Feb	15-Feb	15-Feb	38.7	22.2	8.4	4.8	5.3
1980	05-Feb	14-Feb	13-Feb	12-Feb	12-Feb	14-Mar	01-Mar	21-Feb	18-Feb	12-Feb	37.5	16.2	9.0	7.2	1.0
1981	05-Jan	06-Jan	07-Jan	14-Jan	11-Jan	05-Feb	29-Jan	12-Jan	14-Jan	11-Jan	32.1	24.5	6.0	1.2	1.0
1982	23-Jan	23-Jan	25-Jan	29-Jan	04-Mar	09-Mar	06-Mar	16-Feb	20-Feb	08-Mar	46.4	42.6	23.5	23.9	4.6
1983	09-Feb	11-Feb	09-Feb	NA	NA	17-Feb	13-Feb	12-Feb	NA	NA	9.5	2.6	4.0	NA	NA
1984	10-Jan	15-Jan	24-Jan	09-Feb	NA	07-Mar	09-Mar	20-Feb	14-Feb	NA	56.2	54.4	28.4	6.6	NA
1985	18-Jan	23-Jan	02-Feb	07-Feb	08-Feb	26-Feb	15-Feb	11-Feb	18-Feb	20-Feb	39.9	24.1	9.8	11.3	13.7
1986	23-Jan	05-Feb	16-Feb	21-Feb	28-Feb	10-Mar	07-Mar	05-Mar	03-Mar	28-Feb	46.9	31.0	18.5	11.9	1.0
1987	12-Feb	13-Feb	NA	NA	NA	03-Mar	15-Feb	NA	NA	NA	20.2	3.2	NA	NA	NA
1988	19-Jan	26-Jan	14-Feb	NA	NA	14-Mar	05-Mar	14-Feb	NA	NA	54.9	39.0	1.0	NA	NA
1989	14-Feb	26-Feb	11-Mar	NA	NA	22-Mar	16-Mar	11-Mar	NA	NA	36.6	18.6	1.0	NA	NA
1990	27-Dec	29-Dec	03-Jan	25-Dec	23-Dec	25-Feb	14-Feb	30-Jan	06-Jan	23-Dec	61.7	49.1	27.1	14.2	1.0
1991	17-Jan	29-Jan	25-Feb	NA	NA	05-Mar	21-Feb	25-Feb	NA	NA	48.4	24.2	1.0	NA	NA
1992	26-Jan	03-Feb	13-Feb	15-Feb	15-Feb	16-Mar	08-Mar	15-Feb	15-Feb	15-Feb	49.1	33.8	3.0	1.0	1.0
1993	02-Feb	14-Feb	21-Feb	25-Feb	NA	16-Mar	03-Mar	27-Feb	26-Feb	NA	42.7	18.1	7.2	2.3	NA
1994	11-Jan	15-Jan	26-Jan	03-Feb	10-Feb	13-Mar	07-Mar	21-Feb	19-Feb	01-Mar	61.6	51.8	27.1	17.7	19.5
1995	06-Feb	09-Feb	09-Feb	NA	NA	06-Mar	24-Feb	12-Feb	NA	NA	29.3	16.0	3.5	NA	NA
1996	17-Jan	17-Jan	19-Jan	03-Feb	NA	27-Feb	16-Feb	06-Feb	09-Feb	NA	42.3	31.4	18.6	6.3	NA
1997	22-Jan	27-Jan	10-Feb	NA	NA	16-Mar	19-Feb	10-Feb	NA	NA	53.6	24.6	1.0	NA	NA
1998	24-Jan	05-Feb	NA	NA	NA	09-Feb	08-Feb	NA	NA	NA	17.6	3.9	NA	NA	NA
1999	18-Jan	03-Feb	29-Jan	21-Jan	NA	23-Feb	14-Feb	16-Feb	18-Feb	NA	37.0	12.1	19.1	29.0	NA
2000	21-Jan	31-Jan	02-Feb	31-Jan	NA	18-Feb	11-Feb	02-Feb	31-Jan	NA	28.9	12.1	1.0	1.0	NA
2001	10-Jan	22-Jan	19-Jan	NA	NA	28-Feb	17-Feb	28-Jan	NA	NA	50.6	26.8	10.2	NA	NA
2002	18-Jan	NA	NA	NA	NA	23-Feb	NA	NA	NA	NA	37.4	NA	NA	NA	NA
Maximum	14-Feb	26-Feb	11-Mar	25-Feb	04-Mar	22-Mar	16-Mar	11-Mar	03-Mar	08-Mar	63.4	55.7	39.0	29.0	19.5
Minimum	27-Dec	29-Dec	03-Jan	25-Dec	23-Dec	05-Feb	29-Jan	12-Jan	06-Jan	23-Dec	9.5	1.8	1.0	1.0	1.0
Average	22-Jan	29-Jan	04-Feb	03-Feb	07-Feb	03-Mar	23-Feb	14-Feb	12-Feb	13-Feb	41.8	25.6	11.0	9.2	6.2
Median	20-Jan	31-Jan	08-Feb	03-Feb	11-Feb	04-Mar	21-Feb	15-Feb	18-Feb	19-Feb	41.1	24.1	7.2	6.6	4.6
25% of pdf	17-Jan	23-Jan	24-Jan	30-Jan	08-Feb	25-Feb	15-Feb	08-Feb	10-Feb	14-Feb	33.3	16.2	2.0	1.4	1.0
75% of pdf	26-Jan	05-Feb	13-Feb	13-Feb	14-Feb	12-Mar	06-Mar	21-Feb	20-Feb	28-Feb	50.5	33.8	18.8	13.1	9.5

pdf = probability density function of the cumulative frequency distribution.
NA = no data meeting threshold ice concentration.

Table 3.1 Great Lakes statistics for discrete depth ranges for ice cover concentration≥ 10%.

Winter Season	a) Average date of First Ice					b) Average date of Last Ice					c) Average Duration (days)				
	Depth Range (m)					Depth Range (m)					Depth Range (m)				
	0-20	21-50	51-100	101-200	>200	0-20	21-50	51-100	101-200	>200	0-20	21-50	51-100	101-200	>200
1973	05-Jan	16-Jan	27-Jan	04-Feb	12-Feb	08-Mar	06-Mar	05-Mar	02-Mar	03-Mar	62.9	49.5	37.5	27.1	20.2
1974	11-Jan	20-Jan	29-Jan	06-Feb	16-Feb	22-Mar	17-Mar	17-Mar	28-Mar	31-Mar	71.0	56.4	47.4	50.9	43.9
1975	20-Jan	29-Jan	03-Feb	08-Feb	09-Feb	24-Mar	15-Mar	08-Mar	28-Feb	20-Feb	63.6	46.1	33.5	20.7	12.3
1976	06-Jan	12-Jan	28-Jan	16-Feb	24-Feb	16-Mar	11-Mar	10-Mar	13-Mar	15-Mar	69.5	59.0	41.9	25.6	19.6
1977	22-Dec	27-Dec	06-Jan	15-Jan	17-Jan	31-Mar	30-Mar	26-Mar	31-Mar	03-Apr	101.3	94.9	80.1	76.5	76.6
1978	04-Jan	12-Jan	27-Jan	10-Feb	15-Feb	06-Apr	02-Apr	22-Mar	17-Mar	18-Mar	92.8	80.7	55.0	36.5	32.3
1979	02-Jan	09-Jan	17-Jan	26-Jan	01-Feb	31-Mar	29-Mar	26-Mar	03-Apr	11-Apr	89.6	80.3	69.6	68.4	70.0
1980	19-Jan	29-Jan	08-Feb	08-Feb	15-Feb	24-Mar	22-Mar	18-Mar	16-Mar	10-Mar	64.9	53.3	38.9	36.3	24.1
1981	01-Jan	06-Jan	13-Jan	23-Jan	28-Jan	12-Mar	07-Mar	25-Feb	01-Mar	07-Mar	71.0	61.2	44.1	38.1	38.1
1982	11-Jan	16-Jan	23-Jan	04-Feb	08-Feb	03-Apr	28-Mar	20-Mar	19-Mar	17-Mar	83.5	71.8	57.1	44.0	38.5
1983	18-Jan	20-Jan	21-Jan	29-Jan	31-Jan	02-Mar	23-Feb	10-Feb	16-Feb	24-Feb	43.4	34.9	21.2	18.4	24.8
1984	01-Jan	09-Jan	21-Jan	01-Feb	09-Feb	29-Mar	26-Mar	19-Mar	25-Mar	27-Mar	88.1	77.0	58.9	53.6	46.9
1985	10-Jan	20-Jan	01-Feb	03-Feb	07-Feb	20-Mar	16-Mar	12-Mar	12-Mar	11-Mar	69.8	56.3	40.4	37.9	33.1
1986	29-Dec	07-Jan	28-Jan	04-Feb	13-Feb	26-Mar	23-Mar	17-Mar	19-Mar	20-Mar	88.8	76.1	49.3	43.5	36.6
1987	23-Jan	29-Jan	02-Feb	30-Jan	26-Jan	02-Mar	27-Feb	20-Feb	09-Feb	03-Feb	39.0	30.5	19.8	11.6	9.7
1988	13-Jan	19-Jan	31-Jan	08-Feb	14-Feb	19-Mar	15-Mar	11-Mar	16-Mar	19-Mar	66.2	56.0	40.4	37.4	34.1
1989	09-Jan	26-Jan	07-Feb	14-Feb	19-Feb	04-Apr	31-Mar	03-Apr	07-Apr	11-Apr	85.8	65.0	56.2	53.4	52.4
1990	20-Dec	26-Dec	09-Jan	23-Jan	08-Feb	25-Mar	18-Mar	10-Mar	16-Mar	15-Mar	96.8	84.2	61.2	53.3	35.7
1991	11-Jan	21-Jan	28-Jan	28-Jan	28-Jan	16-Mar	09-Mar	06-Mar	19-Mar	16-Mar	64.9	47.7	38.0	51.1	47.9
1992	13-Jan	24-Jan	09-Feb	23-Feb	02-Mar	30-Mar	22-Mar	22-Mar	25-Mar	24-Mar	76.4	57.3	41.3	31.1	22.8
1993	15-Jan	30-Jan	07-Feb	15-Feb	20-Feb	02-Apr	28-Mar	26-Mar	24-Mar	26-Mar	77.7	58.4	48.0	37.7	34.5
1994	03-Jan	10-Jan	18-Jan	24-Jan	28-Jan	07-Apr	05-Apr	27-Mar	27-Mar	03-Apr	95.3	85.8	69.1	63.5	66.6
1995	23-Jan	05-Feb	16-Feb	25-Feb	26-Feb	20-Mar	17-Mar	12-Mar	10-Mar	13-Mar	57.1	41.3	24.9	14.0	16.1
1996	30-Dec	09-Jan	24-Jan	01-Feb	03-Feb	08-Apr	06-Apr	29-Mar	02-Apr	06-Apr	101.4	88.0	65.0	60.8	62.8
1997	07-Jan	16-Jan	28-Jan	07-Feb	15-Feb	30-Mar	24-Mar	21-Mar	31-Mar	05-Apr	83.2	68.9	53.5	53.1	50.2
1998	10-Jan	18-Jan	26-Jan	23-Jan	14-Jan	04-Mar	01-Mar	19-Feb	05-Feb	28-Jan	53.3	42.4	25.0	13.2	15.2
1999	09-Jan	17-Jan	29-Jan	09-Feb	31-Jan	12-Mar	06-Mar	21-Feb	21-Feb	01-Mar	63.1	49.6	23.4	13.2	30.0
2000	12-Jan	21-Jan	31-Jan	09-Feb	09-Feb	03-Mar	25-Feb	18-Feb	18-Feb	20-Feb	50.6	36.2	19.3	10.1	11.8
2001	30-Dec	07-Jan	30-Jan	21-Feb	28-Feb	24-Mar	19-Mar	08-Mar	21-Mar	27-Mar	86.3	72.1	37.4	28.8	27.9
2002	16-Jan	05-Feb	24-Feb	25-Feb	14-Feb	18-Mar	26-Mar	21-Mar	15-Mar	22-Mar	61.4	49.7	26.0	19.0	37.1
Maximum	23-Jan	05-Feb	24-Feb	25-Feb	02-Mar	08-Apr	06-Apr	03-Apr	07-Apr	11-Apr	101.4	94.9	80.1	76.5	76.6
Minimum	20-Dec	26-Dec	06-Jan	15-Jan	14-Jan	02-Mar	23-Feb	10-Feb	05-Feb	28-Jan	39.0	30.5	19.3	10.1	9.7
Average	08-Jan	17-Jan	28-Jan	05-Feb	09-Feb	22-Mar	18-Mar	12-Mar	14-Mar	16-Mar	74.0	61.0	44.1	37.6	35.7
Median	10-Jan	18-Jan	28-Jan	05-Feb	09-Feb	24-Mar	19-Mar	14-Mar	17-Mar	18-Mar	71.0	57.9	41.6	37.6	34.3
25% of pdf	02-Jan	09-Jan	23-Jan	29-Jan	01-Feb	16-Mar	09-Mar	06-Mar	04-Mar	08-Mar	63.2	49.5	34.5	21.9	23.1
75% of pdf	13-Jan	23-Jan	01-Feb	09-Feb	15-Feb	31-Mar	27-Mar	22-Mar	25-Mar	27-Mar	87.7	75.1	55.9	52.6	46.2

pdf = probability density function of the cumulative frequency distribution.

Table 3.2. Lake Superior statistics for discrete depth ranges for ice cover concentration ≥ 10%.

Winter Season	a) Average date of First Ice					b) Average date of Last Ice					c) Average Duration (days)				
	Depth Range (m)					Depth Range (m)					Depth Range (m)				
	0-20	21-50	51-100	101-200	>200	0-20	21-50	51-100	101-200	>200	0-20	21-50	51-100	101-200	>200
1973	25-Dec	02-Jan	12-Jan	02-Feb	13-Feb	22-Mar	16-Mar	11-Mar	06-Mar	02-Mar	88.9	73.9	58.6	32.4	18.7
1974	04-Jan	09-Jan	18-Jan	03-Feb	20-Feb	18-Apr	12-Apr	07-Apr	03-Apr	31-Mar	105.5	93.9	80.1	60.5	39.8
1975	13-Jan	20-Jan	30-Jan	08-Feb	11-Feb	05-Apr	27-Mar	17-Mar	01-Mar	24-Feb	83.0	66.6	47.1	22.0	14.0
1976	04-Jan	13-Jan	27-Jan	16-Feb	28-Feb	01-Apr	22-Mar	18-Mar	16-Mar	17-Mar	88.1	69.0	51.5	29.0	17.9
1977	19-Dec	23-Dec	30-Dec	10-Jan	18-Jan	17-Apr	14-Apr	10-Apr	06-Apr	05-Apr	120.2	113.6	103.5	86.8	78.2
1978	31-Dec	11-Jan	24-Jan	09-Feb	15-Feb	12-Apr	05-Apr	29-Mar	24-Mar	19-Mar	103.3	84.9	65.8	44.4	32.6
1979	30-Dec	05-Jan	10-Jan	21-Jan	31-Jan	01-May	27-Apr	22-Apr	19-Apr	13-Apr	123.6	113.3	103.3	89.2	72.1
1980	12-Jan	21-Jan	29-Jan	04-Feb	17-Feb	04-Apr	29-Mar	24-Mar	18-Mar	11-Mar	83.5	68.4	54.8	42.2	23.3
1981	31-Dec	06-Jan	11-Jan	22-Jan	29-Jan	31-Mar	24-Mar	18-Mar	10-Mar	08-Mar	90.1	78.3	66.8	48.3	38.7
1982	06-Jan	13-Jan	21-Jan	01-Feb	10-Feb	16-Apr	06-Apr	01-Apr	26-Mar	21-Mar	101.5	84.1	71.2	54.2	39.8
1983	08-Jan	17-Jan	21-Jan	28-Jan	31-Jan	19-Mar	04-Mar	18-Feb	18-Feb	23-Feb	71.0	46.3	28.7	21.8	24.4
1984	27-Dec	01-Jan	13-Jan	29-Jan	12-Feb	14-Apr	10-Apr	04-Apr	31-Mar	28-Mar	110.4	100.1	82.7	61.6	45.0
1985	30-Dec	05-Jan	15-Jan	30-Jan	09-Feb	31-Mar	24-Mar	20-Mar	16-Mar	11-Mar	92.0	78.9	65.1	46.1	31.0
1986	26-Dec	03-Jan	15-Jan	30-Jan	13-Feb	03-Apr	29-Mar	27-Mar	24-Mar	22-Mar	99.9	86.2	72.1	54.3	37.9
1987	15-Jan	22-Jan	29-Jan	05-Feb	31-Jan	05-Mar	19-Feb	12-Feb	11-Feb	06-Feb	49.7	29.0	15.6	6.8	7.7
1988	12-Jan	19-Jan	27-Jan	09-Feb	14-Feb	28-Mar	24-Mar	21-Mar	20-Mar	21-Mar	75.9	65.3	54.2	39.8	36.1
1989	28-Dec	05-Jan	15-Jan	05-Feb	20-Feb	23-Apr	19-Apr	17-Apr	13-Apr	12-Apr	117.3	105.2	92.5	68.6	51.5
1990	18-Dec	24-Dec	30-Dec	21-Jan	05-Feb	08-Apr	02-Apr	29-Mar	25-Mar	17-Mar	113.1	101.3	90.6	64.0	41.1
1991	04-Jan	11-Jan	18-Jan	26-Jan	31-Jan	08-Apr	02-Apr	25-Mar	21-Mar	16-Mar	95.0	81.7	67.3	55.4	44.7
1992	23-Dec	07-Jan	29-Jan	22-Feb	04-Mar	14-Apr	05-Apr	01-Apr	28-Mar	24-Mar	113.7	88.9	62.7	35.8	21.0
1993	04-Jan	14-Jan	30-Jan	13-Feb	22-Feb	12-Apr	06-Apr	01-Apr	28-Mar	26-Mar	98.8	82.5	62.6	43.1	33.0
1994	27-Dec	04-Jan	11-Jan	20-Jan	26-Jan	20-Apr	16-Apr	12-Apr	09-Apr	08-Apr	115.7	103.3	92.3	79.6	72.9
1995	13-Jan	31-Jan	15-Feb	26-Feb	27-Feb	04-Apr	25-Mar	17-Mar	11-Mar	14-Mar	81.7	54.3	30.8	13.9	16.4
1996	27-Dec	10-Jan	21-Jan	29-Jan	03-Feb	08-May	01-May	23-Apr	14-Apr	10-Apr	133.7	112.1	92.6	75.9	66.0
1997	30-Dec	12-Jan	23-Jan	05-Feb	17-Feb	22-Apr	16-Apr	13-Apr	08-Apr	06-Apr	114.5	95.4	80.3	62.4	48.3
1998	03-Jan	14-Jan	18-Jan	22-Jan	12-Jan	14-Mar	25-Feb	12-Feb	04-Feb	24-Jan	70.6	42.6	25.7	13.9	12.5
1999	08-Jan	21-Jan	04-Feb	12-Feb	02-Feb	22-Mar	10-Mar	03-Mar	28-Feb	28-Feb	74.6	48.8	27.7	16.5	26.3
2000	05-Jan	18-Jan	30-Jan	11-Feb	06-Feb	11-Mar	01-Mar	24-Feb	20-Feb	20-Feb	65.1	42.4	26.7	9.9	15.1
2001	30-Dec	16-Jan	04-Feb	24-Feb	01-Mar	13-Apr	05-Apr	31-Mar	26-Mar	28-Mar	106.0	80.4	56.5	30.5	28.0
2002	10-Jan	04-Feb	19-Feb	28-Feb	21-Feb	06-Apr	28-Mar	22-Mar	19-Mar	20-Mar	87.5	53.6	32.6	20.0	28.1
Maximum	15-Jan	04-Feb	19-Feb	28-Feb	04-Mar	08-May	01-May	23-Apr	19-Apr	13-Apr	133.7	113.6	103.5	89.2	78.2
Minimum	18-Dec	23-Dec	30-Dec	10-Jan	12-Jan	05-Mar	19-Feb	12-Feb	04-Feb	24-Jan	49.7	29.0	15.6	6.8	7.7
Average	02-Jan	12-Jan	22-Jan	04-Feb	10-Feb	06-Apr	30-Mar	24-Mar	19-Mar	17-Mar	95.8	78.1	62.1	44.3	35.4
Median	02-Jan	11-Jan	21-Jan	04-Feb	11-Feb	07-Apr	31-Mar	26-Mar	23-Mar	19-Mar	96.9	81.1	63.9	43.8	32.8
25% of pdf	27-Dec	05-Jan	15-Jan	28-Jan	01-Feb	31-Mar	24-Mar	17-Mar	11-Mar	08-Mar	83.1	65.6	48.2	23.8	21.6
75% of pdf	07-Jan	18-Jan	29-Jan	11-Feb	19-Feb	16-Apr	09-Apr	04-Apr	30-Mar	28-Mar	112.4	95.0	80.3	61.3	43.8

pdf = probability density function of the cumulative frequency distribution

Table 3.3. Lake Michigan statistics for discrete depth ranges for ice cover concentration ≥ 10%.

Winter Season	a) Average date of First Ice					b) Average date of Last Ice					c) Average Duration (days)				
	Depth Range (m)					Depth Range (m)					Depth Range (m)				
	0-20	21-50	51-100	101-200	>200	0-20	21-50	51-100	101-200	>200	0-20	21-50	51-100	101-200	>200
1973	02-Jan	08-Jan	19-Jan	28-Jan	NA	01-Mar	23-Feb	18-Feb	06-Feb	NA	59.5	47.0	30.5	10.4	NA
1974	13-Jan	17-Jan	27-Jan	06-Feb	NA	21-Mar	08-Mar	26-Feb	27-Feb	NA	68.3	51.2	30.7	21.2	NA
1975	14-Jan	20-Jan	27-Jan	02-Feb	22-Jan	23-Mar	12-Mar	21-Feb	14-Feb	22-Jan	68.6	51.8	25.6	12.8	1.0
1976	03-Jan	12-Jan	31-Jan	16-Feb	29-Jan	12-Mar	06-Mar	22-Feb	22-Feb	07-Feb	68.6	54.1	22.7	7.3	10.0
1977	21-Dec	26-Dec	12-Jan	20-Jan	25-Jan	30-Mar	26-Mar	18-Mar	23-Mar	30-Mar	101.0	91.6	66.3	62.6	65.2
1978	06-Jan	16-Jan	02-Feb	16-Feb	25-Feb	30-Mar	25-Mar	13-Mar	09-Mar	11-Mar	84.1	69.5	39.9	21.3	14.9
1979	31-Dec	06-Jan	16-Jan	28-Jan	14-Feb	30-Mar	25-Mar	14-Mar	15-Mar	24-Mar	89.8	79.3	58.0	46.9	39.2
1980	19-Jan	29-Jan	12-Feb	11-Feb	19-Feb	18-Mar	12-Mar	05-Mar	05-Mar	19-Feb	59.1	43.0	22.1	22.7	1.0
1981	31-Dec	04-Jan	13-Jan	19-Jan	27-Jan	07-Mar	26-Feb	09-Feb	31-Jan	28-Jan	67.6	54.0	28.1	13.1	1.6
1982	11-Jan	15-Jan	25-Jan	07-Feb	10-Feb	21-Mar	15-Mar	04-Mar	04-Mar	17-Feb	69.9	59.2	39.7	26.6	7.9
1983	18-Jan	22-Jan	28-Jan	02-Feb	NA	06-Mar	26-Feb	19-Feb	13-Feb	NA	47.3	35.8	23.6	11.6	NA
1984	09-Jan	16-Jan	27-Jan	18-Jan	02-Jan	13-Mar	07-Mar	24-Feb	21-Feb	02-Jan	64.5	50.9	28.4	34.4	1.0
1985	12-Jan	24-Jan	11-Feb	24-Feb	NA	19-Mar	13-Mar	04-Mar	04-Mar	NA	67.0	49.6	21.4	9.1	NA
1986	30-Dec	14-Jan	02-Feb	08-Feb	24-Feb	22-Mar	17-Mar	06-Mar	06-Mar	01-Mar	82.8	62.9	33.4	26.8	6.7
1987	18-Jan	24-Jan	29-Jan	29-Jan	NA	23-Feb	28-Feb	19-Feb	19-Feb	NA	36.3	35.5	21.7	22.0	NA
1988	14-Jan	20-Jan	22-Jan	26-Jan	NA	11-Mar	02-Mar	16-Feb	11-Feb	NA	57.8	42.5	26.4	17.9	NA
1989	12-Jan	27-Jan	16-Feb	26-Feb	06-Mar	01-Apr	26-Mar	23-Mar	23-Mar	13-Mar	80.6	59.7	36.0	26.3	7.2
1990	18-Dec	24-Dec	12-Jan	25-Jan	03-Mar	21-Mar	10-Mar	19-Feb	02-Mar	03-Mar	95.9	78.4	39.3	37.1	1.0
1991	05-Jan	17-Jan	31-Jan	17-Feb	NA	11-Mar	04-Mar	28-Feb	13-Mar	NA	65.4	46.8	28.9	24.1	NA
1992	08-Jan	18-Jan	29-Jan	02-Feb	02-Feb	11-Mar	01-Mar	15-Feb	10-Feb	02-Feb	62.6	43.2	18.3	8.5	1.0
1993	16-Jan	29-Jan	12-Feb	22-Feb	28-Feb	20-Mar	14-Mar	13-Mar	06-Mar	28-Feb	64.3	45.0	29.8	13.3	1.0
1994	04-Jan	13-Jan	26-Jan	30-Jan	06-Feb	30-Mar	25-Mar	13-Mar	10-Mar	10-Mar	86.1	71.6	46.8	39.9	33.2
1995	28-Jan	10-Feb	23-Feb	01-Mar	NA	14-Mar	09-Mar	02-Mar	02-Mar	NA	45.8	28.4	7.9	1.9	NA
1996	01-Jan	13-Jan	31-Jan	04-Feb	05-Feb	06-Apr	02-Apr	13-Mar	11-Mar	15-Mar	96.7	80.6	41.5	35.7	38.8
1997	01-Jan	11-Jan	24-Jan	10-Feb	17-Feb	24-Mar	15-Mar	24-Feb	01-Mar	17-Feb	83.0	63.2	31.9	19.3	1.0
1998	13-Jan	18-Jan	28-Jan	26-Jan	NA	04-Mar	27-Feb	01-Feb	26-Jan	NA	51.1	40.9	5.1	1.0	NA
1999	07-Jan	12-Jan	23-Jan	04-Feb	NA	28-Feb	24-Feb	11-Feb	19-Feb	NA	53.6	44.5	19.9	15.5	NA
2000	11-Jan	20-Jan	27-Jan	29-Jan	NA	28-Feb	20-Feb	08-Feb	01-Feb	NA	49.3	31.6	12.7	4.1	NA
2001	24-Dec	05-Jan	18-Jan	05-Feb	NA	19-Mar	09-Mar	08-Feb	08-Feb	NA	87.0	64.0	21.3	4.2	NA
2002	17-Jan	08-Feb	08-Mar	12-Mar	NA	19-Mar	25-Mar	20-Mar	12-Mar	NA	61.7	46.3	13.4	1.0	NA
Maximum	28-Jan	10-Feb	08-Mar	12-Mar	06-Feb	06-Apr	02-Apr	23-Mar	23-Mar	30-Mar	101.0	91.6	66.3	62.6	65.2
Minimum	18-Dec	24-Dec	12-Jan	18-Jan	06-Mar	23-Feb	20-Feb	01-Feb	26-Jan	02-Jan	36.3	28.4	5.1	1.0	1.0
Average	07-Jan	16-Jan	30-Jan	06-Feb	02-Jan	17-Mar	11-Mar	27-Feb	25-Feb	22-Feb	69.2	54.1	29.0	20.0	13.6
Median	08-Jan	17-Jan	28-Jan	04-Feb	09-Feb	19-Mar	10-Mar	25-Feb	01-Mar	28-Feb	67.3	51.1	28.3	18.6	6.7
25% of pdf	01-Jan	12-Jan	24-Jan	28-Jan	08-Feb	11-Mar	01-Mar	18-Feb	13-Feb	07-Feb	59.2	43.5	21.5	9.4	1.0
75% of pdf	13-Jan	21-Jan	01-Feb	14-Feb	30-Jan	23-Mar	16-Mar	11-Mar	08-Mar	11-Mar	83.0	63.1	35.4	26.5	14.9

pdf = probability density function of the cumulative frequency distribution
NA = no data meeting threshold ice concentration

Table 3.4. Lake Huron statistics for discrete depth ranges for ice cover concentration ≥ 10%.

Winter Season	a) Average date of First Ice					b) Average date of Last Ice					c) Average Duration (days)				
	Depth Range (m)					Depth Range (m)					Depth Range (m)				
	0-20	21-50	51-100	101-200	>200	0-20	21-50	51-100	101-200	>200	0-20	21-50	51-100	101-200	>200
1973	30-Dec	13-Jan	06-Feb	13-Feb	19-Feb	14-Mar	12-Mar	07-Mar	02-Mar	26-Feb	76.1	58.8	30.4	18.8	8.0
1974	09-Jan	20-Jan	06-Feb	21-Feb	27-Feb	01-Apr	23-Mar	16-Mar	12-Mar	27-Mar	83.2	63.1	38.6	20.1	29.0
1975	19-Jan	29-Jan	11-Feb	04-Feb	05-Feb	05-Apr	23-Mar	08-Mar	18-Feb	05-Feb	77.3	54.5	26.7	14.6	1.0
1976	30-Dec	05-Jan	26-Jan	20-Feb	02-Mar	27-Mar	21-Mar	15-Mar	07-Mar	02-Mar	87.5	76.2	49.1	15.8	1.0
1977	18-Dec	25-Dec	05-Jan	16-Jan	24-Jan	05-Apr	02-Apr	28-Mar	31-Mar	06-Apr	109.8	99.3	83.6	74.4	72.9
1978	30-Dec	10-Jan	23-Jan	04-Feb	08-Feb	09-Apr	04-Apr	28-Mar	22-Mar	16-Mar	101.4	84.4	64.9	47.8	37.3
1979	30-Dec	06-Jan	17-Jan	31-Jan	06-Feb	04-Apr	28-Mar	27-Mar	26-Mar	25-Mar	96.9	81.9	70.6	55.2	47.5
1980	15-Jan	28-Jan	12-Feb	25-Feb	05-Feb	30-Mar	28-Mar	23-Mar	16-Mar	05-Feb	75.6	60.2	40.1	19.6	1.0
1981	31-Dec	06-Jan	15-Jan	28-Jan	03-Feb	19-Mar	10-Mar	03-Mar	27-Feb	28-Feb	79.5	64.3	47.8	30.8	26.5
1982	09-Jan	16-Jan	23-Jan	07-Feb	18-Feb	12-Apr	03-Apr	27-Mar	18-Mar	17-Mar	93.6	77.7	63.7	39.9	28.1
1983	17-Jan	19-Jan	18-Jan	17-Jan	NA	04-Mar	25-Feb	02-Feb	25-Jan	NA	47.2	38.0	16.0	9.0	NA
1984	30-Dec	08-Jan	21-Jan	10-Feb	11-Feb	04-Apr	29-Mar	24-Mar	16-Mar	11-Mar	96.7	81.2	63.7	35.4	29.6
1985	07-Jan	19-Jan	04-Feb	14-Feb	13-Feb	27-Mar	20-Mar	13-Mar	28-Feb	22-Feb	80.3	61.3	37.8	15.7	9.3
1986	24-Dec	08-Jan	29-Jan	12-Feb	01-Mar	29-Mar	27-Mar	22-Mar	20-Mar	14-Mar	97.4	79.2	53.6	36.3	13.7
1987	20-Jan	28-Jan	06-Feb	31-Jan	NA	09-Mar	04-Mar	26-Feb	21-Feb	NA	49.0	36.1	20.8	22.1	NA
1988	10-Jan	21-Jan	07-Feb	16-Feb	06-Feb	27-Mar	24-Mar	19-Mar	10-Mar	06-Mar	76.7	62.9	41.0	23.7	29.0
1989	02-Jan	20-Jan	13-Feb	08-Mar	13-Mar	11-Apr	08-Apr	02-Apr	24-Mar	20-Mar	100.1	78.3	48.8	16.8	8.5
1990	17-Dec	26-Dec	10-Jan	01-Feb	10-Feb	30-Mar	23-Mar	16-Mar	04-Mar	08-Mar	104.6	88.3	65.7	31.7	27.3
1991	08-Jan	17-Jan	31-Jan	07-Feb	NA	22-Mar	09-Mar	26-Feb	21-Feb	NA	73.8	52.4	26.9	15.4	NA
1992	07-Jan	26-Jan	20-Feb	04-Mar	15-Mar	13-Apr	04-Apr	28-Mar	25-Mar	23-Mar	96.6	68.4	37.4	22.0	9.7
1993	06-Jan	22-Jan	06-Feb	22-Feb	04-Mar	10-Apr	02-Apr	27-Mar	16-Mar	06-Mar	95.2	71.8	49.2	23.2	3.6
1994	01-Jan	07-Jan	14-Jan	24-Jan	26-Jan	15-Apr	12-Apr	06-Apr	01-Apr	27-Mar	104.8	96.4	82.8	67.5	60.7
1995	17-Jan	04-Feb	16-Feb	22-Feb	NA	26-Mar	20-Mar	13-Mar	08-Mar	NA	69.4	44.9	26.4	14.9	NA
1996	22-Dec	05-Jan	21-Jan	02-Feb	11-Feb	16-Apr	10-Apr	05-Apr	26-Mar	19-Mar	116.3	96.3	75.1	53.2	36.5
1997	04-Jan	17-Jan	30-Jan	11-Feb	19-Feb	11-Apr	01-Apr	26-Mar	17-Mar	26-Feb	97.6	75.3	56.1	34.1	7.3
1998	10-Jan	20-Jan	06-Feb	13-Feb	NA	13-Mar	06-Mar	28-Feb	23-Feb	NA	63.1	46.3	23.6	11.5	NA
1999	05-Jan	18-Jan	27-Jan	22-Jan	NA	16-Mar	08-Mar	15-Feb	27-Jan	NA	70.2	49.3	20.1	5.6	NA
2000	07-Jan	21-Jan	03-Feb	25-Jan	NA	08-Mar	01-Mar	19-Feb	28-Jan	NA	61.2	40.1	16.9	3.5	NA
2001	22-Dec	07-Jan	05-Feb	16-Feb	NA	03-Apr	24-Mar	11-Mar	06-Mar	NA	103.7	77.5	35.2	19.0	NA
2002	16-Jan	08-Feb	05-Mar	14-Mar	NA	31-Mar	26-Mar	21-Mar	14-Mar	NA	74.4	47.0	16.3	1.0	NA
Maximum	20-Jan	08-Feb	05-Mar	14-Mar	15-Mar	16-Apr	12-Apr	06-Apr	01-Apr	06-Apr	116.3	99.3	83.6	74.4	72.9
Minimum	17-Dec	25-Dec	05-Jan	16-Jan	24-Jan	04-Mar	25-Feb	02-Feb	25-Jan	05-Feb	47.2	36.1	16.0	1.0	0.0
Average	04-Jan	16-Jan	31-Jan	10-Feb	15-Feb	29-Mar	23-Mar	15-Mar	07-Mar	12-Mar	85.3	67.0	44.3	26.6	22.2
Median	06-Jan	18-Jan	01-Feb	11-Feb	12-Feb	30-Mar	24-Mar	17-Mar	11-Mar	11-Mar	85.4	66.4	40.6	21.1	26.5
25% of pdf	30-Dec	07-Jan	21-Jan	31-Jan	06-Feb	23-Mar	14-Mar	08-Mar	27-Feb	28-Feb	74.7	52.9	26.8	15.5	7.5
75% of pdf	10-Jan	21-Jan	06-Feb	19-Feb	25-Feb	08-Apr	01-Apr	27-Mar	19-Mar	20-Mar	97.6	79.0	61.8	35.1	29.5

pdf = probability density function of the cumulative frequency distribution.
NA = no data meeting threshold ice concentration.

Table 3.5. Lake Erie statistics for discrete depth ranges for ice cover concentration ≥ 10%.

Winter Season	a) Average date of First Ice					b) Average date of Last Ice					c) Average Duration (days)				
	Depth Range (m)					Depth Range (m)					Depth Range (m)				
	0-20	21-50	51-100	101-200	>200	0-20	21-50	51-100	101-200	>200	0-20	21-50	51-100	101-200	>200
1973	16-Jan	07-Feb	19-Feb	NA	NA	02-Mar	04-Mar	05-Mar	NA	NA	45.6	26.5	15.1	NA	NA
1974	13-Jan	31-Jan	22-Jan	NA	NA	28-Feb	06-Mar	12-Mar	NA	NA	46.5	35.4	50.3	NA	NA
1975	26-Jan	12-Feb	25-Feb	NA	NA	08-Mar	05-Mar	04-Mar	NA	NA	41.1	21.8	8.8	NA	NA
1976	07-Jan	17-Jan	25-Jan	NA	NA	23-Feb	26-Feb	08-Mar	NA	NA	47.8	41.3	43.0	NA	NA
1977	21-Dec	28-Dec	29-Dec	NA	NA	18-Mar	27-Mar	29-Mar	NA	NA	89.2	91.7	91.0	NA	NA
1978	30-Dec	07-Jan	14-Jan	NA	NA	05-Apr	11-Apr	11-Apr	NA	NA	96.9	95.2	87.9	NA	NA
1979	02-Jan	11-Jan	13-Jan	NA	NA	19-Mar	26-Mar	30-Mar	NA	NA	76.6	75.6	77.0	NA	NA
1980	23-Jan	03-Feb	03-Feb	NA	NA	20-Mar	24-Mar	04-Apr	NA	NA	56.7	50.5	60.8	NA	NA
1981	02-Jan	06-Jan	06-Jan	NA	NA	03-Mar	09-Mar	29-Mar	NA	NA	61.2	63.2	83.0	NA	NA
1982	13-Jan	17-Jan	17-Jan	NA	NA	28-Mar	02-Apr	11-Apr	NA	NA	74.7	76.2	85.8	NA	NA
1983	27-Jan	23-Jan	17-Jan	NA	NA	16-Feb	25-Jan	17-Jan	NA	NA	21.4	3.0	1.0	NA	NA
1984	30-Dec	01-Jan	02-Jan	NA	NA	01-Apr	04-Apr	10-Apr	NA	NA	94.1	93.9	99.1	NA	NA
1985	15-Jan	25-Jan	30-Jan	NA	NA	10-Mar	15-Mar	28-Mar	NA	NA	55.1	50.0	58.1	NA	NA
1986	25-Dec	27-Dec	27-Dec	NA	NA	21-Mar	24-Mar	01-Apr	NA	NA	88.0	88.6	96.3	NA	NA
1987	27-Jan	05-Feb	16-Feb	NA	NA	27-Feb	26-Feb	27-Feb	NA	NA	31.5	22.0	11.4	NA	NA
1988	08-Jan	15-Jan	09-Jan	NA	NA	14-Mar	18-Mar	03-Apr	NA	NA	65.9	62.6	85.6	NA	NA
1989	17-Jan	06-Feb	03-Feb	NA	NA	18-Mar	17-Mar	17-Mar	NA	NA	60.3	39.8	43.2	NA	NA
1990	18-Dec	24-Dec	24-Dec	NA	NA	13-Mar	14-Mar	17-Mar	NA	NA	86.6	81.6	84.9	NA	NA
1991	19-Jan	06-Feb	08-Feb	NA	NA	02-Mar	01-Mar	04-Mar	NA	NA	43.1	24.3	24.4	NA	NA
1992	23-Jan	03-Feb	07-Feb	NA	NA	19-Mar	15-Mar	17-Mar	NA	NA	56.0	41.4	38.9	NA	NA
1993	25-Jan	15-Feb	16-Feb	NA	NA	30-Mar	30-Mar	01-Apr	NA	NA	64.4	43.4	44.4	NA	NA
1994	05-Jan	13-Jan	15-Jan	NA	NA	28-Mar	04-Apr	17-Apr	NA	NA	83.5	82.9	92.6	NA	NA
1995	21-Jan	07-Feb	11-Feb	NA	NA	15-Mar	20-Mar	21-Mar	NA	NA	54.0	41.7	39.4	NA	NA
1996	26-Dec	08-Jan	13-Jan	NA	NA	25-Mar	30-Mar	02-Apr	NA	NA	91.1	82.0	79.9	NA	NA
1997	09-Jan	17-Jan	23-Jan	NA	NA	06-Mar	12-Mar	23-Mar	NA	NA	57.0	54.7	59.2	NA	NA
1998	13-Jan	28-Jan	NA	NA	NA	28-Jan	28-Jan	NA	NA	NA	16.2	1.0	NA	NA	NA
1999	07-Jan	15-Jan	24-Jan	NA	NA	13-Mar	10-Mar	07-Mar	NA	NA	66.1	55.5	42.8	NA	NA
2000	17-Jan	26-Jan	25-Jan	NA	NA	27-Feb	27-Feb	01-Mar	NA	NA	42.7	33.5	36.2	NA	NA
2001	23-Dec	01-Jan	10-Jan	NA	NA	08-Mar	17-Mar	09-Apr	NA	NA	76.3	76.3	90.1	NA	NA
2002	10-Jan	12-Feb	NA	NA	NA	02-Feb	12-Feb	NA	NA	NA	24.1	1.0	NA	NA	NA
Maximum	27-Jan	15-Feb	25-Feb	NA	NA	05-Apr	11-Apr	17-Apr	NA	NA	96.9	95.2	99.1	NA	NA
Minimum	18-Dec	24-Dec	24-Dec	NA	NA	28-Jan	25-Jan	17-Jan	NA	NA	16.2	1.0	1.0	NA	NA
Average	10-Jan	21-Jan	23-Jan	NA	NA	10-Mar	13-Mar	21-Mar	NA	NA	60.5	51.9	58.2	NA	NA
Median	11-Jan	20-Jan	23-Jan	NA	NA	13-Mar	15-Mar	25-Mar	NA	NA	58.7	50.3	58.7	NA	NA
25% of pdf	02-Jan	09-Jan	12-Jan	NA	NA	02-Mar	05-Mar	08-Mar	NA	NA	45.8	34.0	39.3	NA	NA
75% of pdf	18-Jan	05-Feb	04-Feb	NA	NA	19-Mar	26-Mar	03-Apr	NA	NA	76.5	76.3	85.7	NA	NA

pdf = probability density function of the cumulative frequency distribution.
NA = no data meeting threshold ice concentration.

Table 3.6. Lake Ontario statistics for discrete depth ranges for ice cover concentration ≥ 10%.

Winter Season	a) Average date of First Ice					b) Average date of Last Ice					c) Average Duration (days)				
	Depth Range (m)					Depth Range (m)					Depth Range (m)				
	0-20	21-50	51-100	101-200	>200	0-20	21-50	51-100	101-200	>200	0-20	21-50	51-100	101-200	>200
1973	13-Jan	19-Jan	02-Feb	08-Feb	NA	28-Feb	26-Feb	21-Feb	18-Feb	NA	47.2	38.2	20.1	11.1	NA
1974	13-Jan	19-Jan	22-Jan	27-Jan	20-Feb	24-Feb	18-Feb	02-Feb	04-Feb	20-Feb	42.9	31.4	12.7	8.7	1.0
1975	27-Jan	05-Feb	12-Feb	NA	NA	05-Mar	18-Feb	12-Feb	NA	NA	38.0	14.0	1.0	NA	NA
1976	09-Jan	27-Jan	25-Jan	31-Jan	NA	05-Mar	16-Feb	29-Jan	01-Feb	NA	56.0	21.0	4.3	1.6	NA
1977	01-Jan	07-Jan	12-Jan	28-Jan	04-Feb	19-Mar	13-Mar	28-Feb	05-Mar	11-Mar	77.5	66.7	48.4	36.5	35.8
1978	12-Jan	23-Jan	06-Feb	14-Feb	14-Feb	21-Mar	15-Mar	05-Mar	26-Feb	03-Mar	68.6	51.3	28.3	12.9	18.2
1979	17-Jan	24-Jan	01-Feb	10-Feb	02-Feb	08-Mar	01-Mar	26-Feb	22-Feb	20-Feb	50.9	36.5	25.8	12.7	19.3
1980	30-Jan	05-Feb	13-Feb	16-Feb	10-Feb	10-Mar	07-Mar	05-Mar	27-Feb	12-Feb	39.7	31.5	21.4	11.5	2.2
1981	06-Jan	07-Jan	10-Jan	17-Jan	12-Jan	16-Feb	10-Feb	23-Jan	21-Jan	14-Jan	42.3	35.6	14.0	5.5	3.3
1982	16-Jan	17-Jan	20-Jan	04-Feb	04-Mar	19-Mar	14-Mar	02-Mar	26-Feb	08-Mar	62.4	57.0	41.7	22.7	4.6
1983	27-Jan	30-Jan	31-Jan	NA	NA	15-Feb	09-Feb	01-Feb	NA	NA	19.4	10.7	2.3	NA	NA
1984	10-Jan	15-Jan	24-Jan	04-Feb	07-Feb	09-Mar	12-Mar	21-Feb	11-Feb	07-Feb	58.9	57.5	29.1	8.1	1.0
1985	17-Jan	24-Jan	02-Feb	08-Feb	08-Feb	08-Mar	03-Mar	21-Feb	21-Feb	22-Feb	51.0	38.9	20.3	14.0	15.0
1986	11-Jan	18-Jan	06-Feb	15-Feb	01-Mar	15-Mar	14-Mar	07-Mar	06-Mar	07-Mar	64.1	56.2	30.2	19.8	6.1
1987	05-Feb	12-Feb	NA	NA	NA	07-Mar	23-Feb	NA	NA	NA	30.9	12.4	NA	NA	NA
1988	12-Jan	18-Jan	27-Jan	18-Feb	NA	26-Feb	20-Feb	03-Feb	26-Feb	NA	45.7	34.8	7.6	8.8	NA
1989	11-Feb	24-Feb	05-Mar	12-Mar	NA	20-Mar	14-Mar	09-Mar	14-Mar	NA	38.3	18.8	4.7	3.5	NA
1990	31-Dec	07-Jan	27-Jan	13-Jan	23-Dec	16-Mar	10-Mar	27-Feb	02-Feb	23-Dec	76.9	62.9	32.8	21.6	1.0
1991	15-Jan	23-Jan	28-Jan	26-Jan	NA	27-Feb	19-Feb	29-Jan	26-Jan	NA	43.9	28.8	1.3	1.0	NA
1992	24-Jan	31-Jan	04-Feb	12-Feb	15-Feb	11-Mar	05-Mar	18-Feb	21-Feb	15-Feb	47.0	34.7	14.8	9.7	1.0
1993	24-Jan	09-Feb	21-Feb	01-Mar	04-Mar	26-Mar	20-Mar	08-Mar	14-Mar	16-Mar	62.1	40.5	16.0	14.1	13.4
1994	06-Jan	11-Jan	21-Jan	01-Feb	05-Feb	21-Mar	16-Mar	27-Feb	24-Feb	06-Mar	74.6	64.6	37.8	23.8	29.9
1995	02-Feb	07-Feb	14-Feb	18-Feb	19-Feb	07-Mar	27-Feb	19-Feb	18-Feb	19-Feb	33.7	20.4	6.4	1.0	1.0
1996	12-Jan	14-Jan	20-Jan	11-Feb	14-Feb	08-Mar	03-Mar	15-Feb	23-Feb	19-Feb	56.0	49.5	27.0	13.5	5.8
1997	18-Jan	24-Jan	11-Feb	18-Feb	NA	17-Mar	10-Mar	17-Feb	18-Feb	NA	59.2	46.0	7.2	1.0	NA
1998	19-Jan	27-Jan	29-Jan	29-Jan	NA	19-Feb	04-Feb	29-Jan	29-Jan	NA	31.9	9.7	1.0	1.0	NA
1999	08-Jan	24-Jan	15-Feb	20-Feb	NA	03-Mar	03-Mar	28-Feb	02-Mar	NA	55.4	39.4	14.1	11.4	NA
2000	16-Jan	23-Jan	30-Jan	07-Feb	NA	19-Feb	14-Feb	06-Feb	07-Feb	NA	34.9	22.6	7.1	1.0	NA
2001	31-Dec	11-Jan	10-Feb	17-Feb	NA	02-Mar	23-Feb	18-Feb	17-Feb	NA	62.1	44.1	9.2	1.0	NA
2002	14-Jan	13-Jan	NA	NA	NA	19-Feb	25-Jan	NA	NA	NA	37.6	12.6	0.0	0.0	NA
Maximum	11-Feb	24-Feb	05-Mar	12-Mar	04-Mar	26-Mar	20-Mar	09-Mar	14-Mar	16-Mar	77.5	66.7	48.4	36.5	35.8
Minimum	31-Dec	07-Jan	10-Jan	13-Jan	23-Dec	15-Feb	25-Jan	23-Jan	21-Jan	23-Dec	19.4	9.7	1.0	1.0	1.0
Average	16-Jan	23-Jan	01-Feb	09-Feb	09-Feb	06-Mar	28-Feb	18-Feb	18-Feb	18-Feb	50.3	36.3	17.4	10.7	9.9
Median	14-Jan	23-Jan	31-Jan	09-Feb	12-Feb	07-Mar	02-Mar	20-Feb	21-Feb	20-Feb	49.1	36.1	14.5	10.4	5.2
25% of pdf	10-Jan	15-Jan	25-Jan	31-Jan	05-Feb	27-Feb	18-Feb	05-Feb	08-Feb	14-Feb	38.7	21.4	6.9	2.1	1.0
75% of pdf	22-Jan	29-Jan	10-Feb	16-Feb	19-Feb	16-Mar	12-Mar	28-Feb	26-Feb	06-Mar	61.4	48.6	27.3	13.9	15.8

pdf = probability density function of the cumulative frequency distribution.
NA = no data meeting threshold ice concentration.

Table 4. Frequency of Winters Without Freeze-up at the west arm of Grand Traverse Bay**.

Grand Traverse Bay, Lake Michigan		
Five 30-year periods		
Start	End	Frequency*
1853	1882	5
1883	1912	2
1913	1942	5
1943	1972	5
1973	2002	16

*Number of winters during the 30-winter period that the bay did not freeze-up

** Date updated from Assel 2001