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Great Lakes Ice Cover Climatology Update: Winters 2003, 2004, and 2005

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Great Lakes Ice Cover Climatology Update: Winters 2003, 2004, and 2005

Raymond A. Assel

ABSTRACT

A 30-winter ice concentration climatology (Assel 2003a) is updated for winters: 2003, 2004, and 2005. Original ice charts are from the National Ice Center and the Canadian Ice Service. These data are quality controlled for over-water grid cell location and ice concentration codes to be consistent with Assel (2003a). Data are available in the form of ASCII grids and graphic files. The 2003, 2004, and 2005 ice cycles are described and discussed briefly within the context of dates of first (last) ice, ice duration, daily lake-averages, and spatial and temporal distribution patterns of ice cover and anomalies.

INTRODUCTION

The annual formation and loss of ice cover on the Great Lakes each winter, i.e. the annual ice cycle, affects the lake's ecosystem and the regional economy of the Great Lakes. In 2003, a 30-winter climatology of Great Lakes ice cover was published (Assel 2003a). The information presented here updates the total ice concentration grids of original ice charts digitized by other government agencies during the winters 2003, 2004, and 2005 and also updates the following analysis products given in Assel (2003a): dates of first ice, dates of last ice, ice cover duration, daily ice cover grids, daily lake-averaged ice cover, and computer animations of the seasonal progression of ice cover. Anomaly ice charts for 2003, 2004, and 2005 similar to those in Assel (2005) for winters 1973-2003 are also included in this update. Line plots and ice charts portray the seasonal (temporal) and spatial patterns and trends of ice cover over the winters of the update period, and ASCII files make it practical to use these data in numerical analysis applications. These data, analysis methods, and products are described and discussed briefly. *The primarily purpose of this report is to make access and use of these data feasible to others in need of such information.*

DATA

There are 143 digitized original ice charts in this update, 51, 46, and 46 for winters 2003, 2004, and 2005, respectively (Table 1). In general, two ice charts are produced for each week, one by the National Ice Center and one by the Canadian Ice Service. Ice charts from both sources are on the National Ice Center Web site, http://www.natice.noaa.gov/products/gl-ches/index.htm. The data consists of grids of over-water cells and land cells in a 510 row by 516 column matrix. These data were downloaded to GLERL and quality controlled for location of over-water grid cells and ice codes in order to be consistent with the 30-winter GLERL ice cover climatology. The GLERL, NIC, and CIS ice codes are given in Assel et al. (2002). The center of each GLERL grid cell is cross referenced with latitude and longitude in Assel (2003a), see http://www.glerl.noaa.gov/data/ice/atlas/daily_ice_cover/daily_grids/dailygrids.html for latitude

and longitude files. This facilitates application of these data in a Graphic Information System environment and for other applications in which geographic location information is needed.

Table 1. Summary of Dates of Original Ice Charts

Chart No.	2003			2004			2005		
	Month	Day	Year	Month	Day	Year	Month	Day	Year
1	12	2	2002	12	1	2003	12	2	2004
2	12	5	2002	12	3	2003	12	6	2004
3	12	9	2002	12	8	2003	12	9	2004
4	12	12	2002	12	11	2003	12	13	2004
5	12	16	2002	12	15	2003	12	16	2004
6	12	19	2002	12	18	2003	12	20	2004
7	12	23	2002	12	22	2003	12	23	2004
8	12	26	2002	12	25	2003	12	27	2004
9	12	30	2002	12	29	2003	12	30	2004
10	1	2	2003	1	1	2004	1	3	2005
11	1	6	2003	1	5	2004	1	6	2005
12	1	9	2003	1	8	2004	1	10	2005
13	1	13	2003	1	12	2004	1	13	2005
14	1	16	2003	1	15	2004	1	17	2005
15	1	20	2003	1	19	2004	1	20	2005
16	1	23	2003	1	22	2004	1	24	2005
17	1	27	2003	1	26	2004	1	27	2005
18	1	30	2003	1	29	2004	1	31	2005
19	2	3	2003	2	2	2004	2	3	2005
20	2	6	2003	2	5	2004	2	7	2005
21	2	10	2003	2	9	2004	2	10	2005
22	2	13	2003	2	12	2004	2	14	2005
23	2	17	2003	2	16	2004	2	17	2005
24	2	20	2003	2	19	2004	2	21	2005
25	2	24	2003	2	23	2004	2	24	2005
26	2	27	2003	2	26	2004	2	28	2005
27	3	3	2003	3	1	2004	3	3	2005
28	3	10	2003	3	4	2004	3	7	2005
29	3	13	2003	3	8	2004	3	10	2005
30	3	17	2003	3	11	2004	3	14	2005
31	3	20	2003	3	15	2004	3	17	2005
32	3	24	2003	3	18	2004	3	21	2005
33	3	27	2003	3	22	2004	3	24	2005
34	3	31	2003	3	25	2004	3	28	2005
35	4	3	2003	3	29	2004	3	31	2005
36	4	7	2003	4	1	2004	4	4	2005
37	4	10	2003	4	5	2004	4	7	2005
38	4	14	2003	4	8	2004	4	11	2005
39	4	21	2003	4	12	2004	4	14	2005
40	4	24	2003	4	15	2004	4	18	2005
41	4	28	2003	4	19	2004	4	21	2005
42	5	1	2003	4	22	2004	4	25	2005
43	5	5	2003	4	26	2004	4	28	2005
44	5	8	2003	4	29	2004	5	2	2005
45	5	12	2003	5	3	2004	5	5	2005
46	5	15	2003	5	6	2004	5	9	2005
47	5	19	2003						
48	5	22	2003						
49	5	26	2003						
50	5	29	2003						
51	6	2	2003						

ANALYSIS METHODS

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%. 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% (i.e., ≥10%, ≥20%, ≥30%, ≥40%, ≥50%, ≥60%, ≥70%, ≥80%, ≥90%). A grid search of over-water cells, cell by cell, was made on the original ice chart grids for each winter (Table 1) to determine the first (last) observed date for each of the nine threshold values of ice concentration at each grid cell. These 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 and the fact that daily observations were not made. However, it is likely that for most of the Great Lakes surface, 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. Additional information and details on dates of first (last) ice and ice duration for the 30-winter base period are given in Assel (2003b).

One hundred and eighty-two daily Great Lakes ice cover grids are created for each winter season between December 1 and May 31 (May 30 for leap years). A temporal linear interpolating of ice concentration between consecutive observed ice chart grids, cell by cell, for a given winter

season was used to create the daily grids. Ice cover grids prior to the first observed ice chart and after the last observed ice chart were set to zero for over water grid cells. The daily average ice cover grids are considered to be reasonable estimates of actual ice cover concentration because: (I) the average number of days between observed ice charts (Table 1) is 3 days (2003), 2 days (2004), and 3 days (2005), (II) the date of first and last ice chart are December 2 and June 2 (2003), December 1 and May 6 (2004), and December 2 and May 9 (2005), and (III) the lake averaged ice cover on each Great Lake for the first (last) ice chart was < 1.2% (0%). Assel and Norton (2001) provide further description of the creation of the daily time series and of the graphic files used to create computer animations that portray the seasonal progression of ice cover. Once the graphic files for the animation were produced, any number of different animation programs could produce the actual animations.

Daily lake average ice cover is calculated from the daily grids. A grid encoding the grid cells for each lake and river is given in a fixed formatted text file (GLmask2.txt) in Assel (2003a). Each record in that file has a format of 516 I1. Land grid cells have a code of 0 or 1. The grid cell codes for each lake and river are: 4 for Lake Superior, 5 for Lake Michigan, 6 for Lake Huron, 7 for Lake Erie, 8 for Lake Ontario, 2 for Lake St. Clair, 3 for the Detroit River, and 9 for the St. Marys River. All grid cell ice concentrations for a given lake or river for a given date are summed, and a lake (river) average is then calculated by dividing the sum by the total number of grid cells for that lake (river). The total number of grids cells for each Great Lake are: 13,850 (Lake Superior), 8545 (Lake Michigan), 9161 (Lake Huron), 3574 (Lake Erie), and 2801 (Lake Ontario).

Assel (2005) produced anomaly ice charts for each winter from 1973 to 2002. Ice anomaly charts were produced for each day of the winter by calculating the difference (for each over water grid cell) between the 30-winter weekly median ice concentration grid and the ice concentration grid for a date that corresponds to the mid-week day of the weekly median (e.g., the 30-winter weekly median ice chart for January 12-18 would be used to calculate the ice anomaly chart for an ice chart dated January 15). In a similar manner, ice anomaly charts were produced from the daily ice grids for the three winters of the update period. Ice anomaly charts provide a metric of the trends in ice cover over any date in a given winter season relative to the 30-winter base period. Positive (negative) differences occur when the ice chart for a given winter has ice cover concentration greater (less) than the 30-winter median.

PRODUCTS AND DISCUSSION

Analysis products are summarized in a series of line plots (for lake averaged ice cover) and charts for: (1) dates of first (last) ice, ice duration, (2) daily ice concentration, and (3) daily ice concentration anomalies. ASCII text files containing integer codes for ice are also produced for all the data given in the graphic plot file products. Data and file documentation for dates of first (last) ice and ice duration are given in Appendix 1; daily ice cover and its associated products (daily grids, daily images, computer animations, lake-average plots, and table), are given in Appendix 2; daily ice cover anomalies (animations, images, ASCII grids) are given in Appendix 3. Seasonal and spatial trends are discussed below using selected data from these appendices.

DATES OF FIRST (LAST) ICE AND ICE DURATION

The two extremes, ice ≥ 10% (ice < 10% is considered to be the boundary between ice and open water) and ice cover ≥ 90%, virtually a complete ice cover are shown in Figures 1-3 for dates of first (last) ice and ice duration, respectively. More mid-lake areas of Lakes Superior, Michigan, and Huron formed ice later or were virtually ice free in 2004 and 2005 (Figure 1) relative to 2003. Some shore areas formed ice earlier (December) in 2005 compared to 2003.

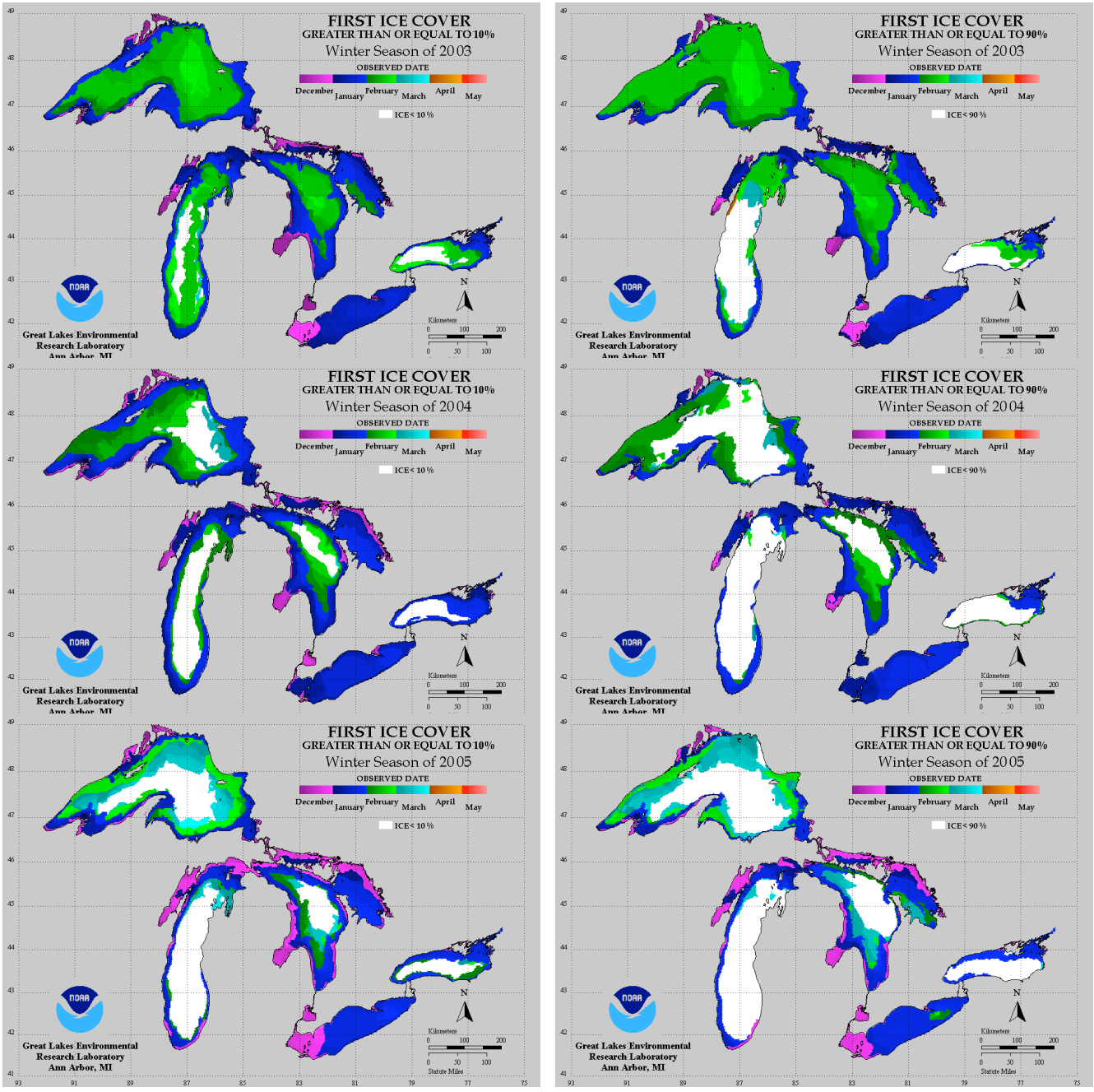

Figure 1. Dates of first reported ice ≥ 10% (left) and ≥ 90% (right) for 2003, 2004, and 2005.

The dates of last ice cover in areas with ice on Lakes Superior, northern Michigan, Huron, and the eastern half of Lake Erie were in general later in 2003 relative to 2004 and 2005 (Fig. 2).

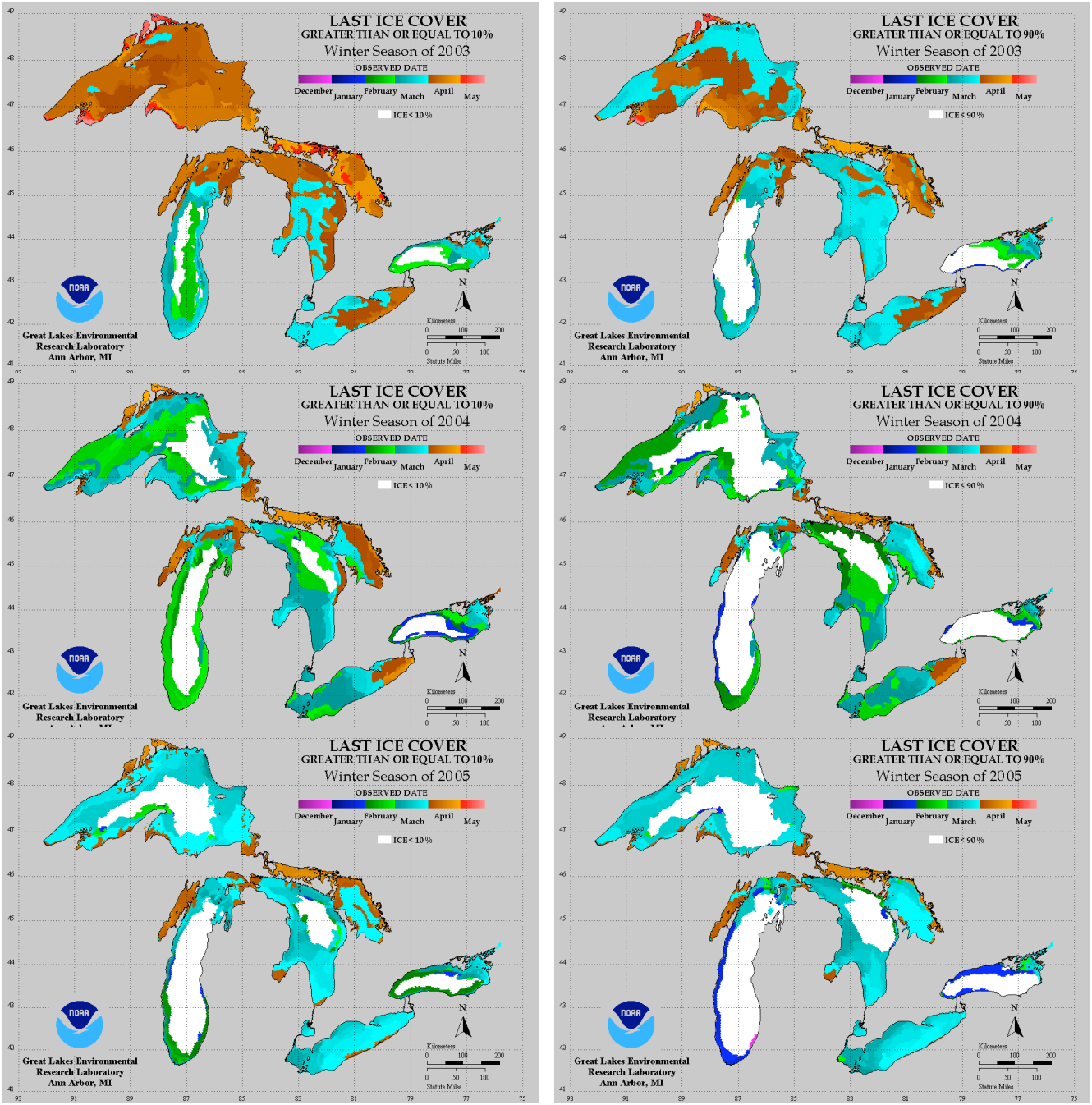

Figure 2. Dates of last reported ice ≥ 10% (left) and ≥ 90% (right) for 2003, 2004, and 2005.

The duration of ice cover (Fig. 3) was in general longer in 2003.

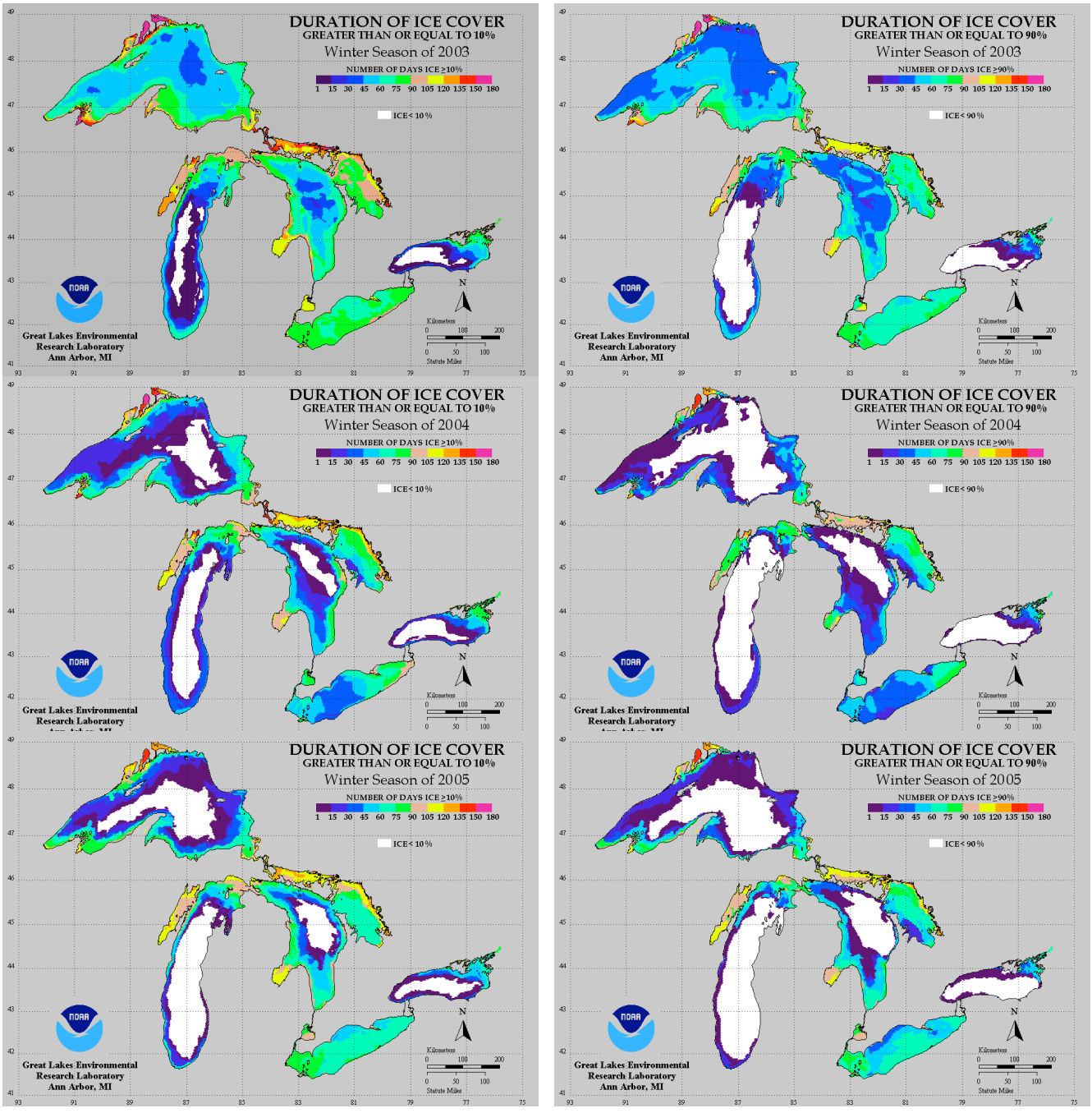

Figure 3. Duration of ice cover ≥ 10% (left) and ≥ 90% (right) for 2003, 2004, and 2005.

SEASONAL PROGRESSION OF ICE COVER

Seven-day moving averages of the daily lake–averaged ice cover and selected charts of ice cover and ice cover anomalies are used to portray the seasonal progression of the 2003, 2004, and 2005 ice cycles. More data and computer animations are given in Appendix 2 and Appendix 3.

The 2003 Great Lakes Ice Cycle

The Great Lakes lake-averaged ice cover in 2003 was above the Long-Term-Median (LTM) most of that winter. In 2003, Lake Erie was near its maximum ice extent (≥ 90%) from the end of the third week of January to the middle of the second week of March (Figure 4). Lakes Superior Huron, and Michigan were near their maximum ice cover (≥ 90%, ≥ 90%, and ≥ 40%, respectively) from the end of February to middle of the second week of March. Lake Ontario was near its maximum ice cover (≥ 40%) the third week of February and again from the end of February to middle of the second week of March. Lake-averaged ice cover was less than 10% on Lake Ontario by the middle of the fourth week of March, on Lake Erie by the end of the first week of April, on Lake Michigan by the end of the second week of April, on Lake Superior by the end of the third week of April, and on Lake Huron by the end of April.

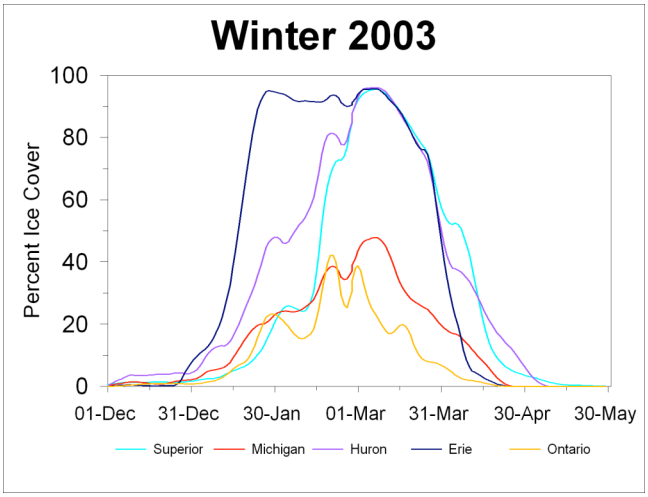

Figure 4. Daily lake-averaged ice cover, winter 2003.

The spatial patterns of ice cover for 2003 for early winter (January 16), mid winter (February 17), early spring (March 24), and mid spring (April 14) along with the spatial patterns of the difference between the 30-winter weekly median ice concentration and the ice chart for a given date, i.e., the ice anomaly charts are shown as Figure 5. In mid-January the ice cover was limited to the shore regions of the Great Lakes, primarily in bays, with the exception of Lake Erie, where it covered the west basin and about half of the center basin of that lake. The corresponding anomaly ice chart for mid January shows that shore ice cover was below the 30-winter median along the shores of Lake Superior and along selected northern areas in Lakes Michigan and Huron. Ice cover was above the 30-winter median in much of the center Lake Erie basin. By the middle of February, ice cover extended over most of Lakes Superior, Huron, and Erie, over the northern portion of Michigan, and over much of the eastern half of Lake Ontario. The ice cover extent in mid-February (February 17) was greater than the 30-winter median over Lakes Superior, Michigan, Huron, and Ontario but not over Lake Erie. Ice cover anomaly chart in early spring (March 24) was similar to the February 17 anomaly chart, i.e. ice cover was still anomalously high over most of Lakes Superior, northern Michigan, and all of Huron. However, Lake Erie now also has anomalously high ice cover. Ice cover was lost over the next three weeks. By April 14 (with the exception of several bays in Lakes Superior, Huron, and Michigan) there were only relatively small areas of ice in the lakes proper; these areas show up in the corresponding anomaly ice chart as above-median ice cover, primarily along and lakeward of the south shore of Lake Superior, in Green Bay and along the north shore of Lake Michigan, and in Georgian Bay in Lake Huron.

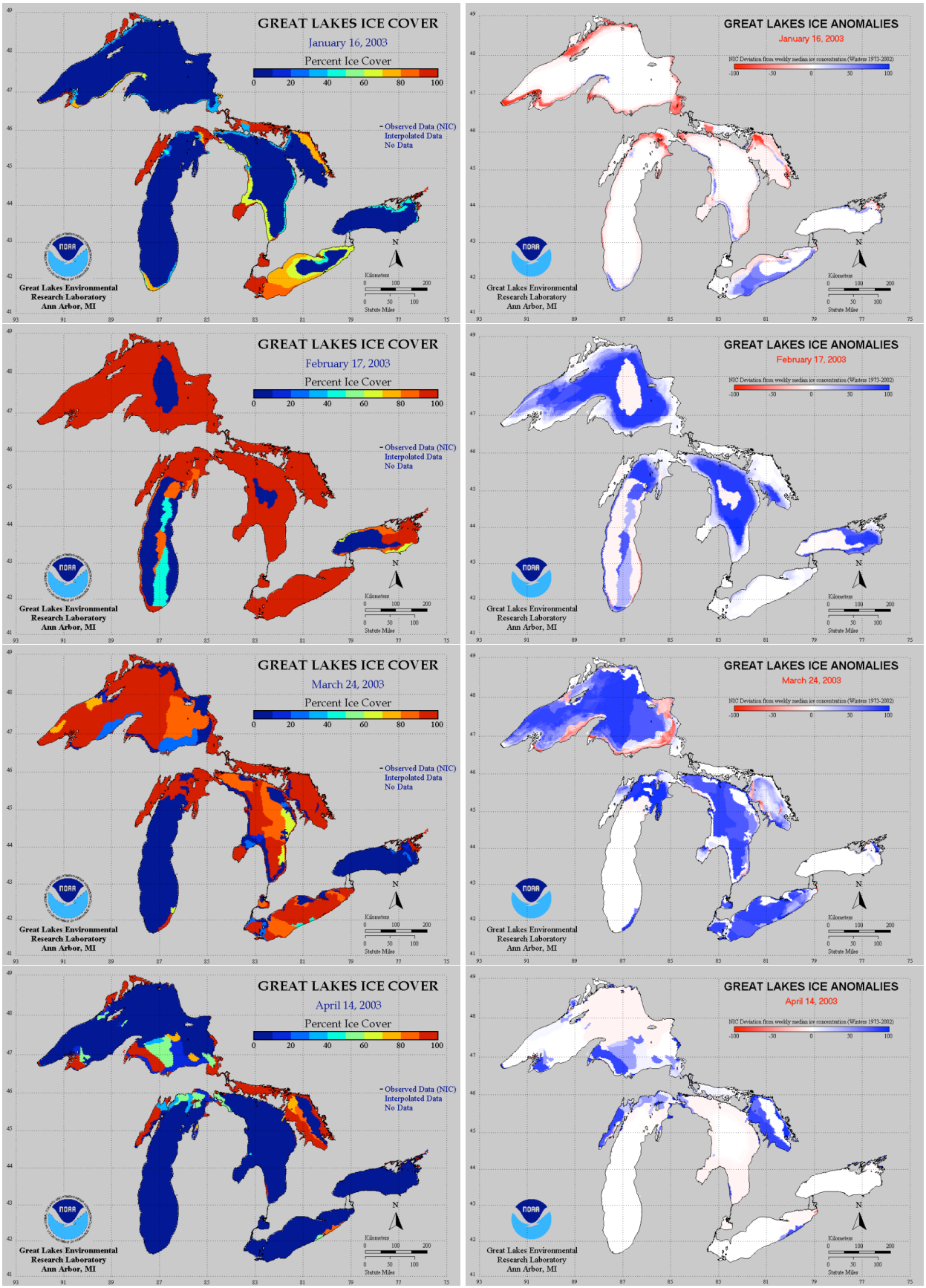

Figure 5. Winter 2003 ice cover and anomaly charts for Jan. 16, Feb. 17, Mar. 24, and Apr 14.

The 2004 Great Lakes Ice Cycle

Seasonal maximum ice cover in 2004 occurred earlier than it did in 2003, did not last as long, and with the exception of Lake Erie, was less than it was in 2003. In 2004, Lake Erie ice cover was ≥ 90% and near its seasonal maximum ice extent (95%) the last week of January through the end of the first week of February and again during the second half of the third week of February (Figure 6). Lake Ontario ice cover was ≥ 30% and near its maximum ice extent (38%) the last week of January. Lake Huron ice cover was ≥ 55% and was near its seasonal maximum extent (65%) from the end of January to the middle of the first week of February and again from the middle of the second week of February to the end of the third week of that month. Lake Michigan ice cover was ≥ 30% and near its seasonal maximum ice extent (36%) from the middle of the first week to the middle of the second week of February, and briefly near the end of the third week of February. Lake Superior ice cover was ≥ 40% and near its seasonal maximum ice extent (52%) from near the end of the first week of February to near the end of the second week of February and again briefly near the end of the third week of that month. The occurrence of lake-averaged ice cover <10% was earlier in 2004 than it was in 2003. Lake-averaged ice cover <10% occurred near the end of the second week of March for Lake Ontario, the end of the third week of March for Lake Superior, the middle of the last week of March for Lake Michigan, the middle of the first week of April for Lake Erie, and at the end of the last week of April for Lake Huron.

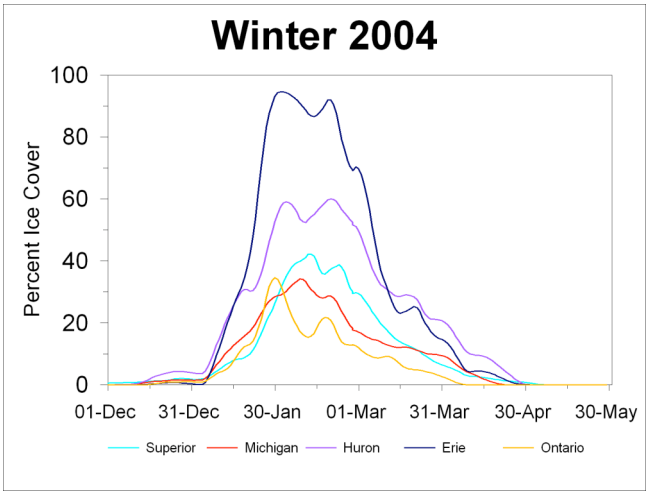

Figure 6. Daily lake-averaged ice cover, winter 2004.

Early winter (January 15) ice cover was a little more extensive in 2004 (Figure 7) relative to 2003 (Figure 5) on Lakes Superior, the north end of Lake Michigan, and the perimeter of Lake Huron. The opposite is true of Lake Erie. By early February (Figure 7), extensive ice cover formed lakeward of the shore. Ice cover was greater than the LTM along the northwest shore and lakeward of other near shore regions of Lake Superior, along the west shore and extending in narrow band along the southeast coast of Lake Michigan, and lakeward of the west coast and the south end of Lake Huron. Ice cover on February 19 was near its seasonal maximum, and the pattern of ice cover anomalies were similar to those of early February. There were still positive anomalies along the southern end of Lake Michigan, mid-lake area of southern Lake Huron, and mid-lake areas of Lake Superior. However, there were now negative anomalies in western Lake Superior (and along portions of its south-central and northeast shore), and a new area of negative anomalies along the northwest shores of Lake Huron and Georgian Bay. By the middle of March 2004, ice cover was limited primarily to portions of the shore and in large bays of the Great Lakes. The ice anomaly chart for March 15 had large negative anomalies in Lake Superior, western Georgian Bay, and central Lake Erie. The March 15, 2004 ice cover was similar to the April 14, 2003 ice cover, and less than March 24, 2003 (Figure 5). Thus, the ice cycle in many areas of the Great Lakes had ended earlier in 2004 than it did in 2003.

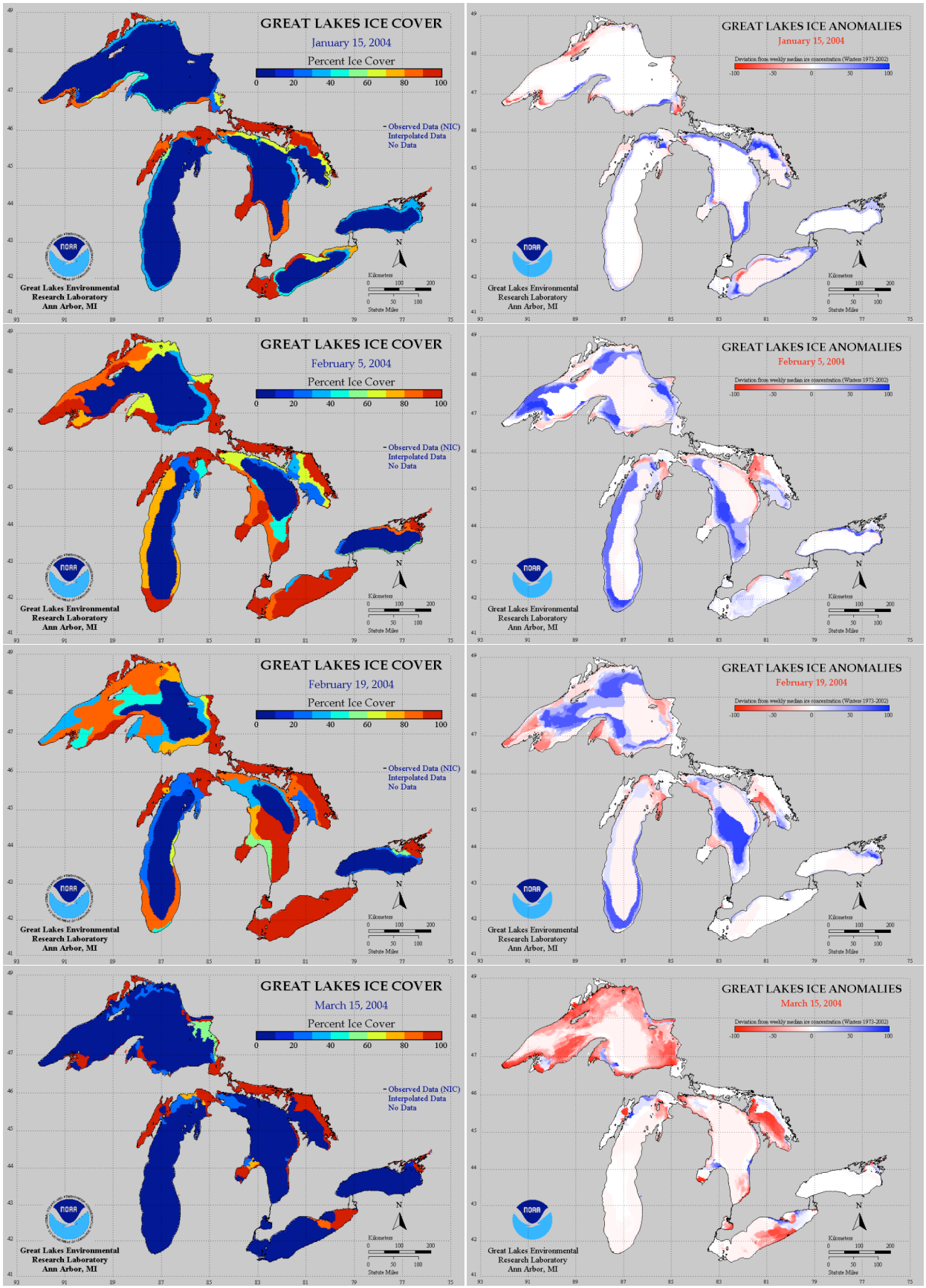

Figure 7. Winter 2004 ice cover and anomaly charts for Jan. 15, Feb. 5, Feb. 19, and Mar. 15.

The 2005 Great Lakes Ice Cycle

The magnitude of the seasonal maximum ice cover was about the same as it was in 2004, and it was bimodal for Lakes Michigan, Huron, and Erie (Figure 8) as it was in 2004 (Figure 6) for Lakes Superior, Michigan, Huron, and Erie. Lake Erie ice cover was ≥ 85% and near its seasonal maximum (93%) from the last week of January to the middle of the second week of February and again during the first week of March. Lake Ontario ice cover was ≥ 30% and near its seasonal maximum extent (38%) from the middle of the last week of January to the middle of the first week of February. Lake Huron ice cover was ≥ 50% and near its seasonal maximum (59%) from the middle of the last week of January to the middle of the first week of February and again from the middle of the first week to the middle of the third week of March. Lake Michigan was near its seasonal maximum (29%) and had ice cover ≥ 20% from the end of the third week of January to the middle of the first week of February and again during the first week of March. Lake Superior had ice cover ≥ 40% and was near its seasonal maximum ice cover (54%) from the middle of the second to the middle of the third week in March. The occurrence of lake-averaged ice cover < 10% in spring 2005 was later than it was in 2004, but earlier than it was in 2003. Lake-averaged ice cover <10% occurred the middle of March for Lake Ontario, the first day of April for Lake Michigan, the third day of April for Lakes Superior and Erie, and near the end of the second week of April for Lake Huron.

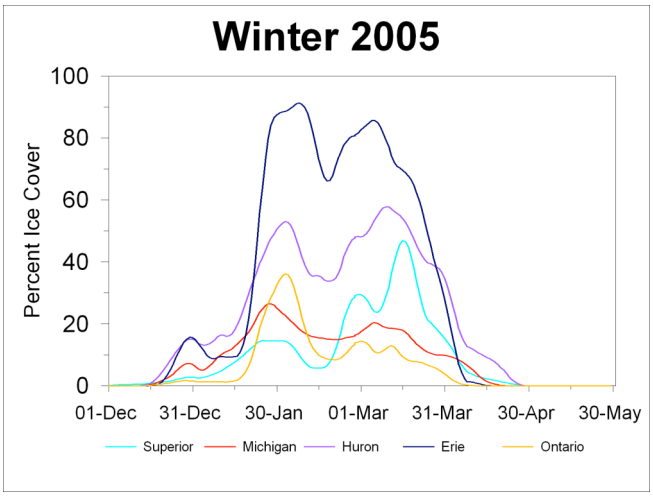

Figure 8. Daily lake-averaged ice cover, winter 2005.

The spatial patterns of ice cover for 2005 for early winter (January 17), near its maximum (February 3), near its maximum for a second time (March 3), and for early spring (April 4) are portrayed in Figure 9. The mid-January ice cover was restricted to large bays and shoal areas of the Great Lakes. A large area of negative ice anomaly was located primarily along the north central shore of Lake Erie, indicating less ice than the LTM for that area. Smaller areas of both positive and negative ice cover anomalies lined the shores of the other four Great Lakes.

The ice cover in early February was near its seasonal maximum. It was still restricted to the shore and shoal areas of Lakes Superior and Michigan. It extended out many miles into the lake from the west shore of Lakes Huron, covered most of Georgian Bay, the perimeter of Ontario, and virtually all of Lake Erie. In lake areas with ice this early, February ice cover was in general greater than the LTM in Lakes Huron, Erie, and Ontario, it was less than the LTM in Lake Superior, and near the LTM in the deeper open lake areas of Lakes Michigan, Superior, Huron, and Ontario.

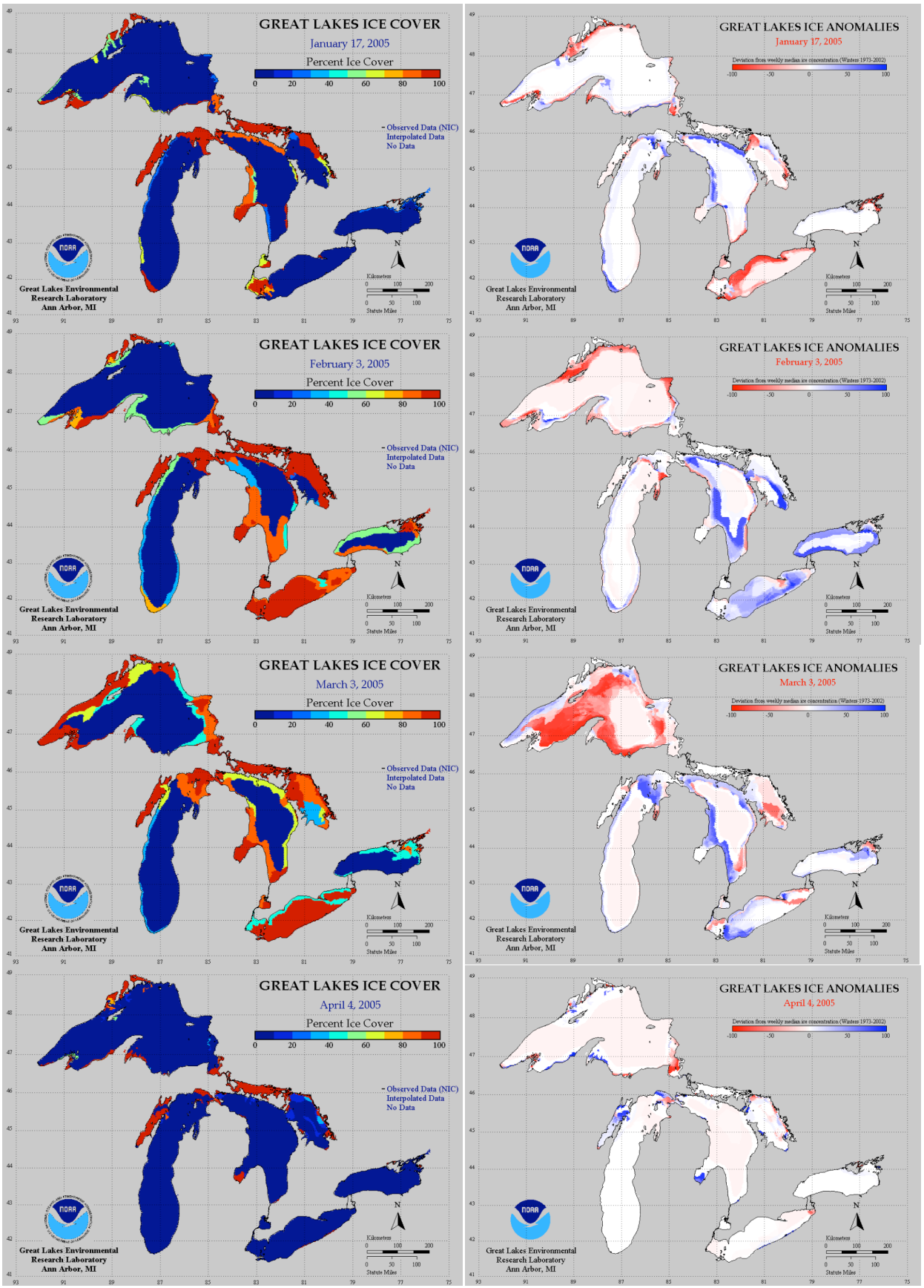

Figure 9. Winter 2005 ice cover and anomaly charts for Jan. 17, Feb. 3, Mar. 3, and Apr. 4.

A month later, March 3, ice cover is again near its seasonal maximum. Ice cover had increased and now extends farther lakeward from the shore and shoal areas of Lake Superior, but for this time of year, it is below the LTM for the western mid lake area and in an offshore band lining the mid-lake eastern lake basin. There is now an extensive ice cover in northern Lake Michigan that is similar to the LTM. However it extends farther southward than the LTM (indicated by positive values on the ice anomaly chart). The ice cover in Lake Huron is now less than it was a month earlier along the west shore of that lake, but it is still greater than the LTM along the western lake shore. Georgian Bay ice cover has also decreased from its early February value. However, it is near the LTM with the exception of an area in the southwest quadrant that is below the LTM. Lake Ontario's ice cover has also receded from its early February extent; the bulk of the remaining ice cover is located in the northeast quadrant. Most of the lake is open water and is near its LTM. High ice concentration still extends over most of Lake Erie with the exception of a linear band along the north shore and off of Long Point. The bulk of Lake Erie's ice cover is near the LTM, it is less than the LTM in the boundary between the west and central lake basin with small patches of positive and negative anomalies elsewhere.

The lakes were virtually free of ice cover by the middle of the first week of April with the exception of small discrete areas of ice near shore and in bays. Anomaly ice charts for April 4 show that there were small patches with both positive and negative ice cover anomalies: positive for the south shore Lake Superior, the north shore of Lake Michigan, Saginaw bay in Lake Huron; negative for the Apostle Islands and Whitefish Bay in Lake Superior, the southwest shore for the Straits of Mackinac on Lake Michigan, the north tip of Georgian Bay in Lake Huron, and the east end of Lake Erie.

CONCLUDING OBSERVATIONS

The differences in the timing of first (last) ice and ice duration for the ice cover in 2003 relative to 2004 and 2005 brings up the following question: are there any corresponding signals in the biological, geochemical, or physical process in the winter and early spring lake ecosystem that relate to the differences in timing of ice cover during these three winters? While beyond the scope of this study, this question need to be addressed.

The description of the ice cover for 2003, 2004, and 2005 was meant to highlight the data and one application of these data, i.e., a very limited descriptive analysis of the annual ice cycle for each winter and a limited comparison with a the 30-winter climatology. These data are also useful for developing ice cover models (statistical and conceptual), assessing the impact of spatial and temporal variations in ice cover on the Great Lakes fauna and flora, assessing the impact of ice cover on the physical processes within the lake and between the lake and atmospheric boundary layer, and for marine engineering, winter navigation, and educational applications.

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APPENDIX 1. DATES OF FIRST ICE, LAST ICE, AND ICE DURATION

The table below contains the file names for the date of first reported ice (FST), the dates of last reported ice (LST), and for ice duration (DUR). Click on ftp://ftp.glerl.noaa.gov/publications/tech_reports/glerl-135/Appendix1/ to download these data.

COMPRESSED	UNCOMPRESSED Names	No. files
FSTYYGRID.ZIP	FSTYYMM.DAT	9
FSTYYPLOT.ZIP	FSTYYMM.GIF	9
LSTYYGRID.ZIP	LSTYYMM.DAT	9
LSTYYPLOT.ZIP	LSTYYMM.GIF	9
DURYYGRID.ZIP	DURYYMM.DAT	9
DURYYPLOT.ZIP	DURYYMM.GIF	9

Where: FST (LST) = first (last) reported ice file, DUR= ice cover duration in days. GRID = ASCII data file, PLOT = ice chart plot file, YY = year (03, 04, 05), MM = threshold, for first (last) reported date and ice duration.
First Ice Cover Plots (ice concentration ≥: 10%, 20%, 30%, 40%, 50%, 60%, 70%, 80%, 90%)
Last Ice Cover Plots (ice concentration ≥: 10%, 20%, 30%, 40%, 50%, 60%, 70%, 80%, 90%)
Ice Duration Plots (ice concentration ≥: 10%, 20%, 30%, 40%, 50%, 60%, 70%, 80%, 90%)

GRID File Structure
There are 510 records for each GRID file. Each record has 516 "cells" in a I3 format, where I3 = a integer.

GRID Data Codes
code = -1 (land)
code = 0 (ice cover concentration is less then the threshold value)
code = 1 to 182 (date that the ice cover concentration threshold value was first (or last) observed or for ice duration this is the number of days between first and last ice reported ice cover. If the first and last date are the same the duration is 1, if there was no ice cover for the given ice concentration value the duration is 0. For example if the date code for a single grid cell on a file of "first date ice cover greater or equal to 90%" was 63, that corresponds to a date of February 1; if the date code for a single grid cell on a file of "last date ice cover greater or equal to 90%" was 122, that corresponds to a date of April 1. See Table 1 below for a complete list of the first / last date codes and associated dates.

Table Summary of the First ice and Last ice date codes and associated calender dates*

Day Code	Day Code	Day Code	Day Code	Day Code	Day Code
001 Dec 1	032 Jan 1	063 Feb 1	091 Mar 1	122 Apr 1	152 May 1
002 Dec 2	033 Jan 2	064 Feb 2	092 Mar 2	123 Apr 2	153 May 2
003 Dec 3	034 Jan 3	065 Feb 3	093 Mar 3	124 Apr 3	154 May 3
004 Dec 4	035 Jan 4	066 Feb 4	094 Mar 4	125 Apr 4	155 May 4
005 Dec 5	036 Jan 5	067 Feb 5	095 Mar 5	126 Apr 5	156 May 5
006 Dec 6	037 Jan 6	068 Feb 6	096 Mar 6	127 Apr 6	157 May 6
007 Dec 7	038 Jan 7	069 Feb 7	097 Mar 7	128 Apr 7	158 May 7
008 Dec 8	039 Jan 8	070 Feb 8	098 Mar 8	129 Apr 8	159 May 8
009 Dec 9	040 Jan 9	071 Feb 9	099 Mar 9	130 Apr 9	160 May 9
010 Dec 10	041 Jan 10	072 Feb 10	100 Mar 10	131 Apr 10	161 May 10
011 Dec 11	042 Jan 11	073 Feb 11	101 Mar 11	132 Apr 11	162 May 11
012 Dec 12	043 Jan 12	074 Feb 12	102 Mar 12	133 Apr 12	163 May 12
013 Dec 13	044 Jan 13	075 Feb 13	103 Mar 13	134 Apr 13	164 May 13
014 Dec 14	045 Jan 14	076 Feb 14	104 Mar 14	135 Apr 14	165 May 14
015 Dec 15	046 Jan 15	077 Feb 15	105 Mar 15	136 Apr 15	166 May 15
016 Dec 16	047 Jan 16	078 Feb 16	106 Mar 16	137 Apr 16	167 May 16
017 Dec 17	048 Jan 17	079 Feb 17	107 Mar 17	138 Apr 17	168 May 17
018 Dec 18	049 Jan 18	080 Feb 18	108 Mar 18	139 Apr 18	169 May 18
019 Dec 19	050 Jan 19	081 Feb 19	109 Mar 19	140 Apr 19	170 May 19
020 Dec 20	051 Jan 20	082 Feb 20	110 Mar 20	141 Apr 20	171 May 20
021 Dec 21	052 Jan 21	083 Feb 21	111 Mar 21	142 Apr 21	172 May 21
022 Dec 22	053 Jan 22	084 Feb 22	112 Mar 22	143 Apr 22	173 May 22
023 Dec 23	054 Jan 23	085 Feb 23	113 Mar 23	144 Apr 23	174 May 23
024 Dec 24	055 Jan 24	086 Feb 24	114 Mar 24	145 Apr 24	175 May 24
025 Dec 25	056 Jan 25	087 Feb 25	115 Mar 25	146 Apr 25	176 May 25
026 Dec 26	057 Jan 26	088 Feb 26	116 Mar 26	147 Apr 26	177 May 26
027 Dec 27	058 Jan 27	089 Feb 27	117 Mar 27	148 Apr 27	178 May 27
028 Dec 28	059 Jan 28	090 Feb 28	118 Mar 28	149 Apr 28	179 May 28
029 Dec 29	060 Jan 29		119 Mar 29	150 Apr 29	180 May 29
030 Dec 30	061 Jan 30		120 Mar 30	151 Apr 30	181 May 30
031 Dec 31	062 Jan 31		121 Mar 31		182 May 31

* Note for Leap years code 91 = Feb 29, code 92 = Mar 1 and so on)

APPENDIX 2. DAILY ICE COVER TIME SERIES

Daily Great Lakes ice cover grid time series were created for each winter season by linear interpolation between observed ice chart grids for each winter season for 2003, 2004, and 2005. Click on the icons (**in blue below**) to go to an ftp site where you can download: 1) computer animations, 2) daily grids, 3) daily images, and 4) daily lake averages. The time series for each winter always begins Dec 1, and is 182 days, so it ends on May 31 for non-leap years and May 30 for leap years.

1. **Computer Animations** - portray temporal changes in spatial patterns of ice cover over a winter season. There are two types of animation files (.AVI and .FLC). File Names YYYYnic.FLC and YYYYnic.AVI, where YYYY = 2003, 2004, or 2005. Click on ftp://ftp.glerl.noaa.gov/publications/tech_reports/glerl-135/Appendix2/ComputerAnimations to download the computer animation files.

2. **Daily Grids** - ASCII files, 510 x 516 grid cells of daily ice concentrations for each winter season. Click on ftp://ftp.glerl.noaa.gov/publications/tech_reports/glerl-135/Appendix2/DailyGrids to download the daily grids.

Zip File Name: YYYYCT.zip
YYYY = year (2003, 2004, or 2005), CT = in an indicator for total ice concentration. Each .zip file has 182 Grid files. The Grid file name encodes the date and type of data: no data, interpolated data, or observed data. Grids prior to the date of the first and after the last ice chart each winter are coded zero.

Grid File Names: YYYdddI.CT
YYY = winter season (103 is for 2003, 104 is for 2004, and 105 is for 2005)
ddd = day of the winter season (101=Dec 1, ...132=Jan 1, …282=May 31, 282 = May 30 for leap years such as 2004)
I = data indicator: I = 0 (no data), I = 1 (interpolated data), I = 2 (the original ice chart data, i.e., data that was downloaded from the National Ice Center and quality controlled for GLERL's ice codes and format).

Grid File Format: 510 records, each record has 516 "grid cells" in I2 format.

Ice Concentration Codes: -1 = land, 0 to 99 = fraction of grid cell covered by ice, expressed as a percent, 100% ice cover was coded as 99 to save room.

Coordinates: The latitude and longitude coordinate of the center of each grid cell is given in the following two fixed formatted text files: Latgrid.zip and Longrid.zip. There are 510 records in each file. The format of each record is: 516 (f 9.5,1x).

3. **Daily Images** - individual images of ice concentration spatial patterns for each day of each winter. Daily image files of color-coded ice concentrations over the Great Lakes were produced from the Daily Grid files. Image files for a given winter (2003, 2004, 2005) are compressed in a .zip file. Click on ftp://ftp.glerl.noaa.gov/publications/tech_reports/glerl-135/Appendix2/DailyImages to download these data.

Zip File Name: **YYYYGIF.ZIP**, YYYY = year (2003, 2004, 2005), Each .zip file has 182 image files
Image File Names: **YYYdddI.gif**, YYY = winter season (103=2003, 104=2004, 105=2005)
ddd = day of the winter season (101=Dec 1, ...132=Jan 1, …282=May 31), I = data indicator: I = 0 (no data), I = 1 (interpolated data), I = 2 (observed data), GIF. = Image file format.

4. **Daily Lake Averages** - spatial averages of ice cover for each Great Lake. Click on ftp://ftp.glerl.noaa.gov/publications/tech_reports/glerl-135/Appendix2/DailyLakeAverages to download these data.

Plots of each lake & winter are named **LakeYY.JPG** where Lake is Sup, Mic, Hur, Eri, Ont, and YY is 03, 04, or 05. Plots are 7-day moving averages of the daily data given in the ASCII file Lake Avg.txt.

The text file **Lake Avg.txt** is a tab delimited ASCII file with 183 records. The first record is a header the remaining records are the daily lake averaged ice cover for each Great Lake from December 1 to May 31 (May 30 for 2004).

APPENDIX 3. DAILY ICE COVER ANOMALIES

Introduction. Ice cover anomaly grids are the difference between the weekly median ice concentration grid and the ice concentration grid for the daily ice chart in a given year with the date (month and day) that corresponds to the center day (fourth day) of the weekly median. Differences were calculated for each over-water grid cell. The first weekly median ice chart is for December 1-7. The last median ice chart is for the week of May 22-28. Thus, anomaly ice charts can be calculated for all days between December 4 and May 25. The actual number of anomaly ice charts for a given winter depends upon the date of the first and the date of the last ice chart. It is not possible to calculate an ice anomaly chart prior to December 4 or prior to the date of the first observed ice chart if it is later than December 4, and after May 25, or after the date of the last observed ice chart if it is earlier than May 25. The daily ice charts used to calculate the median are described in Appendix 2 of this report under "Daily Grids".

Anomaly Ice Charts Grids. Anomaly ice chart grids are in compressed files. The file name encodes the winter of the anomaly charts (AnomYY.zip) where YY is the winter (03, 04, or 05). The anomaly grid files contained in the compressed files have names that encode the date and type of data, i.e., interpolated data, or observed data.

Grid File Names: YYYdddI.ANO

YYY = winter season (103 for 2003, 104 for 2004, and 105 for 2005)
ddd = day of the winter season (101=Dec 1, ...132=Jan 1, …273=May 22)
I = data indicator: I = 1 (interpolated data), I = 2 (observed data)
ANOM is an indicator for ice anomaly data.

Grid File Format:

510 records, each record has 516 "grid cells" in integer (I3) format.
Ice and Land Grid Cell Codes: Land grid cells have a value of 999. Ice cover anomalies can vary from –99 to +99. Over water cells with missing data have a code of 888.

Anomaly Ice Chart Images and Animations. Daily Image files and computer animations of the daily image files of ice concentration anomalies over the Great Lakes for a given winter were produced from the daily anomaly ice chart grid files. Image files for a given winter are contained in a compressed image file. Computer animations are available in two formats: ".AVI" and ".FLC". Image files are arranged by winter season in compressed files.

Compressed Image File Names: YYYYanogif.zip, where YYYY is the winter (2003, 2004, or 2005), "ano" is an indicator for ice anomaly image data, and "gif" defines the image format.

Image File Names: YYYddd.GIF, where "YYY", "ddd", and "gif" are as defined above.

Animation file Names: YYYYano.AVI, and YYYYano.FLC, where "YYYY" and "ano" are as defined above.

Click on ftp://ftp.glerl.noaa.gov/publications/tech_reports/glerl-135/Appendix3/grids to download anomaly ice chart grid files.

Click on ftp://ftp.glerl.noaa.gov/publications/tech_reports/glerl-135/Appendix3/animations to download computer animations for each winter. There are two animations for winters 1989, 1990, 1991, 1992, 1993, 1994, and 1995 because there were separate NIC and CIS ice chart anomaly files those winters.

Click on ftp://ftp.glerl.noaa.gov/publications/tech_reports/glerl-135/Appendix3/images to download images used to create the computer animations.