

Improved Great Lakes Ice Cover Climatology

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Overview

Ice cover affects mass and energy exchange between the planetary boundary layer and the waters of the Great Lakes. The improved ice cover data set and climatology are benchmarks of ice cover that have applications in studies of climate variation and climate change, winter lake ecosystem studies, engineering design studies, and for operational use by the National Ice Center and by the Canadian Ice Service

Historical Great Lakes ice charts were digitized in GLERL's Geographical Information System Laboratory. The National Ice Center and the Canadian Ice Services supplied these ice charts and act as consultants and advisors. The products of this research to date include over 1,200 electronic ice charts spanning the 1973 to 2002 winter seasons, computer animations of ice cover for each winter season, lake averaged ice cover time series for each winter, an analysis of dates of first/last ice and ice duration each winter, and statistical analysis of ice cover for 173 overlapping weekly base periods. The data set of digitized ice charts and ice cover climatology is now available on GLERL's Internet site, as a set of CD-ROMs and as a DVD.

Objectives

The objectives of this research are to create a computer accessible database of Great Lakes ice cover, to use that data to update the NOAA Great Lakes Ice Atlas, and to provide ice cover data and statistics useful for research, engineering, educational, and operational applications.

2005 Plans

Two publications documenting and expanding on the three major ice climatology analysis products will be written. The first report will document the procedures used to develop the weekly ice cover statistics produced in the NOAA Great Lakes ice atlas and will also include supplemental information on weekly ice anomaly grids and charts and lake averages of weekly median ice concentration for specific depth ranges. A second report will update the ice cover concentration climatology for the winters of 2003, 2004, and 2005.

2004 Accomplishments

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 were analyzed for the combined Great Lakes and for each Great Lake over the base period. Average and the composite extremes over the 30 winters were analyzed for ten overlapping ice concentration ranges (from = 10% to = 90%). The lowest range (=10%) defined the ice edge boundary. The 30 winter average (Fig. 1) portrays the typical limit of the ice edge under the current climate. Ice cover for specific depth ranges

was also analyzed for each Great Lake and these statistics have applications for winter ecosystem studies and climate change studies.

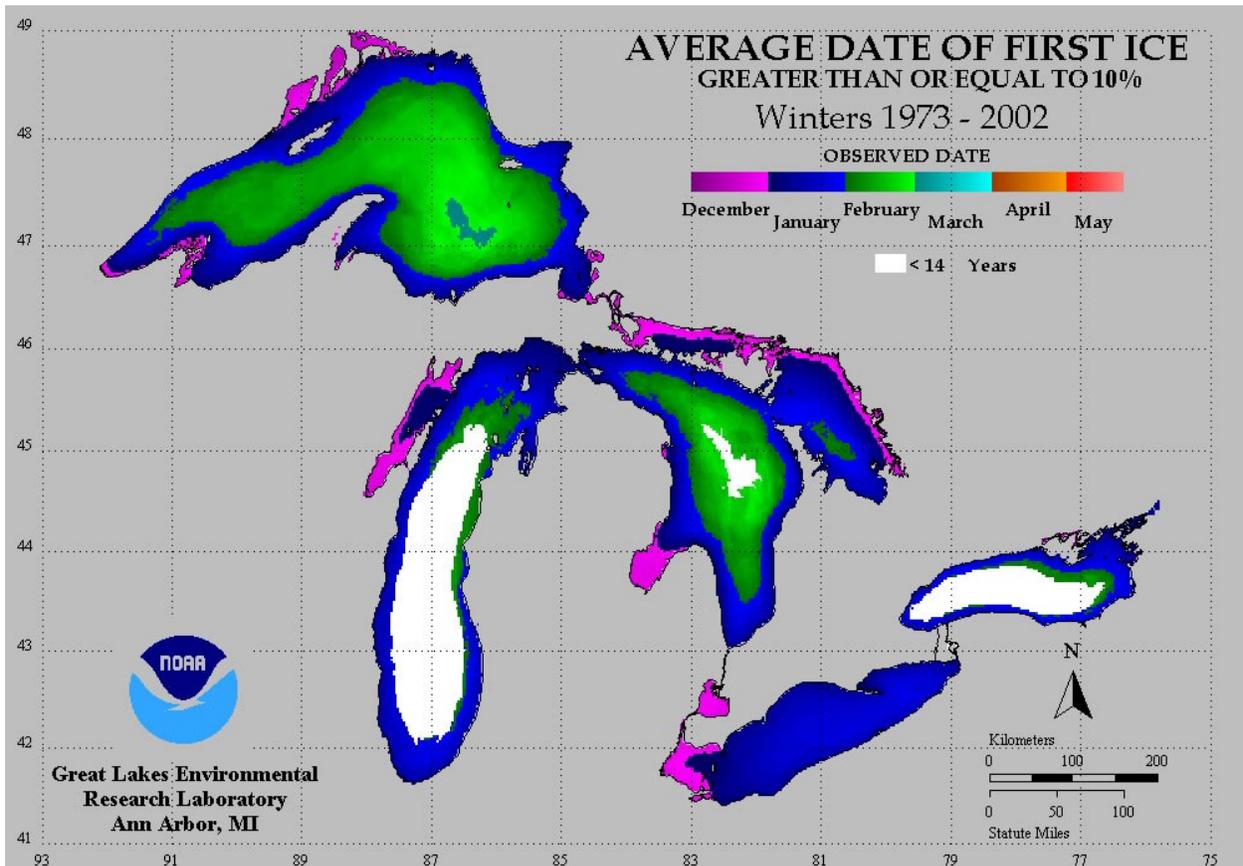


Figure 1: Average date ice cover $\geq 10\%$. a sample of the digitized total ice concentration for the Great Lakes. This is the data for February 13, 1975. Project: Lambert, Spheroid Clarke 1866. Total ice area for all Lakes: 130,712 square km. Percent Ice Cover for all lakes: 51.42%.

Freezing degree-days (FDDs) are used to define winter severity and trends in winter severity, develop empirical models of ice thickness and ice cover and assess the severity of anomalous winters. The third in a series of reports providing climatological information on freezing degree-days (FDDs) was completed in FY 04. The report provides monthly accumulations and seasonal accumulations of FDDs on Beginning of Month Dates (BOM) for a 105-winter period, 1898-2002, and daily FDD accumulations for the period of the update (1984-2002) at 18 stations around the United States shores of the Great Lakes. The objective was to expedite the access of these data for operational and research applications. Monthly and seasonal FDD accumulations on BOM dates were requested by the Navy/NOAA National Ice Center (NIC) for operational applications. These data are used along with the new NOAA Electronic Great Lakes Ice Atlas ice by the NIC in making operational Great Lakes ice chart products. Basic data, methods used in the calculation of: daily, monthly, and seasonal accumulation of FDDs on BOM dates was presented and discussed. An FDD index was used to classify winter severity over the 105-winters. The cumulative value of the normalized regional average of seasonal maximum

FDD accumulations illustrates four trends in winter severity over this past century (Fig. 2). The most recent trend is decline in winter severity since the early 1980s.

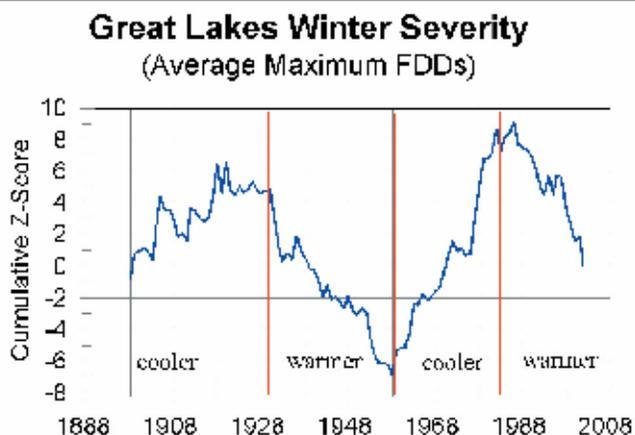


Figure 2: Regional winter severity trends winters: 1898 – 2002 A sample chart of Great Lakes 30 winter median ice concentration by cell. This is the data for March 1-7, 1973-2002. Saginaw Bay, Green Bay and the North Channel are 90-100% ice covered. Lake Michigan below the Straits of Mackinaw, and Lake Ontario (except for the easternmost harbors) and 0-9% ice covered.

In an effort to make annual updates of the ice cover concentration climatology an ongoing and routine activity of the Physical Environment Prediction Program the feasibility of developing a semi-automated standard operating procedure to transform the NIC data to GLERL's ice climatology format, consistent with GLERL's standard set of over-water cells, and GLERL's ice concentration codes is being explored. To date ice concentration files for winters 2003 and 2004 were downloaded from the National Ice Center Web site and some software development was initiated.

2003 Accomplishments

Internet access of a 28-winter (1973-2000) ice cover data set was augmented with the addition of two more winters, 2001 and 2002, including graphic files of total ice concentration to browse the data. The 30-winter ice cover data set and ice climatology were published as an official NOAA Atlas (Assel, 2003). A graphic user interface for that atlas was completed, making it possible to browse the climatology and database on the internet and download selected limited amounts of data. However, because of its large size (approximately 1.4 gigabytes compressed and about 4 gigabytes uncompressed) it is not practical to download the entire atlas from the Internet. Therefore, it was also made available on CD-ROM and DVD. Several technical memorandums supplement the electronic ice atlas and provide detailed documentation of analysis methods and additional analysis products not included in the atlas. The first of those

reports (Assel, Norton, and Cronk, 2002) describes and documents the digital database. A second report (Assel, 2003) describes methods and results of an analysis of the spatial and temporal patterns of dates of first reported ice, dates of last reported ice, and ice duration. The new ice atlas and data set were presented at a professional scientific meeting (Assel, 2003) and at a technical meeting (Assel, 2002) and was featured on NOAA's home web page in October 2003.

A Great Lakes Ice Climatology Workshop was held at GLERL in September. Agencies attending included the NIC, National Snow and Ice Data Center (NSIDC), and CIS. The purpose of the workshop was to facilitate transfer of GLERL's Great Lakes Ice Climatology to NIC and CIS for operational use and to the NSIDC for archiving. Further possible collaboration and coordination between GLERL, NIC and CIS was discussed, including GLERL's plans to develop a Great Lakes ice model component for the Great Lakes Coastal Forecasting System.

2002 Accomplishments

A technical memorandum describing a 28-winter ice cover data set was completed (Assel et al. 2002). The 28-winter data set was provided to the NIC and CIS for operational use. GLERL continues to act in an advisory capacity with NIC and CIS regarding this data set and the development of GLERL products useful for operational applications. GLERL provided an updated copy of its freezing degree-day (FDD) data set to NIC for operational use. The NIC uses FDDs in their analysis of 30-day and 90-day Great Lakes ice cover outlooks. The GLERL ice cover data set was updated for winters 2001 and 2002 by obtaining data from NIC and converting it to GLERL's standard codes and format and performing a limited quality control on these data. However, the ice cover data for these two winters was not completely quality controlled because of a lack of resources. Nevertheless the total ice concentration data for these two winters was used to re-do the multi-year weekly statistical analysis, and average dates of first ice, last ice and ice duration. This effort resulted in the production of a 30-winter (1973 -2002) ice cover concentration climatology. Computer animations for the progression of ice cover patterns for winters 2001 and 2002, and ice charts that portray the spatial pattern of first ice, last ice, and ice duration were also produced for these two winters. Work on a GUI to access the ice cover database and Climatology continued in 2002.

Summary of Accomplishments prior to 2002

Phase 1: Digitizing Paper Ice Charts. In 1999 the digitizing phase this project was complete with 23 winters (1973-1995) of historical ice charts digitized. The sources of the historical ice charts and the equipment, methods, and the procedures developed to digitize and quality control the digital ice chart data is documented in greater detail in Norton et al. (2000). The value of this publication is twofold: it is the metadata record of the origins of the digital ice cover data set, and it provides guidance to others who may wish to digitize other polygon encoded geo-registered data. About 43,000 ice polygons were digitized on 812 ice charts for the 23-winter period. The ice attributes associated with each polygon included ice concentration, ice age, and ice form. In many polygons only ice concentration was reported so that analysis of ice age and ice forms over the years may prove to be problematic. This work included: 1) quality control of the digital vector files of ice cover polygons and the shoreline polygons, 2) translating

and coding the ice attribute text files to GLERL's standardized format and codes, 3) converting the vector polygon files on each ice chart to 14 raster files (one for each ice attribute subcategory) in a CoastWatch compatible projection and 2.5km grid, 4) converting the raster data to ASCII files, 5) quality controlling the ASCII files for ice data coding errors, 6) overlaying a standardized land-water grid to standardize the over-water grid cells. Further details are given in Norton et al (2000) and Assel et al. (2002). The earlier digital ice climatology developed by Assel et al., (1983) is on a 5 km grid. It was converted to 2.5 km grid (Norton et al., 2000). Having this previous ice cover climatology and database on the same scale, 2.5 km grid, as the updated ice cover database and climatology facilitates its use in future studies.

Phase 2: Converting GIS Ice Charts. The NIC started making analyses of Great Lakes ice charts on a Geographic Information System in 1995. This made it feasible for GLERL to augment its digital ice cover data set. The augmented data set was used to update GLERL's ice cover climatology through winter 2000. A computer animation of seasonal progression of ice cover concentration distribution patterns for each winter from 1973 to 2000 was produced and the animations are available on the Internet (Assel and Norton, 2001). One can gain insight into the inter-annual variability of the spatial and temporal patterns of the ice cover by comparing the ice animations for different winters.

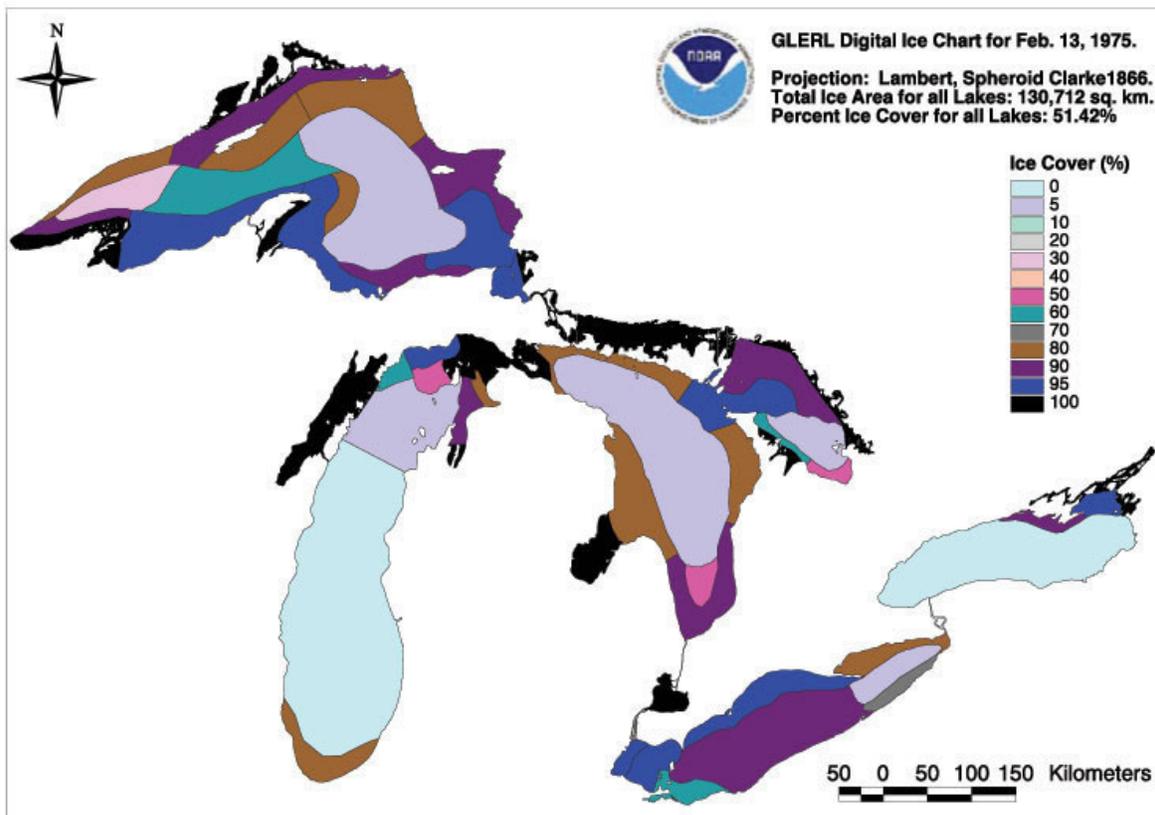


Figure 3: A sample of the digitized total ice concentration for the Great Lakes. This is the data for February 13, 1975.

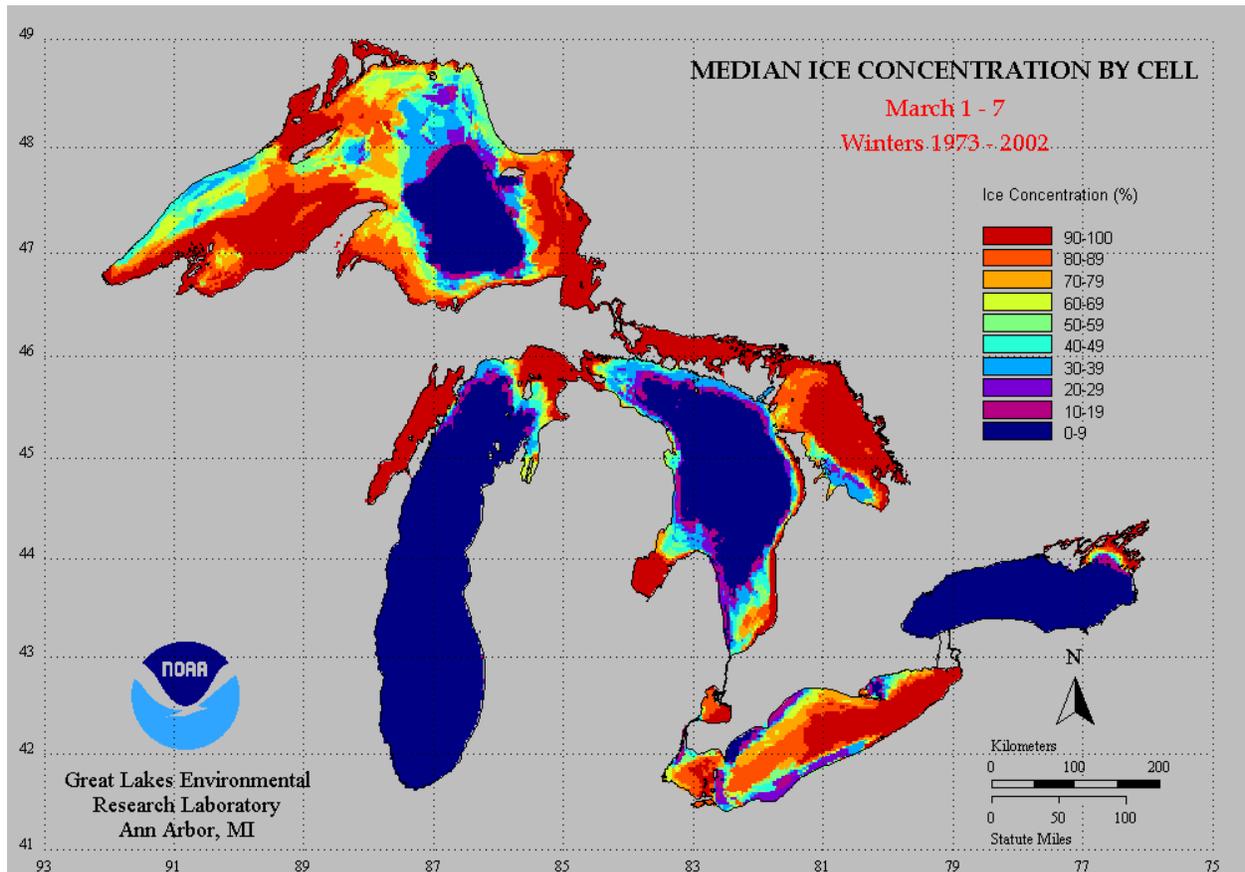


Figure 4: 30-winter median ice concentration for March 1-7

Products

Publications

Assel, R. A. 2003. An Electronic Atlas of Great Lakes Ice Cover, Winters 1973-2002. NOAA Atlas. NOAA, Great Lakes Environmental Research Laboratory, Ann Arbor, MI, 2 CD-ROM Set or DVD.

Assel, R. A., K. Cronk and D. C. Norton. 2003. Recent trends in Laurentian Great Lakes ice cover. *Climatic Change* 57:185-204.

Assel, R. A. and D. C. Norton. 2002. Twentieth century trends in the ice cover of the Laurentian Great Lakes of North America. Ice in the Environment: *Proceedings of the 16th IAHR International Symposium on Ice*, Dunedin, New Zealand, December 2-6, 2002. International Association of Hydraulic Engineering and Research, 321-327.

Assel, R.A. and D.C. Norton. 2001. Visualizing Laurentian Great Lakes Ice Cycles. *EOS Transactions of the American Geophysical Union*. Vol 82, No. 7, Feb. 13, 2001.

NOAA Technical Memoranda

ASSEL, R.A. 2003a. *Great Lakes monthly and seasonal accumulations of freezing degree days – winters 1898-2002*. NOAA Technical Memorandum GLERL-127. NOAA, Great Lakes Environmental Research Laboratory, Ann Arbor, MI, 36 pp.

ASSEL, R. A. 2003b. *Great Lakes ice cover, first ice, last ice, and ice duration*. NOAA Technical Memorandum GLERL-125. NOAA, Great Lakes Environmental Research Laboratory, Ann Arbor, MI, 49 pp.

Assel, R. A., D. C. Norton, and K. C. Cronk. 2002. *A Great Lakes ice cover digital data set for winters 1973-2000*. NOAA Technical Memorandum GLERL-121. Great Lakes Environmental Research Laboratory, Ann Arbor, MI, 45 pp.

Norton, D.C, and others. 2000. *Great Lakes Ice Cover Data Rescue Project*. NOAA Technical Memorandum GLERL-117. Great Lakes Environmental Research Laboratory, Ann Arbor, MI.

Presentations

Schaeffer, J.S., C. Faul, A. Shakoor, and R. Assel. *Status of the Lake Huron Prey Fish Community, 2003*. Lake Huron Technical Committee winter meeting, Port Huron, MI. January, 2004.

Schaeffer, J.S., C. Faul, A. Shakoor, and R. Assel. *Status of the Lake Huron Prey Fish Community, 2003*. MDNR Lake Huron Citizen's Advisory Board, Roscommon, MI, February, 2004.

Schaeffer, J.S., C. Faul, A. Shakoor, and R. Assel. *Status of the Lake Huron Prey Fish Community, 2003*. Great Lakes Fishery Commission Upper Lakes Meeting, Ypsilanti, MI. March, 2004.

Schaeffer, J.S., C. Faul, A. Shakoor, and R. Assel. *Status of the Lake Huron Prey Fish Community, 2003*. Michigan Steelheaders spring meeting, Ubley, MI, April 2004.

Schaeffer, J.S., C. Faul, A. Shakoor, and R. Assel. *Status of the Lake Huron Prey Fish Community, 2003*. Ontario Ministry of Natural Resources Stewardship Council/Parry Sound PAC Meeting, Midland, Ontario, June 18-19, 2004.

Lever, J. and Assel, R. A. 2004. *A Laurentian Great Laks Ice Cover Climatology*. 61st Annual Meeting of the Eastern Snow Conference. Portland, Maine. June 9-11, 2004.

Assel, R.A. *An ice cover data set and climatology for the Laurentian Great Lakes*. Annual meeting of the International Association for Great Lakes Research, Chicago Ill, June 23-26, 2003.

Assel, R. A. *Great Lakes ice cover Climatology*. Presented at the 16th Annual meeting of the United States / Canada Joint Ice Working Group, Falmouth, MA. April 30th, 2002.

Assel, R.A. *A new Great Lakes ice cover data set and climatology*. Present at the U.S. Coast Guard Great Lakes Annual Lakes Ice Breaking Conference. Oct 23, 2002, Cleveland, Ohio.

Assel, R.A. *Great Lakes ice research and Great Lakes ice cover climatology and data base*. Presented at GLERL. 29th International Great Lakes - St. Lawrence Ice Information Workgroup. Canadian Center for Inland Waters, Burlington, Ontario, Nov 21, 2000.

Other Products

Great Lakes Ice Cover Brochure

Updated freezing degree-day data set for winters 1897-2002 (provided in 2002 to the National Ice Center, Suitland, MD)

The digital ice cover data set is proving to be a national and international resource for research, engineering, and educational users. In FY02 portions or all of the 28 winter (1973-2000) digital ice cover data set was provided to:

U.S. National Ice Center and Canadian Ice Service for use in analysis of Great Lakes ice conditions

University of Guelph, (Ontario, CA.) for time series analyses on the effects of environmental conditions on year-class strength and recruitment of lake whitefish populations in Lake Huron.

GLERL (EEGLE) for modeling turbidity in southern basin of Lake Michigan.

Baird & Assoc.,(Oakville, Ontario Ca.) for modeling the effect of ice on shore erosion, part of a federally funded IJC project on Lake Ontario.

Coastal and Hydraulics Lab, US Army Engineer Research and Development Center, Vicksburg, MS., for modeling the wave climatology of the Great Lakes.