

## **A Computer Tutorial for Great Lakes Ice Cover Climatology**

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### ABSTRACT

An interactive menu-driven computer tutorial was developed to provide an overview of the annual Great Lakes ice cycle. The tutorial includes an animation to aid in visualizing the normal seasonal progression and the spatial patterns of ice cover for the base period 1960 - 1979 (Assel and Ratkos 1991). The computer algorithm was developed from data contained in the NOAA Great Lakes Ice Atlas (Assel et al. 1983). Computer diskettes needed to load and run the tutorial are being made available (Assel and Ratkos - in press) to the public at large. This paper abstracts information from that forthcoming publication.

### INTRODUCTION

An interactive menu-driven computer tutorial on the contemporary ice cover climatology (winters 1960 to 1979) of the Great Lakes of North America was developed for educational purposes. The information presented in that tutorial is primarily descriptive in nature. The computer algorithm contains two text modules (1) background information on ice cover data sources and analysis methodology, and (2) an overview of the annual ice cycle (fall cooling, ice formation, ice thickness, maximal ice coverage, ice loss, ice as a hazard) and one animation module (animation of the seasonal progression of the spatial pattern of ice cover of each Great Lake). These data are being made available in floppy diskette format (Assel and Ratkos - in press). Readers interested in receiving a copy should write the author. A Macintosh Plus computer with at least 2 mega-bytes of memory is required to run the tutorial. Methods used to create the animation and the spatial and seasonal patterns of the normal ice cover for the decade of the 1960s and 1970s are discussed below.

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THE ICE COVER ANIMATION

The ice cover animation portrays the progression of the daily spatial distribution of five ranges of ice concentration for each Great Lake from December 1 to May 7. Ice concentration is the percentage of a unit of surface area covered by ice. The daily ice charts are calculated from the normal seasonal distribution of ice cover for nine half-month periods (December 16-31 to April 16-30) given in the NOAA Great Lakes Ice Atlas (Assel et al. 1983) and (the daily ice charts) represent the transition from the normal ice cover distribution pattern from one half-month-period to the next as approximated by a linear interpolation of the normal ice concentration between midpoint dates of the nine half-month periods (Figure 1). It should be cautioned that the daily time series of ice charts produced using this method may not be representative of the true daily normal ice cover distribution pattern for a given date in the winter season or for a given area in the Great Lakes. Nevertheless, it is a useful way to visualize an approximation to the normal seasonal progression of ice cover on the Great Lakes. The lakes were assumed to be ice free on December 1. Ice formation between December 1 and December 22 and ice loss between April 23 and May 7 was arbitrarily simulated as non-linear functions of time and initial ice concentration.

	<u>Ice Atlas</u>	<u>Interpolation periods</u>	
interpolation method		dates for interpolation	# of days
equation 1 }		Dec 1 - Dec 22	21
equation 2 }	Dec 16-31	Dec 23 - Jan 7	16
	Jan 1-15	Jan 8 - Jan 22	15
	Jan 16-31	Jan 23 - Feb 7	16
	Feb 1-14	Feb 8 - Feb 21	14
	Feb 15-28	Feb 22 - Mar 7	16
	Mar 1-15	Mar 8 - Mar 22	15
	Mar 16-31	Mar 23 - Apr 7	16
	Apr 1-15	Apr 8 - Apr 22	15
	Apr 16-30		
equation 3 }		Apr 23 - May 7	15

equation 1:  $i(t) = i(p1) \times t^3 / \text{Days}^3$

equation 2:  $i(t) = i(t_1) + \{ [di / \text{Days}] \times t \}$

equation 3:  $i(t) = i(p9) \times \{ [1/t] - [1/15] \}$

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Where:

$i(t_1)$  = ice concentration at start of period, from ice atlas.

$i(t)$  = interpolated ice concentration for day  $t$ .

$t$  = any day in a given interpolation period.

Days = the number of days in a given period.

$di$  = difference in ice concentration between consecutive ice atlas plates.

$i(p1)$  = ice concentration for ice atlas plate 1 (December 16 -31).

$i(p9)$  = ice concentration for ice atlas plate 9 (April 16 - 30).

Figure 1. Half-month periods in Ice Atlas and associated interpolation periods and equations used to produce daily ice charts of each Great Lake.

A total of 157 daily lake image interpolations were made for each of the five Great Lakes. The individual lake images were combined into a cellular animation, along with ancillary information including a legend, map scale, and calendar. A HyperCard stack was used to make the final product a menu-driven package. Additional details are given in Assel and Ratkos (1991). Selection of a topic is made by simply moving the mouse to direct the on-screen cursor to select one of the menu items (Figure 2).

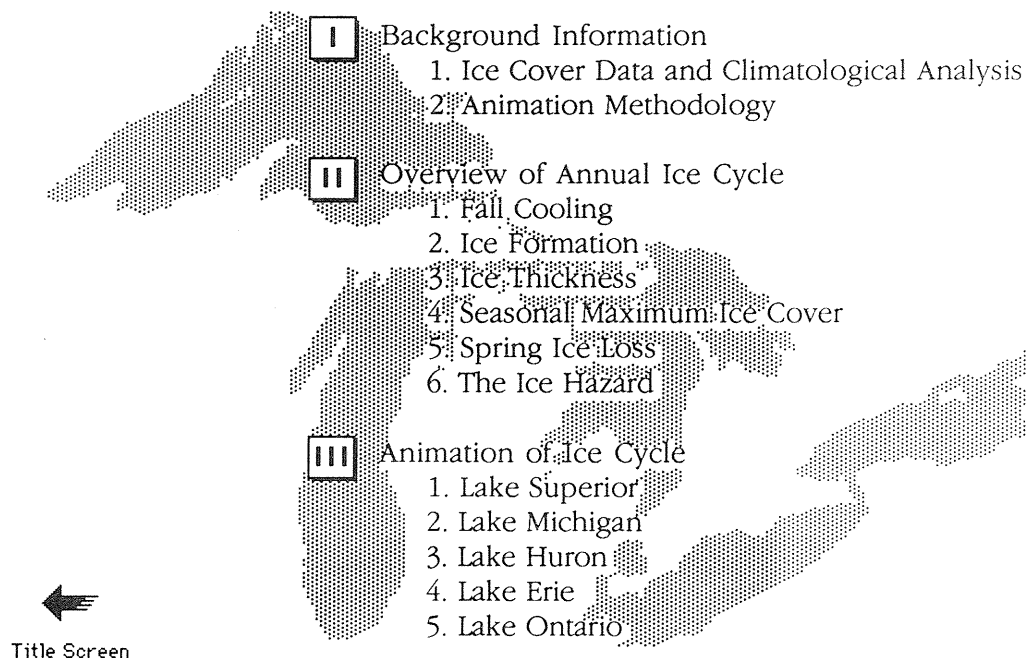


Figure 2. Screen image of menu items for Great Lakes ice cover tutorial.

#### SPATIAL AND SEASONAL ICE COVER CHARACTERISTICS

An example of the ice cover information contained in the animation is given as Figure 3 which portrays the normal spatial distribution pattern of ice cover concentration for Lake Superior during the first half of February. A single screen of text proceeds the ice animation of each Great Lake. It includes a description of the spatial and seasonal trends in ice cover portrayed by the animation and relates these trends to lake bathymetric characteristics, air temperatures, and wind directions. Place names given in the following discussion appear in Figure 4.

##### Lake Superior

Mean monthly air temperature is below freezing in November. Ice forms along the lake perimeter in December and January. Ice forms in the west basin building out from the shallow, southern shore, the west part of the Keweenaw Peninsula, and along the northern lake shore from January 16-31 to February 1-14. Ice forms last in the deep, eastern lake basin in February and March. Monthly air temperatures are above freezing in April. Ice is lost over the entire lake from March 16-31 to April 1-15. Only shore ice remains the second half of April.

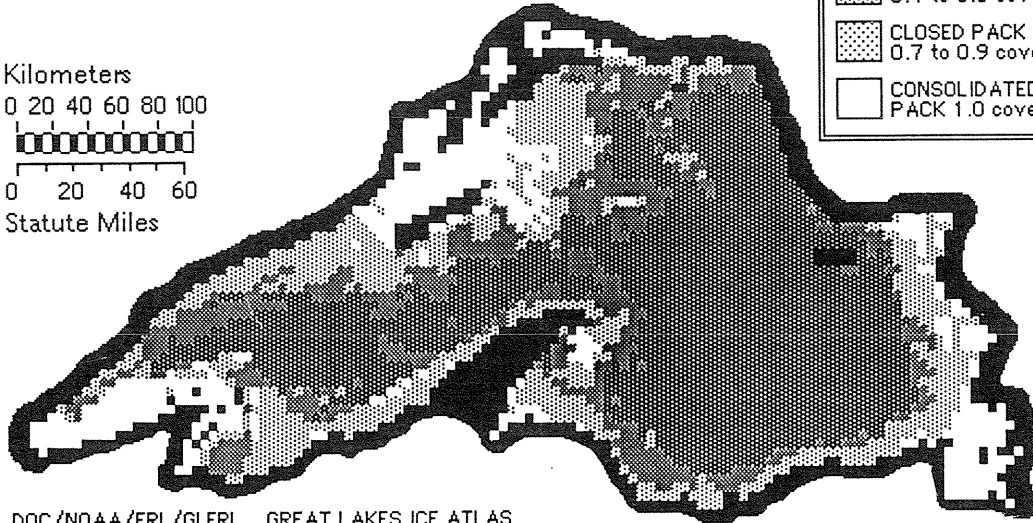
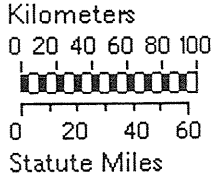
# LAKE SUPERIOR



## NORMAL ICE COVER 1960-1979



ICE COVER LEGEND	
	OPEN WATER
	VERY OPEN PACK 0.1 to 0.3 coverage
	OPEN PACK 0.4 to 0.6 coverage
	CLOSED PACK 0.7 to 0.9 coverage
	CONSOLIDATED PACK 1.0 coverage



DOC/NOAA/ERL/GLERL GREAT LAKES ICE ATLAS

Figure 3. Interpolated Lake Superior ice chart for February 7.

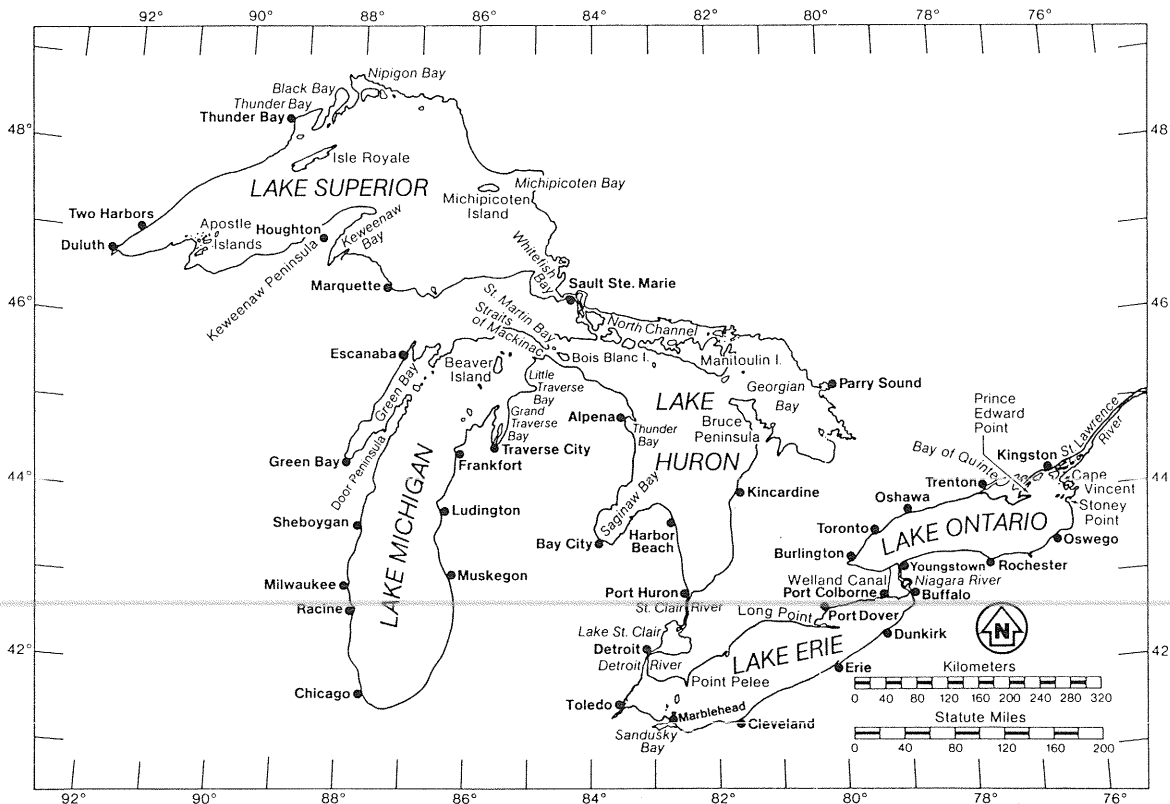


Figure 4. Place Names on the Great Lakes.

### Lake Michigan

Because of the large north to south extent of this lake, mean monthly air temperature is below freezing in November at the northern end of this lake and at the southern end in December. Ice forms along the lake perimeter, in Green Bay, and the shallow, north portion of the lake to Beaver Island starting in December. Ice forms in the midlake areas south of Beaver Island to Milwaukee, Wisconsin in the second half of February. The midlake area south of Milwaukee normally remains relatively ice free. Most of the midlake ice south of Beaver Island is lost during the first half of March. Ice north of Beaver Island and in Green Bay dissipates gradually over the next 6 weeks.

### Lake Huron

Ice formation is restricted to the shallow embayments along the lake perimeter in December and January. Ice gradually builds out to the deeper lake areas in January and February so that only the midlake area between Kincardine, Ontario and Alpena, Michigan remains free of ice by the end of February. This area of open water gradually increases in March. The only areas of extensive ice by mid-April are the large embayments along the northern shore, the Straits of Mackinaw, and the southeast shore. The ice in these areas gradually dissipates over the next 2 to 4 weeks.

### Lake Erie

The progression of ice formation is from the shallow, west lake basin (mean depth 9 m) in mid December to the deep, east lake basin (mean depth 27 m) during the second half of January. By the end of January the lake is approaching its maximal ice cover. Lake Erie remains near its maximal ice cover during February. The ice loss pattern is from west basin to east basin, reflecting the orientation of the lake's axis approximately parallel to the prevailing westerly wind direction. The ice concentration in the first half of March decreases in the western lake basin. By the end of March the western third of the lake is ice free. By the end of April the only extensive ice left in the lake is located in the east end of the lake near Buffalo, New York.

### Lake Ontario

The combination of relatively mild winter air temperatures and large mean lake depth, results in ice formation being restricted to the shallow areas along the lake shore all winter. Extensive shore ice forms first along the shallow embayments along the northeast shore in January and along the entire lake perimeter in February. With the exception of the northeast embayments, ice dissipates from the lake perimeter during the first half of March. The ice in these embayments gradually dissipates over the next 4 to 6 weeks as well, leaving the lake ice free by the end of April.

#### CONCLUDING REMARKS

Because the information presented in this tutorial is simplified to facilitate understanding by non-technical users, it is recommended that it only be used to gain a general overview of the normal ice cover and even then only of the normal ice cover of the 1960s and 1970s. Those readers interested in receiving the computer diskettes needed to run the tutorial should write to the author.

#### ACKNOWLEDGMENTS

This is GLERL contribution number 768.

#### REFERENCES

- Assel, R.A. and J.M Ratkos. -- in press. A computer tutorial and animation of the normal ice cycle of the Laurentian Great Lakes of North America for 1960 - 1979. NOAA Technical Memorandum ERL GLERL xxx. Great Lakes Environmental Research Laboratory, Ann Arbor, MI.
- Assel, R.A. and J.M Ratkos. 1991. Animation of the normal ice cycle of the Laurentian Great Lakes of North America. Preprint Volume of the Seventh International Conference on Interactive Information and Processing Systems for Meteorology, Hydrology, and Oceanography, American Meteorological Society, New Orleans, LA, January 14-18, 1991, pp 331-335.
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