Great Lakes Ice Cover

Introduction

Ice has a deeper connection to the Great Lakes than simply a signal of winter. In fact, the lakes were formed over several thousands of years as mile-thick layers of glacial ice advanced and retreated, scouring and sculpting the basin. In addition, the ebb and flow of glacial meltwaters and rebound of the underlying land from the weight of the massive ice sheets further changed the basin's shape and drainage patterns.

Ice cover still has a major effect on the Great Lakes, making it more important than a connection to the past and an index of winter's severity. Ice cover has an effect on almost every aspect of life on the Great Lakes, from hydropower generation to commercial shipping to the fishing industry. The typical extent and duration of the winter ice cover changes from year to year, and long-term changes may occur because of global warming. Despite its great impact, relatively little research has been done on Great Lakes ice cover largely because of the difficulties of making winter field studies. GLERL is currently the only federal agency with a long-term program to analyze the climatology of the Great Lakes ice cover.

Fig. 1. Ice jams form on rivers when ice floes aggregate and obstruct the normal flow of water. A severe ice jam occurred in April 1984 on the St. Clair River. It established a record for both magnitude and lateness and cost the shipping companies over a million dollars per day in lost time.

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Fig. 2. U.S. Coast Guard vessels assist commercial ships to transit heavy ice fields in the winter. The average hours of assistance typically range from 230 hours for mild winters to 4600 hours for severe winters.

How Ice Affects the Region

● The fishing industry

The formation of ice over the shallow waters where whitefish spawn protects their eggs from destructive wind and wave action. A reduced ice cover could mean greater mortality of the eggs and thus could potentially lower year class strength. Microscopic algae also benefit from clear ice cover with little or no snow cover. Light penetrates through the clear ice promoting algal growth in the stable near surface waters. Algae are the base of the food chain supporting all other life in the lakes, including valuable commercial and sportfish species. With four billion dollars flowing into the commercial and sport fishing industry annually, ice cover is a significant consideration.

● The coastal zone

Huge ice jams can form in the rivers connecting the Great Lakes, such as the St. Mary's, St. Clair, Detroit, and Niagara rivers. The jams constrict the flow of water from one lake to another. This results in flooding above the jam and less water for hyrdopower plants downstream. When the jam finally breaks, the resulting surge of ice and water damage shoreline property (see Fig. 1). In bays, ice forms a stable platform for winter recreational activity such as ice fishing. Stable ice along the lakeshore also protects wetlands and the shore zone from erosion.

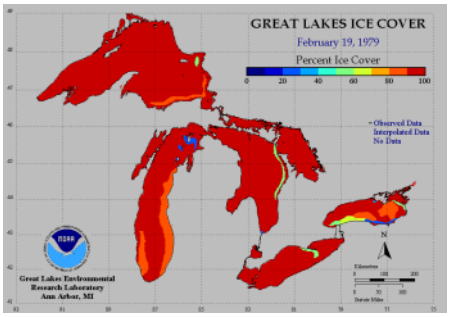
● Lake water levels and navigation

Heavy ice cover in winter can reduce the amount of evaporation from the Great Lakes and thus can contribute to higher water levels the following spring. This is good news for shippers in times of low water levels because it means they can carry more cargo. However, heavy ice conditions in spring months can delay the opening of the shipping season and cause problems for early spring navigation. Ice conditions in late fall and early winter can also be a hazard to navigation (see Fig. 2).

Trends in Lake Michigan Ice Cover

It is rare that Lake Michigan freezes over completely. Despite the area's reputation for harsh winters, the only year we are certain Lake Michigan approached being completely frozen over was 1979, when extended periods of low temperatures resulted in an extensive ice buildup in the southern half of the lake (see Fig. 3). In an average year, ice covers a bit less than half of Lake Michigan's surface. Because the lake stretches about 300 miles from North to South, there is usually much open water over the deeper waters of the southern basin due to milder temperatures. Since airborne and satellite observations of lake ice began four decades ago, only two other years, 1977 and 1994, have seen periods when nearly 90% of the lake was ice-covered. Recently, warmer temperatures have kept the ice cover far below average levels. The icepack covered only 15% of Lake Michigan in 1998, even in late February when the icepack is usually at its greatest.

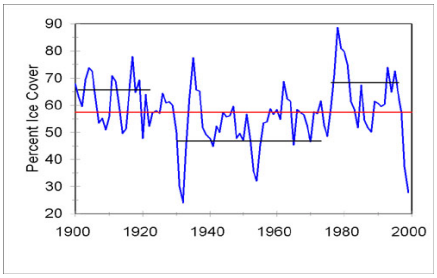
Fig. 3. 1979 ice cover near the time of maximum ice extent.



Past and Present Ice Cover Trends

Twentieth century trends in ice cover, estimated from a model of annual maximum ice cover for winters 1900 to 1962 and direct remotely sensed observations after that, indicate that ice covers were, in general, greater from 1900 to the 1920s and late 1970s to the mid-1990s than in the winters between these periods and at the end of the century (see Fig.4).

Fig. 4. Graph showing three year moving average of annual maximum ice cover. Red line is long-term mean. Black lines are periods of above and below that long-term mean.



Ice records on Grand Traverse Bay in Lake Michigan show that the bay has not frozen over in the past five winters, marking the first time in at least 150 years that the bay had five consecutive winters without freeze-up. This regional trend agrees with long-term lake and river ice records over the Northern Hemisphere that show a trend for later freeze-up and earlier break-up dates over the past 150 years.

Possible Future Ice Cover Trends

Freezing degree-day ice cover models were used to estimate potential ice conditions for Lakes Erie and Superior for global warming scenarios generated from general circulation models of the atmosphere. The ice cover models run under those scenarios indicate winters without mid-lake ice cover, as well as winters with virtually no ice cover at all becoming increasingly more common in the 21st century.

Current Research

Scientists at GLERL are working on computer models to help understand ice covers of the past and predict future ice covers. A thermodynamic model estimates ice cover thickness, mass, and concentration based on the quantity of heat stored in the lakewater and the surface energy balance. Air temperature models of ice allow scientists to simulate the effects of an increase in greenhouse gases in the atmosphere and thus estimate the effects of global warming on Great Lakes ice cover.

An important project taking place currently at GLERL is the updating of the Great Lakes Ice Atlas. Originally compiled in 1983, this atlas provided a detailed analysis of ice cover in the 1960s and 1970s. The atlas was digitized and over 2800 ice charts for winters from 1960 to 1979 can be found at the following website: http://nsidc.org/NSIDC/CATALOG/ENTRIES/F00804.html. This atlas is the major reference for Great Lakes ice cover, and federal and state government agencies, universities, and private industry all take advantage of it. The new edition will bring the atlas up-to-date with information from 1973 to 2000. One of the first products to come out of this project is a set of computer animations of the annual patterns of ice cover extent and concentration for each winter from 1973 to 2000. These animations can be viewed at: ftp://ftp.glerl.noaa.gov/ice/animations/.

Recently completed studies show that Great Lakes ice cover has teleconnections, meaning ice cover is influenced by large ocean and atmospheric patterns a long distance away. A good example of this is provided by the anomalous warming of the tropical Pacific Ocean known as El Nino (see GLERL brochure on El Nino). Research shows that ice cover is below average the winter after an extremely strong El Nino event, shown by the 1997 El Nino event and a record-low winter 1998 Great Lakes ice cover. Such Great Lakes ice cover teleconnections may hold the key to making accurate long-range ice cover forecasts.