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GLACIOLOGICAL DATA

GREAT LAKES ICE

World Data Center A
for
Glaciology
[Snow and Ice]

December 1980

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Washington, D.C., U.S.A., 20418

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1. World Data Centers conduct international exchange of geophysical observations in accordance with the principles set forth by the International Council of Scientific Unions. WDC-A is established in the United States under the auspices of the National Academy of Sciences.

2. Communications regarding data interchange matters in general and World Data Center A as a whole should be addressed to: World Data Center A, Coordination Office (see address above).

3. Inquiries and communications concerning data in specific disciplines should be addressed to the appropriate subcenter listed above.

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Environmental Data and Information Service
Boulder, Colorado 80303 U.S.A.

DESCRIPTION OF WORLD DATA CENTERS[1]

WDC-A: Glaciology (Snow and Ice) is one of three international data centers serving the field of glaciology under the guidance of the International Council of Scientific Unions Panel of World Data Centers. It is part of the World Data Center System created by the scientific community in order to promote worldwide exchange and dissemination of geophysical information and data. WDC-A endeavors to be promptly responsive to inquiries from the scientific community, and to provide data and bibliographic services in exchange for copies of publications or data by the participating scientists.

1. The addresses of the three WDCs for Glaciology and of a related Permanent Service are:

World Data Center A
University of Colorado
Campus Box 449
Boulder, Colorado, 80309 U.S.A.

World Data Centre C
Scott Polar Research Institute
Lensfield Road
Cambridge, CB2 1ER, England

World Data Center B
Molodezhnaya 3
Moscow 117 296, USSR

Permanent Service on the Fluctuations of Glaciers - Department of Geography
Swiss Federal Institute of Technology
Sonneggstrasse 5
CH-8092 Zurich, Switzerland

2. Subject Matter

WDCs will collect, store, and disseminate information and data on Glaciology as follows:

Studies of snow and ice, including seasonal snow; glaciers; sea, river, or lake ice; seasonal or perennial ice in the ground; extraterrestrial ice and frost.

Material dealing with the occurrence, properties, processes, and effects of snow and ice, and techniques of observing and analyzing these occurrences, processes, properties, and effects, and ice physics.

Material concerning the effects of present day and snow and ice should be limited to those in which the information on ice itself, or the effect of snow and ice on the physical environment, make up an appreciable portion of the material.

Treatment of snow and ice masses of the historic or geologic past, or paleo-climatic chronologies will be limited to those containing data or techniques which are applicable to existing snow and ice.

3. Description and Form of Data Presentation

3.1 General. WDCs collect, store and are prepared to disseminate raw[+], analyzed, and published data, including photographs. WDC's can advise researchers and institutions on preferred formats for such data submissions. Data dealing with any subject matter listed in (2) above will be accepted. Researchers should be aware that the WDCs are prepared to organize and store data which may be too detailed or bulky for inclusion in published works. It is understood that such data which are submitted to the WDCs will be made available according to guidelines set down by the ICSU Panel on WDCs in this Guide to International Data Exchange. Such material will be available to researchers as copies from the WDC at cost, or if it is not practicable to copy the material, it can be consulted at the WDC. In all cases the person receiving the data will be expected to respect the usual rights, including acknowledgement, of the original investigator.

[1] International Council of Scientific Unions. Panel on World Data Centers. (1979) Guide to International Data Exchange Through the World Data Centres. 4th ed. Washington, D.C. 113 p.

+The lowest level of data useful to other prospective users.

This Guide for Glaciology was prepared by the International Commission on Snow and Ice (ICSI) and was approved by the International Association of Hydrological Sciences (IAHS) in 1978.

3.2 Fluctuations of Glaciers. The Permanent Service is responsible for receiving data on the fluctuations of glaciers. The types of data which should be sent to the Permanent Service are detailed in UNESCO/IASH (1969)*. These data should be sent through National Correspondents in time to be included in the regular reports of the Permanent Service every four years (1964-68, 1968-72, etc.). Publications of the Permanent Service are also available through the WDCs.

3.3 Inventory of Perennial Snow and Ice Masses. A Temporary Technical Secretariat (TTS) was recently established for the completion of this IHD project at the Swiss Federal Institute of Technology in Zurich. Relevant data, preferably in the desired format**, can be sent directly to the TTS or to the World Data Centers for forwarding to the TTS.

3.4 Other International Programs. The World Data Centers are equipped to expedite the exchange of data for ongoing projects such as those of the International Hydrological Project (especially the studies of combined heat, ice and water balances at selected glacier basins***), the International Antarctic Glaciological Project (IAGP), the Greenland Ice Sheet Project (GISP), etc., and for other developing projects in the field of snow and ice.

4. Transmission of Data to the Centers

In order that the WDCs may serve as data and information centers, researchers and institutions are encouraged:

4.1. To send WDCs raw+ or analyzed data in the form of tables, computer tapes, photographs, etc., and reprints of all published papers and public reports which contain glaciological data or data analysis as described under heading (2); one copy should be sent to each WDC or, alternatively, three copies to one WDC for distribution to the other WDCs.

4.2. To notify WDCs of changes in operations involving international glaciological projects, including termination of previously existing stations or major experiments, commencement of new experiments, and important changes in mode of operation.

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*UNESCO/IASH (1969) Variations of Existing Glaciers. A Guide to International Practices for their Measurement.

**UNESCO/IASH (1970a) Perennial Ice and Snow Masses. A Guide for Compilation and Assemblage of Data for a World Inventory; and

Temporary Technical Secretariat for World Glacier Inventory. Instructions for Compilation and Assemblage of Data for a World Glacier Inventory.

***UNESCO/IASH (1970b) Combined Heat, Ice and Water Balances at Selected Glacier Basins. A Guide for Compilation and Assemblage of Data for Glacier Mass Balance Measurements; and

UNESCO/IASH (1973) Combined Heat, Ice and Water Balances at Selected Glacier Basins. Part II, Specifications, Standards and Data Exchange.

+The lowest level of data useful to other prospective users

FOREWORD

This issue of *Glaciological Data* mainly concerns ice data for the North American Great Lakes. Following a request from the Environmental Data and Information Service, NOAA, a national archive of ice data from the Great Lakes has recently been transferred from the Great Lakes Environmental Research Laboratory, NOAA, in Ann Arbor, Michigan, to the World Data Center-A for Glaciology. This issue describes these data sets and information sources relating to Great Lakes ice, including a selected bibliography of publications. Contributions describing Great Lakes ice programs have been provided by agencies involved in research and operations. Their cooperation is gratefully acknowledged.

Apart from the specific information described here, WDC-A participates in the annual meetings of the U.S.-Canadian Ice Information Working Group and will host the next meeting in Boulder in fall 1981. The center is also willing to assist with enquiries concerning ice research programs and services for the Great Lakes, or direct them to the appropriate groups.

This issue also includes timely communications on other aspects of snow and ice data. While we will continue to publish issues of *GD* emphasizing specific glaciological topics, we will also include other appropriate items of current and broad interest as the occasion arises. We encourage institutions and individuals to submit similar data-related or organizational reports.

R. G. Barry
Director
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Ann M. Brennan
Technical Editor

CONTENTS

GREAT LAKES ICE RESEARCH AND DATA

The Ice Research Program of the Great Lakes Environmental Research Laboratory

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The ice research program of the Lake Survey Center, predecessor organization to the Great Lakes Environmental Research Laboratory, began in 1963 to promote the increased understanding of the Great Lakes ice cover required for many water resource and engineering studies of the Great Lakes. The objectives of the current research program are to develop improved climatological information on the formation, growth, and decay of the ice cover; to develop numerical models and techniques to simulate and forecast the freeze-up, breakup, areal extent, and thickness of the ice cover; and to define the natural distribution and variability of the physical characteristics of the ice cover.

The research is conducted in three broad interrelated areas: ice distribution, ice characteristics, and ice forecasting. Ice charts depicting the extent, concentration, and surface features of the Great Lakes ice cover have been collected for past winters from United States and Canadian government agencies. These charts, along with corresponding air temperature data, formed the basis for a series of annual Great Lakes ice reports, produced from 1962 to the winter of 1978-79, documenting the growth and decay of the ice sheets. The early data collection also resulted in the Great Lakes Ice Atlas (first published in 1969), based upon six years of data. During the 1970s, the collection of ice distribution data, both by airborne observers and by satellite and side-looking airborne radar, increased substantially because of expanded winter navigation and a greater emphasis on evaluating the effects of ice on the environment. The ice cover data collection, including all ice charts from 1960 to 1978, has been digitized on a 5-km grid, forming a computerized data base. These data are being used to revise the old ice atlas to give greater time and space resolution.

Progress to date on the atlas revision includes the complete digitization of all ice charts for each of the Great Lakes. The data for Lakes Superior and Ontario have been edited, with the remaining lakes to be completed by December 1980. Edited Lake Superior data are currently being analyzed as a pilot study for software and graphics development. It is expected that the revised atlas will be available about December 1981.

An 80-year data set of freezing and thawing degree-days for 25 nearshore stations around the Lakes has also been completed. This will be used to define winter severity for the revised ice atlas and for the other Great Lakes climate studies. The data set has recently been published and is available from World Data Center A for Glaciology (WDC-A).

Data on ice thickness and stratigraphy at some 30 nearshore stations distributed throughout the Great Lakes have been collected for a number of years and represent the largest volume of ice-thickness information available for the Great Lakes. The data collection was terminated at the end of the 1978-79 season because a data set sufficient for scientific analysis was then available. The data set has been computerized and hard copy data reports completed. Analysis of the data set is ongoing and involves examination of the temporal variability of total thickness and snow/ice thickness as influenced by the meteorological factors and physical configuration of the sites.

Studies of the optical properties of ice began during the 1975-76 winter season with a field program to investigate the diurnal and seasonal variation of the albedo of the various ice types common to the Great Lakes. The studies were developed to provide an accurate definition of the albedo for ice prediction models and for use as basic ground signature input for remote sensing analysis of ice cover. Recently, two scanning spectroradiometers and photosynthetically active sensors were acquired to further develop the spectral reflectance and transmittance aspects of the field measurement program. The spectroradiometers provide over-ice spectral reflectance data in 10-nm (18.5 km) bandwidths from 300 to 1100 nm (550 to 2035 km). Measurements are usually conducted over snow-free (naturally or artifically cleared) ice surfaces. A relative abundance of existing information on the spectral reflectance of snow, coupled with this new knowledge of the spectral reflectance of snow-free ice surfaces, should enable the remote sensor or energy budget modeler to mechanically "build" an integrated spectral reflectance corresponding to a combined ice-snow surface. In addition, the 10-nm (18.5 km) bandwidth provides the capability to "build" ground truth for any current or future remote sensing detector heads (satellite or aircraft) that operate within the range of the instruments. The spectroradiometers have already produced the first spectral ice and snow reflectance measurements for the Great Lakes region. Substantial additional field work will be conducted over various types of ice peculiar to the Great Lakes during upcoming ice seasons. Data will be collected in the 1980-81 season to determine the significance of ice metamorphosis on spectral reflectance as an aid in development of a radiation energy budget model.

In 1976-77, a program was initiated to obtain information on radiation transmittance through various types of ice common to the Great Lakes in the photosynthetically active range, 400-700 nm, (741-1296 km). Above-ice and below-ice radiation were measured with a specially fabricated under-ice boom and commercially available radiation sensors. The measurements were obtained through a variety of ice types and under some man made conditions, such as snowmobile metamorphism of ice-snow combinations. The results represent the first such measurements obtained for Great Lakes ice with quality sensors. The field program has yielded a set of transmittance values, which are archived and also available from WDC-A. The data can be used by biologists and ecological modelers in a layered ice-snow model developed in conjunction with this project by scientists at the University of Michigan, the Environmental Research Institute of Michigan, and the Great Lakes Environmental Research Laboratory. Some limited field work and analysis is planned to test the model further in multilayered ice-snow systems and to test a depth versus transmittance apparatus developed in our laboratory.

The ice forecasting program includes studies designed to develop, test, and improve techniques for short- and long-range forecasts of ice formation, growth, decay, and transport. Our initial effort, a St. Lawrence River freeze-up forecast technique, was developed, tested for three winters, and made operational in October 1975. We are currently developing a surface energy balance model that simulates ice decay on the St. Lawrence River. This model will be used in developing St. Lawrence River breakup forecast techniques.

There are other ongoing studies to investigate the heat storage characteristics of Lake Superior with expendable bathythermographic data collected during the 8-year fall and winter field program. The demonstration program to extend navigation on the Great Lakes and the St. Lawrence Seaway provided a unique opportunity to document winter water temperatures in Lake Superior for use in developing and verifying models of heat storage, ice formation, and ice decay. During portions of four winter seasons, water temperature surveys were carried out aboard commercial ships taking part in the extended navigation season program. In the summer of 1976, water temperature data were collected from the time of maximum heat storage to the end of the fall overturn in the vertical temperature profile. These measurements were conducted in order to document heat storage and its change as the lake cools. The temperature profiles, down to a maximum depth of 200 meters, were collected along the ship track between Sault Ste. Marie, Michigan, and Duluth or Two Harbors, Minnesota. The analysis of the data will include calculation of heat storage along the ship track for examining the heat flux at the air-water interface. A model will then be developed to simulate the temporal variation of heat storage and predict the end of the fall overturn period.

Research on ice transport modeling and the internal resistance of lake ice is also being conducted under contract. The technical development of the various forecast techniques is also coupled with a continuing assessment of the needs of users, including the National Weather Service, which in many cases issues the operational forecasts.

Bibliography

Assel, R. A. (1976) St. Lawrence River freeze-up forecast procedure. U.S. National Oceanic and Atmospheric Administration. NOAA Technical Memorandum ERL GLERL-6. 12 p.

Assel, R. A. (1980) Great Lakes degree-day summaries and norms, 1897-1977. U.S. National Oceanic and Atmospheric Administration. NOAA Data Report NOAA DR ERL-GLERL-15. 113 p. PB 80-19577.

Assel, R. A. (In press) Maximum freezing degree-day climatology and winter severity index for the Great Lakes, 1897-1977. Monthly Weather Review.

Bolsenga, S. J. (1978) Spectral distribution of radiation in the northern Great Lakes during winter. Journal of Great Lakes Research, 4(2), p. 226-229.

Bolsenga, S. J. (In press) Radiation transmittance through ice in the 400-700 nm range. Journal of Glaciology, No. 95.

Leshkevich, G. A. (1975) Lake Superior bathythermograph data. U.S. National Oceanic and Atmospheric Administration. NOAA Technical Memorandum ERL GLERL-3. 74 p.

Quinn, F. H.; Assel, R. A.; Boyce, D. E.; Leshkevich, G. A.; Snider, C. R.; Weisnet, D. (1978) Summary of Great Lakes weather and ice conditions, winter 1976-77. U.S. National Oceanic and Atmospheric Administration. NOAA Technical Memorandum ERL GLERL-20. 151 p.

Rondy, Donald R. (1971) Great Lakes ice atlas. U.S. National Oceanic and Atmospheric Administration. NOAA Technical Memorandum NOS LSCR-1. 11 p. + 36 plates.

Rumer, R. R.; Crissman, R.; Wake, A. (1979) Ice Transport in Great Lakes. Contract No. 03-78-B01-104. Buffalo, New York, State University of New York, Center for Cold Regions Engineering and Science Technology. 280 p.

Sleator, F. E. (1978) Ice thickness and stratigraphy at nearshore locations on the Great Lakes. GLERL-1-1 (English Units) and GLERL-1-2 (Metric Units). U.S. National Oceanic and Atmospheric Administration. NOAA Data Report ERL GLERL-1-2. 441 p.

GLERL ICE PUBLICATIONS

ADAMS, C.E., JR., 1976. ESTIMATING WATER TEMPERATURE AND TIME OF ICE FORMATION ON THE SAINT LAWRENCE RIVER. LIMNOL. AND OCEANOGR. 1:128-137.

ASSEL, R.A. 1974. GREAT LAKES ICE COVER, WINTER 1973-74. NOAA TECHNICAL REPORT ERL 325-GLERL 1.

ASSEL, R.A. 1976. GREAT LAKES ICE THICKNESS PREDICTION. J. GREAT LAKES RES. 2:248-255.

ASSEL, R.A. 1976. ST. LAWRENCE RIVER FREEZE-UP FORECAST PROCEDURE. NOAA TECHNICAL MEMORANDUM ERL GLERL-6.

ASSEL, R.A. 1980. GREAT LAKES DEGREE-DAY AND TEMPERATURE SUMMARIES AND NORMS, 1897-1977. NOAA DATA REPORT ERL GLERL-15.

ASSEL, R.A., AND QUINN, F.H. 1977. PRELIMINARY CLASSIFICATION OF GREAT LAKES WINTER SEVERITY, 1947-76. GLERL OPEN FILE REPORT.

ASSEL, R.A., AND QUINN, F.H. 1979. A HISTORICAL PERSPECTIVE OF THE 1976-77 LAKE MICHIGAN ICE COVER. MON. WEATHER REV. 107:336-341.

ASSEL, R.A., BOYCE, D.E., DEWITT, B.H., WARTHA, J., AND KEYES, F.A. 1979. SUMMARY OF GREAT LAKES WEATHER AND ICE CONDITIONS, WINTER 1977-78. NOAA TECHNICAL MEMORANDUM ERL GLERL-26.

BOLSENGA, S.J. 1977. PRELIMINARY OBSERVATIONS ON THE DAILY VARIATION OF ICE ALBEDO. J. GLACIOL. 18:517-521.

BOLSENGA, S.J. 1977. THE RADIATION BALANCE OVER A CONTINUOUS SNOW SURFACE: A REVIEW. GLERL OPEN FILE REPORT.

BOLSENGA, S.J. 1978. ON THE USE OF MULTISPECTRAL RADAR TO DEFINE CERTAIN CHARACTERISTICS OF GREAT LAKES ICE. NOAA TECHNICAL MEMORANDUM ERL GLERL-17.

BOLSENGA, S.J. 1978. PHOTOSYNTHETICALLY ACTIVE RADIATION TRANSMISSION THROUGH ICE. NOAA TECHNICAL MEMORANDUM ERL GLERL-18.

BOLSENGA, S.J. 1978. SPECTRAL DISTRIBUTION OF RADIATION IN THE NORTHERN GREAT LAKES DURING WINTER. J. GREAT LAKES RES. 4:226-229.

BOLSENGA, S.J. 1978. A TECHNIQUE FOR ESTIMATING MONTHLY GLOBAL RADIATION. WATER RESOUR. BULL. 14:679-688.

BOLSENGA, S.J. 1979. SOLAR ALTITUDE EFFECTS ON ICE ALBEDO. NOAA TECHNICAL MEMORANDUM ERL GLERL-25.

BOLSENGA, S.J. 1980. NEW OBSERVATIONS ON THE DAILY VARIATIONS OF NATURAL ICE ALBEDO. NOAA TECHNICAL MEMORANDUM ERL GLERL-27.

HAGMAN, B.B. 1976. AN ANALYSIS OF GREAT LAKES ICE COVER FROM SATELLITE IMAGERY. NOAA TECHNICAL MEMORANDUM ERL GLERL-9.

HAGMAN, B.B. 1976. ON THE USE OF MICROWAVE RADIATION FOR GREAT LAKES ICE SURVEILLANCE. NOAA TECHNICAL MEMORANDUM ERL GLERL-13.

LAKE HYDROLOGY GROUP. 1976. LAKE ONTARIO IFYGL ICE STUDIES DATA REPORT. GLERL OPEN FILE REPORT.

LESHKEVICH, G.A. 1975. LAKE SUPERIOR BATHYTHERMOGRAPHY DATA. NOAA TECHNICAL MEMORANDUM ERL GLERL-3.

LESHKEVICH, G.A. 1976. GREAT LAKES ICE COVER, WINTER 1974-75. NOAA TECHNICAL REPORT ERL 370-GLERL 11.

LESHKEVICH, G.A. 1977. GREAT LAKES ICE COVER, WINTER 1975-76. NOAA TECHNICAL MEMORANDUM ERL GLERL-12.

QUINN, F.H., ASSEL, R.A., BOYCE, D.E., LESHKEVICH, G.A., SNIDER, C.R., AND WIESNET, D. 1978. SUMMARY OF GREAT LAKES WEATHER AND ICE CONDITIONS, WINTER 1976-77. NOAA TECHNICAL MEMORANDUM ERL GLERL-20.

RAO, D.B. 1979. LAKE SUPERIOR HEAT STORAGE STUDY CONTINUED. COAST. OCEANOGR. CLIMATOL. NEWS 1:21.

ROGERS, J.C. 1976. EVALUATION OF TECHNIQUES FOR LONG-RANGE FORECASTING OF AIR TEMPERATURE AND ICE FORMATION. NOAA TECHNICAL MEMORANDUM ERL GLERL-8.

ROGERS, J.C. 1976. LONG-RANGE FORECASTING OF MAXIMUM ICE EXTENT ON THE GREAT LAKES. NOAA TECHNICAL MEMORANDUM ERL GLERL-7.

ROGERS, J.C., DEWITT, B, AND DIXON, D. 1975. OPERATIONAL ICE FORECAST FOR THE LITTLE RAPIDS CUT. NOAA TECHNICAL MEMORANDUM ERL GLERL-4.

SLEATOR, F.E. 1978. ICE THICKNESS AND STRATIGRAPHY AT NEARSHORE LOCATIONS ON THE GREAT LAKES (ENGLISH UNITS). NOAA DATA REPORT ERL GLERL-1-1.

SLEATOR, F.E. 1978. ICE THICKNESS AND STRATIGRAPHY AT NEARSHORE LOCATIONS ON THE GREAT LAKES (METRIC UNITS). NOAA DATA REPORT ERL GLERL-1-2.

ADAMS, C.E., JR. 1974. WINTER THERMAL STRUCTURE OF LAKE SUPERIOR. SEVENTEENTH CONFERENCE ON GREAT LAKES RESEARCH, 12-14 AUGUST 1974, HAMILTON, ONTARIO.

ASSEL, R.A. 1975. GREAT LAKES ICE THICKNESS PREDICTION. EIGHTEENTH CONFERENCE ON GREAT LAKES RESEARCH, 20-23 MAY 1975, ALBANY, NEW YORK.

ASSEL, R.A. 1979. PRELIMINARY ANALYSIS OF BATHYTHERMOGRAPH DATA COLLECTED OVER THREE FALL SEASONS ON LAKE SUPERIOR. TWENTY-SECOND CONFERENCE ON GREAT LAKES RESEARCH, 30 APRIL-3 MAY 1979, ROCHESTER, NEW YORK.

ASSEL, R.A. 1980. MAXIMUM FREEZING DEGREE-DAY CLIMATOLOGY AND WINTER SEVERITY INDEX FOR THE GREAT LAKES, 1897-1977. TWENTY-THIRD CONFERENCE ON GREAT LAKES RESEARCH, 19-22 MAY 1980, AT QUEEN'S UNIVERSITY, KINGSTON, ONTARIO.

ASSEL, R.A. AND QUINN, F.H. 1978. A HISTORICAL PERSEPECTIVE OF THE 1976-77 LAKE MICHIGAN ICE COVER. TWENTY-FIRST CONFERENCE ON GREAT LAKES RESEARCH, 9-11 MAY 1978, AT THE UNIVERSITY OF WINDSOR, WINDSOR, ONTARIO.

BOLSENGA, S.J. 1976. ICE ALBEDO OF THE BUFFALO HARBOR AREA. SEMINAR, 13 FEBRUARY 1976, NIAGARA FALLS, NEW YORK.

GREENE, G.M., AND QUINN, F.H. 1979. A ONE-DIMENSIONAL MODEL OF ICE BREAK-UP IN THE ST. LAWRENCE RIVER. TWENTY-SECOND CONFERENCE ON GREAT LAKES RESEARCH, 30 APRIL-3 MAY 1979, ROCHESTER, NEW YORK.

LESHKEVICH, G.A., AND ASSEL, R.A. 1978. DESCRIPTION OF AN AUTOMATED PROCESS FOR DIGITIZING TWO-DIMENSIONAL ICE-COVER INFORMATION. TWENTY-FIRST CONFERENCE ON GREAT LAKES RESEARCH, 9-11 MAY 1978, AT THE UNIVERSITY OF WINDSOR, WINDSOR, ONTARIO.

LESHKEVICH, G.A. 1980. CATEGORIZATION OF NORTHERN GREEN BAY ICE COVER USING LANDSTAT-1 DIGITAL DATA-- A CASE STUDY. TWENTY-THIRD CONFERENCE ON GREAT LAKES RESEARCH, 19-22 MAY 1980, AT QUEEN'S UNIVERSITY, KINGSTON, ONTARIO.

ROGERS, J.C. 1974. A LONG-RANGE FORECASTING METHOD OF FREEZE-UP DATES AND ICE EXTENT ON THE GREAT LAKES. SEVENTEENTH CONFERENCE ON GREAT LAKES RESEARCH, 12-14 AUGUST 1974, HAMILTON, ONTARIO.

ROGERS, J.C. 1975. FORECASTING ST. MARYS RIVER ICE PROBLEMS AT THE LITTLE RAPIDS CUT. EIGHTEENTH CONFERENCE ON GREAT LAKES RESEARCH, 20-23 MAY 1975, ALBANY, NEW YORK.

CONTRACTOR PUBLICATIONS

DILLEY, J.F. 1976. LAKE ONTARIO ICE MODELING. IFYGL PHASE 3 FINAL REPORT PREPARED FOR GLERL BY THE GENERAL ELECTRIC COMPANY, RE-ENTRY AND ENVIRONMENTAL SYSTEMS DIVISION, UNDER CONTRACT NO. 03-5-022-45.

DILLEY, J.F., AND PAVLAK, A. 1974. ANALYSIS OF LAKE SHORE ICE FORMATION, GROWTH, AND DECAY. IFYGL PHASE 2 FINAL REPORT PREPARED FOR GLERL BY THE GENERAL ELECTRIC COMPANY, OCEAN SCIENCES LABORATORY UNDER CONTRACT NO. 3-35163.

OMAN, G., SMITH, D., AND SYDOR, M. 1976. ICE GROWTH IN DULUTH-SUPERIOR HARBOR. REPORT PREPARED FOR GLERL BY THE UNIVERSITY OF MINNESOTA, DEPARTMENT OF PHYSICS, UNDER CONTRACT NO. 04-5-022-13.

RUMER, R.R., JR., AND CRISSMAN, R.D. 1977. EFFECT OF WIND AND WAVES ON ICE TRANSPORT IN THE GREAT LAKES, REPORT PREPARED FOR GLERL BY THE UNIVERSITY OF DELAWARE, DEPARTMENT OF CIVIL ENGINEERING, UNDER CONTRACT NO. NOAA-03-6-022-352636.

RUMER, R.R., JR., CRISSMAN, R.D., AND WAKE, A. 1978. DYNAMICS OF ICE TRANSPORT IN LARGE LAKES. FINAL REPORT PREPARED FOR GLERL BY THE UNIVERSITY OF DELAWARE, DEPARTMENT OF CIVIL ENGINEERING, UNDER CONTRACT NO. NOAA-03-6-022-35236.

RUMER, R.R., JR., CRISSMAN, R., AND WAKE, A. 1979. ICE TRANSPORT IN GREAT LAKES. WATER RESOURCES AND ENVIRONMENTAL ENGINEERING RESEARCH REPORT NO. 79-3 PREPARED FOR GLERL BY THE STATE UNIVERSITY OF NEW YORK AT BUFFALO, DEPARTMENT OF CIVIL ENGINEERING AND THE CENTER FOR COLD REGIONS ENGINEERING AND SCIENCE TECHNOLOGY, UNDER CONTRACT NO. 03-78-B01-104.

STRONG, A.E., 1974. GREAT LAKES TEMPERATURE MAPS BY SATELLITE (IFYGL). IN PROCEEDINGS, SEVENTEENTH CONFERENCE ON GREAT LAKES RESEARCH, PP. 321-333. ANN ARBOR: INTERNATIONAL ASSOCIATION FOR GREAT LAKES RESEARCH.

STRONG, A.E., HART, J.L., AND PRICHARD, J.A. 1975. UTILIZING NOAA SATELLITE DATA FOR THE DEVELOPMENT OF GREAT LAKES TEMPERATURE MAPS. FINAL REPORT PREPARED FOR GLERL BY THE NOAA NATIONAL SATELLITE SERVICE.

WILSON, J.W. 1975. RADAR-GAGE PRECIPITATION MEASUREMENTS DURING THE IFYGL. FINAL REPORT PREPARED FOR GLERL BY THE CENTER FOR THE ENVIRONMENT AND MAN UNDER CONTRACT NO. 03-5-022-17.

Great Lakes Ice Data Archive

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World Data Center A for Glaciology (Snow and Ice)
University of Colorado
Boulder, Colorado, U.S.A.

A Great Lakes ice data archive has been established at the World Data Center A for Glaciology (WDC-A) as part of its mission to serve data and information needs of the glaciological community. This archive was previously located at the Great Lakes Environmental Research Laboratory (NOAA/GLERL) in Ann Arbor, Michigan, and was transferred to the WDC-A to permit GLERL to focus on its research mission. Because the WDC-A has a mandate to store and disseminate data and information, the staff's focus is on organizing data sets and filling user requests for these data.

GLERL will continue to collect and analyze Great Lakes ice data, providing annual updates to several of the data bases. WDC-A will continue its task of organizing the data so that cross-analysis of interrelated data is facilitated. Your comments and suggestions are invited as guidance in developing the data bases to meet user requirements.

Because of the transitional nature of the archive, data sets are stored as discrete units. This paper describes the content and format of each data set, with examples selected from the data whenever possible. Data are available for use at the WDC-A in Boulder, or copies may be ordered at the cost of reproduction. Please contact the WDC-A for current data prices.

Ice Thickness and Stratigraphy

Between 1965/66 and 1976/77, GLERL collected weekly ice thickness and stratigraphy data at up to 90 stations in the 5 Great Lakes basins. In 1978, these data were compiled in NOAA Data Report ERL GLERL-1-1 (English units) and GLERL-1-2 (Metric units), titled "Ice thickness and stratigraphy at nearshore locations on the Great Lakes" (Sleator, 1978).

For ease of analysis, the data have been stored on computer-compatible magnetic tape, sorted by year and station. Station names with latitude, longitude, and period of record are listed in table 1; figure 1 shows data for Duluth Harbor, Michigan, winter 1969/70. This NOAA Data Report, containing listings of all the data, is available from the National Technical Information Service, 5285 Port Royal Road, Springfield, Virginia 22161, NTIS order number PB-295 671 (English units) or PB-297 121 (Metric units).

U.S. Coast Guard Surface Ice Reports

Ice observations from U.S. Coast Guard (USCG) vessels on the Great Lakes, and from USCG Great Lakes shore stations have been collected by the Lake Survey and GLERL beginning in 1961/62. These observations, from daily operational teletype messages and ice-log sheets from the USCG vessels and shore stations, report ice thickness and weather conditions as well as icebreaking activity on the Great Lakes.

A 4.1 million-character file containing data for 1961/62 through 1975/76, sorted by year and station, is stored on magnetic tape. No editing or quality control has been performed on this file, but current plans call for annual updating. Figure 2 is a sample listing of data for Toledo, Ohio, winter 1973/74. The original teletype reports and ice-log forms from 1972/73 through 1979/80 are archived on 16 mm microfilm. The format of these primary data sources is shown in figures 3 and 4.

The digital data set is available on computer-compatible magnetic tape or on punched cards; individual stations can be provided as photocopy of computer listings. The original teletype and ice-log forms are available as copies of the 16 mm archive film, or as hard copy prints from this film.

National Ocean Survey (NOS) Water-Level Gage Ice Reports

Since the winter of 1956/57, ice conditions at National Ocean Survey (NOS) water-level gages on the Great Lakes have been recorded by cooperative observers, and tabulated by Lake Survey and GLERL staff. These daily records show ice type, as well as first and last ice, at an average of 35 locations each ice season. Figure 5 is an example of these records. From 1956/57 to 1959/60, the data collected included daily maximum, minimum, and mean temperatures and ice conditions for the St. Lawrence River at Ogdensburg, New York.

Beginning with the 1980/81 ice season, observers will report directly to the WDC-A, and data will be tabulated in Boulder. The time series 1955/56-1979/80 is now available from the WDC-A as photocopy of hand-written tabulations, in chronological order by gage site.

A map showing gage sites, figure 6, and a table of their latitude and longitude, as well as ice-type codes shown in figure 7 and the instructions to observers are provided with any data request.

132 DULUTH HARBOR N46-46/W092-06

SEASON: 1969-70

STA	YR	MO	DA	TI	LI	SI	ALD	ALD	ALD	ALD	WL	SD	SCON	ICON	EDATE	V
132	70/	2/	2	53	48	5					51			7	10712	
132	70/	2/	9	58	53	5					51	3	23	7	20712	
132	70/	2/	16	63	58	5					61	3	23	7		
132	70/	2/	24	64	61	3					58			7		
132	70/	3/	2	63	58	5					58			7		
132	70/	3/	9	63	58	5					58	5	26	7		
132	70/	3/	16	63	58	5					58	3	14	7		
132	70/	3/	23	61	56	5					56			78		
132	70/	3/	30	49	46	3					46	5	2	7	60604	
132	70/	4/	6	49	41	8					43			89	70604	
132	70/	4/	13												51304	3

Figure 1. Ice thickness and stratigraphy data sample, Duluth Harbor, Michigan, winter 1969/70.

Table 1. Ice measurement stations, locations, and periods of record. (Sleator, 1978).

STATION + NUMBER	LOCATION	65 66	66 67	67 68	68 69	69 70	70 71	71 72	72 73	73 74	74 75	75 76	76 77
108 MOSQUITO BAY	N46-28/W084-28				+	+	+	+	+	+	+	+	+
109 GROS CAP LIGHT	N46-31/W084-36			+	+	+	+	+	+	+	+	+	+
110 MONOCLE LAKE	N46-28/W084-39			+	+	+							
111 PENDILLS LAKE	N46-26/W084-46			+	+	+							
112 WAISKA BAY	N46-25/W084-35			+									
113 LAKE HULBERT	N46-19/W085-10			+	+								
114 TAHQUAMENON BAY	N46-32/W085-01			+	+	+	+	+	+	+	+		
115 WARNERS LAKE	N46-42/W085-02	+	+	+	+	+							
116 BODI LAKE	N46-42/W085-19			+	+								
117 LITTLE LAKE	N46-43/W085-22			+	+								
118 MUSKALLONGE LAKE	N46-40/W085-39			+	+								
119 GRAND MARAIS HARBOR MI	N46-40/W085-59			+									
120 SOUTH BAY-MUNISING	N46-25/W086-39			+	+		+	+	+	+	+	+	+
121 MARQUETTE HARBOR	N46-32/W087-22			+	+								
122 PINE LAKE	N46-52/W087-52			+	+								
123 LANSE BAY-KEWEENAW BAY	N46-46/W088-28			+	+	+	+		+	+	+	+	+
124 LAKE FANNY HOOE	N47-28/W087-52			+	+								
125 COPPER HARBOR	N47-28/W087-52			+	+								
126 BEAR LAKE	N47-14/W088-36			+	+								
127 PORTAGE LAKE-KEWEENAW WATERWAY	N47-02/W088-31		+	+	+		+	+	+	+	+	+	+
128 LAKE GOGEBIC	N46-36/W089-35			+	+	+							
129 CHEQUAMEGON BAY-ASHLAND WI	N46-35/W090-55		+	+	+		+	+	+	+	+	+	+
130 BAYFIELD HARBOR	N46-50/W090-49		+	+									
131 MADELINE ISLAND-APOSTLE IS.	N46-56/W090-47			+	+								
132 DULUTH HARBOR	N46-46/W092-06		+	+	+	+	+	+	+	+	+	+	+
133 LAKE SHAGAWA	N47-55/W091-50			+	+	+							
134 AGATE BAY-TWO HARBORS MN	N47-01/W091-49			+	+								
135 LAX LAKE	N47-21/W091-18			+	+								
136 DEVIL TRACK LAKE	N47-50/W090-27			+	+								
137 GRAND MARAIS HARBOR MN	N47-45/W090-20		+	+									
138 GRAND PORTAGE BAY	N47-57/W089-39			+	+		+	+	+	+	+	+	+
139 TEAL LAKE	N47-59/W089-39		+	+	+								
140 ISLE ROYALE-WASHINGTON HARBOR	N47-55/W089-10			+	+	+	+	+	+	+	+	+	+
152 POINT IROQUOIS	N46-30/W084-37			+	+			+	+	+	+	+	+
153 BIG BAY	N46-50/W087-42			+									
154 LAKE INDEPENDENCE	N46-49/W087-42			+									
156 RICE LAKE	N46-52/W092-10			+									
157 SISKIWIT BAY WI	N46-52/W091-06			+									
164 CEDAR POINT	N46-27/W084-30							+	+	+	+		
165 LAKE SHAGAWA-FWPCA	N47-55/W091-50					+							
166 TWO HARBORS-=1 DOCK	N47-01/W091-40				+								
167 TWO HARBORS-=1 DOCK-NEW SITE	N47-01/W091-40				+								
168 BAY MILLS POINT-WHITEFISH BAY	N46-26/W084-34			+									
169 WHITEFISH POINT HARBOR	N46-46/W084-58			+									
170 TWO HARBORS-INNER HARBOR	N47-01/W091-40			+									
200 GREEN BAY WI	N44-34/W087-55			+	+	+	+		+	+	+	+	+
201 STURGEON BAY	N44-48/W087-23			+	+								

Table 1, continued.

STATION • NUMBER	LOCATION	65 66	66 67	67 68	68 69	69 70	70 71	71 72	72 73	73 74	74 75	75 76	76 77
202 HEDGEHOG HARBOR	N45-18/W087-02			*	*								
203 EUROPE LAKE	N45-16/W086-59			*	*								
204 GIBSON LAKE	N46-10/W088-10			*	*	*							
205 LAKE MICHIGAMME	N46-32/W088-05			*	*	*							
206 LAKE ANTOINE	N45-45/W087-57			*	*	*							
207 LONG LAKE	N45-52/W088-46			*									
209 ESCANABA-LITTLE BAY DE NOC	N45-45/W087-03			*	*		*	*	*	*			*
210 PIG ISLAND LAKE	N46-11/W086-30			*	*								
211 INDIAN LAKE	N46-00/W086-20			*	*								
212 NAUBINWAY HARBOR	N46-05/W085-26			*	*								
213 BEAVER ISLAND-LAKE BARNEY	N45-43/W085-34	*	*	*	*								
214 LITTLE TRAVERSE BAY-PETOSKEY	N45-23/W085-06			*	*			*	*	*	*	*	*
215 LAKE CHARLEVOIX	N45-18/W085-14			*	*	*							
216 S. MANITOU IS.-LAKE FLORENCE	N45-01/W086-07	*	*	*	*								
217 CRYSTAL LAKE	N44-42/W086-14			*	*	*							
218 MUSKEGON LAKE-SNUG HARBOR	N43-15/W086-20			*	*	*	*	*	*				
219 GRAND TRAVERSE BAY-WEST ARM	N44-47/W085-37								*	*			*
220 MENOMINEE MI	N45-06/W087-36							*	*	*	*	*	*
301 LAKE GEORGE	N46-26/W084-07			*	*								
302 LAKE MUNUSCONG	N46-13/W084-10			*	*	*		*	*	*	*	*	*
303 RABER BAY	N46-06/W084-03			*	*	*	*	*	*	*	*	*	*
304 ST. MARTIN BAY	N46-01/W084-41			*	*			*	*	*	*	*	*
305 CHAIN LAKE	N45-52/W084-45			*	*								
306 MACKINAW CITY	N45-46/W084-43			*	*	*	*	*	*	*	*	*	*
307 CHEBOYGAN-DUNCAN BAY	N45-39/W084-26			*	*								
308 THUNDER BAY-ALPENA	N45-03/W083-26			*	*	*	*	*	*	*	*	*	*
309 POINT LOOKOUT-SAGINAW BAY	N44-02/W083-36			*	*	*	*	*	*	*	*	*	*
310 WIGWAM BAY-SAGINAW BAY	N43-59/W083-49							*	*	*	*	*	*
312 CARIBOU LAKE	N46-00/W084-00				*								
313 BOIS BLANC ISLAND-TWIN LAKE	N45-45/W084-28				*	*							
314 DETOUR-ST. MARYS RIVER	N46-00/W083-54							*	*	*	*	*	*
400 MARINE LAKE-ERIE HARBOR	N42-08/W080-08			*	*		*	*	*	*	*	*	*
401 MARBLEHEAD-EAST HARBOR	N41-32/W082-48			*	*								
402 BREST BAY	N41-55/W083-19			*	*		*	*	*	*		*	*
406 BUFFALO HARBOR	N42-45/W078-53				*		*	*	*	*	*	*	
407 DELAWARE LAKE-BUFFALO	N42-55/W078-50				*								
408 MARBLEHEAD-CATAWBA ISLAND	N41-33/W082-52						*	*	*	*	*	*	*
410 LAKE ST. CLAIR-NEW BALTIMORE	N42-40/W082-43			*	*	*	*	*	*	*	*	*	*
411 LAKE ST. CLAIR-SELFRIDGE AFB	N42-37/W082-48						*	*	*				
500 IRONDEQUOIT BAY-ROCHESTER	N43-12/W077-31			*	*	*	*	*	*	*	*	*	*
501 LITTLE SODUS BAY	N43-19/W076-43			*	*								
502 NORTH POND	N43-39/W076-11			*	*		*	*	*	*	*	*	*
503 HENDERSON HARBOR	N43-52/W076-13			*	*		*	*	*	*			
504 WILSON BAY	N44-05/W076-21			*	*		*	*	*	*	*	*	*
505 GALLOO ISLAND-GILL HARBOR	N43-55/W076-23				*	*							
506 LAKE OF THE ISLES-WELLESLEY I.	N44-20/W075-00			*									
507 CAPE VINCENT-ST. LAWRENCE R.	N44-03/W076-20					*		*	*	*	*		

USCG ICE REPORTS BY STATION: 1973-74 TOLEDO OHIO

MO	DA	ICE TYPES			AGE	SURF	TI	LI	SI	SL	SN	C	NAVIG	HI	LO	WS	WD	CT	CC
12	22	RIND	BRASH				0	0	0	0	0	10	UNOBST	30	10	10	190	NS	5
12	23	BRASH					0	0	0	0	0	9	UNOBST	37	26	8	200	CI	9
12	24	BRASH					0	0	0	0	1	8	UNOBST	36	25	11	090	ST	6
12	25	BRASH	PANCAK				0	0	0	0	0	4	UNOBST	50	33	6	040	ST	8
12	26	SLUSH					0	0	0	0	1	3	UNOBST	44	34	18	030	ST	8
12	27	SLUSH					0	0	0	0	0	1	UNOBST	41	32	12	200	CI	9
12	29						0	0	0	0	0	0	UNOBST	26	10	12	270	NS	5
12	30						0	0	0	0	0	0	UNOBST	22	9	8	300	CI	5
12	31		BRASH				0	0	0	0	0	6	UNOBST	29	18	10	010	CU	3
1	1						0	0	0	0	0	0	UNOBST	24	4	8	290	AC	1
1	2	RIND		BRASH	THIN		4	3	1	0	0	9	UNOBST	24	8	6	250	CU	2
1	3						0	0	0	0	0	0	UNOBST	28	17	10	045	CU	2
1	4	BRASH	RIND			RAFTED	0	0	0	0	0	10	UNOBST	28	15	9	270	CI	0
MO	DA	ICE TYPES			AGE	SURF	TI	LI	SI	SL	SN	C	NAVIG	HI	LO	WS	WD	CT	CC
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)	(17)	(18)	(19)	(20)

KEY

(1)	MONTH	(11)	SLUSH THICKNESS
(2)	DAY	(12)	SNOW THICKNESS
(3)	PRIMARY ICE TYPE	(13)	ICE CONCENTRATION
(4)	SECONDARY ICE TYPE	(14)	TYPE OF NAVIGATION POSSIBLE
(5)	TERTIARY ICE TYPE	(15)	DAILY MAXIMUM TEMPERATURE
(6)	ICE AGE	(16)	DAILY MINIMUM TEMPERATURE
(7)	ICE SURFACE CONDITION	(17)	WIND SPEED
(8)	TOTAL ICE THICKNESS	(18)	WIND DIRECTION
(9)	LAKE ICE THICKNESS	(19)	CLOUD TYPE
(10)	SNOW ICE THICKNESS	(20)	CLOUD CONCENTRATION

Figure 2. Sample data for Toledo, Ohio, winter 1973/74, U.S. Coast Guard surface ice observations.

NNNNCZCPGA541
PTTUZYUW RUCIABA7001 0242310-UUUU--RUWTGPA.
ZNR UUUUU
P 242235Z JAN 80
FM USCGC MOBILE BAY
TO ZEN/COMCOGARD9 CKU MILWAUKEE WI
ZEN/NWSFO ANN ARBOR MI
RUWTGPA/NOAA WDCA GLACIOLOGY BOULDER CO
CG GRNC
BT
UNCLAS
TO 0
1. MOBILE BAY 2200Z POSITIONMOORED ESCANABA MI.
2. 2200Z ICE REPORT. STURGEON BAY WI MICHIGAN STREET BRIDGE TO STURGEON BAY CANAL ENTRANCE. TEN. 4/1. FAST. MED FLOW. THIN. SWLIGHT. CLOSED CRAFT. TEMPERATURE 16/08. TRACK STABLE STURGEON BAY CANAL TO PORT DES MORTS PASS. OPEN WATER PORT DES MORTS PASS TO ROCK ISLAND PAS. EIGHT FLUSH. DRIFT. SLH. SS. UNOBSTRUCTED. ICE IN EARLY STAGE OF FREEZING. TRANSITED AREA APPROXIMATELY 6 MI OFFSHORE. ICE SLIGHT CONDUCTED 23 JAN 80. REPORTED OPEN WATER IN THIS AREA. ROCK ISLAND PASS TO MINNEAPOLIS SHOAL LIGHT. TEN 4/1. DRIFT. CK. THIN SWLIGHT. CLOSED CRACK. TRACK STABLE. MINNEAPOLIS SHOAL LIGHT TO ESCANABA. TEN. 12/22. FAST BIG FLOW. MED. RFT. DIFFICULT TRACK STABLE.
BT
#7001

Figure 3. Ice report from U.S. Coast Guard Cutter *Mobile Bay*, moored at Escanaba, Michigan at 2200 hours on 24 January 1980.

Department of Transportation
U. S. Coast Guard
CCGD9-143 (1-71) (o)

ICE LOG

STATION: U.S. Coast Guard Fairport
DATE: Jan 26, 80 TO February 1, 80

POSITION	DATE-TIME (Z)	THICKNESS (INCHES) LAKE ICE	SNOW ICE	SLUSH	SNOW	TOTAL	TYPE AND CONCENTRATION PRIMARY TYPE	PRIMARY CONC	SECOND TYPE	SECOND CONC	TERT TYPE	TERT CONC	TEMP PRES	LAST 24 HRS MAX	LAST 24 HRS MIN	WIND SPEED	WIND DIR	VIS	CLOUD DOM. TYPE	CLOUD COVERAGE	PRES WEA	REMARKS	INITS
W° [illegible] 51° [illegible] 45"	1/26/80 1600Z	½-1	—	—	2	3½	Thin	3 ths	—	—	—	—	34	42	14	5-10	SW	5	—	4	2	CLOUDY ICE FORMING	RC.
" "	1/27/80 1600Z	1-2	—	—	2	4	Thin	3 ths	—	—	—	—	25	31	10	8-10	W	5	—	5,9	1,2	BKN SKIES LIGHT ICE	RC.
" "	1/28/80 1600Z	2-3	—	—	2	6	Thin	3-4 ths	LIGHT RAFTING		—	—	15	20	17	5-10	WNW	2-3	—	9	3,7	LIGHT SNOW LAKE FREEZING	RC.
" "	1/29/80 1600Z	3	½	—	2	5½	Thin	3-4 ths	LIGHT RAFTING		—	—	18	19	12	5-7	SW	4	—	9	2	OCCASIONAL COLD	RC.
" "	1/30/80 1600Z	3 [illegible]"	½	—	2-4	8½	Thin	3-5 ths	LIGHT RAFTING		—	—	18	26	12	Calm	SW	2-3	—	9	7	COLD LIGHT SNOW	RC.
" "	1/31/80 1600Z	3	½	—	2-3	[illegible]	Thin	3-5 ths	1-2	LIGHT RAFT.	—	—	18	18	10	15-25	NW	3-5	—	9	2	COLD CLOUDY	RC.
" "	2/1/80 1600Z	4	½	—	2-3	7½	Thin	3-5 ths	1-2	LIGHT RAFT.	—	—	24	26	10	3-12	NW	5	—	9	2,3	LIGHT SNOW COLD	RC.

Figure 4. Ice log from U.S. Coast Guard Station Fairport, Fairport Harbor, Ohio, 18-25 January 1980.

MARCH 1971

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31
LAKE HURON																															
Mackinaw							B	B	B	B	B	B	B	B	B	B	B	B	B	B	B	B	B	B	B	B	B	B	B	B	B
LAKE MICHIGAN																															
Milwaukee	A	A	A	A	A	A	A	A	A	B	B	C	C	A^{E}	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A
Sturgeon Bay	A	A	A	A	A	A	A	A	E	A	A	A	A	A	A	A	A	A	A	A								A	A	A	A
Port Inland	B^{B}	B	B	B	B^{F}	-	-	A^{B}	A^{B}	A^{B}	F^{B}	F^{B}	-	-	F^{B}	F^{B}	A^{B}	F^{B}	A^{B}	-	A^{B}	A^{B}	F^{B}	F^{B}	F^{B}	B^{B}	-	-	B^{A}	B^{F}	A^{A}
Green Bay	C	-	C	C	C	C	C	C	C	C	-	C	C	A	A	A	A	A	A	A	F	F	F	F	-	F	F	A	A	A	A
ST MARYS RIVER																															
DeTour																															
Below locks	B	B	B	B	B	B	B	B	B	B	B	B	B	B	B	B	B	B	B	B	B	B	B	B	B	B	B	B	B	B	B
Above locks	B	B	B	B	B	B	B	B	B	B	B	B	B	B	B	B	B	B	B	B	B	B	B	B	B	B	B	B	B	B	B
LAKE SUPERIOR																															
Point Iroquois	B	B	B	B	B	B	B	B	B	B	B	B	B	B	B	B	B	B	B	B	B	B	B	B	B	B	B	B	B	B	B
~~Whitefish Point~~																															
Ontonagon	B	B	B	B	B	B	-	B	B	B	B	B	B	-	-	B	B	B	B	B	-	B	B	B	B	B	B	-	B	B	B
Duluth	B	B	B	B	B	B	B	B	B	B	B	B	B	B	B	B	B	B	B	B	B	B	B	B	B	B	B				
Grand Marais	B^{F}	B	B	B	B	B	B	B	B	B	B	B	B	B	A^{B}	A^{B}	A^{B}	A^{B}	A^{F}	F	A^{F}	A	A^{F}	F	A^{F}	A^{F}	A^{B}	A^{B}	B^{B}	A^{B}	A^{B}

Figure 5. Tabulated ice condition codes at selected NOAA/NOS water level gage sites, March 1971.

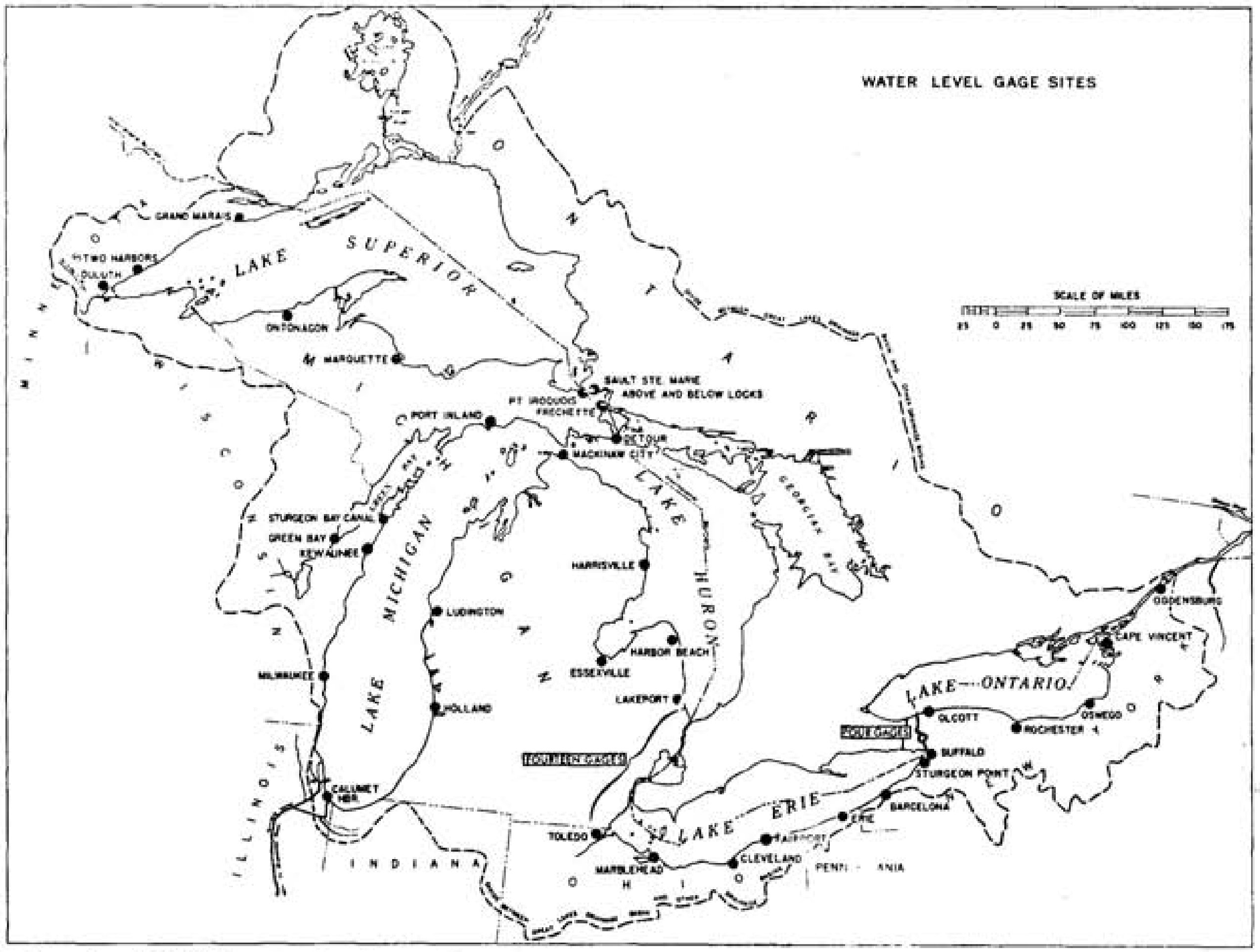

Figure 6. NOAA/NOS water level gage locations.

WEEKLY ICE RECORD		
STREAM St. Clair River		LOCATION ALGONAC
WEEK ENDING SATURDAY DEC 27 1980 ,19		
DAY AND DATE	CODE	REMARKS
Sun 21	A	
Mon 22	B	B- 100' along shore A - in channel
Tue 23	G	400' down river of gage. Blocks half of river.
Wed 24	F	Ice gorge broke about 9 a.m.
Thur 25	F	Moving freely
Fri 26	B	Showing signs of deterioration
Sat 27	A	
SIGNATURE OF OBSERVER John Smith		

Code	Description
A	Open Water, no ice within vision.
B	Solid Ice, little or no signs of deterioration.
C	Honeycombed Ice, full of holes and showing evidence of deterioration.
D	Windrowed Ice, ice heaped up and frequently driven below water due to wind.
E	Slush Ice, borken or crushed ice usually extending well below surface.
F	Drifting Ice, large areas of ice which have broken off from larger fields and are drifting with the current.
G	Ice Gorge, an ice accumulation which wedges in and blocks the river.

Figure 7. Sample weekly observer report and ice condition codes for NOAA/NOS water level gage ice observations.

Air Temperature/Degree Day Climatology

NOAA Data Report ERL GLERL-15, "Great Lakes degree-day and temperature summaries and norms, 1897-1977," (Assel, 1980) includes 25 appendices containing data on which the report is based. These appendices are stored on 35 mm microfilm, one roll for each of the 25 temperature stations (figure 8). These appendices contain daily maximum, minimum, and mean temperatures, and seasonal accumulations of freezing and thawing degree days. Table 2 details contents of the appendices. The data report is available from the National Technical Information Service, NTIS order number PB80-195 977.

Microfilm appendices for each station are available from WDC-A. Also available from the Data Center are daily maximum and minimum temperatures from all stations, either on magnetic tape or punched cards. Data for individual stations, each data file containing approximately 312,000 characters, are available on punched cards. Examples of the data are shown in figures 9 and 10.

Radiation Transmission Through Ice

Data in support of NOAA Technical Memorandum ERL GLERL-18, "Photosynthetically active radiation transmission through ice" (Bolsenga, 1978) is archived by the WDC-A on punched cards. Photocopy of an eight-page line-printer listing of data contained on the cards is also available. Figure 11 shows sample records with data element descriptions.

Copies of the NOAA Technical Memorandum may be obtained from NTIS, order number PB-288 463. A limited number of copies is available from the WDC-A.

Great Lakes Aerial Photography

Between 1963 and 1973 the U.S. Air Force, at GLERL's suggestion, used Great Lakes ice cover as the subject of photographic training flights, producing approximately 50,000 high-quality negatives for GLERL's use (figure 12). This collection of 9" x 9" negatives is now archived at the WDC-A and contains 89 percent black and white, 9 percent color, and 2 percent infrared photographs taken during the months of January through April of 1963, 1965-69, 1971, and 1973. Figure 13 indicates areas of coverage, which are concentrated in regions of historical ice-cover impact on navigation or hydroelectric operations.

The data set has been indexed by GLERL to the extent that geographic coordinates are listed for beginning and end points of each continuous flight segment (figure 14). If there is sufficient interest in this data set, flight lines could be plotted on nautical charts of the lakes.

Prints of the negatives are available, or the collection may be used at the WDC-A. Documentation provided to users includes a map of areas photographed and the log sheet for each roll of negatives pertinent to the request. About 100 mosaics produced from originally separate exposures are scheduled for transfer by the end of 1980. These negatives ranging in size up to 30" x 40" will also be available as prints or for on-site use.

Side-Looking Airborne Radar (SLAR) Data

GLERL is presently analyzing data to be used in the production of an updated ice climatology for the Great Lakes. Data for this effort come from many sources, both surface and aerial, including side-looking airborne radar (SLAR) flights.

NASA/Lewis Research Center developed the SLAR system for ice reconnaissance on the Great Lakes, an "...operational all-weather Great Lakes ice information system" (Gedney, 1975). The SLAR flights by the U.S. Coast Guard provide valuable data from which ice charts have been prepared since 1977. These charts, produced by the Ice Navigation Center, Coast Guard District Nine, Cleveland, Ohio, have been archived by GLERL in hard copy format physically adjacent to the SLAR silver-paper print to which they pertain (figure 15).

After GLERL's analysis of the SLAR images and hand-drawn ice charts is completed, the data set will be transferred to the WDC-A for permanent archiving. It is anticipated that electrostatic or photographic prints of the data will be available for research. A microfilm copy of the data will also be prepared, from which copies could be produced on request.

Figure 8. Location map of temperature stations. (Assel, 1980)

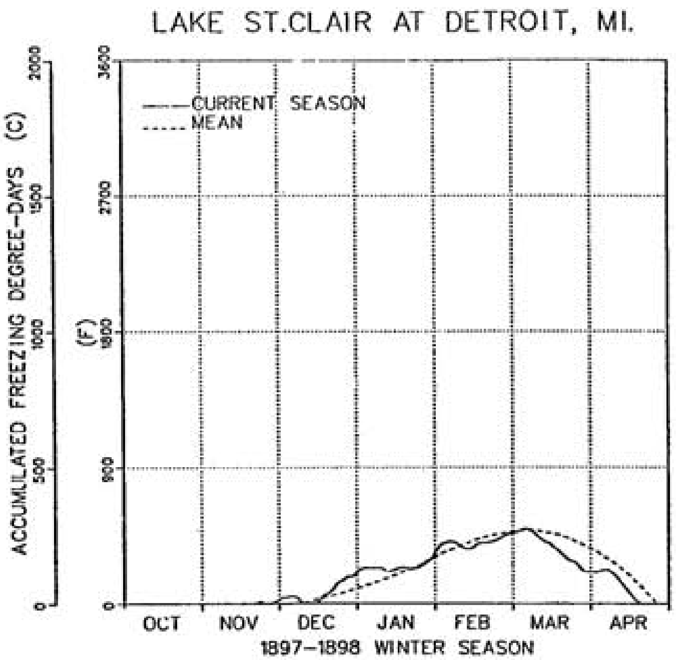

Figure 9. Accumulated freezing degree-days for the 1897-1898 winter season, Lake St. Clair at Detroit.

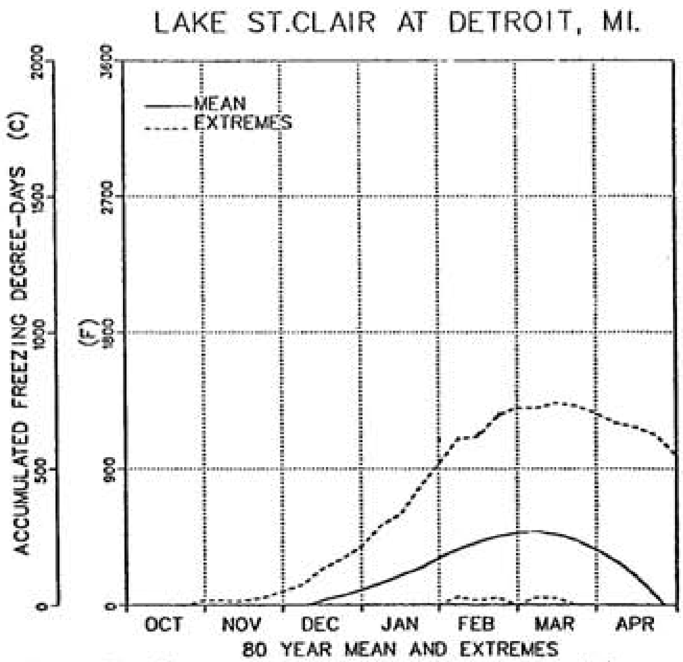

Figure 10. 80-year mean and extremes, accumulated freezing degree-days, Lake St. Clair at Detroit.

Table 2. Sequence and description of data in microfilm appendices (Assel, 1980).

I. Graphic Products

1. Seasonal and mean daily running TDD accumulations alternating with seasonal and mean daily running FDD accumulations. There are 81 TDD graphs starting in 1897 and ending in 1977 and 80 FDD graphs starting in 1897-98 and ending in 1976-77.
2. Daily mean and weekly extreme values of running sum of FDD's.
3. Maximum seasonal value of FDD's for the winters 1897-98 to 1976-77 and the mean of these values.
4. Maximum seasonal value of TDD's for the summers of 1897 to 1977 and the mean of these values.

II. Tabular Products (Mean Values)

1. 81-year mean of FDD's starting in 1897 (degrees Fahrenheit).
2. 81-year mean of TDD's starting in 1897 (degrees Fahrenheit).
3. 81-year statistics on daily mean air temperatures (degrees Fahrenheit) starting in 1897.
4. Same as 1-3, but in degrees Celsius.

III. Tabular Products (Seasonal Values and Statistics)

1. Seasonal tabulations of daily running TDD accumulations alternating with seasonal running FDD accumulations. There are 81 TDD seasons starting in 1897 and 80 FDD seasons starting in the winter of 1897-98.
2. Seasonal accumulation of FDD's at weekly intervals. The weekly intervals are really quarter months as shown below.

Week	Ending Day	
1	8	7*
2	15	14
3	23	21
4	30 or 31	28 or 29

*For February

3. Statistics on running weekly accumulations for 80 years, the mean values, standard deviation and maximum and minimum weekly values for the 80 winters are summarized.
4. Same as (2) above only for FDD accumulations for each week from October to April.
5. Same as (3) above except for FDD accumulations for each week in the winter.
6. End of month accumulations of running sum of FDD's. Same as (2) except for monthly intervals.
7. Statistics for running monthly FDD accumulations for 80 years. Same as (3) above except for monthly time period.
8. Same as (6) above except for accumulations each month from October to April.
9. Same as (7) above except for accumulations each month from October to April.
10. Seasonal maximum FDD accumulation for each of the 80 winters starting in 1897-98, the date of occurrence of the maximum FDD, and the mean and standard deviation of the maximum FDD, and date.
11. Maximum seasonal FDD accumulations for each of the 80 years in descending order.
12. Maximum seasonal TDD accumulations for each of the 81 years from 1897 to 1977 in temporal order.
13. Same as steps (1) through (12) but in degrees Celsius rather than degrees Fahrenheit.

TDD - Thawing degree days

FDD - Freezing degree days

```
1-4  5-8  9-12  13-16 17-18 19-20 21-22 23-24 25-26 29-30    31-42    43-44 46-48 50-51    52-60    61-71
.3551000.315 300  930122276  24                     54     0 1               SILVER LAKE
.3601000.970 100  934122276  24                     54     0 1               SILVER LAKE
.3681000.330 300  936122276  24                     54     0 1               SILVER LAKE
.3711000.750 100  937122276  24                     64   -45 1               SILVER LAKE
.5601000.390 3001055122276   24                     64     0 1               SILVER LAKE
.4201000.345 3001056122276   24                     64   -45 1               SILVER LAKE
.5901000.315 3001057122276   24                     64     0 1               SILVER LAKE
.5901000.355 3001058122276   24                     64   -45 1               SILVER LAKE
.53 1000.50  3001307122276   24                     64     0 1               SILVER LAKE
.52 1000.45  3001308122276   24                     64   -45 1               SILVER LAKE
.4751000.520 300  945122276  24                     79     0 2A              SILVER LAKE
.4851000.379 300  945122276  24                     79   -60 2A              SILVER LAKE
.4851000.399 300  945122276  24                     79   -60 2A              SILVER LAKE
.4901000.340 300  945122276  24                     79   -60 2A              SILVER LAKE
.6501000.760 3001041122276   24                     79     0 2A              SILVER LAKE
.6651000.538 3001042122276   24                     79   -60 2A              SILVER LAKE
.6201000.680 3001044122276   24                     79     0 2A              SILVER LAKE
.6201000.479 3001045122276   24                     79   -60 2A              SILVER LAKE
.66 1000.78  3001256122276   24                     79     0 2B              SILVER LAKE
.64 1000.595 3001257122276   24                     79   -60 2B              SILVER LAKE
.6251000.55  3001258122276   24                     79     0 2C              SILVER LAKE
.62 1000.48  3001259122276   24                     79   -60 2C              SILVER LAKE
.51 1000.65  3001112122276   28                     -1     0 3A              SILVER LAKE
.66 1000.24 10001113122276   28                     -1     0 3A              SILVER LAKE
.59 1000.23 10001114122276   28                     -1     0 3A              SILVER LAKE
.5651000.78  3001118122276   28                     -1   -60 3A              SILVER LAKE
.65 1000.95  3001225122276   28                     -1     0 3A              SILVER LAKE
.67 1000.915 3001226122276   28                     -1     0 3A              SILVER LAKE
.75 1000.3  10001232122276   28                     -1     0 3A              SILVER LAKE
.78 1000.3  10001233122276   28                     -1     0 3A              SILVER LAKE
.69 1000.28 10001115122276   28                     -1     0 3B              SILVER LAKE
.69 1000.89    301116122276  28                     -1     0 3B              SILVER LAKE
```

COLUMN	PARAMETER
1–4	Surface sensor reading
5–8	Scale for surface reading
9–12	Under-ice sensor reading
13–16	Scale for under-ice reading
17–18	Hour of observation, 24 hour clock, EST
19–20	Minutes of observation
21–22	Month
23–24	Day
25–26	Year, last 2 digits
29–30	Ice thickness, cm

COLUMN	PARAMETER
31–42	Not used
43–44	Water depth, cm "-" indicates estimate "-1" is very deep "-99" is not measured
46–48	Under-ice sensor depth below ice bottom surface, cm "-1" indicates estimate
50–51	Site number and letter
52–60	Not used
61–71	Lake name

Figure 11. Sample records from data in support of "Photo synthetically active radiation transmission through ice." (Bolsenga, 1978).

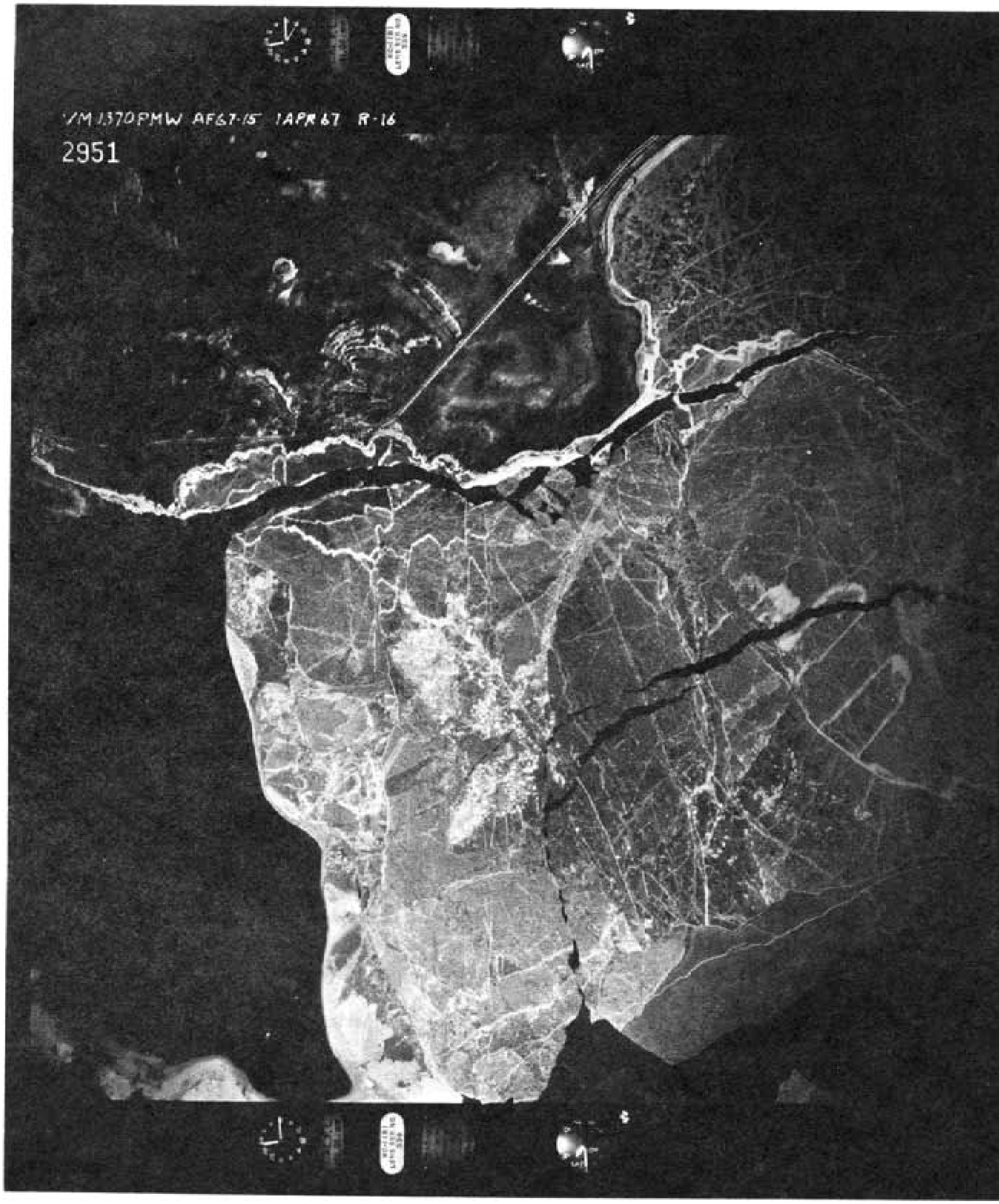

Figure 12. Sample aerial photograph showing ice cover at Pancake Bay, northeastern Whitefish Bay, Lake Superior.

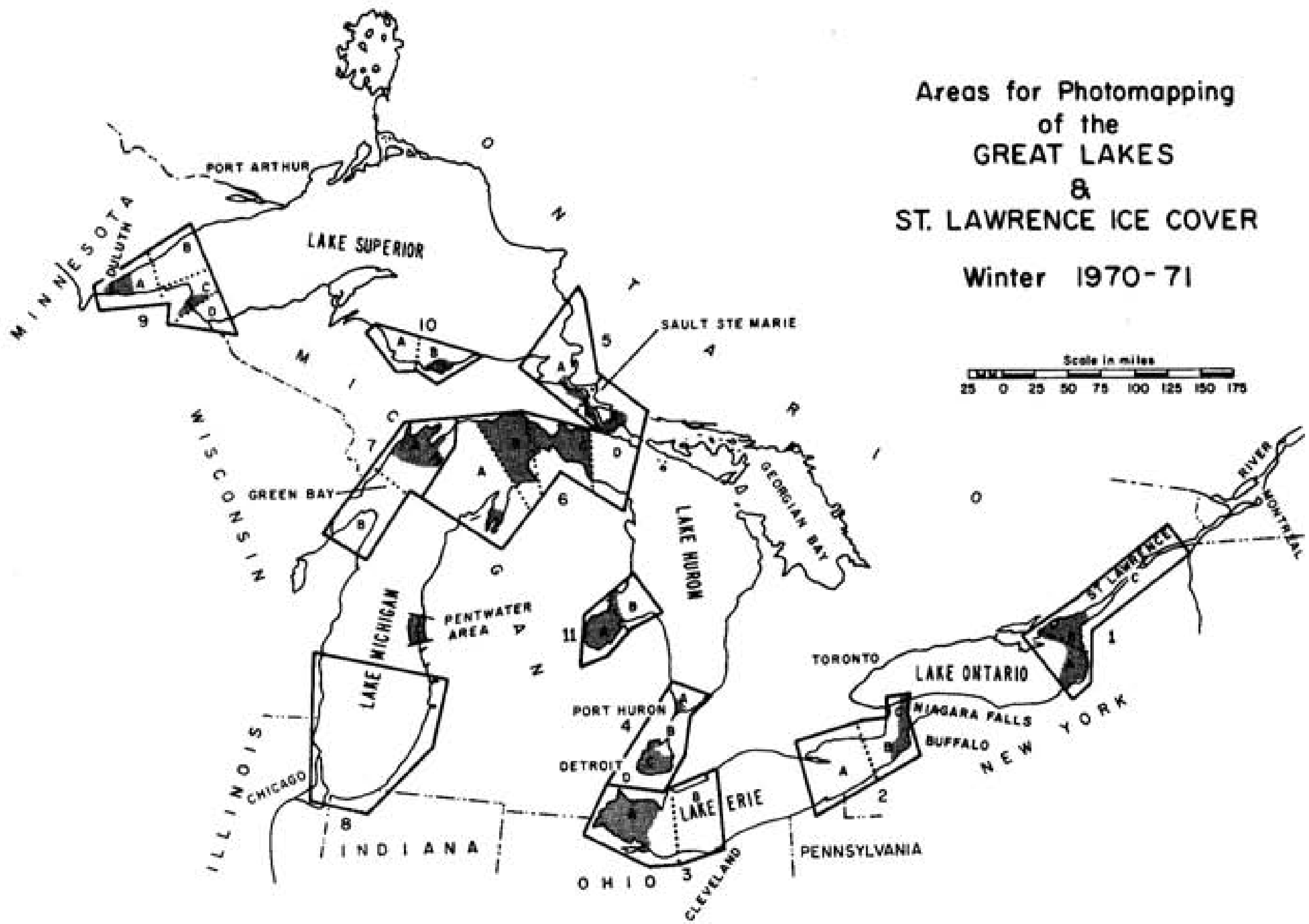

Figure 13. Area covered by Great Lakes aerial photography. Shaded areas indicate areas within which aerial photos were taken during the 1970/71 ice season.

CAN #79

FINAL FILM LOG

PROJECT NAME		PROJECT NUMBER	ROLL NUMBER
Great Lakes	Area 5B	AF66-79	19
FLYING ORGANIZATION		APPROXIMATE PHOTO SCALE	
AST #6, 1370th Photo-Mapping Wing		1:46,000	

CAMERA DATA

	1.	2.	3.
TYPE CAMERA & SERIAL NUMBER	KC-1(B) 62-058		
LENS SERIAL NUMBER	529/203		
CALIBRATED FOCAL LENGTH	151.948 mm.		
MAGAZINE SERIAL NUMBER	64-123		
MAGAZINE SERIAL NUMBER			

The following data will be based on the first and last exposure of each strip listed below and enclosed in this can of film.

STRIP NUMBER	MISSION NUMBER	EXPOSURE NUMBER	DATE FLOWN	APERTURE	SHUTTER SPEED	ALTITUDE ASL	TIME OF DAY (Z)	GEOGRAPHIC COORDINATES OR LOCATION NAME
FIRST 23	24	1037	21 Mar 66	f/8	1/150	23,000	1709	43°33'N 84°08'W
LAST		1039					1711	46°30'N 84°04'W
FIRST 22	24	1040	21 Mar 66	f/8	1/150	23,000	1720	46°33'N 84°16'W
LAST		1057					1728	46°08'N 83°29'W
FIRST 21	24	1058	21 Mar 66	f/8	1/150	23,000	1734	45°58'N 83°20'W
LAST		1083					1748	46°33'N 84°24'W
FIRST 20	24	1084	21 Mar 66	f/8	1/150	23,000	1750	46°32'N 84°28'W
LAST		1107					1800	45°56'N 83°26'W
FIRST 19	24	1108	21 Mar 66	f/8	1/150	23,000	1802	45°55'N 83°30'W
LAST		1126					1812	46°22'N 84°17'W
FIRST 18	24	1127	21 Mar 66	f/8	1/150	23,000	1817	46°17'N 84°17'W
LAST		1144					1824	45°52'N 83°30'W
FIRST 17	24	1145	21 Mar 66	f/8	1/150	23,000	1828	45°56'N 83°40'W
LAST		1159					1835	46°15'N 84°19'W
FIRST								
LAST								
FIRST								
LAST								

DD FORM 1 JAN 64 1516

Figure 14. Sample log for a roll of black and white photos taken on the St. Marys River south of Sault Ste. Marie, 21 March 1966.

NASA
CS-74733

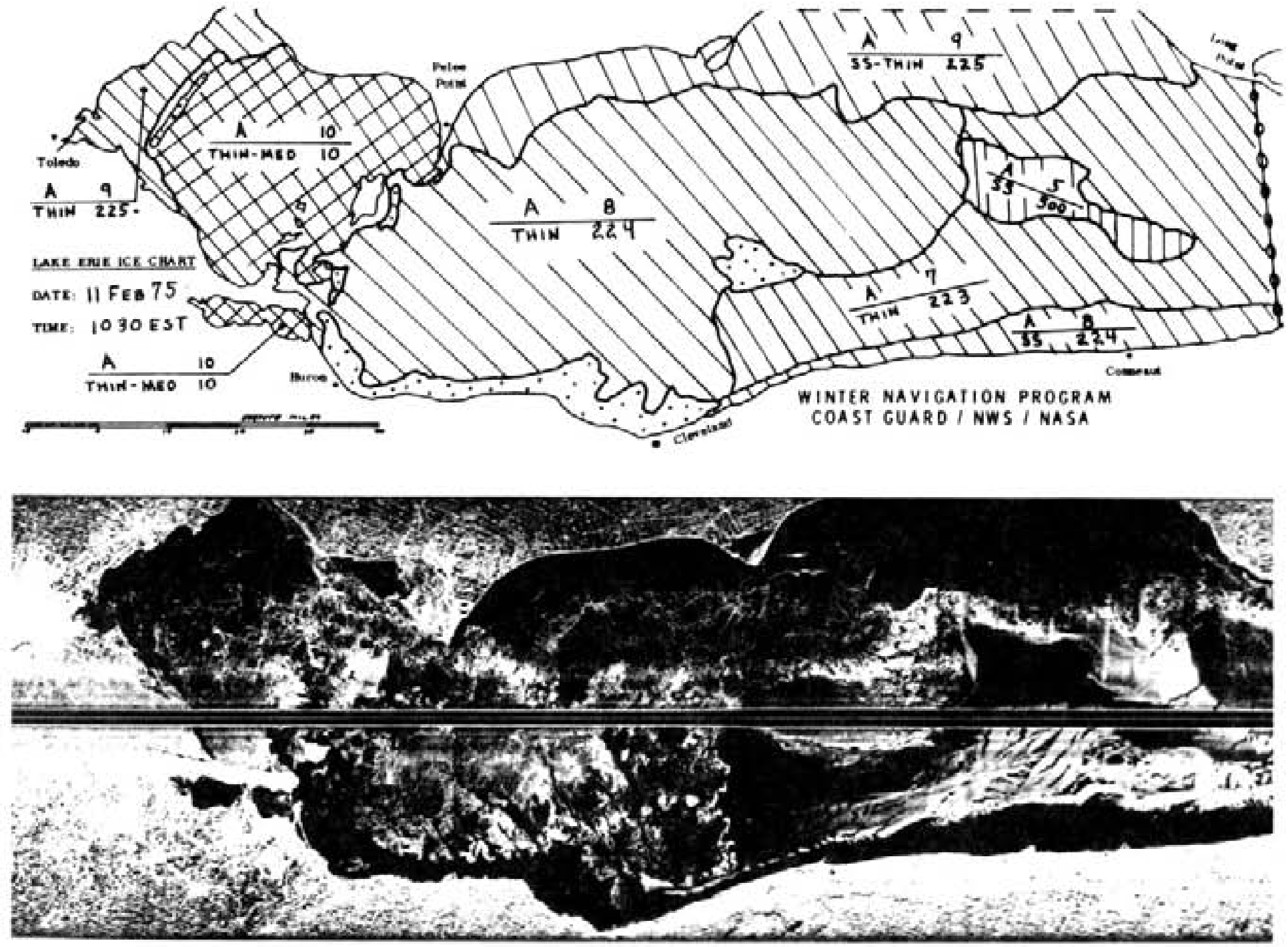

Figure 15. Specimen SLAR image of Lake Erie and the hand-drawn ice chart derived from the image.

Bibliography

Assel, R.A. (1980) Great Lakes degree-day and temperature summaries and norms, 1897-1977. U.S. National Oceanic and Atmospheric Administration. Data Report NOAA DR ERL GLERL-15, 113 p. NTIS: PB80-19577.

Bolsenga, S.J. (1978) Photosynthetically active radiation transmission through ice. U.S. National Oceanic and Atmospheric Administration. Technical Memorandum NOAA ERL GLERL-18, 57 p. NTIS: PB-288 463.

Gedney, R.T. (1975) Operational all-weather Great Lakes ice information system. U.S. National Aeronautics and Space Administraton. Technical Memorandum NASA TM-X-71812, 12 p. NTIS: N76-10605.

Jirberg, R.J.; Schertler, R.J.; Gedney, R.T.; Mark, H. (1973) Application of SLAR for monitoring Great Lakes total ice cover. U.S. National Aeronautics and Space Administration. Technical Memorandum NASA TM-X-71473, 11 p. NTIS: N74-10360.

Schertler, R.J.; Mueller, R.A.; Jirberg, R.J.; Cooper, D.W.; Heighway, J.E. (1975) Great Lakes all-weather ice information system. U.S. National Aeronautics and Space Administration. Technical Memorandum NASA TM-X-71815, 30 p. NTIS: N75-33481.

Schertler, R.J.; Chase, T.L.; Mueller, R.A.; Kramarchuk, I.; Jirberg, R.J. (1979) VHF downlink communication system for SLAR data. U.S. National Aeronautics and Space Administration. Technical Memorandum NASA TM-X-79164, 10 p. NTIS: N79-23313.

Sleator, F.E. (1978) Ice thickness and stratigraphy at nearshore locations on the Great Lakes (English units). U.S. National Oceanic and Atmospheric Administration. Data Report NOAA DR ERL GLERL-1-1, 442 p. NTIS PB-295 671.

Sleator, F.E. (1978) Ice thickness and stratigraphy at nearshore locations on the Great Lakes (Metric units). U.S. National Oceanic and Atmospheric Administration. Data Report NOAA ERL GLERL-1-2, 443 p. NTIS: PB-297 121.

Summary of Satellite Observations of Great Lakes Ice: 1974-1980

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INTRODUCTION

Great Lakes ice technical memoranda have been published by the National Oceanic and Atmospheric Administration (NOAA) since January 1975. The first two memoranda published by the NOAA/National Environmental Satellite Service (NESS) describe the ice formation, movement, and dissipation on Lake Erie based on satellite imagery during January - March 1975 (McMillan, 1976) and the winter 1975-76 (Wartha, 1977). In the memoranda, ice formation and melting are correlated with air temperatures while ice movement is related to wind speed and direction.

The next three reports include summaries of weather and ice conditions for all the Great Lakes during winter 1976-77 (Quinn, 1978), winter 1977-78 (Assel, 1979), and winter 1978-79 (DeWitt, in press). These are Great Lakes Environmental Research Laboratory (GLERL) Technical Memoranda (TM) with input from the National Weather Service (NWS) and NESS. Also in press is a separate NESS TM on Great Lakes ice (with no weather conditions other than local climatological data related to ice formation, movement, and disintegration) for winter 1978-79 (Wartha Clark, in press).

The 1979-80 Great Lakes ice season will again be reported on separately by NOAA/NESS and GLERL. In addition, a recent report, "Satellite studies of fresh-water ice movement on Lake Erie," by Donald R. Wiesnet (1979) discusses typical ice break-up patterns and an atypical one on Lake Erie from 1973-78.

REVIEWS OF THE TECHNICAL MEMORANDA

1. McMillan, M.C.; Forsyth, D.G. (1976). Satellite images of Lake Erie ice: January - March 1975. U.S. National Oceanic and Atmospheric Administration. Technical Memorandum NOAA TM NESS-80, 15 p.

The NOAA-4 polar orbiting environmental satellite provides daily images of the Great Lakes in the visible (0.6 to 0.7 μm) and thermal infrared (10.5 to 12.5 μm) spectral regions from a Very High Resolution Radiometer (VHRR) with a resolution of 1 km. The improved resolutions permit more detailed observations of lake ice than was previously possible.

The radiometer senses 256 different energy levels in both the visible and IR channels. These energy levels are converted to film density levels as shades of gray on a photographic negative. IR data, unlike visible data, have no natural relation to gray shades. By convention, high temperatures are assigned dark shades of gray while low temperatures are assigned light gray shades. Therefore, clouds, ice, and snow, which are normally the coldest objects in view, are displayed in light tones and the warmer lake waters, rivers, and land appear dark.

Air temperatures and wind speeds and directions at four major cities surrounding the lake are used to explain the ice formation and movement. Fifteen images are presented which show the variation and movement of ice fields from 21 January to 18 March, 1975. Lake Erie was selected for this study since, being shallower than the other Great Lakes, its waters cool down and heat up faster, resulting in dynamic freeze-up and melt.

2. Wartha, Jenifer H. (1977). Lake Erie ice: winter 1975-76. U.S. National Oceanic and Atmospheric Administration. Technical Memorandum NOAA TM 90, 68 p.

This is the second in a series of ice reports on Lake Erie. The previous year's ice report included data from only one source, the VHRR on board NOAA's polar orbiting satellite, NOAA-4. This report includes satellite data from: the NOAA-4 VHRR, NOAA's Geostationary Operational Environmental Satellite (GOES) and the National Aeronautics and Space Administration's (NASA) Landsat, Canadian aerial ice reconnaissance, and aircraft Side Looking Airborne Radiometer (SLAR) systems. These data were used to trace the development, movement, and dissipation of Lake Erie ice from 28 December 1975 to 19 April 1976 at intervals of approximately three days.

The NOAA GOES satellite orbital motion matches that of the Earth, therefore, the two GOES satellites appear stationary over fixed points above the equator. The visible band sensors of the Visible and Spin Scan Radiometer (VISSR) aboard the GOES respond to energy in the 0.55 to 0.75 μm range. Most of the illustrations in this report are 1 km resolution GOES visible range images. GOES IR images are not used because the resolution, 8 km, is too poor for effective ice reconnaissance.

Images were obtained from NASA's Landsat at 80 m ground resolution. The imagery can be obtained in four different spectral bands: band 4 (0.5 to 0.6 μm), band 5 (0.6 to 0.7 μm), band 6 (0.7 to 0.8 μm), and band 7 (0.8 to 1.1 μm). Only band 5 Landsat images are used in this report. Imagery is available only once every 18 days (9 days when both Landsat 1 and 2 are operating).

SLAR can penetrate most clouds. The imagery from SLAR can be used to determine roughness or topography of the ice surface and to estimate ice thickness. SLAR vertical range resolution is 80 m; azimuth resolution varies from 45 m at 5 km range to 450 m at 50 km range.

Canadian flights over the Great Lakes carry an Airborne Radiation Thermometer (ART) to determine surface water temperatures. Visual observations provide ice thickness, concentration, and extent.

On 28 December 1975, ice began forming in the western basin of Lake Erie and in the southern half of Lake St. Clair due to low air temperatures (-2° to -9° C). Figure 1 is a GOES satellite image observed on 8 January 1976. Ice, labeled A in the figure, covers the entire western basin except for leads that parallel the western and northern shores. The ice formed in response to persistent below freezing air temperatures starting in late December. The predominant 9-knot westerly and northwesterly winds reported at the land stations blew the ice offshore.

Figure 2, the Landsat image acquired on 8 January, agrees well with the GOES image of figure 1, except the detail is far superior because of the better resolution of Landsat (80 m versus 1000 m). Very thin, newly formed ice extending almost to shore west of Point Pelee, Ontario, and thin fast ice along the shore just east of Point Pelee can be seen here, but is not visible in the GOES image. An interpretation of this image is that ice formed, was blown offshore by the northwesterly and westerly winds, and new ice formed between the older offshore ice and the shore. Later, this new ice formation broke away from shore and cracks that occurred in the ice structure extended from the older ice and continued into the newly formed ice.

Separated by a small lead are two major ice areas west of Point Pelee: A larger one (labeled 1) compacted against the south shore of the west end of Lake Erie and a smaller area (labeled 2) east of the larger one. The islands running longitudinally from Point Pelee to Sandusky, Ohio, tend to confine the ice.

By 17 January low temperatures (-14° to -10° C) caused new ice (figure 3) labeled F to form across the width of the lake west of Erie, Pa. Winds from the north at 9 knots created a lead along the north shore.

The Landsat image (figure 4) taken also on 17 January agrees well with the previous NOAA-4 image (figure 3) except that the Landsat image is more detailed. The Detroit River remains ice free. The two previously separated ice areas labeled 1 and 2 of figures 1 and 2 have united, probably because westerly winds compressed the ice against the island barrier.

Nine days later on 26 January, ice (figure 5) covers a least 75 percent of the lake as revealed on SLAR imagery. Southerly winds probably produced the wide lead parallel to the south shore. By 2 February, Lake Erie was approximately 100 percent ice-covered. A lead then formed east of the island barrier between the two ice areas in Lake Erie, probably in response to persistent westerly winds. This lead widened throughout the month of February. By early March, most of the ice had melted except an ice plug which formed in the eastern end of the lake near Buffalo, New York.

Figure 6 is a Landsat image of the western end of Lake Erie. Extensive mixing of sediment has occurred. The high concentration of sediment in southeastern Lake St. Clair can be seen draining through the Detroit River into the south shore of the western end of Lake Erie.

The entire lake was finally ice-free on 19 April. This late date for clearing was caused more by wind concentrating the ice eastward than by unusually cold weather.

3. Summary of Great Lakes Weather and Ice Conditions, Winter 1976-77; Winter 1977-78, Winter 1978-79.

These three publications generally have the same format. They present summaries of meteorological conditions such as synoptic studies of the winter, freezing degree days, and comparisons with previous winters; summaries of ice conditions such as ice formation and breakup, and ice cycle on each individual lake; descriptions of satellite imagery; and effects on Great Lakes commerce.

A brief abstract of each publication is presented below.

a. Quinn, F.H., et al. (1978). Summary of Great Lakes weather and ice conditions, winter 1976-77. U.S. National Oceanic and Atmospheric Administration. Technical Memorandum NOAA TM ERL-GLERL-20, 155 p.

The winter of 1976-77 was the fifth coldest during the past 200 years. Record-breaking low temperatures occurred from mid-October to mid-February. These low temperatures were associated with an upper air pressure pattern consisting of a strong ridge in the westerly flow over North America and resulted in extraordinary ice cover on the Great Lakes. The progression of early winter, mid-winter, and maximum ice extent was from 4 to 5 weeks earlier than normal. Maximum ice extent occurred in early February, with Lake Superior 83 percent ice-covered, Lake Michigan over 90 percent, Lake Huron 89 percent, Lake Erie 100 percent, and Lake Ontario approximately 38 percent. Spring breakup began in late February in the southern part of the Great Lakes and in early March in the northern part. Most of the ice cover was gone by the last week in April. Shipping was severely hampered by the abnormally large amount and the duration of ice extent.

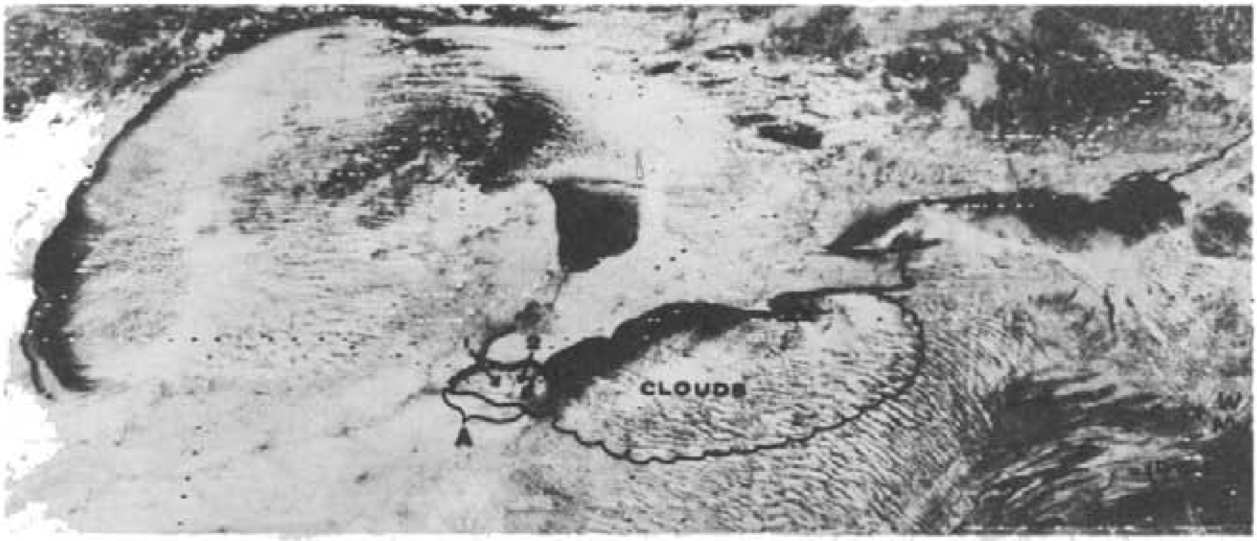

Figure 1. GOES satellite image of Lake Erie, 8 January 1976.

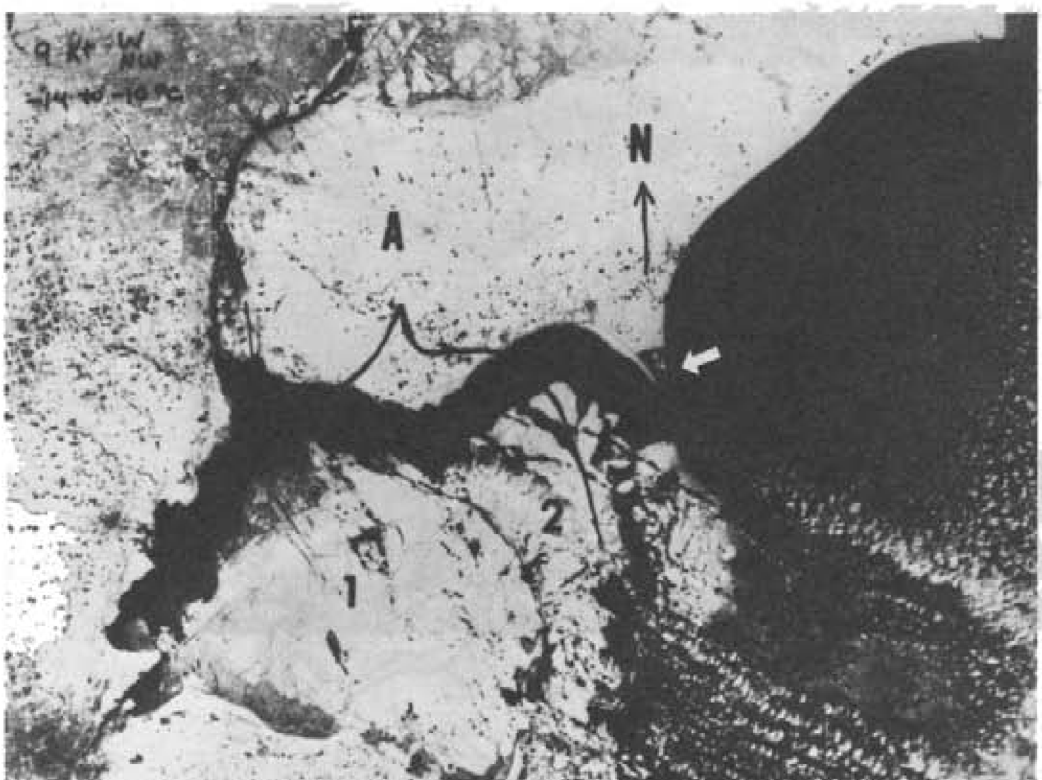

Figure 2. Landsat image of western Lake Erie, 8 January 1976. Point Pelee is indicated by the small arrow. The numbers are referred to in the text. The "A" is a part of the NESS analysis.

Figure 3. NOAA-4, VHRR image of Lake Erie, 17 January 1976.

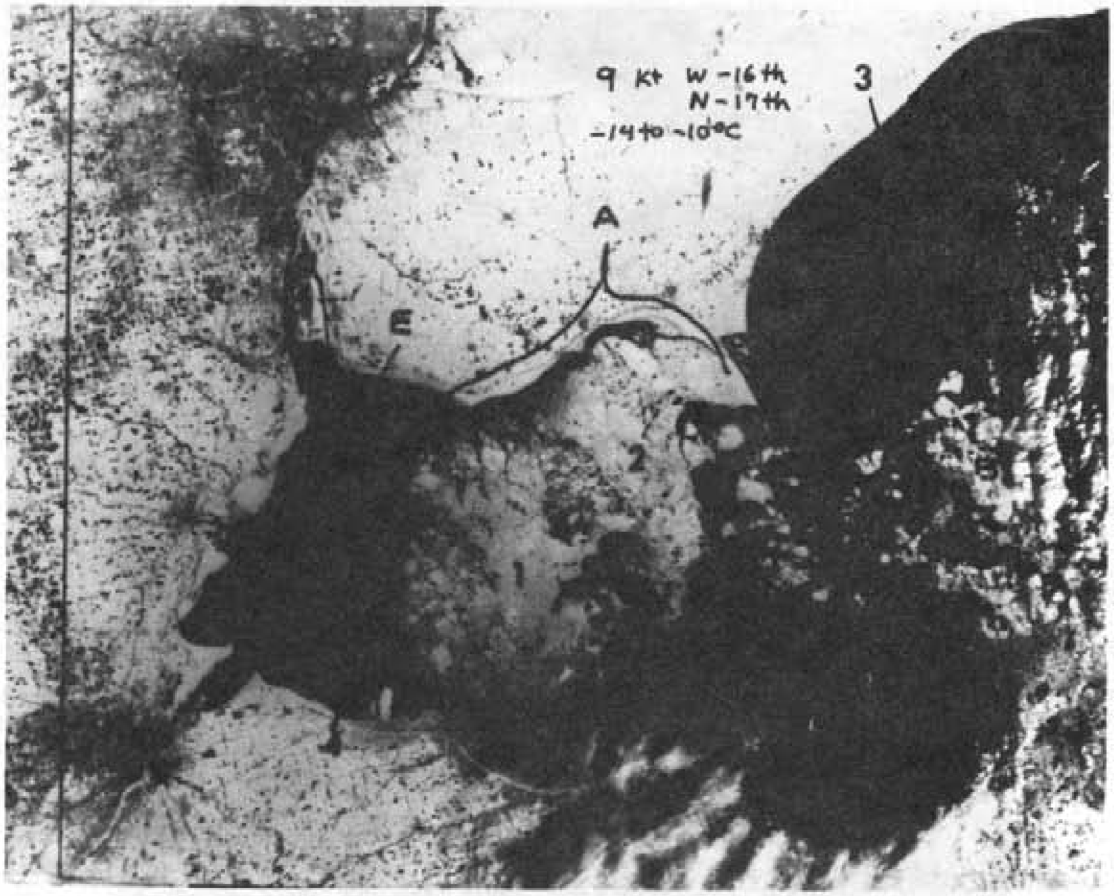

Figure 4. Landsat image of western Lake Erie, 17 January 1976.

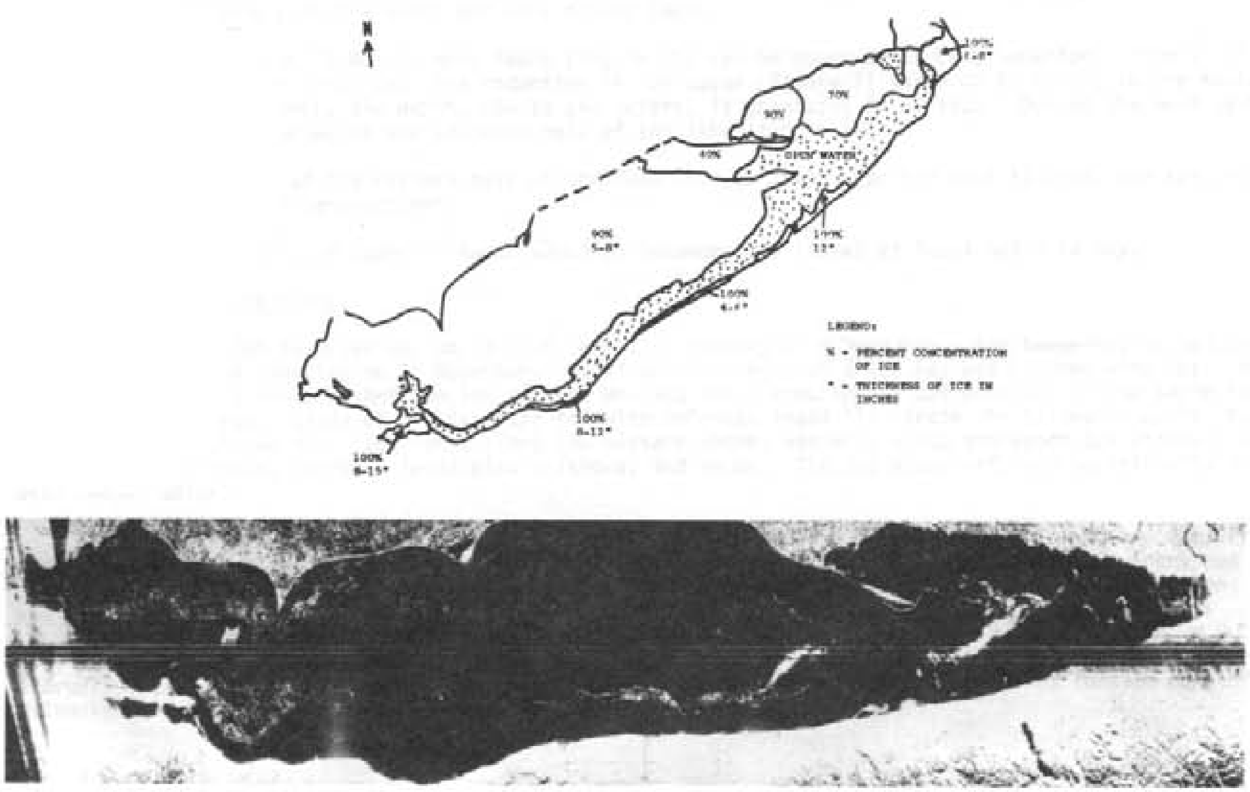

Figure 5. Interpretation and SLAR image of Lake Erie taken on 26 January 1976.

Figure 6. Landsat image of western Lake Erie, 11 March 1976.

b. Assel, R.A., et al. (1979). Summary of Great Lakes weather and ice conditions, winter 1977-78. U.S. National Oceanic and Atmospheric Administration. Technical Memorandum NOAA TM ERL GLERL-26, 123 p.

The winter of 1977-78 was among the coldest in the last century. The northwesterly flow aloft directed anticyclonic centers to the south and west of the Great Lakes region, resulting in the greatest negative air temperature departure from normal ever recorded on the southern Great Lakes. Ice started forming in the shallow areas of the Great Lakes in late November. Maximum ice extent occurred from mid-February to early March; Lake Superior was 82 percent ice covered, Lake Michigan 52 percent, Lake Huron 89 percent, Lake Erie 100 percent, and Lake Ontario 57 percent. Spring breakup started in mid-March. Most of the ice disappeared by April 26; however, ice was observed in eastern Lake Erie as late as 11 May.

c. DeWitt, B.H., et al. (In press). Summary of Great Lakes weather and ice conditions, winter 1978-79. U.S. National Oceanic and Atmospheric Administration. Technical Memorandum NOAA TM ERL GLERL-

The winter of 1978-79 was again extremely cold. It was also the third consecutive severe winter over the Great Lakes region. A persistent northerly and northwesterly flow pattern of the upper air pressure dominated the Great Lakes during January and February 1979. Consequently, record low and near-record low temperatures were recorded over the lakes during this time. On 17 February, all of the Great Lakes were nearly 100 percent ice covered, which is quite unusual. Ice began melting during March. By the end of April the lakes were mostly ice free except for Lake Superior, where significant ice cover continued into May.

4. Wartha Clark, J. (In press). Satellite Observations of Great Lakes Ice: winter 1978-79. U.S. National Oceanic and Atmospheric Administration. Technical Memorandum NESS TM.

Ice conditions on the five Great Lakes and Lake St. Clair were monitored from satellite imagery from December 1978 through May 1979. The formation, movement, and dissipation of ice on each lake was traced. Wind speeds and directions were correlated with ice movement, and air temperatures were related to ice formation and decay. The local daily mean weather conditions for stations surrounding the lakes were used.

Half of the data was gathered by the NOAA polar-orbiting satellite, TIROS-N. The primary sensor on board is the Advanced Very High Resolution Radiometer (AVHRR) with 1.1 km resolution at nadir. The other half of the data was provided by the GOES satellite.

a. Lake Superior Ice Cover

From 19 November to 16 March, temperatures over Lake Superior were mostly below freezing. Owing to cloudiness, ice was not detected until 28 December when it was observed in Nipigon, Black, and Thunder Bays. Figure 7 is a GOES VISSR (visible) image taken on 18 January. Whitefish Bay is 100 percent ice covered with newer ice of 85 percent concentration adjacent to Coppermine Point. Ice can also be detected from Duluth to the Apostle Islands, along shore to Ashland, and eastward along shore to the Keweenaw Peninsula. By 11 February, ice (figure 8) had covered Beaver and Chequamegon Bays. Six days later on 17 February, the extent of ice on Lake Superior reached seasonal peak. Figure 9 shows that ice cover on the lake is nearly 100 percent with the exception of some possible leads and some frozen leads.

One month later, on 16 March, many leads (figure 10) can be observed in Lake Superior. From 17-27 March, temperatures rose above freezing. The reduction in ice cover (figure 11 taken on 27 March) in the eastern one-third of the lake where the depth, 180 to 240 meters, is greatest, is obvious. During the next week only minimal change was detected in the southern half of the lake (figure 12).

By 30 April, most of the eastern half of the lake was ice free. For the next 12 days, the ice melted rapidly because of high temperatures.

The ice season on Lake Superior began about 28 December and lasted at least until 12 May.

b. Lake Michigan Ice Cover

Ice was detected in Green Bay on TIROS-N satellite imagery of 9 December. Air temperatures had generally been below freezing starting on 20 November. By 27 December most of Green Bay was covered with ice. On 5 and 8 January, westerly winds pushed the ice off the western shore creating a lead parallel to the shore from Milwaukee to Chicago. Bands of ice interspersed with refrozen leads illustrate the following cycle characteristic of Lake Michigan ice. Ice forms along the western shore, westerly winds transport ice offshore creating leads, leads refreeze, refrozen leads blow offshore, and so on. The ice blown offshore occasionally dissipates over deeper water.

Fast ice (figure 7) can be discerned in Green Bay on 18 January, between Beaver Island and the Straits of Mackinac and along the lower eastern boundary. By 10 February ice widened on the eastern boundary and covered Grand Traverse Bay. On 11 February, 8-knot winds, generally from the east, caused leads to form along the eastern shore (figure 8).

Maximum ice extent (figure 9) was observed on Lake Michigan as well as on the other Great Lakes on 17 February. The only area of questionable ice cover was in the central part of the lake, located east of Milwaukee and extending southward for 111 km.

Figure 7. GOES visible image of the Great Lakes, 18 January 1979.

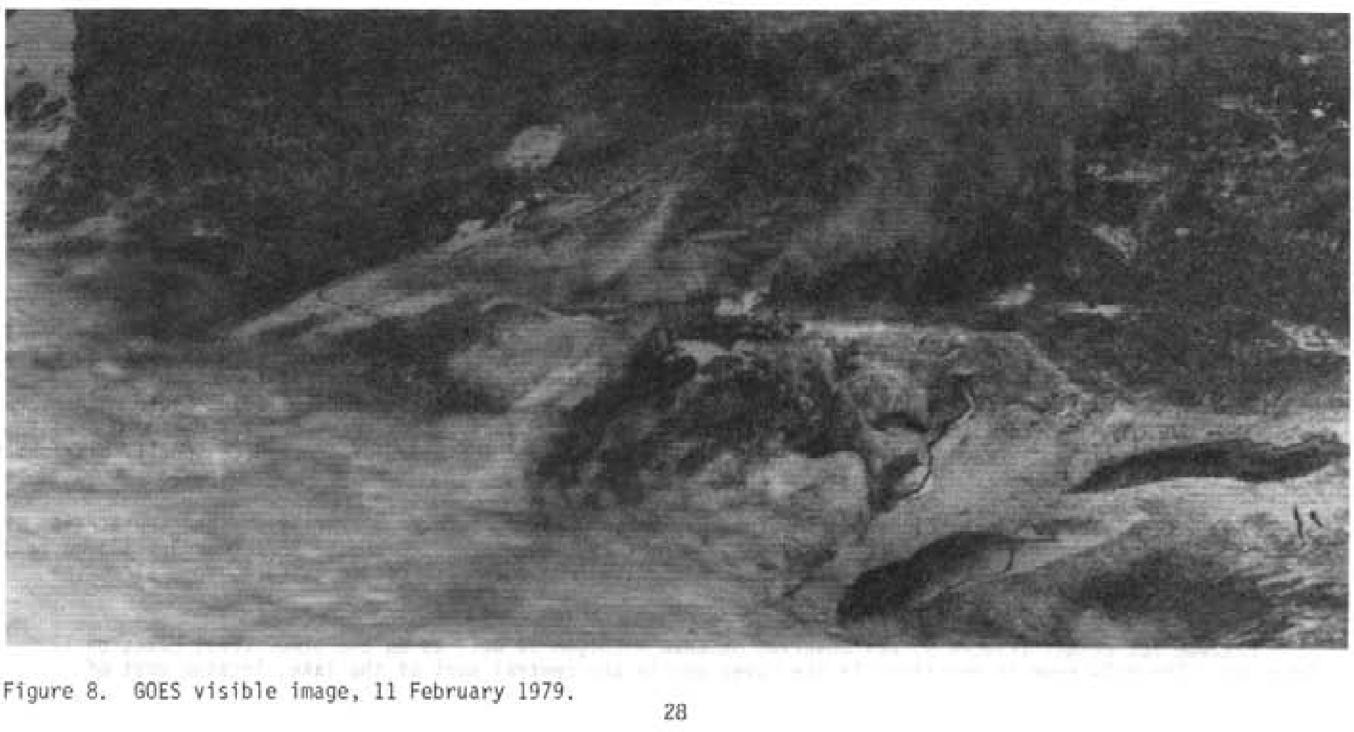

Figure 8. GOES visible image, 11 February 1979.

Figure 9. TIROS-N visible image, 17 February 1979.

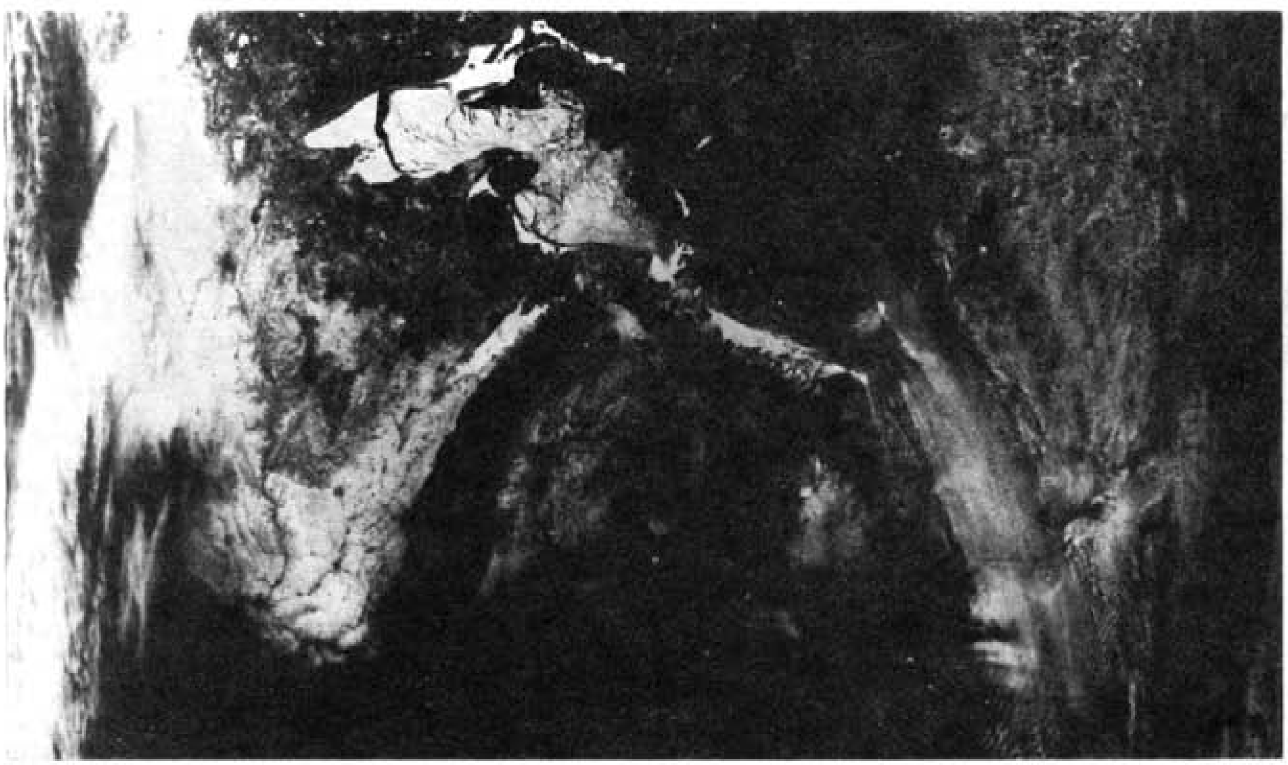

Figure 10. TIROS-N visible image, 16 March 1979.

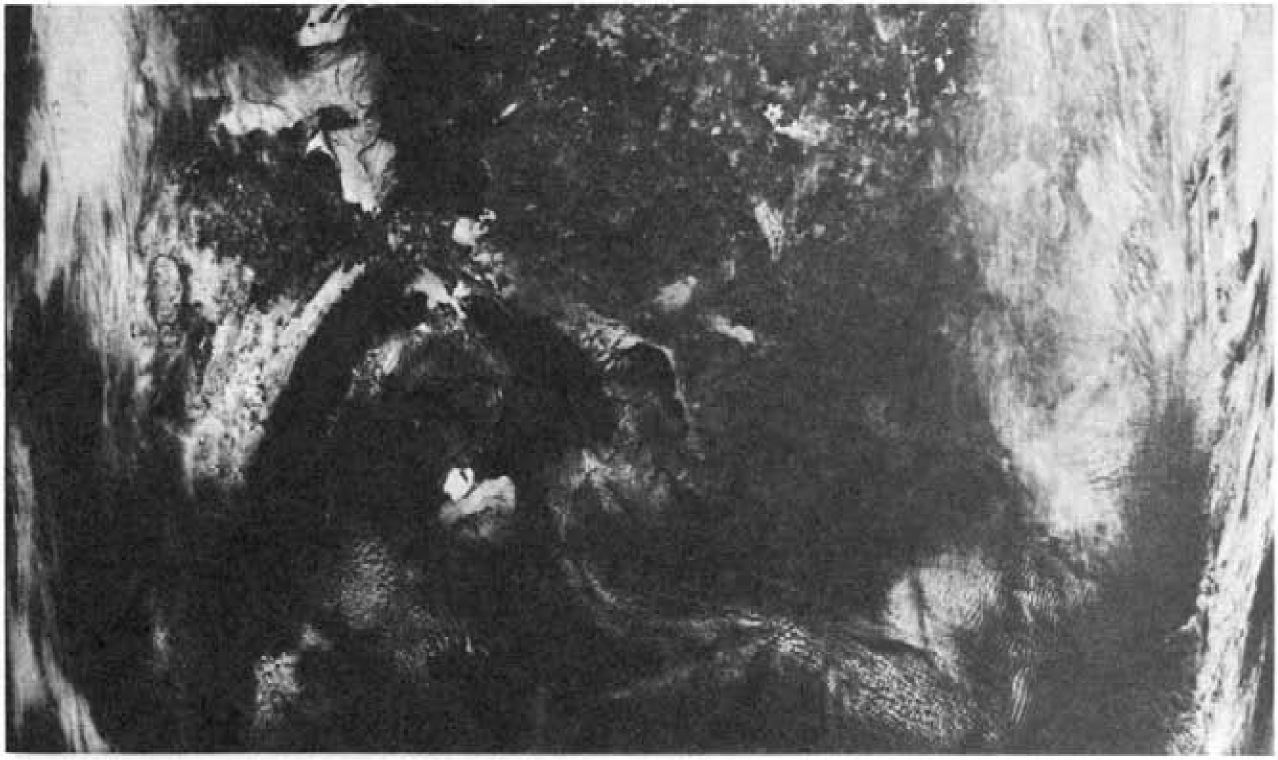

Figure 11. TIROS-N visible image, 27 March 1979.

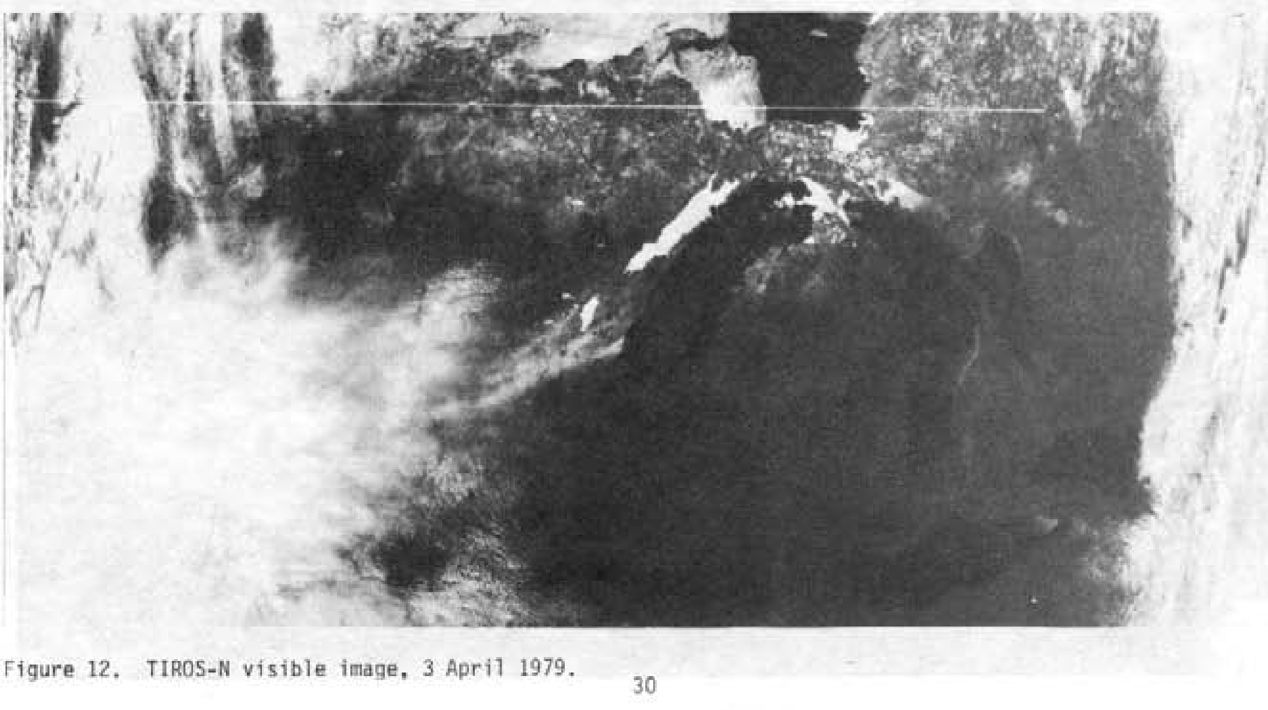

Figure 12. TIROS-N visible image, 3 April 1979.

Air temperature rose above freezing beginning 1 March. By 16 March most of the ice (figure 10) in the lower half of Lake Michigan had melted but fast ice remained in Green Bay. Westerly winds had compressed the ice eastward in the upper half of the lake. One week later on 27 March, much of this compressed ice (figure 11) had dissipated. The most prominent change from 27 March to 3 April was the melt (figure 12) between Beaver Island and the Straits of Mackinac. Ice in the entrance to Green Bay had also begun thawing. By 18 April, Grand Traverse Bay was ice free and only thin ice remained between Beaver Island and the Straits of Mackinac. The lake was nearly ice free except for small areas in Green Bay on 27 April.

c. Lake Huron Ice Cover

Scattered ice in the North Channel of Lake Huron was first observed on 10 December. Temperatures in the area had dropped below freezing beginning on 19 November. Saginaw Bay and North Channel (figure 7) were covered with fast ice as observed on 18 January. Fast ice was also seen clinging to the eastern shore of Georgian Bay. The northern half of Georgian Bay was covered with thick, broken floes of 90 to 100 percent concentration. Ice south of Manitoulin Island was also discernible.

Two weeks later on 2 February, Saginaw Bay and Georgian Bay were 90 percent ice covered. Influenced by 3- to 7-knot winds, leads developed (figure 8) along the eastern-shore fast ice near Goderich on 11 February.

Lake Huron ice cover peaked at 95 percent concentration on 17 February (figure 9). Two refrozen leads parallel to the eastern shore probably formed in response to 3- to 11-knot easterly winds during the period 13-15 February. Fast ice encircled the entire lake and completely covered the North Channel, Straits of Mackinac, and the lower half of Saginaw Bay.

By 27 February, ice (figure 13) was blown from the western side of Saugeen Peninsula and south of Manitoulin Island resulting in a 75 km-wide lead. Ice in Green Bay was less concentrated than it had been on 17 February.

Westerly winds moved the ice (figure 10) eastward from the western side of the lake and in Green Bay creating wide leads from the Straits of Mackinac to Saginaw Bay, and along western Green Bay.

By 27 March, ice (figure 11) had decreased in the northern part of Green Bay and the previous lead along the west coast of Green Bay had disappeared. Some ice melting had taken place in response to above freezing temperatures. Ice in the North Channel was still 100 percent concentrated but thinning.

Ice in Saginaw Bay (figure 12) had decreased rapidly by 3 April and ice in Green Bay was much thinner than previously observed on 27 March. By 18 April, most of the lake was ice free except the North Channel, which finally thawed 28 April.

d. Lake St. Clair Ice Cover

Ice was detected on 15 December in the northeastern basin of Lake St. Clair. By 11 January, Lake St. Clair was 100 percent ice covered. The Detroit River (figure 7) is discernible and probably ice free. This river, connecting Lake St. Clair and Lake Erie, has fast currents which hinder the growth of ice.

Lake St. Clair remained 100 percent ice covered until 11 March, a period of almost 2 months; melt than began at the mouth of the Detroit River (figure 10). Rapid lake-wide melting occurred during a mid-March warming trend until on 27 March, less than 30 percent ice coverage remained (figure 11). By 3 April, only turbid sediments (figure 12) could be seen in the ice-free lake.

e. Lake Erie Ice Cover

Satellite imagery of 15 December showed thin ice in the shallow western basin of Lake Erie. By 11 January ice in the basin west of Pelee and Kelleys Islands and in the eastern basin adjacent to Buffalo had become 100 percent concentrated.

Pelee and Kelleys Islands form a barrier to eastward ice movement. In response to westerly winds, ice is typically separated into two areas divided by a lead at the island obstruction. In figure 7 acquired on 18 January, the wind impact was noticeable. Westerly and southwesterly winds at 4 to 13 knots had moved the two ice areas eastward, creating leads near Toledo, east of the island barrier, and along the north shore from Point Pelee to an area east of Long Point.

On 11 February, three long leads (figure 8) could be seen between Cleveland and Erie extending to the north shore. The entire lake was 90 to 100 percent ice covered on 17 February (figure 9).

From 21 to 24 February, temperatures ranged from -1° to 8° C, causing thin but concentrated ice (figure 13) to melt from Point Pelee to Long Point. Northeasterly winds at 14 to 19 knots moved this thin ice westward so that wide leads appeared from Point Pelee to Long Point.

On 16 March the wind direction and intensity again influenced the ice movement. Westerly winds pushed the ice (figure 10) eastward creating wide leads from Toledo to the Detroit River, as well as east of the Pelee-Kelleys island obstruction, and east of Long Point.

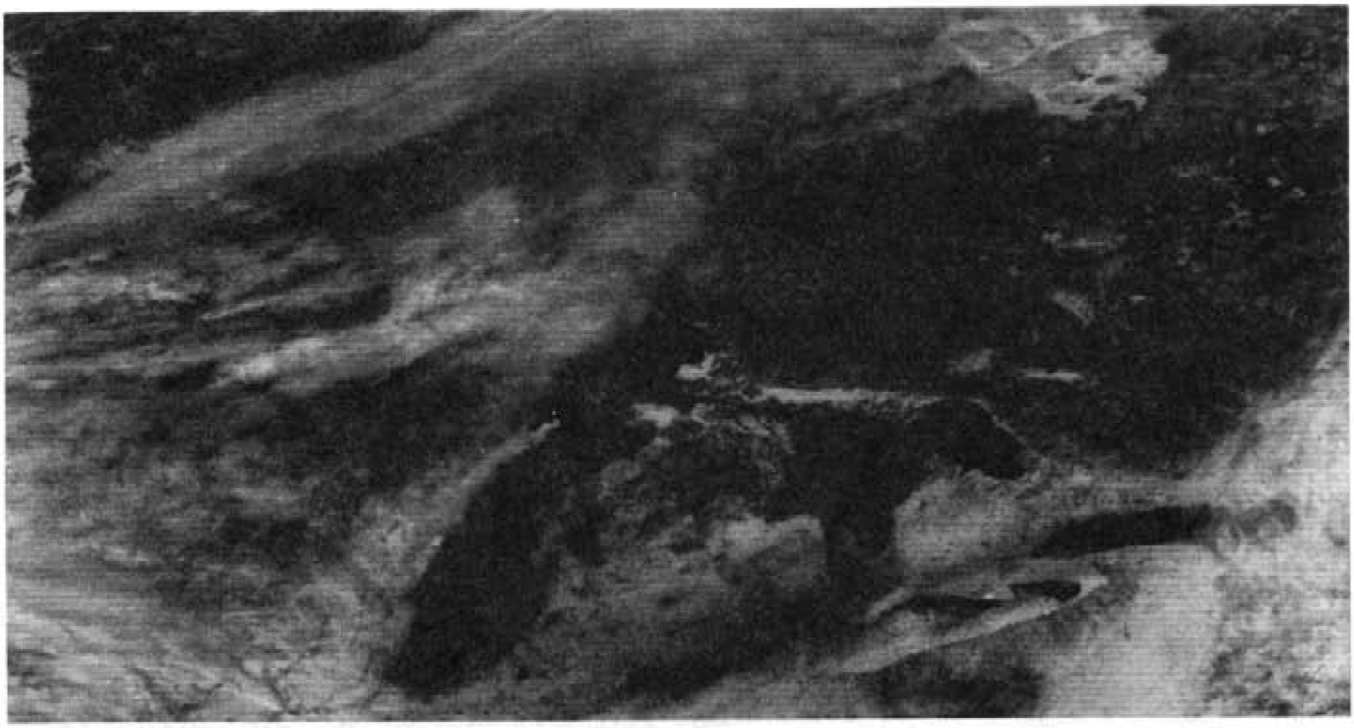
Figure 13. GOES visible image, 27 February 1979.


Figure 14. TIROS-N visible image, 20 February 1979.

Above-freezing temperatures in late March contributed to the ice dissipation. On 27 March the lake was observed as ice free (figure 11) except along shore from Cleveland to Buffalo.

One week later on 3 April, only the ice plug (figure 12) at Buffalo remained. The ice plug finally disappeared on 29 April and sediment could be seen in both Lake St. Clair and Lake Erie.

f. Lake Ontario Ice Cover

In spite of generally below freezing air temperatures, Lake Ontario remained ice free until 9 January. By 18 January, ice east of Prince Edward Peninsula (figure 7) had become 100 percent concentrated. Thin 90 percent concentrated ice also developed south and west of Prince Edward Peninsula.

Clouds covered Lake Ontario from 22 through 30 January and did not totally move off until 3 February. By 11 February, ice (figure 8) extended from Prince Edward Peninsula westward to near Toronto and southward to Rochester.

The satellite image acquired on 17 February (figure 9) depicted unusually heavy ice cover on all the lakes. Lake Ontario was approximately 80 percent ice covered; normal maximum ice cover for this lake is only 25 to 35 percent.

Three days later on 20 February, southerly and easterly winds compressed the ice (figure 14) northward generating a wide lead from Niagara Falls east to Oswego. Note also the unusual occurrence of widespread ice in Chesapeake Bay, along the New Jersey coast, around Long Island, and in Cape Cod Bay.

By 27 February, ice (figure 13) had dissipated in response to higher air temperatures (1° to 4° C). The ice then melted rapidly except east of Prince Edward Peninsula where it remained until 20 March owing to westerly winds concentrating the ice against the shore. Lake Ontario was entirely ice free on 27 March (figure 11).

The NOAA/NESS and GLERL TM's discussed above are available through National Technical Information Service (NTIS), U.S. Department of Commerce, 5285 Port Royal Road, Springfield, Virginia 22161.

References

Assel, R.A.; Boyce, D.E.; DeWitt, B.H.; Wartha, J.; Keyes, F.H. (1979). Summary of Great Lakes weather and ice conditions, winter 1977-78. U.S. National Oceanic and Atmospheric Administration. Technical Memorandum NOAA TM ERL GLERL-26, 123 p. NTIS: PB80-179 203.

DeWitt, B.H. et al. (In press). Summary of Great Lakes weather and ice conditions, winter 1978-79. U.S. National Oceanic and Atmospheric Administration. Technical Memorandum NOAA TM ERL GLERL

McMillan, M.C.; Forsyth, D.G. (1976). Satellite images of Lake Erie ice: January-March 1975. U.S. National Oceanic and Atmospheric Administration. Technical Memorandum NOAA TM NESS 80, 15 p.

Quinn, F.H. et al. (1978). Summary of Great Lakes weather and ice conditions, winter 1976-77. U.S. National Oceanic and Atmospheric Administration. Technical Memorandum NOAA TM ERL GLERL-20, 155 p. NTIS: PB-292 613.

Wartha, J.H. (1977). Lake Erie ice: winter 1975-76. U.S. National Oceanic and Atmospheric Administration. Technical Memorandum NOAA TM 90, 68 p. NTIS: PB-276 386.

Wartha Clark, J.H. (In press). Satellite observations of Great Lakes ice: winter 1978-79. U.S. National Oceanic and Atmospheric Administration. Technical Memorandum NOAA TM

Wiesnet, D.R. (1979). Satellite studies of fresh water ice movement on Lake Erie. Journal of Glaciology, v. 24 (90), p. 415-426.

Ice Information and Ice Control Programs of the Saint Lawrence Seaway Development Corporation

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The St. Lawrence Seaway Development Corporation has been actively participating in research and development activities in the fields of ice information and ice control techniques.

I. Ice Information Program

The principal objectives of the ice information program are to document the specific types and amounts of ice and related environmental data on the International Section of the St. Lawrence River in support of both operational and planning requirements. Figure 1 shows the extent of the Seaway. The major activities comprise:

A. Vertical Aerial Photography

Since December 1972, the Corporation has documented the ice cover on the river between Cape Vincent, New York, and Montreal, Quebec, each winter. Flight frequency is approximately one per week with additional flights near and during the freeze-up and break-up periods. The photographic flights are normally supplemented by aerial visual reconnaissance and oblique photography when weather precludes vertical photography or when local conditions require real-time information. The scale of the aerial photos varies according to the flight altitude; however, it is normally set at 1"=2000'. Aerial photos and indexes of ice cover since December 1972 could be made available through the contractor at the cost of reproduction. Figure 2 is an example of the index.

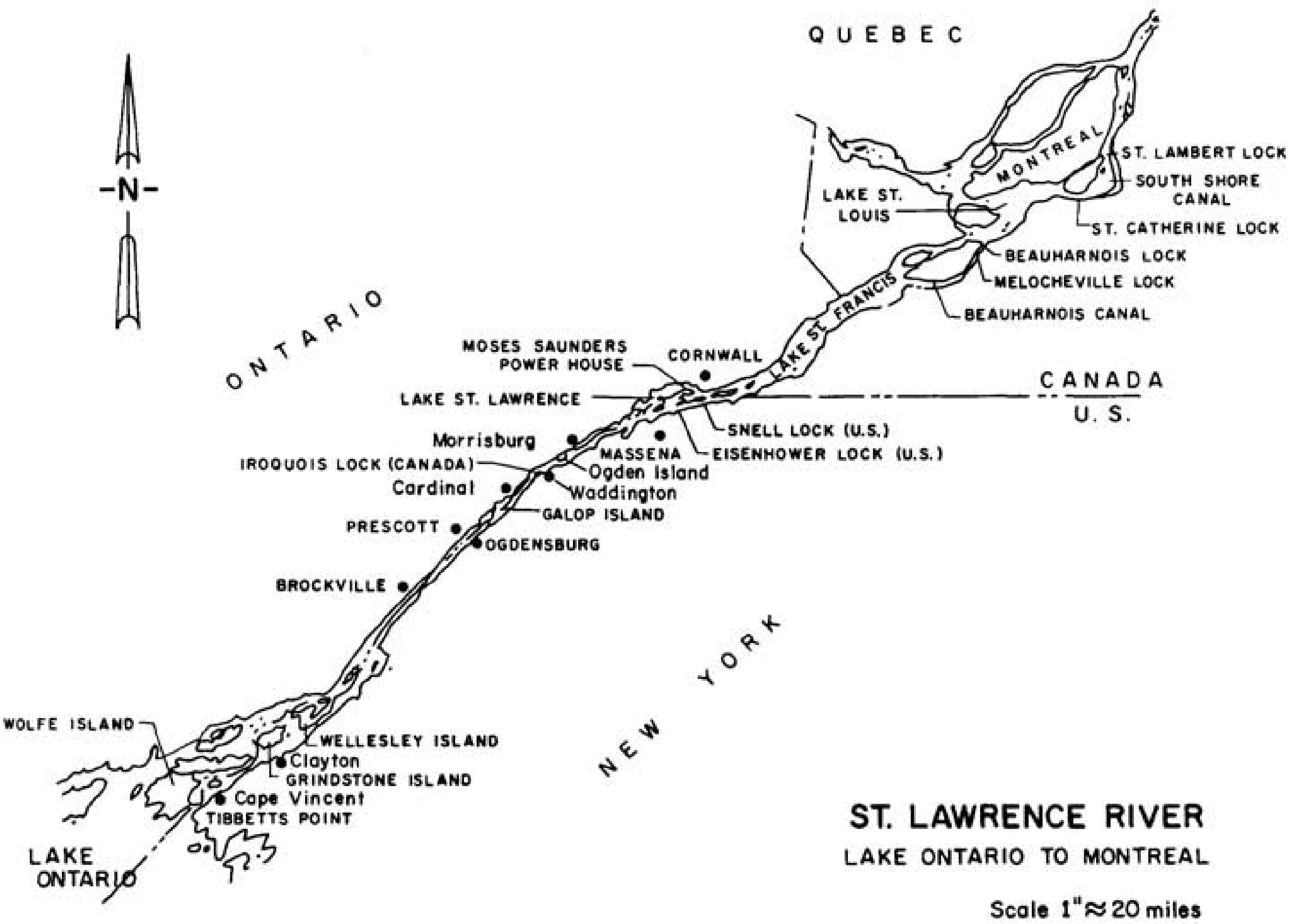

Figure 1. The Saint Lawrence Seaway.

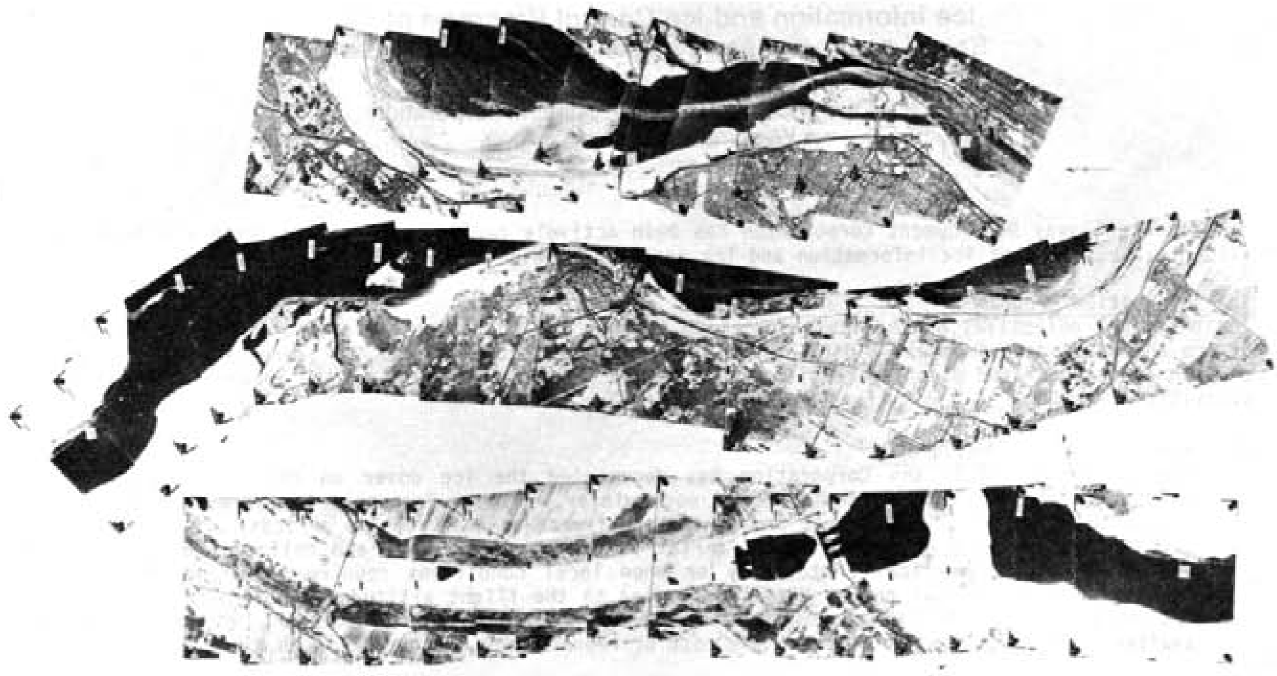

Figure 2. Sample of the index to aerial photography of ice conditions on the Saint Lawrence River.

B. Time Lapse Photography
A time lapse camera has been installed near Ogdensburg, New York to document ice formation and movement in the vicinity of the Ogdensburg-Prescott ice boom.

C. Remote Sensing of Ice Thickness and Hanging Dams
Since 1975, the Corporation has conducted an ice survey and hanging dam study in the reach between Cardinal and Morrisburg, Ontario. The survey has been conducted by helicopter using an electromagnetic radar system normally pulsed at a rate of 50 kHz with a pulse width of three nanoseconds. The remote profiling data is recorded on magnetic tape during flight and later processed through a slower-speed graphic recorder.

In addition to basic data collection, the study is also assessing the feasibility of the operational use of radar remote sensing of the ice thickness, particularly the identification of major hanging dams. A mathematical model of hanging dam formation is also being developed.

D. Water Temperature Measurements
The Corporation, in conjunction with NOAA's Great Lakes Environmental Research Laboratory (GLERL), has installed recording telemetering water temperature gages at Cape Vincent, Clayton, and Waddington, New York. These gages are interrogated daily to provide real-time information during freeze-up and break-up for operational activities, as well as to aid in the prediction of actual freeze-up and break-up dates. Additionally, they provide an historical data base on which ice forecast procedures can be developed.

E. Weather Data Monitoring
A Towner Weather Station located at Ogdensburg, New York, has been maintained by the Corporation to provide an historical microclimate data base, namely, air temperature, wind speed and direction, dew point, barometric pressure, and solar radiation. A second station is being installed at Clayton, New York.

II. Ice Control Program
The objective of this activity is to identify and subsequently demonstrate alternative methods for permitting navigation into and through the winter season while still maintaining or improving the stability of the ice cover and hydraulic integrity of the river. Four major projects have been completed under this program. They are: the installation and testing of the Ogdensburg-Prescott Ice Boom Gate in 1974, the Copeland Cut Ice Boom Testing in the winter of 1974-75, the Copeland Cut Hydraulic/Ice Model Study during 1976 and the St. Lawrence River Ice Boom Modification Study in 1977 through 1980. Work in the Ogden Island area is scheduled to begin in 1980.

III. Publications

The following publications, available from NTIS, 5285 Port Royal Road, Springfield, VA 22161, are examples of the research that the Saint Lawrence Seaway Development Corporation sponsors.

ARCTEC, Inc. (1975) Saint Lawrence Seaway system plan for all-year navigation. Contracted by Saint Lawrence Seaway Development Corporation, Washington, DC, 10C0 p. in 5 volumes. NTIS: PB-251 527.

Adams, Charles E. Jr. (1975) Saint Lawrence Seaway system plan for all-year navigation. Appendix C. Environmental impact. Contracted to ARCTEC, Inc., Columbia, MD, by Saint Lawrence Seaway Development Corporation, Washington, DC, 85 p. NTIS: PB-251 531.

Brayton, D. E.; Reymond, R. D.; Bashaw, P. A. (1973) Seaway information system management and control requirements. Contracted to Transportation Systems Center, Cambridge, MA, by Saint Lawrence Seaway Development Corporation, Washington, DC, 88 p. NTIS: PB-253 340.

Kearney (A. T.), Inc., Chicago, Il (1976) U.S. Great Lakes-Seaway Port Development and Shipper Conference, Dearborn, Michigan, 25-29 April 1976. Sponsored by Saint Lawrence Seaway Development Corporation, Washington, DC., Corps of Engineers, Washington, DC., and Coast Guard, Washington, DC, 179 p. NTIS: PB-260 670.

Lewis, Jack W. (1975) Saint Lawrence Seaway system plan for all-year navigation. Appendix A. Methodology. Contracted to ARCTEC, Inc., Columbia, MD, by Saint Lawrence Seaway Development Corporation, Washington DC, 385 p. NTIS: PB-251 529.

Lewis, Jack W. (1975) Saint Lawrence Seaway system plan for all-year navigation. Appendix B. Seaway simulation. Contracted to ARCTEC, Inc., Columbia, MD, by Saint Lawrence Seaway Development Corporation, Washington, DC, 206 p. NTIS: PB-251 530

Lewis, Jack W. (1975) Saint Lawrence Seaway system plan for all-year navigation. Appendix D. Economics. Contracted to ARCTEC, Inc., Columbia, MD, by Saint Lawrence Seaway Development Corporation, Washington, DC, 276 p. NTIS: PB-251 532.

Lewis, Jack W. (1975) Saint Lawrence Seaway system plan for all-year navigation. Summary report. Contracted to ARCTEC, Inc., Columbia, MD, by Saint Lawrence Seaway Development Corporation, Washington DC, 48 p. NTIS: PB-251 528.

Lewis, Jack W.; Kotras, Thomas J.; Benze, David L.; Etzel, Ronald A. (1979) Mathematical and physical model studies of the Copeland Cut test ice boom. Contracted to ARCTEC, Inc., Columbia, MD by Saint Lawrence Seaway Development Corporation, Massena, NY, 288 p. NTIS: PB80-149 362

Lewis, Jack W.; Benze, David L.; Etzel, Ronald A. (1979) Saint Lawrence River ice boom modification study. Contracted to ARCTEC, Inc., Columbia, MD, by Saint Lawrence Seaway Development Corporation, Washington, DC, 287 p. NTIS: PB80-114 317.

Lewis, Jack W.; Johnson, Robert P. (1980) Saint Lawrence River all-year navigation ice control system. Contracted to ARCTEC, Inc., Columbia, MD, by Saint Lawrence Seaway Development Corporation, Massena, NY, 145 p. NTIS: PB80-183 478.

Saint Lawrence Seaway Development Corporation (1979) U.S. Great Lakes Ports - Statistics for overseas and Canadian waterborne commerce. Washington, DC, 584 p. NTIS: PB80-189 939.

GREAT LAKES ICE: A SELECTED BIBLIOGRAPHY

Claire S. Hoffman, ed.

The Great Lakes ice bibliography is a representative selection of references to ice on Lake Superior, Lake Michigan, Lake Huron, Lake Erie, Lake Ontario, the Saint Lawrence River, the Saint Lawrence Seaway, Lake Saint Clair, and the Detroit, Saint Clair, Saint Marys, and Niagara Rivers. The bibliography has been divided into nine subject categories, with citations repeated in each relevant category. An author index follows the bibliography. The nine subject categories are:

1. General - includes bibliographies, program summaries and historical reviews, overviews of activities
2. Ice - physical and mechanical properties
3. Near-shore geomorphology
4. Meteorology, climatology, and limnology
5. a. Ice climatology

   b. Seasonal summaries of ice or weather conditions
6. Ice forecasting
7. Remote surveillance - data obtained from satellites, aircraft overflights, submerged or surface devices, or studies of such methods of data collection
8. Ice season commerce
9. Maritime engineering - includes vessel design, ice protection and removal, pollution control. (No attempt was made to be complete with respect to problems of oil spills in ice-infested waters.)

This bibliography may be used as an update to the Arctic Institute of North America - NOAA Lake Survey Center Annotated Bibliography on Fresh-water Ice (U.S. National Oceanic and Atmospheric Administration, Lake Survey Center. NOAA Technical Memorandum NOS LS CR-2, September 1971.)

The Great Lakes ice bibliography has been compiled from many different sources, including the automated and manual indexing and abstracting services listed below.

Cold Regions Bibliography, 1965-May 1980.

Meteorological and Geoastrophysical Abstracts, 1970-May 1980.

NTIS (National Technical Information Service), 1964-May 1980.

Oceanic Abstracts, 1964-May 1980.

Georef, 1967-1980.

Geoarchive, 1974-May 1980.

Catalog of the Scott Polar Research Institute Library, cumulated 1976.

Dissertation Abstracts, 1961-May 1980.

Monthly Catalog of U.S. Government Publications, 1976-May 1980.

Aquatic Science and Fisheries Abstracts, 1978-May 1980.

TRIS (Transportation Research Information Service), 1970-May 1980.

Miscellaneous bibliographies.

In the bibliography, we assume that the language of publication is English unless the title is given in a foreign language. Because we do not have all of the original material in hand, we cannot be certain of the completeness of each citation, although every effort possible has been made to ensure accuracy. Since we realize that the maximum value of a bibliography lies in the availability of the original documents, we have marked each item owned by the World Data Center with the "*" symbol. Photocopies of any of these documents can be provided upon request at $.10 per page over 25 pages, $5 minimum) to institutions and individuals. Lengthy publications are available on interlibrary loan to other libraries. Publications with an NTIS number are available in microform or photocopy form from: National Technical Information Service, 5285 Port Royal Road, Springfield, Virginia, 22161 U.S.A. Prices vary according to length of the publication. Ph. D. dissertations may be obtained from University Microfilms International, 300 North Zeeb Road, Ann Arbor, MI 48106, using the order number given in the citation.

We urge you to acquire items not owned by the WDC through your regular library channels or from the publishing agency or author. However, if these methods are unsuccessful, please feel free to call or write the WDC for assistance.

If any individuals or institutions see their publications in this list without an "*", the WDC would appreciate receiving copies of those which are still available.

We would like to thank Dr. Frank H. Quinn and Raymond A. Assel of NOAA's Great Lakes Environmental Research Laboratory (GLERL) for their work in identifying publications produced by GLERL personnel and contractors.

1. GENERAL

*1. Arctic Institute of North America. U.S. National Oceanic and Atmospheric Administration, Lake Survey Center. (1971) Annotated bibliography on fresh water ice. U.S. National Oceanic and Atmospheric Administration. NOAA Technical Memorandum NOS LSCR-2, 425p.

2. Arno, N. (1972) Overview of the programs in the Great Lakes of the United States Corps of Engineers. Federal Conference on the Great Lakes, 1st, Ann Arbor, MI, Dec. 13-15, 1972. Proceedings, p. 103-113. U.S. Environmental Protection Agency.

*3. Aubert, E. J. (1978) Great Lakes Environmental Research Laboratory Annual Report FY 1978. U.S. National Oceanic and Atmospheric Administration. Great Lakes Environmental Research Laboratory. 33p.

4. Aubert, J. (1979) Technical plan for the Great Lakes Environmental Research Laboratory. U.S. National Oceanic and Atmospheric Administration. Great Lakes Environmental Research Laboratory. 68p. NTIS: PB-297 532.

5. Bajorunas, L. (1972) Great Lakes program. Federal Conference on the Great Lakes, 1st, Ann Arbor, MI, Dec. 13-15, 1972. Proceedings, p. 143-149. U.S. Environmental Protection Agency.

6. Bates, C.C. (1972) Great Lakes research from the United States Coast Guard's point of view. Federal Conference on the Great Lakes, 1st, Ann Arbor, MI, Dec. 13-15, 1972. Proceedings, p. 264-273. U.S. Environmental Protection Agency.

*7. Bolsenga, S.J. (1968) River ice jams - a literature review. U.S. Army. Corps of Engineers. Lake Survey. Research Report, no. 5-5, 587p.

8. Boyce, D. (1974) Great Lakes Ice Navigation Center. Mariners Weather Log, 18(1), p. 17-22. NTIS: COM-74-90018-01.

9. Cavan, B.P. (1969) Literature review of dusting technology in deicing. U.S. Army. Corps of Engineers. Lake Survey. Research Report, No. 5-7, 15p.

9a. Ficke, E.R., Ficke, J.F. (1977) Ice on rivers and lakes - a bibliographic essay. U.S. Geological Survey. Water Resources Division. Water Resources Investigations USGS/WRI-77-95, 181p. NTIS: PB-279 528.

10. Fine, J.C. (1977) NESS: National Environmental Satellite Service. Sea Frontiers, 23(4) p. 198-203.

11. McGill University, Montreal. MacDonald Physics Laboratory Ice Research Project. (1970) Annual Report, 1969, 25p.

12. Michigan. University. Great Lakes Research Division. (1976) Chronology of research: 1950 to the present. 71p. NTIS: PB-301 183.

13. Phillips, D.J., Ranahan, W.L., Jenkins, C.F., Laughrun, M., eds. (1974) Canada and the United States. IFYGL Bulletin, no. 12, 66p.

*14. Quinn, F.H. (1974) Ice information collection, dissemination and uses on the Great Lakes. In: Symposium on Advanced Concepts and Techniques in the Study of Snow and Ice Resources, Monterey, CA, Dec. 2-6, 1973. Proceedings, p. 363-369. National Academy of Sciences.

15. Quinn, F.H., (1971) Quantitative dynamic mathematical models for Great Lakes research. University of Michigan, Ph.D. dissertation. University Microfilms order no. 71-23852, 141p.

16. Travers, J., McCaslin, R., Mull, M. (1972) Data requirements in support of the Marine Weather Service program. U.S. National Oceanic and Atmospheric Administration. NOAA Technical Report ERL 228-AOML 7, v. 1, sect. 13, 5p.

17. U.S. Army. Corps of Engineers. Lake Survey Center (1971) Research program, 1971. 57p. NTIS: COM-71-00662.

18. U.S. Department of Transportation. Transportation Research Board. Maritime Research Information Service. (1978) Marine systems in frigid environments: bibliography. Available from: Transportation Research Board Publications Office, Maritime Research Information Service, Washington DC 20418. 35pp.

19. U.S. National Oceanic and Atmospheric Administration. (1974) International Field Year for the Great Lakes. IFYGL Bulletin, no. 10, 96 p. NTIS: COM-74-11268.

20. U.S. National Oceanic and Atmospheric Administration. (1974) International Field Year for the Great Lakes. IFYGL Bulletin, no. 11, 113p. NTIS: COM-74-11662.

21. U.S. National Oceanic and Atmospheric Administration. (1975) International Field Year for the Great Lakes. IFYGL Bulletin, no. 15. 103p. NTIS: COM-75-11462.

* - Indicates that the publication is owned by the WDC-A.

22. U.S. National Oceanic and Atmospheric Administration. Great Lakes Environmental Research Laboratory (1977)
Annual Report, 1977. 39p. NTIS: PB-185 636.

*23. U.S. National Oceanic and Atmospheric Administration. Great Lakes Environmental Research Laboratory. Lake Hydrology Group. (1974)
Lake Ontario IFYGL ice studies data report. GLERL Contribution no. 94, 189p.

24. Wallace, D.H. (1972)
Great Lakes programs of the Department of Commerce. Federal Conference on the Great Lakes, 1st, Ann Arbor, MI, Dec. 13-15, 1972. Proceedings, p. 139-142. U.S. Environmental Protection Agency.

2. ICE PHYSICAL AND MECHANICAL PROPERTIES

*25. Adams, C.E., jr., Smith, L.D., jr. (1973)
Petrographic and chemical properties of Great Lakes ice. In: Conference on Great Lakes Research, 16th, 1973. Proceedings, p. 629-639. International Association for Great Lakes Research.

26. Adams, W.P., English, M.C., Lasenby, D.C. (1979)
Snow and ice in the phosphorus budget of a lake in south central Ontario. Water Research, 13(2), 213-215.

*27. Bolsenga, S.J. (1978)
Photosynthetically active radiation transmission through ice. U.S. National Oceanic and Atmospheric Administration. Great Lakes Environmental Research Laboratory. NOAA Technical Memorandum ERL GLERL-18, 57p. NTIS: PB-288 463.

28. Bryan, M.L., Marcus, M.G. (1972)
Physical characteristics of near-shore ice ridges. Arctic, 25(3), p. 182-192.

*29. Clapper, R.T., jr., Smith D., Stortz, K., Sydor, M. (1975)
Ice growth studies in Duluth-Superior harbor 1974-75. Final Report. 70p. NTIS: PB-272 170.

30. Dozier, J., Marsh, W.M. (1973)
Formation, structure, and geomorphic influence of Lake Superior ice ridges (abstract). In: Association of Pacific Coast Geographers, 35th Annual Meeting. Yearbook, v. 35, p. 180-181.

*31. Dozier, J., Marsh, B.D., Marsh W.M. (1974)
Ice cusp formation on Lake Superior icefoots (abstract). Symposium on the Geologic Action of Drift Ice, 1st, Quebec, April 20-24, 1974. Proceedings, p. 23-24.

32. Evenson, E.B., Cohn, B.P. (1979)
Icefoot complex: its morphology, formation and role in sediment transport and shoreline protection. Zeitschrift fur Geomorphologie, 23(1), p. 58-75.

*33. Fahnestock, R.K., Crowley, D.J., Wilson, M., Schneider, H. (1973)
Ice volcanoes of the Lake Erie shore near Dunkirk, NY, U.S.A. Journal of Glaciology, 12(64), p. 93-99.

34. Frankenstein, G.E. (1961)
Strength data on lake ice. U.S. Army. Snow, Ice and Permafrost Research Establishment. SIPRE Technical Report 80, 23p. NTIS: AD-701 054; PB-163 661.

35. Gold, L.W., Krausz, A.S. (1971)
Investigation of the mechanical properties of St. Lawrence River ice. Canadian Geotechnical Journal, 8(2), p. 163-169.

*36. Green, J.C.,
Finger-rafting in fresh-water ice: observations in Lake Superior. Journal of Glaciology, 9(57) p. 401-404.

37. Hampton, G.R. (1974)
Fresh water ice shelf fabrics of a near-shore area in Lake Michigan. University of Wisconsin, Milwaukee, M.S. thesis, unpaged.

38. Lewis, E.W. (1969)
Calculation of rate of melting of lake ice. Working Paper No. 154. The Bendix Corporation, Aerospace Systems Division, Ann Arbor, MI, 31pp.

*39 Marsh, W.M., Marsh, B.D., Dozier, J. (1973)
Formation, structure, and geomorphic influence on Lake Superior icefoots. American Journal of Science, 273(1), p. 48-64.

*40. Michel, B., Berenger, D. (1975)
Algorithm for accelerated growth of ice in a ship's track. In: International Symposium on Ice Problems, 3rd, Hanover, NH, Aug. 18-21, 1975. Proceedings, Frankenstein, G.E., ed., p. 127-132. International Association of Hydraulic Research.

*41. Roethlisberger, H. (1966)
Ultrasonic pulse measurements in anisotropic lake ice. U.S. Army. Cold Regions Research and Engineering Laboratory. Research Report RR-126, 29p. NTIS: AD-642 110.

*42. Vickers, R.S. (1975)
Microwave properties of ice from the Great Lakes. Final Report. 36p. NTIS: N77-26577.

43. Welsh, J.P., Kingsbury, B.T. (1974)
Characterization of slush ice in the Great Lakes. Final Report. 20p. NTIS: ADA-006 450.

44. Bajorunas, L., Duane, D.B. (1967)
Shifting offshore bars and harbor shoaling. Journal of Geophysical Research, 72(24) p. 6195-6205. NTIS: AD-692 885.

45. Beeton, A.M., Strand, J.W. (1975)
Sources of water quality, lake level, ice, water temperature and meteorological data for the St. Lawrence, Great Lakes. Wisconsin University. Center for Great Lakes Studies. Sea Grant Advisory Report no. 10. 194p. NTIS: COM-75-11177.

*46. Brazel, A.J. (1971)
Winter climatology and ice characteristics: St. Marys River-Whitefish Bay waterway. U.S. National Oceanic and Atmospheric Administration. National Ocean Survey. Lake Survey Center. NOAA Technical Memorandum NOS LSCR-3. 66p. NTIS: AD-733 958.

47. Burbidge, F.E., Lander, J.R. (1957)
Preliminary investigation into break-up and freeze-up conditions in Canada. Canada. Department of Transport. Meteorological Branch. Circular 2939, 13p.

48. Cohn, B.P. (1975)
Beach modification by ice, eastern shoreline of Lake Ontario. Geological Society of America. Abstracts with Programs, 7(1), 1975, p. 40-41.

49. Davis, R.A., jr. (1973)
Coastal ice formation and its effect on beach sedimentation. Shore and Beach, 41(1) p. 3-9.

50. Dilley, J.F., Pavlak, A. (1974)
Analysis of lake shore ice formation, growth, and decay. IFYGL Phase 2 Final Report. Prepared for U.S. National Oceanic and Atmospheric Administration, Great Lakes Environmental Research Laboratory, by General Electric Company, Ocean Sciences Laboratory.

*51. Dilley, J.E. (1976)
Lake Ontario ice modeling IFYGL Phase 3 Final Report. Prepared for U.S. National Oceanic and Atmospheric Administration, Great Lakes Environmental Research Laboratory, by General Electric Company, Ocean Sciences Laboratory. 79p. NTIS: PB-264 998.

52. Dionne, J. C. (1974)
How drift ice shapes the St. Lawrence. Canadian Geographical Journal, 88(2) p. 4-9.

53. Dionne, J.C. (1970)
Aspects morpho-sedimentologiques du glaciel, en particulier des cotes du Saint-Laurent, Morpho-sedimentological aspects of ice action, especially on the St. Lawrence River banks. Laboratoire de Recherches Forestieres, Ste-Foy, Quebec. Rapport d'Information, Oct. 1970-Q-F-X-9. 423p.

54. Dozier, J., Marsh, W.M. (1973)
Formation, structure, and geomorphic influence of Lake Superior ice ridges (abstract). In: Association of Pacific Coast Geographers, 35th Annual Meeting. Yearbook v. 35, p. 180-181.

*55. Dozier, J., Marsh, B.D., Marsh, W.M. (1974)
Ice cusp formation on Lake Superior icefoots (abstract). Symposium on Geological Action of Drift Ice, 1st, Quebec, April 1974. Proceedings, p. 23-24.

*56. Dozier, J., Mitchell, J., Marsh, W.M. (1976)
Modeling of backshore slope processes during the cold season, south shore of Lake Superior. Revue de Geographie de Montreal, 30(1-2), p. 171-177.

57. Evenson, E.B., Cohn, B.P. (1979)
Icefoot complex: its morphology, formation and role in sediment transport and shoreline protection. Zeitschrift fur Geomorphologie, 23(1), p. 58-75.

*58. Fahnestock, R.K., Crowley, D.J., Wilson, M., Schneider, H. (1973)
Ice volcanoes of the Lake Erie shore near Dunkirk, New York, U.S.A. Journal of Glaciology, 12(64), p. 93-99.

59. Hackett, W.R., Ethetton, L.W. (1976)
Near-shore icefoots of southeastern Lake Superior: origin, structure and geomorphic influence. In: First Annual Student Conference in Earth Science, April 9-10, 1976, Milwaukee, WI. Abstracts with Program, unpaged.

60. Hampton, G.R. (1974)
Fresh water ice shelf fabrics of a near-shore area in Lake Michigan. University of Wisconsin, M.S. thesis, unpaged.

61. Lazier, S.S., MacLachlan, F.A. (1970)
Movements in continuous lake ice sheets and temperature gradients in an ice sheet. National Research Council of Canada. Associate Committee on Geotechnical Research. Technical Memorandum, no. 98.

*62. Leshkevich, G.A. (1975)
Lake Superior bathythermograph data. U.S. National Oceanic and Atmospheric Administration. Great Lakes Environmental Research Laboratory. NOAA Technical Memorandum ERL GLERL-3, 71p.

63. Maddukuri, C.S., Friskin, W.R. (1974)
Turbulent kinetic energy balance near the frozen surface of eastern Lake Ontario (IFYGL). Conference on Great Lakes Research, 17th, Aug. 12-14, 1974, Hamilton, Ontario. Proceedings, Pt. 1, p. 288-295.

*64. Marsh, W.M., Marsh, D.B., Dozier, J. (1973)
Formation, structure, and geomorphic influence on Lake Superior icefoots. American Journal of Science, 273(1), p. 48-64.

*65. Marshall, E.W. (1977)
Geology of the Great Lakes ice cover. University of Michigan, Ph.D. dissertation. University Microfilms order no. 77-26298, 643 p.

*66. Oman, G., Smith, D., Sydor, M. (1976)
Ice growth in Duluth-Superior harbor. 22p. NTIS: PB-264 819.

67. Peck, E.L., Larson, L.W., Wilson, J.W. (1973)
Lake Ontario snowfall observational network for calibrating radar measurements. In: Advanced Concepts and Techniques in the Study of Snow and Ice Resources, ed. by Santeford, H.S., Smith, J.L., p. 412-421.

68. Pezzeta, J.M., Moore, J.R. (1978)
Great Lakes shoreline erosion - western Lake Michigan. In: Oceans '78: "The Ocean Challenge": Fourth Annual Combined Conference, September 6-8, 1978, Washington, DC. Marine Technology Society, p. 143-150.

69. Richards, T.L. (1964)
Meteorological aspects of ice cover on the Great Lakes. Monthly Weather Review, 92(6), p. 297-302.

*70. Richards, T.L. (1963)
Meteorological factors affecting ice cover on the Great Lakes. Conference on Great Lakes Research, 6th, Ann Arbor, MI, June 13-15, 1963. Proceedings, p. 204-215.

71. Rumer, R.R. (1977)
Effects of wind and waves on ice transport in the Great Lakes. Prepared for U.S. National Oceanic and Atmospheric Administration, Great Lakes Environmental Research Laboratory, by University of Delaware, Department of Civil Engineering, Contract no. 03-6-022-35236, 244p.

72. Seibel, E., Carlson, C.T., Maresca, J.W., jr. (1976)
Ice ridge formation: probable control by near-shore bars. Journal of Great Lakes Research, 2(2), p. 384-392.

73. Stewart, K. M. (1973)
Winter conditions in Lake Erie with reference to ice and thermal structure and comparison to Lakes Winnebago (Wisconsin) and Mille Lacs (Minnesota). In: Conference on Great Lakes Research, 16th, Huron, OH, 1973. Proceedings, p. 845-857. International Association for Great Lakes Research.

74. Wake, A., Rumer, R.R., jr. (1978)
Development of a thermodynamic model for the ice regime of Lake Erie. In: IAHR Symposium on Ice Problems, Luleaa, Sweden, Aug. 7-9, 1978. Proceedings, Part 2, p. 143-161. International Association for Hydraulic Research.

75. Wake, A. (1979)
Development of a thermodynamic simulation model for the ice regime of Lake Erie. University of New York at Buffalo, Ph.D. dissertation. University Microfilms order no. 77-32712, 259p.

76. Wake, A., Rumer, R.R., jr. (1979)
Modeling ice regime of Lake Erie. American Society of Civil Engineers. Proceedings. Journal of the Hydraulics Division, v. 105(HY7), p. 827-844.

*77. Assel, R.A. (1980)
Great Lakes degree-day summaries and norms, 1897-1977. U.S. National Oceanic and Atmospheric Administration. Great Lakes Environmental Research Laboratory. NOAA Data Report ERL GLERL-15, 113p. NTIS: PB 80-195977.

78. Bolsenga, S.J. (1968)
Great Lakes solar altitude charts and tables. U.S. Army. Corps of Engineers. Lake Survey Center. Research Report RR-5-4. 117p. NTIS: AD-680 961.

79. Bolsenga, S.J. (1977)
Radiation balance over a continuous snow surface: a review. U.S. National Oceanic and Atmospheric Administration. Great Lakes Environmental Research Laboratory. GLERL Open File Report.

*80. Bolsenga, S.J. (1978)
Spectral distribution of radiation in the northern Great Lakes during winter. Journal of Great Lakes Research, 4(2), p. 226-229.

81. Bolsenga, S.J. (1978)
Technique for estimating monthly global radiation. Water Resources Bulletin, v. 14, 679-688.

82. Bryan, M.L., Marcus, M.G. (1972)
Physical characteristics of near-shore ice ridges. Arctic, 25(3), p. 182-192.

83. Burns, N.M., Rosa, F., Gedeon, A. (1978)
Lake Erie in mid-winter. Journal of Great Lakes Research, 4(2), p. 134-141.

84. Coordinating Committee on Great Lakes Basic Hydraulic and Hydrologic Data (1970)
Lake Superior outflow, 1860-1968. 47p. NTIS: AD-741 952.

85. Derecki, J.A. (1976)
Heat storage and advection in Lake Erie. Water Resources Research, 12(6), p. 1144-1150.

86. Eadie, W.J. (1970)
Experimental modification of lake-effect weather. Final report. CAL-VC-2898-P-1. Cornell Aeronautical Laboratories, Inc., Buffalo, NY. 80 p. NTIS: COM-71-00009.

*87. Grumblatt, J.L. (1976)
Great Lakes water temperatures, 1966-1975. U.S. National Oceanic and Atmospheric Administration. NOAA Technical Memorandum ERL GLERL-11-1, 127 p. (ERL GLERL-11-2 contains all data in microfiche form.) NTIS: PB-275 468.

*88. Markham, W.E. (1960)
Freezing and melting degree day computation in spring and fall months. Canada. Department of Transport. Meteorological Branch. Circular 3350, 10p.

89. Noble, V.E. (1965)
Winter temperature structure of Lake Michigan. In: Conference on Great Lakes Research, 8th, Ann Arbor, 1965. Proceedings, p. 334-341. Institute of Science and Technology, University of Michigan.

90. Noble, V.E., Ewing, K.J. (1967)
Winter temperature structure of the Great Lakes. University of Michigan. Great Lakes Research Division. Special Report no. 32, 25p.

91. Palmer, M.D., Izatt, J.B. (1972)
Lake movements with partial ice cover. Limnology and Oceanography, 17(3), p. 403-409.

92. Pinsak, A.P., Rogers, G.K. (1974)
Energy balance of Lake Ontario. In: International Field Year for the Great Lakes Symposium, Washington DC, 8 Apr. 1974. Proceedings p. 86-101. NTIS: COM-74-11671.

93. Pluhowski, E.J. (1974)
Dynamics of suspended sediment plumes in Lake Ontario. Semiannual progress report, 1 Jan-30 Jun 1974, 4p. NTIS: E74-10815.

94. Potok, A.J. (1978)
Upper St. Lawrence River hydraulic transient model. U.S. National Oceanic and Atmospheric Administration. Great Lakes Environmental Research Laboratory. NOAA Technical Memorandum ERL GLERL-24, 104p. NTIS: PB-297 490.

95. Quinn, F.H. (1978)
Hydrologic response model of the North American Great Lakes. Journal of Hydrology, 37(3-4), p. 295-307.

96. Rao, D.B. (1979)
Lake Superior heat storage study continued. Coastal Oceanographic and Climatological News, v. 1, p. 21.

97. Rodgers, G.K., Anderson, D.V. (1963)
Thermal structure of Lake Ontario. In: Conference on Great Lakes Research, 6th, Ann Arbor, MI, June 13-15, 1963. Proceedings, pp. 59-69.

98. Saylor, J.H., Miller, G.S. (1976)
Winter currents in Lake Huron. U.S. National Oceanic and Atmospheric Administration. Great Lakes Environmental Research Laboratory. NOAA Technical Memorandum ERL GLERL-15, 120p. NTIS: PB-275 847.

99. Sheng, P.Y., Lick, W.J., (1973)
Wind-driven currents in a partially ice-covered lake. In: Conference on Great Lakes Research, 16th, Huron, OH, April 16-18, 1973. Proceedings, p. 1001-1008. International Association for Great Lakes Research.

100. Strong, A.E. (1968)
Spring lake anticyclone - its inducement on the atmospheric and water circulations. University of Michigan. Great Lakes Research Division. Special Report No. 34.

101. Thomas, M.K. (1964)
Survey of Great Lakes snowfall. University of Michigan. Great Lakes Research Division. Publication No. 11.

*102. U.S. National Oceanic and Atmospheric Administration (1974)
International Field Year for the Great Lakes. IFYGL Bulletin, no. 10, 96p. NTIS: COM-74-11268.

*103. U.S. National Oceanic and Atmospheric Administration. Environmental Data and Information Service.
Mariners Weather Log, bimonthly. Contains meteorological and climatological information for use by the maritime industry and cooperative National Weather Service marine observers, including ice navigation season summaries. Available from NOAA/NODC/EDIS, Washington, DC 20235.

104. U.S. National Oceanic and Atmospheric Administration.
Monthly Weather Review. In each issue is a description of Northern Hemisphere weather and circulation for the third month preceding the issue date. Available from U.S. Government Printing Office, order no. C55.11.

105. Weickmann, H.K. (1973)
Modification of Great Lakes winter storms. U.S. National Oceanic and Atmospheric Administration. NOAA Technical Report, ERL 265-APCL 26, 103p.

106. Wiggin, B.L. (1950)
Great snows of the Great Lakes. Weatherwise, 3(6), pp. 123-126.

*107. Archibald, D.C., Monsinger, M.N., Kilpatrick, T.B. (1961)
Aerial sea ice observing and reconnaissance. St. Lawrence River, the Gulf of St. Lawrence and the Strait of Belle Isle, 1960. Canada. Department of Transport. Meteorological Branch. Circular 3465, 101p.

*108. Archibald, D.C., Monsinger, M.N., Kilpatrick, T.B. (1961)
Aerial ice observing and reconnaissance. The Great Lakes, 1961. Canada. Department of Transport. Meteorological Branch. Circular 3530, 57p.

*109. Archibald, D.C., Monsinger, M.N., Kilpatrick, T.B. (1962)
Aerial ice observing and reconnaissance. The Great Lakes, 1962. Canada. Department of Transport. Meteorological Branch. Circular 3772, 57p.

*110. Archibald, D.C., Monsinger, M.N., Stasyshyn, E. (1960)
Aerial sea ice observing and reconnaissance programme in the Great Lakes, 1960. Canada. Department of Transport. Meteorological Branch. Circular 3361, 13p.

111. Beeton, A.M., Strand, J.W. (1975)
Sources of water quality, lake level, ice, water temperature and meteorological data for the St. Lawrence, Great Lakes. Wisconsin University. Center for Great Lakes Studies. Sea Grant advisory report no. 10, 194p.

*112. Bolsenga, S.J. (1980)
New observations on the daily variations of natural ice albedo. U.S. National Oceanic and Atmospheric Administration. Great Lakes Environmental Research Laboratory. NOAA Technical Memorandum ERL GLERL-27, 36 p.

*113. Bolsenga, S.J. (1978)
On the use of multispectral radar to define certain characteristics of Great Lakes ice. U.S. National Oceanic and Atmospheric Administration. Great Lakes Environmental Research Laboratory. NOAA Technical Memorandum ERL GLERL-17, 18 p. NTIS: PB-287 873.

*114. Bolsenga, S.J. (1977)
Preliminary observations on the daily variation of ice albedo. Journal of Glaciology, 18(80) p. 517-521.

*115. Bolsenga, S.J. (1979)
Solar altitude effects on ice albedo. U.S. National Oceanic and Atmospheric Administration. Great Lakes Environmental Research Laboratory. NOAA Technical Memorandum ERL GLERL-25. NTIS: PB-301 252.

116. Bolsenga, S.J. (1968)
Total albedo of Great Lakes ice. U.S. Lake Survey Bulletin, B68-1, pp. 16-36.

*117. Brazel, A.J. (1971)
Winter climatology and ice characteristics: St. Marys River-Whitefish Bay waterway. U.S. National Oceanic and Atmospheric Administration. Lake Survey Center. NOAA Technical Memorandum NOS LSCR-3, 66p. NTIS: AD-733 958.

118. Burbidge, F.E., and Lander, J.R., (1957)
Preliminary investigation into break-up and freeze-up conditions in Canada. Canada. Department of Transport. Meteorological Branch. Circular 2939, 13p.

119. Canada. Department of Transport. Meteorological Branch. (1964)
Aerial ice observing and reconnaissance, the Great Lakes. Circular 3987, ICE-13.

120. Chase, P.E. (1969)
Formation and dissolution of fresh water ice with emphasis on the Great Lakes. Final report, Project no. 55183, BSR 2842. The Bendix Corporation, Aerospace Systems Division, Ann Arbor, MI.

*121. Dilley, J.F., Pavlak, A. (1974)
Analysis of lake shore ice formation, growth, and decay. IFYGL phase 2 final report. Prepared for U.S. National Oceanic and Atmospheric Administration, Great Lakes Environmental Research Laboratory, by General Electric Company, Ocean Sciences Laboratory.

122. Dilley, J.F. (1976)
Lake Ontario ice modeling. IFYGL phase 3 final report. Prepared for U.S. National Oceanic and Atmospheric Administration, Great Lakes Environmental Research Laboratory, by General Electric Company, Ocean Sciences Laboratory. 79p. NTIS: PB-264 998.

123. Goedecke, E. (1961)
Uber die Eisverhaltnisse auf den Grossen Seen. Ice distribution in the Great Lakes. Der Seewart, 22(1), p. 31-44.

124. Hamelin, L.E., Letarte, J. (1966)
Glaces de rive et haut estran, Ile d'Orleans, Canada--evolution depuis 1957. Association Francaise Etude Quaternaire Bulletin, 3(7) p. 112-119.

125. Heap, J.A., Noble, V.E. (1966)
Growth of ice on Lake Michigan. University. Great Lakes Research Division. Special Report no. 26, 94 pp.

126. Heap, J.A. (1963)
Some characteristics of the winter ice cover of Lake Michigan, 1962-63. Conference on Great Lakes Research, Ann Arbor, MI, June 13-15, 1963. Proceedings, p.216-218. Michigan University. Great Lakes Research Division.

127. Heap, J.A. (1963)
Winter ice cover in the Great Lakes. Michigan. University. Great Lakes Research Division. Special Report no. 18, 25 p.

128. Lasca, N.P., Taylor, R.W., Willis, D.E. (1976)
Lake Michigan ice studies crack formation. EOS: Transactions of the American Geophysical Union, 57(2), p.85.

129. Lazier, S.S., MacLachlan, F.A. (1970)
Movements in continuous lake ice sheets and temperature gradients in an ice sheet. National Research Council of Canada. Associate Committee on Geotechnical Research. Technical Memorandum, no. 98.

*130. Leshkevich, G.A. (1975)
Lake Superior bathythermograph data. U.S. National Oceanic and Atmospheric Administration. Great Lakes Environmental Research Laboratory. NOAA Technical Memorandum ERL GLERL-3, 71 p.

131. Lewis, E.W. (1969)
Calculation of rate of melting of lake ice. The Bendix Corporation, Aerospace Systems Division, Ann Arbor, MI. Working Paper no. 154, BSR-2675, 31p.

132. Maddukuri, C.S., Friskin, W.R. (1974)
Turbulent kinetic energy balance near the frozen surface of eastern Lake Ontario (IFYGL). Conference on Great Lakes Research, 17th, Hamilton, Ontario, Aug. 12-14, 1974. Proceedings. Part 1, p. 299-295. International Association for Great Lakes Research.

133. Marshall, E.W. (1968)
Great Lakes ice cover. Limnos, 1(4).

134. Marshall, E.W. (1970)
Ice on the Great Lakes: more than a canopy. Water Spectrum, 2(1) p. 24-27.

*135. Marshall, E.W. (1967)
Lake Superior ice characteristics. Conference on Great Lakes Research, 10th, Detroit, MI. Proceedings, p. 214-220. NTIS: AD-692 887.

136. Marshall, E.W. (1965)
Structure of lake ice in the Keweenaw Peninsula, Michigan. Conference on Great Lakes Research, 8th, Ann Arbor, MI. Proceedings, p. 326-333.

*137. Michel, B., Berenger, D. (1975)
Algorithm for accelerated growth of ice in a ship's track. In: International Symposium on Ice Problems, 3rd, Hanover, NH, 18-21 Aug. 1975. Proceedings, ed. by G. E. Frankenstein, p. 127-132. International Association of Hydraulic Research.

*138. Michel, B., Berenger, D. (1973)
L'hiver glaciologique le long du fleuve St-Laurent. Glaciological winter along the St. Lawrence. The Role of Snow and Ice in Hydrology, Proceedings of the Banff Symposia, Sept. 1972, v. 2, p. 1251-1282. Geneva, SZ, WMO-IAHS-Unesco.

139. Noble, V. (1976)
Aerial ice reconnaissance and ice advisory services. The Great Lakes and St. Lawrence Seaway, 1 December 1976 - 15 May 1977. Canada. Atmospheric Environment Service.

140. Oak, W.W. (1955)
Ice on the Great Lakes. Weekly Weather and Crop Bulletin, 42(8), pp.7-8.

141. Oak, W.W., Myers, H.V. (1953)
Ice reporting on the Great Lakes. Weatherwise, 6(1), pp. 7-10.

142. O'Hara, N.W., Ayers, J.C. (1972)
Stages of shore ice development. In: Conference on Great Lakes Research, 15th, University of Wisconsin, Madison, April 5-7, 1972. Proceedings, p.521-535. International Association for Great Lakes Research.

*143. Oman, G., Smith, D., Sydor, M. (1976)
Ice growth in Duluth-Superior harbor. 22 p. NTIS: PB-264 819.

144. Pinsak, A.P., Rogers, G.K. (1974)
Energy balance of Lake Ontario. In: International Field Year for the Great Lakes Symposium, Washington, DC, 8 Apr. 1974. Proceedings, p. 86-101. NTIS: COM-74-11671.

*145. Quinn, F.H. (1974)
Ice information collection, dissemination and uses on the Great Lakes. IN: Symposium on Advanced Concepts and Techniques in the Study of Snow and Ice Resources, Monterey, CA, Dec 2-6, 1973. Proceedings, p. 363-369.

*146. Quinn, F.H. (1971)
Quantitative dynamic mathematical models for Great Lakes Research. University of Michigan, Ph.D. dissertation. University Microfilms order no. 71-23852. 141 p.

147. Ragotzkie, R.A. (1960)
Compilation of freezing and thawing dates for lakes in the north central United States and Canada. University of Wisconsin, Madison. Department of Meteorology. Technical Report no. 3, 61 p.

148. Ramseier, R.O., Dickins, D.F., Weaver, R.J. (1974)
Ice information, Montreal-Lake Ontario section, St. Lawrence River. Canada. St. Lawrence Seaway Authority. Navigation Season Extension Studies, Gulf of St. Lawrence to Great Lakes, Winter 1972-73. 14 p.

149. Ramseier, R.O., Dickins, D.F., Weaver, R.J. (1973)
Ice information, Thousand Islands area, Montreal, Lake Ontario section. St. Lawrence River. Canada. St. Lawrence Seaway Authority. Navigation Season Extension Studies, Gulf of St. Lawrence to Great Lakes, Winter 1971-72. 12 p.

150. Richards, T.L. (1964)
Meteorological aspects of ice cover on the Great Lakes. Monthly Weather Review, 92(6), p. 297-302.

*151. Richards, T.L. (1963)
Meteorological factors affecting ice cover on the Great Lakes. Conference on Great Lakes Research, 6th, Ann Arbor, MI, June 13-15, 1963. Proceedings, p. 204-215.

*152. Richardson, F.A., Burns, B.M. (1975)
Ice thickness climatology for Canadian stations. Canada. Atmospheric Environment Service. ICE-1-75, 60 p.

*153. Rondy, D.R. (1969)
Great Lakes ice atlas. U.S. National Oceanic and Atmospheric Administration. Lake Survey Center. NOAA Technical Memorandum NOS LSCR-1, 48 p. NTIS: AD-692 310 and COM-71-01052.

154. Rondy, D.R. (1976)
Great Lakes ice cover. In: Great Lakes Basin Framework Study. Appendix 4 - Limnology of Lakes and Embayments. Great Lakes Basin Commission, Ann Arbor, MI 48105.

155. Rumer, R.R., Crissman, R.D., Wake, A. (1978) Dynamics of ice transport in large lakes. Final report. Prepared for U.S. National Oceanic and Atmospheric Administration, Great Lakes Environmental Research Laboratory, by University of Delaware, Department of Civil Engineering.

156. Rumer, R.R. (1977) Effects of wind and waves on ice transport in the Great Lakes. Prepared for U.S. National Oceanic and Atmospheric Administration, Great Lakes Environmental Research Laboratory, by University of Delaware, Department of Civil Engineering, Contract No. 03-6-022-35236, 244 pp.

157. Rumer, R.R., Crissman, R., Wake, A. (1979) Ice transport in the Great Lakes. Water Resources and Environmental Engineering Research Report no. 79-3. Prepared for U.S. National Oceanic and Atmospheric Administration, Great Lakes Environmental Research Laboratory, by the State University of New York at Buffalo, Department of Civil Engineering, and the Center for Cold Regions Engineering and Science Technology.

158. Rumer, R.R., jr., Yu, P.M (1978) Modelling ice dissipation in eastern Lake Erie. Journal of Great Lakes Research, 4(2), p. 194-200. NTIS: PB-300 709.

*159. Sleator, F.E. (1978) Ice thickness and stratigraphy at nearshore locations on the Great Lakes (English units). U.S. National Oceanic and Atmospheric Administration. Great Lakes Environmental Research Laboratory. NOAA Data Report ERL GLERL 1-1. NTIS: PB-295 671.

*160. Sleator, F.E. (1978) Ice thickness and stratigraphy at nearshore locations on the Great Lakes (Metric units). U.S. National Oceanic and Atmospheric Administration. Great Lakes Environmental Research Laboratory. NOAA Data Report ERL GLERL 1-2, 443p. NTIS: PB-297 121.

161. Stewart, K.M. (1973) Winter conditions in Lake Erie with reference to ice and thermal structure and comparison to Lakes Winnebago (Wisconsin) and Mille Lacs (Minnesota). In: Conference on Great Lakes Research, 16th, Huron, OH, April 16-18, 1973. Proceedings, p. 845-857. International Association for Great Lakes Research.

162. Sydor, M. (1978) Ice growth in Duluth-Superior harbor. Journal of Geophysical Research, 83(C8), p.4074-4078.

163. Thomson, F.J., Polcyn, F.C., Porcello, L.J., Bryan M.L., Sattinger, I.J. (1973) Summary report of work on ten tasks: Progress report, 1 Jul-31 Dec 72. 50 p. NTIS: E73-10086.

164. U.S. National Oceanic and Atmospheric Administration. Great Lakes Environmental Research Laboratory. Lake Hydrology Group (1976) Lake Ontario IFYGL ice studies data report. GLERL Open File Report.

165. U.S. Navy Fleet Weather Facility. Southern ice limit. Weekly summary.

*166. Wake, A., Rumer, R.R., jr. (1978) Development of a thermodynamic model for the ice regime of Lake Erie. In: IAHR Symposium on Ice Problems, Luleaa, Sweden, Aug. 7-9, 1978. Proceedings, Part 2, p. 143-161. International Association for Hydraulic Research.

167. Wake, A. (1977) Development of a thermodynamic simulation model for the ice regime of Lake Erie. State University of New York at Buffalo, Ph.D. dissertation. University Microfilms order no. 77-32712. 259p.

168. Wake, A. Rumer, R.R., jr. (1979) Modeling ice regime of Lake Erie. American Society of Civil Engineers. Proceedings. Journal of the Hydraulics Division, 105(HY7) p. 827-844.

169. Webb, M. (1972) Surface water temperature and ice regimes of Georgian Bay. Water Resources Research, 8(2), p. 372-389.

170. Weickmann, H.K. (1972) Modification of Great Lakes winter storms. U.S. National Oceanic and Atmospheric Administration. NOAA Technical Report ERL 265-APCL 26, 103 p.

171. Welsh, J.P., Kingsbury, B.T. (1974) Characterization of slush ice in the Great Lakes. 20 p. NTIS: ADA-006 450.

*172. Wiesnet, D.R. (1979) Satellite studies of fresh-water ice movement on Lake Erie. Journal of Glaciology, 24(90), p. 415-426.

173. Wilson, J.W. (1975) Radar-gage precipitation measurements during the IFYGL. Final report. Prepared for U.S. National Oceanic and Atmospheric Administration, Great Lakes Environmental Research Laboratory, by the Center for the Environment and Man.

*174. Yu, P.M.-T. (1977) Ice dissipation in eastern Lake Erie. State University of New York at Buffalo, M.S. thesis.

5B. ICE CLIMATOLOGY: SEASONAL SUMMARIES

175. Allen, W.T.R. (1977)
Freeze-up, break-up and ice thickness in Canada. Canada. Atmospheric Environment Service. CLI-1-77, 185 p.

*176. Archibald, D.C., Monsinger, M.N., Kilpatrick, T.B. (1961)
Aerial ice observing and reconnaissance. The Great Lakes, 1961. Canada. Department of Transport. Meteorological Branch. Circular 3530, 57 p.

*177. Archibald, D.C., Monsinger, M.N., Kilpatrick, T.B. (1962)
Aerial ice observing and reconnaissance. The Great Lakes, 1962. Canada. Department of Transport. Meteorological Branch. Circular 3772, 57 p.

*178. Archibald, D.C., Monsinger, M.N., Stasyshyn, E. (1960)
Aerial sea ice observing and reconnaissance programme in the Great Lakes, 1960. Canada. Department of Transport. Meteorological Branch. Circular 3361, 13 p.

*179. Archibald, D.C., Monsinger, M.N., Kilpatrick, T.B. (1961)
Aerial sea ice observing and reconnaissance. St. Lawrence River, The Gulf of St. Lawrence and the Strait of Belle Isle, 1960. Canada. Department of Transport. Meteorological Branch. Circular 3465, 101 p.

*180. Assel, R.A. (1980)
Great Lakes degree-day and temperature summaries and norms, 1897-1977. U.S. National Oceanic and Atmospheric Administration. Great Lakes Environmental Research Laboratory. NOAA Data Report ERL GLERL-15. NTIS: PB 80-195977.

*181. Assel, R.A. (1972)
Great Lakes ice cover winter 1970-71. U.S. National Oceanic and Atmospheric Administration. Lake Survey Center. NOAA Technical Memorandum NOS LSC-D-4, 81p. NTIS: COM-73-11023.

*182. Assel, R.A. (1972)
Great Lakes ice cover winter 1971-72. U.S. National Oceanic and Atmospheric Administration. Lake Survey Center. NOAA Technical Memorandum NOS LSC-D-6, 61p. NTIS: COM-73-11746.

*183. Assel, R.A. (1974)
Great Lakes ice cover winter, 1972-73. U.S. National Ocean and Atmospheric Administration. Lake Survey Center. NOAA Technical Memorandum NOS LSC-D-7, NTIS: COM-74-11822, 62p.

*184. Assel, R.A. (1974)
Great Lakes ice cover, winter 1973-4. U.S. National Oceanic and Atmospheric Administration. Great Lakes Environmental Research Laboratory. NOAA Technical Report ERL 325-GLERL-1, 60p. NTIS: COM-75-10981.

185. Assel, R.A., Quinn, F.H. (1979)
Historical perspective of the 1976-77 Lake Michigan ice cover. Monthly Weather Review, 107(3) p. 336-341.

*186. Assel, R.A., Quinn, F.H. (1977)
Preliminary classification of Great Lakes winter severity, 1947-1976. GLERL Open File Report, 8 p.

*187. Assel, R.A., Boyce, D.E., DeWitt, B.H., Wartha, J., Keyes, F.A. (1979)
Summary of Great Lakes weather and ice conditions, winter 1977-78. U.S. National Oceanic and Atmospheric Administration. Great Lakes Environmental Research Laboratory. NOAA Technical Memorandum ERL GLERL-26, 123p.

*188. Batson, G.B., Shen, H.T., Ackermann, N.L., Candee, K.I., Landry, S.J. (1979)
Investigation of flow and ice conditions, Sparrowhawk Point to Murphy Islands, St. Lawrence River, winter 1978-1979. Final report. U.S. Department of Transportation. St. Lawrence Seaway Development Corporation, 158p.

*189. Batson, G.B., Ackermann, N.L., Shen, H.T., Candee, K.I. (1978)
Survey of flow and ice conditions in the Ogden Island reach, St. Lawrence River, winter of 1977-1978. U.S. Department of Transportation. St. Lawrence Seaway Development Corporation, 80p.

190. Boyce, D.E. (1973)
1972-73 Great Lakes ice season. Mariners Weather Log, 17(5), p. 285-288. NTIS: COM-73-90027-05.

191. Boyce, D.E. (1974)
1973-74 Great Lakes ice season. Mariners Weather Log, 18(5), p. 298-303. NTIS: COM-74-90018-05.

192. Boyce, D., DeWitt, B. (1976)
Great Lakes ice season, 1975-76. Mariners Weather Log, 20(6), p. 328-336.

193. Boyce, D., DeWitt, B. (1977)
Great Lakes ice season, 1976-77. Mariners Weather Log, 21(6), p. 372-378.

194. Boyce, D. (1978) Great Lakes ice season, 1977-78. Mariners Weather Log, 22(6), p. 401-409.

195. Canada. Atmospheric Environment Service. Ice thickness data for Canadian selected stations.
Freeze-up 1958 - break-up 1961. Circular 3537, ICE-5, 1961.
Freeze-up 1961 - break-up 1962. Circular 3711, ICE-6, 1962.
Freeze-up 1962 - break-up 1963. Circular 3918, ICE-11, 1963.
Freeze-up 1963 - break-up 1964. Circular 4153, ICE-19, 1964.
Freeze-up 1964 - break-up 1965. Circular 4372, ICE-23, 1966.
Freeze-up 1965 - break-up 1966. Circular 4529, ICE-28, 1967.
Freeze-up 1966 - break-up 1967. ICE-2, 1967.
Freeze-up 1967 - break-up 1968. ICE-1-68, 1968.
Freeze-up 1968 - break-up 1969. ICE-2-69, 1969.
Freeze-up 1969 - break-up 1970. ICE-1-70, 1970.
Freeze-up 1970 - break-up 1971. ICE-1-71, 1971.
Freeze-up 1971 - break-up 1972. ICE-1-72, 1972.
Freeze-up 1972 - break-up 1973. ICE-1-73, 1973.
Freeze-up 1973 - break-up 1974. ICE-1-74, 1974.
Freeze-up 1974 - break-up 1975. ICE-1-75, 1975.
Freeze-up 1975 - break-up 1976. ICE-1-76, 1976.
Freeze-up 1976 - break-up 1977. ICE-1-77, 1977.
Freeze-up 1977 - break-up 1978. ICE-1-78, 1978.

196. Canada. Department of Transport. Meteorological Branch (1964) Aerial ice observing and reconnaissance, the Great Lakes. Circular 3987, ICE-13.

197. Canada. Department of Transport. Meteorological Branch (1966) Ice observations 1964, Canadian Inland Waterways.

198. Canada. Department of Transport. Meteorological Branch (1968) Ice observations 1965, Canadian Inland Waterways.

199. Clapper, R.T., jr., Smith, D., Stortz, K., Sydor, M. (1975) Ice growth studies in Duluth-Superior harbor 1974-75. Final report. 70 p. NTIS: PB-272 170.

200. Coordinating Committee on Great Lakes Basic Hydraulic and Hydrologic Data (1970) Lake Superior outflow, 1860 - 1968, 47 p. NTIS: AD-741 952.

*201. Grumblatt, J.L. (1976) Great Lakes water temperatures, 1966-1975. U.S. National Oceanic and Atmospheric Administration. NOAA Technical Memorandum ERL GLERL-11-1. 127p. (ERL GLERL-11-2 contains all data in microfiche form.) NTIS: PB-275 468.

*202. Leshkevich, G.A. (1976) Great Lakes ice cover, winter 1974-75. U.S. National Oceanic and Atmospheric Administration. Great Lakes Environmental Research Laboratory. 46p. NTIS: PB-261 833.

*203. Leshkevich, G.A. (1977) Great Lakes ice cover, winter 1975-76. U.S. National Oceanic and Atmospheric Administration. Great Lakes Environmental Research Laboratory. NOAA Technical Memorandum ERL GLERL-12. 41 p. NTIS: PB-271 255.

204. Linklater, G.D. (1973) 1971-72 Great Lakes ice season. Mariners Weather Log, 17(1), p. 15-16. NTIS: COM-73-90027-01.

205. Noble, V. (1976) Aerial ice reconnaissance and ice advisory services. The Great Lakes and St. Lawrence Seaway, 1 December 1976 - 15 May 1977. Canada. Atmospheric Environment Service.

206. Perham, R.E. (1978) Performance of the St. Marys River ice booms, 1976-1977. U.S. Army. Cold Regions Research and Engineering Laboratory. Report 78-24, 21p. NTIS: ADA-061 431.

*207. Quinn, F.H., Assel, R.A., Boyce, D.E., Leshkevich, G.A., Snider, C.R. (1978) Summary of Great Lakes weather and ice conditions, winter 1976-77. U.S. National Oceanic and Atmospheric Administration. Great Lakes Environmental Research Laboratory. NOAA Technical Memorandum ERL GLERL-20. 155p. NTIS: PB-292 613.

*208. Rondy, D.R. (1969) Great Lakes ice cover winter 1962-63 and 1963-64. U.S. Army. Corps of Engineers. Lake Survey Center. Basic Data Report BD-5-5, 54p. NTIS: AD-695 639.

*209. Rondy, D.R. (1966) Great Lakes ice cover winter 1965-66. U.S. Army. Corps of Engineers. Lake Survey Center. Basic Data Report BD-5-2, 52p. NTIS: AD-658-227.

*210. Rondy, D.R. (1967) Great Lakes ice cover, winter 1966-67. U.S. Army. Corps of Engineers. Lake Survey Center. Basic Data Report BD-5-3, 71p. NTIS: AD-666 223.

*211. Rondy, D.R. (1968) Great Lakes ice cover winter 1967-68. U.S. Army. Corps of Engineers. Lake Survey Center. Basic Data Report BD-5-4, 68p. NTIS: AD-685 846.

*212. Rondy, D.R. (1971) Great Lakes ice cover winter 1968-69. U.S. National Oceanic and Atmospheric Administration. Lake Survey Center. NOAA Technical Memorandum NOS LSCD-1, 50p. NTIS: COM-72-10197.

*213. Rondy, D.R. (1972)
Great Lakes ice cover winter 1969-1970. U.S. National Oceanic and Atmospheric Administration. Lake Survey Center. NOAA Technical Memorandum NOS LSCD-3, 61p. NTIS: COM-72-10917.

214. Schwerdt, R.W. (1972)
Great Lakes navigation, 1971. Mariners Weather Log, 16(3), p. 148-164. NTIS: COM-72-90074-03.

215. Snider, C.R. (1967)
Great Lakes ice season of 1967. Monthly Weather Review, 95(10), p. 685-696.

216. Snider, C.R., Linklater, G.D. (1969)
Great Lakes ice season of 1968. Monthly Weather Review, 97(4), pp. 315-332.

*217. U.S. Deep Waterways Commission, Chicago, IL. (1896)
Ice season.

218. U.S. Naval Oceanographic Office (1968)
Ice observations 1968. Publication no. 606-d.

219. U.S. Navy. Fleet Weather Facility (1976)
Eastern Arctic sea ice analyses 1972-1975. 214 p. NTIS: ADA-033 344.

*220 U.S. Navy. Fleet Weather Facility (1976)
Eastern-Western Arctic sea ice analyses. 210p. NTIS: ADA-043 353.

221 U.S. Navy. Fleet Weather Facility (1978)
Eastern-Western Arctic sea ice analysis. 104 p. NTIS: ADA-072 979.

222. U.S. Navy. Fleet Weather Facility.
Southern ice limit. Available from Naval Polar Oceanography Center, 4301 Suitland Road, Washington, DC 20390.

*223. U.S. Navy. Naval Polar Oceanography Center (1979)
Eastern-Western Arctic sea ice analyses. Available from Naval Polar Oceanography Center, 4301 Suitland Road, Washington, DC 20390.

*224 Wartha, J.H. (1977)
Lake Erie ice: winter 1975-76. U.S. National Oceanic and Atmospheric Administration. National Environmental Satellite Service. NOAA Technical Memorandum NESS-90, 76 p. NTIS: PB-276 386.

225. Wiesnet, D.R., Barazotto, R.M., Forsyth, D.F. (1977)
Satellite record of ice on the Great Lakes during the great winter of 1977. EOS: Transactions of the American Geophysical Union, 58(6), p.384.

*226. Wilshaw, R.E., Rondy, D.R. (1965)
Great Lakes ice cover winter 1964-65. U.S. Army. Corps of Engineers. Lake Survey. Research Report RR 5-1, various pagings.

*227. Adams, C.E., jr. (1976)
Estimating water temperatures and time of ice formation on the St. Lawrence River. Limnology and Oceanography, 21(1), p. 128-137.

*228. Allen, W.T.R., Cudbird, B.S.V. (1971)
Freeze-up and break-up dates of water bodies in Canada. Canada. Meteorological Service. CLI-1-71, 144p.

*229. Allen, W.T.R. (1977)
Freeze-up, break-up and ice thickness in Canada. Canada. Atmospheric Environment Service. CLI-1-77, 185p.

*230. Assel, R.A. (1976)
Great Lakes ice thickness prediction. Journal of Great Lakes Research, 2(2), p. 248-255.

*231. Assel, R.A. (1976)
St. Lawrence River freeze-up forecast procedure. U.S. National Oceanic and Atmospheric Administration. Great Lakes Environmental Research Laboratory. NOAA Technical Memorandum ERL GLERL-6, 13p. NTIS: PB-256 100.

232. Baker, D.G. (1976)
Objective prediction of ice formation, freeze-up and break-up on the Great Lakes. Journal of Applied Meteorology, 15(10), p. 1033-1040.

233. Bolsenga, S.J. (1967)
Great Lakes snow depth probability charts and tables. U.S. Army. Corps of Engineers. Research Report No. 5-2, 47p. NTIS: AD-654 761.

*234. Bolsenga, S.J. (1978)
On the use of multispectral radar to define certain characteristics of Great Lakes ice. U.S. National Oceanic and Atmospheric Administration. Great Lakes Environmental Research Laboratory. NOAA Technical Memorandum ERL GLERL-17, 18p. NTIS: PB-287 873.

*235. Bolsenga, S.J. (1968)
Snow depth probablity in the Great Lakes basin. U.S. Army. Corps of Engineers. Lake Survey. Miscellaneous Paper no. 68-5, p. 162-170.

*236. Bryan, M.L., Larson, R.W. (1975)
Study of fresh-water lake ice using multiplexed imaging radar. Journal of Glaciology, 14(71), p. 445-457.

237. Chase, P.E., Baker, J.L., and Lewis, E.W., (1970)
Ice data collection and usage: emphasis on prediction techniques. Conference on Great Lakes Research, 13th. Proceedings, p. 747-790.

238. Chase, P. (1973)
Using ITOS (Improved Tiros Operational Satellite) vidicon and scanning radiometer data for Great Lakes ice analysis and prediction. Bendix Corporation, Aerospace Systems Division, Ann Arbor, MI, 122p.

*239. Gedney, R.T. (1975)
Operational all-weather Great Lakes ice information system. U.S. National Aeronautics Space Administration. Lewis Research Center. Technical Memorandum NASA-TM-X-71812, 12p.

*240. Markham, W.E. (1960)
Freezing and melting degree-day computations in spring and fall months. Canada. Department of Transport. Meteorological Branch. Circular 3350, 10p.

241. Oak, W.W. (1955)
Ice on the Great Lakes. Weekly Weather and Crop Bulletin, 42(8), pp. 7-8.

242. Oak, W.W., Myers, H.V. (1953)
Ice reporting on the Great Lakes. Weatherwise, 6(1), pp. 7-10.

*243. Quinn, F.H. (1974)
Ice information collection, dissemination and uses on the Great Lakes. In: Symposium on Advanced Concepts and Techniques in the Study of Snow and Ice Resources, Monterey, CA, Dec. 2-6, 1973. Proceedings, p. 363-369.

244. Ragotzkie, R.A. (1960)
Compilation of freezing and thawing dates for lakes in the North Central United States and Canada. University of Wisconsin, Madison. Department of Meterology. Technical Report no. 3, 61p.

245. Robinson, J.R., Witherspoon, D.F. (1975)
Practical application of probability forecasts of water surface temperatures of the St. Lawrence River - Kingston to Montreal. National Research Council, Canada. Associate Committee on Geotechnical Research. Technical Memorandum no. 114, p. 128-133.

*246. Rogers, J.C. (1976)
Evaluation of techniques for long-range forecasting of air temperature and ice formation. U.S. National Oceanic and Atmospheric Administration. Great Lakes Environmental Research Laboratory. NOAA Technical Memorandum ERL GLERL-8, 29p. NTIS: PB-259 695.

*247. Rogers, J.C. (1976)
Long-range forecasting of maximum ice extent on the Great Lakes. U.S. National Oceanic and Atmospheric Administration. Great Lakes Environmental Research Laboratory. NOAA Technical Memorandum ERL GLERL-7, 20p. NTIS: PB-259 694.

*248. Rogers, J.C., DeWitt, B., Dixon, D. (1975)
Operational ice forecast for the Little Rapids Cut. U.S. National Oceanic and Atmospheric Administration. Great Lakes Environmental Research Laboratory. NOAA Technical Memorandum ERL GLERL-4, 22p. NTIS: PB-250 069.

*249. Schertler, R.J., Mueller, R.A., Jirberg, R.J., Cooper, D.W., Heighway, J.E. (1975)
Great Lakes all-weather ice information system. U.S. National Aeronautics and Space Administration. Lewis Research Center Technical Memorandum NASA-TM-X-71815, 30 p.

*250. Schertler, R.J., Chase, T.L., Mueller, R.A., Kramarchuk, I., Jirberg, R.J. (1979)
VHF downlink communication system for SLAR data. U.S. National Aeronautics and Space Administration. Lewis Research Center. Technical Memorandum NASA-TM-X-79164, 10p.

*251. Snider, C.R. (1973)
Great Lakes ice forecasting. U.S. National Oceanic and Atmospheric Administration. National Weather Service. NOAA Technical Memorandum NWS CSD-1, 113 p. NTIS: COM-75-10036.

*252. Snider, C.R. (1971)
Manual of Great Lakes ice forecasting. U.S. National Oceanic and Atmospheric Administration. National Weather Service. NOAA Technical Memorandum NWS-CR-48, 57p. NTIS: COM-72-10143.

*253. Sydor, M. (1976)
Western Lake Superior ice. In: ERTS-1, A New Window on Our Planet. U.S. Geological Survey. Professional Paper 929, p. 169-172.

*254. U.S. Navy. Fleet Weather Facility (1976)
Eastern Arctic sea ice analyses 1972-1975. 214p. NTIS: ADA-033 344.

*255. U.S. Navy. Fleet Weather Facility (1976)
Eastern-Western Arctic sea ice analyses. 210p. NTIS: ADA-043 353.

*256. U.S. Navy. Fleet Weather Facility (1978)
Eastern-Western Arctic sea ice analyses. 104p. NTIS: ADA-072 979.

*257. U.S. Navy. Navy Polar Oceanography Center (1979)
Eastern-Western Arctic sea ice analyses. Unpaged.

258. Williams, G.P. (1970)
Predicting the date of lake ice break-up. Water Resources Research, 7(2), p. 323-333.

259. Wittman, W., Burkhart, M.D. (1973)
Sea Ice. Part 2. Ice distribution and forecast services, North American Arctic waters. Mariners Weather Log, 17(6), p. 343-355. NTIS: COM-73-90027-06.

260. Anonymous (1979)
Satellite monitoring saves U.S. over $172 million annually. Sea Technology, 20(4), 53p.

*261. Archibald, D.C., Monsinger, M.N., Kilpatrick, T.B. (1961)
Aerial sea ice observing and reconnaissance. St. Lawrence River, the Gulf of St. Lawrence and the Strait of Belle Isle, 1960. Canada. Department of Transport. Meteorological Branch. Circular 3465, 101p.

*262. Archibald, D.C., Monsinger, M.N., Kilpatrick, T.B. (1961)
Aerial ice observing and reconnanissance. The Great Lakes, 1961. Canada. Department of Transport. Meteorological Branch. Circular 3530, 57p.

*263. Archibald, D.C., Monsinger, M.N., Kilpatrick, T.B. (1962)
Aerial ice observing and reconnaissance. The Great Lakes, 1962. Canada. Department of Transport. Meteorological Branch. Circular 3772, 57p.

*264. Archibald, D.C., Monsinger, M.N., Stasyshyn, E. (1960)
Aerial sea ice observing and reconnaissance programme in the Great Lakes, 1960. Canada. Department of Transport. Meteorological Branch. Circular 3361, 13p.

*265. Bolsenga, S.J. (1978)
On the use of multispectral radar to define certain characteristics of Great Lakes ice. U.S. National Oceanic and Atmospheric Administration. Great Lakes Environmental Research Laboratory. NOAA Technical Memorandum ERL GLERL-17, 18p. NTIS: PB-287 873.

*266. Bryan, M.L., Larson, R.W. (1975)
Study of fresh-water lake ice using multiplexed imaging radar. Journal of Glaciology, 14((71), p. 445-457.

267. Campbell, W.J. (1973)
Lake and sea ice experiment with Skylab microwave radiometry. Progress report, July 1973. NTIS: E73-10820.

268. Campbell, W.J. (1974)
Lake and sea ice experiment with Skylab microwave radiometry. Progress report, May 1974. NTIS: E74-10616.

269. Campbell, W.J. (1974)
Lake and sea ice experiment with Skylab microwave radiometry. Progress report, Dec. 1974. NTIS: E76-10011.

*270. Campbell, W.J., Ramseier, R.O., Weaver, R.J., Weeks, W.F. (1975)
Skylab floating ice experiment. Final report, 67p. NTIS: E76-10161.

271. Campbell, W.J. (1977)
Visual observations of floating ice from Skylab. U.S. National Aeronautics and Space Administration. Special Report. NASA-SP-380, p. 353-379.

272. Canada. Department of Transport (no date)
Operation Icemap I: report on remote sensing trials, St. Lawrence Seaway, Spring 1969. 36p.

273. Canada. Department of Transport. Meteorological Branch (1964)
Aerial ice observing and reconnaissance, the Great Lakes. Circular 3987, ICE-13.

274. Chase, P. (1973)
Using ITOS (Improved Tiros Operational Satellite) vidicon and scanning radiometer data for Great Lakes ice analysis and prediction. The Bendix Corporation, Ann Arbor, MI. Aerospace Systems Division. 122p. NTIS: COM-73-10897.

*275. Cooper, D.W., Mueller, R.A., Schertler, R.J. (1976)
Measurement of lake ice thickness with a short-pulse radar system. U.S. National Aeronautics and Space Administration. NASA Technical Note D-8189, 12p.

*276. Cooper, D.W., Heighway, J.E., Shook, D.F., Jirberg, R.J., Vickers, R.S. (1974)
Remote profiling of lake ice thickness using a short pulse radar system aboard a C-47 aircraft. U.S. National Aeronautics and Space Administration. Technical Memorandum NASA-TM-X-71588, 4p.

277. Cooper, D.W., Mueller, R.A., Schertler, R.J. (1975)
Remote profiling of lake ice using an S-band short pulse radar aboard an all-terrain vehicle. U.S. National Aeronautics and Space Administration. Technical Memorandum. NASA-TM-X-71801, 19p.

278. Dean, A.M., jr. (1977)
Remote sensing of accumulated frazil and brash ice in the St. Lawrence River. U.S. Army. Cold Regions Research and Engineering Laboratory. CRREL Report 77-08, 24p. NTIS: ADA-039 905.

279. Gedney, R.T. (1975)
Operational all-weather Great Lakes ice information system. 12p. NTIS: N76-10605.

280. Gloersen, P. (1972)
Passive microwave images of lake ice. U.S. National Aeronautics and Space Administration Special Publication no. 331, p. 187-189.

*281. Hagman, B.B. (1976)
Analysis of Great Lakes ice cover from satellite imagery. U.S. National Oceanic and Atmospheric Administration. Great Lakes Environmental Research Laboratory. NOAA Technical Memorandum ERL GLERL-9, 17p. NTIS: PB-261 835.

*282. Hagman, B.B. (1976)
On the use of microwave radiation for Great Lakes ice surveillance. U.S. National Oceanic and Atmospheric Administration. Great Lakes Environmental Research Laboratory. NOAA Technical Memorandum ERL GLERL-13, 18p. NTIS: PB-271 254.

*283. Jirberg, R.J., Schertler, R.J., Gedney, R.T., Mark, H. (1973)
Application of SLAR for monitoring Great Lakes total ice cover. In: Interdisciplinary Symposium on Advanced Concepts and Techniques in the Study of Snow and Ice Resources, Monterey, CA, Dec. 2-6, 1973. ed. by H.S. Santeford and J.L. Smith. Proceedings, p. 402-411. National Academy of Sciences. NTIS: N74-10360.

*284. Kniskern, F.E. (1979)
Ice products derived from satellite at NOAA/NESS (summary). World Data Center A for Glaciology (Snow and Ice). Glaciological Data. Report GD-5, p.27.

*285. Larrowe, B.T., Innes, R.B., Rendleman, R.A., Porcello, L.J. (1971)
Fine-resolution radar investigation of Great Lakes ice cover. Michigan. University. Institute of Science and Technology. Report, no. 1900-1-F, 178p.

286. McClain, E.P. (1972)
Environmental monitoring of the Great Lakes from space. Federal Conference on the Great Lakes, 1st, Ann Arbor, MI, Dec. 13-15, 1972. Proceedings, p. 197-201. U.S. Environmental Protection Agency.

*287. McMillan, M.C., Forsyth, D. (1976)
Satellite images of Lake Erie ice: January-March 1975. U.S. National Oceanic and Atmospheric Administration. National Environmental Satellite Service. NOAA Technical Memorandum NESS-80, 22p. NTIS: PB-258 458.

288. Mark, H., Gedney, R. (1972)
NASA Great Lakes regional earth observations program. Federal Conference on the Great Lakes, 1st, Ann Arbor, MI, Dec. 13-15, 1972. Proceedings, p. 225-245. Environmental Protection Agency.

*289. Marsh, W.M., Bryan, M.L., Dozier, J. (1976)
Aerial imagery of Lake Superior coastal ice. Revue de Geographie de Montreal, 30(1-2), p. 179-186.

290. Marsh, W.M., Bryan, M.L., Dozier, J. (1974)
Ground and aerial imagery of Lake Superior coastal ice (abstract). Symposium on the Geologic Action of Drift Ice, 1st, Quebec, April 20-24, 1974. Proceedings, p. 37.

*291. Marshall, E.W. (1966)
Air photo interpretation of Great Lakes ice features. University of Michigan. Great Lakes Research Division. Special Report no. 25.

292. Noble, V. (1976)
Aerial ice reconnaissance and ice advisory services. The Great Lakes and St. Lawrence Seaway, 1 December 1976 - 15 May 1977. Canada. Atmospheric Environment Service.

293. O'Hara, N.W., Ayers, J.C. (1972)
Stages of shore ice development. In: Conference on Great Lakes Research, 15th, University of Wisconsin, Madison, April 5-7, 1972. Proceedings, p. 521-535. International Association for Great Lakes Research.

294. Peck, E.L., Larson, L.W., Wilson, J.W. (1973)
Lake Ontario snowfall observational network for calibrating radar measurements. In: Interdisciplinary Symposium on Advanced Concepts and Techniques in the Study of Snow and Ice Resources, Monterey, CA, 2-6 Dec. 1973. Proceedings, ed. by H.S. Santeford and J.L. Smith, p. 412-421. National Academy of Sciences.

295. Pluhowski, E.J. (1974)
Dynamics of suspended sediment plumes in Lake Ontario. Semiannual progress report. 1 Jan-30 June 1974, 4p. NTIS: E74-10815.

296. Polcyn, F., Thomson, F., Porcello, L.J., Sattinger, I.J., Malila, W.A. (1972)
ERTS computer compatible tape data processing and analysis. Bimonthly progress report no. 1, 1 Jul-31 Aug 72, 12p. NTIS: E72-10201.

297. Polcyn, F.C., Thomson, F.J., Porcello, L.J., Sattinger, I.J., Malila, W.A. (1972)
ERTS computer compatible tape data processing and analysis. Appendix 1: Utility of imaging radars for the study of lake ice. Bimonthly progress report no. 2, Sept-31 Oct 72, 30p. NTIS: E72-10198.

298. Polcyn, F.C., Thomson, F.J., Bryan, M.L., Sattinger, I., Malila, W.A. (1974)
Infrared, radar, and optical applications of ERTS data. Bimonthly report no. 8, 1 Jan-28 Feb 74, 36p. NTIS: E74-10497.

299. Roethlisberger, H. (1966)
Ultrasonic pulse measurements in anisotropic lake ice. U.S. Army. Cold Regions Research and Engineering Laboratory. Research Report RR-126, 29p. NTIS: AD-642 110.

*300. Rondy, D.R. (1969)
Great Lakes ice cover winter 1962-63 and 1963-64. U.S. Army. Corps of Engineers. Lake Survey Center. Basic Data Report BD-5-5, 54p. NTIS: AD-695 639.

*301. Rondy, D.R. (1966)
Great Lakes ice cover winter 1965-66. U.S. Army. Corps of Engineers. Lake Survey Center. Basic Data Report BD-5-2, 52p. NTIS: AD-658 227.

*302. Rondy, D.R. (1967)
Great Lakes ice cover, winter 1966-1967. U.S. Army. Corps of Engineers. Lake Survey Center. Basic Data Report BD-5-3, 71p. NTIS: AD-666 223.

*303. Rondy, D.R. (1968)
Great Lakes ice cover winter 1967-1968. U.S. Army. Corps of Engineers. Lake Survey Center. Basic Data Report BD-5-4, 68p. NTIS: AD-685 846.

*304. Rondy, D.R. (1971)
Great Lakes ice cover winter 1968-1969. U.S. National Oceanic and Atmospheric Administration. Lake Survey Center. NOAA Technical Memorandum NOS LSCD-1, 50p. NTIS: COM-72-10197.

*305. Rondy, D.R. (1972)
Great Lakes ice cover winter 1969-1970. U.S. National Oceanic and Atmospheric Administration. Lake Survey Center. NOAA Technical Memorandum NOS LSCD-3, 61p. NTIS: COM-72-10917.

*306. Schertler, R.J., Raquet, C.A., Svehla, R.A. (1973)
Application of thermal imagery to the development of a Great Lakes ice information system. In: Interdisciplinary Symposium on Advanced Concepts and Techniques in the Study of Snow and Ice Resources, Monterey, CA, 2-6 Dec. 1973. Proceedings, ed. by H.S. Santeford and J.L. Smith, p. 513-522.

*307. Schertler, R.J., Mueller, R.A., Jirberg, R.J., Cooper, D.W., Heighway, J.E. (1975)
Great Lakes all-weather ice information system. U.S. National Aeronautics and Space Administration. Lewis Research Center. NASA Technical Memorandum NASA-TM-71815, 30p. NTIS: N75-33481.

308. Schertler, R.J., Chase, T.L., Mueller, R.A., Kramarchuk, I., Jirberg, R.J. (1979)
VHF downlink communication system for SLAR data. U.S. National Aeronautics and Space Administration. Lewis Research Center. NASA Technical Memorandum NASA-TM-79164, 10p. NTIS: N79-23313.

309. Stevens, G.H., Ramler, J.R. (1974)
Wide area coverage radar imaging satellite for earth applications. U.S. National Aeronautics and Space Administration. Lewis Research Center. NASA Technical Memorandum TM-X-71515, 111p. NTIS: N74-20536.

310. Strong, A.E. (1972)
Evaluation of ERTS data for certain oceanographic uses. Progress report, Jan-Feb 73, 2p. NTIS: E73-10356.

311. Strong, A.E. (1973)
New sensor on NOAA-2 satellite monitors the 1972-73 Great Lakes ice season. American Water Resources Association. Proceedings, no. 17, p. 171-178.

*312. Sydor, M. (1976)
Western Lake Superior ice. In: ERTS-1, A New Window on Our Planet. U.S. Geological Survey. Professional Paper 929, p. 169-172.

*313. Taylor, R.W., Kovach, J.P., Lasca, N.P. (1976)
Automated seismic monitoring system for Lake Michigan ice studies. Journal of Glaciology, 17(76), p. 347-350.

314. Thomson, F.J., Polcyn, F.C., Bryan, M.L., Sattinger, I., Malila, W.A. (1973)
Multidisciplinary investigations utilizing ERTS-1 data. Bimonthly report, no. 6, 1 Jul-31 Aug 73, 101p. NTIS: E73-11119.

315. Thomson, F.J. (1973)
Processing and analysis of ERTS-1 remotely sensed data. Bimonthly report, 1 Jan-28 Feb 73, 53p. NTIS: E73-10387.

316. Thomson, F.J., Polcyn, F.C., Porcello, L.J., Bryan, M.L., Sattinger, I.J. (1973)
Summary report of work on ten tasks. Progress report, 1 Jul-31 Dec 72, 50p. NTIS: E73-10086.

*317. Vickers, R.S., Heighway, J.E., Gedney, R.T. (1974)
Airborne profiling of ice thickness using a short pulse radar. In: Symposium on Advanced Concepts and Techniques in the Study of Snow and Ice Resources, Monterey, CA, Dec. 2-6, 1973. Proceedings, ed. by H.S. Santeford and J.L. Smith, p. 422-431. National Academy of Sciences.

*318. Vickers, R.S. (1975)
Microwave properties of ice from the Great Lakes. Final report, 36p. NTIS: N77-26577.

319. Welsh, J.P., Kingsbury, B.T. (1974)
Characterization of slush ice in the Great Lakes, 20p. NTIS: ADA-006 450.

320. Wiesnet, D.R., McGinnis, D.F., Matson, M. (1973)
Evaluation of ERTS data for certain hydrological uses. Status and technical progress report, Jan-Jun 73. U.S. National Oceanic and Atmospheric Administration. National Environmental Satellite Service. 28p. NTIS: E73-10869.

321. Wiesnet, D.R. (1974)
Role of satellites in snow and ice measurements. U.S. National Oceanic and Atmospheric Administration. National Environmental Satellite Service. NOAA Technical Memorandum NESS-58, 16p. NTIS: COM-74-11747.

322. Wiesnet, D.R., Barazotto, R.M., Forsyth, D.F. (1977)
Satellite record of ice on the Great Lakes during the great winter of 1977. EOS: Transactions of the American Geophysical Union, 58(6), p. 384.

*323. Wiesnet, D.R. (1979)
Satellite studies of fresh-water ice movement on Lake Erie. Journal of Glaciology, 24(90), p. 415-426.

324. Wiesnet, D.R., McGinnis, D.F., Forsyth, D.G. (1974)
Selected satellite data on snow and ice in the Great Lakes basin, 1972-73 (IFYGL). In: Conference on Great Lakes Research, 17th, Hamilton, Ontario, Aug. 12-14, 1974. Proceedings, Part 1, p. 334-347. International Association for Great Lakes Research.

*325. Wiesnet, D.R., McGinnis, D.F., jr. (1974)
Snow-extent mapping and lake ice studies using ERTS-1 MSS together with NOAA-2 VHRR. U.S. National Aeronautics and Space Administration. Special Report, no. 351. Symposium on Earth Resources Technology Satellite-1, 3rd, Washington, DC, 10-14 Dec 1973. Vol. 1: Technical Presentations, Section B, p. 995-1009.

326. Wilson, J.W. (1975)
Radar-gage precipitation measurements during the IFYGL. Final report. Prepared for U.S. National Oceanic and Atmospheric Administration, Great Lakes Environmental Research Laboratory, by the Center for the Environment and Man.

327. Anonymous (1976)
Extending the seaway season. Ship and Boat International, 29(12), p. 35, 37.

328. Anonymous (1971)
Lakes shippers chip out a longer season. Business Week, no. 2163, p. 50-51.

329. Anonymous (1976)
Problems preclude year-round seaway. Transport Development News, p. 15. Available from: Transportation Development Agency, 1000 Sherbrooke Street, West Montreal, Quebec H3A 2R3, Canada.

330. Anonymous (1979)
Satellite monitoring saves U.S. over $172 million annually. Sea Technology, 20(4), p. 53.

*331. Argiroff, C. (1975)
Planning the Great Lakes-St. Lawrence Seaway navigation season extension program. International Symposium on Ice Problems, 3rd, Hanover, NH, August 18-21, 1975. Proceedings, p. 111-125. International Association of Hydraulic Research.

332. Baum, J.V., Tierney, J.M., Sticksel, P.R. (1973)
Climatological and environmental factors that influence survival on the Great Lakes. Interim Report 28, Nov 72 - 15 Jan 73. 36p. NTIS: AD-768 678.

333. Benford, H., Nowacki, H., Kaldjian, M., Kim, K. (1971)
Cost benefit analysis model for Great Lakes bulk carriers operating during an extended season. Final report, fiscal year 1971, 172p. NTIS: COM-73-10425.

334. Benford, H. (1975)
Transport analysis: Great Lakes and Seaway. Vol. I: Summary and miscellaneous. 45 p. NTIS: MA-RD-930-75050.

335. Bitting, K.R. (1975)
Ice buoy demonstration program: Final report. 32p. NTIS: ADA-031 309.

336. Boyce, D., DeWitt, B. (1975)
Great Lakes ice season, 1974-75. Year round navigation achieved. Mariners Weather Log, 19(5), p. 277-282. NTIS: COM-75-90008-09.

337. Canada. St. Lawrence Seaway Authority (1973)
Navigation season extension studies. Gulf of St. Lawrence to Great Lakes, winter 1971-72. Four papers, various paging.

*338. Canada. St. Lawrence Seaway Authority. (1978)
Navigation season extension studies, St. Lawrence River and Great Lakes, winter 1977-78. Four papers, various pagings.

*339. Canada. St. Lawrence Seaway Authority. (1979)
Navigation season extension studies. Record of conditions, St. Lawrence River and Great Lakes, winter 1978-79. Various pagings.

340. Cowley, J.E. (1976)
Quantitative application of ice climate data to winter navigation studies. Canadian Journal of Civil Engineering, 3(2), p. 229-238.

341. Ficke, E.R., Ficke, J.F. (1977)
Ice on rivers and lakes - a bibliographic essay. U.S. Geological Survey. Water Resources Division. Water Resources Investigations USGS/WRI-77-95, 181p. NTIS: PB-279 528.

*342. Frankenstein, G.E., ed. (1975)
International Symposium on Ice Problems, 3rd, Hanover, NH. Proceedings, 627p. International Association for Hydraulic Research.

343. Frisch, J.V. (no date)
NOAA predictions and a Great Lakes challenge: beat the seaway freeze. Michigan. University. Sea Grant Program. Publication MICHU-SG-76-301, 2 p.

344. Kotras, T., Peter, J. (1975)
Winter rate study for Great Lakes - St. Lawrence Seaway system. Volume I: Final report. 123p. NTIS: ADA-021210.

345. LesStrang, J. (1976)
Seaway: the untold story of North America's fourth seacoast. Seattle, WA, Superior Publishing Co. 214p.

346. Lewis, J.W., Adams, C.E., jr. (no date)
St. Lawrence Seaway system plan for all-year navigation, Final report. Summary report, NTIS: PB-251 528, 48 p. Appendix A, Methodology, NTIS: PB-261 529, 385p. Appendix B, Seaway simulation, NTIS: PB-251 530, 206p. Appendix C, Environmental impact, NTIS: PB-251 531, 85p. Appendix D, Economics, NTIS: PB-251 532, 276p. Complete set, NTIS: PB-251 527-SET (paper copy unit).

347. Linklater, G.D. (1963)
Examination of the relationship between economic factors and the opening of Great Lakes ports. U.S. Weather Bureau, Detroit, MI. 11p. (manuscript).

348. Mellor, M., Vance, G.P., Wuebben, J.L., Frankenstein, G.E. (1978)
Investigation of ice clogged channels in the St. Marys River. Final report, 73p. NTIS: ADA-058 015.

*349. Michel, B., Berenger, D. (1975)
Algorithm for accelerated growth of ice in a ship's track. In: International Symposium on Ice Problems, 3rd, Hanover, NH, August 1975. Proceedings, ed. by Frankenstein, G.E., International Association of Hydraulic Research.

350. Nowacki, H., Benford, H., Kaldjian, M., Martin, D.J. (1972)
Economics of Great Lakes bulk carriers in winter operations: Final report, 160p. NTIS: COM-73-10931.

351. Nowacki, H., Benford, H., Atkins, A. (1973)
Economics of Great Lakes shipping in an extended season: Interim report, 93p. NTIS: COM-73-10930.

352. Nowacki, H., ed. (1975)
Great Lakes winter navigation. Technical and economic analyses. Michigan. University. Department of Naval Architecture and Marine Engineering, 6 volumes. NTIS: PB-270 932-SET (paper copy unit).

353. Oberlin, D.W. (1973)
Mighty teenager. (St. Lawrence Seaway) World Ports, 35(5), p. 10-11, 20-22.

354. O'Dell, J.E., Frisch, J.V. (1976)
Great Lakes water levels: an update : beat the seaway freeze. NOAA Magazine, 6(1), p. 32-39. NTIS: PB-256 715.

*355. Perham, R.E., Racicot, L. (1975)
Forces on an ice boom in the Beauharnois Canal. In: International Symposium on Ice Problems, 3rd, Hanover, NH. August 18-21, 1975. Proceedings, ed. by G.E. Frankenstein, p. 397-407. International Association of Hydraulic Research.

*356. Potok, A.J. (1978)
Analysis of the effect on Lake Ontario water levels of maintaining year-round safe navigation depths in the St. Lawrence River. U.S. National Oceanic and Atmospheric Administration. Great Lakes Environmental Research Laboratory. GLERL Contribution 136, 43p.

357. Quinn, F.H. (1973)
Effects of ice retardation of Great Lakes water levels. In: Conference on Great Lakes Research, 16th, Huron, OH. April 16-18, 1973. Proceedings, p. 549-555. International Association for the Great Lakes Research.

358. Ramseier, R.O., Dickins, D.F., Weaver, R.J. (1974)
Ice information, Montreal-Lake Ontario section, St. Lawrence River. Navigation season extension studies, Gulf of St. Lawrence to Great Lakes, winter 1972-73. 14p.

359. Ramseier, R.O., Dickins, D.F., Weaver, R.J. (1973)
Ice information, Thousand Islands area, Montreal, Lake Ontario section, St. Lawrence River. Navigation season extension studies, Gulf of St. Lawrence to Great Lakes, winter 1971-72, 12p.

*360. Russell, B.E. (1972)
Ice formation in Lake Erie and the Niagara River, its effects and control. International Symposia on the Role of Snow and Ice in Hydrology, Banff, Canada, Sept 1972. Proceedings, v.2, p. 1442-1463. Unesco-WMO-IAHS.

361. Schenker, E., Smith, D. (1972)
Economic merits of extending the St. Lawrence Seaway navigation season. In: Conference on Great Lakes Research, 15th, 1972. Proceedings, p. 737-750. NTIS: COM-73-11540.

362. Schenker, E., Kochan, J. (1970)
Preliminary investigation - extending the shipping season on the St. Lawrence seaway. 23p. NTIS: PB-192 591.

363. Schwerdt, R.W. (1972)
Great Lakes navigation, 1971. Mariners Weather Log, 16(3), p. 148-164.

364. Swift, P.M., Benford, H. (1975)
Economics of winter navigation in the Great Lakes and St. Lawrence seaway. 13p. Available from: Society of Naval Architects and Marine Engineers, One World Trade Center, Suite 1369, New York, NY 10048.

365. Thiele, E.H. (1960)
Ice problem. Shipping and Navigation Problems of the Great Lakes and St. Lawrence Seaway, Papers delivered at a Meeting of the Princeton University Conference, Jan. 19-20, 1960. Princeton Conference Series, no. 21, 123p.

366. U.S. Army Engineer District, Detroit, MI. (1973)
Navigation season extension demonstration program: final environmental impact statement. 285p. NTIS: EIS-MI-1933-F.

367. U.S. Coast Guard (1973)
Coast Guard icebreaking activity on the Great Lakes: draft environmental impact statement. 31p. NTIS: EIS-AA-73-1677-D.

*368. U.S. Coast Guard. Canada. Coast Guard (1979)
Joint U.S. Coast Guard - Canadian Coast Guard guide to Great Lakes ice navigation. 33p.

*369. U.S. Guard (1976)
Ninth Coast Guard District domestic icebreaking plan, Annex W to CCGD Nine Operation Plan No. 1-(FY). Office of the Commander, Ninth Coast Guard District, Cleveland, OH.

370. U.S. Department of Transportation. Transportation Research Board. Maritime Research Information Service. (1978)
Marine systems in frigid environments: bibliography. Available from: Transportation Research Board Publications Office, Maritime Research Information Service, Washington DC, 20418. 35p.

371. U.S. Lake Survey. (1973)
Great Lakes - St. Lawrence Seaway navigation season extension. Mariners Weather Log, 17(3), p. 135-139. NTIS: COM-73-90027-03.

372. U.S. National Oceanic and Atmospheric Administration.
Monthly Weather Review. In each issue is a description of Northern Hemisphere weather and circulation for the third month preceding the issue date. Available from U.S. Government Printing Office, order no. C55.11.

*373. U.S. National Oceanic and Atmospheric Administration. Environmental Data and Information Service.
Mariners Weather Log, bimonthly. Contains meteorological and climatological information for use by the maritime industry and cooperative National Weather Service marine observers, including ice navigation season summaries. Available from NOAA/NODC/EDIS, Washington DC 20235.

*374. U.S. National Oceanic and Atmospheric Administration. National Ocean Survey. (1980) United States Coast Pilot 6, Great Lakes Pilot. NOAA/NOS, Washington, DC. 505p.

375. Anonymous (1069)
Air cushion vehicle thwarts barrier to winter water data. Environmental Science and Technology, 3(4), p. 324-325.

376. Anonymous (1976)
Canadian CG develops ACV icebreaking technique. Ship and Boat International, 29(12), 2 p.

377. Anonymous (1977)
Iceater - first of a new breed. Hovering Craft and Hydrofoil, Aug. 1977. Available from: Engineering Societies Library, 345 East 47th Street, New York, NY 10017. Unpaged.

378. Anonymous (1978)
Innovative icebreaker in service. Harbour and Shipping, August 1978. Unpaged.

379. Anonymous (1977)
New-type icebreaking bow for Great Lakes bulk carriers. Available from: British Ship Research Association, Wallsend Research Station, Wallsend, Northumberland, England. Order no. BSRA 47,077.

380. Anonymous (1972)
Sub-ice tests promising for extending shipping season. World Dredging and Marine Construction, 8(9), p. 9-11.

381. Anonymous (1978)
Vital statistics of the Coast Guard fleet. Canadian Shipping and Marine Engineering, 48(11), p. 24-29.

382. Anonymous (1972)
Methods to improve Great Lakes bulk carrier performance in mush ice fields and clogged channels. Arctec, Inc., Columbia, MD. 2 v., 229p. NTIS: COM-73-10937-SET.

383. Beckett, C.J. (no date)
Grounding of the Imperial St. Clair - a case history of contending with oil in ice. Transport Canada. Central Region. Canadian Coast Guard, Toronto, Ont. M5E 1E5, Canada. 5p.

*384. Boulanger, F., Dumalo, E., LeVan, D., Racicot, L. (1975)
Ice control study, Lake St. Francis - Beauharnois Canal, Quebec-Canada. In: International Symposium on Ice Problems, 3rd Hanover, NH, Aug. 18-21, 1975. Proceedings, ed. by G.E. Frankenstein, p. 39-48. International Association of Hydraulic Research.

*385. Brierley, W.H., Calkins, D.J., DenHartog, S.L., Mellor, M., Ueda, H.T. (1975)
Lock wall deicing with water jets: field tests at ship locks in Montreal, Canada and Sault Ste. Marie, Michigan. U.S. Army. Cold Regions Research and Engineering Laboratory. Special Report 239, 19p. NTIS: AD-021 768.

*386. Bruun, P., Straumsnes, A. (1970)
Piling up of ice on seashores and on coastal structures. In: Symposium on Ice and its Action on Hydraulic Structures, Reykjavik, Iceland, Sept. 7-10, 1970. Papers and discussions, 7p. International Association for Hydraulic Research.

*387. Calkins, D.J., Mellor, M. (1975)
Cost comparisons for lock wall deicing. In: International Symposium on Ice Problems, 3rd, Hanover, NH, August 18-21, 1975. Proceedings, p. 59-67. International Association for Hydraulic Research.

388. Cavan, B.P. (1969)
Literature review of dusting technology in deicing. U.S. Army. Corps of Engineers. Lake Survey. Research Report no. 5-7, 15 p.

*389. Clapper, R.T., jr., Smith, D., Stortz, K., Sydor, M. (1975)
Ice growth studies in Duluth-Superior harbor 1974-75. Final report, 70p. NTIS: PB-272 170.

390. Cowley, J.E., Hayden, J.W., Willis, W.W. (1977)
Model study of St. Marys River ice navigation. Canadian Journal of Civil Engineering, 4(3), p. 380-391.

391. Doud, J.O. (1978)
Ice sheet loads on marina piles. American Society of Civil Engineers. Waterway, Port, Coastal, and Ocean Division. Journal, 104(WW1), p.11-17.

392. Dunne, M., Noble, P. (1977)
Results of full-scale ice impact load studies aboard C.C.G.S. Norman McLeod Rogers. In: International Conference on Port and Ocean Engineering under Arctic Conditions, 4th, Newfoundland, 26-30 Sept. 1977. Proceedings, p. 440.

393. Edwards, R.Y., jr., Lewis, J.W., Wheaton, J.W., Coburn, J.L., jr. (1972)
Full-scale and model tests of a Great Lakes icebreaker. Available from: Society of Naval Architects and Marine Engineers, One World Trade Center, Suite 1369, New York, NY 10048. 31 p.

*394. Foulds, D.M., Wigle, T.E. (1977)
Frazil--the invisible strangler. American Water Works Association. Journal, 69(4), p. 196-199.

395. Frankenstein, G.E. (1961)
Strength data on lake ice. U.S. Army. Snow Ice and Permafrost Research Establishment. SIPRE Technical Report 80, 23p. NTIS: AD-701 054; PB-163 661.

396. Freitag, D.R. (1972)
Application of ice engineering and research to Great Lakes problems. Federal Conference on the Great Lakes, 1st, Ann Arbor, MI, Dec. 13-15, 1972. Proceedings, p. 131-138. U.S. Environmental Protection Agency.

397. Hackman, D.J., Brunel, R.L. (1973)
Design of a combination bubbler-guidance system to be installed in Whitefish Bay, Michigan. 116p. NTIS: AD-773 345.

398. Johansson, B.M., Makinen, E. (1973)
Great Lakes ore carrier series - ice resistance model test program in loaded condition. Final report, 1973. 229p. NTIS: COM-74-10424.

399. Johansson, B.M., Makinen, E. (1973)
Icebreaking model tests ordered by the U.S. Maritime Administration from Wartsila systematic variation of bow lines and main dimensions of hull forms suitable for the Great Lakes. Available from: Society of Naval Architects and Marine Engineers, One World Trade Center, Suite 1369, New York, NY 10048. Unpaged.

400. Kaldjian, M.J., Huang, K.N. (1974)
Great Lakes winter navigation. Technical and economic analyses. Volume V. Ice strengthening of ship hulls using steel, ferrocement or reinforced concrete. 38p. NTIS: PB-270 987; Set of 6 volumes available as PB-270 982-SET.

401. Kaldjian, M.J., Townsend, W.H., Kahn, L.F., Huang, K.N. (1974)
Great Lakes winter navigation. Technical and economic analyses. Volume IV. Strengthening steel plates using ferrocement and reinforced concrete. 74p. NTIS: PB-270 986; Set of 6 volumes available as PB-270 982-SET.

402. Kaldjian, M. (1973)
Ice strengthening of Great Lakes ore carriers -- a computer-aided analysis. 24p. NTIS: COM-73-10932.

403. Kotras, T.V., Kosterich, P.P., Voelker, R.P. (1977)
Ice impact forces on the bow of a Great Lakes bulk carrier. 100p. NTIS: PB-281 696.

404. Laine, A., Johansson, B.M., Makinen, E. (1973)
Great Lakes ore carrier series - ice resistance model tests in ballast conditions. 148p. NTIS: COM-74-10425.

405. Lawrie, C.J.R. (1972)
Ice control measures on the St. Lawrence River. Eastern Snow Conference, 29th. Proceedings, p. 123-146.

406. Lecourt, E.J. (1975)
Icebreaking model tests of the 140-Foot WYTM. 92p. NTIS: ADA-020324.

407. Levine, G.H., Voelker, R.P., Mentz, P.B. (1974)
Advances in the development of commercial ice-transiting ships. Available from: Society of Naval Architects and Marine Engineers, One World Trade Center, Suite 1369, New York, NY 10048. 26p.

408. Levine, G.H., Roth, J.C. (1973)
Full scale tests of Great Lakes bulk carrier Leon Fraser in ice fields 1972-73. Part II: Instrumentation manual. 56p. NTIS: COM-7310935; Set of 3 volumes available as COM-73-10933-SET.

409. Levine, G.H. (1973)
Full-scale tests of Great Lakes bulk carrier Leon Fraser in ice fields 1972-73. Part III: Air coating system design. 85p. NTIS: COM-73-10936; Set of 3 volumes available as COM-73-10933-SET.

410. Levine, G.H., Mentz, P.B., Ransom, W.R. (1974)
Improving ship operations in ice covered waters. Marine Technology Society. Journal, 8(8), p. 54-57.

411. Levine, G.H., Voelker, R.P., Kotras, T.V., Kosterich, P.P., Peter, J.J. (1974)
Results from two years of testing a Great Lakes ore carrier in ice fields. Volume I. 153p. NTIS: PB-267 407.

412. Levine, G.H., Voelker, R.P., Kotras, T.V., Kosterich, P.P., Peter, J.J. (1974)
Results from two years of testing a Great Lakes ore carrier in ice fields. Volume II. 121p. NTIS: PB-267 408.

413. Lewis J.W., Benze, D.L., Etzel, R.A. (1979)
Saint Lawrence River ice boom modification study. 287p. NTIS: PB 80-114317.

414. Lutton, T.C. (1972)
Air cushion vehicle evaluation. San Francisco, California, St. Ignace, Michigan, Milford Haven, Virginia. Transpo 72. 1 September 1971-30 June 1972 - Evaluation report. U.S. Coast Guard. Air Cushion Vehicle Evaluation Unit. 148p. NTIS: AD-755 409.

415. Major, R.A., Berenger, D.M., Lawrie, C.J.R. (1975)
Model to predict hull-ice impact loads in the St. Lawrence. Available from: Society of Naval Architects and Marine Engineers, One World Trade Center, Suite 1369, New York, NY 10048. 23p.

416. Mellor, M., Vance, G.P., Wuebben, J.L., Frankenstein, G.E. (1978)
Investigation of ice clogged channels in the St. Marys River. U.S. Army Cold Regions Research and Engineering Laboratory. 73p. NTIS: ADA-058015.

*417. Mellor, M. (1979)
Towing ships through ice-clogged channels by warping and kedging. U.S. Army. Cold Regions Research and Engineering Laboratory. Report 79-21. 28p. NTIS: ADA-077 801.

418. Mentz, P.B. (1974)
Improving ship operations in ice covered waters. Marine Technology Society. Journal, 8(1), p. 54-57.

419. Milano, V.R. (1975)
Ship resistance to continuous motion in mush ice. Available from: Society of Naval Architects and Marine Engineers, One World Trade Center, Suite 1369, New York, NY 10048. 32p.

420. Oswalt, N.R. (1976)
Ice flushing from St. Lawrence Seaway locks. Final report. 49p. NTIS: ADA-028 021.

421. Perham R. (1974)
Forces generated in ice boom structures. U.S. Army. Cold Regions Research and Engineering Laboratory. Special Report 200. 39p. NTIS: AD-775 822.

422. Perham, R.E. (1978)
Ice and ship effects on the St. Mary's River ice booms. Canadian Journal of Civil Engineering, 5(2), p. 222-230.

423. Perham, R.E. (1978)
Performance of the St. Mary's River ice booms, 1976-1977. U.S. Army. Cold Regions Research and Engineering Laboratory. Report 78-24. 21p. NTIS: ADA-061 431.

424. Perham, R.E. (1977)
St. Marys River ice booms - design force estimate and field measurements. U.S. Army. Cold Regions Research and Engineering Laboratory. Report 77-4. 34p. NTIS: ADA-037 902.

*425. Peter, J.J., Kotras, T.V. (1975)
Simulation of lock operation during winter months. In: International Symposium on Ice Problems, 3rd, Hanover, NH, August 18-21, 1975. Proceedings, ed. by G.E. Frankenstein, p. 49-58. International Association Hydraulic Research.

426. Pruden, F.W., Wardlaw, R.L., Baxter, D.C., Orr, J.L. (1954)
Study of wintertime heat losses from a water surface and of heat conservation and heat addition to combat ice formation in the St. Lawrence River. National Research Council, Canada. Division of Mechanical Engineering. Report, June 30, 1954-MD-42, 200p.

427. Roos, A., Juurmaa, L., Syrjala, H., Makinen, E., Mentz, P.B. (1976)
Great Lakes ore carrier series ice resistance model test program. Method for predicting level ice resistance of ships with main dimensions typical for the Great Lakes bulk carriers. 34p. NTIS: PB-266 815.

428. Rosenberg, H.B. (1968)
Hydraulic factors affecting thermal power plant location in Great Lake (sic) region. In: International Conference on Water for Peace, Washington, DC, May 23-31, 1967. Water for peace, v. 6, p. 207-216. U.S. Government Printing Office.

*429. Rumer, R.R., Atkinson, C.H., Lavender, S.T. (1975)
Effects of Lake Erie-Niagara River ice boom on the ice regime of Lake Erie. In: International Symposium on Ice Problems, 3rd, Hanover, NH, Aug. 18-21, 1975. Proceedings, ed., by G.E. Frankenstein, p. 289-299. International Association of Hydraulic Research.

*430. Russell, B.E. (1973)
Ice formation in Lake Erie and the Niagara River, its effects and control. In: International Symposia on the Role of Snow and Ice in Hydrology, Banff, Canada, Sept. 1972. Proceedings, v.2, p. 1442-1463. Unesco-WMO-IAHS.

431. Snyder, J.C., Ball, M. (1977)
Air cushion icebreaker. Offshore Technology Conference, 1977. Proceedings, p. 289-298.

432. Tsang, G. (1975)
Ice conditions and the proposed containment and removal of spilled oil on St. Clair and Detroit Rivers. Canada. Inland Waters Directorate. Scientific Series, no. 56, 25p.

433. U.S. Coast Guard. Office of Engineering. Naval Engineering Division. (1978)
Preliminary design report for a Great Lakes and eastern Arctic icebreaker. U.S. Government Printing Office order no. TD5.2-IC2/3, 205p.

434. U.S. Coast Guard (1971)
Test project 721314, small scale explosive icebreaker, Muskegon, Michigan. 8p. NTIS: PB-204 463.

*435. Vance, G.P. (1980)
Analysis of the performance of a 140-foot Great Lakes icebreaker: USCGC Katmai Bay. U.S. Army. Cold Regions Research and Engineering Laboratory. Report 80-8, 28 p.

436. Virtanen, J., Johansson, B.M., Makinen, E., Mentz, P.B., Rinehart, V. (1975)
Great Lakes ore carrier series ice resistance model tests draft variation. 94p. NTIS: PB-266 816.

437. Voelker, R.P. (1973)
Full scale tests of Great Lakes bulk carrier Leon Fraser in ice fields 1972-73. Part I: Trial manual. 92p. NTIS: COM-73-10934; Set of 3 volumes available as COM-73-10933-SET.

438. Voelker, R.P., Kim, J.K. (1976)
Summary results of ice resistance tests for Great Lakes bulk carriers from the Wartsila model test series. 372p. NTIS: PB-281 695.

439. Voelker, R.P., Kim, J.K. (1978)
Test and evaluation of ice transiting bow forms for Great Lakes bulk carriers. 156p. NTIS: PB-281 697.

*440. Webb, M.S. (1973)
Assessment of the effect of the Niagara ice boom on ice conditions in eastern Lake Erie. Canada. Atmospheric Environment Service, TEC 795, 21p.

*441. Webb, W.E. (1975)
Ice problems in locks and canals on the Saint Lawrence River. In: International Symposium on Ice Problems, 3rd, Hanover, NH, Aug, 18-21, 1975. Proceedings, ed. by G.E. Frankenstein, p. 15-24. International Association of Hydraulic Research.

442. Welsh, J.P., jr. (1972)
Ice properties and their relationship to ship transit in the Great Lakes. Federal Conference on the Great Lakes, 1st, Ann Arbor, MI, Dec. 13-15, 1972. Proceedings, p. 274-287. U.S. Environmental Protection Agency.

443. Williams, G.P. (1967)
Ice-dusting experiments to increase the rate of melting of ice. National Research Council, Canada. Division of Building Research. Technical Paper no. 239.

444. Wortley, C.A. (1972)
Lake Superior marinas resist ice and snow. Civil Engineering, 422(2), p. 47-50.

445. Wortley, C.A. (no date)
Small-craft harbor structures design for lake ice. 12p. University of Wisconsin, Department of Engineering, Madison, WI 53706.

Snow and Avalanche Research in France

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On 10 February 1970, the "Aiguille du front" avalanche in Val d'Isere was responsible for 39 casualties, setting off a wave of fear in France. This avalanche also emphasized the lack of applied research in the fields of snow and avalanches. The French government quickly set up an official committee assigned two tasks: to find the reasons for the fatalities; and to make proposals for preventative measures so that such a disaster would never again be possible.

It was not necessary to start from scratch in 1970 because researchers in various government departments were already dealing with snow questions; but there was no service officially charged with studying such problems as avalanche forecasting, avalanche zoning, etc. Taking advantage of the significant amount of money granted by the authorities, France has had the opportunity to develop applied research in the area of snow and avalanches. This paper describes the current French organization for snow and avalanche research and the applications of the research to forecasting avalanches and protecting life and property.

The Centre d'Etudes de la Neige (CEN), which is a part of the Etablissement de'Etudes et de Recherches Météorologiques (EERM), the research organ of the Météorologie Nationale, (Delsol, 1975), carries out studies on the mechanical properties of snow. For example, CEN has studied temperature-gradient metamorphism and snow-slab formation. Currently, it is designing an automatic station for measuring local properties of snow and transmitting them via satellite relay. It has developed several statistical models for mountain precipitation, snow rheology, and avalanche forecasting. CEN is also responsible for avalanche forecasting and consequently receives information from 67 stations scattered in the Alps and Pyrenees. CEN prepares tapes giving information about snow and weather conditions, so that mountain travelers may telephone for up to date information.

The Centre Technique du Génie Rural, des Eaux et des Forêts (CTGREF), the technical center for rural engineering, water and forest, deals with avalanche protection. This involves location and mapping of avalanche hazards (with two successive scales, 1:25 000 and 1:2 000), and avalanche control by means of structures or artificial avalanche release. Since 1969, CTGREF has also carried out experimental studies on avalanche dynamics by measuring pressure, local velocity, front velocity, density, etc. It also prepared two models for theoretical calculations: a numerical model for dense avalanches and an analog model for powder avalanches.

Among the other offices contributing to applied research on snow and avalanches are the University of Grenoble and the Centre d'Etudes Nucleaires. Along with CEN and CTGREF, these offices are located in Grenoble. An important role is played by the various departments of the Office National des Forêts, (ONF), which reports local conditions to the various research centers. Among other tasks, ONF collects information about avalanche activity and also takes part in avalanche prevention work.

The work of every person or department concerned with avalanches is coordinated by the National Association for Snow and Avalanche Study (ANENA). It comprises representatives of research centers, as well as those concerned with the application of research, i.e. mayors, ski resort engineers, road and building departments, the army, the rescue corps, etc.

The main concern of French authorities when founding snow research centers at the beginning of the 1970s was the necessity for avalanche mapping. Nearly 6000 km^2 were mapped on the scale of 1:25 000 and each mountain community has restricted building in hazard zones. It is possible to continue improving the community maps by plotting new avalanches as they occur.

However, in spite of the large-scale disaster like that at Val d'Isere, the increase in popularity of winter mountaineering will probably bring a number of casualties during the 1980s. These casualties may not seem so impressive because they are scattered, but the annual totals are significant. The need for better information about the dangers of snow for skiers, and other mountain travelers, mandates continued avalanche research.

Bibliography

Delsol, F. (1975) La prevision du risque d'avalanche. The forecasting of avalanche hazard. Introduction. Neige et Avalanches, no. 11, p. 55-57.

Meyer, L. (1975) Historique et description de l'organisation actuelle. History and description of the present organization. Neige et Avalanches, no. 11, p. 58-63.

Snow Survey of the Northern Hemisphere

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ıtroduction

Snow depth and snow cover charts have been produced in the CLIMAT LAB of the Snynoptic Climatology branch f the U.K. Meteorological Office headquarters, for the regions and periods noted below. This U.K. series is rimarily for use in operational long-range forecasting. It is complemented by certain U.S. and German charts.

I. Charts of Reported Surface Data

A. Central Europe and Scandinavia, 1953-1961: one day's data was plotted in each five-day period (pentad). The area covered is 70N 00E - 70N 30E; 40N 00E - 70N 30E; the scale is 1:30 M. Representative stations used were: from Norway (4 stations), Sweden (6 stations), Finland (4 stations), East Germany (7 stations), Poland (8 stations), and West Germany (approximately 24 stations).

B. Europe/Asia, 1962 to 1970: one day of data was plotted towards the end of each half month and also when required for forecast purposes. The area covered is 30N 130W - 30N 130E; 30 N 50W - 20N 60E; the scale is 1:30 M.

C. North America/Europe/Asia, 1971 to date: one day's data is plotted towards the end of each five-day period. The chart area and scale are the same as I B.

Charts were not produced on a few occasions in high summer when no snow depths were received.

II. Mapping of Snow Cover - Asia and Europe Using Satellite Imagery

Mapping of snow cover was experimentally carried out from December 1975 to March 1978. Six-day runs of Visible satellite imagery were analyzed by a minimum brightness method (independently evolved by Painting and Taylor, unpublished) to establish a snow/no snow-cover state. The snow-limit line so determined proved a useful addition to the ground plots. It was also helpful for regions in central and eastern Asia where snow-lying information is not readily obtainable in real time. This analysis temporarily ceased in March 1978 on the failure of NOAA 5 sensors. It will recommence when suitable alternative sources of data are available.

III. Current Practice

Charts are plotted at approximate pentad intervals from synoptic data, except for a few occasions in high summer when no snow is reported on the mainlands of Asia and North America. Snow depth and state-of-ground reports are extracted automatically from the Synoptic Data Bank for all stations in World Meteorological Organization (WMO) blocks of 01 to 40. For North America (Alaska, Canada, and the United States) use is made of the special 0000 Gmt snow bulletin for that region broadcast on the Global Telecommunication System (GTS). Data are hand plotted on a segment of a 1:30 M circumpolar chart on a polar stereographic projection. A 1" (2-5 cm) isopleth is drawn together with either:

A. The 50 percent probability of 1" depth of snow line at the end of the months, September, October, November, April, and May (Dickson and Posey, 1967), or

B. The mean monthly snow cover limit line for the months of December, January, February, and March (Wiesnet and Matson, 1977).

Fluctuations of the snow line with respect to the mean are readily apparent, and the situations are studied in the long range forecast discussions in connection with thermal conditions of the surface.

For the earlier series of charts, 1953-1962, data were extracted for a special project from the year books of the countries mentioned in I A. The U.S. and German, Deutscher Wetterdienst (DWD), charts received at Bracknell are used as a back-up and when additional information is required.

For a report on the Snow Survey of Great Britain, see Ogden, 1979.

BOOK NOTES

New books of interest include:

Colbeck, S.C., ed. (1980) Dynamics of Snow and Ice Masses. New York, Academic Press, 468p.

Rossiter, J.R.; Bazeley, D.P., eds. (1980) International Workshop on the Remote Estimation of Sea Ice Thickness. Proceedings of a workshop held 25-26 September 1979, at St. John's, Newfoundland. C-Core Publication no. 80-5. St. John's, Newfoundland, Centre for Cold Ocean Resources Engineering, 505p.

Tryde, P., ed.(1980) Physics and Mechanics of Ice. Proceedings of the IUTAM Symposium Copenhagen, 6-10 August 1979. Berlin, New York, Springer-Verlag, 378p.

MEETINGS

WDC-A Radio Glaciology Workshop

A Radio Glaciology Workshop, organized by the World Data Center-A for Glaciology (Snow and Ice), will be held on 4-5 September 1981, in conjunction with the Third International Symposium on Antarctic Glaciology in Columbus, Ohio.

The Workshop will focus on two areas of radio glaciology: data acquisition and processing, and data archiving and distribution. Topics to be considered in the first category include: hardware specifications relating to data quality and quantity; the merits of analog and digital output modes; and post-processing techniques including: 'cleaning', analog compression, A/D conversion, and digital signal processing. A quantitative evaluation of the accuracy of positioning techniques will also be considered. Finally, there will be a review of interpretation problems associated with different display modes.

The second focus of the Workshop will address the development of an archiving and distribution policy for radio glaciology data. Topics for consideration include defining the needs, concerns, and constraints of the radio glaciology community regarding the availability of data, the variety of data products, and the potential for standardization and quality control in a data management environment. Consideration will also be given to data management plans for new data acquisition systems, such as those on satellites.

The Workshop will produce a working document summarizing the key scientific, technical, and data management needs relating to radio glaciology data acquisition, processing, archiving, and distribution.

For details of the Workshop and preregistration contact:

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Fourth International Conference on Permafrost

The Fourth International Conference on Permafrost, organized by the National Academy of Sciences and the State of Alaska, will be held 18-22 July 1983, at the University of Alaska at Fairbanks.

This meeting will deal with all aspects of permafrost and will be of widespread interest to scientists, engineers, and societies concerned with engineering, periglacial and glacial geology, soils, geophysics, marine, and pipeline technology, climatology, hydrology, and ecology.

Topics

Papers dealing with all aspects of permafrost will be welcome. Papers will be accepted for formal presentation or for poster sessions. Details about the submission of abstracts and final papers will be given in the first bulletin (spring, 1981).

Provisional themes for the meeting include:

1. Pipeline construction
2. Embankments (roads, railroads, airfields, drill pads, etc.)
3. Deep foundations
4. Excavations
5. Mining and petroleum engineering
6. Municipal engineering
7. Site and terrain evaluation
8. Geotechnical problems
9. Geophysical exploration
10. Hydrates
11. Subsea permafrost
12. Distribution of permafrost (regional studies)
13. Frost heave and ice segregation
14. Physics and chemistry of frozen ground
15. Hydrology
16. Climate change and geothermal regime
17. Ecology of natural and disturbed areas
18. Planetary permafrost
19. Periglacial phenomena (geocryology)
20. Mechanics of frozen soil
21. Heat transfer processes
22. Other

Publication

The proceedings of the Conference will be published. Papers will be reviewed according to the usual standards before being accepted for publication.

Field Trips

Permafrost underlies 85 percent of Alaska and affects many aspects of daily life in the state. The location of the Conference is therefore ideal for viewing numerous features of continuous and discontinuous permafrost, and construction techniques used to cope with it. Field trips of 3 to 5 days duration are planned to be held before and after the Conference. Local half-day trips will take place during the Conference. Fairbanks permafrost features of interest include frost heave sites, ice wedge exposures, experimental road construction, agricultural practices, strip mining, and tunnel excavation.

Proposed extended trips include the Alaska Railroad (construction techniques in mountainous and permafrost terrain, Mt. McKinley National Park); Fairbanks to the Prudhoe Bay oil field along the trans-Alaska pipeline; Fairbanks to the Mackenzie River Delta by road (periglacial and glacial geology features); and Fairbanks to Anchorage by road through the Copper River Basin.

Cost

A full range of accommodations will be available, including hotels in Fairbanks and inexpensive housing in dormitories on campus. A registration fee will be charged which will cover the cost of conference documents and local field trips. Charter flights to Alaska may be available if there is sufficient interest.

If you want to receive the first bulletin, please contact:

Louis De Goes, Executive Secretary
Polar Research Board
National Academy of Sciences
2101 Constitution Avenue, N.W.
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or

Troy L. Péwé, Chairman
U.S. Organizing Committee
Department of Geology
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Tempe, AZ 85281.

GLACIOLOGICAL DATA SERIES

Glaciological Data, which supercedes *Glaciological Notes*, is published by the World Data Center A for Glaciology {Snow and Ice} several times per year. It contains bibliographies, inventories, and survey reports relating to snow and ice data, specially prepared by the Center, as well as invited articles and brief, unsolicited statements on data sets, data collection and storage, methodology, and terminology in glaciology. Contributions are edited, but not refereed or copyrighted. WDC publications are distributed without charge to interested individuals and institutions.

Scientific Editor: Roger G. Barry
Technical Editor: Ann M. Brennan
Technical Staff: Claire S. Hoffman, Margaret Strauch, and Carol Pedigo

The following issues have been published to date:

- GD-1, *Avalanches*, 1977
- GD-2, Parts 1 and 2, *Arctic Sea Ice*, 1978
- GD-3, *World Data Center Activities*, 1978
- GD-4, Parts 1 and 2, *Glaciological Field Stations*, 1979
- GD-5, *Workshop on Snow Cover and Sea Ice Data*, 1979
- GD-6, *Snow Cover*, 1979
- GD-7, *Inventory of Snow Cover and Sea Ice Data*, 1979
- GD-8, *Ice Cores*, 1980

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