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GLACIOLOGICAL DATA

WORKSHOP ON SNOW COVER AND SEA ICE DATA

World Data Center A
for
Glaciology
[Snow and Ice]

MAY 1979

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An Arctic Sea Ice Data Set, 1901-1956

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The Climatic Research Unit, University of East Anglia, is engaged in a feasibility study of the potential for Arctic sea ice prediction on climatic time scales. The main stages in this research are summarized in appendix I. The program includes the collection of sea ice data for the Arctic covering the 20th century; the statistical analysis of these data to identify the major fluctuations in sea ice extent, both spatially and temporally; correlation with climatic and atmospheric circulation data to determine the immediate causes of these sea ice variations, not excluding the possibility of feedback; and research, both theoretical and empirical, aimed at achieving the degree of understanding of the causes of these variations in climate and sea ice which is a necessary prerequisite to any predictive effort. This paper deals with the first stage in this research: the collection of Arctic sea ice data for the 20th century.

Ongoing digitizing projects by Walsh (1978) and Kukla (personal communication) are concerned with data for the last 25 years or so, but few digitized data are available for the first half of the 20th century. Pronounced changes in sea ice extent occurred during this period, which is considered to be without a climatic parallel during the last few hundred years (Kelly, 1975; Lamb and Morth, 1978). In order to extend the existing sea ice data base, we have digitized, and are currently assessing the reliability of, the circumpolar ice limit contained in a chart series produced by the Danish Meteorological Institute (DMI) for the period 1901 to 1956 (Thomsen, 1947).

During the 1890's, the DMI published reports of ice conditions in the Davis Strait, and later between Greenland and Novaya Zemlya, in the Institute's Yearbook (Nautisk- Meteorologiske Aarbog). In 1900, this work was extended to cover all Arctic regions where data were available. Information was obtained from sources in Canada, Germany, Great Britain, Norway, Sweden, the United States, and the USSR. These observations originated from naval and merchant shipping, shore observers, and, in later years, aircraft reconnaissance. During the periods 1901-39 and 1946-50, the Institute published an annual report, The State of the Ice in Arctic Seas. This publication contained, as text, summaries of the ice extent in the months and regions for which observations were available, and, on multicolored charts, compilations of these observations for the months of April to August (occasionally September) when most information was available.

The observations were plotted on a polar stereographic projection of the Arctic. Direct observations of polar fast ice, winter fast ice, big ice floes, close drift ice, open drift ice, icebergs, and bergy bits were plotted in red, with the date of observation occasionally given. In addition, a red curve indicated observed limits between open sea and ice where available; a dashed line gave a climatological "normal" ice limit (for a period of years which changed during the chart series); and, as defined by a change from a white to a blue-green background on the chart, an ice limit based partially on direct observations and partially on supposition. This final ice limit is henceforward referred to as the estimated ice limit. It indicates the edge of the DMI classification "open drift ice". In certain regions and in certain months, the charts contain the phrase "state of the ice unknown" or "no data", although an estimated ice limit is generally given for such areas.

The number of direct observations plotted on these charts is not great, even in the later years. The coverage is reasonable around Greenland, Iceland, and Spitzbergen. Elsewhere, and particularly in the Western Arctic, the coverage is poor. The question of which information to digitize from the DMI charts posed some problems. Obviously, the direct observations, plotted in red, must be considered the most reliable; however, their variable coverage in space and time precludes rigorous statistical analysis. It was decided, therefore, to digitize the estimated ice limit initially, and perhaps to add to this at a later stage. In regions of good data coverage, the estimated limit conveniently synthesizes the direct observations, and even in regions of poor coverage, may contain some reliable information.

The latitude and longitude coordinates of the estimated ice limit were digitized at a spatial resolution of about 100 km, depending on the distance of the particular set of points from the pole. It was felt that the accuracy of the data and the coarseness of the definition of the limit on the charts did not warrant increased spatial resolution. These coordinates are currently being transferred onto the the grid shown in figure 1. This grid, over the area analyzed in the DMI charts, corresponds to that used by Walsh in his digitization of recent data (Walsh, 1978). The resulting data set will give an ice/no-ice indicator for each square in the grid. At a later stage, details of ice concentration may be substituted for the simple ice/no-ice indicator where data are available. Also, various regions are to be selected for close study, and a finer grid employed.

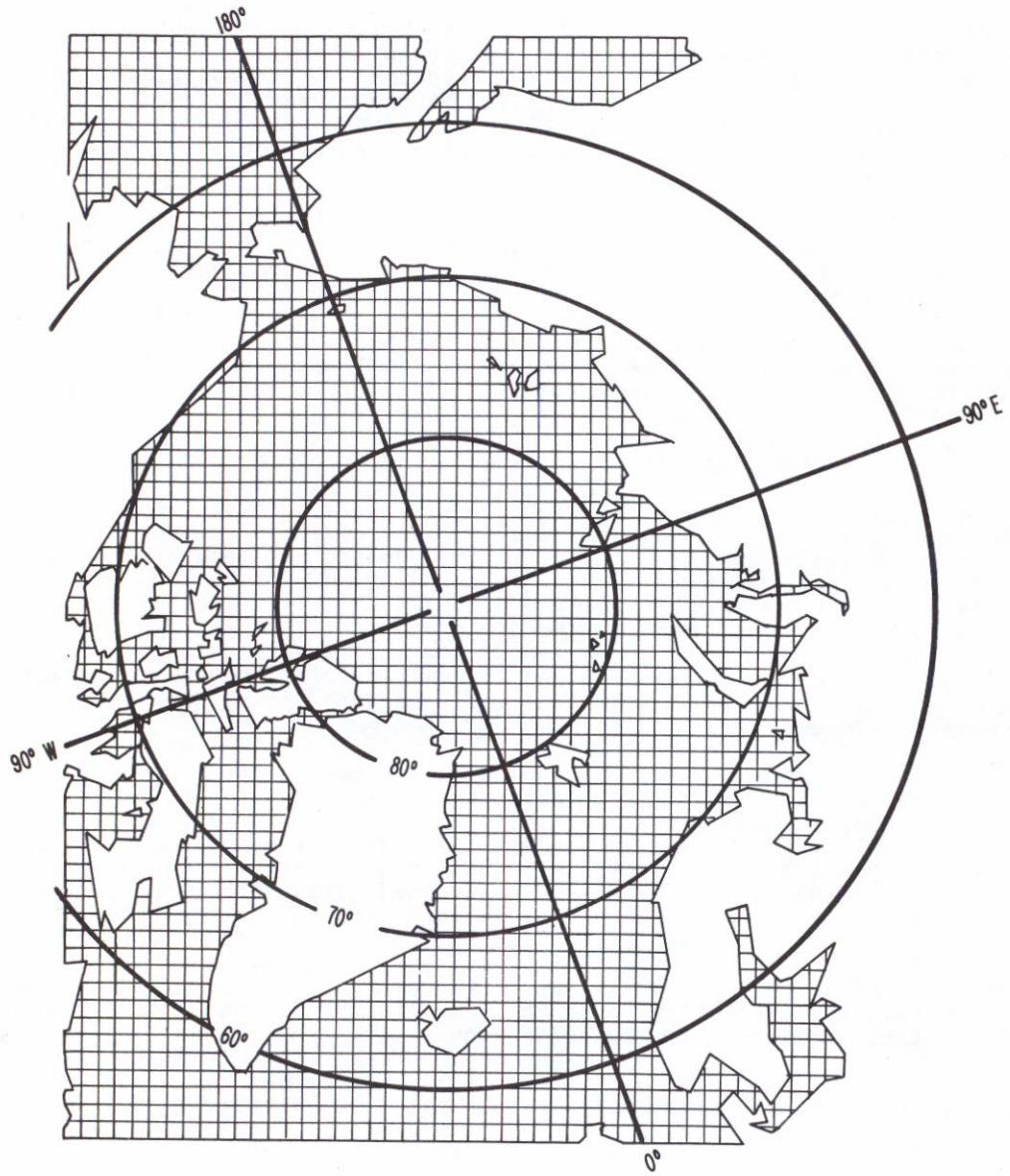

Figure 1. Standard one-degree ice data grid.

As we have digitized the full circumpolar limit, including the estimated limit in regions of little or no data, the question of data reliability or homogeneity is of great importance and is currently being assessed. The following points are being studied:

1. How does the Danish sea ice terminology correspond to recently developed conventions?

2. How reliable were the original shipping and shore observations of sea ice?

3. How, and by whom, were the charts compiled from the direct observations?

4. How was the ice limit estimated in regions of scarce or nonexistent data?

This final question is perhaps the most important. It is obvious that at certain times and in certain regions, the estimated ice limit follows the climatological "normal" also given on the charts. At other times, this is not the case; an extrapolation has somehow been made. There are three fairly obvious possibilities:

1. Extrapolation in space, from adjacent areas where data were available;

2. Extrapolation in time, using data from previous months;

3. Using auxiliary information; perhaps unplotted ice data or possibly climatic or atmospheric circulation data.

The reliability of these estimation methods depends to a great extent on the experience of the chart analyst, and, given the wide variations in sea ice extent during the present century, upon the period of years on which this experience is based. Hence, the importance of determining how, and by whom, the charts were compiled. The preparation of the reports was undertaken by four people during the period 1901-56 -- V. Garde, C.J.H. Speerschneider, H. Thomsen, and M.V.L. Lorck -- well-known names in the history of sea ice investigations.

In order to resolve these problems, two approaches are being taken. First, information pertaining to the compilation of the charts is being sought from the Danish Meteorological Institute and in the relevant scientific literature. Second, various statistical analyses are being undertaken. Principal component or eigenvector analysis is being used to identify the most important spatial patterns of variability in the sea ice and climatic data sets. This technique can also be used to highlight gross errors (Kelly and Chance, 1978). A number of long series of sea extent data at various locations have been collected (see table 1) and these, if based on independent data, will be used to verify the DMI data set. The data set produced by Walsh (1978) overlaps the DMI data set during the period 1953 to 1956 (although it is not strictly independent), and will also be used for comparison purposes.

After this assessment is complete, gross errors will be removed from the DMI data set, the data will be flagged with a reliability rating, and will then be made available to other investigators. A detailed description of the data set will be prepared for publication at that time.

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Table 1. Sea ice data for the Northern Hemisphere.

LOCATION	PARAMETER	PERIOD	SEASON	SOURCE
Arctic Ocean (eastern)	Weighted total of ice in Greenland, Barents and Kara Seas.	1895-1924	April-August	Brooks and Quennel (1928)
Arctic Ocean (eastern)	Index of ice severity in Greenland and Barents Sea and around Spitzbergen.	1897-1938	January-December	Walker (1947)
Kara Sea (a)	Area	1895-1915	April-August	State of the Ice in Arctic Seas: Supplement (1917)
(b)	Severity index	1868-1946		Nazarov (1947)
Barents Sea (a)	Area	1895-1915	April-August	State of the Ice in Arctic Seas (1917)
(b)	Area	1900-1960	April-August	Maksimov, Smirnov and Vorob'ev (1964)
Greenland Sea (a)	Area	1877-1915	April-August	State of the Ice in Arctic Seas: Supplement (1917)
(b)	Area	1924-1968	April-August	Kirillov and Khromtsova (1972)
Iceland	Weeks per year with drift ice on coast	1600-1975	October-September	Lamb (1977), Koch (1945), Thorarinsson (1956)
Baltic (a)	Date of final opening of Port Riga	1530-1958		Lamb (1977), Betin and Preobazensky (1959), Speerschneider (1915, 1927).
(b)	Maximum area	1720-1957		
(c)	Number of days with ice.	1763-1926		
West Greenland	Northward extent of "Storis"	1821-1939		Koch (1945), Lamb (1977)
Newfoundland	Index based on maximum eastward and southward extent of ice	1920-1973	April	Miles (1974)
Western Atlantic: icebergs (a)	Severity index	1886-1939	March-July	Walker (1947)
(b)	Number of icebergs south of 48° N.	1900-1976	September-August	U. S. Coast Guard
Baffin Bay	Date of clearing	1952-1974		Keen (1977), Dunbar (1972)
North Slope, Alaska	Severity index	1953-1976	Summer	Barnett (1978)
Okhotsk Sea	Anomaly of drift ice period (days) at (a) Abashiri (b) Shana	1892-1945		Sawada (1957)

Bibliography

Barnett, D.G. (1976) A practical method of long range ice forecasting for the north coast of Alaska, Part 1. U.S. Fleet Weather Facility. Technical Report TR-1. 16 pp. NTIS: AD-A027 841.

Betin, V.V.; Preobazensky, Iu.V. (1959) Variations in the state of the ice on the Baltic Sea and in the Danish Sound [In Russian]. Moscow. Gosudarstvennyi Okeanograficheskii Institut. Trudy. V. 37, pp 3-13.

Brooks, C.E.P.; Quennel, W.A. (1928) Influence of Arctic ice on subsequent distribution of pressure over the eastern North Atlantic and Western Europe. Great Britain. Meteorological Office. Geophysical Memoirs. V. 4(41).

Danish Meteorological Institute. Nautisk-Meteorologiske Aarbog. (Annual.)

Danish Meteorological Institute (1946-56) The State of the Ice in Arctic Seas. Appendices to Nautical-Meteorological Annuals. Charlottenlund. [published annually]

Dunbar, M. (1972) Increasing severity of ice conditions in Baffin Bay and Davis Strait and its effects on the extreme limits of ice. (In: Karlsson, T. ed Sea Ice: Proceedings of an International Conference. Held 10-13 May 1971, Reykjavik. National Research Council, pp. 87-93.)

Keen, R.A. (1978) The response of Baffin Bay ice conditions to change in atmospheric circulation patterns. International Conference on Port and Ocean Engineering Under Arctic Conditions. 4th, 1977. Proceedings. Held at Memorial University, Newfoundland, pp. 963-971.

Kelly, P.M. (1975) Long-term trends of weather and climate affecting operations at sea. (In: 3rd International Conference for the Exploitation of the Sea and Seabed, Brighton, U.K., 17-21 March 1975. Oceanology International 75. BPS Exhibitions Ltd., 4 Seaford Ct., 220-222 Great Portland St., London W1N 5HH.)

Kelly, P.M. (1978) An Arctic sea ice data set: 1901-1956. Climate Monitor, v. 7(5), pp. 161-163.

Kelly, P.M.; Chance, A. (1978) Spatial and temporal characteristics of mean sea level pressure fluctuations over the northern hemisphere. Unpublished manuscript.

Kirillov, A.A.; Khromtsova, M.S. (1972) Many-year variations of the ice coverage of the Greenland Sea and methods of forecasting it. Aidjex Bulletin, no. 16, pp. 46-55.

Koch, L. (1945) The East Greenland Ice. Meddelelser om Gronland, v. 130(3). 374 pp.

Kukla, G.J.; Kukla, H.J. (1974) Increased surface albedo in the Northern Hemisphere. Did satellites warn of coming weather trouble of 1972 and 1973? Science, v. 183(4126), pp. 709-714.

Lamb, H.H. (1977) Climate: present, past and future. V. 2. London, Methuen and Co., Ltd.

Lamb, H.H.; Morth, H.T. (1978) Arctic ice, atmospheric circulation and world climate. Geographical Journal, v. 144(1), pp. 1-22.

Maksimov, I.V.; Smirnov, N.P.; Vorob'ev, V.N. (1964) Long-range forecasting of secular changes of the ice on the Barents Sea. [In Russian] Publications of the Research Fisheries Ind. Inv., North Basin, Vyp. 4, 75-83. Murmansk: Polar Sc. Res. Inst.

Miles, M.K. (1974) An index of pack-ice severity off Newfoundland and its secular variation. Meteorological Magazine, v. 103, pp. 121-125.

Nazarov, V.S. (1974) Istoricheski khod ledovitosti Karskogo Morya (Historical variation of ice conditions in the Kara Sea). [In Russian] Vses. Geog. Obstich, v. 79(6), pp. 653-655.

Sawada, T. (1957) A study of the statistic forecast of summer temperature over Northern Japan using the amount of sea-ice over Ikhotsk Sea (1). [In Japanese] J. Meteorological Society of Japan, Journal, no. 35, pp. 60-66.

Speerschneider, C.I.H. (1915) Om Isfolderene i danske Farvande i aeldre og nyere Tid: aarene 690-1860, Meddelser, no. 2. Copenhagen (Danske Meteorol. Inst.). 123 pp.

Speerschneider, C.I.H. (1927) Om Isfolholdene i danske Farvande: Aarene 1861-1906. Meddelelser, no. 6, Copenhagen (Danske Meteorologiske Inst.). 84 pp.

Thomsen, H. (1947) The annual reports on the Arctic sea-ice issued by the Danish Meteorological Institute. Journal of Glaciology, v. 1(3), pp. 140-141.

Thorarinsson, S. (1956) The thousand years struggle against ice and fire. Reykjavik, Museum of Natural History. Department of Geology and Geography. Miscellaneous Papers. No. 14. 52 pp.

Walker, G. (1947) Arctic conditions and world weather. Royal Meteorological Society, London. Quarterly Journal. V. 73, pp. 226-256.

Walsh, J.E. (1978) A data set on northern hemisphere sea ice extent, 1953-76. Glaciological Data. Report GD-2, Arctic Sea Ice, Pt. 1, pp. 49-51.

Appendix I

A BASIS FOR FORECASTING THE ARCTIC SEA ICE OVER A FEW MONTHS TO MANY YEARS

The project, which is funded by the U.S. Office of Naval Research, commenced in September 1977. The objective is to lay the foundations of a scientific forecasting ability for the Arctic sea ice on time scales of a fraction of a year to decades.

This is to be accomplished in three stages:

(A) The collection and digitization of available sea ice data for the Arctic extending back to the 19th century.

(B) The identification of past variations in sea ice extent and associated fluctuations in climate and the atmospheric circulation.

(C) If feasible, the development of a forecasting scheme based on a thorough understanding of the mechanisms underlying the variations in sea ice, climate and the atmospheric circulation.