Sea Ice off the coasts of Iceland in the early 20th Century

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Declaration

In accordance with University of Cambridge regulations, *I do hereby declare that:*

This thesis represents my own original work and conforms to accepted standards of citation in those instances in which I have availed myself of the work of others.

This thesis is not now being submitted nor has been submitted in the past for any other degree, diploma, or similar qualification at any university or similar institution.

This thesis does not exceed the maximum allowable length of 20 000 words, excluding footnotes, tables, appendices and references.

Ingibjörg Jónsdóttir

Abstract

This thesis compares different sources of information about sea ice off the coasts of Iceland and presents new indices of sea ice severity for the years 1901-1925. The sea around Iceland is divided into eighteen zones, each of which is given an icecode, referring to the amount of sea ice that was observed in each month. This information is tabulated and the reliability of the data sources is indicated.

Further work with this data includes a description of the frequency of ice in each zone, year and month.

The indices are compared with mean annual temperature in Stykkishólmur, W-Iceland, and with temperature anomalies for the whole Northern Hemisphere.

The effects which the sea ice had in Iceland in this period are discussed.

Contents

List of illustration

Acknowledgements

Before coming to study at the Scott Polar Research Institute, I worked in the Icelandic Meteorological Office, in the Department of Sea Ice Research. The work included collecting different sources of sea ice information from this century. Diaries were of special interest, as many of them can be regarded as a primary source of sea ice information and they reflect what the sea ice meant for people at this time and what effects it could have on people´s lives. The Sea Ice Research Division worked in collaboration with Dr. Torgny Vinje (Norwegian Polar Research Institute) in the E.S.O.P. project (The European Subpolar Ocean Programme) and Dr. Astrid E.J. Ogilvie (University of East Anglia and INSTAAR, Boulder, Colorado) in the I.C.I. project (Impacts of Climate in Iceland). The period was chosen because it was interesting regarding fluctuations in sea ice severity and climate, Dr. Astrid Oglivie was already collecting and analysing information about the years until 1900, and, in 1926, the Icelandic Meteorological Office was formally established. In June 1994, I had the chance to stay at the Norwegian Polar Research Institute in Oslo and go through their collection of sea ice maps and documents on sea ice research in the early 20th century. I will use the opportunity to thank NORFA (Nordisk Forsknings Akademi) for a grant that made this stay possible and Dr. Torgny Vinje for being very helpful and providing all facilities. I would also like to thank Dr. Þór Jakobsson, Mr. Eiríkur Sigurðsson, Ms. Sigþrúður Ármannsdóttir and Mr. Trausti Jónsson at the Icelandic Meteorological office for their help and encouragement. Thanks to all the people that have helped me in my search for diaries and for other sources of sea ice information: Mr. Guðni Halldórsson, Ms. Aðalheiður Sigmarsdóttir, Mr. Þórir Haraldsson, Ms. Sjöfn Kristjánsdóttir, Mr. Ögmundur Helgason and the many other archivists in Iceland. Special thanks to Dr. Unnsteinn Stefánsson for all his support. I would like to thank my supervisor, Dr. Peter Wadhams, Dr. Liz Cruwys, Mr. Robert K. Headland and the staff at Scott Polar Research Institute for all their help and support. Finally, I thank fellow students in the course for their company this year.

"Vár var heldr kalt. Þá gekk Flóki upp á fjall eitt hátt
ok sá norðr yfir fjöllin fjörð fullan af hafísum;
því kölluðu þeir landit Ísland,
sem þat hefir síðan heitið"

Landnáma

"Spring was rather cold, then Flóki walked up one high mountain,
and saw north over the mountains fjord filled with sea ice;
thus they called the land Iceland,
which has been its name since"

From the settlement of Flóki Vilgerðarson
in Iceland, around A.D. 865
Landnáma (The book of settlement)

1. INTRODUCTION

1.1 Definition

The purpose of this thesis is to describe the sea ice conditions off the coasts of Iceland in the early 20th century, particularly the years 1901-1925, and to consider what effects the sea ice had on farming, fishing and navigation. This includes a comparison of different sources of information about the sea ice.

This topic is interesting because it can be related to recent thoughts and theories about climatic change. Climate and climate-related phenomena in the past can show us the magnitude of climatic variations. The Icelandic sea ice data is a good indicator of the climate (Kelly et al, 1987). In order to judge the value of the older data sets, it is also important to know how reliable the sources are. Known sources about sea ice off the coast of Iceland in that period do not agree in every way, and it is therefore important to compare them and add primary sources to the sea ice history.

The sea ice season in Iceland is from October to September of the following year, as the extent of ice is at a minimum in October. A "sea ice year" is defined as such. That is; the "sea ice year" 1918 lasts from October 1917 until September 1918.

An "icemonth" is a month where some ice has been observed in one of the zones around Iceland.

1.2 Construction

This thesis starts by presenting some background information on the oceanography of the North Atlantic, as well as describing sea ice formation, distribution and role in global weather systems. Chapter 3 introduces the sources this work is based on and their advantages and limitation are described. Then, methods of comparing these sources are explained. After that, the sea ice history is introduced and interpreted, different sources are compared and thereafter, the sea ice history is compared with other climatic data. Finally, the effects that the sea ice had on human activities; farming, fishing and transport, are discussed.

2. ARCTIC SEA ICE

2.1 Formation and role in global weather systems

For sea ice to be formed, the temperature of the air has to drop below the freezing point of the sea (Stefánsson, 1994). The salinity of the ocean affects its freezing point (figure 1). If the salinity is more than 24.7‰, which applies to most of the Arctic Ocean and adjacent waters, the density of sea water increases all the way to the freezing point and the cooled surface sea water sinks before it reaches freezing point. This means that the whole water column has to reach a temperature of -1.92 °C (for sea water of salinity S=35 ‰) before sea ice can form at the surface (Stefánsson 1994).

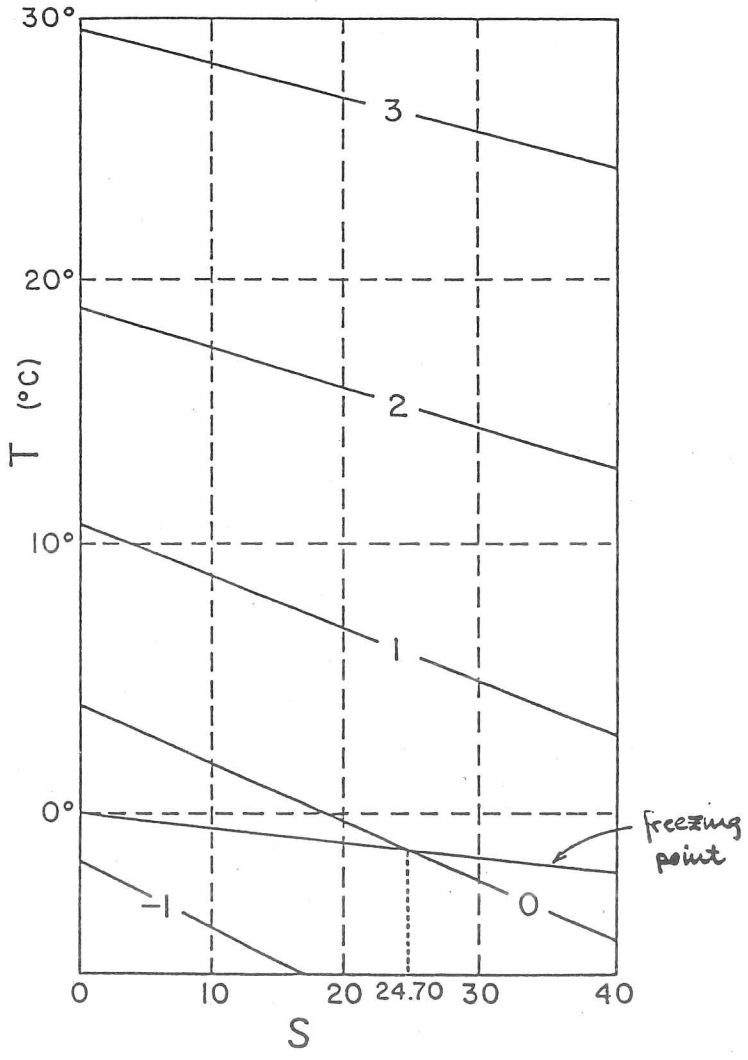

Figure 1. Heat exchange coefficient of sea at one atm. as a function of temperature and salinity. Freezing point (line) is also shown. (From Stefánsson 1991; 84).

A stratified water column hastens the formation of sea ice since a shorter column near the surface has to be cooled (Sigtryggsson and Stefánsson, 1969). This explains why fresh water ice is formed more easily than sea ice; the maximum density of fresh water is at a temperature of 4 °C and water colder than that is less dense and becomes even less dense with increased cooling, thus staying at the surface and freezing.

When sea ice is formed, the energy exchange between sea and atmosphere changes enormously. "Because sea ice is such a thin layer in contrast to the large area that it covers, small changes within the atmosphere or the ocean can cause major changes in the extent and thickness of the ice cover" (Gow and Tucker, 1990: 47). The albedo of the surface increases from 0,10-0,15 to 0,8-0,90; thus reflecting more solar radiation. Therefore, instead of absorbing solar energy and using it to warm the surface, the ice reflects it. Ice cover can therefore hinder energy exchange between sea and air, affecting the weather and climate systems (Wadhams, 1986). This also hinders moisture and momentum exchange.

2.2 Distribution

The Arctic Basin has an area of 14.6×10^6 km^2. It is a mediterranean ocean, surrounded by the American and Eurasian continents. The continental shelves are relatively broad and shallow, especially on the Eurasian side (figure 2). Deep basins near the middle of the Arctic are separated by the Lomonosov Ridge.

Figure 2. Physiography of the Arctic Basin. (Smith, 1990: XV).

There are only two main outlets to other oceans: the Bering Strait (less than 100 m deep) to the Pacific and the Fram Strait (2600 m deep) to the Atlantic. The Fram Strait is thus the only deep outlet to other oceans.

The surface circulation in the Arctic Ocean consists of the Beaufort Gyre over the Canadian Basin and the Transpolar Drift Stream across the Eurasian part of the basin, which then exits through the Fram Strait (Aagaard, 1985). High salinity Atlantic water cools on its way north and sinks north west of Spitsbergen and in the Barents Sea. This forms the mid layer of the ocean. Here, the circulation is opposite to the wind-driven surface circulation because the incoming current is turned to the right, up against the slope of the continental shelf. The deep water is renewed by sea ice formation on the shelves (Wadhams 1994), increasing the salinity of shelf water and helping it to sink down around the slope of the shelf edges. Deep water is also formed by the mid-gyre convection in the open Greenland Sea. Again, sea ice formation (in the Jan Mayen Current) assists this procedure, and this leads to direct overturning.

The structure of the Arctic Ocean thus consists of three water masses in distinct strata, with the whole central Arctic Ocean permanently covered by ice, forming a persistent multiyear system that is harder and thicker than the sea ice around the Antarctic (Foster, 1978, Carmack 1990). The surface water layer has low salinity because the land masses surrounding the Arctic Ocean have large rivers: the Ob, Yenisei, Lena and Mackenzie, discharge large amounts of fresh water and sediments (Malkki 1991). A strong pycnocline forms between the surface layer and the warmer, saltier layer beneath. This limits nutrient and energy fluxes between the two water masses. The bottom layer is cold and has high salinity, and is thus very dense (Stefánsson 1994).

When sea ice is formed in the Arctic Ocean it either remains trapped in the Beaufort Gyre or else, exits through Fram Strait in four years or less. In that time it can reach three or four metres thickness before it flows south via Fram Strait (Wadhams, 1986 and 1994). This narrow strait is the main outflow of sea ice from the Arctic.

In late autumn, ice starts to form and is then driven southward. Maximum ice extent is in late winter in higher latitudes, but as it takes time for the ice to flow southwards, the maximum extent at lower latitudes is later, usually in early or late spring, March to June.

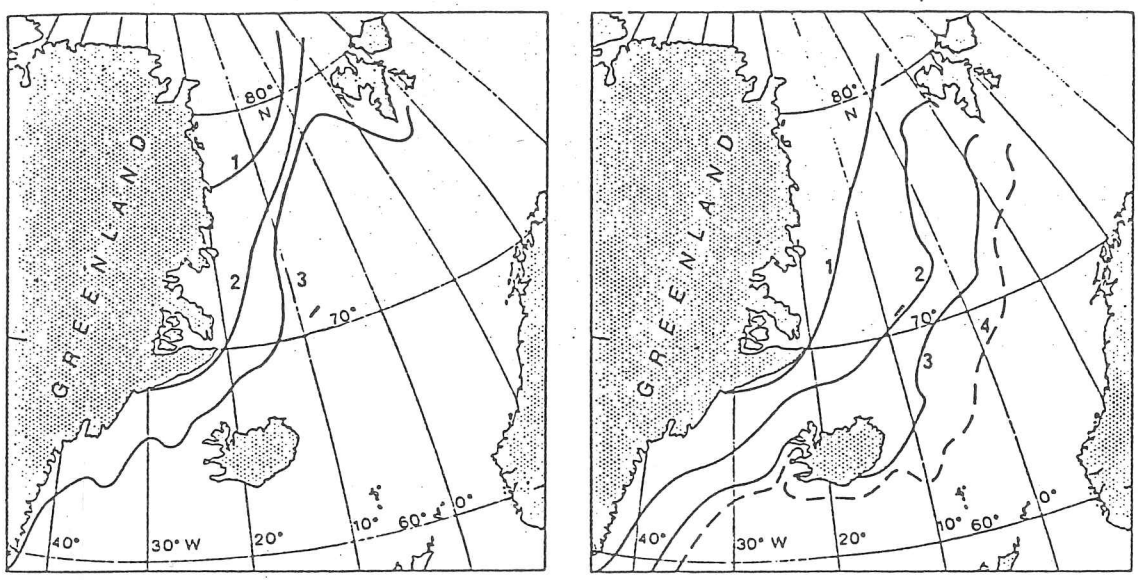

Figure 3. The distribution of sea ice in the Arctic. Left: October. Right: March-May. 1: recent minimum. 2: recent normal. 3: recent maximum. 4: estimated maximum in historical times. (From Eyþórsson and Sigtryggsson, 1971, quoted by Malmberg, 1984).

Figure 3 shows that there are large annual differences in the distribution of sea ice in the Arctic. Sea ice is usually at its minimum in September and October. The location of the ice edge is highly variable, changing a lot from year to year (Vinje, 1977 and 1989) and also within shorter periods, of weeks and days.

There are also great differences between the west and east coasts of the continents; sea ice reaches much further south on the east coast of continents. In the Atlantic, the differences can be 30° of latitude. This is because of the Coriolis force, bending currents towards right in the Northern Hemisphere; the warm Gulf Stream heading North flows along the west coast of Norway whilst the cold East Greenland Current runs south along the East coast of Greenland.

2.3 Sea ice off the coast of Iceland

Iceland is situated in the area of the polar front in air masses in the North Atlantic Ocean, hugged by the warm Irminger Current but also subject to the influence of the cold East Greenland Current (Malmberg 1984 and 1969). Climate in Iceland is thus subject to changes in climate, between harsh periods and more flourishing eras.

Occasionally, sea ice "visits" Iceland. Variations in the occurrence are believed to be due to the relation between the quantity of ice and Arctic water in the East Greenland Current, salinity and temperature distribution in the oceans north of Iceland and the effect of atmospheric pressure fields upon their circulation. The wind field in the Arctic Basin determines how much comes thorough Fram Strait, whilst wind stress in the Greenland Sea determines onward transport (Aagaard, 1972) and local oceanography determines whether ice can reach the coast.

"The cold water system in the Iceland Sea north and east of Iceland, more or less fed by waters from the East Greenland Current, is known as the East Icelandic Current" (Malmberg, 1992: 78). If the cold East Icelandic Current is dominant sea ice is more likely to come to Iceland and stay for a longer period (Malmberg 1984 and 1977). Iceland can then become, in a way, a peninsula of Greenland, with correspondingly harsh conditions. Malmberg described what had happened in the 1960´s when sea ice became common again, after decades of very little or no ice off the coasts of Iceland: "The East Icelandic Current, an ice-free Arctic current in the period 1948-1963, later advanced south and eastwards and developed into a Polar current in 1964-1971, transporting and maintaining drift ice" (Malmberg, 1992: 79).

The sea ice off the coasts of Iceland consists mainly of first year ice from the Greenland Sea and multi year ice from the Arctic Ocean. Investigations based on driftwood collection and analysis suggest that the sea ice that comes to Iceland is mainly from the Siberian sector of the Arctic Ocean (Eggertson, 1994). Driftwood that reaches Iceland must have been frozen fast in the ice because it would not be able to float by itself for such a long time, as it would get soaked and sink earlier.

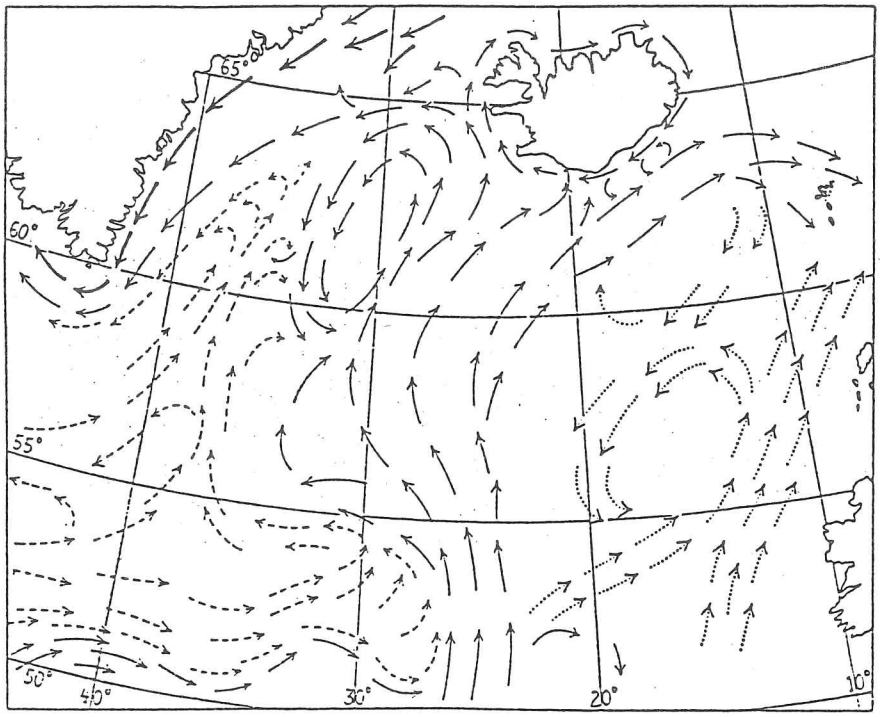

Figure 4. Currents in the Irminger Sea and south of Iceland.

(Stefánsson, 1962: 60)

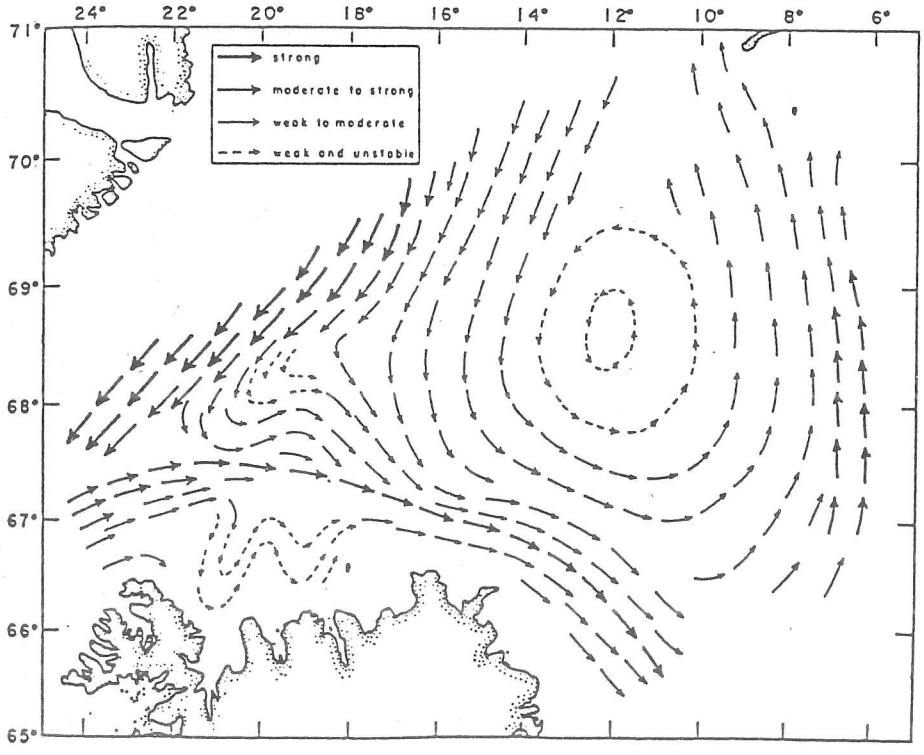

Figure 5. The surface currents of the Iceland Sea. (Stefánsson, 1962: 57)

The sea ice that comes to Iceland is most often of the kind that has broken from the main pack ice, has formed "ice patches" that are pressed up towards the coast and can then form "pack ice" again. The ice can travel very fast, especially if winds and currents work together. The "Nansen rule" is that sea ice can travel with a speed that is 2-6% of the wind speed. The sea ice travels at about 30° to the right of the wind direction (Jakobsson Jónas, 1969, Zubov, 1943).

Icebergs, mostly calving from the Greenland Ice Sheet into Scoresby Sund, but possibly also from North Greenland, Svalbard (Spitsbergen) or Franz Josef Land, occur occasionally, mostly in the autumn. This is when most of the icebergs calve from the glaciers and sea ice extent is at its minimum so the icebergs are not frozen in the sea ice cover and brought to south Greenland but are able to "travel" more freely.

Fjord ice does not form every winter because of the warm Irminger Current flowing clockwise around the island (figure 4 and 5). Shallow fjords and bays freeze when the temperature is low for a long time; ice often forms in them when sea ice is near the coasts as the weather tends to be colder then and the sea is also colder.

Almost every year some sea ice appears at the north-west peninsula "Vestfirðir", and occasionally the ice blocks the north and the east coast (Bergþórsson, 1969, Einarsson, 1969). The south and west coasts are hardly ever visited by ice, due to the warm Irminger Current. The current comes up to the island in the south and flows to the west. Off the North West coast it "meets" the cold East Iceland Current and these currents mix gradually as they flow east along the north coast and then south along the east coast.

When all the north and the east coasts of Iceland are blocked for some time the sea ice affects the local climate to a great extent, with associated impact on vegetation, fishing and navigation. This topic will be discussed in more detail in chapter seven.

3. SOURCES

3.1 Introduction

Comparing and validating sources requires knowledge about where they were written, when, why, how and by whom. Sources are considered to be more reliable if the writer was near to the event in time and space (Ingram et al, 1981 b). It is best if the writer experienced the event himself and wrote the descriptions of it at the same time as it happened. The more intermediate links there are in transferring the information, the more is the risk of error or misunderstanding. Wigley et al (1985) wrote "One of the main problems with using documentary source for climate reconstruction is the quality of the basic data. Only data that are demonstrably accurate, correctly dated and from a known location should be used".

The known sources of data about sea ice off the coasts of Iceland in the early 20th Century used here are those from the Danish Meteorological Institute: "Isforholdene i de Arktiske farvande" (Sea ice in the Arctic waters) and Lauge Koch's "East Greenland Ice". Also known in Iceland is Þorvaldur Thoroddsen's book "Árferði á Íslandi í þúsund ár" (Climate in Iceland in a Thousand Years). The Icelandic Meteorological Office was established in the early Twenties and started collecting sea ice information then. These were sent to the Danish Meteorological Institute as well, where they were published. Other sources used here, not as well known, are maps, showing the sea ice extent, that the Norwegian Polar Research Institute made from sealer´s logbooks. A few diaries, written by farmers, living along the coast of Iceland, are also used. These have not been used for their sea ice information before. A few descriptions of sea ice in different books, either on sea ice or some autobiographies, are used here, but more as an example than a thorough collection of sea ice information from such books.

It is worth noting that even though sources differ in quality, virtually no source is perfect. Errors and misunderstandings can easily get into every source. A good example of this is the change in scales of length; in the early years of the reports from the

Danish Meteorological Institute and in Thoroddsen´s book, "miles" are so-called big miles, that is, four times as long as an ordinary nautical mile. This could easily cause misunderstanding in interpretation.

The possibility of collecting sea ice information was in these years limited to observation from the coast and from ships. New data were probably sent between land stations to help ships to decide which sea route was clear.

Sea ice research was originally connected to exploitation of resources, mainly whales and seals; expeditions to the polar regions, to find "new" lands and new resources; and to find better sea routes (Jónsson, J., 1988). One of the great Arctic researchers was Fridtjof Nansen, who in 1893-6 let his ship, "Fram", freeze fast in the ice with the hope that the ice would carry it over the North Pole. This journey, though not successful in going over the North Pole, added much to sea ice research (Koch, 1945). There is no doubt that the "Titanic" accident in 1912 brought sea ice and icebergs into people´s discussion, and it was the reason behind the founding of the International Ice Patrol (Stefánsson, 1994).

3.2 The Danish Meteorological Institute

The Danish Meteorological Institute was established in the late 19th century. It soon started collecting sea ice information, and its annual report series "Sea ice in the Arctic waters", runs from 1876 onwards. At that time, the institute gathered information from weather stations in Iceland, and from quite a number of ships that sailed in those waters. In the early years, the editor H.Vare complained that not all ships sent information. It was important for the security of sealers, and all ships navigating in Arctic waters, to have good information about the sea ice areas, as well as being important for research on sea ice to get as much information as possible. This is a very well known problem for sea ice research. By giving information about the sea ice edge, fishermen also gave information about where they were fishing.

Table 1 lists the number of ships that sent information about sea ice in the ocean around Iceland.

Table 1. Number of ships that sent information about sea ice in the ocean around Iceland to the Danish Meteorological Institute. 1901-1925. (Garde, 1902-1926).

YEAR	JAN	FEB	MAR	AP	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	SHIPS
1901			2	13	11	9	7	8	4	1			15
1902		1	5	14	10	7	6	6	5	1			18
1903				9	8	9	9	7	1	1			13
1904	3	2	4	8	8	6	7	7	5	4	1	1	11
1905	2	3	4	9	10	12	12	10	7	4	4	2	15
1906	2	4	5	10	11	11	10	10	8	6	1		13
1907	4	5	9	10	9	9	9	9	8	8	5	3	11
1908	1	1	2	1	3	4	5	5	5	2	1	1	7
1909	4	4	4	4	4	6	5	4	4	4	4	4	6
1910	1	1	1	1	1	1	1	1	1	1	1	1	1
1911	1	2	3	5	7	6	6	5	3	1	1	1	8
1912	4	4	4	5	5	6	6	6	5	4	4	4	6
1913	3	3	3	4	4	4	4	4	4	4	4	3	4
1914			1	1	1	1	1	1	1	1	1		1
1915	2	2	3	3	3	3	3	3	3	3	3	2	3
1916			1	1	1	1	1	1	1	1	1	1	1
1917	1	1	1	1	1	1	1	1	1	1	1	1	1
1918	1	1	1	1	1	1	1	1	1	1	1	1	1
1919	1	1	1	1	1	1	1	1	1	1	1	1	1
1920					1								1
1921							1						1
1922	1	1	1	2	1	1	1	1	1	1			2
1923	1	1	1	1	1	1	1	1	1	1	1	1	1
1924		1	1	1	1	3	3	3	2	1	1		4
1925	3	3	3	4	4	4	4	4	4	4	2	2	4

It is surprising to see how few ships sent information in the second half of the period. One could expect to get less information during the First World War, but the situation did not change until 1924 and 1925. Information from the winter months gradually increased after 1903. It is not possible to see where exacly these ships were. There is no doubt that there were more ships around Iceland in these years (Jónsson, J. 1988, Þorsteinsson, 1991).

The weather stations or places where the Institute got reports from are showed in figure 6. Table 2 indicates for what year each place sent sea ice data. Unfortunately, it was only possible to get information from the years 1905 to 1925.

Table 2. Weather stations, and other places, where information about sea ice was collected and sent to the Danish Meteorological Institute. (Garde,1906-1926).

Dalatangi: all years.
Langanes: 1905, 1908-12, 1917-19, 1921, 1923-25.
Grímsey: 1907, 1909, 1912-24.
Sauðanes/Siglufjörður: 1905, 1906-25.
Skeggjastaðir: 1906.
Horn: 1909-1925.

The sea ice conditions are described in the text of the reports and they are backed up with ice charts for the summer months, usually April to August, but sometimes March and September are also included.

3.3 The Icelandic Meteorological Office

The first precursor of an Icelandic Meteorological Office was a department in the Löggildingarstofa (Authorization Office) that in 1920 started collecting information about weather. The Icelandic Meteorological Office was then formally established as an independent institute in 1926 (Jónsson, T. 1993). From the very beginning the Office collected sea ice information. Ships were supposed to send reports about where and when they observed some or any ice. It has always been difficult to collect such information as crews are not necessarily willing to give

information about their main fishing areas. It has also been difficult to get information about clear water; no ice. The Icelandic Meteorological Office continued to send sea ice information to the Danish Meteorological Institute, which then published them in the reports "Sea ice in the Arctic Waters". From 1924 the Office published reports where the ice conditions were described briefly. Later, these were described in more detail in the journal "Jökull" but from late 1960´s the Sea Ice Research Division of the Office has published the report series "Sea Ice off the coasts of Iceland".

Sources from the Icelandic Meteorological Office are only used indirectly here in the reports from the Danish Meteorological Institute.

3.4 Þorvaldur Thoroddsen

Þorvaldur Thoroddsen was a very efficient Icelandic naturalist, who wrote various books on Icelandic nature. In 1916-17 he published a book "Árferði á Íslandi í þúsund ár" (Climate in Iceland in a Thousand Years), descriptions of climate in Iceland since it was settled. His book was based on climatic related comments or descriptions in sagas, annals, books and newspapers, material he had been collecting over 30 years, in parallel with other studies. Þorvaldur argued that the climate in Iceland had not changed significantly in these years; that is, bad years had always come in between better years, but the climate had not changed on the whole (Thoroddsen, 1916-17, Koch, 1945). He said that the writers of the earliest material had not been so interested in climate, it was not news that the sea ice came because it happened so often. Some had even failed to mention volcanic eruptions, events that they must have known about. Thus silence about sea ice and severe years in the early literature did not have to mean that there had not been any. Many of these old descriptions, especially the sagas, were written centuries after the events had actually happened and thus they were not completely reliable. Thoroddsen had not experienced the warming in the early Twenties. Fridtjof Nansen seems to have shared his opinions in this (Koch 1945). Lamb (1981: 292) wrote "Around 1880-1900 it was apparent from the first 100-year series of

weather observations that the climate averages of that time were very similar to those of a century earlier, and it became conventional to treat climate as essentially constant". Thoroddsen´s and Nansen´s opinion must have been coloured by this.

Þorvaldur Thoroddsen´s book has been criticised for not being selective in the material used and not using word-for-word descriptions (Vilmundarson, 1969). In the last years, he relied a lot on the reports from the Danish Meteorological Institute as he stayed in Denmark in these years. However, his book is of great value and has been used by a lot of people studying climate in Iceland. The sources Þorvaldur Thoroddsen uses each year are:

Nautisk Meteorologisk Aarbok (the same information as "Sea ice in the Arctic waters" by the Danish Meteorological Institute): All years.

Þjóðviljinn (Icelandic newspaper, published in Reykjavík and Bessastaðir, SW-Iceland, and Ísafjörður NW-Iceland): 1901, 1902 and 1903.

Stefnir (Icelandic newspaper, published in Akureyri, N-Iceland): 1901 and 1902.

Norðurland (Icelandic newspaper, published in Akureyri, N-Iceland): 1902, 1907, 1908.

Nationaltidende (Söfartstidende) (Published in Denmark): 1911.

Unfortunately, it is difficult to say whether he got hold of Icelandic newspapers for all the years, but found them not adding anything important to the Danish reports, or whether he only read them in these years.

3.5 Lauge Koch

Lauge Koch was a Danish geologist who had worked a lot in Greenland, mainly in mapping the geology. He was very popular in Denmark and most of his work was published in the series "Meddelelser om Grønland". His book, published in these series, "The East Greenland Ice" was originally supposed to describe the ice condition in the years that he had been in the field in Greenland, but it developed and ended as an holistic description of the sea ice off the coasts of Greenland. He wrote it during the Second World War when Denmark was occupied by Nazi Germany,

so he had enough time to write (Koch, 1945). In the preface Koch writes: "Nobody knows better than myself the uncertainty of much of the material utilised in the present paper; even information on the ice condition within the present century should often be employed with great criticism." His book is a great work on the East Greenland ice, but it is very difficult to trace where some of his information comes from and how reliable it is. Even though most of it is reliable, it is hard to recognise the less reliable data Therefore, it is necessary to treat all his information with great care.

3.6 The Norwegian Polar Research Institute

The golden age of Norwegian oceanic research was in the late 19th century and the first 14 years of the 20th, that is, until the First World War started (Jónsson, 1988). The study of sea ice was also blooming at the turn of the century. Fridtjof Nansen´s journey on "Fram" in 1893-1896 was a great achievement which brought much knowledge about sea ice and its behaviour to the scientific world (Jónsson, 1988). Norwegian whalers and sealers followed their prey to the Arctic Ocean as well as the Southern Ocean. Like other ships, they were supposed to send their ship´s logbooks, or a copy of them, to the Meteorological Institute. Many of them reached the Institute, where, later, information from them were used to draw maps on sea ice cover. In a letter from 1923 (Kept in the archive at the Norwegian Polar Research Institute. See Appendix I) Adolf Hoel writes that Otto Sverdrup and A.Hermansen were to go to several places in West and North Norway to collect information about the sea ice near Svalbard (Spitsbergen) and in the Greenland Sea. The reason why this was done must be a combination of the scientific interest as well as security matters of ships navigating in the sea ice zone. Drafts of the maps were prepared in the 1920´s but it was not until the 1980´s and 1990´s that Geir Kjærnli and Torgny Vinje at the Norwegian Polar Research Institute actually finished them. These maps are excellent, they show the ice limit, the reliability of the sources and the ice type, when that is known (See Appendix II). These maps are now being scanned in a database at the institute, using the geographical information system ArcInfo.

3.7 Diaries

Many personal diaries were written in Iceland in the early 20th century, some of which have been given to archives, either in the author´s home county or in Reykjavik. There is no doubt that more diaries could be found by contacting the descendants of "known" diary-writers or by advertising for diaries. These books contain descriptions of the nature: weather, vegetation, earthquakes and other things, as the writers were strongly connected to nature; they were farmers who relied heavily on the climate and its effect on vegetation. Those who lived along the coast were also fisherman; they tried to use all that each season had to offer on the land and in the sea. The arrival of sea ice had influence on their life, but not necessarily always in a negative way. That will be discussed in more detail in chapter seven.

Obviously, the kind and quality of diaries varies a lot. Since it takes a lot of time to read most diaries, especially those whose handwriting is difficult to understand, it is important to carefully choose the ones to use. There are a few matters that is worth having in mind when diaries or diary writers are chosen:

1. Does the writer write every day ? The more often he writes, the more likely the information is to be accurate and reliable.
2. What are his interests in the phenomena, is he trying to prove something and is there any reason why he should show any interest in the information one is looking for ?
3. What are the writers opportunities to observe, in this example, sea ice ? Where is he situated, can he actually see the sea ?
4. Is it clear that the writer stays at the place he says he is at, in the beginning of the diary, all the time ?
5. What is his concept of directions ? It is necessary to know the region of the farms well, place names and how they describe directions, for example north is not always north but quite often follows the landscape up to a certain point.
6. Descriptions like "little", "much" and "large" might not be consistent with the way that others would describe the same thing. These descriptions should be handled with care. "Much" ice

in a period of very little ice might be less than "little" ice in a severe ice period.

7. Does the writer mention events that he, if he were writing at that place and time, should have known about ?

In a thesis like this one, geographical distribution is also important. It is better to choose diaries where there is a lack of other information or observation. Direct comparison of a certain weather station and a diary written near is an interesting but slightly different topic.

One could ask whether the diaries add anything to what we already know about sea ice and if it is worth the time it takes to read them. How good a source are the diaries ?

The diaries give good information about sea ice near their home and add points to the observation network, which in those days was not very dense. If they mention sea ice, one can be almost sure that there was some. If they do not mention ice where other sources mention ice, it does not mean that the writer saw ice but did not mention it. The view is often limited when ice is near the land, as fog is very common at the ice edge.

It is fascinating how these busy men spent time to write down what had happened. In some ways it must have been practical for them to note down things about farming. They had their theories about weather, and knew when there was greater possibility of sea ice because of how the winds had been blowing during the previous weeks and from other signs. Sometimes they gave comments about the sea ice arrival: "This is most peculiar after the strong southerly winds more or less all winter" (Jakobsson, Jónm 1901). They knew which patterns of weather could bring them the ice.

It is important to compare diaries with other information, from weather station and ships, to get to know them as a source of sea ice information, before older data, from times when there were no or little systematic observation existed, are to be used.

Figure 6 shows the situation of diaries used in this thesis. Information about a lot of others was collected, partly because it was necessary to choose carefully which books to read, and partly to be able to check things better if some major question of the

state of ice would arise, and also for further reference if this work should be continued later.

The diaries used are listed below, as well as the period which was read and used:

Mr. Finnbogi Bernódusson, Bolungarvík (NW peninsula): very good diary, good descriptions of sea ice and weather. This diary was read for November and early December 1917, and all year 1923. The diary continues beyond this date (National Library in Iceland, Department of Documents).

Mr. Níels Jónsson, Gjögri (NW peninsula): excellent diary of his work, with long descriptions of the sea ice as well as the weather as a whole. Unfortunately, there was very little time to read it and therefore each month he mentioned sea ice gets a mark but his descriptions of sea ice and its effects are not used here. Hopefully, there will be time to do this later. The handwriting is very easy to understand and sea ice information is often underlined. The period from January 1910 until April 1925 was used, but the diary lasts from 1893 to 1934.

Mr. Þórður í Höfða. Höfða, Grýtubakkahreppi (N-Iceland): a good diary but can be difficult to read. He describes the sea ice well, as well as weather, birds (when they came in the spring, etc.) and his work. This diary was read for the period April and May 1911, May 1915, and November 1917 to early January 1918. His diary lasts the period from 1887 to 1935.

Mr. Jón Jakobsson, Tjörnesi (NE-Iceland): probably the best diary used here. He writes long descriptions about the sea ice, weather, vegetation, earthquakes, birds, ships coming and leaving Húsavík harbour, fisheries, his own work and various events in his county. The handwriting is very beautiful and easy to read (in Icelandic). It would be possible to gain much reliable information from this diary, more than just about sea ice. This diary was read for the period January 1901 to end of April 1915 when unfortunately, the writer became very ill and died in the beginning of May. This diary starts in 1889. An example of his writing is shown in Appendix III.

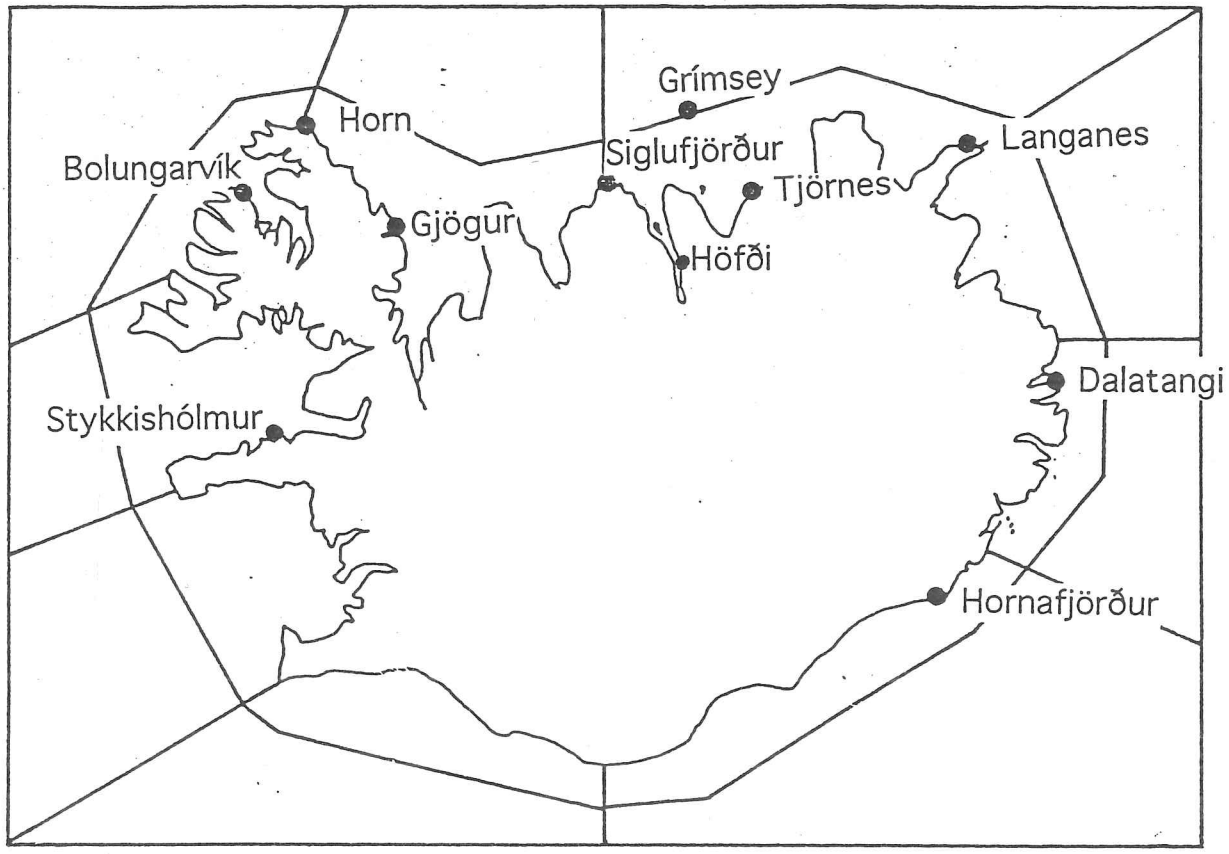

Figure 6. Observations from land: weather stations and diaries.

Mr. Björn Jónsson, Hornafirði (SE-Iceland): short descriptions about sea ice and weather, as well as his work. Handwriting good but very small and thus often difficult to read. This diary was read for the period February to April 1902 but it lasts from 1873 to 1946.

Mr. Þorleifur Jónsson, Hornafirði (SE-Iceland): short descriptions of sea ice conditions and weather. He also describes his work briefly and a few events. Good handwriting and easy to understand. Read from February to May 1902, but is said to run from 1864-1956.

3.8 Others

There is no doubt that other sources of information do exist. There were a lot of ships in Icelandic waters in the beginning of the Twentieth Century: fishing vessels, research expeditions and explorers on their way to the Arctic (Jónsson, 1988). A lot of diaries written in places all around the country are available from archives all around Iceland, and some are privately owned, in many cases by the descendants of the writer. Many autobiographies mention experience of sea ice.

4. METHODS

4.1 Measuring distribution, quality and quantity

Even though we can get fairly good information about the ice edge at many times, information about the ice, what type of ice it is, its thickness and percentage of cover, is much harder to collect and interpret. In the following sections, methods that other people have used are described, as well as the method that was chosen here to describe the sea ice severity in Iceland in the early 20th Century.

4.2 Earlier work

There are three main ways of telling the sea ice history: with written descriptions, maps, or tables and diagrams. This work will focus on tables and diagrams.

Most people who have used statistics to describe the sea ice condition off the coast of Iceland, have chosen to divide the coast into several sectors and to count how often, in weeks or months, each area has had ice.

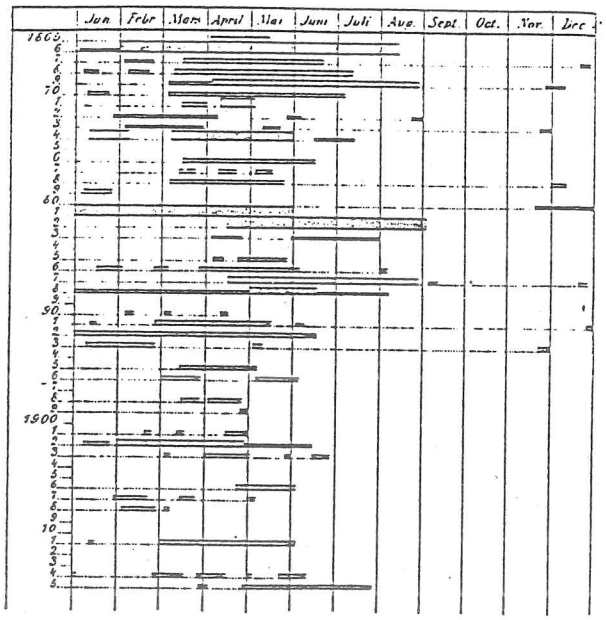

Figure 7. Þorvaldur Thoroddsen´s diagram for the occurrence of sea ice near the coasts of Iceland. The lines show in what month and for how long time the ice was near the coasts of Iceland. The width of the lines indicate roughly the quantity of ice. (Thoroddsen, 1916-17: 358)

Þorvaldur Thoroddsen (1916-1917) made a diagram showing occurrence of ice at the coasts of Iceland in the years 1781-1915 (figure 7, though only the years 1865-1915). The thickness of the lines indicates in a rough way how much ice there was in each month. It is not clear how exactly he decided the thickness. He refers to ice that is very close to the coast or fast ashore, but does usually not mention single ice floes further away.

As well as drawing maps showing maximum ice extent, Lauge Koch used a similar method as Thoroddsen, dividing the coast into sectors and counting the incidences of ice. His indices based on this method are well known and have been used widely. He also defined the ice years in Iceland as follows:

A-years.-The ice belt is narrow all the year round. This means that the outer limit of the ice belt during its maximum width is not very distant from 67° N.lat., 20° W.long. When the ice belt is narrow, the occurrence of the ice along the shores of Iceland will be of short duration.

A.1.-The ice belt does not fill the waterway between Iceland and Greenland. Iceland is free of ice throughout the year.

A.2.-The ice belt touches the north or the west coast. Iceland is almost free of ice.

A.3.-The ice enters Húnaflói and shows a tendency to persist there for some time.

A.4.-The ice is carried by the northern branch of the Irminger Current along the shore to the east coast, in rarer cases to the south coast, and sometimes as far as Vestmannaeyjar.

B-years. -A broad ice belt north of Iceland. In about 67° N. lat. the ice edge occurs near 15° W.long.

B.1.-The ice belt does not reach the coast. Iceland is free of ice.

B.2.-The ice belt reaches the the north or east coast along a short stretch.

B.3.-The ice belt lies along the whole north coast, and part of the ice may be carried by the current down the east coast.

C-years.-A very broad belt of ice north of Iceland. In c. 65° N.lat. the ice edge occurs near 12° W.long.

C.1.-The whole east coast is skirted by a broad belt of ice.

C.2.-The northwest, north, east and south coasts of Iceland are surrounded by large ice masses.

C.3.-The west coast, also, comes into touch with the ice masses, ice drifting into Breiðifjörður or Faxaflói, and the inner ramifications of these two bays are frozen up.

(Quotation from Koch, 1945: 212)

Table 3. Lauge Koch´s classification of sea ice severity for the years 1901-1925.

1901	A3	1911	C1	1921	B2
1902	A4	1912	B2	1922	A1
1903	A3	1913	B1	1923	A3
1904	A2	1914	B3	1924	A2
1905	A2	1915	B3	1925	A3
1906	B3	1916	B2		
1907	B3	1917	B2		
1908	A2	1918	C1		
1909	A2	1919	B3		
1910	A2	1920	A2		

A-years 1. and 2. have hardly any impacts at all while 3. and 4. might do so in a short period. All the B years give rise to a more or less cold climate in the North and hinder navigation greatly at a local level. C-type years affect the climate in the whole of Iceland and hamper navigation greatly (Koch, 1945).

Hlynur Sigtryggsson (1969) has updated Þorvaldur Thoroddsen´s diagram and has also added information to some of them. He studied the information Þorvaldur Thoroddsen had and how he drew the lines to decide how to continue drawing comparable lines. Hlynur Sigtryggsson also updated Lauge Koch´s figures of the ice edge in each month.

Icebergs are not included, to make the figures similar to the older ones, nor is ice further from land than 20 miles. That is in co-ordinates with the distance from land that ships went out for fishing earlier in the century.

Eiríkur Sigurðsson and Þór Jakobsson (1991) made a schematic classification indicating the extent of sea ice around the coasts of Iceland in the 20th century. "Sea ice years" were grouped in the following manner;

A: None or very limited ice.
B1: Scanty ice (in general ice off NW-Iceland).
B2: Medium ice (in general ice off NW- and N-Iceland).
B3: Heavy ice (in general ice off NW-, N- and E-Iceland).

This method gives a good overview of the 20th century (until 1990). The length of time that the ice remained is not included but the probability for a severe ice year increases with a higher B-number. It is worth noting how great the changes are within the century. With a few exceptions, the period between 1920 and 1965 has very little ice, whereas the periods before and after are much more severe.

Interpretation of the years 1901-1990 is listed in table 4.

Astrid Ogilvie has described the history of sea ice in Iceland until the 19th century (Ogilvie 1986 and 1992), and is currently working on the 19th century data. She based her research on annals, sheriffs´ letters, weather diaries and early newspapers. When discussing the 18th century (Ogilvie 1986) Iceland was divided into four zones; West, North, East and South, and each one of them got a mark for each of the four seasons, if ice occurred. From this data she made diagrams showing how many ice-seasons there were in all the zones in a decade. Ogilvie has made a large contribution by evaluating sources and adding "new" information to the climatic history of Iceland.

Table 4. Schematic classification of "sea ice years".

(Sigurðsson and Jakobsson 1991).

1901: B1-B2	1931: A	1961: A
1902: B3	1932: B2	1962: A
1903: B1-B2	1933: A	1963: A
1904: A	1934: A	1964: A
1905: A-B1	1935: A	1965: B3
1906: B1-B2	1936: A	1966: A
1907: B2-B3	1937: A	1967: B2
1908: B1-B2	1938: B2	1968: B3
1909: A	1939: A	1969: B2-B3
1910: A-B1	1940: A	1970: B2-B3
1911: B3	1941: A	1971: B2
1912: A-B1	1942: A	1972: A
1913: A	1943: B1-B2	1973: B1
1914: B3	1944: B2	1974: A-B1
1915: B2-B3	1945: A	1975: B1-B2
1916: B1	1946: A-B1	1976: A-B1
1917: B1	1947: A	1977: B1-B2
1918: B3	1948: A	1978: A
1919: B2	1949: B1	1979: B2-B3
1920: B1	1950: A	1980: A
1921: B1	1951: A	1981: A
1922: A	1952: A	1982: A
1923: A-B1	1953: A	1983: A
1924: B1	1954: A	1984: B1-B2
1925: B1	1955: A	1985: A
1926: A	1956: A	1986: B1-B2
1927: A	1957: A	1987: A
1928: A	1958: A	1988: B1-B2
1929: B1-B2	1959: A	1989: B1
1930: A	1960: A	1990: B1-B2

4.3 Area boundary

The sea around Iceland was divided into distinct parts, referred to as zones 1 to 9 (figure 8), which are numbered clockwise from south Iceland. These zones correlate with the weather forecasting zones used at the Icelandic Meteorological Office, each subdivided into inner and outer (i and o), at a line approximately 6 nm from the coastal extremities.

This was done partly because of the different ways of sampling the data; weather stations and diaries give good information about the inner zones as it is should be easy, if there is no fog, to see ice that is 6 nm from the coast, whereas ships give information about both inner and outer zones. It was also considered useful to be able to distinguish between sea ice very close to the coast and ice further from the land.

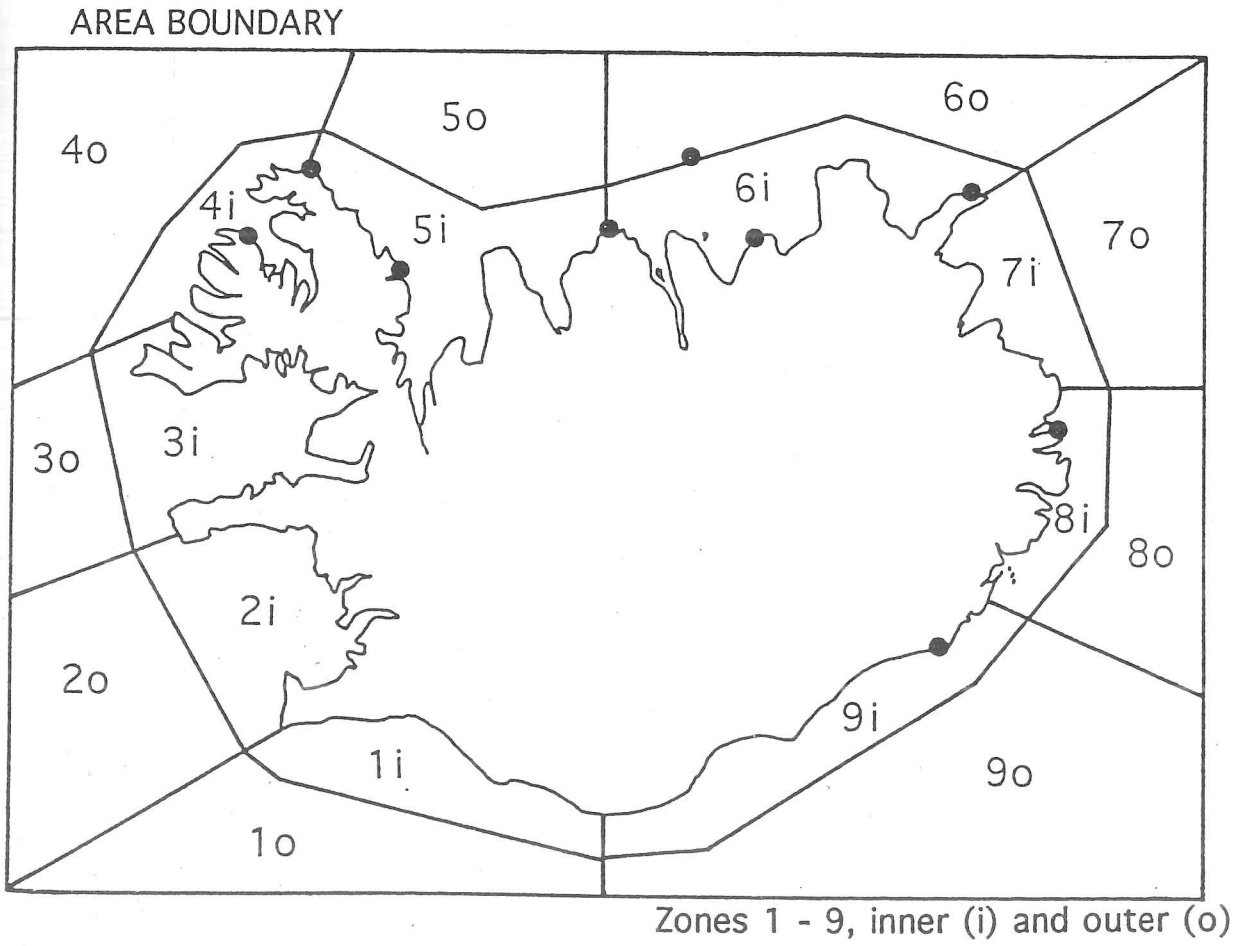

Figure 8. Area boundary. The sea around Iceland was divided into distinct parts, referred to as zones 1-9, inner (i) and outer (o).

4.4 Time units

The sources give us information in different time units. Lauge Koch's maps show maximum ice extent for each month, whereas the Norwegian maps have fourteen day intervals. The Danish Meteorological Institute has a written description for all months and maps, showing the ice extent in some part of a month, for the summer months, usually from April until August. It is in some cases possible to trace the movements or changes in the ice cover day by day in these descriptions. The diaries give information in days, sometimes many times a day.

It was decided here to have a time resolution of one month. This is because the majority of the sources used indicate the amount of sea ice for each month. The number of day to day descriptions in Þorvaldur Thoroddsen´s book and the reports from the Danish Meteorological Institute are not enough to support a finer time scale. The network of diaries is not dense enough yet to support this either. It would be possible to go to a finer time scale after adding information from more diaries to the database, as well as examining the primary sources from the Danish Meteorological Institute and the Norwegian Polar Research Institute. Some difficulties arise when one has to compare monthly data with fourteen day data because these fourteen days do not "fit into" months. The way this was handled is described in section 5.1; "Comparison of different sources".

It should be stressed again that an "icemonth", or an "iceday" is a month or a day where ice has been observed in one of the zones.

4.5 Sea ice code

Each zone was allocated an ice-code for each time unit, depending on how much ice there was in particular zone at the time. Here below, these ice-codes are explained.

(0 No ice.)
1 Some ice, up to 75% of sea ice cover.
2 Much ice, more than 75% of sea ice cover.
(9 State of ice unknown.)

The boundary between "some" and "much" ice was decided to be 75% because at this concentration, ice can easily hinder navigation. In further studies of this topic, it might be considered useful to have more ice codes to distinguish "very little ice", up to 25 % of ice cover, from "some ice " 25-75% cover, or even more steps. These ice-codes have no direct "quantitative" value but they should enable one to get a view over some area or period. When these icemonths are counted together they are an indicator of sea ice severity in Iceland.

It is often difficult to distinguish between "no ice" and "state of ice unknown". This applies especially to the outer zones as ships tend not to send information about clear water. We can only assume that most of the empty spaces in the comparison table, that is introduced later, mean no ice, but it would really be necessary to discover which ships were in Icelandic waters at each time and exactly where they were. After that, one would have to hope that the particular ship would have sent information about ice if it saw any. It would hopefully then be possible to distinguish between no ice and no information.

4.6. The reliability of the sources.

When the information from the sources is analysed, it is necessary to know how much "weight" they should get in the final table. Information was classified according to the assumed reliability of the sources into these groups:

0 Very uncertain information, time and place not clear.
Some of the data from the Norwegian maps.

1 Secondary sources of doubtful or unknown origin.
Lauge Koch´s maps, sometimes Thoroddsen´s information and some newspapers.

2 Secondary sources where the primary source is indicated.
From the Danish Meteorological Institute, and in some cases from Thoroddsen´s book.

3 Good primary sources, where observations are made each day or frequently each day.
The diaries, the Norwegian maps.

One could argue that Lauge Koch does not get a reasonable treatment in this classification, but the problem is that even

though most of his data are very reliable, we cannot spot the more uncertain ones. Therefore, all data stemming from his maps will be treated as if all of it were uncertain.

Information from sources was made into tables (table 5), indicating what kind of reliability each zone got for each time unit. Different sources get different quality numbers, depending on how reliable they are. These numbers are explained in table 5 . This ensures that the reader can see from what source each code came and can trace it or change the reliability factor when and if the sources this work is based on are viewed again. It would, for example, be necessary to go through Lauge Koch´s notes to see what he based his maps on.

4.7 Limitations

The zones are not equally large, so the data set that comes from summing the ice-codes is not a direct quantitative measure of the amount of sea ice in the ocean around Iceland.

One should bear in mind that the ice code only shows maximum ice extent for each time unit. This can mean that if zone was covered with ice only for one day, that zone gets the same ice code as an area that was covered with ice for the whole month. Therefore, when trying to measure the severity of sea ice arrivals, it is necessary to look at the data set as a whole to get a view over what was happening in an area at a certain time. If a zone was covered with ice during the month before and the month after the month of interest, it is likely that it was ice-covered during the month of interest.

Ice code 1 has a very wide spectrum, that is, a little ice floe drifting in the edge of an area gets the same code as an area more than half filled with ice.

5. SEA ICE HISTORY

5.1 Comparison of different sources

The method of presenting the data that is introduced in the following pages results from difficulties in comparing sources that give information in different time units. The diaries, and sometimes Thoroddsen and the Danish Meteorological Institute, give us information about the sea ice conditions in days, whereas the Norwegian maps have resolution of fourteen days and Lauge Koch in a month. The main problem arises because the fourteen day period of the Norwegian maps does not fit into the months.

Where information from the Norwegian maps overlapped two months (with a good quality primary source) and no other source had any information about ice, these rules were applied:

A. Similar number of icedays appear in each month: both get a number indicating some ice, but with an uncertainty mark: 1˜.

B. One month has more icedays in it: The month with more icedays gets some ice without uncertainty mark whereas the month with fewer icedays gets some ice with an uncertainty mark 1 and (1)˜.

C. If one month has only one iceday but the rest of the days fell in the next month, only the latter month gets marked as 1. Of course there is a possibility that the ice was observed precisely in this one day that was the first or last day of a month, but it was considered less descriptive of the sea ice severity to let both months have a mark.

If two or more sources indicate ice in a zone for a particular month, but none of them is reliable, the code in the result table (interpretation, table 6) will have uncertainty mark " ˜ " as well because the sources, in many cases, stem from the same origin and even though many tell the same "unreliable" story it does not get any more reliable with repetition.

Otherwise, the working rule was that all diaries were treated as highly reliable sources for their zone, when they indicated ice, but no ice in their description did not necessarily mean that there was no ice. It is important to have in mind the period that each source gives information about.

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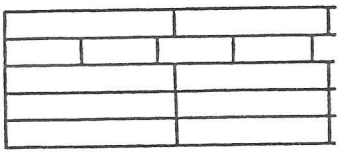
Otherwise, the working rule was that all diaries were treated as highly reliable sources for their zone, when they indicated ice, but no ice in their description did not necessarily mean that there was no ice. It is important to have in mind the period that each source gives information about.

Information from Lauge Koch´s maps is all treated as uncertain, as has been described earlier. The reliability of Þorvaldur Thoroddsen´s reports depended on how they were worded. The maps from the Danish Meteorological Institute do not always indicate maximum ice extent in a month but sometimes the location of the ice edge at, for example, the end of the month. In some cases, this resulted in uncertainty marks when the written reports were ambiguous. This was the case when some ice was said to have been observed, for example, north of some headland, without indicating any distances.

It was only possible to distinguish between "some" and "much" ice in Lauge Koch´s and the Norwegian charts, the description in the other sources did usually not allow this interpretation.

Table 5. Comparison of information from different sources. It must be stressed that sea ice information for each area in a time unit is what is thought to be the maximum ice extent.

Key to comparison tables.



Lauge Koch´s ice charts
The Norwegian ice charts
The Danish Met. Institute
Þorvaldur Thoroddsen
Diaries

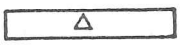
Much ice, over 75% cover (reliable data).

Possibly much ice (sources do not agree).

Definitely ice, up to 75% cover (reliable data).

Probably ice (questionable data).

Possibly ice (unreliable data).



Icebergs.

Zone

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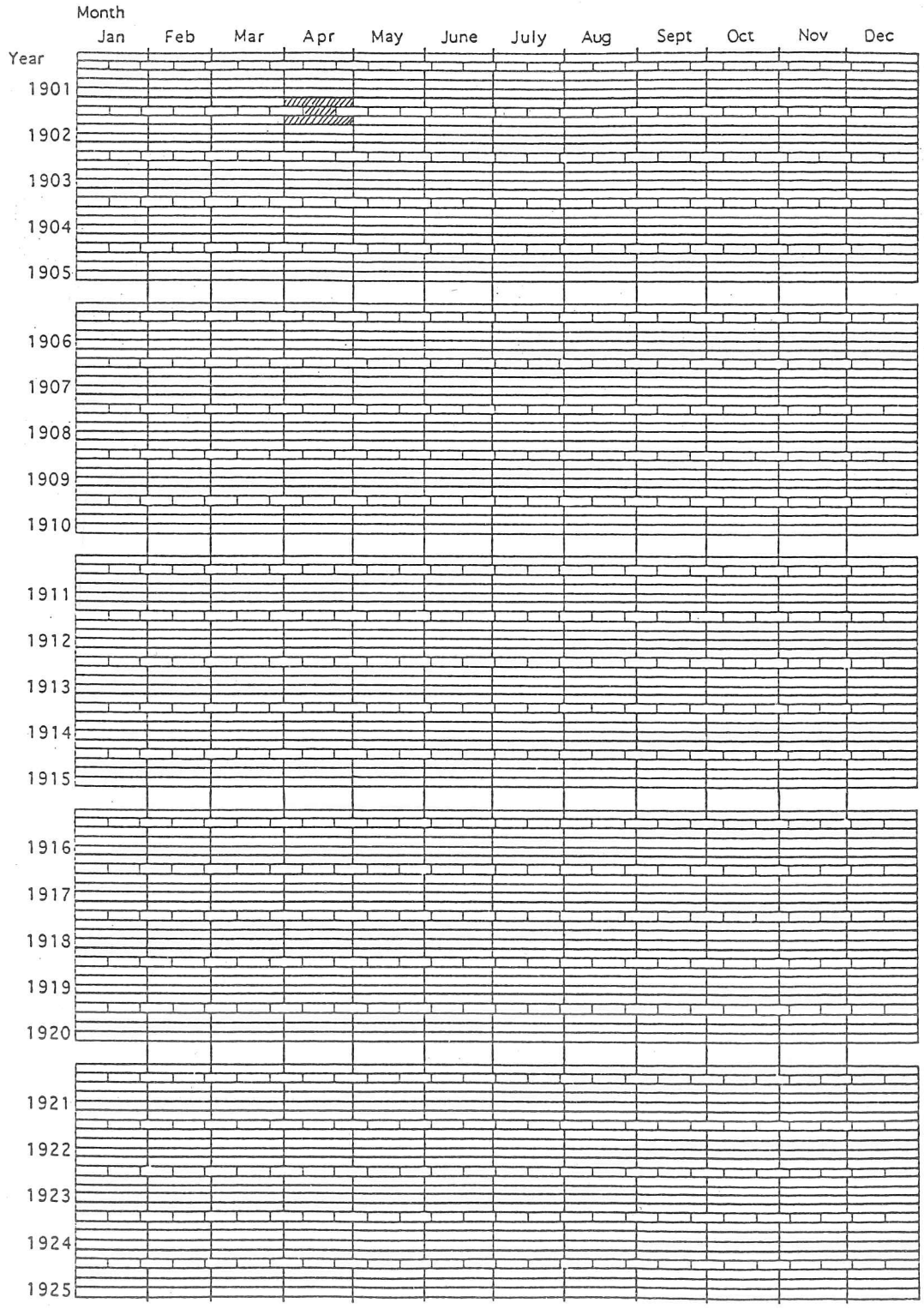
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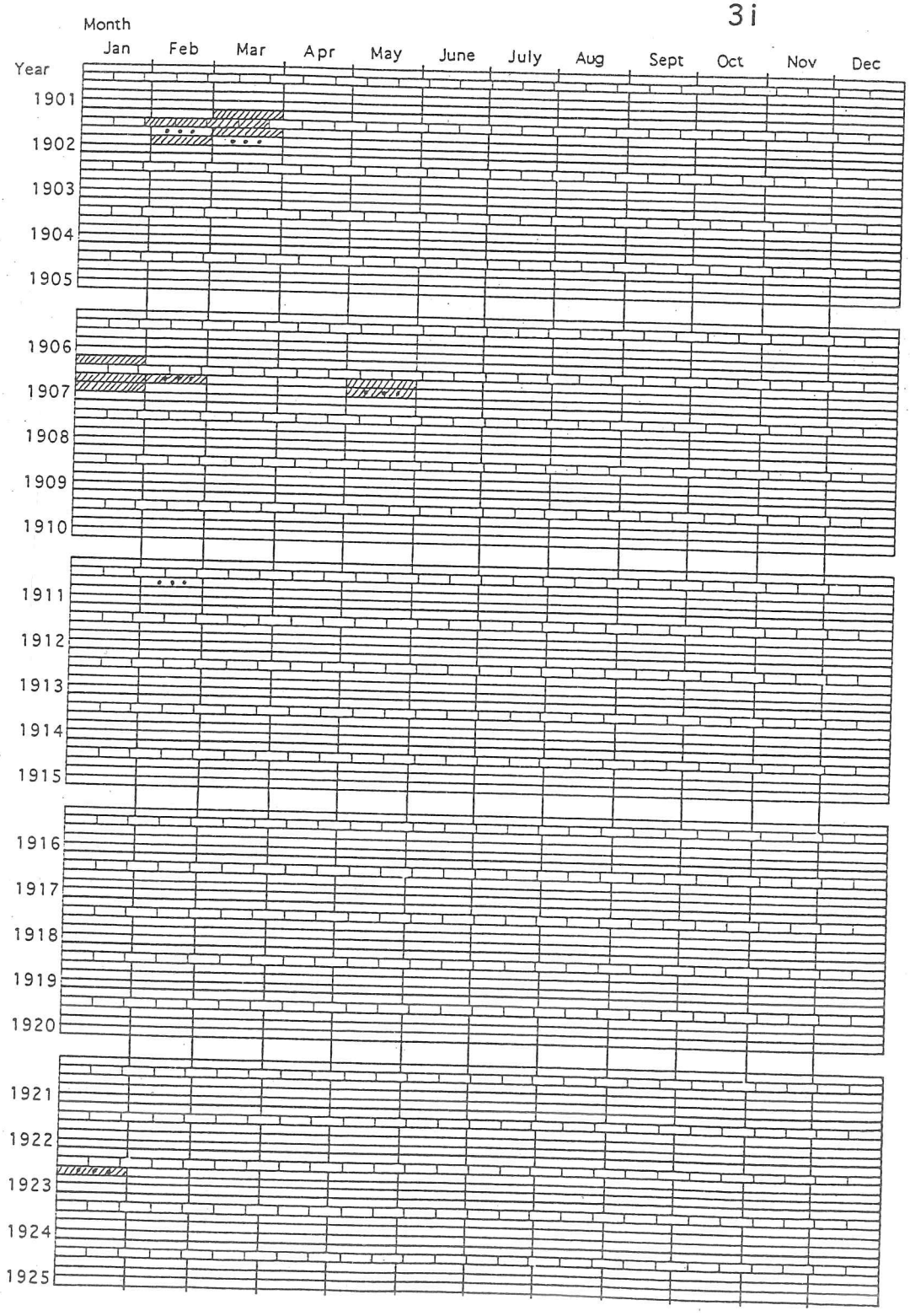
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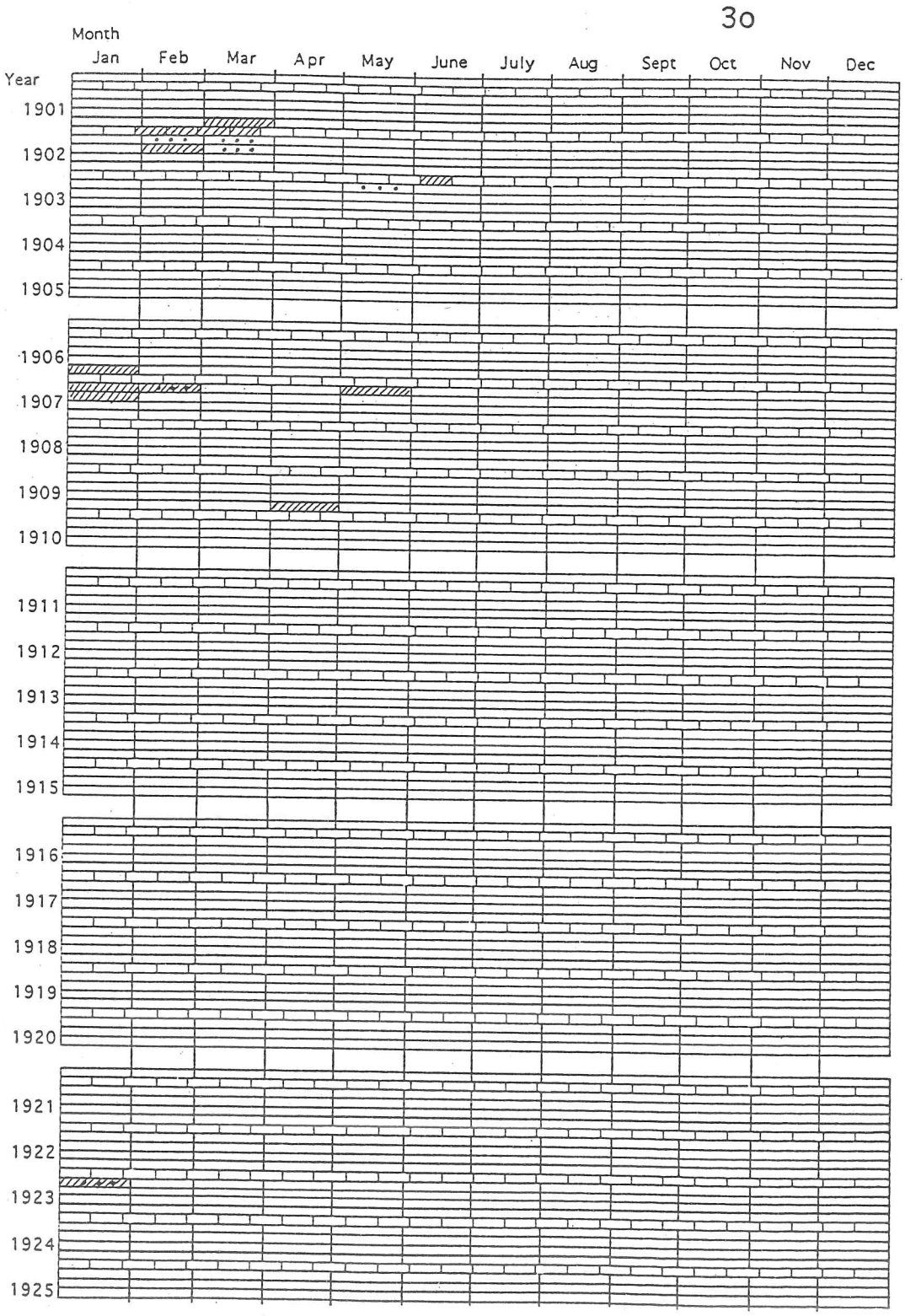
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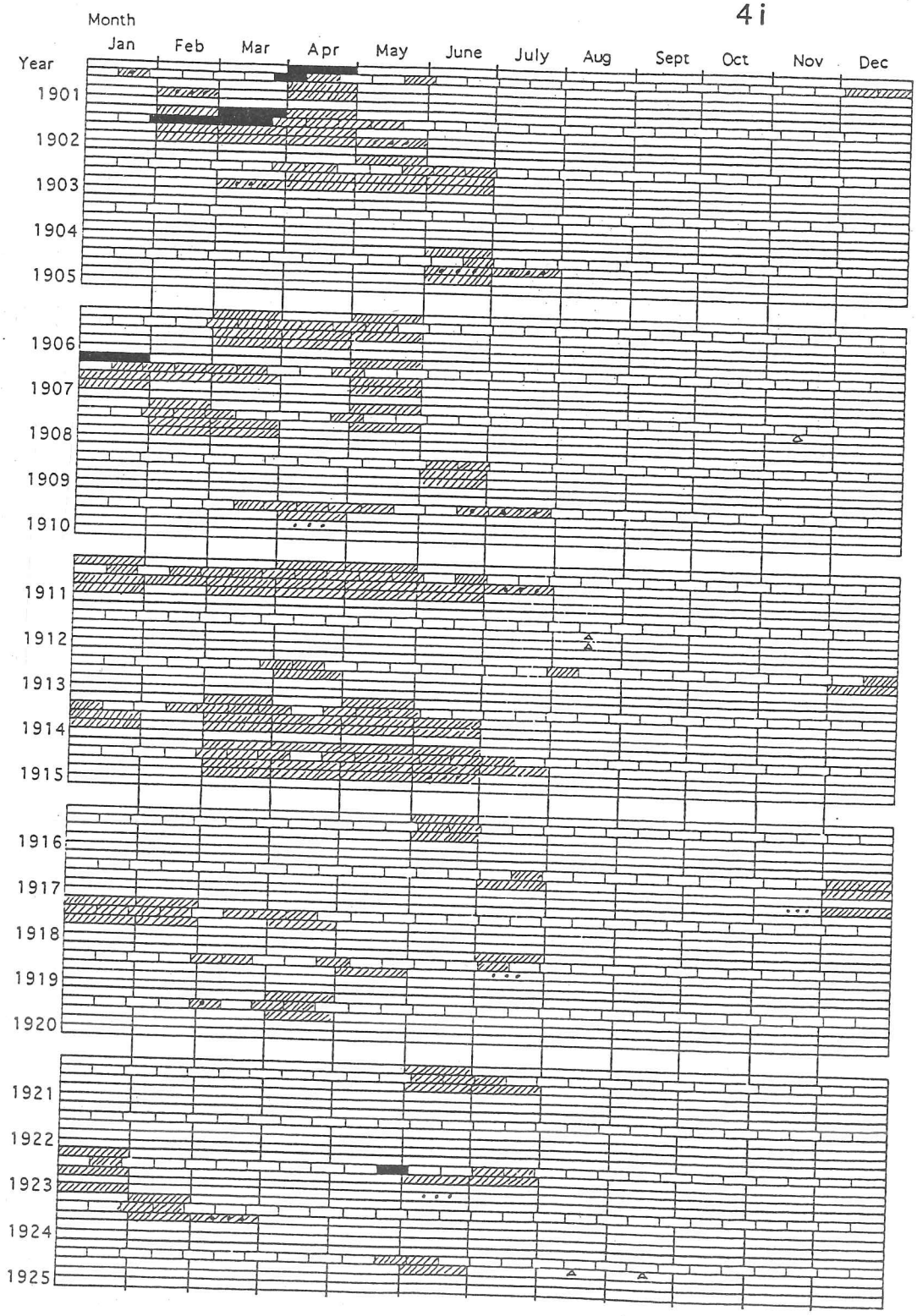
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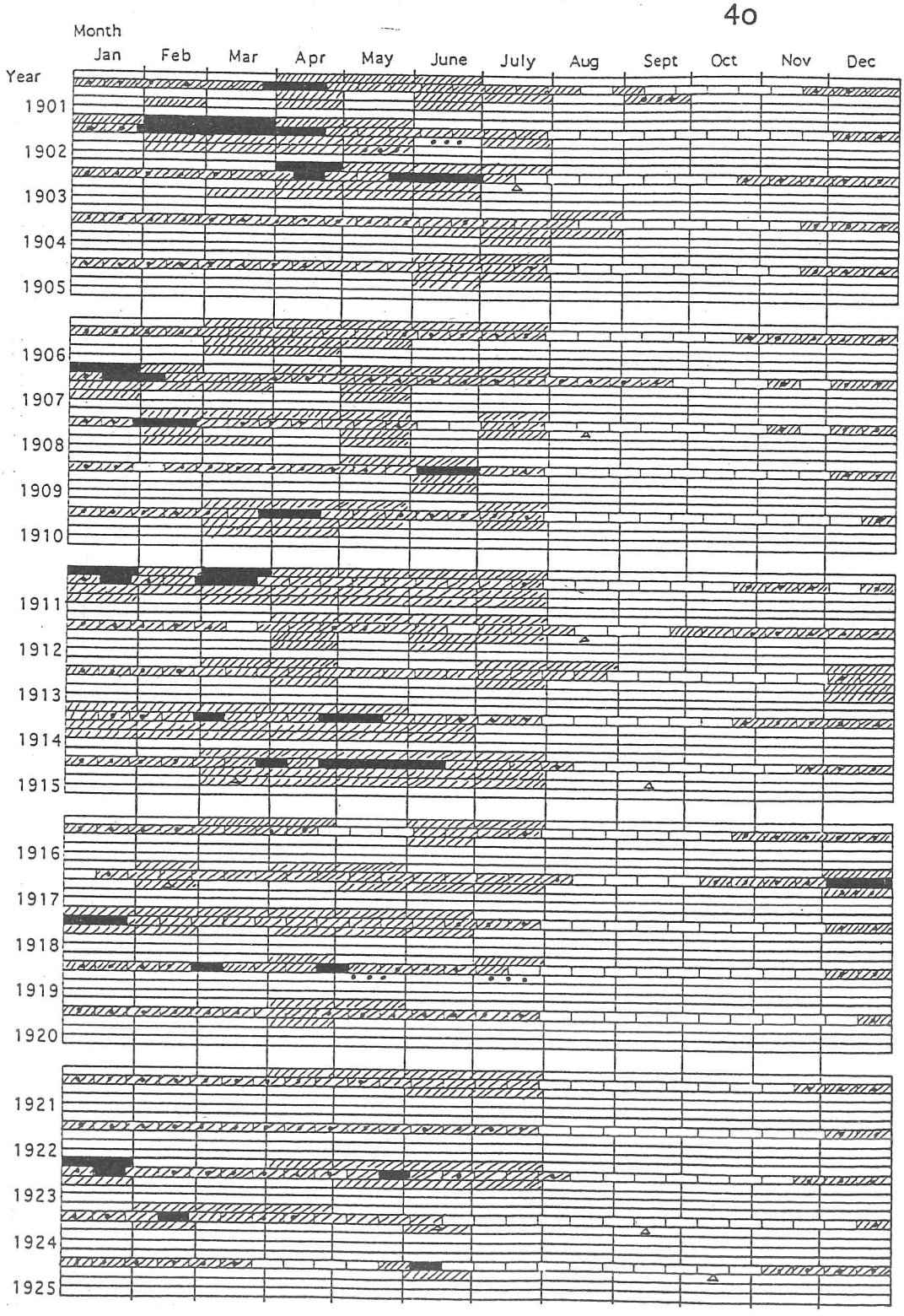
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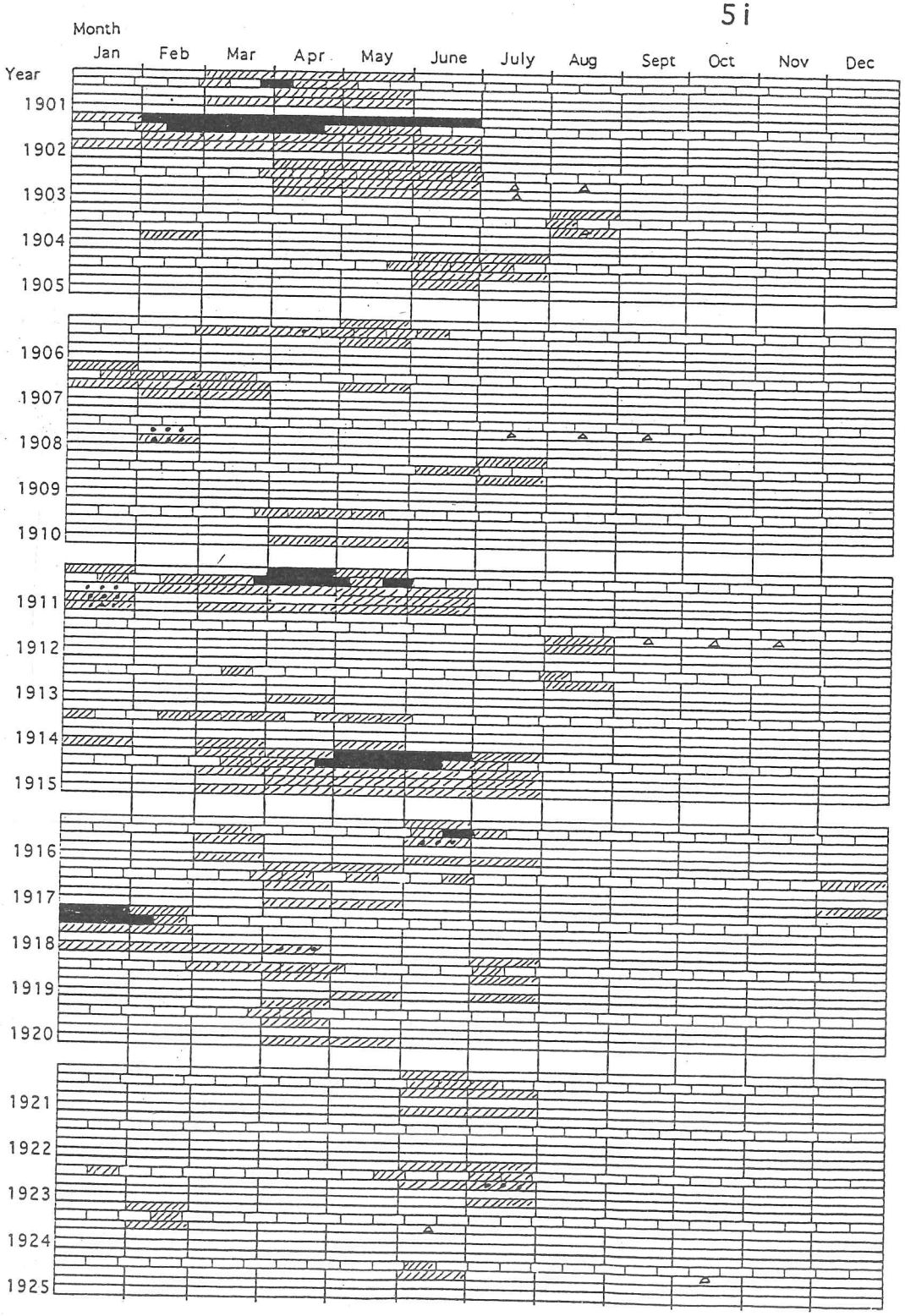
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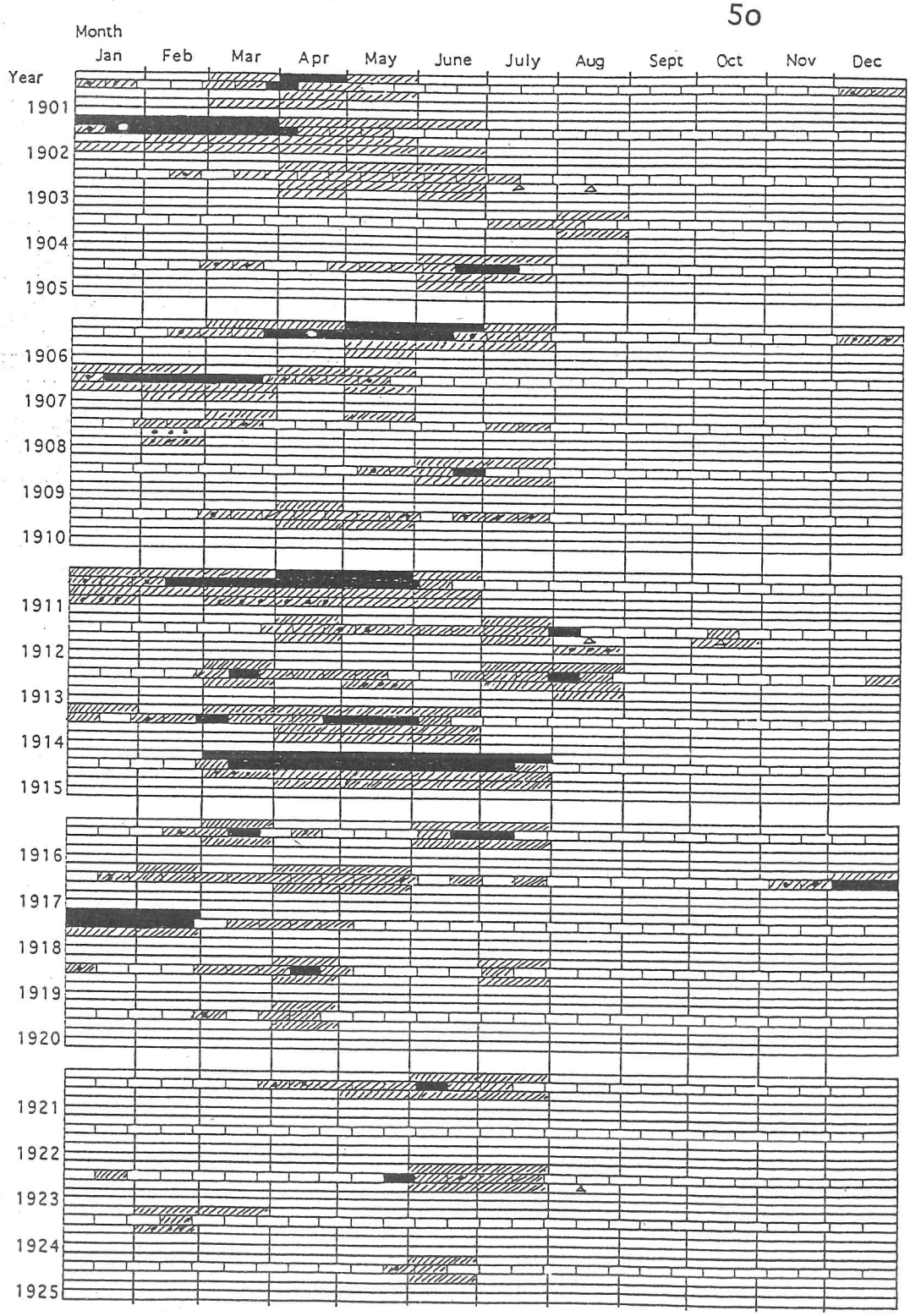
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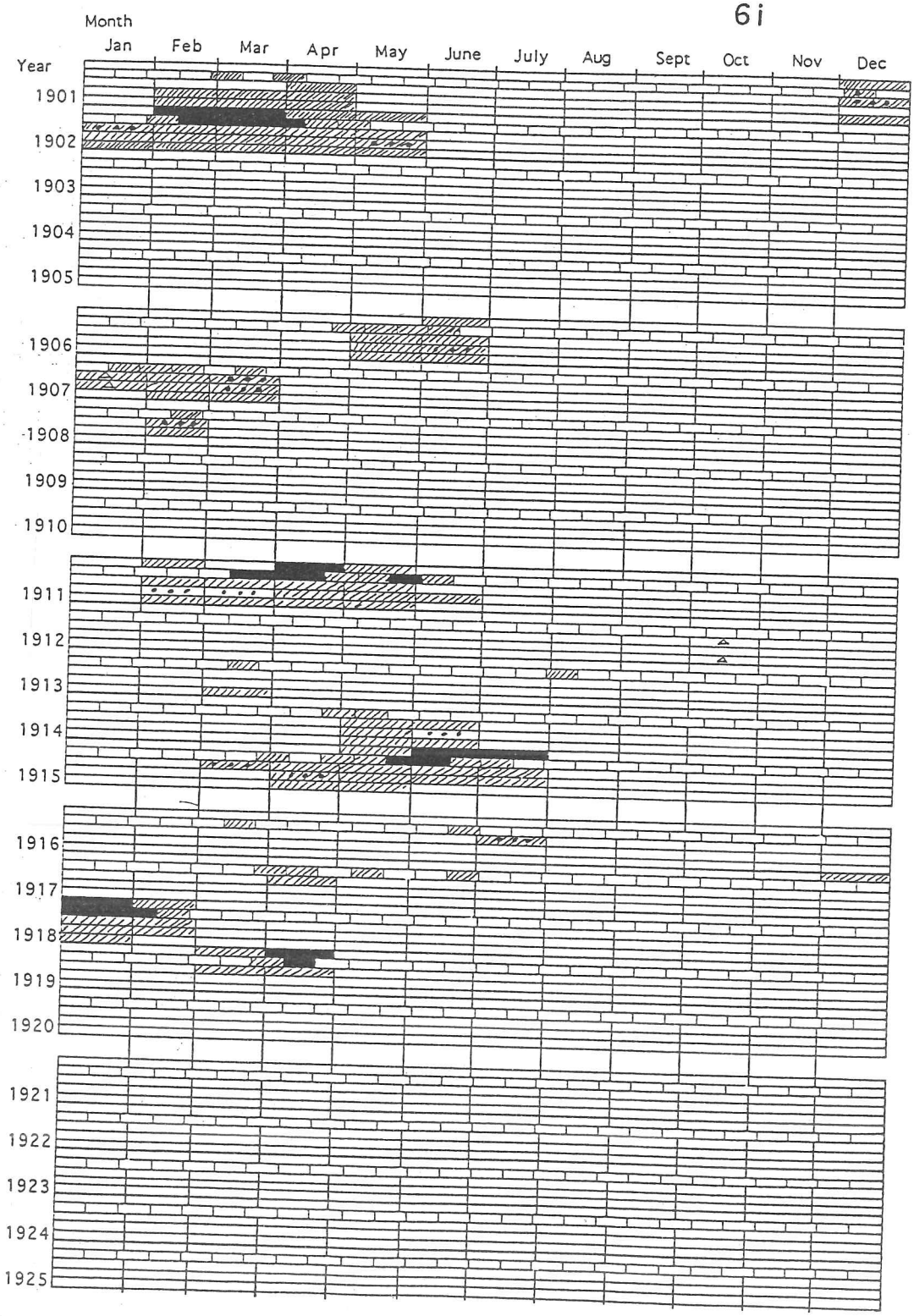
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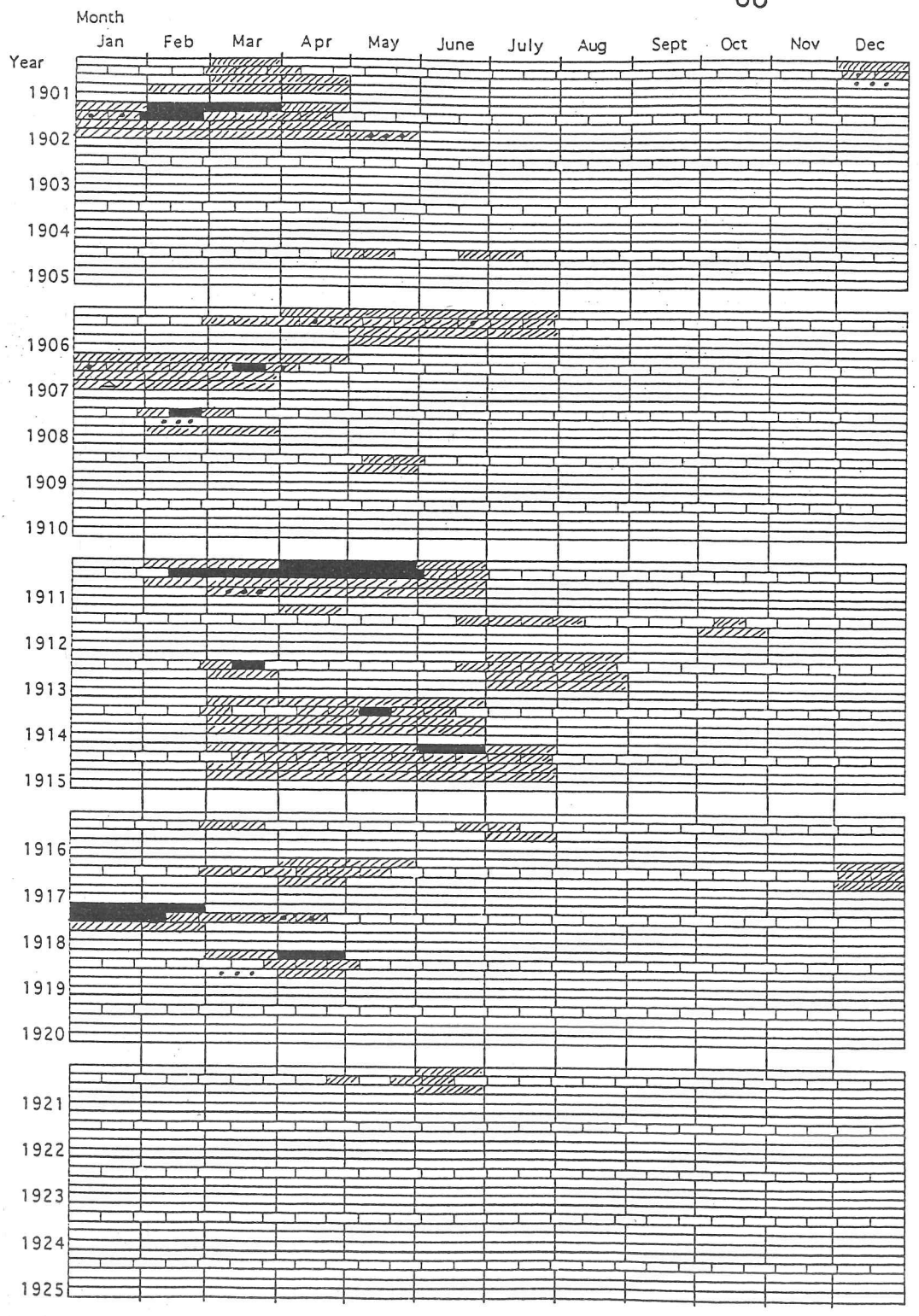
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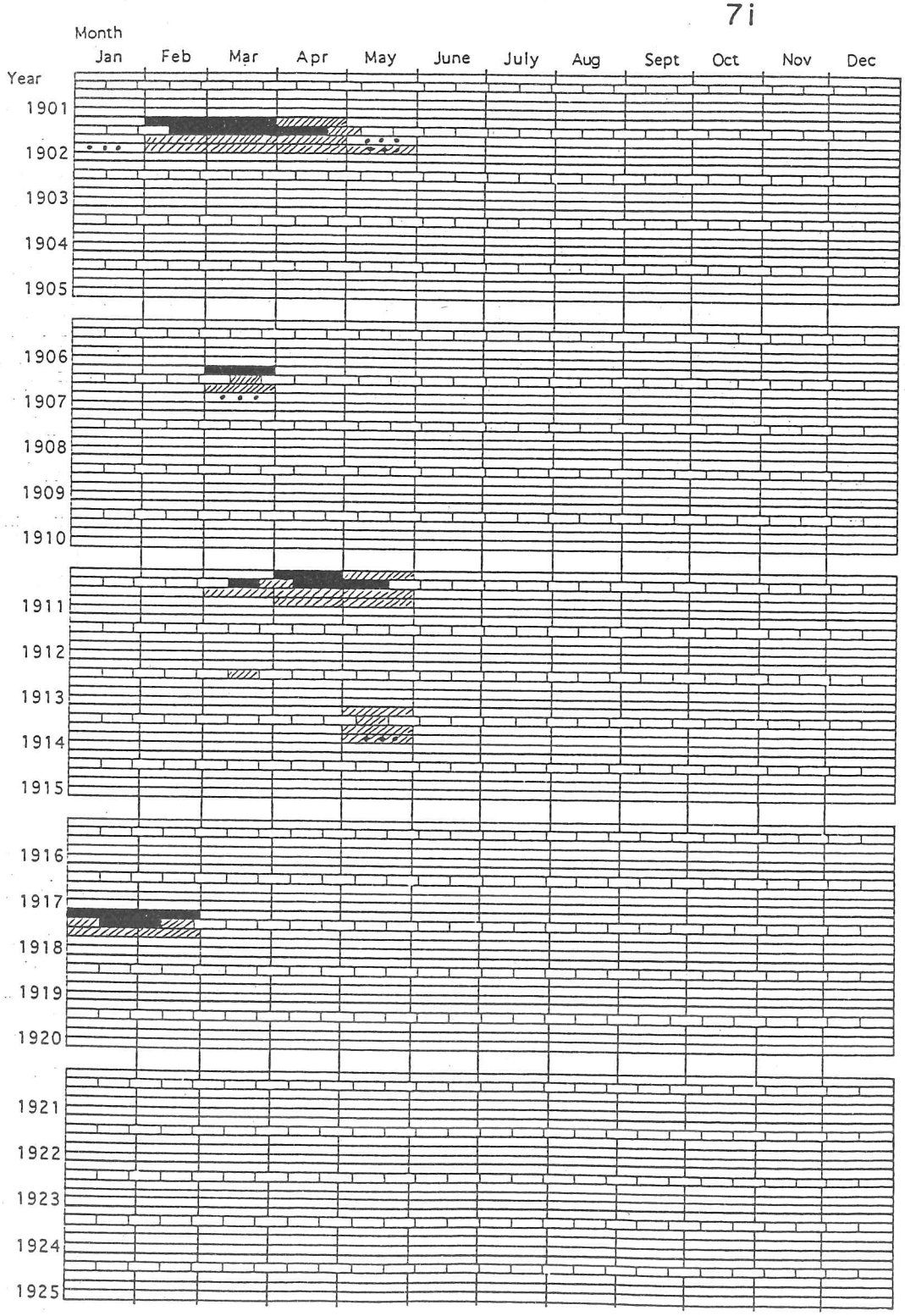
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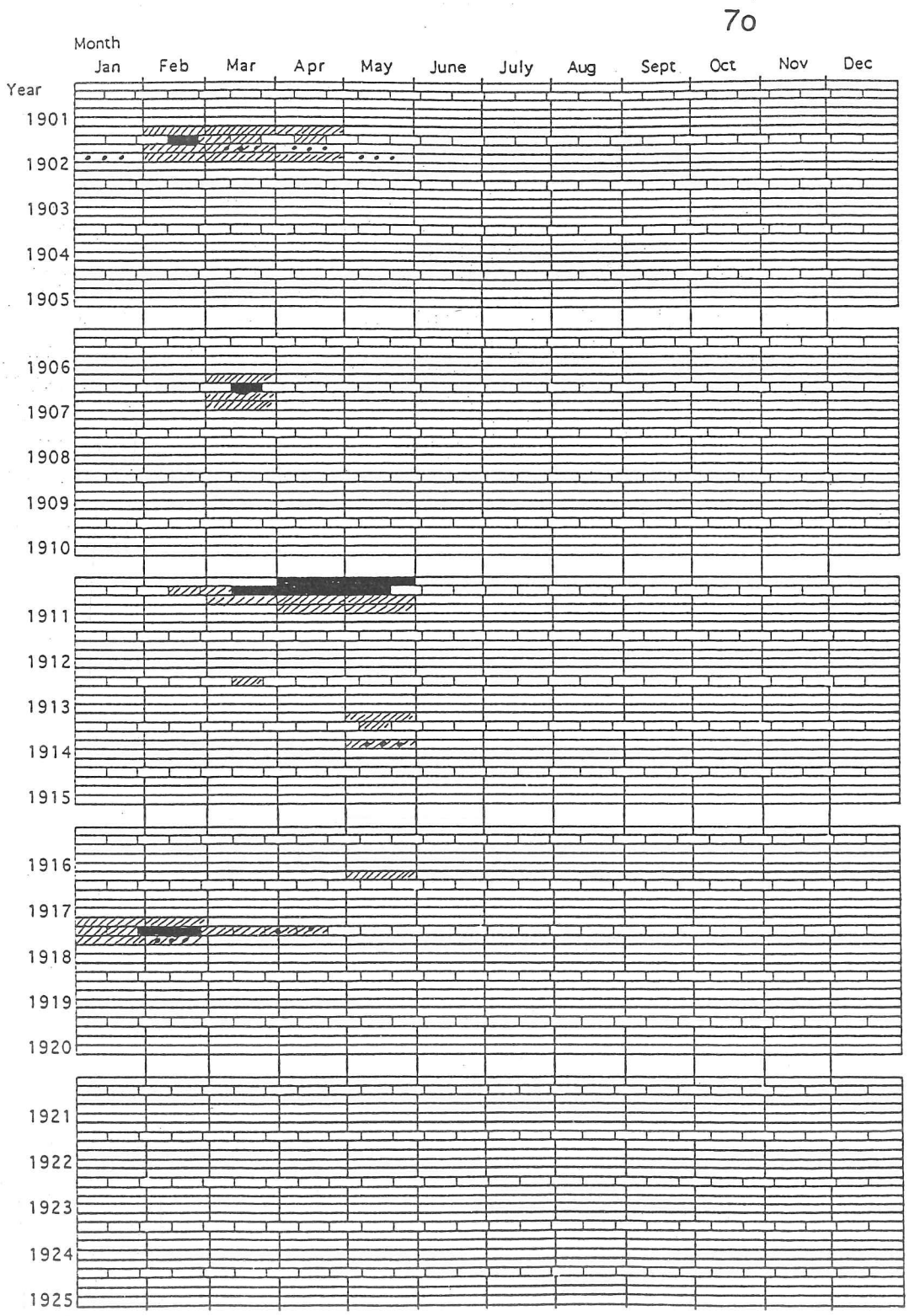
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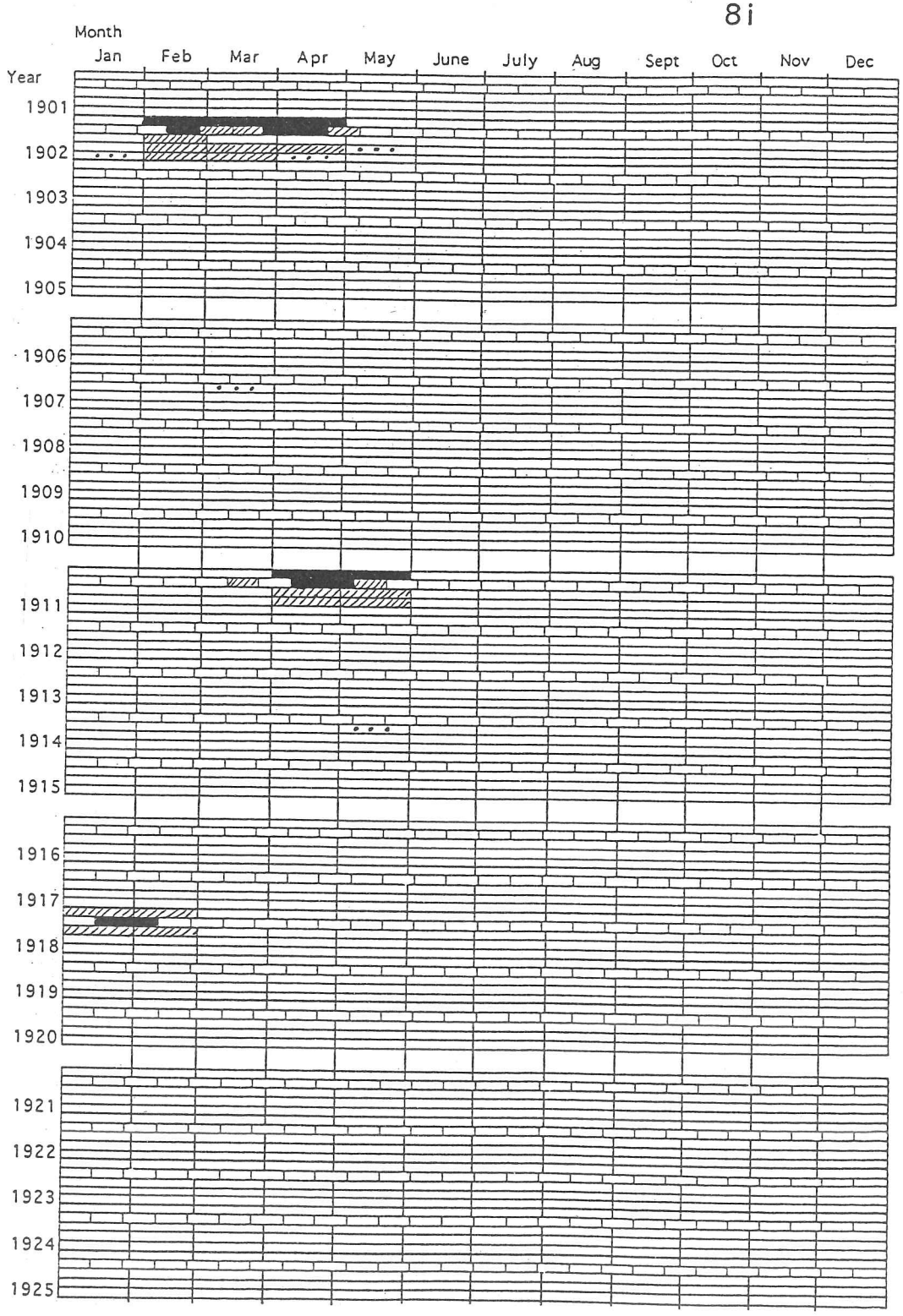
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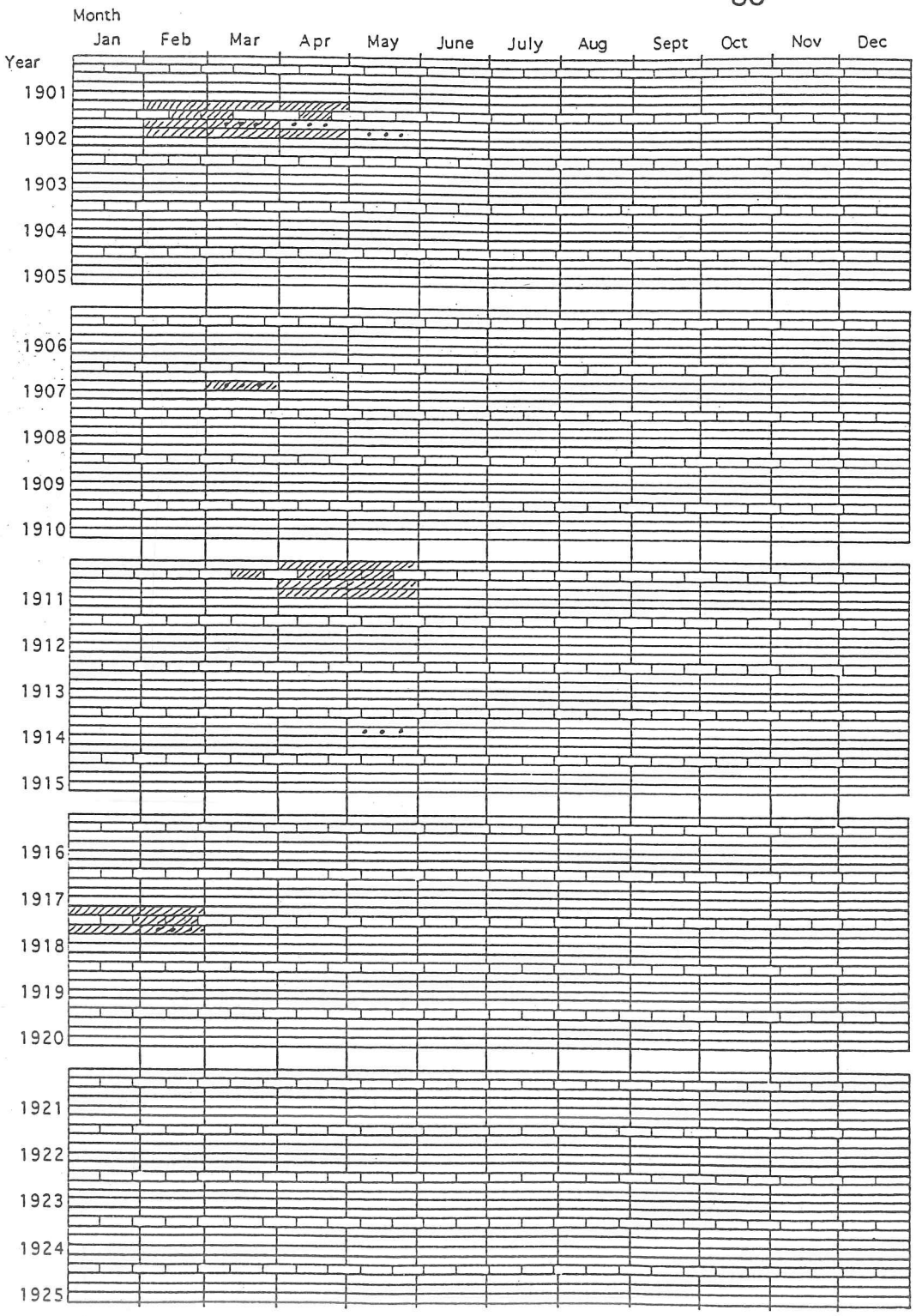
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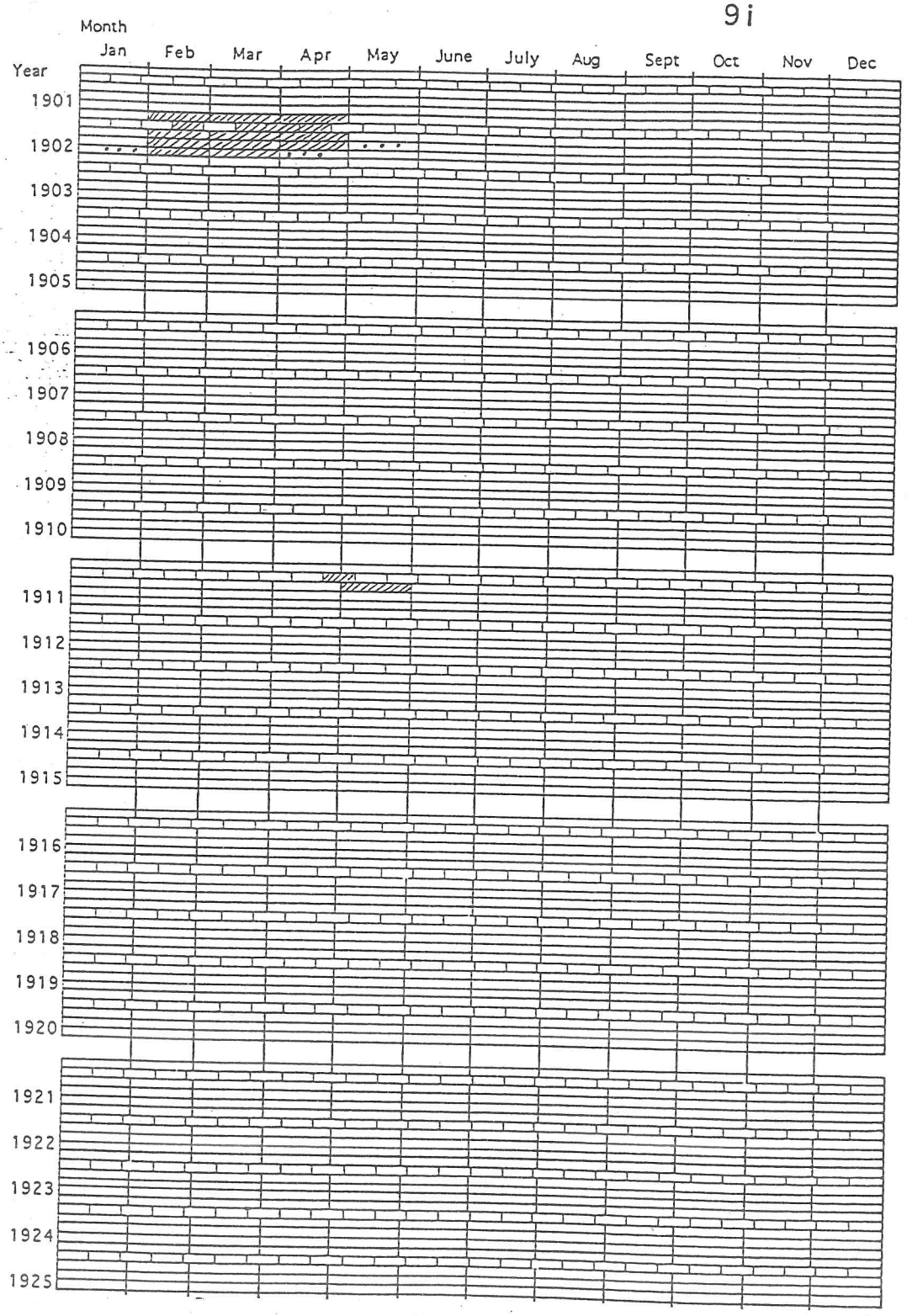
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5.2 Interpretation

Table 6 is an interpretation of table 5. Here, each zone has got an ice code and an indicator of whether the information is reliable. In further analysis of this, the ice codes are added together for each year and zone, and are called "indices of sea ice severity" or simply sea ice indices.

Here below is a key to table 6, similar to the one for table 5 except for different signs:

Table 6. Interpretation of comparison table.

2 Much ice, over 75 % cover (reliable data).
2˜ Possibly much ice (sources do not agree).
1 Definitely ice, up to 75 % cover (reliable data).
1˜ Probably ice (questionable data).
˜ Possibly ice (unreliable data).
* Some comment in "notes" column.

Figures 9, 10 and 11 are all made from table 5.

Zone

Year	Mth	Ii	Io	III	IIo	IIIi	IIIo	IVi	IVo	Vi	Vo	VII	VIo	VIII	VIIo	VIII	VIII	IXi	IXo	Notes
1901	01							1⁻	1⁻		1⁻									
1901	02							1⁻	1			1	1							
1901	03								1	1	1	1	1							
1901	04							2	2	2	2	1	1							
1901	05							1	1	1	1									
1901	06								1											
1901	07								1											
1901	08								1											
1901	09								1											
1901	10																			
1901	11								1⁻											
1901	12							1	1		1	1	1							
1902	01								1	1	2	1	1	-	-	-		-		
1902	02					1	1	2	2	2	2	2	2	2	2	2	1	1		
1902	03					1	1	2	2	2	2	2	2⁻	2	1	2	1	1		
1902	04	1						1	2	2	1	1	1	2	1	2	1	1		
1902	05							1	1	2	1	1	1⁻	1⁻	1⁻	-	-	-		
1902	06								1	2	1									
1902	07								1											
1902	08																			
1902	09																			
1902	10																			
1902	11																			
1902	12								1⁻											
1903	01								1⁻											
1903	02								1⁻		1⁻									
1903	03							1⁻	1		1									
1903	04							1	2	1	1									
1903	05						1⁻	1	2⁻	1	1									
1903	06						1	1	2	1	1									
1903	07								1*	*	1*									*+iceberg
1903	08									*	*									*iceberg
1903	09																			
1903	10								-											
1903	11								1⁻											
1903	12								1⁻											
1904	01								1⁻											
1904	02								1⁻	1⁻										
1904	03								1⁻											
1904	04								1⁻											
1904	05								1⁻											
1904	06								1											
1904	07								1		1									
1904	08								1	1*	1									*iceberg
1904	09																			
1904	10																			
1904	11								1⁻											
1904	12								1⁻											
1905	01								1⁻											
1905	02								1⁻											
1905	03								1⁻		1⁻									
1905	04								1⁻		-	-	-							
1905	05								1	-	1		1							
1905	06							1	1	1	2		1							
1905	07							1⁻	1	1	2		1							
1905	08																			
1905	09																			
1905	10																			
1905	11								1⁻											
1905	12								1⁻											
1906	01								1⁻											
1906	02								1⁻		1⁻									
1906	03							1	1	1	1		1⁻							
1906	04							1	1	1	2		1⁻							
1906	05							1	1	1	2	1	1							
1906	06								1	1	2	1	1							
1906	07								1		1		1							
1906	08																			
1906	09																			

Year	Mth	II	Io	III	IIo	IIII	IIIo	IVI	IVo	VI	Vo	VII	VIo	VIII	VIIo	VIII	VIII+	IXI	IXo	Notes
1906	10								-											
1906	11								1-											
1906	12								1-		1-									
1907	01					1	1	2-	2	1	2	1*	1*							*+iceberg
1907	02					1-	1-	1	2-	1	2	1	1							
1907	03							1	1	1	2	1	2	2-	2	1-	-			
1907	04							-	1		1		1-							
1907	05					1-	1-	1	1	1*	1									*very little
1907	06								1											
1907	07								1											
1907	08								1-											
1907	09								1-											
1907	10																			
1907	11								1-											
1907	12								1-											
1908	01								1-											
1908	02							1	2	1-	1	1	2-							
1908	03							1	1		1		1-							
1908	04							-	1											
1908	05							1	1		1-									
1908	06																			
1908	07								1	*	1									*iceberg
1908	08								*	*										*iceberg
1908	09									*										*iceberg
1908	10																			
1908	11								1-											
1908	12								1-											
1909	01								1-											
1909	02								1-											
1909	03								1-											
1909	04								1-											
1909	05								1		1-		1							
1909	06							1	2	1	2									
1909	07								1	1	1									
1909	08																			
1909	09																			
1909	10																			
1909	11																			
1909	12								-											
1910	01								1-											
1910	02								1-											
1910	03							1	1		1-									
1910	04						1-	1	2	1	1									
1910	05							1	1	1	1									
1910	06							1	1		1									
1910	07							1	1		1									
1910	08																			
1910	09																			
1910	10																			
1910	11																			
1910	12								1-											
1911	01							1	2	1	1									
1911	02					1*		1	1	1	2	1	2		1					*young ice
1911	03							1	2	1	2	2	2	2-	2-	1	1			
1911	04							1	1	2	2	2	2	2	2	2	1	1-		
1911	05							1	1	2	2	2	2	2	2	2	1	1		
1911	06							1	1	1	1	1	1		1					
1911	07							1-	1											
1911	08																			
1911	09																			
1911	10								-											
1911	11								1-											
1911	12								1-											
1912	01								1-											
1912	02								1-											
1912	03								1-											
1912	04								1		1		1-							
1912	05								1		1-									
1912	06								1		1		1							

Year	Mth	Ii	Io	IIi	IIo	IIIi	IIIo	IVi	IVo	Vi	Vo	VIi	VIo	VIIi	VIIo	VIIIi	VIIIo	IXi	IXo	Notes
1912	07								1		1		1							
1912	08							*	1- *	1	2-*		1							*iceberg
1912	09								-	*										*iceberg
1912	10								-	*	1-*	*	1-							*iceberg
1912	11								1-	*										*iceberg
1912	12								1-											
1913	01								1-											
1913	02								1-											
1913	03								1	1	2	1	2	1	1					
1913	04							1	1	1	1									
1913	05								1		1									
1913	06								1		1		1-							
1913	07								1		1		1							
1913	08							1*	1	1	2	1*	1							*very little
1913	09																			
1913	10																			
1913	11																			
1913	12							1	1		1									
1914	01							1	1	1	1									
1914	02							1	1	1	1									
1914	03							1	2	1	2		1							
1914	04							1	2-	1-	2-	-	1							
1914	05							1	2	1	2	1	2	1	1	-	-			
1914	06							1	1		1	1	1							
1914	07								1-											
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1914	09																			
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1914	11								1-											
1914	12								1-											
1915	01								1-											
1915	02								1-											
1915	03							1	1*	1	2	1-	1							*+iceberg
1915	04							1	2	1	2	1	1							
1915	05							1	2	2	2	2-	1							
1915	06							1	2	2	2	2	2-							
1915	07							1	1	1	2	2-	1							
1915	08								-											
1915	09								*											*iceberg
1915	10																			
1915	11								-											
1915	12								1-											
1916	01								1-											
1916	02								1-		1-									
1916	03								1	1	2	1	1							
1916	04								1-		1-									
1916	05																			
1916	06							1	1	1	2	1	1							
1916	07								1	1	2	1-	1							
1916	08																			
1916	09																			
1916	10								-											
1916	11								1-											
1916	12								1-											
1917	01								1-		1-									
1917	02								1*		1									
1917	03								1		1	-	1							
1917	04								1	1	1	1	1							
1917	05								1	1	1	1	1		1-					
1917	06								1	1	1	1								
1917	07							1	1		1									
1917	08								1-											
1917	09																			
1917	10								-											
1917	11							-	1-		1-									
1917	12							1	2	1	2	1-	1							
1918	01							1	2	2	2	2	2	2	1	2	1			
1918	02							1	1	2	2	1	2	2	2	2	1			
1918	03							1	1	1-	1		1		1					

Year	Mth	II	Io	III	IIo	IIIi	IIIo	IVi	IVo	VI	Vo	VII	VIo	VIII	VIIo	VIII	VIII-	IXi	IXo	Notes
1918	04							1	1	-	1		1-		1-					
1918	05								1											
1918	06								1											
1918	07								1-											
1918	08																			
1918	09																			
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1919	01								1-		1-									
1919	02								1-											
1919	03							1	2-	1	1	1	1-							
1919	04							-	2	1	2	2	2-							
1919	05							1	1	1	-									
1919	06								1-											
1919	07							1	1	1	1									
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1920	01								1-											
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1920	03							-	1-		1-									
1920	04							1	1	1	1									
1920	05								1	1										
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1921	05								1		1		1-							
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1921	07							1	1	1	1									
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1922	09																			
1922	10																			
1922	11																			
1922	12								1-											
1923	01					1-	1-	1	2	1*	1									*very little
1923	02								1-											
1923	03								1-											
1923	04								1											
1923	05							2-	2	1-	2-									
1923	06							1	1	1	1									
1923	07							1	1	1	1									
1923	08								1-		*									*iceberg
1923	09																			
1923	10																			
1923	11								1-											
1923	12								1-											

Year	Mth	Ii	Io	IIi	IIo	IIIi	IIIo	IVi	IVo	Vi	Vo	VIi	VIo	VIIi	VIIo	VIIIi	VIIIo	IXi	IXo	Notes
1924	01								1-											
1924	02							1	2	1	1									
1924	03							1-	1		1-									
1924	04								1-											
1924	05								1											
1924	06								1*	*										*+iceberg
1924	07																			
1924	08																			
1924	09								*											*iceberg
1924	10																			
1924	11																			
1924	12								1-											
1925	01								1-											
1925	02								1-											
1925	03								1-											
1925	04																			
1925	05							1-	1-		1-									
1925	06							1	2	1	1									
1925	07																			
1925	08							*												*iceberg
1925	09							*												*iceberg
1925	10								*	*										*iceberg
1925	11								1-											
1925	12								1-											

5.3 The reliability

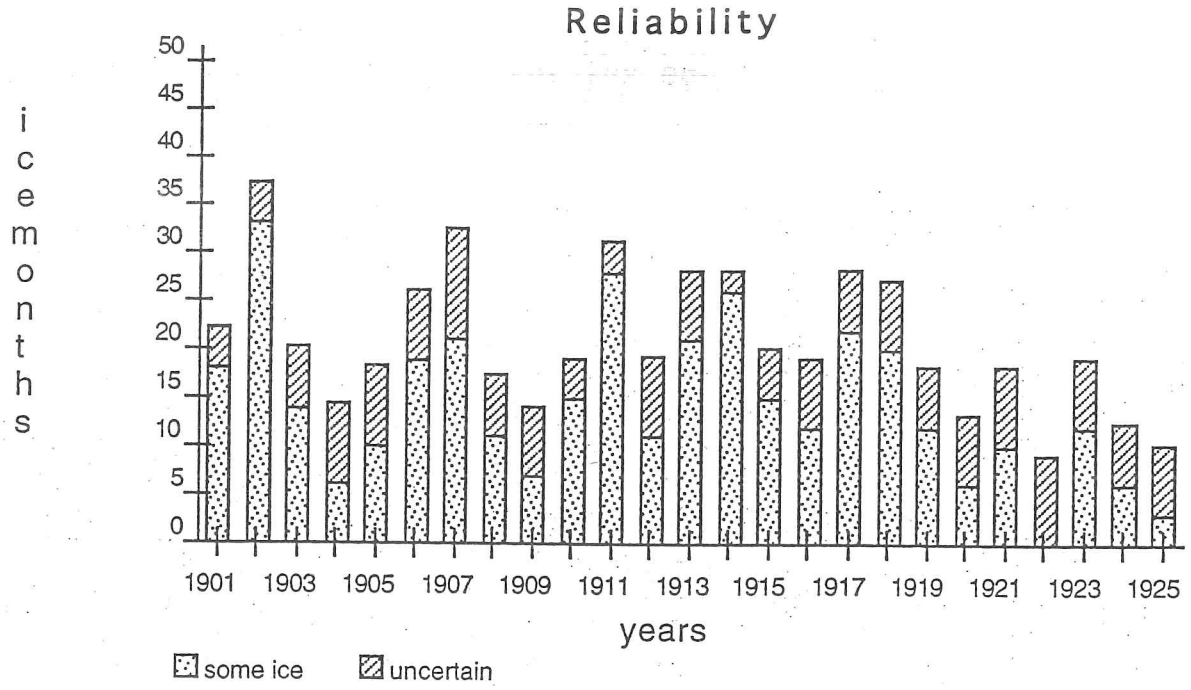

Figure 9. Reliability of all icemonths. Unreliable icemonths, marked " ~ " in table 6, are not included.

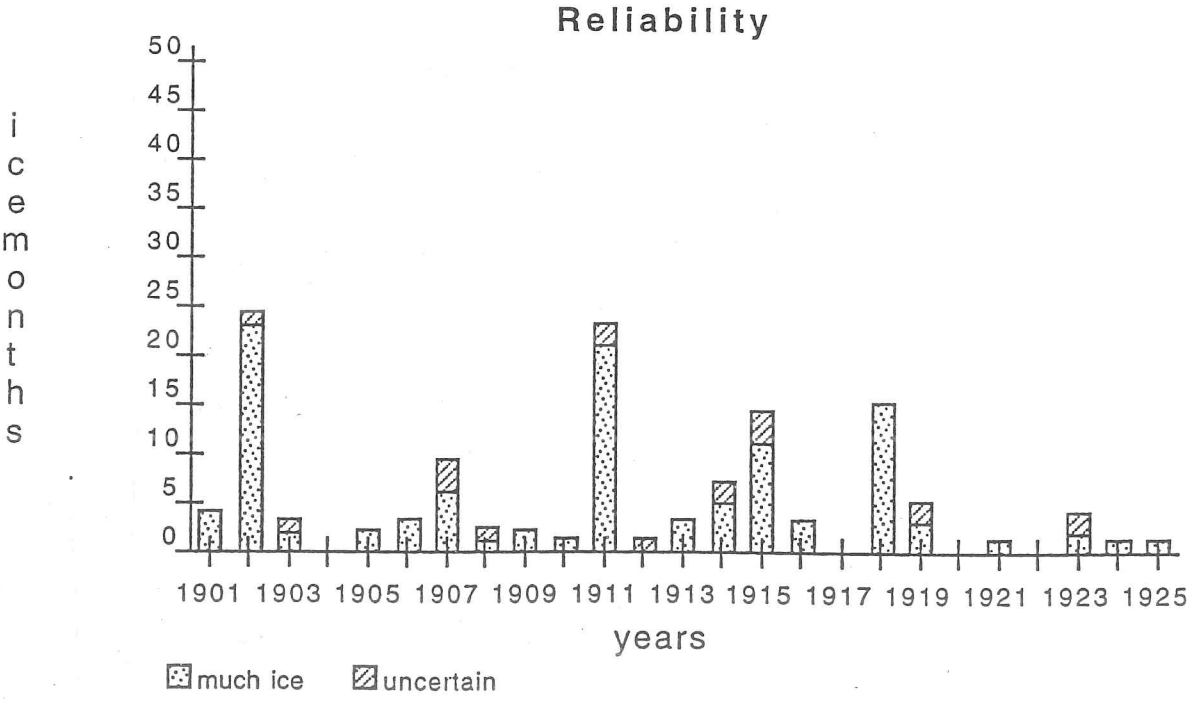

Figure 10. Reliability of severe icemonths (icecode 2). The months marked "uncertain" might not have had more than 75% ice cover, that is, different sources do not agree on the matter.

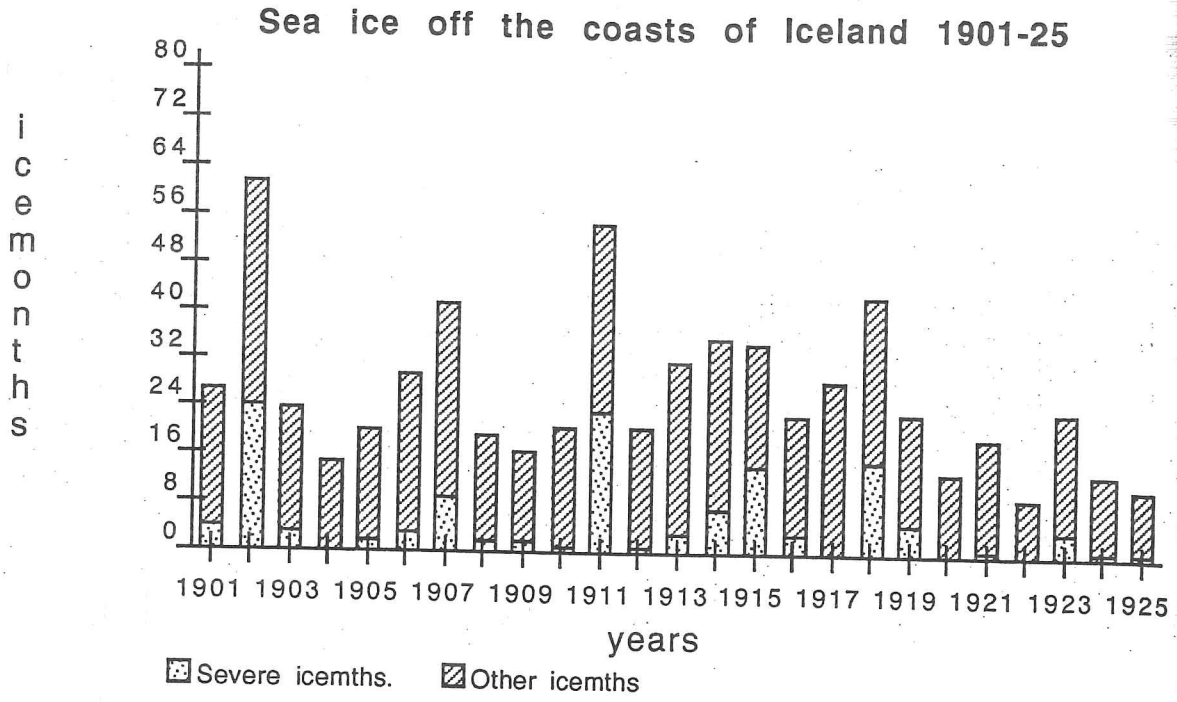

Figure 11. The sea ice history. This illustration shows the results from figures 9 and 10, the number of icemonths there were in the years 1901-1925 and the proportion considered to have been severe.

The most severe years seem to have been 1902 and 1911, but the years 1907, 1914, 1915 and 1918 must also have been difficult. In 1904 and 1922 there was hardly any ice observed. The last years of the period, 1919 onwards, seem to have had relatively little sea ice.

5.4 When and Where ?

Figure 12. shows the number of all icemonths and of them, the severe ones, in each zone. Ice is often observed in zone 4o, but this area also has the highest "uncertainty" number. It appears that the ice edge has been expected to be slightly within the boundaries of this area, and when there was no information, it was often "drawn" there. Zone 3 has few incidences of sea ice, and in all the icemonths there was very little ice and then only in the Northern parts of the zone. In cold winters ice forms in the shallow Breidafjordur of zone 3i. Zone 5o ranks as the second

most often visited one, however, icecode 2 (icecover more than 75%), was most often observed here. Sea ice is quite often observed in the inner areas of 4 and 5. This is not surprising when the ocean currents in this area are considered (figures 4 and 5). Off the north coast of Iceland, sea ice was more frequent in the outer areas and they were also the ones that were more often filled with ice. Off the east coast, the story is different; the inner areas have more often some ice and are also more often filled with ice. In the few times that sea ice drifts all the way to the south coast, the ice has only been observed in the inner areas, and they have not had a high ice concentration. This is also due to ocean currents; they are strongest near the shelf, which lies relatively far away from the north coast but very near to the east and the south coasts.

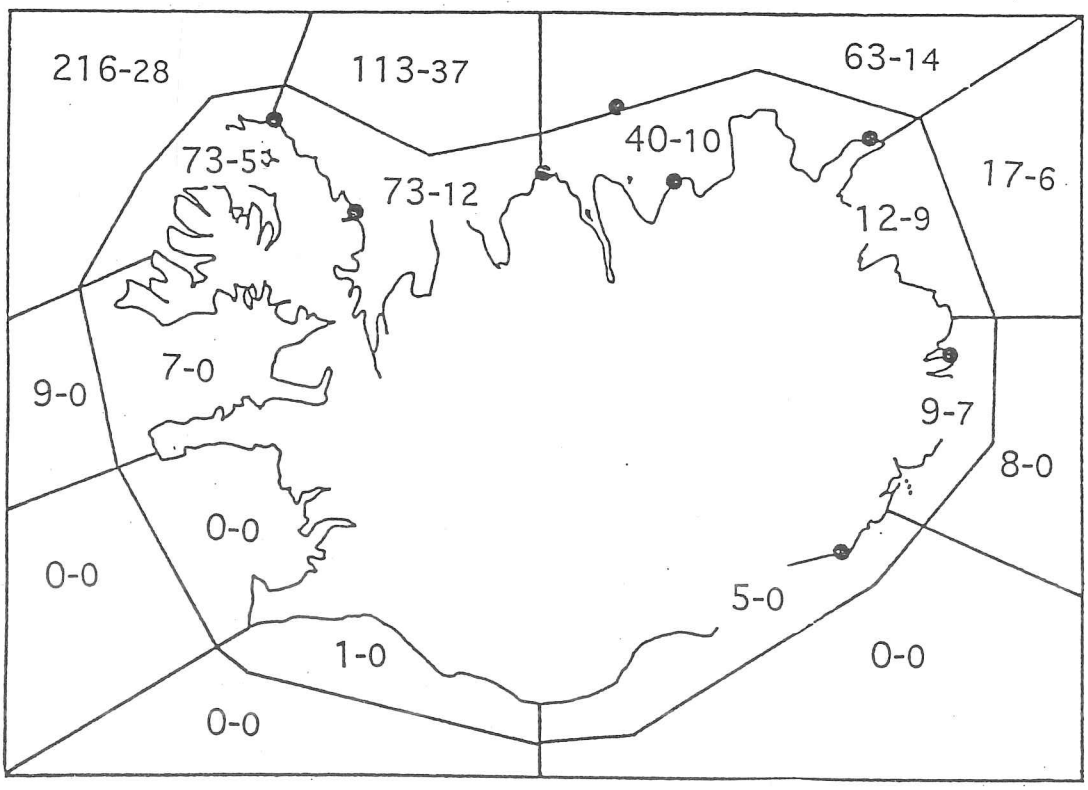

Figure 12. Sea ice observed in different zones around Iceland in the years 1901-1925. The bigger number indicates all icemonths in this period and the smaller the severe icemonths.

It is apparent from table 7 that the sea ice came most frequently, and in most quantities, in the months of spring, March to May, and sometimes June.

Table 7. Frequency of sea ice in each month.

Month	Incidents of ice	-of which are unreliable
January	25	19
February	25	16
March	25	9
April	25	7
May	24	3
June	24	3
July	23	4
August	8	5
September	3	2
October	7	7
November	16	16
December	25	22

The data from winter months are not very reliable. This is when, relatively, there seem to be fewest ships onshore.

6. Discussion

6.1 Sources and sea ice history.

Looking at the comparison table (table 5) in chapter 5, it is surprising how much variability there is between sources, on a local scale, and from month to month. This is specially interesting when it is kept in mind that many of the sources are based on the same primary data. This is at least the case with the reports from the Danish Meteorological Institute, that both Lauge Koch and Þorvaldur Thoroddsen rely on. Lauge Koch has had more information to build on, as many ships journals have been sent in after the reports themselves were published and other sources of information might have come. He has probably had emphasis on much ice, as he does not always mention ice that is described in the reports from the Danish Meteorological Office (table 5.).

Þorvaldur Thoroddsen does not always mention ice when the Danish reports do. This could be because the ice did not reach land. He says in the preface of his work that he only mentions the main ice and has not bothered to mention all the times when scattered ice was observed somewhere off the coast. His information often has "gaps" in it (table 5) that do not necessarily mean that there was no ice at that time. He describes when ice came to a certain part of the coast and when it was all gone, but the months that may be in-between do not get a reliable ice code because so much can happen in a short time. His descriptions are short, and almost suggest that the reader should read between the lines.

The Norwegian maps have in most cases ice in December and quite often in November as well, even though the other sources hardly mention ice at that time of year. The "iceweeks" in zone 4o at the end of the year are probably over estimated. The Norwegian maps correlate quite well with Jón Jakobsson's diary in zone 6i.

The diaries do not always seem to notice ice in their zone. This does not mean that they are not reliable when they see ice. There is often fog at the ice edge that limits the view to a great extent.

In some cases, the diaries confirm the other sources when there is some doubt. This happens, for example, in April and May 1910, when the diary from zone 5i (Gjögur) together with the Norwegian charts, indicate ice which no other sourse reports.

For the country as a whole, the general sea ice history has not been altered much by this comparison of different sources. However, locally, and from month to month there can be great changes.

6.2 Other climatic data

If the sea ice indices are compared with mean annual temperature (for a year starting in October and ending in September) in Stykkishólmur W-Iceland, it shows that some of the severe ice years were very cold (figure 13). The Stykkishólmur weather station was chosen to represent the whole country because it is a typical coastal site away from the main ice areas. The mean temperature for these years is 3.12°C, with a standard deviation of 0.698. The coldest year was 1918, with mean temperature of only 1.36°C. The years 1902 and 1907 were cold as well, but 1911, which ranks as the second most severe ice year, was not very cold and nor was the year 1915. The year 1910, which had very little ice, was quite cold; 2.43°C.

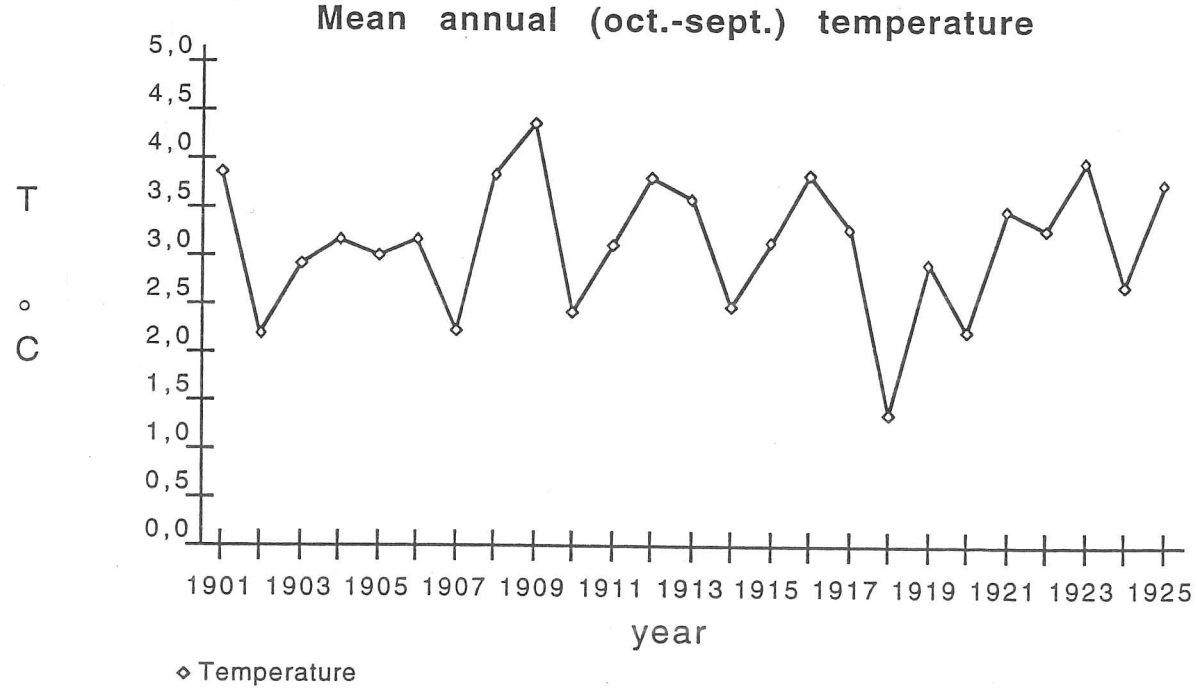

Figure 13. Mean annual temperature in Stykkishólmur, W-Iceland. A year is defined from October to September; the "year" 1911 starts in October 1910 and ends in September 1911. (Based on Jónsson 1993)

If the three data sets - the sea ice index for all icemonths; the index for severe icemonths (sea ice cover more than 75% in a zone); and the mean annual temperature in Stykkishólmur - are run through a cross correlation program, (SYSTAT), the results are as following; (table 8)

Table 8. Correlation between sea ice indices and mean annual temperature in Stykkishólmur W-Iceland.

(1). Correlation between all icemonths and severe icemonths.

LAG years	Correlation coefficient	Standard error
-5	.082	.224
-4	.285	.218
-3	-.095	.213
-2	-.185	.209
-1	.052	.204
0	.917	.200
1	-.122	.204
2	-.122	.209
3	.087	.213
4	.176	.218

(2). Correlation between mean annual (Oct.- Sept.) temperature in Stykkishólmur and number of all icemonths:

LAG years	Correlation coefficient	Standard error
-5	-.111	.224
-4	-.161	.218
-3	-.258	.213
-2	.190	.209
-1	-.061	.204
0	-.440	.200
1	.057	.204
2	.453	.209
3	.098	.213
4	-.112	.218

(3). Correlation between temperature and severe icemonths.

LAG year	Correlation coefficient	Standard error
-5	-.072	.224
-4	-.098	.218
-3	-.308	.213
-2	.116	.209
-1	.142	.204
0	-.425	.200
1	-.061	.204
2	.450	.209
3	.240	.213
4	-.234	.218

(1): The correlation between the two ice indices is very high: .917, which is significant at the 99% level. This shows that both indices do agree well in their estimate of ice severity.

(2): The correlation between all icemonths and temperature in Stykkishólmur is (-.440 ± .200). This is significant at the 97% level, and means that there is a statistically valid, but not very strong, negative correlation between ice severity and air temperatures of the same year. The more ice there is, the more likely the year is to be cold.

(3): These results are similar to the correlation between temperature and all icemonths. The correlation is (-.425 ± .200), significant at the 96% level, which indicates that there is a negative correlation between air temperature and sea ice severity in Iceland. Thus, it is not possible to say whether the sea ice severity is partly caused by the cold air temperature or vice versa.

Surprisingly, there is a positive correlation of the same magnitude at lag 2 years, i.e. between air temperature and the ice severity two years later. That is, a warm year would indicate high ice severity two years later. There does not seem to be any physical reason for this that is immediately apparent.

There is a "habit" of using Stykkishólmur as an indicator of weather in Iceland. This is partly because it is the oldest continually working weather station. That, as well as reasons mentioned earlier in this chapter indicate that it is reasonable to use it as an rough indicator of the weather in Iceland as a whole. The sea ice is believed to have great local effects on the weather. Temperatures in the north-west, north and sometimes the east are therefore likely to show stronger correlation with the sea ice severity. Further research on this topic would include more temperature data from other weather stations, preferably one from each zone.

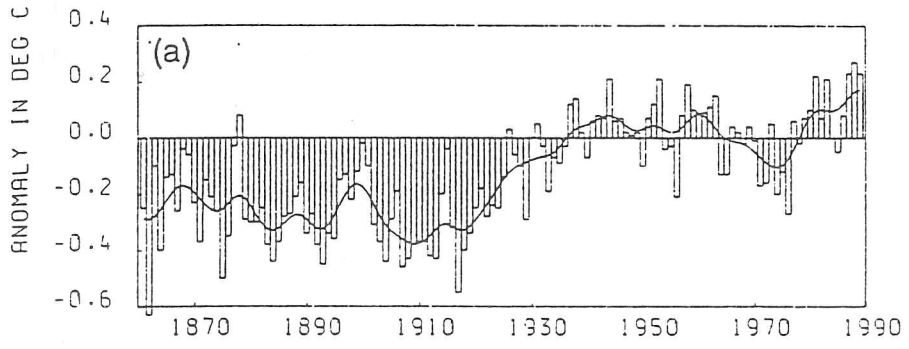

Figure 14. Combined land-air and sea surface temperature anomalies, relative to 1951-1980, for the whole Northern Hemisphere.

Combined land-air and sea surface temperature anomalies, relative to 1951-1980, for the whole Northern Hemisphere (Folland, 1990: 213) show that the years around 1900 were relatively warm, but then there was a cooling until 1910 when it started warming again, slowly, with a short cooling period in the late 1910´s. From 1920 there was a rapid warming that lasted for two decades. This agrees in some ways with the sea ice indices. The years after 1920 had not much ice, but it is difficult to trace other symptoms.

The temperature set from Stykkishólmur (running 12 months mean temperature) (Jónsson, T. 1993) shows great variation between years, but on the whole it appears that the warming did not start until after 1920. The cooling period after 1900 is not visible in the data set.

This is not surprising, as there are great regional variation in climatic changes, which often occur in steps.

7. THE "ANCIENT FIEND"

7.1 Introduction

Farming and fishing were the main sources of income in Iceland for centuries (Þorsteinsson and Jónsson 1991). Both are climate dependent activities in a country situated under the Northern Hemisphere´s major wind system, the North Atlantic westerlies. The sea ice was usually connected with cold weather, especially in North Iceland. The summers in Iceland are short, and when the sea ice stayed until late spring or early summer, it could cause enormous difficulties in farming (Bergþórsson, 1982, Lárusson, 1969).

Being so subjected to weather, people were generally very interested in it and its variability. Interest in sea ice was just one factor of this awareness of weather. People would try to find reasons for this, as it seemed, random arrival of sea ice. In earlier centuries, these events were connected with God´s wrath (Sigurbjörnsson, 1968). Through time, knowledge about sea ice was collected and passed on. In the early 20th Century, people seemed well informed about sea ice. Some of this knowledge came from reading. Literacy was relatively high in Iceland. Children had to learn to read before their confirmation, and a typical evening´s entertainment in the past was asking someone to read for the other people working in the living room (Þorsteinsson and Jónsson, 1991). Several Icelandic naturalists wrote articles that became widely read.

The way of living was changing, slowly but firmly, at the beginning of the 20th century. The current of people, many of them very poor, moving to North America after the severe years of the late 19th century, was decreasing, and settlements along the coast were blooming (Þorsteinsson and Jónsson, 1991). This happened in parallel with the fisheries becoming more important. The infrastructure was getting better, better roads and bridges were built, cars were imported and telegraph communications were established. The nation was seeking independence from Denmark (Þorsteinsson and Jónsson, 1991), as well as sovereignty over its fishing grounds (Þór, 1991).

However, the main industries were still farming and fishing. The farming in Iceland has always been predominantly sheep farming. With grass as the main crop, farmers had to harvest enough hay to be able to keep their stock alive during winter.

This chapter describes how the sea ice could affect people´s lives in farming, fishing and transport. This is not a thorough treatment of the extent to which the sea ice affected people´s lives; in order to do that one would have to take many other natural phenomena and historical events into account (Gunnarsson, 1980 and 1983). It is also very difficult to state the extent to which sea ice affects human activities; Its effects are different in different parts of the country, to different people etc (Ingram et al, 1981 a). Many of the things discussed later on are hard to judge or to find the exact truth about, however, these things were connected with sea ice in many people´s minds and are therefore mentioned here.

7.2 Predictions

We will start by describing long term predictions first, and then go on to describe those nearer to the events in time.

Dreams. In late summer, autumn or even early winter some dreams, that the dreamer found unusually clear and bound to have some meaning, were interpreted as predictions about how severe or mild the winter would be. A few examples of dreams that were interpreted as warnings for a cold and severe sea ice winter will be mentioned. A warning would be important because a farmer had to decide how many animals he thought he could feed during the winter. A hard winter meant that the animals could not graze outside for part of the winter but were more or less dependent on the hay that the farmer had been able to harvest during the summer. Dream 1: A man dreamt that he saw a large, white horse come from the north ocean (Pétursson, 1968). He found it magnificent and powerful. Dream 2: A man dreamt that he and his brother (who was dead at that time) were fishing north of the Arctic Circle and they caught a large skate, and the white side of it was facing up (Friðfinnsson, 1968). As mentioned before it is hard to judge whether some people really got these early signs and whether they really were interpreted before the

event, the sea ice arrival, occurred. It is also impossible to say how many actually believed in this, or how many interpreted dreams in a way that never came true. I have not found similar descriptions in the diaries used here. These two descriptions are interesting because in both cases the sea ice appears, or is interpreted, as a big, white, living creature.

Signs from Nature. It was believed to be a sign of a hard winter when mice were near farms in great numbers in the autumn (Pétursson, 1968). They were said to be looking for extra supplies of food to be able to survive the coming winter. A hard winter would mean a frozen surface and a supply of hay (which the mice shared, as unwelcome visitors, as far as the farmer was concerned, with sheep, cows and horses). There are many theories about how it is possible to interpret animal behaviour and many of them might be true. Unfortunately, we will not be able to cast any light on these theories here.

If the waves in the sea were not very big when the wind came from the north (or from the direction that the sea ice usually came from) it was meant to be a sign of the sea ice being near the country and tempering the waves. Many papers have been published on this, for example Wadhams (1986), and Squire et al (1995) and this has proven to be true; the ice attenuates waves that pass through it, and also if the ice edge is close it reduces the fetch of the wind over the open water, so the wind cannot generate waves that are as high as expected. Bernódusson (1923) mentions very large waves in the sea, when there had been northerly winds, and interpreted that as ice being further away than other people had expected.

If the sea was very cold and froze or created grease ice near the coast, the sea ice was supposed to be near. This is very likely, since the sea is colder when the ice is near. A cold sea can indicate sea ice being near, but this does not necessarily have to be the case. Jón Jakobsson mentions cold sea quite often, and not always if ice near (according to other sources).

Driftwood was a sign of sea ice, but also came after the ice had been there. Eggertson (1994) describes that driftwood along the coast of Iceland is dependent on ice, that is, wood could never make it to Iceland (from Siberia) if it had not frozen into sea ice.

It takes the ice 2-3 years to reach the coasts of Iceland, but driftwood can only float for 12-20 months in the sea before it sinks.

A green-yellow or yellow-grey gleam in the sky over the horizon was called "ísglotti", or ice-blink. This, too, has proven to be true, as the light reflects differently from ice and sea to the sky, especially to low clouds. This has been described in various diaries, and the diary writers often mention that the weather or the view is ice-like (esp. Jón Jakobsson´s diary).

All these symptoms can mean that the ice is near, but they do not have to mean it. If two or more of them came together, people might have been more convinced that the ice would come to the coasts.

Communications. News about the sea ice seem to have spread rather quickly over the country. Before telecommunications, people who travelled by land or sea brought the news and that, obviously, took more time. There are many examples of news about sea ice in the diaries. It seems to have been one of the major questions to ask people: "Has anybody seen any ice this winter ?". When diary writers met farmers or fishermen from other parts of the country, news about sea ice was often the only thing that was worth writing into the diary. This is especially apparent in Jakobsson´s diary. The ships that brought goods to the harbours sailed either clockwise or anticlockwise around the country and stopped in many places. The people on board must have learned quickly to watch for all signs of ice, as they must have had to answer a lot of questions about sea ice, where ever they landed.

When news about ice had spread, it was not uncommon for people to try to look for the ice, if it was supposed to be near or on its way. One thing to do was to climb up a mountain to get a better view. Þórður í Höfða did this in early December 1917, because he had heard news from Siglufjörður, which is west of Höfði, that the ice had been seen.

7.3 Behaviour

When it then became clear, by whatever reason, that the sea ice had arrived, there was usually not very much to do about it. One

could never tell for how long the ice was going to be present or how severe its effects would be. Some might have tried to buy hay (if the farmer had any money), collect staple foods in case the ships could not make it in to the harbours and the shops became empty. The road system was not very good in this time, and the ice often came in late winter when snow was hindering transport by land.

When the ice came fishing could become dangerous because the ice could move very fast. People tried to save their boats either by dragging them onto the shore or by stretching a cable in the sea to protect the harbour. However, if there was not too much ice, people could still fish.

7.4 Concomitants

Several poems have been dedicated to sea ice. Most of them are negative, such as "Art thou here again, country´s ancient fiend ?!" (from Icelandic, Matthías Jochumson). The sea ice has also been described as the ocean´s marble graveyard. However, the ice did not always bring bad luck. In old annals the writers sometimes describe sea ice arrival as being "of no use". This suggests that the sea ice could sometimes bring benefits. In the following section some effects of sea ice, good and bad, will be described.

Weather. Cold weather usually followed the sea ice, at least in the North. Iceland surrounded by sea ice has been described as a peninsula of Greenland. People mention unstable weather before the sea ice actually comes to the island, but cold, stable weather after the ice has fastened to the land. It is very likely that in very cold years and when the sea ice half surrounds the country, the polar front lies further south and Iceland is underneath an Arctic high with stable but cold weather.

Fog (or ice-fog). Fog is often mentioned as one of the sea ice "followers". Some people found this fog worse than the sea ice itself, their view had been taken from them and they felt entombed in a silent world. This fog is a result of water evaporating from the open water surface. This water vapour is then blown by the wind over the ice, where the air is cooler and the water vapour is precipitated out as fog.

Fish. The sea at the ice edge is usually very nutrient rich (Sakshaug,1989. Nybakken, 1993. Smith, 1990), which encourages fish to stay there to feed. The fish then attracts seals, polar bears and fishermen. The effects that the sea ice has on fish and fishing is complicated. If the sea is very cold, some species seem to move to other grounds (Jakobsson, Jakob, 1969, Jónsson, J. 1969).

Seals. As mentioned above, seals often stay at the ice edge to feed. They were, in the past, considered to be one of the benefits of having sea ice near the coast. Jakobsson´s diary often mentions seals and sealing in connection with ice.

Polar bears were a constant threat to people when sea ice was near the coast (Víkingur, 1968. K. Jónsson, 1968 a) It was an unpleasant thought to meet a polar bear without any weapon or a shelter. Many farmers had guns, but they certainly did not carry them with them when working at the farm. The poor farmers who did not have any guns had nothing with which to protect themselves or their animals. People were wary about suspicious footprints and news about bears "landing" travelled fast. It was important to get the polar bears before they killed people or the cattle. When polar bears became stranded in Iceland they were usually very hungry and equally aggressive. Polar bears are much better off on the ice where they can usually find enough to eat, as there are many seals there. Occasionally, bears are carried by ice floes away from the main ice, and when the ice melts they can become stranded. There are many examples of polar bears killing people in earlier centuries (Thoroddsen 1916-17), but this does not seem to have happened in the period 1901-1925. The fur of polar bears was thought to be a precious thing, often donated to the church.

Sharks and whales. There are many examples of sharks and whales being trapped in an open sea near the coast when there are great quantities of ice around the country (Jón Jakobsson´s diary, for example from 1902). They were caught for food as well as for the oil.

Driftwood. As mentioned before, driftwood was one of the sea ice "followers". In a country with almost no forest, driftwood was an important building material. Farmers had to

watch their beaches well, in order to be able to get the wood that stranded on their land, because it was easily taken away again by the sea, or ice.

7.5 Impacts; good and bad

Navigating. Ships have difficulties getting through sea ice, especially if it is dense and thick ice, but also because the conditions can change very quickly. Relatively small icebergs can be very dangerous because they can be difficult to see in darkness or in the fog that often "follows" the ice. Many ships were damaged in the ice and some were wrecked.

The difficulties ships faced, often resulted in a shortage of goods in the towns. Quite often, goods were brought to the country in the spring. As the frequency of ships in the early centuries was not high, this could cause a serious lack of supplies.

Fishing. Even though the ice edge could bring large catches of fish, fishing could also be brought to a halt if the ice was very dense. Fishermen tried to fish if there was any possibility. Many of them lost their fishing-gear, as the ice conditions could change suddenly. The loss of catches could be very bad for some fishermen or even whole villages.

There a are few stories about cod or other fish being blind in one eye. This is supposed to be because they always turn the same eye towards the sea ice or swim around one piece of ice, the same way all the time (Friðfinnsson, 1968).

Sea weed. Some people mention the effects that the sea ice has on sea weed in the coastal zone. The ice can scrape the sea weed from the stones, leading to large quantities of sea weed on the shore soon after the ice has been there. Sheep are able to graze on this, but for the next two or three years, there is no or very little sea weed available for grazing (Friðriksson 1969). This was potentially very bad for farmers on small farms, who lived along the coast and depended highly on this extra food for their sheep.

Eider ducks need polynyas or leads to survive. When all the leads froze or when the ice was very dense, the birds either froze into the ice and/or were eaten by foxes or other birds. (Jónsson

K., 1968b) describes the experience of witnessing this, and says that not being able to help the birds was very depressing. This and the cold in the springtime could greatly affect the ducklings, causing a decrease in numbers. However, if the birds could survive farmers often got more eiderdown after the breeding season because the adult birds seem to have taken more of their eiderdown to insulate the nests. It should be noted that the down was collected after the ducklings had left the nest, rather than shooting birds and plucking them.

Vegetation. If the sea ice stayed until late spring or summer, the blooming of the vegetation, especially in the north, was delayed, and large areas of the fields could be damaged by frost. This was not good, as many of the farmers would have already finished their winter feed supply early and were waiting to be able to let their stock graze outside. The hay harvest, after a severe ice winter or spring, was often poor, which could be extremely bad, if the following winter was severe as well.

Transport. The sea ice did, in some cases, make transport easier. If fjords or bays were filled with sea ice or frozen, people could walk directly from headland to headland, making a journey shorter and easier. However, there seem to be more examples of the ice hindering transport or making it difficult or dangerous. The ice was often rough and difficult to walk on, and the conditions could change very rapidly.

7.6 The early 20th century

It can be argued that the first two decades of the 20th century were not too bad for people in Iceland, in general. There were never two successive hard ice years, and the ice usually did not stay until summer. However, farmers living near the coast in northern Iceland must have suffered, especially the ones that were poor, because they had less opportunities to buy extra supplies of hay. The late 19th century seems to have been worse, and indeed that was a colder period and the sea ice conditions were more severe.

But one could also ask why was the Icelandic society so vulnerable in the past ? The Icelandic culture of making use of sea ice was very different from that of the Inuit in Greenland,

Northern America and Siberia, mainly because the ice was different and came only occasionally. The ice could move very quickly and be dangerous for people walking on it as well as for boats.

Things are different now. Even though many scientists argue that the climate is warming and the sea ice is generally decreasing in the North Atlantic and the Arctic Ocean, it is interesting to consider what effects many sea ice years or severe years would cause Icelandic society today. Some fishermen who experienced the cold years of 1965-1970 said that they had got used to sailing in the sea ice, but it had been difficult, and often dangerous in ships that were not strengthened (Jónsson, K. 1968 c)

It is a common saying that Iceland lies on the boundary of the inhabitable world. One could argue that it needs to be more clearly defined whether this means the Northern or the Southern limits. This has definitely a straw of truth in it, because one of the difficulties that the people in the country faced in the past was the variability of the climate, one of the consequences of being on the boundary.

Generally, the sea ice seems to have brought more difficulties than benefits.

8. CONCLUSION

8.1 Quality of the sources

Most of the sources are good in themselves, but none of them tells the whole story of the sea ice conditions in Iceland in the early 20th century. Being of differing natures, they complement each other well. However, it is necessary to be critical and to remember the various emphasis of each source.

Since the ice charts were made from relatively few observations, in the era before satellites images and aerial surveys, the diaries can add a lot to the sea ice history and they also reflect the many effects that sea ice had on people´s lives in the early 20th Century.

8.2 The sea ice history

Sea ice was observed near the Icelandic coast in most of the years 1901-1925. The most severe years were 1902 and 1911, but in 1907, 1914, 1915 and 1918 there were also large quantities of ice. The year with very little, or possibly no ice, was 1922, where no ice was observed with any certainty. The years 1904 and 1909 had also a very little ice. The last six years of the period were the least severe.

Ice comes most often to the Northwest peninsula and North West Iceland. Only twice in the period did the ice reach the south coast.

March, April and May are the months when ice is observed most often with any certainty and in largest quantities.

Comparison of mean annual temperature in Stykkishólmur, W-Iceland, with the sea ice indices introduced in the work, showed that there is a negative correlation between them, though not very strong.

8.3 The impacts of sea ice on Icelandic society

The period 1901-1925 does not seem to have been very severe regarding sea ice, especially if compared with late 19th Century.

In some of these years, however, life must have been a struggle for farmers and fishermen in North West and North Iceland. Navigation was never hindered for a long period, and there seems only to have been a serious lack of goods in some places of the North in the year 1902.

The sea ice did not only bring bad luck for people, in many ways it could also be of benefit, especially for bringing sharks, seals and driftwood.

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Appendix I

Letter written by Adolf Hoel 1923.

Instruks.

Kaptein Otto Sverdrup med bistann av kaptein A. Hermansen skaḥ forta en reise til Tønsberg, Aalesund, Harstad, Tromsø, Hammerfest, Vardø, og Vadsø og landdistriktene nordpå, hvor det har været eller er sælfangst, for å samle materiale til belysning av isforholdene i Spitsbergenfarvannene. Der må søkes utlånt journaler fra fangstfartøier, likesom der tas avskrifter av dem som ikke kan fåes utlånt. Dagbøker fra overvintrende fangstfolk er det også av stor betydning å få utlånt eller avskrevet. Ennvidere innhente mundtlige oplysninger fra sælfangere og overvintrende fangstfolk. Av stor interesse vil det være å få sikre oplysninger om torskefiskeriene ved Spitsbergen i 1870-årene.

Da isforholdene er avhengig av vinn- og temperaturforhold, må der også legges vekt på å få med oplysninger om disse.

Da isforholdene i Spitsbergenfarvannene er avhengig av isforholdene i de omgivne hav, bør oplysningene gjelle hele strøket fra Karahavet (inklusive) tiḥ Grønlands østkyst.

Kristiania, 30. januar, 1923.

Adolf Hoel

Appendix II

An example of the Norwegian ice charts.

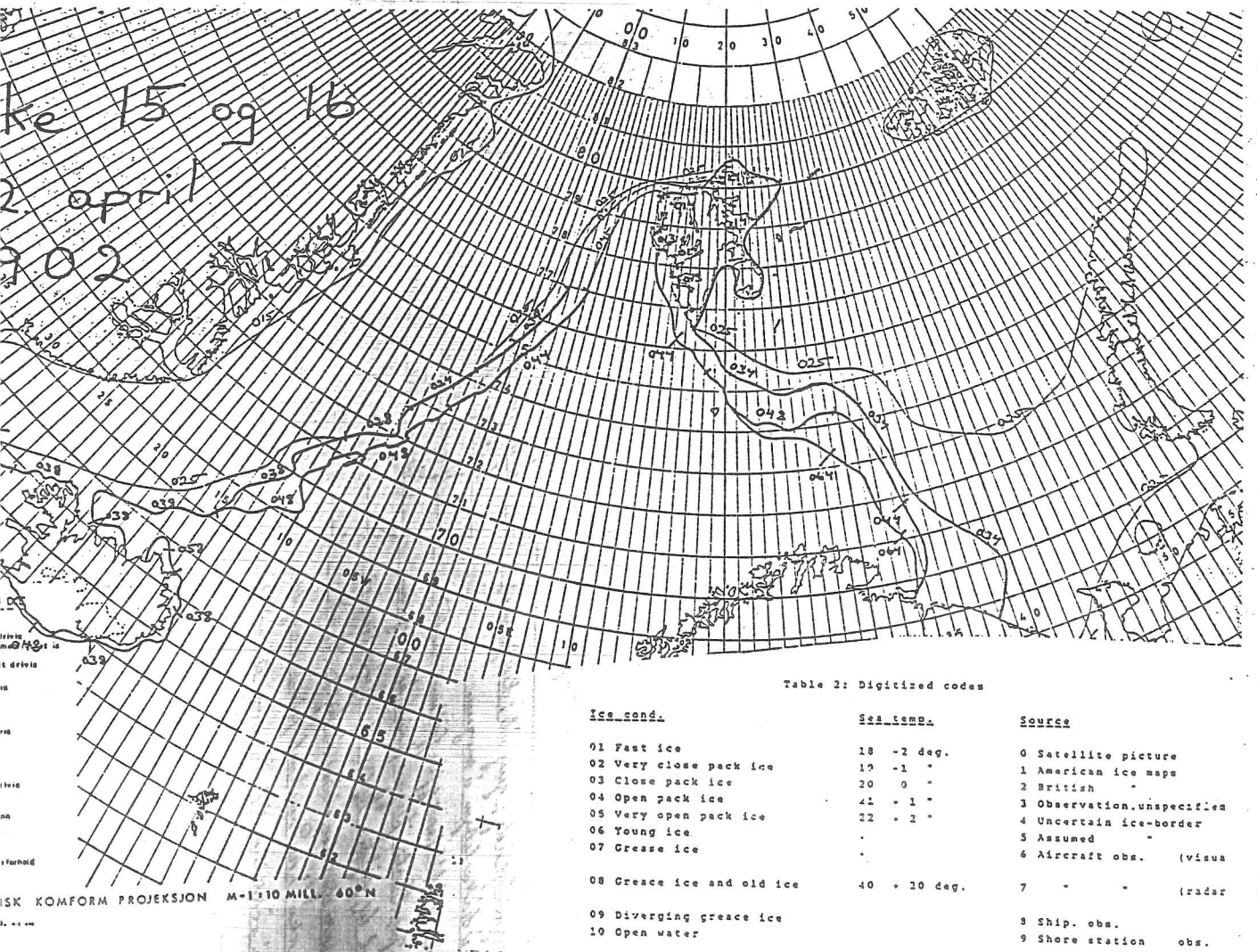

Table 2: Digitized codes

Ice cond.	Sea temp.	Source
01 Fast ice	18 -2 deg.	0 Satellite picture
02 Very close pack ice	19 -1 "	1 American ice maps
03 Close pack ice	20 0 "	2 British "
04 Open pack ice	21 + 1 "	3 Observation.unspecified
05 Very open pack ice	22 + 2 "	4 Uncertain ice-border
06 Young ice	.	5 Assumed "
07 Grease ice	.	6 Aircraft obs. (visua
08 Grease ice and old ice	40 + 20 deg.	7 " " (radar
09 Diverging grease ice		8 Ship. obs.
10 Open water		9 Shore station obs.

Appendix III

From Jón Jakobsson´s diary.