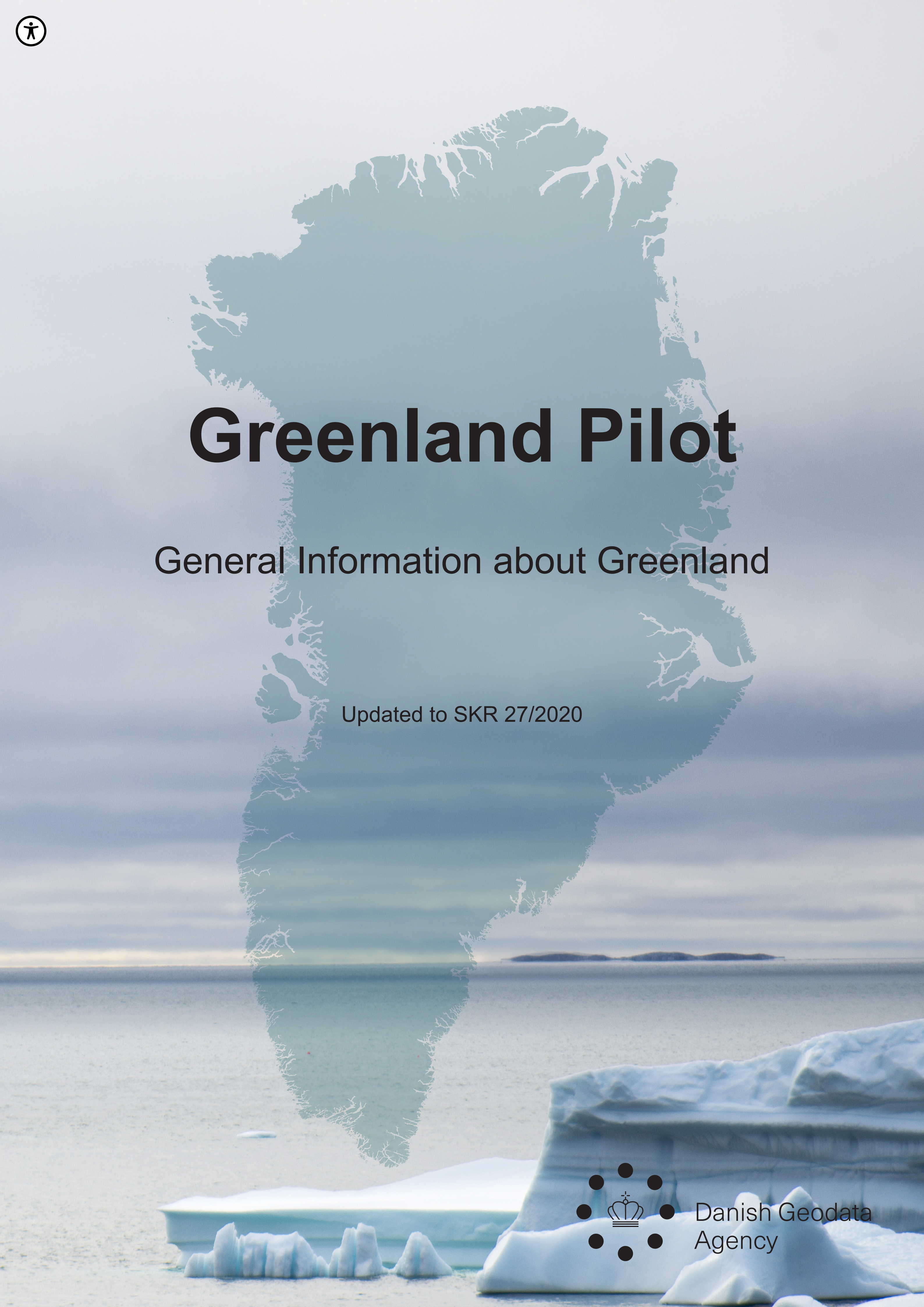

Greenland Pilot

General Information about Greenland

Updated to SKR 27/2020

Danish Geodata Agency

Greenland Pilot

General Information about Greenland

Danish Geodata Agency

Preface

”Greenland Pilot – General Information about Greenland” has been prepared on the basis of information in ”Greenland Pilot – General Information about East Greenland” and ”Den grønlandske Lods I, Vestgrønland” as well as information from Greenlandic and Danish authorities, institutions, locals, etc.

Collection of accurate information regarding the Greenland coastlines is very difficult, and in some places the description is not sufficient, but supplementary information as well as in-for-mation about any deficiencies are received with thanks by the Danish Geodata Agency.

All positions and altitudes in the text are approximate and derive from different data collection methods. They aim to guide the mariners by the combination of the book and the relevant cards. However, it is the hope of the Danish Geodata Agency that this edition may be helpful during navigation in Greenland.

The publication contains information on topics and conditions that are necessary to be aware of when navigating in Greenland waters.

Regarding to sailing directions for East Greenland and West Greenland see respectively ”Greenland Pilot – Sailing Directions for East Greenland” and ”Greenland Pilot – Sailing Directions for West Greenland”.

In the publication, Greenlandic place names are written with new Greenlandic orthography. In the charts, covering the East Greenland waters, place names are written with old Greenlandic orthography. In the charts covering West Greenland waters, place names are written with old Greenlandic orthography in the old charts. New orthography will be used in new charts.

The difference between new and old orthography can be found in the publication ”The Greenland Pilot – Explanations of Place Names”, which can be read and downloaded at www.gst.dk. Here is a list of English translation / explanation of the Greenlandic place names contained in this publication.

With the release of ”Greenland Pilot – General Information about Greenland”, the ”Greenland Pilot – General Information about East Greenland” has been canceled.

Corrections to this publication will be published in Danish Chart Corrections at www.gst.dk.

Record of amendments - Danish Chart Corrections

Year	No.	Subject

Cover photos Colorbox

Copyright

This version of the
“Greenland Pilot – General Information about Greenland”
is updated to SKR 27/2020.

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Danish Geodat Agency 8. July 2020.

Table of Contents

Introduction 2

CHAPTER 1
Danish Geodata Agency's nautical products 6

CHAPTER 2
Names of Greenland's waters 23

CHAPTER 3
General information about Greenland 26

CHAPTER 4
Sailing directions along Greenland 29

CHAPTER 5
Advice for navigation in Greenland waters with smaller vessels 33

CHAPTER 6
Depths off Greenland 57

CHAPTER 7
Surface currents around Greenland 61

CHAPTER 8
Tide 65

CHAPTER 9
Ice 69

CHAPTER 10
Climatic conditions in Greenland 94

Appendix 111

Illustrations 160

CHAPTER 1

Danish Geodata Agency’s nautical products

Charts and publications and their maintenance

Official Danish charts and publications covering Danish, Greenlandic and Faroese waters are issued by GST. Charts and publications can be obtained via Rosendahls, Vandtårnsvej 83A, 2860 Søborg, Denmark, tel. +45 4322 7300, e-mail: distribution@rosendahls.dk, www.rosendahlsboghandel.dk.

Publishing

GST publishes charts covering Danish, Greenlandic and Faroese waters.
The following publications are published in Danish and English, and can be downloaded free of charge at GST’s homepage:

- Chart 1 – INT 1 (symbols, abbreviations and terms used on charts)
- Behind the Nautical Chart (surveying, reliability and use)
- Danish Chart Corrections
- Greenland Pilot – General information about Greenland
- Greenland Pilot – Sailing Directions for East Greenland
- Greenland Pilot – Sailing Directions for West Greenland
- Greenland Pilot – Explanation of the place names.
-

The following publications are published in Danish only, and can be downloaded for free at GST’s homepage:

- Catalogue of nautical publications with index maps of the charts
- Sailing Directions concerning Danish and Faroese waters.
- Updated information on all Danish harbours and bridges can be accessed on
- www.danskehavnelods.dk.
- Updated information on all Greenland harbours can be accessed on Greenland Harbour Pilot on www.gronlandskehavnelods.dk.
- Information on current editions of charts and latest print of these is given continuously on www.gst.dk.

Publication of charts (new editions, updated reprints and new charts) is announced in Danish Chart Corrections.
Updated reprints do not cancel the previous print of the same edition but due to the continuous correction work, users are advised to order updated reprints. When extensive changes occur the charts will be published as new editions which will cancel the previous edition.
As updated charts are most important for safe navigation users are recommended to keep charts updated and always use the latest edition. Cancelled charts and publications should not be used as Danish Notices to Mariners, Danish Chart Corrections and supplements to

the publications only refer to the latest edition. Please note that corrections to charts after the date of printing must be carried out by the user.

Updating

GST publishes Danish Chart Corrections weekly, describing in Danish and English the corrections necessary for the maintenance of charts and publications. Danish Chart Corrections can be accessed on www.gst.dk. Danish Notices to Mariners provide information of significance to navigation, including information of preliminary and temporary character. Part of this information may be of importance to charts and publications and should be added as amendments or remarks.
Users of Danish Chart Corrections with internet access can download the publication free of charge to their own PC or print corrections from the GST website. The digital issue of Danish Chart Corrections is published every Wednesday and can be obtained at the GST website.
Notifications of errors and omissions on charts and nautical publications are appreciated and should be submitted to GST, Lindholm Brygge 31, 9400 Nørresundby, Denmark, e-mail sfo@gst.dk.

Units and terminology used in this publication

Heights and depths are given in metres, distances in metres (m) or nautical miles (M).
1 nautical mile is 1852 metres.

Temperatures are set to Celsius (º C).

Courses, directions and bearings are indicated true in degrees clockwise from 000º to 359º.

Light sectors indicated are seen from the sea, and the limits are described clockwise. Light sector means the angle at which the light is visible.
The nominal ranges of the lights are given in nautical miles and in clear weather, which corresponds to a visibility during day at 10 M, nautical miles.

All latitude and longitude markings, bearings and distances are approximate, since the entries are intended to provide guidance in a comparison between the book and charts. The length is calculated from Greenwich meridian.

Current and tidal stream is described by the direction towards which they flow. The speed of the current is indicated in knots.

Winds are described by the direction from which they blow.

Symbols, abbreviations and terms used on charts and in books in accordance with INT 1.

Abbreviations used in The Greenland Pilot:

Directions:

N	North	S	South
NNE	North north east	SSW	South south west
NE	North east	SW	South west
ENE	East north east	WSW	West south west
E	East	W	West
ESE	East south east	WNW	West north west
SE	South east	NW	North west
SSE	South south east	NNW	North north west

Units:

hPa	hectopascal	m/sec	metres per second
km	kilometre(s)	UTC	Co-ordinated Universal Time
kn	knot(s)	ºC	degrees Celsius
M	International Nautical Mile(s) (1852 m)		

Abbreviations:

CHS	Canadian Hydrographic Service
DGHL	Greenland Harbour Pilot
DMA	Danish Maritime Administration
DMI	Danish Meteorological Institute
ECDIS	Electronic Chart Display and Information System
Efs	Etterretninger for sjøfarende, (Norwigian Notices to Mariners)
EfS	Efterretninger for Søfarende, (Danish Notices to Mariners)
GP	Greenland Pilot
GST	Danish Geodata Agency
JAC	Joint Arctic Command
LAT	Lowest Astronomical Tide
LORAN	LOng RAnge Navigation
NOTMAR	Notices to Mariners, CA
SKR	Søkortrettelser (Danish Chart Corrections)
WMO	World Meteorological Organization

Greenlandic place names

Generally about Greenlandic place names

Most Greenlandic place names are a description of the nature or appearance of the location in question rather than an actual name for the place. The same individual place names can therefore be found in virtually all inhabited areas along the Greenland coasts, and they are often so close together that it can be difficult sometimes to distinguish between places with the same name and explain which of them is being referred to in the given case.
On the other hand, Greenlandic place names can sometimes provide information about the appearance and uniqueness of the named location, and can thereby help one to orient oneself when off a part of the extensive coast of Greenland, of which one may have no prior personal knowledge. In order to exploit the aid to navigation that may result from the Greenlandic place names included in the charts, see the publication ”Greenland Pilot - Explanation of the place names”.

Changes to place names

It must be expected that during a transitional period, Greenland Pilot uses place names spelled in both the old and new Greenlandic orthography. Any Danish name will be provided in brackets, e.g. Nuuk (Godthåb) or a Greenlandic place name may be added, e.g. Orsiivik (Polaroil), Tuttut Nunaat (Renland), Aqissip Kangertiva (Rypefjord), Nannut Qeqertaat (Bjørneøer), Kangertittivaq (Scoresby Sund) and Kangikajik (Kap Brewster).
Furthermore, it must be expected that the new charts of areas that are not currently covered by the charts will contain new names that are not found in Greenland Pilot. It is also likely that Greenland Pilot will contain place names that do not appear on the charts.
In the coming years, place names will be officially changed from Danish to Greenlandic for e.g. large fjords, coastal or land areas along the coasts of Greenland. Kronprins Christian Land will become Nuna Kronprins Christian, and Kejser Franz Josef Fjord will become Kangerluk Kejser Franz Josef.

Examples of East Greenlandic place names used on charts and in publications:

Greenlandic, new orthography	**Greenlandic, old orthography**	**English**
Anoritooq	Anoritôq	Where it is very windy
Ikaasak	Ikâsak	The sound (seaway)
Ikeq	Ikeq	The bay, the broad, the sound
Ikertivaq	Ikertivaq	The big bay
Ikkatteq	Íkáteq	The shallows
Immikkeerteq	Ingmíkêrteq	The island
Immikkeertikajiit Martik	Ingmíkêrtikajît martik	The two bad Islands
Immikkeertikajik	Immikkêrtikajik	The bad Island
Isertoq	Isertoq	The turpid, muddy one
Kangeq	Kangeq	Promontory, cape
Kangerluk, Kangertiva *) Kangertivit *)	Kangerluk, Kangertiva *) Kangertivit *)	Fjord
Kattertooq	Kagtertôq	Where there is much blue ice

Nigertuluk	Nigertuluk	Where it is very windy from the NE
Nuiarteq	Nuiarteq	The one that just emerges - a skerry
Nuna, Nunat, Nunaa *), Nunap *)	Nuna, nunat, nunâ *), nunap *)	Land, lands
Nuuk	Nûk	Foreland, promontory
Qeertaartivit	Qêrtârtivit	The small islands
Qeertartivaq	Qêrtartivaq	The big island
Qeqertaq	Qeqertaq	Island
Qeqertarsuaq	Qeqertarssuaq	Big island
Qeqertat	Qeqertat	Islands
Sarfaq, sarfat	Sarfaq, sarfat	Current, currents
Sarpaq	Sarpaq	The current
Seeraq	Sêraq	The sand
Sermilik	Sermilik	The glacial fjord
Tini	Tini	Low water

Examples of West Greenlandic place names used on charts and in publications:

Greenlandic new orthography	Greenlandic old orthography	English
Ikeq, Ikerup *)	Ikeq	Bay, broad, sound
Ikerasak, Ikerasaa *)	Ikerasak	Sound (seaway)
Ikersuaq		Big bay, broad, sound
Ikkanneq, Ikkannera *)		Bank
Ikkarluit	Íkardluit	The skerries
Ikkarluk, Ikkarlui *)	Íkardluk, íkardlue *)	Skerry
Ikkarlunnguaq	Íkardlúnguaq	Small skerry
Ikkarlussuaq	Íkardlugsssuaq	The big skerry
Ikkattoq	Íkátoq	The shallows
Imaq, Imaa + Imartaq *)	Imaq, Imâ *)	Sea, ocean
Imarsuaq	Imarssuaq	Big sea area
Imartuneq	Imartuneq	Bay, broad, gulf
Inussuk	Inugsuk	Cairn
Isortoq	Isortoq	The turpid, muddy one
Itineq, Iterna *)		Trench
Kangaarsuk	Kangârssuk	Promontory, cape
Kangeq	Kangeq	Promontory, cape
Kangerluarsuk	Kangerdluarssuk	Small fjord
Kangerluk, Kangerlua *)	Kangerluk, Kangerlua *)	Fjord
Kangerlussuaq	Kangerdlussuaq	Big or long fjord
Kingittoq	Kingigtoq	Tower
Kinngaq	Kíngaq	Mountain
Kuuk	Kûk	River, stream
Kuussuaq	Kûgssuaq	Big river, stream
Marraq	Marraq	Clay
Nuna, Nunat, Nunaa *),		

Nunap *)	Nuna, nunat, nunâ *),	
nunap *)	Land, lands	
Nuuk	Nûk	Foreland, promontory
Nuussuaq	Nûgssuaq	Big foreland, promontory
Qaqqaq	Qáqaq	Mountain
Qeqertaq	Qeqertaq	Island
Qeqertarsuaq	Qeqertarssuaq	Big island
Qeqertat	Qeqertat	Islands
Sarfaq, sarfat	Sarfaq, sarfat	Current, currents
Sarfarsuaq	Sarfarsuaq	Strong current
Sineriak		Coast
Sioraq	Sioraq	Sand
Talittarfik, talittarfiat *)		Berth, pier, quay
Tini	Tine	Low water
Umiarsualivik, Umiarsualivia *)		Harbour, port

*) The use of complex compounds, West- and East Greenland:

Qaarsup Ikerasaa, Qaersup ikerasâ
Sioqqap Sioraata Ikkannera (Ravns Banke), Qeqertarsuup Ikkannera (Disko Banke), Ikerup Ikkannera
Simiutarsuup Ikkarlui (den store props skær)
Avannaata Imaa (Baffin Bugt), Issittup Imaa (Arktiske Hav), Attup Imaa, Agtup imâ
Iviangiusat Imaat, Iviangiussat imât
Allumersat Sioraata Iterna (Danas Dyb)
Nuup Kangerlua, Nûp kangerdlua (Godthåbsfjord)
Ammassaliip Kangertiva (Ammassalik Fjord), Kangertivit Anginersaat (Storefjord)
Kangerluk Kejser Franz Joseph
Isaarutip Nunaa, Isârutip nunâ (Hollænderø)
Ujuaakajiip Nunaa, Ujuâkajîp nunâ (Danmark Ø), Nunat Dronning Margrethe II
Nunap Isua (Kap Farvel)
Kangerlussuup Umiarsualivia [Søndre Strømfjord]
Sineriak Lauge Koch (Lauge Koch Kyst)
Immikkeertikajiit Martik (Murray Ø og Reynolds Ø)
Sarfap Qeqertaarsua
Umiarsuaaqqat Talittarfiat

Sund / Sound (definition in Greenlandic)
1) The continuation of a fjord through the archipelago = **ikeq**
2) Between one or two islands and the mainland, or between two groups of islands or coasts = **ikerasak**

Paper charts

Since time immemorial, navigation has depended on the transfer of important nautical information from navigator to navigator. This concerned verbal descriptions with information on distances from harbour to harbour, coastal appearance, landmarks and the location of hazardous shoals. The first written sailing directions are from about 500 BC.
In the 13th century, sailing directions were supplemented by the first nautical charts (the portolan charts, also called the harbour location charts), which mainly showed the Mediterranean and the Black Sea. It was not until 1462 that a portolan chart showed a reasonably acceptable representation of the North Sea coast.
In 1569, Gerhard Mercator (1512-1594) constructed a world map “for the seafarer to use for navigation of the major seas” in a special projection. The map projection has since been known as the “Mercator Projection”, and today it is still the most widely used for the production of nautical charts.

Greenland nautical chart history

Greenland has always had a special place in both history, surveying and cartography.
In 1825, The Danish Hydrographic Office published a nautical chart of the NW coast of Greenland. This was practically a sketch map made by W.A. Graah (1793-1863), naval officer and hydrographer. The chart was accompanied by some port descriptions from the same area. Since the Royal Greenland Trading Company had a state monopoly, navigation in the colony was not unrestricted. This meant that charts of the colonial ports and their navigation channels were not publicly available until almost 1930.
Surveying of Greenland’s coastal waters was only properly organized after the arrival of radio positioning systems.
From the end of the 1940s until 1953, from 1959 until 1980 and from 1989 until 2014, fully equipped survey ships have operated in Greenland waters.
The Greenland charts began to be redrawn from around 1960. They utilized aerial photography of the coast and modern techniques for chart production. This was combined with a shading of the mountains to produce a new series of navigation charts, which had a beautiful appearance and whose “plastic” production was of major assistance to navigators. Many areas, both offshore and in sheltered waters, have been measured over the last 60 years, but large areas still remain that only have with individual soundings recorded during passing sailings.

Laws and regulations concerning paper charts

According to Danish and international rules governing the maritime area, all ships must have updated navigation charts and nautical publications on board in order to be considered seaworthy.
The ship disaster in 1912 when “Titanic” sank was the starting gun for a number of initiatives. Among other things, the International Convention for the Safety of Life at Sea (SOLAS) was adopted in 1914.

Since the founding of the IMO (International Maritime Organization), SOLAS and navigation safety have been the responsibility of the IMO. SOLAS includes requirements for nautical charts and nautical publications on board ships, as stated in Chapter 5 on "Safety of Navigation". The convention has been implemented in Danish law.

The following are excerpts from "Notice B - Technical regulation for ship construction and equipment etc." from Danish Maritime Authority, specifically Chapter 5 on "Safety of Navigation". Regulation 2 on definitions includes the following definition: 'Nautical chart or nautical publication' is a special-purpose map or book, or a specially compiled database from which such a map or book is derived, that is issued officially by or on the authority of a Government, authorised Hydrographic Office or other relevant government institution and is designed to meet the requirements of maritime navigation.

Regulation 19 on the requirements for shipborne navigational systems and equipment states that all ships, irrespective of size, shall have:
• Nautical charts and nautical publications to plan and display the vessel's route for the intended voyage and to plot and monitor positions throughout the voyage; an electronic chart display and information system (ECDIS) may be accepted as meeting the chart carriage requirements of this sub-paragraph.
• A back-up arrangement to meet the functional requirements above, if this function is partly or fully fulfilled by electronic means.

In Regulation 27: Nautical charts and nautical publications, such as sailing directions, lists of lights, notices to mariners, tide tables and all other nautical publications necessary for the intended voyage, shall be adequate and up to date. It can be concluded from the 3 regulations above that the requirements for and about navigation charts can be satisfied by having the following on board:
1) official and updated paper charts, or
2) a type-approved electronic chart display and information system (ECDIS), which uses official and updated electronic navigation charts (ENC), as well as an adequate backup arrangement.

The nautical charts and nautical publications which satisfy the definition in Regulation 2 are often referred to as "official" navigation charts and publications. All other navigation charts and publications are by definition unofficial. They are often referred to as private navigation charts and publications and do not satisfy the statutory requirements and may not therefore be used for navigation on board ships.

Categories of paper charts

Since large scale navigation charts provide the most detailed information, and since corrections are often made most accurately and easily on large scale charts, one should alwaysuse these charts whenever possible. A small error in determining the ship's position is of far greater importance on a chart with a small scale than on a chart with a large scale. This is of particular importance when navigating in restricted waters and in anchorages.

Navigation charts are available in several categories, referred to as:

Overview charts

Charts with a scale between 1:2 500 000 and 1:400 000 These charts cover very large areas. The charts are only used for navigation in open seas and for planning voyages. The navigational and hydrographic information is therefore greatly simplified or completely omitted in areas close to shore.

General charts

Charts on the scale1:100 000 and 1:80 000. These charts contain detailed navigational and hydrographic information, so that the main waters and the most important navigation channels can be navigated.

Coastal charts

Charts on the scale 1:50 000 and 1:40 000. The aim is that these charts shall contain sufficient navigational and hydrographic information so that the harbours shown in the chart can be navigated. In areas described in detail or in areas that are covered by a special chart, there may be a simplification of the information.

Harbour charts

Chart in very large scale (greater than 1:40 000). They show areas that can be difficult to navigate, such as narrow channels, harbours or anchorages.
Harbour plan chart
Plans in very large scale (greater than 1:40 000). They show areas that can be difficult to navigate, such as narrow channels, harbours or anchorages.

Great circle chart

Chart in a projection which presents the great circle as a straight line. The charts cover very large sea areas and can only be used for planning, where great circle navigation is of significance, because the charts do not contain information of a nautical and hydrographic nature.

Contents of paper charts

A navigation chart contains topographic, hydrographic and navigational information. The amount of this information depends on the scale of the chart. The larger the scale, the more information the chart contains.

Topographic information in paper navigation charts

Topographic information means coastlines, glaciers, roads, cities and the like. Similarly, a large number of landmarks that can be used for navigation purposes will be displayed on the chart. These could include churches, antenna masts, towers and distinctive chimneys.

Hydrographic information in paper navigation charts

The hydrographic information consists of depths, types of bottom and obstructions in the form of shoals, rocks and wrecks. The information on the chart about water depth has been collected over a very long period of time.
Some information on Danish charts is based on surveys made around 1900 with plumb line or measuring pole. The positioning of the measured soundings was made by double-angle measurement or some other form of manual determination of the position. The depths on the charts refer to a so-called Chart Datum. Chart Datum for Danish charts, covering the waters inside Skagen[1]), is Mean Sea Level, MSL.
On Danish charts off Skagen[1]) (including Greenland), depths are indicated at Lowest Astronomical Tide (LAT). Note, however, that in extreme weather situations, water depths may be experienced that are larger or smaller than those indicated on the chart due to high water or low water caused by wind pressure and current direction. Depth contours are lines drawn along depths of equal value and they help to make the depth information easier to read. The depth contours are drawn with different intervals and the scale of the chart will be the deciding factor for which depth contours are displayed. However, there is the caveat that there may be circumstances about which the Danish Geodata Agency is unaware and also that the aforementioned weather conditions may cause the water depth to change temporarily.

Navigational information on paper charts

The navigational information is information about lights, beacons, buoys, maritime limits, routes, magnetic variation etc. All the symbols and abbreviations used are explained in the publication ”INT 1” (Symbols, abbreviations and terms used on charts).

Positions

All positions on the Danish charts for Greenland that are published by the Danish Geodata Agency are either in Qornoq 1927, WGS-84 datum or without datum in East Greenland. Refer also to the chart's title field. Further information about horizontal and vertical datums should be read in the publication “Behind the nautical chart” (Surveying, reliability and use).

1) Inside Skagen is defined by a line which connects the Skagen lighthouse at the position 57°45,0'N 010°35,8'E alongside the latitude 57°45'N to the Swedish coast.

Notes

There may be informative or cautionary notes on the charts. These notes may be of major importance for the navigator, who is thereby made aware of traffic conditions, magnetic interference, special sailing directions, depth soundings, cables and pipelines, and current conditions.

Reliability

Although the Danish Geodata Agency endeavours to ensure the accuracy of the information on the charts and in the nautical publications, the navigator should be aware that the information is not always complete, fully updated or positioned according to modern surveying standards.

No charts are infallible

The contents of the chart may deviate from reality for a variety of reasons. This can be attributed to:

1) the depth information may be incomplete and/or inaccurate due to the survey methods employed in the past,
2) the depth information may have changed due to extraction, sand migration and the like,
3) buoys may have drifted or been pulled out of position,
4) construction and installation works in or near harbours, etc. can have commenced.
5) Navigators must always be aware of points 1 and 2, especially when navigating in shallow and/or narrow waters.

Navigators must keep themselves informed with regard to points 3 and 4 by reading (P) and (T) notices in EfS (Danish Notices to Mariners) and by following the navigational warnings broadcast by radio, Navtex or satellite.
The navigator always has a responsibility to assess the reliability of the information in their possession in order to ensure the safety of navigation to the greatest extent possible.
A detailed description of the accuracy and reliability of the chart can be found in the publication "Behind the nautical chart" (Surveying, reliability and use).

The reliability of the charts depends primarily on the surveying. The older the survey that forms the basis for the chart, the less reliable the chart, partly because the means of surveying have become more accurate over time, and partly because the seabed is subject to change in many places. The closer the sounding lines are to each other, the more reliably the depth conditions can be indicated on the chart. However, it should always be remembered that even the most careful surveys do not rule out the possibility that there may be rocks and shoals with shallower depths between the sounding lines.
One should therefore try to avoid crossing shoals and shoals with shallow water, even when the chart shows that there is greater depth than the draught of the ship.
For the sake of clarity, the charts only indicate a larger or smaller portion of the measurements taken with soundings.
If the soundings are scattered and unevenly distributed, this is an indication that the survey was carried out in less detail.

Locations that are completely devoid of soundings should be regarded as not being surveyed. However, if the surrounding depths are large and uniform, it can be presumed that there is deep water at these locations, but if the surrounding depths are shallow or it is otherwise indicated on the chart that the waters contain reefs, banks or rocks, these places should be avoided or only navigated with extreme caution.

Locations where there are isolated soundings that are shallower than the immediately surrounding depths should be avoided in all circumstances.

When there are only isolated soundings close to land, particularly near protruding rocky points, one should not be misled into believing that there is no water shallower than indicated by the soundings, because such places have not been carefully surveyed. You should maintain a suitable distance from these shores and, in particular, you should not round these points too closely and remember that any coast must be considered foul, when it is not apparent from the charts and descriptions that it is clear.

The more often waters, a harbour or anchorage is navigated, the more reliable is the chart, at least in the buoyed waters, because shoals, rocks or other obstructions that are not found by the survey are likely to be found later by shipping and then immediately added to the charts.

Always use charts of the largest scale

Since charts with a large scale provide better information than a chart with a smaller scale, the former should always be used.

Publishing and updating

As discussed on page 12, every master has a duty under Danish and international law to ensure that the ship's charts are constantly updated.

Publishing of charts

Information regarding the publication of new charts, new editions or updated prints are published in Danish Chart Corrections. Information on the current edition of a chart can be seen in the bottom right-hand corner of the navigation chart and on www.gst.dk.

New charts

The Danish Geodata Agency produces and publishes a new chart if this is necessary due to changes in shipping patterns, changes in the requirements for the chart's coverage/scale etc. A new chart can either replace an existing chart or it may supplement the chart collection. The intended publication of the new chart will be announced in Danish Chart Corrections 2-3 months in advance.

New editions

The previous edition of the chart is cancelled upon publication of the new edition. The intended publication of the new edition will be announced in Danish Chart Corrections 2-3 months in advance.

Updated reprint

An updated reprint of a chart is issued when this is required due to the number of corrections on a chart, or when the chart is almost sold out.
An updated reprint contains all the corrections that have been published in Danish Chart Corrections. Publication of an updated reprint does not annul earlier prints with the same edition number, since the user has been able to continuously update the chart via Danish Chart Corrections. Users are advised to purchase the updated reprints, however, in order to benefit from the continuous correction work. The intended publication of the updated reprint will be announced in Danish Chart Corrections 5-6 weeks in advance.

Updating

When purchasing navigation charts, it should be noted that the corrections announced after the publication date must be implemented by the users themselves. When they are published, navigation charts are corrected up to and including the version number of Danish Chart Corrections shown in the bottom left-hand corner of the chart.

Correction of paper navigation charts

Corrections should be made to the charts immediately.

It is important when correcting a chart not to obscure or change anything other than the information affected by the correction. Poorly performed corrections can in worst cases obstruct the navigator’s work to such an extent that the safety of the ship may be endangered.

All corrections published in Danish Chart Corrections are permanent corrections. These must be entered on the chart and the year and number of the correction must be indicated in the bottom left-hand corner. The same cartographic symbols must be used as those printed in the chart or in INT 1.

Corrections of a temporary nature, e.g. (P) and (T) notices in EfS (Danish Notices to Mariners), shall be entered on the chart, and removed again when they are no longer relevant.

Datum and index charts

Datum in the W-Greenland charts are mostly Qornoq 1927, while new charts are produced in the WGS-84 datum. Notes on the charts specify how positions are set in the chart when switching to charts with different datum.

Note that all E-Greenland charts has no datum indicated.

Datum for each chart is indicated in the chart’s title field and in the Product Catalogue.

Index Chart Greenland can be seen on http://www.danskehavnelods.dk/indexkort_gronland/gronlandskesoekort.html and in the Product Catalogue.

Using navigation charts

Beacons in Greenland

In West Greenland, beacons are used as side markings. The beacons are set on the rocks, furthest towards the waters they mark and appear with yellow stem and red top design with daylight fluorescent material.
The beacons are provided with 3 or 4 individual black numbers and / or letters on yellow bottom, as also shown in the chart.

Beacons to be held to starboard with ingoing derection:
Color: Yellow stem with black numbers and / or letters.
Top mark: 1 red triangle with tip upwards.
Reflex: 2 horizontal green ribbons.

Beacons to be held to port with ingoing derection:
Color: Yellow stem with black numbers and / or letters.
Top mark: 1 red cylinder.
Reflex: 2 horizontal red ribbons.

Note that all the beacons are shown on the charts with red color.

Fig. 1.1 – Nukariit (Tre Brødre)

Fig. 1.2 – Port beacon with number

Tidal current

When navigating in waters where there is a large tidal range, this must always be kept in mind, but sailing directions and tide tables or nautical yearbooks can always be used under normal conditions to determine an approximate sea level correction.

Cotidal hour

is the number of hours and parts of hours to be added to the lunar culmination time at a location in order to provide the time for the occurrence of the next high tide.

Magnetic variation

This is always stated in the charts by displaying compass roses at different places on the chart. However, the magnetic variation indicated corresponds to a particular year. Since the magnetic variation is subject to a specific change that is different at different locations on the earth, this must be taken into account. The charts always indicate the year in which the specified magnetic variation applies and the size of the annual change.

Magnetic disturbances

There are many places where a ship's magnetic compass can suddenly be subjected to abnormal effects, and the compass needle can display a large or small deflection. This is due to influences from the sea bed. Usually, these magnetic disturbances only extend over a small area, unless there are many centres of magnetic disturbance close to each other. Charts or sailing directions provide information about places where it is known that such magnetic disturbances can occur.

Comments on the charts, sailing directions etc. published by the Danish Geodata Agency

Except for a few special charts, the charts use the Mercator projection. The scale stated on the charts corresponds to a specific latitude.

The basis for the charts with respect to land is the Geodetic Institute's scale and, with respect to the sea, the basis is the chart material gathered from the surveying ships and municipal authorities, etc.

The lower left corner of the charts indicates the last edition of the "Danish Chart Corrections" according to which they were corrected, so that any significant changes that have been announced in the "Danish Chart Corrections" as having come into force up to and including the latest edition indicated, have been included in the charts.

Sailing directions

Supplements to the books published by the GST are issued so that they contain the necessary information to keep the books corrected. New editions of charts and books, as well as the cancellation of previous editions, are announced in "Danish Chart Corrections".

Cancelled charts and books must not be used, because supplements and corrections only refer to the latest edition.

Charts with the largest possible scale should always be used for navigation, especially in Greenland waters.

The GST has facilitated the navigator's task by providing the margins with a magenta/ brown/ yellow colour for the nautical charts in the nearest larger scale that are available for the area, or where it is considered more practical, only the chart number is provided.

Similarly, information about the adjoining charts can be found in the chart margin.

Due to a lack of information, large sections of these charts contain few soundings, and they will probably remain like this for several years to come for several areas. Since the information in the charts has usually been obtained from reconnaissance or perhaps from earlier reports in which the determination of the precise location has been of poor quality, they must be used with a degree of caution, which is also indicated as a warning note on the charts.
On the other hand, information about the land in the newer charts is as good as it is possible to obtain, as they are plotted according to the best methods based on aerial photographs, and it will therefore be possible to determine the ship's position by means of bearings and distances to the edges of islands, etc.
In these charts, the land is also provided with elevations for prominent mountains and islands, and contour lines have been plotted in. The land is also provided with a topographic shading. All this should make it easier for navigators to orient themselves and, at the same time, it will be of assistance during radar navigation. It should be noted, however, that even though the GST makes its new charts of Greenland waters as complete and accurate as possible, individual errors should always be expected.
For example, it may be difficult from aerial photographs to distinguish small islands from ice, which means that very small islands or rocks may be missing or may be incorrectly included in the charts.
The GST is always grateful to receive information regarding errors and inaccuracies, and naturally the more comprehensive the information, the better. But approximate positions are also of great value for surveys that will be conducted in the future.

Reporting of errors in lights etc.

Any ships or vessels etc. that observe a fault in a light in Greenland, fallen or missing beacons and errors in navigation charts are requested, depending on the circumstances, to report the matter to the Joint Arctic Command, Nuuk (Godthåb).
For charts, please also provide the information that is printed in the lower left corner of the chart, i.e. the chart number, when it was printed and the latest issue of "Danish Chart Corrections" to which it was corrected.

CHAPTER 2

Names of Greenland’s waters

2.1 Names of East Greenland’s waters

The East Greenland coast is bounded by the following waters (from N):

2.1.1 Issittup Imaa (Arktiske Hav) [Arctic Ocean] located N of the Grønlandshavet [Greenland Sea].

2.1.2 Grønlandshavet [Greenland Sea], which is bounded by the following:

To the N: A line from the northernmost point in Greenland to the northernmost point on Spitsbergen.
To the E: The west coast of Vestspitsbergen.
To the SE: A line from the southernmost point of Spitsbergen to the northernmost point of Jan Mayen, along the west coast of this to Gerpir on Iceland, approx. 65º05’N 013º30’W.
To the S: The Icelandic coast from Gerpir to Straumnes on Iceland, approx. 66º26’N 023º08’W.
To the SW: A line between Straumnes and Kap Nansen on Blosseville Kyst, approx. 68º15’N 029º30’W.

2.1.3 Danmark Stræde (Denmark Strait), which is bounded by the following:

To the N: A line between Straumnes on Iceland, approx. 66º26´N 023º08´W, and Kap Nansen on Blosseville Kyst, approx. 68º15’N 029º30’W.
To the E: The Icelandic coast from Straumnes to Bjargtangar.
To the S: A line between Bjargtangar, approx. 65º30’N 024º30’W and Naajanngivit (Kap Dan) 65º31’N 037º10´W.
To the W: The Greenlandic coast from Kap Nansen to Naajanngivit (Kap Dan).

2.1.4 Irmingerhavet (Irminger Sea), which is bounded by the following:

To the N: A line between Bjargtangar, approx. 65º30’N 024º30’W and Kap Dan 65º31’N 037º10´W.
To the E: The Icelandic coast from Bjargtangar to Reykjanes.
To the S: A line between Reykjanes, approx. 63º48’N 022º41’W and Nunap Isua (Kap Farvel), approx. 59º46´N 043º53´W.
To the W: The Greenlandic coast from Naajanngivit (Kap Dan) to Nunap Isua (Kap Farvel).
The Irmingerhavet forms part of the W part of the North Atlantic.

2.2 West Greenland

The West Greenland coast is bounded by the following waters (from N):

2.2.1 Issittup Imaa (Arktiske Hav) [Arctic Ocean] located N of Imartaq Lincoln (Lincoln Hav) [Lincoln Sea].

2.2.2 Imartaq Lincoln (Lincoln Hav), which is bounded by the following:

To the N: A line from Kap Morris Jesup to Cape Columbia (Ellesmere Island).
To the S: The North Coast of Greenland from Kap Morris Jesup to Kap Bryant, from there a line to Cape Sheridan (Ellesmere Island) and the N-coast of Ellesmere Island to Cape Columbia.

2.2.3 Ikeq (Nares Stræde) between Ellesmere Island and Greenland,

which can be divided into the Robeson Kanal, Hall Bassin, Kennedy Kanal, Ikersuaq (Kane Bassin) and Smith Sund. Ikeq (Nares Stræde), which is bounded by the following:
To the N: A line between Kap Bryant and Cape Sheridan.
To the E: The Greenland coast to Ullersuaq (Kap Alexander).
To the W: Ellesmere Island coast to Cape Isabella, 78º19'N 075º03'W.
To the S: A line from Cape Isabella to Ullersuaq (Kap Alexander).
The whole of Ikeq (Nares Stræde) is included in Avannaata Imaa (Baffin Bugt) [Baffin Bay].

2.2.4 Avannaata Imaa (Baffin Bugt), which is bounded by the following:

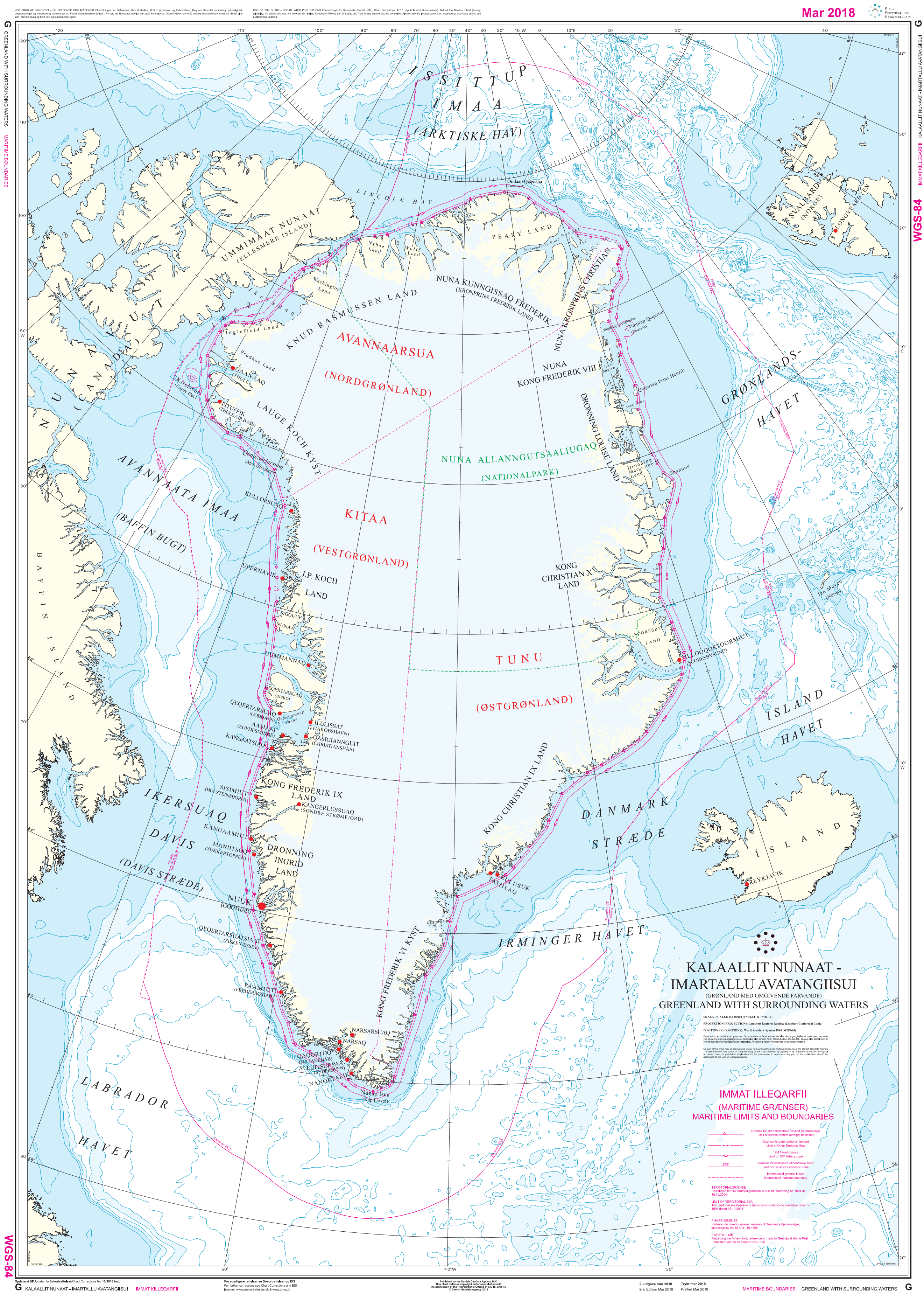
To the N: A line from Cape Isabella to Ullersuaq (Kap Alexander).
To the E: The Greenland coast to 70º00'N.
To the S: 70º00'N between Qeqertarsuaq (Disko) and Baffin Island.
The NE part of Avannaata Imaa (Baffin Bugt) is called Qimusseriarsuaq (Melville Bugt) (Melville Bay).
From Avannaata Imaa (Baffin Bugt) expires towards SE Nordost Bugt between the peninsulas Sigguk (Svartenhuk) and Nuussuaq and Sullorsuaq (Vaigat).

2.2.5 Ikersuaq Davis (Davis Stræde) [Davis Strait], which is bounded by the following:

To the N: 70º00'N between Qeqertarsuaq (Disko) and Baffin Island.
To the E: The west coast of Greenland.
To the S: 60º00'N between Greenland and Labrador
To the W: By Baffin Island E-Coast.

2.2.6 Labrador Havet [Labrador Sea], which is bounded by the following:

To the N: 60º00'N between Greenland and Labrador.
To the SE: A line from Nunap Isua (Kap Farvel) to Cape St. Francis, 47º45'N 052º27'W (Newfoundland).
To the W: By Newfoundland and Labrador E-coast.


Mar 2018
ISSITTUP IMAA (ARKTISKE HAV)
LINCOLN HAV
PEARY LAND
NUNA KUNNGISSAQ FREDERIK (KRONPRINS FREDERIK LAND)
NUNA KRONPRINS CHRISTIAN
KNUD RASMUSSEN LAND
AVANNAARSUA (NORDGRØNLAND)
NUNA KONG FREDERIK VIII
DRONNING LOUISE LAND
NUNA ALLANNGUTSAALIUGAQ (NATIONALPARK)
LAUGE KOCH KYST
UMMIMAAT NUNAAT (ELLESMERE ISLAND)
NUNAVUT (CANADA)
AVANNAATA IMAA (BAFFIN BUGT)
BAFFIN ISLAND
KITAA (VESTGRØNLAND)
KULLORSUAQ
UPERNAVIK
J.P. KOCH LAND
KONG CHRISTIAN X LAND
TUNU (ØSTGRØNLAND)
ITTOQQORTOORMIIT (SCORESBYSUND)
GRØNLANDSHAVET
UUMMANNAQ
QEQERTARSUAQ (GODHAVN)
ILULISSAT (JAKOBSHAVN)
AASIAAT (EGEDESMINDE)
QASIGIANNGUIT (CHRISTIANSHÅB)
KANGAATSIAQ
SISIMIUT (HOLSTEINSBORG)
KONG FREDERIK IX LAND
KANGERLUSSUAQ (SØNDRE STRØMFJORD)
KANGAAMIUT
MANIITSOQ (SUKKERTOPPEN)
DRONNING INGRID LAND
IKERSUAQ DAVIS (DAVIS STRÆDE)
NUUK (GODTHÅB)
KONG CHRISTIAN IX LAND
DANMARK STRÆDE
ISLAND HAVET
ÍSLAND
REYKJAVÍK
TASIILAQ
KULUSUK
IRMINGER HAVET
QEQERTARSUATSIAAT (FISKENÆSSET)
PAAMIUT (FREDERIKSHÅB)
KONG FREDERIK VI KYST
NARSARSUAQ
NARSAQ
QAQORTOQ (JULIANEHÅB)
ALLUITSUP PAA (SYDPRØVEN)
NANORTALIK
Uummannarsuaq (Kap Farvel)
LABRADOR HAVET
SVALBARD (NORGE)
LONGYEARBYEN
Jan Mayen (Norge)
KALAALLIT NUNAAT - IMARTALLU AVATANGIISUI
(GRØNLAND MED OMGIVENDE FARVANDE)
GREENLAND WITH SURROUNDING WATERS
IMMAT ILLEQARFII
(MARITIME GRÆNSER)
MARITIME LIMITS AND BOUNDARIES
WGS-84

CHAPTER 3

General information about Greenland

Greenland's territory lies between the lines of latitude 59º46'N and 83º39'N and between the meridians 011º39'W and 073º08'W, with Nunap Isua (Kap Farvel) as the S-most point, Oodaap Qeqertaa (Oodaaq Ø) the N-most point, Ullersuaq (Kap Alexander) the W-most point and Nordostrundingen the E-most point. Greenland's total area is 2,127,600 km^2, of which 1,833,900 km^2 is covered by the ice cap. The thickness of the ice in the centre is calculated to be approximately 2,700 m. The ice-free area along the coast is approx. 341,700 km^2. At its highest point, the ice cap rises to approx. 2,000 – 3,000 m above sea level and slopes gently down towards the coasts, where an almost continuous, ice-free mountain range surrounds it. The highest point is Gunnbjørn Fjeld (3,700 m) which is located on Greenland's SE coast between Tasiilaq and Ittoqqortoormiit (Scoresbysund).

Greenland's E-coast is very indented and is home to Greenland's longest fjord, Kangerluk Kong Oscar and the second largest island, Ilimananngip Nunaa (Milne Land) (3,800 km^2).

Greenland's W-coast is a distinct archipelago coast and the largest island is Qeqertarsuaq (Disko) (8700 km^2). On the W-coast between Upernavik and Innaanganeq (Kap York) lies Qimusseriarsuaq (Melville Bugt), where the coast is an almost unbroken wall of ice with only high mountain peaks. The Southermost 2/3 (900 M) of West Greenland from Nunap Isua (Kap Farvel) to Upernavik has many fjords, one of the longest, Kangerlussuaq (Søndre Strømfjord), stretches 90 M into the country.

The ice cap itself is enormous and fills the area between the coastal mountains and even covers the mountains in many places. In several places, only the tops of the mountains protrude through the ice in the interior part of the landscape. The ice cap has two elevations, both located E of the centre line through the country. One elevation is located at approx. 65ºN and rises to a height of approx. 2,500 m. The other is at approx. 75ºN and rises to a height of approx. 3,000 m. From here, the ice cap initially slopes evenly out to the coast, but gradually it falls off more steeply. At the outer edges of the ice cap, where it is relatively thin, the bare mountain cliffs protrude through the ice in many places. These peaks are called "nunataks". Along the coastal area, the ice cap has a large number of crevices in many places and it is extremely dangerous to venture out onto it. This is especially true if you are unfamiliar with the techniques used to move about on the ice cap.

The ice cap grows by precipitation and probably discharges a volume equivalent to the precipitation through glaciers, melt water and evaporation. The ice-free coastal areas along Greenland's E coast vary in width from approx. 1 – 120 M. There are many islands of varying size along this coast, which incidentally are less accessible than the islands in West Greenland, because the East Greenland Current carries large volumes of pack ice and old/polar ice with it.

The majority of the population of Greenland lives in the S-most 2/3 of West Greenland. The largest towns in West Greenland are Nanortalik, Qaqortoq (Julianehåb), Narssaq, Paamiut (Frederikshåb), Nuuk (Godthåb), Maniitsoq (Sukkertoppen), Sisimiut (Holsteinsborg), Aasiaat (Egedesminde), Qasigiannguit (Christianshåb), Ilulissat (Jakobshavn), Qeqertarsuaq (Godhavn), Uummannaq and Upernavik.
The towns in East Greenland are Ittoqqortoormiit (Scoresbysund) and Tasiilaq.

3.1 General information about East Greenland's coastal area

From Nunap Isua (Kap Farvel), the E coast of Greenland extends approx. 375 M in a NNE direction to the area at Tasiilaq, and from there the coastline continues in a NE direction for a distance of approx. 450 M to the area next to Kangertittivaq (Scoresby Sund).

From Kangertittivaq (Scoresby Sund), the coastline turns N and extends in this direction to the waters at Nordostrundingen, a distance of approx. 660 M, and from there it extends in a NW direction to Kap Morris Jesup. There is a belt of ice along this entire coastline that is always in motion, and which is carried by the current from Issittup Imaa (Arktiske Hav) and from the Siberian N-coast respectively.
This ice belt is called the East Greenland Ice, and its width and density varies somewhat with the seasons. Some of these waters are frozen and inaccessible to ordinary shipping for most of the year, and there are still very large areas where no ship has ever been, so that a portion of the available information was collected during expeditions in which the participants used small vessels and motorboats to sail in the shore lead between the coastal area and the drift ice, or from air reconnaissance or using sleighs to travel over the sea ice along the coast. Generally, the information is sparse and must therefore be used with due caution.

The coastal area between Nunap Isua (Kap Farvel) and Tasiilaq (Kong Frederik VI Kyst) is characterized by having many, relatively small and short fjords and many small islands. There is a narrow stretch of ice-free land along this coastline, and further inland the ice cap rises rapidly to a height of between 2,000 and 3,000 m. The coastal area between Tasiilaq and Ittoqqortoormiit (Scoresbysund) (Kong Christian IX Land) can be divided into three quite different areas, namely the areas between:

3.1.1 Tasiilaq and Kangerlussuaq,

where widely branching fjords cut deeply into the land, forming a great number of irregular peninsulas and islands separated by narrow channels. The land is predominantly mountainous with many peaks, several of which rise to heights of over 1,525 m.

3.1.2 Kangerlussuaq and Blosseville Kyst,

where the coast consists of steep headlands and fjords, whose innermost parts are reached by active glaciers that extend down from the ice cap. Gunnbjørn Fjeld (3,700 m) is located here.

3.1.3. Blosseville Kyst,

where the ice cap protrudes all the way out to the coastal area, which is only lightly indented, and where there are a few islands relatively close to the coast.

3.2 Time zones in Greenland

All of Greenland has the same time, namely GMT ÷3 hours, with the exception of the Ittoqqortoormiit (Scoresbysund) area, which has GMT ÷2 hours. Furthermore, Pituffik (Thule Air Base) uses GMT ÷4 hours.

CHAPTER 4

Sailing directions along Greenland

4.1 Sailing directions along East Greenland

4.1.1 General information

The drift ice along the coastal area between Nunap Isua (Kap Farvel) and Tasiilaq usually does not extend to any large extent in an E-W direction, as it is almost always relatively close to the coast. Even strong offshore winds fail to remove the ice more than 1 – 2 M from the coast. Because of this ice belt, it is normally difficult to approach the coastal area for most of the year, but the width of the ice belt varies greatly depending on the season and from year to year. It is usually best to approach this stretch of coastline in the period from mid-August to mid-October. NE of Tasiilaq, the drift ice usually lies somewhat farther from the coastline than it does further S, but navigation here is sometimes hampered by the many icebergs that are discharged from the fjords in this area. It is very difficult to approach this coastline from the sea because the pack ice here tends to be pushed toward the coast, and further obstacles arise because the strong current causes severe ice packs. The East Greenland ice N of Ittoqqortoormiit (Scoresbysund) is present throughout the year, but it has been possible using ice class vessels to navigate East Greenland and deliver supplies by sea to weather stations located as far N as Danmarkshavn.
Station Nord on Nordostrundingen cannot be navigated and is therefore supplied by air via Pituffik (Thule Air Base).

4.1.2 Approaches

Instructions for approaching Greenland through the East Greenland ice can only be given in very broad terms. Quite open water sometimes appears in the S part of East Greenland, but N of Danmark Stræde, however, it must be expected that it will be necessary to pass a more or less wide belt of pack ice before reaching the coast, and navigation must therefore be planned according to the current ice conditions. Information about this can best be obtained during the navigation season from the DMI Ice Service, where the collection of ice reports, weather reports and the position of ships takes place.
It is known from experience that there are some locations off the coast where the opportunities to pass the ice are better than elsewhere, and where, when the most difficult part of the ice belt has been passed, it is possible to find shore lead or lighter concentrations of ice, and thus to reach places on the coast, off which there is usually only a level of packed ice through which it is possible to navigate. The time when it is most appropriate to pass the ice also varies off the different parts of the coast. It applies to the entire N part that there have been some years, albeit rarely, where the ice conditions have been such that single or multiple vessels have been forced to abandon their attempt to reach the coast. The location on the N

part of the east coast where it has been possible to reach land earliest during the year, is the stretch between Germania Havn and Gael Hamke Bugt (about 74º30'N 74º00'N). There are usually possibilities to navigate here as early as the beginning of June, and these possibilities usually improve during the following month.
The smallest ice concentration is usually encountered by approaching the edge of the ice at 74º30'N. It is usually possible here to find channel systems westwards through the 120 M wide ice belt that drifts towards the S along the coast. Before commencing navigation through the ice belt, information should always be obtained from DMI Ice Service about where the ice concentration is least and where it is easiest to navigate through the ice belt. If information about the ice cannot be obtained, existing navigation possibilities must be assessed on the basis of the nature of the ice, the width of the ice belt and the distribution of water sky over the ice. After passing the outer part of the ice belt at approx. 74º30'N, a belt of heavier ice is often encountered between 017º30'W and 016º00'W, within which there is another area with reduced ice concentration or shore lead.
Navigation of Danmarkshavn is easiest in August. It seems to be appropriate here to approach the edge of the ice by steering towards Danmarkshavn from the point 74º35'N 005º00'W, and then proceeding in this direction taking account of ice conditions and water sky.
When navigating both Daneborg and Danmarkshavn, it is strongly recommended to obtain information about ice conditions from the DMI Ice Service before navigating through the ice.
Navigation of Ittoqqortoormiit (Scoresbysund) is easiest from early July to mid-September. It is common to meet pack ice at 68º40'N 018º00'W or a little closer to Kangikajik (Kap Brewster), but the ice is often encountered more than 100 M from the coast, and the width of the ice belt varies greatly.
Navigation to Tasiilaq can normally occur from mid-June to mid-October. In October, the new ice begins to be an obstacle in the inshore waters, and navigation is also hampered because of the long, dark nights even at this time of the year, so that the possibilities for navigation are best in August and September.
It is difficult to say at what point it is easiest to get through the ice off Tasiilaq if there is a lot of ice in the sea, and it is recommended to contact DMI Ice Service. It was a useful rule previously to enter the ice at the latitude of Naajanngivit (Kap Dan), 65º30'N, and if the vessel was forced to stop, it would be carried SSW by the pack ice. This rule is not infallible, however, and sometimes there is a broad belt of packed ice off Naajanngivit (Kap Dan), while to the S there is relatively open water as far as Tasiilaq. This is probably due to the outflow of melt water from Sermilik. Normally, it is best to approach Tasiilaq from S whenever there is a lot of ice in these waters.

4.2 Sailing directions along West Greenland

4.2.1 Passage of Nunap Isua (Kap Farvel)

The distance in which one can pass S of Greenland depends on the polar ice, whose mean limit has its greatest extent towards S in May, namely a little S of 59º00'N. In the other months of the year, this mean limit is found at 59º00´N or somewhat N of. During most of

the sailing period, the voyage to Greenland along the great circle from E one can therefore expect to pass the longitude of Nunap Isua (Kap Farvel) on 59º00´N, if one is not already in advance from the DMI Ice Service, has received information about unusual ice conditions. During the voyage towards W, the daily meteorological weather forecasts should be updated about the weather conditions in Greenland's S-part, where strong Northerly winds can drive the ice far to the S, either as an ice tongue from the ice edge or as part of the pack ice as an isolated part (an "island"). If such winds have blown for some time, keep more to the S after passing the 040º00´W in order to pass Nunap Isua (Kap Farvel) at a greater distance.
In May and June, the ice belt S of Greenland can be approximately 100 M wide, ie. reach to 58º00'N. Icebergs are observed 240 M SE for Nunap Isua (Kap Farvel) and experience has shown that it can be an advantage to keep as far S as possible.

Fig. 4.1 - Nunap Isua (Kap Farvel) seen from W.

4.2.2 Passage along West Greenland

After the passage of Nunap Isua (Kap Farvel), the further course of the ship depends on the destination:
4.2.2.1 Ikersuup Sioraa (Julianehåb Bugt)
4.2.2.2 Ilorput (Arsuk Fjord), Paamiut (Frederikshåb)
4.2.2.3 The coast N of Paamiut (Frederikshåb)
4.2.2.4 Upernavik – Innaanganeq (Kap York)

4.2.2.1 Ikersuup Sioraa (Julianehåb Bugt)

Depending on the ice and visibility conditions, after the passage of Nunap Isua (Kap Farvel) you can either:
a) in visible weather follow the ice edge or coast towards W and N or
b) keep W until 046º00'W and then keep N or towards Nunakuluut. About approaches and navigation in Ikersuup Sioraa (Julianehåb Bay), refer to GP – Sailing Directions for West Greenland.

4.2.2.2 Ilorput (Arsuk Fjord) or Paamiut (Frederikshåb)

From the longitude of Nunap Isua (Kap Farvel) keep W until 046º00´W then keep towards 60º00´N 049º00´W.
From this point on (if ice conditions permit) keep N until landfall at Nunakuluut or the land around Ilorput (Arsuk Fjord) or possibly even more northerly, keeping well clear of Kitsissut (Outer Kitsissut) and Kitsissunnguit (Inner Kitsigsut) W of Nunakuluut.
Concerning the approaches and navigation in Ilorput (Arsuk Fjord), see GP – Sailing Directions for West Greenland.
If you are destined for Paamiut (Frederikshåb), after landfall, keep along the coast towards N. About the approaches and navigation of Paamiut (Frederikshåb), refer to GP – Sailing Directions for West Greenland.

4.2.2.3 The coast N of Paamiut (Frederikshåb)

From the longitude of Nunap Isua (Kap Farvel) keep W until 046º00´W. Then keep towards 60º00'N 050º00´W from which point the course is set towards Fyllap Ikkannera (Fyllas Banke). During navigation N-ward in Ikersuaq Davis (Davis Stræde) - depending on your destination - keep over the banks in 10 – 30 M distance from the coast. N of Sisimiut (Holsteinsborg), however, you can be forced to stay short distance from the coast, early in the year, if the West Ice lies far to the E. About the passage of the strech Sisimiut (Holsteinsborg) – Aasiaat (Egedesminde), refer to GP – Sailing Directions for West Greenland.

4.2.2.4 Upernavik – Innaanganeq (Cape York)

The usual route from Upernavik to Qimusseriarsuaq (Melville Bay) S part runs offshore in 2 – 3 M distance from the outer visible islands and rocks. The island group Kingittortallit in approx. 73º00´N and Kitsissorsuit (Edderfugleøer) in 74º00´N can be passed quite close. However, the ice can suddenly be pushed ashore, if the force of the wind increaces from SW or W.
When navigating from Upernavik to Innaanganeq (Kap York), the course is usually set from a position clear of the islands off Upernavik directly towards Innaanganeq (Kap York).

CHAPTER 5

Advice for navigation in Greenland waters with smaller vessels

5.1 Navigation

Navigation in Greenland's inner territorial waters must take place in accordance with DMA Executive Order No. 1697, 11.12. 2015 by using a pilot or kendtmand (a mariner with local knowledge). Kendtmand is defined as a person with qualifications that corresponds to the requirements of DMA Executive Order No. 1697.

See also DMA Executive Order No. 1697 in appendix.

If the vessel is forced into unknown waters around an archipelago, speed should be reduced, the anchor should be lowered to approx. 15 m, soundings should be taken continuously and a sharp lookout should be kept from the bow or, even better, from the crow's nest. Be prepared to manoeuvre quickly. As far as possible, enter with a rising tide. Where possible, send a boat in advance to take soundings by hand. Stay well clear of low headlands and choose rather to stay closer to steep slopes. The swell and sea will often reveal the blind rocks (shoals) and breakers and irregular sea should be avoided.

5.2 Navigation in ice

Exercise the greatest possible caution when navigating in waters with ice. Keep a sharp lookout and proceed with reduced speed.

Turn away for even small growlers – they are bigger than you think.

Never get too close to icebergs.

Never sail at full speed into the fast ice, even if it seems to be thin. One is often unpleasantly surprised.

Not only in darkness and reduced visibility, but also in daylight under adverse lighting and weather conditions, it can be difficult to spot growlers of a size that you should not come into contact with. In fresh weather with breakers on the sea and under special lighting conditions, smaller growlers can be extremely difficult to see. Even in broad daylight and in favourable lighting conditions, blue ice (the crystal clear glacial ice) may be difficult to see.

In calm conditions, light winds and no swell, and with a reliable man in the lookout position on the mast, it is almost always possible to find a way forward, even in fairly closely packed ice (old ice). But vessels should not proceed into the ice when there is a swell unless it is very open, so open that it is possible to navigate without coming into contact with the ice.

The swell can be both 5 and 10 M into an ice belt. Be careful of going into "pockets".

One should not depend on "shore lead" within the ice.

Fast ice cannot be seen from far away, but appears suddenly.

Sailing in narrow waters with strong currents and pack ice can be a very dangerous activity.

The ice can behave in the strangest and most unpredictable ways. The greatest possible vigilance is required. Such navigation should preferably be avoided completely.
If you feel trapped in the old ice, do not blindly make unplanned attacks on the ice. Stop, wait and reconnoitre from the crow's nest. There is almost always a way out.
In terms of drift ice (pack ice, old ice), the situation can change rapidly (waters that are blocked can become open for navigation in a matter of hours).
Collections of larger icebergs are usually a sign of small water depths (shoal, bank, iceberg bank etc.)

5.3 Anchoring

During a gathering storm, it is better to stand out to sea rather than to seek an unsafe anchorage (shelter).
Avoid "dragging" the anchor as much as possible during anchoring, as the anchor can often become fouled with sea grass, seaweed, etc. and thereby lose the ability to take hold.
If anchoring with one anchor, always keep the second anchor ready for use.
At anchor: Recover any launched vessels at night, have the engine ready for immediate use, make the ship sea ready, if possible have a projector ready, and keep a hand lead ready on deck. Keep an eye on the barometer, even though it often requires special experience to interpret the readings correctly.

5.4 Additional instructions

5.4.1 Position-fixing from bearings and horizontal angle measurement.

Great care must be taken in connection with position-fixing from bearings and horizontal angle measurement, especially if in northern Greenland, where visibility often allows measurement over long distances.
It must be remembered that the sights are great circles, while they are indicated on navigation charts as compass lines. The correction (Mercator correction) to be applied to the great circle bearing to obtain the bearing along the compass line is:

60°N Lat.: 0.43 x L
70°N Lat.: 0.47 x L
80°N Lat.: 0.49 x L

where L is the difference of longitude between the ship's estimated location and the point by bearing.
When the bearing is indicated continuously from N through E (0º - 360º), the correction is positive if the point is further E than the ship, and negative if the point is further W than the ship.
For horizontal angle measurement, a correction applies that can be expressed by the same formula as for bearings, although L in this case means the difference of longitude between the two points to which the measurement is made. The correction here is positive if the left point is furthest W, and negative if the left point is furthest E.

5.4.2 Anchorage and mooring

During anchoring in harbours or fjords, determine carefully whether the anchor or anchors are holding. In many places there is very heavy growth of large seaweed plants, which can prevent the anchor from getting a firm hold in the seabed.
Mooring in the harbours (towns) where there is no berth with sufficient depth shall occur in a manner appropriate for each harbour. It can be said in general that as soon as the anchor is dropped, the vessel should be clear along the side of the ship to deploy a manila hawser or nylon rope into the mooring location. Motor boats shall always be used for line handling. After securing the rope ashore and pulling it in, wires/ropes shall be secured to the available ring bolts or stocks aft of the ship, and possibly also moorings from the front. It is recommended to immediately deploy enough moorings that the ship can be safe during a storm. Storms in Greenland can arrive suddenly and if additional moorings shall be connected to the land after the storm has arrived, this can sometimes prove to be impossible and will always be associated with major and difficult work. Larger vessels should as far as possible connect each mooring to a separate ring bolt or stock. It has sometimes occurred that older ring bolts to which vessels were moored have broken during a storm. If a vessel is moored to ring bolts, the rope should also be attached to the actual bolt and not just to the weaker ring.

5.4.3 Fresh water supply

Water filling in Greenland mainly occurs directly from a hose on land. For smaller ships, water can also be filled from rivers, and in icy waters in northernmost West and East Greenland, from melt water lakes on growlers and ice floes.
Some precautions must be taken when filling water directly from a river:

1. Only rivers with plenty of water should be used.
2. There must not be any settlement close to a river used for water filling. The river must not be located where dogs or (in South Greenland) sheep regularly are present.
3. The hose used for water filling (fitted with a canvas funnel) shall be deployed well above the high tide mark on the rocks.
4. If water filling occurs in a falling tide, care must be taken that the water filling vessel remains afloat and does not get stuck on the rocks.

5.4.4 Ultra violet light. Snow blindness

Ultraviolet light causes snow blindness by damaging the cornea. Eyes must be protected from the UV light that is reflected from snow and ice by wearing sunglasses with UV filter as long as the sun is out. In an emergency, a pair of effective glasses can be made of cardboard or other material. Cut two narrow, horizontal eye slits in the material and the glasses can be held in place with a strap or elastic band.
Some protection can also be achieved by colouring the face black around the eyes, nose and cheeks with soil, charcoal or soot. You can become snow blind in cloudy or overcast weather just as easily as in direct sunlight, because the ultraviolet light is always present. One attack makes you receptive to another. The symptoms occur after some time. Tiny blisters are formed that burst and leave small sores. These sores are very painful, but they heal again within a few days. During this period, it is best to stay in the dark.
Refer also to the sun warning (UV-index for Greenland) on:
https://www.dmi.dk/vejr-og-atmosfare/temaforside-ozonlaget-og-uv-straling/uv-indeks/

5.4.5 Rabies
There are sometimes epidemics of rabies among dogs in Greenland. The infection comes from the fox population. In principle, other animals can cause infection, such as wolves, musk oxen, reindeer, horses and cats. Due to various circumstances, foxes seek out contact with the settlements to a greater extent than in the past and they are therefore more dangerous. Foxes infected with rabies are also aggressive to humans. If a human is bitten by a fox or a dog suspected of having rabies, a doctor should be consulted immediately.

5.4.6 Icing and measures against it
Icing is always a serious problem, since icing is a risk to the ship, and precautions against icing should be taken by both ship-owners as masters when navigating off Greenland during the winter months.
The risk of ice accumulation is greatest in the months from November to March, when the air temperature is low.
However, it is rare for icing to result in a really dangerous situation, since the ships used for navigation in Greenland usually have additional freeboard (reserve carrying capacity) and therefore usually also have sufficient stability to withstand relatively heavy icing.
Icing of the ships' rescue equipment, especially lifeboats and life-rafts with davits and hoists, pose the risk that it may not be possible during heavy icing to put lifeboats/rafts into the water during an emergency situation.

5.4.7 Precautions against icing
There does not appear to be any effective remedy for icing available at present, but the occurrence of icing also depends on whether the master knows his ship and knows how it can best be handled in the sea in order to take the least possible volume of water over the deck and hatches. If possible, rescue equipment should be kept clear of ice by the crew clearing it of ice at appropriate intervals, but it can be, and usually is, very difficult work in bad weather.
Inflatable life-rafts appear to be more appropriate as rescue equipment in these waters than boats, as rafts are not as prone to icing and also have a significant strength during inflation, which is able to break a relatively thick layer of ice.
By observing sensible, maritime precautions, the risk can often be reduced so much that it does not become a serious obstacle to safe navigation all year round. As icing usually occurs during a storm or gale with low air and water temperatures, it has been successfully practised to keep the ship into the wind and sea with such a low speed that it is just about able to steer. If this is not possible, the ship should be turned with the wind and sea approx. 30º-45º onto the side, however, it seems that this is when the risk of icing is greatest, since the spray from the sea then has the largest surface area of the ship on which to become attached. If the weather is so poor that icing on a large scale cannot be avoided by keeping the ship facing into the weather, the vessel should run before the wind with the least possible steerage way, as this reduces the spray to a minimum. If it is not possible to reduce icing, and if it is feared that the ship's stability will deteriorate to such an extent that it will pose a risk to the safety of the ship, it may be possible to increase the ship's stability by filling empty bottom tanks, but this must be carried out in good time, since stability deteriorates while the tanks are being

filled due to the free liquid surfaces in the tanks. Moreover, the load distribution can be taken into account when loading the ship, in order to ensure that as much heavy cargo as possible is loaded in the bottom of the ship during winter voyages.

5.4.8 Observed heavy ice formation

It was reported that on 25 January, a ship became covered in ice during a NW hurricane 200 M ESE of Kap Farvel. The air temperature was between approx. - 4ºC and - 8ºC and snow fell almost continuously. Sea spray caused icing on the entire vessel and the vessel was forced to heave to, keeping its speed so low that the ship could just manage to steer a course between 30º and 40º from the wind.
After 2 days the force of the wind dropped to around 14-20 m/s, and an attempt was made to increase the speed, but this increased the formation of ice and the speed had to be reduced again to steerage way. After a few days, during which the icing continued to occur, a change in the ship's stability could clearly be felt, and it was estimated that the weight of the ice formed was equal to approx. 250 tonnes. It was then decided to sail with the wind aft in a SE direction until warmer waters were reached and de-icing could be carried out.
The master also tried stopping the engine and allowing the ship to drift, but in bad weather the water still came over the ship, and due to the ice in Greenland waters, it is also important that a ship can manoeuvre quickly.

In mid-March, a ship at position 59º24'N 037º45'W also experienced severe icing, but it was also possible to restrict the icing so that the stability of the vessel did not deteriorate dangerously. The air temperature at the time of the icing was approx. -5.5ºC.
In Denmark Strait, it has been necessary to turn around due to icing and proceed aft with the wind and sea with only steerage way for 24 hours. The risk of icing is probably least if ships can stay clear of the cold ocean currents from Denmark Strait in winter, i.e. stay well clear S of Kap Farvel, but there are no safe rules, since the ship's destination must also be taken into account, and each master must assess the circumstances of each case.
The waters at Kap Farvel are not navigated by many merchant ships during the winter months, other than those bound for towns and locations in Greenland, but there are often a number of large foreign fishing vessels and large trawlers in these waters.
Navigation to towns and weather stations in East Greenland N of Tasiilaq only occurs during the summer months, and no significant icing occurs at this time of year. Icing of a ship as a result of sea spray only occurs rarely inside the pack ice, where the waves do not reach any great height.

Windchill factor															
Temperature C			**10**	**5**	**0**	**-5**	**-10**	**-15**	**-20**	**-25**	**-30**	**-35**	**-40**	**-45**	**-50**
Wind speed															
Km/h	**M/s**	**Kn**													
0	**0**	**0**	10	5	0	-5	-10	-15	-20	-25	-30	-35	-40	-45	-50
7	**2**	**4**	9	3	-2	-8	-14	-20	-26	-32	-37	-43	-49	-55	-61
14	**4**	**7**	8	2	-4	-10	-17	-23	-29	-35	-41	-47	-53	-60	-66
22	**6**	**11**	7	1	-5	-12	-18	-25	-31	-37	-44	-50	-56	-63	-69
29	**8**	**15**	7	0	-6	-13	-19	-26	-32	-39	-45	-52	-58	-65	-71
36	**10**	**19**	6	0	-7	-14	-20	-27	-34	-40	-47	-53	-60	-67	-73
43	**12**	**22**	6	-1	-8	-14	21	-28	-35	-41	-48	-55	-61	-68	-75
50	**14**	**26**	5	-1	-8	-15	-22	-29	-35	-42	-49	-56	-63	-70	-76
58	**16**	**30**	5	-2	-9	-16	-22	-29	-36	-43	-50	-57	-64	-71	-78
65	**18**	**33**	5	-2	-9	-16	-23	-30	-37	-44	-51	-58	-65	-72	-79
72	**20**	**37**	5	-2	-9	-16	-23	-31	-38	-45	-52	-59	-66	-73	-80
79	**22**	**41**	4	-3	-10	-17	-24	-31	-38	-45	-52	-59	-67	-74	-81
86	**24**	**44**	4	-3	-10	-17	-24	-32	-39	-46	-53	-60	-67	-74	-82
94	**26**	**48**	4	-3	-10	-18	-25	-32	-39	-46	-54	-61	-68	-75	-82
101	**28**	**52**	4	-3	-11	-18	-25	-32	-40	-47	-54	-61	-69	-76	83
108	**30**	**56**	4	-4	-11	-18	-26	-33	-40	-47	-55	-62	-69	-77	-84
115	**32**	**59**	4	-4	-11	-19	-26	-33	-41	-48	-55	-63	-70	-77	-85

Wind chill	By continuous impact and properly dressed
0 to -27	Low to moderate risk, but risk of frostbite for longer stays
-28 to -39	Increased risk, light frostbite of exposed skin within 10-30 min.
-40 to -54	Increased danger risk of frostbite on exposed skin within 2-10 min.
-55 and colder	Great danger, frostbite on exposed skin within less than 2 min.

Fig. 5.1 Windchill factor

5.5 Navigating in ice regions

Approximate Finnish-Swedish regulations (Baltic classes) and other ice classes correspondence.					
Classification Society	Ice Class				
Finnish-Swedish Ice Class Rules	IA Super	IA	IB	IC	Category II
Russian Maritime Register of Shipping (Rules 2007)	Arc 5	Arc 4	Ice 3	Ice 2	Ice 1
Russian Maritime Register of Shipping (Rules 1995)	UL	L1	L2	L3	L4
Russian Maritime Register of Shipping (Rules 1999)	LU5	LU4	LU3	LU2	LU1
American Bureau of Shipping	IAA A1	IA A0	IB	IC	D0
Bureau Veritas	IA SUPER	IA	IB	IC	ID
CASPPR, 1972	A	B	C	D	E
China Classification Society	Ice Class B1*	Ice Class B1	Ice Class B2	Ice Class B3	Ice Class B
Det Norske Veritas	ICE-1A* ICE-10	ICE-1A ICE-05	ICE-1B	ICE-1C	ICE-C
Germanischer Lloyd	E4	E3	E2	E1	E
Korean Register of Shipping	ISS	IS1	IS2	IS3	IS4
Lloyd's Register of Shipping	1AS	1A	1B	1C	1D
Nippon Kaiji Kyokai	IA Super	IA	IB	IC	ID
Registro Italiano Navale	IAS	IA	IB	IC	ID
Polski Rejestr Statków	L1A	L1	L2	L3	L4
IACS Polar Rules	PC6	PC7			

Fig. 5.2 – Table of ice classes.

5.5.1 Ice navigation

Navigation in polar waters is special because the extent of the ice, and sometimes its difficult dimensions, place great demands on the ship's condition and on the navigator's knowledge of the individual waters and the effects of the seasons on the ice and its distribution.
The navigator should acquire a thorough knowledge of the currents and the weather conditions.
There is ice all year-round, to a greater or lesser extent, in the waters of Greenland. The ice originates in different ways and locations and is referred to as icebergs, glacial ice, polar ice (old ice) as well as winter ice and West Ice (East Canadian winter ice).
Voyages should be planned so as to avoid unnecessary contact with the ice and it is often possible to sail around it.
The ice dimensions in Greenland waters are impossible to break for normal types of ships. For ships with adequate ice-strengethening and engine power, it is possible to break the ice in certain sea areas and at certain times of the year.
Navigation in the ice must be directed towards locating and exploiting openings and channel systems between growlers and ice floes in order to reach the intended destination.
The ice in Greenland waters is constantly changing due to the prevailing winds and currents. The navigator must assess and understand the changing conditions in order to use them to plan for safe navigation.

If the ship's progress is stopped because of ice compression, the ship shall be safeguarded in the best possible way by taking advantage of bays and openings in the ice where the ice pressure is the least possible. If the ice is compressed so strongly that it poses a risk to the safety of the ship, all equipment shall be used to save the crew and passengers.
Navigation in Greenland waters requires the navigator's intimate knowledge of the prevailing weather and ice conditions and a thorough familiarity with the ship's manoeuvring properties and limitations.

5.5.2 Knowledge of the ice

As an important part of the navigation planning before the ship sails into ice-covered waters, the navigator must obtain information about the weather, currents and ice conditions. Ice charts are particularly vital for the planning and implementation of safe and convenient navigation. Ice charts will help to provide the navigator with an overview of the extent and concentration of the ice, and will indicate where it may be most suitable to sail into the ice in relation to the ship's intended destination.
The navigator should use all available information (ice and weather charts, marine forecasts, etc.) to plan the voyage.

5.5.3 Preparation for navigation in ice-covered waters

Before the ship sails into ice- covered waters, the forepeak tanks should be filled, if possible, in order to provide the bow with extra strength if the ice is impacted.
The ice projectors should be made ready.
The necessary precautions should be taken in winter, when there is a possibility of icing occurring, such as covering the mooring/anchor winch, knocking off ice, especially on vertical surfaces, and draining fire mains on the outer deck.
The greatest possible care should be taken and the look-out service should be reinforced in adverse weather conditions, particularly as smaller growlers can be difficult to detect, even with the latest modern radar systems.

5.5.4 Navigation in ice with different ship types

The most common types of vessels used for navigation in Greenland waters are fully-welded steel ships, wooden ships and fibreglass boats. A steel ship that is not specially reinforced for ice class navigation, should not come into contact with old ice in particular. Such a ship can be navigated with caution through waters with small concentrations of the occurring ice types.
For higher concentrations of ice, especially old ice and winter ice, the ship should have sufficient ice-strengethening to avoid damage to the ship's hull, propeller and rudder.
A strongly-built wooden ship is more elastic than a steel ship. If it is also equipped with ice sheathing (sheets of copper or iron in the water line), it is particularly suitable for polar ocean navigation, since it is far more resistant to exposure to shocks and ice pressure than a steel ship. Fibreglass boats shall navigate with due consideration for the same factors as the other ship types.
Fibreglass is a flexible material that can withstand shocks and ice pressure.
It applies for all types of ships that collisions with ice floes and growlers, even at low speed, may cause indentations on the ship's sides and ribs.

5.5.5 A ship's most vulnerable places

are usually at the stern and the sides of the ship close to the engine and boiler rooms. At the stern, which is usually designed to be weaker than the bow, the ice can easily cause damage, for example by destroying the propeller and rudder. In ships intended to navigate in ice, therefore, the propeller and rudder should be located deep and be well protected. Ample water lines in the stern of the ship will help to protect the rudder and propeller. It shall be possible for ice that collides with the stern of the ship or that slides past the stern when the ship is moving forward, to be deflected at as great a distance as possible from the propeller and rudder. In earlier ice classed vessels, the propeller was usually made of cast iron, but in modern ice classed vessels they are mostly made of copper/nickel/aluminium or stainless steel in a special alloy.
In order to protect the propeller and the crankshaft, separation bolts can be used in one of the flange couplings on the propeller axle's inboard section. The separation bolts shall be adapted so that they will be sheared before the propeller and the crankshaft are damaged.
A ship's engine room is often weaker when exposed to transverse pressure than the rest of the ship, which must be taken into account in case of ice pressure or packing, where the focus should be on relieving the ice pressure on this part of the ship.

5.5.6 Ice classed vessels

These ships are designed and equipped specifically for the particular conditions that apply in ice-covered waters. The ship's hull is constructed strongly enough so that it can withstand large external forces. The ship's hull should also be designed so that it offers as few vulnerable areas as possible. A suitable ice classed vessel is short and wide with its propeller and rudder deep in the water. Such a ship has the greatest possibility of coping with the varying ice condi- tions and can more easily manoeuvre between ice floes and growlers.
In order to protect the propeller and rudder, the ship is equipped with ice cutters to deflect the ice. A modern ice classed vessel has large engine power. Diesel machinery is the most widely used means of propulsion, either directly or as diesel-electric power transmission to the propeller. In order to improve their manoeuvring properties, the vessels are equipped with an adjustable propeller, as well as a bow propeller and possibly a stern propeller.
The stem of an ice classed vessel is raked, so that the ship can slide up over the ice and use the weight of the ship to break the ice and it also helps to reduce the impact of the ice on the hull when the ship impacts the ice.
Ice classed vessels are often equipped with facilities for handling helicopter operations.
Ice classed vessels may be equipped with a crow's nest which is installed as high on the mast of the vessel as possible. The crow's nest is closed and equipped so that it is possible to manoeuvre the ship from there.

5.5.7 Crow's nest

An important part of ice classed vessels' equipment is the crow's nest, which is placed as high as possible on a mast.
While the view over the packed ice from the bridge is restricted to the closest ice floes, the view from a high crow's nest in clear weather extends farther out over the ice and therefore makes it easier to exploit channels and weaknesses in the ice. When navigating in poorly

surveyed waters or close to the coast, the view from the crow's nest provides the opportunity, if the water is clear, to see rocks and shoals in time to avoid running aground. It will also be possible from the crow's nest to observe the ice that is directly in front of the bow and close to the propeller and the rudder. In dense ice, a ship should as far as possible be navigated from the crow's nest.

An ideal crow's nest should be placed as high as possible and should be constructed as a closed housing with large windows all the way around, so that the view is unobstructed. It should also be heated. The crow's nest shall contain all the necessary controls for ship manoeuvring, compass with bearing diopter, communications system to the bridge and engine room and other instruments required for navigation.

In newer ships, all manoeuvring can be performed directly from the crow's nest.

5.5.8 Various equipment

The following special equipment must/should be carried by an ice classed vessel under various conditions: Searchlight, ice projectors, ice anchors, ice axes, long boat hooks and poles in small vessels, good wires to shift the ice in all vessels, artificial horizon, portable pump with long hoses for water filling from the ice, weapons and ammunition for hunting and defence against bears, backpacks or similar equipment with emergency provisions, sleeping bags, wind-proof mittens and hats and one or more light boats to take out onto the ice if the ship must be abandoned. A reserve propeller should always be carried, along with materials for rigging an emergency rudder. A water telescope is useful for visual inspection of the rudder and propeller. It was previously recommended to bring an ice saw, explosives and ice drill, but explosives and ice saws have little effect in severe old ice, compared to modern polar ships' engine power. However, small vessels may benefit from saws and explosives.

5.5.9 Meeting the ice

When navigating towards the ice, it is possible that the ice will not be seen until the ship is very close to it, since the weather at the edge of the ice is often dim and foggy. In calm weather, radar will be able to detect the ice edge at a distance of a few M (2-4 M).

Under favourable weather conditions, it is possible to visually observe drift ice and fast ice at a distance of 4-6 M during the day, whereas the larger icebergs can be observed as far away as 10-20 M. In choppy seas and heavy rain/snow showers with a lot of SEACLUTTER / RAINCLUTTER, the ice can sometimes be extremely difficult to see on the radar.

Rounded growlers and floes of blue ice floating at a neutral equilibrium are also extremely difficult to observe, both visually and by radar.

It can be difficult to spot growlers, not only in darkness and reduced visibility, but also in daylight under adverse lighting and weather conditions. Steering straight toward a dazzling ray of sunshine during the day or dazzling moonlight at night should be avoided. It is better to steer a couple of degrees to either side.

There will often be areas around icebergs with smaller and larger bergy bits caused by calving. It is important to exercise extreme caution and turn away for even small growlers, since they are often larger than one would immediately expect. Reduce speed to suit the conditions, never sail at full speed into fast ice, even if it appears to be thin. One can often be unpleasantly surprised.

The following signs may indicate that there is ice in the vicinity:
1. Fog, as already mentioned, will usually appear at the edge of the ice.
2. A bright glow in the sky, ice blink, which is the light reflected from the ice fields and which can be seen in the direction of the ice.
3. That a fresh breeze does not produce heavy seas or movement in the water, which indicates that there is ice (or land) in the direction from which the wind is blowing.
4. Decreasing air and water temperature. The air temperature decreases at the ice, but often only in its immediate vicinity. A reduction in water temperature may indicate either a meeting with the ice or with a cold ocean current. Although a temperature decrease is thus not an unmistakeable sign of the proximity of the ice (it has even been found in some cases that the water temperature increased slightly close to the ice), the temperature changes should be monitored when approaching an ice belt by taking frequent readings of the temperature of the air and water.
5. The sea changes colour. The water may have a whitish colour close to melting ice, which probably comes from the drifting glacial ice between the sea ice.
6. The appearance of seals, birds and other animals that live on and near the ice. Because of the material contained in the ice, the sea close to ice that is melting is rich in animal and botanical plankton, and fish, birds, seals, whales and bears all seek out the edge of the ice looking for food. The appearance of these animals, therefore, is always a clear sign that the ice is near. Outside the period when the ice melts, however, there is virtually no life at the ice edge, neither on the ice itself or in the water close to it.
7. Splashing or rushing in the water. When approaching the ice in fog and calm weather, the sound of waves breaking against growlers will often be heard before it is possible to see the ice itself or the whitish glow above the growlers.

In clear weather without a mirage, the sea ice can be seen at the distance of the visible horizon as a white, often jagged stripe on the visible horizon. Icebergs in ice can be seen significantly farther off, generally at 10-12 M distance from the bridge. There is a tendency to overestimate the distance to observed icebergs, as you generally think you can see farther than you really can.

5.5.10 Information from the radar

Under certain conditions, you should not expect to detect the presence of ice by using radar, since smooth, “worn” ice appears on the screen to look like the surrounding water masses. If the icebergs are close to each other, they can easily be confused with land masses, since they will melt together on the screen. Radar does not always provide reliable information about the presence of small icebergs, since ice only reflects radar beams poorly, and because these are often deflected upwards by the hot air over areas of scattered ice.

5.5.11 Precautions before entering the ice

Before entering dense ice, be aware that when navigating in ice, you must always be prepared for the fact that the vessel could sink at short notice. List should therefore have been prepared of the crew’s distribution to the vessels, their supply of provisions, water, primus stoves with fuel and matches in waterproof packaging, rifles with ammunition, compass, binoculars, fog- horn, clothing, etc. and a list of which of these provisions must always be on the vessels, and what each of the crew, where appropriate, shall collect and carry.

Moreover, while the ship is in the ice, such provisions and other equipment shall be prepared on the deck which, if the ship sinks, can be expected to float or which can easily be moved onto the ice if the ship sinks over a longer period.
Ships should generally make as much progress as possible in open water. Even if this means making a detour, this will often take a considerably shorter time than a direct course through the ice. In reduced visibility, it is almost always a good idea to stay away from the ice, even if it appears to be open.

5.5.12 Ice blink and water sky

Before navigating into the ice, examine its condition as far in as possible with regard to the possibilities for navigation. A bright light will be visible on the clouds far out over the ice, the so-called ice blink, which is produced by the reflection of light from the white ice. This light is very clear on days with clear air and with a light and even cloud cover over the entire sky and especially when there is newly fallen snow. Over places where there is no ice, or where the ice is scattered, there will be no reflection or greatly reduced reflection of light towards the sky. The clouds here therefore maintain their normal, or nearly normal, colour and appear as a dark contrast, the so-called water sky, to the bright ice blink. The distribution and intensity of water sky over the ice can therefore be used, under good conditions, to obtain a good impression of the distribution of water and ice in the pack ice, sometimes as far as 40 M into the ice, and you should then proceed in the direction where the sky appears darkest. Water sky is one of the most important means for the ice navigator to find a way through the ice, because the phenom- enon provides a kind of map of the location of the ice.
If the sky is cloudless, there will be no real ice blink and therefore no water sky, but there may then be a mirage that raises the apparent horizon and allows you to see the ice far away. The ice may then appear to be closer than it really is, and some parts may appear reversed and simultaneously suspended in the air, but where there is open water, this will appear with a dark blue colour.

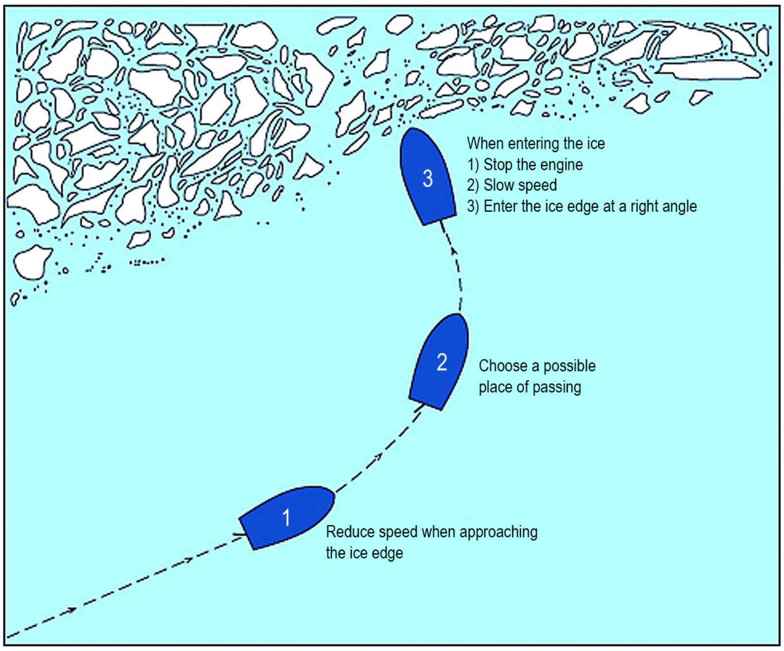


Fig. 5.3 – Approaching the ice edge.

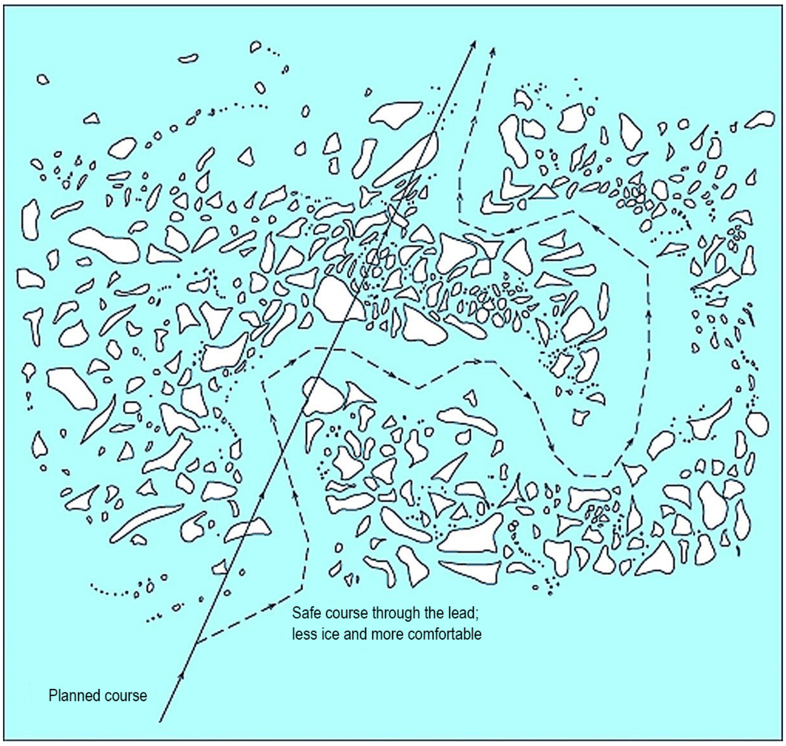


Fig. 5.4 – The route through the ice.

5.5.13 Fog at the ice edge

If the fog at the edge of the ice is persistent, but not too dense, and the weather is also quiet and you have the impression that the ice is fairly scattered, you can always try to go in only as far as you know that you can easily get out again. There is then a possibility that the fog becomes lighter further into the ice, or even that it clears up completely. During bad weather, however, you should remain patiently outside the ice until you can see what you are entering into.

5.5.14 When there is a gale or storm in on the ice

it is difficult and dangerous to pass the edge of the ice. If the ice edge is very compacted with large growlers in between, no ship will have a chance of surviving the collision with the ice masses, which are tossed violently up and down in the swell, while the sea breaks over them like over a coral reef. Under such conditions, however, the ice may also be quite open, but if the ship is not especially suited for ice navigation, it should still not proceed into the ice under these circumstances. It may be tempting to try, because the swell will decrease markedly even a short distance into the ice. With a strong ice classed vessel, however, it may be possible to escape unscathed in between the unruly pieces of ice, but care must be taken to protect the propeller and to carefully judge distances and timing before venturing inwards.

5.5.15 Swell in the ice

can be more dangerous than ridged ice; as already mentioned, the swell decreases rapidly in on ice. In scattered ice, however, strong swell may be felt at a distance of up to 60 M from the open sea, while in close ice it can only be felt for a quarter of this distance.

5.5.16 Passing the ice edge going out

One must be careful in crossing the ice edge when going inwards, but this applies even more when leaving the ice in a gale, because in the calmer conditions inside the ice it is more difficult to judge the severity of the swell and the sea at the edge.

5.5.17 Passage location

Often at the edge of the ice there are large or small inlets into the ice, either open or protected by a narrow rim of brash ice or by an ice tongue, which can be used in order to find the best shelter before the swell during the passage. If the ice edge is dense, try to find the weakest point on the ice, like during passages of ice patches blown together within the ice, where the ice will open more easily and offer the least resistance to the vessel passing through.

5.5.18 Manoeuvring the ship through ice

As mentioned earlier, the ship should be manoeuvred through the ice from the wheelhouse or in some cases from the crow's nest. For reasons of safety of navigation, one person should be assigned to conducting manoeuvres and another to navigating the ship, including using the radar, radio and echo sounder etc.

When a ship is navigated through the ice, the development of the ice must be carefully monitored at all times, so that no changes in the movement and concentrations of the ice escape the attention of the navigator.

Conditions in drift ice can change very quickly because of ocean currents and changes of wind direction. Tidal currents will usually make the ice compact and slacken twice every day. The tidal current has its strongest effect on the ice outside the mouths of fjords, especially around spring tide.

Under favourable ice and weather conditions, the situation must be exploited immediately. If conditions are unfavourable, it is not necessarily a waste of time to consider the situation and await an improvement in ice and weather conditions.

The navigator should await more favourable ice conditions if there is a risk that the ship comes in beset and loses steerage way.

If possible, the ship should maintain steerage way to enable it to escape from a critical situation.

While navigating through drift ice, the navigator should constantly seek out the areas with the most slack in the ice and the areas with the smallest ice floes and growlers. This applies above all to adapting the speed to the conditions and avoid that the stern and thus the rudder and propeller collide with the passing growlers.

Violent reverse and evasive manoeuvres should be avoided. During reverse manoeuvres, the rudder should be kept amidships.

There are almost always icebergs and large growlers of glacial ice among the drift ice. The icebergs' direction and speed of movement is not always the same as the drift ice, so any icebergs encountered in the drift ice should be given a wide berth. If it becomes necessary to get close to growlers and icebergs, the navigator should be constantly on guard against colliding with or possibly sailing over an ice foot.

The navigator should be aware that shoals and underwater rocks often appear as slack in the ice or ice-free areas.

During night-time navigation and in poor visibility, the navigator should mainly rely on the radar image.
In close ice, the radar image may look somewhat chaotic, but by selecting an appropriately low "range" and appropriate "sea-clutter", the navigator will be able to obtain an overview of the ice that is located close to the ship. Special attention should be focused on the fact that an iceberg in the drift ice often casts shadows on the radar that resemble open water, or slack in the ice. Such "false" open water areas will always show up on the radar as part of a sector without any echoes.
Since there are many echoes on the radar screen when navigating in ice, the navigator should be aware that an echo may be another ship or vessel, and that there may be a possibility that a ship or vessel is "hiding" behind an iceberg.
If a ship is equipped with two radar installations, one of these should be configured as described above, at an appropriately low range and the other should be configured at an appropriate higher range. This will provide the navigator with maximum overview and the possibility to orientate himself and search for areas of low ice concentration and any areas with open water.
Normal radar installations "hit" the edge of the ice at a distance of 3-5 M.
When sailing at night in the ice, it is necessary to use an ice projector with a wide angle of coverage.
In this way it is possible to monitor that the ship does not swing into large growlers and icebergs that pass close to the ship.

Fig. 5.5 – Polar ice 7-9/10. East Greenland.

During navigation in drift ice, you will often experience that the ice pressure increases due to the effects of tides, freshening winds or ocean currents. The ice can be pressed so hard that it is impossible to proceed. In such situations, the only course of action is to wait until the pressure of the ice decreases.
With a freshening wind, it may be advisable to turn into the wind at slow speed, so the ship hits the ice with the bow and not with the leeward side. All modern vessels drift faster than

the ice. Navigation in narrow waters with currents and drift ice can be a very dangerous endeavour, because the ice can behave in strange and unpredictable ways. The greatest possible vigilance is required. If you feel trapped in the drift ice, do not blindly make unplanned attacks on the ice. Stop, wait and reconnoitre. There is almost always a way out.
Navigation in fast ice will not usually cause problems for ice class ships. If the ship cannot break the ice, it may be necessary to stop and reverse and possibly give the ship a run-up. The rudder should be kept amidships during the reverse manoeuvre and the navigator should take care that the stern does not swing in over the solid ice edge.
It may be advisable to stop the vessel while it is still drifting a little forward. This will avoid the ship "settling". If the ship has settled, it can almost always be freed again by trimming with the heeling tanks or running a heavy burden from side to side (with boom or crane) while the engine is running in full reverse.
In the fast ice, there will almost always be ridged ice, which are much thicker than fast ice. If it is not possible to sail around the ridged ice, one must try to sail perpendicular to the ridged ice. It may often be necessary to make more than one "run-up" to get through a ridge. It is often experienced that the ice is pushed hard in the ridges.

Fig. 5.6 – Polar ice. Umiivik, East Greenland.

5.5.19 Fog

In the ice, clear weather and dense fog can change suddenly. One must always be alert for the appearance of fog, and where the ice is not very scattered, and when the fog is approaching, one should quickly find an ice floe that projects well above the water, and which should preferably be substantially larger than those around it, and then moor the ship in the lee of this ice floe. The higher the floe, the deeper it will also be. As a result, it will not drift as fast as the lower, less deep floes, and there will therefore always be open water in the lee of the floe.

If there is no floe nearby that is significantly different than the others, it may be possible to find a floe with an inlet or with a pair of projections forming a kind of natural harbour. The ship can then be moored there, where it will be relatively calm. In any case, there is a possibility that any other ice that drifts down towards this location will come to rest against the floe's protrusion, and will not reach the ship.

Fig. 5.7 – Fog and polar ice.

5.5.20 Mooring in the ice

If you need to moor in the ice, place the stem against the ice floe and thereby keep the en- gine slowly running, while one man is set down on the ice and places the ice anchor to which the mooring rope is attached. An ice anchor is in fact a heavy iron hook, or preferably a double hook with two arms, so that it will not easily tip over on its side and lie flat along the ice. The hook (or hooks) are attached in a fracture or behind an upstanding edge a suitable distance in on the floe or usually, in a hole that is made in the surface of the floe with an ice axe or ice pick. If a vessel is moored like this, it is obvious that one must still remain vigilant and be able to use the engine at short notice. While drifting, the floe can turn and it may become necessary to shift along its edge to follow in the "wake" in the ice, or it may drift down towards an even larger and deeper floe or ice field, which is drifting more slowly than one's own floe, or against an iceberg.

5.5.21 Additional information and precautions in the ice

Even if one is idle and waiting, it is often most correct for the ice navigator to remain in the crow's nest or at least to be up there frequently for some time while the ship is moored. Even

in the densest fog, just the slightest breeze sometimes will produce a gap in the banks of fog through which it will be possible to get a view of the nearest ice.
Fog is always unpleasant at sea, but in the ice it is even worse than elsewhere, because it is necessary here to examine the channels between the ice fields from a long distance in order to choose the route that leads right through.
If this is not possible, you risk continuing into a bay or a blind channel and must then waste time and fuel getting back out again, or even getting stuck. The same applies in darkness in the ice: It is better to wait than get involved in something risky.
If you are in fog or in dark places with scattered ice or in open water where ice can be expected, and there is a strong wind blowing at the same time, it may be practical to turn the bow into the wind with enough speed to maintain steerage way so that it is possible to turn away as quickly as possible if sea ice appears ahead. It is important to get away from the lee side of the ice as quickly as possible because under these conditions, the floes are generally moved faster by the wind than the ship itself would move with a stopped engine.
Everything seems to change appearance in fog. The impression you receive of the size of the floes changes, because all contours are blurred and you lose the ability to make comparisons. A small growler may thus appear to be an iceberg, and a small opening may appear to be a wide channel. If you sail in a light fog in scattered ice, from the crow's nest you will have the impression of being in almost open water because, despite the limited visibility, you will think that it is the situation all the way out at the horizon that you are looking at, like when there is full clear visibility. If it suddenly clears up with sunshine from a cloudless sky, the first immediate impression you get of the ice conditions is that everything is closed around you, since the view initially focuses on the seemingly close and highly reflective ice on the horizon. If you have sunlight directly in your eyes and it is shining over a smooth surface of the sea with scattered pieces of ice, these seem to merge into one continuous mass of ice. If you need to sail directly into the sun under such conditions, steering and orientation are made considerably more difficult, even when using sunglasses. Radar can then be of great help.

5.5.22 Navigation close to fast ice

If, while you are in the pack ice, get close to fast ice along the coast, you must be careful of the zone between this and the drifting ice. With drift ice outside, you should not push the ship past the fast ice, as long as onshore winds are blowing, but rather turn into the wind and wait. If you are surprised by the fast ice (which can in many places be found far out at sea), you can take refuge behind one of the protrusions in the fast ice edge, which is often found in it or behind a grounded iceberg, or you can even cut and chop a dock in the ice edge. Should the fast ice edge break up under the influence of the drift ice, one must try to saw oneself further in. If the fast ice belt is not very wide, it is a dangerous place under such circumstances, if the wind conditions do not quickly improve.

5.5.23 Work out the reckoning

During navigation in the ice, it is necessary to work out the reckoning with the greatest possible accuracy. It cannot be expected to get reckoning to completely add up, when you have to wind your way between the floes, but precisely because of the many sources of error that can occur, it is of the utmost importance that each change of course and speed, even the most insignificant, is immediately recorded on the bridge, and that the ship's position is carefully plotted on the chart.

5.5.24 Manoeuvring between ice floes

During manoeuvring between the floes, the rudder must be constantly turned from one side to the other. Both the work with the rudder and the duty in the crow's nest can be very strenuous, and there must be good cooperation between the personnel on duty in order for everything to function as required.

Reverse manoeuvre in the ice:
a) first let the propeller wash away the ice just aft of the ship.
b) let the engine go into reverse until shortly before the stern touches the ice.
c) then stop the engine and let the ship drift into the ice under its own momentum.
d) when all the ice has floated up to the surface, give it another burst of power forward and then stop the engine again.
e) reverse again immediately afterwards and repeat this until enough space is obtained for a run-up.

In an ice classed vessel that can be manoeuvred from the crow's nest, the manoeuvre could be performed faster and more precisely than in ships that do not have such an arrangement.

5.5.25 Narrow channels

The channels between the ice floes are sometimes no wider than that the ship can only just pass through. Very narrow channels should not be entered unless it is absolutely necessary, especially if they are not very short, and even then one should under no circumstances attempt to force the ship through if the ice is coming together, because in these circumstances it is easy to get stuck, which under the circumstances is virtually synonymous with being sunk. The only thing to do is wait and try to keep the ship clear of places where the ice is hummocking.
Channels that are filled with smaller pieces of ice can be cleaned up by putting the bow against a suitably large floe and allowing the propeller to run with an appropriate speed forwards. Poles can be used to help smaller pieces of ice to move astern.

5.5.26 Walking and navigating across the ice

People who are sent out onto the ice should hold a boat hook or an ice pick horizontally in their hands as a means to avoid falling completely through a hidden, partially covered crack. A solid, long plank pulled behind one of those despatched across the ice can be very useful during passage of places that are too wide to jump over.
Although sea ice of 5 cm thickness is considered strong enough to support one man, one should not send someone out on ice that thin unless it is absolutely necessary. In practice, this will rarely be required, since ice of that thickness will not be a hindrance to any ship and will also not cause significant difficulties for passage by boats.
Sea ice of less than 16 cm thickness is usually not strong enough for a sled. If the ice thickness is between 16 and 18 cm, it may possibly be justified to make an attempt if it only involves a short distance. For journeys over longer distances, where there is a risk that the

ice may be broken up by wind and current, the ice should be so thick that even a smaller broken ice floe could bear the sled with its crew.

5.5.27 Water filling in the ice

Fresh water, which can be used for drinking water, etc., can be found during the summer in melt water lakes on thick and high ice floes which are more than one winter old and are not drifting or have not drifted too close to the ice edge or at large openings in the ice, where they may have been sprayed with salt water during a storm. If, when you wish to moor in the ice, you come close to a usable melt water lake (freshwater), a pump with suction and hoses can be used in order to take large quantities of fresh water on board in a short period of time. The melt water on ice that was formed during the last winter is too salty to be used as drinking water. When filling water from a melt water lake, one must always ensure that there is no connection (holes) at the bottom to the sea under the floe. It is not enough to taste the water, which may be fresh on the surface, but salty underneath.

5.5.28 Fire hole

If you become frozen in, make sure to keep a water hole open in the ice in case of fire on board in order to be able to get water. This fire hole must be cut through and maintained 1 or 2 times a day.

5.5.29 Use of explosives

In some cases, explosives may be used for blasting in order to relieve pressure on the sides of the ship when the ice becomes packed, and also to blast some large, hard ice floes, but normally gunpowder and dynamite blasting does not have much effect on the ice. Explosives must not be detonated too close to the ship, and there should normally be a distance to the ship’s side of 10 m, depending on the size of the explosive charge.

5.5.30 Winding channels

It is sometimes necessary to turn very sharply in winding channels. By turning appropriately with the bow towards the growlers you wish to impact, you can with minimal turning radius turn the vessel 90º without losing speed completely. You must then take care that the stern is not simultaneously swung into the growler you have just impacted, and that the stem is not swung with excessive force against the floe on the opposite side of the channel. The force with which you can impact the ice depends on the design and material strength of the ship. The stronger the vessel, the more speed can be maintained during manoeuvres and the sooner the difficulties can be passed.

5.5.31 Clustered growlers

If two or more growlers are located together and are blocking the passage, it is often possible by placing the bow between two floes and by twisting the ship with the propeller and rudder, to force the floes apart. It should be remembered, however, that such manoeuvres causes major stress to the sides of the ship, when these are hit by the ice and the frames are easily bent. It is usually better to try to break off one of the tips of the floe by running up against it with the bow.

5.5.32 Ice navigation near the coast

It is dangerous to get stuck in the pack ice near the coast. Within a short distance from the coast, there is a risk of being grounded by the wind, and if it is not possible to escape from the ice drift, try to get into the wake of grounded icebergs or heavy ice floes. If there is an im- minent danger of being grounded, the vessel should be given a list toward the ground in order to better withstand the ice pressure.

Fig. 5.8 – Polar ice, 4-6/10, South Greenland.

5.5.33 Ice ridge / hummock

If the vessel is trapped in the ice, you will recognize incipient ice packs as vibrations in the rig- ging or as short blows against the hull. With a well-built and strong wooden ship, which is not too heavy in the water, one can hope that an ice pack will work its way under the vessel and lift it up. After ice packing, picks, ice saws and explosives should be used to work any walls of packed ice away from the sides of the ship and try to get the ship clear again. It is possible that the vessel could be trapped by an ice foot or a growler that protrudes so deeply under the bottom from the ice on one side that you cannot reach it with picks and axes and do not dare to use explosives so close to the ship. Under such conditions, it can sometimes be a help to work the ice away from the opposite side of the ship where it may be easier to access, so that the ship can be hauled sideways away from the ice foot that is causing the problem.

If the ship is pressed to pieces by an ice pack, the ice fields that are pressing against each other will often hold up the ship until the ice packing and the ice pressure ceases, after which it will sink in the channel. If a ship sinks in this way, there will sometimes be time to bring prepared supplies out onto the ice in the period before the actual sinking and the ship's disappearance. During an overwintering, a ship has kept open water in a hole in the ice by inserting an iron pipe filled with kerosene down into the hole.

5.5.34 Icebergs

Outside the pack ice areas, icebergs can be encountered almost everywhere in the waters near Greenland.

Do not get too close to icebergs. Do not moor onto an iceberg that resembles a sea ice growler, even if it is very low and flat. A seemingly insignificant piece of ice falling from one side may cause the edge at which the ship is moored to suddenly rise up several metres and damage the ship. In some severe situations during icing in the pack ice, however, it may be necessary to moor to a grounded iceberg in order to maintain a position in the iceberg's wake, but in this case you should use as long a mooring line as the wake permits, and keep both rope ends of the hawser on board in order to be able to quickly cast off. If you need to pass a floating iceberg, one should always go to the windward side of the iceberg if there is room, in order to avoid the calf ice bits that drift down to leeward of it.

As already mentioned, large icebergs can be seen from a great distance from the bridge in clear visibility during the day, usually from a distance of 10-12 M, and as they are rarely too close together, they cause no difficulty in open seas under these circumstances. However, in the dark and in reduced visibility and particularly during heavy snowfall and blizzards, you must still keep a sharp lookout for icebergs ahead and take precautions to avoid collision with them. Your speed should be adapted to the current visibility conditions and should not be greater than that the speed of the vessel can be reduced by going astern before reaching a sighted iceberg. In moonlight under very favourable conditions, a large iceberg can be seen with binoculars at up to 8 M distance and with the naked eye up to 5 M distance, whereas small icebergs (and individual, drifting sea ice growlers) are more difficult to spot.

A ship which in late spring or early autumn in a very clear, dark night is sailing northwards in the direction of the brighter northern sky, must be careful, since icebergs and sea ice ahead will not be as clearly visible ahead as one might expect. Under these conditions, it is easier to see the ice when sailing southwards, since the southern sky is usually dark during these months. In dense fog, an iceberg will only be seen at a distance of 100 m if the sun is shining, and it then appears as a bright, white mass. If there is no sun, you will often only notice the iceberg as a dark shadow when you are very close to it. In light, low fog, the first thing you will notice of the iceberg will often be the ice and the stripes at the iceberg's water line and the sea lapping at its sides.

Fig. 5.9 – Icebergs in the inner route, South Greenland.

5.5.35 Use of sirens

When sailing in fog, it is possible to get echoes from high icebergs by using sirens. Under good conditions, an echo can be heard nearly 0.5 M away from icebergs, and in places where there are likely to be icebergs, the siren should be used regularly. Do not depend totally on hearing an echo from icebergs ahead, because some of them will not throw the sound straight back because of their shape. It should also be remembered that even fog banks are known to reflect sound well in certain conditions.

5.5.36 Periphone and sonar systems

Periphone systems have been used to investigate the possibility of listening to icebergs by horizontal echo sounding. The experiments showed that when the depth at the position was greater than 500 metres, icebergs gave a clear echo at a distance of up to 1400 m. If the depth was less than 400-500 m, the echo from the seabed greatly interfered with and distorted the echoes from the icebergs. In recent years, efforts have also been made to use sonar to locate icebergs, but you still find that some rounded icebergs neither bounce back ultrasonic sound vibrations in water or radio waves from radar sufficiently to avoid the need for visual sightings. The false sense of security that radar and sonar may give the navigator in such situations, may be worse than not having these otherwise excellent navigation aids.

5.5.37 Turn away for icebergs

If you pass stretches where there are very many icebergs, such as along Northwest Greenland, one must be aware, particularly in reduced visibility, that every time you turn away from an iceberg ahead, your course line shifts a certain amount to the side, possibly by a few hundred metres. After meeting with only 10 icebergs, which can happen in a short time, you are therefore drawn about 1 M to the side, if all the turns are made to the same side.

5.5.38 The presence of icebergs

The presence of a large iceberg or of scattered icebergs will normally mean that the depth of the water at these positions is large. If, on the other hand, you encounter a collection of closely spaced icebergs, you should be prepared that there is a shoal or some underwater rocks (an “iceberg trap”) nearby.

5.5.39 Radar observation

Radar can provide good information about icebergs and large growlers, and it is thus a valuable aid in waters where icebergs and scattered ice occurs. It must be borne in mind, however, that even quite large growlers can be overlooked.

In pack ice and dense drift ice, however, the radar is of less assistance because icebergs can cast “shadows” that can be perceived as open channels that do not exist.

Radar observations must therefore be used with caution in waters where ice occurs, and you should still observe the safety rules dictated by good seamanship.

5.6 Navigation in Ikeq (Nares Stræde) between Ellesmere Island and Greenland

For navigation in these waters, refer to the use of Canadian charts, since Danish charts do not cover these waters fully. An overview of Canadian charts can be found on the CHS website: http://www.charts.gc.ca/index-eng.asp
Corrections to Canadian charts are available in NOTMAR at: http://www.notmar.gc.ca/

5.7 Navigation in waters between Greenland and Svalbard

For navigation in these waters, refer to the use of Norwegian charts, since Danish charts do not cover these waters fully. An overview of Norwegian charts can be seen at the Norwegian Mapping Authority’s website: https://www.kartverket.no/en.
Corrections to Norwegian charts are available in Efs at: https://www.kartverket.no/en

CHAPTER 6

Depths off Greenland

6.1 Depths off East Greenland

An underwater ridge, Nansenryggen, extends from Nordostrundingen to Svalbard. This ridge has an irregular shape and the maximum depth is assumed to be 1,750-2,000 m. Nansenryggen ridge separates the great depths in Arctic Ocean and the Greenland Sea. There are depths of over 3,600 metres in the sea both N and S of Jan Mayen. There is also an underwater ridge S of the Greenland Sea that extends over Danmark Stræde and from Iceland, over Føroyar to the Shetland Islands. Between Iceland and Greenland, the largest measured depth over the ridge is 450 m in a narrow channel 90 M W of Önundarfjörður.

The 1,000 m contour in the N part of the Greenland Sea lies 160 M from the coast of East Greenland and the islands that lie outside this at latitudes between 79º and 77º N. S of the latitude 76ºN, the 1,000 m contour approaches the coast and is found 50 M E of Shannon and 70 M SE of Kap Broer Ruys. Off Liverpool Land, it is located 50-60 M from the coast and off the mouth of Kangertittivaq (Scoresby Sund) it is 60 M to the E. It is also found at a distance of 40 M from the N part of Blosseville Kyst and extends into Danmark Stræde to 70 – 75 M NW of Straumnes.

In the waters of Irminger Sea, the 1,000 m contour from the Atlantic Ocean reaches the S boundary of Danmark Stræde, and from 90 M SE of Naajanngivit (Kap Dan) it extends SW and then takes a somewhat more southerly direction. Approx. 100 M S of Naajanngivit (Kap Dan), it follows a WSW direction to within 35 M E of Saqqisikuik (Skjoldungen). From outside Saqqisikuik (Skjoldungen) to Nunap Isua (Kap Farvel), the 1,000 m contour generally follows the coastline, although it has a rather erratic course because of the many underwater fjords that protrude in over the continental shelf in this area. Off the islands S of Prins Christian Sund, the 1,000 m contour lies 25 M from the coast.

Inside the 1,000 m contour, the depths generally decrease rapidly to 300 – 400 m. Knowledge of the depths over the continental shelf along the coast of East Greenland is deeply flawed due to the presence of pack ice, the frequent deteriorations in visibility and the lack of electronic aids for accurate determination of position. The small amount of data collected over time seems to indicate the following:

6.1.1

Deep water extends from 76º30'N 007º00'W in a NW direction over the continental shelf and into the area between the island of Qeqertaq Prince Henrik and Belgica Banke to the NE. There is less than 100 metres of water over Belgica Banke.

6.1.2

A deep of more than 400 m goes from 75º15'N 012º00'W in a W direction between the banks that lie E of Germania Land and Store Koldewey and E of Shannon. The deep water continues S and W of Store Koldewey and northwards in Storebælt to the S part of Dove Bugt. The depth is less than 100 m S between Shannon and Hochstetter Forland.
From 74º30'N 017º00'W, a deep with more than 300 metres of water extends in a WNW direction, S of Shannon Banke and in between Shannon and Bass Rock (Lille
Pendulum). In the area E of Germania Land and Store Koldewey, there appear to be 3 isolated banks with depths less than 200 m and the bank furthest S has depths of less than 100 m.

6.1.3

From Irminger Sea, a deep with more than 400 m of water extends approximately N to the mouth of Kangerlussuaq at 68º00'N 031º30'W.

6.1.4

Ammassaliip Kangertiva (Angmagssalik Fjord) and Sermilik (Egede og Rothe Fjord) continue S with two deeps with depths up to 625 m and 960 m. However, with depths of over 500 meters these deeps do not extend over the entire width of the continental shelf.

6.1.5

From 63º30'N 038º45'W, a deep with depths of more than 500 m extends in a NW direction towards the Greenland coast at Umiivik.
For further information on depths, refer to GP – Sailing Directions for Eat Greenland.

6.1.6 East Greenland banks

The following banks can be found along the E coast of Greenland from Nunap Isua (Nunap Isua (Kap Farvel)) travelling N:

Ikkanneq Kap Walløe (Kap Walløe Banke) 60°30´N 042°45´W
Napasorsuup Ikkannera (Tordenskjold Banke) 61°46´N 040°36´W
Akorninnaap Ikkannera (Skjoldungen Banke) 62°35´N 040°38´W
Kulusuup Ikkannera 65°41´N 037°21´W
Dohrn Banke 65°55´N 029°42´W
Shannon Banke 74°50´N 014°40´W (chart 2000)
Dagny Banke 75°45´N 016°15´W (chart 2000)
Belgica Banke 79°00´N 013°30´W (chart 2000)

6.2 Depths off West Greenland

In Ikersuaq Davis (Davis Stræde), the 1,000 m contour line goes from the Atlantic Ocean N to 64º00'N. The contour line continues 30 M S around Nunap Isua (Kap Farvel) at a distance of 45-20 M from Greenland's W coast and 100 M from Labrador's E coast.

The 2,000 m contour line follows the 1,000 m contour line at a distance of only a few M along Greenland's W coast as far as 63º00'N, except for just S of Nunap Isua (Kap Farvel), where it protrudes out as a tongue in the direction 236º until 95 M from the land. Along the Labrador coast, the contour line stays 30 M outside the 1,000 m contour.

In Avannaata Imaa (Baffin Bay), the largest, reliably measured depth to date is 2,350 m, located 120 M W of Upernavik.

Southwards as far as off Qimusseriarsuaq (Melville Bay), the 1,000 m contour line goes into Avannaata Imaa (Baffin Bay) at a distance of 100-140 M from Greenland. It lies 50 M S of Innaanganeq (Kap York), but does not continue into Smith Sund, in whose S part the greatest depth probably does not exceed 650 m.

The depth increases somewhat in the N part of Smith Sund. There is an isolated deep in Kangerlussuaq (Inglefield Bredning) and Ikerssuaq (Hvalsund), which has depths of up to 950 m, and outside Kangaarsussuaq (Kap Parry), it probably continues 10 M S along Steensby Land.

6.2.1 West Greenland banks

There are a number of banks of greater or lesser extent within the 1,000 m contours along the W coast of Greenland from Nunap Isua (Kap Farvel) to Innaanganeq (Kap York). The most important of these are as follows, starting from S:

Nanortallip Ikkannera (Nanortalik Banke)
Narsallip Ikkannersua (Narsalik Banke)
Frederikshåbs Banke
Sioqqap Sioraata Ikkannera (Ravns Banke)
Danap Ikkannera (Danas Banke)
Qeqertarsuatsiaat Ikkannersuat (Fiskenæs Banke)
Fyllap Ikkannera (Fyllas Banke)
Toqqusap Ikkannersua (Toqqusaq Banke)
Maniitsup Ikkannersua (Sukkertoppen Banke)
Lille Hellefiskebanke
Qalerallit Ikkannersuat (Store Hellefiskebanke)
Qeqertarsuup Ikkannera (Disko Banke)
Qorfiit (Kap York Isfjelds Banke)

There are also a number of banks from Upernavik to Innaanganeq (Kap York), at 72º52'N 058º05'W and 74º02'N 058º42'W.

The banks are separated from each other by deep channels, most of which extend in towards the coast in an ENE or NE direction. Inside some of the banks there is again deeper water, while the shoal water on other banks continues all the way in to the coast.

Several of the banks provide good anchorages in calm weather. The bottom is smooth without underwater rocks or other abrupt changes in depth. An exception to this, however, is the NE part of the southerly Qeqertarsuup Ikkannera (Disko Banke), with Ikkarlussuaq (W Parry Skær) and Aappilattoq (E Parry Skær), whose very uneven bottom differs markedly from the other banks. The same applies to the interior part of Qalerallit Ikkannersuat (Store Hellefiskebanke), immediately off the coast, where there are several rocks, and which must be considered a transition between the smooth banks outside and the skerries within.
A further area with uneven ground near the navigation route along the coast lies on a bearing of 281º from the W point of Nunakuluut. At a distance of 17 M from the point, within the 200 m contour, there are depths of 14-39 m, and 32 M on a bearing of 281º from the same point, there is an isolated area with depths of less than 200 metres which extends in a N-S direction for a good 7 M, and over which the minimum depth is 81 m.

CHAPTER 7

Surface currents around Greenland

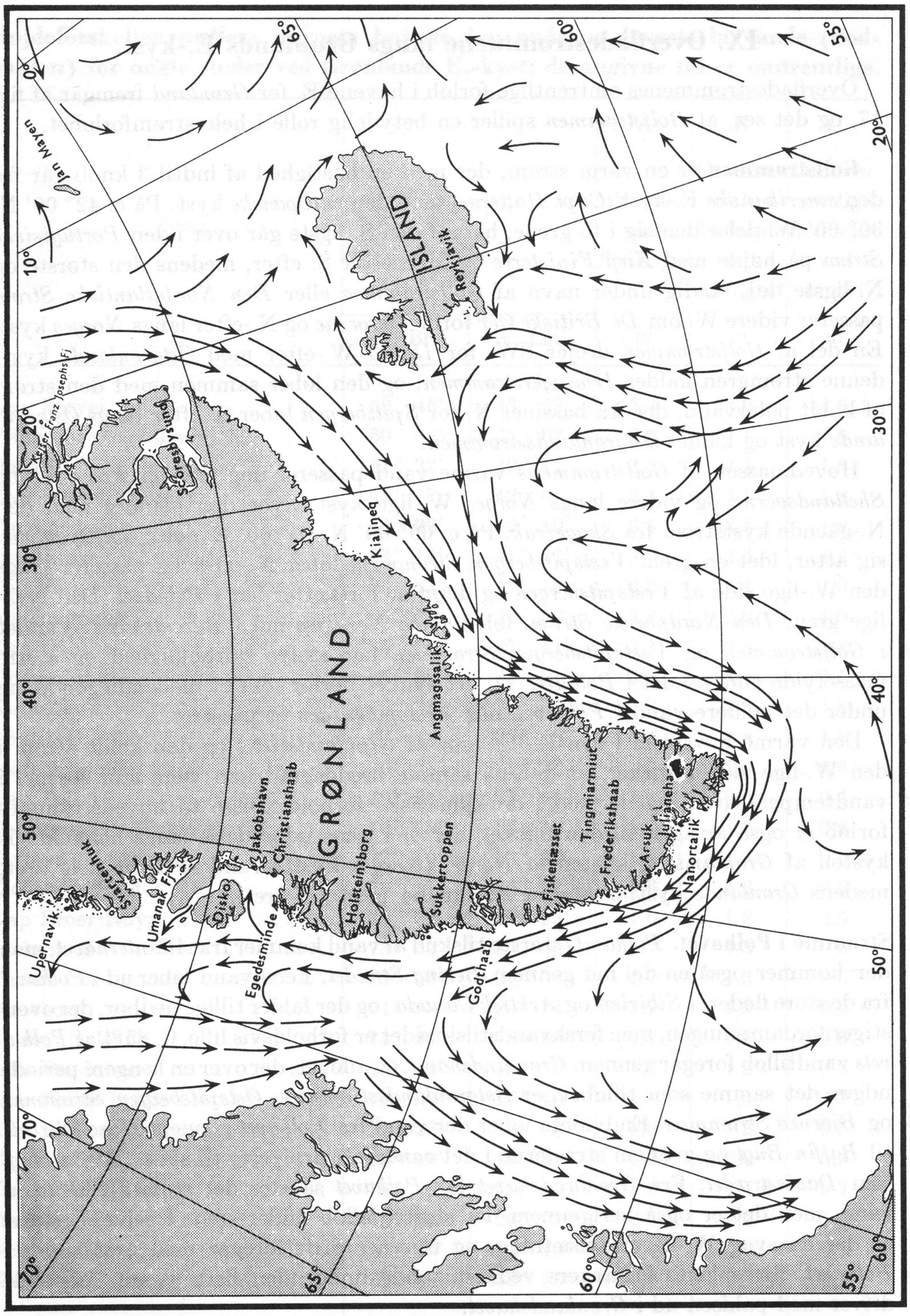


Fig 7.1 shows the general course of the surface currents around Greenland S of 73°N.

7.1 Surface currents along Greenland’s E-coast

The approximately course of surface currents in the waters E of Greenland are shown in Fig. 7.1, and it can be seen that the Gulf Stream plays a significant role for the entire system of sea currents.

7.2 The Gulf Stream

is a warm current that flows with a top speed of up to 3 kn from the American E-coast (Cape Hatteras) towards the European coast. It divides in two at 42º00’N 030º00’W. The southernmost current turns into the Portuguese Current at the latitude of Capo Finisterre and then continues S, while the largest and northernmost part, still under the name of the Gulf Stream or the North Atlantic Current, passes further W of the British Isles, past the Faroe Islands and N along the Norwegian coast. Part of the Gulf Stream turns SW of Iceland, westwards towards the coast of East Greenland. This branch of the current is called the Irminger Current, and it joins the flow of cold polar water that flows from the basin N of Svalbard, S along the coast of East Greenland and is called the East Greenland Current.
The main body of warm water in the Gulf Stream, however, passes between the Faroe Islands and the Shetland Islands and continues along the W coast of Norway, where it is mixed with the coastal current flowing N from Skagerrak. At 69º00’N 010º00’E, the Gulf Stream splits again and one branch, the Vestspitsbergen Current flows northwards and passes along the W side of Svalbard and then continues into Arctic Ocean. The NE branch, the North Cape Current, flows past North Cape into the Barents Sea. The water in the Gulf Stream and the West Spitsbergen Current has greater salinity and density than the water in Arctic Ocean, and it therefore sinks as an intermediate layer under the colder water in Arctic Ocean when it has passed Svalbard.
The warm ocean current on the E side of the Greenland Sea and the cold current on the W side means that, at the same latitude, there may be large differences in water temperature and therefore also in the climatic conditions. These two main currents are also the reason for the difference in the extent of the ice along the coasts of Greenland and Norway respectively. (Norway’s coastal waters are ice-free throughout the year, while Greenland’s coastal waters are ice-filled for most of the year).

7.3 Currents in Arctic Ocean

Most of the water flowing into Arctic Ocean comes from the Atlantic Ocean, but some also flows in through the Bering Strait. Freshwater flows out into Arctic Ocean from the major rivers in Siberia and Arctic Canada, and there is also precipitation that exceeds the evaporation, but the inflow of freshwater is relatively small. About 85% of the water entering Arctic Ocean comes through the Greenland Sea, and the outflow, which over time is equivalent to the inflow, is the East Greenland Current, the East Spitsbergen Current and the Bear Island Current.
Water also flows from Arctic Ocean through Ikeq (Nares Stræde) to Avannaata Imaa (Baffin Bugt) [Baffin Bay] and through the straits of the Canadian Archipelago to both Avannaata Imaa (Baffin Bugt) and Ikersuaq Davis (Davis Stræde) [Davis Strait]. The Arctic Ocean therefore receives most of its addition of water from the Greenland Sea, but it is also through the Greenland

Sea that the largest discharge takes place. In Arctic Ocean, there is a weak current flowing westwards and the ice drifts clockwise around Arctic Ocean. Some ice islands sometimes drift around the pole several times before finally drifting with the pack ice out into the Greenland Sea.

7.4 The East Greenland Current

is a very cold current. It flows with an average speed of approx. 0.5 kn from Arctic Ocean, along the coast of East Greenland, through Denmark Strait, passes around vel and then follows the coast northwards into Davis Strait at a speed of about 1 kn on average.

The speed of the current along the coast of East Greenland is greatest close outside the 200 m contour and it decreases in towards the coast.

Between 75°00’N and 70°00’N, the current sometimes turns in towards or out from the large fjord complex in this area. The flow of the current away from the coast occurs in June and July and is probably due to melt water from the snow in this area and to the NW wind. When this outgoing current ceases, the current flows in the opposite direction, and this current can almost block the fjords and bays in this area. The East Greenland Current fills most of Denmark Strait, but a branch of the warm Irminger Current flows northwards along the W coast of Iceland, and the outer boundary of this current is located close to the 200 m contour. Close to the 200 m contour, therefore, there is therefore a dividing line between the warm current flowing N and the cold current flowing S. The main direction of the East Greenland Current is along the coast, but because of the banks with occasional great depths that occur along the continental shelf, there may be major or minor local variations. Between Kangertittivaq (Scoresby Sund) and Denmark Strait, the outer part of the current seems to turn SE and E and then continues NE around Iceland as part of the East Iceland Current.

7.5 The Irminger Current

In the area around 58º00’N and 015º00’W to 022°00’W, a branch of the warm Gulf Stream (the Irminger Current), turns N towards the S coast of Iceland, and close SW off Iceland it divides such that the main current flows W and joins the East Greenland Current S of Denmark Strait, while a smaller branch flows N along the W coast of Iceland and continues E along the N coast of Iceland before tuning S. There is therefore an unnamed current that flows clockwise around Iceland.

7.6 The West Greenland Current

The current flowing westwards S of Nunap Isua (Kap Farvel), which under the name of the West Greenland Current turns N along Greenland’s W coast, is a continuation of the two currents that flow parallel of the southernmost part of East Greenland, namely the East Greenland Current from the Greenland Sea, which is cold, and the warmer Irminger Current from the Irminger Sea.

The variations to which these latter two currents are subject, both individually and in relation to each other, are continued in the West Greenland Current as changes in the current’s speed, width, water temperature and direction. The most important variations in the direction of the current seem to affect the outer parts of the current belt. It can be generally said about the West Greenland Current that the speed decreases with distance from the coast. The current is strongest in its southerly part, as far as Ilorput (Arsuk Fjord). The speed then decreases somewhat northwards to Nuuk (Godthåb).

Between Nuuk (Godthåb) and Sisimiut (Holsteinsborg), the main part of the West Greenland Current turns W along the S slope of the ridge between Baffin Island and Greenland and joins with the Canadian Current, which becomes the Labrador Current off Hudson Strait. N of Sisimiut (Holsteinsborg), there is only a weak current northwards along the coast.

The currents along West Greenland also change with the seasons.

The West Greenland Current appears to be weakest in October. In summer, melt water from the land and the coastal waters warmed by the sun increase the coastal current northwards. Off Qeqertarsuup Tunua (Disko Bugt) [Disko Bay], over whose mouth the currents from Davis Strait seem to pass in early summer without entering the bay, the increased coastal current turns E along the S side of the bay and, even later in the summer, continues all the way through Qeqertarsuup Tunua (Disko Bugt) and Sullorsuaq (Vaigat).

About the current conditions in Qeqertarsuup Tunua (Disko Bugt), refer to GP – Sailing Directions for West Greenland.

The currents in Avannaata Imaa (Baffin Bugt) are discussed in section 9.3.2.1 Current and ice conditions in the West Ice area, since it has greatest relevance in connection with the description of ice conditions.

CHAPTER 8

Tide

8.1 East Greenland

In Denmark Strait, the largest tidal range may be 3 – 4 times as large as the smallest, but it varies at different locations. The tidal current is strongest off prominent points and in waters narrowed by islands and reefs, and its speed at such places can be up to 5 – 7 kn at spring tide, but at some distance from such prominent points, the speed of the current decreases to 2 – 3 kn and off the open coasts, where the tidal current does not meet any obstacles, its maximum speed is about 3 kn.

On days with a new and full moon, the tidal wave occurs at SW Iceland approx. 4½ hours and at Tasiilaq about 6 hours after the moon's meridian passage.

The tidal wave in the Atlantic Ocean can be up to 5 m, but it shows great variation in time from the theoretical tides, which is due to the fact that, in the Atlantic, a tidal wave occurs whose main direction is from S to N. This tidal wave is caused by the tidal wave from the Indian Ocean, because after passing the S tip of Africa, some of this tidal wave turns N and continues up through the Atlantic Ocean, where it appears as a free wave that is independent of the local lunar tide. For each 12½ hours approximately, i.e. half a moon day, a new wave like this spreads N. It turns out that when one tidal wave has passed the S tip of Africa, the preceding wave has reached the parallel of latitude through Madeira, while the one before that has reached the English Channel. At Iceland, the tidal wave moves clockwise around the island and at the W coast of Iceland it moves at a speed of approx. 80 kn. The largest tidal range on the E-coast of Greenland occurs in the southern locations and is approx. 3.5 m. At Kap Morris Jesup, it is only approx. 0.4 m.

Fig. 8.1 provides an overview for some localities of the variations in water level occurring within a lunar day due to tides, i.e. the height difference between the day's highest high tide and lowest low tide. The table includes (A) the maximum height difference that may occur, (B) the average height difference at spring tide and (C) the average height difference at neap tide. Spring tide occurs at 1½ – 2½ days after the new and full moon.
The table in Fig. 8.1 can be used as a rough guide to tidal conditions along Greenland's E coast. A detailed calculation of the tidal conditions at the different locations can be made using the tide tables for Greenland.

Location	Position		A Highest Tide	B Mean High Water Springs	C Mean Low Water Neaps
	N	W	m	m	m
Nunap Isua (Kap Farvel)	59º46’	043º53’	3,4	3,0	1,6
Ikerasassuaq (Prins Christian Sund)	60º04’	043º02’	3,5	3,1	1,6
Qulleq	61º32’	042º17’	3,5	3.1	1,8
Kangeq (Kap Daniel Rantzau)	61º47’	042º05’	3,5	3,1	1,8
Timmiarmiut	62º32’	042º10’	3,5	3,1	1,8
Saqqisikuik (Skjoldungen)	63º14’	041º27’	3,0	2,6	1,2
Finnsbu	63º23’	041º18’	2,8	2,4	1,0
Tasiilaq	65º37’	037º38’	2,8	2,0	1,0
Kulusuk (Kap Dan)	65º34’	037º11’	3,1	2,3	1,3
Kuummiit	65º52’	037º01’	3,3	2,5	1,5
Kulusuk Mittarfik (Flyveplads)	65º35’	037º09’	3,3	2,8	1,8
Aputiteeq	67º48’	032º16’	3,3	2,8	1,8
Ittoqqortoormiit (Scoresbysund)	70º28’	021º58’	1,5	1,0	0,6
Ujuaakajiip Nunaa (Danmark Ø) (Hekla Havn)	70º25’	026º10’	1,7	1,3	0,6
Nyhavn	72º16’	023º57’	1,7	1,3	0,6
Eleonore Bugt	73º27’	025º22’	1,6	1,2	0,5
Kap Broer Ruys	73º32’	020º23’	1,6	1,2	0,5
Jackson Ø	73º55’	020º00’	1,7	1,3	0,6
Finsch Øer	73º59’	021º08’	1,7	1,3	0,6
Daneborg	74º18’	020º14’	1,7	1,3	0,6
Germania Havn	74º32’	018º50’	1,7	1,3	0,6
Lille Pendulum	74º40’	018º30’	1,6	1,2	0,5
Kap Philip Broke	74º50’	017º40’	1,8	1,4	0,7
Kap Børgen (Shannon)	75º26’	018º03’	1,6	1,2	0,5
Maroussia Ø	76º40’	018º34’	2,2	2,0	0,9
Danmarkshavn	76º46’	018º46’	1,8	1,4	0,7
Mørkefjord	76º56’	020º27’	2,2	2,0	1,3
Nordostrundingen	81º36’	012º10’	1,0	0,6	0,3
Kap Morris Jesup	83º38’	032º35’	0,4	0,3	0,2

Fig. 8.1 – The height difference between the highest high tides and lowest low tide of the day (tidal height) for some locations on the E coast of Greenland. The figures are approximate.

8.2 West Greenland

Along the coast of West Greenland from Kap Farvel to Kennedy Kanal, the tide is very strong and the height of the tide is considerable, especially on the stretch between Orsiivik (Polaroil) and Sisimiut (Holsteinsborg) and in Smith Sund. The largest height of the tides known on Greenland's W and NW coasts, occurs in Nuuk (Godthåb), where the height of tide can reach 5.1 m. The height of the tide decreases significantly N of Ikersuaq (Kane Bassin), and tidal movement is insignificant on Greenland's N coast.

Two high tides and two low tides occur during a lunar day, but the two high and low tides, respectively, are usually not of equal height. This daily inequality is greatest on the coast from Sisimiut (Holsteinsborg) to Svartenhuk. S of Sisimiut (Holsteinsborg) and N of North Star Bugt, the daily inequality is somewhat less.

Location	Position		A Highest Tide	B Mean High Water Springs	C Mean Low Water Neaps
	N	W	m	m	m
Nanortalik	60º08'	045º15'	3,5	3,0	1,5
Qaqortoq (Julianehåb)	60º43'	043º02'	3,2	2,8	1,4
Narsaq	60º54'	046º01'	3,6	3,0	1,6
Kangilinnguit (Grønnedal)	61º13'	048º07'	3,3	3,0	1,6
Orsiviik (Polaroil)	63º42'	051º33'	4,0	3,6	2,0
Nuuk (Godthåb)	64º11'	051º45'	5,1	4,4	2,1
Maniitsoq (Sukkertoppen)	65º24'	052º53'	4,8	4,2	2,0
Sisimiut (Holsteinsborg)	66º56'	053º45'	4,4	3,8	2,0
Uummannaq (Rifkol)	67º55'	053º50'	3,3	2,9	1,6
Aasiaat (Egedesminde)	68º43'	052º53'	3,1	2,6	1,5
Kitsissut (Kronprinsens Ejland)	68º59'	053º21'	3,0	2,4	1,3
Qeqertarsuaq (Godhavn)	69º15'	053º33'	2,9	2,4	1,4
Qaamarujuk	71º08'	051º23'	2,3	2,0	1,3
Iita (Etah / Port Foulke)	78º18'	072º40'	4,3	3,8	2,0
Rensselaer Bugt	78º38'	070º56'	4,1	3,6	1,7
Thank God Harbour	81º37'	061º40'	2,2	1,9	0,9
Kap Bryant	82º21'	054º30'	0,7	0,6	0,3

Fig. 8.2 The height difference between the highest high tides and lowest low tide of the day (tidal height) for some locations on the W and N coasts of Greenland. The figures are approximate.

Fig. 8.2 provides an overview for some localities of the variations in water level occurring within a lunar day due to tides, i.e. the height difference between the day's highest high tide and lowest low tide. The table includes (A) the maximum height difference that may occur, (B) the average height difference at spring tide and (C) the average height difference at neap tide. Spring tide occurs at 1½ – 2½ days after the new and full moon.

The table in Fig. 8.2 can be used as a rough guide to tidal conditions along Greenland's W coast.

8.3 Effect of meteorological conditions on tides

The following 3 general rules can be used as a guide to the impact of meteorological conditions on both tides and tidal currents:

1. The water level rises in the direction in which the wind is blowing, and falls in the direction from which the wind is blowing.
2. In open waters, the current caused by the wind will be deflected a little to the right when you turn your back to the wind. (This applies only to the N hemisphere, since the deflection in the S hemisphere will be to the left).
3. Low barometric pressure increases the water level, while high barometric pressure lowers it. (Theoretically, a change in barometric pressure of 10 millibars corresponds to a change in the water level of 10 cm).

Tide Tables for Greenland can be seen on DMI: http://ocean.dmi.dk/tides/tides_grl.uk.php

CHAPTER 9

Ice

9.1 The ice found in the sea consists of sea ice and glacial ice (icebergs)

9.1.1 Sea ice

Ice forms in winter in all waters in the Polar Area, and sea ice occurs all year round almost everywhere in varying quantities. Every summer, large volumes of ice melt in the various Arctic waters, and other volumes of ice are carried away by ocean currents to other areas. In Issittup Imaa (Arktiske Hav) [Arctic Ocean], therefore, the extent of the ice is smallest around the end of September and early October, after which winter ice begins to form again. This occurs slowly at first, since the sea water must first be cooled sufficiently to reach freezing point. The formation of the ice only reaches its maximum rate in February and March. After this time, the further formation of ice is somewhat prevented by the effect of the sun, but it continues until the beginning of May, after which the volume of ice reduces again. This decrease occurs most quickly in July and August.

As soon as the winter cooling begins, the upper layer of sea water becomes progressively colder and heavier and it therefore sinks and is replaced by water from the underlying layer of water that has not yet been cooled. This creates the vertical currents, which can reach to greater or lesser depths depending on the distribution of the density in the water layers and on the intensity of the cooling process. The smaller the depth to which these vertical currents need to reach, the faster the surface water will cool to its freezing point. The ice therefore forms first in places with relatively shallow water, such as near the coast or over shallow banks and in places where the upper layer of water is significantly less saline than the underlying layer. This situation occurs especially where rivers/streams discharge into the sea or in areas that receive large volumes of meltwater.

The formation of ice begins very late in areas with deep water, especially where the difference in salinity between the upper and the deeper water levels are not large.

In areas with strong currents, the constant renewal of the water in the area will prevent the formation of ice, and recently formed ice at these sites will soon be carried away, at least in the beginning. Since the current goes around banks in the sea, the formation of ice will also occur more quickly there than in the deeper water.

Generally, the formation of new ice occurs on the surface of the sea. However, if the cooling of the water occurs very rapidly, in strong gales and under clear skies, as well as during rapid vertical circulation and mixing of the water layers, the first ice formation can take place anywhere in the body of water that is cooled in this way.

If this mixing process extends all the way down to the bottom, ice will be formed down there (anchor ice) around stones etc. This ice will float up to the surface as soon as its buoyancy is greater than the weight of the object around which it has formed.

The formation of ice below the surface can also occur in places where almost-fresh surface water (e.g. meltwater) glides over the salt water, where it is cooled to a temperature below the freezing point of the surface layer (pancake ice).

9.1.1.1 Hardness and salinity of sea ice

Ice that has newly formed on the sea contains salt and therefore has physical properties different from fresh-water ice. The temperature to which the sea water must be cooled before ice begins to form depends on the water's salinity. For example, the freezing point of water with a salinity of 25‰ is -1.35°C and water with a salinity of 35‰ freezes at -1.91°C. When ice formation begins, the first crystals of ice are quite fresh, since the water molecules separate from the dissolved salts. The ice crystals usually accumulate in a network of fine needles and long prisms, which propagates downwards, sideways, and sometimes as beams and plates. The salt solution from the sea water that is left over when the water molecules freeze, will begin to sink due to their greater density but will be more or less prevented from doing so by the ever expanding network of ice crystals. The faster the formation of ice takes place, the more salt is enclosed in the ice that has formed. The presence of these many small cells filled with brine make the sea ice in this form less hard than freshwater ice.
As soon as the surface of the sea is covered with ice, the formation of ice continues on the underside of the ice that has already formed, but at an increasing slower pace due to the low thermal conductivity of ice.
As a result, the salt content of the new ice is greatest close to the upper surface, where the ice formation occurs fastest, and it decreases downwards through the ice. This salt distribution persists throughout the winter. When the air temperature rises in the spring and summer, more and more of the enclosed salt particles melt, and as the cooling and warming processes proceed, the cells and pores expand and contract in the ice. This causes the brine to slowly sink down through the highest parts of the ice floes, which gradually come to resemble freshwater ice. The floes that are piled up over each other in several layers and hummocks, therefore, quickly become quite fresh.

9.1.1.2 Different types of sea ice

The sea ice masses can be divided into fast ice and drift ice.

9.1.1.2.1 Fast ice

In the Arctic waters, enormous volumes of fast ice are formed each year from the coast and outwards over the shallow waters near the coasts, as well as in sounds, fjords and bays where the conditions for ice formation are particularly favourable. The two largest areas for the formation of fast ice in the north polar regions are the wide north Siberian continental shelf out towards Issittup Imaa (Arktiske Hav) and the sounds of the North American Archipelago.
In Greenland, fast ice forms in the numerous sheltered fjords and bays. The further one goes north, the greater the extent and thickness of the fast ice on the coast. Qeqertarsuup Tunua (Disko Bugt) and Uummannap Kangerlua (Uummannaq Fjord) can freeze over every winter, and at Qimusseriarsuaq (Melville Bugt), the ice generally forms in an arc from Kiatassuup Nuua (Wilcox Head) to Innaanganeq (Kap York), 30 – 40 M from the coast.
During the winter, the fast ice achieves a thickness of 60 – 100 cm in Northwest Greenland and approx. 2 m in the northernmost parts of Greenland. It's extent from the coast is regulated by the sea and the destructive effect of the drift ice on the outer edge of the fast ice.

The fast ice therefore usually reaches its maximum horizontal extent as early as December, but it continues to increase in thickness until May.
The inner, narrow belt of fast ice that freezes to the coast, undisturbed by waves and tidal movement, is called the Icefoot. It is usually considerably thicker than the other fast ice which, in connection with the upward and downward movement of the part of the ice that is lying out over sea, results in the formation of the first one, and then a number of tidal channels adjacent to and parallel to the coast.
The fast ice is not only the type of ice that forms earliest in the autumn. It is also the type of ice that normally disappears first, at least as fast ice. When the sun begins to gain in strength in the spring, the relatively warm melt-water flows together with sand and mud from the coast out onto the ice, whose innermost part quickly melts. The outer mass of ice, which is thus detached from the land and is eventually broken up by the wind and sea, will start to drift and unite with the drift ice in the sea.
In the sheltered fjords out towards Issittup Imaa (Arktiske Hav), under conditions which makes it difficult or impossible for the ice to melt in the summer, and which mean that the ice rarely or never breaks up, the ice becomes quite fresh over a period of 10 – 25 years and also takes on a such a grainy structure that it cannot be distinguished from glacial ice.
The build-up of snow over many years, which is then turned into ice, means that this type of ice can reach a thickness of 20 – 30 m. Such areas of ice are called ice islands after they are torn loose, and they often have an area of several square kilometres.

9.1.1.2.2 Drift ice

Drift ice is a comprehensive term that covers any kind of drifting sea ice, regardless of its appearance and distribution. The drift ice can contain systems of channels between the ice fields. Due to offshore wind and tidal and melt-water from the shore, a belt of open water and scattered ice may form right next to the coast. This is called the shore lead.
Depending upon the ease with which it is possible to pass the ice, this is said to be more or less open, and a distinction is made between the following concentrations, given in tenths of ice-covered water surface:

Concentration of the drift ice		
Compact ice	(10/10)	No water is visible
Consolidated ice	(10/10)	The floes are frozen together
Very close ice	(9/10)	Less than (10/10)
Close ice	(7/10-8/10)	The floes are usually in contact with each other
Open ice	(4/10-6/10)	Many channels and passages. The floes are generally not in contact with each other
Very open ice	(1/10-3/10)	Water predominates over ice

Fig. 9.1 – Concentration of the drift ice.

The extent of the drift ice depends on the season, but it can also undergo major changes in the same month from year to year, and its extent and concentrations can change markedly in the space of just a few hours.

9.1.2 Glacial ice (icebergs)

Glacial ice forms on land and consists of solid, granular ice formed from snow that does not manage to melt, but rather accumulates from year to year. During the snow's conversion into ice, a large amount of air is trapped in the ice, so that its structure differs from ordinary pure ice. On average, 10% of the volume of the ice is air. Under the influence of the immense pres- sure, particularly in the lowest parts of the ice, the air in the numerous small bubbles is compressed forcefully together and these cause a cracking sound when they are released from the melting ice.

9.1.2.1 Icebergs

The icebergs are rarely completely uniform. Often they are criss-crossed with blue or green stripes consisting of frozen melt water, which once ran into cracks in the ice from the upper side of the glacier. Caution should be exercised with regard to this clean melt-water ice, which is often seen near icebergs as quite large bergy bits. It is considerably harder than the usual iceberg ice and is difficult to see, as it is almost crystal clear and lies deeper in the water as a result of its greater density.

9.1.2.2 The icebergs' depth

Due to the differences in specific gravity due to the uneven distribution of air in the ice and the nature of the ice, not all floating icebergs have the same ratio for the part of the iceberg that extends above the water and the part that is below the water. This ratio, which is 1:7 on average, is also of purely theoretical interest, because icebergs almost always extend further out under water than above the water surface and they also have irregular shapes. Thus, it is not possible to estimate the depth of an iceberg solely on the basis of its height above the surface of the water. However, by drawing up a scale for the icebergs' appearance that ranges from the more simple, solid icebergs to the perforated icebergs that are partly melt-ed above the surface of the water, the following values have been obtained based on direct measurement of the grounded icebergs, where the stated ratio between the iceberg's height above the water and its depth, varies according to the shape of the iceberg:

The icebergs' depth		
1	Block-shaped icebergs with steep sides	1/5
2	Rounded icebergs	1/4
3	Lighter, clefted (picturesque) icebergs	1/3
4	Markedly clefted icebergs with slender spires	1/2
5	Icebergs and growlers in the final stage before melting, washed and eroded	1/1

Fig. 9.2 – The icebergs' depth

It can be seen that icebergs have a somewhat smaller depth than generally assumed, which should be borne in mind e.g. when approaching a location with grounded icebergs.

9.1.2.3 Disintegration of the icebergs

Once an iceberg is detached from the glacier, it begins to disintegrate. This process gener-ally takes place very slowly as long as it remains in Arctic waters, but even here, different

circumstances can also affect its destruction. While solar heat above the water's surface may produce trickling waterfalls along the sides of the iceberg, the lower portion is attacked by the surrounding salt water, especially at the waterline, by the solar-heated surface water and by the impact of waves. Attrition at the waterline can cause pieces of the iceberg's sides to fall off. Such bergy bits can drop deep into the water and then shoot up to the surface again at great speed and far out to the side of the iceberg. Above the waterline, the melting is accelerated where there is mud, clay or other impurities on the ice. As the disintegration of the iceberg progresses, its balance can be disturbed and it tumbles over until its stability is re-established. Additional large parts may break off during this process. Finally, the iceberg may be so "rotten" that a further disruption of its balance, especially if it is grounded, will cause it to completely disintegrate. In this way, a large iceberg can be transformed in just a few minutes and with enormous noise, into volumes of close brash ice and large and small pieces of bergy bits, which shoot out in all directions at very high speed, covering the sea in a wide area.
It is usually possible to see whether an iceberg is rotten. Deep cracks, loose fallen blocks, strongly creviced shapes and many penetrating holes are all signs that an iceberg is rotten. Larger calvings are usually preceded a few minutes beforehand by smaller calvings or a strong rocking motion of the iceberg and a loud roar.

9.1.3 The effect of the wind on the ice

9.1.3.1 Sea ice

The drifting of the sea ice is influenced much more by the wind than by the ocean currents. Nevertheless, the fact that drift/pack ice still generally follows the East Greenland Current and the currents along Baffin Island and Labrador and are not scattered across the sea, depends partly on the fact that the direction of the wind drift at those places largely coincides with the direction of flow, and partly on the fact that the sea ice melts rapidly if it is driven significantly outside the cold water currents.

9.1.3.2 Regrouping of ice floes

If they were all under the influence of the current and had a uniform depth, the drift ice floes would be carried relatively evenly along and with roughly the same relative positions of the individual floes and fields, but the wind causes a constant regrouping of these floes and makes the ice more or less open or else packs it together.
The surface of the drift ice is generally extremely uneven. The countless number of compacted ice pieces, hummocks and other irregularities that are distributed over the extended surface of the drift/pack ice function like so many small sails, which the wind acts upon and causes the ice mass to move with significant momentum. The direction in which the ice is driven by the wind is about 45° to the right of the direction in which the wind blows.
If the ice is spread over a relatively large area of the sea, the wind drives the floes together into chains, at right angles to the direction of flow. When the wind changes, the chains break and others are formed according to the new wind direction.
A storm blowing from a fast ice edge sweep the drift ice away from it.
Wind blowing toward a coast or towards fast ice reduces the amount of open water in the ice, and if it is strong enough, it causes hummocking.

9.1.3.3 Hummocking

When the ice hummocks, the floes are pushed above and below each other in several layers, or the edges of the fields are pressed together and crushed into large and small pieces, which tower up into walls which, in cases of extreme hummocking, can reach 8-10 m. Ice hummocks are usually weaker in the summer than in autumn and winter. This is because firstly, there is most water between the ice fields in the summer and, secondly, in the higher summer temperature, the ice is not as hard as in winter.

9.1.3.4 Ice floes with different depth

The effect of the current and the wind means that ice floes of varying depths do not drift at the same speed, because the deeper ice fields usually drift at a slower rate than lighter floes. On a large, heavy ice field that drifts together with closely spaced, lighter ice floes, a wake will therefore form in the ice on one of its sides, which may change its position in relation to the ice field, however, due to the rotating movements of the ice while it is drifting.

9.1.3.5 Icebergs

Unlike sea ice, actual icebergs have a large depth. The part of the iceberg that is under water therefore causes great resistance to the movement otherwise caused by the wind pressure against the small part of the iceberg projecting above the water. The drifting of larger icebergs is therefore not greatly affected by the wind. However, smaller remains of icebergs and calved ice which, like the sea ice, do not extend below the current generated in the upper layers of the water by a steady strong wind, will drift faster and differently than the large icebergs. Calved ice can therefore also be observed drifting on the leeward side of the iceberg from where they have fallen.

9.1.3.6 The effect of the wind on different types of icebergs

Observations and calculations have provided the following approximate results regarding the effect of the wind on the various types of icebergs (cf. the following table).

1) Large, heavy icebergs floating on the water in the ratio:
The iceberg's height above the water divided by the iceberg's depth = 1/5 to 1/3, are driven in the direction 40º to the right of the direction in which the wind is blowing, with the follow- ing speed:
1. Wind force 4-5 Beaufort: 2.8 M per day
2. Wind force 6-7 Beaufort: 4.3 M per day

2) Small, light icebergs and ice pieces (float ratio 1/2 or 1/1) are driven 54º to the right of the wind direction with the following speed:
1. Wind force 4-5 Beaufort: 6.7 M per day
2. Wind force 6-7 Beaufort: 10.2 M per day

9.1.3.7 Icebergs in drift ice current

As a result of what is described above, icebergs that drift together with the drift-ice/pack-ice will drift differently in calm weather because of the difference between the surface current and the current in the underlying layers of water (the flow rate usually decreases deeper in the sea, and the current may have a different direction in the deeper layers), and in windy weather because of the different effect of the wind on icebergs and on drift-ice/pack-ice floes.

When surrounded by pack ice therefore, there is a risk of being driven down on the icebergs. Conversely, it is possible during ice drift to take advantage of the wake, which usually forms in the lee of icebergs, which then act as large icebreakers in the pack ice.

9.2 Ebb and flow

It is a familiar experience among those who navigate in sea ice that the ice becomes closer twice a day and slacks up twice and this is strongest at spring tide. Occasionally, the phenomenon, which is caused by the passage of the tidal wave, is only noticeable once a day. These movements of the ice are greatest at its outer edges, while in the central part Issittup Imaa (Arktiske Hav) it is not noticed significantly.
If the ice is closely packed, the tidal movement can produce significant hummocking. This tidal hummocking occurs especially at changes of the moon and is strongest and most frequent in connection with a new moon.

9.3 Types of ice in Greenland waters

The ice that occurs in the waters around Greenland can be roughly divided into the following main types: Old ice, west ice, winter ice and icebergs.
The old ice (polar ice) [sikorsuit][1] is very heavy sea ice formed in Issittup Imaa (Arktiske Hav) over more than one winter and is about 3 m thick or more. Through a process of hummocking, ice packing and subsequent freezing together, significantly greater thicknesses of ice are formed. The ice contains very little salt and almost no air bubbles, which means that it is both hard and heavy. From Issittup Imaa (Arktiske Hav), most of the ice is sooner or later discharged into the waters between Greenland and Svalbard.
West ice [Kitaata sikua] is sea ice that forms at Ellesmere Island and Baffin Island and which the ocean currents carry out into the central part of Avannaata Imaa (Baffin Bugt) and Ikersuaq Davis (Davis Stræde). Since it is normally only formed over one winter and at a latitude further S than the polar ice, it is not as heavy as the polar ice.
Winter ice is the ice that forms during the winter in fjords [kangerluup sikua] and along the coasts. It is one year old and in West Greenland it rarely reaches thicknesses greater than 0.70 m. Icebergs [ilulissat][2] are formed by the calving of glaciers (land ice) at sea level.

9.3.1 Old ice

9.3.1.1 The extent of old ice along Greenland's E-coast

The main body of ice (old ice) flowing out from Issittup Imaa (Arktiske Hav) passes between Svalbard and Greenland. Smaller volumes pass S around Svalbard and between Greenland and Ellesmere Island, and some also passes through the straits of the North American Archipelago. On the basis of ice drifts of ice islands, ships, wreckage and buoys over Issittup Imaa (Arktiske Hav), it is estimated that the average age of polar ice floes is 4-5 years when they are carried away from Issittup Imaa (Arktiske Hav). The old ice is carried S by the East Greenland Current, along the East Greenland coast to Nunap Isua (Kap Farvel) and further N along Greenland's SW coast.

[1] From Greenlandic siku (ice on the sea or a lake)
[2] Plural of Greenlandic iluliaq, Ilulissat (Jakobshavn)

The speed at which the ice is carried S along the East Greenland coast is the result of the current's setting and the effect of the predominantly N and NE winds. The speed of the current is calculated at 5-12 M per day in the E (outer) part of the current, with decreasing speeds closer to the land. The ice drift's average speed southwards can be something greater with N-winds, i.e. up to 14 M per day in the outer part of the ice belt and 4-5 M per day in its inner part. Between Tasiilaq and Nunap Isua (Kap Farvel), the average speed of the ice is estimated to be 9 M per day.

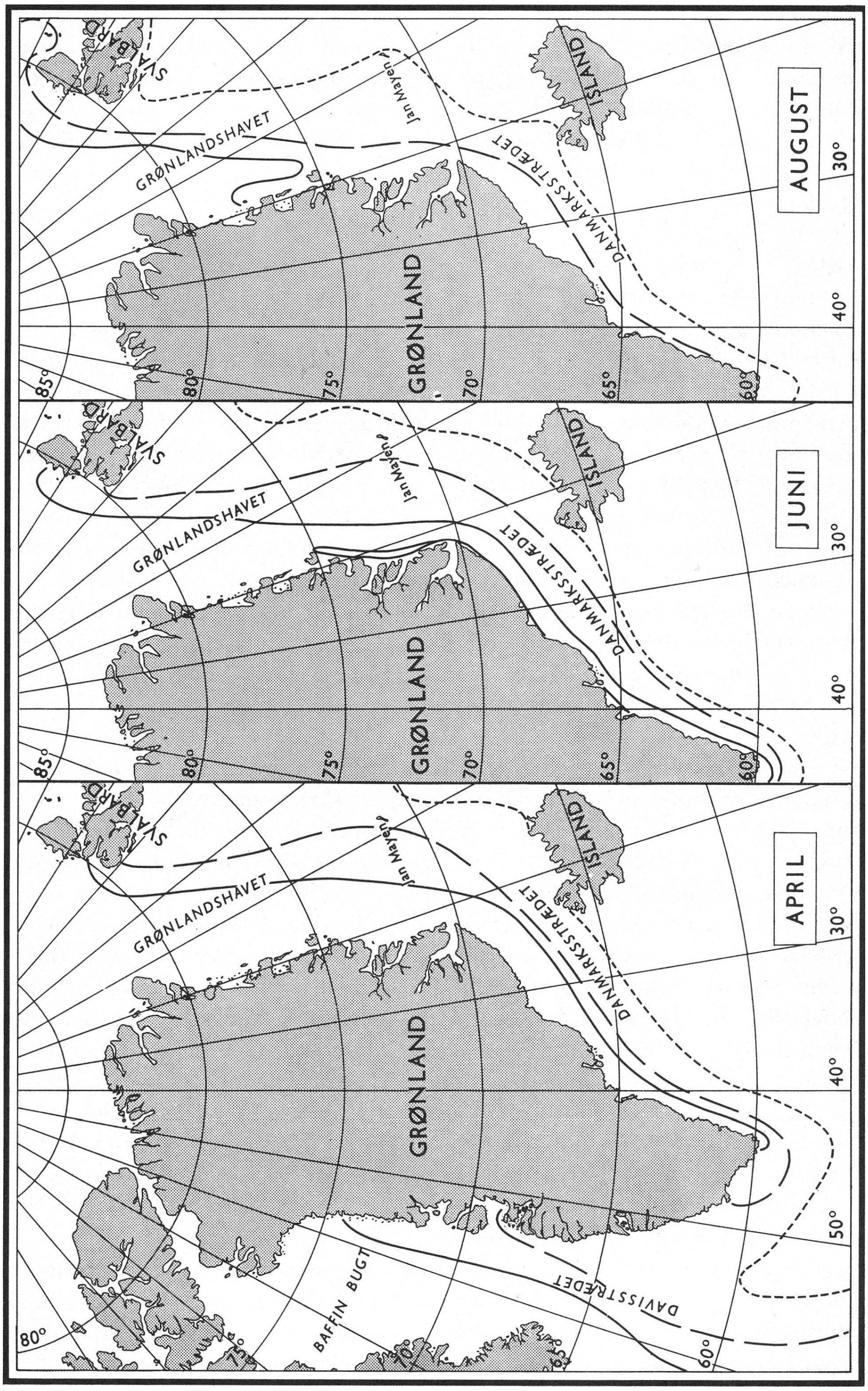


Fig. 9.3 – Limits of sea-ice in Denmark Strait and Greenland Sea.

Legend:
––––– Almost 100% probability of drift ice inside the line
–– –– Almost 50% probability of drift ice inside the line
- - - - - Very low probability of drift ice outside the line (except for icebergs)

The drift in the central and inner part of the ice belt is highly irregular. The wind here plays an important role in the non-periodic changes and hummocking in the drift ice.
The volume of old ice changes with the seasons. It increases as winter approaches, as large volumes of heavy ice drift from the N into the Greenland Sea, where, over the following months, together with the locally produced ice, it gradually penetrates southwards along the East Greenland coast, off which the width of the ice belt is then continuously growing.
In spring, the N part of Denmark Strait is usually more or less filled with ice, while at this stage during severe ice years, the ice may extend all the way to the N coast of Iceland and S along Iceland's E coast. The limit of the ice N of Iceland always has a characteristic tendency to spread eastwards, probably under the influence of the East Icelandic Current. The first part of the advancing increase in the ice mass at the beginning of winter manifests itself at Scoresby Sund in October, at Tasiilaq in early November and at Kap Farvel in the second half of January. The E limit of the ice in April-May usually extends from the NW point of Svalbard, over Jan Mayen to just N of Iceland, and from there W across the Denmark Strait to Tasiilaq, where the ice belt becomes narrower. It continues from there to Nunap Isua (Kap Farvel), see Figure 9.3. At Tasiilaq, where the current carries the ice out from the coast, which turns W here, the sea may be virtually free of ice as early as July, and on average the sea is free of ice in August every second year. October is the most ice-free month at this location and it is very rare for there to be ice in the water at this time of year.

9.3.1.2 The arrival of old ice at Nunap Isua (Kap Farvel)

As mentioned above, the first old ice usually passes Kap Farvel in January-February, but it can pass through at very different times and the arrival date may vary by several months from one year to the next. In the 60 years from 1900 – 1959, the earliest date for the arrival of the ice was 21 November (1951), and the latest date was 20 May (1947). The average date for the passing of the old ice over the 60 years was 23 January.
An early passage of the old ice at Nunap Isua (Kap Farvel) does not necessarily mean that there will be a large volume of ice in Julianehåb Bugt that year. The old ice often passes Kap Farvel in portions, and an early passage of old ice may be a small precursor to the main volume of ice, which may not arrive until much later.

9.3.1.3 The extent of the old ice S of Nunap Isua (Kap Farvel)

Old ice may be found S of Nunap Isua (Kap Farvel) throughout the year. The risk of encountering old ice in this area is least during the months from September to December. The ice belt can be over 100 M wide in May and June. Strong winds between N and E can push the ice far out into the Labrador Sea, but there is no reason to expect that the old ice will ever be driven across the waters from Nunap Isua (Kap Farvel) towards Hamilton Inlet, Labrador (54º29'N 057º05'W), and join with the Labrador Current ice.

9.3.1.4 The extent of the old ice along Greenland's W coast

As already mentioned, after passing Nunap Isua (Kap Farvel), the old ice drifts along Greenland's W coast. The outer part of the drift ice belt often consists of scattered ice floes with small growlers.

Larger, harder and sometimes densely packed ice floes, possibly with hummocked walls of ice, will sometimes be encountered in the central parts of the drift ice belt. Within this area, there will also be channels and open areas with varying volumes of ice and of greatly varying width.

A belt of open water, or so-called shore lead, will often be found at the coast. The shore lead varies in width with the changing wind directions and tides.

The greatest difficulties due to ice usually occur in Ikersuup Sioraa (Julianehåb Bugt), which can act as a pocket that traps the old ice and can for long periods prevent it from drifting further N.

N of Nunakuluut, the ice often lies at some distance from the coast, creating good opportunities to sail around the old ice. However, a W or SW wind can quickly push the ice in towards the coast.

Old ice can be encountered throughout the year in the S part of West Greenland. This is least likely to occur in the months from September to December.

The extent of the old ice to the N varies greatly from year to year. In the 57 years from 1900 to 1956, the old ice only reached as far north as Nuuk (Godthåb) or further in 14 of those years. One year (1947), the old ice only reached as far as Nanortalik. In that year, it was also in the period when the ice came latest to Nunap Isua (Kap Farvel). The average of the furthest N extent of the ice in the period 1900-1956 was to Qeqertarsuatsiaat (Fiskenæsset).

The furthest N extent of the ice is often reached in May, June or July, but it has sometimes occurred as early as March or as late as August.

West Greenland is usually free of old ice in the autumn months from August until the "new" old ice arrives, which usually occurs in January or February.

9.3.2 West ice

The West Ice (the North American drift ice), which is formed in Avannaata Imaa (Baffin Bugt) and is supplemented by ice from the straits of the North American Archipelago, and to a lesser extent from Issittup Imaa (Arktiske Hav), forms a southerly drift ice/pack ice current along the coast of North America.

9.3.2.1 The current conditions for ice in the West Ice area

The current carrying the ice in Avannaata Imaa (Baffin Bugt) goes N along Greenland to the S part of Qimusseriarsuaq (Melville Bugt). Part of the current here goes into this bay, outside and inside the various banks, and continues past Kap York N into Smith Sund, while another part flows NW and W to N of Lancaster Sound. At Ullersuaq (Kap Alexander), the north-flowing current in Smith Sund joins with the current on the W side of the sound that is flowing S from Issittup Imaa (Arktiske Hav), which during its continued journey S is joined by the currents from Jones Sound and Lancaster Sound. Off the S end of Lancaster Sound, some of the current spreads to the SE, and is seen at approx. 100 M in a direction of 259º degrees from Upernavik. The Canadian Current can thus absorb the westernmost 2/3 of the width of the waters between Upernavik and Baffin Island. The current conditions in Avannaata Imaa (Baffin Bugt) are still relatively unknown and it must be expected that the bay's central part contains one or more weak eddies.

The Canadian Current carries the ice through the W part of (Ikersuaq Davis (Davis Stræde) and along Baffin Island. Along the Labrador Coast, the ice is carried S by the Labrador Current and then past Newfoundland, where it normally reaches its maximum extent in February-March, after which it disperses and melts away. Growlers from this flow of drift ice/pack have been observed as far S as 120 M SE of the S tip of Grand Bank, SE of Newfoundland.
September is the month when there is least drift ice (west ice) in Avannaata Imaa (Baffin Bugt) and (Ikersuaq Davis (Davis Stræde). Over the following months, the volume increases until the west ice reaches its maximum extent, which usually occurs in March, after which the volume decreases again.
As early as October, the ice in the west may have spread so far to the E that it reaches the coast of Northwest Greenland, and in the following months it blocks a larger and larger part of North Greenland's W coast. Almost every year in December and January, the west ice can be seen in the Aasiaat (Egedesminde) area, and in January it can reach the West Greenland coast at 66ºN at the mouth of Kangerlussuaq (Søndre Strømfjord).
From Qeqertarsuup Tunua (Disko Bugt) and further N, the drift ice/pack ice freezes together with the winter ice at around this time of the year. It can still be present at the coast in significant volumes on this stretch of coast in April and May, and from Uummannap Kangerlua (Uummannaq Fjord) and further N in June. The coast is clear of ice until N of Upernavik from July to October.
The ice conditions are more variable N of Upernavik. In some years there may be open water along the coast all the way to Ikersuaq (Kane Bassin), while in other years Qimusseriarsuaq (Melville Bugt) and the sea outside is filled with closely packed ice. In the S part of Smith Sund, however, between the ice flow along Ellesmere Island and the Greenland coast, there is an area where even in severe winters, the water remains open to a surprisingly high degree. Different factors interact here to maintain this so-called "North Water" (Nordvand). However, the North Water's "ice-free" condition must be understood in relation to the more closely packed areas with ice immediately to the N and S.
When the ice in Smith Sund breaks up in June and July, it can fill a part of the North Water, but it is quickly driven away by the current and over into the W side of the waters.

9.3.3 The winter ice

The thickness and duration of the winter ice varies greatly along the coast of West Greenland. Because of the frequent storms and the relatively large tidal range, the winter ice has little chance of remaining on the outer coast, unless the old ice or west ice provides shelter and cooling. In the inner fjords and between the archipelago islands, the winter ice is always formed, also without the assistance of old ice or west ice.

9.3.3.1 The stretch of coast from Kap Farvel to Nuuk (Godthåb)

Winter ice is rarely found in significant volumes at the towns of Nanortalik, Qaqortoq (Julianehåb), Paamiut (Frederikshåb) and Nuuk (Godthåb), which are all located near the open coast. In the fjord areas, however, winter ice is formed that may obstruct navigation. This applies to e.g. Narsaq and also to Kangilinnguit (Grønnedal). The old ice, especially if it arrives early, can increase winter ice formation so that the outer coast also freezes.

9.3.3.2 The stretch of coast from Maniitsoq (Sukkertoppen) to Sisimiut (Holsteinsborg)

Winter ice that prevents navigation usually occurs, although Maniitsoq (Sukkertoppen) can sometimes remain ice-free all year. The winter ice in Maniitsoq (Sukkertoppen) and Sisimiut (Holsteinsborg) is often broken up by storms. The presence of west ice at Sisimiut (Holsteinsborg) can sometimes aggravate ice conditions.

Fig. 9.4 – Rotten winter ice with old sled track.

9.3.3.3 The stretch of coast from Aasiaat (Egedesminde) and further N

The winter ice remains stuck in the harbours and usually also on the outer coast, where it can freeze together with the west ice. The duration of ice cover and the thickness of the winter ice increases as one travels N. There is fast ice in Smith Sund from October to May, and the ice here usually reaches a thickness of over 1 m.

9.3.4 Icebergs

Icebergs may be encountered in Greenland waters throughout the year. They almost all originate from Greenland's ice cap, as small local glaciers play only a minor role, and icebergs from Arctic Canada do not normally reach Greenland waters.
The discharge of icebergs from Greenland's glaciers is prevented in winter by the winter ice, and the greatest drift of icebergs therefore occurs when the winter ice has broken up. The fact that icebergs can nevertheless be encountered in Greenland waters throughout the year is due to the icebergs' irregular drift progress, with frequent groundings in connection with the fact that large icebergs can be preserved for several years in the cold waters of Greenland.

9.3.4.1 East Greenland icebergs

The East Greenland glaciers are neither as numerous nor productive as the glaciers in West Greenland. The icebergs that are discharged on the N part of the east coast are generally prevented from drifting S by the sea ice. Even though icebergs can be encountered along almost the entire coast spread by the East Greenland Current, it is only S of Kangertittivaq (Scoresby Sund) that they occur in large numbers, rather than individually, out in the actual ice belt.
Many icebergs are discharged from Storstrømmen Bræ in Dove Bugt, but they are often trapped there for several years if the ice in the bay does not break up during the summer. The glaciers in Kangertittivaq (Scoresby Sund) produce large, tall icebergs, and the Kangerlussuaq fjord at around latitude 68°N produces a substantial proportion of the East Greenland icebergs. There are also several productive glaciers S of Tasiilaq.

9.3.4.2 Icebergs at Nunap Isua (Kap Farvel)

As a result of the many obstacles encountered by the East Greenland icebergs on their way along the coast, only a small proportion of them reach Nunap Isua (Kap Farvel). From Nunap Isua (Kap Farvel), the icebergs are carried further to the N. Only a few reach as far as off Nuuk (Godthåb), from where those that are not grounded on the banks are carried away from the coast.

Fig. 9.5 – Tower/block shaped iceberg, NW Greenland.

While most of the drifting icebergs and the old ice remain in the East Greenland Current and its extension along West Greenland, storms can drive some of them far outside the cold polar current. In places where the relatively warm, temperate water would quickly destroy a sea ice growler, an iceberg can last for a long time due to its large mass. For this reason, icebergs have been sighted up to 240 M SE of Nunap Isua (Kap Farvel) and 200 M WSW of Arsuk. This last position is approximately halfway between Greenland and Labrador. However, there is no passage of icebergs directly from Nunap Isua (Kap Farvel) southwards out into the Atlantic Ocean or across the sea to Labrador.

9.3.4.3 West Greenland icebergs

The majority of the icebergs come from the West Greenland glaciers. While only a few small icebergs are discharged from the southern fjords, such as Narsalik and Sermilik ice fjords, thousands of very large icebergs come from North Greenland, particularly from Ilulissat (Jakobshavn) Ice Fjord, Torsukattak, Uummannaq Fjord, Karrat Fjord, Upernavik district and from glaciers in Melville Bay. The glaciers in Uummannap Kangerlua (Uummannaq Fjord) and especially the glaciers in Qimusseriarsuaq (Melville Bugt) produce a large number of large, flat icebergs, while the more jagged and cleft icebergs originate mainly from Ilulissat (Jakobshavn) Isfjord.

9.3.4.4 The icebergs' route

The discharge of icebergs from glaciers in the NW part of Greenland is prevented in the winter when the fast ice lies off the coast, but when this is gone, the icebergs are carried away from the land northwards by the wind and currents. An iceberg that is freed from the fast ice in Qeqertarsuup Tunua (Disko Bugt) and Uummannap Kangerlua (Uummannaq Fjord) in June, can spend the summer at sea, overwinter in Qimusseriarsuaq (Melville Bugt), be released from here in the following summer, pass Cape Dyer on Baffin Island in October and then reach S of Newfoundland the following May, where it is rapidly melted in the warm water of the Gulf Stream. However, this itinerary for icebergs is by no means normal. Most icebergs are kept securely underway for years by banks, reefs and fast ice, and a total of only about 400 icebergs annually reach Newfoundland, i.e. about 5% of the icebergs produced in West Greenland.

WMO egg code used on ice charts

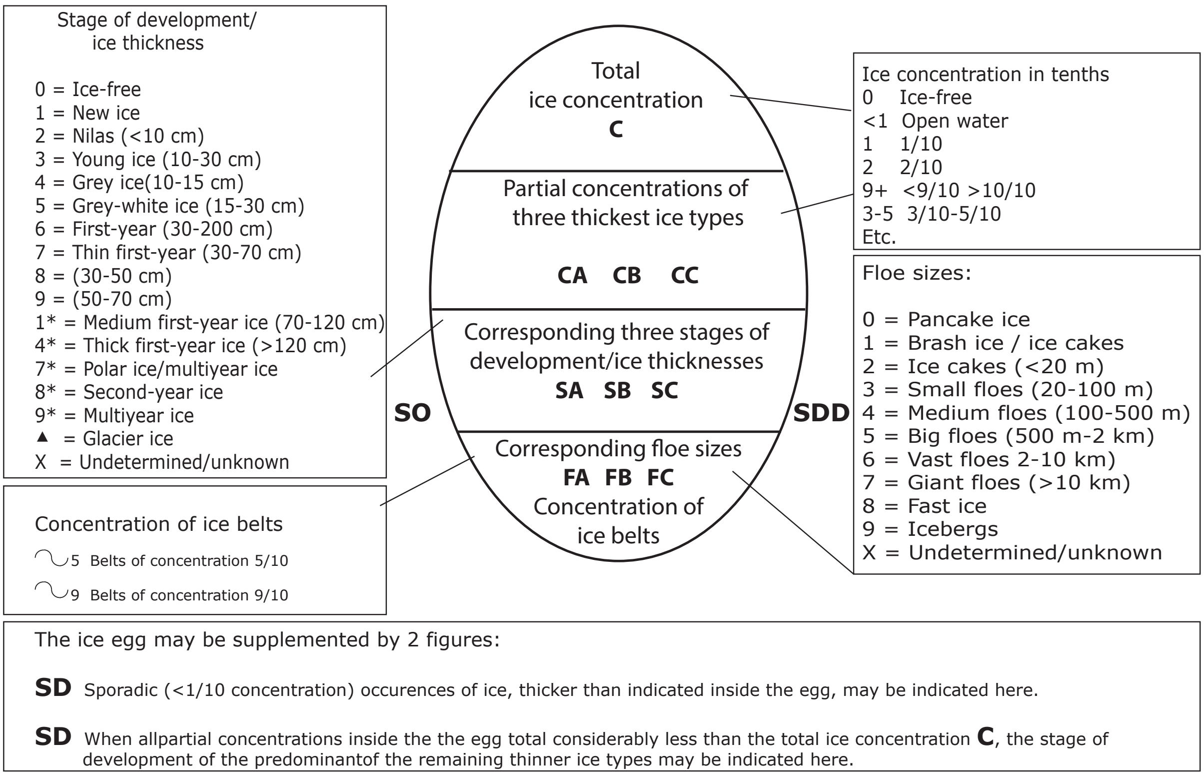


Fig. 9.6 – The Egg Code.

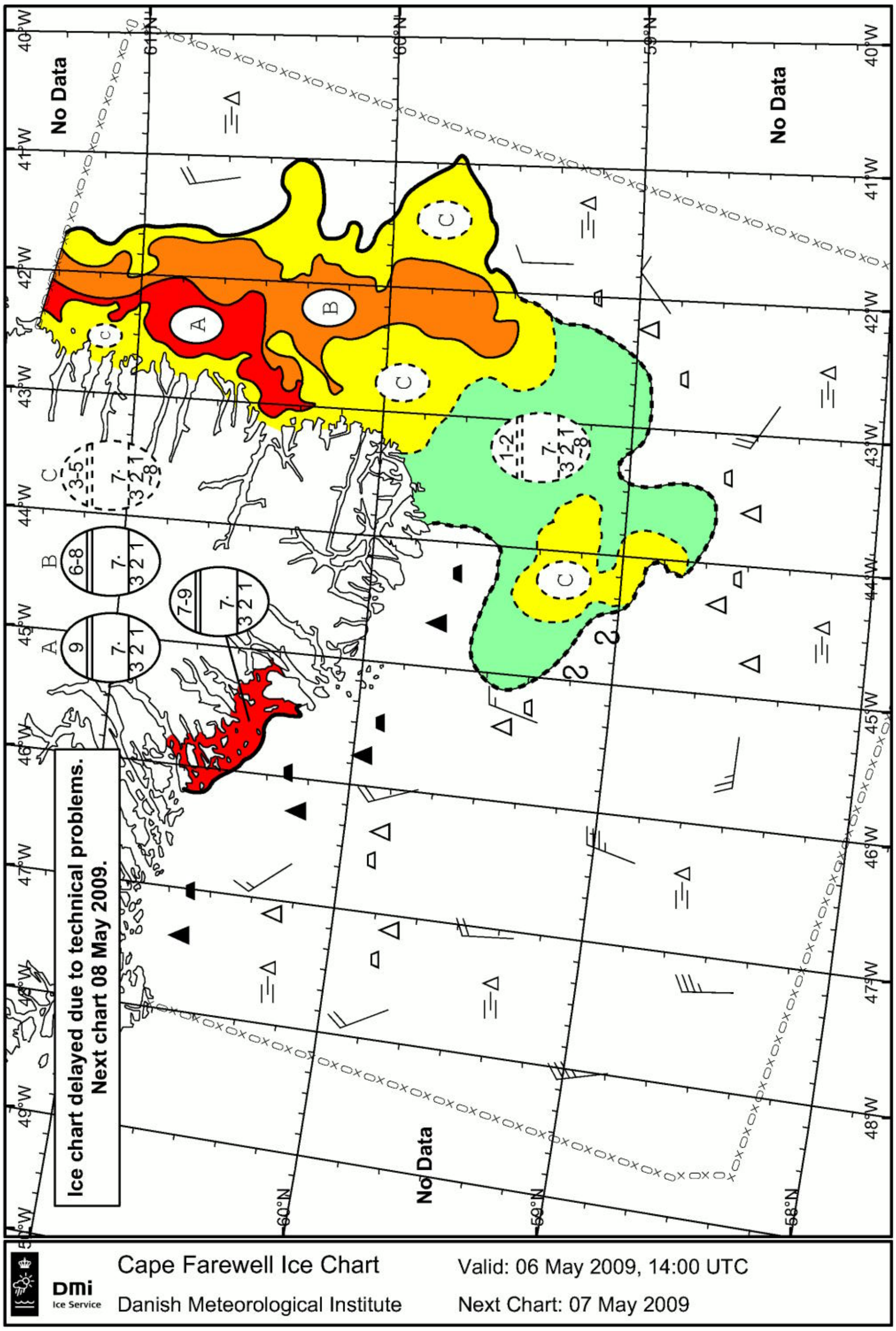


Fig. 9.7 – Ice chart for Nunap Isua (Kap Farvel) area.

Ice concen-tration	WMO symbols		Explanation	WMO ice nomenclature
	Color	B/W		
0/10			Ice-free	4.2.8
< 1/10			Open water	4.2.6
01-03-10			Very open ice 1-3/10	4.2.5
04-06-10			Open ice 4-6/10	4.2.4
07-08-10			Close ice 7-8/10	4.2.3
9/10 9+/10 10/10			Very close ice 9/10 Consolidated ice 10/10	4.2.2, 4.2.1, 4.2.1.1
10/10			Fast ice	1.1.1, 3.1
#			Icebergs, but no or less than 1/10 sea ice	#
#			Few icebergs	#
#			Many icebergs	#
#			Few growlers/bergy bits	#
#			Many growlers/bergy bits	#
#			New ice	#
#			Ice patches	4.4.1.4

Fig. 9.8 – Ice concentration, WMO symbols, explanation and WMO ice nomenclature.

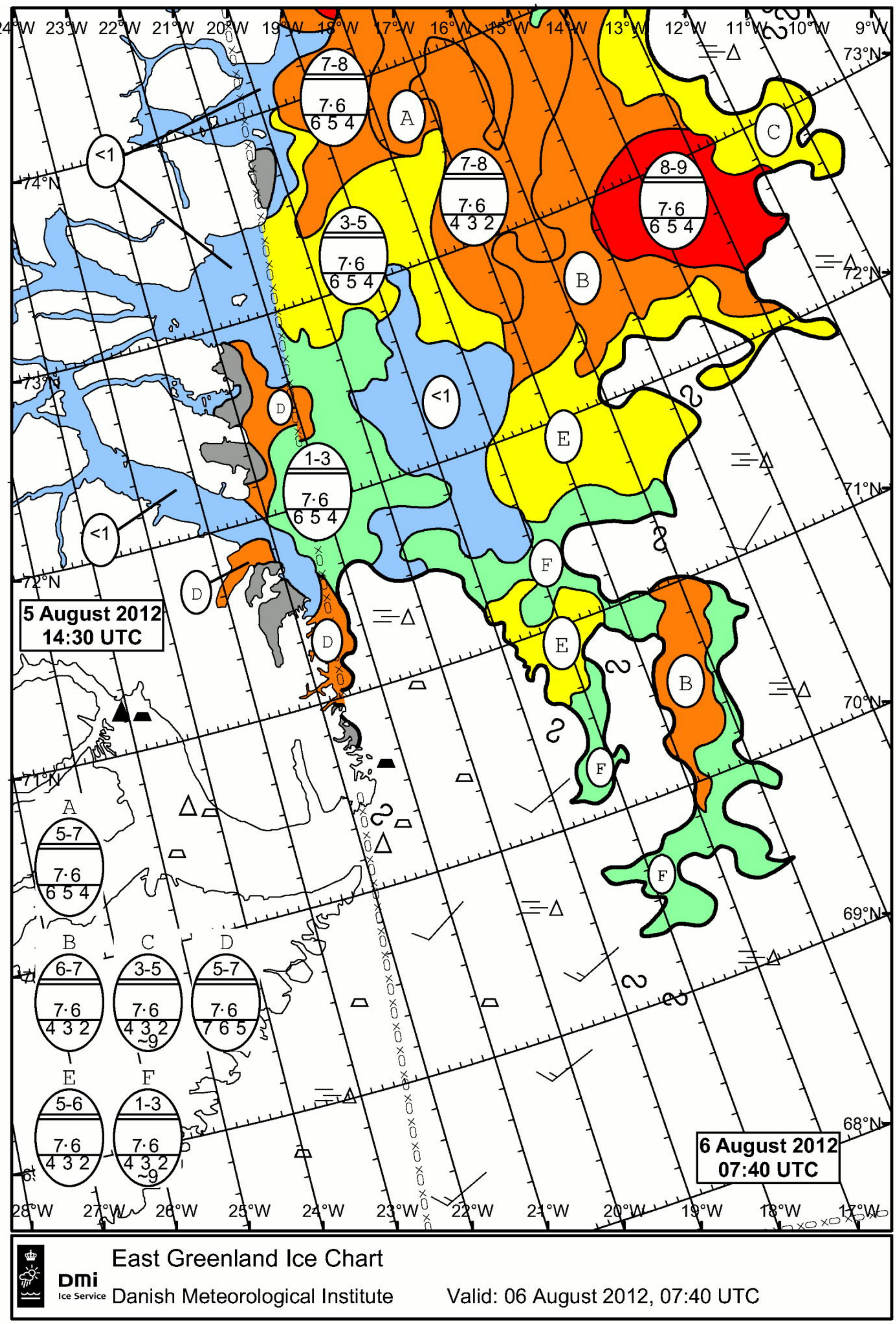


Fig. 9.9 – Ice chart for part of E Greenland.

WMO Total Concentration Colour Code Standard - Sea Ice

Colour		Total concentration (definition from WMO Nomenclature)
alternative	prime	
		Ice-free
		Less than one tenth (open water)
		1/10 - 3/10 (very open ice)
		4/10 - 6/10 (open ice)
		7/10 - 8/10 (close ice)
		9/10 - 10/10 (very close ice)
		Fast ice
		Ice shelf
	????	Undefined ice
Optional		7/10-10/10 new ice
		9/10-10/10 nilas, grey ice (mainly on leads)

Fig. 9.10 – Total concentration.

WMO Stage of Development Colour Code Standard - Sea Ice

Colour		Stage of development (SoD)	Thickness
alternative	prime		
		Ice free	
		<1/10 ice of unspecified SoD (open water)	
		New ice	< 10 cm
		Grey ice	10-15 cm
		Grey-white ice	15-30 cm
		First-year ice (FY)	>= 30 cm
		FY thin ice (white ice)	30-70 cm
		FY medium ice	70-120 cm
		FY thick ice	> 120 cm
		Old ice	
		Second-Year Ice	
		Multi-Year Ice	
		Fast Ice of Unspecified SoD	
		Ice shelf	
	????	Ice of undefined SoD	
		Drifting ice of land Origin (icebergs)	

Fig. 9.11 – Development stage.

Colour		Stage of development (SoD)	Thickness
alternative	prime		
		Dark nilas	<= 5cm
		Light nilas	> 5 cm
		Young ice	10-30 cm
		FY thin ice (white ice) first stage	30-50 cm
		FY thin ice (white ice) second stage	50-70 cm

Fig. 9.12 – Development stage – further codes.

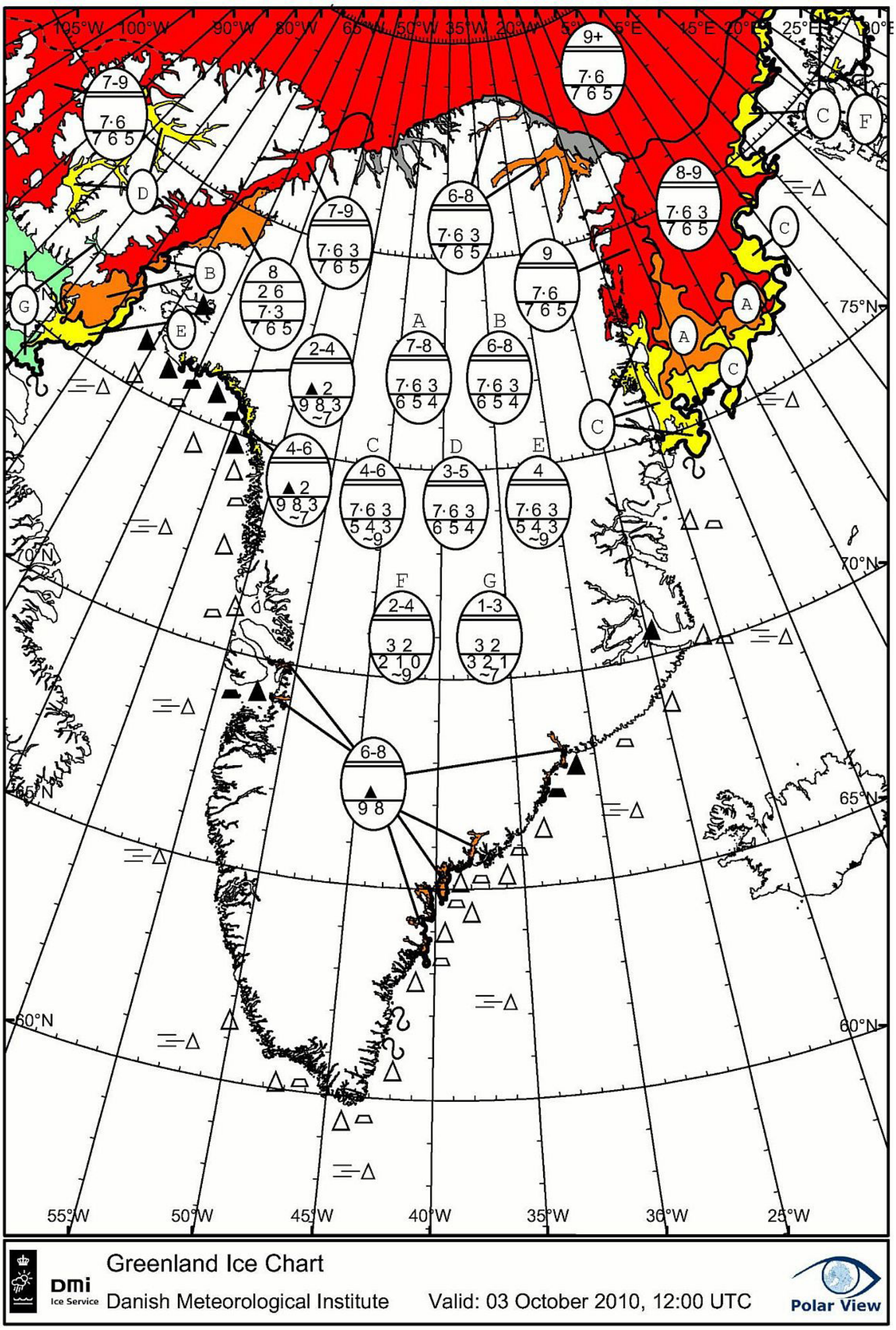


Fig. 9.13 – Overview chart.

Fig. 9.14 – Ice floe or rock? Ice floes in the inner part of Ikersuaq (Bredefjord).

Fig. 9.15 – Rotating growler, Ikerasassuaq (Prins Christian Sund).

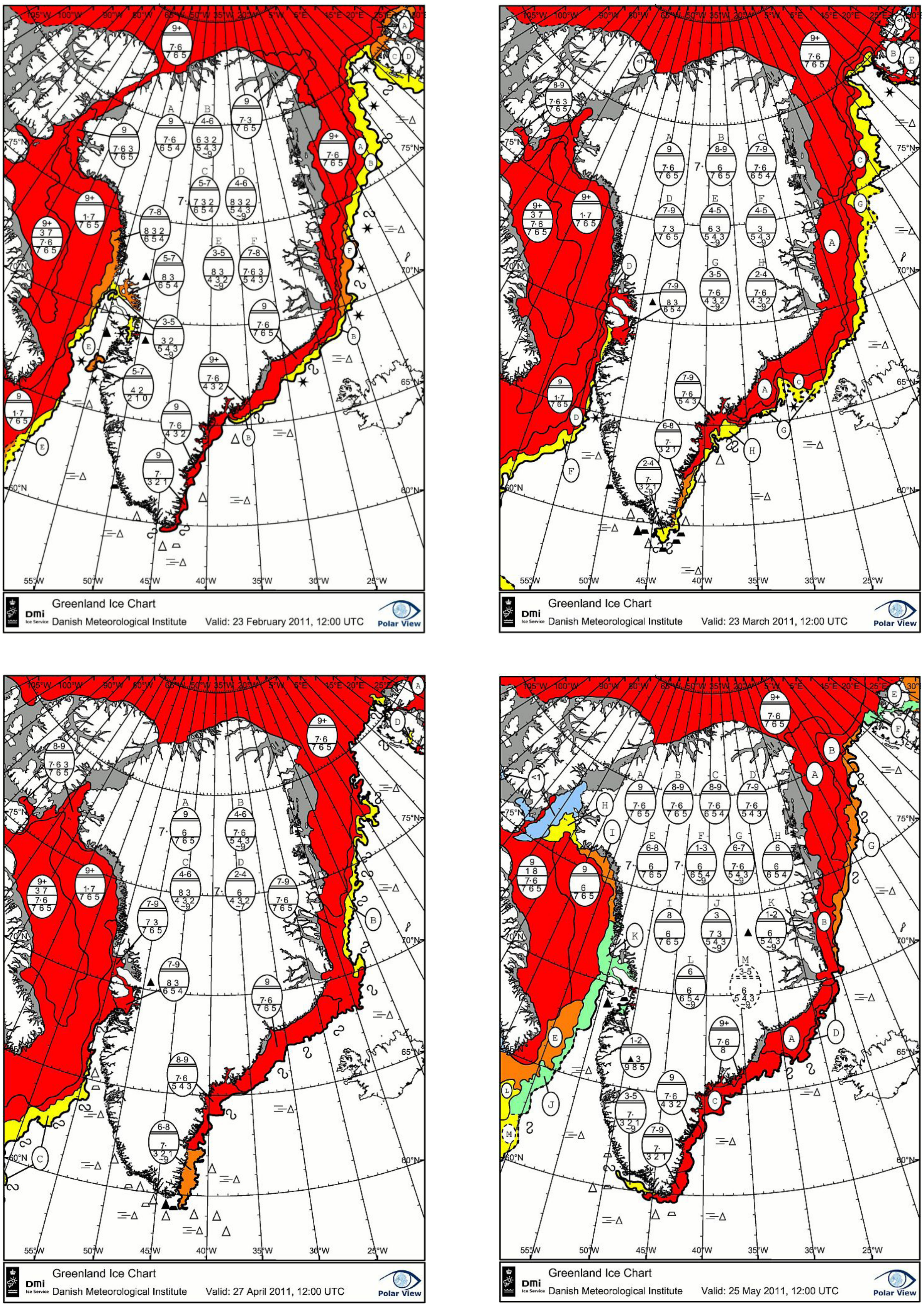


Fig. 9.16 – Ice charts from a period of 12 months (1-4).

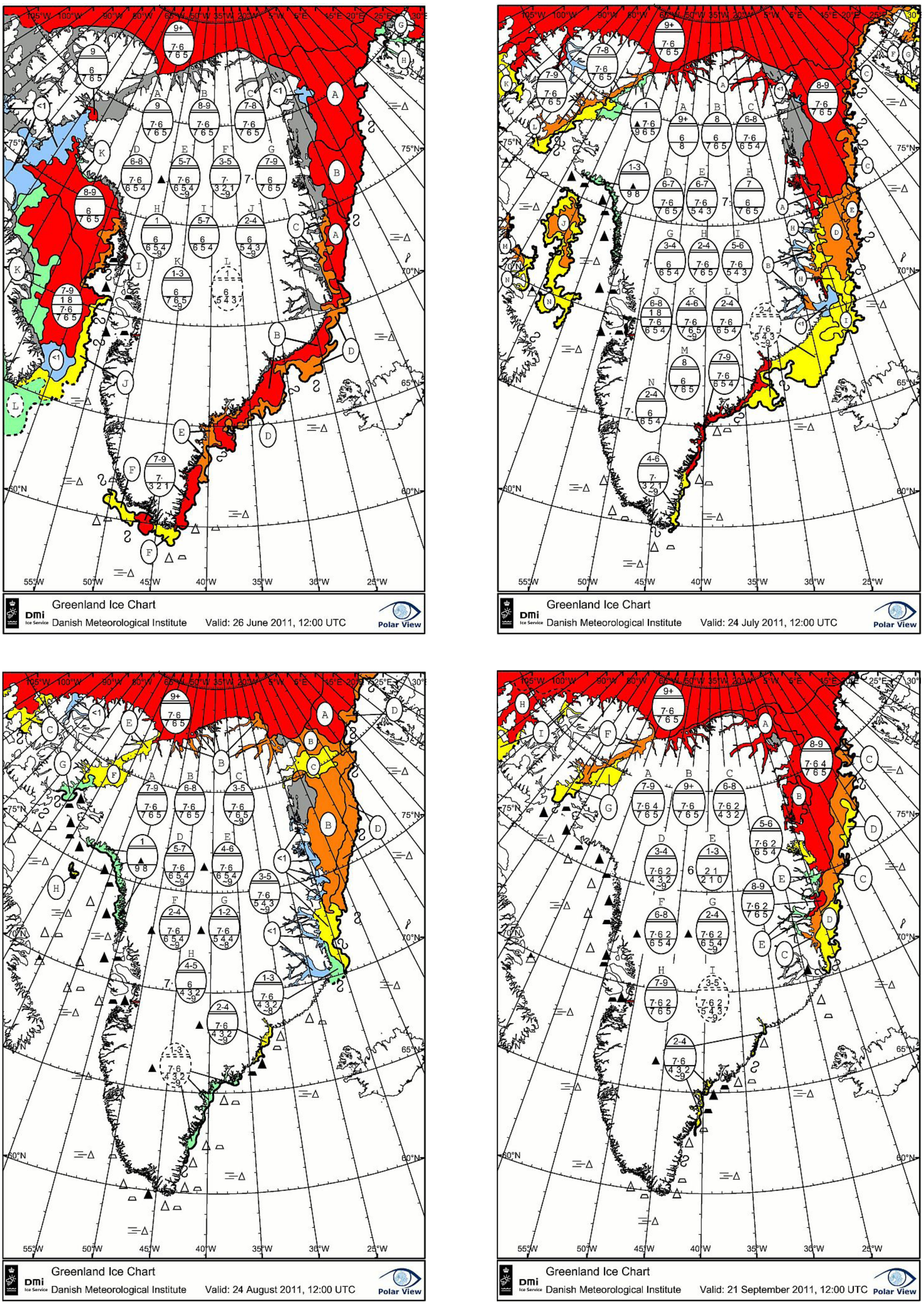


Fig. 9.16 – Ice charts from a period of 12 months (5-8).

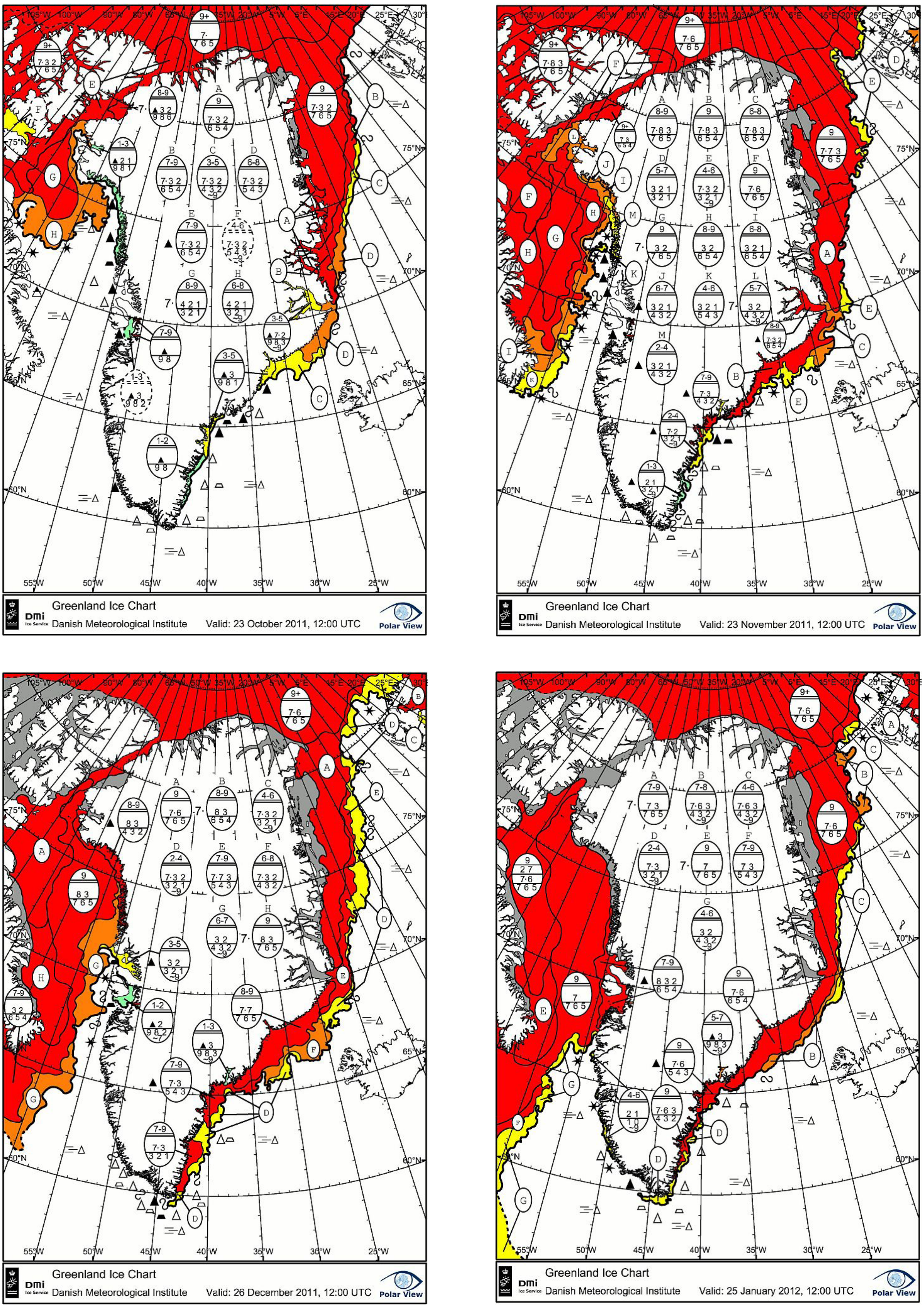


Fig. 9.16 – Ice charts from a period of 12 months (9-12).

CHAPTER 10

Climatic conditions in Greenland

10.1 Introduction

Two factors are important for weather and climate in the Greenland area. One is the land's location: N and E-continental. This creates the basis for a severe winter, though in the southern part moderated by the inflow from Ikersuaq (Davis Stræde) and the Labrador Sea, which remains partially ice-free and thus relatively warm. Summers are cool and can be described as west oceanic, dominated by the inflow of cold, southward flowing ocean currents carrying ice. The second important factor is Greenland's large extent in a N-S direction and the considerable height of the ice cap (usually 2-3 km). Together, these form an obstacle to the flow of the lowest and densest part of the atmosphere in an E-W direction and favours an airflow in a N-S direction. In this way, Greenland contributes to the exchange of air masses between high and low latitudes. This also affects the development and movement and the polar front low-pressure systems in the area. The steep coasts create the preconditions for wind pressure and associated high wind speeds.

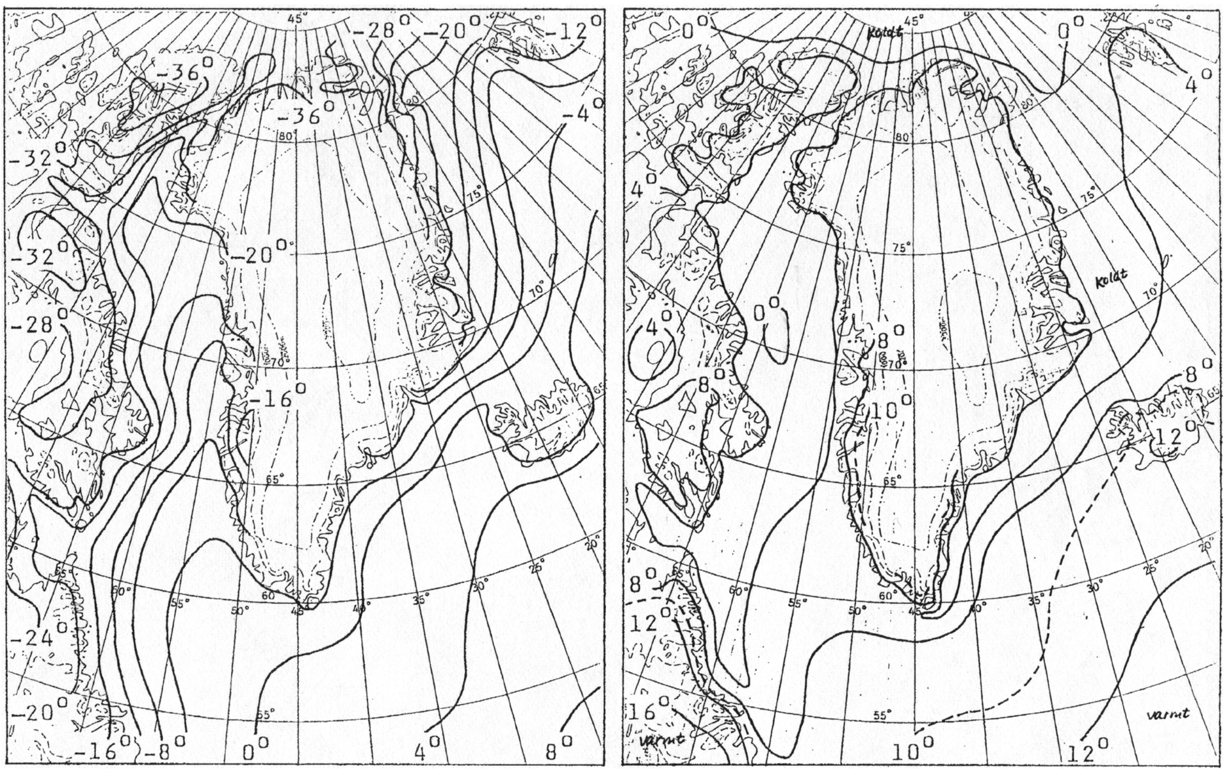


Fig. 10.1 – The air temperature at sea level, to the left in January, to the right in July. Many details cannot be described in the charts. The dotted 10°C isotherm marks the boundary between the polar climate and the temperate climate. This is also regarded as the limit of possible forest growth.

The following provides a general description of the area's climate, and also discusses weather conditions that are characteristic of the area.

10.2 Temperature conditions

Mean temperature distribution near sea level in January and July, respectively, are shown in Fig. 10.1. The difference between sea and land or ice is striking. In winter, the sea is relatively warm, but the temperature drops quickly when we move away from the open water. Conversely, in July the highest temperatures are found furthest inside the fjords, where the mean temperature locally in the S part is slightly above 10°C. Even in the interior of Peary Land farthest to the north, the mean temperature is above 5°C, but the summer here is rather short. The average temperature above sea level in summer is close to the sea surface temperature, i.e. from approx. 5°C and down to freezing point, where there is drift ice. When passing the sharp boundary between warm Atlantic Ocean water and the cold East Greenland Current, one will therefore experience a very noticeable change in air temperature. At the same time, the visibility and the nature of low clouds can change.

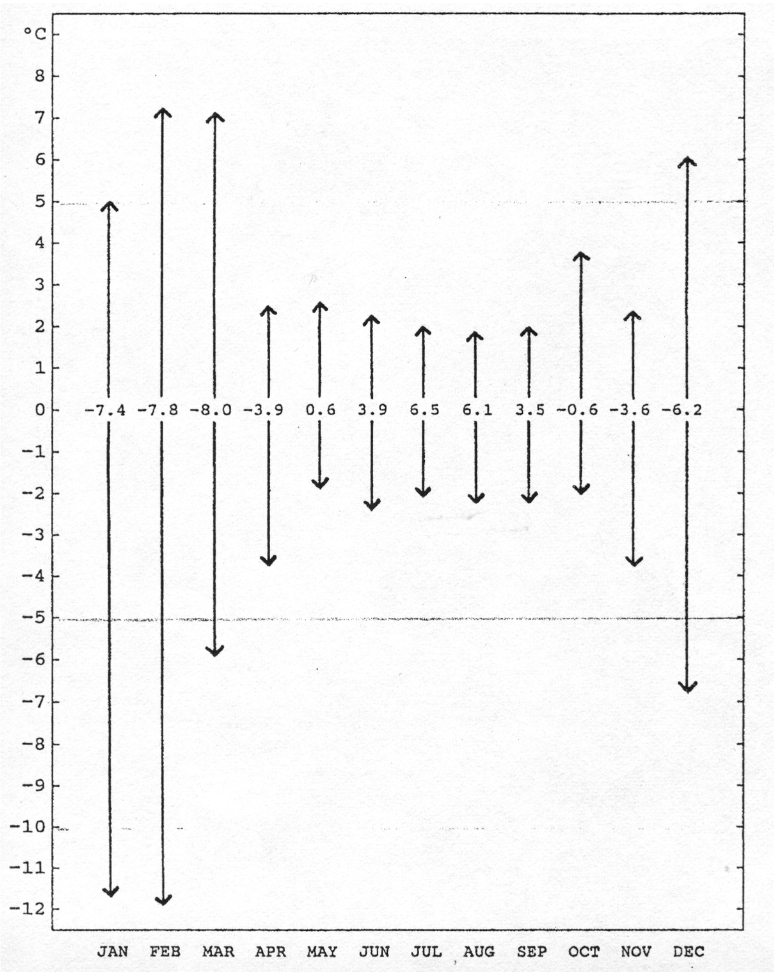


Fig. 10.2 – Deviations from the normal temperature in Nuuk (Godthåb) in the period 1961-90. The February extremes are from 1984 and 1986, respectively, cf. Fig. 10.6.

While summer temperatures (but not weather) are relatively uniform and are largely determined by the temperature of the sea, the severity of the winter is determined by the air mass distribution, which fluctuates widely from year to year, as shown in Fig. 10.2. The reasons for the variations are discussed in the section on cyclone tracks.
The highest temperatures year round will always be associated with Foehn winds, which mainly occur deep in the fjords or locally on the lee side of a mountain. In such situations during the summer, temperatures have been measured of up to 25°C in the S half of the country and about 15°C furthest N. The corresponding values in the winter are slightly above 15°C in the S and slightly above 0°C in the N. Foehn winds reduce the snow cover and can lead to the break-up of winter ice in exposed fjords.

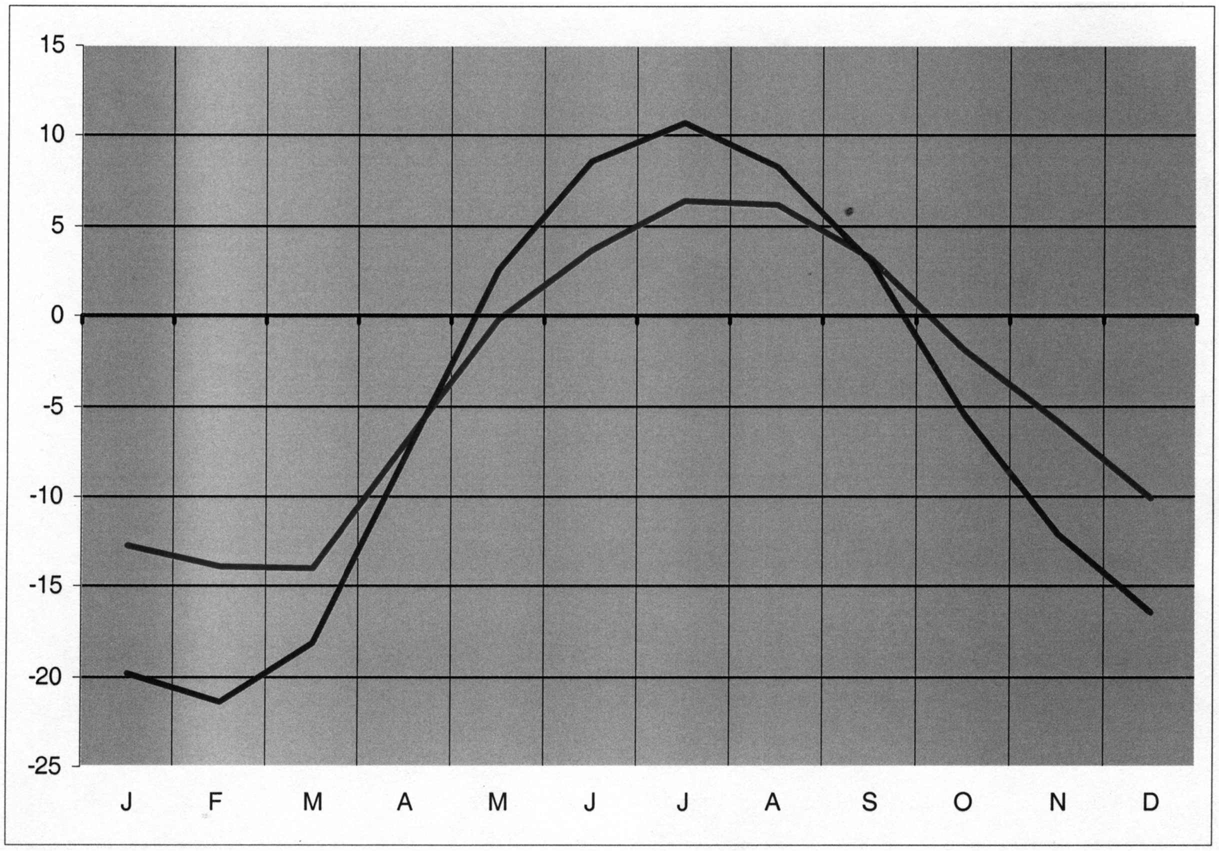


Fig. 10.3 – The temperature trend over the year in the coastal town of Sisimiut (Holsteinsborg) and the inland station at Kangerlussuaq (Søndre Strømfjord). The intersection points between the graphs mark the end of winter and summer, respectively.

10.3 Atmospheric stability

An important element in the description of the Arctic is the temperature's vertical distribution.
In the polar region, the surface is often cold compared to the atmosphere. This cools the lower layer of air so that, instead of falling, the temperature increases with the height. This condition is called inversion (i.e. anything that is reversed). There is also a stable stratification, because an inversion acts as a barrier to vertical movements. This means that the wind at the surface has a tendency to blow around rather than over larger obstacles. Another effect is an amplification of refraction in the atmosphere of electromagnetic waves. This can lead to mirages and the propagation conditions for radio and radar waves are distorted so that a "false echo" may be received.
In winter, inversions are frequent and severe over continuous ice and snow, which has been cooled by radiation emission. A temperature increase of 20°C through the lowest few hundred metres is not uncommon. Inversions are rare over ice-free waters, but they can develop as a result of the inflow of warm air, e.g. in the form of Foehn winds.
In summer, inversions occur mainly over the cold sea water. In calm weather ("high pressure weather"), the inversion lies close to the surface and often leads to the formation of fog, since the moisture that is constantly fed into the lowest layer of air through evaporation is unable to escape. Freshening winds will cause turbulence that will result in mixing of the air, and the fog will then usually be lifted to a low cloud cover.
An unstable stratification (a temperature decrease with height of more than 1°C per 100 metres) may be encountered during the winter over ice-free seas when the water is warmer than the atmosphere, which is normal. This leads to strong vertical mixing of the air with the development of cumulus clouds and possibly snowfall, but otherwise provides good visibility. If the convective layer is sufficiently deep, the shower activity may be strong and unstable low-pressure systems may develop ("polar low", see below). In summer, instability with the development of cumulus clouds (possibly squall clouds) may occur inland, but rarely over the sea.

10.4 Visibility

Visibility is generally good in winter in Greenland waters when there is no precipitation. Snow may markedly reduce visibility. Fog (visibility of less than 1,000 metres) may develop in the very cases where the stratification is stable due to the influx of air that is warmer than the sea, as mentioned above. Another form of wintry fog is frost smoke. This occurs when cold air from the land or from the ice cover, flows out over the open water, and has the nature of "vapour clouds" with varying visibility. Often it is very local, but it can cover large areas in a very cold air mass.
The atmosphere over the sea is generally stable in summer, as described above. The frequency of fog is therefore high. The season for fog begins in May, peaks in July and reduces in September. In coastal waters in July, fog occurs around 20-30% of the time, but when the sea is at its coldest and more or less filled with ice, the probability of experiencing fog is probably more than 30%. The fog is driven into the fjords by the sea breeze in summer, but it usually vanishes quickly on contact with the sunlight-heated land, and the further inland you go, the less often fog occurs. The location of the airports in Kangerlussuaq (Søndre Strømfjord) and Narsarsuaq is ideal from this perspective.

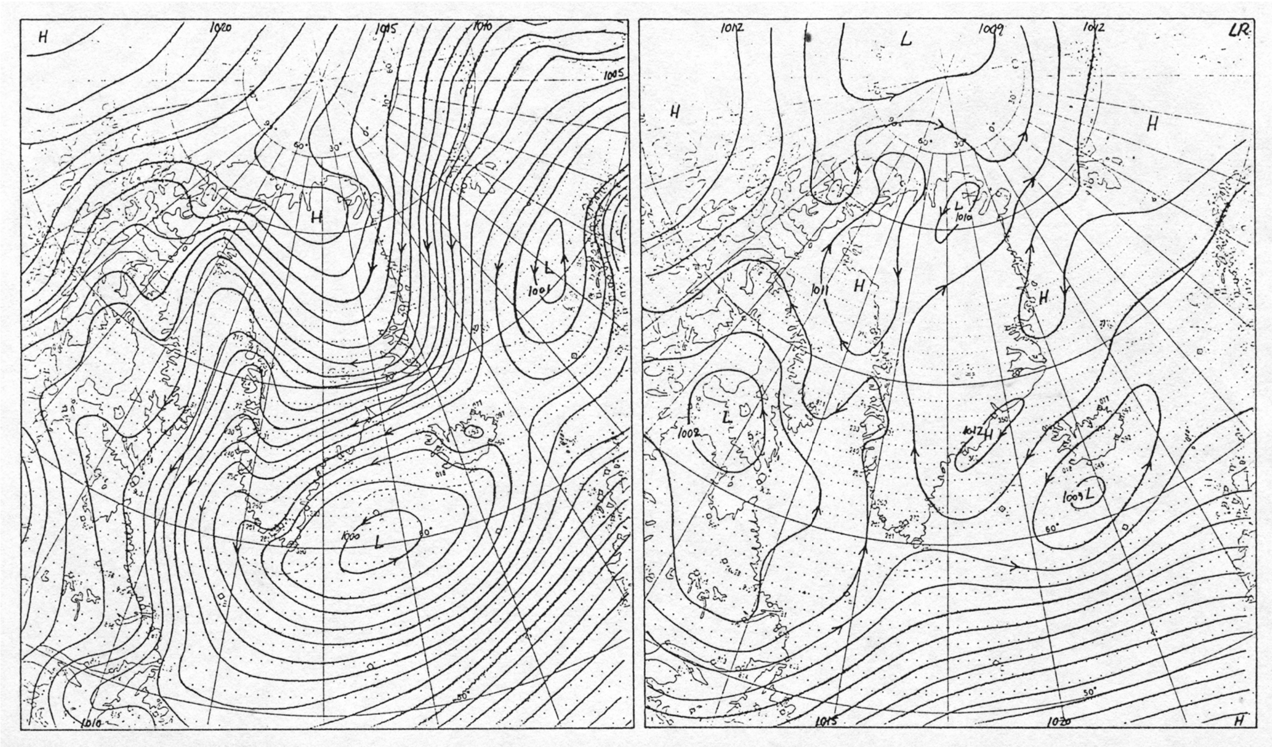


Fig. 10.4 – The air pressure at sea level in January and July. Isobar interval: 1 hPa.

10.5 Air pressure and low pressure tracks

The air pressure decreases with height. This happens most quickly where the atmosphere is coldest and therefore densest. Compared to Greenland, therefore, a weather chart for the 500 hPa surface (about 5 km height) will on average show a low pressure towards the NW (in winter) or N (in summer). This means that the high-elevation flow in the area is predominantly from SW or W, see Fig. 10.6, and since it is the high-elevation flow that controls the movement of the “surface weather” (the migratory low pressure and high pressure systems), Greenland gets most of its weather from Canada.

The chart of mean air pressure at sea level, Fig. 10.4, differs greatly from the height chart, especially in winter.

The cold air in the NW causes a high-pressure system in January, while there is low pressure at elevation. The low-pressure channel that extends from Newfoundland up towards Iceland and further to the sea N of Norway, describes the main track of the polar front low-pressure system that moves on the border between the warm and cold air, with the warm air to the right of the direction of movement. A secondary low-pressure track causes a pressure trough along the W coast of Greenland. Both sides of Greenland are dominated by winds from the N, a winter monsoon, if you will.

In July, the mean pressure differences around Greenland are quite small. The low-pressure systems are less developed than in winter. The preferred tracks extend from W to E, but are often further N than in winter. This makes the weather more volatile, especially in West Greenland.

The variation in pressure difference over the year between Station Nord and Ikerasassuaq (Prins Christian Sund) is illustrated in Fig. 10.5. It is a measure of the north wind’s dominance, which culminates from January-March and then rapidly declines with the sun's return and then completely disappears in July. It then increases evenly in line with the cooling of the atmosphere and the ocean.

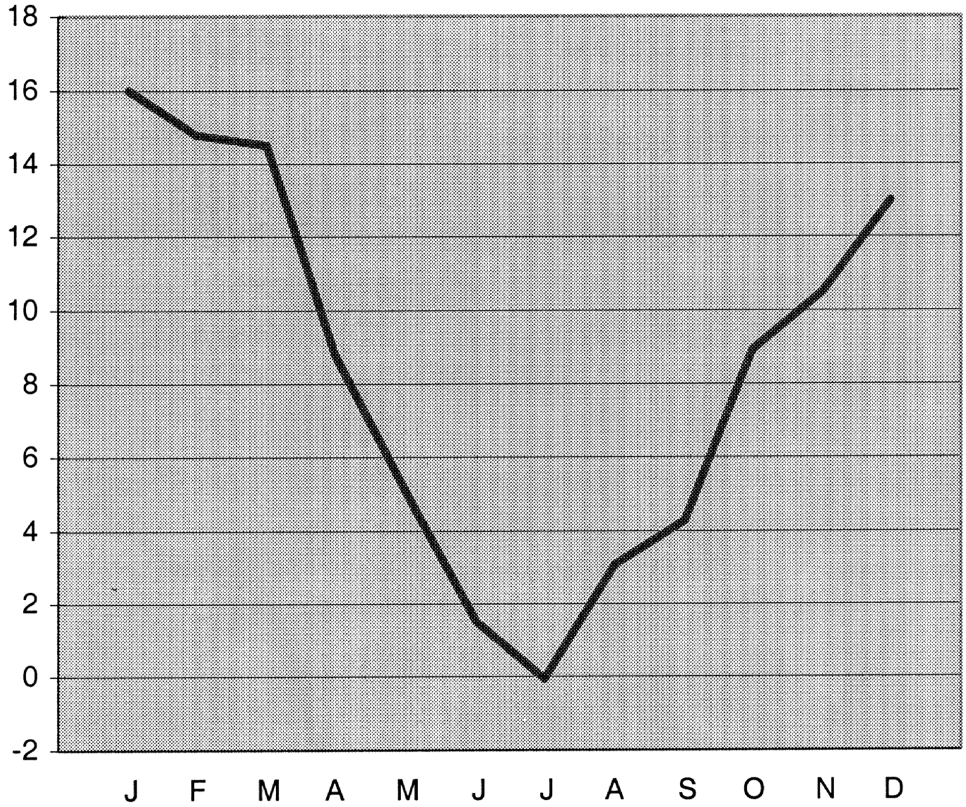


Fig 10.5 – Variation in pressure difference (hPa) over the year between Station Nord and Ikerasassuaq (Prins Christian Sund) (see the text).

10.6 Deviating low pressure tracks

Over shorter or longer periods (days, weeks), the circulation pattern on a large scale may differ significantly from the norm. The entire North Atlantic region may be affected. As an example, Fig. 10.6 compares the high-elevation flow in February 1984 and February 1986 with the normal field. In 1984, the polar high-elevation low-pressure system shifted to West Greenland and the polar front was displaced far to the S over the Atlantic Ocean. In 1986, a blocking high-pressure system appeared near Iceland, and a large part of Greenland was flooded with air from the S. The difference between the two February months was especially noticeable in Aasiaat (Egedesminde), Fig.10.7. Although deviations of this type may be very disturbing, the cause must be attributed to “chance”, and forecasts beyond the usual limit of 5-10 days do not seem to be possible.

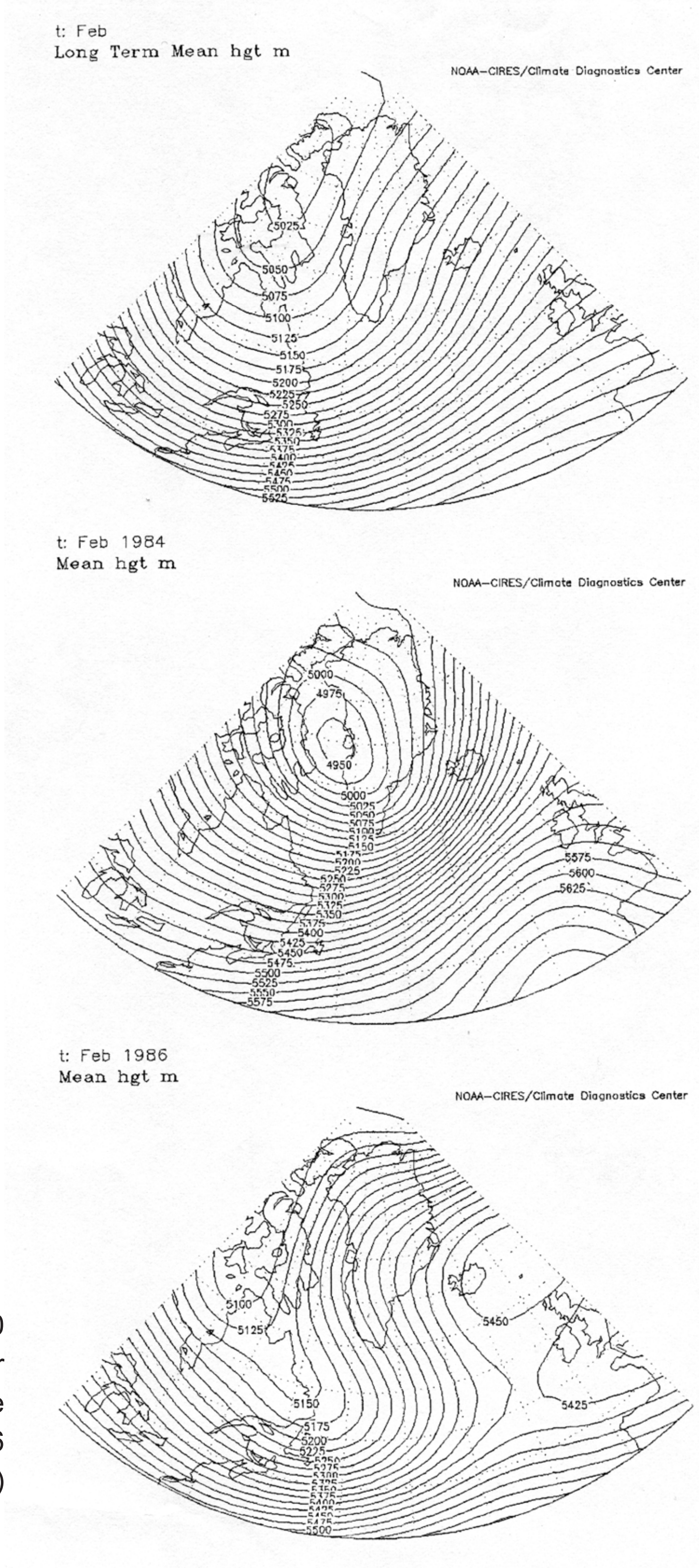


Fig. 10.6 – Height chart for the 500 hPa surface in February, on top for the period 1948-2002, in the middle for 1984 and underneath for 1986 (heights in metres)

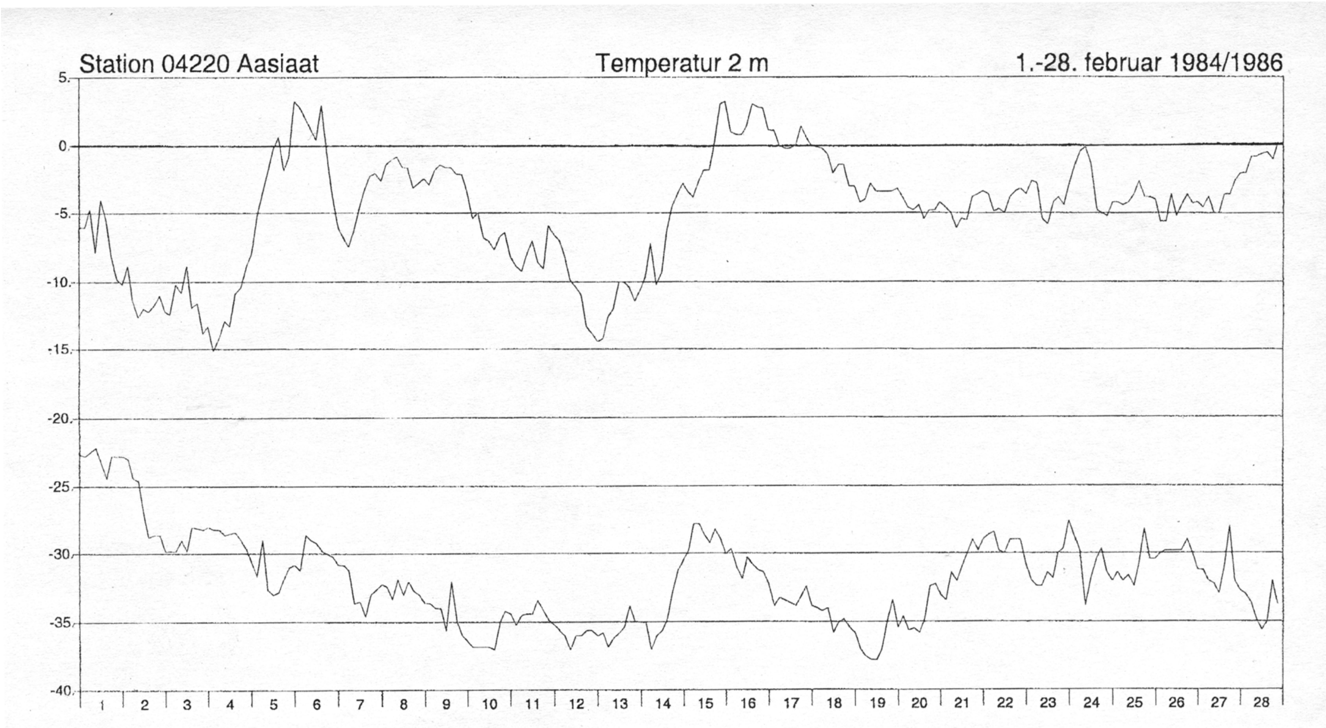


Fig. 10.7 – Temperature development in Aasiaat (Egedesminde), at the top for February 1986 and underneath for 1984.

10.7 Deformation of the pressure field

Where the wind blows against a steep coast like the coast of Greenland in conditions with stable stratification, it is deflected in the direction of the low pressure, whereby it is accel- er- ated. We are talking about a barrier wind. The accumulation of air causes an increase in pressure which has the effect of propagating itself further along the coast in the direction of lower pressure, A in Fig. 10.8.

Conversely, a pressure drop occurs where the wind blows away from the coast because the cold bottom layer is replaced by warmer and lighter air coming down from above. Also, the effect is transmitted along the coast, but towards higher pressures, B in Fig. 10.8.

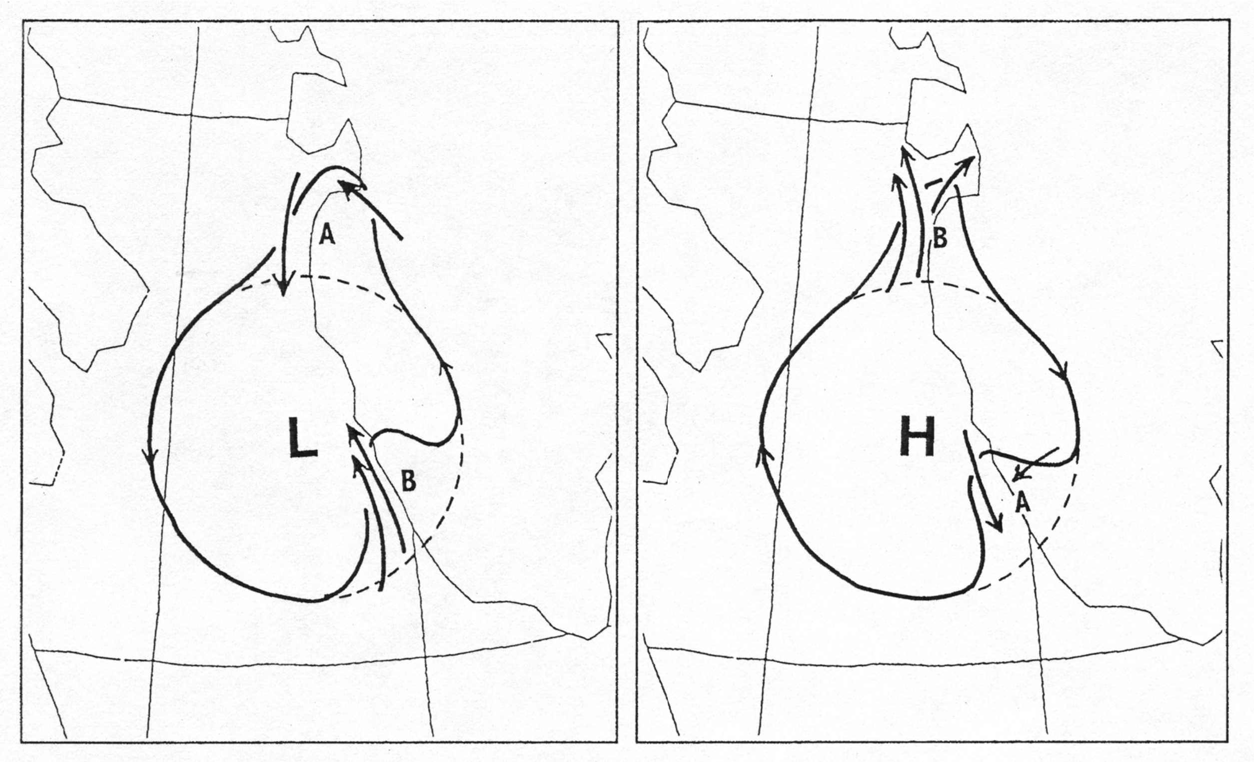


Fig. 10.8 – Deformation of the pressure field at a steep coast.

Fig. 10.9 illustrates how, when there is a low-pressure system passing over Greenland, a sub-low-pressure system develops according to the pattern described above. This situation is extremely common. On their way, the constricted low-pressure systems will cause rapid wind shifts and sometimes strong winds of shorter duration. The phenomenon occurs on a small scale and is often underestimated in the weather forecast. With decreasing stability, the effect is reduced and may even disappear completely when the air is unstable.

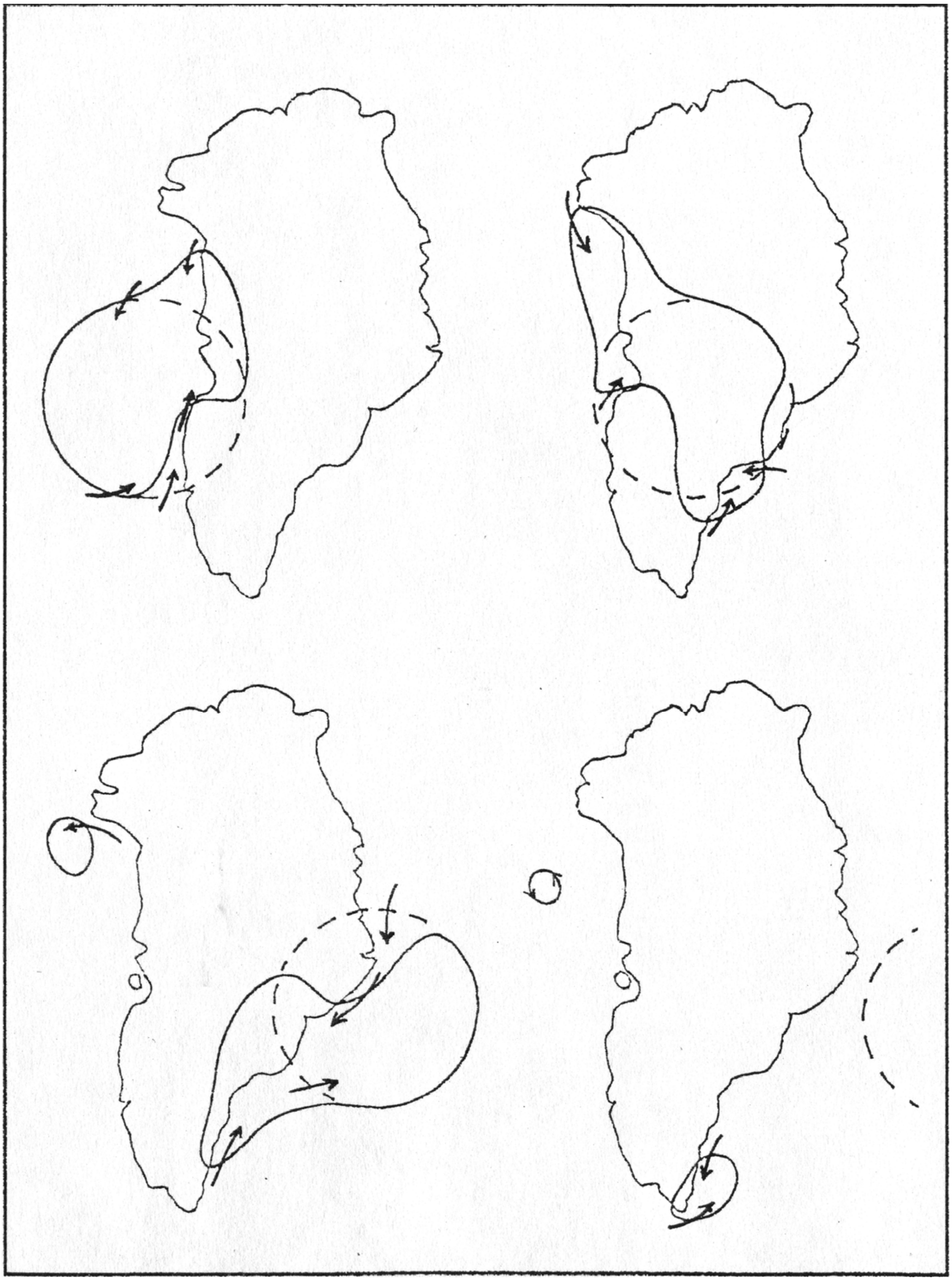


Fig. 10.9 – Schematic representation of the changes in the pressure field when a low-pressure system passes over Greenland.

10.8 Low pressure on small scale

The above-mentioned local small, low-pressure systems are classified as lee low-pressure. They often remain stationary at preferred positions on the east coast, for example just NE of Nunap Isua (Kap Farvel) or off Tasiilaq and on the W coast off Paamiut (Frederikshåb) (when the main low-pressure system is located south of Nunap Isua (Kap Farvel)) or in Qimusseriarsuaq (Melville Bugt) The polar low-pressure system is another type of low-pressure system on a smaller scale. They develop over ice-free ocean when the atmosphere is very cold, usually between Labrador and West Greenland and sometimes also off Greenland's E coast, but always quite a distance N of the polar front. A polar low usually has a diameter of 2-300 km and can be quite intense. It is accompanied by gales, sometimes storms and often by temperatures down to ÷10°C and heavy snowfall.
The life expectancy is around 24 hours, sometimes more, and at a certain stage of its development, the system can have a cloud structure similar to a tropical hurricane. This is not a coincidence. Like tropical hurricanes, polar low-pressure systems take their energy from heat and humidity that is supplied to the air mass from ocean surface that is significantly warmer than the air above it.

10.9 Wind conditions

Storms in the Greenland area are usually associated with the passing of low-pressure systems. Between these storms, uninterrupted periods of shorter or longer duration occur throughout the year, where local conditions determine the winds.

10.9.1 The land's own wind

One example is the ice cap's katabatic (downhill) wind system. In cloudless weather, the air near the ice surface cools markedly, and the cold and heavy air seeps down from the central part towards the peripheral regions, Fig. 10.10, slightly different from the fall line because of the Earth's rotation. The movement accelerates with the increasing slope of the surface and the topography can cause channelling, so that the speed at the edge of the ice can be great. The altitude change and the associated increase in pressure causes "adiabatic heating" (1°C per 100 metres). Whether the outflowing air reaches into the coastal fjords depends on its temperature relative to the air in the fjord. If it is warmer (lighter) than the fjord air, it will only be able to displace this locally, mainly at the furthest point inside the fjord, where it is experienced as a warm Foehn wind. If it is colder (heavier), it will easily penetrate out through the fjord as a cold down wind, and possibly out over the sea. The fjord's orientation is critical for whether this occurs. If it deviates from the wind direction, the fjord will remain undisturbed or will possibly be struck by a brief mountain gust, which may still be extremely violent.
The katabatic wind system is reinforced or countered by the general wind pattern. The most extreme example of an amplification of the wind occurs in the 60 km long and uninhabited east coast fjord Kangerlussuaq, where a low-pressure system east of Iceland often results in hurricane-like winds. From a protected branch of the fjord, it is possible to both hear and see the storm, the latter in the form of the driving snow or sea spray it raises. The further and more subdued progress out over the Danmark Strait can be detected using satellite imagery,

often out to a distance of more than 200 km from the coast. The weather station at Aputiteeq at about 67º48'N 032°16'W, is located just outside the "firing line" and is rarely affected. Usually, however, the "undisturbed weather" in the fjords is calm, albeit with sea breezes in summer and land breezes in the winter, and is driven by local temperature differences in the normal way. The pattern is so dominant that several places have what resembles a monsoon system (seasonal winds that are caused by uneven heating of land and sea). The wintry land winds tend to keep the many snow showers over the sea and away from the coast, while the summer sea wind, to varying degrees, brings the sea mist into the fjords.

10.9.2 Winds associated with migratory pressure systems

As mentioned above, strong winds associated particularly with the passing of low-pressure systems can reinforce or degrade winds that are dependent on local conditions, but they also have their own patterns, determined by topography, but are noticeably far out at sea. Fig. 10.11 shows the prevailing wind directions during storms. In the coastal zone, the nature of the wind depends on its direction relative to the coast. As previously discussed, if it blows towards the coast, it will be deflected to the left (clockwise in relation to the land) and has the character of barrier wind. Exceptions are the north wind west of Qaanaaq (Thule), which drains cold air from Issittup Imaa (Arktiske Hav) to the somewhat warmer Avannata Imaa (Baffin Bugt), and the west wind at Nunap Isua (Kap Farvel), which similarly drains air from colder to warmer surroundings.

The storms that blow off the land towards the sea are either warm Foehn winds (especially in West Greenland) or cold down winds (especially in East Greenland). They are strongly influenced by the terrain, as shown in Fig. 10.12. The frequency of strong winds is greatest at Nunap Isua (Kap Farvel), where winds of gale force or more (i.e. over 13.8 m/s) is over 30% in winter, but less than 5% in the summer.

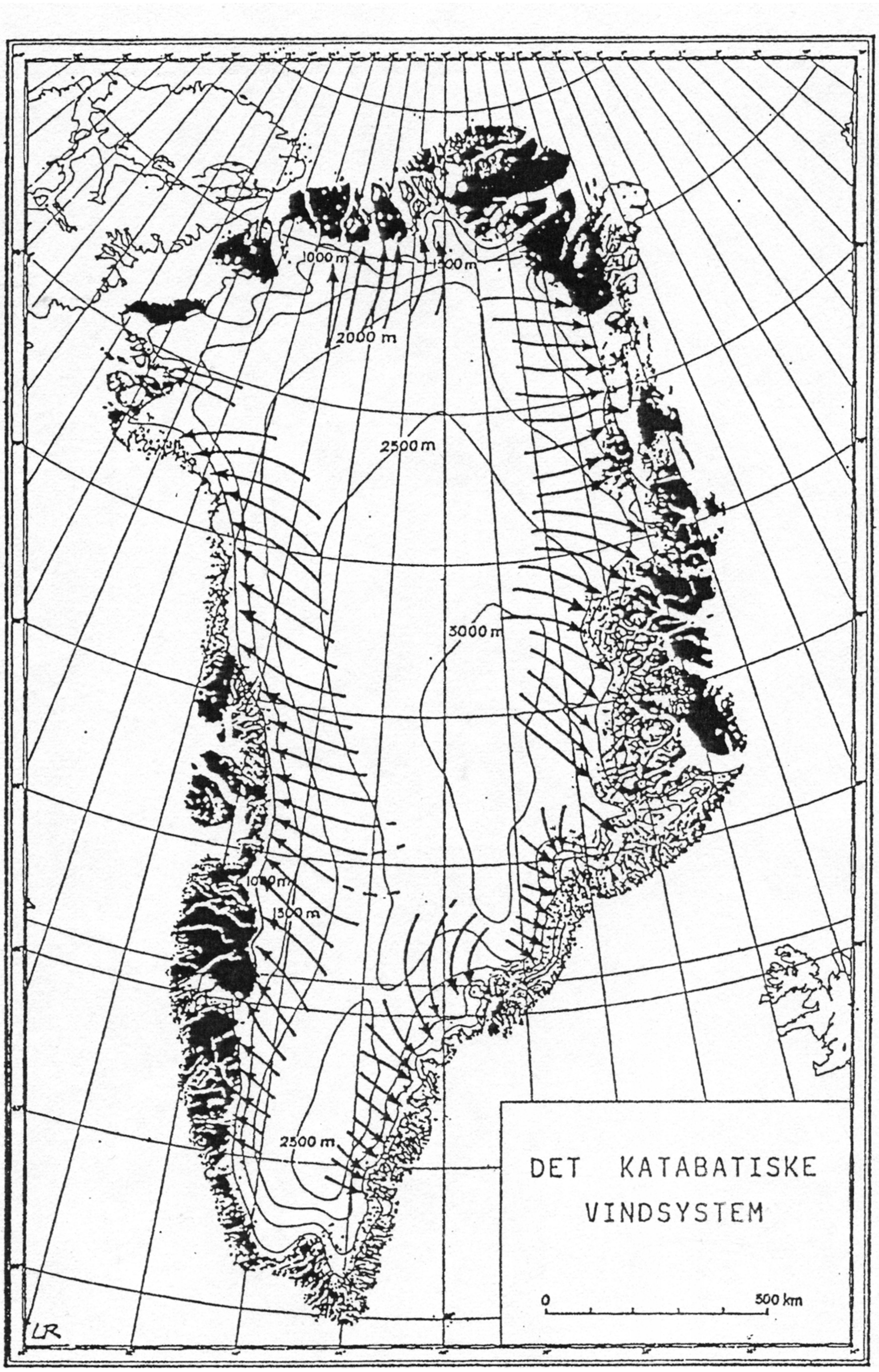


Fig. 10.10 – The ice cap's katabatic wind system, mapped based on the surface structure of the ice, as observed by satellite.

A distinctive feature of Greenland is that the transition from calm to storm can be very abrupt. In Greenlandic this is expressed by the word 'piteraq', which is especially used for strong down winds on the east coast. They typically occur when cold air of Canadian origin, at the back of a NE low-pressure system, reaches East Greenland via the ice cap. The topography of the ice channels the air-flow down towards parts of the coastal zone. The most exposed area is the wide sea bay S of Tasiilaq, see Fig. 10.12.
The boundary of a strong wind field may similarly be very marked, not only in fjords, but also out at sea. Fig. 10.13 shows some typical lee effects, seen in relation to the position of a low-pressure system. Knowledge of these effects can be useful when navigating through the areas in question.

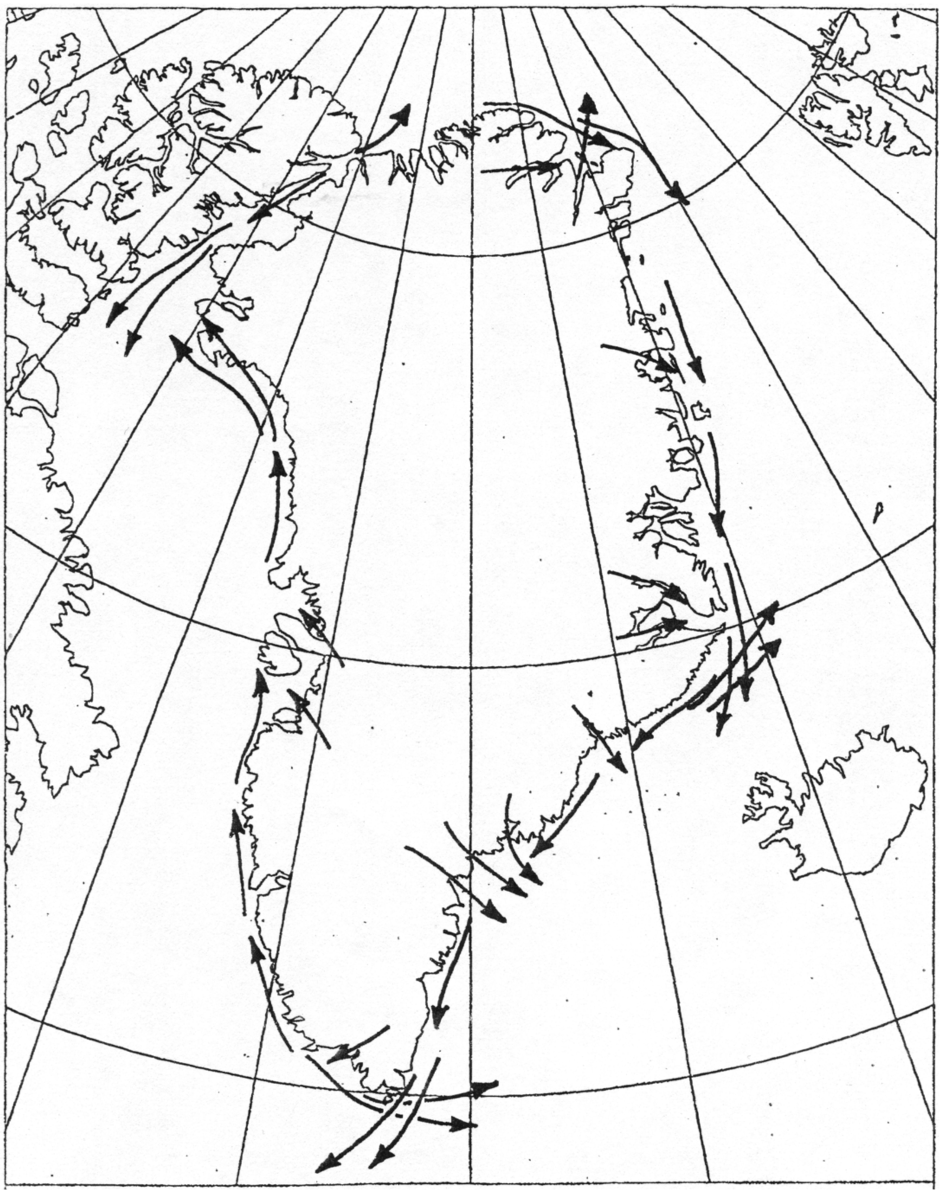


Fig. 10.11 – The prevailing wind directions in storms. The barrier winds parallel to the coast reach their maximum where the coast is protruding, while Foehn winds and fall winds especially occur where the coast is receding, ref. Fig. 10.12.

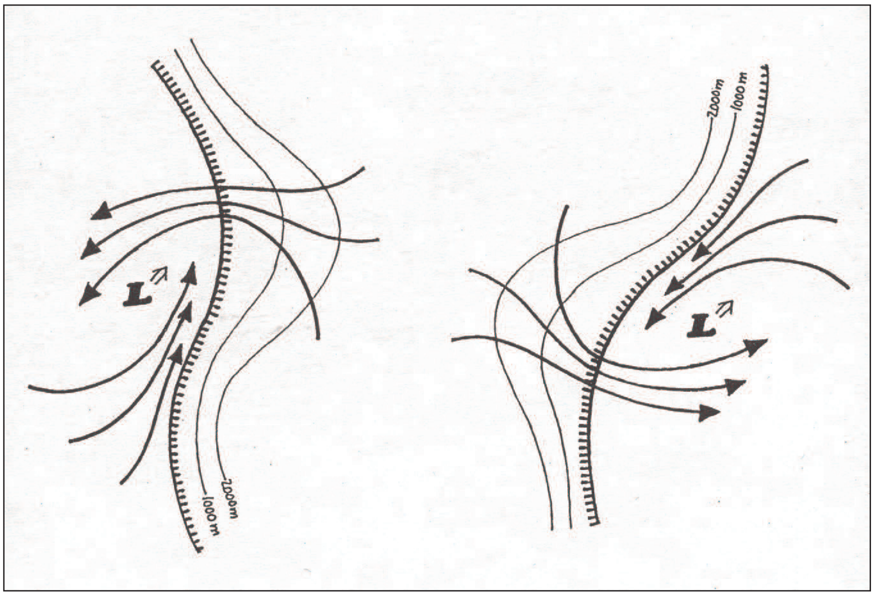


Fig. 10.12 – To illustrate “front side weather” and “rear side weather” (weather on front of or behind a cold weather front): Typical wind patterns around a low-pressure system moving N or NE off West and East Greenland, respectively. In West Greenland, the front side weather is characterized by Foehn winds with increasing temperature and mostly with good visibility, while the rear side weather entails barrier wind with precipitation and gradually colder weather. In East Greenland, we find the barrier wind and precipitation on the front side of low-pressure systems, while at the rear side there is Foehn winds or down winds with clearing conditions. The infamous “piteraq” in Tasiilaq is just such a rear side wind.

10.10 Icing

The conditions for icing of ships are often present in Greenland waters in winter. The essential reason is freezing sea spray. The extent of the icing therefore depends on the temperature of the sea and air and on wind speed. It also depends on the size of the ship and not least on the chosen course and the ship’s speed.

Icing warnings are issued routinely in DMI’s forecasts for the Greenland waters. You should be aware that the very diverse conditions within the individual districts makes a detailed description almost impossible.

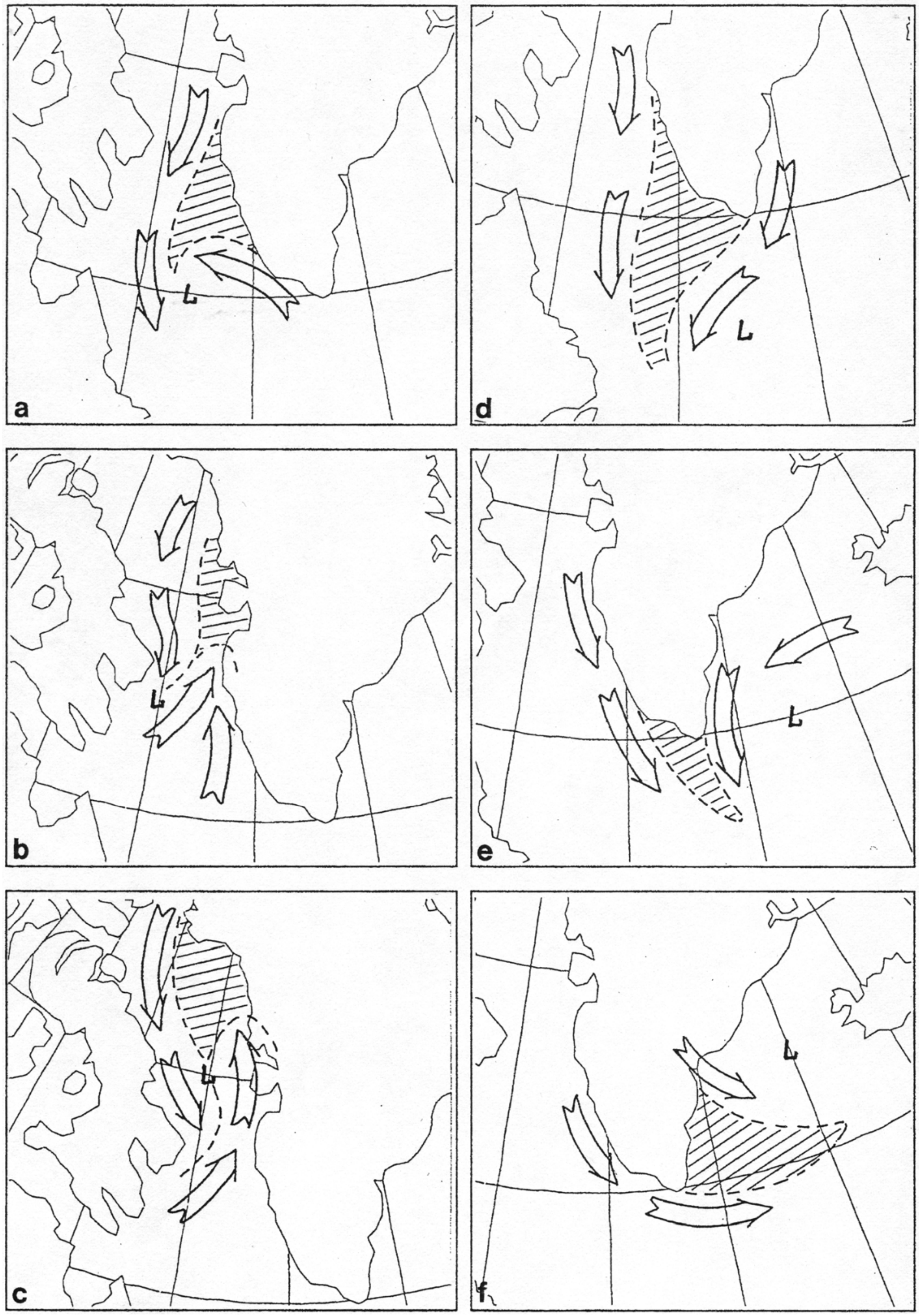


Fig. 10.13 – Examples of orographic influence on the wind field at sea in the context of a large low-pressure system. Arrows indicate a strengthening of the wind. Shading indicates a reduction in the wind.

Fig. 10.14 – Light frost smoke over Nuup Kangerlua (Godthåbsfjord).

WMO sea-ice nomenclature

1 Floating Ice
Any form of ice found floating in water. The principal kinds of floating ice are lake ice, river ice, and sea ice which form by the freezing of water at the surface, and glacier ice (ice of land origin) formed on land or in an ice shelf. The concept includes ice that is stranded or grounded.

1.1 Sea ice
Any form of ice found at sea which has originated from the freezing of sea water.

1.1.1 Fast ice, Cf. 3.1
Sea ice which forms and remains fast along the coast, where it is attached to the shore, to an ice wall, to an ice front, between shoals or groundedicebergs. Vertical fluctuations may be observed during changes of sea-level.Fast ice may be formed in situ from sea water or by freezing of floating ice of any age to the shore, and it may extend a few metres or several hundred kilometres from the coast. Fast ice may be more than one year old and may then be prefixed with the appropriate age category (old, second-year, or multi-year). If it is thicker than about 2 m above sea-level it is called an ice shelf.

1.1.2 Drift ice / pack ice
Term used in a wide sense to include any area of sea ice other than fast ice no matter what form it takes or how it is disposed. When concentrations are high, i.e. 7/10 or more, drift ice may be replaced by the term pack ice*.
*Note: Previously the term pack ice was used for all ranges of concentration.

1.2 Ice of land origin
Ice formed on land or in an ice shelf, found floating in water. The concept includes ice that is stranded or grounded.

1.3 Lake ice
Ice formed on a lake, regardless of observed location.

1.4 River ice
Ice formed on a river, regardless of observed location.

2 Development

2.1 New ice

A general term for recently formed ice which includes frazil ice, grease ice, slush and shuga. These types of ice are composed of ice crystals which are only weakly frozen together (if at all) and have a definite form only while they are afloat.

2.1.1 Frazil ice

Fine spicules or plates of ice, suspended in water.

2.1.2 Grease ice

A later stage of freezing than frazil ice when the crystals have coagulated to form a soupy layer on the surface. Grease ice reflects little light, giving the sea a matt appearance.

2.1.3 Slush

Snow which is saturated and mixed with water on land or ice surfaces, or as a viscous floating mass in water after a heavy snowfall.

2.1.4 Shuga

An accumulation of spongy white ice lumps, a few centimetres across; they are formed from grease ice or slush and sometimes from anchor ice rising to the surface.

2.2 Nilas

A thin elastic crust of ice, easily bending on waves and swell and under pressure, thrusting in a pattern of interlocking ‘fingers’ (finger rafting). Has a matt surface and is up to 10 cm in thickness. May be subdivided into dark nilas and light nilas.

2.2.1 Dark nilas

Nilas which is under 5 cm in thickness and is very dark in colour.

2.2.2 Light nilas

Nilas which is more than 5 cm in thickness and rather lighter in colour than dark nilas.

2.2.3 Ice rind

A brittle shiny crust of ice formed on a quiet surface by direct freezing or from grease ice, usually in water of low salinity. Thickness to about 5 cm. Easily broken by wind or swell, commonly breaking in rectangular pieces.

2.3 Pancake ice

Predominantly circular pieces of ice from 30 cm - 3 m in diameter, and up to about 10 cm in thickness, with raised rims due to the pieces striking against one another. It may be formed on a slight swell from grease ice, shuga or slush or as a result of the breaking of ice rind, nilas or, under severe conditions of swell or waves, of grey ice. It also sometimes forms at some depth at an interface between water bodies of different physical characteristics, from where it floats to the surface; its appearance may rapidly cover wide areas of water.

2.4 Young ice

Ice in the transition stage between nilas and first-year ice, 10-30 cm in thickness. May be subdivided into grey ice and grey-white ice.

2.4.1 Grey ice

Young ice 10-15 cm thick. Less elastic than nilas and breaks on swell. Usually rafts under pressure.

2.4.2 Grey-white ice

Young ice 15-30 cm thick. Under pressure more likely to ridge than to raft.

2.5 First-year ice

Sea ice of not more than one winter's growth, developing from young ice; thickness 30 cm - 2 m. May be subdivided into thin first-year ice/white ice, medium first-year ice and thick first-year ice.

2.5.1 Thin first-year ice / white ice

First-year ice 30-70 cm thick.

2.5.1.1 Thin first-year ice / white ice first stage

30-50 cm thick.

2.5.1.2 Thin first-year ice / white ice second stage

50-70 cm thick.

2.5.2 Medium first-year ice

First-year ice 70-120 cm thick.

2.5.3 Thick first-year ice

First-year ice over 120 cm thick.

2.6 Old ice

Sea ice which has survived at least one summer's melt; typical thickness up to 3 m or more. Most topographic features are smoother than on first-year ice. May be subdivided into second-year ice and multi-year ice.

2.6.1 Second-year ice

Old ice which has survived only one summer's melt; typical thickness up to 2.5 m and sometimes more. Because it is thicker than first-year ice, it stands higher out of the water. In contrast to multi-year ice, summer melting produces a regular pattern of numerous small puddles. Bare patches and puddles are usually greenish-blue.

2.6.2 Multi-year ice

Old ice up to 3 m or more thick which has survived at least two summers' melt. Hummocks even smoother than in second-year ice, and the ice is almost salt-free. Colour, where bare, is usually blue. Melt pattern consists of large interconnecting irregular puddles and a well-developed drainage system.

3 Forms of fast ice

3.1 Fast ice

Sea ice which forms and remains fast along the coast, where it is attached to the shore, to an ice wall, to an ice front, between shoals or grounded icebergs. Vertical fluctuations may be observed during changes of sea-level. Fast ice may be formed in situ from sea water or by freezing of floating ice of any age to the shore, and it may extend a few metres or several hundred kilometres from the coast. Fast ice may be more than one year old and may then be prefixed with the appropriate age category (old, second-year, or multi-year). If it is thicker than about 2 m above sea-level it is called an ice shelf.

3.1.1 Young coastal ice

The initial stage of fast ice formation consisting of nilas or young ice, its width varying from a few metres up to 100-200 m from the shoreline.

3.2 Icefoot

A narrow fringe of ice attached to the coast, unmoved by tides and remaining after the fast ice has moved away.

3.3 Anchor ice

Submerged ice attached or anchored to the bottom, irrespective of the nature of its formation.

3.4 Grounded ice

Floating ice which is aground in shoal water.

3.4.1 Stranded ice

Ice which has been floating and has been deposited on the shore by retreating high water.

3.4.2 Grounded hummock

Hummocked grounded ice formation. There are single grounded hummocks and lines (or chains) of grounded hummocks.

DMI displays images of the various types of sea ice on https://www.dmi.dk/hav-og-is/havis-leksikon/ (Danish language only).

4 Occurrence of floating ice

4.1 Ice cover
The ratio of an area of ice of any concentration to the total area of sea surface within some large geographic local; this local may be global, hemispheric, or prescribed by a specific oceanographic entity such as Baffin Bay or the Barents Sea.

4.2 Concentration
The ratio expressed in tenths* describing the amount of the sea surface covered by ice as a fraction of the whole area being considered. Total concentration includes all stages of development that are present, partial concentration may refer to the amount of a particular stage or of a particular form of ice and represents only a part of the total.
*Note: In historical sea-ice data octas have been used by some countries.

4.2.1 Compact ice
Floating ice in which the concentration is 10/10 and no water is visible.

4.2.1.1 Consolidated ice
Floating ice in which the concentration is 10/10 and the floes are frozen together.

4.2.2 Very close ice
Floating ice in which the concentration is 9/10 to less than 10/10.

4.2.3 Close ice
Floating ice in which the concentration is 7/10 to 8/10, composed of floes mostly in contact.

4.2.4 Open ice
Floating ice in which the ice concentration is 4/10 to 6/10, with many leads and polynyas, and the floes are generally not in contact with one another.

4.2.5 Very open ice
Floating ice in which the concentration is 1/10 to 3/10 and water preponderates over ice.

4.2.6 Open water
A large area of freely navigable water in which sea ice is present in concentrations less than 1/10. No ice of land origin is present.

4.2.7 Bergy water
An area of freely navigable water in which ice of land origin is present in concentrations less than 1/10. There may be sea ice present, although the total concentration of all ice shall not exceed 1/10.

4.2.8 Ice-free
No ice present. If ice of any kind is present this term should not be used.

4.3 Forms of floating ice

4.3.1 Pancake ice

Predominantly circular pieces of ice from 30 cm - 3 m in diameter, and up to about 10 cm in thickness, with raised rims due to the pieces striking against one another. It may be formed on a slight swell from grease ice, shuga or slush or as a result of the breaking of ice rind, nilas or, under severe conditions of swell or waves, of grey ice. It also sometimes forms at some depth at an interface between water bodies of different physical characteristics, from where it floats to the surface; its appearance may rapidly cover wide areas of water.

4.3.2 Floe

Any relatively flat piece of sea ice 20 m or more across. Floes are subdivided according to horizontal extent as follows:

4.3.2.1 Floe giant

Over 10 km across.

4.3.2.2 Floe vast

2-10 km across.

4.3.2.3 Floe big

500-2000 m across.

4.3.2.4 Floe medium

100-500 m across.

4.3.2.5 Floe small

20-100 m across.

4.3.3 Ice cake

Any relatively flat piece of sea ice less than 20 m across.

4.3.3.1 Small ice cake

An ice cake less than 2 m across.

4.3.4 Floeberg

A massive piece of sea ice composed of a hummock, or a group of hummocks frozen together, and separated from any ice surroundings. It may typically protrude up to 5 m above sea-level.

4.3.4.1 Floebit

A relatively small piece of sea ice, normally not more than 10 m across composed of (a) hummock(s) or part of (a) ridge(s) frozen together and separated from any surroundings. It typically protrudes up to 2 m above sea-level.

4.3.5 Ice breccia
Ice of different stages of development frozen together.

4.3.6 Brash ice
Accumulations of floating ice made up of fragments not more than 2 m across, the wreckage of other forms of ice.

4.3.7 Iceberg, Cf. 10.4.2
A massive piece of ice of greatly varying shape, protruding more than 5 m above sea-level, which has broken away from a glacier, and which may be afloat or aground. Icebergs may be described as tabular, dome-shaped, sloping, pinnacled, weathered or glacier bergs.

4.3.8 Glacier berg, Cf. 10.4.2.1
An irregularly shaped iceberg.

4.3.9 Tabular berg, Cf. 10.4.2.2
A flat-topped iceberg. Most tabular bergs form by calving from an ice shelf and show horizontal banding (cf. ice island).

4.3.10 Ice island, Cf. 10.4.3
A large piece of floating ice protruding about 5 m above sea-level, which has broken away from an Arctic ice shelf, having a thickness of 30-50 m and an area of from a few thousand sq.m to 500 km² or more, and usually characterized by a regularly undulating surface which gives it a ribbed appearance from the air.

4.3.11 Bergy bit, Cf. 10.4.4
A large piece of floating glacier ice, generally showing less than 5 m above sea-level but more than 1 m and normally about 100-300 m² in area.

4.3.12 Growler, Cf. 10.4.5
Piece of ice smaller than a bergy bit and floating less than 1 m above the sea surface, a growler generally appears white but sometimes transparent or blue-green in colour. Extending less than 1 m above the sea surface and normally occupying an area of about 20 m², growlers are difficult to distinguish when surrounded by sea ice or in high sea state.

4.4 Arrangement

4.4.1 Ice field
Area of floating ice consisting of any size of floes, which is greater than 10 km across (cf. patch).

4.4.1.1 Large ice field
An ice field over 20 km across.

4.4.1.2 Medium ice field
An ice field 15-20 km across.

4.4.1.3 Small ice field
An ice field 10-15 km across.

4.4.1.4 Ice patch
An area of floating ice less than 10 km across.

4.4.2 Ice massif
A variable accumulation of close or very close ice covering hundreds of square kilometers which is found in the same region every summer.

4.4.3 Belt
A large feature of drift ice arrangement; longer than it is wide; from 1 km to more than 100 km in width.

4.4.4 Tongue
A projection of the ice edge up to several kilometers in length, caused by wind or current.

4.4.5 Strip
Long narrow area of floating ice, about 1 km or less in width, usually composed of small fragments detached from the main mass of ice, and run together under the influence of wind, swell or current.

4.4.5.1 Ice isthmus
A narrow connection between two ice areas of very close or compact ice. It may be difficult to pass, whilst sometimes being part of a recommended route.

4.4.6 Bight
An extensive crescent-shaped indentation in the ice edge, formed by either wind or current.

4.4.7 Ice jam
An accumulation of broken river ice or sea ice not moving due to some physical restriction and resisting to pressure.

4.4.8 Ice edge
The demarcation at any given time between the open sea and sea ice of any kind, whether fast or drifting. It may be termed compacted or diffuse (cf. ice boundary).

4.4.8.1 Compacted ice edge
Close, clear-cut ice edge compacted by wind or current; usually on the windward side of an area of drift ice.

4.4.8.1.1 Jammed brash barrier

A strip or narrow belt of new, young or brash ice (usually 100-5000 m wide) formed at the edge of either drift or fast ice or at the shore. It is heavily compacted mostly due to wind action and may extend 2 to 20 m below the surface but does not normally have appreciable topography. Jammed brash barrier may disperse with changing winds but can also consolidate to form a strip of unusually thick ice in comparison with the surrounding drift ice.

4.4.8.2 Diffuse ice edge

Poorly defined ice edge limiting an area of dispersed ice; usually on the leeward side of an area of drift ice.

4.4.8.3 Ice limit

Climatological term referring to the extreme minimum or extreme maximum extent of the ice edge in any given month or period based on observations over a number of years. Term should be preceded by minimum or maximum (cf. mean ice edge).

4.4.8.4 Mean ice edge

Average position of the ice edge in any given month or period based on observations over a number of years. Other terms which may be used are mean maximum ice edge and mean minimum ice edge (cf. ice limit and median ice edge).

4.4.8.5 Median ice edge

Median (50% occurrence) position of the ice edge in any period based on a sufficient number of observations (cf. ice limit and mean ice edge)

4.4.8.6 Fast-ice edge

The demarcation at any given time between fast ice and open water.

4.4.9 Ice boundary

The demarcation at any given time between fast ice and drift ice or between areas of drift ice of different concentrations (cf. ice edge).

4.4.9.1 Fast ice boundary

The ice boundary at any given time between fast ice and drift ice.

4.4.9.2 Concentration boundary

A line approximating the transition between two areas of drift ice with distinctly different concentrations.

4.4.10 Iceberg tongue, Cf. 10.4.2.3

A major accumulation of icebergs projecting from the coast, held in place by grounding and joined together by fast ice.

5 Floating-ice motion processes

5.1 Diverging

Ice fields or floes in an area are subjected to diverging or dispersive motion, thus reducing ice concentration and/or relieving stresses in the ice.

5.2 Compacting

Pieces of floating ice are said to be compacting when they are subjected to a converging motion, which increases ice concentration and/or produces stresses which may result in ice deformation.

5.3 Shearing

An area of drift ice is subject to shear when the ice motion varies significantly in the direction normal to the motion, subjecting the ice to rotational forces. These forces may result in phenomena similar to a flaw (q.v.).

6 Deformation processes

6.1 Fracturing
Pressure process whereby ice is permanently deformed, and rupture occurs. Most commonly used to describe breaking across very close ice, compact ice and consolidated ice.

6.2 Hummocking
The pressure process by which sea ice is forced into hummocks. When the floes rotate in the process it is termed screwing.

6.3 Ridging
The pressure process by which sea ice is forced into ridges.

6.4 Rafting
Pressure processes whereby one piece of ice overrides another. Most common in new and young ice (cf. finger rafting).

6.4.1 Finger rafting
Type of rafting whereby interlocking thrusts are formed like "fingers" alternately over and under the other. This is commonly found in nilas and in grey ice. (It was noted that finger rafting in grey ice is common in Antarctica).

6.5 Shore ice ride-up
A process by which ice is pushed ashore as a slab.

6.6 Weathering
Processes of ablation and accumulation which gradually eliminate irregularities in an ice surface.

7 Openings in the ice

7.1 Fracture
Any break or rupture through very close ice, compact ice, consolidated ice, fast ice, or a single floe resulting from deformation processes. Fractures may contain brash ice and/or be covered with nilas and/or young ice. Length may vary from a few meters to many kilometers.

7.1.1 Crack
Any fracture of fast ice, consolidated ice or a single floe which may have been followed by separation ranging from a few centimeters to 1 m.

7.1.1.1 Tide crack
Crack at the line of junction between an immovable ice foot or ice wall and fast ice, the latter subject to rise and fall of the tide.

7.1.1.2 Flaw
A narrow separation zone between drift ice and fast ice, where the pieces of ice are in chaotic state; it forms when drift ice shears under the effect of a strong wind or current along the fast ice boundary (cf. shearing).

7.1.2 Very small fracture
1 to 50 m wide.

7.1.3 Small fracture
50 to 200 m wide.

7.1.4 Medium fracture
200 to 500 m wide.

7.1.5 Large fracture
More than 500 m wide.

7.2 Fracture zone
An area which has a great number of fractures.

7.3 Lead
Any fracture or passage-way through sea ice which is navigable by surface vessels.

7.3.1 Shore lead
A lead between drift ice and the shore or between drift ice and an ice front.

7.3.2 Flaw lead
A passage-way between drift ice and fast ice which is navigable by surface vessels.

7.4 Polynya

Any non-linear shaped opening enclosed in ice. Polynyas may contain brash ice and/or be covered with new ice, nilas or young ice.

7.4.1 Shore polynya

A polynya between drift ice and the coast or between drift ice and an ice front.

7.4.2 Flaw polynya

A polynya between drift ice and fast ice.

7.4.3 Recurring polynya

A polynya, which recurs in the same position every year.

8 Ice-surface features

8.1 Level ice
Sea ice which has not been affected by deformation.

8.2 Deformed ice
A general term for ice which has been squeezed together and in places forced upwards (and downwards). Subdivisions are rafted ice, ridged ice and hummocked ice.

8.2.1 Rafted ice
Type of deformed ice formed by one piece of ice overriding another (cf. finger rafting).

8.2.1.1 Finger rafted ice
Type of rafted ice in which floes thrust ‘fingers’ alternately over and under the other.

8.2.2 Ridge
A line or wall of broken ice forced up by pressure. May be fresh or weathered. The submerged volume of broken ice under a ridge, forced downwards by pressure, is termed an ice keel.

8.2.2.1 New ridge
Ridge newly formed with sharp peaks and slope of sides usually 40°. Fragments are visible from the air at low altitude.

8.2.2.2 Weathered ridge
Ridge with peaks slightly rounded and slope of sides usually 30° to 40°. Individual fragments are not discernible.

8.2.2.3 Very weathered ridge
Ridge with tops very rounded, slope of sides usually 20-30°.

8.2.2.4 Aged ridge
Ridge which has undergone considerable weathering. These ridges are best described as undulations.

8.2.2.5 Consolidated ridge
A ridge in which the base has frozen together.

8.2.2.6 Ridged ice
Ice piled haphazardly one piece over another in the form of ridges or walls. Usually found in first-year ice (cf. ridging).

8.2.2.6.1 Ridged ice zone
An area in which much ridged ice with similar characteristics has formed.

8.2.2.7 Shear ridge
An ice ridge formation which develops when one ice feature is grinding past another. This type of ridge is more linear than those caused by pressure alone.

8.2.2.7.1 Shear ridge field
Many shear ridges side by side.

8.2.3 Hummock
A hillock of broken ice which has been forced upwards by pressure. May be fresh or weathered. The submerged volume of broken ice under the hummock, forced downwards by pressure, is termed a bummock.

8.2.3.1 Hummocked ice
Sea ice piled haphazardly one piece over another to form an uneven surface. When weathered, has the appearance of smooth hillocks.

8.2.3.2 Rubble field
An area of extremely deformed sea ice of unusual thickness formed during the winter by the motion of drift ice against, or around a protruding rock, islet or other obstruction.

8.3 Standing floe
A separate floe standing vertically or inclined and enclosed by rather smooth ice.

8.4 Ram
An underwater ice projection from an ice wall, ice front, iceberg or floe. Its formation is usually due to a more intensive melting and erosion of the unsubmerged part.

8.5 Bare ice
Ice without snow cover.

8.6 Snow-covered ice
Ice covered with snow.

8.6.1 Sastrugi
Sharp, irregular ridges formed on a snow surface by wind erosion and deposition. On drift ice the ridges are parallel to the direction of the prevailing wind at the time they were formed.

8.6.2 Snowdrift
An accumulation of wind-blown snow deposited in the lee of obstructions or heaped by wind eddies. A crescent-shaped snowdrift, with ends pointing down-wind, is known as a snow barchan.

9 Stages of melting

9.1 Puddle

An accumulation on ice of melt-water, mainly due to melting snow, but in the more advanced stages also to the melting of ice. Initial stage consists of patches of melted snow.

9.2 Thaw holes

Vertical holes in sea ice formed when surface puddles melt through to the underlying water.

9.3 Dried ice

Sea ice from the surface of which melt-water has disappeared after the formation of cracks and thaw holes. During the period of drying, the surface whitens.

9.4 Rotten ice

Sea ice which has become honeycombed and which is in an advanced state of disintegration.

9.5 Flooded ice

Sea ice which has been flooded by melt-water or river water and is heavily loaded by water and wet snow.

9.6 Shore melt

Open water between the shore and the fast ice, formed by melting and/or as a result of river discharge.

10 Ice of land origin

10.1 Firn
Old snow which has recrystallized into a dense material. Unlike ordinary snow, the particles are to some extent joined together; but, unlike ice, the air spaces in it still connect with each other.

10.2 Glacier ice
Ice in, or originating from, a glacier, whether on land or floating on the sea as icebergs, bergy bits or growlers.

10.2.1 Glacier
A mass of snow and ice continuously moving from higher to lower ground or, if afloat, continuously spreading. The principal forms of glacier are: inland ice sheets, ice shelves, ice streams, ice caps, ice piedmonts, cirque glaciers and various types of mountain (valley) glaciers.

10.2.2 Ice wall
An ice cliff forming the seaward margin of a glacier which is not afloat. An ice wall is aground, the rock basement being at or below sea-level (cf. ice front).

10.2.3 Ice stream
Part of an inland ice sheet in which the ice flows more rapidly and not necessarily in the same direction as the surrounding ice. The margins are sometimes clearly marked by a change in direction of the surface slope but may be indistinct.

10.2.4 Glacier tongue
Projecting seaward extension of a glacier, usually afloat. In the Antarctic, glacier tongues may extend over many tens of kilometres.

10.3 Ice shelf
A floating ice sheet of considerable thickness showing 2-50 m or more above sea-level, attached to the coast. Usually of great horizontal extent and with a level or gently undulating surface. Nourished by annual snow accumulation and often also by the seaward extension of land glaciers. Limited areas may be aground. The seaward edge is termed an ice front.

10.3.1 Ice front
The vertical cliff forming the seaward face of an ice shelf or other floating glacier varying in height from 2-50 m or more above sea-level (cf. ice wall).

10.4 Calved ice of land origin

10.4.1 Calving

The breaking away of a mass of ice from an ice wall, ice front or iceberg.

10.4.2 Iceberg

A massive piece of ice of greatly varying shape, protruding more than 5 m above sea-level, which has broken away from a glacier, and which may be afloat or aground. Icebergs may be described as tabular, dome-shaped, sloping, pinnacled, weathered or glacier bergs.

10.4.2.1 Glacier berg

An irregularly shaped iceberg.

10.4.2.2 Tabular berg

A flat-topped iceberg. Most tabular bergs form by calving from an ice shelf and show horizontal banding (cf. ice island).

10.4.2.3 Iceberg tongue

A major accumulation of icebergs projecting from the coast, held in place by grounding and joined together by fast ice.

10.4.3 Ice island

A large piece of floating ice protruding about 5 m above sea-level, which has broken away from an Arctic ice shelf, having a thickness of 30-50 m and an area of from a few thousand sq.m to 500 km² or more, and usually characterized by a regularly undulating surface which gives it a ribbed appearance from the air.

10.4.4 Bergy bit

A large piece of floating glacier ice, generally showing less than 5 m above sea-level but more than 1 m and normally about 100-300 m² in area.

10.4.5 Growler

Piece of ice smaller than a bergy bit and floating less than 1 m above the sea surface, a growler generally appears white but sometimes transparent or blue-green in colour. Extending less than 1 m above the sea surface and normally occupying an area of about 20 m², growlers are difficult to distinguish when surrounded by sea ice or in high sea state.

11 Sky and air indications

11.1 Water sky
Dark streaks on the underside of low clouds, indicating the presence of water features in the vicinity of sea ice.

11.2 Ice blink
A whitish glare on low clouds above an accumulation of distant ice.

11.3 Frost smoke
Fog-like clouds due to contact of cold air with relatively warm water, which can appear over openings in the ice, or leeward of the ice edge, and which may persist while ice is forming.

12 Terms relating to surface shipping

12.1 Beset
Situation of a vessel surrounded by ice and unable to move.

12.2 Ice-bound
A harbour, inlet, etc. is said to be ice-bound when navigation by ships is prevented on account of ice, except possibly with the assistance of an icebreaker.

12.3 Nip
Ice is said to nip when it forcibly presses against a ship. A vessel so caught, though undamaged, is said to have been nipped.

12.4 Ice under pressure
Ice in which deformation processes are actively occurring and hence a potential impediment or danger to shipping.

12.5 Difficult area
A general qualitative expression to indicate, in a relative manner, that the severity of ice conditions prevailing in an area is such that navigation in it is difficult.

12.6 Easy area
A general qualitative expression to indicate in a relative manner, that ice conditions prevailing in an area are such that navigation in it is not difficult.

12.7 Area of weakness
A satellite-observed area in which either the ice concentration or the ice thickness is significantly less than that in the surrounding areas. Because the condition is satellite observed, a precise quantitative analysis is not always possible, but navigation conditions are significantly easier than in surrounding areas.

12.8 Ice port
An embayment in an ice front, often of a temporary nature, where ships can moor alongside and unload directly onto the ice shelf.

13 Terms relating to submarine navigation

13.1 Ice canopy

Drift ice from the point of view of the submariner.

13.2 Friendly ice

From the point of view of the submariner, an ice canopy containing many large skylights or other features which permit a submarine to surface. There must be more than ten such features per 30 nautical miles (56 km) along the submarine's track.

13.3 Hostile ice

From the point of view of the submariner, an ice canopy containing no large skylights or other features which permit a submarine to surface.

13.4 Bummock

From the point of view of the submariner, a downward projection from the underside of the ice canopy; the counterpart of a hummock.

13.5 Ice keel

From the point of view of the submariner, a downward-projecting ridge on the underside of the ice canopy; the counterpart of a ridge. Ice keels may extend as much as 50 m below sea-level.

13.6 Skylight

From the point of view of the submariner, thin places in the ice canopy, usually less than 1 m thick and appearing from below as relatively light, translucent patches in dark surroundings. The undersurface of a skylight is normally flat. Skylights are called large if big enough for a submarine to attempt to surface through them (120 m), or small if not.

14 National Danish and Greenlandic concepts

14.1 Blue Ice*)

14.1 Crystal clear, rounded pieces of glacier ice, which may be difficult to detect, since they are located deep in the water and has a dark blue appearance.

14.2 Black ice*)

1) Thin, apparently dark sea ice (new ice) without snow.
2) Crystal clear glacier ice (bergy bit), located deep in the water, and as seen from above has a dark appearance. Also known as blue ice.
3) Soil mixed bergy bit.

14.3 Polar Ice, Storis*), Sikorsuit (Greenlandic)

Expressions used on the ice, which passes along the coast of East Greenland, around Nunap Isua (Cape Farewell) to West Greenland.

14.4 West Ice*)

Expression for the NE Amrerican drift ice in Baffin Bay.

14.5 First-year (Winter Ice*)

Fast ice no more than one winter's growth. Thickness from 15 cm to 2 m. Moderate to severe winter ice: 15- 30 cm.

14.6 Ice Fjord*)

Fjord with a glacier that discharges substantial quantities of ice.

14.7 Sikkussat*) (Greenlandic)

"Deck" of ice, surrounded by ice and has become fast ice.

Wind force

Beaufort Wind Scale

Beau-fort	Descriptive Term	Mean Wind Speed Equivalent		Deep Sea Criterion	Likely mean wave height (m) *)
		Knots	m/s		
0	Calm	<1	0-0,2	Sea is like a mirror	0
1	Light air	1-3	0,3-1,5	Ripples with the appearance of scales are formed, but without foam crests	0,1 (0,1)
2	Light breeze	4-6	1,6-3,3	Small wavelets, still short but more pronounced. Crests have glassy appearance and do not break	0,2 (0,4)
3	Gentle breeze	7-10	3,4-5,4	Large wavelets. Crests begin to break. Foam of glassy appearance. Perhaps scattered whitecaps	0,6 (1,0)
4	Moderate breeze	11-16	5,5-7,9	Small waves, becoming longer. Fairly frequent whitecaps	1,0 (1,5)
5	Fresh breeze	17-21	8,0-10,7	Moderate waves, taking a more pronounced long form. Many whitec aps are formed. Chance of some spray	2,0 (2,5)
6	Strong breeze	22-27	10,8-13,8	Large waves begin to form. The white foam crests are more extensive everywhere. Probably some spray	3,0 (4,0)
7	Near gale	28-33	13,9-17,1	Sea heaps up and white foam from breaking waves begins to be blown in streaks along the direction of the wind	4,0 (5,5)
8	Gale	34-40	17,2-20,7	Moderately high waves of greater length. Edges of crests begin to break into the spindrift. The foam is blown in well-marked streaks along the direction of the wind	5,5 (7,5)
9	Strong gale	41-47	20,8-24,4	High waves. Dense streaks of foam along the direction of the wind. Crests of waves begin to topple, tumble and roll over. Spray may affect visibility	7,0 (10,0)
10	Storm	48-55	24,5-28,4	Very high waves with long overhanging crests. Dense white streaks of foam. Surface of the sea takes a white appearance. The tumbling of the sea becomes heavy and shock-like. Visibility affected	9,0 (12,5)
11	Violent storm	56-63	28,5-32,6	Exceptionally high waves. Sea completely covered with long white patches of foam. Visibility affected	11,5 (16,0)
12	Hurricane	>64	>32,7	Air filled with foam and spray. Sea entirely white with foam. Visibility seriously impaired	>14

*** The figures in this column are only intended as a rough guide to indicate what might be expected in the open sea, remote from land. Those in brackets indicate the likely maximum heights. In enclosed waters, or when close to land, with an offshore wind, wave heights will be smaller and the waves steeper.**

Distances in Greenland

Distances within Greenland

Qaanaaq (Thule)																							
98	Pituffik (Thule Air Base)																						
444	330	Upernavik																					
544	486	175	Uummannaq																				
662	565	255	180	Ilulissat (Jakobshavn)																			
687	588	275	210	36	Qasigiannguit (Christianshåb)																		
634	540	248	180	52	49	Qeqertarsuaq (Godhavn)																	
669	574	275	205	49	39	37	Aasiaat (Egedesminde)																
759	668	365	310	194	184	152	145	Sisimiut (Holsteinsborg)															
884	805	490	435	319	309	277	270	150	Kangerlussuup Umiarsualivia														
865	767	460	405	304	294	252	245	125	145	Maniitsoq (Sukkertoppen)													
945	855	545	485	394	384	351	340	205	225	100	Nuuk (Godthåb)												
948	872	570	504	386	376	358	337	220	250	120	34	Orsiivik (Polaroil)											
1086	991	682	610	527	517	485	474	335	365	235	175	130	Paamiut (Frederikshåb)										
1157	1066	745	685	580	587	555	539	400	428	310	235	207	90	Kangilinnguit (Grønnedal)									
1250	1145	850	790	692	682	650	640	478	498	400	330	286	175	125	Qaqortoq (Julianehåb)								
1255	1152	860	805	715	705	673	656	507	527	419	342	293	185	135	25	Narsaq							
1285	1177	888	833	745	735	690	684	535	565	447	370	318	213	163	53	28	Narsarsuaq						
1302	1177	915	860	687	668	652	641	487	507	409	353	379	185	145	70	110	138	Nanortalik					
1387	1303	1032	977	834	824	792	785	646	665	567	490	444	335	290	209	224	252	140	Ikerasassuaq (Prins Chr. Sund)				
1544	1471	1190	1135	1042	1032	996	989	850	870	753	651	612	496	451	380	385	413	323	190	Timmiarmiut			
1767	1674	1413	1358	1258	1253	1223	1208	1073	1089	976	874	817	719	653	605	598	626	548	386	235	Tasiilaq		
1929	1865	1575	1520	1420	1415	1385	1370	1235	1250	1138	1036	1006	881	842	755	775	805	698	540	330	293	Aputiteeq	
2194	2138	1840	1788	1685	1680	1650	1635	1500	1516	1403	1301	1279	1146	1101	1020	1040	1068	963	805	620	625	293	Ittoqqortoormiit (Scoresbysund)

Distances between Greenland and Europe / America

Distances between Greenland and Europe / America

	St. John's, Canada	Strait of Gibraltar	Skagen	Fair Isle	Tórshavn	Reykjavík	Pentland Firth	Nanortalik	Qaqortoq (Julianehåb)	Kangilinnguit (Grønnedal)	Paamiut (Frederikshåb)	Orsiivik (Polaroil)	Nuuk (Godthåb)	Maniitsoq (Sukkertoppen)	Kangerlussuup Umiarsualivia	Sisimiut (Holsteinsborg)	Aasiaat (Egedesminde)	Qeqertarsuaq (Godhavn)	Qasigiannguit (Christianshåb)	Ilulissat (Jakobshavn)	Uummannaq	Upernavik	Pituffik (Thule Air Base)	Tasiilaq
St. John's, Canada																								
Strait of Gibraltar	2182																							
Skagen																								
Fair Isle			415																					
Tórshavn			624	207																				
Reykjavík	1416	1905	815	400	516																			
Pentland Firth	1855	1598	450	845	220	687																		
Nanortalik	821	2138	1757	1352	1210	737	1291																	
Qaqortoq (Julianehåb)	827		1825	1410	1268	892		145																
Kangilinnguit (Grønnedal)	849	2304	1915	1500	1343	980	1440	235	125															
Paamiut (Frederikshåb)			1965	1550	1391	955		285	175	90														
Orsiivik (Polaroil)	969	2444	2054	1649	1507	1043	1597	379	286	207	130													
Nuuk (Godthåb)	1005	2477	2145	1730	1537	1076	1630	465	330	235	175	34												
Maniitsoq (Sukkertoppen)	1075	2547	2215	1800	1612	1146	1700	535	410	310	240	120	105											
Kangerlussuup Umiarsualivia	1198	2676		1885	1743	1274	1828	507	498	428	365	250	225	145										
Sisimiut (Holsteinsborg)	1172	2649	2310	1895	1712	1248	1802	630	495	405	335	220	205	125	150									
Aasiaat (Egedesminde)	1294	2772	2445	2030	1831	1371	1925	765	640	545	475	337	345	250	270	145								
Qeqertarsuaq (Godhavn)			2460	2045	1851	1483		780	650	555	485	358	355	270	277	170	37							
Qasigiannguit (Christianshåb)	1333	2679	2485	2070	1869	1278	1963	805	685	585	515	376	385	295	309	205	39	56						
Ilulissat (Jakobshavn)	1341	2819	2490	2075	1879	1418	1972	810	690	590	520	386	390	300	319	210	48	52	36					
Uummannaq			2600	2185	1997	1562		920	800	695	620	504	495	415	435	315	210	185	210	185				
Upernavik	1532	3011	2655	2240	2063	1610	2164	980	860	760	690	570	560	475	490	375	275	250	280	255	175			
Pituffik (Thule Air Base)	1800	3299	2912	2508	2365	1898		1238	1145	1066	991	923	855	767	805	668	574	540	588	565	486	330		
Tasiilaq			1550	135	910	490		475	620	710	760	817	940	1010	1089	1105	1240	1255	1280	1285	1395	1455	1674	
Ittoqqortoormiit (Scoresbysund)			1215	845	635	450		985	1130	1220	1270	1279	1450	1520	1516	1615	1750	1765	1790	1795	1905	1965	2138	625

Kangilinnguit (Grønnedal) - Colon, Panama 3536 M, - New York, USA 1933 M, - Murmansk 2395 M
Paamiut (Frederikshåb) - New York, USA 1959 M,
Qaqortoq (Julianehåb) - Montreal, Canada (via Strait of Belle Isle) 1470 M, - New York, USA 1911 M
Nunap Isua (Kap Farvel) - Jan Mayen 1100 M, - Longyearbyen, Svalbard 1630 M, - Hammerfest 1798 M, - Bergen 1520 M
Ittoqqortoormiit (Scoresbysund) - Jan Mayen 271 M, - Longyearbyen, Svalbard 768 M

Conversion between seconds and decimal minutes

″	,0	,1	,2	,3	,4	,5	,6	,7	,8	,9
0	0,000	0,002	0,003	0,005	0,007	0,008	0,010	0,012	0,013	0,015
1	0,017	0,018	0,020	0,022	0,023	0,025	0,027	0,028	0,030	0,032
2	0,033	0,035	0,037	0,038	0,040	0,042	0,043	0,045	0,047	0,048
3	0,050	0,052	0,053	0,055	0,057	0,058	0,060	0,062	0,063	0,065
4	0,067	0,068	0,070	0,072	0,073	0,075	0,077	0,078	0,080	0,082
5	0,083	0,085	0,087	0,088	0,090	0,092	0,093	0,095	0,097	0,098
6	0,100	0,102	0,103	0,105	0,107	0,108	0,110	0,112	0,113	0,115
7	0,117	0,118	0,120	0,122	0,123	0,125	0,127	0,128	0,130	0,132
8	0,133	0,135	0,137	0,138	0,140	0,142	0,143	0,145	0,147	0,148
9	0,150	0,152	0,153	0,155	0,157	0,158	0,160	0,162	0,163	0,165
10	0,167	0,168	0,170	0,172	0,173	0,175	0,177	0,178	0,180	0,182
11	0,183	0,185	0,187	0,188	0,190	0,192	0,193	0,195	0,197	0,198
12	0,200	0,202	0,203	0,205	0,207	0,208	0,210	0,212	0,213	0,215
13	0,217	0,218	0,220	0,222	0,223	0,225	0,227	0,228	0,230	0,232
14	0,233	0,235	0,237	0,238	0,240	0,242	0,243	0,245	0,247	0,248
15	0,250	0,252	0,253	0,255	0,257	0,258	0,260	0,262	0,263	0,265
16	0,267	0,268	0,270	0,272	0,273	0,275	0,277	0,278	0,280	0,282
17	0,283	0,285	0,287	0,288	0,290	0,292	0,293	0,295	0,297	0,298
18	0,300	0,302	0,303	0,305	0,307	0,308	0,310	0,312	0,313	0,315
19	0,317	0,318	0,320	0,322	0,323	0,325	0,327	0,328	0,330	0,332
20	0,333	0,335	0,337	0,338	0,340	0,342	0,343	0,345	0,347	0,348
21	0,350	0,352	0,353	0,355	0,357	0,358	0,360	0,362	0,363	0,365
22	0,367	0,368	0,370	0,372	0,373	0,375	0,377	0,378	0,380	0,382
23	0,383	0,385	0,387	0,388	0,390	0,392	0,393	0,395	0,397	0,398
24	0,400	0,402	0,403	0,405	0,407	0,408	0,410	0,412	0,413	0,415
25	0,417	0,418	0,420	0,422	0,423	0,425	0,427	0,428	0,430	0,432
26	0,433	0,435	0,437	0,438	0,440	0,442	0,443	0,445	0,447	0,448
27	0,450	0,452	0,453	0,455	0,457	0,458	0,460	0,462	0,463	0,465
28	0,467	0,468	0,470	0,472	0,473	0,475	0,477	0,478	0,480	0,482
29	0,483	0,485	0,487	0,488	0,490	0,492	0,493	0,495	0,497	0,498
30	0,500	0,502	0,503	0,505	0,507	0,508	0,510	0,512	0,513	0,515
31	0,517	0,518	0,520	0,522	0,523	0,525	0,527	0,528	0,530	0,532
32	0,533	0,535	0,537	0,538	0,540	0,542	0,543	0,545	0,547	0,548
33	0,550	0,552	0,553	0,555	0,557	0,558	0,560	0,562	0,563	0,565
34	0,567	0,568	0,570	0,572	0,573	0,575	0,577	0,578	0,580	0,582
35	0,583	0,585	0,587	0,588	0,590	0,592	0,593	0,595	0,597	0,598
36	0,600	0,602	0,603	0,605	0,607	0,608	0,610	0,612	0,613	0,615
37	0,617	0,618	0,620	0,622	0,623	0,625	0,627	0,628	0,630	0,632
38	0,633	0,635	0,637	0,638	0,640	0,642	0,643	0,645	0,647	0,648
39	0,650	0,652	0,653	0,655	0,657	0,658	0,660	0,662	0,663	0,665
40	0,667	0,668	0,670	0,672	0,673	0,675	0,677	0,678	0,680	0,682
41	0,683	0,685	0,687	0,688	0,690	0,692	0,693	0,695	0,697	0,698
42	0,700	0,702	0,703	0,705	0,707	0,708	0,710	0,712	0,713	0,715
43	0,717	0,718	0,720	0,722	0,723	0,725	0,727	0,728	0,730	0,732
44	0,733	0,735	0,737	0,738	0,740	0,742	0,743	0,745	0,747	0,748
45	0,750	0,752	0,753	0,755	0,757	0,758	0,760	0,762	0,763	0,765
46	0,767	0,768	0,770	0,772	0,773	0,775	0,777	0,778	0,780	0,782
47	0,783	0,785	0,787	0,788	0,790	0,792	0,793	0,795	0,797	0,798
48	0,800	0,802	0,803	0,805	0,807	0,808	0,810	0,812	0,813	0,815
49	0,817	0,818	0,820	0,822	0,823	0,825	0,827	0,828	0,830	0,832
50	0,833	0,835	0,837	0,838	0,840	0,842	0,843	0,845	0,847	0,848
51	0,850	0,852	0,853	0,855	0,857	0,858	0,860	0,862	0,863	0,865
52	0,867	0,868	0,870	0,872	0,873	0,875	0,877	0,878	0,880	0,882
53	0,883	0,885	0,887	0,888	0,890	0,892	0,893	0,895	0,897	0,898
54	0,900	0,902	0,903	0,905	0,907	0,908	0,910	0,912	0,913	0,915
55	0,917	0,918	0,920	0,922	0,923	0,925	0,927	0,928	0,930	0,932
56	0,933	0,935	0,937	0,938	0,940	0,942	0,943	0,945	0,947	0,948
57	0,950	0,952	0,953	0,955	0,957	0,958	0,960	0,962	0,963	0,965
58	0,967	0,968	0,970	0,972	0,973	0,975	0,977	0,978	0,980	0,982
59	0,983	0,985	0,987	0,988	0,990	0,992	0,993	0,995	0,997	0,998

INTERNATIONAL MARITIME ORGANIZATION

IMO

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SUB-COMMITTEE ON SAFETY OF NAVIGATION
55th session
Agenda item 20

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ANY OTHER BUSINESS

Precautions in using navigational charts in Greenland waters

Submitted by Denmark

SUMMARY

Executive summary:	This document provides information regarding precautions in use of navigational charts in Greenland waters in terms of inaccuracies in paper charts due to incorrect positioning of the coastline, geographical datum and hydrographic survey. Further, this document informs of precautions regarding the use of electronic navigation in Greenland coastal waters.
Strategic direction:	5.2
High-level action:	5.2.4
Planned output:	-
Action to be taken:	Paragraph 35
Related documents:	MSC 86/3; SN.1/Circ.276, SN.1/Circ.255, SN/Circ.213, SN.1/Circ.207/Rev.1 and MSC/Circ.1056

Introduction

1 At its eighty-sixth session, the Maritime Safety Committee is expected to adopt a carriage requirement for an Electronic Chart Display and Information System (ECDIS) for SOLAS vessels with an implementation period from 2012 to 2018. In this context, Denmark has found it essential to provide guidance on navigation in Greenland waters in the light of the still limited coverage of Electronic Navigational Charts (ENC) in these waters in 2012 and ahead.

2 Greenland covers a large Arctic area (2,127,600 km^2) and is navigationally considered a remote area. The distances between the settlements in Greenland are large, and the consequences of an accident may be greater in Greenland compared to more densely navigated waters, where search and rescue facilities are seldom far away. In addition to this, an accident could have a serious impact on the vulnerable Arctic environment.

3 Navigation in Greenland waters differs significantly from navigation in other (non-Arctic) waters. In general, it is difficult for mariners who are not familiar with the conditions to navigate around Greenland. It is, to a high degree, due to the climate and the influence of the weather. Furthermore, instruments such as magnetic compasses may be unusable and gyrocompasses may be unreliable.

4 In waters with more frequent maritime traffic, markings and other navigational systems have normally been established to assist mariners. Due to the remote Arctic location and the historically low density of maritime traffic, the assistance offered to mariners in the form of charts within the scope of relevant IHO standards and other facilities has not reached the same level in Greenland. Furthermore, floating markings are not an option due to ice conditions and great depths.

5 In addition, systematic and completely covering hydrographic surveys have not been carried out in many areas along the coasts of Greenland due to the wide extent of the sea area and the Greenland archipelago. In other words, depth conditions will be unknown or depth data will be of poor quality in large areas. For mariners it is essential to understand the limitations in the source material providing the basis for the production of paper charts and, consequently, the information given in the paper charts must be interpreted with caution.

6 Modern navigation is based on Global Navigational Satellite Systems (GNSS) as, e.g., GPS. The continuous marking of the ship's position on an ENC in the ECDIS system is made by means of GNSS. Positions obtained from satellite navigation systems refer to World Geodetic System 1984 (WGS 84) datum.

7 The use of ECDIS in Greenland waters requires the availability of ENCs which refer to WGS 84 datum and are produced with a correct positioning of topography, including coastline, and hydrography in the geographic net. At present, ENCs are not available for Greenland coastal navigation, except for a very few exceptions.

8 In Greenland coastal waters, the inaccuracies in the present paper charts could endanger safety of navigation if the navigator relies on satellite based electronic navigation instead of the use of terrestrial navigation.

Navigation in Greenland waters in terms of inaccuracies in paper charts

9 At present, the paper charts available for Greenland waters are not compatible with GNSS navigation, as, e.g., GPS, for several reasons.

10 <u>Incorrect positioning of topography and hydrography in the geographic net.</u> A major difficulty with the paper charts available for Greenland waters is the incorrect positioning of the coastline in the geographic net in the charts. At the northern and eastern coastlines where the uncertainty is most distinct, the coastline may be positioned several nautical miles incorrect. In other parts of Greenland, the uncertainty may be less, but still at a substantive level when comparing with the accurate position achievable from a GNSS receiver. In general, charts of the northern and eastern Greenland coastlines are misplaced by 0-5,000 metres, and in some areas of the extreme northeast Greenland even more. Charts of the west Greenland coastlines are misplaced by 0-1,000 metres.

11 Due to this fact a note has been inserted in the paper charts covering the Greenland west coast, stating, e.g., *Due to age, quality and some of the source material, it must be expected that positions obtained from satellite navigation system are more accurate than those on this chart*.

12 In the paper charts covering the Greenland east coast, the following note is found: *The difference between satellite-derived positions and positions on this chart cannot be determined; mariners are warned that these differences MAY BE SIGNIFICANT TO NAVIGATION and are therefore advised to use alternative sources of positional information, particularly when closing the shore or navigating in the vicinity of dangers.*

13 Conclusion: In the paper charts available for Greenland waters, the positioning of the information in the charts (i.e. topography, including coastline, and hydrography, etc.) is inaccurate, which means that ships cannot navigate safely by means of satellite navigation on the basis of the present paper charts.

14 It is important to emphasize that, despite the inaccuracies of the paper charts; it is possible for ships to navigate in coastal areas if they use their radar equipment as the primary positioning instrument and rely on terrestrial navigation methods when navigating in Greenland waters.

15 Chart datum. The paper charts available for west Greenland waters are produced in the geographical datum "Qornoq 1927". On each paper chart a note has been inserted giving the correction to be used if positions are obtained from a satellite navigation system, such as GPS, which refers to WGS 84 datum. This could state, e.g., *Positions obtained from satellite navigation systems refer to WGS 84 datum; they should be moved 0.08' northward and 0.25 westward to agree with the chart*.

16 For paper charts covering northern and eastern Greenland waters, the source material for chart datum may be unknown.

17 It is important to notice that the correction may vary from one chart to another and the correction is only to be used if the GNSS receiver has not been pre-selected to the "Qornoq 1927" datum.

18 The use of the geodetic datum "Qornoq 1927" instead of the WGS 84 may have the following effect for Automatic Identification System (AIS) which relays the ship's position signal from a GNSS receiver. It can get this information in two ways: From an external or a built-in receiver. AIS with an internal receiver transmits the ship's position in WGS 84 coordinates. AIS with an external receiver can transmit the ship's position in WGS 84 or in Qornoq 1927. This can give rise to misunderstandings and misinterpretations when AIS is used for anti-collision purposes.

19 Conclusion: GNSS should be used only as a secondary positioning instrument, and if used as such, mariners must be aware of the necessary correction between the reference chart datum in the paper charts and the information received from GNSS.

20 Hydrographic survey. IHO Special Publication No. 55 Third Edition (2004) on status of hydrographic surveying and nautical charting worldwide, latest update of 8 May 2009, states the following for Greenland: "*The coastline of Greenland is very complex and the total sea area of the EEZ is ca. 2,000,000 square kilometres. Due to permanent ice cover, the limit for navigable waters has been set to 75 degrees northern latitude. The east coast is sparsely populated and only surveyed near populated areas. A prioritised programme is in force to resurvey navigable routes to and between populated areas on the west coast of Greenland, to modern standards*".

21 The lack of survey data or its poor quality is reflected in the charts by, e.g., waters where depths are given only by passages of reconnaissance lines or even as white unsurveyed areas in the chart. Attention is also drawn to the fact that source diagrams are lacking in many of the paper charts available for Greenland waters. The basic lack of IHO compatible survey data for

chart production should make ships keep an additional safety distance when passing underwater rocks and obstructions.

22 Unfortunately, it will be many years before all areas have been surveyed or re-surveyed and all paper charts revised accordingly. Until then, mariners should remain cautious to the dangers mentioned in this document.

Caution to be taken before navigating in Greenland coastal waters

23 In summary, at present caution must be taken in consideration that:

- official ENCs are not available for coastal navigation;
- only paper charts are available for coastal navigation, but these are not compatible with GNSS navigation;
- paper charts have incorrect positioning of coastlines in the geographic net;
- chart datum "Qornoq 1927" is used for some areas, mostly at west Greenland, instead of WGS 84 datum;
- for other areas, mostly north and east Greenland, the source material for chart datum may be unknown and the accuracy may be affected by the age and quality; and
- hydrographic surveys may be sporadic and areas may be considered as unexplored. In some areas, depths are only given by sounding tracks from passages of a reconnaissance nature.

24 Since official ENCs are not available for coastal navigation, voyages conducted primarily by means of GNSS navigation should not be chosen as a solution at present.

25 Furthermore, it must be noted that digital raster navigational charts (RNC-charts) used in an approved ECDIS or an Electronic Chart System (ECS) are not considered an acceptable method for safe navigation. In the case of Greenland waters, raster charts will have been produced by means of digitalization of paper charts and will, consequently, have inherited the topographic and hydrographic inaccuracies of paper charts.

26 Even if a position obtained from a GNSS receiver is corrected to the datum of the paper chart, where available, the navigator cannot trust the inserted GNSS-position in the paper chart due to the inaccurate positioning of the coastline in the geographic net.

27 It is important to be aware that terrestrial navigation, including the use of radar navigation, gyro, log, echo sounder and visual input, is the best method for conducting safe navigation when satellite navigation becomes uncertain. Paper charts and nautical publications become primary sources when planning and conducting a safe voyage. Terrestrial navigation will be relative to the surrounding coastline when using radar and visual observation methods.

Present status and future developments of nautical charts for Greenland waters

28 Guidance to mariners on navigation in Greenland is generally given by publishing official nautical charts, nautical publications and Notices to Mariners.

29 The nautical charts available for Greenland waters include paper charts, port plans and, in very few cases, electronic navigation charts (ENC). Today, Greenland waters are covered by 94 paper charts of various scales, while only 4 ENCs have been produced by early 2009. ENC coverage is, consequently, a long-term process, which has only just begun.

30 In 2006, the Danish Hydrographic Office launched a project with the purpose of producing improved paper charts in terms of the geometric precision of the paper charts (i.e. topography, including coastline, and hydrography, etc.). In addition to this improvement, the paper charts will also be transformed into WGS 84 datum. In the improved paper charts, the coastline will be provided with a degree of precision that makes the use of satellite navigation sound and secure.

31 It is expected that ENCs corresponding to the improved paper charts will be produced and published as an ongoing process ahead. Among the ENCs published, ENCs in usage band overview (corresponding to scale 1:3500000 for sea passage) are expected to be published before 2012. Navigational and hydrographic information will be much simplified or completely left out in areas close to land. Consequently, it will only be possible to use these ENCs in usage band overview for navigation in open waters.

32 Conclusion: At present ENCs are not available for Greenland coastal navigation, except for a very few exceptions. It is expected that the ENC coverage will be continuously improved, but complete ENC coverage in coastal areas cannot be expected in 2012. In coastal areas, ships will therefore as a general rule have to use paper charts for navigation.

Recommendations on charts, ECDIS and voyage planning

33 Before planning a voyage to Greenland, the following IMO guidelines and resolutions should be consulted further in addition to the ordinary use of paper charts and nautical information:

- SN.1/Circ.207/Rev.1 on Differences between RCDS and ECDIS;
- SN/Circ.213 on Guidance on chart datums and the accuracy of positions on charts;
- SN.1/Circ.255 on Additional guidance on chart datums and the accuracy of positions on charts;
- SN.1/Circ.276 on Transitioning from paper chart to ECDIS navigation;
- Resolution A.893(21) on Guidelines for voyage planning;
- Resolution A.999(25) on Guidelines on voyage planning for passenger ships operating in remote areas; and
- MSC/Circ.1056 on Guidelines for ships operating in Arctic ice-covered waters.

These guidelines and resolutions and other IMO guidance material can be downloaded from the IMO website, www.imo.org.

Planned Safety of Navigation (SN) circular

34 Denmark will, before the implementation date of the new carriage requirement for ECDIS, forward a Safety of Navigation circular to the Organization providing the latest information on chart availability and quality for Greenland waters.

Action requested of the Sub-Committee

35 The Sub-Committee is invited to note the information provided.

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Ref. T2/2.07

SN/Circ.213
31 May 2000

GUIDANCE ON CHART DATUMS AND THE ACCURACY OF POSITIONS ON CHARTS

1 The Maritime Safety Committee, at its seventy-second session (17 to 26 May 2000), approved guidance on chart datums and the accuracy of positions on charts, given at annex.

2 Member Governments are invited to bring this guidance to the attention of all concerned for information and action, as appropriate.

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ANNEX

GUIDANCE ON CHART DATUMS AND THE ACCURACY OF POSITIONS ON CHARTS

1 Many different definitions of a horizontal datum (also known as geodetic datum) exist. However, a practical working definition in use is:

> "A horizontal datum is a reference system for specifying positions on the Earth's surface. Each datum is associated with a particular reference spheroid that can be different in size, orientation and relative position from the spheroids associated with other horizontal datums. Positions referred to different datums can differ by several hundred metres."

2 The practical result is that a given geographical position, not associated with a specific datum, could refer to different physical objects. In other words, a physical object can have as many geographical positions as there are datums. For example, South Foreland Lighthouse, United Kingdom, has the following positions:

GEOGRAPHICAL POSITION	HORIZONTAL DATUM
51°08′.39 N 001°22′.37 E	referred to OSGB(36) Datum (the local datum for the United Kingdom)
51°08′.47 N 001°22′.35 E	referred to European (1950) Datum (the continental datum)
51°08′.42 N 001°22′.27 E	referred to World Geodetic System 1984 (WGS84) Datum (the world-wide datum used by Global Positioning System (GPS))

3 Most charts are not yet referred to WGS84 Datum. This means that, in those cases, positions obtained from satellite navigation receivers will not be directly compatible with the chart and **must** not be used without adjustment. Hydrographic offices are attempting to refer as many new charts as possible to WGS84, but there remain many areas of the world where information does not exist to enable the transformation to be performed.

4 When known, the horizontal datum of the chart is usually named in the chart title albeit, on its own, this information is of limited benefit to the mariner. Since 1982 many hydrographic offices have been adding "Satellite-Derived Positions" notes (usually situated close to the title) when charts have been revised. This note provides a latitude and longitude adjustment to be applied to positions obtained directly from satellite navigation systems (such as GPS) to make them compatible with the horizontal datum of the chart.

5 The following provides a worked example:

Satellite-Derived Position (WGS-84 Datum)	64º22′.00 N	021º30′.00 W
latitude/longitude adjustments	0′.07 S	0′.24 E
Adjusted position (compatible with chart datum)	64º21′.93 N	021º29′.76 W

In this example, the shift equates to approximately 230 metres which can be plotted at scales larger than 1:1,000,000.

6 Where known, these adjustments are an average value for the whole area covered by the chart and are quoted to 2 decimal places of a minute in both latitude and longitude, so that the maximum uncertainty is about 10 metres in both latitude and longitude (0.005' and 0.014' will both be rounded to 0.01'). This uncertainty can be plotted at scales larger than 1:30,000 (where it is represented by 0.3 mm on the chart).

7 Inevitably, cases exist where overlapping charts show different latitude or longitude shift values. For example, one chart might show 0.06' and its neighbour 0.07'; for each individual chart the value will be an average, but in the area common to both charts the value will range from 0.064' to 0.066'.

8 In the cases where an adjustment cannot be determined because of the lack of knowledge about the relationship between WGS84 Datum and the datum of the chart, the hydrographic office may add a note to that effect warning that adjustments "may be significant to navigation". The largest difference between satellite navigation derived and charted position reported so far is 7 miles in the Pacific Ocean, but even larger undiscovered differences may exist. Where charts do not contain any note about position adjustment it **must** not be assumed that no adjustment is required.

9 Most manufacturers of GPS receivers are now incorporating datum transformations into their software which enable users to (apparently) receive positions referred to datums other than WGS84 Datum. Unfortunately, many cases exist where a single transformation will not be accurate for a large regional datum. For example, the relationship between WGS84 Datum and European Datum (1950) is very different between the north and south of the region, despite the datum name being the same. Therefore, the position transformed to European Datum (1950) in the receiver by means of a Europe -wide average may differ from the WGS84 Datum position output by the receiver, amended to European Datum (1950) by the shift note on an individual chart. In the light of the 100 metre accuracy of the Standard Positioning Service of GPS this may not be significant, but it is an additional source of error and is of major significance if differential GPS (DGPS) is being used for navigation.

10 It must not be assumed that all charts in a region are referred to the regional datum. For example, although most metric charts of mainland European waters are referred to European Datum (1950), many charts are also referred to local datums. Additionally, as there are no international standards defining the conversion parameters between different horizontal datums; the parameters used by the GPS devices may be different. The hydrographic offices use the best adopted parameters, so mariners are advised to keep their GPS receiver referred to WGS84 Datum and apply the datum adjustment note from the chart.

11 Apart from the differences in positions between different horizontal datums, two other aspects affect charted positional accuracy. These aspects are:

- the accuracy to which features are surveyed (paragraphs 12 to 16; and
- the accuracy with which they are compiled on to a chart (paragraphs 17 to 21).

Surveying

12 Hydrographic surveys are generally conducted using the best position-fixing technology available at the time. This was limited to accurate visual fixing until the Second World War, but used terrestrial based electronic position fixing (such as Decca, Hifix, Hyperfix and Trisponder) until the 1980s. DGPS is the current standard for most hydrographic surveys.

13 Generally, position fixing for surveying was more accurate than that for navigation in the first two categories, but DGPS is being made more widely available for use by all mariners with the appropriate equipment. The result is that current navigation with DGPS is, commonly, more accurate than position-fixing used for surveys conducted before 1980. The consequence is that, although a modern vessel may know its position to an accuracy of better than 10 metres, the positions of objects on the seabed may only be known to an accuracy of 20 metres or much worse, depending on the age of the latest survey and/or its distance from the coast.

14 Furthermore it is only since the 1970s that surveying systems have had the computer processing capacity to enable the observations to be analysed to enable an estimate of the accuracy of position fixing to be generated. The result is that, although the current accuracy standard of position fixing surveys can be stated (see paragraph 15 below), it is impossible to provide anything other than general estimates for older surveys.

15 The current accuracy standard for positioning is 13 metres for most surveys with the standard of ±5 metres (both 95% of the time) for certain special purpose surveys. It can be confidently stated that the former value is often significantly improved upon. Further improvements will undoubtedly be made as a result of technological developments, but at present there has to be a balance between the cost of a survey and the quality and quantity of the results achieved.

16 In summary, although the positions of maritime objects derived from modern surveys will be accurate to better than 10 metres, this cannot be used as a general statement about all such objects.

Chart compilation

17 Most paper charts and their derived digital versions are assembled from a variety of sources such as maps, surveys, photogrammetric plots etc. The intention is to provide the mariner with the best available information for all parts of that chart and the usual procedure is to start with the most accurate sources, but it is often impossible to complete the whole chart without resource to older, less accurate, sources. When sources are referred to different datums, transformations have to be calculated and applied to make the sources compatible. The intention is for such transformations to have an accuracy of 0.3 mm at chart scale, this being the effective limit of manual cartography, but, depending on the information available, this may not always be possible.

18 When the positions of objects critical to navigation are accurately known, the intention is that they are located on a chart to an accuracy of 0.3 mm. The obvious consequence is that accuracy varies with chart scale:

0.3 mm at a scale of 1:10,000 is 3 metres
0.3 mm at a scale of 1:50,000 is 15 metres
0.3 mm at a scale of 1:150,000 is 45 metres

19 The situation will change as chart data becomes available digitally, but much of the early digital data will be derived from these paper charts and the limitations will remain. Furthermore, a pixel on a computer display screen is approximately 0.2 mm square, roughly equivalent to the accuracy available on the paper chart.

20 The situation for mariners is improving with recent surveys referred directly to WGS84 Datum, increasing numbers of charts referred to WGS84 Datum (or to North American Datum 1983 which is the same to all practical purposes) and increased international co-operation in the exchange of information. Unfortunately, it will be many years before all areas are re-surveyed and all charts revised.

21 Until such time, mariners should remain alert to danger. A satellite navigation receiver may output a position to a precision of three decimal places of a minute, but that does not mean that all its positions are accurate to 2 metres or that the resulting position is compatible with the positions of objects shown on modern charts (paper or digital) which may have been established 100 years ago and not surveyed since. The chart title notes and cautions and the source Diagram, which shows the ages of surveys must always be consulted for indications of limitations.

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Ref. T2-OSSHE/2.7.1

SN.1/Circ.255
24 July 2006

ADDITIONAL GUIDANCE ON CHART DATUMS AND THE ACCURACY OF POSITIONS ON CHARTS

1 The Sub-Committee on Safety of Navigation, at its fifty-second session (17 to 21 July 2006), approved additional guidance on chart datums and the accuracy of positions on charts, given at annex. This guidance is provided in addition to the guidance contained in SN/Circ.213 dated 31 May 2000.

2 Member Governments are invited to bring this guidance to the attention of all concerned for information, in particular, by having them published in pertinent official nautical publications and action, as appropriate.

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ANNEX

ADDITIONAL GUIDANCE ON CHART DATUMS AND THE ACCURACY OF POSITIONS ON CHARTS

In some areas of the world there are charts that are based on old surveys for which there is no determined geodetic datum or the datum is imprecise. Therefore in such areas, paper charts (and thus raster navigational charts) are not compatible with GNSS navigation, and it will take some time to resolve this problem. This makes it extremely difficult to accurately plot the ship's position obtained by the GNSS in relation to surrounding dangers on such charts. The difference in the plotted position can often be significant and could lead to a casualty or unnecessary risk in restricted waters.

Cross-checking of position using visual or radar fixing or ECDIS radar overlay can provide for the immediate detection of datum inconsistencies in electronic charts, and immediately alert the mariner on potential positional shifts required for particular charts. Some ECDIS equipment exceeds the minimum requirements of the ECDIS Performance standards, by providing such features as radar overlay.

In general, when navigating with GNSS, mariners should undertake all available measures to check the position of the ship obtained by continuous position fixing systems and plotted on any charts, such as using radar and visual observation methods.

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Courtesy translation. Only the Danish version is authentic.

Technical Regulation no. 169 of 4 March 2009 issued by the Danish Maritime Authority

DMA Technical regulation on the use of ice searchlights during navigation in Greenland waters

In pursuance of section 1(3), section 3, section 6 and section 32 of the Act on Safety at Sea, cf. Consolidated Act no. 903 of 12 July 2007, as put into force by Decree no. 882 of 25 August 2008 on the entry into force of the Act on Safety of Sea in Greenland, after consultation with the Greenland Home Rule and by authority, the following provisions are laid down:

Application

Section 1. This technical regulation shall apply to:

1) Danish and Greenland cargo and passenger ships with a gross tonnage of or above 150 engaged in voyages in Greenland territorial waters.
2) Foreign passenger ships with a gross tonnage of or above 150 engaged in voyages in internal Greenland territorial waters, roadsteds, port facilities and places of call.
3) Foreign cargo ships with a gross tonnage of or above 150 engaged in regular service on Greenland.

Definitions

Section 2. A "fixed ice searchlight" shall mean a searchlight that cannot be moved in relation to the direction in which it has been fitted.

Subsection 2. "Internal Greenland territorial waters" shall mean waters within the base line stipulated in accordance with Decree no. 191 of 27 May 1963, as amended by Decree no. 636 of 6 September 1991. The base line is shown on official Danish charts.

Subsection 3. "Territorial waters" shall mean internal and external territorial waters extending 3 nautical miles from the base line.

Equipment requirements

Section 3. Ships with a gross tonnage of or above 150, but below 500, shall be equipped with one fixed ice searchlight, which shall in so far as possible be located in the forepart of the ship.

Subsection 2. Ships with a gross tonnage of or above 500 shall be equipped with two fixed ice searchlights located in the forepart of the ship.

Functional requirements

Section 4. Ice searchlights shall be located and mounted so that the wheelhouse visibility is not obstructed.

Subsection 2. Ice searchlights shall be capable of giving out light in the forward direction in a small sector with such an effect that an object will reflect the light at a distance corresponding to the longest of the following:

1) For the ships mentioned in section 3(1), either minimum 500 m or minimum twice the stop distance at full speed.
2) For the ships mentioned in section 3(2), either minimum 1000 m or minimum twice the stop distance at full speed.

Subsection 3. In order to be able to function in all conditions, ice searchlights shall be fitted with:

1) operation from the wheelhouse;
2) a functionality for focusing the cone of light, operated from the wheelhouse;
3) means for securing the starter function at low temperatures; and
4) an anti-condensation function of the searchlight housing.

Use

Section 5. Ice searchlights shall be used during navigation in darkness for early ice detection. If the master finds that precipitation or other conditions would mean that the light from the ice searchlight would impair bridge visibility, the master may decide to turn of the searchlight. In such case, special caution shall be observed during navigation.

Subsection 2. Ice searchlights shall be turned of while in port unless otherwise stipulated by the port regulations.

Penalty clauses

Section 6. Contraventions of sections 3-5 shall be punishable by fine or imprisonment for a period not exceeding 1 year.

Subsection 2. The penalty may be increased to imprisonment for a period not exceeding 2 years if

1) the contravention has caused damage to life or health or risk of such damage;
2) an injunction or order has previously been issued in connection with the same or equivalent situations; or
3) the contravention has produced or has been intended to produce financial benefits to the contravener or others.

Subsection 3. Companies etc. (legal personalities) may be liable to punishment according to the provisions of chapter 5 of the Penal Code.

Section 7. If the circumstance is covered by the Decree on the entry into force for Greenland of the Act on Safety at Sea, measures may be laid down in accordance with the Criminal Code for Greenland.

Subsection 2. The circumstances referred to in section 4(2) shall be regarded as aggravating circumstances.

Subsection 3. If the contravention has been committed by companies etc. (legal entities), liability to pay a fine may be incurred by the legal entity as such. If the contravention has been committed by the State, the Greenland Home Rule, a municipality, a municipal cooperative covered under section 64 of the Landsting Act on municipal councils and local authorities etc. or a local authority, liability to pay a fine may be incurred by the relevant public authority as such.

Subsection 4. If the relevant party is not resident in Greenland or his connection to Greenland society is otherwise so remote that the prerequisites for measures to be taken do not exist, legal proceedings may be instigated or the case may be referred for trial in Denmark.

Entry into force

Section 8. This technical regulation shall enter into force on 15 June 2009.

Danish Maritime Authority
Per Sønderstrup / Carsten G. Jensen

DMA Order on techniccal regulation on safety of navigation in Greenland territorial waters

Courtesy translation. Only the Danish version has legal validity.

Order no. 1697 of 11 December 2015
issued by the Danish Maritime Authority

Order for Greenland on the safe navigation, etc. of ships

In pursuance of section 1(3), section 3, section 6 and section 32 of the act on safety at sea (*lov om sikkerhed til søs*), cf. consolidated act no. 72 of 17 January 2014, as amended by act no. 618 of 12 June 2013 and act no. 724 of 25 June 2014, as enacted for Greenland by royal decree, cf. consolidated decree no. 1674 of 16 December 2015, as well as in pursuance of section 12(2) and (3), section 24(7) and section 34(4) of the pilotage act (*lodsloven*), act no. 567 of 9 June 2006, as amended by act no. 478 of 30 May 2012, act no. 1231 of 18 December 2012, act no. 600 of 12 June 2013 and act no. 725 of 25 June 2014, as enacted for Greenland by decree no. 985 of 24 August 2015, by authority and after consultation with the Government of Greenland, the following provisions are laid down:

Part 1
Purpose and application of the order

Section 1. The purpose of this order is to enhance safety of navigation in Greenland waters.

Subsection 2. This order shall apply to cargo ships with a gross tonnage of at least 150 and to ships carrying more than 12 passengers in Greenland territorial waters, cf. however subsections 3-5.

Subsection 3. Part 4 shall only apply to ships carrying more than 250 passengers.

Subsection 4. As regards foreign ships, the provisions of sections 7-9, section 13 and section 16 shall apply only in connection with voyages in the inner territorial waters around Greenland as well as in connection with passage through the outer territorial waters around Greenland not covered by the provisions on innocent passage stipulated in the United Nations' Convention on the Law of the Sea.[1]

Subsection 5. Ships of war, troopships and naval auxiliaries as well as other ships owned or operated by a State and used only for public, non-commercial service shall not be covered by the provisions of part 3.

Part 2
Definitions[2]

Section 2. For the purposes of this order, the following definitions shall apply:

1) An “iceberg” means massive ice of varied form, broken away from a glacier and rising more than 5 metres above the sea, which may be floating or grounded.
2) "Sea ice” means any kind of ice generated through the freezing of sea water.
3) “Open water” is used as a concept when there is less than one-tenth "sea ice" and navigation is not impeded.
4) “No sea ice” means ice-free, except that ice of land origin may be present the concentration of which is less than one-tenth.
5) “Good visibility” means a visibility of more than 10 km.

Subsection 2. Inner and outer territorial waters are evident from official Danish charts and are shown in annex 1.

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1 The provisions on passage as well as on exemption from the requirements on design, construction, manning or equipment are stipulated in promulgation no. 17 of 21 July 2005 of the United Nations' Convention on the Law of the Sea of 10 December 1982.

2 The description of ice follows that of the Danish Meteorological Institute (www.dmi.dk).

Navigation zones around Greenland

Section 3. The two navigation zones shown in the chart in annex 1 extend to 3 nautical miles from the base line and cover the inner and outer territorial waters around Greenland.

1) The northern navigation zone extends from north of Tasiilaq (66° N) on the east coast of Greenland, north of Greenland, to north of Upernavik (72° N) on the west coast of Greenland.
2) The southern navigation zone extends from north of Tasiilaq (66° N) on the east coast of Greenland, south of Greenland, to north of Upernavik (72° N) on the west coast of Greenland.

Part 3

Safety requirements

Section 4. Ships shall navigate with enhanced vigilance in consideration of the risk of unknown submarine obstacles in areas where depths are given by a single sounding line. Such sounding lines are merely to be considered as reconnaissance.

Subsection 2. Intensified lookout for ice shall be kept by all means available when navigating areas that may present a risk of collision with ice that may constitute a danger to the ship. The speed shall be adjusted so that it is possible for the ship to stop or circumnavigate ice. The ship shall use ice searchlights in darkness in order to light up the sea in front of the ship.[3]

Subsection 3. Ships shall keep a safe distance to icebergs, and the master shall set safe distances to icebergs in consideration of the safety of the ship, the crew and the passengers. If, in order to call at a port, roads or place of call or to navigate narrow fairways or the like, it is necessary to sail close to icebergs, the greatest possible distance permitted by the actual conditions of the waters shall be kept.

Section 5. When planning the ship's voyage, the master of the ship shall take appropriate account of the safety requirements of this order and especially be attentive to the following factors:

1) The safety procedures of the ship's safety management system related to navigation in arctic waters;
2) any restrictions in the information on charts and aids to navigation;
3) information about the extension and type of ice and icebergs in the vicinity of the planned voyage on an ongoing basis;
4) statistical information about ice and temperatures from previous years;
5) any possible places of refuge where the ship may be protected or receive assistance;
6) any sea areas designated especially protected areas in the vicinity of the route; and
7) voyages in areas with limited search and rescue facilities.

Subsection 2. When planning the voyage, the master of the ship shall observe the recommendations adopted by the IMO on navigation in desolate areas.[4] [5]

Section 6. Navigation shall be prohibited in areas delimited in the chart by a dotted line with information about "talrige skær/numerous rocks".

Subsection 2. Navigation in areas given in the chart as "urent område/foul" or "uopmålt/unsurveyed" shall take place only if

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[3] Cf. order no. 169 of 4 March 2009 on technical regulation on the use of ice searchlights when navigating Greenland waters.

[4] MSC.1/Circ.1184 on "Enhanced contingency planning guidance for passenger ships operating in areas remote from SAR facilities".

[5] A.999(25) on "Guidelines on voyage planning for passenger ships operating in remote areas".

1) the ship follows previously used tracks that the master has assessed would have a sufficient safety margin in relation to the ship's greatest draught and width; or
2) appropriate measures are taken on board in order for the voyage to be safe, including:
   a) That the determination of the ship's position takes place by means of terrestrial and/or radar navigation,
   b) that voyages are made only in daylight and with "good visibility",
   c) that the ship proceeds only at the speed necessary to keep the ship's manoeuvrability, and
   d) that the waters ahead of the ship are sounded by casting the lead or similarly to the extent possible.

Section 7. Ships shall have at least one person available on board with the necessary local knowledge of the waters to be navigated. This person shall hold the qualifications that would entitle him to navigate the ship concerned or be trained to and have several years' experience navigating ships of similar size.

Subsection 2. The master of the ship shall be able to document the relevant person's local knowledge as well as experience with and knowledge about navigation in arctic and icy waters.

Section 8. Open lifeboats shall not form part of the ship's emergency preparedness.

Section 9. Navigation in ice shall form part of the ship's voyage planning only if the ship is structurally designed for operation in the relevant types and concentrations of ice.

Section 10. Ships obliged to have a safety management system in accordance with the International Management Code for the Safe Operation of Ships and for Pollution Prevention (ISM Code) shall have procedures and contingency plans in the safety management system that take account of the special conditions related to navigation in arctic waters, including the search and rescue preparedness available.

Subsection 2. The procedures and contingency plans mentioned in subsection 1 shall be drawn up in consideration of the guidelines adopted by the IMO for navigation in arctic waters and remote areas.[6]

Part 4

Special requirements for ships carrying more than 250 passengers

Section 11. Ships carrying more than 250 passengers shall, in connection with voyages in the inner and outer territorial waters around Greenland, take a pilot certified to perform pilotage assignments in the area concerned.

Subsection 2. Ships may be permitted to navigate without a pilot if the applicant documents that he has the necessary qualifications and experience navigating the waters concerned.

Section 12. The ship shall have contingency plans taking special account of the number of persons on board as well as the period to be expected before being assisted in case of an accident.

Subsection 2. The contingency plans shall include agreements on cooperation with the rescue service in the area, cf. Notice B from the Danish Maritime Authority, regulation V/7.3, and the corresponding provision in the SOLAS Convention.

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[6] MSC.1/Circ.1184 on "Enhanced contingency planning guidance for passenger ships operating in areas remote from SAR facilities".

Section 13. The ship shall, at any time, have an ice class corresponding, as a minimum, to the ice that it is navigating.

Subsection 2. In connection with voyages in the northern navigation zone (see annex 1), the ship shall have minimum Baltic ice class 1C or an equivalent ice class.

Subsection 3. In connection with voyages in "open waters" or "no sea ice", cf. section 2(iii) and (iv), in the southern navigation zone (see annex 1), the ship need not be ice classed.

Section 14. Around Nuuk, the ship shall follow the recommended routes.

Section 15. In connection with the planning of the voyage, the shipping company and the master shall be capable of documenting that it would be possible to be assisted by other ships or SAR facilities within a reasonable period of time and with sufficient rescue capacity.

Subsection 2. The master shall ensure that an overall assessment of the risks that the ship is expected to meet during the voyage is made on an ongoing basis.

Section 16. The shipping company shall ensure that the ship's master and deck officers are educated and trained in accordance with the provisions of part B-V/g of the STCW Code before commencing service.

Subsection 2. The shipping company shall determine an education and training programme for the ship's master and deck officers ensuring that they are educated and trained in accordance with the training requirements stipulated in subsection 1. The shipping company may consider at least three months' documented seagoing service as a navigating officer in polar waters under similar ice conditions equal to such an education and training programme.

Subsection 3. The shipping company and the master of the ship shall be able to document that the crew have completed the education and training programme or have acquired the necessary seagoing service in polar waters under similar ice conditions, cf. subsection 2.

Part 5

Measures

Section 17. In case of contraventions of sections 4-16, measures may be laid down in accordance with the criminal code *(kriminalloven)* for Greenland.

Subsection 2. When determining such measures, it shall be regarded as aggravating circumstances if:

1) the contravention has caused damage to life or health or risk of such damage;
2) an injunction or order has previously been issued in connection with the same or equivalent situations; or
3) the contravention has produced or has been intended to produce financial benefits to the contravener or others.

Subsection 3. If the profits gained through the contravention are not confiscated in pursuance of the provisions of the criminal code, particular account shall, when meting out penalties, including additional penalties, be taken of the scale of any economic benefit achieved or sought.

Subsection 4. If the contravention has been committed by companies, etc. (legal entities), liability to pay a fine may be incurred by the legal entity as such. If the contravention has been committed by the State, the Government of Greenland, a municipality, a municipal cooperative covered under section 64 of the Landsting act on municipal councils and local authorities, etc. or a local authority, liability to pay a fine may be incurred by the relevant public authority as such.

Part 6

Penalty provisions

Section 18. If the relevant party is not resident in Greenland or his connection to Greenland society is otherwise so remote that the prerequisites for measures to be taken do not exist, legal proceedings may be instigated or the case may be referred for trial in Denmark.

Subsection 2. In the cases stipulated in subsection 1, contraventions of sections 4-16 may be punishable by fine or imprisonment for a period not exceeding 1 year.

Subsection 3. The penalty may be increased to imprisonment for a period not exceeding 2 years if

1) the contravention has caused damage to life or health or risk of such damage;
2) an injunction or order has previously been issued in connection with the same or equivalent situations; or
3) the contravention has produced or has been intended to produce financial benefits to the contravener or others.

Subsection 4. Companies etc. (legal personalities) may be liable to punishment according to the provisions of part 5 of the penal code (*straffeloven*).

Part 7

Entry into force

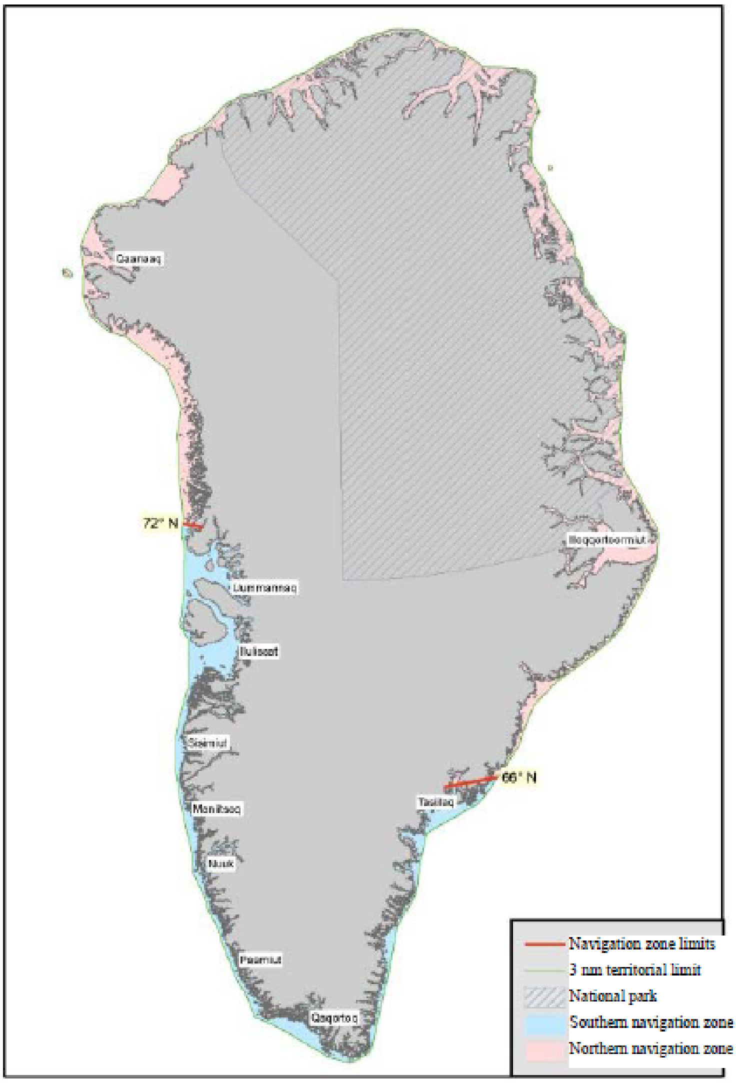
Section 19. This regulation shall enter into force on 1 January 2016, cf. subsection 2.

Subsection 2. Section 11 shall enter into force on 1 July 2016.

Subsection 3. Order no. 417 of 28 May 2009 on technical regulation on the safe navigation of ships in Greenland territorial waters shall be repealed.

Danish Maritime Authority, 11 December 2015

Troels Blicher Danielsen / Michael Skov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Illoqqortoormiut
Navigation zone limits
3 nm territorial limit
National park
Southern navigation zone
Northern navigation zone

Glossary Danish English

Danish	English	Danish	English
Bakke	Hill	Løb, løbet	Channel
Banke	Bank	Nor	Cove
Bjerg(-e)	Mountain(-s)	Nord	North
Bredning	Broad	Nordre	Northern
Bræ	Glacier	Nunatak	Nunatak
Bugt	Bay	Næs	Head, Point
Dal	Valley	Odde	Point
Dyb	Trench	Pynt	Point
Ejland	Island	Rende	Trench, channel
Elv	Stream	Skær	Rock(-s)
Fjeld(-e)	Mountain(-s)	Skærgård	Archipelago
Fjord	Fjord	Stor(-e)	Great
Flak	Shoal	Strand	Beach
Gletscher, gletsjer	Glacier	Strøm	Current, stream
Grund	Shoal	Sund	Sound
Halvø	Peninsula	Syd	South
Hav	Sea	Sø	Lake
Havn	Harbour, port, anchorage	Søndre	Southern
Holm, lille ø	Islet	Tange	Narrow point
Høj	Hill	Varde	Cairn
Is	Ice	Vest	West
Isfjord	Ice fjord	Vester, Vestre	Western
Kap	Cape	Vig	Cove
Klippe	Cliff, rock	Ø, øer, øerne	Island, islands
Kyst	Coast	Øst	East
Lille	Little	Øster, Østre	Eastern

Consulates in Greenland

1 In Nuuk
The following contries has established consulates:
Iceland
Belgium, the Netherlands and Luxembourg
Canada
Finland
France
Norway
Great Britain and Northern Ireland
Sweden
South Korea
Czech Republic
Germany

2 Outside Nuuk
The following contries has established consulates:
Iceland in Tasiilaq
Latvia in Qaqortoq

Illustrations

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Cover, all illustations . . . . Colorbox

Fig. 1.1 . . . . Tine Fallemann Jensen

Fig. 1.2. . . . . DMA

Fig. 4.1 . . . . Olaf Andersen

Fig. 5.1 . . . . DMI

Fig. 5.2. . . . . Finish Transport Agency

Fig. 5.3 and 5.4 . . . . Bundesamt für Seeschifffart und Hydrandraphie

Fig. 5.5, 5.6, 5.7, 5.8, and 5.9 . . . . Olaf Andersen

Fig. 7.1, 8.1 and 8.2 . . . . GST

Fig. 9.1, 9.2 and 9.3 . . . . GST

Fig. 9.4 and 9.5 . . . . Olaf Andersen

Fig. 9.6 and 9.7 . . . . DMI

Fig. 9.8. . . . . WMO

Fig. 9.9. . . . . DMI

Fig. 9.10, 9.11 and 9.12 . . . . WMO

Fig. 9.13 . . . . DMI

Fig. 9.14 and 9.15. . . . . Olaf Andersen

Fig. 9.16 . . . . DMI

Fig. 10.1 - 10.13 . . . . DMI

Fig. 10.14 . . . . Olaf Andersen

Explanations for illustrations on the back cover

From top and clockwise around.

1 Sledge dog team, Qeqertarsuaq (Godhavn)

2 Walrus *(Odobenus Rosmarus)*, Greenlandic Aaveq

3 Polar Bear *(Ursus Maritimus)*, Greenlandic Nanoq

4 Broad-leafed Willow-herb, River Beauty, *(Chamaenerion latifolium,Epilobium latifolium)* Greenland's national flower, Greenlandic Niviarsiaq *[A young girl]*

5 Humpback Whale *(Megaptera novaeangliae)*, Greenlandic Qipoqqaq

6 Hardwood forest, South Greenland

7 Arctic Station, Qeqertarsuaq (Godhavn)

8 Sheep, South Greenland

9 center, Navigating in the midnight sun, Qeqertarsuup Tunua (Disko Bugt)