

WORLD METEOROLOGICAL ORGANIZATION

**SEA-ICE INFORMATION SERVICES
IN THE WORLD**



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FOREWORD

Many ocean and sea areas of the world, in addition to the polar seas, are susceptible to sea ice (for example, the Baltic Sea and parts of the Yellow Sea). Sea ice occurs in a wide range of character and form, and affects significantly and directly marine transport and navigation. Economic and social developments are engendering significant increases in international shipping, particularly in areas susceptible to sea ice. The specialized Meteorological Services, which evolved initially in support of local marine users, have since developed into a wide range of sea-ice information services designed to meet many user requirements. The joint World Meteorological Organization/Intergovernmental Oceanographic Commission (WMO/IOC) Technical Commission for Oceanography and Marine Meteorology QCOMM (formerly the Commission for Marine Meteorology, CMM) Subgroup on Sea Ice has been the focal point for promoting and coordinating international cooperation in the acquisition, exchange, archival and dissemination of sea-ice information.

The WMO publication *Sea-Ice Services in the World* (WMO-No. 574) was first published in 1981. Following a recommendation of the twelfth session of the former CMM in 1997, the Subgroup on Sea Ice undertook a major review and revision of this important publication. This present fully revised version was prepared by Messrs Jan-Eric Lundquist (Sweden) and Vasiliy Smolianitsky (Russian Federation), with the support of the WMO Secretariat, and includes contributions from 19 countries involved in some way in sea-ice activities. It has also been reviewed extensively by the Subgroup on Sea Ice and the Baltic Sea Ice Meeting.

I believe that this revised publication will continue to enhance the exchange of information relating to sea ice and sea-ice services to the benefit of many national Meteorological Services. In addition to providing operational information to mariners, marine operations and controllers, it will also aid other national Meteorological Services, which are developing their own sea-ice services.

On behalf of the World Meteorological Organization, I would like to express my sincere appreciation to Messrs Lundquist and Smolianitsky, as well as to all the members of the Subgroup on Sea Ice, for their contributions to the preparation of this valuable publication.

A handwritten signature in black ink, appearing to read 'G. O. P. Obasi', written over three horizontal lines.

(G. O. P. Obasi)
Secretary-General

INTRODUCTION

Mariners have known of the existence and perils of sea ice since vessels first ventured into northern regions. The numerous polar expeditions of the last century brought new understanding of the types and variability of conditions affecting these vast ocean areas, it was not until misfortune struck the S.S. TITANIC, however, that thoughts of international co-operation in sea-ice information gained any strength. After 1918, increasing emphasis upon navigational safety and the need for agreed shipping routes led to contacts between nations who had established their own sea-ice observational information systems. Discussions about reporting methods, code forms and symbology (within the confines of the limited extent of observation at that time) continued steadily until 1959. Advances in communications, the advent of aircraft observations and routine reporting created the basis for the development of sea ice information services by several nations by the mid-1950s. The first international sea-ice conferences were held and the Commission for Marine Meteorology established a working group concerned with sea-ice affairs.

Since that time many further strides forward have been made both in observational and processing techniques, and information services are provided now as routine for all the commonly frequented sea-ice regions.

The 1st edition of the WMO-No.574 publication "Sea-ice Information Services in the World" was prepared and published by 1981. Since then, due to advances in remote sensing, computational means and telecommunication, significant progress has been made towards the number and the complexity of sea-ice products. Also, the changes in the number of sea-ice services and regions of their responsibility occurred and should be described.

Current 2nd edition follows the structure of the previous one publication, and has been designed to describe sea-ice services as they are today, to provide clear factual and updated details of the sources, background, preparation and presentation of these services. Special attention is given to a) processing and presentation of various satellite imagery and b) using Internet in relay of sea-ice products to the users.

The publication consists of two parts:

Part I - A general description of the nature of sea ice, methods of observation; and the basis of ice information services.

Part II - A listing of the sea-ice information services available from twenty nations, given regionally, and in each case detailing:

- (a) Organization;
- (b) Data acquisition;
- (c) Output products;
- (d) Forecasts;
- (e) Publications;
- (f) Mailing and Internet addresses.

These details are supported by twelve annexes containing sample charts and illustrating a wide selection of the products mentioned in Part II, including chart remotely sensed background, complexity, dissemination methods and national and international practices where relevant.

The extent to which sea-ice information services have now developed will be very evident to readers. It is hoped that this 2nd review may in turn, through its users and those involved in related services, itself contribute further to more advances in the future.

PART I GENERAL

1. The nature of sea ice

Several forms of floating ice may be encountered at sea. The most common is that which results from the freezing of the sea surface, namely sea ice. The other forms are river ice and ice of land origin. River ice is encountered in harbors and estuaries where it is kept in motion by tidal streams and normally presents only a temporary hindrance to shipping. Ice of land origin in the form of icebergs is discussed separately below.

Both icebergs and sea ice can be dangerous to shipping and always have an effect on navigation. Sea ice also influences the normal processes of energy exchange between the sea and the air above it. The extent of sea ice cover can vary significantly from year to year and has a great effect both on adjacent ocean areas and on the weather over large areas of the world. Its distribution is therefore of considerable interest to meteorologists and oceanographers.

1.1 *Formation and development of sea ice*

1.1.1 *Ice less than 30 cm thick*

The first indication of ice formation is the appearance of small ice spicules or plates in the top few centimeters of the water. These spicules, known as frazil ice, form in large quantities and give the sea an oily appearance. As cooling continues the frazil ice coalesces to form grease ice, which has a matt appearance. Under near-freezing, but as yet ice-free conditions, snow falling on the surface may result in the sea surface becoming covered by a layer of slush. These forms may be regrouped by the action of wind and waves to form shuga and all are classified as new ice.

With further cooling, sheets of *ice rind* or *nilas* are formed, depending on the rate of cooling and on the salinity of the water. *Ice rind* is formed when water of low salinity freezes into a thin layer of *brittle ice* which is almost free of salt. *Ice rind* may have thickness up to 5 cm. At the same time when water of high salinity freezes, especially if the process is rapid and the wind is very light, the ice has an elastic property which is characteristic of *nilas*. *Nilas* is subdivided, according to its thickness, into *dark* and *light nilas*; the first one reach thickness of 5 cm, while the second, more advanced stage reaches a maximum thickness of 10 cm. Ice rind, dark and light nilas may be referred to as nilas ice.

Pancake ice may be formed in the boundary between two water layers of different salinity - the lower layer with a high salinity has a temperature below freezing point of the upper layer of lower salinity. Eventually the *pancakes* will surface due to buoyancy forces. 'False' *pancake ice* may be formed by breaking up of *nilas* or *ice rind* due to action of wind and waves. It must be noted that the process of *pancake ice* formation is still inconsiderably investigated due to lack of observations.

Ice rind, *nilas* or *pancake ice* may thicken into *grey ice* and *grey-white ice*, the first one having thickness 10-15 cm and the latter one attaining thicknesses up to 30 cm. These forms of ice are referred to collectively as *young ice*. Rough weather may break this ice up into ice cakes, *pancake ice* or floes of varying size.

1.1.2 *Ice 30 cm - 2 m thick*

The next stage of development is known as *first-year ice* and is subdivided into *thin*, *medium* and *thick* categories. *Thin first-year ice* has a thickness of 30-70 cm and is subdivided according to its thickness into *thin first-year ice first stage* (30-50 cm) and *thin first-year ice second stage* (50-70 cm). *Medium first-year ice* has a range of thickness from 70 to 120 cm while in polar areas *thick first-year ice* may attain a thickness of approximately 2 m at the end of the winter.

1.1.3 Old ice

Thick first-year ice may survive the summer melt season and is then classified as *old ice*. This category is subdivided into *second-year* and *multi-year ice* depending on whether the floes have survived one or more summers. The thickness of *old ice* is normally in the range 1.2 to 5 m or more prior to the onset of the melt season. *Old ice* may often be recognized by a bluish surface color in contrast to the greenish tint of *first year ice*.

1.2 Decay of sea ice

During the winter the ice usually becomes covered with snow of varying thickness. While this snow cover persists, almost 90% of the incoming radiation are reflected back to space. Eventually, however, the snow begins to melt as air temperatures rise above 0°C in early summer and the resulting fresh water forms puddles on the surface. These puddles absorb (instead of reflect) about 90% of the incoming radiation and rapidly enlarge as they melt the surrounding snow or ice. Eventually the puddles penetrate to the bottom surface of the floes and are known as thawholes. This decay process is characteristic of ice in the Arctic Ocean and seas where movement is restricted by the coastline or islands. Where ice is free to drift into warmer waters (e.g. the Antarctic and the Labrador Sea) puddling is less prevalent and decay is accelerated by wave erosion as well as warmer air and sea temperature.

1.3 Movement of sea ice

Sea ice is divided into two main types according to its mobility. One type is drift ice, which is continually in motion under the action of wind and current stresses; the other is fast ice, attached to the coast or islands, which does not move.

Wind stress in the drift ice causes the floes to move approximately in a downwind direction. The rate of movement due to wind drift varies not only with the wind speed, but also with the concentration of the *drift ice* and the extent of deformation (see below). In very *open ice* (1/10-3/10) and *open ice* (4/10-6/10) there is much more freedom to respond to the wind than in *close ice/pack ice* (7/10-8/10) and *very close* (9/10-10/10) where free space is very limited. No water is visible within the *compact ice* (10/10) or *consolidated ice* (10/10) where the floes are frozen together. 2% of the wind speed is a reasonable average for the rate of ice drift caused by the wind in *close ice*, but much higher rates of ice drift may be encountered in *open ice*. Since it is afloat, a force is exerted on *drift ice* by currents that are present in the upper layers of the water, whether these are tidal in nature or have a more consistent direction due to other forces. It is usually very difficult to differentiate between wind- and current-induced ice drift but in any case where both are present the resultant motion is always the vector sum of the two. Wind stress normally predominates the short term movements, particularly in offshore areas, whereas the average long term transport is dominated by the prevailing surface currents.

1.4 Deformation of sea ice

Where the ice is subjected to pressure its surface becomes deformed. In *new* and *young ice* this may result in *rafting* as one ice floe overrides its neighbor; in thicker ice it leads to the formation of *ridges* and *hummocks* according to the pattern of the convergent forces causing the pressure. During the process of *ridging* and *hummocking*, when pieces of ice are piled up above the general ice level, large quantities of ice are also forced downward to support the weight of the ice in the *ridge* or *hummock*. The underwater parts may be termed respectively *ice keel* and *bummock*. The draught of a ridge can be three to five times as great as its height and these deformations are thus major impediments to navigation. Freshly-formed ridges are normally less difficult to navigate than older, weathered and consolidated ridges.

1.5 Icebergs

Icebergs are large masses of floating ice derived from glaciers. The under water mass and draught of a berg, compared with its mass and height above water varies widely with different composition and shapes of bergs. The underwater mass of an Antarctic *iceberg* derived from a floating ice shelf is usually less than the underwater mass of *icebergs* derived from Greenland glaciers. A typical Antarctic *tabular berg*, of which the uppermost 10-20 m is composed of old snow, will show one part of its mass above the water to five parts below. The ratio for an

Arctic berg, composed almost wholly of ice with much less snow is generally smaller, rather one to seven. However, because of their irregular shape the latter icebergs have a height-to-draught ratio averaging 1:3.

Icebergs diminish in size in three different ways: by calving, melting and combined melting + erosion caused by wave action. A berg is said to calve when a piece breaks off; this disturbs its equilibrium, so that it may float at a different angle or it may capsize. Large underwater projections, which may be difficult to observe, are a usual feature of *icebergs* in any state. In cold water, melting takes place mainly on the water line while in warm water a berg melts mainly from below and calves frequently. It is particularly dangerous to approach a berg in this state for it is unstable and may fragment or overturn at any time. There are likely to be many *growlers* and *berg bits* around rapidly disintegrating *icebergs*, which form a particular hazard to navigation.

Weathered bergs are poor reflectors of radar pulses and cannot always be detected by these means. Their breakdown fragments - *berg bits* and *growlers* - are even more difficult to detect with ships' radar for the background clutter from waves and swell often obscures them. These smaller fragments are especially dangerous to shipping for, despite their low profile they represent sufficient mass to damage a vessel, which comes into contact with them at normal cruising speed. Some *growlers* consisting of pure *blue ice* hardly break the sea surface and are extremely difficult to detect.

2. Ice observing methods

Although broad knowledge of the extent of sea ice cover has been revolutionized by satellite imagery, observations from shore stations, ships and aircraft are still of great importance in establishing the "ground truth" of satellite observations. At present, observations of floating ice depend on instrumental and to lesser extent on visual observations. The instrumental observations are by conventional aircraft and coastal radar, visual and infra-red airborne and satellite imagery, and more recent techniques, such as passive microwave sensors, laser airborne profilometer, side-looking (airborne) radar (SLAR/SLR) or synthetic aperture radar (SAR, satellite or airborne).

The four most important features of sea ice, which affect marine operations are:

- (a) Its thickness (stage of development);
- (b) The amount present - (concentration, usually estimated according to the tenths or percent of the sea surface covered by the ice);
- (c) The form of the ice, whether it is fast or drift ice and the size of the constituent floes; and
- (d) Any movement of the ice.

On a ship or at a coastal station it is obvious that a better view of the ice is obtained if the observation is made from a point as far above the sea as possible. From the bridge of a ship 10 m above the sea, the horizon is about 12 km away and good observations can cover a radius of only 7-8 km. From the top of a coastal lighthouse 100 m above the sea the visual range is almost 40 km and the observation may then cover a radius of 20 km.

Shore locations may provide an ice report several times a day as the ice changes in response to wind and current but the total area of ice being reported is very small. From a ship progressing through the ice, a summary report of the ice encountered during day-time progress may represent an area of the sea ice 15 km wide and 100 km long (assuming a ship's speed of approximately 5 kt). In some marine areas, such as the Baltic Sea, coastal settlements, lighthouses and ships may be present in sufficient numbers that a reasonable proportion of an ice cover can be reported each day by an organized surface network. In others such as the Gulf of St. Lawrence, where the waterways are broad and the shores often unsettled, no shore reporting system can provide data on more than a very small percentage of the total ice cover. Although surface-based reports can provide excellent detail about the ice, especially its thickness, it is generally recognized that for most areas, the surface reports are not really adequate to describe ice conditions fully.

Reports about the ice cover taken from the air, i.e. helicopters and fixed-wing aircraft, have the advantage of a much better viewing angle, the platform's flying speed allows a great deal more of the sea ice to be reported and problems of remoteness from airports or other suitable landing sites can be overcome by using long-range aircraft. In many countries, ice observers are trained to recognize the various stages of development of sea ice, to estimate its amount, to note its deformation and the snow cover or stage of decay. All these data are provided by visual estimate and both training and experience are required to make the information reliable.

Comprehensive aerial reporting has its own particular requirements beginning with an accurate navigational system when out of sight of land. Inclement weather-fog, precipitation and low cloud will restrict or interrupt the observations and the usual problems of flying limits at the aircraft base may also be a factor even if the weather over the ice is adequate for observing.

Recent advances in technology are now permitting more precise data to be obtained by aerial observations. SLAR and SAR can provide information, which documents precisely the distribution and nature of the ice in one or two belts along the flight path of the aircraft for the distances up to 100 km on each side. Unlike most other sensors, the radar has the capability of monitoring the ice under nearly all weather conditions. It responds mainly to the roughness of the ice surface but the dielectric properties of each ice floe also affect the response.

When no fog or low clouds are present a laser airborne profilometer can be used to measure the height and frequency of ridges on the ice, and under similar conditions an infra-red airborne scanning system can provide excellent information with regard to floe thickness in the ranges below 30 cm.

The advent of Earth-orbiting meteorological satellites has added a third mode of observing sea ice but again there are some restrictions. The spectral range of the sensors may be visible, infrared, passive or active microwave or a combination of these. Satellite coverage may be broad at low resolution or cover a narrow swath at high resolution. In the latter case, data from a particular location may be obtained only at temporal intervals of many days. There is always the problem of rates of data transmission from space and the orbital altitude of the satellite, which affects the range of reception at each receiving station.

In general, most meteorological satellites provide 10-12 passes daily in the polar regions. These satellites provide visible and infrared imagery with resolutions of about 1 km and passive microwave data at coarser resolutions of 12-70 km. Visible and infrared data do not have cloud-penetrating capability while passive microwave data are practically cloud independent. SAR data are characterized by improved ground resolution (approximately 10-100 meters), reduced coverage due to narrow swathes and greater revisit time between exact repeat orbits.

Manual or visual interpretation of imagery from visible and infrared sensors requires a certain amount of skill as, for example, a picture element which is composed of 50 per cent white ice and 50 per cent water will have the same greyness in the visible image as another element in which the whole surface is covered with thin (grey) ice. Snow cover on the ice and puddles on the floes are other complicating factors. Interpretation of SAR images may be even more difficult due to the ambiguities associated with SAR backscatter from sea ice features that vary by season and geographic region. Therefore, in recent years automated digital processing techniques have been developed to aid in the interpretation of satellite data. Techniques include interactive image enhancements, various types of image recognition and classification, which are based on data from a single sensor or combination from several ones.

Space-borne sensors can provide precise data on the location and type of ice boundary, concentration or concentration amounts (in tenths or percent) and the presence or absence of leads, including their characteristics if radar sensors are used. Less accurate information is provided on the sea ice stages of development, forms, including indicator whether ice is land-fast or drifting, and ice surface roughness. Floe motion over approximately 12-24 hour intervals can often be determined through use imagery from sequential orbits.

3. Integrated observational systems

Any well-designed ice services system must consist of three major components:

- (a) A surface observation network consisting of in-situ reports and remotely sensed data;
- (b) A communication systems to gather and distribute the ice information; and
- (c) A digital data integration, analysis and production system.

Surface reports from shore stations, ships and drifting buoys provide accurate information on ice amount, thickness, motion and its deformation over rather small areas. When many vessels and fixed observing points are available an accurate information can be provided in restricted waterways. Many areas of the Kattegat and Baltic Sea coastline fall into this category and landline facilities are available for relay of these reports to national or regional centres.

When waterways are more open or more remote from populated areas, either aerial observations or satellite data must be integrated into the system. Aerial data is normally prepared by the observers in map format as they fly along the prescribed track. An air-to-ship communication line is needed to pass the data directly to vessels in the area. This may be merely a voice channel, a radio facsimile broadcast or perhaps digital network link, which enables radar data or the ice chart itself to be passed to the ships. In most cases, these data are also passed via facsimile or text message to the ice centre for integration into regional-scale analysis products.

Satellite data are typically passed in real-time (less than 6 hours) from satellite ground stations to the ice centres via high-speed communication links. Visible, infrared, passive microwave, SAR and in-situ are then digitally processed, integrated with meteorological guidance products and ice model output and then analyzed on computer workstations. Image enhancement techniques and various other automated algorithms are often employed in the production of an ice analysis. Ice analyses are produced as charts on varying scales (typically ranging to 1:2,500,000) depending on the size of the area and the level of detail required. The ice charts are often made available as simple electronic charts in Graphics Interface Format (GIF) which can be viewed with almost any web browser and/or graphics viewer and data coverages in Geographic Information System (GIS) formats. Charts are typically labeled using the World Meteorological Organization (WMO) international sea ice symbology. Other ice analysis products include annotated satellite imagery usually in JPEG and TIFF formats, text messages and electronic charts.

4. Ice Information services

Once the observational material from all sources has been combined into an ice chart which represents existing conditions the ice centre then has the task of relaying the chart to the users while it is still timely. The ice data can also be combined with meteorological and oceanographic parameters in a prediction model to provide further guidance to vessels in or near the ice.

Relay of charts of existing ice conditions is mostly conducted by radio facsimile or in recent times via digital network link. Time allotments and schedules usually dictate the scale and number of charts provided by the broadcast station in the area of concern. Direct broadcast by the ice centre is obviously ideal but not always feasible.

Forecasts of ice conditions are difficult to prepare for, besides the drift caused by the wind, the floes are also affected both by residual and tidal currents. The results are complicated, and knowledge of the detail of the oceanographic factors is not often available, in some cases the wind drift alone is specified and it is left to individual ships' captains to interpret this in relation to his own position. Recent advances in computer models for ice prediction are allowing more detailed data to be provided (as in the case of Gulf of Bothnia - for example) but these require further facsimile or digital network transmission time, which may not be available.

Usually, ice forecasts are prepared once each day for a period of 24 to 144 hours because they are tied to the frequency of the data input. These are tactical forecasts, for scheduled radio broadcast to ships which may provide advice of difficult ice conditions forming or dissipating, the general motion of the pack, opening and closing of leads, etc. They are strongly influenced by meteorological prediction and should always be used in concert with the weather forecast.

Other longer-range predictions - those covering periods from 7-10 days to 30 days and seasonal predictions - are usually based on climatological and analogue methods. They are more commonly distributed by ground or electronic mail to shipping companies and agents rather than to individual ships.

After the ice data have been processed operationally and used in relation to the existing marine traffic, they can then be passed to a climatological unit of the ice service which compiles and analyses them in relation to averages, and which prepares atlases to be consulted by planners, marine architects and others who deal with longer-term aspects of the ice conditions and their effect on human activity.

5. International cooperation

In some areas of the world a regional approach to ice services is far more economical and efficient than one based solely on national facilities. For example, in North America, a coordinated effort involving the U.S.A. and Canada has been adopted as the best method of supporting winter shipping in the Great Lakes. In the Baltic area, an even more sophisticated system has evolved, which includes data exchange between Denmark, Estonia,

Federal Republic of Germany, Finland, Latvia, Lithuania, Netherlands, Norway, Poland, Russian Federation and Sweden. A common numerical ice-reporting code (The Baltic Sea Ice Code), sea ice charts (international sea ice symbols), integrated data broadcasts in clear English and similar shipping control regulations are used. In special situations, icebreaker assistance is integrated, all for the common aim of supporting the marine traffic.

On a larger scale the World Meteorological Organization, through the CMM (from the year 2001 JCOMM) Sub-Group on Sea Ice, has been instrumental in developing an internationally accepted terminology and formats to exchange operational and archived data on sea ice. An illustrated glossary was published together with a set of chart symbols for international use (*Sea-ice nomenclature* (WMO-No.259.TP.145 (English, French, Russian, Spanish), and a set of formats was designed or is under development (SIGRID, WMO 1989, SIGRID-2, WMO 1994).

Until 1980s, most ice services have been directed towards shipping and offshore exploration. As a result, the needs have been very specific but national or regional in nearly every case. With more interest and study being directed towards the world's climate in recent years, there is a growing need for international data exchange for use by meteorological and oceanographic researchers. This required a creation of data banks on a coarser scale than in operational services. Within the WMO project «Global Digital Sea Ice Data Bank», which started in 1989, historical sea ice information for the major part of the twentieth century was archived in electronic form due to collaborative efforts of several ice services, institutions and Data Centres (from Canada, Finland, Japan, Russian Federation, Sweden, U.S.A., etc.).

PART II
REGIONAL AND NATIONAL PRACTICES
NORTHERN HEMISPHERE

North and North-east Asia and North Europe

CHINA

1. Organization

The national ice service is provided by National Marine Environment Forecast Center (NMEFC), State Ocean Administration (SOA). Major users of the services are China Offshore Oil Bohai Corporation (COOBC) and coastal and harbour activities. In the period from December to March, ice observation and forecasting services are provided for the Bohai Sea and the northern Yellow Sea. The ice services for local operation and specific task are provided by the Group of Sea Ice Management (GSIM) of COOBC. Ice forecasting service is also provided by Qingdao Marine Forecasting Observatory (QMFO) of SOA.

2. Data acquisition

Sea ice type, thickness, concentration and temperature are operationally measured according to "The Specification for Offshore Observations" (GB/T 14914-94, SOA) at 11 coastal stations along the Bohai Sea and the northern Yellow Sea. Icebreakers are used by the Navy and COOBC for operational observations of sea ice edge, thickness and type according to "The Specification for Oceanographic Survey" (GB/T 12763-91, SOA) and for special survey. Ice condition reports are also provided by SOA patrol ship. The ice temperature, thickness and type are obtained from aerial remote sensing and the aerial survey of sea ice are provided as one of the operational observations during January to February. The North Sea Branch (Qingdao) of SOA manages the operation of a dedicated aircraft equipped for ice reconnaissance missions in the Liaodong Gulf, Bohai Gulf, Laizhou Bay and in the shore of northern Yellow Sea. The helicopter reconnaissance flight is managed by COOBC for special missions. Radar imagery from Bayuquan station of SOA and real-time ice data at the platform JZ-20-2 (40°27'N, 121°17'E) in the Liaodong Gulf are provided daily. The visible and infrared satellite imagery from NOAA (AVHRR) and the visible imagery from GMS are received by NMEFC and used for monitoring and forecasting of sea ice in the Bohai Sea and the northern Yellow Sea.

3. Output products

(a) Chart Output

A ice chart on the scale 1:2 000 000 (Mercator projection), showing ice conditions in the Bohai Sea using the international system of sea-ice symbols, is transmitted weekly by facsimile and computer network from GSIM to each sea area and related units (Fig.II-1, Annex II). The analyzed chart of ice concentration, thickness and edge on the same base is prepared daily and transmitted by NMEFC (fig.II-2 and fig.II-3, Annex II). A 1-5 day numerical sea ice forecast chart, covering the Bohai Sea and the northern Yellow Sea, is prepared daily by NMEFC and transmitted by facsimile and computer network to COOBC, companies for shipping and other units (fig.II-4, Annex II).

(b) Coded Output

Forecasted fields of ice concentration, thickness and velocity at grid points in tenths of degrees of latitude and longitude, at 12-hour intervals up to 120-hour and analyzed fields are transmitted daily by computer network.

(c) Plain Language

- (1)* Plain-language ice information with images and 10-day outlook of ice condition in the Bohai Sea and the northern Yellow Sea are prepared by NMEFC and are disseminated from CCTV and the radio at each 10-day during winter.

- (2) A long-range outlook for the next winter is prepared and mailed. It is also transmitted by facsimile in October from NMEFC.
- (3) A 10-day forecast and an outlook up to one month are mailed and transmitted by facsimile for each 10-day and month period from NMEFC and QMFO respectively.
- (4) A Sea Ice Management Brief Report including sea ice conditions, forecasts of ice and weather for the next week, information about sea ice monitoring and forecasting, as well as suggestion to coastal and offshore operation is prepared by GSIM, and mailed and transmitted by facsimile weekly from GSIM.

4. Forecasts

Numerical sea ice forecasts for up to 5-day ahead for the Bohai Sea and the northern Yellow Sea are prepared daily by NMEFC using a thermodynamic-dynamic ice model. The forecast products contain fields of ice thickness, concentration and velocity, ice edge, parameters of ice ridge and local estimate of ice thickness and tracks of ice floes near drilling platforms.

The 10-day and the 30-day forecasts are prepared using statistical methods to determine ice-edge, mean and maximum of ice thickness in Liaodong Gulf, Bohai Gulf, Laizhou Bay and northern Yellow Sea by NMEFC and QMFO/SOA.

The long-range seasonal outlook is prepared using statistical methods to estimate the hierarchy of ice conditions of the Bohai Sea and the northern Yellow Sea in the next winter.

5. Publications

The China Ocean Annuals, China Marine Environment Annual Report and China Marine Disaster Bulletin (all in Chinese) are annually prepared by SOA. These publications include sea ice conditions and disaster and activities about sea ice for the year.

6. Mailing addresses

National Marine Environment Forecast Center,
8, Dahuisi Rd., Haidian District
Beijing, 100081,
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Qingdao Marine Forecasting Observatory of SOA
22 Fushun Road,
Qingdao, 266033,
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Group of Sea Ice Management
C/o General Dispatch Office
China Offshore Oil Bohai Corporation
P.O. Box 501 Tanggu
Tianjin 300452
China

JAPAN

1. Organization

Sea-ice information services in Japan are provided by two governmental agencies: the Japan Meteorological Agency (JMA) and the Maritime Safety Agency (MSA) mainly for fishing, shipping, and coastal and harbour activities.

2. Data acquisition

The sea-ice on the Sea of Okhotsk and the northern part of the Japan Sea is mainly formed from December to May.

Seven weather stations of the JMA and eight stations of the MSA make daily visual ice observations on amount of sea-ice, concentration, speed and direction of floe etc. Patrol ships of the MSA routinely report the sea-ice conditions such as kind of sea-ice, concentration, ice thickness and difficulties of navigation. The two agencies exchange these data by telefax, and disseminate derived products to users.

Aerial observations (30 or more times per year) are carried out, at the request from the JMA, by the Japan Defense Agency (JDA). MSA also conducts aerial observations 10 or more times per year. Each aerial observation chart is used for sea-ice analysis in JMA and MSA.

Visible, infrared satellite images from the Geostationary Meteorological Satellite (GMS) and NOAA, and passive microwave satellite sounding data from the US Defense Meteorological Satellite Program (DMSP) are utilized for sea-ice analysis by JMA and MSA. The Institute of Low Temperature Science of Hokkaido University provides JMA and MSA with radar observations along the north-eastern coast of Hokkaido by telefax. The radar imagery is also available on Internet for public usage (<http://www.hokudai.ac.jp/lowtemp/sirl/sirl-e.html>).

3. Output products

- (a) Sea-ice condition charts of the JMA are broadcast by meteorological radio facsimile on short waves (call sign: JMH) twice a week (Tuesdays and Fridays). The chart covers the Sea of Okhotsk, the Sea of Japan, the northern part of the Yellow Sea, Po-Hai, the vicinity of Hokkaido, the Kuril Islands and the Kamchatka. The chart shows ice edges and five classes of sea-ice concentration with a description on sea-ice movements in plain language. Example of the chart is given on fig.VII-1 (Annex VII).
- (b) Numerical sea-ice forecast charts for coming seven days are made by the JMA. The forecast chart is objectively prepared by a numerical sea-ice model, in which physical processes of formation/melting and drift of sea-ice due to wind and ocean current are considered. The charts depicts the expected distribution and concentration of sea-ice two and seven days ahead are broadcast by meteorological radio facsimile (call sign: JMH) twice a week (Wednesdays and Saturdays). Examples of the forecast charts are given on fig.VII-2 (Annex VII).
- (c) Coastal sea-ice information in plain language and detailed chart and forecasts are prepared by local meteorological offices of the JMA and are disseminated to the authorities for disaster prevention of local governments and the news media etc. The Ice Information Center of the First Regional Maritime Safety Headquarters of MSA also disseminates the daily coastal sea-ice chart by telefax and Internet (<http://www.jhd.go.jp/cue/KANI/1center.html>).

4. Publications

- (a) "Monthly Ocean Report": Monthly publication of JMA, which contains the sea-ice conditions in the Sea of Okhotsk and in the Polar Regions.
- (b) "Results of Sea Ice Observations": Annual publication of JMA which contains the annual summary of sea-ice conditions with 5-day sea-ice charts in the Sea of Okhotsk and monthly sea-ice charts in the polar regions.
- (c) "Kaihyou Sokuhou" (Prompt report of sea-ice): Every 10-day issue of the First Regional Maritime Safety Headquarters of MSA, for description of the daily coastal sea-ice conditions.
- (d) "Kaiyou Gaihou—Kaihyou-hen" (Summary report of oceanographic condition—special issue of sea-ice): Annual publication of the First Regional Maritime Safety Headquarters of MSA, which conditions the annual summary of coastal sea-ice conditions.

5. Mailing and Internet addresses

Maritime Meteorological Division
Climate and Marine Department
Japan Meteorological Agency
1-3-4 Ote-machi, Chiyoda-ku
Tokyo 100-8122,
Japan

Internet: <http://www.kishou.go.jp/> (in Japanese)

Internet: <http://www.jodc.jhd.go.jp/inf/institute/jma/jma.html> (In English)

RUSSIAN FEDERATION

1. Organization

Sea-ice information services in Russia are provided by the center of ice hydrometeorological information at the Arctic and Antarctic Research Institute in St.Petersburg (AARI), and also by the Hydro-Meteorological Center in Moscow (Hydrometcenter) and eight local hydro-meteorological offices in the Arctic, all belonging to the Russian Federal Hydro-Meteorological Service (Roshydromet). AARI provides centralized services mainly for shipping and coastal and harbour activities within the Northern Sea Route, for the Central Arctic Basin and Arctic seas – Greenland, Kara, Laptev, Eastern-Siberian, Chukha as well as for the seas with the seasonal ice cover – Baltic, White, Bering, Okhotsk and also Antarctic seas.

2. Data acquisition

Coastal weather polar stations of Roshydromet make daily visual and instrumental ice observations on sea ice concentration and stages of ice development, ice thickness, forms of ice, ice drift etc. Icebreakers routinely report the same mentioned main ice parameters plus parameters describing ice navigation.

Before 1994 aircraft ice reconnaissance flights were conducted in the Arctic mainly on the monthly scale during interval between navigation (November-April) and on 10-days scale during navigation in summer. From 1995 air ice reconnaissance flights are conducted only occasionally during hydro-meteorological support of certain applied and scientific activities. Scope of ice information collected during air ice reconnaissance include visual observations both on main ice parameters (mentioned above excluding thickness and ice drift) as well as navigational ones as location, orientation and form of ice boundary, polynyas, leads, cracks and channels and additional ones as hummocks and ridges concentration, level of compacting, snow cover and ice contamination concentrations and stages of melting (in summer period). Airborne instrumental observations include radar (SLAR) images and radar thickness measurements. Collected data are fixed onboard by ice observer in log-books and in mapped form and further are used for sea-ice analysis at AARI or local meteorological offices.

AARI satellite reception station provides visible and infrared satellite images both from Russian (METEOR, OKEAN, RESURS) and USA (NOAA) satellites. OKEAN satellite also provides SLAR and passive microwave sounding data. All data are utilized for sea-ice analysis by AARI. Sample products received at AARI and station reception mask are available via AARI web page.

AARI, Hydrometcenter and the eight local meteorological offices of the Roshydromet exchange described sea-ice data by facsimile, telex and Internet and disseminate derived products to users. In the case AARI operational center lacks initial data to compile an ice map for specific area, necessary information is requested and if available, is obtained within several hours via communicational relays.

3. Output products

- (a) Common usage sea-ice condition charts of the Arctic and Antarctic are available via AARI web page for public usage weekly. Charts depict ice boundary and five classes of sea-ice concentration in summer period or stages of development (thickness) in winter period. Also supplied is a description on sea-ice movements in plain language. Sample sea-ice conditions charts for the Arctic and for the Antarctic are presented on fig.X-1 and fig.X-2 (Annex X).
- (b) Common usage numerical forecast charts of mean daily drift of sea ice, currents and level elevation for six days in advance are available on AARI web page for public usage weekly. Forecast charts are prepared on the basis of the output from thermo-dynamical and dynamical sea-ice models run at AARI. Sample sea-ice forecast charts for sea ice drift are presented on fig.X-3a and fig.X-3b (Annex X).
- (c) Detailed sea-ice conditions and forecast charts and coastal sea-ice information in plain language are prepared on request and/or on different time scales by AARI and local meteorological offices of Roshydromet and are disseminated to the authorities of local governments for disaster prevention, shipping companies, news media etc. Sample detailed sea-ice chart is presented on fig.X-4 (Annex X) for Pechora Sea.
- (d) From winter 1998/1999 AARI started to compile daily ice conditions charts for the Gulf of Finland, sample chart is presented on fig.X-5 (Annex X).

4. Publications

Following publications are issued by AARI with different periodicity:

- (a) “Trudi AANII” (AARI Transactions). 2-3 volumes are published per year.
- (b) “Problemi Arktiki i Antarktiki” (Problems of Arctic and Antarctic). 1-2 volumes are published per year.
- (c) Express information, informational bulletins of Russian Antarctic expedition, monographs etc.

Complete list of AARI publications from 1990 till present moment is available for common usage via AARI web page (in Russian).

5. Mailing and Internet addresses

Arctic and Antarctic Research Institute
38 Bering str., St.Petersburg, Russia, 199397

Telephone.: +7(812)352-1520

Telefax: +7(812)352-2688

e-mail: service@aari.nw.ru

Internet: <http://www.aari.nw.ru> (AARI main web page)

Internet: <ftp://aari.nw.ru> (AARI ftp-server)

North-east Atlantic and Baltic Sea areas

DENMARK

Two government institutions in Denmark issue sea ice information:

- (a) The Admiral Danish Fleet is responsible for the Danish Ice Breaking Service and ice information for the Danish Waters.
- (b) The Danish Meteorological Institute is responsible for sea ice monitoring and information for the Greenland Waters.

I. DANISH ICE SERVICE

1. Organization

The Danish Ice Service was transferred from the Danish Ministry of Commerce to the Danish Ministry of Defense in January 1996 and is now operated by Admiral Danish Fleet HQ situated in Århus. The Danish Ice Service consists of two parts; the ice reporting and the icebreaking services respectively. The Danish Ice Service is assisting navigation in Danish waters and harbors. The Danish Ice Service has four icebreakers and some icebreaking tugs at its disposal for icebreaking purpose. The Icebreaking Service collaborates closely with the German, Swedish and Finnish icebreaking services and all ships entering the area are subject to the same regulations concerning icebreaker assistance in all the countries. The Danish Ice reporting Service is distributing ice information daily (in English and Danish) by coastal radio station Lyngby. The information contains a short review of the ice and navigational conditions in Danish domestic waters.

2. Data acquisition

Visual surface observations are reported daily from approximately 140 ice observers, who reports the ice conditions for about 260 different sections in Danish domestic waters. Visual surface observations are typically received from harbor authorities, some ferries and all the ships of the Danish Navy including the Danish icebreakers. Satellite images or dedicated flight reconnaissance are not being utilized. Observers are reporting daily information concerning ice concentration, thickness, type and navigational conditions to Admiral Danish Fleet HQ.

3. Output products

- (a) Ice charts
Compiled ice charts (Annex III) are mailed as a weekly (or daily) annex to the Danish ice bulletin.
- (b) Coded information
Coded sea ice information from 48 areas in Danish waters is issued once a day in the Baltic Ice Code and is distributed by coastal radio station Lyngby by radiotelephony and radiotelegraphy. Coded sea ice information is also issued to Estonia, Finland, Germany, Latvia, Lithuania, Netherlands, Norway, Poland, Russia and Sweden daily by TELEX or TELEFAX. The specific waterways are identified by an alphanumeric code, nine districts of six areas each. The ice information is also mailed to various agencies and ship owners.
- (c) Plain language information
Sea ice reports – a description of the ice conditions at sea, operational areas for icebreakers - issued in Danish and English once a day are transmitted nation-wide through Denmark Radio and via coastal radio station Lyngby. The sea ice reports are also transmitted via TELEX or TELEFAX to the Baltic Sea countries once a day.

4. Forecasts

Forecasts are only given in qualitative form indicating, for example, that ice is likely to compact, grow or melt rapidly, drifting into the area or out of the area, etc. during the next 24 hours.

5. Statistics

No weekly or monthly summaries are issued. An annual publication indicating the number of frost days, freezing degree-days, etc. from selected stations and number of days with various ice types present at each reporting site is made. Further, the annual report may contain several statistics comparing various years.

6. Mailing address

Søværnets Operative Kommando
Istjenesten
Postboks 483
DK-8100 Århus C
DENMARK

Telephone: +45 89 43 30 99, +45 89 43 32 53 (Ice-Breaking Service and Ice-reporting Service)
Telefax: +45 89 43 32 30
Telephone answering unit: + 45 89 32 44.
Telex: 64527 SHIPPOS DK
e-mail: bk4@sok.dk (Attention: Danish Ice Service)

II. THE DANISH METEOROLOGICAL INSTITUTE

1. Organization

The Danish Meteorological Institute (DMI) is responsible for sea ice monitoring and information for the Greenland Waters. The purpose of the sea ice mapping is to aid navigation and to provide strategic and tactical support in the Greenland waters. The main areas of concern are the waters around Cape Farewell. Furthermore, the ice outside the Cape Farewell area is mapped in selected periods and regions, depending on navigational needs and the actual ice distribution.

DMI operates a two-branch ice service. At Narsarsuaq Airfield in South Greenland, the DMI Ice Observation and Warning Service, 'Ice Central Narsarsuaq' was established in 1959. A specially equipped Twin-Otter is permanently chartered for about 2½ months during the summer, when melt water on the ice surface complicates the interpretation of SAR images, while ship piloting and ice reconnaissance of the South Greenland inshore routes and the inner parts of the Julianehåb Bay is carried out year round by a dedicated helicopter. The ice observers - there are currently five of them - are all ships officers with a thorough knowledge of navigating in the

Greenland waters. They are on loan from the shipping company Arctic Umiaq Line (AUL). Four of the officers now serve at Narsarsuaq where a twenty-four-hour watch duty is maintained so that calls are answered and ice piloting can be provided at short notice. The fifth officer is now permanently stationed at DMI in Copenhagen.

The second branch, 'Ice and Remote Sensing Division', is located at the Danish Meteorological Institute in Copenhagen, Denmark. The launch of RADARSAT with its ScanSar Wide capabilities marked the beginning of a new era and satellite data are now the main data source for the production of ice charts for all Greenland Waters, except in the melt season (Cape Farewell). The mapping on satellite data takes place at DMI in close coordination with the office in Narsarsuaq. Also NOAA-AVHRR and to some extent DMSP-SSM/I are important data sources in the Ice Service. Satellite data are always analyzed by experienced and special trained ice analysts.

No ice breaking service is provided except for a few local arrangements. Ship piloting in ice covered waters is coordinated by Ice Central Narsarsuaq. Ships and shipping companies can order existing routine ice charting information free of charge, while special services (e.g. piloting or information requiring separate flights or additional acquisition of radar images) in principle are delivered against a marginal fee, unless there is an immediate safety risk. Special services for the offshore industry, among these are tactical and strategic support for seismic profiling, are always covered by fees.

2. Data acquisition

Visual observations from helicopter and visual/radar observations from aircraft. NOAA-AVHRR-, RADARSAT- and DMSP-SSM/I-imagery resampled, geocoded and displayed by special dedicated computers and software for sea ice mapping. Actual meteorological information (observations, model output) is utilized when analyzing the satellite data.

3. Output products

- (a) Ice charts for the Cape Farewell area are updated and issued 3-4 times a week when sea ice occurs. Outside the melt season a new ice chart is published once a week
- (b) Ice charts, primarily based NOAA-AVHRR and RADARSAT, for other areas in Greenland are produced 1-6 times weekly depending on the actual ice situation and navigational needs.
- (c) Ice conditions near or in shore ship routes in South Greenland are mapped on a weekly basis.
- (d) A weekly summary chart for all Greenland waters is published once per week.
- (e) Ice charts follow international standards (Egg code) and are published by use of telefax, INMARSAT, facsimile and Internet. Further, ice information is broadcasted by radio, radiolinks, telex, telephone and mail. Samples of output products are in given in Annex III.

4. Forecasts

No forecasts are given.

5. Publications

No weekly or monthly summaries are prepared.

6. Mailing and Internet addresses

Danmarks Meteorologiske Institut
Lyngbyvej 100
DK-2100 Copenhagen
DENMARK

Iscentralen Narsarsuaq
3923 Narsarsuaq
GREENLAND

Internet: <http://www.dmi.dk> (DMI main page)

Internet: <http://www.dmi.dk/vejr/gron/iskort.html> (ice charts)

Internet: <http://iserit.greenet.gl/isc/ice/> (ice charts)

e-mail: isc@greenet.gl

ESTONIA

1. Organization

Estonian Meteorological and Hydrological Institute (EMHI) is responsible for the sea-ice information service in Estonia. The service is in particular intended to meet the needs of international and Estonian shipping services. Service is also given to all other activities, where sea-ice information is required, in particular: fisheries, coastal and harbour activities, meteorological forecasting and climatology.

The ice service in the Baltic begins at the end of October, when ice starts to form, and lasts until the end of May.

2. Data acquisition

Daily ice information reported in Baltic Sea Ice Code, from 16 stations, which are situated along the Estonian coast.

In addition to the daily coded information each station send some information about thickness of fast ice with the depth and density of snow cover on it. Most observations are visual.

EMHI at present receives satellite pictures from NOAA and METEOR, the last one operates only in the visual band, so useful information can be received from mid-February onward. Satellite images are used in preparing the composite ice charts, which are distributed to users.

By special agreement the coastal guard carries out ice reconnaissance by aircraft.

All meteorological information, such as observations, weather charts, forecasts, are received from the weather service of the EMHI.

Ice information in Baltic Sea Ice Code is received daily via GTS from Finland, Germany, Norway, Poland, Sweden, Latvia, Lithuania, and Russia. Ice charts are received by facsimile from Finland, Germany, Sweden, and Russia.

3. Output products

- (a) Ice charts:
 - (i) The ice bulletin/chart covers the Gulf of Finland, Gulf of Riga, the northern part of Baltic;
 - (ii) Proper, the Irben Strait;
 - (iii) The actual chart contains ice information, sea-surface isotherms of wave height;
 - (iv) The symbology used on actual charts is common for all countries around Baltic sea and is printed on the chart.
- (b) Coded information

A complete listing of Estonian areas in the Baltic Sea Ice Code is issued daily and sent by GTS to Riga.
- (c) Plain language information:
 - (i) Sea-ice bulletin - a description of the ice situation at sea, restrictions to navigation, - is issued in Estonian and English and daily sent by fax to Sweden, Latvia, Lithuania, Russia;
 - (ii) Ice report, ice chart and ice forecasts are distributed daily by fax to users (approximately 20);
 - (iii) Similar bulletin is issued in Estonian once daily by Estonian Radio.

Sample ice chart is given in Annex IV.

4. Forecasts and forecast methods

Generally one-day forecast: ice forecast for next day is provided on a daily basis. The forecast describes in general terms the expected ice development such as ice drift, opening of leads, areas with ice pressure, ice formation or melting. The ice forecast is published daily in the printed ice bulletin.

Ice information forecast includes: date of ice formation, freeze-over, break-up and ice disappearance up to 30 days in advance. The predictions are produced by statistical methods.

5. Publications issued

Table of sea-ice observation from shore stations are prepared as internal reports of EMHI, but not published.

6. Mailing address

Estonian Meteorological and Hydrological Institute EMHI
Rävala 8
EE - 0001 Tallin
Estonia

Telephone +372 6461561
Telefax +372 6461577
e-mail: emhi@online.ee

FINLAND

1. Organization

Institution providing sea services: Finnish Institute of Marine Research.

2. Data acquisition

(a) Sea ice.

Ground truth input data: Daily Finnish and Swedish icebreaker reports in plain language, daily or weekly coastal stations rapport in plain language, ice charts over observation areas and ice and snow thickness profiles, daily or weekly reports from ships in plain language. Air-borne input data: annually 20-30 visual reconnaissance flights by fixed-wind planes with hard-copy map output delivered to the Finnish ice service, daily or weekly Finnish icebreaker-based helicopter visual reconnaissance flights with hard-copy map output delivered to the Finnish ice service. Space-borne: All NOAA AVHRR passes in 1.1 km resolution. 100 RADARSAT ScanSAR Narrow screens a winter in 100 m resolution.

(b) Sea surface temperatures.

Ground truth input data: Twice a week measurements from 20-30 coastal stations, automatic stations, icebreakers, 20-30 merchant vessels with hull thermometers measuring along track covering the Baltic Sea. Air-borne input data: Annually 20-30 visual reconnaissance flights by fixed-wind planes with infrared soundings along the track. Space-borne input data: NOAA AVHRR.

3. Output production

Ice charts are issued daily during the ice season. On Mondays and Thursdays also SST included. Charts are telefaxed (hard copies) or e-mailed (soft copies) to the users daily. On Mondays and Thursdays also mailed. Charts are available 24 h a day via Call-fax.

Type of chart: (scale, areas, others): Mercator projection, Baltic Sea north of 58°50'N. If sea ice is present more in the south charts cover the whole Baltic Sea, Kattgat and Skagerrak to 53°30'N and 7°00'E. Simplified ice chart over the Baltic sea is issued once a week at <http://ice.fmi.fi/tilanne.html>

Coded and/or plain language information issued: WMO ice chart symbols and egg-codes. Restrictions to navigation. On Mondays and Thursdays 30-year average ice extent and mean ice thickness and 30-year mean SST.

Bulletins on ice conditions in the Baltic Sea (mailed, broadcasted, telefaxed on request): Finnish Ice Report in plain language in Finnish, Swedish and English and in the Baltic Sea Ice Code broadcasted, mailed, telefaxed, telefaxed by Call-fax, coastal radio stations on daily basis. Mailed on weekdays only.

Other information products: Digital satellite images and SAR automatic classifications (special equipment are needed).

Sample ice chart is in given in Annex V.

4. Forecasts and forecasting methods

- (a) Forecast methods: Ice drift model (Finnish-Chinese). Thermodynamic model (Finnish-Chinese);
- (b) Forecasts are provided for: the Baltic Sea, 72 hours.

5. Publication issued

- (a) Regularity: in 5-year intervals;
- (b) Irregularly.

6. Mailing and Internet addresses

Finnish Institute of Marine Research
 Finnish ice service
 P.O. Box 304
 FIN-00181 HELSINKI
 FINLAND

Telephone: +358 9 6857659
 Telefax: +358 9 6857638 or 6857639
 call-fax: +358 60018668
 e-mail: info@ice.fmi.fi
 Internet: <http://ice.fmi.fi>

GERMANY

1. Organization

The ice service provided by the Federal Maritime and Hydrographic Agency (BSH), the former Hydrographic Institute (DHI), covers the German Bight and the Baltic Sea west of Bornholm during the winter. The institute is separate from the Meteorological Service but both are part of the Ministry of Traffic. Radio transmission of ice reports and a daily facsimile broadcast of ice charts are provided for fisheries, national and international shipping in the Baltic Sea and for harbour activities, maritime agencies and off-shore activities. An overall ice report for the whole Baltic Sea and the southeastern North Sea with relevant ice charts is offered to subscribers via mail, telefax, e-mail and WWW. On request world wide ice information is provided.

2. Data acquisition

Daily ice information is reported in Baltic ice code from 133 areas or fairway sections along the coast of the southwestern Baltic Sea and the German Bight. A selection of these form 56 main areas or fairways grouped in 11 districts. Details are given in WMO No. 9, Volume D - Information for shipping. In addition to the coded information a great many stations perform ice-thickness measurements. The other data sources are observations from regular aerial reconnaissance, icebreakers and merchant ships, reported in plain language, and, to increasing extent from satellite visual/infrared and SAR imagery. Reports, data and charts are also exchanged with foreign ice services via mail, telefax and e-mail, and via telex (GTS) transmission of plain language reports and coded data. WWW access to ice information products of foreign services is largely used.

3. Output products

- (a) Ice charts
 - (i) A printed ice chart, print scale - depending on the ice extent - either approximately 1: 3.150.000 or 1: 4.100.000 (Mercator projection) of the ice conditions in the Baltic Sea using the international system of sea-ice symbols is mailed, telefaxed and e-mailed twice weekly and presented on WWW,
 - (ii) A printed ice chart, print scale 1: 2.250.000 (Mercator projection), showing ice conditions in the western Baltic and German Bight using the international system of sea-ice symbols is mailed, telefaxed and e-mailed three times a week when ice is present, and shown on WWW,

- (iii) A facsimile broadcast of the data in (ii) is made daily when ice is present using a Mercator chart scale 1:3.400.000,
- (iv) A facsimile broadcast is made daily in spring and early summer showing ice edge in the western Atlantic and iceberg limits provided by IIP using a Mercator chart, scale 1:11.800 000.

Notice: Charts (i) - (iii) are constructed with the digital ICEMAP programme. Larger scale (appr. 1:850.000) sub-regional charts are prepared at need.

Sample ice chart is given in Annex VI.

(b) Coded and plain language information

- (i) A bulletin describing ice conditions in the Baltic Sea using plain English and German language and the Baltic ice code is mailed, telefaxed, e-mailed and presented on WWW Monday to Friday. An ice outlook for four to six days is included,
- (ii) Similar bulletins covering the western Baltic and the German Bights are prepared daily in English and German for telex (GTS) and radio relays as well as for distribution via mail, telefax and e-mail and for presentation on WWW.

4. Forecasts

Forecasts of the date of formation of new and young ice are provided for the western Baltic using thermodynamic methods. The analogue method is for the decay of ice. Models run on an experimental basis.

5. Publications

A publication on the ice season is presented regularly in *the Deutsche Hydrographische Zeitschrift*. Other publications are prepared only at irregular intervals.

6. Mailing and Internet addresses

BSH – Eisdienst
Postfach 301220
20305 Hamburg

Telephone: +49 40 3190 3290
Telefax: +49 40 3190 5032
e-mail: ice@bsh.d400.de
Internet: <http://www.bsh.de> (in German/English)

ICELAND

1. Organization

The Icelandic Meteorological Office provides all sea ice information services in Iceland. The Icelandic sea ice service covers Icelandic waters, defined by the ocean area inside the limit of the economic zone around Iceland.

2. Data acquisition

Sea ice in Icelandic waters is mainly encountered in the eastern side of the Greenland Strait (Denmark Strait) between Iceland and Greenland and in the Iceland Sea north of Iceland.

Visual observations are collected from lighthouses and coastal meteorological stations, and both visual and radar observations from ships at sea.

Aerial reports, both visual and radar, are made by Icelandic Coast Guard ice reconnaissance aircraft and ice is also reported by commercial aircraft.

Satellite imagery is also received and integrated into the charts. These are mainly NOAA visible and infrared images received many times a day at the forecast department of the Icelandic Meteorological Office. Further, sea ice charts are received from abroad. Ice charts and satellite imagery on the internet is also utilized.

3. Output products

Ship reports are prepared for display on Internet, as well as Icelandic Coast Guard sea ice charts giving ice edges and, when available, concentration and stage of development. The area covered is variable within 65-69 N and 11-28 W. Information on the position of ice edges is sent to ships by Navtex. Ice charts are sent to customers and other ice centers by fax. An information web page is being developed.

4. Forecasts

Regular, formal ice forecasts are not prepared. However, probability statements on future sea ice movements and changes in sea ice extent are made available on request or made public through news media.

5. Publications

A monthly summary is prepared and included in a climatic bulletin issued by the Icelandic Meteorological Office.

An annual report - Sea Ice off the Icelandic Coasts - is also issued in Icelandic and English.

6. Mailing and Internet addresses

Icelandic Meteorological Office
Bustadavegur 9
IS-150 Reykjavik
Iceland

Telephone: +354 560 0600

Telefax: +354 552 8121

Internet: <http://www.vedur.is>

LATVIA

1. Organization

The sea-ice services are provided by the Latvian Hydrometeorological Agency (LHMA). LHMA is subordinate to the Ministry of Environmental Protection and Regional Development.

The collection, processing and dissemination of operational sea-ice information as well as ice forecasts are carried out for the Gulf of Riga and the Latvian economic zone in the Baltic Sea. The ice season in the region begins in November-December, when ice starts to form in the northern Gulf of Riga and in the Bay of Pärnu. The season lasts until the complete decay of the ice in April-May.

The major users of sea-ice data are the Latvian Maritime Administration, local port authorities, the Latvian Shipping Company, fishing industry and also various institutions and services involved in operations at sea. All the users are provided with the data and forecasts under bilateral agreements or on request.

2. Data acquisition

The principal data sources are coastal observations and satellite data (visual and infra-red imagery).

Visual sea-ice observations are made daily at 06 GMT during the season by the LHMA's regular coastal hydrometeorological network of 10 stations on the Baltic coast and in the Gulf of Riga. The ice observation data (concentration, development stages, topography, motion of pack ice, extent and thickness of fast ice with the depth of snow cover on it) accompanied by records of sea level, wind, wave, air and water temperatures are transmitted, using the regional code, via a telex to the seat of LHMA in Riga. In addition, some Latvian Shipping Company's cargo ships report ice conditions in plain language. Daily ice reports, both coded and in plain language, are received from Finland, Sweden, Germany and from the bordering countries - Estonia, Russia and Lithuania. In addition, ice charts covering all the Baltic Sea regions from Sweden and Germany, ice bulletins from Germany (by fax) and from Poland (by mail) are received as well.

Since the 1996/97 ice season the NOAA satellite images received by a russian made SCANEX HRPT receiver are operationally used in preparing of ice reports and ice charts of the Gulf of Riga and adjacent Baltic Sea waters.

Visual aerial observations are made on special occasions only.

3. Output products

(a) Coded and plain language information

After the transformation of all data received at the moment into the Baltic Sea Ice Code, daily the coded and plain language (English) are transmitted via the GTS circuit Riga-Norrköping. The data refer to the main fairways, harbour approaches and harbours (see a map with the fairway sections and areas for Latvian ice reports). The plain language (Latvian) reports of the ice conditions are also provided to the main customers or on request. Compiled ice bulletins on Baltic Sea ice conditions in English are sent daily to local customers.

A brief description of the actual ice conditions is included in the LHMA's hydrometeorological bulletin issued five times a week (on weekdays). Occasionally brief reports are made on the public radio and TV.

(b) Ice charts

Compiled ice charts for the Gulf of Riga and for the Latvian territorial waters in the Baltic Sea are prepared one to three times a week during the ice season (see a sample chart, Annex VIII). The major information sources for the charts are the coastal observations and satellite data. The charts typically contain information on the date of the observation, ice edges and concentration boundaries, ice thickness, data on actual ice conditions in the main Latvian harbours. The charts are printed for mailing or faxing to the main national users. No free facsimile broadcasts are made.

Sample ice chart is in given in Annex VIII.

4. Forecasts

Outlooks of the expected ice development in the Gulf of Riga with a lead time of up to 3-4 days based on the meteorological forecasts are included in the daily local ice reports.

Monthly ice forecasts for the Gulf of Riga and the Latvian economic zone in the Baltic Sea based on the analogous and statistical analyses and monthly meteorological forecasts are made during the ice season.

5. Publications

No weekly summaries are made. Short monthly summaries in Latvian are included in the LHMA's monthly reports. The seasonal summaries are prepared and published both in Latvian and English in the LHMA's Annual Reports in case of severe winters mainly.

6. Mailing address

Latvian Hydrometeorological Agency
165, Maskavas Str.
LV- 1019 Riga
Latvia

LITHUANIA

1. Organization

At present there are two subdivisions of the Ministry of Environment involved activity on sea-ice information: Centre of Marine Research (CMR) and the Klaipeda Department of the Lithuanian Hydrometeorological Service (LHMS). The Centre of the Marine Research, besides the other observation units on sea hydrology, includes three sea-ice observation posts. Daily observation data of the mentioned institution are promptly transmitted to the LHMS Klaipeda Department. From here data exchange is being conducted with hydrometeorological services of foreign countries. Data on sea-ice observations are accumulated and shelved as well as analysed in the Centre of Marine Research.

Referring to CMR data on sea-ice and including extra information the Klaipeda Department of the Lithuanian Hydrometeorological Service provides information and advises on sea-ice state as well as on navigation conditions in the Baltic sea according to consumers' request.

2. Data acquisition

There are three sea-ice observation posts in the Lithuanian coastal area. Observations are started with ice appearance and continued until full ice break. The ice state in the ice observation posts is observed daily at 8 a.m. of local time. At later day break observation time is being changed transferring it closer to noon. Under the circumstances of poor visibility when the sea surface is poorly visible or invisible at all, the observations are repeated after the visibility has improved.

The following basic sea-ice characteristics are determined during observations:

- (a) The range of the sea surface vision;
- (b) The sea-ice width and limits, area of ice-free water;
- (c) The fast ice and pack ice amount, concentration and limits;
- (d) The area of ice-free water;
- (e) The ice forms, ice types;
- (f) Ice decomposition;
- (g) Ice pollution;
- (h) Snow amount on ice;
- (i) Pack ice compactness, ice direction and velocity;
- (j) Extra characteristics of ice cover state;
- (k) Ice thickness measurements.

The sea-ice state as a result of observations is being outlined in diagrams. The daily express information on sea-ice from posts is sent by telegrams to the LHMS Klaipeda Department.

To ensure safe navigation in the Baltic Sea the LHMS Klaipeda Department picks up the following information:

- (a) CMR daily sea-ice observation data in the Lithuanian Baltic Sea coastal area;
- (b) Daily sea-ice observation data in the Latvian Baltic Sea coastal area and Gulf of Riga from Latvian Hydrometeorological Agency;
- (c) The sea-ice report of Estonian Hydrometeorological Institute in the Estonian coastal area Baltic Sea and Gulf of Riga;
- (d) The sea-ice report Russian Hydrometeorological Service in the Gulf of Finland;
- (e) The sea-ice report of the Hydrometeorological Service of Finland in the Bothnia sea and Bothnian Bay and Gulf of Finland;
- (f) Monthly sea-ice forecast from Latvian Hydrometeorological Agency in the Irben Strait and Gulf of Riga;
- (g) All available information on sea-ice distribution and development received from fishing-boats and merchant vessels entering Klaipeda seaport;
- (h) Sea-ice map on ice situation in the Baltic Sea and Belt from Swedish Meteorological and Hydrological Institute broadcasted through Germany;
- (i) The sea-ice report taken during air survey over Lithuanian economic zone in severe winters.

3. Output products

LHMS Klaipeda Department is publishing the information on sea-ice in the Lithuanian coastal zone in daily marine bulletin. Under request of ship owners and masters, according to the information available, they are consulted and the maps are provided on sea-ice situation in the following parts of the Baltic:

- (a) In the Gulf of Riga (sailing to Riga port);
- (b) In the Gulf of Finland (sailing to St. Petersburg);
- (c) In the Belt sea (sailing to the North Sea and Atlantic Ocean).

4. Forecasts and forecasts methods

In addition to the sea-ice observations and information on sea-ice distribution the Centre of Marine Research and LHMS Klaipeda Department also carry on observations and forecast ice situation in the Curonian Lagoon.

The Curonian Lagoon is very closed fresh water basin connected by narrow (600-800 m width) strait with Baltic. The main Lithuanian river Nemunas falls into this lagoon. The northern part of the Curonian Lagoon depends to Lithuania. This part is significantly influenced by Baltic Sea waters during storms of autumn-winter season, and the ice formed, often has the sea-ice properties.

There are three ice observation posts in the Lithuanian port of the Curonian Lagoon. Daily express information on ice situation from there is received by LHMS Klaipeda Department. This Department provides forecasts-warnings to shipping and fishing companies on following items:

- (a) Information on formation of the new ice forms;
- (b) Information on fast ice formation and total freezing of the lagoon;
- (c) Information on ice break out;
- (d) Information on total ice-break.

5. Mailing and Internet addresses

CMR
Taikos str. 26, 5802 Klaipeda,
Lithuania

tel. (+ 3706) 250324
fax (+ 3706) 250930
CMR@klaipeda.omnitel.net

LHMS Klaipeda Department
Taikos str.26, 5802 Klaipeda,
Lithuania

Telephone (+ 3706) 252247;
Telefax (+ 3706)2 52247;
e-mail. khmo@klaipeda.aiva.lt

NETHERLANDS

1. Organization

Institution providing sea services: Rijkswaterstaat / Riza

2. Data acquisition

Daily ice information reported in Baltic Sea Ice Code. Number of areas, regions, stations: areas: 10 stations national.

Other sources of information: NOAA Satellite, governmental ships. Data exchanged with foreign services daily, via GTS: by fax.

Ice charts are received from Sweden and Germany.

3. Output products

- (a) Ice charts are issued daily in ice seasons. Mailed and telefaxed to the users via telefax and mail.
- (b) Type of ice charts: areas
- (c) Coded and/or plain language information issued: report in Dutch and English.
- (d) Conditions in the Baltic Sea: ships, telefaxed.
- (e) Ice bulletins covering other areas: waters at Dutch / German border.

4. Forecasts and forecast methods

Forecasts are provided for: Netherlands, coastal waters for 24 hours.

5. Publications

Regularly.

Irregularly: season

6. Mailing and Internet addresses

Rijkswaterstaat / Riza
Information and Warning Centre
Postbox 17
8200 AA Lelystad
NETHERLANDS

Telephone: +31 320 298550, +31 320 298888

Telefax: +31 320 298580

e-mail bc@riza.rws.minvenw.nl

NORWAY

1. Organization

Institution providing sea services is DNMI (Norwegian Meteorological Institute). Information for the Oslo-Skagerrak area is provided by the Norwegian coast Directorate.

2. Data acquisition

Daily ice information during ice season from the Oslofjord-Skagerrak area is reported in Baltic Sea Ice Code.

Ice service receives ice information from Jan Mayen, Bear Island and Hopen in a code proposed for WMO from 1971 and ship observations.

Other sources of information:

- (a) AHVRR + SSM/I available;
- (b) Data exchanged with foreign services daily, via GTS;
- (c) Ice charts are received: dissemination day is Tuesday.

3. Output products

- (a) Ice charts issued weekly through the whole year. Mailed and telefaxed to the users via mail and telefax. Ice positions on telex. Type of Ice charts European Arctic 1:7,5 mill.
- (b) Coded and/or plain language information issued.
- (c) Bulletins on ice conditions in the Baltic Sea
- (d) Ice bulletins covering other areas: for Spitsbergen: some info in plain language.

4. Forecasts and forecast methods

Forecasts are provided for experimental forecast model.

5. Publications issued

Regularly.

Irregularly.

6. Mailing and Internet addresses

Vervarslinga for Nord-Norge
Postboks 2501
9002 Tromsø
Norway

telephone: +47 77 68 40 44
telefax: +47 77 68 90 04
Internet: <http://www.dnmi.no>

POLAND

1. Organization

The Ice Service is provided by the Institute of Meteorology and Water Management, Maritime Branch (Instytut Meteorologii i Gospodarki Wodnej, Oddział Morski), Hydrological/Ice Section of Maritime Weather Office in Gdynia - and covers Polish waters.

The Service is provided for all marine activities (fisheries, navigation, drilling, harbors).

2. Data acquisition

Visual data are collected from 35 coastal stations and ships. Aerial reconnaissance is made only under very severe ice conditions.

The use of satellite data has just begun.

Details on 21 coastal stations are listed in WMO-Publication No.9. Vol.D - Information for Shipping.

Data are also exchanged with foreign ice services via GTS, telex, fax and mail.

3. Output products

A coded ice report is broadcast daily by Gdynia Radio on ice conditions in Polish waters. Plain language report is also provided in Polish and English.

Ice charts (scale 1:4400000 in conic projection) of the whole Baltic Sea, the Kattegat and Skagerrak are prepared twice a week (Tuesday, Friday) in the ice season for distribution by messengers and mail (by fax on request). Sample chart is given in Annex IX.

Ice bulletins are prepared three times a week for distribution by messenger and mail giving plain-language report on ice conditions in Polish waters and coded reports from all the Baltic countries.

Ice bulletin in plain-language (Polish) giving ice conditions in the Polish waters, is prepared daily from Monday to Friday during the ice season for distribution by messenger and mail. It includes coded reports for the open Baltic Sea and coastal waters of all the Baltic countries.

4. Forecasts and forecast methods

A 35-hour ice forecast for Polish waters is included in the ice bulletins. It uses subjective dynamical methods and the forecast of meteorological conditions.

5. Publications issued

Descriptive summaries of sea-ice conditions are published by the Maritime Branch in Gdynia in the year-book containing hydrological and oceanographic data.

6. Mailing and Internet addresses

Instytut Meteorologii i Gospodarki Wodnej, Oddział Morski
Waszyngtona 42,
PL 81-342 GDYNIA
Poland

Telephone: +48 58 6205221 (operator), +48 58 6201641 (ice team 06-14Z)
Telefax: +48 58 6205493
e-mail: pga@stratus.imgw.gdynia.pl
Internet: <http://www.imgw.gdynia.pl/>

SWEDEN

1. Organization

The Swedish Meteorological and Hydrological Institute (SMHI) is responsible for the sea-ice information service in Sweden. The service is intended to meet the needs of international shipping and the activities where sea-ice information is required, in particular fisheries, coastal and harbour activities, meteorological forecasting and climatology. The ice season in the Baltic begins at the end of October, when ice starts to form in the northernmost archipelagoes of the Bay of Bothnia and lasts until the end of May or beginning of June.

2. Data acquisition

Daily ice information is reported in the Baltic Sea Ice Code from 337 areas or fairway sections along the Swedish coast. A section and/or combination of these form 129 main areas or fairways grouped in 19 districts. Details are given in the WMO Publication No. 9, Volume D - information for shipping.

Icebreakers report on the ice situation is obtained four times a day in plain language. An irregular number of ships provide information at their own initiative or upon request when not assisted by icebreakers. The information is given in plain language via telex or fax. WMO codes are not used.

Helicopter ice reconnaissance is carried out by icebreaker deck officers and ice charts are transmitted to SMHI by fax via mobile telephone. Normal area of coverage is approximately 40x60 Nm. No regular ice reconnaissance by fixed-wing aircraft is carried out by SMHI. At present SMHI receives AVHRR images from NOAA satellites. Radarsat (mainly ScanSAR Narrow) is used periodical.

All meteorological information such as observations, weather charts, forecasts etc. is received from the weather service of the SMHI. Ice information in the Baltic Sea Ice Code and in plain language is received daily via the GTS from Denmark, Estonia, Finland, Germany, Latvia, Lithuania, Netherlands, Poland and Russia.

3. Output products

(a) Ice charts

All ice charts are in Mercator projection and cover the Gulf of Bothnia, the Baltic Proper, Gulf of Finland, Gulf of Riga, the Sound and the Belts, Kattegat and the Skagerrak.

The scales are at 60°N 1:2 000 000 on the Facsimile chart (northern and southern Part due to ice extension) or 1:4 000 000 (whole area).

Ice charts are issued daily in ice season and transmitted by telefax, e-mail or Internet and mail (twice a week). The Swedish ice chart is retransmitted once a day on radiofacsimile by the German stations Hamburg/Pinneberg, Offenbach/Mainflingen.

The ice chart can also be provided to vessels by mobile fax or e-mail on request. Sample ice chart is given in Annex XI.

(b) Ice report or ice bulletins.

Coded and /or plain language. A sea ice bulletin – a description of the ice situation at sea, restrictions to navigation, operational areas for icebreakers – is issued in English twice daily from coastal stations and by Navtex and once daily by the GTS or telex to Baltic countries. Coded sea-ice information from 129 areas or fairways in the Baltic Sea Ice Code is included on GTS. An abridged bulletin is issued in Swedish once daily by Swedish Radio Broadcast.

A printed sea-ice bulletin – as above is issued in Swedish and English during weekdays and sent by mail, E-mail, Internet or telefax to subscribers.

4. Forecasts and forecasts methods

General five-day forecasts: ice forecasts for subsequent five days are provided for the icebreaking service on a daily basis. They describe in general terms the expected ice developments such as ice drift, opening of leads, areas with ice pressure, ice formation or melting. The ice forecast is published in the printed ice bulletin twice a week.

Ice-formation forecasts: the forecasts are based on two kinds of models. The first one predicts water cooling due to net heat loss and turbulent mixing. The model is based on transient Ekman dynamics with buoyancy effects due to temperature and salinity in their one-dimensional form and with turbulent exchange coefficients calculated with a kinetic energy-dissipating model of turbulence.

The second one predicts expected coverage of ice (in percent). The model is based on statistical correlation between the ice extension, air temperature and wind.

Ice dynamics forecasts: The forecasts are based on dynamically methods and are run on the institute's computer using the numerical weather forecast as input. The parameters of forecasts are: ice drift (direction and speed), ice concentration (in percent), changes in ice concentration, ice deformation.

5. Publications

A monthly summary with meteorological, oceanographical and hydrological conditions is published.

Furthermore a summary of the ice season, including a description of the ice development month by month, illustrated by ice charts. It gives a statistical summary of selected fairways, a weather summary and sea-surface temperature statistic. It also includes a summary of the ice-breaking activities.

6. Mailing and Internet addresses

Swedish Meteorological and Hydrological Institute, SMHI.
Marine Service
S - 601 76 Norrköping
Sweden

Telephone: +46 (0)11 495 8400
Telefax: +46 (0)11 495 8403
e-mail: ice@smhi.se
Internet: <http://www.smhi.se> (main web-page)
Internet: <ftp://ftp.smhi.se> (ftp-server)

UNITED KINGDOM

1. Organization

Since the last issue of the WMO publication "Sea ice Information Services of the World" the UK Met Office has stopped producing routine sea ice analyses. No sea ice information is available.

2. Mailing address

OPR, Meteorological Office
London Road
Bracknell, Berks
RG12 2SZ

Telephone: 44-1344-856647

North America

CANADA

1. Organization

The Canadian Ice Service, a division of the Department of Environment, is a centre of expertise for ice related information for all of Canada and its surrounding waters. The Ice Service co-operates closely with the Canadian Coast Guard, which operates Canada's fleet of icebreakers to assist marine transportation in Canadian waters.

The Canadian Ice Service promotes safe and efficient maritime operations and protects Canada's environment by providing reliable and timely information about ice conditions in Canadian waters. For example, the Ice Service provides timely warnings of icebergs and ice conditions that pose immediate threats to ships, ports and other marine operations; advises on ice conditions in shipping routes for navigators; provides information to help shipping, fishing and offshore operators plan their seasonal operations in a safe and efficient manner.

To meet its mission, the Canadian Ice Service collects and analyses data on ice conditions in all regions of the country affected by the annual cycle of pack ice growth and disintegration. In summer, the focus is on conditions in the Arctic and the Hudson Bay region. In winter and spring, attention shifts to the Labrador Coast and East Newfoundland waters, the Gulf of St. Lawrence, the Great Lakes and St. Lawrence Seaway.

Major users of Ice Service products and services are:

- (a) The Canadian Coast Guard uses weather and ice information for marine safety, icebreaking operations and efficient marine transportation;
- (b) Port authorities obtain site-specific information on current and long-term ice conditions in ports and shipping routes;
- (c) The commercial shipping industry uses ice information for strategic and tactical vessel passage planning;
- (d) Fishing fleets obtain enroute and on-site ice conditions for ice-encumbered areas;
- (e) The offshore oil and gas companies use iceberg and sea ice information for exploration and production, both on-site and in transit;
- (f) The marine construction industry uses site-specific current and historical data for offshore and onshore projects, such as bridges and port facilities;
- (g) The tourism industry gets technical and general information for the operation of cruise ships and the enjoyment of passengers;
- (h) The marine insurance industry uses ice information for risk assessment for offshore operations affected by ice;
- (i) Environmental consultants use ice data, analyses and expert advice for environmental impact assessments;
- (j) Research scientists use ice information relating to research on transportation, construction, climate change, meteorology, oceanography, biology and socio-economic impacts.

The Canadian Ice Service operates a comprehensive ice information service, encompassing reconnaissance, analysis and forecasting, ice climatology, data archiving, informatics support and research and development. It has a staff of approximately 80 people working at the Ice Centre in Ottawa, aboard Coast Guard icebreakers and in field offices.

2. Data acquisition

Radar imagery from aircraft and satellites is the principal data source, augmented by visual observations from fixed-wing aircraft and helicopters. Radarsat synthetic aperture radar (SAR) data provides extensive and detailed (up to 30 metres) coverage of ice conditions. Covering the Arctic in one day and the rest of Canada every three days, Radarsat transmits cloud-free radar images of the surface to two Canadian receiving stations. From there, the data are processed and delivered to the Canadian Ice Service and disseminated to marine users within hours. Some SAR data from the European Space Agency's ERS satellites is also used.

The Ice Service operates one aircraft with side-looking airborne radar (SLAR) exclusively for ice reconnaissance. The aircraft is outfitted to facilitate visual observation to complement the radar. It is equipped with telecommunication technology that allows transmission of data to Coast Guard icebreakers and regional ice offices and to the Ice Centre in real time. The aircraft also transmits ice charts by facsimile to commercial ships. Visual and infrared imagery from the U.S. NOAA TIROS and DMSP satellites are also used extensively in the ice analysis program.

Experienced ice observers are stationed on many of the Coast Guard icebreakers and in regional ice offices. They conduct local visual reconnaissance by helicopter, which are transmitted to the Ice Centre within hours of the flight.

The Canadian Ice Service is integrated with the national meteorological network and has access to the necessary meteorological and oceanographic inputs. Co-operation with research institutes, universities and other federal departments also provide other valuable data.

3. Output products and forecasts

The Canadian Ice Service provides its clients and the Canadian public with a variety of accurate and timely analyses and forecasts of ice conditions ranging from daily bulletins on ice hazards to seasonal outlooks. Information on ice conditions posing immediate threats, such as ice hazard bulletins and special warnings for ships, are directly available from the Ice Service web site and through weather and marine radio broadcasts.

Ice information products and services are provided in those areas of Canada's waters where there is marine activity in the vicinity of sea ice. Arctic areas are active from June to November while southern areas, including the Gulf of St. Lawrence and the Great Lakes are active from December to May.

Specialized products and services to meet the short-term tactical and longer-range planning needs of clients are also available. These products include detailed ice analysis charts, radar and satellite imagery, image analysis charts, and special forecasts covering days to months. These products are distributed in a variety of formats, including mail, e-mail, fax, and Internet.

The Ice Service provides a variety of field services, normally through the Coast Guard, for clients who need specialized ice information. Tactical support is supplied by specially equipped reconnaissance aircraft that collect data on ice and iceberg conditions. Ice Service Specialists provide field support to clients on shore and aboard ships, with direct analysis of ice conditions and special visual observations. Customized aerial reconnaissance services are also available for clients requiring ice information in specific areas. Depending on the client's needs, radar imagery and other ice information collected on reconnaissance flights can be transferred directly to a client's vessel or shore facilities.

The Canadian Ice Service has expertise in ice modelling, remote sensing and climatological ice conditions in and around Canada. It supports research and development by scientists working in government, universities and the private sector. Drawing on the Canadian Ice Service national ice data archive, ice analysts work directly with clients to identify and analyze appropriate climatological ice information and provide advice on historical ice and iceberg conditions.

(a) Ice charts

Ice charts graphically illustrate ice or iceberg conditions at a particular time, presenting data in the WMO ice code. Charts may be used for strategic and tactical planning. Charts available from the Canadian Ice Service include:

- (i) Regional Weekly Ice Charts;
- (ii) Daily Iceberg Analysis Charts;
- (iii) Daily Ice Analysis Charts;
- (iv) Ice Reconnaissance Charts;
- (v) Radarsat Image Analysis Charts.

(b) Bulletins

Bulletins provide advice on present and forecast ice or iceberg conditions in simple text format. The following bulletins are available from the Canadian Ice Service:

- (i) Daily Ice Hazard Warning Bulletins;
- (ii) Daily Iceberg Bulletins;
- (iii) NAVTEX ice bulletins;

- (iv) Daily St. Lawrence River Ice Bulletins;
- (v) 30-day Ice Forecast Bulletins every 2 weeks;
- (vi) Seasonal Ice Summary;
- (vii) Seasonal Ice Outlook.
- (c) Images

In preparing the charts and bulletins, the Canadian Ice Service uses airborne-radar and satellite data collected from its network of aircraft and satellites. Raw images are available to users depending on their ability to receive image data:

 - (i) SLAR images from Ice Reconnaissance Aircraft;
 - (ii) Visual / Infrared Satellite Imagery;
 - (iii) SAR images from Radarsat.
- (d) Weather maps

The Canadian Ice Service makes available the following weather maps produced by Environment Canada:

 - (i) Surface Analysis Weather Map;
 - (ii) 500 HPA Height Analysis Map;
 - (iii) Surface Prognostic Weather Map out to 120 hours;
 - (iv) 500 HPA Prognostic Weather Map out to 120 hours;
 - (v) Public and Marine Weather Forecast Bulletins;
 - (vi) Significant weather depiction charts;
 - (vii) Ocean wave analysis;
 - (viii) 12-24-36 hour ocean wave prognosis.
- (e) Special Services

The Canadian Ice Service responds to enquiries from users and provides a range of specialized forecasting, consultation and advisory services to meet their special needs.

Samples of output products are given in Annex I.

4. Publications

The Canadian Ice Service has a collection of reference material related to sea ice and icebergs. Representative publications include:

- (a) MANICE - Manual of Standard Procedures for Observing and Reporting Ice Conditions
- (b) Ice Summary and Analysis for Canadian waters
- (c) Ice Limits Eastern Canadian Seaboard
- (d) Ice Atlases for Canadian waters
- (e) Weekly Historical Ice charts
- (f) Summary of Freezing and Melting Degree day Accumulations
- (g) Ice Thickness Climatology 1961-1990
- (h) Freeze-up and Break-up and Ice Thickness in Canada
- (i) SAR Ice Interpretation Guide
- (h) SLAR Users Manual
- (k) SLAR Catalogue for Southern Canada Ice Interpretation, Eastern Arctic and Western Arctic
- (l) Arctic winter Ice Analysis and SAR imagery for Arctic the Canadian

5. Mailing and Internet addresses

Canadian Ice Service – Environment Canada
 373 Sussex Drive, Block E - 3rd floor
 Ottawa, Ontario
 Canada K1A 0H3
 Telephone: (613) 996-1550 or toll-free in North America (800) 767-2885
 Telefax: (613) 947-9160
 e-mail: cis.client@ec.gc.ca
 Internet: <http://www.cis.ec.gc.ca>

UNITED STATES

1. Organization

Ice products and services in the U.S.A. are provided through the collective efforts of three Federal Government agencies: the National Oceanic Atmospheric Administration (NOAA), the U.S. Navy (USN) and the U.S. Coast Guard (USCG). Manpower and fiscal resources contributed by each agency are used in the collaborative operation of the National Ice Center (NIC). The mission of NIC is to provide global sea ice, Great Lakes and Chesapeake Bay ice information in support of shipping, cryospheric research and other maritime activities in ice-encumbered waters. NIC ice guidance products and services include: regional-scale graphical ice analyses, annotated satellite imagery, short and long-term ice forecasts, legacy ice information (1972-present), ice climatologies, Optimum Track Ship Routing (OTSR) recommendations, pre-sail ship briefings, aerial ice reconnaissance and ship rider services. NIC Alaskan and Great Lakes ice products are augmented by services provided by the NOAA National Weather Service (NWS) field offices located in Anchorage, Alaska and Cleveland, Ohio, respectively. Additionally, the National Center for Environmental Prediction (NCEP) Ocean Modeling Branch (OMB) and the fleet numerical meteorological and oceanographic center (FNMOC) provide Arctic ice modeling output. Iceberg information for the North Atlantic is provided by the USCG International Ice Patrol (IIP).

2. Data acquisition

NIC ice guidance products are produced in a digital workstation environment using data from polar orbiting satellites, aerial ice reconnaissance missions, ship/shore station reports, drifting buoys, meteorological guidance products, ice model predictions and government partners including foreign ice services. Among the presently available operational data sources, satellite imagery now constitutes over 95% of the information received and integrated into NIC ice analysis products. The timing and location of operational activities in or near the ice pack are often dictated by events, whether economic, military or environmental, far beyond the control of the monitoring agency. Traditional data collection methods, such as visual aerial ice reconnaissance, require extensive pre-planning, are limited in geographic scope and are not cost effective. Real-time satellite data in the visible, infrared and microwave bands of the spectrum are now used extensively, and are an essential requirement at NIC to ensure safety of navigation and protect life and property in ice-covered seas.

The primary remotely sensed data sources used by NIC are the NOAA TIROS-N and Defense Meteorological Satellite Program (DMSP) satellites. Visible and infrared imagery from the TIROS-N Advanced Very High Resolution Radiometer (AVHRR) and the DMSP Operational Linescan System (OLS) are received on a daily basis from the NOAA National Environmental Satellite Data Information Service (NESDIS) and Air Force Weather Agency (AFWA), respectively. AVHRR data has a 1.1 km spatial resolution and is received in the High Resolution Picture Transmission (HRPT) and Local Area Coverage (LAC) transmission modes. DMSP OLS fine data, which has a 0.55 km spatial resolution, is used extensively for detailed regional-scale ice mapping. Unfortunately, all visual and infrared imagery are limited by the extensive cloud cover that frequently obscures the ice pack in the polar regions. Climatologically, cloud cover may be present nearly 80% of the time over the Arctic ice pack and the marginal ice zone during the important summer shipping months.

NIC has compensated for weather limitations in the polar regions by integrating microwave data into the majority of ice analysis products. DMSP Special Sensor Microwave Imager (SSM/I) sensor data (19 and 37 GHz channels) are routinely processed by FNMOC and the NWS NCEP using the CAL/VAL and NASA Team ice concentration algorithms, respectively. These algorithms produce 25 km gridded mosaic ice maps which assist in the general delineation of the ice edge and inner pack concentrations in cloud-covered areas. These passive microwave-based products are instrumental in the production of NIC weekly composite Arctic/Antarctic ice maps. Unfortunately, the coarse resolution precludes detailed analyses and great care must be taken into account for contamination errors induced by surface meltwater and coastlines.

At NIC, higher resolution, tactical-scale ice analysis products now benefit from the availability and use of Synthetic Aperture Radar (SAR) data from the Canadian RADARSAT. RADARSAT is the world's first radar satellite specifically designed to maximize its usefulness for sea ice monitoring. Of primary importance to this effort is RADARSAT's C-band ScanSAR Wide mode, which provides these all-weather data in a 500 km wide swath with 100 m resolution. This wide swath provides a high repeat imaging capability essential for operational ice

monitoring. By virtue of this wide swath, RADARSAT can image every point on the earth's surface north of 65N latitude at least once every day. North of 45N, the entire globe can be covered in 3 days or less. The NIC routinely receives imagery from three Command Data Acquisition (CDA) station masks (Fairbanks, Alaska; Gatineau, Canada; and Tromsø, Norway) to provide near complete Arctic coverage. Images are processed at each of the three Arctic ground stations within six hours of receipt and transferred to the NIC via dedicated communication lines or via the Internet. No SAR imagery are routinely integrated into ice analyses of the Antarctic seas because of data delivery delays associated with communications to/from the McMurdo ground receiving station.

The importance of and need for visual ice reconnaissance data from aircraft has decreased dramatically in conjunction with the growing capabilities of satellites. Used extensively to map sea ice distribution during the 1970's and 80's, the use of aerial reconnaissance is now inhibited by limited range at comparatively high costs. On a restricted basis, NIC continues to employ USCG aircraft equipped with real aperture Side Looking Airborne Radars (SLAR) to map ice in the Great Lakes and for specific special polar operations. Unfortunately, SLAR data from these aircraft are distributed in an analog format and suffer from errors induced by subjective interpretation, a lack of reliability due to material readiness of legacy sensor suites and the need for manual integration into NIC digital ice guidance products. Visual ice reconnaissance and other in-situ data (ship and shore reports) do, however, have great value as "ground-truth data" for validating newly developed automated SAR ice detection and classification algorithms. Visual reconnaissance missions and ships operating in or near the ice also regularly report ice parameters (topography, divergence/convergence and measured ice thickness) which are presently not possible to extract from satellite data. Coastal station reports, regularly received from Alaska and the Great Lakes, describe measured ice thickness, extent of landfast ice and conditions within the immediate off-shore ice pack.

NIC obtains Arctic meteorological and ice drift information from the 20-30 drifting buoys that comprise the observational data network maintained by the International Arctic Buoy Program (IABP). All IABP drifting buoys report surface air pressure, surface air temperature and positional information 10-12 times per day via the Service ARGOS Data Collection and Location System (DCLS). These data are made available to NIC and other weather/ice forecasting centers via the Global Telecommunications System (GTS). Air pressure and temperature data are used to initialize numerical weather models, which in turn provide input to ice prediction models. NIC uses air temperature data to compute freezing degree-days and corresponding theoretical ice thicknesses while buoy positional data are used to validate ice model drift predictions. NIC also uses the buoy positional data to track and hindcast the southernmost limit of dangerous Arctic multiyear sea ice. NIC provides the management for the U.S. contribution to the IABP including the funding of the University of Washington/Polar Science Center (UW/PSC) to produce quality controlled annual data compilations and derived synoptic field products.

Numerical weather and ice prediction model forecasts are received at NIC from FNMOC and NWS NCEP. Output from FNMOC's Navy Operational Global Atmospheric Prediction System (NOGAPS) and NCEP Medium Range Forecast (MRF) models assist NIC analysts in forecasting future sea ice expansion and recession by predicting surface and near-surface wind direction, wind velocity and thermal advection patterns. FNMOC subsequently uses NOGAPS model output and daily in-house SSM/I ice concentration fields to initialize the Polar Ice Prediction System (PIPS 2.0) model. PIPS 2.0 is an moderate resolution (35 km) ice-ocean coupled model which provides daily forecasts of ice drift velocity, ice thickness, ice concentration and convergence/divergence for most of the ice covered seas in the Northern Hemisphere (north of 30°N). Dynamics are based upon the Hibler ice model that couples ice momentum, ice concentration and ice thickness via ice rheology and ice strength formulations. Thermodynamics and ice growth/decay are specified in terms of a three-dimensional ocean basin in the Cox ocean model. NCEP OMB also produces routine ice drift predictions for the Alaskan seas. An ice model covering the entire Arctic remains in development at NCEP. NIC has no operational access to Antarctic ice model forecasts.

Information from U.S. Government and international partners consists mainly of satellite data, in-situ observations or detailed ice analyses. RADARSAT data covering the Great Lakes and Baffin Bay are obtained from the Canadian Ice Service (CIS) in exchange for equivalent amounts of data in the Western Arctic. Ship reports are routinely received from USCG icebreakers and NOAA survey vessels operating in polar seas. Visual ice observations are received from aerial reconnaissance missions flown by the Danish Meteorological Institute (DMI) in southern Greenland waters and from the U.S. Dept of Interior - Minerals Management Service as part of their annual whale survey each autumn in the Beaufort Sea. NIC also receives detailed ice analyses in regional seas from

the Japanese Meteorological Agency (JMA), Norwegian Meteorological Institute (DNMI), Canadian Ice Service (CIS), Swedish Meteorological and Hydrological Institute (SMHI) and the German Hydrographic Institute.

3. Products and services

The NIC provides a diverse suite of digital and analog ice guidance products in support of operations and climate research in the polar regions. Routine NIC ice guidance products include regional-scale ice analyses, alphanumeric text messages, annotated satellite imagery, short and long-term ice forecasts, legacy ice information, ice climatologies and iceberg reports. NIC services available via special request include Optimum Track Ship Routing (OTSR) recommendations, pre-sail ship briefings, aerial ice reconnaissance and ship rider support. Sea ice features of most frequent interest include ice edge position, ice concentration, ice thickness or stage of development, forms (or floe size) of ice, ice motion, location of landfast ice, areas of compression and heavy surface deformation (topography) and the location/orientation of open water or thin ice-covered leads/polynyas. Information on North Atlantic icebergs is provided daily by the USCG IIP. NIC also tracks large tabular icebergs in the Antarctic and maintains a historical database of date iceberg was sighted, position, size of the iceberg and source of the information.

(a) Ice Analysis Charts

NIC produces weekly regional-scale analyses for all ice-covered Arctic and Antarctic seas. Analyses are done on a bi-weekly basis for the Alaskan waters, Great Lakes and the infrequently frozen Chesapeake/Delaware Bays on the U.S. east coast. Prior to 1997, this weekly global analysis product was manually produced on two 1:10,000,000 scale polar azimuthal equidistant/stereographic paper charts for the Arctic and two 1:16,000,000 scale polar azimuthal equidistant/stereographic paper charts for the Antarctic. Since 1997, this global analysis product has been produced in a digital format as 35 separate Arctic analyses (north of 35 degrees north) and 12 separate analyses in the Antarctic. Scales of these Arctic/Antarctic ice maps vary between 1:3,000,000 to 1:7,000,000 depending on the size of the area. Great Lakes and Chesapeake Bays charts are 1:1,500,000.

All NIC ice analyses are produced through the integration and analysis of all available remotely sensed and in-situ oceanographic/meteorological data. NIC currently hosts these data on SUN SPARC and Ultra workstations using the U.S. Naval Research Laboratory's Naval Satellite Imaging Processing System (NSIPS), SeaSpace, Inc. Terascan software and the Environmental Systems Research Institute's (ESRI) ARC/INFO Geographic Information System (GIS) and ArcView. NSIPS and Terascan image processing packages allow the display and manipulation of the array of satellite, in-situ and model data sources required to produce an ice analysis. The NIC uses NSIPS and Terascan to warp all data to a common polar stereographic projection so that analysts can overlay and annotate imagery to depict the ice edge and other various ice parameters. Analysis lines are then joined with a base map and labelled with attributes using NSIPS and ARC/INFO GIS to produce the final digital ice charts.

All digital ice charts are produced following standard NIC analysis procedures that optimize the use of remotely sensed and in-situ data that vary widely in availability, scale, and resolution. Highest priority in the analysis process is always given to data sources with superior spatial resolution and timeliness of receipt. When available, in-situ observations, SAR and OLS fine data are used for detailed mapping while AVHRR and SSM/I data provide general guidance. NIC weekly regional ice analyses are therefore often "composite analyses" since they may be derived from several data sources. Spatial differences in data are often subjectively "smoothed" during the delineation of ice map contours. Temporal differences in data are compensated for by estimating changes in ice conditions using ice model forecasts, surface wind/temperature predictions and ice climatologies. Typically no data later than 72 hours old is used in the global ice analysis product. Date and time of data acquisition as well as the percentage of each data type used in weekly composite analyses are documented in a metadata narrative.

Digital formats of these ice analyses include: a) simple electronic charts in Graphics Interface Format (GIF) which can be viewed with almost any web browser and/or graphics viewer, b) GIS-compatible (ESRI ARC/INFO .e00 export format) coverages and c) WMO SIGRID and SIGRID-2 formats. GIF charts are labeled using WMO international sea ice symbology. ARC/INFO vector coverages are produced in Polar Stereographic (standard parallel at 60N) and Geographic projections. All ARC/INFO sea ice attribute information is coded in modified text strings derived from the SIGRID format. All NIC digital ice products use this attribute standard to describe analyzed sea ice parameters. Plans are in place to also produce digital data in the Federal Geographic Data Committee (FGDC) Spatial Data Transfer Standard (SDTS). All sea ice analyses (in whatever format) are distributed via the NIC Internet web page.

The NWSFO located in Anchorage, AK produces a daily analysis of ice conditions in Cook Inlet, the eastern Bering, Chukchi and Beaufort Seas. Data sources available for this analysis include in-situ reports and NOAA TIROS AVHRR data. Analysis products are distributed as GIF files via the NWSFO, Anchorage Internet web page.

(b) Alphanumeric Text Messages

Alphanumeric Text messages describing ice conditions are routinely generated and distributed for U.S. Department of Defense customers in Over-the-horizon Targeting Gold (OTG) Overlay 2 (OVLY2) message format. OTG is the U.S. Navy standard for encoding geographic information into a man/machine readable format. These ice data messages consist of three sections including: a (LINE) section that contains a series of latitude/ longitude pairs; a narrative (NARR) line identifying and describing the ice feature (e.g. ice edge) and a remarks (RMKS) or text (TEXT) section for other descriptive comments such as a short-term forecast. A complete listing of NIC alphanumeric text messages is contained in the following table:

PRODUCT	FREQUENCY	DESCRIPTION
Special Arctic Oceanographic Synopsis (SPAROS)	Daily (Year Round)	Depicts the ice edge, 100% concentration boundary and a 24 hour forecast
Ice Hazard	Weekly - Tuesday, Friday (November 15 – June 15)	Depicts the ice edge, 100% concentration boundary and a 24 hour forecast
Fractures, Leads and Polynyas (FLAP)	As Required (Year Round)	Describes the location and orientation of exploitable openings or thin ice features in the ice pack
Global Ice Edge (plain Language message (ADL))	Weekly – Friday	Summarizes the weekly southern and northern limit (ice edge) of all known ice in Arctic and Antarctic
Arctic Buoy Message	Weekly – Wednesday (Year Round)	ARGOS ID and WMO ID

All alphanumeric text messages are distributed via AUTODIN or via the NIC Internet Web page.

(c) Annotated Satellite Imagery

DOD and other U.S. Government customers may request from NIC tailored, high resolution (tactical-scale) products that focus on a specific geographic areas. These requests often originate from vessels operating either within the ice pack or adjacent to the ice edge. This support is typically of short duration and requires extensive coordination to schedule airborne reconnaissance or the collection of appropriate satellite imagery. Most recently, SAR (in ScanSAR or standard modes) and OLS fine visual imagery are analyzed to aide vessels in the exploitation of the ice cover or more importantly, to avoid the ice and ensure safety of navigation. Upon request, recommended paths through the ice pack can be provided to shorten vessel transit time resulting in a decrease of overall operating costs. Satellite images annotated with analysis graphics are saved in GIF and Joint Photographic Experts Group (JPEG) formats and may be viewed with a variety of web browsers or graphics viewers. Dissemination of these NIC products is restricted to authorized users via the NIC Internet web page.

The NWSFO located in Anchorage, AK distributes annotated NOAA TIROS AVHRR imagery when images are mostly cloud-free and therefore of value to vessels at sea. These image products are distributed as GIF files via the NWSFO, Anchorage Internet web page.

(d) Legacy Ice Information

From the late 1950's to 1971, sea ice information in the polar regions originated only from scattered ship/shore reports and visual observations from limited numbers of U.S. Navy aerial reconnaissance missions. In 1972, the U.S. Navy began to produce routine weekly Arctic sea ice analyses based almost exclusively on visible/infrared data from the early NOAA polar orbiting satellites (beginning with NOAA-2) and passive microwave information from the DMSP series of satellites (beginning with NIMBUS-5). Routine Antarctic ice analyses began in 1973. In the following years, the NIC exploited a series of different U.S. and foreign satellites to obtain global sea ice information for all Arctic (north of 45°N) and Antarctic (south of 55°S) seas. These historical Arctic/Antarctic sea ice analyses (1972-present) and associated metadata (documenting available data sources) are available in analog (paper) and digital formats. Paper atlases are available from the Defense Technical Information Service (DTIC) and the National Snow and Ice Data Center (NSIDC). Digital ice analysis files (ASCII GIS "export" files in ESRI .e00 format and WMO SIGRID files) are available via CD-ROM from the NSIDC or by contacting NIC through the NIC Internet web page. In 1999, total ice concentration charts derived from all legacy ice analyses (1972-present) will also be available. A separate data base of ice analyses (1984-present) is also available for the Yellow Sea, Bo Hai and Korea Bay. Great Lakes ice analyses were produced by NWSFO (Ann Arbor, MI) from 1973-87 and NIC from 1988-present. These analyses are available in analog or digital format from either the NSIDC or the Great Lakes Environmental Research Laboratory (GLERL).

(e) Ice Climatologies

In 1986, the NIC issued an Arctic/Antarctic climatological ice atlas based on 12 years (1972-82) of unclassified ice analyses. Statistical parameters were derived on a bi-monthly basis by compositing 25 km gridded fields (SIGRID) of those ice analyses centered closest to the 1st and 15th of each month. In 2000, the Arctic climatology will be superceded by a monthly climatology produced under aegis of the Gore-Chernomyrdin Commission Environmental Working Group (GCC-EWG). This climatology is derived from 19 years (1972-90) of 12.5 km gridded ice analyses based on a blend of unclassified and formerly classified national security data. Climatological ice parameters include probability of occurrence of any ice, ice extent extremes (including maximum, median and minimum values) and median ice concentration charts. Areal statistics (in square kilometers) for total ice extent (all grid cells with ice) and ice coverage (grid cells with ice multiplied by tenth's of concentration) are available for all weekly Arctic/ Antarctic ice analyses (1972-present). A separate climatology based on 14 years of ice analyses (1984-1997) is also available for the Yellow Sea, Bo Hai and Korea Bay. The output grid cell size was 0.01 degrees, since the units of the coverages were degrees latitude/longitude. The Yellow Sea climatology was produced using a 1 km ground sampling distance, which ensured adequate detail in small inlets and around islands. A Great Lakes ice climatology based on historical ice charts (1960-79) is available in analog or digital format from either the NSIDC or GLERL. An update, adding analyses from 1980-1998, is planned for this Great Lakes product and will be issued by GLERL in the near future.

(f) Iceberg Reports

Since 1914, the USCG has been tasked with the management and operation of the International Ice Patrol (IIP). This internationally funded organization monitors and distributes information on the southern limit of icebergs in the North Atlantic/Grand Banks region of Newfoundland. During the iceberg season (Feb-Aug), this information consists of two (every 12 hours) message bulletins and a daily radio facsimile chart illustrating the extent of all-known limits of icebergs. Data sources used in the analysis include visual observations from regular aerial reconnaissance flights, ship reports and RADARSAT also. Size and time of sighting for all reported icebergs are routinely entered into an iceberg forecast model. Initialized daily with surface wind and ocean current information, this model predicts iceberg drift and estimated rates of deterioration. Model output is critical in predicting movement and longevity of icebergs in North Atlantic shipping lanes. Iceberg navigational hazard information is distributed via various broadcasts including facsimile, INMARSAT SafetyNet, SITOR, NAVTEX and Internet. Broadcast times and frequencies of messages and iceberg graphics are available via the IIP Internet web page.

Large tabular icebergs calving from the numerous ice shelves in the Antarctic are identified and tracked by NIC. Due to the enormous numbers of icebergs in this region, candidate icebergs must measure at least 10 nautical miles along the long axis. In most cases, these icebergs are detected and tracked using AVHRR and OLS visible/infrared imagery. All icebergs are also assigned “names” based upon the Antarctic quadrant in which they originate. A text summary of all known icebergs is issued on a weekly basis and input quarterly into a historical archive (1976-present). Both iceberg products are available via the NIC Internet web page.

(g) Special Request Services

Other NIC services are available via special request. These services include: Optimum Track Ship Routing (OTSR) recommendations, pre-sail ship briefings, aerial ice reconnaissance and ship rider support. OTSR recommendations, highlighting the preferred and safest route through the ice pack are available to all U.S. Government vessels. This support is provided via text message or annotated imagery. The NIC Customer Liaison Branch provides pre-sail ship briefings emphasizing NIC support capabilities and legacy/climatological information for mission planning. A detailed description of all NIC product/services is available in the NIC Environmental Services Guide. On a select basis and dependent upon availability of aircraft, the NIC aerial reconnaissance team provides on-scene visual/SLAR ice observations. Similarly, enlisted Navy Aerographer mates and civilian analysts are also available for on-scene ship-rider ice interpretation and guidance services.

Samples of output products are given in Annex XII.

4. Ice forecasts

Real-time analyses of sea ice conditions are produced through the integration of remotely sensed and in-situ oceanographic and meteorological data. These analyses represent the baseline or starting point from which formation, ablation and drift of sea ice are predicted and assembled into a NIC ice forecast. Predicted changes to these ice conditions range from short-term (24-168 hour) site-specific tactical forecasts to monthly and seasonal (90 day) predictions. Theoretical ice thicknesses, weather model output and PIPS 2.0 model output for variable time periods (24-120 hours) are used to produce short-term forecasts. These site-specific operational forecasts are used primarily to ensure safety of navigation. In contrast to the specific nature of short-term ice forecasts, seasonal forecasts focus on the expected extent of summer ice cover and the opening/ closing dates of coastal shipping lanes. Other forecast produced by U.S. Government organizations include ice bi-weekly 5-day forecasts produced by the NWSFO in Anchorage, Alaska for Alaskan waters.

A complete listing of NIC ice forecasts is contained in the table in the next page.

5. Publications

1. National Ice Center:

- (a) *Annual Ice Atlases* - compilation of weekly sea ice analyses in paper book format from 1972 – 1996 for the Arctic, and from 1973 – 1997 for Antarctica. In 1999, it is anticipated that NIC will transition and distribute Arctic/Antarctic ice atlases on CD-ROM for 1995, 1996, 1997 and 1998.
- (b) *Guide to Environmental Services* - provides a brief overview of the environmental conditions typical of the Arctic and Antarctic. The guide also contains an in-depth summary of the products and services available at the NIC.
- (c) *Ice Observation Handbook* - prepared by the NIC Aerial Ice Reconnaissance Unit. It is used as an aid to understanding the characteristics of sea ice. The handbook also contains a description of standard techniques and procedures used in sea ice observation and reporting.
- (d) *Seasonal Ice Outlooks* - prepared annually (since 1976) for the Eastern Arctic - Baffin Bay/Davis Straits region; the Western Arctic - North Slope of Alaska/Beaufort Sea; the Antarctic - Ross Sea and entrance to McMurdo Sound and for the Great Lakes. These long-range forecasts are prepared 90 days in advance of the shipping season for each region. The two Arctic outlooks are issued in May, the Antarctic in October and the Great Lakes in December of each year.
- (e) *Sea Ice Climatic Atlases* - prepared by Naval Oceanographic Command Detachment (NOCD), Asheville NC for NIC. Statistical parameters were derived on a bi-monthly basis by compositing NIC Arctic/Antarctic ice analyses centered closest to the 1st and 15th of each month. Climatological

parameters include: probability of occurrence of all ice, ice extent extremes (maximum, mean, minimum), mean ice concentration, mean ice concentration when ice is present and extent of 5/10th's or more of ice charts for the Arctic and Antarctic. The Arctic ice summaries are derived from 574 weekly NIC ice analyses produced from 1972 through 1982. The Antarctic ice summaries are derived from 521 weekly ice analyses produced from 1973-1982.

FORECAST	FREQUENCY	DESCRIPTION
7-day Air Force Forecast	Weekly – Wednesday	Depicts the ice edge, 100% concentration boundary and a 7 day forecast
Special Arctic Oceanographic Synopsis (SPAROS)	Daily (Year Round)	Depicts the ice edge, 100% boundary and a 24 hour forecast
Ice Hazard	Biweekly: Tuesday/Friday	Depicts the ice edge, 100% concentration boundary and a 72/96 hour maximum extent of sea ice
Great Lakes 30- Day Forecast	First Friday of each month (Dec 1 – Mar 1)	Depicts forecast ice edge and inner pack boundaries
Great Lakes 90-day outlook	Annually (Dec 1)	Depicts climatology and forecast ice edge and inner pack boundaries
West and East Arctic 30-day forecast	Monthly (First Friday of each month)	Depicts forecast ice edge and inner pack boundaries
West Arctic 90-day forecast	Annually (June 1)	Forecasts opening and closing dates of navigational checkpoints and parts along the Alaskan coast in the Chukcha and Beaufort seas, predicts and ranks severity of ice conditions
Ross Sea-McMurdo Sound Seasonal outlook	Annually (Dec 1)	Depicts climatology and forecast ice edge and inner pack boundaries for the Ross Sea shipping season
Eastern Arctic Seasonal outlook	Annually (May 1)	Depicts climatology and forecast ice edge and inner pack boundaries for the Gulf of St Lawrence, Labrador Sea, Davis Sts, and Baffin Bay for Thule resupply

- (f) *Legacy Arctic/Antarctic Ice Data (1972-94)* - in 2000, NIC will re-release legacy (1972-1994) Arctic weekly sea ice analyses as part of the EWG CD-ROM (described below). All 1972-94 Arctic ice analyses were translated into ARC/INFO GIS coverages and checked extensively for digitizing and production errors. This CD- ROM will contain Arctic weekly analyses in WMO SIGRID format, ARC/INFO GIS coverages (in .e00 export format in geographic projection) and NSIDC EASE format. Antarctic analyses (1972-1994) will also be re-released in a future CD-ROM. Other additions to the NIC legacy data base will be weekly digital ice analyses from 1984-97 for the region consisting of Yellow Sea, Bo Hai and Korea Bay, an ice climatology for this region and a historical Antarctic iceberg archive (1976 - present) in text format.
- (g) *EWG Arctic Sea Ice Atlas* - in 2000, the GCC EWG will release an Arctic compendium of sea ice information. Included on this CD-ROM will be a NIC monthly Arctic climatology derived from unclassified and classified ice data (1972-90). Statistics include: probability of occurrence of all ice, ice extent extremes (maximum, mean, minimum) and median ice concentration charts.

NOAA Offices:

- (a) *Cook Inlet Ice Summary* – prepared and distributed by WSFO, Anchorage from biweekly analyses of ice conditions in Cook Inlet.
 - (b) *Great Lakes Ice Climatology* – prepared by GLERL and based on compilation of historical ice charts (1960-79). This climatology is available in analog or digital format from either the NSIDC or GLERL. An update, adding analyses from 1980-present, is planned for this Great Lakes product and will be issued by GLERL in the near future.
2. International Ice Patrol:
North Atlantic Iceberg Summary - an annual report summarizing the ice, meteorological and oceanographic conditions during the North Atlantic iceberg season (Feb-Aug). Annual reports are available for the iceberg seasons of 1913 to the present. Reports of research and development projects may also be included in these reports.

6. Mailing and Internet Addresses

1) Mailing Addresses:

Director
National Ice Center
4251 Suitland Road, FB4
Washington, DC 20395
Tel: (301) 457-5303/-5300 (Fax)
e-mail liaison@natice.noaa.gov

Commander
International Ice Patrol
1082 Shennecossett Road
Groton, CT 06340-6095
Tel: (860) 441-2626/-2773 (Fax)

Defense Technical Information Center
Attn: DTIC BCR
8725 John J. Kingman Road
Suite 0944 DTIC/OCA
Fort Belvoir, VA 22060-6218
Tel: (703) 767-8271/-8228

NOAA/National Weather Service
National Centers for Environmental Prediction
Central Operations Room 301
WWB 5200 Auth Road
Camp Springs, MD 20746
Tel: (301) 763-8441

National Technical Information Service
5285 Port Royal Road
Springfield, VA 22161
Tel: (800) 553-6847

User Services – National Snow and Ice Data Center
CIRES Campus Box 449
University of Colorado
Boulder, CO 80309
Tel: (303) 492-6199

Fleet Numerical Meteorology and Oceanography Center
 Commanding Officer
 7 Grace Hopper Ave. Stop 1
 Monterey, CA 93943-5005
 Tel: (831) 656-4302

Polar Science Center
 Applied Physics Laboratory
 University of Washington
 1013 NE 40th Street
 Seattle, WA 98105-6698
 Tel: (206) 543-6613/-3521 (fax)

NWSFO Anchorage
 222 West 7th Avenue
 Building #23 Room 517
 Anchorage, AK 99513-7575
 Tel: (907) 266-5113/-5188 (fax)

Great Lakes Environmental Research Laboratory (GLERL)
 2205 Commonwealth Blvd
 Room 212
 Ann Arbor, MI 48105-2945
 Tel: (734) 741-2262/-2055 (fax)

Air Force Weather Agency/ X00R
 106 Peacekeeper Drive Suite 2N3
 Offutt AFB NB, 68113

2) Internet Addresses:

NIC - (<http://natice.noaa.gov>)
 NWFSO, Cleveland - (<http://www.csuohio.edu/nws/marine/marine.html>)
 NWFSO, Anchorage - (http://www.alaska.net/~nwsar/html/ice/ice_marine.html)
 NWS/NCEP/OMB - (<http://polar.wwb.noaa.gov/seaice/>)
 USCG IIP - (<http://www.rdc.uscg.mil/iippages/home.html>)
 UW/PSC/IABP - (<http://iabp.apl.washington.edu>)
 AFWA - (<http://www.afwin.afwa.af.mil>)
 FNMOC - (<http://www.fnmoc.navy.mil/>)
 FNMOC (NOGAPS) - (<http://152.80.56.202/wxmap/doc/wxmap.nogaps.html>)
 NWS/NCEP (MRF) - (<http://sgi62.wwb.noaa.gov:8080/web2/homepage.html>)
 SAA (RADARSAT) - (<http://swig.saa.noaa.gov/>)
 ECMWF - (<http://www.ecmwf.int/charts/charts.html>)
 CIS - (<http://www.tor.ec.gc.ca/ice/>)
 DTIC - (<http://www.dtic.mil/>)
 NTIC - (<http://www.fedworld.gov/ntis/ntishome.html>)
 GLERL - (<http://www.glerl.noaa.gov>)
 NSIDC - (<http://www.nsidc.colorado.edu>)

SOUTHERN HEMISPHERE

ARGENTINA

1. Organization

Elementary sea ice information services in Argentina are provided by the Argentine Navy Meteorological Service (SMARA) of the Naval Hydrographic Service, through the Glaciological Division at Buenos Aires and the Naval Meteorological Central at Río Grande (in Tierra del Fuego Island). Information services are also provided by the Icebreaker A.R.A. "ALMIRANTE IRIZAR", upon request, when sailing or operating in Antarctic waters (mainly in Weddell and Eastern Bellingshausen Seas). No sea ice charts or coded information are regularly prepared and transmitted, except for sea ice edge and icebergs locations (when available) included in Notice to Mariners for NAVAREA VI.

Ships may obtain sea ice information service provided that notice is given in advance.

2. Data acquisition

Data sources are based on low (APT) and high resolution satellite images, sea ice observations from shore and ship (IILL & IISS codes after NIC U.S.A.) and reference data obtained from analysis prepared by NIC U.S.A.

Six Antarctic Argentine stations report sea ice and icebergs twice a week whilst the Argentine icebreaker and other auxiliary ships report four daily sea ice observations when sailing or operating in Antarctic waters.

Visual aerial reports are drafted during glaciological explorations flights (non routine).

3. Output products

The following products are available upon request for Weddell Sea zones, as well as those of adjacent waters of the Antarctic Peninsula, Eastern Bellingshausen Sea and adjacent South Pacific Ocean:

- (a) Sea ice edge position and concentrations, openings, stages of development, sea ice fields under processes of pressure, and areas of weakness may be provided by the Glaciological Division in Buenos Aires for specific locations, in plain language, ice maps using the WMO egg symbology or coded messages;
- (b) Sea ice edge position, openings and a sea ice concentration outlook may be supplied by the Naval Meteorological Central at Río Grande in plain-language;
- (c) Sea ice information similar to that under paragraph (b) may also be provided by the Icebreaker A.R.A. "ALMIRANTE IRIZAR" while sailing or operating in Antarctica (c.f. point 1. Organization), except for more detailed information on its area of operations.

4. Forecasts

Sea ice forecasts, mostly constrained to specific locations, are prepared upon request in plain language by the Glaciological Division in Buenos Aires. The forecasts specially refer to sea ice edge movement, changes in concentrations, areas of pressure and zones of weakness.

5. Publications

There are no regular publications, however, two sea ice Atlases have been published for Antarctic waters between 0°W and 90°W; one covering the period 1972-1990 and the other for 1973-1982. Statistics on sea ice boundaries for nonstandard periods may be compiled, since 1972, and made available to users.

6. Mailing address

Servicio Meteorológico de la Armada Argentina. Glaciología.
Edificio Libertad
Comodoro Py 2055, 15-37
1104 BUENOS AIRES
Argentina

Fax: +54 11 43172309
e-mail: cnhsmara@rina.ara.mil.ar

Central Meteorológica Naval Río Grande
Base Aeronaval
9420 RIO GRANDE. Tierra de Fuego.
Argentina.
Fax: +54 2 0964 433092
e-mail: meteogra@infovia.com.ar

Icebreaker A.R.A. "ALMIRANTE IRIZAR"
Antarctic HF frequency: 4490 Khz.
VHF frequency: channel 16
Inmarsat phones: 008741540117, 008711540117

AUSTRALIA

1. Organization

During the Austral summer (approx November to March) the Antarctic Meteorological Centre at the Australian Station, Casey, Antarctica, provides weekly analyses of sea ice concentrations for the Antarctic coasts in the Casey to Bunker Hills area and in the Davis to Mawson area. These analyses are broadcast on HF radio. Analyses of sea ice concentrations are also provided on request for any Antarctic coastal area between about the DateLine and about 50°E. Moreover, AVHRR images of the following coastal areas are regularly updated on the world wide web (currently provided to registered users at: <http://www.bom.gov.au/weather/tas/inside/amc/satindex.shtml> but subject to change): Casey Area; Davis Area; Dumont D'Urville Area; Mawson Area; Shackleton Ice-Shelf Area; Terra Nova Bay Area; and the West Ice-Shelf Area.

2. Mailing address

Bureau of Meteorology Tasmania/Antarctica Region
GPO Box 727G, Hobart
AUSTRALIA, 7001

Telephone: +61 3 6221 2021
Fax: +61 3 6221 2080

NEW ZEALAND

Information not available at the moment of editorship

ANNEXES

SAMPLE CHARTS AND OUTPUT PRODUCTS OF NATIONAL SERVICES

ANNEX I

Canada

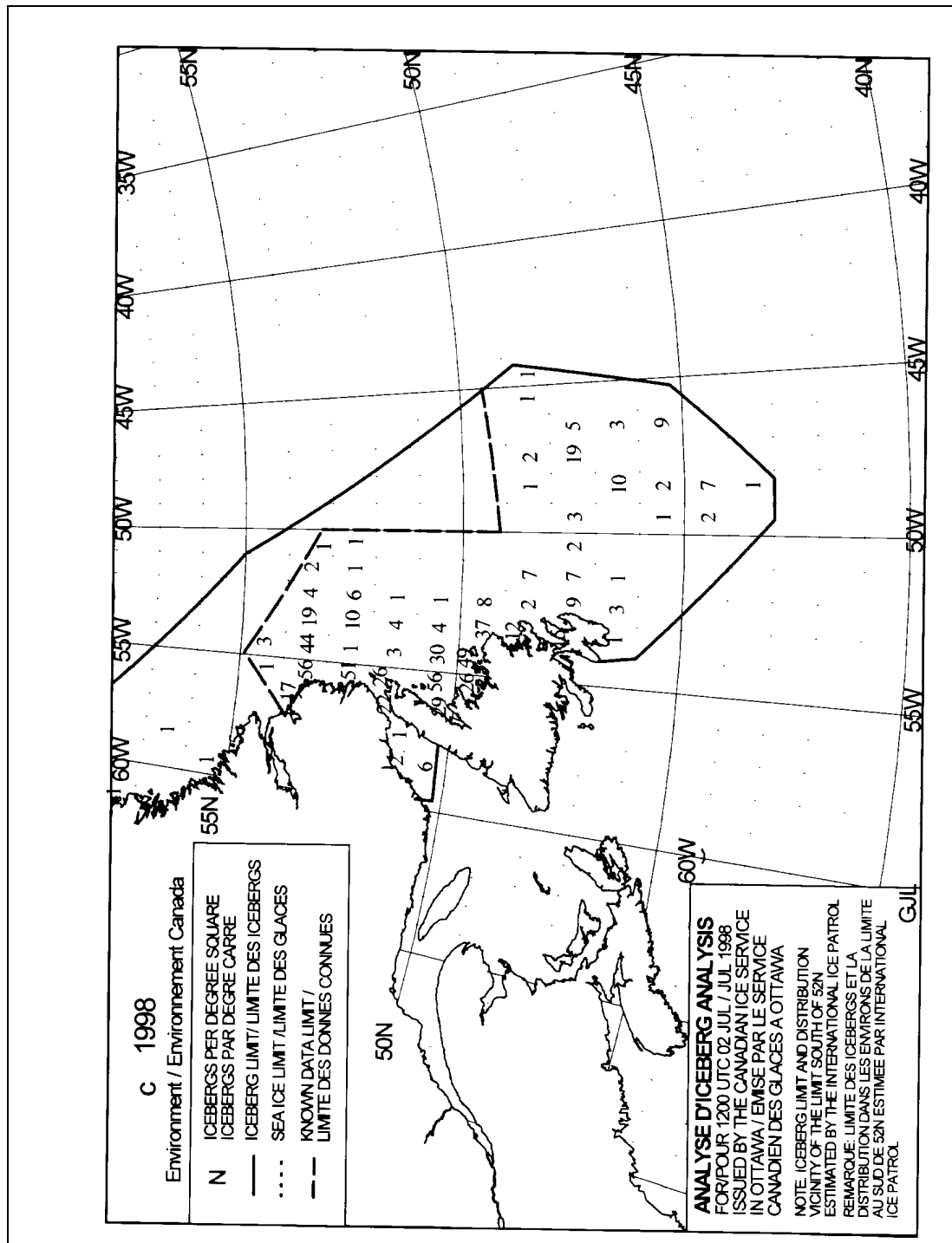


Fig I-1. Daily iceberg analysis chart. (East Canadian coast).

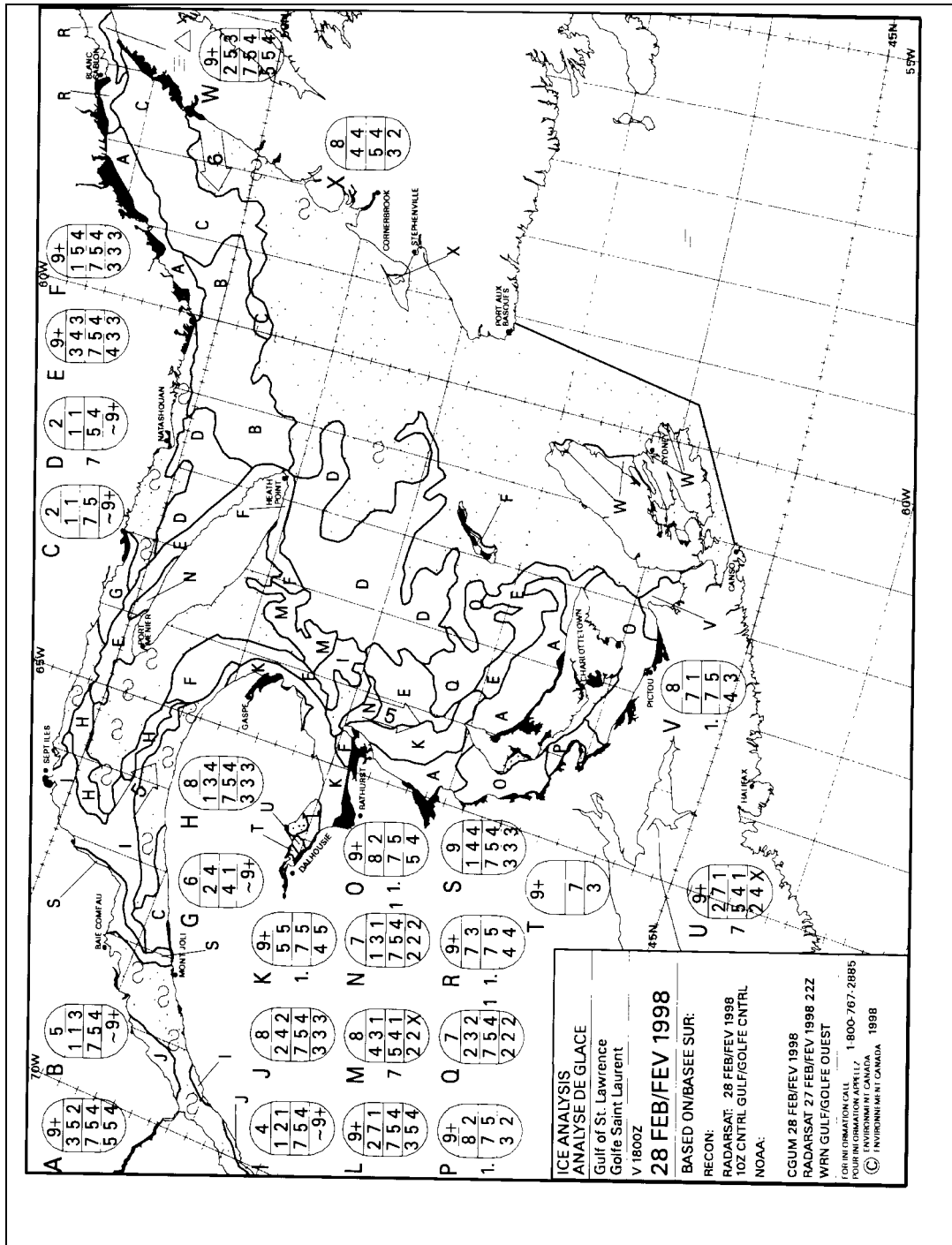


Fig.I-2. Daily ice analysis chart. (Gulf of St.Lawrence).

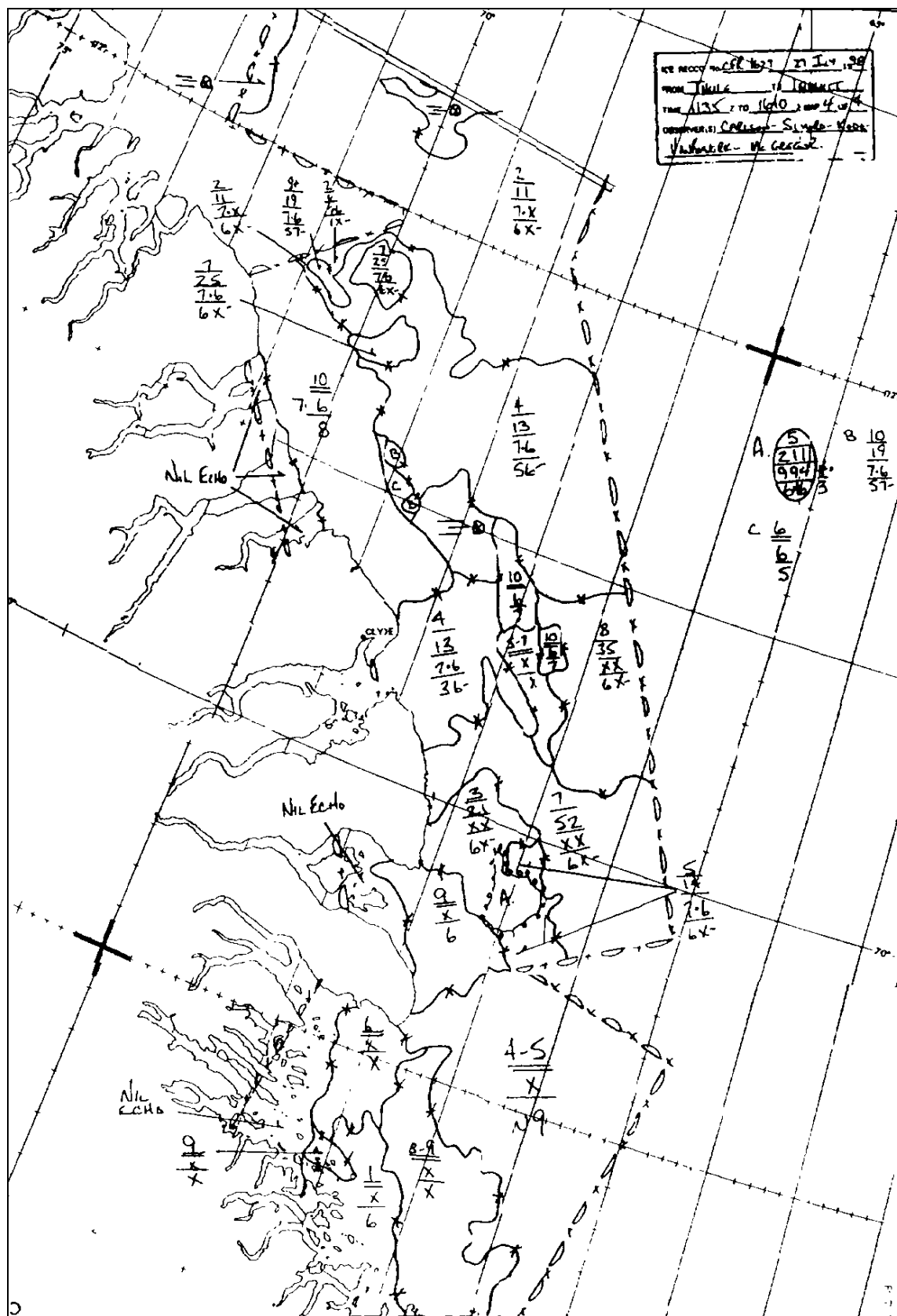


Fig.I-3. Ice reconnaissance chart. (Baffin bay).

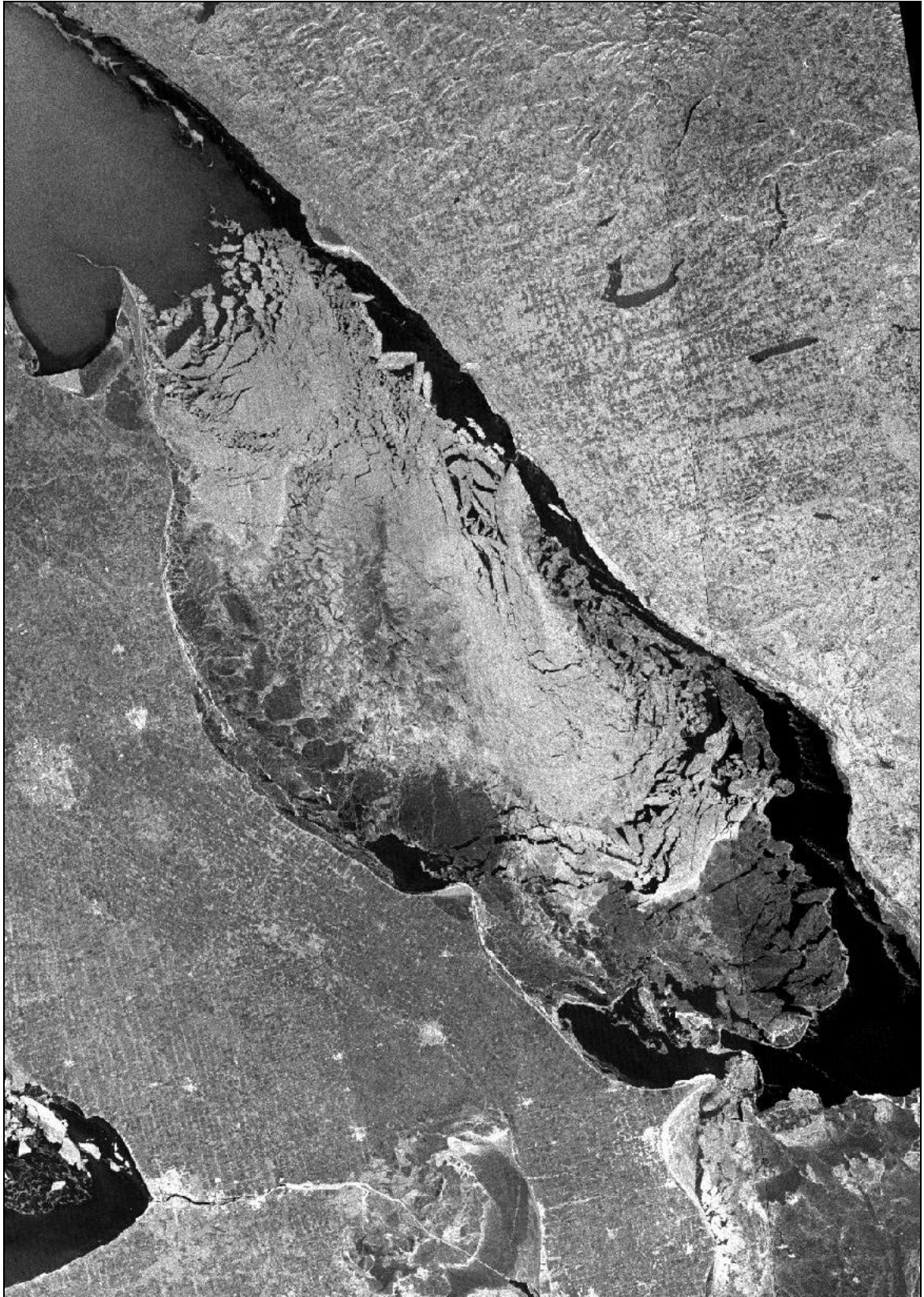


Fig.I-4. Radarsat imagery. (Lake Erie).

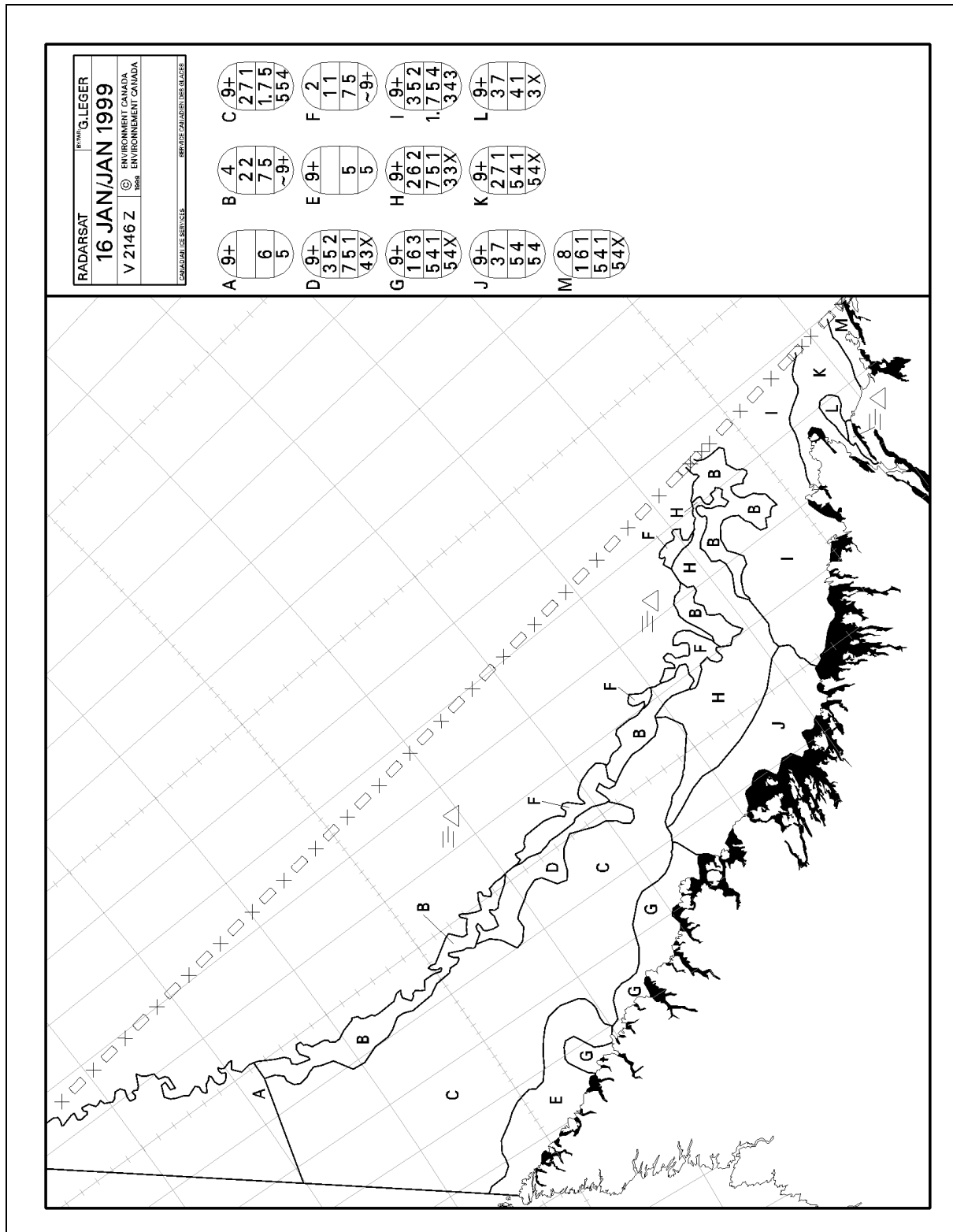


Fig.I-5. Radarsat image analysis chart. (Labrador coast).

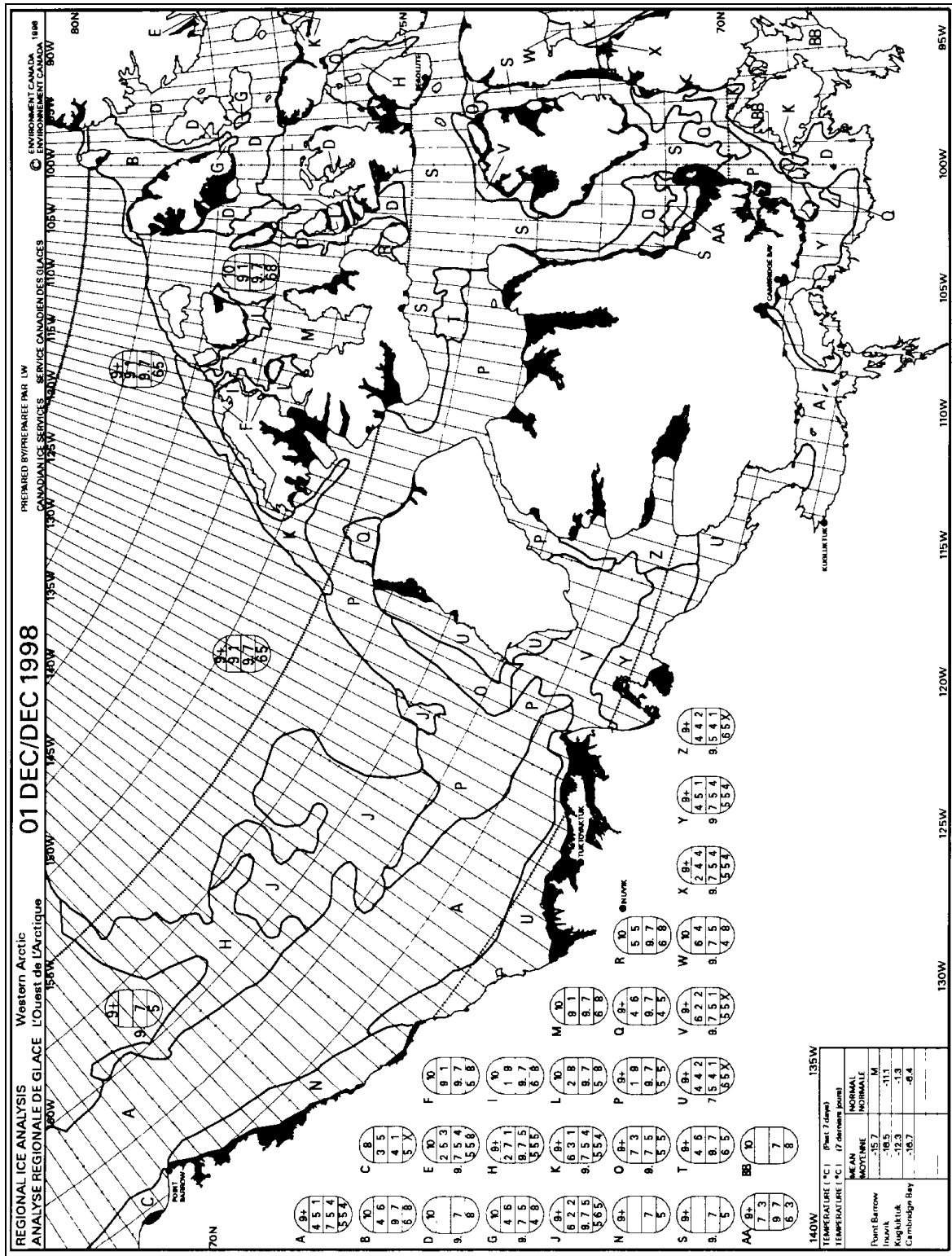


Fig I-6. Regional weekly ice chart. (Western Canadian Arctic).

China



Fig.II-1. Sea Ice condition in the Bohai Sea on 25 January 1997

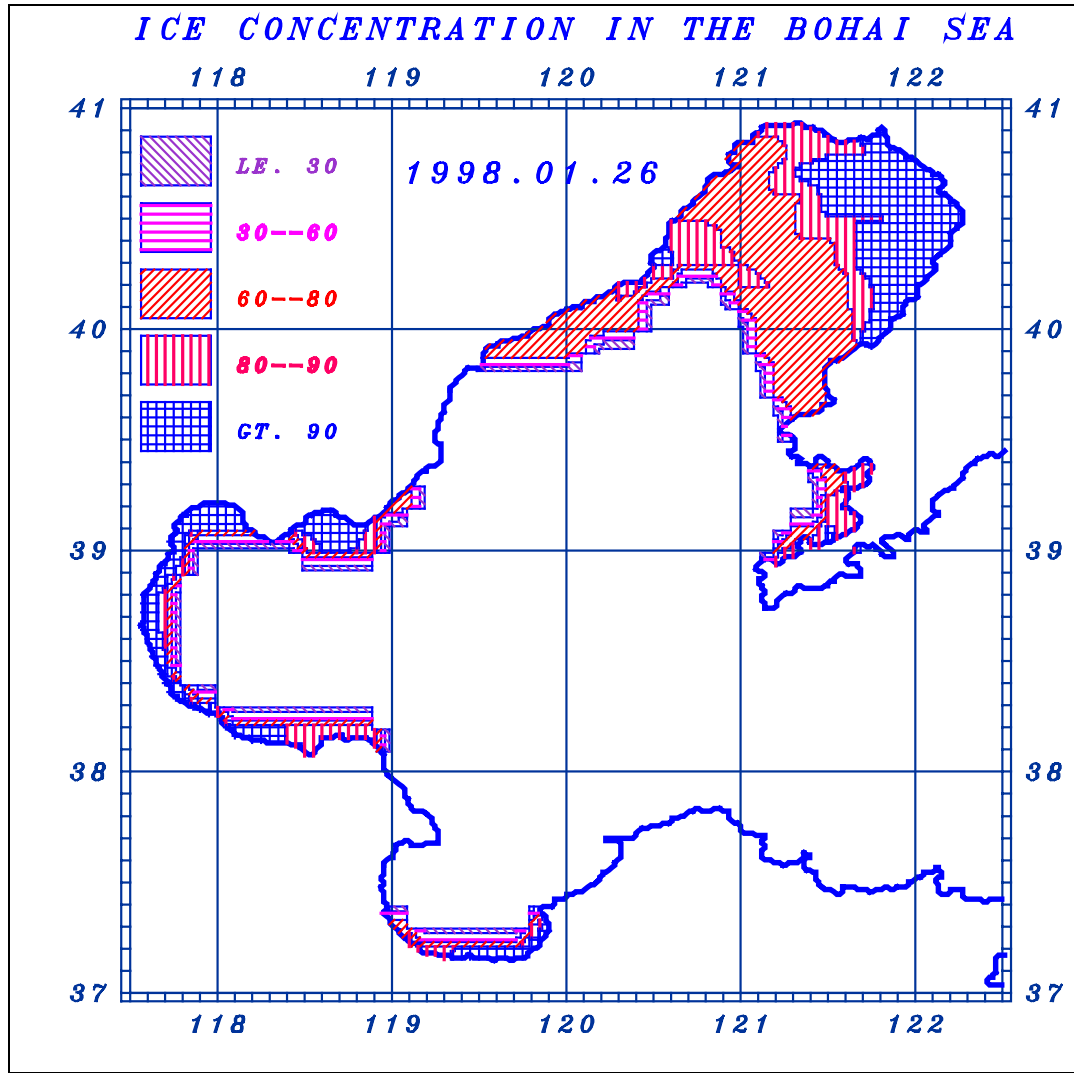


Fig.II-2. The analyzed chart of ice concentration and edge of the Bohai Sea on 26 January 1998.

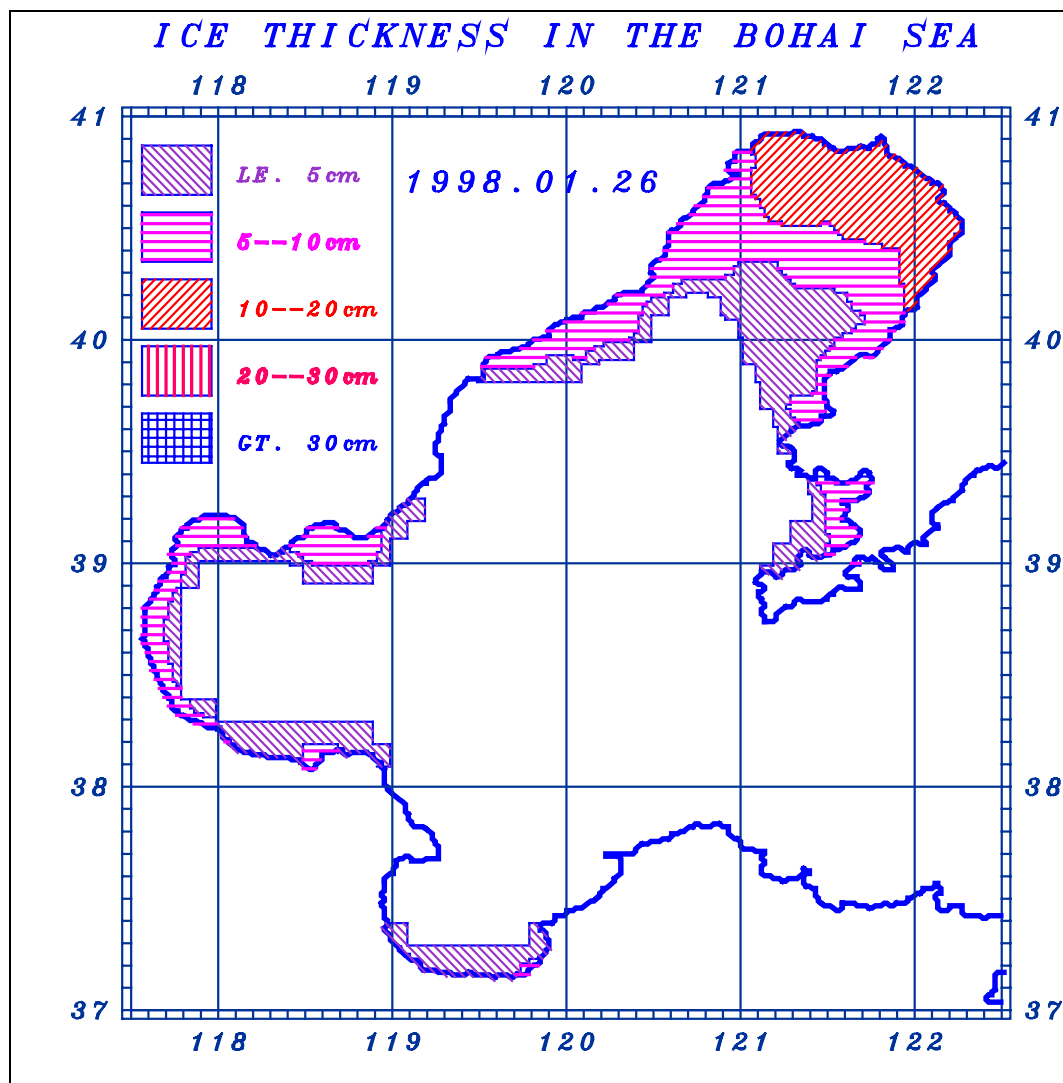


Fig.II-3. The analyzed chart of ice thickness and edge in the Bohai Sea on 26 January 1998.

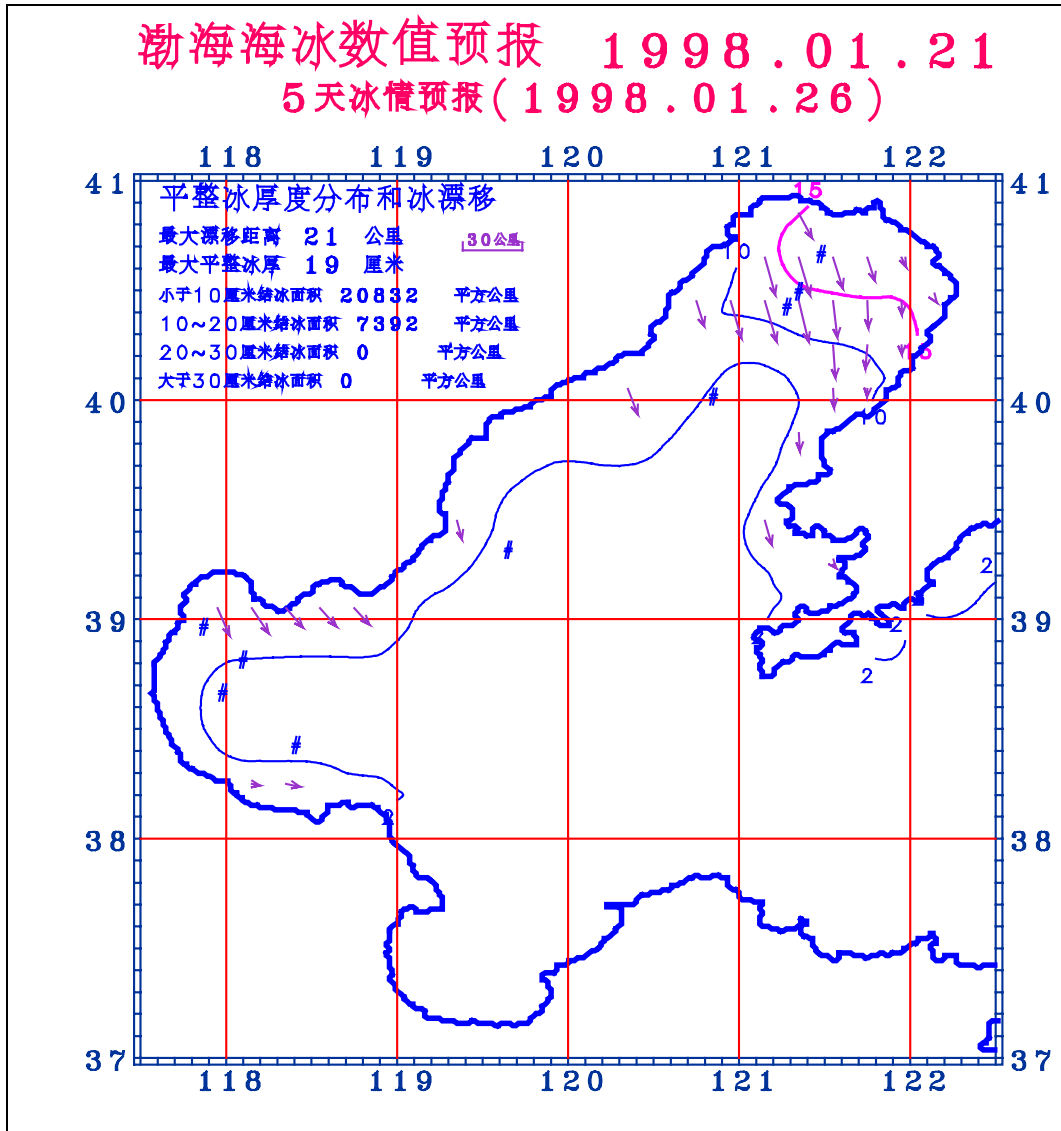
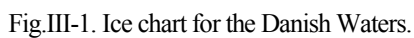


Fig.II-4. The 5-day forecast of ice drift arrow and thickness (isoline) from 21 January 1998 in the Bohai Sea

Denmark



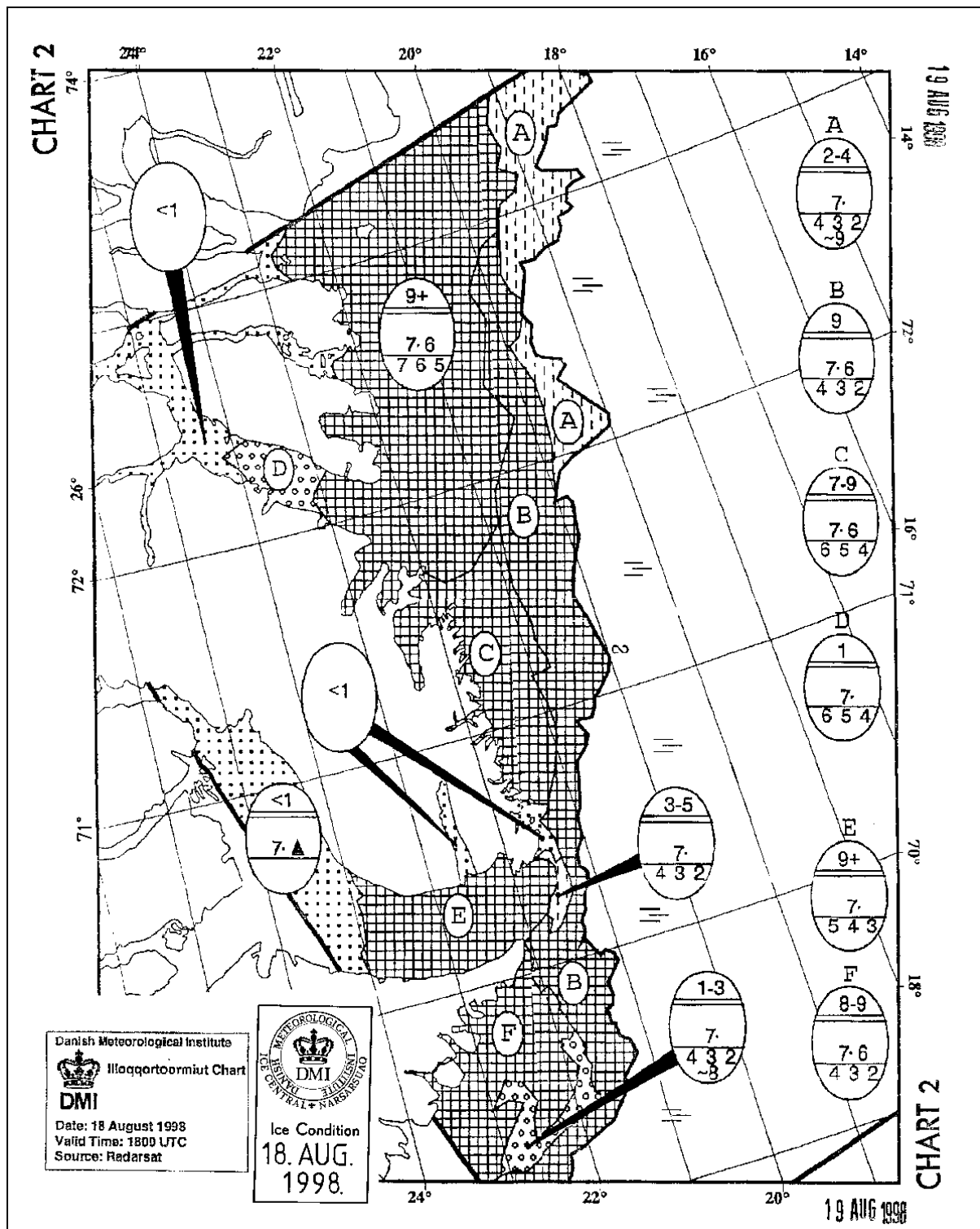


Fig.III-3. Ice chart based on RADARSAT SCANSAR WIDE for Greenland waters for 18 August 1998.

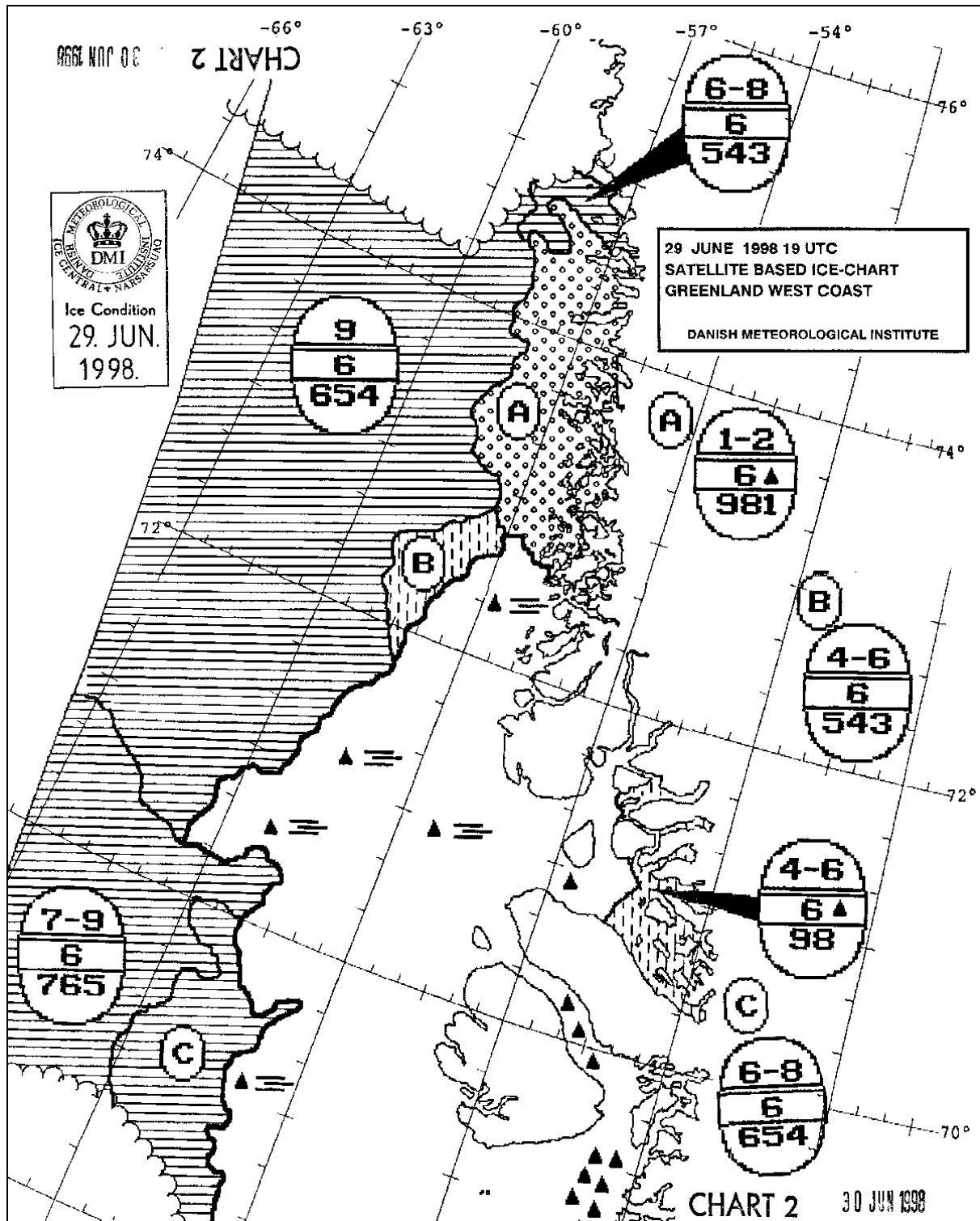


Fig III-4. Ice chart based on NOAA-AVHRR for Greenland waters for 29 June 1998.

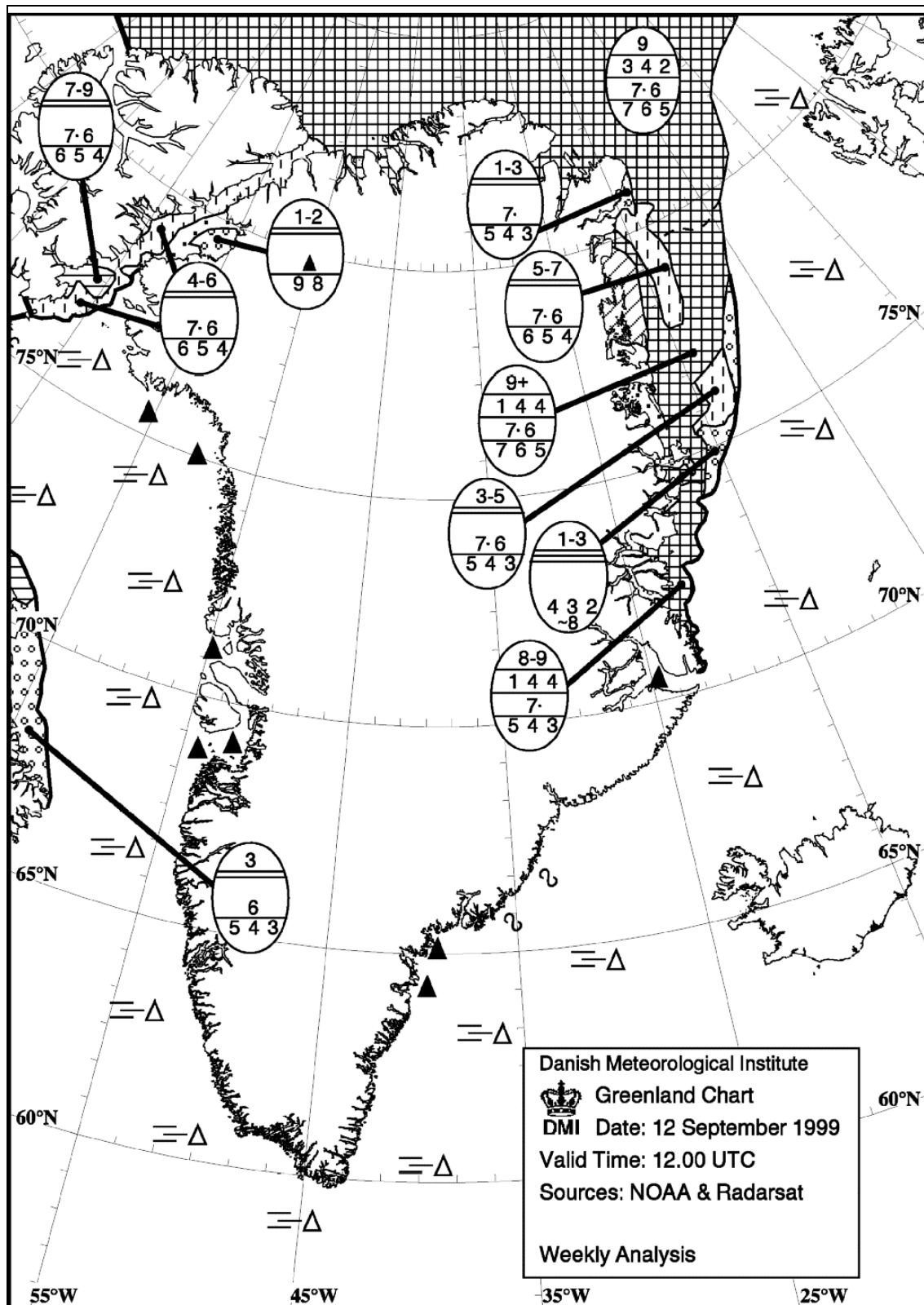


Fig.III-5. Weekly ice analysis for Greenland.

Estonia

Finland



ANNEX VI

Germany

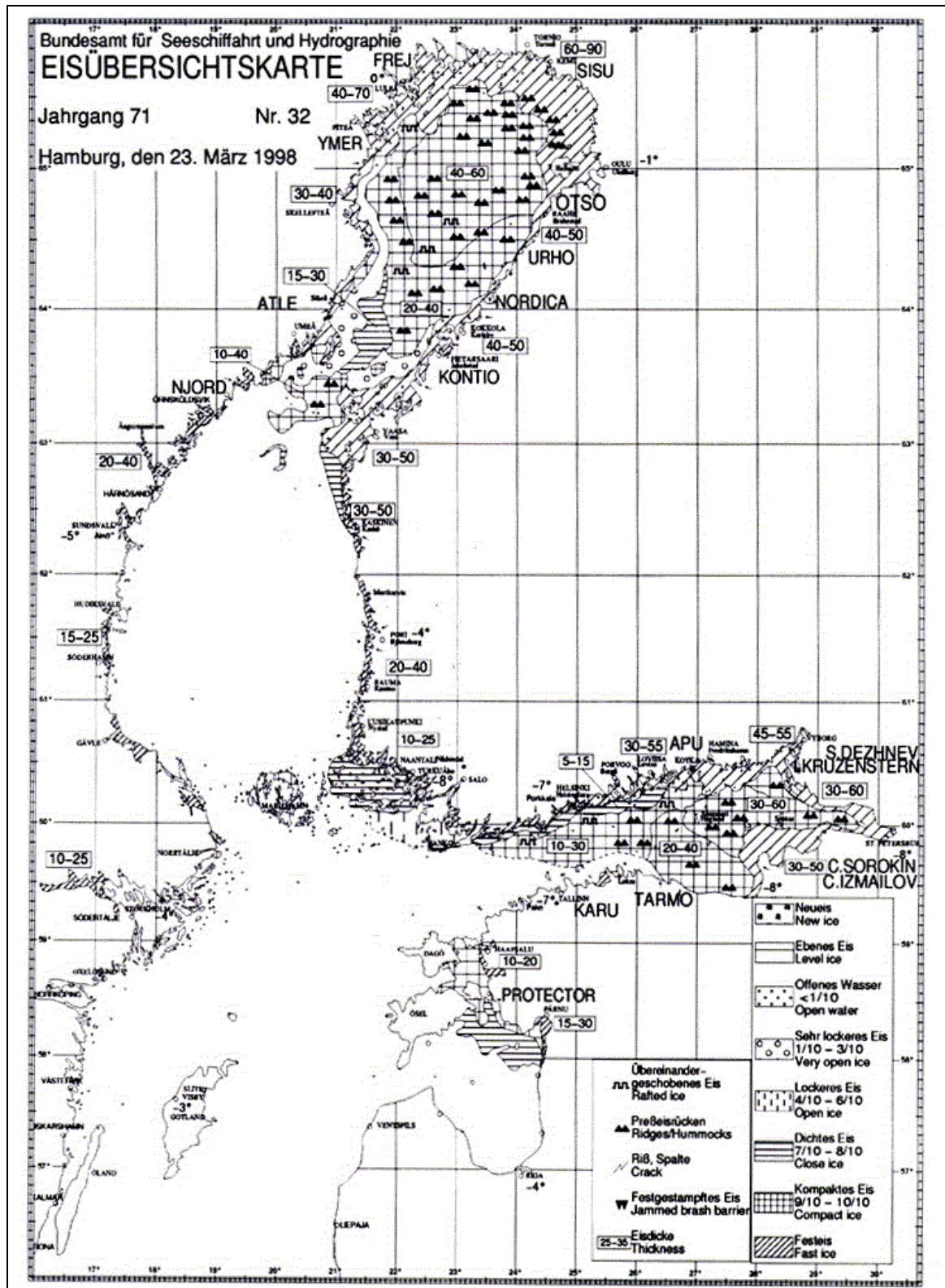


Fig. VI-1. Ice chart for the Baltic Sea for 23 March 1998.

ANNEX VII

Japan

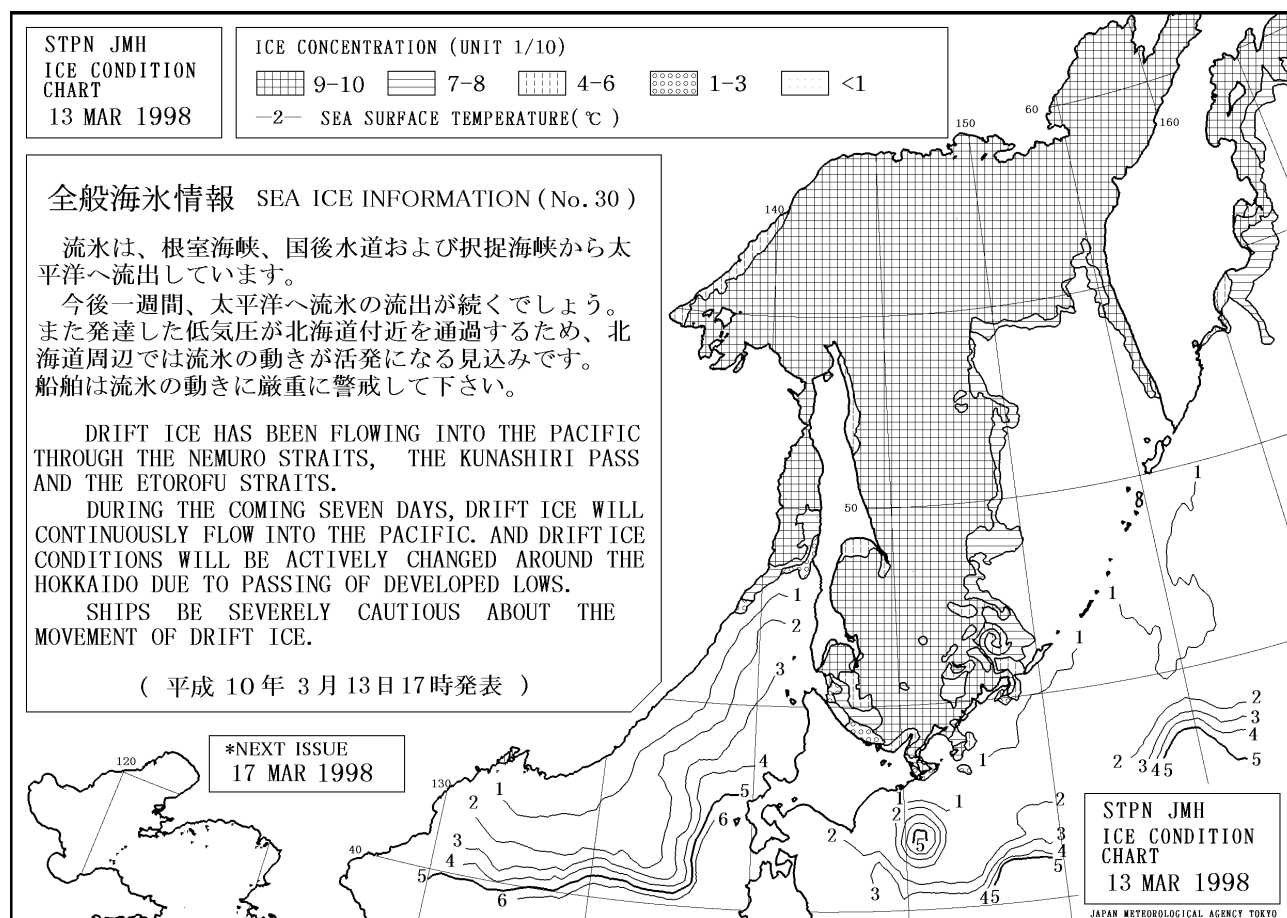


Fig.VII-1. Ice chart for the Sea of Japan and Sea of Okhotsk for 13 March 1998.

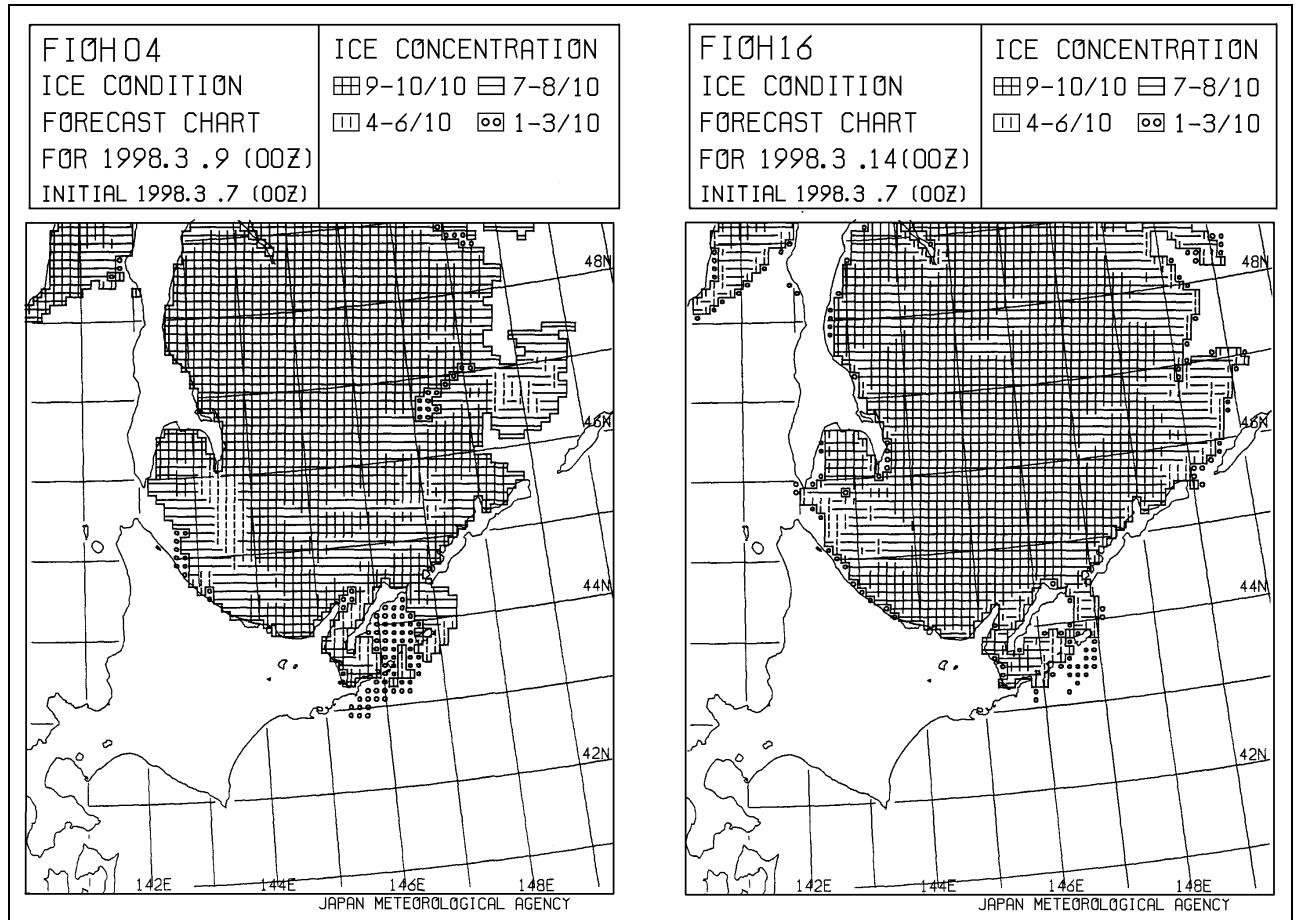


Fig. VII-2. Ice condition forecast charts for the Sea of Japan and the Sea of Okhotsk for 9 and 14 March 1998
(initial conditions from 7 March 1998).

ANNEX VIII

Latvia

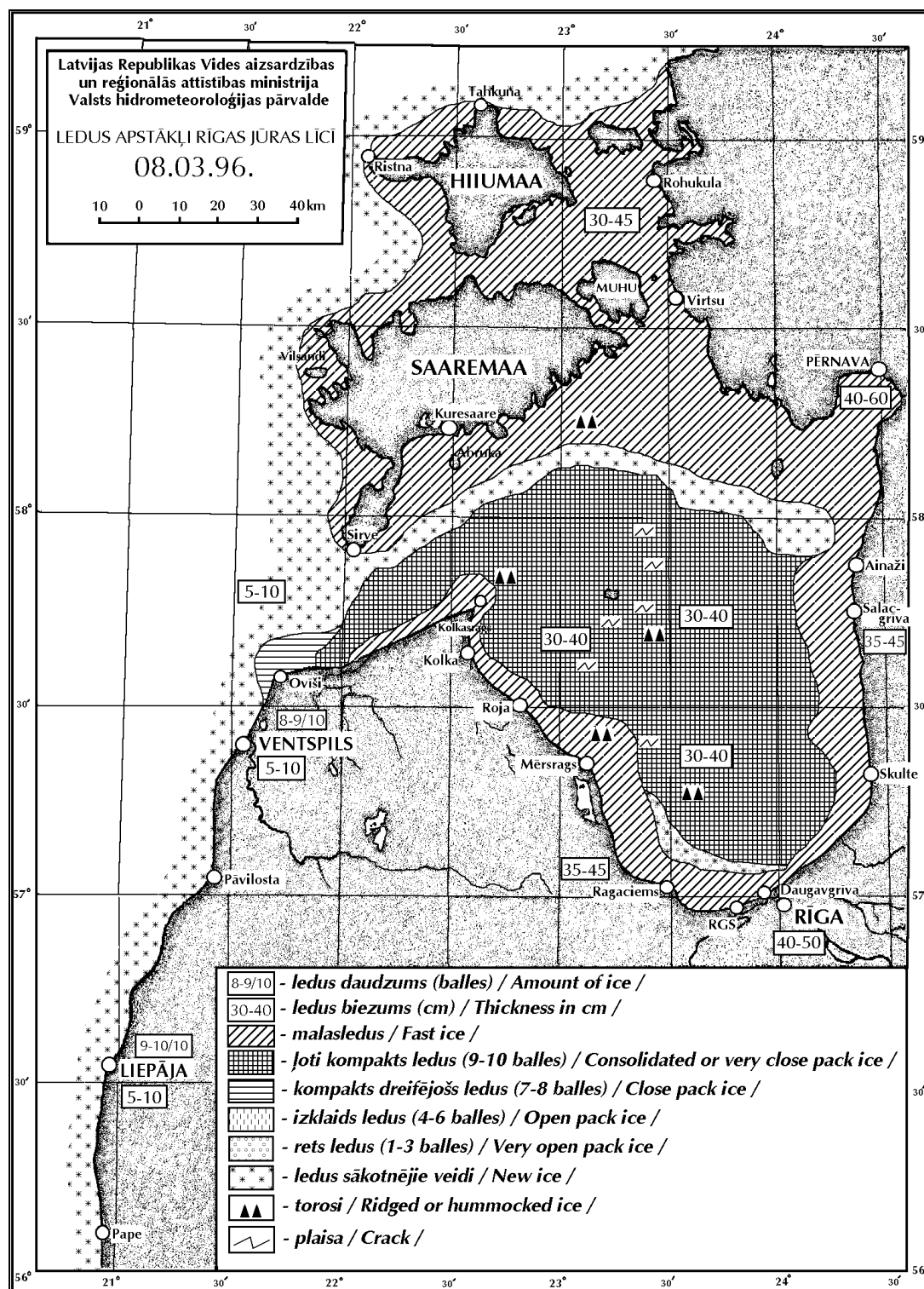


Fig. VIII-1. Ice chart for the Gulf of Riga for 8 March 1996.

ANNEX IX

Poland

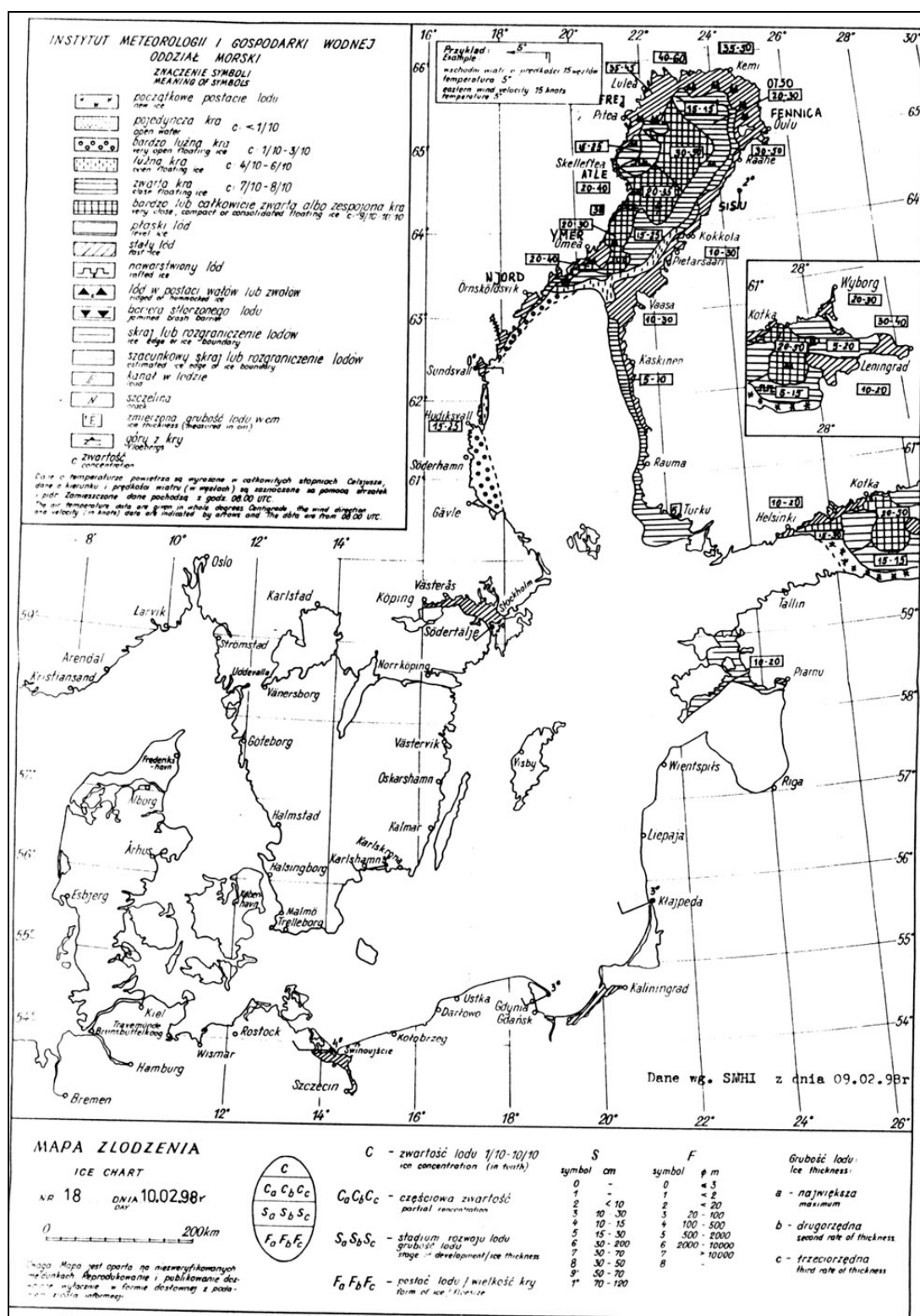


Fig.IX-1. Ice chart for the Baltic proper for 10 February 1998.

ANNEX X

Russian Federation

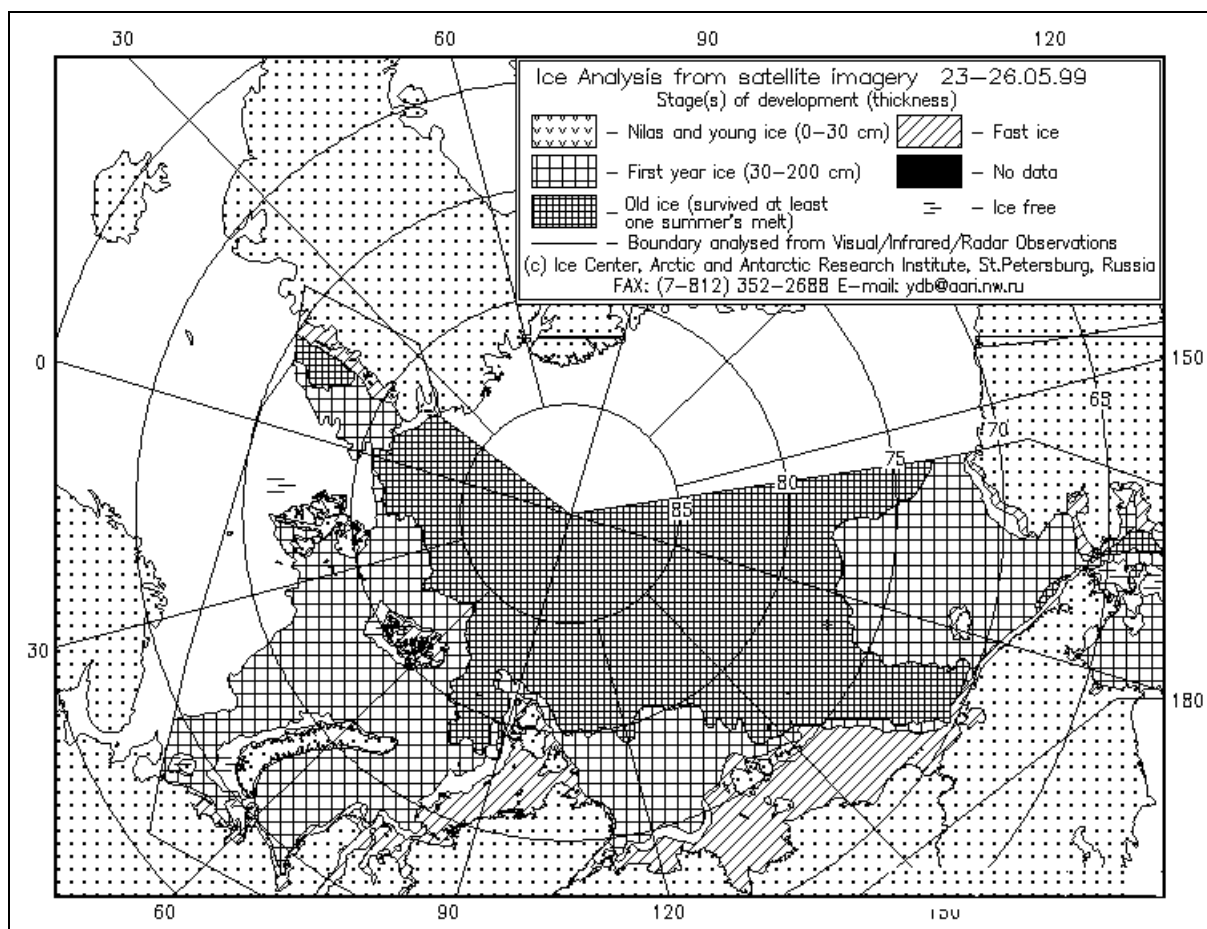


Fig.X-1. Common usage ice chart for the Arctic for 23-26 May 1999.

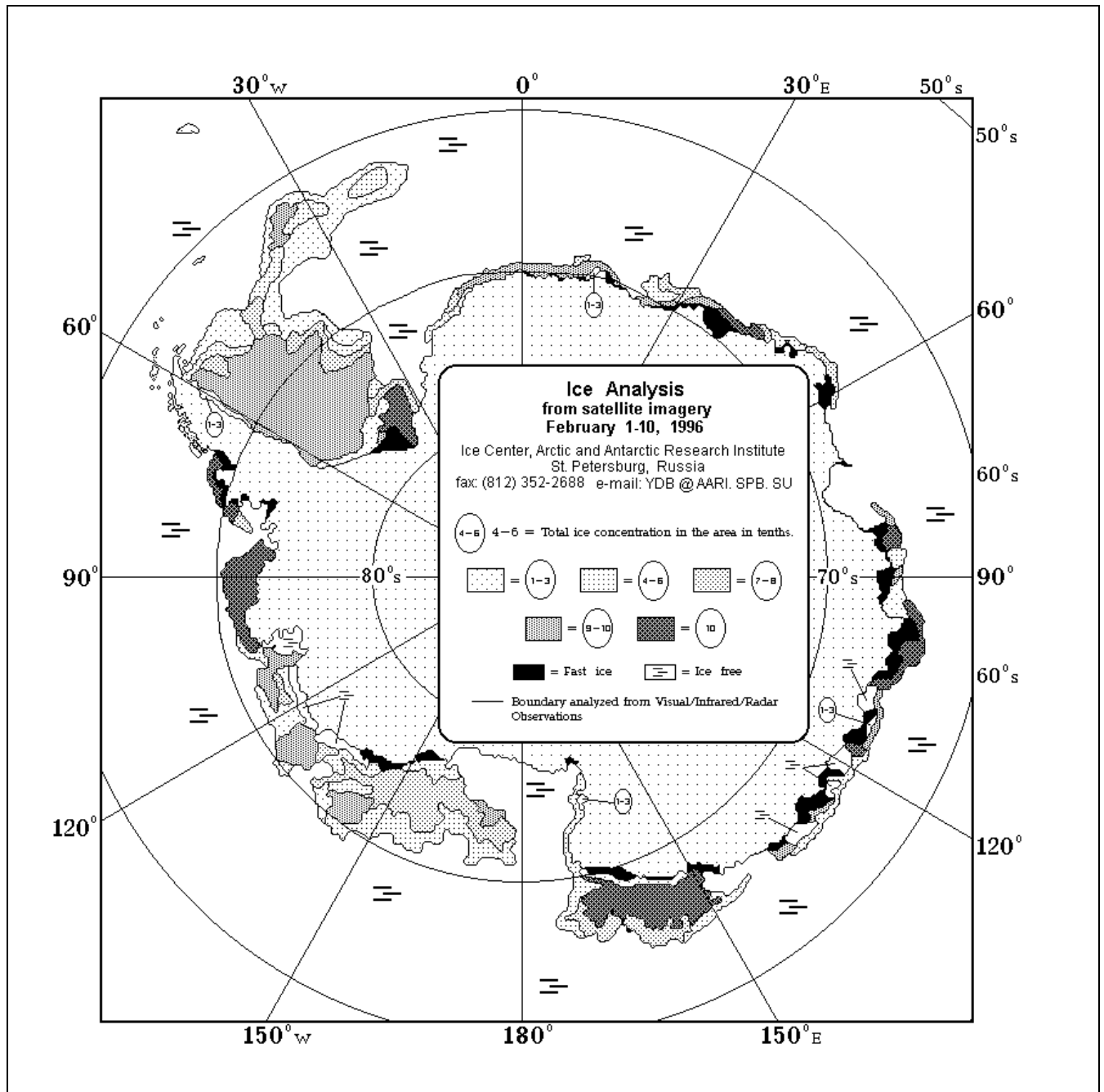
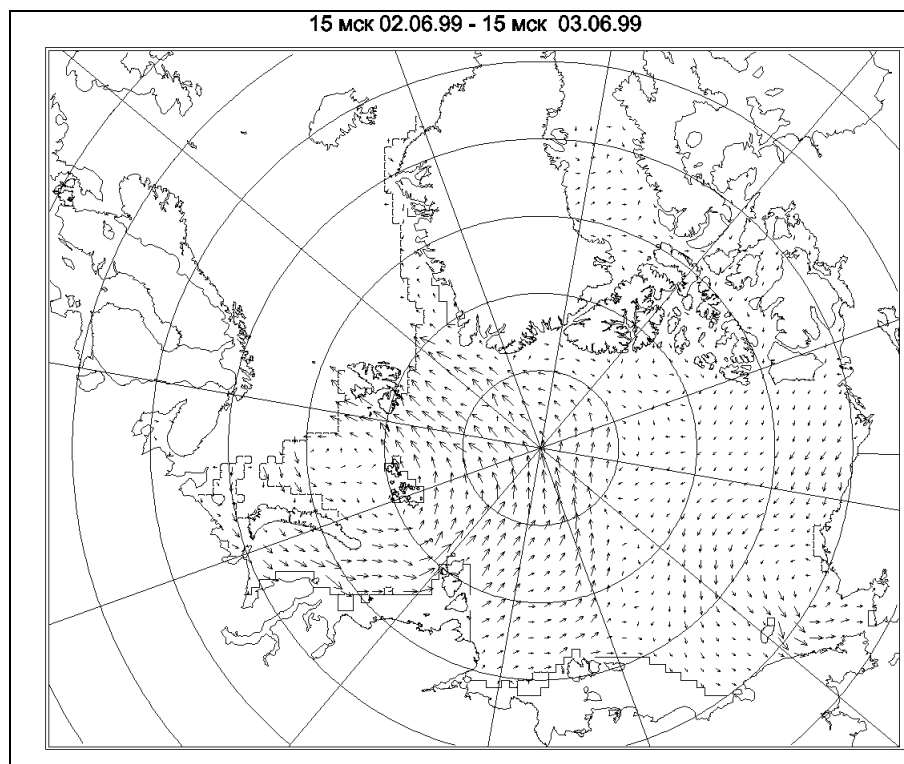
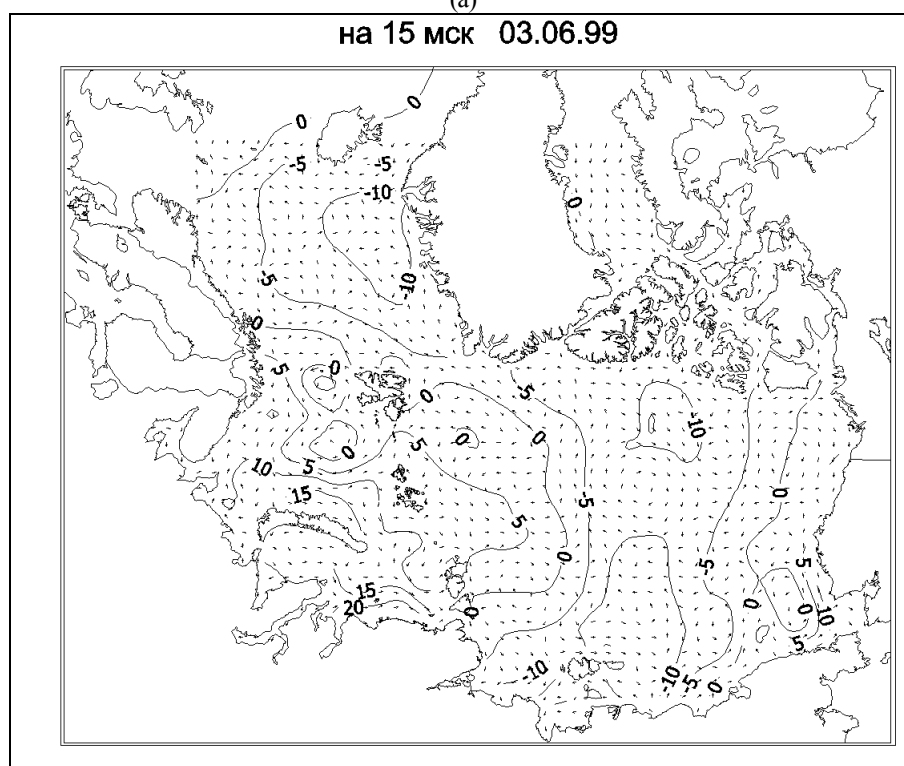


Fig.X-2. Common usage ice chart for the Antarctic for 1-10 February 1996.



(a)



(b)

Fig.X-3. Forecast charts for the Arctic sea-ice drift (a) and currents and level elevation (b), 3 May 1999.

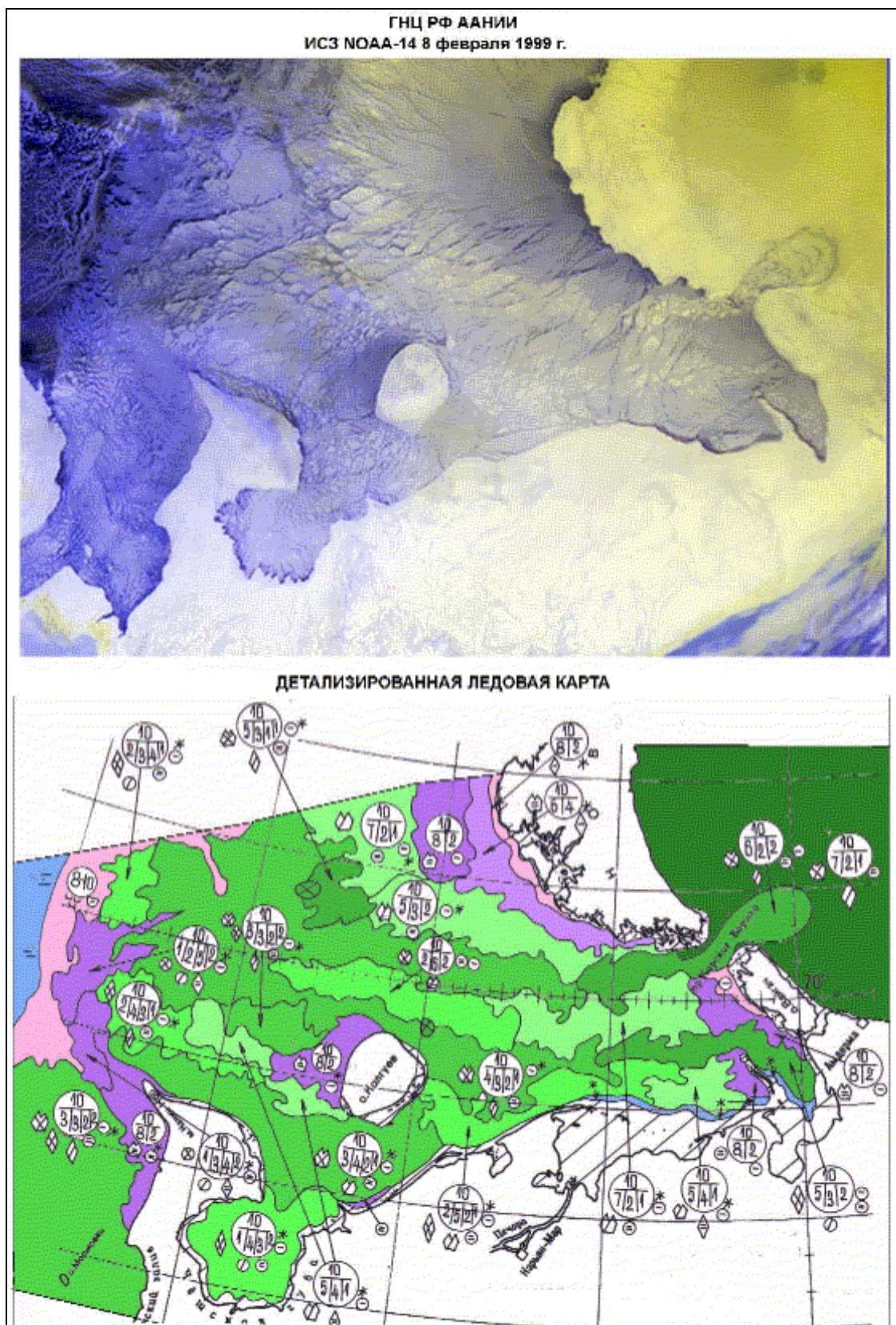


Fig.X-4. Initial NOAA-14 satellite imagery and detailed ice chart for Pechora Sea, February 8, 1999.

Изображение ИСЗ "NOAA-14" 10 февраля 1999 г.

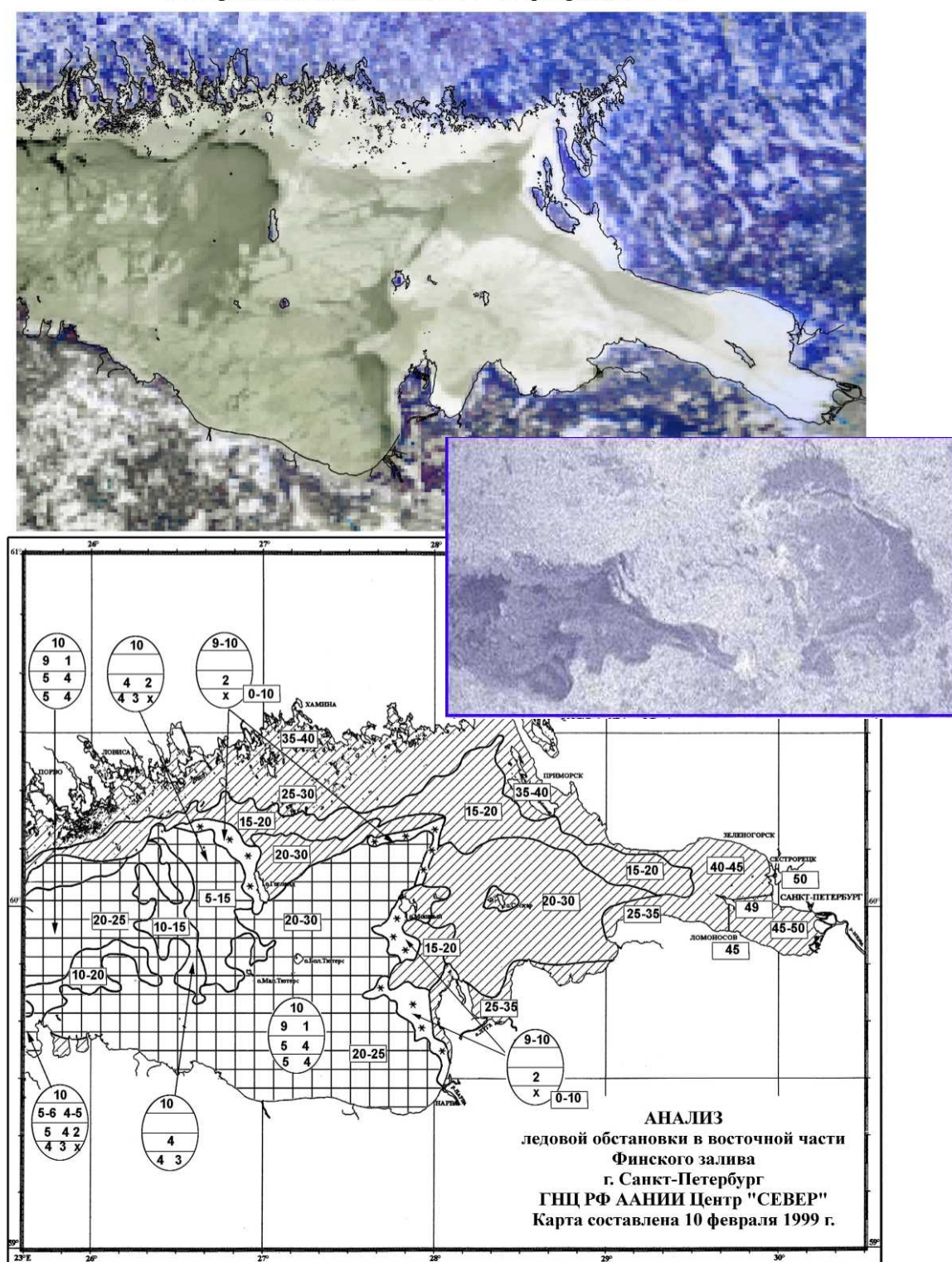


Fig.X-5. Ice chart for the Gulf of Finland for 10 February 1999 superimposed with the NOAA AVHRR and OKEAN SLAR imagery.

ANNEX XI

Sweden

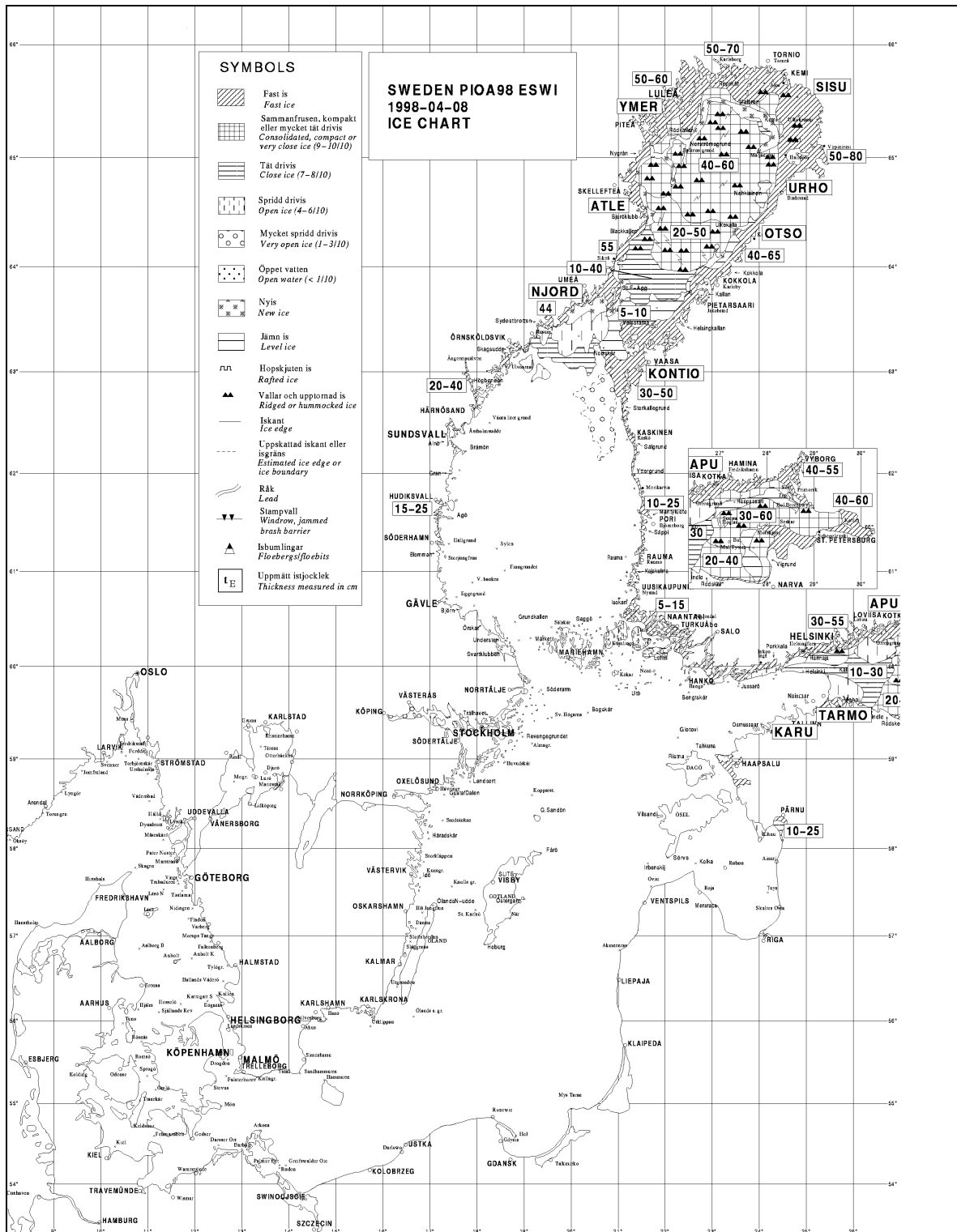


Fig.XI-1. Ice chart for the Baltic Sea for 8 April 1998

ANNEX XII

United states

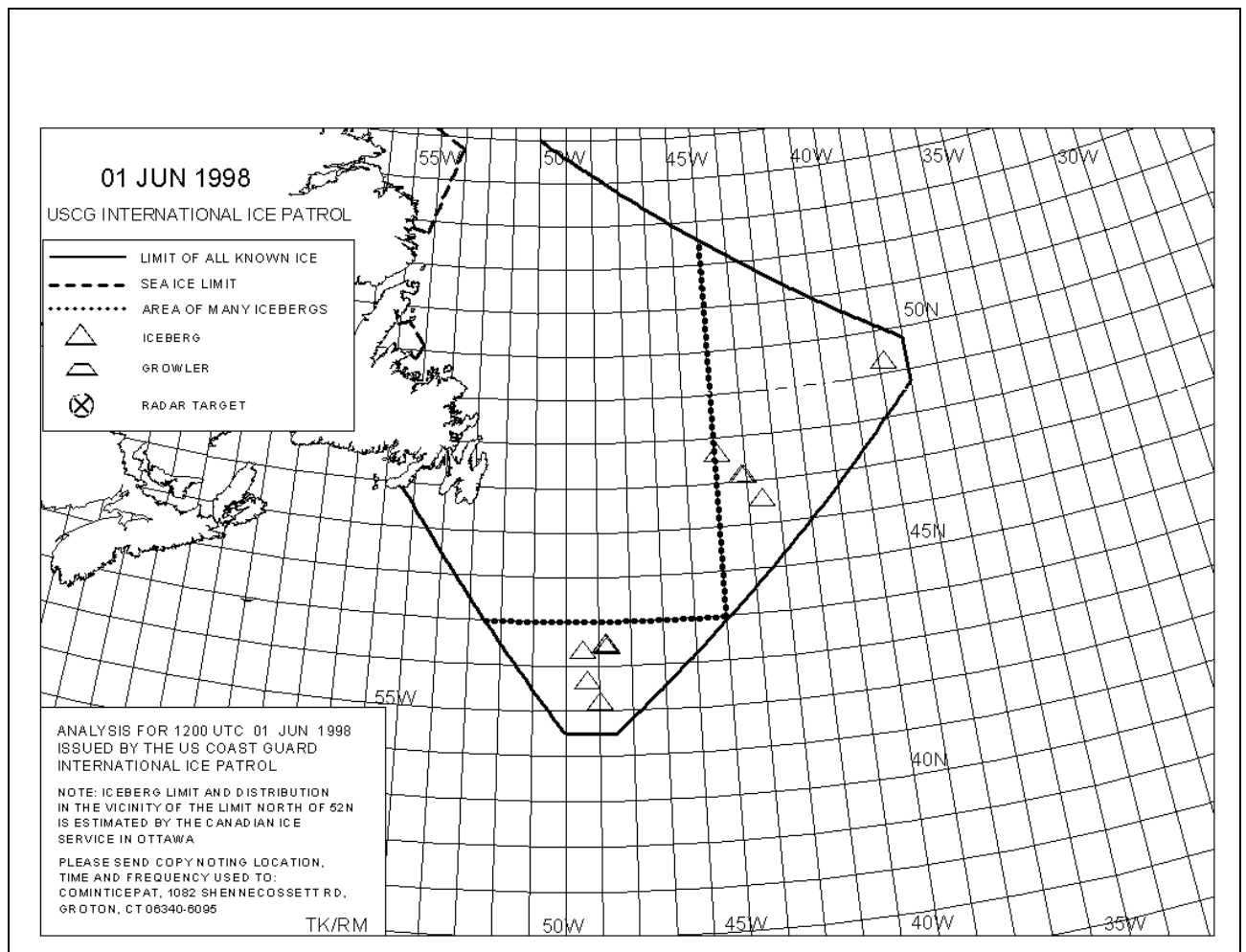


Fig.XII-1. Iceberg chart produced by the US Coast Guard International Ice Patrol for 1 June 1998.

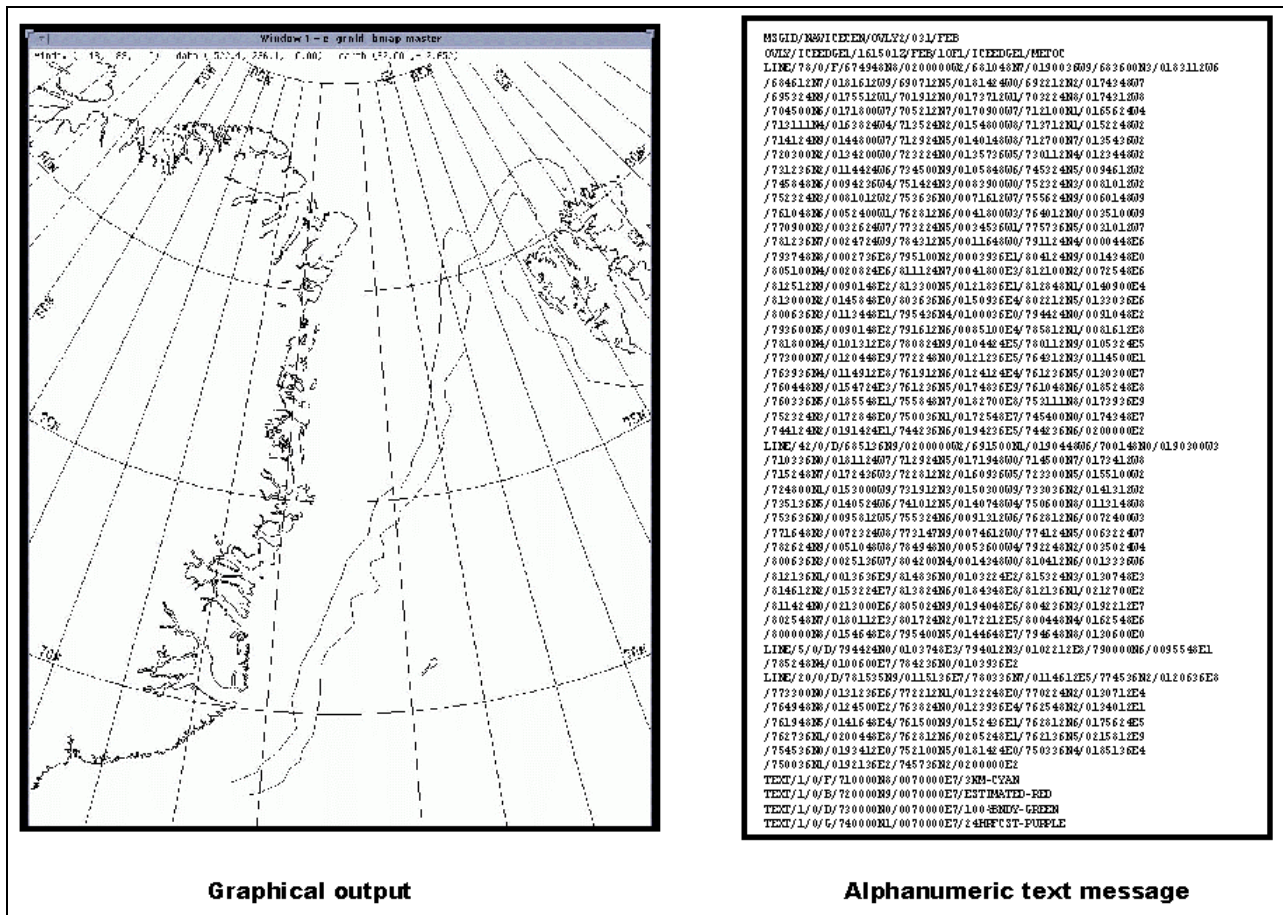


Fig.XII-2. Alphanumerical text message and corresponding graphical output for the ice edge position in the Greenland Sea.

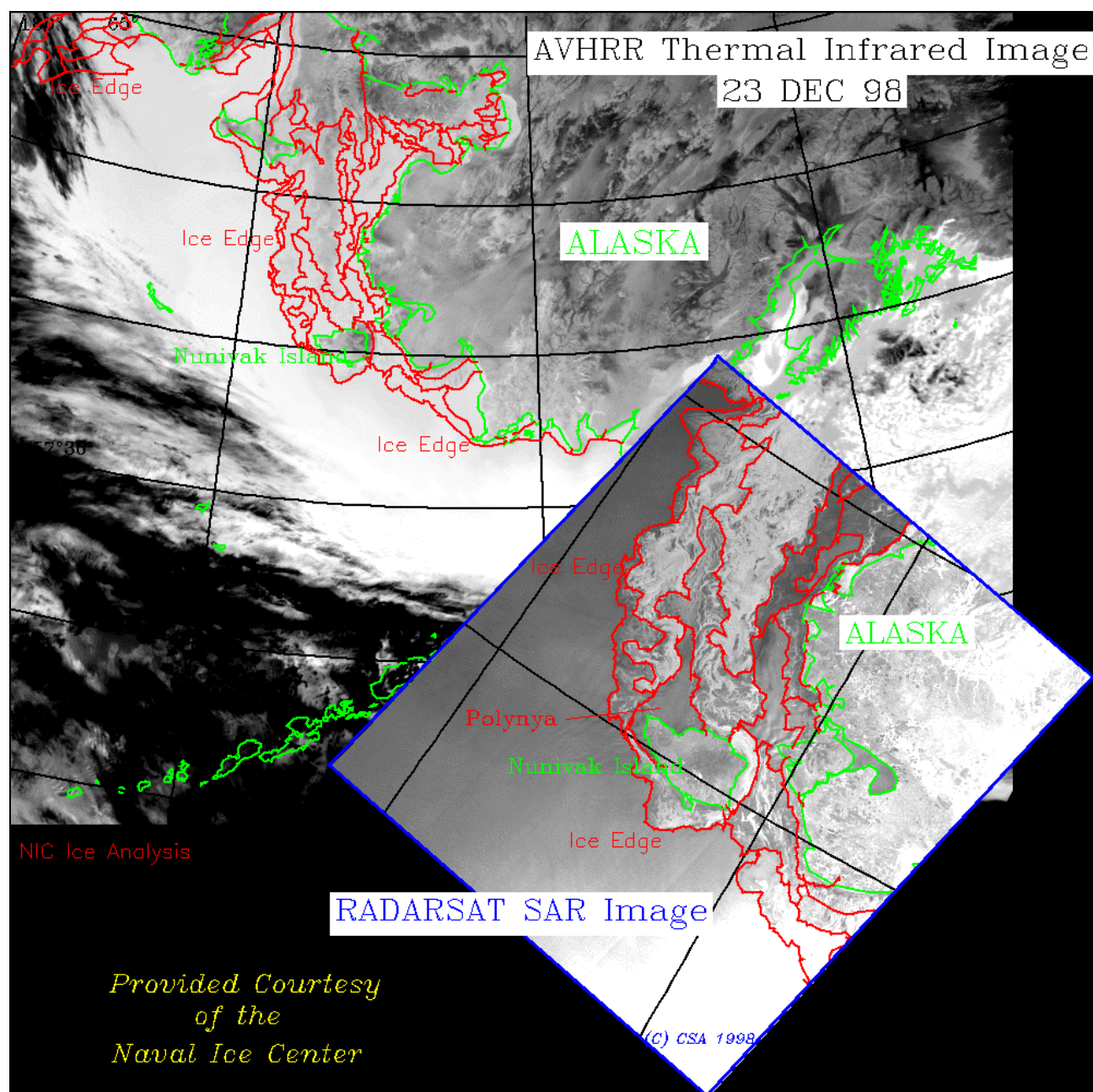


Fig.XII-3. Superimposed NOAA AVHRR and Radarsat imagery for the Bering Sea for 23 December 1998.

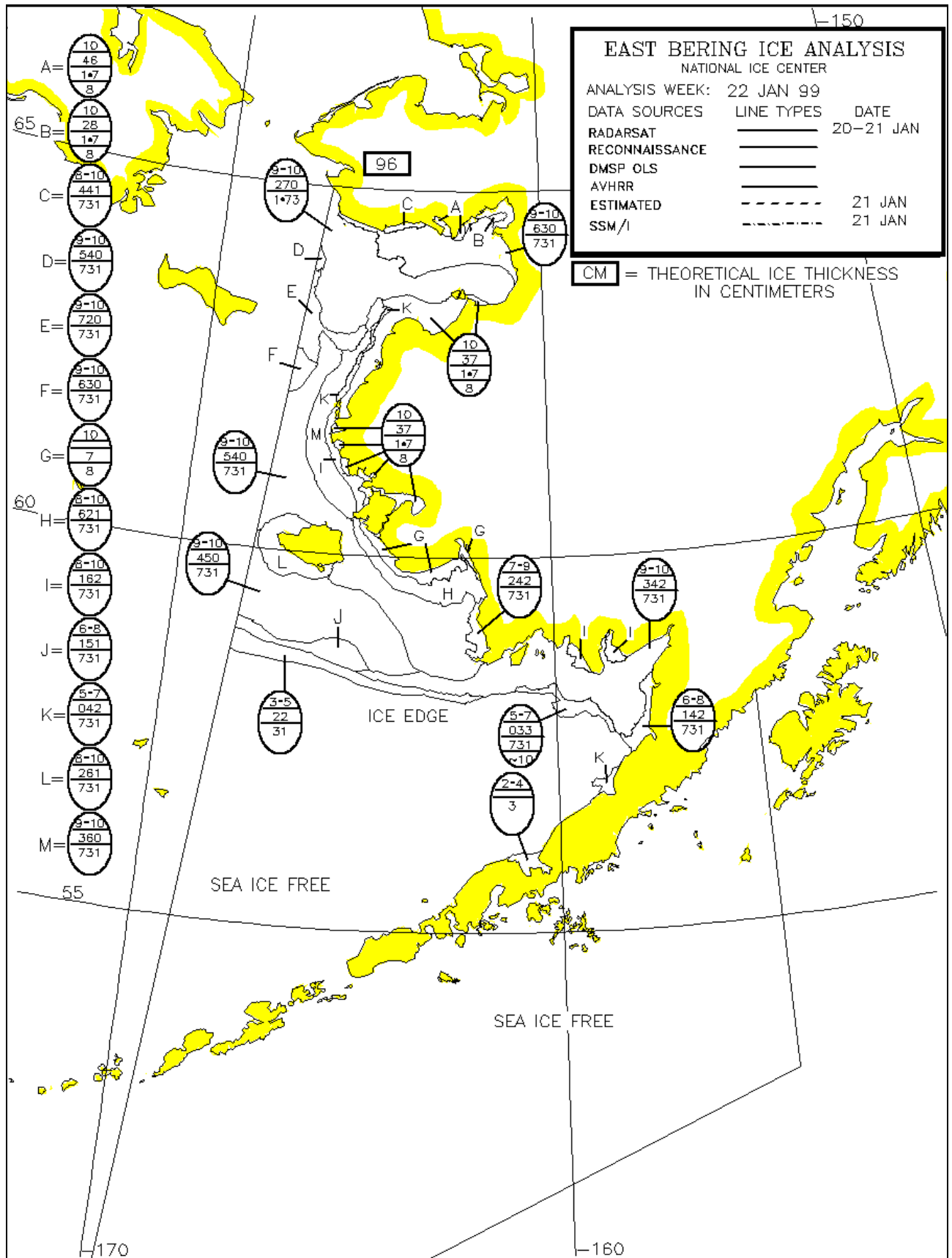


Fig.XII-4. Ice chart for the Bering Sea for 22 January 1999.

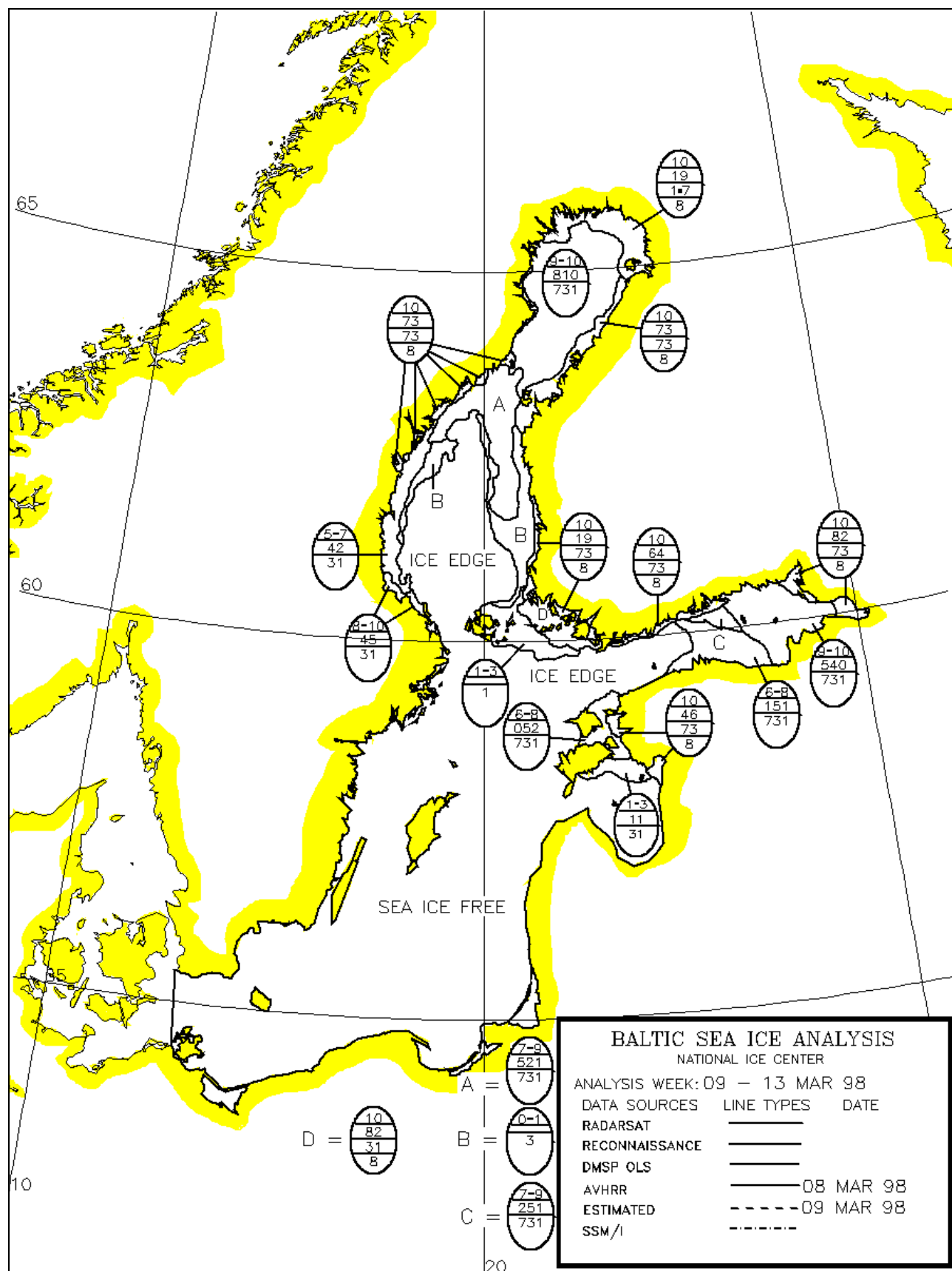


Fig.XII-5. Ice chart for the Baltic Sea for 9-13 March 1998.

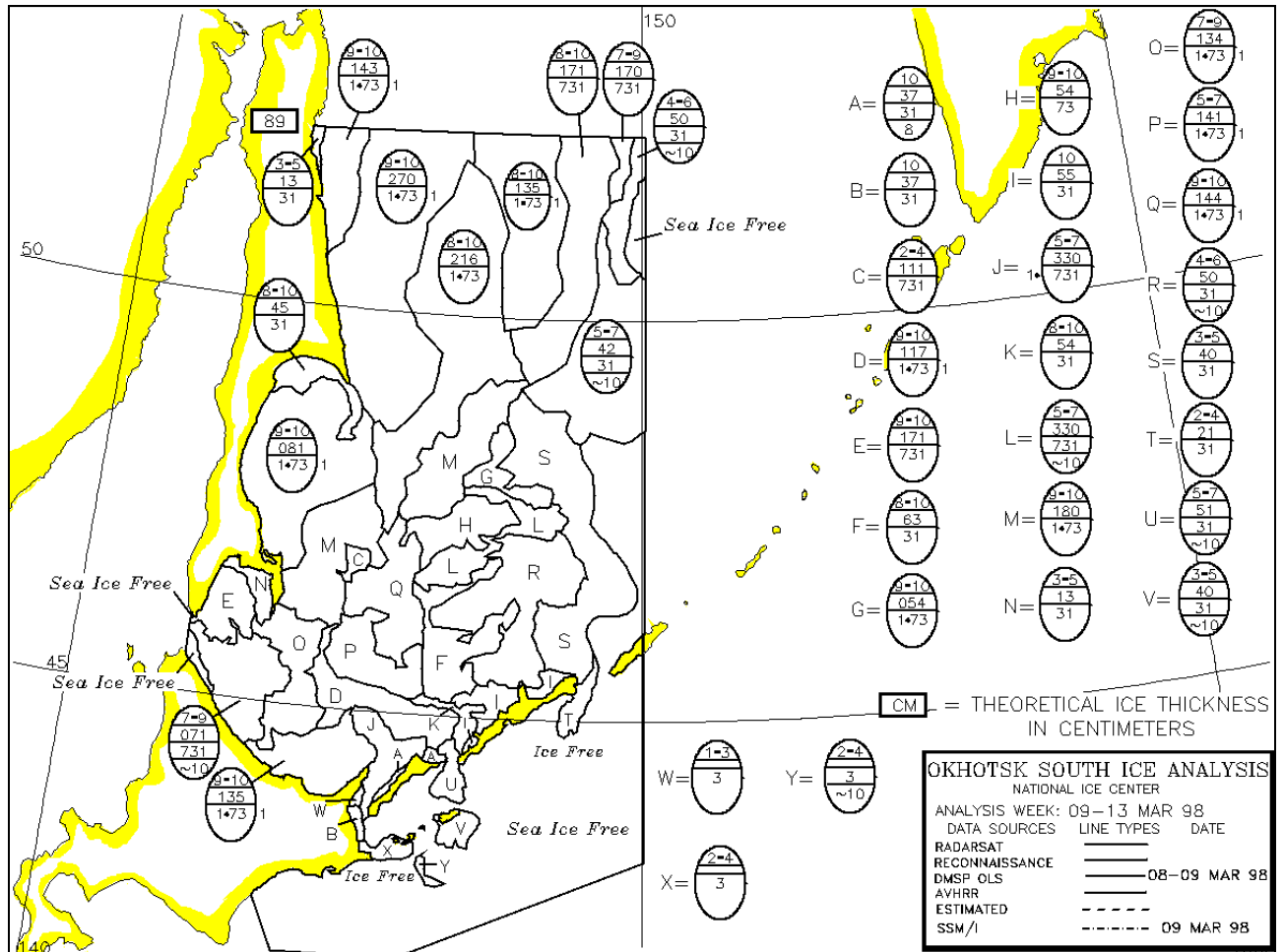


Fig.XII-6. Ice chart for the southern part of the Sea Of Okhotsk for 9-13 March 1998.

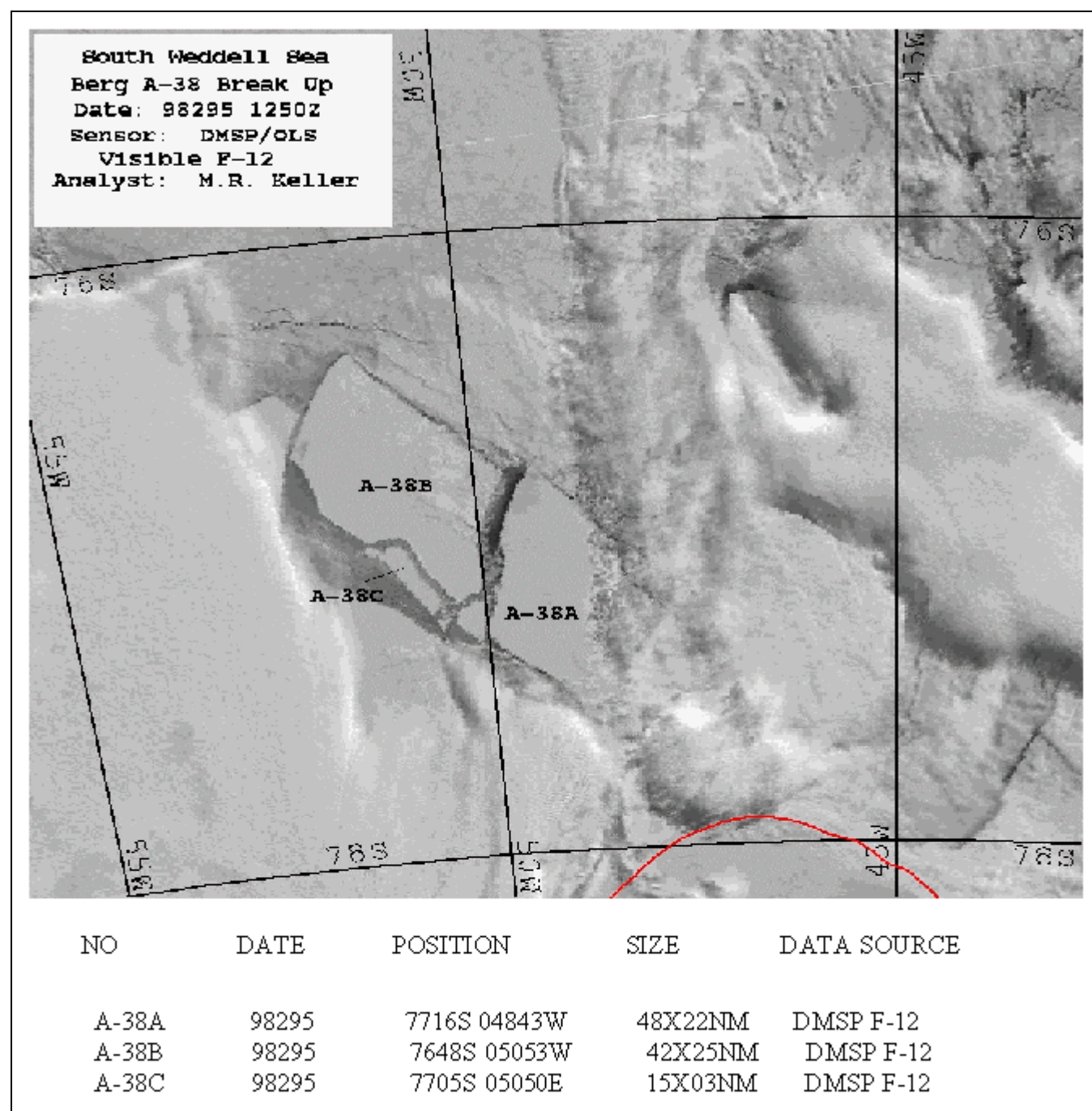


Fig.XII-7. DMSP satellite imagery depicting break up of A-38 iceberg in the South Weddell sea.

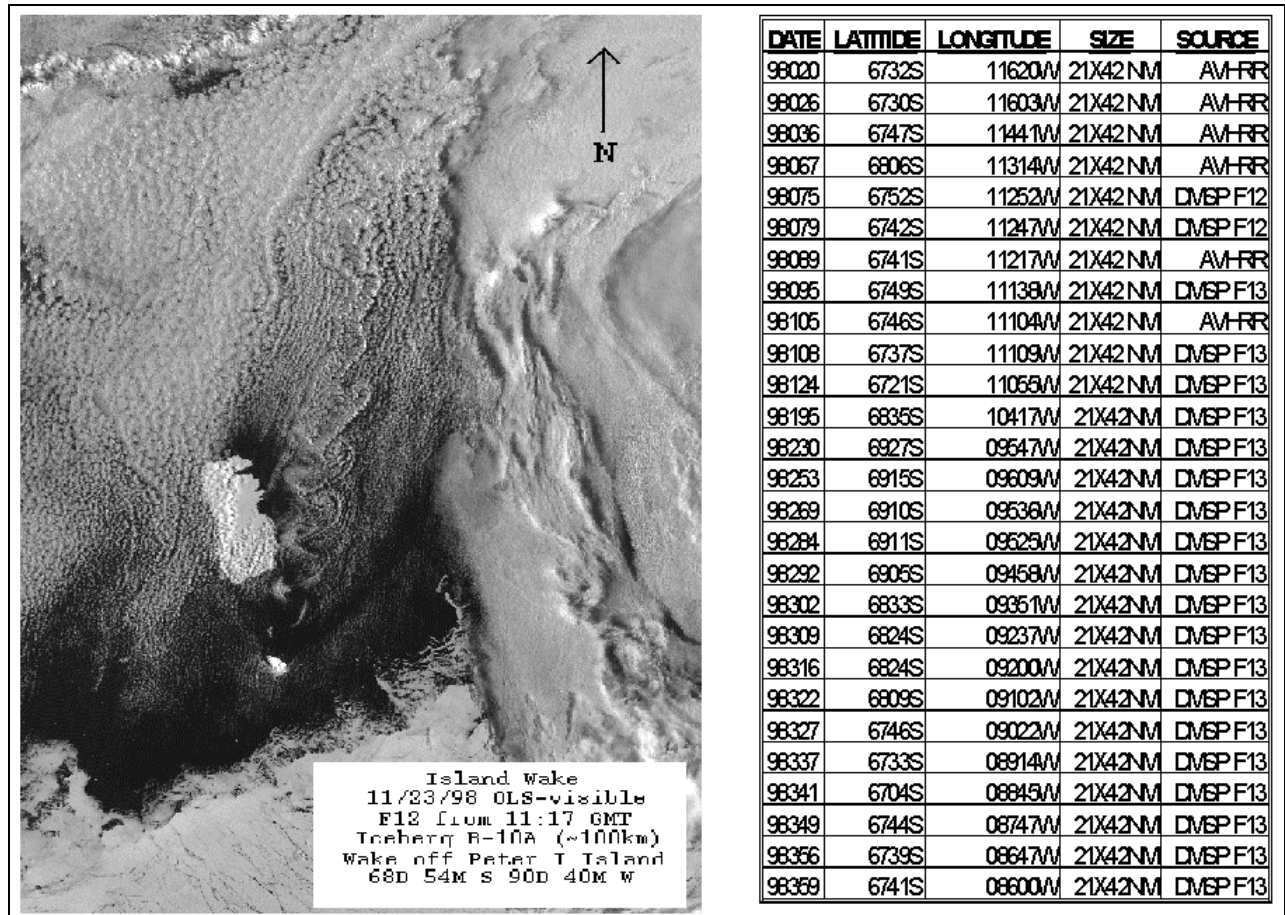


Fig.XII-8. DMSP F12 imagery and position tracking of B-10A iceberg, Bellingshausen Sea.

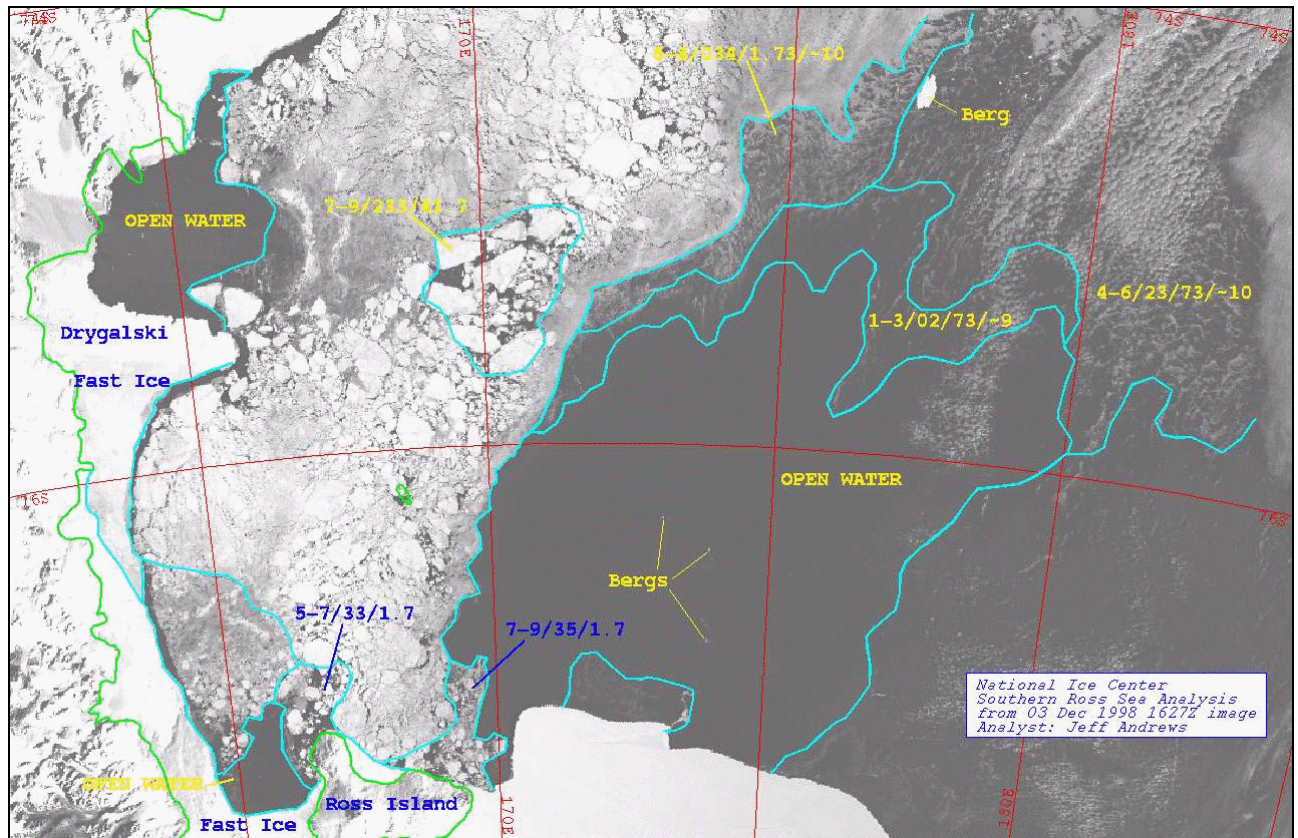


Fig.XII-9. Ross Sea annotated image.