Sea-ice Information and Services

2021 edition

WEATHER CLIMATE WATER

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INTRODUCTION

Mariners have known of the existence and perils of sea ice since vessels first ventured into the northern regions. The numerous polar expeditions of the nineteenth and twentieth centuries brought a new understanding of the types and variability of conditions affecting these vast ocean areas. It was not until misfortune struck the SS Titanic, however, that thoughts of international cooperation in sea-ice information gained any strength. After 1918, an increasing emphasis on navigational safety and the need for agreed shipping routes led to contacts between nations that 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 observations 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. It was at this point that the first international sea-ice conferences were held and the WMO Commission for Marine Meteorology (CMM) established a working group concerned with sea-ice affairs.

Since then, many strides have been made in both observational and processing techniques, and information services are now routinely provided for all the commonly frequented sea-ice regions.

This publication is intended to provide general information on sea ice and ice observing methods and systems, as well as information on the sea-ice services available worldwide to mariners and other users, supplementing *Weather Reporting Volume D – Information for Shipping* (WMO-No. 9).

The first edition of this publication was prepared and published in 1981.[1] Since that time, due to advances in remote sensing, computational means and telecommunications, significant progress has been made regarding the number and complexity of sea-ice products. There have also been changes to the number of sea-ice services and their regions of responsibility. Following the recommendation of the Commission for Marine Meteorology at its twelfth session in 1997, the Subgroup on Sea Ice (SGSI) undertook a review of the publication, and a second fully updated edition was issued in 2000.

Further progress in sea-ice information systems, the need for comprehensive information on sea-ice services, and planning for the 2007–2008 International Polar Year predetermined the decision of the SGSI successor, the Joint WMO/Intergovernmental Oceanographic Commission (IOC) Technical Commission for Oceanography and Marine Meteorology (JCOMM) Expert Team on Sea Ice (ETSI), in 2004, to update this publication on a regular basis. The third edition was published in 2006 and was available in the WMO online library. Preliminary revisions to the 2006 edition were used during the WMO Year of Polar Prediction (YOPP) project (2017–2019). During the Eighteenth World Meteorological Congress in 2019, JCOMM was disbanded. At the time of publication of this latest revision, the responsibilities of the former JCOMM ETSI were in the process of being incorporated into the new Technical Commission structures.

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[1] This publication was formerly known as Sea-Ice Information Services in the World.

1. THE NATURE OF ICE

This publication is predominately concerned with sea ice and icebergs in the Arctic and Antarctic waters. Sea ice is formed when seawater freezes, and it accounts for the majority of floating ice encountered at sea. Icebergs do not form from seawater but from fresh water or compacted snow originating from glaciers or land-based ice sheets and pose significant hazards to navigation. River and lake ice form from fresh water and are not specifically discussed in this publication.

Sea ice and icebergs present hazards to any ship. A clear understanding of the nature of sea ice is critical in order to increase the safety of ships operating in and near ice-affected waters. In addition to the clear dangers of sea ice with respect to navigation, information on sea ice is also critical to understanding ocean circulation, atmosphere–ocean heat transfer and global climate.

The location and characteristics of sea ice are also critical factors that influence not only navigation and climate but also wildlife and the livelihood of the people who live in areas where sea ice is present.

Definitions of sea-ice types and icebergs are available in *Sea Ice Nomenclature* (WMO-No. 259).

1.1 Formation and development of sea ice

For seawater to freeze and form ice, it first must be cooled to its freezing point. The water must lose heat. Ocean water loses heat through the processes of evaporation, conduction, convection and advection, and short- and long-wave radiation. Sea-surface temperatures for seawater of normal salinity of 35 practical salinity units (psu) must fall below -1.8 °C for the seawater to begin to freeze. Initial sea-ice formation starts at the surface of the water, where the heat loss is greatest. Sea-ice is characterized primarily by its stage of development, as described below.

1.1.1 *New and young ice – 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 centimetres of the water. These spicules, known as frazil ice, form in large quantities and give the sea an oily appearance. The environmental conditions during the initial stage of sea-ice formation affect the type of new ice that develops.

With extreme light winds and no waves, frazil ice coalesces to form grease ice, which has a matt appearance. Under near-freezing but still ice-free conditions, snow falling on the surface may result in the sea surface becoming covered by a layer of slush. Grease ice and slush may be regrouped by the action of wind and waves to form spongy, white, lumpy ice called shuga. Frazil ice, grease ice, slush and shuga are all classified as new ice (NI).

With further cooling, sheets of ice rind or nilas (NL) are formed, depending on the rate of cooling and 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 be up to 5 cm thick. 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 nilas (DN) and light nilas (LN); the former can be up to 5 cm thick, while the latter, a more advanced stage, can be up to 10 cm thick. Ice rind and dark and light nilas are referred to as nilas ice. Sheets of nilas ice have a tendency to raft rather than ridge if pushed together, sometimes interlocking in a distinct finger-rafting pattern.

Under turbulent wave action, frazil ice at or near the sea surface coalesces to form clumps. These clumps collide with each other, accreting further frazil crystals around the edges. This creates a raised rim, and with the clumps developing into rounded floes, gives this type of distinctly new ice the name pancake ice. “False” pancake ice may be formed by the breaking up of nilas or ice rind due to the action of wind and waves.

Ice rind, nilas and pancake ice may thicken into grey ice (GR) and grey-white ice (GW). Grey ice is 10–15 cm thick and grey-white ice is up to 30 cm thick. Ice crystals within these types of ice are randomly orientated due to their frazil ice origin. Grey ice and grey-white ice are referred to collectively as young ice (YI). Rough weather may break young ice into ice cakes, pancake ice or floes of varying size.

New ice (NI): 0 to 5 cm	Nilas (NL): 5 to 10 cm	Young ice (YI): 10 to 30 cm
Frazil ice	Ice rind: 5 cm	Grey ice (GR): 10 to 15 cm
Grease ice	Dark nilas (DN): 5 cm	Grey-white ice (GW): 15 to 30 cm
Slush	Light nilas (LN) including pancake ice: 5 to 10 cm	
Shuga		

1.1.2 *First-year ice – ice 30 cm to 2 m thick*

The next stage of development is known as first-year (FY) ice and is subdivided into thin (FL), medium (FM) and thick (FT) categories. FL ice has a thickness of 30–70 cm and is subdivided according to its thickness into thin first-year ice first stage (F1), which has a thickness of 30–50 cm, and thin first-year ice second stage (F2), which has a thickness of 50–70 cm. FM ice ranges in thickness from 70 to 120 cm. In polar areas, FT ice may develop and attain a thickness of 200 cm by the end of the winter.

In addition to thickness, the various types of first-year ice can be distinguished according to surface roughness. Thin first-year ice has a smooth surface, medium first-year ice shows incipient ridges and thick first-year ice surface has fully developed ridges. Ice thickness develops either through the vertical downward growth of ice crystals, producing a distinct columnar ice crystal structure different from the randomly orientated crystals of new ice growth, or through snow accumulation on the surface (especially in the Antarctic). The weight of the snow can cause the ice surface to become flooded by seawater that then freezes into a layer of superimposed ice.

Thin first-year ice (FL): 30 to 70 cm	Medium first-year ice (FM): 70 to 120 cm	Thick first-year ice (FT): 120 to 200 cm
First stage (F1): 30 to 50 cm		
Second stage (F2): 50 to 70 cm		

1.1.3 *Old ice*

Sea ice that has survived at least one summer’s melt season is termed “old ice” (OI). Old ice is divided into residual ice, second-year (SY) ice and multi-year (MY) ice.

Residual ice is first-year ice that has survived one summer’s melt and is in a new cycle of growth. Historically, its thickness averages 30–180 cm depending on its location. After 1 January in the northern hemisphere and after 1 July in the southern hemisphere, this sea ice is referred to as second-year ice.

Second-year ice is ice that has survived one summer’s melt and has completed its new cycle of growth. It is discernible from first-year ice due to its thickness: it is thicker than first-year ice and stands higher out of the water. The typical thickness of level second-year ice in winter is normally in the range of 200 to 250 cm.

Multi-year ice is ice that has survived at least two summers’ melts. It is smoother than second-year sea ice. During the melt season, sea ice becomes less saline because of brine drainage, and air pockets in the ice disappear. After two summers’ melts, MY ice is almost free of salt and is very hard. OI can often be recognized by its bluish surface colour in contrast to the greenish tinge of FY ice. The typical thickness of MY ice in the Arctic Basin in winter varies from 250 cm to 400 cm.

Residual ice: 30–180 cm	Second-year (SY) ice: 200–250 cm in winter	Multi-year (MY) ice: 250–400 cm in winter
First-year (FY) ice that has survived one summer's melt and is now in a cycle of new growth	Ice that has survived one summer's melt and has completed its new cycle of growth	Ice that has survived at least two summers' melts

1.2 **Sea-ice decay**

During the winter, ice usually becomes covered with snow of varying thicknesses. This snow cover initially persists as almost 90% of the incoming solar radiation is 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, called melt ponds, on the surface. These melt ponds absorb, rather than reflect, around 90% of the incoming radiation, and they rapidly enlarge as they melt the surrounding snow or ice. Eventually, the melt ponds penetrate to the bottom surface of the floes and are known as thawholes. At the same time, salt pockets in the ice enlarge and move downward through the ice. These channels are another path for the ponded water to drain through.

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 (for example, the Antarctic Sea and the Labrador Sea), melt ponds are less prevalent. The warmer air and water temperatures serve to weaken and melt the ice, and decay is accelerated by the break-up of the floes due to wave erosion.

1.3 **Sea-ice movement**

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

The movement of ice in the Arctic Ocean is caused by wind, the Coriolis force, ocean currents and internal stress; however, it is mainly caused by wind. The shape of the sea ice itself is important with respect to how the wind affects it. Wind exerts a force on sea ice known as wind stress. Wind stress is proportional to the square of the wind speed and the roughness of the sea-ice surface. The greater the wind speed and ice surface roughness, the greater the wind stress.

Wind stress in drift ice causes 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 coverage) and open ice (4/10–6/10 coverage), there is much more freedom to respond to the wind than in close ice or pack ice (7/10–8/10 coverage) and very close ice (9/10–10/10 coverage), where free space is very limited. No water is visible within compact ice (10/10 coverage) or consolidated ice (10/10 coverage), where floes are frozen together. Two per cent 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. Due to its momentum, ice may continue to move even after the wind has stopped.

A force is also 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 where both are present, the resultant motion is always the vector sum of the two. Wind stress normally predominates short-term movements, particularly in offshore areas, whereas the average long-term transport is dominated by the prevailing surface currents.

1.4 **Sea-ice deformation**

Where 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 neighbour. 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 processes 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 submerged part of the ridge is called the ice keel, and the submerged part of the hummock is called the bummock. The maximum draught of a ridge is usually three to six times as great as its maximum height but may occasionally exceed a factor of 10. 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 freshwater ice derived from glaciers and ice shelves. The underwater mass and draught of an iceberg, compared to its mass and height above the water, varies widely according to the composition and shape of the berg. The ratio of the below-water mass to the above-water mass of an Antarctic iceberg derived from a floating ice shelf is usually less than that 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 about five parts below. In contrast, the ratio for an Arctic iceberg composed almost wholly of ice with much less snow is generally lower, closer to one to seven. However, given their irregular shape, Arctic icebergs have an average height-to-draft ratio of one to three.

Antarctic icebergs may be many nautical miles in diameter and of the tabular category. Through deterioration, other iceberg types, bergy bits and growlers may be present. In Arctic waters, icebergs are smaller, and icebergs larger than half a nautical mile are only observed occasionally.

Icebergs diminish in size in three different ways: by calving, by melting, and by melting combined with erosion caused by wave action. An iceberg is said to calve when a piece breaks off, disturbing its equilibrium and causing it to float at a different angle or 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, an iceberg melts mainly from below and calves frequently. It is particularly dangerous to approach an iceberg in this state for it is unstable and may calve or overturn at any time. There are likely to be many growlers and bergy bits around rapidly disintegrating icebergs, which form a particular hazard to navigation.

Icebergs surrounded by sea ice can be protected from waves and are less likely to calve. They can be quite difficult to detect. Since icebergs tend to be driven by deeper currents, they can move at a different rate than the surrounding sea ice.

Weathered icebergs are poor reflectors of radar pulses and cannot always be detected by such means. Their breakdown fragments – bergy bits and growlers – are even more difficult to detect with ship radar, as background clutter from waves and swell often obscures them. These smaller fragments are especially dangerous to shipping, despite their low profile, as they have sufficient mass to damage a vessel that 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.

Depending on the keel depth, icebergs may be grounded for longer periods, but they will typically also travel long distances with drifting sea ice or cold ocean currents. Icebergs and debris ice are serious hazards in ocean shipping lanes.

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2. ICE OBSERVING METHODS

Satellite imagery is the tool most frequently used to gather data about and analyse sea ice and icebergs. However, observations from shore stations, ships and aircraft are still essential for establishing the "ground truth" of satellite observations. At present, observations of floating ice depend on instrumental observations (for example, from buoys) and, to a lesser extent, visual observations. Instrumental observations include coastal radar and electromagnetic induction sensors. Satellite-borne instruments include visible and infrared imagers, passive microwave radiometers, scatterometers, laser and radar altimeters, and synthetic aperture radars (SARs).

The five most important features of floating ice which affect marine operations, are:

(1) The origin of the ice (sea ice or icebergs);

(2) The thickness of the ice (stage of development);

(3) The amount of ice present – for sea ice, the concentration, usually estimated according to the tenths or percentage of sea surface covered by the ice; for icebergs, the size and shape of the iceberg;

(4) The form of the ice, whether it is fast or drift ice and the size of the constituent floes; and

(5) Any movement of the ice.

From the bridge of a ship 10 m above the sea, the horizon is about 12 km away, and observations can cover a radius of 7–8 km. From the top of a coastal lighthouse 100 m above the sea, the visual range is almost 40 km, and observations can 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 currents, but the total area of ice reported is very small. From a ship progressing through the ice, a summary report of the ice encountered during daylight progress may represent an area of sea ice 15 km wide and 100 km long (assuming the speed of the ship to be approximately 5 knots). In some marine areas, coastal settlements, lighthouses and ships may be present in sufficient numbers that a reasonable proportion of the ice cover can be observed and shared via an organized surface network. Shore reporting on waterways that are broad only provides data on a small percentage of the total ice cover, however.

Surface-based reports can provide excellent details about the ice, especially its thickness, using drilling or electromagnetic induction sensors. Reports on the ice cover based on observations from the air, that is, via helicopters and fixed-wing aircraft, have the advantage of being drawn up based on observations made with a much better viewing angle and of a larger area. Trained ice observers can recognize the various stages of development of sea ice, estimate its amount, and note its deformation and the snow cover or stage of decay. For icebergs, these ice observers can determine the size and shape of the icebergs, which is critical for accurate drift and deterioration modelling.

Recent advances in technology now permit more precise data than ever before to be obtained by aerial observations. Sophisticated radar systems used with real aperture, SAR, and inverse SAR modes can provide information regarding the precise distribution and nature of the ice 360 degrees around the flight path of the aircraft for distances of up to 100 km. Unlike most other sensors, radar is capable of monitoring the ice in 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 infrared airborne scanning system can provide excellent information about floe thickness in ranges below 30 cm.

Earth-orbiting satellites are the predominant means of observing sea ice, but there are some restrictions to this method. Satellite sensors are limited to the visible, infrared, passive or active microwave spectral ranges, or a combination of these. In addition, satellite coverage is broad at low resolution and covers a narrow swath at high resolution. (The higher the resolution, the smaller the area that can be imaged and the less frequently the area can be resampled.)

In general, most meteorological satellites provide complete coverage of the polar regions once or twice a day.

Some of these satellites contain instruments that produce visible and infrared images with resolutions of 250 m to 1 km (National Oceanic and Atmospheric Administration (NOAA) Advanced Very-High-Resolution Radiometer (AVHRR), SUOMI National Polar-orbiting Partnership (NPP), Earth Observing System (EOS) Moderate Resolution Imaging Spectroradiometer (MODIS), Defense Meteorological Satellite Program (DMSP) Operational Linescan System (OLS), Sentinel-3 Sea and Land Surface Temperature Radiometer (SLSTR) and Ocean and Land Colour Instrument (OLCI)), while others contain instrumentation which generates passive microwave and scatterometer data at coarser resolutions of 6–70 km (Advanced Microwave Scanning Radiometer 2 (AMSR2), NOAA Advanced Microwave Sounding Unit (AMSU), DMSP Special Sensor Microwave Imager/Sounder (SSMIS), Advanced Scatterometer (ASCAT)). Visible and infrared data do not have cloud-penetrating capability, while microwave data are practically cloud independent. Active microwave SAR data (obtained via RADARSAT-2, Sentinel-1, TerraSAR-X, Constellation of Small Satellites for Mediterranean basin Observation (COSMO-SkyMed), and Advanced Land Observing Satellite 2 (ALOS-2)) are characterized by improved ground resolution (approximately 10–100 m) but lesser coverage due to narrow swaths and greater revisit time between exact repeat orbits. Ice services are also starting to use data from radar altimetry satellites such as Cryosat and Sentinel-3 and high-resolution (20 m or better) optical imagery from Sentinel-2.

Spaceborne sensors can provide precise data on the location and type of ice boundary and concentration and the presence or absence of leads. They can also provide less precise information on the stage of development, form, stage of ice melting and ice surface roughness. Floe motion over approximately 12- to 24-hour intervals can be determined through the use of imagery from sequential orbits.

Manual or visual interpretation of imagery from visible and infrared sensors requires experience and training in ice analysis. 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. These difficulties have been mitigated by SAR satellites with dual or full polarimetry modes of operations as the cross-polarization channels are better at distinguishing between areas of sea ice and open water.

Advances in automated sea-ice classification aid sea-ice services by adding more detailed ice information, decreasing the workload associated with the manual analysis process currently used in most sea-ice services. Coupled air–ice–ocean environmental models are also improving; these models facilitate the analysis process by providing reanalysis and forecast information regarding ice edges, ice concentration, ice thickness and ice drift.

3. INTEGRATED OBSERVATIONAL SYSTEMS

Any well-designed ice service system must include three major components:

(1) A surface observation network consisting of in situ reports and remotely sensed data;

(2) A communication system to gather and distribute ice information; and

(3) A digital data integration, analysis and production system.

Operators now have various sea-ice reporting regimes. Synoptic ship observation reports provide limited ice information. However, groups in both the Arctic and Antarctic have developed software programs to encourage the collection of shipborne observations from research and voluntary participants. For example, in the Arctic, the Arctic Shipborne Sea Ice Standardization Tool (ASSIST), sponsored by the WMO World Climate Research Programme (WCRP), provides a software program designed to capture sea-ice conditions and processes. In the Antarctic, the Antarctic Sea Ice Processes and Climate (ASPeCt) expert group, sponsored by the Scientific Committee on Antarctic Research (SCAR/WCRP), seeks to collect the same data.

When waterways are more open or more remote with respect to populated areas, satellite data or, in a lesser number of cases, aerial observations are integrated into the system. Satellite data are typically passed in near real time from satellite ground stations to ice centres, digitally processed, integrated with meteorological guidance products and ice model output and then analysed, typically using a geographical information system (GIS) environment. Image enhancement techniques and various other automated algorithms are often employed in the production of an ice analysis.

Sea-ice and iceberg products are provided as charts at varying scales depending on the size of the area and the level of detail required. The ice charts are made available in GIS formats – typically using the SIGRID-3 format (*SIGRID-3: A Vector Archive Format for Sea Ice Charts* (WMO/TD-No. 1214)) and simple graphic formats such as GIF or PNG. Charts are typically labelled and coloured using WMO sea-ice symbology (see *Sea Ice Nomenclature* (WMO-No. 259)) and the *Ice Chart Colour Code Standard* (WMO/TD-No. 1215). Other ice products include annotated satellite imagery, usually in JPEG and TIFF formats, text messages and electronic products for the Electronic Chart Display and Information Systems (ECDIS).

4. ICE INFORMATION SERVICES

Observed 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.

Usually, ice forecasts are prepared once a day for a period of 24 to 144 hours. These are tactical forecasts which may provide advice on difficult ice conditions forming or dissipating, the general motion of the pack, opening and closing of leads, and so forth. They are strongly influenced by meteorological predictions and should always be used in concert with weather forecasts.

Other longer-range predictions – those covering periods from 7 to 10 days and monthly and seasonal predictions – are based on climatological and analogue methods as well as the emerging capabilities of coupled long-range dynamic models and ensemble techniques.

Ice information collected over a long period of time can be used for climatological purposes. Information such as the average ice concentration at different times or the average ice stage of development can be provided and used for planning.

The distribution of charts of operational ice conditions is mostly conducted via digital network links or by radio facsimile. Most ice charts and other ice information are now available on the Internet.

5. INTERNATIONAL COOPERATION

A regional approach to ice services is far more economical and efficient than one based solely on national facilities. In 2003, the United States of America and Canada established a joint service known as the North American Ice Service (NAIS). NAIS is composed of the Canadian Ice Service (CIS), the U.S. National Ice Center (USNIC), and the United States Coast Guard (USCG) International Ice Patrol (IIP). The similar Baltic Sea Ice Services (BSIS) includes a mechanism to allow information exchange among Denmark, Estonia, Germany, Finland, Latvia, Lithuania, the Netherlands, Norway, Poland, the Russian Federation and Sweden. In Finland and Sweden, icebreaker assistance is integrated in the Gulf of Bothnia. In special situations, such as when the Baltic Sea is totally ice covered, all icebreaker assistance in the Baltic Sea is integrated, with the common aim of supporting marine traffic. This is done under the development of the Baltic Icebreaking Management (BIM), which is the cooperation body of the Baltic Sea icebreaking organizations. Within Europe, the ice services of Denmark, Finland, Iceland, Norway and Sweden have a similar agreement in the form of the European Ice Services (EIS). The European Union Copernicus Marine Environment Monitoring Service (CMEMS) programme (http://marine.copernicus.eu) includes partners from national services as well as from research and industrial communities and is designed to implement a coherent operational oceanography system for high latitudes, consisting of sea ice, meteorological and oceanographic services.

On a larger scale, until it was disbanded at the Eighteenth World Meteorological Congress in 2019, JCOMM ETSI[2] was instrumental in developing internationally accepted terminology, formats to exchange operational and archived data on sea ice, and other guidance material. JCOMM ETSI actively collaborated with other international sea-ice groups such as the International Ice Charting Working Group (IICWG) and the Baltic Sea Ice Meeting (BSIM). The international sea-ice terminology, including an illustrated glossary and a system of sea-ice symbols, was developed and first published in 1971 in English, French, Russian and Spanish (see *Sea Ice Nomenclature* (WMO-No. 259)) and since that time has been regularly updated and amended.

In the 1980s and 1990s, several formats were developed to archive the exchange of sea-ice information: SIGRID, designed by WMO in 1989 and SIGRID-2, designed by WMO in 1994. In addition, in cooperation with IICWG, two JCOMM Technical Report Series documents, *SIGRID-3: A Vector Archive Format for Sea Ice Charts* (WMO/TD-No. 1214) and the *Ice Chart Colour Code Standard* (WMO/TD-No. 1215), were prepared and issued in 2004.

In March 2007, JCOMM ETSI adopted the *Electronic Chart Systems Ice Objects Catalogue* version 4. (JCOMM-TR-080) as the sea-ice extension of the International Hydrographic Organization (IHO) S-57 format for Electronic Navigational Charts (ENCs).

In March 2014, based on the *Electronic Chart Systems Ice Objects Catalogue* (JCOMM-TR-080), the German Ice Service (Bundesamt fuer Seeschifffahrt und Hydrographie (BSH)), as part of JCOMM ETSI, produced *S-411 Ice Information Product Specification* (JCOMM-TR-081) in response to a requirement to produce an ice-data product that could be used for navigation within ECDIS. The ice-information product specification is based on the IHO S-100 framework specification, the Geography Markup Language (GML) Encoding Standard and the ISO 19100 series of standards.

The most recent versions of the above-mentioned documents, as well as additional sea-ice information, can be found on the WMO Sea-Ice Documents page of the WMO Community website.

Until the 1980s, most ice services were focused on shipping and offshore exploration. The needs of users were 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 information to be exchanged internationally so that it can be used by meteorological and oceanographic researchers. This has resulted in the creation of databanks at a coarser scale than those used in operational services. Within the WMO project, the Global Digital Sea Ice Data

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[2] At the time of publication of this document, the responsibilities of the former ETSI were being incorporated into the new WMO Technical Commission structures.

Bank (GDSIDB), which started in 1989 and contains historical sea-ice information for much of the twentieth century, was archived in electronic form in collaboration with several ice services, institutions and data centres (from Argentina, China, Canada, Denmark, Finland, Japan, the Russian Federation, Sweden and the United States). Presently, GDSIDB has two archiving centres, located at the Arctic and Antarctic Research Institute (AARI), St Petersburg, Russian Federation (http://wdc.aari.ru/), and the National Snow and Ice Data Center, Boulder, USA (http://nsidc.org/noaa/gdsidb). These centres hold mapped ice data covering periods from 7 to 30 days, beginning in 1933, for the Arctic, and beginning in 1971, for the Antarctic.

IICWG and JCOMM ETSI jointly contributed to the development of the Ice Logistics Portal in support of International Polar Year (IPY) 2007/2008. The Portal provides a single interactive website for operational sea-ice information from ice services in both hemispheres. Since 2009, the Ice Logistics Portal has been supported technically by BSH (http://www.bsis-ice.de/IcePortal).

In December 2014, following the recommendations and decisions of JCOMM ETSI and IICWG, Norway (Norwegian Meteorological Institute (NMI)), the Russian Federation (AARI) and the United States (USNIC) initiated a pilot project on integrated sea-ice analysis for Antarctic waters. Joint activities include weekly hemispheric sea-ice charting and southern hemispheric tabular iceberg analysis by USNIC, hemispheric sea-ice charting every other week and weekly hemispheric tabular iceberg analysis by AARI, and weekly regional Antarctic peninsula sea-ice charting by NMI.

6. NATIONAL AND REGIONAL SEA-ICE SERVICES

Information regarding national and regional sea-ice services will be available on the WMO website soon.[3]

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[3] At the time of publication of this document, this information was being compiled.

LIST OF ACRONYMS

AARI	Arctic and Antarctic Research Institute
ALOS-2	Advanced Land Observing Satellite 2
AMSR2	Advanced Microwave Scanning Radiometer 2
ASCAT	Advanced Scatterometer
ASMU	Advanced Microwave Sounding Unit
ASPeCt	Antarctic Sea Ice Processes and Climate
ASSIST	Arctic Shipborne Sea Ice Standardization Tool
AVHRR	Advanced Very-High Resolution Radiometer
BIM	Baltic Icebreaking Management
BSIS	Baltic Sea Ice Services
CIS	Canadian Ice Service
CMEMS	European Union Copernicus Marine Environment Monitoring Service Programme
CMM	Commission for Marine Meteorology
DMSP	Defense Meteorological Satellite Program
DN	Dark nilas
ECDIS	Electronic Chart Display and Information Systems
EIS	European Ice Services
EOS	Earth Observing System
ETSI	Expert Team on Sea Ice
F1	First year ice first stage
F2	First year ice second stage
FL	Thin first-year ice
FM	Medium first-year ice
FT	Thick first-year ice
FY	First-year ice
GDSIDB	Global Digital Sea Ice Data Bank
GIS	Geographical Information System

GML	Geography Markup Language
GR	Grey ice
GW	Grey-white ice
IHO	International Hydrographic Organization
IICWG	International Ice Charting Working Group
IIP	International Ice Patrol
IOC	Intergovernmental Oceanographic Commission of UNESCO
IPY	International Polar Year
JCOMM	Joint WMO/IOC Technical Commission for Oceanography and Marine Meteorology
LN	Light nilas
MODIS	Moderate Resolution Imaging Spectroradiometer
MY	Multi-year ice
NAIS	North American Ice Service
NI	New ice
NL	Nilas
NOAA	National Oceanic and Atmospheric Administration
NPP	National Polar-orbiting Partnership
OI	Old ice
OLCI	Ocean and Land Colour Instrument
OLS	Operational Linescan System
PSU	Practical salinity units
SAR	Synthetic aperture radar
SCAR	Scientific Committee on Antarctic Research
SGSI	Subgroup on Sea Ice
SLSTR	Sea and Land Surface Temperature Radiometer
SSMIS	Special Sensor Microwave Imager/Sounder
SY	Second-year ice
USCG	United States Coast Guard
USNIC	U.S. National Ice Center

WCRP	World Climate Research Programme
YI	Young ice
YOPP	Year of Polar Prediction

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